**NONRESIDENT TRAINING COURSE**

**Date: October 2010**

# BUILDER ADVANCED

## NAVEDTRA 14045A

## S/N 0504LP1100960

**Notice: NETPDTC is no longer responsible for the content accuracy of the NRTCs.**

**For content issues, contact the servicing Center of Excellence: Center for Seabees and Facilities Engineering (CSFE); Fax: (805) 982-5508 or DSN: 551-5508.**

**DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.**

## NAVEDTRA 14045A COPYRIGHT MATERIAL

Copyright material has been identified, approved and is listed below within this document.

| Copyright Owner | Date | Chapter | Pages | Remarks |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

# Table of Contents

# Chapter 1

# Technical Administration

## Topics



To hear audio, click on the box.

## Overview

When a particular task is assigned to a group, or one individual, the steps in each function must be planned. Individuals who perform these tasks must be properly trained, well-organized, and supervised. As either Crew/Squad Leaders or Project Supervisors, you will be responsible for planning, training, organizing, and supervising any assigned task.

Additionally, you will be responsible for various administrative duties that require paperwork. These duties will include: conducting Seabee Skill Assessment interviews, maintaining reports, drafting evaluations, planning work assignments, and identifying safety and environmental hazards.

Your assigned command determines the way you are to carry out your administrative responsibilities. Your skills in planning, organizing, applying effective supervisory techniques and abilities will determine whether you attain your goals in the Seabee community, regardless of your assignment.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the administrative duties and responsibilities of a Builder Second and First Class Petty Officer in relation to the Seabee Skills Assessment program.
2. Identify the administrative duties and responsibilities of a Builder Second and First Class Petty Officer in relation to training.
3. Identify the administrative duties and responsibilities of a Builder Second and First Class Petty Officer in relation to construction administration.
4. Identify the administrative duties and responsibilities of a Builder Second and First Class Petty Officer in relation to safety.
5. Identify the administrative duties and responsibilities of a Builder Second and First Class Petty Officer in relation to environmental protection.

6. Identify the administrative duties and responsibilities of a Builder Second and First Class Petty Officer in relation to hazardous waste.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.0.0 SEABEE SKILL ASSESSMENT

The Seabee Skill Assessment has replaced the former Personnel Readiness Capability Program (PRCP) for interviewers. It provides steps and information necessary to interview members of NCF and other units with Occupational Field Thirteen (OF-13) personnel and identify in-rate skills obtained through practical experience or undocumented training. The program assures the NCF that personnel granted a skill through this process have at least a minimum working knowledge of that skill. It is not a training management system or an overall inventory of skill descriptions for all required Naval Construction Force (NCF) training. Training management for NCF units is specified in applicable joint or individual Second and Third Naval Construction Brigade directives. The training commands' course catalog or the Navy Enlisted Classification (NEC) System Manual provide skill descriptions for courses.

The *Seabee Skill Assessment Manual, NAVFAC P-1105,* provides procedures and skill interview questions for all primary and secondary naval warfare mission related skills that units may award individuals for practical experience or undocumented training. These interviews are important to units, as they provide a method for awarding skills obtained by means other than established schools. Individuals benefit from interviews by avoiding repetitive training and earning credit for on-the-job training. Units must conduct these interviews at appropriate times to assist in their training plan. Primary or secondary skills listed in the COMSECONDNCB/COMTHIRDNCBINST 1500.IA are only attainable through attending training conducted by an approved source. They are not listed here.

The Seabee skill assessment interview process significantly improves the previous program. It provides interviewers specific skill questions which allow the interviewee to verbally demonstrate knowledge of the skill. It also identifies critical skill requirements within each skill and provides overall pass/fail guidelines. This section describes in detail the steps in the interview process.

## 1.1.1 Steps for Interviewing

The following steps specifically outline the procedure for conducting an interview. *Figure 1-1* provides a flow chart of the interview process. Training departments that use skill assessment coordinators are responsible for developing and maintaining a list of subject matter experts available to conduct interviews.

1. **Set Atmosphere.** Conduct interviews at the most convenient place for the interviewee. Actual work sites or shops will work for practical demonstrations. However, if an interviewer uses work sites or shops, a work space with a table and chairs, limited distractions, and minimal noise is required. The interviewer should be prepared to adjust to the situation, not the interviewee.

2. **Explain the Scope.** It's important for interviewees to understand why they are being interviewed. Explain to interviewees the importance of the interview, for both them and the unit.

   **Individual** - The Seabee receives credit for skills obtained through practical experience and avoids attending class for a skill already mastered. Additionally, the interview provides skill attainment to help in advancement and job assignments and documents individual training.

   **Unit** – The interview eliminates redundant training, provides accurate accounting of skills, and provides information for assigning skilled personnel to specific jobs in the unit. During this explanation, provide interviewees with their training skill list and review it with them. Be prepared to answer questions related to non-interviewable as well as interviewable skills. Briefly describe how the interview will be conducted. Read a general skill definition to interviewees, then ask specific questions, if warranted.

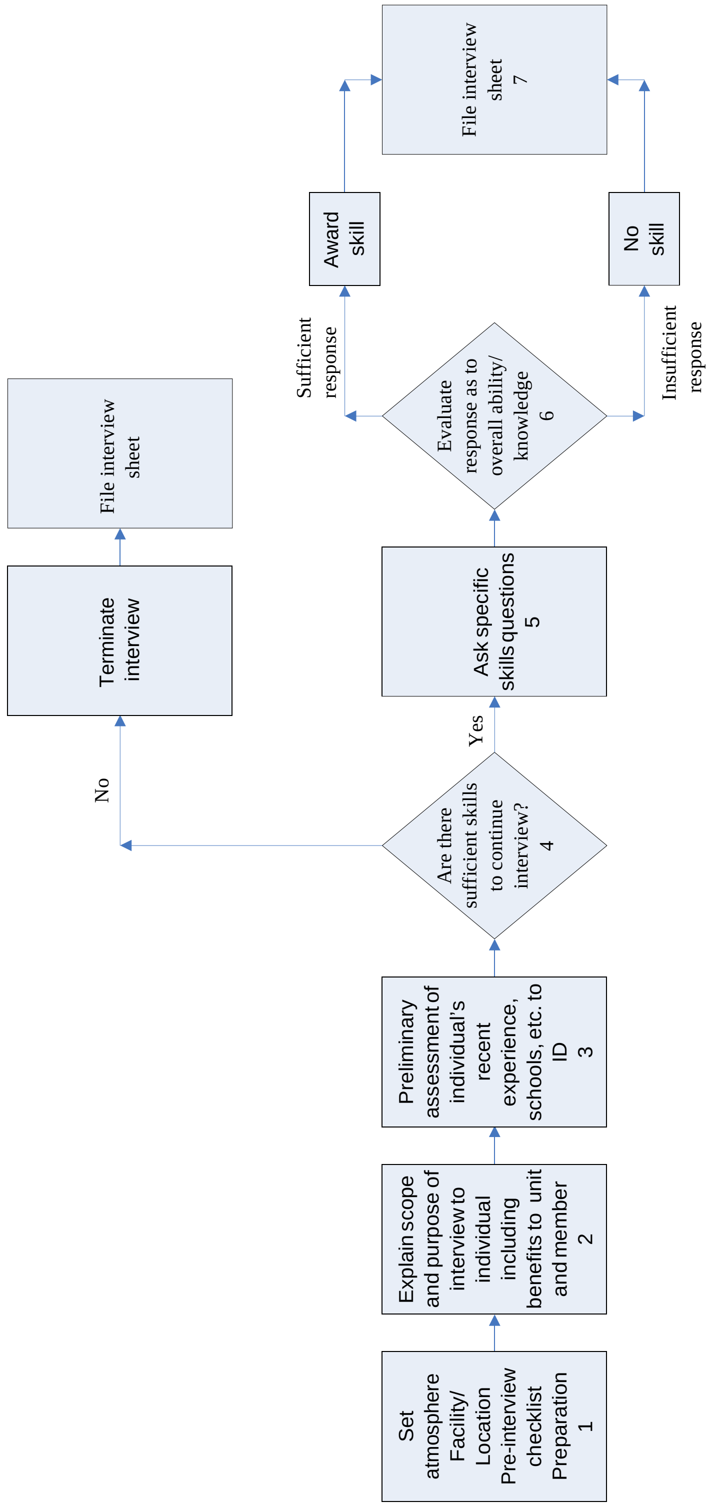



**Figure 1-1 – Seabee skill assessment interview process.**

3. **Preliminary Assessment.** During the review of the training skill list the interviewee should identify any schools attended that are not listed. If the interviewee cannot provide proof of approved course completion, the skill must

be interviewed. Ask what work the interviewee has done, civilian, military, or other practical experience that relates to the skill. Ask questions that help focus on skills (e.g., Did you actually lay block or did you carry block and mix mortar?). During this assessment, use the back of the Interview Worksheet shown in *Figure 1-2* and check the boxes within the interviewee's rate to be interviewed.

**Seabee Skill Assessment Interview Worksheet**

**Date:**

| | | |
|---|---|---|
| **Interviewer:** | **Rate:** | **SSN:** |
| **Interviewee:** | **Rate:** | **SSN:** |
| **Interview Type:** □ **Initial** □ **Update** | | |
| **Date of Last Interview:** | | |
| **Schools Attended (and not listed on profile sheet):** | | |
| **Project(s) Assignment (since last interview);** | | |
| **Skills Interviewed (for individual's rate and 800 skills only):** | | |
| **Skills Awarded (include date of skill, not the interview date):** | | |

**Note: As interviewer, by signing this form I certify that I possess the skills for which I am interviewing and I am qualified to conduct this interview.**

**Interviewer Signature** **Interviewee Signature**

**Submit to S7 when completed**

**Figure 1-2 – Seabee skill assessment interview worksheet.**

4. **Continue the Interview.** Based on this assessment, determine whether the interviewee has gained sufficient skills since the last interview to continue. If so, go to step 5. If not, complete and file the interview sheet.
5. **Questions.** Ask the interviewee the specific questions. Ask questions relating to the skill that closely follow the content of questions as they are written. Ask additional questions for clarification if necessary, but avoid asking questions in areas not covered. Skills identified by an asterisk are critical and must be answered correctly in order to award the skill. The date he or she obtained the skill should be during the period of skill attainment, not the date of the interview. The interviewee's answers should be detailed enough to demonstrate thorough knowledge of the skill. If the interviewee cannot respond appropriately to the specific questions, do not award the skill.
6. **Evaluate Response.** Evaluate the interviewee's response to each question. Ensure that the interviewee provides complete detailed answer to demonstrate his or her possession of the skill. If he or she gives sufficient answers and meets the **minimum** number, including all critical skills, award the skill number.

The skills that you will interview on are very specific. A listing of the skills for the Builder rate is shown in *Figure 1-3*.

| | |
|---|---|
| 103.1 | Planning and Estimating |
| 130.2 | Concrete Forming and Reinforcing II |
| 132.2 | Mixing, Placing, and Finishing Concrete II |
| 140.2 | Masonry Unit Construction II |
| 150.2 | Light Frame Construction II |
| 162.1 | Roofing |
| 164.1 | Finish Carpentry I |
| 170.1 | Heavy Construction I |
| 170.2 | Heavy Construction II |
| 190.2 | Painting and Preservation II |

**Figure 1-3 – Interviewable skills listing for the Builder rate.**

### Test your Knowledge (Select the Correct Response)

1. **(True or False)** The Seabee Skill Assessment replaces the former Personnel Readiness Capability Program (PRCP) for interviewers.

   A. True
   B. False

## 2.0.0 TRAINING

There is no best training method that applies to every situation. According to the *Naval Construction Force (NCF)* Manual, NAVFAC P-315, each training program is formulated to provide personnel the skills needed to accomplish current missions in the NCF. *The Organization and Function for Public Works Departments,* NAVFAC P-318, does not cover training. The majority of Public Works training is through OJT.

Any training program is developed according to the pattern, priorities, and tempo established by the Commanding Officer and covers many phases from orientation courses to special technical courses.

The success of any training program depends upon operational commitments, policies, and directives from higher authorities. The experience, the previous training of assigned personnel, and the availability of training facilities will also affect the success of the training program.

## 2.1.0 Training Organization

Navy regulations state that in Naval Mobile Construction Battalions (NMCBs), the Executive Officer (XO) supervises and coordinates the work, exercises, training, and education of command personnel. The XO supervises the training of officers, coordinates the planning and execution of training programs, and when necessary, acts to correct deficiencies. The Executive Officer's main assistant is the plans/training officer (S-7). Public Works and associated non-NCF units do not have training departments and must rely heavily on OJT and General Military training (GMT).

### 2.1.1 Company Commanders

Company Commanders are directly responsible for training their company's personnel and for meeting the training goals established by the Commanding Officer. The Company Commanders help formulate training programs, supervise the training of subordinate officers, and direct the technical military and general training of their companies. Company Commanders also designate their own training Petty Officer to assist in Coordinating training among company personnel and the S-7 department.

### 2.1.2 Platoon Commanders

Platoon Commanders monitor the training progress of personnel in their platoons. They directly supervise on-the-job training and some military training. All Petty Officers are responsible for training their personnel by means of lectures, discussions, project work, and so on.

### 2.1.3 Training Officer

The Training Officer (S-7), normally a Lieutenant, is assisted by a permanently assigned staff consisting of one Chief Petty Officer and two to four Petty Officers. This group is concerned with the formulation and administration of both the formal military training program and the formal technical training program. These programs include formal schools, Special Construction Battalion Training (SCBT), advanced base construction, and disaster recovery training. Individual class assignments are administered within each company and must correspond to the guidelines established by the S-7 department. *Figure 1-4* shows a typical battalion training organizational chart.

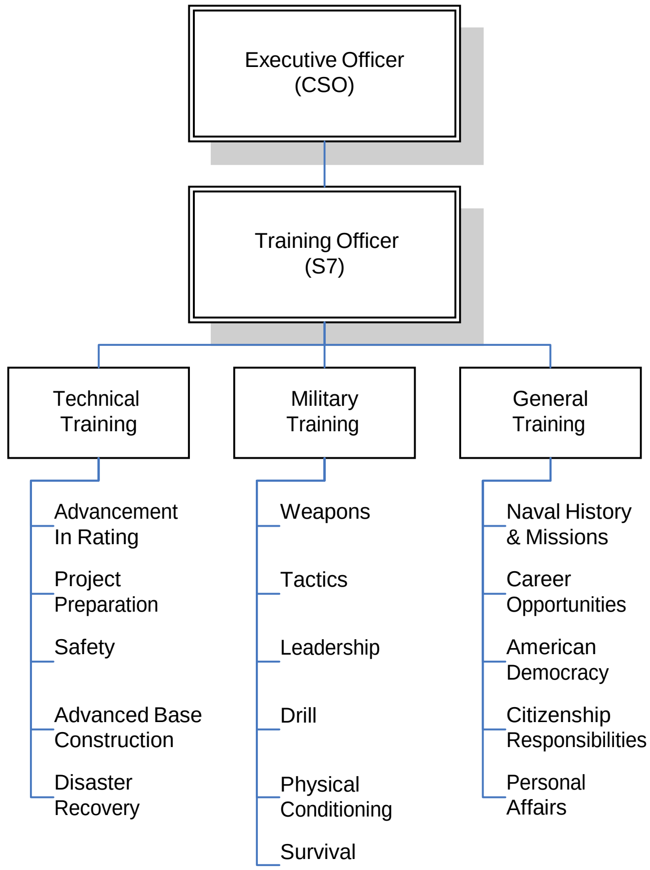



**Figure 1-4 – NMCB training organizational chart.**

## 2.2.0 Training Guidelines

In general, make sure training is consistent with the following guidelines:

Closely integrate and coordinate training with the daily operations of the unit's mission. The adopted plan and organization for training must not interfere with essential construction functions.

Notwithstanding the guideline just listed, keep the construction schedule flexible to make use of opportunities for training that might even expedite the construction schedule.

Take maximum advantage to train everyone for the opportunities that exist, because those who simply "muster and make it" deprive themselves of becoming well trained Seabees and Builders and make advancement difficult to achieve.

## 2.3.0 Training Needs

Training for advancement is an ongoing concern for all personnel at all levels. The Navy benefits when you advance in rate. Highly trained personnel are essential to the Navy's mission. With each advancement, you become more valuable as a technical specialist and as a person who can supervise, plan, lead, and train others.

As the Navy implements training programs, so does the NCF. Training our Seabees in battalion during home port periods becomes the primary mission. They expect to spend about 75 percent of the available man days in formalized technical, military, and general training classes. In addition, the planning and estimating teams that plan deployment projects may be considered to be engaged in OJT.

Approximately 2 months before an NMCB returns from deployment, it sends a training team back to its home port regiment for a training conference to prepare the training schedule for the battalion's home port stay. This team schedules the training required for the battalion to meet the operational readiness and construction tasking for its next deployment. The team also coordinates home port support for berthing, supplies, recreation, and billets for training support (FSB/PRE). All personnel are trained in the areas of technical, military, and general topics.

Programs may be tailored to meet the specialized mission of the battalion's next deployment. If one of the projects scheduled is the repair of an airstrip, there will be a great deal of training on rapid runway repair (RRR). This is when the Naval Construction Regiments (NCRs) play a vital role in training. You will need to know how many qualified personnel are available and whether you need to train more to repair the airstrip. Take advantage of any opportunities to train as many of your personnel as possible. "Muster and make it" is NOT a training evolution.

As supervisor, you may check a member's service records, conduct Seabee Skill Assessment interviews, and select those best suited for training given at a Navy C-1 advanced school or at a special construction battalion training course (SCBT).

## 2.4.0 On-the-Job Training

On-the-job training (OJT) plays a major role in the development of our Seabees. As a Crew Leader or Project Supervisor, make sure your troops are being properly trained. Remember how and when you were trained. For example, one person helps another learn the trade and that person's experience is passed on to others. That is OJT.

OJT happens around us all the time. There are as many examples of OJT as there are contacts between personnel in the Seabees. In a Seabee organization, OJT is important because of the continuous changes in equipment and personnel. It also provides continuous opportunities for new and better methods of doing construction work.

In the Seabee community, as well as in private industry, the term on-the-job training means helping an individual acquire the necessary knowledge, skill, and habits to perform a specific job. This definition implies that job training applies not only to the Construction man or to new personnel in an organization but also to any other person assigned to a new job. Furthermore, OJT is a continual process among Seabees. No one is completely trained; we are constantly learning new techniques (tricks of the trade) every time we work on a project.

Remember that OJT is an active process, and it requires supervisors to be aware of the needs of the trainees and to motivate them to learn.

Use methods that add meaningful experiences to the trainee's storehouse of knowledge; listen to suggestions, and give precise direction. Then you, as a Crew Leader and Project Supervisor, will gain proficiency.

A supervisor who does a good job of training personnel benefits in many ways. For one thing, well trained crew members brag about their supervisor, especially to their buddies in other crews. When you have a valuable skill, knowledge, or attitude and impart either of the same to ten others, you have multiplied your effectiveness considerably.

### 2.4.1 Training Methods

When conducting OJT, you must tailor the training methods around the nature of the subject, the time available, and the capabilities of the trainee.

No other method of training is as effective, intelligent, or interesting as coach-pupil instruction. In addition to being a quick way of fitting a new worker into the operation of a unit, it serves as one of the best methods of training, because without specific directions and guidance, a worker is likely to waste time and material and form bad work habits.

Many industries have apprenticeship programs designed to train workers in a trade or skill. Most apprentice training consists of both coach-pupil instruction with skilled worker supervision and periodic group instruction.

Self study is important for the OJT trainee; encourage the practice of it. Skilled and semiskilled jobs require a considerable amount of job knowledge and judgment ability. Even in simple jobs, there is much basic information a worker must learn. The more complicated technical jobs involve highly specialized technical knowledge and related skills that must be taught.

Group instruction is a practical adjunct to direct supervision and self study. It is a time saver when several workers need the same job related knowledge or procedures. The supervisor or trainer can check training progress and clarify matters the trainees find difficult to understand. Group instruction, when intelligently used, speeds up production. Suppose you have six trainees learning the same job. Four of the trainees are having trouble with a certain job element, while the other two have learned it. The four people having trouble can be brought over to the other two, and in a short time, the difficulty will most likely be solved. In OJT, this is called group instruction. As you can see, group instruction is not the same as classroom or academic instruction.

Another type of OJT is piecemeal instruction. For instance, a crew member asks you for information and you supply it. That is piecemeal instruction. A supervisor’s orders are, in a sense, a piecemeal method of instruction because they should let others know what, when, where, how, and why. Other examples of piecemeal instruction are explaining regulations, procedures, and orders; holding special meetings, indoctrinating a new person, and conducting organized meetings.

### 2.4.2 Trainee Development

In any type of effective training in which one individual is working directly under the supervision of another, the trainers and trainees must understand the objectives of the training. Factors deserving your careful consideration as a supervisor include determining the trainees’ training needs, defining the purpose of training, and explaining or discussing job training concerns with the trainees.

In determining training needs, it is often a good idea to interview the trainees. Through proper questioning you can get a summary of their previously acquired skills and knowledge related to the job. Compare jobs the trainees know how to do with those they will be doing. Then determine the training needs, the required knowledge and skills minus the knowledge and skills the trainees already possess. Training needs should be determined for each job pertaining to the trainee’s position assignment. Next, analyze the job to be done and have all the necessary equipment and materials available before each job training situation.

When you define the purpose of training, clearly explain the purpose of the job, the duty, or the task to be performed by the trainees. Then point out to the trainees their place on the team and explain to them their role in accomplishing the mission of the unit. Stress the advantages of their doing the job well and how the training benefits them, their organization, and the Seabees.

The trainers should also explain facts about the job to be done, principles that are proven and workable, and directions on ways to do the job safely, easily, and economically. Also explain any technical terms or techniques that will improve the skills of the trainees. Stress the importance of teamwork and attention to detail in each operation of a job.

The trainers and trainees are to discuss the problems that arise in doing a job, and try to clear up any questions the trainees may have concerning the job. Trainers are to point out to the trainees the similarities of different jobs. Trainers are also to cover the relationship of procedures in a particular job to things with which the trainees are already familiar. This way the trainees learn through association with past experiences. It is also important for trainers to discuss the progress of the trainees.

The most valuable end product of a peacetime military operation is well trained personnel. Regardless of the unit's mission, you must have trained personnel to carry it out. All Petty Officers in the Navy are responsible for training the personnel under their immediate supervision. Do NOT take this responsibility lightly.

## 2.5.1 Systematic Training

Effective training requires a great deal of planning and directed effort. To prevent a haphazard approach to the job of training, organize materials into a logical sequence and use an accurate method to measure the results. When any learning takes place, there will be results. When no learning takes place, you have not trained. The following four steps are provided to help you plan and carry out your training programs:

- Encourage learning by using the correct training methods.
- Measure achievement at regular intervals to assure that learning is taking place.
- Record results to document progress and to improve your training system.
- Reward or recognize those who perform.

### 2.5.1 Evaluation

Evaluations are worthwhile tools. Both you and the trainee will want an evaluation of the work accomplished. Generally, the most valid trainer evaluations are obtained by testing the trainees. When they have learned to perform in a highly satisfactory manner, this is the best indication that training has occurred. Personnel must be trained correctly. Improper training, in many cases, is worse than no training at all.

### 2.5.2 Performance Testing

Performance testing enables you to do a better job of conducting an OJT program. Use performance tests to find out how well your trainees are doing their jobs. It can be difficult to find a test that truly assists you in evaluating performance. Performance tests should enable you to rate the work of subordinates accurately enough to carry out the following objectives:

- Determine the qualifications of personnel
- Rate the improvement of persons

- Determine whether trainees can actually perform
- Assign new people to particular jobs
- Locate trainees' strengths and weaknesses

Since it is a practical check on a work project, a performance test must be conducted in a sample work situation in which the trainee performs some active task that can be examined. The test is not designed to measure what a person knows about the job, a written or oral test may fill that need for you. Instead, it is intended to help you rate that person's ability to actually do the job. Do your best in organizing and administering the performance test. There will always be room for improvement in most of the testing that you do.

### Test your Knowledge (Select the Correct Response)

2. The priorities, patterns, and tempo of a battalion training program are usually established by what authority?

   A. The Chief of Naval Operations
   B. The Commanding Officer
   C. The Executive Officer
   D. The Operations Officer

3. In a Seabee organization, what is the primary purpose of on the job training?

   A. Muster and make it
   B. To assist supervisors in developing management skills
   C. To help individuals acquire the necessary knowledge, skills, and habits to do a specific job
   D. To indoctrinate new personnel

# 3.0.0 CONSTRUCTION ADMINISTRATION

Proper administration and planning are the backbone of any project, large or small, and they are just as important as constructing the project.

You will have personnel assigned to you whom you must employ effectively and safely. Your supervisor expects you not only to meet production requirements and to conduct training, but also to learn the process of paperwork. Be patient. If you plan well, you will succeed. The following section contains information to assist you in planning, organizing, and coordinating work assignments. You must master these skills to meet the production schedule.

## 3.1.1 Planning Work Assignments

Planning is the process of determining the requirements and developing the methods and schemes of action for performing a task. Proper planning saves time and money and ensures that the project is completed in a professional manner. Remember, proper planning prevents poor performance. When planning various assignments, you must consider many factors. The following paragraphs highlight some, but not all of the factors to consider during the planning stage.

When you are assigned a project, whether in writing or orally, one of the first things to do is to make sure you clearly understand just what is to be done. Study the plans and specifications carefully. When you have questions, seek and find the answers from those in a position to supply the information you need. Also make sure you understand the priority of the project, the expected time of completion, and any special instructions.

In planning for a small or large project, you must consider the capabilities of your crew. Determine who is to do what and how long it should take to complete the assignment. Also consider the tools and equipment you will need and arrange to have them available at the job site when the work is to get under way. Determine who will use the tools, and make sure the crew members to whom they are assigned know how to use them properly and safely.

To be certain a project is done properly and on time, consider the way it is to be accomplished. When there is more than one way of doing a particular task, analyze the methods and select the one most suited to the job conditions. Listen to suggestions from others. If you can safely simplify a method and save time and effort, by all means do it.

As a Crew Leader, your goal is to get others to work together to complete their assignments. Always maintain an approachable attitude toward your crew, so each crew member feels free to seek your advice when in doubt about any phase of work. Emotional balance is especially important; you must neither panic before your crew, nor be unsure of yourself in the face of conflict.

Be tactful and courteous in dealing with your crew. Never show partiality to certain members. Keep your crew members informed on matters that affect them personally or concern their work. Also seek to maintain a high level of morale because low morale will have a definite negative effect on the quantity and quality of their work.

Establish goals for each workday and encourage your crew members to work together as a team to accomplish them. You should set goals to keep your crew busy, but make sure they are realistic. Discuss the project with your crew members so they know what you expect from them. During an emergency, most crew members will make an all-out effort to meet the deadline. However, people are not machines, and when there is no emergency, do not expect them to work continuously at an excessively high rate. The importance of teamwork cannot be overemphasized, and neither can the importance of daily crew briefings. Daily crew briefings provide a vital communication link to the quality completion of the project. You do not want to keep any member of the crew in the dark.

As the Petty Officer in charge of a crew, you are responsible for time management of the crew member and for yourself. You must plan constructive work for your crew. Always remember to plan ahead. A sure sign of poor planning is when crew members stand idle each morning while you plan the events of the day. At the close of each day, confirm plans for the next workday. In doing so, you may need answers on the availability and the use of manpower, equipment, and supplies. Keep the following questions in mind:

- **Manpower.** Who is to do what? How is it to be done? When is it to be finished? Since idleness may breed discontent, have you arranged for another job to start as soon as the first one is finished? Is every crew member being fully employed?
- **Equipment.** Are all necessary tools and equipment on hand to do the job? Is safety equipment on hand?
- **Supplies.** Are all necessary supplies on hand to start the job? If not, who should take action? What supply delivery schedules must you work around?

You must set a definite work schedule and inspection plan, and set up daily goals or quotas. Plan personal inspections at intervals to check the work being done and progress toward meeting the goals. This will involve a spot check for accuracy, workmanship, and the need for training.

### 3.1.1 Organization

As a Crew Leader, you must organize. This means analyzing the requirements of a job and structuring the sequence of events that will bring about the desired results.

Develop the ability to look at a job and estimate how many man hours are required for completion. You will probably be given a completion deadline along with the job requirements. Next, or perhaps even before making your estimate of man hours, plan the job sequences. Make sure you know the answers to the following questions. What is the size of the job? Are the materials on hand? What tools are available, and what is their condition? Is anyone scheduled for leave? Will you need to request outside support? After getting answers to these questions, you should be able to assign your crews and set up tentative schedules. When work shifts are necessary, arrange for smooth transition from one shift to another with a minimum of work interruption. How well you do so is directly related to your ability to organize.

### 3.1.2 Delegation

In addition to organizing, you must delegate. This is one of the most important attributes of a good supervisor. Failure to delegate is a common weakness of a new supervisor. It is natural for you to want to carry out the details of a job yourself, particularly when you know that you can do it better than any of your subordinates. When you try to do too much, however, you can quickly get bogged down in details and slow down a large operation.

On some projects, you may have crews working in several different places. Obviously, you cannot be in two places at once. There will be many occasions when a Builder needs assistance or instruction on some problem that arises. When your personnel have to wait until you are available, valuable time may be lost. So it is important that you delegate authority to one or more of your crew members to make decisions in certain matters. Remember that although you delegate authority, you are still responsible for the job.

### 3.1.3 Coordination

As a Crew Leader, you must coordinate. When several jobs are in progress, you are to coordinate the completion times so one follows another without delay. Your coordinating skills also play a very helpful role when you work closely with other companies. Coordination is not limited to projects only. You would not want to approve a leave chit for a crew member only to find that person is scheduled for school during the same time. You would not schedule a crew member for the rifle range only to find the range coach unavailable at that time.

### 3.1.4 Production

The primary responsibility of every Crew Leader is production. You and your crew will be at your best by practicing the following guidelines:

- Plan, organize, and coordinate the work to get maximum production with minimum effort and confusion.
- Delegate as much authority as possible but remain responsible for the final product.
- Continuously supervise and control to make sure the work is done properly.

- Be patient. Seabees are flexible and resourceful.

### 3.1.5 Safety, Health, and Physical Welfare of Subordinates

Safety and production go hand in hand since the only efficient way to do anything is the safe way. Production is sure to fall when your personnel are absent because of injury, your shop equipment is down because of damage, or completed work is destroyed by accident. You must teach and stress safety constantly and set examples by always observing safety precautions yourself. Teach safety as part of each training unit, and plan each job with safety in mind. Safety will be covered later in this chapter.

### 3.1.6 Daily Work Assignments

The assignment of work is an important matter. On a rush job, you may have to assign the best qualified person available to meet the deadlines. When time and workload permit, rotate work assignments so each person has an opportunity to acquire skills and experiences in the different phases of their rating. When assignments are rotated, the work becomes more interesting for the crew. Another good reason to rotate work assignments is to prevent a situation in which only one person is capable of doing a certain type of work. This specialization could be a severe disadvantage if that person were to be transferred or hospitalized or to go on leave for a lengthy period of time.

Give special consideration to work assignments for non-designated personnel. They should be assigned to jobs of gradually increased levels of difficulty. Non-designated personnel may be useful assistants on a complicated job, but they may not fully understand the different phases of the job unless they have worked their way up from basic tasks.

In assigning work, be sure to give the worker as much information as necessary to do the job properly. An experienced worker may need only a general statement concerning the finished product. A less experienced worker is likely to require more instruction concerning the layout of the job and the procedures to follow.

Often you may want to put more workers on a job than it really requires. Normally, the more workers you use, the less time it will take to get the job done, but there is a limit to the number of workers that can successfully work on one job at any given time. You should not overlook the advantages of assigning more crews or crew members to a project when their services are needed or when presented an opportunity to learn a unique phase of the rating. Teamwork, versatility, and new skills can be learned from a variety of work assignments.

## 3.2.0 Timekeeping

In battalions, and at shore based activities, your duties will involve posting working hours on time cards for military personnel. You should know the type of information required on time cards and understand the importance of accuracy in labor reporting. You will find that the labor reporting system primarily used in Naval Mobile Construction Battalions (NMCBs) and the system used at shore based activities are similar.

A labor accounting system is mandatory for you to record and measure the number of man hours that a unit expends on various functions. In this system, labor usage data is collected daily in sufficient detail and in a way that enables the operations department to compile the data readily. This helps the Operations Officer manage manpower resources and prepare reports for higher authority.

Although labor accounting systems may vary slightly from one command to another, the system described here can be tailored to record labor at any command.

Any unit must account for all labor used to carry out its assignment so management can figure the amount of labor used on the project. Labor costs are figured and actual man hours are compared with previous estimates based on jobs of a similar nature. When completed, this information is used by unit managers and higher commands to develop planning standards.

The labor accounting system covered in this section is based upon the procedures and guidelines established by both Naval Construction Brigades (NCBs) for NMCB use.

## 3.3.0 Time Cards

Time cards are the basis of your situation reports (SITREPs) input, therefore it is imperative that time cards are filled out correctly and accurately. COMSECONDNCB/ COMTHIRDNCBINST 5312.1 is the instruction that governs time keeping procedures. *Figure 1-5* is an example of a time card used by the prime or lead company for keeping labor. Subcontractors also use a similar form for accounting their time on a project. A sample of these time cards can be located and copied from the *Naval Construction Force Crew Leader's Handbook*.

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crewleader: | Signature: | | | | Company: | | | | | Crew Size: | | | | | Transfers This Date: | | | | |
| Project Number: | Project Title: | | | | | | | | | | | | | | Date: | | | | |
| Crew Member's Rate/Name | Direct Labor by Construction Activity Number | | | | | | | | | Indirect | | | | | Readiness and Training | | | | |
| | | | | | | | | | Total | | | | | Total | | | | | Total |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| Totals | | | | | | | | | | | | | | | | | | | |

**Figure 1-5 – Prime time card.**

## 3.4.1 Labor Categories

All man hours will be recorded under a specific code in one of three labor categories. There will be no time keeping requirements for Headquarters companies and Details (DFTs) which perform administrative functions. The categories are listed below:

- Direct Labor
- Indirect Labor
- Readiness and Training

### 3.4.1 Labor Codes

Direct labor includes all man days expended (ME) directly on assigned construction tasks, either in the field or in the shop, which contribute to completing the project. Remember, man days are computed on the basis of an eight hour day, regardless of the length of the scheduled workday. All tasked projects are normally assigned a project number and labor expended on a specific project will be reported under that project's number as shown in *Figure 1-6*. Included under direct labor, besides construction, are such tasks as:

- Project and site surveying.
- Shop work that contributes directly to the completion of the project.
- Camp Maintenance when accomplished as part of the battalion direct labor tasking such as Emergency Service Requests (ESRs), Standing Job Orders, and Specific Job Orders.
- Mineral products operations for either a tasked project or as a specific tasked project.
- Construction equipment operation when assigned to a tasked project.

Indirect labor includes all labor required to support construction operations but does not usually produce an end product itself. Therefore, this time is not reported under a project number but under an indirect labor code, as shown in *Figure 1-6*.

| | | | |
|---|---|---|---|
| X0l | Construction Equipment Repair, and Records | X06 | Material Support |
| X02 | Project and Camp Maintenance Support | X07 | Tools |
| X03 | Project Management | X08 | Administration and Personnel |
| X04 | Location Moving | X09 | Lost Time |
| X05 | Project Travel | X010 | Other |

**Figure 1-6 – Labor codes.**

Readiness and training comprise all manpower expended in actual military operations, unit embarkation, and planning and preparations necessary to ensure the military and mobile readiness of the unit. It also includes attendance at service schools, factory and industrial courses, fleet level training, military training, and organized training conducted within the battalion or unit. Report or record these man hours under a specific name such as MIL/OPS, Embark, or GMT.

Your report will be submitted on a typical daily time card form, like the one shown in the *Naval Construction Force Crew Leader's Handbook (NCF/CLH)*. The form provides a breakdown by man hours of the activities in the various labor codes for each crew member for each day on any given project. The staff and Platoon Commander review this form at the company level then the company commander initials it before it is forwarded to the operations department. the management division of the operations department tabulates it along with all of the daily labor distribution reports received from each company and department in the unit.

The Crew Leader will prepare a daily account of all man hours expended on a time card form, like the one shown in *Figure 1-5*. The time cards can be submitted daily to the project manager or can be kept until the two week labor summary report is due. Once you complete this two week report, it will help you prepare your SITREPs. This report is the means by which the operations office analyzes the labor distribution of total manpower resources for each day. It also serves as feeder information for preparation of the monthly OPS/SITREP reports and any other source reports required of the unit. This information must be accurate and timely. Each level in the company organization should review the report for an analysis of its own internal construction management and performance.

### Test your Knowledge (Select the Correct Response)

4. What is the first step to take when assigned a project?

   A. Determine the cost of the job
   B. Determine the priority
   C. Make sure you have enough crew members for the job
   D. Make sure you understand the assignment clearly

5. Of the following mistakes, which one is the most common mistake made by a new supervisor?

   A. Failure to coordinate
   B. Failure to delegate authority
   C. Failure to organize properly
   D. Failure to produce

## 4.0.0 SAFETY PROGRAM

As an individual and a Petty Officer, you must be familiar with the safety program at your activity. You cannot function effectively as a Petty Officer unless you are aware of how safety fits into this program. You should know who or what group arbitrates and establishes the safety policies and procedures you must follow. You should also know who provides guidelines for safety training and supervision. All NCF units and shore commands are required to implement a formal safety organization.

In the Seabees, **everyone** is responsible for safety. According to the *NCF Safety Manual, COMSECONDNCB/COMTHIRDNCBINST 5100.1 (series)*, the battalion safety office administers the battalion safety program and provides technical guidance. Overall guidance comes from the *Navy Occupational Safety and Health Program Manual (NAVOSH*), OPNAVINST 5100.23 (series). If you have any questions concerning safety on the project, the safety office is the best place to get your questions answered.

It is not the responsibility of the safety office to prevent you from doing something you know or suspect is unsafe, but they do have the authority to stop any operation when there is impending danger of injury to personnel or damage to equipment or property. Safe construction is your responsibility, and ignorance is no excuse. It is your responsibility to find out how to do construction in a safe manner.

## 4.1.0 Safety Training

The key to any successful safety and health program is the application of goal oriented techniques, past experiences, adherence to safe operating practices and procedures, and the full cooperation of personnel. This goal is reached most effectively through a well-developed and well coordinated training program.

### 4.1.1 Formal Training

Navy Enlisted Classification (NEC) 6021, NAVOSH is a 2 week class that trains you on the 29 CFR PART 1926. This document contains the occupational safety and health standards for construction as promoted by the Occupational Safety and Health Administration as of August 1991.

The NCF Supervisory Safety course is a 40 hour course taught by NCRs or the battalion Safety Officer. Attendees are familiarized with the safety program, the use of safety manuals, the identification of construction hazards, and the inclusion of safety in project planning. All E5-E6 personnel in line companies and details, all project safety representatives, and all Crew Leaders are required to attend the course.

The Hazard Recognition/Mishap Prevention course is a 16 hour course taught by the safety chief to familiarize working level personnel with common hazards and safe work practices. Project safety representatives and Crew Leaders who have not attended the NCF Supervisory Safety course are required to attend it.

OJT is a continuous evolution to train crew members, and the Crew Leader needs to use all the references listed above, plus past experiences, knowledge, previous training, and daily stand-up safety lectures.

## 4.2.1 Mishap Prevention

The goal of our safety program is to prevent mishaps. Seabees do not use the word *accident* because it implies the absence of fault (accidents happen). Mishaps most commonly result from one's failure to follow safe construction practices. First, let's define a **mishap** in the following way:

> A **mishap** is an unplanned event or series of events that result in death, injury, occupational illness, or damage and/or loss of equipment.

You may be appointed to assist the Safety Officer in administering the Mishap Prevention Program. The following is a seven step process to consider and practice in preventing mishaps.

1. **Recognize hazards.** Begin by recognizing that construction is a dangerous business. The potential for death or serious injury is present daily on job sites. Identify very specifically what hazards could cause death or injury.

   **Hazard** is defined as a workplace condition that might result in injury, health impairment, illness, disease, or death to any worker who is exposed to the condition or in damage or loss to property/equipment.

   **Serious hazard** is a workplace condition of a Category I or Category II nature as defined below.

Category I - Catastrophic: May cause death of an individual or the loss of a facility.

Category II - Critical: May cause severe personnel injury, severe occupational illness, or major property damage.

Category III - Marginal: May cause minor personnel injury, minor occupational illness, or minor property damage.

Category IV - Negligible: Probably would not affect personnel safety or health but is nevertheless in violation of specific criteria.

2. **Identify corrective action.** Our primary reference for preventive measures is the Occupational Safety and Health Standards for the Construction Industry, 29 CFR PART 1926. Our secondary reference is the U.S. Army Corps of Engineers Safety and Health Requirements Manual, EM 385.
3. **Obtain equipment/material/training.** The operations department and safety department will provide assistance for setting up training and any equipment or material necessary for the task.
4. **Ensure personnel awareness.** A key to a successful mishap prevention program is personnel awareness. The purpose of the daily 5 minute stand-up safety lecture is to make sure everyone is properly trained to perform the task at hand. These lectures must address all hazards identified on NCF CAS sheets or any construction task performed by the Seabees.
5. **Proper supervision.** The Crew Leader is responsible for making sure the crew members are provided with the proper training, equipment, and material to perform their tasks.
6. **Emergency response.** To ensure that an emergency response is not delayed in the event of a mishap, post on the job site the location of the nearest phone, a map of the nearest medical facility, and emergency phone numbers.
7. **Investigate and report.** Any mishap or near mishap must be documented to minimize the chance of it happening again. Crew leaders must initiate a mishap report.

### 4.2.1 Mishap Reporting

When a MISHAP occurs in your shop or office or within your crew, you must submit an accident/mishap report to the Safety Officer. Use the sample message format shown in *Figure 1-7*, as described in OPNAVINST 5102.1.

General:

The format and content shown below is to be used for reporting personnel injuries/death and material (property) damage mishaps. Submit as much of the information as is available. Submit supplementary reports as necessary to supply the missing information when available. OMIT ITEMS THAT DO NOT APPLY OR ARE NOT RELEVANT TO THE MISHAP.

Content and Format:

(Precedence-normally ROUTINE. See paragraphs 302b(3) and 402(3) when higher precedence is required.)

FROM: REPORTING ACTIVITY

TO: NAVSAFECEN NORFOLK VA

INFO: (As may be directed by higher authority)

UNCLAS //N05102//FOUO (Normally UNCLAS unless classified information must be included.)

THIS IS A (LIMITED/GENERAL) USE MISHAP REPORT TO BE USED ONLY FOR SAFETY PURPOSES IN ACCORDANCE WITH OPNAVINST 5102.1A

SUBJ: PID/MPD REPORT-(REPORT SYMBOL OPNAV 5102-1 (PID) and/or OPNAV 5102-02 (MPD))

REFERENCES: (If follow-up message, refer to prior message.)

ALFA: 1. UIC OF REPORTING ACTIVITY

2. TYPE OF MISHAP (Flooding, Fire, Injury/Death, Equipment Casualty, etc.)

3. LOCAL DTG OF MISHAP

4. GEOGRAPHIC LOCATION (If classified, gIve general area)

5. LOCATION WHERE MISHAP OCCURRED (If at duty station, give workstation or description, e.g., torpedo room, main deck frame. If other, so indicated; e.g., at home, on/off base, football, etc.)

6. EVOLUTION AT TIME OF MISHAP (TYT, REFIT, ISE, MAINTENANCE, UNREP, etc.)

7. SHIP'S STATUS (Under way, anchored, submerged, dry-docked, etc. For mishaps ashore, leave blank.)

BRAVO: 1. EQUIPMENT DAMAGED OR DESTROYED BY THE MISHAP (Include EIC, TEC, or NSN if applicable; describe damage.)

2. ESTIMATED, COST TO REPAIR OR REPLACE DOD PROPERTY. (Provide a total cost including man hours at $14 per hour plus cost of material and equipment.)

3. ESTIMATED COST OF NON-DOD PROPERTY DAMAGE.

CHARLIE: REPORTABLE INJURIES

NAME/SSN/AGE/SEX (If more than one person involved, information in this section must be explicit as to which individual is being described. Report items 1 through 8 for each individual.)

RANK/DESIGNATOR/RATE/GRADE: JOB AND EMPLOYMENT STATUS (For employment status specify USN, USNR, Navy Civilian, etc.)

DUTY STATUS (On or off duty)

SPECIFIC JOB OR ACTIVITY ENGAGED IN AT TIME OF MISHAP (PMS, watch standing, football, woodworking, etc.)

NUMBER OF MONTH'S EXPERIENCE AT THE JOB OR ACTIVITY (The experience the person possessed for the activity engaged in.)

MEDICAL DIAGNOSIS (Include parts of body and type of injury. For occupational illnesses specify the type as outlined in the Note below.)

FATALITY OR EXTENT OF INJURIES OR OCCUPATIONAL ILLNESSES (Specify if fatality, missing, permanent total disability, permanent partial disability, or no disability likely.)

ESTIMATE OF LOST TIME

TOTAL LOST WORKDAYS AWAY FROM JOB

DAYS ACTUALLY HOSPITALIZED

DELTA: 1. CAUSE OF MISHAP (Personnel error, unsafe condition, improper procedures, material failure, improper design, environment, unknown, or combination of the above. Elaborate in the narrative and explain how each factor contributed to the mishap. Complete items 2 through 4 only if personnel error is involved.)

2. WHO CAUSED THE MISHAP (Supervisor or foreman , operator, maintenance worker, off-duty military, other, or unknown.)

3. WHAT DID HE/SHE FAIL TO DO? (Correctly operate controls, perform PMS or maintenance properly, recognize hazardous situation, use proper caution for known risk, use protective clothing or equipment, use proper tool or equipment, plan adequately, supervise progress of work, or other.)

4. WHAT DID HE/SHE FAIL TO CARRY OUT ACTION OF DELTA 3? (Lack of concern/interest, distracted or inattentive, haste, overconfidence, emotionally aroused, inadequate knowledge, insufficient experience, fatigue, alcohol, drugs, illness, misunderstanding, design, or other.)

5. ESTIMATED SHIP OPERATING DAYS LOST

6. ASSOCIATED MESSAGES (If not included under referents.)

ECHO: NARRATIVE: Chain of events leading up to, through, and subsequent to mishap; if fire give class (A, B, C, D), source, and how extinguished (water, fog, $CO_2$, PKP, AFFF, Halon, protein foam, other (specify).) If flooding, give source and how denatured (installed eductor system, portable eductor, submersible pump, P-250, other (specify).) If collision, give estimate of damage and identification of other ship or structure; give commendations; lessons learned; elaborate with remarks so that the who, what, where, when, and how of the mishap is known.

**Figure 1-7 – Mishap report format.**

When you properly use this report, it is one of your best mishap prevention tools. In many cases, the difference between a minor mishap and a major one is a matter of good fortune. Do not ignore mishaps that result in small cuts and bruises, investigate the reason for them and correct the cause. If you persist in doing this, you will have a safe and efficient job site, shop, or office.

### 4.2.2 Mishap Investigation

Before filling out a mishap report, you must conduct a mishap investigation to get the answer to questions, such as those in the following six categories:

1. **Unsafe conditions.** Was the equipment improperly guarded, unguarded, or inadequately guarded? Was the equipment or material rough, slippery, sharp-edged, decayed, worn, or cracked? Was there a hazardous arrangement, such as congested work space, lack of proper lifting equipment, or unsafe planning?

Was the proper safety apparel being worn? Were the proper respirators, goggles, and gloves provided?

2. **Type of mishap.** Did an object strike the person? Did the person fall at the same level or from a different level, or did the person get caught between objects or slip (not fall)?
3. **Unsafe act.** Was the person operating a machine without proper authorization or at an unsafe speed; that is, too fast or too slow? Was a safety device made inoperative; that is, blocked out or removed? Was a load made unsafe or were tools or equipment left in an unsafe place where they would fall? Did someone fail to wipe oil, water, grease, or paint from working surfaces? Did the injured person take an unsafe position or posture or lift with a bent back or while in an awkward position? Did the person lift jerkily or ride in an unsafe position on a vehicle or use improper means of ascending or descending? Was the injury caused by failure to wear the provided safety attire or personal protective devices, such as goggles, gloves, masks, aprons, or safety shoes?
4. **Unsafe personal factor.** Was the person absentminded or inattentive, unaware of safe procedures, unskilled, or unable to recognize a hazardous situation? Did the person fail to understand the instructions, regulations, or safety rules? Did this person willfully disregard instructions or safety rules; or did this person have a personal weakness, such as poor eyesight, defective hearing, or a hernia?
5. **Type of injury.** Did the injured person sustain cut, sprain, strain, hernia, or fracture?
6. **Part of body affected.** Did the injury involve an arm, legs, ribs, feet, fingers, or head?

These categories suggest some but not all of the things you must investigate and report when mishaps occur.

Remember, there are some questions in these categories that require medical information that can only be obtained from a doctor. Each mishap is different, and each is to be investigated and judged on its own merits. Do not jump to conclusions. Start each investigation with an open mind. The most important reason for any mishap investigation is to prevent similar mishaps from occurring.

## 4.3.0 Hearing and Sight Conservation

The Navy's goal is to prevent occupational hearing and sight loss within the workplace and to assure that the exposure of members to potential hazardous noises and eye hazards are held to a minimum. The Navy's policy is also to provide the necessary medical care, surveillance, documentation, and treatment to all personnel.

### 4.3.1 Hearing Conservation

Environments that produce potentially hazardous noise should be modified to reduce the noise level to acceptable levels whenever it is technologically and economically feasible. The reduction of noise at the source is in the best interest of the Navy and its personnel. The Navy's Hearing Conservation Program includes the following recommendations:

- Work environments are to be surveyed to identify any potentially hazardous noise levels.
- Periodic hearing examinations are to be conducted to monitor the effectiveness

of the hearing conservation program.

- Education is vital to the overall success of a hearing conservation program.

The Navy's Permissible Exposure Limit (NPEL) for occupational noise is 84 decibels (unit of measure to express sound pressure levels) for an 8 hour time weighted average (TWA). When TWA exposures exceed 84 dB, then include personnel in the Navy's Hearing Conservation Program. The formulas to compute decibels are in the OPNAVINST 5100.23.1802.2

Any work area where the TWA sound level exceeds 84 dB and where the noise level would peak at 140 dB will be designated as hazardous noise areas and labeled as per *Navy Medicine, NAVMED 6260/2 (series)*. These labels should read Hazardous Noise Warning Decal, 8 inches by 10 1/2 inches (displayed on stationary equipment and all entryways) and Hazardous Noise Labels, 1 inch by 1 1/2 inch (displayed on power tools). These are approved decals and labels for marking hazardous noise areas and equipment.

Remember Builders, you work mainly with power tools and machinery for which the decibels will range from 50 dB (power saws) to 140 dB (radial saw at peak operations), so it is your responsibility to protect your hearing. If you have any further questions regarding hazardous noise areas, do not hesitate to contact your Safety Officer.

### 4.3.2 Sight Conservation

Navy policy requires that Navy personnel exposed to eye hazards be provided adequate eye protection at government expense. The following basic program requirements are to be implemented:

- A complete survey of all activity work areas, equipment, and processes must be conducted to determine which eye hazards exist, which personnel require eye protection, and what type of eye protection is required.
- All areas designated as eye hazards must be posted with the appropriate warning signs. Such signs should be consistent with the requirements of 29 CFR 1910.145 and are to be located at all entrances to designated areas as practical.
- Emergency eyewash stations must be provided in all areas where the eyes of any crewmember may be exposed to corrosive materials.

Remember Builders, your eyesight is the most valuable tool you will ever possess.

For further references to safety, contact your Safety Officer or refer to the O*PNAVINST 5100.23 (series)*, Naval Safety Supervisor course (TRAMAN), and *Army Corps of Engineers, EM-385*.

## Test your Knowledge (Select the Correct Response)

6. What instruction provides the overall guidance for the Navy's safety program?

   A. OPNAVINST 5100.1
   B. OPNAVINST 5100.23
   C. SECNAVINST 5100.2
   D. SECNAVINST 5200.23

# 5.0.0 POLLUTION

Pollution abatement is the responsibility of all Navy personnel, military and civilian. We need to become more innovative in finding ways to reduce pollution in our environment.

Land, air, and water are the three primary parts that make up this planet and are ecologically balanced. When one of the parts is severely damaged, it has an equally damaging effect on the other two parts. It is absolutely essential for us to review practices that have or may have a detrimental effect on the environment and to determine whether measures can be taken to reduce or eliminate these undesirable effects.

Historically, the most prevalent polluters have been in the fields of manufacturing, facilities maintenance, construction, and waste disposal. NCF personnel can do little to control manufacturing pollution. However, they can provide some control over the methods in which many manufactured items are used and the ways in which residues, such as construction waste and potential pollution materials, are disposed of. This is particularly important when it could have an adverse effect on the immediate environment at an NCF job site.

## 5.1.1 Pollution Impact Areas

Nearly all pollution is caused by substances from the following categories of materials:

- **Hazardous.** Any material, substance, chemical, and so forth, that is regulated as hazardous (harmful, exposing one to risk), requiring an MSDS.
- **Nonhazardous.** Any material, substance, chemical, and so forth, that is not regulated and does not require an MSDS.
- **Organic.** A material or substance generally characterized by chains of connected carbon atoms. A larger number of known organic chemicals have been synthesized in the laboratory, and our society is dependent on such synthetic materials as plastics, synthetic fibers, dyes, detergents, and insecticides. The vast majority of synthetic products are derived from petroleum. Ninety percent (90%) of all organic chemicals are made from materials derived from petroleum and natural gas.
- **Inorganic.** This term describes the properties and the behavior of all elements and their compounds (brass, copper, gold, etc.), except for the majority of the carbon compounds which are the domain of organic chemistry. Exceptions to this are carbon monoxide, carbon dioxide, and calcium carbonate.

Environmental protection and hazardous waste disposal are two serious concerns in the NCF today. Cleaners, acids, mastics, sealers, and even paints are just a few of the hazardous materials that may be present on a project site. As a Crew Leader, you are responsible for the protection of your crew and their safety. You are equally responsible for protecting the environment. Stiff fines and penalties that apply to NCF and civilian work may be charged to those who do not protect the environment. The bottom line is that you can go to jail for not providing an environmentally safe job site. Therefore, you should contact your environmental representative or safety office immediately in case of any environmental problem such as a spill, permits, planning, etc.

## 5.2.0 Water and Ground Pollution

Some wastes should never be flushed into a sewer. Sewage treatment plants and industrial waste treatment plants are not designed to, nor can they, adequately treat all wastes. Sewers cannot handle some wastes, such as those containing more than a trace of oil, cleaning fluids, gasoline or other volatile, toxic chemicals, acids or alkalis, and some solid materials.

Besides creating a fire hazard, oil and other petroleum-related products pose many possible pollution threats when they are spilled in the water, dumped into the storm or sanitary sewer system, or spilled on the ground. Oil products on the ground infiltrate and contaminate surface water supplies with the groundwater runoff caused by rain. Oil products dumped or carried into storm or sanitary sewers are also potential explosion hazards.

Collect and dispose of waste oils, filters, and contaminated fuel in a nonpolluting manner. Most naval activities collect and dispose of waste oil periodically through a contractor. The contractor may bum it in a boiler plant or heating system or reprocess it in an oil reclaimer unit. The naval supply fuel farms usually have the means to dispose of waste oils properly.

There will be times when you see what could be a potential hazard, such as contaminated water running off the equipment on the wash rack. It is your responsibility to check with the person in charge of the wash rack to be sure this wastewater is treated and not discharged into the storm system. Provisions must be made for pretreating or separating oil products and cleaning solvents used at the wash rack.

### 5.2.1 Water Pollution

Pollution results from many activities of both mankind and nature. Water becomes polluted when wastes from activities flow into a lake or stream in such quantities that the natural ability of the water to cleanse itself is lessened or completely destroyed.

These wastes have placed a serious strain on our wastewater treatment systems and our waterways. Some types of waste are difficult to remove. Other types respond to conventional treatment, but there are not enough treatment facilities to keep them out of our waters. Solving the pollution problem is not easy, but it must be solved if we are to have an adequate supply of safe, clean water for future use.

An oil slick on the surface of the water blocks the flow of oxygen from the atmosphere into the water. This is harmful to the fish and to other aquatic life. If the fish do not die from the oil coating on their gills or from eating the oil or oil-laden food, their flesh is tainted and they are no longer fit for human consumption. Besides harming aquatic life, oil can contaminate drinking water. Drinking water from wells and surface storage facilities is treated with chemicals to rid the water of harmful bacteria. However, no amount of treatment can rid a system of contamination from waste oil products. The system must be abandoned.

**CAUTION**

Always be careful of what you dispose of and where! READ labels and MSDSs to avoid these types of mishaps.

### 5.2.2 Ground Pollution

Construction site work, repair, and maintenance of facilities have the immediate potential for becoming polluting activities. Since the majority of construction efforts take place on land, Project Supervisors must identify potential pollution hazards and take steps to minimize their effects. Some of the most common pollution activities that affect the ground areas and water ecosystems are grubbing and equipment repair operations.

Large-scale clearing and grubbing during the initial stages of a project often produce damaging environmental effects, such as increased soil erosion, reduction of atmospheric oxygen, and destruction of wildlife habitat. Another primary concern is the introduction of particulate matter into streams and riverbeds. Particulate matter released into waterways causes increased siltation and algae growth.

To prevent these damaging effects, you should save as much vegetation as possible such as trees, grass, and other plants that hold the soil in place. Consider allowing tree rows to be left in place until the project is completed. Replant cleared areas. Construct a shallow trench around the perimeter of a project to help contain water runoff into streams and rivers and to prevent siltation. The decision to burn scrubs and stumps should be based on atmospheric conditions. You should burn only when conditions are favorable and the material to be burned is totally dry. A burn permit is required for all burning operations. To prevent wild fires and smog, do NOT use petroleum-based fuels to start fires. Petroleum-based fuels do not burn completely, and the residue seeps into the underground water table.

## 5.3.0 Air Pollution

As a Crew Leader, be aware of work conditions that cause air pollution and the efforts required to minimize or correct such problems.

When incomplete combustion occurs in base boilers, space heaters, and stoves, the unburned hydrocarbons and the various other fuel components combine chemically to form by-products. Many of these by-products are harmful to people and the environment.

The by-products that have the most adverse effect on the air are carbon monoxide, particulate matter, sulfur oxides, unburned hydrocarbons, nitrogen oxides, and lead. The most effective means of controlling air pollution from incomplete fuel combustion is to maintain the equipment properly and frequently. Another means of lessening air pollution, not always under your control, is the use of only the best grade of fuel. High-grade fuel contains low particulate matter, low water and sulfur content, and few contaminants.

## 5.4.1 Solid Waste

The Environmental Protection Agency (EPA) defines solid waste as “any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant, air pollution control facility, or any other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial (including construction), commercial, mining, or agricultural operations or community activities.” Solid waste is a growing international concern and it has reached critical proportions in many areas.

The present practice of disposing of construction waste by burying the material on site is no longer considered a viable method of disposal. All construction and demolition materials must be disposed of in a safe, logical way to prevent future damage to the ecosystems. Recycling is a very good alternative to disposing of certain material.

Solid wastes are best disposed of in one or more of the following ways:

- Shredding
- Baling
- Source separation
- Recycling
- Comporting

- Incineration
- Landfill disposal

The term *disposal* identifies the point at which the Navy relinquishes control of its solid waste or provides for its ultimate disposal in Navy-operated facilities. The Navy has recycling and incineration facilities currently in operation. In many locations, the Navy uses a heat reclamation unit to produce steam. Each of the disposal methods helps to reduce the initial volume of solid waste, but each method leaves varying amounts of residuals behind that must eventually be deposited in a controlled sanitary landfill facility.

At all levels of society, we must take appropriate action to abate (contain or dispose of) pollution and to preserve the environment by properly disposing of solid waste material.

Since all Navy facilities must conform to the laws and regulations of federal, state, and local environmental agencies, the Navy has produced its own instruction and guidelines. The information developed specifically for Navy use is as follows: *29 CFR 1910 (OSHA), 40 CFR 240-262 (series), OPNAVINST 5090.1 (series), Environmental and Natural Resources Protection Manual; NAVFAC MO-213, Solid Waste Management; and NAVFAC DM 5.10, Solid Waste Disposal.*

### Test your Knowledge (Select the Correct Response)

7. Navy and NCF personnel have the least control over which of the following potential pollution sources?

   A. Commercial manufacturing
   B. Facilities maintenance
   C. Military construction
   D. Waste disposal

8. Of the following methods for disposal of construction project waste, which one is NOT considered viable in the NCF?

   A. Recycling
   B. Shredding
   C. Site burial
   D. Source separations

# 6.0.0 HAZARDOUS MATERIAL CONTROL

The Hazardous Material Control Program is a Navy-wide program that enforces the correct storage, handling, usage, and disposition of hazardous material. Hazardous waste disposal is a serious concern to the NCF today. Cleaners, acids, mastics, sealers, and even paints are just a few of the hazardous materials that may be present in your shop or on your project site. As a Crew Leader, you are responsible for the safety and protection of your crew.

## 6.1.1 Properties of Hazardous Waste

Few discarded materials are so compatible with the environment or so inert as to have no short or long term impact. Hazards that appear minor may have unexpected impacts long after disposal. When two or more hazards pertain to a material, the lesser may not receive the necessary consideration. When two discarded substances are mixed, a chemical reaction with severe and unexpected consequences may result.

Since waste is generally a mixture of many components, its physical and chemical properties cannot be defined with any degree of accuracy. Whenever possible, the approximate composition of a hazardous waste should be ascertained from the originating source or from the manifest accompanying the waste being transported. Generally, when one component predominates, the physical and chemical properties of the waste mixture are nearly those of the major component. This is not true for the hazardous properties of waste mixtures consisting of relatively harmless major components and small amounts of highly toxic, radioactive, or etiologically (disease-producing) active components. The hazard, in this case, is determined by the smaller component.

The EPA defines hazardous solid waste as any material that has the potential to produce the following results:

- Cause, or significantly contribute to, an increase in mortality or any serious, reversible, or incapacitating reversible illness.
- Pose a substantial hazard to human health or the environment when the hazardous material is improperly stored, treated, transported, or disposed of.

By EPA standards, the determining factor for a material to be classified as hazardous waste is that it must meet one or more of the conditions of being ignitable, corrosive, reactive, or toxic, as covered in the following information.

### 6.1.1 Ignitable

- It is a liquid, other than an aqueous solution, containing less than 24 percent alcohol by volume and has a closed-cup flash point of less than 60°C (140°F).
- It is not a liquid, but is capable under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes, and when ignited, burns so vigorously and persistently that it creates a hazard.
- It is an ignitable, flammable compressed gas, which is defined as a gas that forms a flammable mixture when mixed with air at a concentration less than 13 percent (by volume) or has a flammability range with air that is greater than 12 percent, regardless of its lower flammable limit.
- It is an oxidizer, such as a chlorate, permanganate, inorganic peroxide, nitrocarbon nitrate, or a nitrate that yields oxygen readily, and stimulates the combustion of organic matter.

### 6.1.2 Corrosive

- It is a watery solution with a pH less than or equal to 2 or greater than or equal to 12.5.
- It is a liquid that corrodes steel at a rate greater than 6.35 mm (0.25 inch) per year at a test temperature of 55ºC (130ºF).

### 6.1.3 Reactivity

- It is normally unstable and readily undergoes violent change without detonating.
- It reacts violently with water.
- It forms potentially explosive mixtures with water. When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a

danger to human health or to the environment.

- It is a cyanide or sulfide bearing waste that, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or to the environment.
- It is capable of detonation or explosive reaction when it is subjected to a strong initiating source or if heated under confinement.
- It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.
- It is a known forbidden substance or a class A or B explosive.

### 6.1.4 Toxic

- It is a material that contains or degrades into toxic components in concentrations that poses a potential hazard to the environment or to the public health and that may be fatal to humans in low doses.

## 6.2.1 Hazardous Warning Markings and Labels

To determine specific hazards at a glance, refer to the warning markings and labels that identify hazardous materials. Hazardous warning markings and labels are necessary to show clearly the hazardous nature of the contents of packages or containers at all stages of storage, handling, use, and disposal. When unit packages, marked packages that are part of a larger container, are removed from shipping containers, the continuity of the specific hazard warning must be preserved. This is normally done by applying the appropriate identifying hazardous label to the hazardous material container or package.

The Department of Transportation (DOT) labeling system shown in *Figure 1-7* is a diamond-shaped symbol segmented into four parts. The upper three parts reflect hazards relative to health, fire, and reactivity. The lower part reflects the specific hazard peculiar to the material.

There are four specific labels that are designed to illustrate each hazard:

- **Health Hazard (blue, left).** The ability of a material to either directly or indirectly cause temporary or permanent injury or incapacitation.
- **Fire Hazard (red, top).** The ability of the material to bum when it is exposed to a heat source.
- **Reactivity Hazard (yellow, right).** The ability of a material to release energy when it contacts with water. This term can be defined as the tendency of a material, when in its pure state or as a commercially produced product, to polymerize, decompose, condense vigorously, or otherwise become self-reactive and undergo violent chemical changes.
- **Specific Hazard (white, bottom).** This term relates to a special hazard, concerning the particular product or chemical, which was not covered by other labeled hazard items.

The degree of hazard is expressed by a numerical code as follows:

4 = extremely dangerous material

3 = dangerous hazard

2 = moderate hazard

1 = slight hazard

0 = no hazard

**Figure 1-7 – Hazardous Code Chart.**

The example shown in *Figure 1-8* describes the hazards of methyl ethyl ketone. Methyl ethyl ketone is usually found mixed with paints, oils, and greases from solvent cleaning, paint removers, adhesives, and cleaning fluid residues. The numbers on the label identify this chemical compound as follows:

- Health Hazard 2, “Hazardous”
- Fire Hazard 4, “Flash point below 73°F extremely dangerous material”
- Reactivity 3, “Shock or heat may detonate, dangerous material”
- Specific Hazard, “None”

**Figure 1-8 – Hazard warning label for methyl ethyl ketone.**

Other specific labeling requirements are provided in the *NAVSUPINST 5100.27 (series)*. All supervisors are to review this instruction carefully.

## 6.3.0 Hazardous Material Storage

The safest practice concerning hazardous material is for users to draw only the amount of material that can be used that day. On the job site, store hazardous materials in approved storage containers. Place the containers a minimum of 50 feet away from any ignition device or source. Plan for the delivery of proper storage equipment before hazardous materials are delivered to the job site. Since many hazardous materials require separate storage containers; for example, corrosives and flammables cannot be stored together; consult your safety office.

## 6.4.0 Hazardous Material Turn In

Dispose of excess material through an authorized hazardous material disposal facility. The proper labeling of hazardous materials is critical. Properly labeled waste can be disposed of for a relatively low price. Unidentified material must first be analyzed, which is extremely expensive. Any time you turn in hazardous material, include a legible MSDS with the material. This saves valuable time and expense and it makes the job easier for supply.

Avoid mixing unlike types of waste. Do not mix waste paint thinner in a waste oil drum. The Navy sells uncontaminated waste oil for a profit. If only minor amounts of any other substance are present in the waste oil, the Navy must pay high prices for analysis and disposal. The best disposal method is for you to properly label the materials and return them, unmixed, to the supply department. Clearly label each container, preferably with the BM line item or other supply tracking documentation. It is always best for you to check with the battalion MLO staff or safety office for proper disposal procedures.

## 6.5.1 Material Safety Data Sheet

Many different materials are used in the workplace throughout the Navy, most of which are hazardous. A key to the NAVOSH program is informing workers about these hazards and the measures necessary to control hazardous materials. To track all hazardous materials, the Department of Defense (DoD) has established the *Hazardous Material Information System (HMIS), OPNAVINST 5100.23 (series)*, which acquires, stores, and disseminates data on hazardous materials procured for use. This information is readily available through every supply department.

A Material Safety Data Sheet (MSDS) has a variety of formats and is required for each hazardous item procured. The sample shown in *Figure 1-9* is a recommended format from the U.S. Department of Labor. It should be submitted to the procuring activity by the contractor/manufacturer/vendor. The MSDS contains nine sections which provide the user with the following information:

- General information
- Hazardous ingredients
- Physical/chemical characteristics
- Fire and explosion hazard data
- Reactivity data
- Health hazard data
- Spill or leak procedures
- Special protection information
- Control measures/special precautions

| **Material Safety Data Sheet**<br><br>May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements. | **U.S. Department of Labor**<br>Occupational Safety and Health Administration<br>(Non-Mandatory Form)<br>Form Approved<br>OMB No. 1218-0072 |
|---|---|
| IDENTITY (As Used on Label and List) | Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must |

| | |
|---|---|
| | be marked to indicate that. |

**Section I**

| | |
|---|---|
| Manufacturer's Name | Emergency Telephone Number |
| Address (Number, Street, City, State, and ZIP Code) | Telephone Number for Information |
| | Date Prepared |
| | Signature of Preparer *(optional)* |

**Section II - Hazardous Ingredients/Identity Information**

| Hazardous Components (Specific Chemical Identity; Common Name(s)) | OSHA PEL | ACGIH TLV | Other Limits Recommended | %(optional) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Section III - Physical/Chemical Characteristics**

| | | | |
|---|---|---|---|
| Boiling Point | | Specific Gravity ($H_2O$ = 1) | |
| Vapor Pressure (mm Hg) | | Melting Point | |
| Vapor Density (AIR = 1) | | Evaporation Rate (Butyl Acetate = 1) | |
| Solubility in Water | | | |
| Appearance and Odor | | | |

**Section IV - Fire and Explosion Hazard Data**

| | | | |
|---|---|---|---|
| Flash Point (Method Used) | Flammable Limits | LEL | UEL |
| Extinguishing Media | | | |
| Special Fire Fighting Procedures | | | |
| Unusual Fire and Explosion Hazards | | | |

**Section V - Reactivity Data**

| | | | |
|---|---|---|---|
| Stability | Unstable | | Conditions to Avoid |
| | Stable | | |
| Incompatibility (Materials to Avoid) | | | |

<table>
<tr><td colspan="4">Hazardous Decomposition or Byproducts</td></tr>
<tr><td rowspan="2">Hazardous Polymerization</td><td>May Occur</td><td></td><td rowspan="2">Conditions to Avoid</td></tr>
<tr><td>Will Not Occur</td><td></td></tr>
</table>

| **Section VI - Health Hazard Data** | | | |
|---|---|---|---|
| Route(s) of Entry: | Inhalation? | Skin? | Ingestion? |
| Health Hazards (Acute and Chronic) | | | |
| Carcinogenicity: | NTP? | IARC Monographs? | OSHA Regulated? |
| Signs and Symptoms of Exposure | | | |
| Medical Conditions Generally Aggravated by Exposure | | | |

| **Section VII - Precautions for Safe Handling and Use** |
|---|
| Steps to Be Taken in Case Material is Released or Spilled |
| Waste Disposal Method |
| Precautions to Be taken in Handling and Storing |
| Other Precautions |

| **Section VIII - Control Measures** | | |
|---|---|---|
| Respiratory Protection *(Specify Type)* | | |
| Ventilation | Local Exhaust | Special |
| | Mechanical *(General)* | Other |
| Protective Gloves | Eye Protection | |
| Other Protective Clothing or Equipment | | |
| Work/Hygienic Practices | | |

**Figure 1-9 – Material Safety Data Sheet.**

Hazardous materials purchased by the military exchange systems for resale do NOT require Material Safety Data Sheets.

Upon drawing any hazardous material, MLO provides the Crew Leader with an MSDS. The MSDS identifies any hazards associated with exposure to that specific material. It also identifies any personnel protective equipment or other safety precautions required, as well as the needed first aid or medical treatment for exposure. The Crew Leader is required by federal law to inform crew members of the risks and all safety precautions associated with any hazardous material present in the shops or on the job site. Do this during each daily safety lecture. Additionally, the MSDS must be posted conspicuously at the job site, shop spaces, and any other approved hazardous material storage area.

## 6.6.0 Common Hazardous Construction Wastes

Collect refuse of a highly combustible nature, such as dry wastepaper, excelsior (fine wood shavings), and so forth, in metal containers and do not allow them to accumulate. When stored in quantity, keep these materials away from buildings, roadways, and ignition sources by a distance of 50 feet or more. Transport materials to an incinerator or landfill on a frequent schedule to minimize fire hazard.

### 6.6.1 Drying Oils

Rags, paper, paint rollers, brushes, and so forth, that have absorbed drying types of oils, are subject to spontaneous heating. Keep them in well-covered metal cans and thoroughly dry them before collection for transport. Consider for example, the oils listed below. When you apply these oils, the materials used are subject to spontaneous heating and could ignite if not disposed of properly.

- **Linseed oil** is a very common oil made from the flaxseed plant. Researchers find this oil very combustible when it is absorbed by rags and stored improperly. The chemical methyl ethyl ketone, an ingredient of linseed oil, is a highly flammable organic solvent used as a thinner and a drying agent.
- **Tung oil** is a fast drying oil produced from the seed of a Chinese tree and contains the chemical methyl ethyl ketone. Tung oil has a relatively high flash point of 140°F, but the rags used to absorb the oil are very combustible if not disposed of properly.
- **Form oil** is made up of modified polyurethane and resin based materials. Usually applied by spray-on methods but at times applied by rubbed-on or rolled-on methods with various material. These materials are subject to spontaneous heating.

### 6.6.2 Flammable Liquids, Adhesives, and Waste Solvents

Flammable liquids, adhesives, and waste solvents have variable flash points and hence varying hazards, depending upon their composition. Some may contain solids, tars, waxes, and other combustible materials. Chlorinated solvents and water may also be present. Note the following examples:

- **Contact cement** is a rubber or butane based liquid adhesive, which is highly volatile. Methyl ethyl ketone is one of the chemicals in the makeup of this adhesive.
- **Roofing cement** is a petroleum based product with asphalt binders and primers mixed in, and it is NOT environmentally friendly. Disposal of this product is a nightmare for our supply system and landfills.
- **Curing compounds** consist of waxes, chlorinated rubber, resins, and highly volatile solvents. There are water based curing compounds that are environmentally friendly.
- **Oil based paints** consist mainly of a drying oil (usually linseed), and they are mixed with one or more pigments (insoluble solids). The disposal of oil based paints is also a nightmare to the supply system and our landfills.

These construction products are also covered in the *NAVFAC MO 110, Paints and Protective Coatings*.

### 6.6.3 Asbestos

Another air pollutant that you must be knowledgeable of and concerned with is asbestos dust. Asbestos is a fibrous mineral that can be woven like wool. Through a variety of processes, asbestos can be turned into thousands of construction products. These products were used extensively from the 1930s through the 1960s. Asbestos, used by mankind for over 2,500 years, was found to be a health hazard in the early 1980s.

Then, only miners and workers in industrial manufacturing plants were believed to be affected by asbestos. However, as research continued, asbestos was discovered to be the main cause of asbestosis, a generic term for a wide range of asbestos related disorders and mesothelioma. Mesothelioma at one time was a rare form of lung cancer. Now it occurs much more frequently among people exposed to asbestos dust particles.

The three terms associated with asbestos dust particle length that you need to know are *micron, nanometer,* and *angstrom.* To give you an idea of their size, realize that in 1 meter, there are 1 million microns, 1 billion nanometers, and 10 billion angstroms. Within this size range, air that appears to be dust free can contain millions of disease producing asbestos particles. These minuscule asbestos particles have led to many laws, regulations, and clean up problems. These invisible particles can remain suspended in the air for months. To solve this problem, you must take air samples to ascertain the severity of the situation. To remove these particles, the air must be scrubbed with a special air filtration machine, called a High Efficient Particulate Air (HEPA) filtered vacuum. This vacuum will filter out 99.97 percent of asbestos particles from the air.

Normally, asbestos removal is not conducted by NCF personnel. See *COMSECONDNCB/COMTHIRDNCBINST 5100.1 (series)* for detailed guidance on NCF asbestos policy and procedures. However, if you are stationed at an overseas Public Works Department (PWD), you might have to abate this fibrous material. To remove asbestos**,** you must be qualified through the National Asbestos Training Center (NATC) or equivalent agencies. *OPNAVINST 5100.23 (series)* covers asbestos very thoroughly, or you may refer to the *Department of Labor (DOL) or CFR 1910.1001 and* for control of asbestos exposure. For many years, asbestos was used for the following types of applications:

- Roofing, siding, and flooring products
- Friction products, that is, brakes and clutch facings
- Reinforcing materials in cement pipe, concrete asbestos board (CAB), lagging, and thickening agents used in some paints
- Thermal and acoustical insulation

In all cases, you must constantly research the laws governing asbestos. If you continually work with or around asbestos, stay informed of current regulations and laws regulating its use. Asbestos laws are constantly changing and being updated. Legislation is in place to outlaw all forms and uses of asbestos. The Navy has received some exceptions to this, as older installations have asbestos in place that would be too costly to replace. When in doubt about whether you’ve had contact with asbestos, consult your safety office.

## Test your Knowledge (Select the Correct Response)

9. **(True or False)** The EPA classifies material that is highly reactive or corrosive as hazardous waste.

   A. True
   B. False

10. **(True or False)** A Material Safety Data Sheet (MSDS) is required for each hazardous item you procure.

   A. True
   B. False

# Summary

This chapter provides various, but limited insight into the Seabee Skill Assessment, construction administration, training, safety, environmental pollution, and hazardous material. You need to study the information given and the references listed to advance, hone your skills, and become an outstanding Seabee.

## Review Questions (Select the Correct Response)

1. The Seabee Skill Assessment interview process includes which of the following?

   A. Specific skill questions
   B. Critical skill requirements
   C. Pass/fail guidelines
   D. All of the above

2. The preliminary assessment includes which of the following?

   A. Proof of approved course completion
   B. Skills acquired during civilian or military work
   C. Practical experience related to the skill being interviewed
   D. Any of the above

3. What is the first step in the Seabee Skill Assessment?

   A. Explain the scope
   B. Preliminary assessment
   C. Set the atmosphere
   D. Questions

4. What is the NAVFAC manual that provides procedures and skill interview questions for the Seabee Skill Assessment?

   A. NAVFAC P-1049
   B. NAVFAC P-1100
   C. NAVFAC P-1105
   D. NAVFAC P-1410

5. What is the NAVFAC number assigned to the Naval Construction Force (NCF) Manual?

   A. NAVFAC P-315
   B. NAVFAC P-318
   C. NAVFAC P-405
   D. NAVFAC P-458

6. What officer coordinates the training and education of the personnel assigned to an NMCB?

   A. The Company Commander
   B. The Executive Officer
   C. The Operations Officer
   D. The Training Officer

7. What officer is in charge of the S-7 department?

   A. Education Officer
   B. Executive Officer
   C. Operations Officer
   D. Plans/training Officer

8. **(True or False)** To meet training requirements, Public Works and associated non-NCF units must rely heavily on on-the-job training and General Military training.

   A. True
   B. False

9. When used properly, what training method is most effective for providing on-the-job training?

   A. Coach-pupil
   B. Academic
   C. Self study
   D. Group

10. In on-the-job training, the term “group instruction” relates to what other type of instruction?

    A. Classroom
    B. Self study
    C. Piecemeal
    D. Case study

11. **(True or False)** Piecemeal instruction includes letting others know what, when, where, how and why; explaining regulations, procedures, and orders; and holding special meetings.

    A. True
    B. False

12. Interviews between the trainee and the trainer in a developmental on-the-job training program do NOT accomplish which of the following objectives?

    A. Establishing specific training requirements
    B. Formulating overall training objectives
    C. Assessing progress of the trainee
    D. Resolving trainee questions

13. **(True or False)** The most valuable end product of a peacetime military operation is a well trained person.

    A. True
    B. False

14. Which, if any, of the following methods would be effective in evaluating the success of a training program?

    A. Checking the work schedule backlog
    B. Spot checking work performance
    C. Testing the trainee
    D. None of the above

15. **(True or False)** Your supervisor expects you to meet production requirements and conduct training and to learn the process of paperwork.

    A. True
    B. False

16. **(True or False)** When planning a project, you must consider the capabilities of your crew.

    A. True
    B. False

17. As the Crew Leader, you are responsible for the time management for each crew member. When is the best time to confirm plans for the next workday?

    A. At the beginning of each day
    B. At the beginning of each week
    C. At the close of each day
    D. At the close of each week

18. For you to plan a project properly, you must be able to ORGANIZE. What is the first step in organizing a project?

    A. Plan for the equipment
    B. Plan the job sequences
    C. Schedule the material
    D. Schedule the tools

19. **(True or False)** One of the most important attributes a good supervisor has is the ability to maintain firm control and to delegate authority as little as possible.

    A. True
    B. False

20. To get maximum production with minimum effort and confusion, you must

    A. gain firm control
    B. schedule daily staff meetings
    C. plan, organize, and coordinate
    D. make the resolution of complaints from your subordinates a top priority

21. **(True or False)** By delegating authority, you are relieved of the responsibility for a project.

A. True
B. False

22. When filling out a time card, you annotate what labor code for labor that does not produce an end product itself?

A. Direct
B. Indirect
C. Overhead
D. Training

23. What report provides the information needed by the operations office to analyze the labor distribution of total manpower resources for each day?

A. Direct Labor Report
B. MANREP
C. Ops Report
D. SITREP

24. **(True or False)** The goal of any safety program is to prevent mishaps.

A. True
B. False

25. What serious hazard category constitutes a severe personnel injury?

A.I
B.II
C.III
D.IV

26. When a mishap occurs in your shop, you must submit an accident/mishap report to what person?

A. The NAVOSH manager
B. The Operations Officer
C. The Project Manager
D. The Safety Officer

27. The Navy's permissible exposure limit (NEPL) for occupational noise is set at what number of decibels?

A. 75
B. 84
C. 96
D. 99

28. **(True or False)** Eyesight is the most valuable tool a Builder will ever possess.

A. True
B. False

29. An oil slick on a water surface blocks the flow of what element from the atmosphere into the water?

A. Carbon dioxide
B. Hydrogen
C. Oxygen
D. Ozone

30. Petroleum-based fuels should not be used for burning brush, scrub, and stumps for which of the following reasons?

A. They are too expensive to waste on scrub burning.
B. They become carcinogenic when mixed with water.
C. They coagulate and become solids, creating an impermeable soil strata.
D. They do not burn completely and may seep into the underground water table.

31. When unburned hydrocarbons and various other fuel components combine chemically, which of the following by-products is normally formed?

A. Carbon dioxide
B. Carbon monoxide
C. Lead sulfate
D. Sulfur dioxide

32. A liquid that corrodes steel at a rate greater than 6.35 mm per year at 130°F test temperature presents what type of hazard?

A. Corrosive
B. Ignitable
C. Reactivity
D. Toxic

33. A material that normally is unstable and can readily undergo violent change without detonating presents what type of hazard?

A. Corrosive
B. Ignitable
C. Reactivity
D. Toxic

34. A material that can degrade into components that are poisonous, even in low doses, to the environment or to the public health presents what type of hazard?

A. Corrosive
B. Ignitability
C. Reactivity
D. Toxic

In answering Questions 35 through 37, refer to the figure to the right.

**Hazard warning label for methyl ethyl ketone.**

35. According to the example shown, what is the flash point of this material?

A. Above 200°F
B. 200°F and below
C. Below 100°F
D. Below 73°F

36. According to the example shown, what is the reactivity hazard of this material?

A. Oxidizes rapidly
B. Shock or heat may detonate
C. Unstable if chilled
D. Violent chemical

37. According to the example shown, what is the health hazard of this material?

A. Deadly
B. Extreme danger
C. Hazardous
D. Slightly hazardous

38. Project storage areas for combustible materials should be separated from other sources of ignition by what minimum distance?

A. 10 feet
B. 20 feet
C. 50 feet
D. 60 feet

39. What type of highly combustible drying oil is made from the flaxseed plant?

A. Canola oil
B. Form oil
C. Linseed oil
D. Tung oil

40. Methyl ethyl ketone is one of the chemicals used to produce which of the following products?

A. Canola oil
B. Contact cement
C. Form oil
D. Roofing cement

41. **(True or False)** Oil based paints are made from drying oils and insoluble solids.

A. True
B. False

42. The size of asbestos particles detected in the air is reported in terms of what measurements?

A. Centimeter, micron, nanometer
B. Centimeter, millimeter, micron
C. Micron, nanometer, angstrom
D. Millimeter, micron, angstrom

43. **(True or False)** A High Efficient Particulate Air (HEPA) filtered vacuum is used to scrub asbestos particles from contaminated air.

A. True
B. False

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

**NOTE**

Although the following references were current when this NRTC was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology or revised methods, practices, or procedures; therefore, you need to ensure that you are studying the latest references.

Environment and Natural Resources Protection Manual, OPNAVINST 5090.1 (series), Department of the Navy, Washington, DC, 1994.

*Military Requirements for Petty Officer Second Class, NAVEDTRA 12045*, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1987.

*Military Requirements for Petty Officer First Class, NAVEDTRA 12046*, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1987.

*Naval Construction Force Manual, NAVFAC P-315*, Naval Facilities Engineering Command, Alexandria, VA, 1988.

*NCF Occupational Safety and Health Program Manual, COMSECONDNCBI COMTHIRDNCBINST 5100.1 (series)*, Commander, Second Naval Construction Brigade, Norfolk, VA, and Commander, Third Naval Construction Brigade, Pearl Harbor, HI, 1992.

*NCF/Seabee 1 & C, NAVEDTRA 12543*, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

NMCB Operations Officer's Handbook, COMSECONDNCB/COMTHIRDNCBINST 5200.2, Naval Facilities Engineering Command, Alexandria, VA, 1988.

Occupational Safety and Health Program Manual, OPNAVINST 5100.23 (series), Department of the Navy, Washington, DC, 1992.

Organization and Functions for Public Works Departments, NAVFAC P-318, Naval Facilities Engineering Command, Alexandria, VA, 1985.

*Paints and Protective Coatings, NAVFAC MO-322*, Naval Facilities Engineering Command, Alexandria, VA, 1984.

*Personnel Readiness Capability Program, NAVFAC P-458*, Naval Facilities Engineering Command, Alexandria, VA, 1981.

*Procedures for Naval Construction Force Timekeeping, COMSECONDNCBI COMTHIRDNCBINST 5312.1*, Commander, Second Naval Construction Brigade, Norfolk,VA, and Commander, Third Naval Construction Brigade, Pearl Harbor, HI, 1985.

Safety and Health Requirements Manual, EM 385-1-1, Department of the Army, Washington, DC, 1992.

*Seabee Crewleader's Handbook*, Civil Engineering Corps Officer School (CECOS) CBC, Port Heuneme, CA, 1997.

*Seabee Planner's and Estimator Handbook*, NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

http://www.osha.gov/dsg/hazcom/msds-osha174/msdsform.html

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write or email us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

________________________________________________

________________________________________________

________________________________________________

(Optional) Correction

________________________________________________

________________________________________________

________________________________________________

(Optional) Your Name and Address

________________________________________________

________________________________________________

________________________________________________

# Chapter 2

# Planning, Estimating, and Scheduling

## Topics



To hear audio, click on the box.

## Overview

Good construction planning and estimating procedures are essential for any Seabee. They enable Seabees to provide quality construction to the customer. This chapter gives you helpful information for planning, estimating, and scheduling construction projects normally undertaken by Seabees. It will help you understand the concepts and principles, but it is NOT intended to be a reference or to establish procedures. Planning, estimating, and scheduling can be done by various techniques. This chapter describes suggested, proven methods that result in effective planning and estimating. Your responsibility is to decide how and when to apply these techniques.

To plan any project, you must first be familiar with the construction drawings and specifications for that project. The construction of any structure or facility is described by a set of related drawings that gives the Seabees a complete sequential graphic description of each phase of the construction process. In most cases, a set of drawings shows the location of the project, the boundaries, contours, and outstanding physical features of the construction site and its adjoining areas. Succeeding drawings give further graphic and printed instructions for each phase of construction.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the categories of construction drawings based on their intended purpose.
2. Identify the policy and procedures for preparing and developing complete, accurate, and explicit drawings to use in contracts for the construction of naval facilities.
3. Identify the main divisions of project drawings used in Seabee construction.
4. Understand how detailed written instructions define and limit materials and

fabrication to the intent of the engineer or designer.

5. Identify the major components of planning, including understanding the plans and specifications and understanding and analyzing the available resources. Identify the basic components of network analysis.
6. Understand how to determine the amount and type of work to be performed and the quantities of material, equipment, and labor required.
7. Understand how to determine when an action must be taken and when material, equipment, and manpower are required. Identify the four basic types of schedules.
8. Understand the importance of Engineered Performance Standards (EPS) in facilities maintenance and repair standards.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

<table>
<tr><td>Advanced Base Functional Components and Field Structures</td><td rowspan="9">↑</td><td rowspan="9">B<br>U<br>I<br>L<br>D<br>E<br>R<br><br>A<br>D<br>V<br>A<br>N<br>C<br>E<br>D</td></tr>
<tr><td>Heavy Construction</td></tr>
<tr><td>Maintenance Inspections</td></tr>
<tr><td>Quality Control</td></tr>
<tr><td>Shop Organization and Millworking</td></tr>
<tr><td>Masonry Construction</td></tr>
<tr><td>Concrete Construction</td></tr>
<tr><td>Planning, Estimating, and Scheduling</td></tr>
<tr><td>Technical Administration</td></tr>
</table>

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is

incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.0.0 Types of Construction Drawings

Drawings are generally categorized according to their intended purposes. This section covers some of the types of drawings commonly used in military construction.

## 1.1.0 Master Plan Drawings

Master Plan Drawings are commonly used in architecture, topography, and construction. They show sufficient features to be used as guides in long-range area development. They usually contain section boundary lines, horizontal and vertical control data, acreage, locations and descriptions of existing and proposed structures, existing and proposed surfaced and unsurfaced roads and sidewalks, streams, rights-of-way and appurtenances, existing utilities, north point indicator (arrow), contour lines, and profiles. Master plan and general development drawings on existing and proposed Navy installations are maintained and constantly upgraded by the Resident Officer in Charge of Construction (ROICC) and the Public Works Department (PWD).

## 1.2.0 Presentation Drawings

Presentation Drawings present the proposed building or facility in an attractive setting in its natural surroundings at the proposed site. These often consist of perspective views complete with colors and shading. Presentation drawings are actually used to sell an idea or a design concept.

## 1.3.0 Shop Drawings

Shop Drawings are drawings, schedules, diagrams, and other related data used to illustrate a material, product, or system for some portion of the work prepared by the construction contractor, subcontractor, manufacturer, distributor, or supplier. Product data include brochures, illustrations, performance charts, and other information by which the work will be judged. As a Builder, you may be required to draft shop drawings for minor shop and field projects. Whenever possible, let the Engineering Aids do these drawings.

## 1.4.0 Working Drawings

A Working Drawing, also called a project drawing, is any drawing that furnishes the information the craftsmen requires to manufacture a machine part or a builder crew requires to erect a structure; it is prepared from a freehand sketch or design drawing. The information presented in a set of working drawings is complete enough that the user requires no further information. Project drawings include all of the drawings necessary for the different Seabee ratings to complete the project. These are the drawings that show the size, quantity, location, and relationship of the building components.

A complete set of project drawings consists of general drawings, detail drawings, and assembly drawings. General drawings consist of plans (views from above) and elevations (side or front views) drawn on a relatively small defined scale, such as 1/8 inch = 1 foot. Most of the general drawings are drawn in orthographic projections, although sometimes details may be shown in isometric or cavalier projections. Detail drawings show a particular item on a larger scale than that of the general drawing in which the item appears, or it may show an item that is too small to appear at all on a general drawing. Assembly drawings are either an exterior or a sectional view of an object showing the details in the proper relationship to one another. Usually, assembly drawings are drawn to a smaller scale than are detail drawings. This procedure provides a check on the accuracy of the design of detail drawings and often discloses errors.

Construction drawings are reviewed and evaluated for design and technical accuracy by NAVFACENGCOM to ensure the good quality, consistency, and cost effectiveness of the design. Special terms covered in the following paragraphs describe these procedures from the initial development of the project to the final phase of construction.

## 1.5.1 Preliminary Drawings

Preliminary Drawings are the initial plans for projects prepared by the designer or architect's and engineer's (A/E) firm during the early planning or promotional stage of the building development. They provide a means of communication between the designer and the user (customer). These drawings are NOT intended to be used for construction, but for exploring design concepts, material selection, preliminary cost estimates, approval by the customer, and as a basis for the preparation of finished working drawings.

Notice that most of the design work incorporated into the preliminary drawings at the 35 percent stage of completion contains, as a minimum, the following information:

- Site plans
- Architectural floor plans
- Elevations
- Building sections
- Preliminary finish schedule and furniture layouts
- Interior and exterior mechanical and electrical data
- Civil and structural details

All of the preliminary project drawings scheduled for use by the Seabees are reviewed by the COMSECONDNCB or COMTHIRDNCB, as appropriate, for construction methods or procedures; preliminary contract drawings are reviewed by the ROICC.

## 1.6.0 Final Drawings

Final Drawings are 100 percent complete, signed by the contracting officer, and used for bidding purposes. This set of plans becomes the official contract drawings once the contract is awarded. Final drawings are often revised to show changes made by a scope change or by a change order with the concurrence of both the contractor and the contracting officer. At this stage of completion, no further functional input may be introduced into the final drawings because of time constraints. In general, final drawings, together with project specifications, cost estimates, and all of the calculations, comprise the final stages of design requirements.

## 1.7.0 Red-Lined Drawings

Red-Lined Drawings are the official contract drawings that you will mark up during construction to show as-built conditions. They are marked in the color red to indicate either a minor design change or a field adjustment.

### 1.8.0 As-Built Drawings

As-Built Drawings are the original contract drawings (or sepia copies) that you will change to show the conditions from the red-lined drawings. When the facilities have been completed, the construction contractor or the military construction force (NMCB) is required to provide the ROICC with as-built drawings, indicating construction deviations from the contract drawings. All of the as-built marked up prints must reflect the exact conditions on all features of the project as constructed. After the project is completed, the ROICC transmits the as-built marked up prints to the engineering field division (EFD).

### 1.9.0 Record Drawings

The original contract drawings, corrected according to the marked prints, provide a permanent record of as-built conditions when the construction work on a project is completed. The original Record Drawings may be retained in the custody of the EFD or transferred to the station commanding officer in a current status.

### Test your Knowledge (Select the Correct Response)

1. To plan a project, you must be familiar with which of the following documents?

   A. Master plan and presentation drawing
   B. Working and detail drawings
   C. Construction drawings and specifications
   D. Final and as-built drawings

## 2.0.0 Project Drawings Preparation

All Naval Facilities Engineering Command (NAVFACENGCOM) project drawings are prepared according to DoD-STD-100. The policy and procedures for preparing and developing these drawings are outlined in the *Military Handbook,* MIL-HDBK 1006/1. Project drawings must be complete, accurate, and explicit since they, together with the design specifications, form the basic ingredients used in contracts for the construction of naval facilities.

### 2.1.0 Policy and Standards

The design criteria for project drawings are set by NAVFACENGCOM. These criteria also apply to definitive designs and standard drawings and to project specifications. EFDs and A/Es are allowed latitude in new concepts, creative thinking, and the use of new materials; however, when they consider deviations from mandatory criteria, EFDs and A/Es need to obtain prior clearance from NAVFACENGCOM headquarters.

For dimensions on project drawings, use customary U.S. dimensions unless the project is in an area in which System International (SI) is normally used. The International System of Units is the internationally accepted metric system. Refer to ASTM E380-82, *Standard for Metric Practice,* for generic conversions and ASTM E621-79, *Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction,* for conversions in engineering and design.

## 2.2.1 Order of Drawings

Project drawings for buildings and structures are arranged in the following order:

1. Title Sheet and Index – Contains specific project title and an index of drawings. Used only for projects containing 60 or more drawings.
2. Site or Plot Plans – Contains either site or plot plans or both, as well as civil and utility plans. For small projects, this sheet should include an index of drawings.
3. Landscape and Irrigation – If applicable.
4. Architectural – Including interior design as applicable.
5. Structural
6. Mechanical – Heating, ventilation, and air conditioning.
7. Plumbing
8. Electrical
9. Fire Protection

## 2.3.0 Drawing Sheet Sizes

Standard drawing sheet sizes are used to facilitate readability, reproduction, handling, and uniform filing. Blueprints, produced from standard size drawing sheets, are easily assembled insets for project stick files. The NCF uses two format sizes. These are flat and roll sizes according to ANSI Y14.1, and they are approved for use by DoD-STD-100. Flat size refers to drawings that are relatively small in size and should be stored or filed flat. Roll size refers to drawings that are filed in rolls due to their length. *Table 2-1* shows several standard flat sizes for drawing sheets.

**Table 2-1 – Standard Flat Sizes for Drawing Sheets.**

| Type | Size (in inches) | Description |
|---|---|---|
| Flat (C size) | 17 x 22 | When small sheets are required |
| Flat (D size) | 22 x 34 | For project and other drawings |
| Flat (F size) | 28 x 40 | Option to 22 x 34 |

## 2.4.1 Title Block

The title block identifies each sheet in a set of drawings, as shown in *Figure 2-1*.

| | | | | |
|---|---|---|---|---|
| DSGN | DEPARTMENT OF THE NAVY | | | WASHINGTON, D.C. |
| DR | | | | |
| CHK | NAVAL FACILITIES ENGINEERING COMMAND | | | |
| PROJ LDR | | | | |
| BR HD | | | | |
| SPL DES HD | | | | |
| DIRECTOR | | | | |
| APPROVED<br>DATE | SIZE | CODE IDENT NO.<br>**80091** | NAVFAC DRAWING NO. | |
| | | | CONSTR CONTR NO. | |
| FOR COMMANDER, NAVFAC | SCALE | | SPEC | SHEET OF |

**Figure 2-1 – Title block.**

Generally, the title block is located at the bottom right corner of the drawing, regardless of the size of the drawing (except for vertical title block). For further information on the layout of title blocks, refer to the *Military Handbook,* MIL-HDBK 1006/1, or the *Engineering Aid Basic,* NAVEDTRA 12535.

The information provided in the title block is very important information that you, the Builder, MUST understand. In addition to the size of the drawing, other information provided in the title block is as follows:

- Architect’s name
- Architect’s seal
- Drawing title
- Date prepared
- Revisions
- Designed by
- Checked by
- Drawing numbers
- Name of local activity
- Code ID number (80091 NAVFAC)
- Letter designation
- Size of drawing
- Scale of drawing
- ABFC drawing number (if applicable)

- Approved by

There are many variations to title blocks, depending on the preparing activity (NAVFAC, NCR, NMCB, A&E, etc.). All title blocks should contain the same information listed previously, regardless of the format used by the preparing activity. The code ID number of the Federal Supply Code of Manufacturers (FSCM) "80091" is required in the title block of all NAVFAC drawings. The layout and title blocks are also shown in the *American National Standard Institute* (ANSI Y14.1-1980) manual.

## 2.5.0 Drawing Numbers

NAVFACENGCOM drawing numbers issued to individual engineering field divisions are within the limits shown in *Table 2-2*.

**Table 2-2 – Drawing Number Ranges by Division.**

| **Division** | **Range** | | |
|---|---|---|---|
| Northern Division | 2 000 000 | to | 2 999 999 |
| Chesapeake Division | 3 000 000 | to | 3 999 999 |
| Atlantic Division | 4 000 000 | to | 4 999 999 |
| Southern Division | 5 000 000 | to | 5 999 999 |
| Western Division | 6 000 000 | to | 6 999 999 |
| Pacific Division | 7 000 000 | to | 7 999 999 |

NAVFACENGCOM headquarters retains custody of all of the numbers up to and including 1 999999 and all other drawing numbers not assigned. Each cognizant EFD is responsible for the control of assigned numbers and for issuing, assigning, and recording these numbers for its own use or the use of activities within its geographical area. Each activity maintains an assignment record including locations and drawing titles of drawing numbers assigned to it. *Figure 2-2* is an example of a local activity, such as the Civil Engineering Support Office (CESO), using a drawing number assigned by the Western Division (WESTDIV).

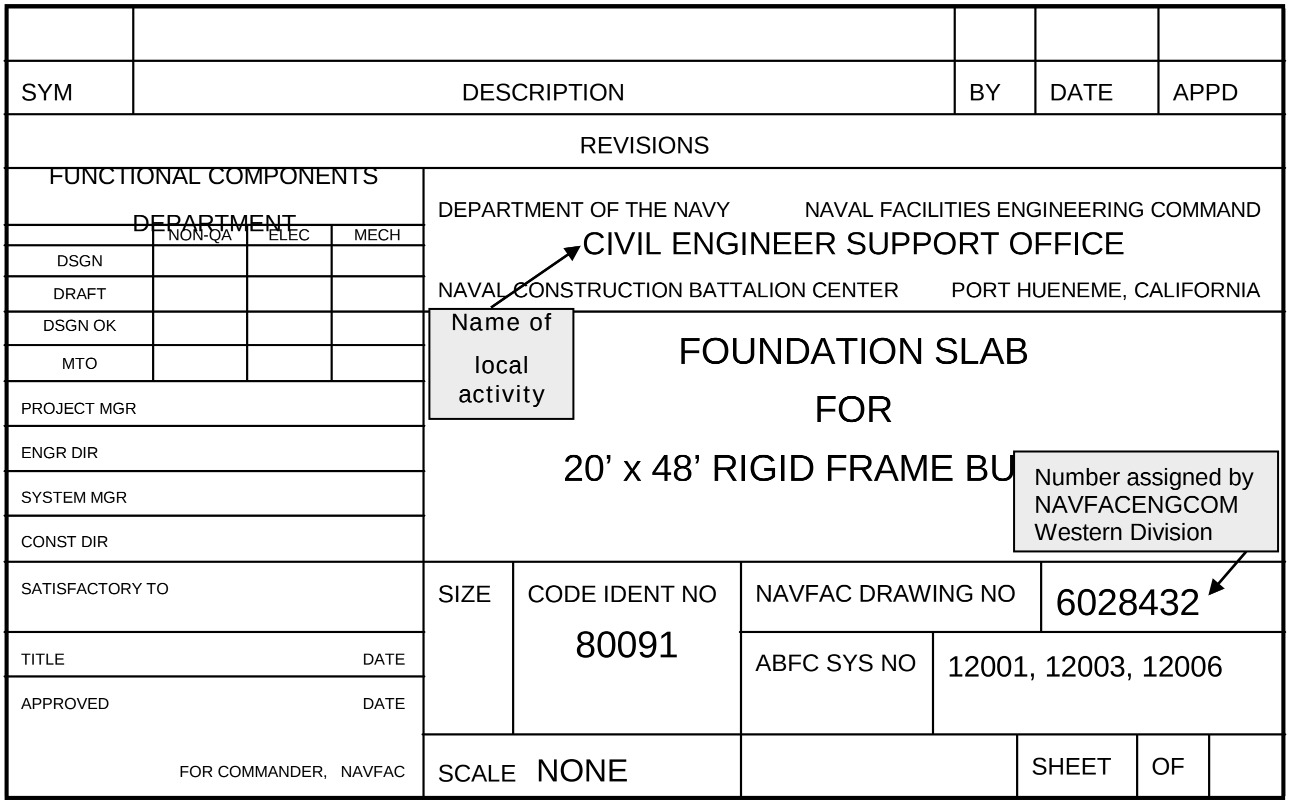



**Figure 2-2 – CESO drawing number.**

You may not use a NAVFACENGCOM assigned number for any other drawing, even though the drawing to which it has been assigned is not being used. Sometimes, because of extensive revision on a particular drawing, it becomes necessary to prepare a new drawing and to assign a new NAVFACENGCOM drawing number.

If you find major problems within a drawing, you can identify who prepared the drawing by these drawing numbers. Make sure you communicate through your chain of command before contacting these divisions.

## 2.6.0 Drawing Revisions

A Revision block contains a list of revisions made to a drawing. The Revision block is in the upper right-hand corner. Drawing revisions to NAVFACENGCOM project drawings are made according to DoD-STD-100C. The Revision block may include a separate PREPARED BY column to indicate the organization, such as an A/E firm, that prepared the revision. Like title blocks, revision blocks may vary in format with each command.

## 2.7.0 Graphic Scales

Graphic scales are in the lower right-hand corner of each drawing sheet with the words *Graphic Scales* directly over them. Each drawing must prominently show the correct graphic scales, because as drawings are reduced in size, the reductions are often NOT to scaled proportions. Remember, scale a drawing only as a last resort.

## 2.8.0 Drawing Symbols

Because of the small scale used in most drawings, standard graphic symbols are used to present complete information concerning construction items and materials. Because these typical symbols are used so frequently in construction drawings, their meanings must be familiar not only to the preparer, but also to the user. The main information sources for a particular symbol are the Military (Drawing) Standards (MIL-STD) and the American National Standards Institute (ANSI). Refer to these standards before using other references. *Table 2-3* shows a list of the most commonly used military standards.

**Table 2-3 – Commonly Used Military Standards for Drawing Symbols.**

| Standard | Description |
|---|---|
| MIL-STD-14 | Architectural Symbols |
| MIL-STD-17-1 | Mechanical Symbols |
| MIL-STD-18 | Structural Symbols |
| ANSI Y32.9-1972 | Graphic Symbols for Electrical Wiring and Layout Diagrams Used in Architectural and Building Construction |
| ANSI Y32.4-1977 | Graphic Symbols for Plumbing Fixtures for Diagrams Used in Architectural and Building Construction |
| NSI/AWS A2.4-1986 | Symbols for Welding |

As a Builder, you will find that your knowledge of the applicable symbols will assist you greatly in doing the job correctly and promptly, and above all, with confidence. *Figure 2-3* shows symbols used to identify sections, elevations, and details that are commonly misinterpreted.

**Figure 2-3 – Symbols used to identify sections, elevations, and details.**

Some of the basic architectural symbols, as shown in *Figure 2-4*, are commonly found on site or plot plans.

**Figure 2-4 – Sample legend of symbols.**

Structural symbols are shown in NAVFAC P-405, the *Steelworker Basic NRTC*, and the *Engineering Aid Basic NRTC.*

## 2.9.0 Drawing Notes

Notes are brief, clear, and explicit statements regarding material use and finish and construction methods. Notes in a construction drawing are classified as specific and general.

### 2.9.1 Specific Notes

Specific Notes are used either to reflect dimensioning information on the drawing or to be explanatory. As a means of saving space, many of the terms used in these notes are expressed as abbreviations.

### 2.9.2 General Notes

General Notes refer to all of the notes on the drawing not accompanied by a leader and an arrowhead. As used in this manual, general notes for a set of drawings that cover one particular type of work are placed on the first sheet of the set. General notes are usually placed a minimum of 3 inches below the Revision block. General notes for architectural and structural drawings may include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable unit stresses of all the construction materials used in the design. General notes for civil, mechanical, electrical, sanitary, plumbing, and similar drawings of a set may include, when applicable, references for vertical and horizontal control, including sounding, and basic specific design data.

General notes may also refer to all of the notes grouped according to materials of construction in a tabular form, called a Schedule. Schedules for items like doors, windows, rooms, and footings are somewhat more detailed. Formats for these are covered later in this chapter.

## Test your Knowledge (Select the Correct Response)

2. In the preparation of construction drawings, most engineers use symbols adopted by what authority?

   A. National Association of Home Builders
   B. American Engineering Society
   C. National Institute of Construction Engineers
   D. American National Standards Institute

## 3.1.1 Main Divisions of Project Drawings

Generally, working or project drawings are divided into the following major divisions:

- Civil
- Architectural
- Structural
- Mechanical
- Electrical
- HVAC
- Fire protection

In Seabee construction, the major divisions most commonly used are as follows:

- Civil
- Architectural
- Structural
- Mechanical

- Electrical

As a Builder, you will deal mainly with the civil, architectural, and structural divisions. For the electrical division, refer to the *Construction Electrician (CE) Advanced NRTC* along with the fire protection division. For information pertaining to the mechanical division, along with heating, venting, and air conditioning (HVAC), refer to the *Utilitiesman Advanced NRTC.*

Regardless of the category, working drawings serve the following functions:

- They provide a basis for making material, labor, and equipment estimates before construction begins.
- They give instructions for construction, showing the sizes and locations of the various parts.
- They provide a means of coordination between the different ratings.
- They complement the specifications; one source of information is incomplete without the others.

### 3.1.1 Civil Drawings

Civil Working Drawings encompass a variety of plans and information, including the following:

- Site preparation and site development
- Fencing
- Rigid and flexible pavements for roads and walkways
- Environmental pollution control
- Water supply units (pumps and wells)

Depending on the size of the construction project, the number of sheets in a set of civil drawings may vary from a bare minimum to several sheets of related drawings. Generally, on an average size project, the first sheet has a location map, soil boring log, legends, and sometimes site plans and small civil detail drawings. Soil boring tests are conducted to determine the water table of the construction site and to classify the existing soil. Civil drawings are often identified with the designating letter C on their title blocks.

A Site Plan, as shown in *Figure 2-5*, furnishes the essential data for laying out the proposed building lines. It is drawn from notes and sketches based upon a survey. It shows the contours, boundaries, roads, utilities, trees, structures, references, and other significant physical features on or near the construction site. By showing both existing and finished contours, the field crews (Equipment Operators) are able to estimate and prepare the site for construction and to finish the site, including landscaping, upon completion of construction. As a Builder, you should be familiar with the methods and symbols used on maps and topographic drawings. Site plans are drawn to scale. In most instances, the engineer’s scale is used, rather than the architect’s scale. Refer to the *Engineering Aid Basic NRTC* and the *Engineering Aid Advanced NRTC* for more information.

**Figure 2-5 – Site plan.**

### 3.2.1 Architectural Drawings

Architectural Drawings are identified with the designating letter A on their title blocks. These drawings consist of all the architectural design and composition of the building. A set of architectural drawings includes the following:

- Floor plans
- Building sections
- Exterior and interior elevations
- Millwork details and schedules
- Door and window details and schedules
- Interior and exterior finish schedules
- Special architectural treatments

For small, uncomplicated buildings, the architectural drawings might also include foundation and framing plans, which are generally included as part of the structural drawings.

### 3.2.1 Floor Plan

The Floor Plan is the key drawing in a set of project drawings, the drawing that all of the construction personnel look at. The purpose of the floor plan is to show the following information:

- Location and type of construction
- Location of doors and windows
- Location of built-in fireplaces
- Location of stairs
- Location of rooms
- Location of exterior and interior features

Ideally, drawings of floor plans should be drawn to 1/4 inch = 1 foot scale for easy readability. *Figure 2-6* represents a drawing of a first-floor plan.

**Figure 2-6 – A first-floor plan.**

### 3.2.2 Elevations

Elevations are orthographic projections showing the finished interior and exterior appearance of the structure. Interior elevations are required for important features such as built-in cabinets and shelves, but it is not uncommon for elevations to be drawn for all interior walls in each room of a building. Cabinet elevations show the cabinet lengths and heights, distance between base cabinets and wall cabinets, shelf arrangements, doors and direction of door swings, and materials used. Interior wall elevations show wall lengths, finished floor-to-ceiling heights, doors, windows, other openings, and the types of finish materials used.

Exterior elevations show the types of materials used on the exterior, the finished grade around the structure, the roof slope, the basement or foundation walls, footings, and all of the vertical dimensions.

Basically, the following four elevations are needed in a set of drawings to complete the exterior description: the front, the rear, and two sides of a structure as they would appear projected on vertical planes. A typical elevation is drawn at the same scale as the floor plan, either 1/4 inch = 1 foot or 1/8 inch = 1 foot. Occasionally, a smaller scale may be used because of space limitations, or a larger scale maybe used to show more detail.

Several methods are used to identify each elevation as it relates to the floor plan. The method Seabees most commonly use is labeling the elevations with the same terminology used in multi-view and orthographic projection: Front, Rear, Right Side, and Left Side Elevations or sometimes North, South, East, and West.

## 3.3.0 Structural Drawings

The Structural Drawings, usually identified with the designating letter S on the title block, consist of all of the drawings that describe the structural members of the building and their relationship to each other. A set of structural drawings includes foundation plans and details, framing plans and details, wall sections, column and beam details, and other plans, sections, details, and schedules necessary to describe the structural components of the building or structure. The general notes in the structural drawings also include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable stresses of all material used in the design.

### 3.3.1 Foundation Plan

A Foundation Plan is a top view of the footings or foundation walls showing their area and their location by distances between centerlines and by distances from reference lines or boundary lines. It is a horizontal section view cut through the walls of the foundation and showing beams, girders, piers or columns, and openings, along with dimensions and internal composition.

Primarily, the building crew uses the foundation plan to construct the foundation of the proposed structure. In most Seabee construction, foundations are built with concrete masonry units (CMU) or cast-in-place concrete. *Figure 2-7* shows a plan view of a 20’ x 48’ PEB as it would look if projected into a horizontal plane that passes through the structure. Notice that this typical drawing shows only the placement of the anchor bolts, along with a typical detailed drawing of the footing, the column, and the slab.

**Figure 2-7 – Foundation plan with detail drawings.**

### 3.3.2 Framing Plan

The Framing Plans show the size, the number, and the location of the structural members constituting the building framework. Separate framing plans are drawn for the floors and roofs. Occasionally, the Draftsman will draw a wall framing plan; wall framing plans are generally viewed in the sectional views or detail drawings.

The Floor Framing Plan must specify the sizes and spacing of the joists, girders, and columns used to support the floor. Detail drawings must be added, if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings.

The floor framing plan is basically a plan view showing the layout of the girders and joists. *Figure 2-8* shows the manner of presenting floor framing plans. The unbroken double-line symbol indicates joists. Joist symbols are drawn in the position they will occupy in the completed building. Double framing around openings and beneath bathroom fixtures is shown where used. Bridging is also shown by a double-line symbol that runs perpendicularly to the joist. In *Figure 2-9*, the number of rows of cross bridging is controlled by the span of the joist; place the rows no more than 8 feet apart. A 14-foot span may need only one row of bridging, but a 16-foot span needs two rows.

**Figure 2-8 – Floor framing plan.**

Dimensions need not be given between joists. Such information is given along with the notes. For example, 2'' x 8'' joists @ 2’-0” OC indicates that the joists are to be spaced at intervals of 2 feet 0 inches on center (OC). Lengths may not be indicated in framing plans; the overall building dimensions and the dimensions for each bay or distances between columns or posts provide such data. Notes also identify floor openings, bridging, girts, or plates.

The Roof Framing Plans show the construction of the railers used to span the building and support the roof. The plan also shows the size, spacing, roof slope, and all of the details. The roof framing plan is drawn in the same manner as the floor framing plan; it shows rafters in the same manner as joists. *Figure 2-9* is an example of a roof framing plan for a wood-framed roof.

**Figure 2-9 – Roof framing plan.**

Roof framing plans in the construction world today are very technical and highly engineered for wind resistance, load bearing capacity, etc. In most stick frame construction, pre-fab yards or truss manufacturers from the civilian sector provide your roof systems.

### 3.3.3 Sections

Sections are used as necessary in each of the main divisions of construction drawings to show the types of construction required, the types of materials used, their locations, and the method of assembling the building parts. Although they may be used in each of the divisions, the most common sections are generally located in the architectural and structural divisions.

All properly prepared sections are important to those responsible for constructing a building. To Builders, the most important sectional drawings are the wall sections, such as those shown in *Figure 2-10*.

**Figure 2-10 – Sectional view.**

These sections, commonly drawn at a scale of 3/4 inch = 1 foot and normally located in the structural division, provide a wealth of information necessary to understand structural arrangement, construction methods, and material composition of the walls of the building.

### 3.3.4 Details

Details are large scale drawings of the construction assemblies and installation that were not clearly shown in the sections. These enlarged drawings show the Builder how the various parts of the structure are to be connected and placed. The construction of specific types of foundations, doors, windows, insulation, cornices, and so forth is customarily shown in the detail drawings located within their appropriate main division of the construction drawings. Details are usually grouped together so that references may be made readily available. *Figure 2-8* shows a detail of a typical concrete footing.

The scale selected for details depends on how large it needs to be drawn to explain the necessary information clearly. Details are usually drawn at a larger scale than sections, generally 3/4 inch, 1 1/2 inches, or 3 inches = 1 foot. Details commonly used are readily available in the Architectural Graphics Standard (AGS).

### 3.3.5 Schedules

Schedules are tabular or graphic arrangements of extensive information or notes related to construction materials. The use of schedules presents a quick and easy way for planners, estimators, and suppliers to share similar data, reducing construction errors and saving time. In the Seabees, the success of the planners and estimators (P & E) in accurately preparing takeoff, of the supply department (S-4) in properly ordering construction materials, and of the construction crew (line companies and detachments) in installing the materials in their proper locations depends greatly upon the efficiency with which the relevant information is conveyed on the drawing (plans).

The material information most commonly placed in schedules relates to doors, windows, room finishes, lintels, and other structural elements.

#### 3.3.5.1 Door Schedules

A Door Schedule varies from being a bare minimum for small jobs to being extensive for large projects. A door schedule may include the following:

- Door number
- Quantity
- Mark or code number
- Type
- Size
- Material description
- Lintel
- Remarks

An example of a tabular door schedule is shown in *Table 2-4*. Doors are commonly marked with a number or numbers and letters. Letter *D* is a common designation used for doors and is sometimes enclosed in a circle or other shape.

**Table 2-4 – Door Schedule.**

| Mark | Size | Description | Remarks |
|---|---|---|---|
| 1 | 3’-0” x 6’8” x 1 3/4” | EXT. Metal Insul | Décor |
| 2 | 2-3’-0” x 6’-8” x 1 3/4” | EXT. S/C OAK/ 4 lite | French |
| 3 | 2’-8” x 6’-8” x 1 3/8” | INT. H/C S/PINE | Flush |

#### 3.3.5.2 Window Schedules

A Window Schedule provides an organized presentation of the significant window characteristics. Information often includes the following:

- Mark
- Window type
- Size
- Required opening size
- Material type
- Lintel
- Remarks

Windows are often marked with letters or letters with numbers. The letter *W* is used most commonly for window schedules. An example of a window schedule is shown in *Table 2-5*.

**Table 2-5 – Window Schedule.**

| Mark | Size | Description | Remarks |
|---|---|---|---|
| | 3'-0" x 3'-0" | Alum. Frame DSB | Dbl/hung |
| | 4'-5 1/8" x 4'-2 5/8" | Metal frame DSB | Jalousie |

#### 3.3.5.3 Material Finish Schedules

A Material Finish Schedule may include the following:

- Room number
- Material finish for floors
- Material finish for walls
- Material finish for base
- Remarks

Where several rooms in a row have an identical finish, a common practice is to use the ditto mark (") or the initials DO. It is essential that you take care when making changes in the material finish used in a particular room, because the changes you make will greatly affect other rooms below it. Errors are less likely to occur and revisions will be easier to handle when each space in the schedule is lettered individually. An example of a material finish schedule is shown in *Table 2-6*.

**Table 2-6 – Material Finish Schedule.**

| Room | Floor | Walls | Ceiling | Baseboard | Trim |
|---|---|---|---|---|---|
| Dining and living | 1" x 4" Oak | 1/2" Drywall paint white | 1/2" Drywall paint white | Wood | Wood |
| Bedroom | Carpet w/ foam pad | 1/2" Drywall paint beige | 1/2" Drywall paint white | Wood | Wood |
| Bathroom | Linoleum – tan | 1/2" Drywall paint white | 1/2" Drywall paint white | Lino-cove | Wood |
| Kitchen | Linoleum – tan | 1/2" Drywall paint white | 1/2" Drywall paint white | Lino-cove | Wood |
| Utility room | Linoleum – tan | 1/2" Drywall paint white | 1/2" Drywall paint white | Lino-cove | Vinyl |

Remember, whenever possible, to place all of the schedules on the same sheet as their respective drawings on the building.

### Test your Knowledge (Select the Correct Response)

3. In what main division of a set of project drawings for a new building should you look to find the types and sizes of the windows?

   A. Architectural
   B. Civil
   C. Mechanical
   D. Structural

# 4.0.0 Written Specifications

Because many aspects of construction cannot be shown graphically, even the best prepared construction drawings often inadequately show some portions of a project. For example, can anyone show the quality of workmanship required for the installation of doors and windows, or who is responsible for supplying the materials on a drawing? These are things that can be conveyed only by hand lettered notes. The standard procedure is to supplement construction drawings with detailed written instructions. These written instructions, called specifications (or more commonly specs), define and limit materials and fabrication to the intent of the engineer or designer.

Usually it is the design engineer's responsibility to prepare project specifications. As a Builder, you will be required to read, interpret, and use these in your work as a Crew Leader or supervisor. You must be familiar with the various types of federal, military, and nongovernmental reference specifications used in preparing project specs. When assisting the engineer in preparing or using specifications, you also need to be familiar with the general format and terminology used.

## 4.1.0 NAVFAC Specifications

The Naval Facilities Engineering Command (NAVFACENGCOM) prepares NAVFAC specifications and sets standards for all construction work performed under its jurisdiction. This includes work performed by the Seabees. The three types of NAVFAC specifications are covered in the following information.

### 4.1.1 NAVFACENGCOM Guide Specifications

NAVFACENGCOM guide specifications (NFGS) are the primary basis for preparing specifications for construction projects. These specifications define and establish the minimum criteria for construction, materials, and workmanship and must be used as guidance in the preparation of project specifications. Each of these guide specifications (of which there are more than 300) encompass a wide variety of materials, construction methods, and circumstances. Therefore, they must be tailored to suit the work actually required by the specific project.

To better explain this, let's look at *Figure 2-11*, which is a page taken from a NAVFACENGCOM guide specification.

NFGC-07310 (August 1983)

PART 3 – EXECUTION

3.1 SURFACES AND CONDITIONS: Do not apply shingle roofing on surfaces that are unsuitable or that prevent a satisfactory application. Ensure that roof is smooth, clean, dry, and without loose knots. Cover knotholes and cracks with sheet metal nailed securely to the sheathing. Properly flash and secure vents and other roof projections and drive projecting nails firmly home.

3.2 APPLICATION: The manufacturer's written instructions shall be followed for applications not listed in this specification and in cases of conflict with this specification. (I)

3.2.1 Underlayment (for Roof Slopes 4 Inches Per Foot and Greater): Apply underlayment consisting of one layer of No. 15 asphalt-saturated felt to the roof deck. Lay felt parallel to roof eaves continuing from eaves to ridge, using 2 inch head laps, 6 inch laps from both sides over all hips and ridges, and underlayment up vertical surfaces not less than 4 inches.

**OR**

3.2.1 Underlayment (for Roof Slopes (Between 2 inches and 4 inches Per Foot) (4 Inches Per Foot and Greater)): Apply underlayment consisting of two layers of No. 15 asphalt-saturated felt to the roof deck. Provide a 19 inches wide strip of felt as a starter sheet to maintain the specified number of layers throughout the roof. Lay felt parallel to roof eaves continuing from eaves to ridge, using 19 inch head laps in the field of the roof. Nail felt sufficiently to hold until shingles are applied. Confine nailing to the upper 17 inches of each felt. Turn underlayment up vertical surfaces not less than 4 inches. (I) (J)

3.2.2 Metal Drip Edges: Provide metal drip edges as specified in Section 07600, "Flashing and Sheet Metal," applied directly on the wood deck at the eaves and over the underlayment at the rakes. Extend back from the edge of the deck not more than 3 inches and secure with fasteners spaced not more than 10 inches on center along the inner edge.

(3.2.3 Eaves Flashing (for Roof Slopes 4 Inches Per Foot and Greater): Provide eaves flashing strips consisting of 55-pounds or heavier smooth-surface roll roofing. The flashing strips shall overhang the metal drip edge 1/4 to 3/8 inch and extend up the slope far enough to cover a point 12 inches inside the interior face of the exterior wall. Where overhangs require flashings wider than 36 inches, locate the laps outside the exterior wall face. The laps shall be at least 2 inches wide and cemented. End laps shall be 12 inches and cemented.) (K)

**Figure 2-11 – Sample page from a NAVFACENGCOM guide specification.**

In this figure, there are two paragraphs numbered 3.2.1. This indicates that the spec writer must choose the paragraph that best suits the particular project for which he or she is writing the specification. The capital letters *I, J,* and *K* in the right hand margin next to those paragraphs refer to footnotes contained elsewhere in the same guide specification that the spec writer must follow when selecting the best paragraph. Additionally, you can see that some of the information in *Figure 2-12* indicates other choices that the spec writer must make. Guide specifications should be modified and edited to reflect the latest proven technology, materials, and methods.

### 4.1.2 EFD Regional Guide Specifications

Engineering Field Division (EFD) regional guide specifications are used in the same way as the NAVFACENGCOM guide specifications, but only in areas under the jurisdiction of an EFD of the Naval Facilities Engineering Field Command. When the spec writer is given a choice between using an EFD regional guide specification or a NAVFACENGCOM guide specification with the same identification number, the writer must use the one with the most recent date. This is because there can only be one valid guide specification for a particular area at any one time.

### 4.1.3 Standard Specifications

Standard specifications are written for a small group of specialized structures that must have uniform construction to meet rigid operational requirements. NAVFAC standard specifications contain references to federal, military, other command and bureau, and association specifications. NAVFAC standard specifications are referenced or copied in project specifications and can be modified with the modification noted and referenced. An example of a standard specification with modification is shown below.

> "The magazine shall be Arch, Type I, conforming to specifications S-M8E, except that all concrete shall be class F-1."

## 4.2.0 Other Specifications

The following specifications establish requirements mainly in terms of performance. Referencing these documents in project specifications assures the procurement of economical facility components and services while considerably reducing the number of words required to state such requirements.

### 4.2.1 Federal and Military Specifications

Federal specifications cover the characteristics of materials and supplies used jointly by the Navy and other government agencies. These specifications do not cover installation or workmanship for a particular project, but specify the technical requirements and tests for materials, products, or services. The engineering technical library should have all the commonly used federal specifications that are pertinent to Seabee construction.

Military specifications are those that have been developed by the Department of Defense (DoD). Like federal specifications, they also cover the characteristics of materials. They are identified by DoD or MIL preceding the first letter and serial number.

### 4.2.2 Technical Society and Trade Association Specifications

Technical society specifications should be referenced in project specifications when applicable. The organizations publishing these specifications include, but are not limited to, the American National Standards Institute (ANSI), the American Society for Testing and Materials (ASTM), the Underwriters Laboratories (UL), and the American Iron and Steel Institute (AISI). Trade association specifications contain requirements common to many companies within a given industry.

### 4.2.3 Manufacturer's Specifications

Manufacturer's specifications contain the precise description for the manner and process for making, constructing, compounding, and using any items the manufacturer produces. They should not be referenced or copied verbatim in project specifications but may be used to aid in the preparation of them.

## 4.3.0 Project Specifications

Construction drawings are supplemented by written project specifications. Project specifications give detailed information regarding materials and methods of work for a particular construction project. They cover various factors relating to the project, such as general conditions, scope of work, quality of materials, standards of workmanship, and protection of finished work. Usually, drawings are accompanied by a set of project specifications. The drawings and project specifications are inseparable. Drawings indicate what the project specifications do not cover. Project specifications indicate what the drawings do not portray and clarify details the drawings do not cover amply. When you are preparing project specifications, it is important that the specifications and drawings be closely coordinated to minimize discrepancies and ambiguities. Whenever there is conflicting information between the drawings and project specs, the specifications take precedence over the drawings.

## 4.4.1 Organization of Specifications

For consistency, the Construction Specifications Institute (CSI) has organized the format of specifications into 16 construction divisions. These divisions, used throughout the military and civilian construction industry, are listed in order as follows:

1. **General Requirements** include information that is of a general nature to the project, such as inspection requirements and environmental protection.
2. **Site Work** includes work performed on the site, such as grading, excavation, compaction, drainage, site utilities, and paving.
3. **Concrete** includes precast and cast in place concrete, formwork, and concrete reinforcing.
4. **Masonry** includes concrete masonry units, brick, stone, and mortar.
5. **Metals** include such items as structural steel, open web steel joists, metal stud and joist systems, ornamental metal work, grills, and louvers. Sheet metal work is usually included in Division 7.
6. **Wood** and **Plastics** include wood and wood framing, rough and finish carpentry, foamed plastics, fiberglass reinforced plastics, and laminated plastics.
7. **Thermal** and **Moisture Protection** includes such items as waterproofing, damp proofing, insulation, roofing materials, sheet metal and flashing, caulking, and sealants.
8. **Doors** and **Windows** include doors, windows, finish hardware, glass and glazing, storefront systems, and similar items.
9. **Finishes** include such items as floor and wall coverings, painting, lath, plaster, and tile.
10. **Specialties** include prefabricated products and devices, such as chalkboards, movable partitions, firefighting devices, flagpoles, signs, and toilet accessories.

11. **Equipment** includes such items as medical equipment, laboratory equipment, food service equipment, kitchen and bath cabinetwork, and countertops.
12. **Furnishings** include prefabricated cabinets, blinds, drapery, carpeting, furniture, and seating.
13. **Special Construction** includes such items as pre-engineered structures, integrated ceiling systems, solar energy systems, aquatic facilities, and air supported structures.
14. **Conveying Systems** include dumbwaiters, elevators, moving stairs, material handling systems, scaffolding, and other similar conveying systems.
15. **Mechanical Systems** include plumbing, heating, air conditioning, fire protection systems, and refrigeration systems.
16. **Electrical Systems** include electrical service and distribution systems, electrical power equipment, electric heating and cooling systems, lighting, and other electrical items.

Each of the previous divisions is further divided into sections. You can find information on the required sections of Division 1 in the MIL-HDBK-1006/1, *Policy and Procedures for Project Drawing and Specification Preparation.* The Division 1 section is generally common to all projects done under a construction contract. Divisions 2 through 16 contain the technical sections that pertain to the specific project for which the spec writer has prepared the specification. These technical sections follow the CSI recommended three part section format.

- Part 1, General, includes requirements of a general nature.
- Part 2, Products, addresses the products or quality of materials and equipment to be included in the work.
- Part 3, Execution, provides detailed requirements for performance of the work.

Some construction industries have developed a Division 17 or 18 to the CSI due to the changing technology of construction. Even NAVFAC has developed a Division 17, called Expeditionary Structures, which includes K-SPAN and High Tension Fabric buildings. Refer to Chapter 9 or the P-405 for more information on Division 17.

## 4.5.0 Guidance

The engineer or spec writer usually prepares each section of a specification based on the appropriate guide specification listed in the *Engineering and Design Criteria for Navy Facilities, MIL-HDBK-1001/1.* This Military Handbook is published annually by the Naval Construction Battalion Center, Port Hueneme, California, lists current NAVFACENGCOM guide specifications, standard specifications and drawings, definitive drawings, NAVFAC design manuals, and military handbooks that are used as design criteria.

The preceding material provides only a brief overview of construction specifications. For additional guidance regarding specification preparation, refer to *Policy and Procedures for Project Drawing and Specification Preparation,* MIL-HDBK-1006/1, and *Engineering Aid Advanced NRTC.*

## Test your Knowledge (Select the Correct Response)

4. How many types of NAVFAC specifications govern work performed by Seabees?

   A. One
   B. Two
   C. Three
   D. Four

# 5.0.0 Planning

Planning is the process the Builders use to determine requirements and to devise and develop methods and actions for constructing a project. Good construction planning is a combination of understanding the plans and specifications and understanding and analyzing the available resources, such as material, equipment, and manpower. Planning is also the process of determining the working environment, quality control, and safety procedures/precautions. All of these elements depend upon each other and must be considered in any well planned project.

In the late 1950s, a new system of project planning, scheduling, and control came into widespread use in the construction industry. The critical path analysis (CPA), critical path method (CPM), and project evaluation and review technique (PERT) are three examples of about 50 different approaches. The basis for each of these approaches is the analysis of a network of events and activities. The generic title of the various networks is network analysis.

## 5.1.1 Network Analysis

The Network Analysis approach is now the accepted method of construction planning in many organizations. Network analysis forms the core of project planning and control systems. Network analysis separates the planning of the sequence of jobs from the scheduling of times for the jobs, thus overcoming simultaneous, and less effective, planning and scheduling.

All projects consist of separate but interrelated operations. In network analysis, these interrelated operations are called activities. Activities are broken down into two phases: master activities (Level IIs) and construction or detailed activities (Level IIIs). Master and construction activities will be covered throughout this section.

The first stage in applying this technique is the preparation of a list of all activities that constitute the project to be scheduled. This list can be obtained in the following ways:

- Study of the plans and the specifications, as shown in *Figure 2-12*
- Study of the manufacturer's specifications
- Bill of materials (BMs)
- Modifications to previous projects
- Work sheets from previous projects
- Work element checklist (NAVFAC P-405)
- Project turnover files
- NCBs/NCRs

**REDICHECK Plan and Specification Review**

1. Preliminary Review
   a. Quickly make an overview of all sheets, spending no more than one minute/sheet to become familiar with the project.
2. Specification Check
   a. Check spec for bid items. Are they coordinated with the drawings?
   b. Check spec for phasing of construction. Are phases clear?
   c. Compare architectural finish schedule to specification index. Ensure all finish materials are specified.
   d. Check major items of equipment and verify they are coordinated with contract drawings. Pay particular attention to horsepower ratings and voltage requirements.
   e. Verify that items specified “as indicated” or “where indicated” are in fact indicated on contract drawings.
   f. Verify that cross reference specification sections exist.
   g. Try not to indicate thickness of materials or quantities of materials in the specifications.
3. Plan Check Structural
   a. Verify property line dimensions on site plan against architectural.
   b. Verify building is located behind set back lines.
   c. Verify column lines on structural and architectural.
   d. Verify all column locations are same on structural and architectural.
   e. Verify perimeter slab on structural matches architectural.
   f. Verify all depressed or raised slabs are indicated.
   g. Verify slab elevations.
   h. Verify all foundation piers are identified.
   i. Verify all foundation beams are identified.
   j. Verify roof framing plan column lines and columns against foundation plan column lines and columns.
   k. Verify perimeter roof line against architectural roof plan.
   l. Verify all columns and beams are listed in column and beam schedules.
   m. Verify lengths of all columns in column schedule.
   n. Verify all sections are properly labeled.
   o. Verify all expansion joint locations against architectural.
   p. Verify dimensions.
4. Plan Check Architectural
   a. Verify all concrete columns and walls against structural.
   b. Verify on site plans that all existing and new work are clearly identified.
   c. Verify building elevations against floor plans. Check in particular roof lines, window and door openings, and expansion joints.
   d. Verify building sections against elevations and plans. Check roof lines, windows, and door locations.

**REDICHECK Plan and Specification Review**

   e. Verify wall sections against architectural building sections and structural.
   f. Verify masonry openings for windows and doors.
   g. Verify expansion joints through building.
   h. Verify partial floor plans against small scale floor plans.
   i. Verify reflected ceiling plan against architectural floor plan to ensure variance with rooms. Check ceiling materials against finish schedule, check light fixture layout against electrical, check ceiling diffusers/registers against mechanical, check all soffits and locations of vents.
   j. Verify all room finish schedule information including room numbers, names of rooms, finishes and ceiling heights. Look for omissions, duplications, and inconsistencies.
   k. Verify all door schedules information including sizes, types, labels, etc. Look for omissions, duplications, and inconsistencies.
   l. Verify all rated walls.
   m. Verify all cabinets will fit.
   n. Verify dimensions.
5. Plan Check Mechanical and Plumbing
   a. Verify all new electrical, gas, water, sewer, etc. lines connect to existing.
   b. Verify all plumbing fixture locations against architectural. Verify all plumbing fixtures against fixture schedule/specs.
   c. Verify storm drain system against architectural roof plan. Verify size of all pipes and that all drains are connected. Verify wall chases are provided on architectural to conceal vertical piping.
   d. Verify sanitary drain system pipe sizes and that all fixtures are connected.
   e. Verify HVAC floor plans against structural.
   f. Verify sprinkler heads in all rooms.
   g. Verify that all sections are identical to architectural/structural.
   h. Verify that adequate ceiling height exists at worst case duct intersections.
   i. Verify all structural supports required for mechanical equipment are indicated on structural drawings.
   j. Verify dampers indicated at smoke and dire walls.
   k. Verify diffusers against architectural reflected ceiling plan.
   l. Verify all roof penetrations (ducts, fans, etc.) are indicated on roof plans.
   m. Verify all ductwork is sized.
   n. Verify all notes.
   o. Verify all A/C units, heaters, and exhaust fans against architectural roof plans and mechanical schedules.
   p. Verify all mechanical equipment will fit in spaces allocated.
6. Plan Check Electrical
   a. Verify all plans are identical to architectural.
   b. Verify all light fixtures against architectural reflected ceiling plan.
   c. Verify all major pieces of equipment have electrical connections.
   d. Verify location of all panel boards and that they are indicated on the electrical

**REDICHECK Plan and Specification Review**

riser diagram.

e. Verify all notes.

f. Verify that there is sufficient space for all electrical panels.

7. Plan Check Kitchen/Dietary

   a. Verify equipment layout against architectural plans.

   b. Verify all equipment is connected to utility systems.

**Figure 2-12 – Redicheck plan and specification review.**

There are no specific definitions as to what constitutes an activity, and it is largely a matter of individual interpretation according to the requirements of a particular project. A good rule is, DO NOT plan a project in any more detail than is necessary to manage the scheduling of the work properly. For most NCF projects, construction activities should not be less than 1 day in duration, preferably not less than 3 days. Refer to the *Planner's and Estimator's Handbook,* NAVFAC P-405 and the *Seabee Crewleader's Handbook* for more information on network analysis.

## 5.2.0 Project Planning

There are two basic ground rules in analyzing a project. First, planning and scheduling are separate operations. Second, planning must always precede scheduling. If you do not plan sequentially, you will end up with steps out of sequence, which may delay the project substantially. Each NCF project, from the initial planning phase through the execution phase to the closeout phase, is documented in a standard five section package. This section focuses on the planning phase of a project.

The project folder, or package, consists of five individual project files. These files not only represent the project in a paper format but also give you, as the Project Crew Leader, Project Manager, or Crew Member, exposure to the fundamentals of construction management. This package will be presented to OPS in phases; refer to the *Seabee Crewleader's Handbook* for more information pertaining to project management.

Listed below are the instructions needed to complete a typical NCF project package. The forms marked with an asterisk are mandatory on all projects. Small projects of short duration or ABFC projects may require only the mandatory forms. Other forms are used as needed. Forms may be computer-generated but must have the same content as shown.

A. NCF Project Package Contents: To be placed at the beginning of the project package 3-ring binder.

B. Section #1: General Information and Correspondence:

   1. 1A Cover Sheet: Recommend using tabbed dividers for all section cover sheets.

      a. *Tasking Letter/Correspondence: Distributed by S3 early in homeport, sample in *Seabee Crewleader's Handbook*.

      b. *Outgoing Messages and Correspondence: File in chronological order, oldest on bottom to newest on top.

      c. *Incoming Messages and Correspondence: File in chronological order, oldest on bottom to newest on top.

2. 1B Cover Sheet:

   a. Project Scope Sheet: Outlines the scope of the project in paragraph format, sample in *Seabee Crewleader's Handbook*.

   b. Project Organization: In addition to this, include a complete list of all prime and sub personnel assigned to the project.

   c. Project Planning Milestones: This list can be added to if necessary. Contact Ops when assigning dates.

   d. Project Package Sign-Off Sheet: To be signed off prior to the RDE.

   e. Deployment Calendar: Outlines the important dates for deployment, sample in *Seabee Crewleader's Handbook*.

   f. Preconstruction Conference Summary: Outlines contacts and information gathered during a conference before construction begins, sample in *Seabee Crewleader's Handbook*.

   g. Predeployment Site Visit Summary: Outlines information gathered during a site visit before deployment signed off by ROICC Representative and S3, sample in *Seabee Crewleader's Handbook*.

   h. Joint Turnover Memorandum: Both battalions' personnel will complete this jointly for turnover projects. After completion forward to Ops. Also include the minutes of the turnover conference.

   i. Pre-BOD Inspection Request: The Crew Leader will complete this two working days prior to the requested date of inspection.

C. Section #2 Activities and Network.

1. 2A Cover Sheet:

   a. *Level II Barchart: Take particular care in man day totals recorded on this form. All numbers will match Level III calculations. Horizontal and vertical totals will match exactly.

   b. *Two Week Schedule: The Crew Leader will complete this each week. The company will present it to Ops at the weekly Ops meeting. The Crew Leader will brief the crew on this and post on the job site.

   c. *Master Activity Listing: List each master activity and describe exactly what is included in it. This will make clear to all personnel where one master activity stops and another begins.

   d. *Master Activity Summary Sheets: Complete this after the Level III bar chart and CAS sheets are finalized.

   e. **Level III Precedence Diagram:

2. 2B Cover Sheet:

   a. Level III Barchart: Complete this after you determine the construction schedule on the precedence network.

   b. Construction Activity Summary Sheets: This is one of the most important forms in the project package. Almost all the rest of the project package and project execution are driven by the CAS sheet. Be sure all entries are as accurate as possible. Be specific (but use plain language) on the Safety, QC, and Environmental blocks. Include all requirements. Your Safety, QC, and Environmental Plans will match this.

c. Completed Activities CAS sheets: File in numerical order as construction activities are completed. Be sure to record actual man-days and duration.

d. Two Week Labor Summary: The Crew Leader completes this daily prior to submitting time cards to company.

e. SITREP Feeders: Forward to Ops on a biweekly basis.

f. Other Computer Printouts/Reports:

D. Section #3 Resources:

1. 3A Cover Sheet:

a. *30/60/90-Day Material List: Forward a copy to MLO upon completion. MLO will enter material status from PCR/PSR and forward to Ops for action. Submit a separate form for each (30/60/90-day) requirement.

b. *30/60/90-Day Material List Letter: Ops will forward this to the cognizant regiment after receiving material status from MLO. You may use one form as long as you separate 30/60/90-day requirements.

c. *Typical Bill of Materials: Ops will supply to the company after the detailed MTO is completed. Transfer information from this to the BM/MTO Comparison Worksheet.

d. *Tool Requirement Summary: Submit Add-on BM for special tools if not already on the BM.

e. *Equipment Requirement Summary: Ensure a copy is routed to ALFA Company after completion.

2. 3B Cover Sheet:

a. List of Possible Long Lead Items: This does not need to be kept in the project package. It is provided for planning purposes only.

b. List of Long Lead Items: Forward a copy to MLO after completion. Crew Leader and MLO will track through homeport.

c. Material Take Off Worksheet: Use this form when doing a detailed MTO. Transfer information to the BM/MTO Comparison Worksheet.

d. BM/MTO Comparison Worksheet: For any shortage of material, forward an Add-on/Reorder BM to MLO.

e. Material Transfer Request: Forward to MLO for project to project transfer only. Do not use for excess material.

f. Add-on/Reorder Justification: Attach this to all Add-on/Reorder BMs.

g. Add-on/Reorder BM: Use this along with the Justification Form when adding or reordering material; circle Add-on or Reorder. For excess material, forward this as an Add-on BM along with a 1250-1 signed by S3. Remember, an Add-on is adding another line item to the BM. A Reorder is ordering more of the same materials already on the BM.

h. Borrow Log: Crew Leader will log all project to project transfers. This is used to keep track of transfers because MLO keeps the Material Transfer Request until receiving the replacement material.

E. Section #4 Plans:

1. 4A Cover Sheet:

   a. *Quality Control Plan Cover Sheet: First sheet of the QC Plan.

   b. *Quality Control Plan: The project QC Plan will come directly from the CAS sheets. QC will produce a separate plan. Project and QC will compare plans and resolve any differences.

   c. *Safety Plan Cover Sheet: First sheet of the project Safety Plan.

   d. *General Safety Plan: Second sheet of the project Safety Plan. These are general items that apply to almost all construction activities. Specific items will be included on the Safety Plan.

   e. *Safety Plan: The project Safety Plan will come directly from the CAS sheets. Include all safety items not covered on the General Safety Plan. The Safety Department will produce a separate plan. Project and Safety will compare plans and resolve any differences.

   f. **Environmental Plan: The project Environmental Plan will come directly from the CAS sheets.

2. 4B Cover Sheet:

   a. Daily Quality Control Inspection Report: Completed daily by the QC inspector.

   b. Field Adjustment Request (FAR) Submittal Log: Use this to record all FARs whether approved or disapproved.

   c. FAR: Use for all changes to the project. Keep these to a minimum. Construct project according to plans and ***specifications*** if possible. Be clear and concise when completing this. Attach drawings and extra items as needed.

   d. Request for Information (RFI) Submittal Log: Self explanatory.

   e. RFI: Use for clarification of plans or specifications only. All requests for changes on the project will be submitted on a FAR.

   f. Design Change Directives (DCD): Include all ROICC directed changes to the project.

   g. Concrete Placement Clearance Form: Must be completed, at a minimum, 24 hours in advance of concrete placement.

   h. Pre-placement photos for concrete placement: Include views of forms, RST and anchor bolts.

   i. Asphalt Placement Clearance Form: Must be completed at a minimum 24 hours in advance of asphalt placement.

   j. Utility Interruption request: This is a typical form. Each deployment site may be different. Submit to Ops at least two weeks in advance of required outage or within the host required time frame.

k. Excavation Request: This is a typical form. Each deployment site may be different. Submit to Ops at least two weeks in advance of required excavation or within the host required time frame.

l. Road Closure Request: This is a typical form. Each deployment site may be different. Submit to Ops at least two weeks in advance of required closure or within the host required time frame.

m. Engineering Service Request: Submit to Ops at least five days in advance of required service.

n. Mineral Products Request: Submit to MLO at least two weeks in advance of required delivery date.

o. Other QC Forms:

p. Daily Safety Inspection Report: Battalion's Safety inspector will complete daily.

q. Emergency Phone Numbers: Remove this from the project package and post on the job site.

r. Navy Employee Report of Unsafe or Unhealthful Working Conditions: This will be removed from the project package and posted on the job site.

s. Required Safety Equipment: Check the Safety Plan to verify the equipment required for this project.

t. Daily Safety Lecture Log: Record daily and forward a copy to Safety as required.

u. Accident/Near Mishap/Mishap Reports: In the event of a mishap, submit this to Safety as required. This does not take the place of medical reports or other reports that may be required by Safety.

v. Highlighted 29 CFR 1926:

w. Hazardous Materials Inventory Sheet: Submit a copy to Environmental/Safety as required.

x. Other Safety Forms:

F. Section #5 Drawings/Specifications:

1. 1A Cover Sheet:

   a. *Project Plans:

   b. **Highlighted Specifications:

2. 1B Cover Sheet:

   a. Site Layout:

   b. Shop Drawings:

   c. Detailed Slab Layout Drawings:

   d. Forming Plans:

   e. Rebar Bending Schedule:

   f. Other Sketches/Drawings:

   g. Technical Data:

The OPS Department should also assign a Project Planning Milestones checklist, shown in *Figure 2-13*, at the beginning of the home port for each project.

| **Project Planning Milestones** | | Project: _ | |
|---|---|---|---|
| **Milestones** | Date: | Required | Completed |
| Designate Project Supervisor | | | |
| Preplanning Conference | | | |
| Review Plans and Specs | | | |
| Identify Long Lead Time Items | | | |
| Identify Required Skills and Training | | | |
| Complete Project Scope Sheet | | | |
| Complete Master Activity Summary Sheets | | | |
| Develop Level II Network | | | |
| Develop BM/MTO Discrepancy List | | | |
| Complete Construction Activity Summary Sheets | | | |
| Develop Level III Network | | | |
| Input Network into Computer | | | |
| Resource Level Project | | | |
| Develop Level II Barchart | | | |
| Develop Level III Barchart | | | |
| Consolidate NCFSU and TOA Tool Requirements | | | |
| Consolidate NCFSU and TOA Equipment Requirements | | | |
| Consolidate Safety Plan | | | |
| Consolidate Quality Control Plan | | | |
| Prepare Readiness to Deploy Briefing | | | |

**Figure 2-13 – Project planning milestones checklist.**

## Test your Knowledge (Select the Correct Response)

5. What section of the project package contains the two week schedule?

   A. One
   B. Two
   C. Three
   D. Four

6. CPA, CPM, and PERT are techniques used in the analysis of a flow of events and activities of a construction project. What is the generic title covering these construction management techniques?

   A. Planning and estimating
   B. Flow charting
   C. Network analysis
   D. Project analysis

# 6.0.0 Estimating

Estimating is the process of determining the amount and type of work to be performed and the quantities of material, equipment, and labor required. Lists of these quantities and types of work are called estimates.

## 6.1.0 Preliminary Estimates

Preliminary Estimates are made from limited information, such as the general description of projects or the preliminary plans and specifications, and have little or no detail. Preliminary estimates are prepared to establish costs for the budget and to program general manpower requirements.

## 6.2.0 Detailed Estimates

Detailed Estimates are the precise statements of quantities of material, equipment, and manpower required to construct a given project. Underestimating quantities can cause serious delays in construction and can even result in unfinished projects. A detailed estimate must be accurate to the smallest detail to quantify requirements correctly.

## 6.3.0 Material Estimates

Material Estimates consist of a listing and description of the various materials and the quantities required to construct a given project. Obtain the information you will need to prepare material estimates from the activity estimates, drawings, and specifications. A material estimate is sometimes referred to as a Bill of Material (BM) or a Material Takeoff (MTO) sheet. We will cover the BM and the MTO a little later in this chapter.

## 6.4.0 Equipment Estimates

Equipment Estimates are listings of the various types of equipment, the amount of time, and the number of pieces of equipment required for you to construct a given project. Information such as that obtained from activity estimates, drawings, specifications, and an inspection of the site, provides the basis for preparing the equipment estimates.

## 6.5.0 Labor Estimates

The Labor Estimates consist of a listing of the number of direct labor man-days required to complete the various activities of a specific project. These estimates may show only the man-days for each activity, or they may be in sufficient detail to list the number of man-days for each rating in each activity: Builder (BU), Construction Electrician (CE), Equipment Operator (EO), Steelworker (SW), and Utilitiesman (UT). Man-day estimates are used for determining the number of personnel and the ratings required on a deployment. They also provide the basis for scheduling labor in relation to construction progress.

When the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405 is used, a man-day is a unit of work performed by one person in one 8-hour day.

Battalions set their own schedules, as needed, to complete their assigned tasks. In general, the work schedule of the battalions is based on an average of 55 hours per person per week. The duration of the workday is 9 hour per day not to include 1 hour lunch hour, which starts and ends at the job site.

Direct labor includes all labor expended directly on assigned construction tasks, either in the field or in the shop, that contributes directly to the completion of the end product. Direct labor must be reported separately for each assigned construction item. In addition to direct labor, the estimator must also consider indirect labor and readiness and training. Indirect labor includes labor required to support construction operations but which does not, in itself, produce an end product. Refer to the COMSECONDNCB/ COMTHIRDNCBINST 5312.1 for more information on labor.

## 6.6.0 Estimator

An Estimator is a person who evaluates the requirements of a task. A construction estimator must be able to picture the separate operations of the job mentally, as the work progresses through the various stages of construction and be able to read and obtain accurate measurements from drawings. The estimator must have an understanding of math, previous construction experience, and a working knowledge of all branches of construction. The estimator must use good judgment to determine what effect numerous factors and conditions have on project construction and what allowances should be made for each of them. The estimator must be able to do careful and accurate work. A Seabee estimator must have ready access to information about the material, equipment, and labor required to perform various types of work under conditions encountered in Seabee deployments. The collection of such information on construction performance is part of estimating. Since this kind of reference information may change from time to time, the estimator should review it frequently.

The tables and diagrams in the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405 will save you time in preparing estimates, and when understood and used properly, provide you with accurate results. Whenever possible, the tables and diagrams used were based on Seabee experience. Where suitable information was not available, construction experience was adjusted to represent production under the range of conditions encountered in Seabee construction. Thorough knowledge of the project drawings and specifications makes you alert to the areas in which errors may occur.

### 6.6.1 Need for Accuracy

Quantity Estimates are the basis for purchasing materials, determining equipment, and determining manpower requirements. They are also the basis for scheduling in terms of material deliveries, equipment, and manpower. Accuracy in preparing quantity estimates is extremely important since these estimates have widespread uses, and errors can be multiplied many times. For example, a concrete slab is to measure 100 feet by 800 feet. If you misread the dimension for the 800 foot side as 300 feet, the computed area of the slab will be 30,000 square feet, when it should actually be 80,000 square feet. Since area is the basis for ordering materials, there will be shortages. Concrete ingredients, lumber, reinforcing materials, and everything else involved in mixing and placing the concrete, including equipment time, manpower, and man-hours, will be seriously underestimated and ordered.

### 6.6.2 Checking Estimates

The need for accuracy in checking estimates is vital. Check quantity estimates to eliminate as many errors as possible. One of the best ways for you to check a quantity estimate is to have another person make an independent estimate and then to compare the two. Any differences should be noted to determine which is right. A less effective way of checking is for another person to take your quantity estimate and check all measurements, recordings, computations, extensions, and copy work, keeping in mind the most common error sources, which are listed in the next section.

### 6.6.3 Error Sources

Your failure to read all of the notes on a drawing or failure to examine reference drawings results in many omissions. For example, you may overlook a note that states “symmetrical about the center line” and thus compute only half the required quantity.

Errors in scaling obviously mean erroneous quantities. Take great care in scaling drawings to record correct measurements. Common scaling errors include using the wrong scale, reading the wrong side of a scale, and failing to note that a detail being scaled is drawn to a scale different from that of the rest of the drawing. Remember that some drawings are not drawn to scale. Since these cannot be scaled for dimensions, you must obtain dimensions from other sources. Scaling blue prints should only be used as a last resort when no other means are available to obtain accurate information.

Sometimes wrongly interpreting a section of the specifications causes errors in the estimate. If there is any doubt concerning the meaning of any part of the specification, request an explanation of that particular part.

Omissions are usually the result of careless examination of the drawings. Thoroughness in examining drawings and specifications usually eliminates errors of omission. Use checklists to assure that all activities or materials have been included in the estimate. When drawings are revised after material takeoff, compare new issues with the copy used for takeoff and make the appropriate revisions in the estimate.

Construction materials are subject to waste and loss through handling, cutting to fit, theft, normal breakage, and storage loss. Failure to make proper allowance for waste and loss results in erroneous estimates. Other error sources are inadvertent figure transpositions, copying errors, and math errors.

## 6.7.0 Activity Estimates

The Crew Leader is responsible for making sure all required resources are identified. The Crew Leader must estimate materials, equipment, and labor required to complete each construction activity. All required resources are listed on CAS sheets. The scheduled start and finish dates for each activity are taken from the Level III bar chart and shown on the CAS sheet. The resources are then tied to the schedule, and any action required to track or request resources can be monitored on the CAS sheet.

### 6.7.1 Master Activities

The Naval Construction Regiments (NCRs) usually assign master activities to the projects. The master activities can be broken into at least five construction activities. Most commonly, master activities number between eight and ten. These activities identify functional parts of the facility and are often tied to a particular company or rating. It must be clear to all personnel involved in the planning process exactly what work is included in each master activity. That is the purpose of the master activity listing.

A good narrative description of each master activity makes clear to all where each work element falls and reduces the chance of omitting any work items from the estimate. Master activities for a typical building might look like the list shown in *Table 2-7*.

**Table 2-7 – Master Activities.**

| Code | Activity |
|---|---|
| 01XX | General |
| 02XX | Site Work |
| 03XX | Concrete Construction |
| 04XX | Masonry |
| 05XX | Metals |
| 06XX | Carpentry |
| 07XX | Moisture Protection |
| 08XX | Doors, Windows, and Glass |
| 09XX | Finishes |
| 10XX | Specialties |
| 11XX | Architectural |
| 12XX | Furnishings |
| 13XX | Special Construction |
| 14XX | Conveying Systems |
| 15XX | Mechanical Systems |
| 16XX | Electrical Systems |
| 17XX | Expeditionary Structures |

### 6.7.2 Construction Activities

As the Crew Leader, you must break the master activities into construction activities. The work element checklist, contained in Appendix A in the NAVFAC P-405 and the *Seabee Crewleader's Handbook,* is an excellent reference for the development of the construction activity list. A typical Naval Mobile Construction Battalion (NMCB) project might contain between 15 and 50 construction activities. Construction activity numbers are usually four digits. The first two identify the master activity, and the second two show a specific construction activity within a master activity. Looking at the list of master activities example, this project could have a construction activity for pre-fab forms numbered 0312. The number 03 represents master activity concrete construction; the 1 distinguishes concrete formwork, and the 2 represents pre-fab forms from the order of precedence in that master activity. Refer to the *Seabee Crewleader's Handbook* for the construction activities listing.

#### 6.7.2.1 Man Day Estimates and Durations

You need to know how to calculate man-days and duration days for each construction activity. The P-405 is the primary reference for Seabee man-day estimates. The P-405 lists the number of man-hours required to do one unit of work. It also gives the size of the unit. The quantity of work is divided by the unit size and multiplied by the man-hours required to do one unit. You then divide by 8 man-hours per man-day and multiply by a delay factor (DF). Tasking, estimating, and reporting are always done in 8-hour man-days, regardless of the length of the workday. Note the following formula:

**MDs = QTY OF WORK ÷ UNIT SIZE X MHRS PER UNIT ÷ 8 x DF**

For example, to install 16,000 square feet of 1/2 inch drywall over wall studs would require how many man-days? The equation should be as follows:

**MDs = 16,000 SF ÷ 1000 SF x 33 MHRS ÷ 8 = 66 x DF**

### 6.7.2.2 Production Efficiency Factors

Production efficiency factors are the first step in adjusting man-day estimates based on your unique circumstances. The intent of a production efficiency factor is to adjust for factors that will make you more or less productive than the average Seabee. In calculating a production efficiency factor, consider only those factors that affect the crew while on the job. *Table 2-8* lists eight production elements in the far left column.

**Table 2-8 – Production Efficiency Guide Factor Chart.**

| ELEMENTS | LOW PRODUCTION | AVERAGE PRODUCTION | HIGH PRODUCTION |
|---|---|---|---|
| | Production Elements in Percent<br>25 35 45 55 | 65 75 85 | 90 95 100 |
| 1. Work Load | Construction requirement high, miscellaneous overhead high | Construction requirement normal, miscellaneous overhead normal | Construction requirement low, miscellaneous overhead low |
| 2. Site Area | Cramped work area, poor laydown/access | Work area limited, average laydown/access | Large work area, good laydown/access |
| 3. Labor | Poorly trained/motivated crew | Adequately trained/ motivated crew | Highly trained/motivated crew |
| 4. Supervision | Poorly trained/motivated or inexperienced | Adequately trained/ motivated and experienced | Highly trained/ motivated, and experienced |
| 5. Job Conditions | High quality work required, short fuse | Average quality work required, adequate time | Rough/unfinished work required, well planned |
| 6. Weather | Abnormal rain, heat, or cold | Moderate rain, heat, or cold | Favorable rain, heat, or cold |
| 7. Equipment | Poor condition, maintenance, repair, or application | Fair condition, maintenance, repair, or application | Good condition, maintenance, repair, or application |
| 8. Tactical/ Logistical | Slow supply, frequent tactical delays | Normal supply, few tactical delays | Good supply, no tactical delays |

You need to consider the impact of each of these production elements on each activity given a specific crew, location, equipment condition, and so on. Then assign a production factor between 25 (low production) and 100 (high production) for each element. A production factor of 67 is considered average. Average these eight factors to figure your production efficiency factor (PEF).

Let’s calculate a production efficiency factor for our 16,000 square feet of drywall. Let’s say we are going to do this drywall work as part of a project to rehab the CO’s administrative space. We must evaluate each production element from the table and assign a factor.

| Production Element | Percentage | Remarks |
|---|---|---|
| Work Load | 67 | No specific impact |
| Site Area | 75 | Good access, work area |
| Labor | 35 | Crew inexperienced, OJT required |
| Supervisor | 75 | Good supervisor |
| Job Condition | 45 | High quality work required |
| Weather | 67 | No impact |
| Equipment | 70 | Sufficient tools in adequate condition |
| Tactical/Logistical | 75 | Materials on-hand believed sufficient |

**PEF = 509/8 = 63.6**

### 6.7.2.3 Delay Factors

Before you can adjust the man-day estimate, you must convert the production efficiency factor to a delay factor according to the graph shown in *Figure 2-14*.

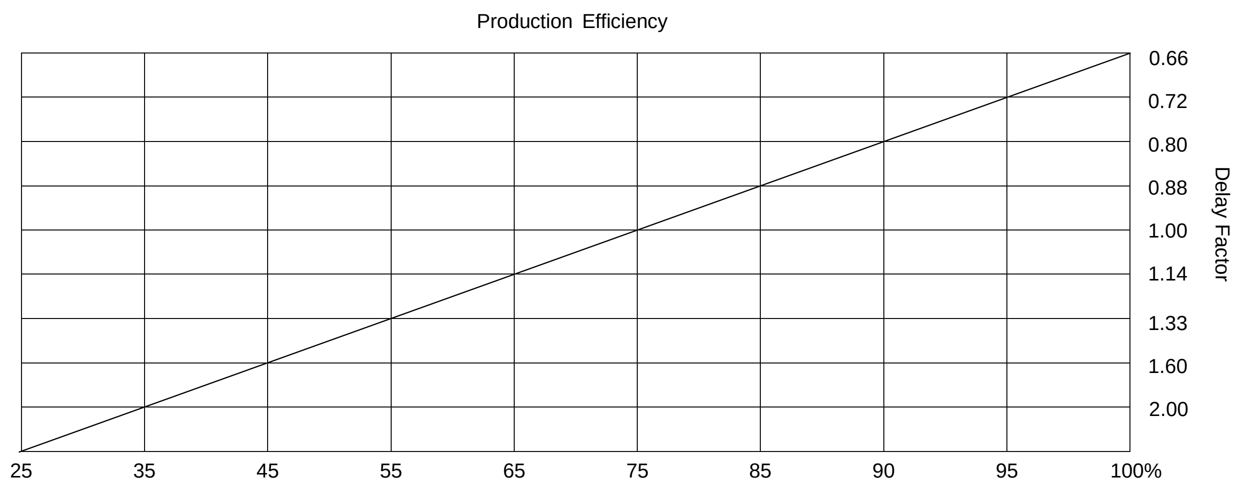



**Figure 2-14 – Production efficiency graph.**

You can find the delay factor by dividing the average production factor by the production efficiency factor calculated using the production elements in *Table 2-8*.

**DF = Average PEF/Calculated PEF**

**67/63.6 = 1.05**

Using the delay factor of 1.05, adjust the original man-day estimate as shown in the following equation:

**Adjusted MDs = Original MDs x DF**

**66 x 1.05 = 69.3 or 70 MD**

This mathematical procedure has limitations. If, for example, you were working outside in extremely bad weather and all other factors were considered average (weather = 25, all others = 67), you would obtain a production efficiency factor of 62 and a delay factor of 1.08. This 8 percent increase in the man-day estimate would not adequately compensate for working in extreme weather. You are not limited to the method of delay factors in the P-405. Use common sense when impacted by extreme circumstances. Come up with what you feel is a reasonable delay factor and discuss it with your chain of command. You are not bound by either the delay factors or the production rates in the P-405. To figure man-day estimates, use your experience to determine the logical production rates to use. Keep in mind that the delay factor is only used to determine the man-day estimate for a particular construction activity. Each activity will have a different delay factor. All other calculations use the availability factor.

#### 6.7.2.4 Availability Factors

Availability factors take into account that Seabees assigned as direct labor are not available 100 percent of the time. Each Naval Construction Brigade provides the availability factors for planning purposes. Availability factors are sometimes still referred to as site efficiency factors. These factors vary between 0.75 for main body sites to 0.85 for detail sites. Using the following equation, you can determine the man-day capability (MC) for the main body and each detail.

**MC = DL x WD x ME x AF**

where DL represents the number of direct labor assigned

WD represents the number of available workdays

ME (Man-Day Equivalent) represents the number of man-days expended (actual man-hours swinging hammers) in a typical workday

AF represents the availability factor

Availability Factor takes into account that Seabees assigned as direct labor are not available 100% of the time. Multiply these four factors to figure the man-day capability (MC). You can use this same equation to determine the direct labor manning for a detail if you substitute tasked man-days for MC and plug in AF, ME, and WD. The number of workdays (WD) is taken from the deployment calendar.

**ME = WD - Lunch - Travel - Breaks - Actual MHRS/work day**

#### 6.7.2.5 2.5 Construction Activity Duration

The man-day capability (MC) equation can also be used to determine construction activity durations expressed in the following equations:

**Duration = MD estimated (CS x AF x ME)**

**or**

**Duration = MD estimated ÷ CS ÷ AF ÷ ME**

The activity duration is increased by including the availability factor to account for time lost from the project site. The actual crew you would expect to see on the job site on the average day would be the assigned crew multiplied by the availability factor. Always use the availability factor. If in the drywall example you had a crew of 12 assigned, 1 hour for lunch each day, total travel to and from the job site is 1 hour, and a total of 30 minutes for breaks each day, how long would it take to complete this task if the availability factor is 0.75, and the man-day equivalent is .9375? Remember to use the revised man-day estimate, which includes the delay factor. The equation would be written as follows:

**Duration = 70 ÷ 12 ÷ 0.75 ÷ .9375 = 8.3**

**or 9 workdays.**

### 6.7.3 Construction Activity Summary (CAS) Sheets

Once the master activities have been broken into construction activities, you will need to use a CAS sheet, shown in *Figures 2-15* and *2-16*, for each activity. In addition to the activity description and the scheduled dates, all the required resources are shown on the front. Safety and QC requirements are on the back. Use the space at the bottom of the back page for man-day and duration calculations.

**CONSTRUCTION ACTIVITY SUMMARY SHEET**

Project Title: _
B.M. Code: __ Prepared By: _ Checked By: _
Start Scheduled: _ _ Finish Scheduled: __
Actual: _ _ Actual: _

Act. No. _ Group Code: __ _
Act. Title: _ _
Description of Work Method: _ _
_
_

Duration: Estimated __ Man-Days: Estimated __
Actual _ _ Actual _
Production Efficiency Factor: _ _ Resulting Delay Factor: _

Labor Resources:

| No. | Description | Qty. | No. | Description | Qty. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

Equipment Resources:

| No. | Description | Qty. | No. | Description | Qty. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

Material Resources:

| No. | Description | Qty. | No. | Description | Qty. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Assumptions: _

**Figure 2-15 – Construction activity summary sheet (front).**

Activity Number: _ Activity Description: _

**Safety Hazard** Spec. Ref. Required Action

**Quality Control Requirement** Spec. Ref. Remarks/Results

**Environmental Hazards** Spec. Ref. Action Required

Construction Comments:

**Figure 2-16 – Construction activity summary sheet (back).**

The CAS sheets should be able to stand alone. They should contain all of your notes, information, and calculations pertaining to man-days, durations, tools, and equipment. In this way, if you are not available, someone else can use this information and the project can continue. It is very important that CAS sheets be filled out correctly since almost all of your remaining planning is driven from them. Always use a pencil to fill them out, because they change constantly.

## 6.8.0 Material Estimates

Material Estimates are also used to procure construction material for a given project to determine whether sufficient material is available to construct a given project, and to determine the labor involved to install the material. The following is a suggested procedure for preparation of a material estimate. First, obtain a work element checklist by referring to the P-405, then estimate the quantity of material needed for each activity by using the P-405 and any previous experience. Use the conversion chart from *Table 2-9*, whenever possible, for estimating waste factors and the conversion of material.

**Table 2-9 – Conversion and Waste Factors.**

| Material | Conversion | % Waste |
|---|---|---|
| Concrete Construction | | |
| Concrete (1:2:4) | | |
| Cement | 6.0 sk/cy | 10 |
| Fine Aggregate | 0.6 cy/cy | 10 |
| Coarse Aggregate | 1.0 cy/cy | 10 |
| Curing compound | 0.5 gal/100 sf | 10 |
| Forms | | |
| Footings and piers | 1.5 lf/sfcs | 20 |
| 2 x 4 | 0.2 lf/sfcs | 10 |
| 2 x 8 | 0.7 lf/sfcs | 5 |
| Ground slabs | | |
| 1 x 4 | lf/sf area | 20 |
| 2 x 4 | 0.1 lf/sf area | 5 |
| Walls and columns | | |
| 2 x 4 | 1.3 lf/sfcs | 20 |
| Plywood (50% reuse) | 0.5 sf/sfcs | 5 |
| Beams and susp slabs | | |
| 1 x 6 | 0.3 lf/sfcs | 5 |
| 2 x 4 | 0.5 lf/sfcs | 20 |
| 2 x 10 | 0.1 lf/sfcs | 10 |
| 4 x 4 | 0.4 lf/sfcs | 5 |
| 4 x 6 | 0.1 lf/sfcs | 5 |
| Plywood | 0.5 sf/sfcs | 5 |
| Form oil | 0.5 gal/100 sf | 10 |
| Tie wire | 12.0 lb/ton | 10 |
| Snap tie wedges | 0.1 EA/sfcs | 5 |
| Snap ties | 0.1 EA/sfcs | 5 |
| She bolts | 0.1 set/sfcs | 5 |
| Nails (bf lumber + sf plywood, ordered as mfbm) | | |
| 6d box | 6 lb/mfbm10 | 10 |
| 8d common | 4 lb/mfbm | 10 |
| 16d common | 6 lb/mfbm | 10 |
| 20d common | 2 lb/mfbm | 10 |
| 6d duplex | 4 lb/mfbm | 10 |
| 8d duplex | 9 lb/mfbm | 10 |
| 16d duplex | 9 lb/mfbm | 10 |
| Reinforcing steel | | |
| #3 | 0.4 lb/lf | 10 |
| #4 | 0.7 lb/lf | 10 |
| #5 | 1.0 lb/lf | 10 |
| #6 | 1.5 lb/lf | 10 |
| #7 | 2.0 lb/lf | 10 |
| #8 | 2.7 lb/lf | 10 |
| Constr joint (bitumen) | 3.0 gal/100 sf | 10 |
| Floor hardener | 3.0 lb/100 sf | 10 |
| Non-slip floor finish | 25.0 lb/100 sf | 10 |
| Masonry Construction | | |
| Block (8 x 16) | 112.5 EA/100sf | 10 |
| | .89sf/EA | |
| Brick (2 1/4 x 8) – 3/8 joint | | |
| 4" Wall | 6.6 EA/sf | 10 |
| 8" Wall | 13.1 EA/sf | 10 |
| 12" Wall | 19.6 EA/sf | 10 |

| Table 2-9 – Conversion and Waste Factors. | | |
|---|---|---|
| **Material** | **Conversion** | **% Waste** |
| Glazed structural tile | | |
| 5 1/3 x 8 | 3.3 EA/sf | 10 |
| 4 x 12 | 3.0 EA/sf | 10 |
| 5 1/3 x 12 | 2.2 EA/sf | 10 |
| Ceramic and quarry tile | | |
| 6 x 6 | 4.0 EA/sf | 10 |
| 9 x 9 | 1.7EA/sf | 10 |
| Mortar | | |
| Block (8 x 16) – 3/8 joint | | |
| 4" Wall | cy/100 blocks | 20 |
| 8" Wall | cy/100 blocks | 20 |
| 12" Wall | 0.3 cy/100 blocks | 20 |
| Brick (2 1/4 x 8) – 3/8 joint | | |
| 4" Wall | cy/1000 brick | 20 |
| 8" Wall | cy/1000 brick | 20 |
| 12" Wall | 0.4 cy/1000 brick | 20 |
| Structure tile (12 x 12) – 3/8 joint | | |
| 4" Wall | cy/100 tile | 20 |
| 8" Wall | cy/100 tile | 20 |
| 12" Wall | 0.5 cy/100 tile | 20 |
| Tile grout | 20.0 lb/100 sf | 10 |
| Plastering | | |
| Lath | | |
| Channel (3/4") | 0.3 lb/lf | 10 |
| Lath | 3.4 lb/sy | 5 |
| Nails (4d) | 0.1 lb/sy | 10 |
| Tie wire | 1.8 lb/sy | 10 |
| Plaster (3/4") | | |
| Scratch coat | 15 cf/100 sy | 10 |
| Brown coat | 20 cf/100 sy | 10 |
| Finish coat | 10 cf/100 sy | 10 |
| Carpentry | | |
| Nails | | |
| Framing | | |
| 8d common | 5 lb/mfbm | 10 |
| 10d common | 15 lb/mfbm | 10 |
| 16d common | 10 lb/mfbm | 10 |
| Sheathing (8d common) | 30 lb/mfbm | 10 |
| Flooring (8d common) | 30 lb/mfbm | 10 |
| Roofing (8d common) | 30 lb/mfbm | 15 |
| Wallboard (6d common) | 15 lb/1000 sf | 10 |
| Trim | | |
| 4d finish | 3 lb/1000 lf | 10 |
| 6d finish | 7 lb/1000 lf | 10 |
| 8d finish | 14 lb/1000 lf | 10 |
| Lumber | | |
| Framing | - | 15 |
| Sheathing | - | 25 |
| Flooring | - | 25 |
| Roofing | - | 25 |
| Wallboard | - | 15 |
| Trim | - | 10 |
| Steel Erection | | |
| Rivets (field) | 25 EA/ton | 10 |
| Bolts (field) | | |
| Temporary | 5 EA/ton | 5 |
| Permanent | 25 EA/ton | 5 |
| Sheet metal | - | 10 |

**Table 2-9 – Conversion and Waste Factors.**

| Material | Conversion | % Waste |
|---|---|---|
| Roofing | - | ? |
| Corrugated steel (6” end lap) | | |
| 26” width | 115 sf/sq | 10 |
| 27.5” width | 122 sf/sq | 15 |
| Wood shingles | | |
| 16” (4” exposure) | 900 EA/sq | 15 |
| 18” (6” exposure) | 600 EA/sq | 15 |
| 24” (8” exposure) | 450 EA/sq | 15 |
| Nails (4d) | 4 lb/1000 shingles | 15 |
| Built-up roofing (four-ply) | | |
| Sheathing paper | 1 sq/sq | 20 |
| Felt | 4 sq/sq | 20 |
| Pitch | 125 lb/sq | 10 |
| Gravel | 400 lb/sq | 10 |
| Tiling | | |
| Floor tile | | |
| Asphalt vinyl asbestos | - | 10 |
| Primer | 5 gal/1000 sf | 20 |
| Adhesive | 10 gal/1000 sf | 20 |
| Cleaner | 5 gal/1000 sf | 20 |
| Wax | 5 gal/1000 sf | 20 |
| Acoustic tile | | |
| Tile | - | 10 |
| Cement | 25 gal/1000 sf | 2 |
| Glass and Glazing | | |
| Glass | | |
| 8 x 12 | 75 panes/box | 1 |
| 10 x 16 | 45 panes/box | 1 |
| 12 x 20 | 30 panes/box | 1 |
| 14 x 24 | 22 panes/box | 1 |
| 16 x 28 | 16 panes/box | 1 |
| Glazing clips | - | |
| Putty | | |
| 8 x 12 | 0.6 lb/pane | |
| 10 x 16 | 0.8 lb/pane | |
| 12 x 20 | 1.9 lb/pane | 20 |
| 14 x 24 | 1.1 lb/pane | |
| 16 x 28 | 1.4 lb/pane | |
| Caulking | | |
| Primer | 2 gal/1000 lf | 1 |
| Compound (1/2 x 1/2) | 13 gal/1000 lf | 1 |
| Painting | | |
| Metal | | |
| Enamel | 0.2 gal/100 sf | 1 |
| Zinc white | 0.2 gal/100 sf | 10 |
| White lead | 0.2 gal/100 sf | 10 |
| Wood | | |
| Enamel | 0.2 gal/100 sf | 10 |
| Zinc white | 0.2 gal/100 sf | 10 |
| White lead | 0.3 gal/100 sf | 10 |
| Varnish | 0.2 gal/100 sf | 10 |
| Flat | 0.2 gal/100 sf | 10 |
| Gloss | 0.3 gal/100 sf | 10 |

This conversion should be done on a work sheet when the estimator records how each quantity of material was obtained. A typical material estimate work sheet is shown in *Figure 2-17*. Each step can readily be understood when the work sheets are reviewed.

| ESTIMATING WORK SHEET | | | | | |
|---|---|---|---|---|---|
| Prepared By: | Proj Location<br>Diego Garcia | Sheet _1_ of _5_ | Drawing No<br>1,337,494/7,604,980 | | Proj Title Cantonnment Area Interim Water System Bldg. |
| Checked By: | Proj Section<br>Architectural | Activity No<br>Node _71_ to Node _64_ | BM No.<br>DIW-112 | MTO No. | Date Prepared<br>19 FEB '92 |

| Item No | Description | Prefab Forms / Refer to DIW QC Sect. V Par B1C PP 7-8 | BM No. | BM Line Item No. | | Unit of Issue | | Total Qty | REMARKS<br>Use, Loc, Procedures, Etc. |
|---|---|---|---|---|---|---|---|---|---|
| | Building Footing | L / W / T | | | | | | | Slab/Footing edge |
| | | 26'-8" / 20'-0" / 12" | | | | | | | forms - to be used at |
| 1. | ¾" plywood | 2(26'-8")+(20')2=53'-4'+40'=93'-4" | | 1 | | SH | 0 | 3 | Transmitter site bldg. |
| | BB Exterior Type | | | | | | | | |
| | 4' x 8' | 8' x 4' plywood ripped 12": 32' | | | | | | | |
| | | 93.33/32' = 3 sheets | | | | | | | |
| | | | | | | | | | |
| 2. | Lumber 1 x 6 x RL | 6 length x 2 ea. corner X 4 corners = | | 2 | | BF | 15 | 30 | Bldg layout |
| | Gr 2 or better | 8 pcs / 6 long | | | | | | | batter boards |
| | | | | | | | | | |
| 3. | Lumber 2 x 4 x RL | 16' – 48 pcs = 16' x 2 x 4 = 48 pcs | | 3 | | BF | 15 | 590 | Use reusable 2 x 4 at |
| | | | | | | | | | transmitter site bldg. |
| | Ramp and Door Stop Forms | | | | | | | | |
| 4. | 3/4" plywood 4' x 8' | (13'-8") + 2(6') + 3(4') = 37'-8" | | 1 | | SH | 0 | 1 | Edge forms reuse at |
| | | Rip plywood into 8" strips | | | | | | | transmitter site bldg. |
| | | = 6 x 8 = 48 | | | | | | | |
| | Beams | | | | | | | | |
| | B-1 | 2 ea 26'-8" bond beams | | | | | | | |
| 5. | 3/4" plywood Gr BB | | | | | | | | B-1 side forms |
| | Ext Type 4' x 8' | 26'-8" x 4 sides = 106'-8" | | | | | | | Reuse at transmitter |
| | | | | | | | | | site bldg |
| | | | | | | | | | |

**Figure 2-17 – Typical estimating work sheet.**

### 6.8.1 Estimating Work Sheet

The estimating work sheet shown in *Figure 2-17*, when completed, shows the various individual activities for a project with a listing of the required material. Material scheduled for several activities or uses is normally shown in the Remarks section. The work sheet should also contain an activity description, the item number, the material description, the cost, the unit of issue, the waste factors, the total quantities, and the remarks. The field supervisor keeps the estimating work sheets during construction to ensure the use of the material as planned.

### 6.8.2 Material Takeoff Sheet

The material takeoff sheet (MTO) is shown in *Figure 2-18*. In addition to containing some of the information on the estimating work sheet, the MTO also contains the suggested vendors or sources, the supply status, and the required delivery date.

| MATERIAL TAKEOFF WORKSHEET | | | | | | Page _1 of _5 |
|---|---|---|---|---|---|---|
| Project Location: Diego Garcia | Project Title: Cantonment Area, Interim Water Sys Bldg | | Project Number: 1938.97 | | BM Number: DIW-112 | Date Prepared: 19 FEB '92 |
| Project Section: Architectural | Master Activity Number: | Drawing Number: 1,337,494/7,604,980 | Prepared By: | | Checked By: | |
| Construction Activity Number | Description/Calculations | | MTO U/I | MTO Qty | Remarks: | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Figure 2-18 – Typical material takeoff (MTO) work sheet.**

### 6.8.3 Bill of Material

The bill of material (BM) sheet shown in *Figure 2-19* is similar in content to the material takeoff sheet. However, the information is presented in a format suitable for data processing. Use this form for requests of supply status, issue, or location of material and for preparing purchase documents. When funding data is added, use these sheets for drawing against existing supply stocks.

| BILL OF MATERIAL | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project EL8-830 | | Project Title Administration Bldg | | | | Authority/Originator 31st NCR | | | | BM No GER-110 | | Section: Struct | | |
| RID | M&S | SERV & REONR | DEM | SERV & SUPP ADD | SIG | FUND | DIS | PRI | PRI | JON | ROS | Accounting Data | | |
| 4-6 | 7 | 30-35 | 44 | 45-50 | 51 | 52-53 | 54 | 57-59 | 60-61 | 62-64 | 72-77 | | | |
| P96 | 3 | N66450 | R | N62604 | A | BC | W | QQH | 06 | 309 | OHC T04 | | | |
| DOC ID | COG | NSN | | | Unit of Issue | QTY | Document Number | | | ADV | L/I | Description/Vendor Source Intended use | Unit Price | Total Cost |
| 1-3 | 55-56 | 8-20 | | | 23-24 | 25-29 | 36-43 | | | 65-66 | | | | |
| AOE | | 5510-00-220-6146 | | | BF | 6508 | 0214-1744 | | | | 1 | Lumber 2"xx4"x12' | .32 | 2082.56 |
| AOE | | 5510-00-220-6196 | | | BF | 420 | 0214-1745 | | | | 2 | Lumber 2"x6"x12' | .32 | 134.40 |
| AOE | | 5315-00-010-4663 | | | BX | 3 | 0214-1746 | | | | 3 | Nail 16D Common 50 lb | 16.86 | 50.58 |
| AOE | | 5640-00-847-0235 | | | EA | 90 | 0214-1747 | | | | 4 | Wallboard 5/8"x4'x8' | 12.50 | 1125.00 |
| AOE | | 5315-00-753-3890 | | | PG | 2 | 0214-1748 | | | | 5 | Nail Finishing 6D | 2.15 | 4.30 |
| AOE | | 5315-11-100-0139 | | | BX | 5 | 0214-1749 | | | | 6 | Hilti Nails 2 7/8" | 21.20 | 106.00 |
| AOE | | 1377-11-100-0464 | | | BX | 8 | 0214-1750 | | | | 7 | Hilti Charges Purple | 19.40 | 155.20 |
| AOE | | 5640-00-634-8891 | | | RO | 8 | 0214-1751 | | | | 8 | Tape, Wallboard 250' | 1.40 | 11.20 |

**Figure 2-19 – Sample bill of material (BM) sheet.**

Between procurement and final installation, construction material is subject to loss and waste. This loss may occur during shipping, handling or storage, or from the weather. Waste is inevitable where material is subject to cutting or final fitting before installation.

Frequently, material such as lumber, conduit, or pipe has a standard issue length longer than required. More often than not, the excess is too short for use and ends up as waste. Waste and loss factors vary depending on the individual item and should be checked against the conversion and waste factors found in NAVFAC P-405.

### 6.8.4 Long Lead Items

Long lead items are not readily available through the normal supply system. They require your special attention to ensure timely delivery. Items requiring a long lead time are non-shelf items, such as steam boilers, special door and window frames, or items larger than the standard issue. *Figure 2-20* shows some of the long lead items. Identify and order these items early. Make periodic status checks of the orders to avoid delays in completing the project.

| **Possible Long Lead Items** | |
|---|---|
| • Pre-Engineered Buildings<br>• Marine Piles<br>• Telephone Poles<br>• Doors<br>• Windows<br>• Screens<br>• Transformers<br>• Circuit breakers<br>• Switch Stations<br>• Fire Alarm Systems<br>• Intrusion Alarm Systems<br>• Air Conditioning Systems<br>• Specialty Electrical Items<br>• Partitions<br>• Water Heaters<br>• Timber (especially large sizes)<br>• Lumber, Plywood (large orders)<br>• Roof Systems<br>• Pre-Fab Joists<br>• Structural Steel Members<br>• Louvers<br>• Treated Wood Products<br>• Specialty Coatings | • Structural Pipe<br>• Marine Hardware<br>• Carpet<br>• Rubber Fender Systems<br>• Bolted Steel Tanks<br>• Epoxy Mortars/Grouts<br>• Galvanized Metal Products<br>• Chain Link Fence Fabric<br>• HVAC Components<br>• Fire Protection Systems<br>• Large Quantities/Odd Sizes of Pipe/Fittings<br>• Fire Pumps<br>• Control/Feedback System<br>• Enunciator Panels<br>• Power Panels<br>• Explosion Proof Systems<br>• Large Quantity or Specialty Cable<br>• Cathodic Protection Systems<br>• High Intensity Discharge Light Fixtures/Lamps<br>• High Voltage Specialty Switchgear<br>• Silver Solder<br>• Cabinets (wood and metal)<br>• Hardware/Locks/Cipher Locks |
| Finish items such as decorative brick, clay tiles, and unusual carpeting may require time to locate.<br>Large purchases of any item (over $20K or $25K depending on local purchase authority) require time to competitively bid.<br>Electrical items tend to be unique to each installation and require additional time. | |

**Figure 2-20 – Possible long lead items.**

## 6.9.0 Equipment Estimates

Equipment estimates are used with production schedules to determine the construction equipment requirements and constraints for Seabee deployment. Of these constraints, the movement of material over roadways is frequently miscalculated. Factors such as road conditions, the number of intersections, the amount of traffic, the hauling distances, and the speed limits are all variables that play into your estimate. You must consider the types of material hauled, safety (machine limitations and personnel), operator experience, condition of the equipment, work hours, and the local climate as other major factors in your estimate.

Determine equipment production in order to select the amount and type of equipment. Equipment production rates are available in the *Seabee Planner's and Estimator's Handbook*. The tables in this handbook provide information about the type of equipment required. Estimate the production rate per day for each piece of equipment. Consider the factors previously covered, along with information obtained from NAVPAC P-405 and your experience. The quantity of work divided by the production rate per day produces the number of days required to perform the project. After determining the number of days of required equipment operation, consult the project schedule to find the time allotted to complete the activities. Prepare the schedule for the total deployment. Use the project schedule to determine when the work will be performed. The schedule should also indicate peak usage. It may have to be revised for more even distribution of equipment loading, thereby reducing the amount of equipment required during the deployment.

After the review of the project and material estimate are complete, prepare a list of equipment required. This list must include anticipated downtime, and sufficient reserve pieces must be added to cover any downtime.

To aid you in preparing the equipment estimate schedule, use forms such as those shown in *Figures 2-21* and *2-22*. The important information on the forms includes the sheet number, the name of the estimator, the name of the checker, date checked, battalion and detachment number, location of deployment, year of deployment, project number, and a brief description of the project.

Sheet 1 of 2

Estimated By Brown Date 6/13/92
Checked By Green Date 6/23/92

# EQUIPMENT ESTIMATE

NMCB Location Guam Year 1992

Project No. 013 Description Site Preparation

Earth Fill – 36,000 CY loose measurement required.
Haul one way 2-1/2 miles.
Use 2-1/2 CY front end loader and 10 CY dump trucks.

Front end loader capacity 100 CY/hours.

$\frac{36,000}{100}$ = 360 hours or 45 eight-hour days.

$\frac{100}{10}$ = 10 trucks loaded per hour.

Average hauling speed estimated at 15 MPH.

2 x 2.5 = 5 miles round trip.

$\frac{5}{15}$ x 60 = 20 minutes hauling time.

$\frac{60}{10}$ = 6 Minutes loading time.

Estimated 4 minutes dumping time

30 minutes total time per truckload.

$\frac{60}{30}$ = 2 loads per hour per truck.

$\frac{10}{2}$ = 5 trucks required to keep front end loader working at capacity.

100 x 8 = 800 CY hauled per 8-hour day.

Need one bulldozer (can spread 1400 CY daily).

Need one grader to keep haul road in shape.

1 bulldozer (can spread 1400 CY daily).

1 tractor & tandem sheepfoot roller (can compact 1200 CY daily).

1 water truck with sprinkler for moisture control.

1 rubber-tired wobbly wheel roller on standby for compaction and sealing fill when rain is expected. (Can be towed by above bulldozer or tractor.)

**Figure 2-21 – Sample equipment estimate (sheet 1 of 2).**

Sheet 2 of 2

Estimated By Brown Date 6/13/92
Checked By Green Date 6/23/92

EQUIPMENT ESTIMATE

NMCB Location Guam Year 1992

Project No. 013 Description Site Preparation

NOTE: Preceding is not very efficient, as spreading equipment is not used to full capacity. Suppose that when the work schedule is prepared, completion of fill will be required in 18 days. Assume that climate is such that 3 days in every 17 working days will be lost due to rain. Therefore, 15 working days would be available in an 18 day schedule.

$\frac{3,600}{15}$ = 2,400 CY must be hauled daily to complete the work on schedule.

$\frac{2,400}{800}$ = 3 times the output of loading and hauling spread shown previously.

Equipment required for loading and hauling:

- 3 – 2-1/2 CY front end loaders.
- 1 – bulldozer to keep pit in shape.
- 1 – grader to keep haul road in shape.
- 15 – 10-ton trucks hauling (1 or 2 extra trucks should be used to assure that a truck will always be waiting to be loaded so that the front end loader will work at full capacity).

2,400 CY will be hauled each day.

$\frac{2,400}{1,200}$ = 2 tractors and tandem sheepfoot roller for compaction.
2 bulldozers to spread earth.

$\frac{2,400}{1,400}$ = 6 Minutes loading time.

1 wobbly-wheel roller (standby for sealing of fill before rains).

NOTE: This is a more efficient operation, as production has been tripled but equipment has not, and total equipment working at or close to capacity as can be expected.

**Figure 2-22 – Sample equipment estimate (sheet 2 of 2).**

The Table of Allowance (TOA) for the NMCBs contains specific information on the quantities and characteristics of construction equipment available to the NMCBs. The TOA-01 contains equipment and tool kit descriptions. Kit descriptions are presented by their section and numerical sequence as listed in the NMCB TOA-01, followed by assembly numbers, as shown in *Figure 2-23*. Also refer to Appendix B of the P405 for a complete listing of tool kits and equipment.

**80019 Kit, Carpenters**

Designed for: Field crew of 4 Builders, F/4 personnel

This kit contains the basic hand tools for various carpentry jobs in the field. Contained in the kit are: hammers, chisels, hand saws, nail sets, rasps, hatchet, framing squares, and other small hand tools. No electrical or pneumatic tools are included in this assembly. Refer to Power Tool Assemblies located at the end of this section for a listing of the various individual power tools.

**C80030 Kit, Mason Tools**

Designed for: Field crew of 4 block or brick layers, F/4 personnel

This kit contains the basic hand tools required for laying masonry units in place. Contained in this kit are: masonry chisels, trowels, hammers, levels, and other small hand tools.

**C80056 Kit, Concrete Placement**

Designed for: Finishing concrete

This kit contains the basic hand tools required for finishing concrete. Contained in the kit are: floats, trowels, tampers, canvas tool bag, and other small hand tools. This kit may be augmented by the various assemblies located under Power Tools at the end of this section.

**C80031 Miscellaneous Construction Tools**

Designed for: Augmenting construction tool specialty tools

This assembly contains equipment and tools not included in other construction kits such as: wheelbarrows, concrete carts, air-operated sump pump, shovels, water jugs, door hinge mortising kit, and other small hand tools such as saws, auger bits, Dumpy builder level, and post hole digger.

**Figure 2-23 – Kit assemblies for BUs.**

## 6.10.0 Labor Estimates

Preliminary labor estimates and detailed labor estimates are the two types covered in the following sections.

### 6.10.1 Preliminary Estimates

Use preliminary labor estimates to establish budget costs and to project labor requirements for succeeding projects and deployments. The estimates are prepared from limited information, such as general descriptions or preliminary plans and specifications that contain little or no detailed information. In some cases, you can make a comparison with similar facilities of the same basic design, size, and type of construction. A good preliminary estimate varies less than 15 percent from the detailed estimate.

The Advanced Base Functional Component (ABFC) system is an excellent source for preliminary estimates. This system can be used to find estimates for a wide range of facilities and assemblies most commonly constructed by the NCF. The ABFC system gives not only the man-hours required but also a breakdown of the construction efforts by rating as well as lapse time. The ABFC system estimates all labor on 10-hour workdays; do not mistake this with the normal workday of 8 man-hours per man-day.

### 6.10.2 Detailed Estimates

Use detailed material estimates and equipment estimates to assist you in determining the labor requirements for constructing a given project. Take the individual activity quantities from the activity work sheet to prepare your detailed estimates and then the man-hours per unit figure from the appropriate table in P-405 and multiply it by the quantity to obtain the total man-hours required. When preparing the activity estimates in the format covered earlier, use a copy of the activity estimates as a labor estimate work sheet by adding four columns to it with the headings of Activity, Quantity, Man Hours per Unit, and Total Man Days required. Prepare work sheets, whether on the activity work sheet or in another format, in sufficient detail to provide the degree of progress control desired.

When you prepare labor estimates, weigh the various factors that affect the amount of labor required to construct a project. These include weather conditions during the construction period, skill and experience of personnel who will perform the work, time allotted for completing the job, size of the crew to be used, accessibility of the site, and types of material and equipment to be used.

### 6.10.3 Production Efficiency Guide Chart and Graph

The production efficiency guide chart shown in *Table 2-8* lists eight elements that directly affect production. Each production element is matched with three areas for evaluation. Each element contains two or more foreseen conditions to select from for the job in question. Evaluate each production element at some percentage between 25 and 100 according to your analysis of the foreseen conditions. The average of the eight evaluations is the overall production efficiency percentage. Now, convert the percentage to a delay factor, using the production efficiency graph shown in *Figure 2-15*, or by the Seabee average for production (67 percent) or by the average of the eight production elements. The field or project supervisors are strongly recommended to reevaluate the various production elements and make the necessary adjustments to man-day figures based on actual conditions at the job site.

In reading the graph, note that the production elements have been computed into percentages of production efficiency, which are indicated at the bottom of the graph. First, place a straightedge so that it extends up vertically from the desired percentage, and then place it horizontally from the point at which it intersected the diagonal line. You can now read the delay factor from the values given on the right-hand side of the chart. Let's look at an example of the process of adjusting man-hour estimates.

Assume that from the work estimate taken from the tables in P-405, you find that 6 man-hours are needed for a given unit of work. To adjust this figure to the conditions evaluated on your job, assume that the average of foreseen conditions you rated is 87 percent. The corresponding delay factor read from the production efficiency graph is 0.80. You find the adjusted man-hour estimate by multiplying this delay factor by the man-hours from the estimating tables (6 MH x 0.8 = 4.8 as the adjusted man-hour estimate).

The activities in the various labor estimating tables are divided into units of measurement commonly associated with each craft and material takeoff quantities. There is only one amount of man-hour effort per unit of work. This number represents normal Seabee production under average conditions. As used here, 1 man-day equals 8 man-hours of direct labor.

No two jobs are exactly alike, nor do they have exactly the same conditions. Therefore you, as the estimator, must exercise some judgment about the project being planned. The production efficiency guide chart and graph (*Table 2-8* and *Figure 2-14*) are provided to assist you in weighing the many factors that contribute to varying production conditions and the eventual completion of a project. You can then translate what is known about a particular project and produce a more accurate quantity from the average figures given on the labor estimating tables.

### Test your Knowledge (Select the Correct Response)

7. **(True or False)** Scheduling is the process of determining the amount and type of work to be performed to complete a given task.

   A. True
   B. False

8. What NAVFAC publication is an excellent source for preliminary labor estimates?

   A. P-315
   B. P-405
   C. P-415
   D. P-437

## 7.1.1 Scheduling

Scheduling is the process of determining when an action must be taken and when material, equipment, and manpower are required. There are four basic types of schedules:

- Progress
- Material
- Equipment
- Manpower

Progress schedules coordinate all the projects of a Seabee deployment or all the activities of a single project. They show the sequence, the starting time, the performance time required, and the time required for completion. Material schedules show when the material is needed on the job. They may also show the sequence in which materials should be delivered. Equipment schedules coordinate all the equipment to be used on a project. They also show when it is to be used and the amount of time each piece of equipment is required to perform the work. Labor schedules coordinate the manpower requirements of a project and show the number of personnel required for each activity. In addition, they may show the number of personnel of each rating (Builder, Construction Electrician, Equipment Operator, Steelworker, and Utilitiesman) required for each activity for each period of time. The time unit shown in a schedule should be some convenient interval, such as a day, a week, or a month.

## 7.1.0 Elements

A network represents any sequencing of priorities among the activities that form a project. This sequencing is determined by hard or soft dependencies. Hard dependencies are based upon the physical characteristics of the job, such as the necessity for placing a foundation before building the walls. A hard dependency is normally inflexible. Soft dependencies are based upon practical considerations of policy and may be changed if circumstances demand. The decision to start at the north end of a building rather than at the south end is an example.

## 7.2.0 Precedence Diagrams

Network procedures are based upon a system that identifies and schedules key events into precedence-related patterns. Since the events are interdependent, proper arrangement helps in monitoring the independent activities and in evaluating project progress. The basic concept is known as the critical path method (CPM). Because the CPM places great emphasis upon task accomplishment, a means of activity identification must be established to track the progress of an activity. The method currently in use is the activity on node precedence diagramming method (PDM) where a node is simply the graphic representation of an activity. An example of this is shown in *Figure 2-24*.

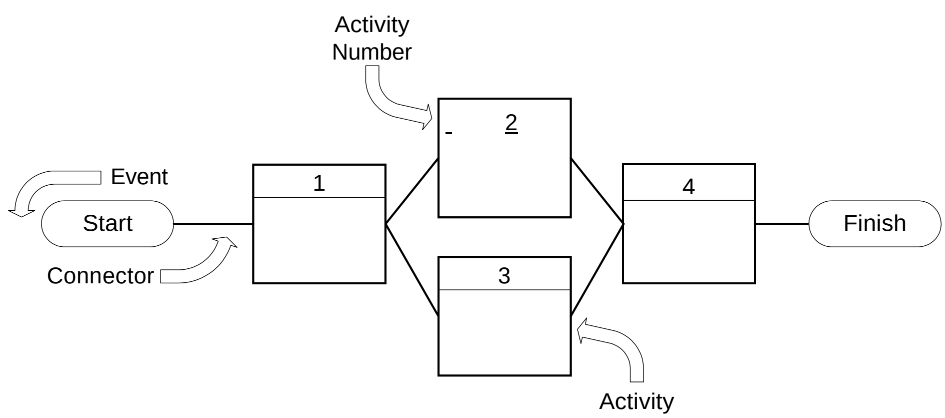



**Figure 2-24 – Precedence diagram.**

### 7.2.1 Activities

To build a flexible CPM network, the manager needs a reliable means of obtaining project data to be represented by a node. An activity in a precedence diagram is represented by a rectangular box and identified by an activity number.

The right side represents the completion. Lines linking the boxes are called connectors. The general direction of flow is evident in the connectors themselves. *Figure 2-25* shows a typical activity block used by the NCF.

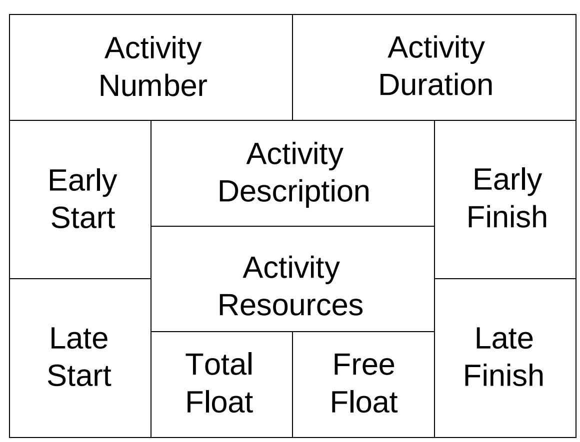



**Figure 2-25 – Information for a precedence activity.**

Activities may be divided into the following two distinct groups:

1. Working Activities – Activities that relate to particular tasks.
2. Critical activities – Activities that together comprise the longest path through the network. This is represented by two slashes drawn through an activity connector.

The activities are sequenced logically to show the activity flow for the project. The activity flow can be determined by answering the following questions:

- What activities must precede the activity being examined?
- What activities can be concurrent with this activity?
- What activities must follow this activity?

#### 7.2.1.1 Working Activities

With respect to a given activity, these representations indicate points in time for the associated activities. Although the boxes in the precedence diagram represent activities, they do not represent time, and therefore they are not normally drawn to scale. They only reflect the logical sequence of events.

#### 7.2.1.2 Critical Activities

A critical activity is an activity within the network that has zero float time. The critical activities of a network make up the longest path through the network (critical path) that controls the project finish date. Two slash marks drawn through an activity connector, as shown in *Figure 2-26*, denote a critical path.

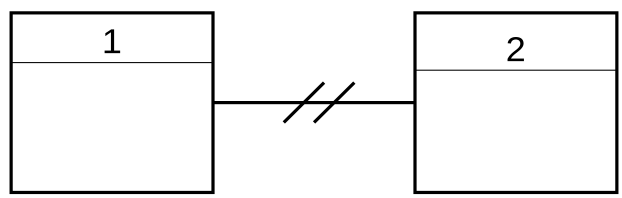



**Figure 2-26 – Designation of a critical path.**

The rule governing the drawing of a network is that the start of an activity must be linked to the ends of all completed activities before that start may take place. Activities taking place at the same time are not linked in any way. In *Figure 2-24*, both Activity 2 and Activity 3 start as soon as Activity 1 is complete. Activity 4 requires the completion of both Activities 2 and 3 before it may start.

### 7.2.2 Use of Diagram Connectors

Within a precedence diagram, connectors are lines drawn between two or more activities to establish a logic sequence. In the next paragraphs, we will look at the diagram connectors commonly used in the critical path method (CPM).

#### 7.2.2.1 Finish to Start Connector

The Finish to Start connector, shown in *Figure 2-27*, is the most widely used connector in a precedence diagram. This connector represents the finish of one activity and the start of another. In the activity block are boxes labeled Early Finish (EF), Late Finish (LF), Early Start (ES), and Late Start (LS), which are very critical in computing the forward pass and backward pass. These terms are covered later in this section.

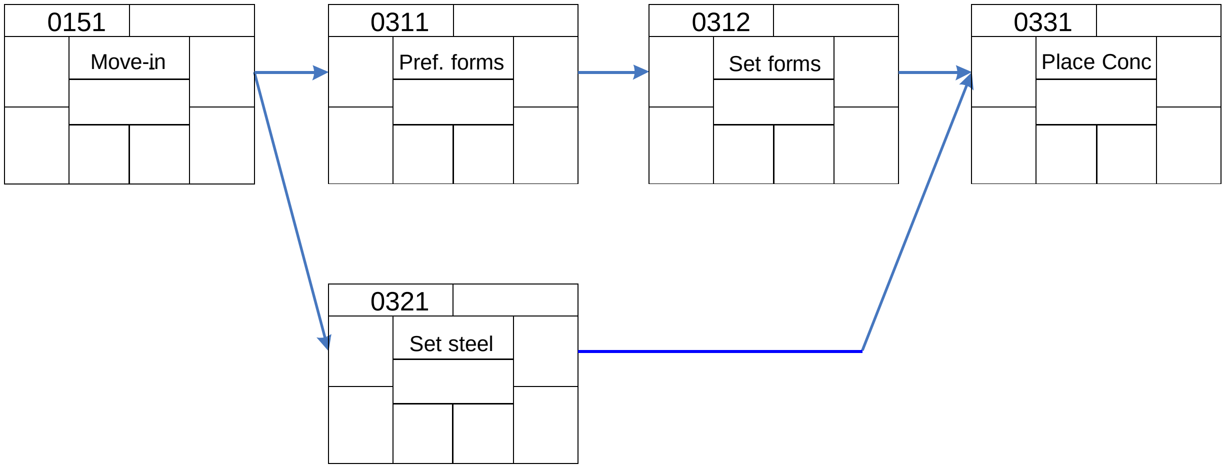



**Figure 2-27 – Finish to start connector.**

### 7.2.2.2 Start to Start Connector

The Start to Start connector, shown in *Figure 2-28*, represents activities that can either parallel each other or that may start at the same time or be delayed a day or two. For example, pre-fab forms can start at the same time as building layout starts, or setting forms can begin at the same time as excavation, but you might want to delay the setting of forms by 1 day for the EOs to excavate and make sure they are clear of where your crew is working.

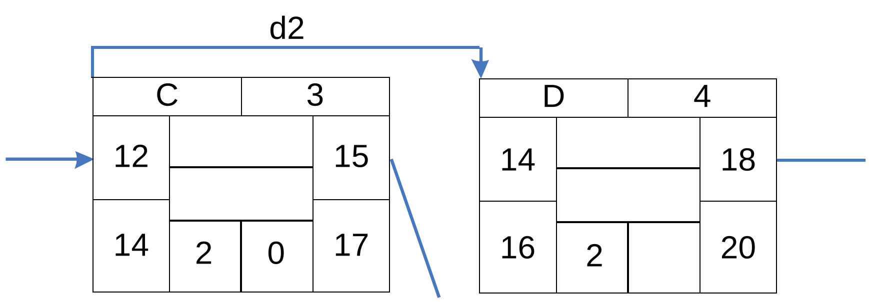



**Figure 2-28 – Start to start connector with a delay.**

### 7.2.2.3 Finish to Finish Connector

The Finish to Finish connector, shown in *Figure 2-29*, is possible when the start of an activity is independent but is not completed before another activity is completed. Exercise care when you use this logic connection. If possible, use the Finish to Start connector for all planning.

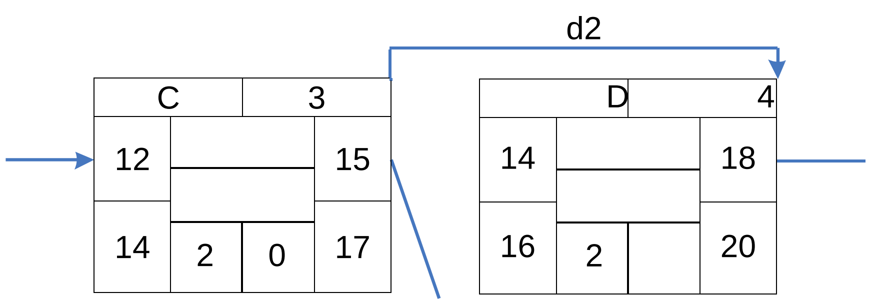



**Figure 2-29 – Finish to finish connector with a delay.**

#### 7.2.2.4 Representation of a Delay

Representation of a Delay, in certain cases, is used when there may be a delay or lag between the start of one activity and the start of another. In this case, the delay may be indicated on the connector itself, preceded by the letter *d,* as shown in *Figure 2-29*. Here Activity C may start, but Activity D must wait two days before starting. The delay is stated in the basic time units of the project, so the word *days* can be omitted.

#### 7.2.2.5 Splitting Connectors

Splitting Connectors are seldom used except when the network is of a great size. When two activities are remote and have to be connected, the lines tend to become lost or difficult to follow. In such cases, it is not necessary to draw a continuous line between the two activities. Their relationship is shown by circles with the following activity number in one and the preceding activity number in the other. In *Figure 2-30*, both Activities 2 and 3 are dependent upon Activity 1.

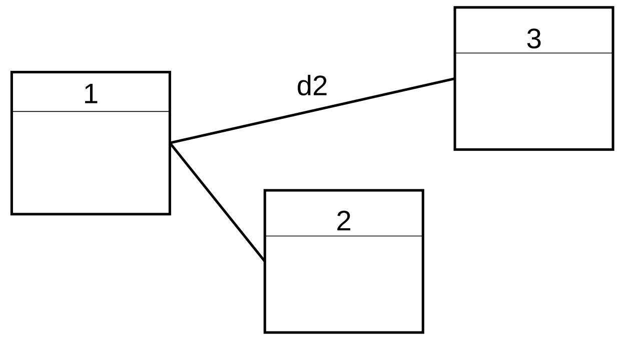



**Figure 2-30 – Splitting connectors.**

### 7.2.3 onstruction Schedule

You must put together realistic, workable schedules during the planning and estimating stages of a project if you hope to finish the tasking on schedule during the deployment. Crucial to a workable schedule is the proper, logical sequence of activities and good realistic durations. Performing the forward and backward pass will identify the critical path. The critical path gives you a list of milestones (activity completion dates) that must be met. If these milestones are met, the project will be on track and finished by the scheduled completion date.

#### 7.2.3.1 Level II Roughs

As the construction schedule unfolds, a commitment of resources (labor and equipment) from several different companies is required to ensure you can maintain the schedule. Rough Level II schedules coordinate the planning effort between companies and ensure that no particular company or rating is overtasked during any phase of the deployment. Good coordination in the beginning is less painful than a major overhaul later. Having determined the sequence and approximate duration of each master activity, you can construct a Level II bar chart. Each project will have a Level II. The OPS officers and the company commanders typically track projects using a Level II. Bar charts are covered in greater detail later in this chapter.

#### 7.2.3.2 Logic Network

The logic network, also referred to as precedence diagramming, is the basic management tool for controlling, monitoring, and distributing all resources directly related to time. The logic network at the planning stage is a pure dependency diagram. All activities are drawn in the order in which they must be accomplished without regard to particular construction preference. One of the major uses of the logic network during the planning stage is to indicate all activities that must be accomplished to complete a particular project, as shown in *Figure 2-31*. The individual network activities should be well defined elements of work within the project and should normally be limited to a single rating. As a general rule, an activity should be created for any function that consumes or uses direct labor resources. Resources (manpower, equipment, tools, or materials) MUST be tied directly to the CAS sheet and network.

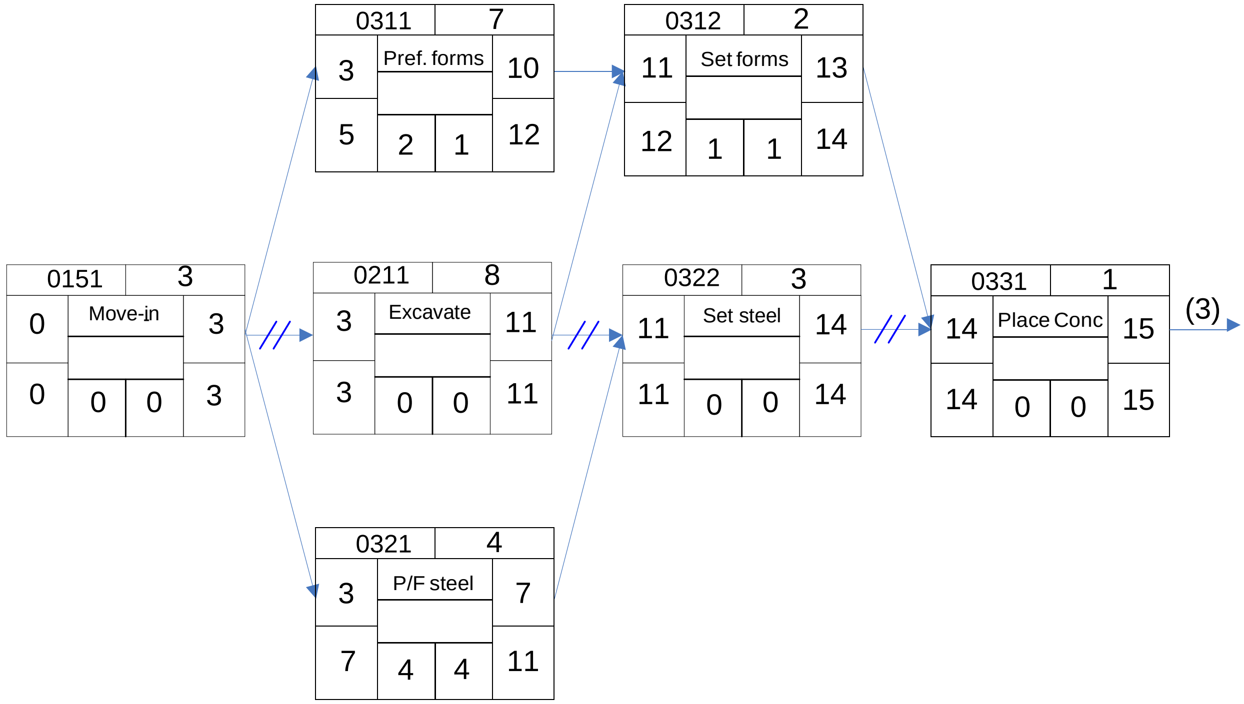



**Figure 2-31 – Logic network.**

The Crew Leader constructs a logic network, showing the sequence of construction activities from the first to the last and the dependencies between activities. Make sure no items of work are left out. It is important that you do the logic network when breaking the project down into construction activities. You do not yet have construction activity durations, so you are concerned only about the sequence of work. Each construction activity is represented by an activity block. In the network shown in *Figure 2-31*, activities 0311, 0321, and 0211 cannot start until activity 0151 is finished. Activity 0312 cannot start until 0311 and 0211 are finished, and activity 0331 cannot start until all previous activities are finished.

### 7.2.3.3 Basic Schedule (Forward and Backward Pass)

Using the crew sizes, now you can determine the construction activity durations. Go back to the logic diagram and insert the durations to determine the basic schedule. Practice with the example here and those included later. Some minor revisions may be required to the basic schedule (see resource leveling) before setting the final schedule. On the precedence network, you will need to insert into an activity block the activity number, the description, and the duration for each activity.

The first step in determining the basic schedule is to do a forward pass. The forward pass gives you the total duration of your project. Start with the very first activity and plug in a zero for its early start date. Then add the duration to the early start date to get the early finish date. The early finish date for an activity becomes the early start date for the next activity. Notice that activity 0312 in *Figure 2-31* has two preceding activities (0211 and 0311) and you chose the larger of the early finish dates (11 vice 10). Remember to add any lag time between the activities. Lag or delay times are mandatory wait times between activities. A common example is concrete cure times. Cure times require you to wait several days to weeks after placing concrete before you strip the forms.

**Early Start + Duration = Early Finish**

**Early Finish + Lag (if any) = Early Start (next activity)**

Look at the network in *Figure 2-31*; the early start and finish dates for an activity depend on the number and duration of the activities that have to precede it.

The next step in determining the basic schedule is a backward pass. The backward pass determines your critical path. Start by taking the early finish date for the last activity and making it the late finish for the last activity. For each activity, subtract the duration from the late finish date to get the late start date. The late start date will become the late finish date for the preceding activity. Notice that activity 0211 in *Figure 2-32* has two follow-on activities and you took the smaller of the late starts (11 vice 12). Follow the equations shown through the network in *Figure 2-31*. For any activity where the early start is the same as the late start and the early finish is the same as the late finish, that activity is critical!

**Late Finish - Duration = Late Start**

**Late Start - Lag (if any) = Late Finish (preceding activity)**

#### 7.2.3.4 Total Float

Total float is the number of days an activity can be delayed without delaying the project completion date. Looking at activity 0311 in *Figure 2-31*, you see that it could finish as early as day 10 or as late as day 12. The 2 days of leeway between day 10 and day 12 inactivity 0311 are called total float. To calculate the total float, subtract the early finish date from the late finish date or the early start date from the late start date. The numbers will be the same. If not, you made a math error.

**Total Float = Late Start - Early Start (or Late Finish - Early Finish)**

#### 7.2.3.5 Free Float

Free float is the number of days an activity can be delayed without taking float away from the next activity. Another way of saying the same thing is that free float is the number of days an activity can be delayed without delaying the early start date of the next activity. To calculate the free float for an activity, subtract any lag time and the early finish for the activity from the early start for the next activity. To calculate the free float for activity 0311 in *Figure 2-31*, take the early start for activity 0312, subtract any lag time between 1020 and 1050 (zero in this case), and subtract the early finish for activity 0311 (11 - 0 - 10 = 1). Free float for activity 0311 is 1 day. You can see that delaying activity 0311 by 1 day will not delay activity 0312 from its early start date. Delaying activity 0311 by 2 days will delay the start of activity 0312 until day 12 and reduce the float for activity 0312 by 1 day (to zero, in this case). The delay of activity 0311 by more than 2 days will delay the project completion date because 0311 has only 2 days of total float.

**Free Float = Early Start (next activity) - Lag time (if any) - Early Finish**

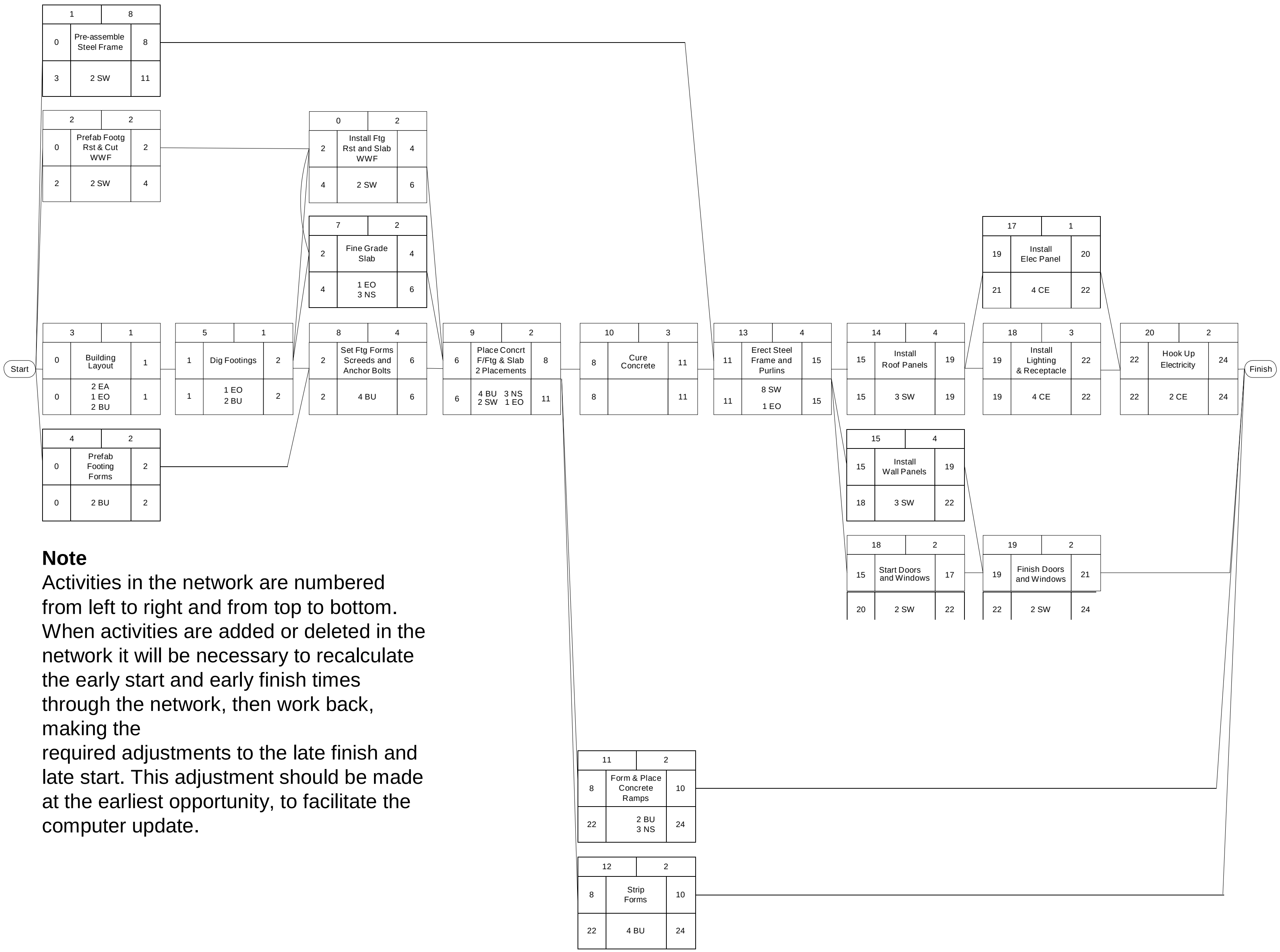
#### 7.2.3.6 Critical Path

Looking at activity 0311 in *Figure 2-31*, you could start that activity as early as day 3 or as late as day 5. Now subtract 3 from 5 and enter 2 days as the total float. Where the early start and late start are the same, there is no float. No float means you have to start that activity on its early start date. It cannot be delayed without delaying the project completion date. Activities with no float are said to be critical. The first and last activities will always be critical, and there will be a critical path of activities between them. The critical path in *Figure 2-31* is 0151-0211-0322-0331. The critical path allows management to focus attention on those activities that cannot slip.

### 7.2.4 Advantages of Diagrams

Precedence networks are easy to draw because all the activities can be placed on small cards, laid out on a flat surface, and easily manipulated until a logical sequence is achieved. It is also easy to show the interrelationships and forward progress of the activities. Just draw connector lines. *Figure 2-32* shows a typical diagram for a 40 by 100 foot rigid frame building.

Figure 2-32 – Typical precedence diagram for a 40 by 100 foot rigid frame building.




**Note**

Activities in the network are numbered from left to right and from top to bottom. When activities are added or deleted in the network it will be necessary to recalculate the early start and early finish times through the network, then work back, making the
required adjustments to the late finish and late start. This adjustment should be made at the earliest opportunity, to facilitate the computer update.

### 7.2.5 Level III Bar Charts

Having determined the construction schedule on the precedence network, you must now transfer that information to a bar chart. You can manually draw the bar chart or generate it on the Microsoft Project computer program. All of the construction activities are listed down the left hand column of the bar chart. Refer to the *Seabee Crewleader's Handbook* for a computer-generated Level III bar chart. A time scale is at the top of the page. The time scale goes from the first workday of the project to the last workday. The start date, finish date, and duration of each construction activity are shown on the bar chart. The double horizontal dash lines represent critical construction activity durations. The single dash lines represent noncritical activity durations. Free floats are shown as dots behind each noncritical activity. For activities with no free float, look at the activity that they are sharing floats with to find the total float.

### 7.2.6 Resource Leveling

Resource leveling involves matching the construction activities scheduled to the crew size available. You want the entire crew to be gainfully employed every day. You also want to keep up with the scheduled work and not fall behind. To perform resource leveling, you need a known crew size, a time-scaled schedule, and a histogram. The histogram shows how many people in each rating are required on a daily basis to complete the tasks scheduled. You can create these documents by hand or computer. The numbers give the required resources needed to complete the critical activities scheduled for each day. These activities cannot be moved without delaying the project!

The primary task in resource leveling is to schedule the noncritical work as you have people to do the work. You have resource leveled this project for a small detachment scenario. Here the prime/sub arrangement is not practical, and extensive cross-rate use of personnel is common. Some minor adjustments on crew sizes and durations may be required to ensure the full use of the assigned crew. Once all the activities are scheduled, input the noncritical resources and delayed start dates using lags, and create a new bar chart. You can create this new bar chart with the computer or manually.

### 7.2.7 Level II Bar Chart

You make a Level II bar chart from the information gained from the Level III. *Figure 2-33* is a Level II bar chart with master activities listed in a column on the left and the weeks of the entire deployment across the top.

**Figure 2-33 – Level II bar chart.**

The date used is always the Monday of that week. Next to each master activity is the man-day estimate for that master activity. The next column is the weighted percent, which is the master activity man-day estimate divided by the total project man-day estimate expressed as a percent (multiplied by 100). If you look at the Level II bar chart, you will see that master activity 03 has 140 man-days scheduled during the weeks beginning with 19 May through the week of 28 July. *Figure 2-33* has a horizontal bar connecting the weeks of 19 May and running to the end of week of 28 July for master activity 03 (concrete construction). The scheduled man-days for activity 03 are printed above the bar.

Once you have all the bars signifying master activity durations and the man-days scheduled on the bar chart, total the man-days scheduled for each 2-week period at the bottom of each column. The cumulative man-days scheduled are equal to the man-days scheduled for each 2-week period added to all previous man-days scheduled. The percent complete scheduled (plot) is equal to the cumulative man-days scheduled divided by the total project man-days. You then draw the scheduled progress curve by plotting the percent complete scheduled at the end of each 2-week period plotted against the percentage scale on the right of the Level II bar chart.

### Test your Knowledge (Select the Correct Response)

9. Which rule governs the drawing of a network?

   A. All working activities do not contain float.
   B. Critical nodes must have two slash marks.
   C. Simultaneous activities are always linked.
   D. The start of an activity is linked to the end of all completed activities.

# 8.0.0 Engineered Performance Standards (EPS)

Engineered Performance Standards (EPS) is one of many sources of facilities maintenance and repair standards. Developed by the Department of Defense, it is the only source of facilities maintenance and repair standards used by DoD personnel.

## 8.1.0 History of EPS

In the early 1950s, the Department of Defense (DoD) became concerned about managing real property maintenance activities. All the services faced a growing problem of maintaining an ever- increasing inventory of facilities (many of which were World War II vintage) being utilized far beyond their original designed life capacity. Where breakdown maintenance had been the operating policy, the new direction was to raise the level of maintenance so that these facilities could continue to be utilized. However, no additional resources were provided. In the meantime, accelerated new construction programs continually added more maintenance and repair requirements as permanent facilities were completed and turned over to the government.

To realize the fullest and most efficient utilization of available resources, industrial engineering procedures and techniques were applied and maintenance management systems developed. Within its framework came the idea of developing standards for maintenance work. This effort, beginning in 1957, formed the basis for the Navy's system. Several years later the Army and Air Force, who had been developing standards of their own, adopted the Navy's more advanced *Engineered Performance Standards* Program for estimating maintenance work.

EPS was developed by engineers using proven industrial engineering techniques and years of experience and expertise which have gone into the development of these standards.

## 8.2.0 Definition

Engineered Performance Standards represent the average time necessary for a qualified worker, working at a normal pace, under capable supervision and experiencing normal delays, to perform a defined amount of work of a specified quality while following acceptable trade methods.

EPS data is a tool used by planner/estimators to develop consistent, uniform, and accurate facilities maintenance and repair estimates. Any trained planner and estimator who has a good working knowledge of the trade should be able to develop good labor estimates using these standards.

## 8.3.0 Training

The Department of Defense has designed a training aid to the EPS system called the *Work Estimating Desk Guide for Real Property Maintenance Activities Planners and Estimators.* This manual emphasizes the use and application of the Engineered Performance Standards. Any supervisor stationed at a Public Works Center (PWC) or Public Works Department (PWD) should go through this course using this manual as a reference.

## 8.4.0 Advantages of EPS

Engineered Performance Standards are designed specifically for facilities maintenance type work through the observation of maintenance workers at work. The work is measured through the use of proven industrial engineering techniques, such as Methods-Time Measurement (MTM), work sampling, and time studies. They are designed to relate a given amount of work to the labor hours needed to accomplish the work.

EPS estimates are based on the labor hours needed to do a specified amount of work under normal conditions. When EPS is properly applied under those normal conditions, the craft time should be valid at any work site in any geographical location.

EPS is the only facilities maintenance work estimating source that provides consistent measures of maintenance work productivity. As a benchmark, EPS provides a means of measuring productivity. The variance between EPS estimates and the actual labor time can be evaluated to identify work process problems impeding both the productivity of the work force and the quality of the work output.

Facilities maintenance work does not lend itself to pinpoint accuracy for any single job or task. Rather, the accuracy of EPS-based estimates increases as the size of the job increases and the effect of averaging levels the variables stated in the EPS definition: normal pace, capable supervision, normal delays, and acceptable trade methods.

Engineered Performance Standards are developed and consistently applied so that planners/estimators can estimate a greater variety of jobs with increased accuracy in less time and with less formal data than using conventional data. All EPS data is applied in the same way.

## 8.5.0 Planning and Estimating

The planner/estimator holds the key position in the Shore Facilities Maintenance System. This person or these persons are responsible for planning technical jobs and estimating the number of man-hours needed to complete the maintenance work.

The estimator defines the scope of a project by specifying the work to be accomplished and the skills required. To help the estimator in this job, the Navy has developed *Engineered Performance Standards* (EPS), which gives estimates of the time needed to complete the particular craft phases of a job. You will find a complete description of EPS in the NAVFAC P-700 series. Since these standards save time and usually provide more reliable estimates than individual judgment, the estimators should use them. When an engineered design is needed, the Engineering Branch provides it to the estimator. Two types of estimates are used and each conforms to a particular need.

### 8.5.1 Scoping Estimate

Typically, the scoping estimate helps management get an estimate of job costs before assigning a job priority. The formal planning and estimating process can provide this, but only at significant expense. Since a ball park estimate is normally adequate, NAVFAC has encouraged the use of the scoping estimate as a rough, quick estimate of costs. The scoping estimate is particularly useful when you deal with reimbursable customers. You can inform them of the approximate job costs and ask if they want to go on with the work. Use *Unit Price Standards,* NAVFAC P-716.0 when preparing scoping estimates.

### 8.5.2 Final Estimate

Do not authorize a final estimate until the job is approved. This type of estimate shows all the work operations listed on the job plan and considers the analysis of work operations in detail. The final estimate should be the most accurate forecast possible of the costs, the man-hours, and the material requirements for a given job. Make every effort to provide a final estimate within a reasonable time. After planning and estimating the job, formalize it as a job order by assigning a job order number and completing the accounting data. The job is ready for scheduling (first into a specific month, then into a specific week) for completion by the Maintenance Branch.

## 8.6.0 Work Input Control and Scheduling

To assure completion of authorized work efficiently, you must set up some means of control. To help in the orderly flow and completion of work, you need to use work input control and scheduling procedures. These procedures require you to use several forms and charts.

### 8.6.1 Work Input Control

Work input control is a formal means of managing the total PWD work load. It also serves as a central source of work status information of the Job Requirements and Status Chart, the Manpower Availability Summary, and the Work Plan Summary.

### 8.6.2 Job Requirements and Status Chart

The Job Requirements and Status Chart, shown in *Figure 2-34*, provides a ready reference for tracking all the specific and minor jobs established as known maintenance requirements. The chart includes all customer-financed individual jobs and minor construction, alteration, and improvement work. In addition, this chart provides information on proposed planning to determine the status of work not programmed for shop accomplishment. Upon approval, you should enter all new work on this chart. The entry should remain until the authorization of work for shop completion, cancellation, or completion by contract is granted. You can maintain a different Job Requirement and Status Chart for each major type of work, such as alterations and minor construction, customer work, and maintenance and repair.

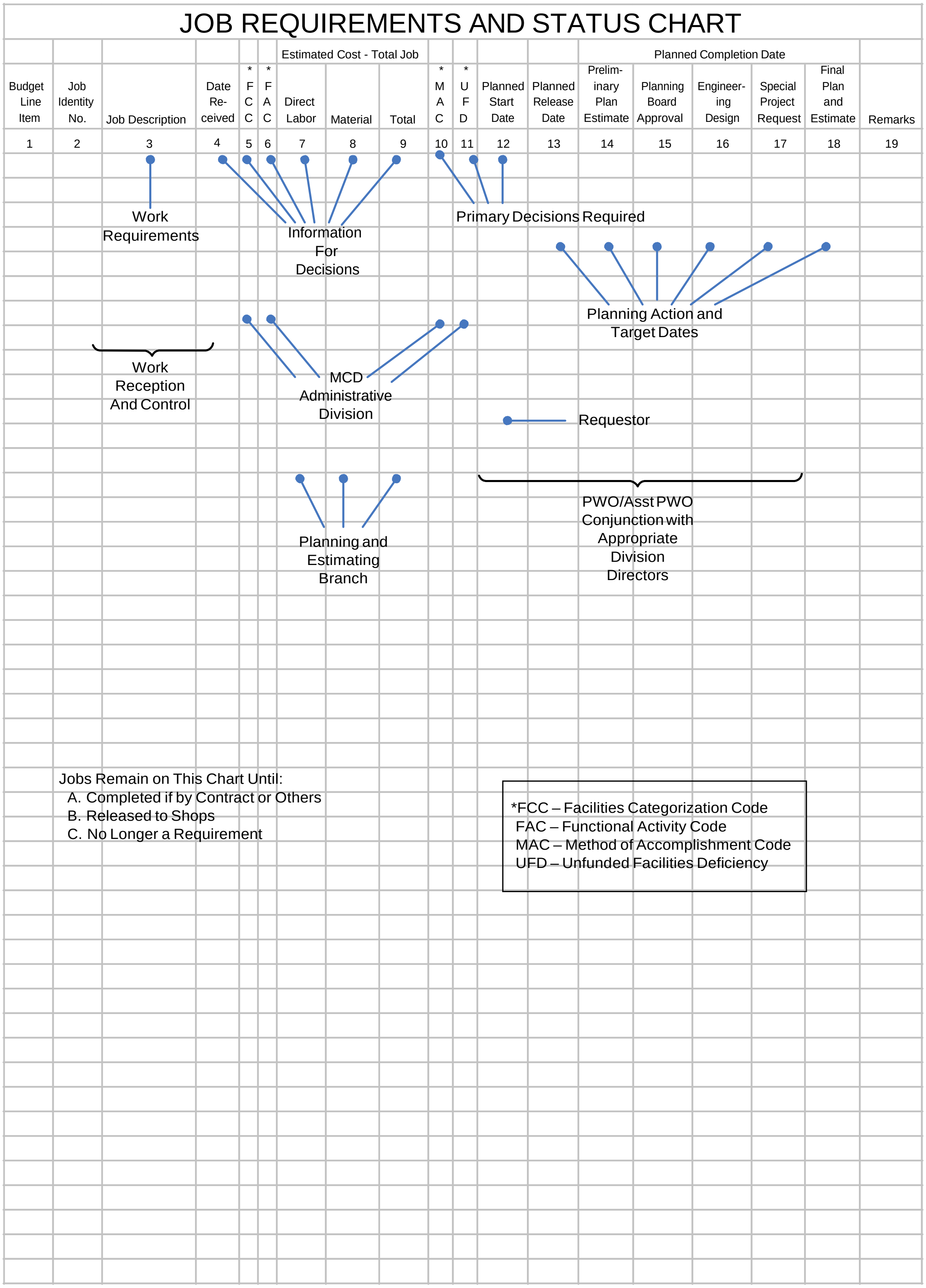



**Figure 2-34 – Job requirements and status chart.**

## 8.6.3 Manpower Availability Summary and Work Plan Summary

The Manpower Availability Summary and Work Plan Summary in *Figure 2-35* show the department's plan for using the Maintenance or Utilities Branch work force. Breaking down the Work Plan Summary by funding sources shows a payroll support plan.

Before formulating and adjusting the monthly shop work load, the job order programmer must know the man-hours available for programming within each work center. When customer funds provide significant support to the PWD, the programmer must know the number of man-hours allotted to each funding source. To decide this information, the programmer should develop a Manpower Availability Summary and a Work Plan Summary for each month.

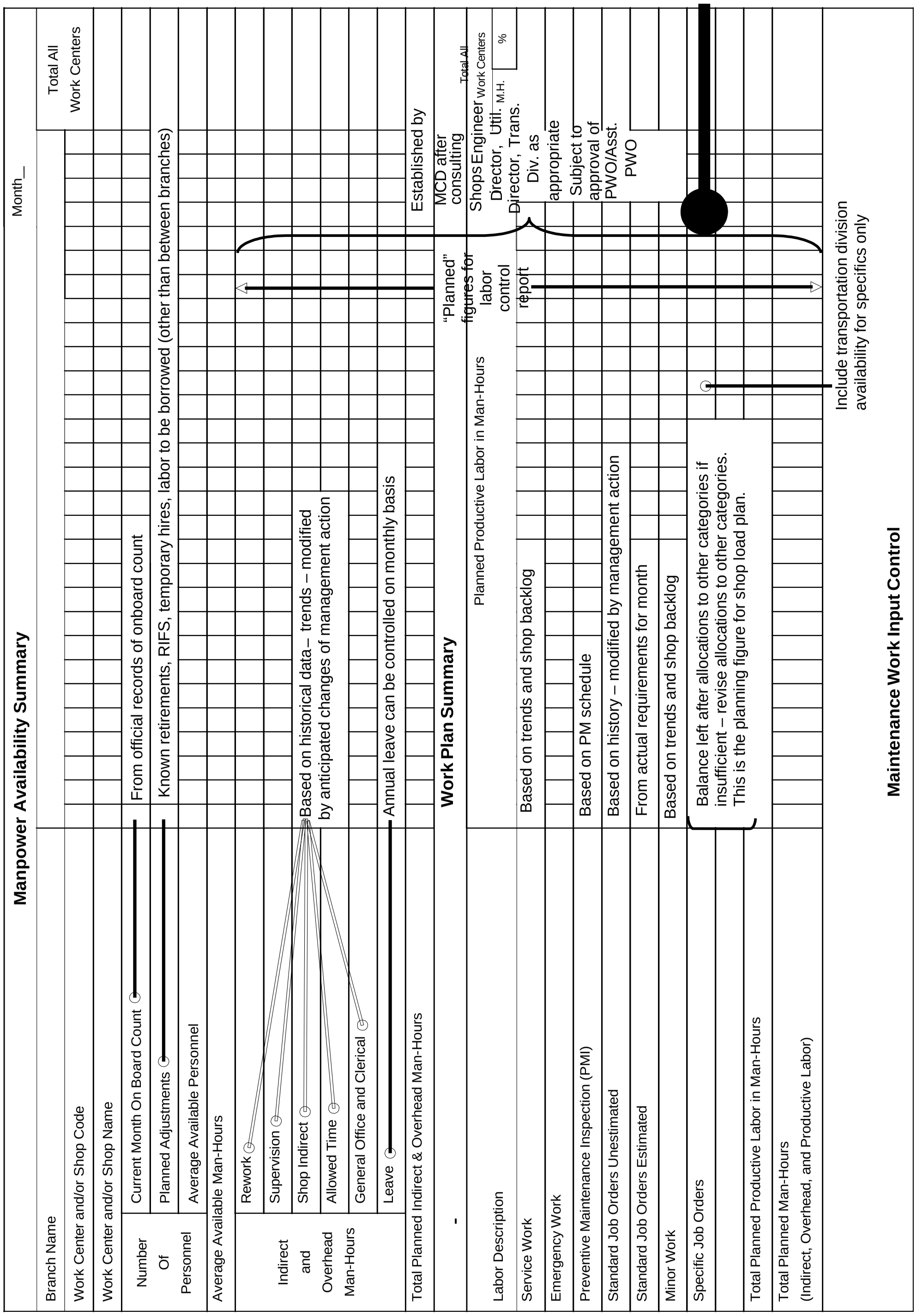



**Figure 2-35 – Manpower availability summary and work plan summary.**

## 8.6.4 Monthly Shop Load Plan

The work control method used within the Maintenance Management System is the Shop Load Plan (SLP) shown in *Figure 2-36*. The SLP is the Public Works management plan for using shop force and specific job orders for a given month. This monthly plan provides the shop planner with direction on what jobs to schedule within the month. All levels of management from the shop's divisions up to the PWO participate in its preparation.

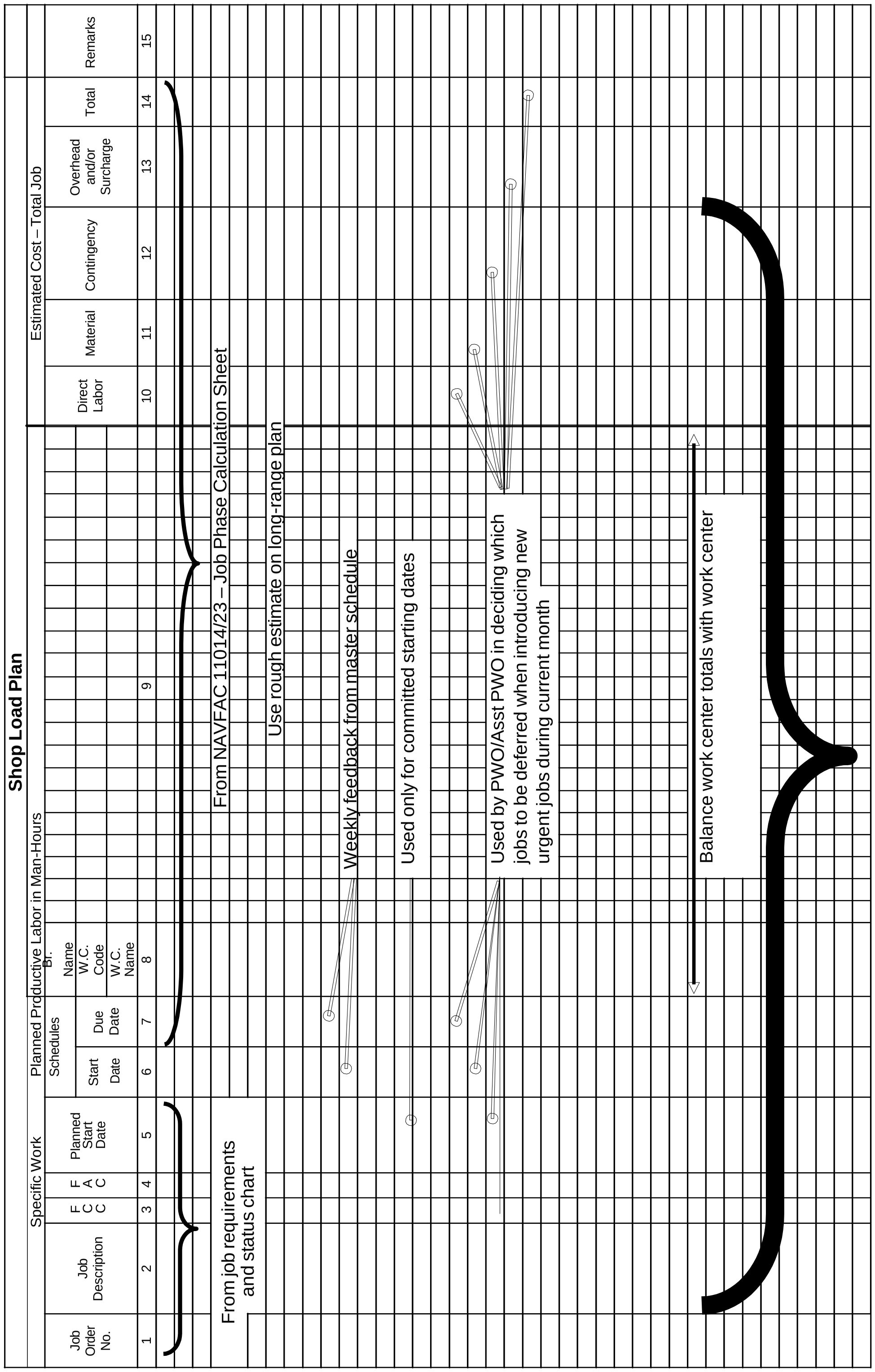



**Figure 2-36 – Shop load plan.**

Express the SLP by the obligation of the known available man-hours for each work center and for each job scheduled. The SLP consists of sections for short-range and long-range planning. The short-range plan covers the nearest 3 months, and the long-range plan covers the following 9 months. The suggested loading for the short-term plan is 100 percent for the first month, 90 percent for the second month, and 80 percent for the third month. Jobs that appear on the SLP become the shop backlog. For maximum productivity, always try to have a 3- to 6-month backlog to balance the work that goes to the shops.

### 8.6.5 Shop Scheduling

Shop scheduling takes place in a two-stage scheduling system: (1) master scheduling of specific job orders and (2) weekly and work center scheduling of specific and minor job orders. Master scheduling connects specific jobs to each work center for accomplishment during the following week. Work center scheduling takes up where master scheduling leaves off. The work center supervisor breaks down the weekly assignments into daily assignments for the workers in the shop. After making the daily assignments on specific job orders, the work center supervisor assigns work to the remaining uncommitted shop forces.

The shop planner/scheduler, using the SLP for the coming month, consults with the proper shop supervisor to schedule the work for the coming weeks. The man-hour schedule should be consistent with the available man-hours identified for specific job order work on the Manpower Availability Summary and Work Plan Summary.

On a weekly basis, compare the master schedule with the actual man-hours expended by the work center to find out if jobs meet the estimate of the master schedule. If a job is off schedule, adjust the work center schedule of the following week without making major changes to the master schedule.

The shop supervisor reviews the master schedule and prepares the work center schedule each week. He or she reviews it daily to ensure the maximum use of shop resources. The shop supervisor coordinates with other shops when a requirement for more than one craft exists.

Shop scheduling is required throughout the job when the shop performs at various stages of the work. For example, the Builders would open an area to allow the plumbers to make a repair and they would then close the area after the repair with the painters arriving later for final touches. To schedule the job properly, divide the carpenter’s time between two distinct work phases. You must make sure all the plumbing repairs are done before the carpenters return to the work place. Do not schedule the painters until all the other workers have finished their assignments.

This chapter does not attempt to tell you everything about planning, estimating, and scheduling of a construction project; however, the information given you and the references listed throughout this chapter are what you need to know in order to understand planning and estimating procedures.

## Test your Knowledge (Select the Correct Response)

10. Engineered Performance Standards (EPS) are designed for ________.

    A. facilities maintenance-type work
    B. estimation of job costs
    C. use by the drafting section in an Engineering Department
    D. assignment of work to an NMCB

## Summary

This chapter provides various, but limited insight into the Seabee Skill Assessment, construction administration, training, safety, environmental pollution, and hazardous material. The information given and the references listed are what you need to study to advance, hone your skills, and become an outstanding Seabee.

## Review Questions (Select the Correct Response)

1. What is the official contract drawing that you will mark on during construction to show the actual as-built conditions?

   A. As-built
   B. Final
   C. Project
   D. Red-lined

2. When a construction project is completed, what type of drawing must be submitted to ROICC?

   A. As-built
   B. Final
   C. Red-lined
   D. Working

3. What type of plan shows the spot where a building is to be placed on a piece of land?

   A. Engineering
   B. Floor
   C. Site
   D. Structural

4. To find the size and placement of reinforcing steel in the grade beam for a building, you should look in what main division of the drawings?

   A. Architectural
   B. Civil
   C. Mechanical
   D. Structural

5. Which of the following divisions should contain the environmental pollution controls?

   A. Architectural
   B. Civil
   C. Mechanical
   D. Structural

6. Specifications from which of the following sources, combined with drawings, define the project in detail and show exactly how it is to be constructed?

   A. The American Society for Testing and Materials
   B. The American National Standards Institute
   C. Manufacturers specifications
   D. Project specifications

7. **(True or False)** Whenever there is conflicting information between the drawings and project specs, the specifications take precedence over the drawings.

   A. True
   B. False

8. The Construction Standards Institute (CSI) has organized the format of specifications into 16 construction divisions, but NAVFAC has added a 17$^{th}$ division. What is the name of this division?

   A. ABFC
   B. Expeditionary structures
   C. PEB
   D. Technology

9. **(True or False)** In most NCF projects, construction activities should NOT be less than six days in duration.

   A. True
   B. False

10. What section of the project package contains the Bill of Materials?

   A. Three
   B. Four
   C. Five
   D. Six

11. The work schedule of a battalion for one person per week is based on an average of how many hours?

   A. 40
   B. 48
   C. 50
   D. 55

12. In an NMCB, what is the normal duration of a workday, in hours, to and from the job site?

   A. 8
   B. 9
   C. 10
   D. 12

13. NAVFAC P-405, *Seabee Planner's and Estimator's Handbook* defines a man-day as how many hours per day?

   A. 6
   B. 8
   C. 10
   D. 12

14. What type of estimates are the basis for purchasing materials, determining equipment, and determining manpower requirements?

    A. Activity
    B. Material
    C. Quality
    D. Quantity

15. Master activities are usually assigned to the projects by what authority?

    A. CBUs
    B. NCBs
    C. NCRs
    D. NMCBs

16. Which of the following activities is NOT an activity that would be listed on a Master Activities List for a typical building project?

    A. Furnishings
    B. Moisture protection
    C. Paint
    D. Specialties

17. What NAVFAC publication lists the number of man-hours to accomplish one unit of work?

    A. P-315
    B. P-405
    C. P-415
    D. P-417

18. **(True or False)** The man-day capability equation is used to calculate the duration of a construction activity.

    A. True
    B. False

19. For planning purposes, what authority assigns an availability factor to an NMCB?

    A. Naval Construction Brigade
    B. Naval Construction Regiment
    C. Naval Mobile Construction Battalion
    D. On-site commander

20. Which of the following information is NOT documented on Construction Activity Summary sheets?

    A. Man-day calculations
    B. Notes
    C. PRCP skills
    D. Tool requirements

21. Material estimates are NOT used to determine which of the following elements for a project?

A. Description of the material
B. Sufficiency of available material
C. Amount of administrative support needed
D. Identification of construction material to be procured

22. During the construction phase of a project, what person should have control of the estimating work sheets?

A. A crew chief
B. The activity commander
C. The field supervisor
D. The project engineer

23. **(True or False)** The estimating work sheet shows the various individual activities for a project with a listing of the required material.

A. True
B. False

24. **(True or False)** A Bill of Material sheet is used to check the status of supplies and the location of material, and to prepare purchase documents.

A. True
B. False

25. To determine the construction equipment requirements for a deployment, use equipment estimates with what type of schedules?

A. Equipment
B. Material
C. Production
D. Project

26. Which of the following items is NOT a long-lead item?

A. Cabinets
B. Lumber (small purchase)
C. Pre-engineered buildings
D. Treated wood products

27. **(True or False)** To estimate the number of days equipment will be used on a project, divide the quantity of work by the production rate per day.

A. True
B. False

28. The ABFC system provides labor estimates that are based on what number of hours per workday?

A. 6
B. 8
C. 10
D. 12

29. You use the production efficiency graph to determine what factor?

A. Availability
B. Delay
C. Labor
D. Production

30. What is the average production rate for a Seabee?

A. 62%
B. 67%
C. 75%
D. 85%

31. **(True or False)** The Production Efficiency Guide Chart is a tool used to assist in weighing factors that contribute to the successful completion of a project.

A. True
B. False

32. Which of the following schedules is NOT a basic type of schedule used on a project?

A. Equipment
B. Material
C. Progress
D. Working

33. What method is the basis of the concept used to develop precedence diagrams?

A. Network path
B. Dependencies
C. Critical path
D. Activity path

34. You must use an activity block to show work sequence. What does the left side of the activity block represent?

A. Completion
B. Man-day
C. Man-hour
D. Start

35. Activities are divided into what total number of groups?

A. Two
B. Three
C. Four
D. Five

36. Two slash marks drawn through an activity connector on a precedence diagram identifies what type of activity?

A. Critical
B. Equipment
C. Heavy construction
D. Working

37. What concept do the boxes on a precedence diagram provide?

A. Priority of events
B. Task functions
C. Logical sequence of events
D. Timed events

38. What connector is used most often in a precedence diagram?

A. Finish to finish
B. Finish to start
C. Start to finish
D. Start to start

39. What connector on a precedence diagram represents parallel activities?

A. Critical to finish
B. Finish to start
C. Start to finish
D. Start to start

40. What symbol is used on a precedence diagram to identify a delay?

A. d
B. d@L
C. DEL
D. L

41. What type of schedule is used to coordinate the planning effort between companies to ensure that no particular company or rating is over-tasked?

A. Level I Roughs
B. Level II Roughs
C. Level III Roughs
D. Level IV Roughs

42. The logic network, also referred to as precedence diagramming, is the basic management tool for controlling all resources that are directly related to what factor?

A. Logistics
B. Material
C. Supply
D. Time

43. When computing a forward pass, start with the very first activity and plug in what numerical value?

A. 0
B. 1
C. 2
D. 3

44. The equation Early Start minus Lag Time minus Early Finish is used to calculate what time factor?

A. Duration
B. Forward pass
C. Free float
D. Lead time

45. What equation is used to calculate total float?

A. Duration minus Lag time
B. Early Start minus Duration
C. Late Start minus Early Start
D. Late Start minus Lag time

46. **(True or False)** A histogram shows how many people in each rating are required on a daily basis to complete the tasks scheduled.

A. True
B. False

47. **(True or False)** The primary task in resource leveling is to schedule the critical work as you have people available to do the work.

A. True
B. False

48. What person in the PWD organization is responsible for developing a manpower availability summary and a work plan summary on a monthly basis?

A. Job order programmer
B. Maintenance manager
C. Shop foreman
D. Shop scheduler

49. The scheduling system used for shop scheduling is composed of what total number of stages?

A. One
B. Two
C. Three
D. Four

50. The Public Works management plan for using shop force and specific job orders for a given month is known as the ________.

A. Master Job Plan (MJP)
B. Shop Force Plan (SFP)
C. Shop Leader's Schedule (SLS)
D. Shop Load Plan (SLP)

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*Engineering Basic,* NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

*Engineering Performance Standards,* NAVFAC P-700 (series), Naval Facilities Engineering Command, Alexandria, VA, 1995.

*Military Handbook,* MIL-HDBK 1006/1, “Policies and Procedures for Project Drawings and Specifications,” Chesapeake Division, Chesapeake, VA, 1987.

*NCF/Seabee Petty Officer 1 & C,* NAVEDTRA 12543, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

*Seabee, Crewleader’s Handbook,* Civil Engineering Corps Officer School (CECOS) CBC, Port Hueneme, CA, 1997.

*Seabee Planner’s and Estimator’s Handbook,* NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write or email us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

________________________________________

________________________________________

________________________________________

(Optional) Correction

________________________________________

________________________________________

________________________________________

(Optional) Your Name and Address

________________________________________

________________________________________

________________________________________

# Chapter 3

# Concrete Construction

## Topics



To hear audio, click on the box.

## Overview

Concrete construction, once confined largely to paving and foundations, has been developed to the point where both large and small buildings are now constructed entirely of concrete with concrete joists (usually called floor or grade beams), concrete studs (usually called columns), concrete walls, concrete floors, and concrete roofs.

This chapter explains some of the major factors in the design of concrete forms, as well as the various methods by which you can select the proportions for quality concrete mixtures and adjust these mixtures to suit job requirements. We also cover types and uses of admixtures and slump testing procedures. We point out some of the types of equipment you are likely to encounter in concrete construction. A brief discussion is also included on precast construction.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Understand potential hazards in working with concrete and identify ways to safely work with concrete.
2. Understand and be able to apply the principle objectives of using formwork; economy, quality, and safety.
3. Identify the different types of reinforcing steel and understand the uses of each type.
4. Determine the correct amount of cement, water, and coarse and fine aggregates for concrete mixtures. Understand the effects of admixtures.
5. Identify precast and tilt-up construction. Understand methods for fabricating and placing precast members.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

## 1.1.1 CONCRETE SAFETY

Concrete construction, like all types of construction, involves a certain degree of danger. To help you do your concrete work safely, we will discuss the various safety precautions concerning concrete.

- Form construction and concrete placement have peculiarities in each job; however, certain natural conditions will prevail in all situations. Wet concrete will always develop hydrostatic pressure and strain on the forms. Therefore, be sure to properly secure and inspect all stakes, braces, and other supporting members before placing the concrete.
- All formwork, shoring, and bracing should be designed, fabricated, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that might be applied until the structure can support loads.
- Correctly place and secure all nailing according to the plans and specifications. Careless nailing and exposed nails in formwork are a major cause of accidents.
- Build adequate scaffolding to permit crew members to stand clear of pouring areas.
- Rebar caps are a MUST for all exposed vertical rebar.
- Inspect tools frequently, particularly hammers. GFCIs must be used with all power tools. Ensure the location of the GFCIs is close to your equipment.

Supervisor(s) should check all forms before each pour. Stripped forms should be piled in advance of any movement or change of direction. During night operations, all equipment should be equipped with sufficient flood spotlights to make the perimeter of the operations clearly visible. The pouring bucket and the boom of the paver operating controls should have a synchronized warning device to function automatically with the motion of either the boom or the traveling bucket.

- Personnel may be subject to cement poisoning (lime); therefore, ensure they have their shirt sleeves rolled down and wear gloves and goggles when working with concrete.
- If concrete buckets and cranes are used in pouring, provide each bucket with a tag line or two, depending on the location. A crew member should never ride a concrete bucket during a pour.
- Do not attempt raising of large form panels by hand or by crane in heavy gusts of wind.
- Inspect skip loader cables and brakes frequently to prevent injuries caused by falling skips.
- The mixer operator must never lower the skip without first ensuring there is no one under it.
- Keep the area around the mixer clear.
- Dust protection equipment must be issued to crew members engaged in handling cement, and they must wear the equipment when so engaged. Workers should stand with their backs to the wind, whenever possible, to prevent cement and sand from being blown into their eyes and faces.

- Whenever the mixer drum is being cleaned, the switches must be open, the throttles closed, and the control mechanism locked in the OFF position.
- Whenever possible, a flagman or watchman should be stationed near the mixer to warn all hands when a batch truck is backing up to the skip. The watchman should use a whistle to warn any personnel in the danger zone. “DANGER-KEEP AWAY” signs should be placed where they can readily be seen.

# 2.0.0 FORMWORK

Formwork is a temporary structure that supports its own weight and that of the freshly placed concrete as well as the live loads imposed upon it by materials, equipment, and personnel. The most commonly used form materials are earth, metal, lumber, plywood, and fiber.

As a Builder serving in the capacity of a form designer or as the supervisor of a form building crew, you should take into account the three principle objectives when using formwork – economy, quality, and safety.

Economy is the major concern since formwork may represent as much as one third of the total cost of a concrete structure. Savings depend on the ingenuity and experience of the formwork designer or supervisor. Judgment in the selection of materials and equipment, in planning fabrication and erection procedures, and in scheduling reuse of forms will expedite the job and help reduce formwork costs. In designing and building formwork, aim for maximum economy without sacrificing quality or safety. Shortcuts in design or construction that endanger quality or safety may be false economy. For example, if the forms do not produce the specified surface finish, much hand rubbing of the concrete may be required; or if forms deflect excessively, bulges in the concrete may require expensive chipping and grinding. Obviously, economy measures that lead to formwork failure also defeat their own purpose.

## 2.1.0 Form Design

Forms must be designed for all the weight to which they are liable to be subjected, including the dead load of the forms, the plastic concrete in the forms, the weight of crew members, the weight of equipment and materials that may be transferred to the forms, and the impact due to vibration. These factors vary with each project, but do not neglect any of them. Ease of erection and removal are also important factors in the economical design of forms. Platforms and ramp structures independent of formwork are sometimes preferred to avoid displacement of forms due to loading and impact shock from crew members and equipment. Formwork for concrete must support all vertical and lateral loads that may be applied until the concrete structure itself can carry these loads. Loads on the forms include the weight of reinforcing steel and fresh concrete, the weight of the forms themselves, and various live loads imposed during the construction process. Consideration must be given to such conditions as unsymmetrical placement of concrete, uplift, and concentrated loads produced by storing supplies on the freshly placed slab. Rarely will there be precise information about the loads to which the formwork may be subjected; therefore, the architect or Builder must make some safe assumptions that will hold good for conditions generally encountered.

### 2.1.1 Vertical Loads

Vertical loads on formwork include the weight of reinforced concrete together with the weight of the forms themselves, which are regarded as dead loads, and the live loads imposed by the crew members and the equipment used during construction. The majority of formwork involves concrete weighing 150 pounds per cubic foot. Minor variations in this weight are not significant, and in most cases, 150 pounds per cubic foot, including the weight of the reinforcing steel, is commonly assumed for design. Formwork weights vary from as little as 3 or 4 pounds per square foot (psf) to 10 to 15 pounds per square foot. When the frame work weight is small in relation to the weight of the concrete plus the live load, it is frequently neglected. If concrete weighs 150 pounds per cubic foot, it will place a load on the forms of 12.5 pounds per square foot for each inch of slab thickness. Thus a 6 inch slab would produce a dead load of 6 by 12.5 or 75 pounds per square foot, excluding the weight of forms. The recommended minimum construction live load to provide for the weight of crew members and equipment is 50 pounds per square foot of horizontal projection. If powered concrete buggies are used in concreting operations, it is recommended that 75 pounds per square foot be used as a minimum construction live load.

### 2.1.2 Lateral Pressure

When concrete is placed in the form, it is in a plastic state and behaves temporarily like a fluid, producing a hydrostatic pressure that acts laterally on the vertical forms. If concrete acted as a true liquid, the pressure developed would be equal to the density of the fluid (150 pounds per cubic foot is commonly assumed for concrete) times the depth in feet to the point at which the pressure was being considered. However, plastic concrete is a mixture of solids and water whose behavior only approximates that of a liquid, and then only for a limited time. This lateral pressure is comparable to a full-liquid head when concrete is placed full height within the period required for its initial set. With slower rates of placing, concrete at the bottom of the forms begins to harden, and the lateral pressure is reduced to less than full-fluid pressure by the time concreting is completed in the upper parts of the form.

The effective lateral pressure, a modified hydrostatic pressure, has been found to be influenced primarily by the rate of placing and the temperature of the concrete mix. Other variables that have been found to have an effect on lateral pressure include consistency of concrete, amount and location of reinforcement, vibration, maximum aggregate size, and placing procedures. However, with usual concreting practices, the range of the effects of these variables is generally small and is either neglected or compensated for in design tables.

### 2.1.3 Lateral Loads

Adequate lateral bracing is extremely important to stability and safety in formwork construction, but all too often, it is treated carelessly or even omitted entirely. Formwork must be braced to resist all foreseeable lateral loads, such as those imposed by wind, dumping of concrete, or any other impact, such as starting and stopping of equipment. There are many types of braces that can give forms stability. The most common type is a diagonal member and horizontal member nailed to a stud or wale. The diagonal member should make a 45-degree angle with the horizontal member. Additional bracing may be added to the form by placing vertical members (strongbacks) behind the wales or by placing vertical members in the corner formed by the intersecting wales.

## 2.2.0 Wall Form Design

Concrete forms must be constructed to resist the pressure exerted on them by the freshly placed concrete without deflection (side displacement) beyond a specified maximum. This maximum is very small; for a wall form, for example, the maximum deflection of sheathing, studs, and wales is not over 1/270th of the span.

Placing concrete exerts a very considerable lateral (side) pressure on the form sheathing. The pressure at the bottom of the freshly placed concrete is greater than that at the top and the pressure increases with the height of the form.

When designing formwork, you must design the sheathing, the stud, and the waler spacing to a given pressure (vertical rate of placement).

### 2.2.1 Vertical Rate of Placement

To determine the vertical rate of placement for concrete wall forms, divide the quantity of concrete (mixer output) placed into the form in an hour (in cubic feet) by the horizontal area of the form space being filled. Suppose you are filling a wall section for a wall 30 feet long by 12 inches thick. The horizontal area would then be 30 square feet. See the formula below.

$$\textbf{Mixer output (cubic feet/ hour)} = \frac{\textbf{Mixer yield (cubic feet)}}{\textbf{Batch time (minutes)}} \textbf{ x 60 minutes/hour}$$

Let's take the hourly rate of the 11 S mixer (11 cubic feet per load) which has an hourly output of 4 to 8 cubic yards or from 108 to 216 cubic feet (depending on personnel) in a continuous operation. However, the quantity of concrete placed in the form per hour will depend on how continuous the mixer operation is and how rapidly the mix is transferred from the mixer to the form. This quantity you will have to determine according to your knowledge and circumstances at the job site. Let's assume that you estimate 8 cubic yards or 216 cubic feet will be placed in the form per hour. In this case, the vertical rate of placement is 216 cubic feet divided by 30 square feet of horizontal area, or about 7 feet per hour. See the formula below.

$$\textbf{Rate of placing (R) (feet/hour)} = \frac{\textbf{Mixer output (cubic feet/hour)}}{\textbf{Plan area (square feet)}}$$

**NOTE**

For an economical design, try to keep the rate of placement to 5 feet/hour or less.

### 2.2.2 Pressure from Vertical Rate of Placement

To determine the maximum concrete pressure, the Builder must know the temperature of the concrete and the rate of placement per square foot. When you know these things, you can determine the maximum concrete pressure by using the chart shown in *Figure 3-1*.

For example, to find the maximum concrete pressure, first make a reasonable estimate of the temperature of the concrete, let's say 70° F, and it has a rate of placement at 7 feet per hour. Move across the table to 70°F, and then move down the table to 7 feet per hour. In this case, the maximum pressure of concrete is 1,050 pounds per square foot (psf).

#### 2.2.2.1 Maximum Spacing of Wall Form Studs

Suppose you want to know the maximum spacing when using 3/4 inch sheathing with a concrete pressure of 600 pounds per square foot. Refer to *Table 3-1*.

**Figure 3-1 – Maximum concrete pressure graph.**

**Table 3-1 – Maximum Stud (Joist) Spacing for Plywood Sheathing.**

| **Maximum Concrete Pressure** | **Strong way (in) 5-ply sanded, face grain, parallel to span** | | | | **Weak way (in) 5-ply sanded, face grain, perpendicular to span** | | | |
|---|---|---|---|---|---|---|---|---|
| (lb/sf) | 1/2 | 5/8 | 3/4 | 1/7 ply | 1/2 | 5/8 | 3/4 | 1/7 ply |
| 75 | 20 | 24 | 26 | 31 | 13 | 18 | 23 | 30 |
| 100 | 18 | 22 | 24 | 29 | 12 | 17 | 22 | 28 |
| 125 | 17 | 20 | 23 | 28 | 11 | 15 | 20 | 27 |
| 150 | 16 | 19 | 22 | 27 | 11 | 15 | 19 | 25 |
| 175 | 15 | 18 | 21 | 26 | 10 | 14 | 18 | 24 |
| 200 | 15 | 17 | 20 | 25 | 10 | 13 | 17 | 24 |
| 300 | 13 | 15 | 17 | 22 | 8 | 12 | 15 | 21 |
| 400 | 12 | 14 | 16 | 20 | 8 | 11 | 14 | 19 |
| 500 | 11 | 13 | 15 | 19 | 7 | 10 | 13 | 18 |
| 600 | 10 | 12 | 14 | 17 | 6 | 9 | 12 | 17 |
| 700 | 10 | 11 | 13 | 16 | 6 | 9 | 11 | 16 |
| 800 | 9 | 10 | 12 | 15 | 5 | 8 | 11 | 15 |
| 900 | 9 | 10 | 11 | 14 | 4 | 8 | 9 | 15 |
| 1,000 | 8 | 9 | 10 | 13 | 4 | 7 | 9 | 14 |
| 1,100 | 7 | 9 | 10 | 12 | 4 | 6 | 8 | 12 |

| Maximum Concrete Pressure | Strong way (in) 5-ply sanded, face grain, parallel to span | | | | Weak way (in) 5-ply sanded, face grain, perpendicular to span | | | |
|---|---|---|---|---|---|---|---|---|
| 1,200 | 7 | 8 | 10 | 11 | - | 6 | 7 | 11 |
| 1,300 | 6 | 8 | 9 | 11 | - | 5 | 7 | 11 |
| 1,400 | 6 | 7 | 9 | 10 | - | 5 | 6 | 10 |
| 1,500 | 5 | 7 | 9 | 9 | - | 5 | 6 | 9 |
| 1,600 | 5 | 6 | 8 | 9 | - | 4 | 5 | 9 |
| 1,700 | 5 | 6 | 8 | 8 | - | 4 | 5 | 8 |
| 1,800 | 4 | 6 | 8 | 8 | - | 4 | 5 | 8 |
| 1,900 | 4 | 5 | 8 | 7 | - | 4 | 4 | 7 |
| 2,000 | 4 | 5 | 7 | 7 | - | - | 4 | 7 |
| 2,200 | 4 | 5 | 6 | 6 | - | - | 4 | 6 |
| 2,400 | - | 4 | 5 | 6 | - | - | 4 | 6 |
| 2,600 | - | 4 | 5 | 5 | - | - | - | 5 |
| 2,800 | - | 4 | 4 | 5 | - | - | - | 5 |
| 3,000 | - | - | 4 | 5 | - | - | - | 5 |

Move down the chart to 600 pounds per square foot, and then go down the chart to 3/4 inch plywood sheathing. You will find that 14 inch spacing per stud is required. This chart refers to the forms with the face grain running across the supports. If the concrete pressure value falls between the two values in the column, round up to the higher value. To determine the uniform load on a stud (ULS), multiply the maximum concrete pressure by the maximum stud spacing. Then convert the answer to pounds per linear foot by dividing the result by 12. For example, the maximum concrete pressure is 1,050 pounds per square foot and the stud spacing is 14 inches. Multiply the two values together then divide by 12 which equals 1,225 (lbs/lin ft).

$$\textbf{Uniform Load on Stud (ULS) (pounds/linear foot)} = \frac{\textbf{Maximum concrete pressure (pounds/square foot)} \times \textbf{Maximum stud spacing (inches)}}{\textbf{12 inches/foot}}$$

### 2.2.2.2 2.2 Maximum Spacing of Wall Form Wales

When you know the spacing of the studs, the sheathing, and the maximum concrete pressure, the maximum wale spacing is not difficult to determine using the charts shown in *Table 3-2* and *Table 3-3*.

**Table 3-2 – Maximum Spacing (in inches) for Wales, Ties, Stringers, and 4 inch by 4 inch or Larger Shores Where Member to be Supported is a Single Member.**

| Uniform load (lb/linear ft) | Supported Member Size (S4S) | | | | |
|---|---|---|---|---|---|
| | 2 x 4 | 2 x 6 | 3 x 6 | 4 x 4 | 4 x 6 |
| 100 | 60 | 95 | 120 | 92 | 131 |
| 125 | 54 | 85 | 110 | 82 | 124 |
| 150 | 49 | 77 | 100 | 75 | 118 |
| 175 | 45 | 72 | 93 | 70 | 110 |
| 200 | 42 | 67 | 87 | 65 | 102 |
| 225 | 40 | 63 | 82 | 61 | 97 |
| 250 | 38 | 60 | 77 | 58 | 92 |
| 275 | 36 | 57 | 74 | 55 | 87 |
| 300 | 35 | 55 | 71 | 53 | 84 |
| 350 | 32 | 50 | 65 | 49 | 77 |
| 400 | 30 | 47 | 61 | 46 | 72 |
| 450 | 28 | 44 | 58 | 43 | 68 |
| 500 | 27 | 41 | 55 | 41 | 65 |
| 600 | 24 | 38 | 50 | 37 | 59 |
| 700 | 22 | 36 | 46 | 35 | 55 |
| 800 | 21 | 33 | 43 | 32 | 51 |
| 900 | 20 | 31 | 41 | 30 | 48 |
| 1,000 | 19 | 30 | 38 | 29 | 46 |
| 1,200 | 17 | 27 | 35 | 27 | 42 |
| 1,400 | 16 | 25 | 33 | 25 | 39 |
| 1,600 | 15 | 23 | 31 | 23 | 36 |
| 1,800 | 14 | 22 | 29 | 22 | 34 |
| 2,000 | 13 | 21 | 27 | 21 | 32 |
| 2,200 | 13 | 20 | 26 | 20 | 31 |
| 2,400 | 12 | 19 | 25 | 19 | 30 |
| 2,600 | 12 | 19 | 24 | 18 | 28 |
| 2,800 | 11 | 18 | 23 | 17 | 27 |
| 3,000 | 11 | 17 | 22 | 17 | 26 |
| 3,400 | 10 | 16 | 21 | 16 | 25 |
| 3,800 | 10 | 15 | 20 | 15 | 23 |
| 4,500 | 9 | 14 | 18 | 13 | 21 |

**Table 3-3 – Maximum Spacing (in inches) for Ties and 4 inch or Larger Shores Where Member to be Supported is a Double Member.**

| Uniform load (lb/linear ft) | Supported Member Size (S4S) | | | | |
|---|---|---|---|---|---|
| | 2 x 4 | 2 x 6 | 3 x 6 | 4 x 4 | 4 x 6 |
| 100 | 85 | 126 | 143 | 222 | 156 |
| 125 | 76 | 119 | 135 | 105 | 147 |
| 150 | 70 | 110 | 129 | 100 | 141 |
| 175 | 64 | 102 | 124 | 96 | 135 |
| 200 | 60 | 95 | 120 | 92 | 131 |
| 225 | 57 | 89 | 116 | 87 | 127 |
| 250 | 54 | 85 | 109 | 82 | 124 |
| 275 | 51 | 81 | 104 | 78 | 121 |
| 300 | 49 | 77 | 100 | 75 | 118 |
| 350 | 46 | 72 | 93 | 70 | 110 |
| 400 | 43 | 67 | 87 | 65 | 102 |
| 450 | 40 | 63 | 82 | 61 | 97 |
| 500 | 38 | 60 | 77 | 58 | 92 |
| 600 | 35 | 55 | 71 | 53 | 84 |
| 700 | 32 | 51 | 65 | 49 | 77 |
| 800 | 30 | 47 | 61 | 46 | 72 |
| 900 | 28 | 44 | 58 | 43 | 68 |
| 1,000 | 27 | 43 | 55 | 41 | 65 |
| 1,200 | 25 | 39 | 50 | 38 | 59 |
| 1,400 | 23 | 36 | 46 | 35 | 55 |
| 1,600 | 21 | 34 | 43 | 33 | 51 |
| 1,800 | 20 | 32 | 41 | 31 | 48 |
| 2,000 | 19 | 30 | 39 | 29 | 46 |
| 2,200 | 18 | 29 | 37 | 28 | 44 |
| 2,400 | 17 | 27 | 36 | 27 | 42 |
| 2,600 | 17 | 26 | 34 | 26 | 40 |
| 2,800 | 16 | 25 | 33 | 25 | 39 |
| 3,000 | 15 | 24 | 32 | 24 | 38 |
| 3,400 | 14 | 23 | 30 | 22 | 35 |
| 3,800 | 14 | 21 | 28 | 21 | 33 |
| 4,500 | 12 | 20 | 25 | 19 | 30 |

Suppose you want to find the maximum wale spacing for 2 by 4 studs and the concrete pressure is 600 pounds per square foot. Move down the chart until you reach 600 pounds per square foot, then go across to 2 by 4 lumber and you will find that the spacing for the waler and ties are 24 inches. To determine the uniform load on a wale (ULW), multiply the maximum concrete pressure (600 pounds per square foot) by the maximum wale spacing (24 inches). Convert the answer to feet by dividing the result by 12, which equals 1,200 (pounds per linear foot).

**Uniform load on a wale (ULW) (pounds/linear foot) =**

**Maximum concrete pressure (pounds/square foot) x Maximum wale spacing (feet)**

Use *Table 3-2* or *Table 3-3,* depending on the type of waler system, to determine the tie spacing based on the ULW. This number is the maximum tie spacing in inches based on wale size.

Tie wires or snap ties, depending on what system you use, must be installed at the intersection of studs and wales. Place the first tie at one half of the maximum tie spacing from the end of the wale.

### 2.2.3 Estimating Studs and Wales

To determine the number of studs on one side of a form, divide the form length by the maximum stud spacing, and add one for a starter. The first and last stud must be placed at each end of the form.

$$\textbf{Number of studs} = \frac{\textbf{Length of form (feet) x 12 (inches/foot)}}{\textbf{Stud spacing (inches) +1}}$$

To determine the number of wales for one side of a form, divide the form height by the maximum wale spacing and round up to the next whole number. Place the first wale one half of the maximum space up from the bottom and the remainder at the maximum wale spacing.

To determine the time required to place concrete, divide the height of the form by the rate of placement. This does NOT include the length of the form. For example, wall height of the form is 10 feet and the vertical rate of placement is 5 feet/hour. Your answer is 2 hours. *Figure 3-2* shows how you can estimate man-hours per cubic yard in most situations. These estimates are based on Seabee experiences.

| Man-Hours Per Unit | | | | | |
|---|---|---|---|---|---|
| **Work Element Description** | **Unit (CD)** | **Direct from Chute** | **Wheeled** | **Pumped** | **Crane and Bucket** |
| Place Footings, Foundations: | | 1.0 | 2.0 | 1.50 | 1.50 |
| Grade Beams | | 1.5 | 3.0 | 2.00 | 2.50 |
| Slabs on Grade | | -- | -- | 1.68 | 2.24 |
| Walls to 10’ High | | -- | -- | 1.68 | 2.24 |
| Columns | | -- | -- | 1.68 | 2.24 |
| Suspended Slabs | | -- | -- | 1.68 | 2.24 |
| Beams and Girders | | -- | -- | 1.68 | 2.24 |
| Stairs | | 2.4 | 4.8 | 1.68 | 2.88 |

Figure 3-2 – Placing concrete labor estimates from P-405.

The following rules apply to *Figure 3-2*:

1. For each 40 feet waled, add 25%.
2. For upper stories, add per story: Placed by pump, 7%; placed by bucket or crane, 5%.
3. Construction that moves in and out of ramps, runways, or staging is not included. For moving in and out use 0.22 man-hours per linear foot.
4. Major items of consideration in planning concrete placement are: method of placement, accessibility, the rate of placement in regard to form design, and the amount and frequency of delivery being governed by the ability to screed, tamp, and finish.

#### 2.2.4 cing of Wall Forms

Braces are used against wall forms as shown in *Figure 3-3* to keep the forms in place and in alignment despite mishaps due to external forces, such as wind, personnel, equipment, vibration, and accidents. For most military applications, this force is assumed to be 12.5 times the wall height, in feet. Braces, normally 2 by 4s, should be as strong in tension as in compression strength, or used on both sides of a wall form.

Leave designing wall forms and the bracing for wall forms to the engineers. We do not have the time or the space in this section to cover all the formulas necessary to design forms. Refer to the *American Concrete Institute* (ACI) or the *Architectural Graphic Standards* (AGS) for more information on designing of forms.

**Figure 3-3 – Diagonal bracing supports.**

### 2.3.1 Column Form Design

As with wall forms, column forms are designed according to step-by-step procedures. Wooden forms for a concrete column should be designed by the following steps:

1. Determine the materials available for sheathing, yokes, and battens. Standard materials for columns forms are 2 by 4s and 3/4 inch plywood.
2. Determine the height of the column.
3. Determine the largest cross-sectional dimension of the column.
4. Determine the yoke spacing, as shown in table 3-4, by reading down the first column until reaching the correct height of the column. Then read horizontally across the page to the column headed by the largest cross-sectional dimension. The center-to-center spacing of the second yoke above the base yoke will be equal to the value in the lower interval that is partly contained in the column

height line. Obtain all subsequent yoke spacings by reading up the height column to the top. This procedure gives maximum yoke spacings.

*Figure 3-4* is based upon use of 2 by 4s and 3/4 inch sheathing. For example, if you had to construct a 9 foot column, the spacing of the yokes starting from the bottom yoke would be 8", 8", 10", 11", 12", 15", 17", 17", and 10". The space between the top two yokes has been reduced because of the limits of the column height.

Because of their height and relatively small cross-sectional area, column forms require four-way bracing to ensure alignment and resistance to wind and various other lateral forces that may occur during the placement of the concrete.

**Figure 3-4 – Column Yoke Spacing.**

## 2.4.0 Overhead Slab Form Design

The general goal of slab form design is a balanced form design. Give careful consideration to the design of the formwork due to the danger of failure from the weight of the concrete and the live load (LL) of the equipment and personnel on the forms. The following procedures uses some of the same figures used in the wall form design. See *Figure 3-5* for the nomenclature for a typical overhead form.

### 2.4.1 Sheathing

Sheathing shapes and holds the concrete. Plywood (usually 3/4 inch thick) or solid sheet metal (usually corrugated) is the best for use.

### 2.4.2 Joists

Joists support the sheathing against deflection. Joists perform the same function as studs in a wall form. Normally, you should use 4 inch lumber for joists; however, 2 inch or 3 inch stock can be used for joists if properly designed.

### 2.4.3 Stringers

Stringers support the joists against deflection. Stringers perform the same function as wales in a wall form, except stringers do not need to be doubled. Use 2 inch-thick lumber or larger.

### 2.4.4 Shores

**Figure 3-5 – Typical overhead slab form.**

Shores support the stringers against deflection. Shores perform the same functions as ties in a wall form and also support the concrete at the desired elevation. The lumber used for this must be as large as the stringers but never smaller than 4 by 4 inches in dimension.

### 2.4.5 Lateral Bracing

Lateral bracing may be required between adjacent shores to keep the shores from bending under load. Usually 1 by 6 inch or larger stock is used for bracing. Bracing of some type will always be required to support the formwork.

### 2.4.6 Wedges

Wedges are normally used for two purposes: leveling of the forms and making the forms easier to strip.

### 2.4.7 Mudsills

Mudsills are continuous timber placed on the ground that distributes a load and provides a level surface for scaffolding and shoring.

### 2.4.8 Design Procedures

There is a nine step procedure for designing overhead forms.

1. The engineer will design and specify the materials you need to construct the overhead forms. Ensure that all the correct materials are on the job site and your crew is familiar with the materials and structural members.
2. Determine the maximum total load the forms will have to support. The rule of thumb for figuring the total load is live load (LL) plus dead load (DL). The live load (materials, personnel, and equipment) is estimated to be 50 pounds per square foot unless the forms will support engine-powered equipment. In this case, the LL would be 75 pounds per square foot. The dead load (concrete/rebar) is estimated at 150 pounds per cubic foot. However, you cannot add dead load to live load until you convert the dead load to square feet (SF). The formulas are as follows:

   **Total Load (TL) = Live Load (LL) + Dead Load (DL)**

   **LL = 50 pounds/square foot**
   **or 75 pounds/square foot with power equipment**

   $$DL = - \frac{\text{150 pounds/cubic foot x slab thickness (inches)}}{\text{12 inches/foot}}$$

For example, if the slab is 6 inches in thickness, the formula would be as follows:

$$DL = - \frac{\text{150 lbs/cf x 6 in}}{\text{12 in/ft}}$$

**DL = 75 lbs/sf**

**TL = 50 lbs/sf (LL) + 75 lbs/sf**

**TL = 125 lbs/sf**

3. Determine the maximum joist spacing. Use *Table 3-1* and read the joist spacing based on the sheathing material. Use the maximum TL in place of the maximum concrete pressure. For example, the sheathing is 3/4 inch plywood (strong way), the TL is 150 pounds per square foot, and the joist spacing would be 22 inches.
4. Calculate the uniform load on the joist. The same procedure is used as for determining uniform loads on the structural members in the wall form design.

   $$\text{Uniform Load on Joist (ULJ)} = \frac{\text{2L x Joist spacing (inches)}}{\text{12 inches/foot}}$$

5. Determine the maximum stringer spacing. Use *Table 3-2*; the uniform load on the joist is calculated in step 4. Round this load up to the next higher load located in the left column of the table, then read right to the column containing the lumber material used as the joist. This is the member to be supported by the stringer. The value at this intersection is the on center (OC) spacing of the stringer.
6. Calculate the uniform load on the stringer.

   **Uniform Load on the Stringer (ULS str) =**

   $$\frac{\text{TL x Maximum stringer spacing (inches)}}{\text{12 inches/foot}}$$

7. Determine the maximum shore spacing.

   (a) Maximum shore spacing is based on the stringer strength. Use *Table 3-2* or *Table 3-3*, depending on the type of stringer, and the uniform load on the stringer, rounded to the next higher load shown in the left column of the table. Read right to the stringer material column. This intersection is the OC spacing of the shore, which assures proper support of the stringer.

(b) Maximum shore spacing is also dependent on shore strength and end bearing of the stringer on the shore. Use the allowable load, as shown in *Tables 3-4* and *3-5*, based on the shore strength and the bearing stress strength of the stringer.

**Table 3-4 – Allowable Load in Pounds on Wood Shores, Based on Shore Strength**

| Unsupported Length (in feet) | Nominal Lumber Size (in inches) (R indicates rough lumber; S4S indicates surfaced 4 sides | | | | | |
|---|---|---|---|---|---|---|
| | 4 x 4 P | 4 x 4 S4S | 4 x 6 R | 4 x 6 S4S | 6 x 6 R | 6 x 6 R |
| 4 | 9,900 | 9,200 | 15,300 | 14,400 | 23,700 | 22,700 |
| 5 | 9,900 | 9,200 | 15,300 | 14,400 | 23,700 | 22,700 |
| 6 | 9,900 | 9,200 | 15,300 | 14,400 | 23,700 | 22,700 |
| 7 | 8,100 | 7,000 | 12,500 | 11,000 | 23,700 | 22,700 |
| 8 | 6,200 | 5,400 | 9,600 | 8,400 | 23,700 | 22,700 |
| 9 | 4,900 | 4,200 | 7,600 | 6,700 | 23,700 | 22,700 |
| 10 | 4,000 | 3,400 | 6,100 | 5,400 | 23,000 | 21,700 |
| 11 | 3,300 | 2,800 | 5,100 | 4,500 | 19,000 | 17,300 |
| 12 | 2,700 | 2,400 | 4,300 | 3,700 | 16,000 | 14,600 |
| 13 | 2,300 | 2,000 | 3,600 | 3,200 | 13,600 | 12,400 |
| 14 | 2,000 | 1,700 | 3,100 | 2,700 | 11,700 | 10,700 |
| 15 | 1,800 | | 2,700 | | 10,200 | 9,300 |
| 16 | | | | | 9,000 | 8,300 |
| 17 | | | | | 7,900 | 7,300 |
| 18 | | | | | 7,100 | 6,500 |
| 19 | | | | | 6,400 | 5,800 |
| 20 | | | | | 5,700 | 5,200 |
| **NOTE** | | | | | | |
| The values in the table above are based on wood members with the following strength characteristics: Compression parallel to grain = 750 psi; E = 1,100,000 psi. | | | | | | |

**Table 3-5 – Allowable Loads on Specified Shores, Based on Bearing Stresses**

| Compression Perpendicular to Member Supported | Nominal Lumber Size (in inches) | | | | | |
|---|---|---|---|---|---|---|
| | 4 x 4 R | 4 x 4 S4S | 4 x 6 R | 4 x 6 S4S | 6 x 6 R | 6 x 6 S4S |
| 250 | 3,000 | 3,100 | 5,100 | 4,800 | 7,900 | 7,600 |
| 350 | 4,600 | 4,300 | 7,100 | 6,700 | 11,100 | 10,600 |
| 385 | 5,100 | 4,700 | 7,800 | 7,400 | 12,200 | 11,600 |
| 400 | 5,300 | 4,900 | 7,700 | 7,700 | 12,700 | 12,100 |
| For the table above: When the compression perpendicular to the grain of the member being supported is unknown, assume the most critical compression perpendicular to the grain. | | | | | | |

**NOTE**

**Unsupported Length (UL) =**

**Height above the sill - Sheathing thickness - Joist thickness - Stringer thickness**

This length has been rounded up to the next higher table value. For example, UL = 8 feet in height, minus 3/4 inch sheathing, minus 3 1/2 inch joist thickness, minus 3 1/2 inch stringer thickness, equals 7 feet 4 1/4 inches (round up to 8 feet), so the UL = 8 feet.

(c) Select the most critical shore spacing. Compare the spacing of the shore, based on the stringer strength (Step 7 (a)) and shore load (Step 7 (b)) and select the smaller of the two spacings.

8. Shore bracing check.

(a) Verify that the unbraced length (1) of the shore (in inches) divided by the least dimension (d) of the shore does not exceed 50. If l/d exceeds 50, the lateral and cross bracing are necessary. *Table 3-1* indicates the l/d is greater than 50 shore lengths and can be used if the shore material is sound and unspliced.

(b) In any case, it is good engineering practice to provide both lateral and diagonal bracing to all shore members if the material is available.

9. Summary.

### 2.4.9 Overhead Slab Design Form Procedures – Example Problem

Design the form for a roof of a concrete structure 6 inches thick by 20 feet wide by 30 feet in length. The roof will be 8 feet high above the floor (to the bottom of the slab). The concrete pump truck will be used to place the concrete.

1. Identify the material.

**Sheathing: 3/4 inch plywood (strong way)**

**Joists: 4" x 4" lumber (S4S)**

**Stringers: 4" x 4" lumber (S4S)**

**Bracing: 1" x 6" lumber (S4S)**

**Mudsills: 2" x 12" lumber (S4S)**

2. Determine the TL.

**DL = Concrete load =** $\frac{\textbf{150 pounds/cubic feet x 6 inches}}{\textbf{12 inches/foot}}$

**= 75 pounds/square foot**

**LL = 75 pounds/square foot**

**TL = 75 pounds/square foot + 75 pounds/square foot**

**TL = 150 pounds/square foot**

3. Determine the maximum joist spacing. Use *Table 3-1*.

**3/4" plywood (strong way) and TL = 150 pounds/square foot**

**Joist spacing = 22 inches**

4. Calculate the ULJ.

**ULJ =** $\frac{\textbf{TL x joist spacing (inches)}}{\textbf{12 inches/foot}}$ **=** $\frac{\textbf{150 lbs/sf x 22 in}}{\textbf{12 in/ft}}$

**= 275 lbs/lin ft**

5. Determine the maximum stringer spacing by using *Table 3-2*.

**Load = 275 pounds/linear foot**

**Joist material = 4" x 4" lumber (S4S)**

**Maximum stringer spacing = 55 inches**

6. Calculate the UL stringer.

**TL :** $\frac{\textbf{Maximum stringer spacing (inches)}}{\textbf{12 inches/foot}}$

**= 150 lbs/sf x 55 in = 12 in/ft**

**ULS str = 687.5 lbs/ft**

7. Determine the maximum shoring spacing.

(a) Spacing based on stringer strength. Refer to *Table 3-2*.

**Load = 687.6 pounds/foot (round up to 700)**

**Stringer material = 4" x 4" (S4S)**

**Maximum shore spacing = 35 inches**

(b) Spacing based on the shoring strength and end bearing of the stringer, based on the allowable load in *Tables 3-4* and *3-5*.

- Allowable load based on shore strength as shown in *Table 3-4*.

  **Unsupported length = 8' - 3/4" - 3 1/2" - 3 1/2" = 7' 4 1/4" (round up to 8 ft)**

  **Allowable load = 5,400 pounds**

- Allowable load based on end bearing stresses as shown in *Table 3-5*. Since we do not know what species of wood we are using, you must assume the most critical and lowest compression perpendicular to the grain equals 250 and the allowable load for a 4 by 4 (S4S) equals 3,100 pounds.

- Select the most critical load.
- Determine shore spacing based on allowable load.

$$\textbf{Shore spacing} = \frac{\textbf{3,100 pounds}}{\textbf{ULS str (pounds/foot)}} \times \textbf{12 inches/foot}$$

$$= \frac{\textbf{3,100 lb}}{\textbf{687.5 lb/ft}} \times \textbf{12 in/ft}$$

$$= \textbf{54.1 in}$$

- Select the most critical shore spacing. The spacing determined in step 7(a) is less than the spacing determined in step 7(b); therefore, the shore spacing to use is 35 inches.

8. Shore deflection check.

**l = 8’ - 3/4” - 3 1/2” - 3 1/2” = 7’ 4 1/4”**

**d = the actual dimension of a 4 x 4 = 3.5”**

$$\textbf{l/d} = \frac{\textbf{7' 4 1/4''}}{\textbf{3.5''}} = \frac{\textbf{88.25''}}{\textbf{3.5''}} = \textbf{24.21} \leq \textbf{50}$$

Therefore, lateral and cross bracing are not required.

9. Summary.

**Sheathing: 3/4 inch plywood**

**Joists: 4" x 4" (S4S) lumber spaced @ 22 inch OC**

**Stringers: 4" x 4" (S4S) lumber spaced @ 55 inch OC**

**Shores: 4 x 4 (S4S) lumber spaced@ 35 inch OC**

**Bracing: Not Required**

## 2.5.0 Beam Form Design

Beam forms, like slab forms, carry a vertical load, and are also subjected to the lateral pressure of freshly placed concrete just as wall forms are. Beams can be formed independently to span walls and columns or monolithically (one continuous pour) as part of a floor slab system. When formed as part of a slab system, a part of the load from the slab forms may be carried by the beam form to the supporting shores and must be accounted for in the formwork design.

**Figure 3-6 – Typical interior beam.**

*Figure 3-6* shows a typical interior beam form with slab forming supported on the beam sides. This drawing indicates that 3/4 inch plywood serves as the beam sides and that the beam bottom is a solid piece of 2 inch dimension lumber supported on the bottom by 4 by 4 inch T-head shores.

Close examination of *Figure 3-5* shows that when a beam is to be formed as part of a slab system, some of the design procedures have been completed. For example, the lateral pressure against the beam sides is compensated for by the slab joists which butts against the beam sides and rests on the attached ledger. All that remains to complete the design of a beam form is to determine the design load for which the form must be designed. If you know the design load, you can determine the maximum allowable bottom sheathing span (shore spacing) for the materials available. Next determine the total load per shore and complete the design with the selection of shore and bracing material that will safely support the vertical and lateral loads. You can accomplish each of these steps of beam form design by using the applicable procedures discussed in the previous section on overhead slab form design.

## 2.6.0 Labor Estimates

In this section we will briefly cover labor estimates for formwork according to the Seabee *Planner's and Estimator's Handbook,* NAVFAC P-405. *Figure 3-7* shows the labor chart from the P-405 which is self-explanatory on how to estimate labor. To calculate manpower estimates, you must first estimate the square footage of contact surface (SFCS). After estimating the SFCS of the work element, you then need to determine the units (100 SFCS/unit).

| Work Element | Man-Hours Per Unit | | | | |
|---|---|---|---|---|---|
| Description | Unit | Fabricate | Erect | Strip | Repair |
| Footing, Foundation Walls, and Grade Beams | 100 SFCS | 9 | 7 | 4 | 4 |
| Walls to 10 feet high | 100 SFCS | 8 | 7 | 5 | 5 |
| Columns and Piers | 100 SFCS | 9 | 10 | 5 | 5 |
| Suspended Slabs | 100 SFCS | 8 | 12 | 4 | 5 |
| Beams and Girders | 100 SFCS | 11 | 10 | 5 | 5 |
| Slabs on Grade and Screed (up tp 8: thick including edge form) | 100 SFCS | 13 Complete | | | |
| Stairs | 100 SFCS | 55 Complete | | | |
| Thicken Edge and Slabs Greater then 8" Thick. Use Grade Beam Estimate | N/A | N/A | | | |

Suggested Crew Size: Forming/Stripping: Five Builders
Forming/Stripping (Gang forms): Five Builders and two Equipment Operators

**NOTES**

1. Concrete forming estimates are based on using form accessories, form ties, and steel column clamps.
2. Suspended slabs, beams, and girders are figures that use 4 inch x 4 inch shores and wooden wedges. For adjustable shores, deduct 10% from erection time.
3. When forming and stripping are combined, stripping and cleaning forms will be approximately 17% of total labor.
4. On multiple use jobs, allow three man-hours for form repair per 100 sf of contact surface after four uses.
5. Gang forming usually requires a crane, an operator, and a signalman.
6. Forming walls over 10 feet high, and other high work will increase erection time 10 to 50%.

**Figure 3-7 – Formwork labor chart.**

For example, if you estimated 800 square feet of contact surface, then it is only a matter of dividing 800 by 100, which equals 8 units. Now enter the column for estimating man-hours per unit and you will see four separate columns: fabricate, erect, strip, and repair. It's just a matter of what scope of work you are performing and multiplying the work element by the scope of work.

You have just finished estimating 800 square feet of contact surface for your foundation wall and now you need to fabricate the formwork. To determine the man-hours required, just multiply the number of units (8) by man-hours per unit (9), which equals 72 man-hours. To find man-days, divide 72 man-hours by the number of hours you work in 1 day (determined by your unit) normally 8 hours per day, which will equal 9 duration days per person. So if you had a crew of three, it would take your crew 3 duration days to fabricate the formwork.

## 3.0.0 REINFORCED CONCRETE

Reinforced concrete refers to concrete containing steel (bars, rods, strands, wire, and mesh) as reinforcement and designed to absorb tensile and shearing stresses. Concrete structural members, such as footings, columns and piers, beams, floor slabs, and walls, must be reinforced to attain the necessary strength in tension. In this section, we will cover reinforcing steel and briefly discuss column, beam, and wall reinforcement.

### 3.1.0 Reinforcing Steel

Steel is the best material for reinforcing concrete because the coefficients of expansion of the steel and the concrete are almost the same; that is, at a normal temperature, they will expand and contract at an almost equal rate. (At very high temperatures, steel will expand more rapidly than the concrete, and the two materials will separate.)

Steel also works well as reinforcement for concrete because it makes a good bond with the concrete. This bond strength is proportional to the contact area surface of the steel to the concrete. In other words, the greater the surface of steel exposed to the adherence of the concrete, the stronger the bond. A deformed reinforcing bar is better than a plain round or square one. In fact, if you used plain bars of a given diameter instead of deformed bars, you would have to use approximately 40 percent more plain bars.

The adherence of the concrete depends on the roughness of the steel surface; the rougher the steel the better the adherence. Thus steel with a light, firm layer of rust is superior to clean steel, but steel with loose or scaly rust is inferior. Loose or scaly rust may be removed from the steel by rubbing the steel with burlap. The requirements for reinforcing steel are that it be strong in tension and, at the same time, ductile enough to be shaped or bent cold.

Reinforcing steel may be used in the form of bars or rods that are either plain or deformed or in the form of expanded metal, wire, wire fabric, or sheet metal. Each type is useful for a different purpose, and engineers design structures with these purposes in mind.

Plain bars are round in cross section. They are used in concrete for special purposes, such as dowels at expansion joints, where bars must slide in a metal or paper sleeve, for contraction joints in roads and runways, and for column spirals. They are the least used of the rod type of reinforcement because they offer only smooth, even surfaces for the adherence of concrete.

Deformed bars differ from plain bars in that they have indentations, ridges, or both on them, in a regular pattern. The twisted bar, for example, is made by twisting a plain, square bar cold. The spiral ridges along the surface of the deformed bar increase its bond strength with concrete.

Other forms used are the round and square corrugated bars. These are formed with projections around the surface that extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting. *Figure 3-8* shows a few of the various types of deformed bars available. In the United States, deformed bars are used almost exclusively, while in Europe, both deformed and plain bars are used.

**Figure 3-8 – Various types of deformed bar.**

Eleven standard sizes of reinforcing bars are in use today. *Table 3-6* lists the bar number, area in square inches, weight, and nominal diameter of the 11 standard sizes. Bars No. 3 through 11 and 14 and 18 are all deformed bars.

**Table 3-6 – U.S. Standard Reinforcing Steel Bars.**

| Bar Size Designation | Area Square Inches | Weight Pounds Per Foot | Diameter | |
|---|---|---|---|---|
| | | | Inches | Millimeters |
| #3 | .11 | .376 | .375 | 9.53 |
| #4 | .20 | .668 | .500 | 12.7 |
| #5 | .31 | 1.043 | .625 | 15.88 |
| #6 | .44 | 1.502 | .750 | 19.05 |
| #7 | .60 | 2.044 | .875 | 22.23 |
| #8 | .79 | 2.670 | 1.000 | 25.40 |
| #9 | 1.00 | 3.400 | 1.128 | 28.58 |
| #10 | 1.27 | 4.303 | 1.270 | 31.75 |
| #11 | 1.56 | 5.313 | 1.410 | 34.93 |
| #14 | 2.25 | 7.650 | 1.693 | 43.00 |
| #18 | 4.00 | 13.600 | 2.257 | 57.33 |

*Table 3-7* lists the bar number, area in square inches and millimeters, and nominal diameter of the 11 standard sizes. At some overseas sites, rebar procured locally could be metric. Remember that bar numbers are based on the nearest number of one-eighth inch included in the nominal diameter of the bar. To measure rebar, you must measure

across the round/square portion where there is no deformation. Do not measure the raised portion of the deformation when measuring the rebar diameter.

**Table 3-7 – Comparison of U.S. Standard and Metric Rebar.**

| U.S. Standard Bar | | Metric Bar | | Metric Bar Is: |
|---|---|---|---|---|
| **Bar Size** | **Area Square Inches** | **Bar Size** | **Area Square Inches** | |
| #3 | .11 | 10m | .16 | 45% larger |
| #4 | .20 | 10m | .16 | 20% smaller |
| #4 | .20 | 15m | .31 | 55% larger |
| #5 | .31 | 15m | .31 | Same |
| #6 | .44 | 20m | .47 | 6.8% larger |
| #7 | .60 | 20m | .47 | 22% smaller |
| #7 | .60 | 25m | .78 | 30% larger |
| #8 | .79 | 25m | .78 | 1.3% smaller |
| #9 | 1.00 | 30m | 1.09 | 9% larger |
| #10 | 1.27 | 30m | 1.09 | 14% smaller |
| #10 | 1.27 | 35M | 1.55 | 22% larger |
| #11 | 1.56 | 35m | 1.55 | 0.6% smaller |
| #14 | 2.25 | 45m | 2.33 | 3.5% larger |
| #18 | 4.00 | 55m | 3.88 | 3.0% smaller |

**NOTE**

Percent difference is based upon area of rebar in square inches.

### 3.1.1 Reinforcing Bars

Reinforcing bars are hot-rolled from a variety of steels in several different strength grades. Most reinforcing bars are rolled from new steel billets, but some are rolled from used railroad-car axles or railroad rails that have been cut into rollable shapes. An assortment of strengths is available.

The *American Society for Testing Materials* (ASTM) has established a standard branding for deformed reinforcing bars. Two general systems of bar branding are used. Both serve the basic purpose of identifying the marker size, type of steel, and grade of each bar. In both systems an identity mark, denoting the type of steel used, is branded on every bar by engraving the final roll used to produce the bars so as to leave raised symbols between the deformations. The manufacturer's identity mark that signifies the mill that rolled the bar is usually a single letter or, in some cases, a symbol. The bar size follows the manufacturer's mark and is followed by a symbol indicating new billet steel (-N-), rolled rail steel (-I-), or rolled axle steel (-A-). *Figure 3-9* shows the two-grade marking system.

The lower strength reinforcing bars show only three marks: an initial representing the producing mill, the bar size, and the type of steel. The high strength reinforcing bars use either the continuous line system or the number system to show grade marks. In the line system, one continuous line is rolled into the 60,000 psi bars, and two continuous lines are rolled into the 75,000 psi bars. The lines must run at least five deformation spaces, as shown in *Figure 3-9*. In the number system, a "60" is rolled into the bar following the steel type of mark to denote 60,000 psi bars, and a "75" is rolled into the 75,000 psi bars.

AMERICAN STANDARD BAR MARKS

Lower strength bars show only 3 marks (no grade mark):
- 1st – Producing Mill (usually an initial)
- 2nd – Bar Size Number (#3 through #18)
- 3rd – Type (-N- for new Billet, A for Axle, T for Rail)
- Mark "S" is a special billet steel, #14 and #18 only.

High strength bars must also show grade marks:
- 60 or One (1) line for 60,000 psi strength

(Grade mark lines are smaller and between the two main ribs which are on opposite sides of all American bars.)

**REINFORCING BAR SPECIFICATIONS**

U.S. standard specifications for enforcing bars are established by the American Society for Testing and Materials (ASTM). These standards govern strength grades, rib patterns, sizes, and markings of bars.

Reinforcing bars are produced from three kinds of steel; new billet, axle, or rail; in three grades of useful (yield) strengths. The yield strength of a bar is its useful strength.

The three ASTM Bar Specifications are:
- A615 – Billet steel deformed bars
  - Grade 40 – Sizes #3-#11
  - Grade 60 – Sizes #3-#11, #14 and #18
- A616 – Rail steel deformed bars
  - Grade 40 – Sizes #3-#11
  - Grade 60 – Sizes #3-#11
- A617 – Axle steel deformed bars
  - Grade 40 – Sizes #3-#11
  - Grade 60 – Sizes #3-#11

**Figure 3-9 – American standard reinforcing steel bar marks.**

### 3.1.2 Expanded Metal and Wire Mesh Reinforcement

Expanded metal or wire mesh is also used for reinforcing concrete. Expanded metal is made by partly shearing a sheet of steel, as shown in *Figure 3-10, View A*. The sheet steel has been sheared in parallel lines and then pulled out or expanded to form a diamond shape between each parallel cut. Another type is square rather than diamond shaped, as shown in *Figure 3-10, View B*. Expanded metal is customarily used during plastering operations and light reinforcing concrete construction, such as sidewalks and for small concrete pads that do not have to bear substantial weight, such as transformer and air-conditioner pads.

**Figure 3-10 – Expanded or diamond mesh steel reinforcement.**

### 3.1.3 Welded Wire Fabric

Welded wire fabric, shown in *Figure 3-11*, is fabricated from a series of wires arranged at right angles to each other and electrically welded at all intersections. Welded wire fabric, referred to as WWF within the NCF, has various uses in reinforced concrete construction. In building construction, it is most often used for floor slabs on well-compacted ground. Heavier fabric, supplied mainly in flat sheets, is often used in walls and for the primary reinforcement in structural floor slabs. Additional examples of its use include road and runway pavements, box culverts, and small canal linings.

**Figure 3-11 – Welded wire fabric reinforcement.**

Four numbers are used to designate the style of wire mesh; for example, 6 by 6 - 8 by 8 (sometimes written 6 x 6 x 8 x 8 or 6 x 6 - W 2.1 x W 2.1). The first number (in this case, 6) indicates the lengthwise spacing of the wire in inches; the second number (in this case, 6) indicates the crosswise spacing of the wire in inches; the last two numbers (8 by 8) indicate the size of the wire on the Washburn and Moen gauge. More recently the last two numbers are a W number that indicates the size of the cross-sectional area in the wire in hundredths of an inch. See *Table 3-8*. WWF is currently available within the Navy stock system using the four-digit system, 6 by 6 - 8 by 8, as of this writing, but if procured through civilian sources, the W system is used.

Light fabric can be supplied in either rolls or flat sheets. Fabric made of wire heavier than W4 should always be furnished in flat sheets. Where WWF must be uniformly flat when placed, fabric furnished in rolls should not be fabricated of wire heavier than W 2.9. Fabricators furnish rolled fabric in complete rolls only. Stock rolls will contain from 700 to 1,500 square feet of fabric determined by the fabric and the producing location. The unit weight of WWF is designated in pounds per one hundred square feet of fabric, as shown in *Table 3-8*. Five feet, six feet, seven feet, and seven feet six inches are the standard widths available for rolls, while the standard panel widths and lengths are seven feet by twenty feet and seven feet six inches by twenty feet.

**Table 3-8 – Common Stock Sizes of Welded Wire Fabric.**

| Style Designation | | Weight Approximate Pounds per 100 Square Feet |
|---|---|---|
| Current Designation (by W-Number) | Previous Designation (by Steel Wire Gauge) | |
| **Panels/Sheets** | | |
| 6 x 6 – W 1.4 x W 1.4 | 6 x 6 – 10 x 10 | 21 |
| 6 X 6 –W 2.1 X W 2.1 | 6 X 6 – 8 X 8 | 29 |
| 6 X 6 – W 2.9 X W 2.9 | 6 x 6 – 6 x 6 | 42 |
| 6 x 6 – W 4.0 x W 4.0 | 6 x 6 – 4 x 4 | 58 |
| 4 x 4 – W 1.4 x W 1.4 | 4 x 4 – 10 x 10 | 31 |
| 4 x 4 – W 2.1 x W 2.1 | 4 x 4 – 8 x 8 | 43 |
| 4 x 4 – W 2.9 x W 2.9 | 4 x 4 – 6 x 6 | 62 |
| 4 x 4 – W 4.0 x W 4.0 | 4 x 4 – 4 x 4 | 86 |
| **Rolls** | | |
| 6 x 6 – W 1.4 x W 1.4 | 6 x 6 – 10 x 10 | 21 |
| 6 x 6 – W 2.9 x W 2.9 | 6 x 6 – 6 x 6 | 42 |
| 6 x 6 – W 4.0 x W 4.0 | 6 x 6 – 4 x 4 | 58 |
| 6 x 6 – W 5.5 x W 5.5 | 6 x 6 – 2 x 2 | 80 |
| 4 x 4 – W 4.0 x W 4.0 | 4 x 4 – 4 x 4 | 86 |

## 3.2.0 Column Reinforcement

A column is a slender, vertical member that carries a superimposed load. Concrete columns, especially those subjected to bending stresses, are always reinforced with steel. A pier or pedestal is a compressive member that is short (with height usually less than three times the least lateral dimension) in relation to its cross-sectional area and carries no bending stress. A bearing wall could be classified as a continuous pier. In concrete columns, vertical reinforcement is the principal reinforcement. A loaded column shortens vertically and expands laterally; so lateral reinforcements in the form of lateral ties are used to restrain the expansion. Columns reinforced in this manner are called tied columns, shown in *Figure 3-12, View A*. If the restraining reinforcement is a continuous winding spiral that encircles the core and longitudinal steel, the column is called a spiral column as shown in *Figure 3-12, View B*.

**Figure 3-12 – Reinforced concrete columns.**

## 3.3.0 Beam Reinforcement

Beams are the principal load-carrying horizontal members. They take the load directly from the floor and carry it to the columns. Concrete beams can either be cast in place or precast and transported to the job site. *Figure 3-13* shows several common types of beam reinforcing steel shapes. Both straight and bent-up principal reinforcing bars are needed to resist the bending tension in the bottom over the central portion of the span. Fewer bars are necessary on the bottom near the ends of the span where the bending movement is small. For this reason, some bars may be bent so that the inclined portion can be used to resist diagonal tension. The reinforcing bars of continuous beams are continued across the supports to resist tension in the top in that area.

**Figure 3-13 – Typical shapes of reinforcing steel.**

## 3.4.0 Wall Reinforcement

The placement of steel reinforcement in load-bearing walls is the same as for columns, except that the steel is erected in place and not preassembled. Horizontal steel is tied to vertical steel at least three times in any bar length. The wood block is removed when the form has been filled up to the level of the block, as shown in *Figure 3-14*.

**Figure 3-14 – Steel in place in a wall.**

# 4.1.1 DESIGN of CONCRETE MIXTURES

From your previous studies, you know that the basic ingredients used in the production of concrete are cement (usually Portland cement), water, and both fine and coarse aggregates. You also know that certain admixtures are used occasionally to meet special requirements. The design of a concrete mixture consists of determining the correct amount of each ingredient needed to produce a concrete that has the necessary consistency or workability in the freshly mixed condition and that has desired strength and durability characteristics in the hardened condition.

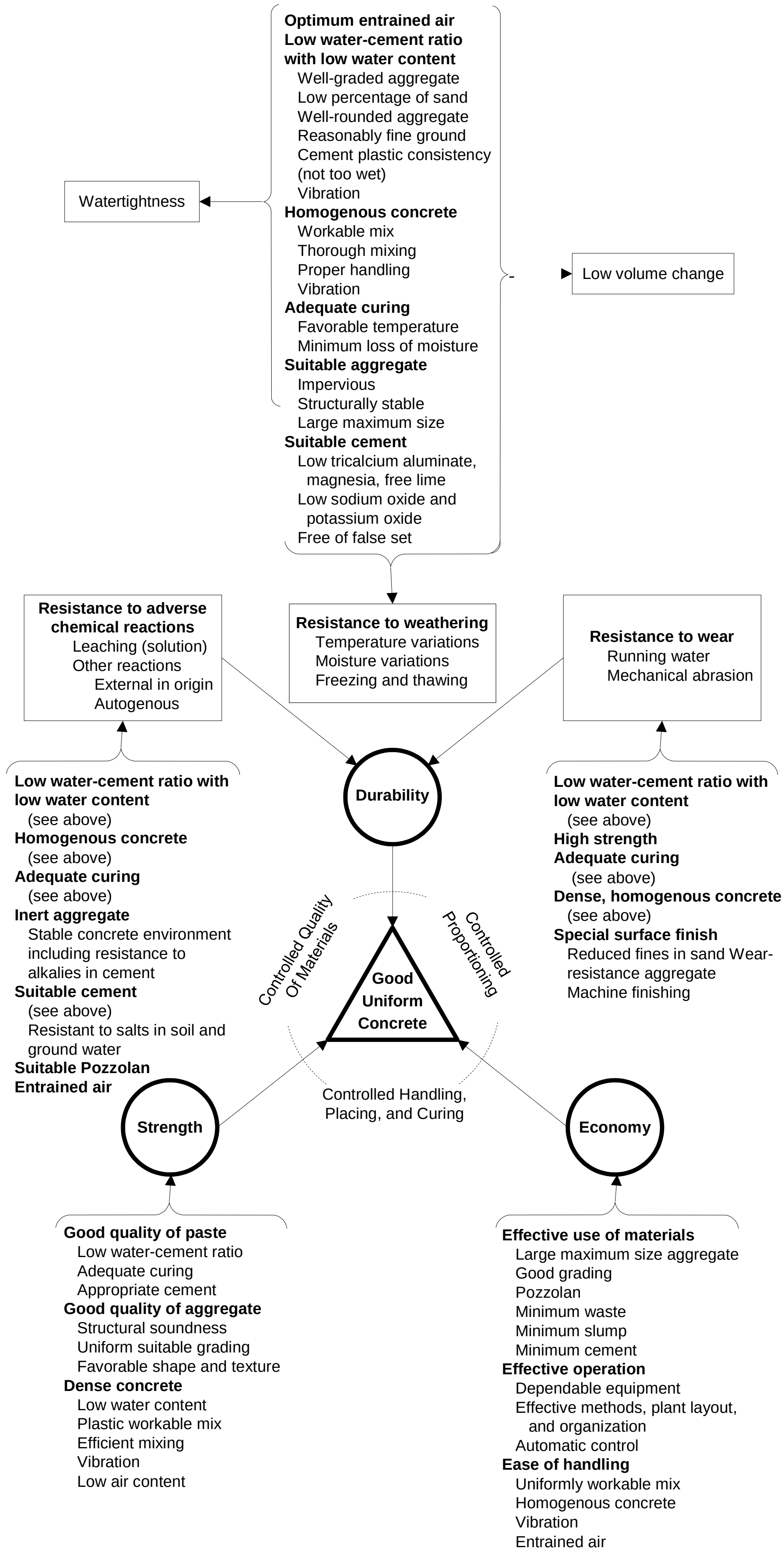



**Figure 3-15 – Concrete proportions.**

Consider the characteristics of concrete on a relative basis and in terms of degree of quality required for a given construction project. *Figure 3-15* shows some of the properties of good concrete, their interrelationships, and various elements that control the properties. A study of this figure points up the relative basis of the characteristics. A single batch of concrete cannot possess the maximum of strength, durability, and economy. For example, entrained air makes handling easier and is, therefore, conducive to economy; entrained air promotes watertightness, but entrained air makes concrete less dense and thereby reduces the strength. The goal is to achieve an optimum balance of all the elements. A thorough discussion of all the factors involved in the production of good concrete is beyond the scope of this manual. A wealth of information is available to you in government and commercial publications, especially the *American Concrete Institute* (ACI) manuals.

The design of or the selection of a mix, the necessity for a trial mix, the methods of controlling the mix proportions, and the units of measure to be used in the batching all depend on the nature and size of the job and the extent to which requirements are set forth in the specifications or on the plans. An example of the simplest form of concrete batching is the mixing of a very small amount of concrete using the 1:2:4 carpenter's mix. The relative volumes of cement, sand, and gravel could be measured in bucketfuls, or even in shovelfuls, and with sufficient water added to give reasonable consistency. A more refined procedure is to fabricate a 1 cubic foot wooden measuring box to give you greater control over the proportions of the ingredients. To mix approximately 1 cubic yard of 1:2:4 concrete, you use the "Rule of 42." Add the numbers of the mix design together 1 + 2 + 4 = 7, then divide the rule (42) by the mix design (7), which equals 6. This means it will take 6 parts per cubic foot of material. For example:

**Cement (1 x 6) 6 cubic feet**

**Sand (2 x 6) 12 cubic feet**

**Gravel (4 x 6) 24 cubic feet**

**Total of dry mix 42 cubic feet = 1 cubic yard produced**

**NOTE**

One bag of cement equals one cubic foot of cement.

In addition to the carpenter's mix, there are other popular rule-of-thumb mixes:

1:1:2 – very rich mix. Use when great strength is required.

1:2:5 – a medium mix. Use in large slabs and walls.

1:3:5 – a lean mix. Use in large foundations or as a backing for masonry.

1:4:8 – a very lean mix. Use only in mass placing.

To achieve more control over the proportional quantities of cement, water, and aggregate for a concrete mix, you can use one of three methods: book, trial batch, or absolute volume. These three methods of proportioning concrete mixtures will be briefly covered in this section.

- The BOOK METHOD is a theoretical procedure establishing data to determine mix proportions.
- The TRIAL BATCH METHOD is based on an estimated weight of concrete per unit volume.

- The Absolute Volume method is based on calculations of the ABSOLUTE VOLUME occupied by the ingredients used in the concrete mixture.

For a more thorough discussion, you should refer to the most recent edition of *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete* (ACI 211.1), published by the American Concrete Institute (ACI), and the *Engineering Aid Intermediate/Advanced.*

## 4.1.0 Book Method

The Book Method is a theoretical procedure in which established data is used to determine mix proportions. Because of the variation of the materials (aggregates) used, mixes arrived at by the book method require adjustment in the field following the mixing of trial batches and testing. Design concrete mixtures to give the most economical and practical combination of the materials that will produce the necessary workability in the fresh concrete and the qualities in the hardened concrete.

### 4.1.1 Selecting Mix Characteristics

Certain information must be known before a concrete mixture can be proportioned. The size and shape of structural members, the concrete strength required, and the exposure conditions must be determined. The water-cement ratio, the aggregate characteristics, the amount of entrained air, and the slump are significant factors in the selection of the appropriate concrete mixture.

### 4.1.2 Water-Cement Ratio

The water-cement ratio is determined by the strength, durability, and watertightness requirements of the hardened concrete. The ratio is usually specified by the structural design engineer, but you can arrive at tentative mix proportions from knowledge of a prior job. Always remember that a change in the water-cement ratio changes the characteristics of the hardened concrete. Use *Table 3-9* to select a suitable water-cement ratio for normal weight concrete that will meet anticipated exposure conditions. Note that the water-cement ratios in *Table 3-9* are based on concrete strength under certain exposure conditions.

**Table 3-9 – Maximum Permissible Water-Cement Ratios for Various Exposure Conditions.**

| Exposure Condition | Normal-weight Concrete, Absolute Water-Cement Ratio by Weight |
|---|---|
| Concrete protected from exposure to freezing and thawing and exposure to de-icer chemicals. Select water-cement ratio on basis of strength, workability, and finishing needs. | |
| Watertight concrete: | |
| In fresh water | 0.50 |
| In sea water | 0.45 |
| Frost resistant concrete: | |
| Thin sections: any section with less than 2inch cover over reinforcement and any concrete exposed to deicing salts | 0.45 |
| All other structures | 0.50 |
| Exposure to sulfates: | |
| Moderate | 0.50 |
| Severe | 0.45 |
| Placing concrete under water | Not less than 650 pounds of cement per cubic yard (386 kilograms per cubic meter) |
| Floors on grade | Select water-cement ratio for strength, plus minimum cement requirements. |

If possible, perform the tests using job materials to determine the relationship between the water-cement ratio you select and the strength of the finished concrete. If you cannot obtain laboratory test data or experience records for the relationship, use *Table 3-10* as a guide. Enter *Table 3-10* at the desired $f'_c$ (specified compressive strength of the concrete in pounds per square inch, psi) and read across to determine the maximum water-cement ratio.

**Table 3-10 – Relationship Between Water-Cement Ratios and Compressive Strength of Concrete.**

| Specified Compressive Strength | Maximum Absolute Permissible Water-Cement Ratio, by Weight | |
|---|---|---|
| $f'_c$ psi* | Non-Air-Entrained Concrete | Air-Entrained Concrete |
| 2,500 | 0.67 | 0.54 |
| 3,000 | 0.58 | 0.46 |
| 3,500 | 0.51 | 0.40 |
| 4,000 | 0.44 | 0.35 |
| 4,500 | 0.38 | ** |
| 5,000 | ** | ** |
| * 28-day strength. With most materials, the water-cement ratios shown will provide average strengths greater than required.<br>** For strengths above 4,500 psi (non-air-entrained concrete) and 4,000 psi (air-entrained concrete) proportions should be established by the trial batch method. | | |

You can interpolate between the values. When both exposure conditions and strength must be considered, use the lower of the two indicated water-cement ratios. If flexural strength, rather than compressive strength, is the basis of design, such as in a pavement, perform the tests to determine the relationship between the water-cement ratio and the flexural strength. An approximate relationship between flexural strength and compressive strength is as follows:

**$f'_c$ = compressive strength, psi**

**R = flexural strength, psi**

**k = a constant, usually between 8 and 10**

### 4.1.3 Aggregate

Use fine aggregate to fill the spaces between the coarse aggregate particles and to increase the workability of a mix. In general, aggregate that does not have a large grading gap or an excess of any size, but gives a smooth grading curve, produces the best mix.

Use the largest practical size of coarse aggregate in the mix. The maximum size of coarse aggregate that produces concrete of maximum strength for a given cement content depends upon the aggregate source as well as the aggregate shape and grading. The larger the maximum size of the coarse aggregate, the less paste (water and cement) required for a given concrete quality. The maximum size of aggregate should never exceed one fifth of the narrowest dimension between side forms, one third of the depth of slabs, or three fourths of the distance between reinforcing bars.

### 4.1.4 Entrained Air

Use entrained air in all concrete exposed to freezing and thawing, and, sometimes under mild exposure conditions, to improve workability. Always use entrained air in paving concrete regardless of climatic conditions. *Table 3-11* gives recommended total air contents of air-entrained concretes. When mixing water remains constant, air entrainment increases slump. When cement content and slump remain constant, less mixing water is required. The resulting decrease in the water-cement ratio helps to offset possible strength decreases and improves other paste properties such as permeability. The strength of air-entrained concrete may equal, or nearly equal, that of non-air-entrained concrete when cement contents and slump are the same. The upper half of *Table 3-11* gives the approximate percent of entrapped air in non-air-entrained concrete, and the lower half gives the recommended average total air content percentages for air-entrained concrete based on level of exposure.

**Table 3-11 – Approximate Mixing Water and Air Content Requirements for Different Slumps and Maximum Sizes of Aggregates.**

| **Water, Pounds per Cubic Yard of Concrete, for Indicated Maximum Sizes of Aggregate*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Slump, inches | 3/8 inch | 1/2 inch | 3/4 inch | 1 inch | 1 1/2 inch | 2 inch** | 3 inch** | 6 inch** |
| Non-Air-Entrained Concrete | | | | | | | | |
| 1 to 2 | 350 | 335 | 315 | 300 | 275 | 260 | 240 | 210 |
| 3 to 4 | 385 | 365 | 340 | 325 | 300 | 285 | 265 | 230 |
| 6 to 7 | 410 | 385 | 360 | 340 | 315 | 300 | 285 | |
| | | | | | | | | |
| Approximate Amount of Entrapped Air In Non-Air-Entrapped Concrete, % | 3 | 2.5 | 2 | 1.5 | 1 | 0.5 | 0.3 | 0.2 |
| | | | | | | | | |
| Air-Entrained Concrete | | | | | | | | |
| 1 to 2 | 305 | 295 | 280 | 270 | 250 | 240 | 225 | 200 |
| 3 to 4 | 340 | 325 | 305 | 295 | 275 | 265 | 250 | 220 |
| 6 to 7 | 365 | 345 | 325 | 310 | 290 | 280 | 270 | -- |
| | | | | | | | | |
| Recommended Average Total Air Content, % for Level of Exposure | | | | | | | | |
| Mild Exposure | 4.5 | 4.0 | 3.5 | 3.0 | 2.5 | 2.0 | 1.5 | 1.0 |
| Moderate Exposure | 6.0 | 5.5 | 5.0 | 4.5 | 4.5 | 4.0 | 3.5 | 3.0 |
| Extreme Exposure | 7.5 | 7.0 | 6.0 | 6.0 | 5.5 | 5.0 | 4.5 | 4.0 |

* These quantities of mixing water are for use in computing cement factors for trial batches. They are maximums for reasonably wellshaped angular coarse aggregates graded within limits of accepted specifications.

** The slump values for concrete containing aggregate larger than 1 1/2 inches are based on slump tests made after removal of particles larger than 1 1/2 inches by wet screening.

#### 4.1.4.1 Mild Exposure

Mild exposure includes indoor or outdoor service in a climate that does not expose the concrete to freezing or de-icing agents. When you want air entrainment for a reason other than durability, such as to improve workability or cohesion or to improve strength in low cement factor concrete, use air contents lower than those required for durability.

#### 4.1.4.2 Moderate Exposure

Moderate exposure means service in a climate where freezing is expected but where the concrete is not continually exposed to moisture or free water for long periods before freezing, or to deicing agents or other aggressive chemicals. Examples are exterior beams, columns, walls, girders, or slabs that do not contact wet soil or receive direct application of deicing salts.

#### 4.1.4.3 Severe Exposure

Severe exposure means service where the concrete is exposed to deicing chemicals or other aggressive agents, or where it continually contacts moisture or free water before freezing. Examples are pavements, bridge decks, curbs, gutters, sidewalks, or exterior water tanks or sumps.

## 4.2.0 Trial Batch Method

In the trial batch method of mix design, use actual job materials to obtain mix proportions. The size of the trial batch depends upon the equipment you have and the number of test specimens you make. Batches using 10 to 20 pounds of cement may be big enough, although larger batches produce more accurate data. Use machine mixing if possible, since it more nearly represents job conditions. Always use a machine to mix concrete containing entrained air. Be sure to use representative samples of aggregate, cement, water, and air-entraining admixture in the trial batch. Prewet the aggregate and allow it to dry to a saturated, surface-dry condition. Then place it in covered containers to maintain this condition until you use it. This action simplifies calculations and eliminates errors caused by variations in aggregate moisture content. When the concrete quality is specified in terms of the water-cement ratio, the trial batch procedure consists basically of combining paste (water, cement, and usually entrained air) of the correct proportions with the proper amounts of fine and coarse aggregates to produce the required slump and workability. Then calculate the large quantities per sack or per cubic yard. Refer to the *Engineering Aid Advanced NRTC* for further information and calculations of the trial batch method and the absolute volume method.

## 4.3.0 Absolute Volume Method

The absolute volume method is based on calculations of the volume occupied by the ingredients used in the concrete mixture. For this procedure, select the water-cement ratio, slump, air content, and maximum aggregate size, and estimate the water requirement as you did in the trial batch method. Before making calculations, you must have certain other information such as the specific gravities of the fine and coarse aggregate, the dry-rodded unit weight of the coarse aggregate, and the fineness modulus of the fine aggregate (refer to ACI 214). Now you can determine the dry-rodded unit weight of coarse aggregate and calculate the quantities per cubic yard of water, cement, coarse aggregate, and air. Finally, subtract the sum of the absolute volumes of these materials in cubic feet from 27 cubic feet per 1 cubic yard to give the specific volume of the aggregate. If needed, more trial batches should be mixed to obtain the desired slump and air content while you keep the water-cement ratio constant.

## 4.4.0 Mix Variations

The proportions arrived at in determining mixes will vary somewhat depending upon which method is used because of the nature of the methods. One method is not necessarily better than another. Each method begins by assuming certain needs or requirements and then proceeds to determine the other variables. Since the methods begin differently and use different procedures, the final proportions vary slightly. This is to be expected, and it further points out the necessity of trial mixes in determining the final mix proportions.

## 4.5.0 Mix Adjustments

Construction crews in the field convert the designed trial mix proportions into field mix proportions suitable for the mixing equipment available. Remember, however, that the trial mix method was designed under controlled conditions based on certain assumptions that may not exist in the field. For this reason, field crews must often adjust the mix for moisture and entrained air.

## 4.6.0 Admixtures

Admixtures include all materials other than Portland cement, water, and aggregates that are added to concrete, mortar, or grout immediately before or during mixing. Admixtures are sometimes used in concrete mixtures to improve certain qualities such as workability, strength, durability, watertightness, and wear resistance. They may also be added to reduce segregation, reduce heat of hydration, entrain air, and accelerate or retard setting and hardening. The same results can often be obtained by changing the mix proportions or by selecting other suitable materials without resorting to the use of admixtures (except air-entraining admixtures when necessary). Whenever possible, compare these alternatives to determine which is more economical and/or convenient. Any admixture to be in concrete should be added according to current specifications and under the direction of the engineer in charge.

The most commonly used admixture in concrete mixtures is an air-entraining agent of the type discussed in the previous section on Mix Adjustments for entrained air. In general, air-entraining agents are derivatives of natural wood resins, animal or vegetable fats or oils, alkali salts of sulfated or sulfonated organic compounds, and water-soluble soaps. Most air-entraining agents are in liquid form for use in the mix water. The instructions for the use of the various agents to produce a specified air content are provided by the manufacturer.

Automatic dispensers, made available by some manufacturers, permit more accurate control of the quantities of air-entraining agents used in the mix. The main reason for using intentionally entrained air is to improve the resistance of the concrete to freezing and thawing exposure. However, there are other important beneficial effects in both freshly mixed and hardened concrete, which include workability, resistance to deicers, sulfate resistance, strength, abrasion resistance, and watertightness.

## 4.7.0 Slump Test

The slump test measures the consistency of concrete. Do not use it to compare mixes having wholly different proportions or containing different sizes of aggregates. When different batches are tested, changes in slump indicate changes in materials, mix proportions, or water content. *Table 3-12* gives recommended slump ranges for various types of construction.

**Table 3-12 – Recommended Slumps for Various Types of Construction.**

| Concrete Construction | Maximum Slump (in inches*) | Minimum Slump (in inches*) |
|---|---|---|
| Reinforced Foundation Walls and Footings | 3 | 1 |
| Plain Footings, Caissons, and Substructure Walls | 3 | 1 |
| Beams and Reinforced Walls | 4 | 1 |
| Building Columns | 4 | 1 |
| Pavements and Slabs | 3 | 1 |
| Mass Concrete | 2 | 1 |
| * May be increased 1 inch for consolidation by methods such as rods and spades.<br>1 inch – 25 mm | | |

## 4.8.1 Compressive Test

The compressive strength of concrete (the ability to resist a crushing force) is, as previously explained, controlled by the water-cement ratio. However, the theoretical compressive strength related to a particular water-cement ratio will be attained only if the actual amount of water added is carefully regulated according to the considerations previously mentioned. Samples cast from the mix being used must be cured and tested to determine what compressive strength was actually attained.

The first step is to obtain a sample of the concrete. The sample should consist of not less than 1 cubic foot when it is to be used for strength tests. Smaller samples may be permitted for routine air content and slump tests.

During the sampling procedures, use every precaution that will assist in obtaining samples representative of the true nature and condition of the concrete sample, as follows:

1. Sampling from stationary mixers except paving mixers. The sample must be obtained by passing a receptacle completely through the discharge stream of the mixer at about the middle of the batch or by diverting the stream completely so that it discharges into a container. Care must be taken not to restrict the flow from the mixer in such a manner as to cause the concrete to segregate. These requirements apply to both tilting and non-tilting mixers.
2. Sampling from paving mixers. The contents of the paving mixer must be discharged, and the sample must be collected from at least five different portions of the pile.
3. Sampling from revolving drum truck mixers or agitators. The sample must be taken at three or more regular intervals throughout the discharge of the entire batch, except that samples must not be taken at the beginning or end of the discharge. Sampling must be done by repeatedly passing a receptacle through the entire discharge stream or by diverting the stream completely so that it

discharges into a container. The rate of discharge of the batch must be regulated by the rate of revolution of the drum, and not by the size of the gate opening.

Transport the sample to the place where test specimens are to be molded or where the test is to be made and remix it with a shovel at the minimum amount to ensure uniformity. Protect the sample from sunlight and wind during the period between taking and using, which must not exceed 15 minutes.

Tests are made on 6 by 12-inch cylinders, cast in cylindrical molds. For the final test, a cylinder is cured for 28 days; however, the probable 28-day strength that a mix will attain can be estimated by determining the 7-day strength (which actually runs about 2/3 of the 28-day strength). Therefore, one or more cylinders are tested after 7 days of curing.

Test cylinders are cast in either metal or heavy cardboard molds. For filling, place a mold on a metal base plate. To avoid loss of the mix water, you can seal the bottom of the mold to the base plate with paraffin. A cardboard mold is expendable, that is, for stripping it from the test cylinder, it is simply torn off. A metal mold is hinged so that it can be stripped by opening. Before the mold is filled, lightly oil the inside surface and base to prevent the concrete from bonding (adhering) to the mold and plate.

Form the test specimens by placing the concrete in the mold in three layers of approximately equal volume. In placing each scoopful of concrete, move the scoop around the top edge of the mold as the concrete slides from it to ensure a symmetrical distribution of the concrete within the mold. Further distribute the concrete with a circular motion of the tamping rod. Rod each layer with 25 strokes of a 5/8-inch round rod, approximately 24 inches in length and tapered for a distance of 1 inch to a spherically shaped end having a radius of approximately 1/4 inch. Distribute the strokes uniformly over the cross section of the mold, making sure they penetrate into the underlying layer. Rod the bottom layer throughout its depth. Where voids are left by the tamping rod, tap the sides of the mold to close the voids. After the top layer has been rodded, strike the surface of the concrete off with a trowel and cover with a glass or metal plate to prevent evaporation.

After about 24 hours of hardening, strip the mold off and immerse the cylinder in either water, moist sand, moist sawdust, or moist earth for curing. At the expiration of the curing period (7 or 28 days), cap the cylinder on both ends with a thin layer of gypsum casting plaster or sulfur capping compound. For testing, place the cylinder under the piston of a machine capable of applying a very high pressure (for a 6 inch-diameter cylinder with a compressive strength of about 6,000 pounds per square inch, the rupturing pressure must reach about 170,000 pounds). Apply pressure, increasing it until the cylinder collapses.

## 4.9.0 Flexural Test

The flexural strength is its ability to resist a breaking force. The flexural strength of concrete is considerably less than its compressive strength. For a flexural strength test, a test beam cast in a test beam mold, like the one shown in *Figure 3-16*, is cured and then broken by a beam breaker.

**Figure 3-16 – Test beam mold.**

The test specimen must be formed with its long axis horizontal. Place the concrete in layers approximately 3 inches in depth, and rod each layer 50 times for each square foot of area. The top layer must slightly overfill the mold. After rodding each layer, spade the concrete along the sides and ends with a mason's trowel or other suitable tool. When the rodding and spading operations are completed, strike off the top with a straightedge and finish with a wood float. The test specimen must be made promptly and without interruption. Cure the test beams for a period of 28 days. Like cylinders, the flexural strength may be determined after 7 days, utilizing the probable 28-day strength of concrete.

## 4.10.0 Computing Concrete

To compute the volume of concrete required for a concrete pad, multiply the length of the pad by its width times its thickness to get cubic feet (length x width x thickness). For example, a concrete pad is 20 feet long by 30 feet wide with a slab thickness of 4 inches. First convert the 4 inches into feet by dividing 3 by 12 to get 0.333 feet. Next, multiply the 20 feet by 30 feet to get 600 square feet. Then multiply 600 square feet by 0.333 to determine the volume in cubic yards of concrete required for the pad which, in this case, is 200 cubic feet.

Concrete is ordered and produced in quantities of cubic yards. To calculate the number of cubic yards required for the pad, divide the cubic feet of the pad by 27. This is required because there are 27 cubic feet in 1 cubic yard. Therefore, the concrete pad described in the previous paragraph, which has a volume of 200 cubic feet, requires 7.41 cubic yards of concrete.

$$\textbf{CD} = \frac{\textbf{Length x Width x Thickness (feet)}}{\textbf{27 cubic feet/cubic yard}}$$

**30’ x 20’ x 4” = 30’ x 20’ x .333’ = 200 cubic feet**

$$\frac{\textbf{200 cubic feet}}{\textbf{27 cubic feet/cubic yard}} = \textbf{7.41 cubic yards}$$

Concrete projects often present varying degrees of difficulty; therefore, extra concrete is required to compensate for these difficulties. Once the total number of cubic yards of concrete is computed, add a little extra, normally 10 percent, to compensate for waste. To calculate the excess needed, multiply the cubic yards by 10 percent. In the above case, multiply 7.41 cubic yards by .10 to get 0.741 cubic yards. Add the 0.741 percentage to the 7.41 cubic yards for a total of 8.15 cubic yards required for the concrete pad.

Another method for estimating concrete is shown in Table 3-52 of the NAVFAC P-405, which covers the 037 rule. This is a decimal equivalent to 1 cubic yard divided by 27 cubic feet which equals .037037. This method is accurate; however, the Seabees prefer the *L* x *W x T ÷ 27* method.

## 4.11.0 Batching Concrete

Batching is the process of weighing or volumetrically measuring, and introducing into a mixer the ingredients for a batch of concrete. To produce a uniform quality concrete mix, measure the ingredients accurately for each batch. Most concrete specifications require that the batching be performed by weight rather than by volume because of inaccuracies in measuring aggregate, especially damp aggregate. Water and liquid air-entraining admixtures can be measured accurately by either weight or volume. Batching by using weight provides greater accuracy and avoids problems created by bulking of damp sand. Volumetric batching is used for concrete mixed in a continuous mixer and in the mobile concrete mixer (crete mobile) where weighing facilities are not at hand.

Specifications generally require that materials be measured in individual batches within the following percentages of accuracy: cement 1%, aggregate 2%, water 1%, and air-entraining admixtures 3%.

The equipment used should be capable of measuring quantities within these tolerances for the smallest to the largest batch of concrete produced. The accuracy of the batching equipment should be checked periodically and adjusted when necessary.

### 4.11.1 xing Concrete

Concrete should be mixed until it is uniform in appearance and all the ingredients are evenly distributed. Do not load mixers above their rated capacities, and operate them at approximately the speeds for which they were designed. If the blades of the mixer become worn or coated with hardened concrete, the mixing action will be less efficient. Replace worn blades and periodically remove the hardened concrete, preferably after each production of concrete.

When a transit mixer (TM), shown in *Figure 3-17*, is used for mixing concrete, 70 to 100 revolutions of the drum at the rate of rotation designated by the manufacturer as *mixing speed* are usually required to produce the specified uniformity. No more than 100 revolutions at mixing speed should be used. All revolutions after 100 should be at a rate of rotation designated by the manufacturer as *agitating speed.* Agitating speed is usually about 2 to 6 revolutions per minute, and mixing speed is generally about 6 to 18 revolutions per minute. Mixing for long periods of time (about 1 or more hours) at high speeds can result in concrete strength loss, temperature rise, excessive loss of entrained air, and accelerated slump loss.

**Figure 3-17 – Transit mixer.**

Deliver and discharge concrete mixed in a transit mixer within 1 1/2 hours or before the drum has revolved 300 times after the introduction of water to cement and aggregates or the cement to the aggregates. Always operate mixers and agitators within the limits of the volume and speed of rotation designated by the equipment manufacturer.

#### 4.11.1.1 Overmixing Concrete

Overmixing concrete damages the quality of the concrete, tends to grind the aggregate into smaller pieces, increases the temperature of the mix, lowers the slump, decreases air entrainment, and decreases the strength of the concrete. Also, overmixing puts needless wear on the drum and blades of the transit mixer.

To select the best mixing speed for a load of concrete, estimate the travel time to the project (in minutes) and divide this into the minimum desired number of revolutions at mixing speed, 70. The results will be the best drum speed; for instance, if the haul is 10 minutes, 70 divided by 10 equals 7. With this drum speed, the load will arrive on the job site with exactly 70 turns at mixing speed with no overmixing of the concrete mix and no unnecessary wear on the equipment. If the concrete cannot be discharged immediately, the operator should turn the drum at the minimum agitating speed of 2 revolutions per minute. When the transit mixer arrives at the project having used the minimum amount of mixing turns, the operator is able, if necessary, to delay discharging the concrete. The maximum delay is 300 rotations.

#### 4.11.1.2 Remixing Concrete

Concrete begins to stiffen as soon as the cement and water are mixed. However, the degree of stiffening that occurs in the first 30 minutes is not usually a problem; concrete that is kept agitated generally can be placed within 1 1/2 hours after mixing.

Fresh concrete left to agitate in the mixer drum may be used if upon remixing it becomes sufficiently plastic to be compacted in the forms. Under careful supervision a small amount of water may be added to remix the concrete provided the following conditions are met:

1. Maximum allowable water-cement ratio is not exceeded.
2. Maximum allowable slump is not exceeded.
3. Maximum allowable mixing and agitating time (or drum revolutions) is not exceeded.
4. Concrete is remixed for at least half the minimum required mixing time or number of revolutions.

Adding too much water to make concrete more fluid should not be allowed because this lowers the quality of the concrete. Remixed concrete can be expected to harden quickly. Subsequently, a cold joint may develop when concrete is placed next to or above the remixed concrete.

**Figure 3-18 – Mobile concrete mixer plant.**

### 4.11.2 Mobile Concrete Mixer Plant

The trailer-mounted mobile concrete mixer plant shown in *Figure 3-18* carries cement, sand, and coarse aggregates in divided bins mounted on the unit. The cement is carried in a separate bin located across the rear of the unit, and the sand and aggregate are carried on each side of the unit. Water is carried in a single tank mounted in front of the aggregate bins and is pumped to the mix auger. Sand and aggregates are accurately proportioned by weight and simultaneously dropped with a mixture of cement from the material feed system into the charging end of the mix auger/conveyor at the rear of the unit. At this point, a predetermined amount of water enters the mix auger.

The action of this combined auger and paddle homogenizer mixes the ingredients and water rapidly, thoroughly, and continuously to produce a continuous flow of uniformed quality concrete. The material mixing action is a continuous process that can proceed until the aggregate bins are empty. On the other hand, mixing and delivery may be stopped at any time and then started again at the will of the operator. This permits production to be balanced to the demands of the placing and finishing crews and other job requirements.

Operators assigned to the crete mobile must thoroughly read and understand the technical manual before operating the plant.

The following are the mobile concrete mixer plant cautions and warnings:

- Follow all preventive maintenance procedures.
- Do not allow any foreign matter in the cement bin.
- Do not allow particles larger than 1 1/2 inch in the aggregate bin.
- Do not allow the waterlines and flow meters to freeze with water in them.
- Do not run the water pump dry.
- Do not continue to operate the machine if the hydraulic oil temperature exceeds 190°F.
- Wash out the auger within 20 minutes of the last use.
- Never attempt to operate the unit while in motion.
- Never attempt to repair the machine while in operation; always turn the power source off.
- Keep your entire body clear from all moving parts.
- Never attempt to walk on top of the aggregate bin to cross from the cement bin to the water tank. Use the ladder.
- Never walk or stand under the auger.
- Never climb inside the aggregate bin; use a small pole to dislodge any aggregate that has bridged.
- Never enter the cement bin while in operation; there are moving parts inside the bin.

## 4.12.1 Transit Mixer Safety

The use of transit mixers on construction projects impose traffic problems that must be considered. Caution must be used during backing of the transit mixer. Backing should be controlled by a signalman, positioned so the operator can clearly observe the directions given. Extreme caution must be used when traveling over uneven terrain on a construction site. The stability of the mixer is greatly reduced with the extra weight of the concrete in the mixer unit. In such cases, a slow speed is recommended. Some additional safety precautions that must be enforced are as follows:

1. Secure the discharge chute properly using the lock provided.
2. Check to make certain other personnel are in the clear before starting the mixer charging or discharging.
3. Make sure you stop the mixer before making any adjustments.

# 5.0.0 PRECAST and TILT-UP CONCRETE

Precast and tilt-up construction is the fabrication of structural members or panels at a place other than its final position of use. This fabrication can be done anywhere, although these procedures are best adapted to a factory or prefab yard. Job site precasting is not uncommon for large projects. Precast concrete can be produced in several different shapes and sizes, including piles, girders, and roof members. Prestressed concrete is especially well adapted to precasting techniques.

Tilt-up concrete is a special type of precast concrete in which the units are tilted up and placed using cranes or other types of lifting devices.

Wall construction, for example, is frequently done with precast wall panels originally cast horizontally (sometimes one above the other) as slabs. This method has many advantages over the conventional method of casting in place in vertical wall forms. Since a slab form requires only edge forms and a single surface form, the amount of formwork and form materials required is greatly reduced. The labor involved in slab form concrete casting is much less than that involved in filling a high wall form. One side of a precast unit cast as a slab may be finished by hand to any desired quality of finishing. The placement of reinforcing steel is much easier in slab forms, and it is easier to attain thorough filling and vibrating. Precasting of wall panels as slabs may be expedited by mass production methods not available when casting in place.

## 5.1.0 Precast Concrete

Generally, structural members, including standard highway girders, poles, electric poles, masts, and building members, are precast by factory methods unless the difficulty or impracticability of transportation makes job site casting more desirable. On the other hand, concrete that is cast in the position that it is to occupy in the finished structure is called cast-in-place concrete.

### 5.1.1 Precast Concrete Floors, Roof Slabs, Walls, and Partitions

The most commonly used precast slabs or panels for floor and roof decks are the channel and double-T types shown in *Figure 3-19, Views A* and *B*.

The channel slabs vary in size with a depth ranging from 9 to 12 inches, width from 2 to 5 feet, and thickness from 1 to 2 inches. They have been used in spans of up to 50 feet. If desired or needed, the legs of the channels may be extended across the ends and, if used in combination with the top slabs, may be stiffened with occasional cross ribs. Wire mesh may be used in the top slabs for reinforcement. The longitudinal grooves, located along the top of the channel legs, may be grouted to form keys between adjacent slabs.

The double-T slabs vary in size from 4 to 6 feet in width and 9 to 16 feet in depth. They have been used in spans as long as 50 feet. When the top slab size ranges from 1 1/2 to 2 inches in thickness, it should be reinforced with wire mesh.

**Figure 3-19 – Typical precast panels.**

The tongue and groove panel shown in *Figure 3-19, View C* could vary extensively in size according to the design requirement. These panels are placed in position much like tongue and groove lumber, that is, the tongue of one panel is placed inside the groove of an adjacent panel. They are often used as decking panels in large pier construction.

Matching plates are ordinarily welded and used to connect the supporting members to the floor and roof slabs.

Panels precast in a horizontal position, in a casting yard or on the floor of the building, are ordinarily used in the makeup of bearing and nonbearing walls and partitions. These panels are placed in their vertical positions by cranes or by the tilt-up procedure, as shown in *Figures 3-20* and *3-21*.

**Figure 3-20 – Precast panels being erected by use of crane and spreader bars.**

**Figure 3-21 – Precast panels in position.**

Usually, these panels are solid, reinforced slabs, 5 to 8 inches thick, with the length varying according to the distances between columns or other supporting members.

When windows and door openings are cast in the slabs, extra reinforcements should be installed around the openings.

A concrete floor slab with a smooth, regular surface can be used as a casting surface. When this smooth surface is used for casting, it should be covered with some form of liquid or sheet material to prevent bonding between the surface and the wall panel. The upper surface of the panel may be finished as regular concrete is finished by troweling, floating, or brooming.

Sandwich panels are panels that consist of two thin, dense, reinforced concrete-face slabs separated by a core of insulating material such as lightweight concrete, cellular glass, plastic foam, or some rigid insulating material.

These panels are sometimes used for exterior walls to provide additional heat insulation. The thickness of the sandwich panels varies from 5 to 8 inches, and the face slabs are tied together with wire or small rods, or in some other manner. Welded or bolted matching plates are also used to connect the wall panels to the building frame, top and bottom. Caulking on the outside and grouting on the inside should be used to make the joints between the wall panels watertight.

### 5.1.2 Precast Concrete Joists, Beams, Girders, and Columns

Small closely spaced beams used in floor construction are usually called joists; however, these same beams when used in roof construction are called purlins. The cross sections of these beams are shaped like a T or an I. The ones with the inverted T-sections are usually used in composite construction where they support cast-in-place floor or roof slabs.

Beams and girders are terms usually applied to the same members, but the one with the longer span should be referred to as the girder. Beams and girders may be conventional precast design or prestressed. Most of the beams will be I-shaped unless the ends are rectangular. The T-shaped ones can also be used.

Precast concrete columns may be solid or hollow. If the hollow type is desired, heavy cardboard tubing should be used to form the core. A looped rod is cast in the column footing and projects upward into the hollow core to help hold the column upright. An opening should be left in the side of the column so that the column core can be filled with grout. This causes the looped rod to become embedded to form an anchor. The opening is dry packed.

### 5.1.3 Advantages of Precast Concrete

Precast concrete has the greatest advantage when identical members are to be cast because the same forms can be used several times. Some other advantages are listed below.

- Quality of concrete can be controlled.
- Smoother surfaces and plastering are not necessary.
- Less storage space is needed.
- Concrete member can be cast under all weather conditions.
- There is better protection for curing.
- Weather conditions do not affect erection.
- Erection time is faster.

## 5.2.0 Pre-Stressed Concrete

A pre-stressed concrete unit is one in which engineered stresses have been placed before it has been subjected to a load. When pre-tensioning is used, the reinforcement (high tensile strength steel strands) is stretched through the form between the two end abutments or anchors. A predetermined amount of stress is applied to the steel strands. The concrete is then poured, encasing the reinforcement. As the concrete sets, it bonds to the pre-tensioned steel. When it has reached a specified strength, the tension on the reinforcement is released. This pre-stresses the concrete, putting it under compression, thus creating a built-in tensile strength.

Post-tensioning involves a precast member that contains normal reinforcing in addition to a number of channels through which the pre-stressing cables or rods may be passed. The channels are usually formed by suspending inflated tubes through the form and casting the concrete around them. When the concrete has set, the tubes are deflated and removed. Once the concrete has reached a specified strength, pre-stressing steel strands or tendons are pulled into the channels and secured at one end. They are then stressed from the opposite end with a portable hydraulic jack and anchored by one of several automatic gripping devices.

Post-tensioning may be done where the member is poured or at the job site. Each member may be tensioned, or two or more members may be tensioned together after erection. In general, post-tensioning is used if the unit is over 45 feet long or over 7 tons in weight. However, some types of pre-tensioned roof slabs will be considerably longer and heavier than this.

When a beam is pre-stressed, either by pre-tensioning or post-tensioning, the tensioned steel produces a high compression in the lower part of the beam. This compression creates an upward bow or camber in the beam, as shown in *Figure 3-22*. When a load is placed on the beam, the camber is forced out, creating a level beam with no deflection.

**Figure 3-22 – Comparison of plain and pre-stressed concrete beams.**

Those members that are relatively small or that can be readily precast are normally pre-tensioned. These include precast roof slabs, T-slabs, floor slabs, and roof joists.

## 5.3.0 Special Types of Concrete

Special types of concrete are essentially those with unique physical properties or those produced with unusual techniques and/or reproduction processes. Many special types of concrete are made with Portland cement as a binding medium; some use binders other than Portland cement.

### 5.3.1 Lightweight Concrete

Conventional concrete weighs approximately 150 pounds per cubic foot. Lightweight concrete weighs 90 to 120 pounds per cubic foot, depending on its intended use. Lightweight concrete can be made by using either gas-generating chemicals or lightweight aggregates such as expanded shale, clay, or slag. Concrete containing aggregates like perlite or vermiculite is very light in weight and is primarily used as insulating material. Lightweight concrete is usually classified according to its weight per cubic foot.

Semi-lightweight concrete has a unit weight of 115 to 130 pounds per cubic foot and an ultimate compressive strength comparable to normal concrete. Sand of normal weight is substituted partially or completely for the lightweight fine aggregate.

Insulating lightweight concrete has a unit weight ranging from 15 to 90 pounds per cubic foot, and its compressive strength seldom exceeds 1,000 psi. This type of concrete is generally used for insulating applications, such as fireproofing.

Structural lightweight concrete has a unit weight of 85 to 115 pounds per cubic foot and a 28-day compressive strength in excess of 2,500 psi. This type is used primarily to reduce the dead-load weight in concrete structural members such as floors, walls, and roof sections in high-rise structures.

### 5.3.2 Heavyweight Concrete

Heavyweight concrete is produced with special heavy aggregates and has a density of up to 400 pounds per cubic foot. This type is used principally for radiation shielding, for counterweights, and for other applications where higher density is desired. Except for density, the physical properties of heavyweight concrete are similar to those of normal or conventional weight concrete.

## 5.4.0 Tilt-Up Construction

Tilt-up concrete construction is a special form of precast concrete building. This method consists basically of job site prefabrication in which the walls are cast in a horizontal position, tilted to a vertical position, and then secured in place. Tilt-up construction is best suited for large one-story buildings, but it can be used in multi-story structures. Usually, multi-story structures are built by setting the walls for the first story, placing the floor above, and then repeating the procedure for each succeeding floor. An alternate method is to cast two to four story panels.

The wall panels are usually cast on the floor slab of the structure. Care must be exercised to ensure that the floor slab is smooth and level and that all openings for pipes and other utilities are temporarily plugged. The casting surface is treated with a good bond-breaking agent to ensure the panel does not adhere when it is lifted.

### 5.4.1 nforcement of Tilt-Up Panels

The steel in a tilt-up panel is set in the same manner as it is in a floor slab. Mats of reinforcement are placed on chairs and tied as needed. Reinforcement should be as near the center of the panel as possible. Reinforcing bars are run through the side forms of the panel. When welded wire fabric or expanded wire mesh is used, dowel bars are used to tie the panels and their vertical supports together. Additional reinforcement is generally needed around openings.

The panel is picked up or tilted by the use of pickup inserts. These inserts are tied into the reinforcement. As the panel is raised into its vertical position, maximum stress will occur; therefore, the location and number of pickup inserts are extremely important. Some engineering manuals provide information on inserts, their locations, and capacities.

#### 5.4.1.1 Tilt-Up Panel Foundations

An economical and widely used method to support tilt-up panels is a simple pad footing. The floor slab, which is constructed first, is NOT poured to the perimeter of the building to permit excavating and pouring the footings. After the panel is placed on the footing, the floor slab is completed. It may be connected directly to the outside wall panel, or a trench may be left to run mechanical, electrical, or plumbing lines.

A commonly used alternative method  is to set the panels on a grade beam or a foundation wall at floor level. Regardless of the type of footing, the panel should be set into a mortar bed to ensure a good bond between the foundation wall and the panel.

#### 5.4.1.2 Panel Connections

The panels may be tied together in a variety of ways. The location and the use of the structure will dictate what method can or CANNOT be used. The strongest method is a cast-in-place column with the panel reinforcing steel tied into the column. This does NOT allow for expansion and contraction. It may be preferable to tie only the corner panels to the columns and allow the remaining panels to move.

Various other methods of connecting the panels are also used. A butted connection, using grout or a gasket, can be used if the wall does NOT contribute any structural strength to the structure. Steel columns are welded to steel angles or plates secured in the wall panel. Precast columns can also be used. Steel angles or plates are secured in both the columns and plate, and welded together to secure the panel.

When panel connections that do not actually hold the panels in place are used, the panels are generally welded to the foundation and to the roof by using steel angles or plates. All connections must provide waterproof joints. This is accomplished by the use of expansion joint material.

### 5.4.2 Prefabrication Yard

Precasting is done either in central prefabrication plants or on-site prefabrication plants, depending upon the product and its application. On-site or temporary prefabrication plants are generally more suitable for military operations. These plants are without roofing and are subject to weather and climate considerations. The prefabrication yard is laid out to suit the type and quantity of members to be processed. It must be on firm, level ground, providing ample working space and access routes. Bridge T-beams, reinforced concrete arches, end walls, and concrete logs are typical members produced at these plants. A schematic layout of a prefabrication yard suitable for producing such members is shown in *Figure 3-23*. A prefabrication unit of this size can be expected to produce approximately 6,000 square feet of precast walls per day. The output will vary according to the experience of the personnel, equipment capabilities, and product requirements.

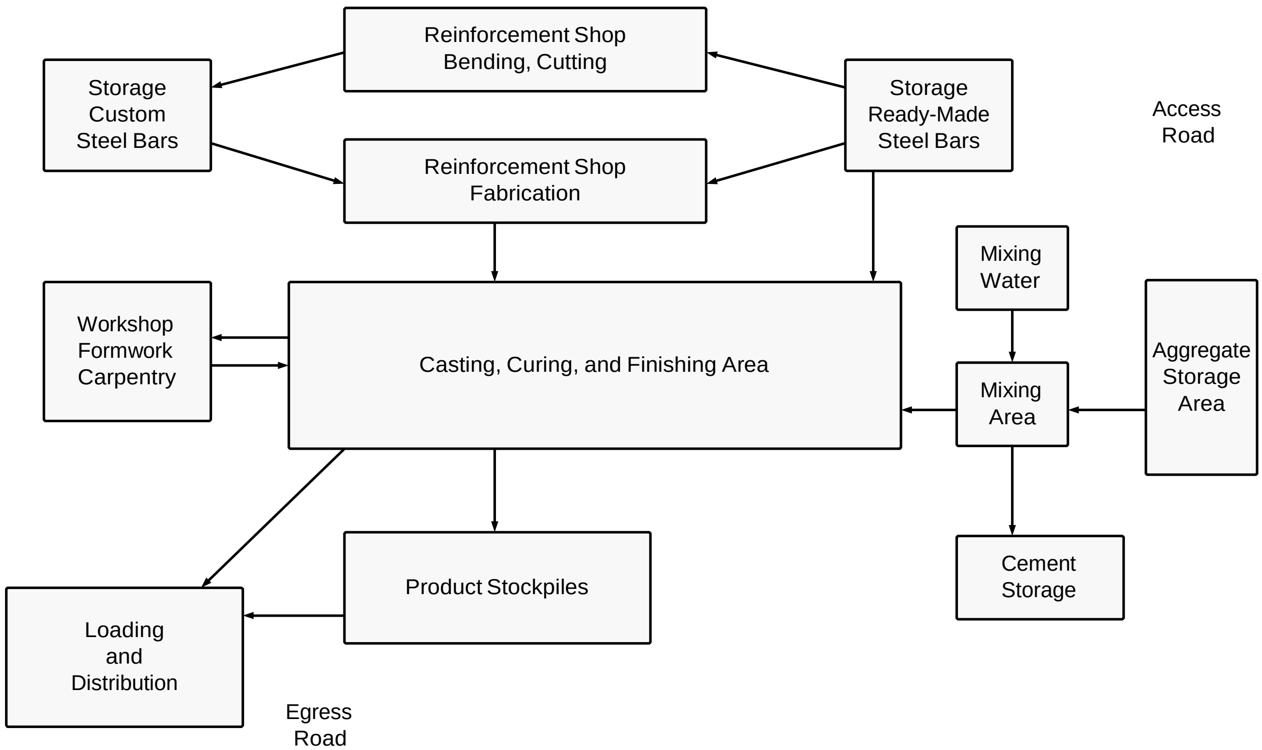



**Figure 3-23 – Layout of prefab yard.**

### 5.4.2.1 Casting

The casting surface is very important in making precast concrete panels. In this section, we will cover two common types: earth and concrete. Regardless of which method you use, a slab must be cast in a location that will permit easy removal and handling.

Castings can be made directly on the ground with cement poured into forms. These earth surfaces are economical but only last for a couple of concrete pours. Concrete surfaces, since they can be reused repeatedly, are more practical.

When building casting surfaces, you should keep the following points in mind:

- The sub-base should be level and properly compacted.
- The slab should be at least 6 inches thick and made of 3,000 psi or higher reinforced concrete. Large aggregate, 2 1/2 inches to 3 inches maximum, may be used in the casting slabs.
- If pipes or other utilities are to be extended up through the casting slab at a later date, they should be stopped below the surface and the openings temporarily closed. For wood, cork, or plastic plugs, fill almost to the surface of the opening with sand, insert the plug, and top with a thin coat of mortar that is finished flush with the casting surface.
- It is important to remember that any imperfections in the surface of the casting slab will show up on the cast panels. When finishing the casting slab, ensure there is a flat, level, and smooth surface without humps, dips, cracks, or gouges. If possible, cure the casting surface, keeping it covered with water (pending). However, if a curing compound or surface hardener is used, make sure it will not conflict with the later use of bond-breaking agents.

#### 5.4.2.2 Forms

The material most commonly used for edge forms is 2-by lumber. The lumber must be occasionally replaced, but the steel or aluminum angles and channels may be reused many times. The tops of the forms must be in the same plane so that they may be used for screeds. They must also be well braced to remain in good alignment.

Edge forms should have holes in them for rebar or for expansion/contraction dowels to protrude. These holes should be one fourth of an inch larger in diameter than the bars. At times, the forms are spliced at the line of these bars to make removal easier.

The forms, or rough bucks, for doors, windows, air conditioning ducts, and so forth, are set before the steel is placed and should be on the same plane as the edge forms.

#### 5.4.2.3 Bond-Breaking Agents

Bond-breaking agents are one of the most important items of precast concrete construction. The most important requirement is that they must break the bond between the casting surface and the cast panel. Bond-breaking agents must also be economical, fast drying, easily applied, easily removed, or leave a paintable surface on the cast panel, if desired. They are broken into two general types: sheet materials and liquids.

Many commercially available bond-breaking agents are available. You should obtain the type best suited for the project and follow the manufacturer's application instructions. If commercial bond-breaking agents are not available, several alternatives can be used.

- Paper and felt effectively prevent a bond with a casting surface, but usually stick to the cast panels and may cause asphalt stains on the concrete.
- Plywood, fiberboard, or metal joints, when oiled, can effectively break a bond and can be used many times. However, the initial cost is high, and joint marks are left on the cast panels.
- Canvas gives a very pleasing texture and is used where cast panels are lifted at an early stage. It should be either dusted with cement or sprinkled with water just before placing the concrete.
- Oil gives good results when properly used, but it is expensive. The casting slab must be dry when the oil is applied, and the oil must be allowed to absorb before the concrete is placed. Oil should not be used if the surface is to be painted, and crankcase oil should never be used.
- Waxes, such as spirit wax (paraffin) and ordinary floor wax, give good to excellent results. One mixture that may be used is 5 pounds of paraffin mixed with 1 1/2 gallons of light oil or kerosene. The oil must be heated to dissolve the paraffin.
- Using liquid soap requires special care to ensure that an excess amount is not used, or the surface of the cast panel will be sandy.

Materials should be applied after the side forms are in place and the casting slab is clean but before any reinforcing steel is placed. To ensure proper adhesion of the concrete, keep all bond-breaking materials off the reinforcing steel.

#### 5.4.2.4 Reinforcements and Inserts

Reinforcing bars (rebar) should be assembled into mats and placed into the forms as a unit. This allows for rapid assembly on a jig and reduces walking on the casting surface which has been treated with the bond-breaking agent.

Extra rebars must be used at openings. They should be placed parallel to and about 2 inches from the sides of openings or placed diagonally across the corners of openings.

The bars may be suspended by conventional methods, such as with high chairs or from members laid across the edge forms. However, high chairs should not be used if the bottom of the cast panel is to be a finished surface. Another method is to first place half the thickness of concrete, place the rebar mat, and then complete the pour. However, this method must be done quickly to avoid a cold joint between the top and bottom layers.

When welded wire fabric (WWF) is used, dowels or bars must still be used between the panels and columns. WWF is usually placed in sheets covering the entire area and then clipped along the edges of the openings after erection.

If utilities are going to be hidden or flush-mounted, pipe, conduit, boxes, sleeves, and so forth should be put into the forms at the same time as the reinforcing steel. If the utilities pass from one cast panel to another, the connections must be made after the panels are erected but before the columns are poured. If small openings are to go through the panel, a greased pipe sleeve is the easiest method of placing an opening in the form. For larger openings, such as air-conditioning ducts, forms should be made in the same manner as for doors or windows.

After rebar and utilities have been placed, all other inserts should be placed. These will include lifting and bracing inserts, anchor bolts, welding plates, and so forth. Make sure these items are firmly secured so they will not move during concrete placement or finishing.

#### 5.4.2.5 Pouring, Finishing, and Curing

With few exceptions, pouring cast panels can be done in the same manner as other pours. Since the panels are poured in a horizontal position, a stiffer mix can be used. A minimum of six sacks of cement per cubic yard with a maximum of 6 gallons of water per sack of cement should be used along with well graded aggregate. As pointed out earlier though, you will have to reduce the amount of water used per sack of cement to allow for the free water in the sand. Large aggregate, up to 1 1/2 inches in diameter, may be used effectively. Work the concrete into place by spading or vibration, and take extra care to prevent honeycombing around outer edges of the panel.

Normal finishing methods should be used, but many finishing styles are available for horizontally cast panels, including patterned, colored, exposed aggregate, broomed, floated, or steel troweled. Regardless of the finish used, finishers must do the finishing of all panels in a uniform manner. Spots, defects, uneven brooming or troweling, and so forth will be highly visible when the panels are erected.

Without marring the surface, start curing as soon as possible after finishing. Proper curing is important, so cast panels should be cured just like any other concrete to achieve proper strength. Curing compound, if used, prevents bonding with other concrete or paint.

### 5.4.3 Lifting Equipment and Attachments

Tilt-up panels can be set up in many different ways and with various kinds of power equipment. The choice depends upon the size of the job. Besides the equipment, a number of attachments are used.

#### 5.4.3.1 Equipment

The most popular power equipment is a crane, but other equipment includes a winch and an A frame, used either on the ground or mounted on a truck. When a considerable number of panels are ready for tilting at one time, power equipment speeds up the job.

#### 5.4.3.2 Attachments

Many types of lifting attachments are used to lift tilt-up panels. Some of these attachments are locally made and are called hairpins; other types are available commercially. You can make hairpin types on the job site by making 180 degree bends in the ends of two vertical reinforcing bars. Then place the hairpins in the end of the panel before pouring the concrete. These lifting attachments must protrude from the top of the form for attaching the lifting chains or cables, but go deep enough in the panel form so they will not pull out.

Among the commercial types of lifting attachments, you will find many styles with greater lifting capacities that are more dependable than hairpins if properly installed. These are used with lifting plates. For proper placement of lifting inserts, refer to the plans or specs.

#### 5.4.3.3 Spreader Bars

Spreader bars may be permanent or adjustable but must be designed and made according to the heaviest load they will carry plus a safety factor. They are used to distribute the lifting stresses evenly, reduce the lateral force applied by slings, and reduce the tendency of panels to bow.

### 5.4.4 Point Pickup Methods

Once the concrete has reached the desired strength, the panels are ready to be lifted. The strength of the inserts is governed by the strength of the concrete.

**CAUTION**

An early lift may result in cracking the panel, pulling out the insert, or total concrete failure. The time taken to wait until the concrete has reached its full strength prevents problems and minimizes the risk of injury.

Several different pickup methods are used. The following are just some of the basics. Before using these methods on a job, make sure that you check the plans and the specs to see if these are stated there. *Figure 3-24* shows four different pickup methods: 2, 2-2, 4-4, and 2-2-2.

**Figure 3-24 - Different types of pickup points.**

The 2-point pickup is the simplest method, particularly for smaller panels. The pickup cables or chains are fastened directly from the crane hook or spreader bar to two pickup points on or near the top of the precast panel.

The 2-2 point pickup is a better method and is more commonly used. Variations of the 2-2 are 4-4 and 2-2-2 or combinations of pickup points as designated in the job site specifications. These methods use a combination of spreader bars, sheaves, and equal length cables. The main purpose is to distribute the lifting stresses throughout the panel during erection. Remember, the cables must be long enough to allow ample clearance between the top of the panel and the sheaves or spreader bar.

### 5.4.5 Erecting, Bracing, and Jointing Panels

Erecting is an important step in the construction phase of the project. Before you start the erecting phase, for increased safety you should make sure that all your tools, equipment, and braces are in proper working order. All personnel must be well informed and the signalman and crane operator understand and agree on the signals to be used. During the erection of the panels, make sure that the signalman and line handler are not under the panel and that all unnecessary personnel and equipment are away from the lifting area. After the erection is complete, make sure that all panels are properly braced and secured before unhooking the lifting cables.

Bracing is an especially important step. After all the work of casting and placing the panels, you want them to stay in place. The following are some steps to take before lifting the panels:

- Install the brace inserts into the panels during casting if possible.
- Install the brace inserts into the floor slab either during pouring or the day before erection.
- Install solid brace anchors before the day of erection.
- If brace anchors must be set during erection, use a method that is fast and accurate.

Although there are several types of bracing, pipe or tubular braces are most common. They usually have a turnbuckle welded between sections for adjustment. Some braces are made with telescoping sleeves for greater adaptability. Cable braces are normally used for most projects. Wood bracing is seldom used except for low, small panels or for temporary bracing.

Joining the panels is simple. Just toe all the panels together, covering the gap between them. You can weld, bolt, or pour concrete columns or beams. Steps used to tie the panels should be stated in the plans and specs.

## Summary

This chapter provided information on the hazards inherent in working with concrete, and the steps you should take to provide for the safety of your crew. You also learned about different characteristics associated with concrete form design and concrete mix design, as well as the procedures in batching concrete. You should now be able to estimate concrete construction and labor, and identify the procedures and methods associated with precast and tilt-up construction.

## Review Questions (Select the Correct Response)

1. Before placing concrete, you should inspect all supporting members because wet concrete will always exert what type of pressure on them?

   A. Hydraulic
   B. Hydrostatic
   C. Kinetic
   D. Pneumatic

2. Nailing requirements must comply with what directive(s)?

   A. Crew Chief's Handbook and local regulations
   B. Manufacturer's recommendations only
   C. NAVFAC instructions and blueprints
   D. Plans and specifications

3. **(True or False)** Supervisors should inspect all forms before and after each pour.

   A. True
   B. False

4. When working with concrete, personnel should wear gloves and protective goggles and have their shirt sleeves rolled down to prevent what hazardous result?

   A. Aggregate poisoning
   B. Asphyxiation
   C. Concrete rash
   D. Cement poisoning (lime)

5. **(True or False)** When working with concrete, personnel should stand with their backs to the wind to prevent cement and sand from being blown into their eyes.

   A. True
   B. False

6. What term is used to refer to a temporary structure that can support its own weight and that of freshly placed concrete, as well as the weight of materials, workmen, and equipment imposed upon it?

   A. Superstructure
   B. Formwork
   C. Subfoundation
   D. Scaffolding

7. As a supervisor of a form building crew, you should consider what factors as your principal objectives?

   A. Time lines and crew training
   B. Load size and job site location
   C. Economy, quality, and safety
   D. Local laws, cost of lumber, and blueprints

8. Formwork may represent as much as what percentage of the cost of a concrete structure?

   A. 33
   B. 40
   C. 45
   D. 50

9. Concerning formwork, in what area(s) will good judgment and ingenuity on the part of the supervisor help reduce costs?

   A. Selection of materials and equipment
   B. Planning fabrication and erection procedures
   C. Scheduling reuse of forms
   D. All of the above

10. Forms must be designed to meet what weight factor?

   A. Weight of crew members they must support
   B. Weight of the concrete they must support
   C. Weight of the equipment they must support
   D. Total weight to which they may be subjected

11. **(True or False)** Earth, metal, lumber, plywood, and fiber are the most commonly used types of form material.

   A. True
   B. False

12. The majority of all formwork involves concrete. Concrete weighs a total of how many pounds per cubic foot?

   A. 100
   B. 125
   C. 150
   D. 175

13. For each inch of slab thickness, concrete slabs place a total load of how many pounds per cubic foot on the formwork?

A. 12.5 pounds per square foot
B. 14.5 pounds per square yard
C. 15 pounds per cubic inch
D. 40 pounds per cubic yard

14. In pounds per square foot of horizontal projection, what is the minimum recommended construction live-load provision for the weight of crew members and equipment?

A. 10
B. 20
C. 50
D. 75

15. When powered concrete buggies are used in concrete operations, what is the minimum construction live-load recommended for use in psf?

A. 65
B. 75
C. 85
D. 95

16. What bracing technique is most often used to brace forms against lateral pressure?

A. Attaching vertical plates behind the wales
B. Attaching horizontal plywood sheets
C. Nailing a diagonal member and a horizontal member to a stud or wale with the diagonal member at a 45-degree angle to the horizontal member
D. Nailing plywood sheets and studs to the wales

17. Which of the following factors does NOT have an effect on lateral pressure?

A. Consistency of the concrete
B. Amount and location of reinforcement
C. Vibration
D. Sulfate content

18. You have been given the assignment of determining the maximum concrete pressure for a form. The rate of placement is 5 feet per hour and the temperature is 70 degrees. What is the maximum concrete pressure for the form in psf?

A. 600
B. 700
C. 800
D. 900

19. To determine the uniform load on a stud (ULS), you multiply the maximum concrete pressure by the maximum stud spacing. Then, by dividing the result by 12, you convert the answer into what unit of measurement?

    A. Pounds per linear foot
    B. Pounds per cubic foot
    C. Pounds per square inch
    D. Pounds per square foot

20. **(True or False)** To determine the time required to place concrete, you divide the height of the form by the rate of placement.

    A. True
    B. False

21. Braces are used against wall forms to protect from mishaps due to external forces. The value of the external force is estimated to be how many times the wall height in feet?

    A. 10.5
    B. 11.5
    C. 12.5
    D. 13.5

22. Designing wall forms and the bracing for them should be the responsibility of what person?

    A. Crew chief
    B. On-site supervisor
    C. Forms manager
    D. Project engineer

23. What is the first step in designing wooden forms for a concrete column?

    A. Determine the height of the column.
    B. Determine the largest cross-sectional column.
    C. Determine the materials available for sheathing, yokes, and battens.
    D. Determine the yoke spacing.

24. In which of the following forms may reinforcing steel be used?

    A. Bars or rods
    B. Sheets or rolls
    C. Squares or triangles
    D. Rectangles or hexagons

25. To calculate manpower estimates, you must first estimate what factor?

A. Square footage of contact surface (SFCS)
B. Square footage of building surface (SFBS)
C. Square yards of rebar lay
D. Square yards of concrete

26. Reinforced concrete refers to concrete containing steel to reinforce and absorb what type of stresses?

A. Heat and gravitational
B. Hydraulic and static
C. Tensile and shearing
D. Geologic and kinetic

27. Reinforcing bars are hot rolled from steel recovered from which of the following sources?

A. Steel billets, railroad car axles, and railroad rails
B. Pile drivers and bikes
C. Ships and aircraft
D. Steel doors and hatches

28. When mixed properly, a good uniform batch of concrete should possess maximum values in durability, economy, and ________.

A. ductility
B. appearance
C. strength
D. tension

29. What type of mix is considered the simplest form of concrete batching?

A. 1:2:4 standard
B. 1:2:4 builder's
C. 1:2:4 carpenter's
D. 1:2:4 mason's

30. When a very rich mix is needed because great strength is required, you should use what mix design?

A. 1:1:2 mix
B. 1:2:5 mix
C. 1:3:5 mix
D. 1:4:8 mix

31. When a mix is required for large foundations or as a backing for masonry, you should use what mix design?

A. 1:1:2
B. 1:3:5
C. 1:4:8
D. 1:5:8

32. When large slabs and walls are to be poured, you should use what mix design?

A. 1:1:2
B. 1:2:5
C. 1:3:5
D. 1:4:8

33. You can use one of which of the following methods to achieve more control over the proportional quantities of the cement, water, and aggregate for a concrete mix?

A. Scratch batch or carpenter's batch
B. Mason's batch or aggregate plus
C. Luke's or Builder's batch
D. Book, trial batch, or absolute volume

34. Construction crews in the field must convert the designed trial mix proportions into field mix proportions by adjusting the mix for moisture and ________.

A. aggregates
B. lime
C. entrained air
D. concrete

35. **(True or False)** Admixtures are added to concrete, mortar, or grout immediately after mixing.

A. True
B. False

36. What admixture is most commonly used in concrete mixtures?

A. Air-entrained agent
B. Chlorine bleach agent
C. Dehumidifier agent
D. Alkaline agent

37. The primary reason for using an air-entraining agent in a concrete mix is to improve what property of the concrete?

A. Hardness
B. Tensile strength
C. Resistance to freezing and thawing exposure
D. Color

38. When sampling for a strength test, you should get a sample of not less than how many cubic feet?

A. 1
B. 2
C. 3
D. 4

39. Samples taken from revolving drum truck mixers must be taken at a minimum of how many intervals?

A. 1
B. 2
C. 3
D. 4

40. In obtaining a sample of concrete from a paving mixer, it should be collected from at least how many portions of the pile?

A. 1
B. 2
C. 3
D. 5

41. You must take a sample to another location to conduct a compressive strength test. The time lapse between taking and molding the sample cannot exceed how many minutes?

A. 15
B. 30
C. 35
D. 45

42. With how many strokes should you rod each layer of concrete placed in the compressive strength test mold?

A. 10
B. 15
C. 20
D. 25

43. The flexural strength of concrete is its ability to resist ________.

A. rust
B. heat
C. humidity
D. a breaking force

44. You have a concrete pad that has a length of 60 feet, a width of 15 feet, and a thickness of 6 inches. What is the volume of the concrete pad in cubic feet?

A. 350
B. 450
C. 500
D. 900

45. **(True of False)** Test cylinders are cast in either metal or wooden molds.

A. True
B. False

46. A total of how many layers of concrete should you place in the mold when preparing a compressive strength test specimen?

A. 1
B. 2
C. 3
D. 4

47. To calculate the number of cubic yards required for a pad, divide the cubic feet of the pad by what number?

A. 27
B. 28
C. 30
D. 40

48. **(True or False)** Concrete specifications most often require that batching be performed by volume.

A. True
B. False

49. How many rotations of the drum on a transit mixer at mixing speed are required to produce concrete of the specified uniformity?

A. 10 to 30
B. 30 to 50
C. 70 to 100
D. 90 to 120

50. Which of the following structures is NOT an example of a precast concrete structure?

A. Electric pole
B. Cast-in-place concrete wall
C. Highway girder
D. Building member

51. You should not continue to operate a mobile concrete mixer plant if the hydraulic oil temperature exceeds what temperature?

A. 190°
B. 200°
C. 210°
D. 220°

52. What type of panel consists of two thin, dense reinforced concrete-faced slabs separated by a core of insulating material?

A. Gate
B. Sandwich
C. Girder
D. Bellow

53. Post-tensioning is used if a unit weighs over 7 tons or is over how many feet long?

A. 10
B. 25
C. 30
D. 45

54. Conventional concrete weighs approximately how many pounds per cubic foot?

A. 100
B. 130
C. 150
D. 170

55. Depending on its intended use, the weight of lightweight concrete falls within what range, in pounds per cubic foot?

A. 10 to 15
B. 20 to 28
C. 30 to 75
D. 90 to 120

56. Heavyweight concrete has a density of up to how many pounds per cubic foot?

A. 400
B. 425
C. 450
D. 475

57. What type construction is a special form of precast concrete building?

A. K-span
B. Tilt-up concrete
C. S-80
D. Butler

58. When building casting surfaces for precast concrete panels, you should use 3,000 psi or higher reinforced concrete and ensure the slabs are at least how thick, in inches?

A. 2
B. 4
C. 5
D. 6

59. What material is most often used for edge forms?

A. 1-inch concrete slabs
B. 2-inch steel sheets
C. 2-by lumber
D. 4-inch aluminum rods

60. Bond-breaking agents are classified into what two types?

A. Paraffin and wax
B. Acidic and alkaline
C. Liquid and solid material
D. Sheet materials and liquids

61. A good bond-breaking agent can be made by mixing 5 pounds of paraffin with how many gallons of kerosene?

A. 1 1/2
B. 2 1/2
C. 3
D. 5

62. **(True or False)** When welded wire fabric (WWF) is used, dowels or bars are NOT needed between the columns and panels.

A. True
B. False

63. **(True or False)** To achieve proper strength, cast panels must be cured just like any other concrete.

A. True
B. False

64. At the job site, what type of lifting attachments can be made from rebar?

A. Hooks
B. Inserts
C. Hairpins
D. Spreaders

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*American Concrete Institute* (ACI Standards 200 & 300 series), Box 19150, Redford Station, Detroit, MI, 1987.

*Concrete and Masonry,* FM 5-742, Headquarters, Department of the Army, Washington, DC, 1985.

*Design and Control of Concrete Mixtures,* 13th ed., Portland Cement Association (PCA), Skokie, IL, 1989.

*Engineering Aid Advanced,* Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

*Equipment Operator Advanced*, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

*Naval Construction Force Manual,* NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

*OSHA Standards for the Construction Industry, 29* CFR, Part 1926, Commerce Clearing House, Inc., 4025 West Peterson Avenue, Chicago, IL, 1991.

*Safety and Health Requirements Manual,* EM 385-1-1, Department of the Army, Washington, DC, 1991.

# CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write or email us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.


Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil


Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

____________________________________________________________

____________________________________________________________

____________________________________________________________

(Optional) Correction

____________________________________________________________

____________________________________________________________

____________________________________________________________

(Optional) Your Name and Address

____________________________________________________________

____________________________________________________________

____________________________________________________________

# Chapter 4

# Masonry Construction

## Topics



To hear audio, click on the box.

## Overview

Masonry has become increasingly important as a construction method for Seabee construction. The commonly accepted definition of masonry, or unit masonry as it is sometimes called, is a construction method made up of prefabricated masonry units (such as concrete block, brick, clay tile, and stone) laid in various ways and joined together by mortar. In the Builder Basic training manual, we covered concrete masonry units (CMUs) in depth, and the construction techniques used to lay them. This chapter covers the construction techniques of laying brick, structural clay tile, and stone, and the estimating procedures associated with CMUs.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Estimate material and labor for concrete masonry units according to NAVFAC P-405.
2. Estimate material for brick construction.
3. Identify the components, requirements, and construction techniques of structural clay tile.
4. Identify the components, requirements, and construction techniques of stone masonry.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.0.0 ESTIMATING CONCRETE MASONRY UNITS (CMU)

Concrete masonry walls are laid out so as to make maximum use of full- and half-length units. This is called modular planning. Architectural and Engineering (A&E) firms and Builders strive to build modular structures because it minimizes cutting and fitting of units on the job, which in turn saves on labor and cost. *Table 4-1* lists the nominal lengths of concrete masonry walls by stretchers.

**Table 4-1 – Nominal Lengths of Concrete Masonry Walls in Stretchers.**

| Number of Stretchers | Nominal Lengths of Concrete Masonry Walls | |
|---|---|---|
| | Units 15 5/8” long and half units 7 5/8” long with 3/8” thick head joints | Units 11 5/8” long and half units 5 5/8” long with 3/8” thick head joints |
| 1 | 1’ 4” | 1’ 0” |
| 1 1/2 | 2’ 0” | 1’ 6” |
| 2 | 2’ 8” | 2’ 0” |
| 2 1/2 | 3’ 4” | 2’ 6” |
| 3 | 4’ 0” | 3’ 0” |
| 3 1/2 | 4’ 8” | 3’ 6” |
| 4 | 5’ 4” | 4’ 0” |
| 4 1/2 | 6’ 0” | 4’ 6” |
| 5 | 6’ 8” | 5’ 0” |
| 5 1/2 | 7’ 4” | 5’ 6” |
| 6 | 8’ 0” | 6’ 0” |
| 6 1/2 | 8’ 8” | 6’ 6” |
| 7 | 9’ 4” | 7’ 0” |
| 7 1/2 | 10’ 0” | 7’ 6” |
| 8 | 10’ 8” | 8’ 0” |
| 8 1/2 | 11’ 4” | 8’ 6” |
| 9 | 12’ 0” | 9’ 0” |
| 9 1/2 | 12’ 8” | 9’ 6” |
| 10 | 13’ 4” | 10’ 0” |
| 10 1/2 | 14’ 0” | 10’ 6” |
| 11 | 14’ 8” | 11’ 0” |
| 11 1/2 | 15’ 4” | 11’ 6” |
| 12 | 16’ 0” | 12’ 0” |
| 12 1/2 | 16’ 8” | 12’ 6” |
| 13 | 17’ 4” | 13’ 0” |
| 13 1/2 | 18’ 0” | 13’ 6” |
| 14 | 18’ 8” | 14’ 0” |
| 14 1/2 | 19’ 4” | 14’ 6” |
| 15 | 20’ 0” | 15’ 0” |
| 20 | 26’ 8” | 20’ 0” |

**NOTE**

Actual wall length is measured from outside edge to outside edge of units and equals the nominal length minus 3/8” (one mortar joint).

*Table 4-2* lists nominal heights of concrete masonry walls by courses.

**Table 4-2 – Nominal Heights of Concrete Masonry Walls in Courses.**

| Number of Courses | Nominal Heights of Concrete Masonry Walls | |
|---|---|---|
| | **Units 7 5/8" high with 3/8" thick bed joints** | **Units 3 5/8" high with 3/8" thick bed joints** |
| 1 | 0' 8" | 0' 4" |
| 2 | 1' 4" | 0' 8" |
| 3 | 2' 0" | 1' 0" |
| 4 | 2' 8" | 1' 4" |
| 5 | 3' 4" | 1' 8" |
| 6 | 4' 0" | 2' 0" |
| 7 | 4' 8" | 2' 4" |
| 8 | 5' 4" | 2' 8" |
| 9 | 6' 0" | 3' 0" |
| 10 | 6' 8" | 3' 4" |
| 15 | 10' 0" | 5' 0" |
| 20 | 13' 4" | 6' 8" |
| 25 | 16' 8" | 8' 4" |
| 30 | 20' 0" | 10' 0" |
| 35 | 23' 4" | 11' 8" |
| 40 | 26' 8" | 13' 4" |
| 45 | 30' 0" | 15' 0" |
| 50 | 33' 4" | 16' 8" |

**NOTE**

For concrete masonry units 7 5/8" and 3 5/8" in height laid with 3/8" mortar joints, height is measured from center to center of mortar joints.

*Table 4-3* lists the average number of concrete masonry units by size and the approximate number of cubic feet of mortar required for every 100 square feet of a concrete masonry wall.

**Table 4-3 – Average Concrete Masonry Units and Mortar per 100 Square Feet of Wall**

| Description, Size of Block (inches) | Thickness Wall (inches) | Number of Units per 100 Square Feet of Wall Area | Mortar (Cubic Feet) |
|---|---|---|---|
| 8 x 8 x 16 | 8 | 112.5 | 8.5 |
| 8 x 12 x 16 | 12 | 112.5 | 8.5 |
| 8 x 3 x 16 | 3 | 112.5 | 8.5 |
| 8 x 3 x 12 | 3 | 151.5 | 9.5 |
| 8 x 4 x 16 | 4 | 112.5 | 8.5 |
| 8 x 4 x 12 | 4 | 151.5 | 9.5 |
| 8 x 6 x 16 | 6 | 112.5 | 8.5 |

**NOTE**

Mortar is based on 3/8" joint with a face-shell mortar bed and 10% allowance for waste.

As a Builder, you might find yourself in the field without the tables handy. To solve that problem, we will cover two methods of estimating concrete masonry units (CMUs) without the tables.

## 1.1.0 Chasing the Bond

Chasing the bond uses the 3/4 rule and the 3/2 rule. When estimating, always use outside measurements to calculate the number of blocks required per course. In most Seabee construction, 8” x 8” x 16” block is used.

### 1.1.1 Using the 3/4 Rule

Using the 3/4 rule (three full block [fb] per 4 feet in length) or .75, multiply the length of the wall by .75. For example, a retaining wall that is 100 feet in length (1,000 square feet) will require 75 block for the first course.

**Length of course in feet x rule 3/4 = number of CMU per course**

### 1.1.2 Using the 3/2 Rule

Using the 3/2 rule (three full block per 2 feet in height), multiply the height of the wall by 1.5. For example, the height of the retaining wall is 10 feet. Multiply 10 by the rule 3/2 (1.5), which will equal 15 block high (courses high).

**Height of wall in feet x rule 3/2 = courses high**

Then, to find the total number of full block in the retaining wall, multiply the number of block in length by the number of block in height, which in this example is 75 CMUs in length times 15 courses high, which equals 1,125 fb. Let’s take another example, using a building 20 feet long by 8 feet wide by 8 feet high.

**.75 x 20 x 2 (sides) = 30 (8” x 8” x 16” block)**

**.75 x 8 x 2 (sides) = 12 (8” x 8” x 16” block)**

Or you can find the total linear feet (lf) of the building and multiply by .75.

**20 x 2 (sides) + 8 x 2 (sides) = 56 lf**

**56 x .75 = 42 fb**

**1.5 x 8 = 12 courses high**

**42 fb x 12 courses = 504 total fb**

## 1.2.0 Square Foot Method

The square foot method is usually the quickest and simplest method but NOT the most accurate. As the estimator, however, you will use this method quite frequently. In the first example the retaining wall was 10 feet high and 100 feet long. To find square feet, all you do is use the equation L x H = SF; in this example, the answer is 1,000 square feet (sf). To find the number of 9” x 8” x16” block required, you must determine the square footage of one CMU, which is .89 sf per block. Next you divide 1,000 sf by 89 sf/CMU, which equals 1,124 fb. You calculated the block for 1,000 sf, and the difference is 1 less block figuring by the square foot method.

**Total sf divided by sf/CMU = total number of CMU**

Now calculate the 20’ x 20’ x 8’ building:

**20 x 8 = 160 sf x 2 (sides) = 320 sf**

**8 x 8 = 54 sf x 2 (sides) = 128 sf**

**Total = 448 sf**

**448 sf / .89 sf/CMU – 503.4 or 504 total fb**

Or, you can multiply the square footage of the building times the number of block per square foot (1.125 CMU/sf).

**448 SF x 1.125 CMU/SF = 504 CMU**

If you were planning a modular building, you would use the square foot method for quicker estimating, but there is an additional step you need to take, calculating the duplicating factor, which takes into account that every course will have a half block at each corner. For example, you estimated 504 fb for this building. To estimate the fb accurately, you would deduct two f /course or multiply 12 courses x .5 (half block [hb]) x four corners = 24 fb. Then deduct the 24 fb from the total fb as shown in the following formula:

**12 courses x .5 x 4 corners = 24 fb**

**504 fb - 24 fb = 480 fb**

## 1.3.0 Estimating Door and Window Openings

When you estimate CMUs, usually the window and door openings are designed to be modular and the window and door frames are of the same mode. If the design is NOT modular, you can expect a lot of cutting time. When you estimate for openings, just calculate the area of the opening, and then subtract the area of the opening(s) from the overall area of the wall or building to get the net area. Finally, multiply the number of CMU per square foot by the net area.

## 1.4.0 Estimating Mortar

Builders have found that it takes about 38 cubic feet of raw materials to make 1 cubic yard of mortar. Therefore, you can use rule 38 for calculating the raw material needed to mix 1 cubic yard of mortar without having to do a great deal of paper work. However, this rule does not accurately calculate the required raw materials for large masonry construction jobs. For larger jobs, use the absolute volume or weight formula. In most cases, though, and particularly in advanced base construction, you may use rule 38 to make a quick estimate of the quantities of raw materials required.

Here is how you use rule 38 for calculating mortar: Take the rule number and divide it by the sum of the quantity figures specified in the mix. For example, let's assume that the building specification calls for a 1:3 mix for mortar, *1 + 3 = 4*. Since *38 ÷ 4 = 9 1/2,* you need 9 1/2 sacks, or 9 1/2 cubic feet, of cement. To calculate the amount of fine aggregate (sand), you multiply 9 1/2 by 3. The product (28 1/2 cubic feet) is the amount of sand you need to mix 1 cubic yard of mortar using a 1:3 mix. The sum of the two required quantities should always equal 38. This is how you can check whether you are using the correct amounts. In the previous example, 9 1/2 sacks of cement plus 28 1/2 cubic feet of sand equal 38.

*Table 4-3* shows that it takes 8.5 cubic feet (cf) of mortar to lay 100 sf of 8" x 8" x 16" block. In the previous example, you estimated the building at 480 sf of wall area. To calculate the amount of mortar to lay the CMU, first convert the 480 sf to units.

**480 sf ÷ 100 sf = 4.8 units**

Then multiply the units by the number of cubic feet of mortar;

**4.8 units x 8.5 cf = 40.8 cf of mortar**

To calculate the ingredients needed to make 40.80 cf of mortar with a 1:1/4:3 mix, the 1/4 being hydrated lime, first calculate the amount of cement using rule 38. Remember the formula: 9 1/2 sacks of cement (94 lb/sk) per cubic yard.

Use the following formula: First, convert cubic feet of mortar to cubic yards:

**40.8 cf ÷ 27 cf/cy = 1.51 cubic yard**

| | |
|---|---|
| **Cement:** | **(1) x 9 1/2 cf = 0 1/2 (sacks) x 1.51 cd = 14 sks (cf)** |
| **Sand:** | **3/4 x 9 1/2 = 28 1/2 / 38 (cf) x 1.51 cd = 43 cf** |
| **Lime:** | **(1/4) x 9 1/2 cf = 2.5 (cf) x 1.51 cd = 4 cf** |
| **Total:** | **61 cf** |

## 1.5.0 Estimating Mixing Time

Let's briefly cover the mixing time it will take to mix mortar. A typical mortar mixer has a capacity of mixing 4 to 7 cubic feet per batch, and each batch must be mixed for a minimum of 3 minutes. In the most recent example, we calculated a total of 61 cubic feet of raw materials needed to construct this building. Now just divide the number of cubic feet per batch by the total number of cubic feet of raw materials, and then multiply that number by the number of minutes per batch.

**61 cf / 4 cf/batch = 15 batches**

**15 batches x 3 minutes/batch = 45 minutes**

The time indicates only the required continuous mixing time and does not include the cleaning, staging, or transporting time of the material or the time required for you to lay the CMU. Batching procedures will vary with individual preference. Experience is the key to good results in obtaining the desired mix.

## 1.6.0 Estimating Labor

This section briefly covers labor estimates for concrete masonry units according to the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405. *Table 4-4* shows the labor table from the P-405 on how to estimate labor.

**Table 4-4 – Labor Chart for Masonry.**

| Work Element Description | Unit | Man hours per Unit |
|---|---|---|
| **Concrete Block** | | |
| 12” x 8” x 16” | 1,000 sf | 167 |
| 8” x 8” x 16” | 1,000 sf | 160 |
| 6” x 8” x 16” | 1,000 sf | 146 |
| 4” x 8 “ x 16” | 1,000 sf | 118 |
| **Common Brick** | | |
| 8” thick wall | 1,000 sf | 500 |
| 12” thick wall | 1,000 sf | 700 |
| 4” thick brick veneer | 1,000 sf | 280 |
| Grouting (conventional method) | CD | 16 |
| Core fill (.125 cf/cell) (conventional method - mortar mixer and bucket) | CD | 16 |
| Core fill (TM and pump method) | CD | 2 |
| Grouting brickwork | CD | 16 |

When using this table, you will see that 8" x 8" x 16" block takes one person (skilled labor) 160 man hours to lay 1,000 square feet of CMUs. If you were to break this labor down into how many CMUs are laid in an 8-hour period, it would be calculated as follows:

**1000 sf of wall area = 1,125 CMU**

**160 man hours ÷ 8 hour days = 20 duration days**

**1125 CMU ÷ 20 days= 56.25 CMU/day**

Let’s return to the building example. How many man hours (MH) will it take with a crew of one skilled and three non-skilled laborers? This is the ratio/proportion part of this calculation.

If 160 MH equals 1,000 sf of wall area (NAVFAC P-405), then, X (MH) equals the square footage of the wall area.

**160 (MH) :1000 sf :: x (MH) : 448 sf =**

**160 x 448 :: 1000 x**

**71680 ÷ 1000 x = 71.68**

**X = 72 MH**

Another method you may use to calculate this number is as follows:

**x/160 = 448/1000**

In this equation, you simply cross multiply the following:

**160 x 448 = 71680**

**X times 1000 = 1000 x, then divide**

**71680 ÷ 1000 x**

**X = 71.68 or 72 MH**

In this example, it takes 72 man hours to lay 448 sf or 504 CMUs. Now divide the number of MH by 8-hour days. It would equal 9 duration days. To see how close the estimate is, one person (skilled) lays 56.25 CMU/day and you calculated 9 days. Then multiply 56.25 times 9 which equals 506 block. There is a two block difference, which is not much in this example, but it could be if you were estimating thousands of square feet of CMU.

# 2.0.0 BRICK CONSTRUCTION

Brick masonry is masonry construction in which units of baked clay or shale of uniform size, small enough to be placed with one hand, are laid in courses with mortar joints to form walls. Bricks are kiln-baked from various clay and shale mixtures. The chemical and physical characteristics of the ingredients vary considerably. These characteristics and the kiln temperatures combine to produce brick in a variety of colors and hardnesses. In some regions, individual pits yield clay or shale which, when ground and moistened, can be formed and baked into durable brick. In other regions, clay or shale from several pits must be mixed.

## 2.1.1 Brick Classification

A finished brick structure contains face brick, brick placed on the exposed face of the structure, and backup brick, brick placed behind the face brick. The face brick is often of higher quality than the backup brick; however, the entire wall may be built of common brick. Common brick is made from pit-run clay with no attempt at color control and no special surface treatment like glazing or enameling. Most common brick is red.

Although any surface brick is a face brick as distinguished from a backup brick, the term face brick is also used to distinguish high quality brick from brick of common quality or less. Applying this criterion, face brick is more uniform in color than common brick and may be obtained in a variety of colors as well. It may be specifically finished on the surface, and, in any case, it has a better surface appearance than common brick. It may also be more durable as a result of the use of select clay and other materials or as a result of special manufacturing methods.

Backup brick may consist of brick that is inferior in quality even to common brick. Brick that has been underburned or overburned, or brick made with inferior clay or by inferior methods, is often used for backup brick.

Still another type of classification divides brick into grades according to the probable climatic conditions to which they are to be exposed. These are as follows:

- Grade SW is brick designed to withstand exposure to below-freezing temperatures in a moist climate like that of the northern regions of the United States.
- Grade MW is brick designed to withstand exposure to below-freezing temperatures in a drier climate than that mentioned in the previous paragraph.
- Grade NW is brick primarily intended for interior or backup brick. It may be used exposed; however, it can be used only in regions where no frost action occurs.

## 2.2.0 Estimating Brick and Mortar

When estimating the number of brick and the quantity of mortar, you need to know the exact size of the brick and the thickness of the mortar joint. This information is found in the plans or specifications. *Table 4-5* shows the quantities of material required for brick walls.

**Table 4-5 – Quantities of Material Required for Brick Walls.**

| Size of Brick | Wall Area (sf) | Number of Brick | Joint Size | Mortar (cf/1000 brick) |
|---|---|---|---|---|
| 2 1/4” x 3 3/4” x 8” | 100 | 616 | 1/2” | 11.7 |
| 2 1/4” x 3 5/8” x 7 5/8” | 100 | 686 | 3/8” | 8.7 |
| 3” x 4 1/4” x 9” | 100 | 480 | 1/2” | 5.7 |

**NOTE**

Quantities of brick include the thickness of the mortar joint with no allowance for waste.

The following example shows the square foot method of estimating the number of bricks for a 4 inch wall measuring 8 feet high and 14 feet long. Specifications call for the use of U.S. standard brick with a 1/2 inch mortar joint. The brick face with its mortar joints measures 2 3/4 inches high by 8 1/2 inches long. The correct steps to follow are these:

1. Find the surface area by multiplying the height and the length of a brick (include mortar joint). In this case:

   **2 3/4" x 8 1/2 = 2.75 x 8.50 = 23.38 square inches per brick**

2. Find the number of bricks per square foot of wall. In this case, the number of bricks is 6.16 per square foot for a 4 inch wall.
3. Find the area of the brick wall by multiplying its height by its length.

   **8 feet x 14 feet = 112 square feet**

4. Multiply the area of the wall by the number of bricks per square foot. In this case:

   **112 x 6.16 or 690 bricks plus 10% waste which equals 760 bricks**

**NOTE**

If there are windows, doors, and other openings on the wall, you subtract the area of these openings from the overall area of the wall to get the net area. Then in Step 4, you multiply the number of bricks per square foot by the net area.

In finding how much mortar is required to build this wall, divide the number of bricks by 1,000, then multiply the result by the factor given in *Table 4-5* and allow 20% for waste.

**760 ÷ 1000 = .76**

**.76 x 11.7 (cubic feet of mortar per 1000 bricks) = 8.90 cf of mortar**

**8.90 x 20% (waste) = 10.68 or 10.7 cubic feet of mortar**

Therefore, to construct this wall with U.S. standard brick with a 1/2 inch mortar joint, you require 760 bricks and 10.7 cubic feet of mortar.

# 3.0.0 STRUCTURAL CLAY TILE

Hollow masonry units made of burned clay or shale are variously called structural tiles, hollow tiles, structural clay tiles, structural clay hollow tiles, and structural clay hollow building tiles, but they are most commonly called building tile. In building tile manufacture, plastic clay is pushed through a die, and the shape that emerges is cut off into units. The units are then burned much as bricks are burned.

The apertures in a building tile, which correspond to the cores in a brick or a concrete block, are called cells. The solid sides of a tile are called the shell, and the perforated material enclosed by the shell is called the web. A tile that is laid on one of its shell faces is called a side construction tile; several sizes and shapes are shown in *Figure 4-1.*

**Figure 4-1 – Standard shapes of side construction building tiles.**

A tile that is laid on one of its web faces is called an end construction tile; several sizes and shapes are shown in *Figure 4-2.*

**Figure 4-2 – Standard shapes of end construction building tiles.**

Special shapes for use at corners and openings or for use as closures are also available.

## 3.1.0 Physical Characteristics

The compressive strength of the individual tile depends on the materials used and the method of manufacture in addition to the thickness of the shells and webs. A minimum compressive strength of tile masonry of 300 pounds per square inch based on the gross section may be expected. The tensile strength of structural clay tile masonry is small. In most cases, it is less than 10 percent of the compressive strength.

The abrasion resistance of clay tile depends primarily upon its compressive strength. The stronger the tile, the greater is its resistance to wearing. The abrasion resistance decreases as the amount of water absorbed increases.

Structural clay facing tile has excellent resistance to weathering. Freezing and thawing action produces almost no deterioration. Tile that will absorb no more than 16 percent of its weight of water has never given unsatisfactory performance in resisting the effect of freezing and thawing action. Only Portland cement lime mortar or mortar prepared from masonry cement should be used if the masonry is exposed to the weather.

Walls containing structural clay tile have better heat-insulating qualities than walls composed of solid units because of the dead air space that exists in tile walls. The resistance to sound penetration of this type of masonry compares favorably with that of the resistance of solid masonry walls, but it is somewhat less.

The fire resistance of tile walls is considerably less than the fire resistance of solid masonry walls. It can be improved by the application of a coat of plaster to the surface of the wall. Partition walls of structural clay tile 6 inches thick will resist a fire for 1 hour provided the fire produces a temperature of not more than 1700°F.

The solid material in structural clay tile weighs about 125 pounds per cubic foot. Since the tile contains hollow cells of various sizes, the weight of the tile varies depending upon the manufacturer and type. A 6 inch tile wall weighs approximately 30 pounds per square foot, while a 12 inch tile wall weighs approximately 45 pounds per square foot.

## 3.2.0 Uses for Structural Clay Tile

Structural clay tile may be used for the exterior walls of either the load bearing or non-load bearing type. It is suitable for both below grade and above grade construction.

Structural load bearing tile is made from 4 to 12 inch thicknesses with various face dimensions. The use of these tiles is restricted by building codes and specifications, so consult the project specification.

Non-load bearing partition walls from the 4 to 12 inch thicknesses are frequently made of structural clay tile. These walls are easily built, light in weight, and have good heat and sound insulating properties.

*Figure 4-3* shows the use of structural clay tile as a back unit for a brick wall.

**Figure 4-3 – Structural tile used as a backing for bricks.**

*Figure 4-4* shows the use of 8 x 5 x 12 inch tile in wall construction. Exposure of the open end of the tile can be avoided by the application of a thin tile, called a soap, at the corner.

# 4.0.0 STONE MASONRY

Stone masonry units consist of natural stone. In rubble stone masonry, the stones are left in their natural state without any kind of shaping. In ashlar masonry, the faces of stones that are to be placed in surface positions are squared so that the surfaces of the finished structure will be more or less continuous plane surfaces. Both rubble and ashlar work may be either random or coursed.

**Figure 4-4 – Eight inch structural clay tile wall.**

Random rubble is the crudest of all types of stonework. Little attention is paid to laying the stones in courses, as shown in *Figure 4-5*. Ashlar coursed masonry is at the opposite end of the stone masonry spectrum, having structured courses and squared stone faces, as shown in *Figure 4-6*.

**Figure 4-5 – Random rubble stone masonry.**

**Figure 4-6 – Coursed ashlar stone masonry.**

Each layer must contain bonding stones that extend through the wall, as shown in *Figure 4-7*. This produces a wall that is well tied together. The bed joints should be horizontal for stability, but the builds or head joints may run in any direction.

**Figure 4-7 – Layers of bond in random stone masonry.**

Coursed rubble consists of roughly squared stones assembled in such a manner as to produce approximately continuous horizontal bed joints, as shown in *Figure 4-8*.

The stone used in stone masonry should be strong and durable. Durability and strength depend upon the chemical composition and physical structure of the stone. Some of the more commonly found stones that are suitable are limestone, sandstone, granite, and slate. Unsquared stones obtained from nearby ledges or quarries, or even fieldstones may be used. The size of the stone should be such that two people can easily handle it. Using a variety of sizes avoids using large quantities of mortar.

**Figure 4-8 – Coursed rubble masonry.**

The mortar used in stone masonry may be composed of Portland cement and sand in the proportions of 1 part cement to 3 parts sand by volume. Such mortar shrinks excessively and does not work well with the trowel. A better mortar to use is Portland cement lime mortar. Mortar made with ordinary Portland cement will stain most types of stone. If staining must be prevented, non-staining white Portland cement should be used in making the mortar. Lime does not usually stain the stone.

## Summary

You have learned how to estimate material and labor for concrete masonry units according to NAVFAC P-405. You also learned to estimate materials for brick construction, and are now able to identify the components, requirements, and construction techniques for laying structural clay tile and stone masonry.

## Review Questions (Select the Correct Response)

1. Masonry is a construction method made up of prefabricated masonry units laid together in various ways and joined together by what type of mix?

   A. 2:4:2 concrete
   B. Mortar
   C. Clay and straw
   D. Epoxy

2. What type of planning ensures concrete masonry walls are laid out so maximum use is made of full-length and half-length masonry units?

   A. Modular
   B. Masonry
   C. Standard
   D. Developmental

3. In most construction accomplished by Seabees, what size concrete masonry units (CMUs) are used?

   A. 8" x 3" x 12"
   B. 8" x 4" x 12"
   C. 8" x 4" x 16"
   D. 8" x 8" x 16"

4. Which one of the two methods used by Builders to estimate CMUs is the quickest, but NOT the most accurate?

   A. Solving for CMUs
   B. Chasing the bond
   C. Square foot method
   D. Metric inch method

5. Building specifications call for a 1:2 mortar mix. Using rule 38, how many sacks of cement are required to make up a 2 cubic yard mix?

   A. 10
   B. 13
   C. 20
   D. 26

6. It takes one person (skilled labor) a total of how many man hours to lay 1,000 square feet of 8" x 8" x 16" concrete block?

   A. 118
   B. 146
   C. 160
   D. 167

In answering question 7, refer to the Table below.

| Work Element Description | Unit | Man hours per Unit |
|---|---|---|
| **Concrete Block** | | |
| 12” x 8” x 16” | 1,000 sf | 167 |
| 8” x 8” x 16” | 1,000 sf | 160 |
| 6” x 8” x 16” | 1,000 sf | 146 |
| 4” x 8 “ x 16” | 1,000 sf | 118 |
| **Common Brick** | | |
| 8” thick wall | 1,000 sf | 500 |
| 12” thick wall | 1,000 sf | 700 |
| 4” thick brick veneer | 1,000 sf | 280 |
| Grouting (conventional method) | CD | 16 |
| Core fill (.125 cf/cell) (conventional method - mortar mixer and bucket) | CD | 16 |
| Core fill (TM and pump method) | CD | 2 |
| Grouting brickwork | CD | 16 |

7. How many man hours are required to construct 1,500 square feet of wall area using 8 inch by 8 inch by 16 inch CMU?

   A. 200
   B. 220
   C. 240
   D. 260

8. What type of brick is designed to withstand exposure to below freezing temperatures in a moist climate?

   A. LW
   B. MW
   C. NW
   D. SW

9. Tile masonry has a compressive strength of how many pounds per square inch?

   A. 100
   B. 200
   C. 300
   D. 400

10. Partition walls of clay tile 6 inches thick can resist for 1 hour a fire that produces heat not exceeding what temperature, in degrees Fahrenheit?

    A. 1100
    B. 1200
    C. 1700
    D. 1900

11. **(True or False)** The use of structural load bearing tiles is restricted by building codes.

    A. True
    B. False

12. Stone masonry units are classified into what two types?

    A. Coursed and rectangle
    B. Random and regular
    C. Ashlar and rubble
    D. Squared and cubic

13. What type of rubble stonework is the crudest of all types?

    A. Standard
    B. Unsquared
    C. Random
    D. Coursed

14. What type of rubble consists of roughly squared stones assembled in such a manner as to produce approximately horizontal bed joints?

    A. Rough
    B. Random
    C. Modified
    D. Coursed

15. The mortar used in stone masonry should be composed of what ratio of cement to sand?

    A. 1 to 3
    B. 2 to 3
    C. 3 to 4
    D. 4 to 5

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*American Concrete Institute* (ACI Standards 200 & 300 series), BOX 19150, Redford Station, Detroit, MI, 1987.

*Concrete and Masonry*, FM 5-742, Headquarters, Department of the Army, Washington, DC, 1985.

*Design and Control of Concrete Mixtures, 13th ed.*, Portland Cement Association (PCA), Skokie, IL, 1989.

*Engineering Aid Advanced*, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

*Equipment Operator Advanced*, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

*Naval Construction Force Manual*, NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

*OSHA Standards for the Construction Industry*, 29 CFR, Part 1926, Commerce Clearing House, Inc., 4025 West Peterson Avenue, Chicago, IL, 1991.

*Safety and Health Requirements Manual*, EM 385-1-1, Department of the Army, Washington, DC, 1991.

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write or email us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

___

___

___

(Optional) Correction

___

___

___

(Optional) Your Name and Address

___

___

___

# Chapter 5

# Shop Organization and Millworking

## Topics



To hear audio, click on the box.

## Overview

As a first class or second class petty officer, you will at some point in your naval career be in charge of or supervise a shop. You may even be tasked to plan the layout of equipment and materials needed to set up a new shop from scratch. In doing so, you will find that certain factors applicable in setting up a new shop are also applicable when taking over as a supervisor of a shop already in existence.

Once a shop is set up, you will be responsible for projects that include Millworking and Cabinetmaking. Your task will be to have your crew produce the best possible product on schedule at a reasonable price.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the purpose and arrangement of a Shop.
2. Identify different types of millwork.
3. Identify the products of cabinetmaking and determine the designs, materials, and processes to create them.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.0.0 SHOP ORGANIZATION

Where there are Seabees, there is likely to be some sort of Builder or maintenance shop. When taking over an established shop, you may find it worthwhile to make a study of the layout of equipment and materials to determine if changes could help provide a smoother work flow and higher production.

## 1.1.0 Purpose of a Shop

Carefully analyze the purpose of the shop when planning its layout and organization. What kind of work will be done here? How much work must be turned out under normal conditions? Is the shop a specialized shop or a general purpose shop? Does the shop meet all safety and environmental precautions?

Give safety top priority. It is strongly recommended that all portions of the area be clearly visible to the instructor and the students. Designate travel aisles by painted lines and make sure the aisles are a minimum of 3 to 4 feet wide. Use nonskid flooring in critical areas. Arrange equipment and storage racks so the entrances and exits to the building are kept clear and are accessible in case of fire or emergency. Locate stationary machines so the moving parts will not constitute a hazard to either the operator or to other shop personnel. Be certain that your shop layout allows easy access to fire fighting equipment, electrical control panels, and junction boxes. Because safety and environmental requirements continually change, we cannot cover every aspect of safety in a shop. Refer to the *School Shop Development Manual* by Rockwell Manufacturing Company, the *Navy Occupational Safety and Health Manual,* OPNAVINST 5100.23, and the *Occupational Safety and Health Standards for the Construction Industry, Code of Federal Regulations* (29 CFR PART 1910).

Consider the particular advantages and limitations of the proposed shop space. How large is it? How many personnel are expected to work in the shop at the same time? What kind of tools will be available? Where are the power outlets located? Can good lighting be arranged? What type of ventilation will be available?

The function of the shop has an important bearing on the equipment needed and the minimum space required. You may not get the amount of space desired and may have to do the best you can with the available space. In some instances, two spaces may be available, but one is unacceptable because of major problems that would be encountered.

## 1.2.1 Arrangement of a Shop

Good arrangement is required in all shops, regardless of a shop's function. Arrange the equipment, layout tables, and so on in a shop in the order of the work flow of the shop's dominant project. The layout in *Figure 5-1* may be used as a guide in laying out a carpentry shop.

1. **Arbor saw**
2. **Radial arm saw**
3. **Band saw**
4. **Jointer**
5. **Drill press**
6. **Finishing machine**
7. **Planer**
8. **Grinder**
9. **Vacuum cleaner**
10. **Utility locker**
11. **Supply cabinet**
12. **Workbench**
13. **Toolbox storage**
14. **Roller conveyor sections**
15. **Clamp rack**
16. **Saw blade rack**
17. **Nail bins**
18. **Broom rack**

**Figure 5-1 – Typical layout of a carpentry shop.**

Consider such factors as the sequence of operations, working space, clear shop entrance and exit, adequate workbenches, and safety when planning the arrangement of equipment. The positioning of equipment, layout tables, and so on does not have to be the same in one shop as in another.

Try to place stationary machines so that the work flows in an orderly and logical sequence. It is probably easier to do this in a specialized shop than n a general purpose shop where the work differs considerably from one day to the next.

In shops where a series of operations is performed, the relative position of the various pieces of equipment has an important bearing on efficient operations. The equipment must be accessible, and arranged in a way that reduces wasted motion and walking distance.

Your personnel will turn out more work when their equipment is close at hand, and adequate clearance between adjacent machines will keep the operators out of each other's way. Electrical outlets should be readily available to the workbenches. Rigging extension cords from poorly located outlets causes needless delays.

Your plans should also include adequate storage for tools and materials. When considerable amounts of materials must be kept on hand and space permits, use a special storeroom for storage of materials, and possibly a portion of this storeroom for storage of tools and equipment. Even when a storeroom is available, it may still be advantageous to store certain material in the shop near the machines or the equipment on which it is used. Refer to the *Occupational Safety and Health Standards for the Construction Industry, Code of Federal Regulations* (29 CFR PART 1910) for more information on storage of tools, material, and equipment.

The amounts and types of materials stored in your shop depend largely on the space available and the intended purpose of your shop. In most shops you need facilities for storing items such as bolts, nuts, nails, screws, and paint. Whatever the type of shop, make an effort to ensure that your storage facilities are arranged to give the greatest possible amount of free working space.

### 1.2.1 Floor

In today's industry, concrete is the most widely used flooring material, but possibly the most unsatisfactory flooring material for shops. Even when painted or sealed to eliminate dust, the concrete floor is still hard and very slippery. This is why nonskid paints are used so extensively.

Wood is the preferred floor material, but it is the most expensive. Tile floors have become popular recently due to their low initial cost and ease of replacement. Exercise some caution in specifying the exact type of tile, keeping in mind solvents and other inherently damaging materials used in a shop.

### 1.2.2 Walls and Ceilings

The walls should be made of concrete masonry units (CMUs), tile, or other materials that are very durable and can be easily cleaned. Windows should be placed as high up in the walls as possible to let natural light in. Generally, windows are required to be placed a minimum of 54 inches from the floor. If you want to put an acoustical plaster or other soundproof material on the walls, be sure it is a minimum of 5 feet from the floor. Shop ceilings should be at least 12 feet high. Although cost is a factor, acoustical material or treatment is highly recommended for the ceiling.

### 1.2.3 Office Space

You will also need space for an office. Try to locate the office in an area of the shop where you will be least disturbed by noise. The shop layout plan should make provision for a bulletin board where safety posters, maintenance posters, instructions and notices, plan of the day, and other such information may be posted.

The bulletin board should be located in a prominent place in the shop, preferably near the entrance where personnel will be likely to pass it during the day. If necessary, provide artificial lighting so that material on the bulletin board can be easily read. The material posted on the bulletin board should be changed frequently, expired notices removed promptly, current plan of the day posted early, and posters and other material rotated periodically.

## 2.1.1 MILLWORKING

Millwork is shaped items of wood made, in most cases, from well seasoned kiln-dried lumber (with 4 to 9 percent moisture content) that requires manufacturing. Most millwork products are used in the interior of buildings and are installed by finish carpenters. Builders do various types of construction, and understanding millwork concepts and construction techniques is essential.

Millworking includes interior trim products as well as casework, doors, kitchen and bathroom cabinets, window frames and sashes, stairs, furniture, specialized items made to order, and woodwork that is turned. The majority of the millwork in the construction industry is constructed and sold by two methods:

- Setup millwork is assembled and ready to be installed with minimal or no fitting, such as prehung doors, molding, and cabinets.
- Knocked down millwork is assembled by the Builder on the jobsite, such as window frames, doorframes, flooring products, some furniture units, stairs, and accessories.

Most products are produced in a manufacturing mill or plant and are ready to be installed by fastening to the wall or floor. If you need to install these types of products, refer to the manufacturer's instructions and/or the plans and specifications.

As the Builder in charge of a shop, you and your crew will be tasked at times to make plaques, flag cases, bookcases, shelving units, and cabinets. Many of these projects will be nothing more than an idea. You will be required to interpret the idea by sketching it on paper and developing the idea into a workable drawing.

In the Builder Basic training manual, you learned the basic concepts of drawings, interior and exterior trim, and casework mentioned in this section. With the large scope of products and changing technology, these products could not be covered sufficiently due to time and space constraints. The next section covers designing, constructing, and installing millwork products.

# 3.0.0 CABINETMAKING

Cabinetmaking is primarily used in interior finish carpentry, such as furniture, kitchens, bathrooms, and casework. Architecture and Engineering firms, Builders, or cabinetmakers that specialize in cabinetry usually plan their cabinetwork as a built-in unit. Floor plans usually show the cabinetwork location, while elevation plans usually provide detailed dimensions, as shown in *Figure 5-2*.

**Figure 5-2 – Typical dimensions for cabinetwork.**

## 3.1.1 Designing a Project

Builders are often provided with complete working drawings of a product to be constructed. The drawings usually contain information on building the product, such as size, style, material, construction, and finish. Sometimes the Builder must design, sketch, and make a working drawing from the customer's verbal specifications or from simple line drawings. To make a working drawing from the incomplete instructions supplied by the customer, the Builder must do the following:

1. Know the principles of good cabinet design
2. Be familiar with popular cabinet styles
3. Develop a sketch that meets the customer's specifications and conforms to good design principles
4. Make a working drawing from the sketch in order to build the product

When you design a product, consider the purpose, strength, size and shape proportion, appearance, time, and cost of the product. The time spent designing helps avoid mistakes and saves time in the long run. One of the most important considerations in designing a product is its purpose. A product's purpose may be the deciding factor in determining the design. For example, a bookcase must be the proper size and strength to hold the desired quantity and kind of books. Cabinets and furniture are usually made only strong enough to fulfill their purpose. The strength required of an object may determine such things as the type of joint, the size, and the kind of wood. It is often better to use strong woods like oak, ash, or maple to give the strength required by a product. Oversized softwood, like pine, may also be used. Using oversize parts gives a massive and awkward appearance to a product.

Some furniture and cabinets must be built to standard sizes to serve their purpose. A dining table that is too low will not serve its purpose. A kitchen counter top that is too narrow will not accommodate a sink. In addition to size and shape, the designer must also consider proportion. A cabinet's proportion is the relationship between its dimensions, which include its width, height, and length. Some proportions are more pleasing to the eye than others.

The appearance of a cabinet may be largely due to its purpose, location, and finish. If the product will be painted, a less expensive material may be used. If it will be stained with a clear finish, a better quality material should be used. The appearance of cabinet doors may be changed by cutting shapes in doors instead of using solid doors. The edges of the doors may be lipped or cut square according to the appearance desired.

Another important consideration in designing cabinetwork is the time required to construct it. Time may affect the type of joint, kind of material and fasteners, method of construction, and kind of finish. To save time, you may use one of these:

- a butt joint reinforced by corrugated fasteners instead of the more complicated and time-consuming mortise and tenon joint
- nails instead of screws
- a quick drying sprayed finish

The quality of the finished product is also a factor in designing. High quality products take more time and cost more to construct. The Builder must decide the minimum acceptable quality level and produce it at minimum cost.

### 3.1.1 Making a Sketch

A sketch is a freehand drawing which lets the designer experiment with the elements of a design. It is the preliminary step to a working drawing. The first step in designing and building an object is to make several drawings to experiment with design, size, and proportion. After you determine the design and size, determine the type of wood to use, finish, construction details such as joints, style (Early American, traditional, contemporary, etc.), and location and type of fasteners. Different kinds of drawings may be used according to which best illustrates the information, such as perspective, orthographic projection, pictorial, and/or detailed drawing. You may also use an exploded drawing as shown in *Figure 5-3*.

**Figure 5-3 – Exploded drawing and nomenclature of a cabinet.**

Refer to the *Architectural Graphics Standard (AGS)* for complete information on these kinds of drawings.

### 3.1.2 Working Drawings

When enough sketches have been made, put the ideas developed into the form of working drawings. A working drawing is one made with drawing tools, such as the T square, triangle, and compass. It is drawn to exact scale, as shown in *Figure 5-4*. It provides most of the information required to build the object. Some features, like the type of joint, glue, or fasteners, are left to the discretion of the Builder.

**Figure 5-4 – A working drawing of a bookcase.**

Drafting standards are followed closely when working drawings are developed. The drawing should be centered on the page. Lines should be standard weights. The drawings should be adequate dimensions and include all necessary notes. Lettering should be neat and legible.

## 3.2.0 Plan and Layout

After the working drawings are completed and approved, a plan and layout of procedures are done. This saves time and eliminates mistakes. A good cabinetmaker always lays out and plans the work before starting to build. A number of construction problems are solved during this planning period. With a good layout and plan, those who do the work should have few questions.

### 3.2.1 Layout Rod

One of the most common ways to lay out work is to use a rod. A rod is normally a 1” x 2” strip of lumber which indicates the actual location of all the parts of the cabinet. One side of the rod is used for marking the width, another for marking the height, the third for marking the depth, and the fourth side is used if other cabinets are to be built that differ in only one dimension. This technique is similar to laying out studs on a floor in rough framing. The rod shows the locations of the cuts, drawers, shelves, rails, and stiles, and any detail necessary to construct a cabinet. Cabinetmakers use different techniques and methods in developing rods and making a layout rod easier to read.

### 3.2.2 Making a Cutting List

Once the rod layout is complete, take all measurements for cutting the stock from it. Make a cutting list with all the parts and sizes. A cutting list must include the quantity of each component, the thickness, width, and length of the stock, the exact cut of each component, and the type of joint for each component.

### 3.2.3 veloping a Plan of Procedure

Develop a plan of procedure before making a piece of cabinetwork. This involves writing down all the steps of construction.

Though the complexity of the work may determine the order of the steps to complete a job, in most cases, use the following order:

1. Make a layout rod from the sketch or drawing. Many Builders or cabinetmakers bypass this step due to their experience in cabinetry.
2. Make a cutting list, using the measurements obtained from the layout rod and drawings.
3. Select the right type of stock for the project, and then cut the stock to rough lengths. Rough length is 2 or 3 inches longer than what is actually required. Cutting to rough lengths makes handling the stock easier and facilitates machining.
4. Face one side of the stock. Facing produces a straight surface and eliminates any cup, bow, or twist.
5. Plane the stock to thickness. This is the first step in bringing the stock to size. Make sure all parts are planed at the final setting of the planer to ensure equal thicknesses.
6. Joint one straight edge on each piece. Hold this straight edge against the fence of the table saw for ripping to width.
7. Rip the stock to the required width. Use the correct saw blade for the desired smoothness of the edge. Rip all pieces of the same width without changing the setting of the rip fence.
8. Cut the stock to the overall length. This is the last step in cutting the pieces to their overall finished size. Use a stop block to cut equal lengths.
9. Make rabbets, dadoes, mortises, tenons, and bore holes. Perform other machining as necessary. Set up machinery and make all similar cuts without changing the setup.

10. Sand the inside faces before assembling. Once you assemble the inside of a cabinet, it is difficult to sand. These surfaces must be smoothed before assembling.

11. Assemble the parts. When possible, assemble the parts using only clamps (no glue or fasteners) to check the quality of the fit. Then assemble the piece permanently as required. After assembly, wipe off any excess glue that may make finishing difficult.

12. Prepare exterior surfaces for finishing by sanding if the exterior surfaces were not sanded before assembly. Handle the pieces carefully to avoid marring the finished surfaces.

13. Apply the finish. The finish may include filling, staining, and applying clear or pigmented coatings.

14. Install the necessary hardware. Hardware can be installed before finishing, and then removed and replaced after finishing. If there is no danger of marring the finish, the hardware is installed after finishing. The finish is not usually applied to the hardware.

## 3.3.0 Casework Construction

Casework is defined as the boxlike components of cabinetwork, normally rectangular. Casework includes bookcases, chests, desks, display cases, and kitchen cabinets. Casework consists of a skeleton frame, face frame, two ends, legs, and the bottom, back, and top. Casework may contain shelves for storage, as shown in *Figure 5-5*.

**Figure 5-5 – Case construction with open storage.**

Casework may contain drawers for storage, and may have doors or covers fitted to enclose the storage space, as shown in *Figure 5-6*.

**Figure 5-6 – Case construction with closed storage.**

### 3.3.1 Skeleton Frames

The skeleton frame fits in the interior of the case. It consists of stiles (vertical members) and rails (horizontal members) only. Panels fitted into the frame are called dust panels. The skeleton frame serves a number of purposes:

- It provides a means of fastening the case top to the case and of holding the ends together at the top.
- It fastens and holds the ends together at the bottom.
- It separates and supports the drawers.
- It is used vertically as divisions when solid partitions are not required.

Assemble skeleton frames before installing them in the case. Dowels, biscuit joints, or mortise and tenon joints are recommended to make a skeleton frame.

#### 3.3.1.1 Ends

The case ends are made of solid edge glued lumber or plywood. They may also be paneled frames with stiles and rails and plywood or hardboard panels. Paneled ends are made similar to paneled doors, using either doweled or mortise and tenon joints.

The back edge is usually rabbeted to receive the cabinet back. If the case will be fitted to the wall, the rabbet is cut deep to recess the back and allow the projecting material to be scribed to the wall.

The front edge is joined to the face frame with a butt, rabbeted, or mitered joint. If you use a butt joint, make the front stile of the case end narrower than the back stile because of the thickness of the face frame.

Case ends may also be dadoed to receive the top, bottom, fixed shelves, skeleton frame, and dust panels of the case.

#### 3.3.1.2 Legs

Sometimes the stiles of the case ends extend below the bottom and act as legs. The front stiles of the ends also act as a stile for the front frame. In this type of construction, it is usual for the skeleton frame to be notched around the leg. It then extends to the front and becomes the face frame and dividing rails for the drawers.

#### 3.3.1.3 Partitions and Sleepers

Partitions are vertical members dividing the interior of the case into sections. They tie the top and the bottom of the case together and are usually dadoed into the top and bottom. The skeleton frame, dust panels, and shelves are cut in between the partitions and are usually dadoed into the partitions. Partitions are also known as divisions or standards.

Sleepers extend from the bottom of the case to the floor and are located directly under the partitions. They provide support of the case to the floor and keep the bottom from sagging.

#### 3.3.1.4 Shelves

Shelves must be strong enough to support the weight placed on them. They must also be wide enough and correctly spaced for their intended purpose. Shelves may be made of solid wood, plywood, particle board, or glass.

Bookcase shelves should be from 8 to 10 inches wide and spaced 10 to 14 inches apart. The length of a 3/4 inch thick shelf without intermediate supports should be no more than 36 to 42 inches. Supports should be spaced close enough to keep shelves from sagging under the weight placed on them.

One way of increasing the strength of a shelf is by installing strongbacks. A strongback is a strip of wood screwed on the edge to the underside of the shelf. It is placed either on or near the front or back edge of the shelf or both edges of the shelf.

Fixed shelves are usually dadoed in or supported on wood cleats, as shown in *Figure 5-7*. A cleat is a small strip of wood screwed to the inside of the case to support the shelf. A through dado or dovetail dado may be used to support a shelf. A better method is to use a blind dado to conceal the joint.

**Figure 5-7 – Fixed shelf construction.**

Adjustable shelves may be supported with metal shelf standards and clips that are either surface mounted or set flush in grooves. A pair of notched and numbered standards supports the shelves at both sides of the case. They are fastened 1 to 2 inches in from the back and front edges. When they are installed, the same number appears right side up at the bottom of all four standards. The clips are then inserted in the correct notch so the shelf lies flat.

Another method of supporting adjustable shelving is by inserting wood dowel pins or commercial shelf pins into four holes at each shelf location. Two vertical rows of equally spaced, 1/4 inch holes are drilled on either side of the case about 1 to 2 inches in from the front and back edges. The holes are spaced approximately 2 inches apart for ordinary work. The holes should be drilled deep enough so the pins will not fall out when the shelf is placed on them.

Adjustable shelves are sometimes installed by using ratchet strips. Ratchet strips are strips of wood with notches cut at equal intervals on one edge. These strips are fastened to the front and back edges of the case on the inside. A ratchet cleat is cut to length with ends matching the notches to fit in between the ratchet strips. The ratchet cleat may be moved to any notch to support the shelf.

Another method of making ratchet strips is by boring a series of equally spaced, 3/4 inch holes along strips of 1” x 4” lumber. Cut the strips in half along the center lines of the holes. Cut ratchet cleats with rounded ends to match the ratchet strips.

#### 3.3.1.5 1.5 Bottoms and Toeboards

The bottom of a case is usually made of solid lumber, particleboard, or plywood, unless a dust panel is used when a drawer is supported by the bottom. Case bottoms are sometimes raised above the bottom rail of the face frame to act as a stop for doors. Another design eliminates the bottom rail of the face frame. The door or drawer then covers all of the bottom edge, which also acts as a stop.

Install a toeboard to cover the space between the bottom and the floor and to provide toe clearance. Set the toeboard back from the face of the case 2 1/2 to 3 inches.

### 3.3.2 Cabinet Facing

Apply finished facing strips to the front of the cabinet frame after completing the frame construction and shelving. These strips are sometimes assembled into a framework called a faceplate or face frame by commercial sources before they are attached to the basic cabinet structure. The vertical members of the facing are called stiles, and the horizontal members are known as rails. As previously mentioned for built-in-place cabinets, you cut each piece and install it separately. The size of each piece is laid out by positioning the facing stock on the cabinet and marking it. Then the finished cuts are made. A cut piece can be used to lay out duplicate pieces.

Cabinet stiles are generally attached first, and then the rails, as shown in *Figure 5-8*. Sometimes a Builder will attach a plumb end stile first, and then attach rails to determine the position of the next stile. Use finishing nails and glue to install facing. When you nail hardwoods, drill nail holes where you think splitting might occur.

### 3.3.3 Face Frames

Face frames are preassembled units, usually joined with dowels, biscuits, or mortise and tenon joints, into which drawers and doors are fitted, as shown in *Figure 5-8*. Face frames are joined to cabinet ends with a butt, rabbeted, or mitered joint. The face frame must fit the case accurately, so doors and drawers may be installed easily at a later stage.

**Figure 5-8 – Placing facing on a cabinet.**

If flush doors will be hung on the face frame, the frame is made about 1/16 inch thicker than the door to be hung. This prevents the doors from binding against the door stops. If the end of the case will be fitted against a wall, approximately 1/2 inch is added to the width of the stile on that end for scribing.

Doorstops are installed on the back side of the face all around the door openings if flush doors will be hung. Doorstops project about 5/16 inch inside the opening and usually are made of thinner material than the face frame. They are applied with screws and glue because they take much abuse and a strong joint is needed.

### 3.3.4 Case Tops

The case top is installed according to its location. If it is above the line of vision, the top is cut in between the case ends, so the ends of the top are not visible. The top may also be lowered between the case ends. This provides clearance between the ceiling and the top of the case and also acts as a stop for the top ends of doors. If the top is below the line of vision, it is placed above the case ends.

In most cases, tops are fastened to the cabinet with screws driven up through the top of the skeleton frame.

### 3.3.5 ounter Tops

The standard kitchen counter top is 36 inches high, 25 inches deep, and 1 1/2 inches thick. This provides enough room for an average size sink and ample working space on the surface. The counter top is held in place by driving screws up through the top frame of the base unit.

The counter top usually has a 3/4 inch overhang made of plywood or particle board. It is doubled up by fastening a 2 1/2 inch wide strip flush with the edges and ends. This gives the appearance of a heavier counter top.

If a backsplash is used, it is usually 4 inches high. It has a 1/4 inch projection on the side that goes against the wall. This projection allows the installer to scribe the counter top to uneven wall surfaces. Prefabricated counter tops may be purchased and cut to any desired length. Special fasteners hold the lengths together.

## 3.4.0 Designing Cabinets

The Builder should know the proper procedures and correct dimensions on how to build and install cabinets. There are two basic kinds of cabinets, the base unit and the wall unit. The base unit rests on the floor; the wall unit hangs on the wall.

The distance between the wall and base units is usually 16 to 18 inches. The distance is enough accommodate most items that are placed on counter tops, like coffee pots, toasters, blenders, and mixers. The top shelf in the wall unit should not be over 6 feet from the floor if it is to be within easy reach.

### 3.4.1 Base Unit

The height of the base unit must be 36 inches to the surface of the countertop. The width must allow for the 3/4 inch overhang of the counter top. A standard base unit is usually 34 1/2 inches high by 24 1/4 inches deep. Toe space is provided beneath the base unit. The back edges of the end pieces project 1/4 inch beyond the cabinet back to allow for scribing.

Usually the base unit is constructed with drawers just below the counter top. The drawer opening height is 5 1/2 inches. Some base units contain all drawers or all doors as, shown in *Figure 5-9*.

**Figure 5-9 – Typical base units.**

The base unit has a face frame and skeleton frame. A number of joints can be used to fasten the stiles and rails together, as shown in *Figure 5-10*.

**Figure 5-10 – Types of joints.**

The stiles are always mortised and the rails are always tenoned, as shown in *Figure 5-11*.

**Figure 5-11 – Types of mortise and tenon joints.**

### 3.4.2 Wall Unit

A typical full size wall unit is usually 12 inches deep and 30 inches high, as shown in *Figure 5-12*. A wall unit above a range is 18 inches high. Above a sink, it is 22 inches high, while over a refrigerator, it is only 15 inches high.

The number and spacing of shelves depend on the purpose of the cabinet. Shelves may be fixed or adjustable. Shelves are usually spaced from 3 to 12 inches according to the customer's wishes.

The wall unit, like the base unit, has a face frame on which to fit and hang doors. These face frames are usually made of 1" x 2" solid lumber. The actual size is 3/4 inch by 1 1/2 inch.

**Figure 5-12 – Typical wall units.**

Make an allowance on the back edges of the end pieces for scribing. Include mounting strips in the wall units, since screws are driven through these strips to hold the cabinet on the wall.

## 3.5.1 Constructing a Base Unit

Earlier we covered the steps on how to plan a procedure before constructing a piece of cabinetry. The following steps are a guide to constructing the base unit of a cabinet.

1. Review your drawings and specifications.
2. Select the lumber or plywood to be used, and then develop a cutting list from the layout rod and/or drawing.
3. Determine the best joints to use on the face frame and on the skeleton frame stiles and rails.
4. Cut out and assemble the face frame by gluing and clamping. After the glue has set, remove the clamps and sand both faces. Set the frame aside.

5. For the base unit, cut out the skeleton frame similar to Steps 3 and 4. Then cut a groove (dado) 1/4 inch wide by 1/2 inch deep on one edge of the four skeleton frame stiles.
6. Use a stub mortise and tenon joint 1/4 inch thick by 1/2 inch long on all the skeleton frame rails.
7. Lay out the location of the rails on the stiles and assemble the skeleton frames by clamping and gluing. When they are dry, remove the clamps and set them aside until needed.
8. Rabbet the back edges of the ends 1/2 inch by 1/2 inch. This rabbet will allow the end panels to project out beyond the plywood back for scribing the cabinet to the wall. Make sure the rabbet is cut from the inside face of the plywood, so the good face will show on the outside of the cabinet.
9. Lay out and cut the toe spaces on each end panel. The top of the cut is flush with the bottom rail of the face frame. The bottom of the cut is flush with the toeboard.
10. Cut out the toe spaces so that you have a right hand and left hand end panel. Cut from the inside face to avoid splintering the face side.
11. Dado the inside of the end panels 3/16 inch deep and 3/4 inch wide for the bottom, shelf, and skeleton frame. Make a blind dado for the cabinet shelf.
12. Assemble the end panels, bottom, shelf, and skeleton frames with glue and clamps, finish nails, or screws. Make sure all edges line up.
13. Install the toeboard between the end panels by fastening with glue and finish nails through the end panels and down through the case bottom. Remove any bow by keeping the toeboard the same distance from the front edge of the bottom all along its length.
14. The back helps hold the case rigid. The case must be absolutely square before fastening the back. Use the Pythagorean Theorem to find the diagonals. This will square up the frame.
15. Fasten the back to the end panels, bottom, shelf, and skeleton frame. Straighten any bow when fastening.
16. Fasten the face frame to the front of the case. Keep the top edge of the bottom rails flush with the top surface of the case bottom, and the outside stiles flush with the face of the case ends.

### 3.6.1 Constructing a Wall Unit

Almost all of the steps in constructing the base unit apply to constructing the wall unit. There are certain steps that are not needed, since they are not included in a wall unit. The steps that are not needed for a wall unit are these:

- constructing toeboards
- constructing openings for drawers
- installing a counter top

## 3.7.0 Other Construction Methods

Cabinets are constructed in a number of different ways other than those described in this chapter. Construction depends on the quality desired, the time required, the materials used, and the experience of the craftsmen.

Cabinets may be made of hardwood, plywood, solid hardwood, or a combination of softwood, plywood, and solid softwood lumber. Often particle board is used, sometimes with a vinyl coating on one side to eliminate finishing the inside of the cabinet.

In many cases, the end panels are not dadoed to receive the interior pieces. Skeleton frames can be eliminated. The end panels are then held together at the top by the back and face frames. Sometimes the back is not installed and a 1” x 3” or 1” x 4” strip is used between the ends at the top, flush with the back edge.

Members of the face frame in lesser quality work are butted against each other. They are fastened together with power-driven corrugated fasteners on the inside of the frame. In some cases, the bottom rail of the frame is eliminated. The front end of the bottom acts as the bottom rail of the face frame.

## 3.8.0 Installing Cabinets

The cabinetmaker often is required to install kitchen and bathroom cabinets. Cabinets must be installed in a straight, level, and plumb line. This requires skill because floors and walls may not be level or plumb, especially in older buildings.

When cabinets are installed, many installers prefer to mount the wall units first, so work does not have to be done over base units. Let’s cover the installation of a kitchen cabinet, as shown in *Figure 5-13*.

**Figure 5-13 – Kitchen cabinet details.**

### 3.8.1 Wall Units

There are several steps to prepare for installing wall units.

1. Locate the bottom of the wall unit (normally 52 inches), and then measure up 52 inches from the lowest point of the floor. This usually leaves a 16 inch space between the counter top of the base unit and the bottom of the wall unit.
2. Use a level and straightedge to draw a level line from the mark across the wall. The bottoms of the wall units are installed to match this line.
3. Locate the wall studs. When a stud is found, mark the location with a pencil, and then measure 16 inches in both directions from the first mark to locate the next studs. Drive a finish nail to test for solid wood. If studs are not found at 16 inch intervals, then tap the wall with a hammer to locate each stud or use a stud finder.
4. At each stud, use a level to draw a plumb line down below the line for the bottom of the wall cabinets. Projecting below the wall units makes it easier to locate the studs when installing both wall and base units.
5. Mount a temporary ledger board (1” x 2”) to the wall along the bottom of the cabinet line. This action will help level and support the wall unit.

The following procedures are only a guide to installing the wall units:

1. Place the unit on the ledger board or a stand that holds it near the line of installation. If the unit is not level, use wood shims to bring the unit to level.
2. Test the front edge of the unit with a level for plumb. If the unit is not plumb, shim it between the wall and its back edge with wood shims until it is plumb. If the unit is not plumb to the wall, you need to cut the back edge of the cabinet.
3. Scribe the back edge by riding a set of dividers against the wall and marking the back edge of both end panels to the contour of the wall.
4. Take the cabinet down off the ledger board, and then cut the back edges with either a handsaw or a plane to the scribed line. Use a plane if you have to take off less than 1/8 of an inch. Use a handsaw rather than the saber or circular saw, because these saws cut on the upstroke and can splinter out the face side. The handsaw cuts on the downstroke which will not splinter the face.
5. Place the cabinet back into position, and then fasten the cabinet into place with wood screws. Screws should be of sufficient length to hold the cabinet securely.

Adjacent cabinets are installed in the same manner. Scribe the back edges of these cabinets so their face frames are flush with the cabinet previously installed. Fasten adjacent cabinets to each other by means of screws or bolts through the ends or through the stiles of the face frame.

### 3.8.2 Base Units

Before base cabinets are installed, draw a level line 16 inches plus the thickness of the countertop below the line previously drawn for the location of the wall units. This will be the location of the top of the base units without the counter top. Check your plans and specifications for the proper height on the counter top because it may vary.

1. Locate and mark the location of all wall studs where the cabinets are to be hung. Find and mark the highest point in the floor. This will ensure the base cabinet is

level on uneven floor surfaces. Shims should be used to maintain the cabinet at its designated leveled height.

2. Start the installation of a base cabinet with a corner or end unit. After all base cabinets are in position, fasten the cabinets together. To get maximum holding power from screws, place one hole close to the top and one close to the bottom.
3. Starting at the highest point in the floor, level the leading edges of the cabinets. After leveling all the leading edges, fasten them to the wall at the studs to obtain maximum holding power.

Here are some helpful hints for the general construction of cabinets:

- Fasten cabinet parts together with screws or nails. Set them below the surface, and then fill the holes with putty. Use glue at all joints. Use clamps to produce better fitting glued joints.
- A better quality cabinet is rabbeted where the top, bottom, back, and side pieces come together. Butt joints are also used. If panels are less than 3/4 inch thick, use a reinforcing block with the butt joint. Dado fixed shelves into the sides.
- Screws should go through the hanging strips and into the stud framing. Never use nails. Toggle bolts are required when studs are inaccessible. Join units by first clamping them together and then, while aligned, install bolts and T nuts.

### 3.8.3 ounter Tops

After the base units are fastened in position, the counter top is laid on top of the units and against the wall. Here are some helpful hints for installing counter tops.

1. Move the counter top, if necessary, so that it overhangs the same amount over the face frame of the base cabinets.
2. Adjust dividers for the difference between the amount of overhang and the desired amount of overhang. Scribe this amount on the backsplash if it has a scribing strip.
3. Cut the backsplash to the scribed line and fit it to the wall.
4. Fasten the counter top to the base cabinets with screws up through the top skeleton frame of the base units. Use a stop on the drill bit so you do not drill through the counter top.

In some cases, backsplashes are not built with scribing strips. To fit the backsplash to the wall, hold the counter top in the desired position. Press the backsplash against the wall at intervals and mark its outside face on the countertop. Remove the countertop and fasten the backsplash to the counter top on the marked lines. Fasten the counter top and backsplash in position.

Another method is to leave off the laminate on the face of the backsplash. Fasten the counter top in position. Hold the backsplash down tight on the counter top and nail it to the wall through its face. Then laminate the face of the backsplash on the job after it has been fastened in position. The disadvantage of this method is that it is difficult to remove the backsplash if the counter top has to be replaced.

## 3.9.0 Drawers

Builders use many methods of building drawers. The three most common methods are the multiple dovetail, lock shouldered, and square shouldered methods, as shown in *Figure 5-14*.

**Figure 5-14 – Three common types of joints used in drawer construction.**

Several types of drawer guides are available. The three most commonly used are the side guide, corner guide, and center guide, as shown in *Figure 5-15*.

**Figure 5-15 – Types of drawer guides.**

**Figure 5-16 – Types of drawer faces.**

The two general types of drawer faces are the lip and flush faces, as shown in *Figure 5-16.* A flush drawer must be carefully fitted. A lip drawer must have a rabbet along the top and sides of the front. The lip style overlaps the opening and is much easier to construct.

Drawer dimensions are usually given as width, height, and depth, in that order. The width of the drawer is the distance across the drawer opening. The height is the vertical distance of the opening. The depth is the distance from the front to the back.

Drawer fronts are usually made of 3/4 inch plywood or solid wood. The design must be in keeping with the cabinet. Sides and backs are generally 1/2 inch thick solid wood. Sides are made thicker if they will be grooved for certain types of drawer guides. The drawer bottom is usually made of 1/4 inch plywood or hardboard. Smaller drawers may have 1/8 inch hardboard bottoms.

## 3.10.1 Cabinet Doors

The four types of doors commonly used on cabinets are the flush (inset), lipped, overlay, and sliding doors.

- A flush door, like the flush drawer, is the most difficult to construct. For a finished look, this type of door must be fitted in the cabinet opening within 1/16 inch clearance around all four edges.
- A lipped door is simpler to install than a flush door since the lip, or overlap, feature allows you a certain amount of adjustment and greater tolerances. The lip is formed by cutting a rabbet along the edge.
- Overlay doors are designed to cover the edges of the face frame.
- Several types of sliding doors are used on cabinets. One type of sliding door is rabbeted to fit into grooves at the top and bottom of the cabinet. The top groove is always made to allow the door to be removed by lifting it up and pulling the bottom out.

### 3.10.1 Door Construction

Doors are constructed as solid, flexible, folding, or paneled doors.

- Solid doors are made of plywood, hardboard, particle board, or glued up solid lumber. Designs are often grooved into the door with a router, or molding may be applied to give the door a more attractive appearance.
- Flexible doors are made of thin strips glued together on a canvas back or held together with special edge joints. They are used on roll top desks and other cabinets when the door must slide around a comer.
- Paneled doors have an exterior framework of solid wood and a center containing one or more panels. The panels may be solid wood, plywood, hardboard, metal, plastic, glass, or some other material, and come in many different designs. The exterior framework can be shaped in a number of ways also.

### 3.10.2 Door Installation

Cabinet doors can be installed as overlay, lipped, flush, and sliding.

- Overlay doors cover the opening, usually by 3/8 inch on all sides, and swing on overlay hinges.
- Lipped doors are rabbeted over the opening and swing on offset hinges.
- Flush doors fit inside the opening and swing on either surface hinges or butt hinges.
- Sliding doors roll on tracks of metal or plastic.

## 3.11.1 Hinges

Hinges are made in many styles and shapes. If the kind of hinge is not specified, select a design that blends well with the cabinet being constructed. Some types of hinges are the surface, butt, offset, semi-concealed, pivot, piano hinge, and European style.

- The surface hinge mounts on the exterior surface of the door and frame. It is made straight for flush doors or offset for lipped doors. This type of hinge is used when it is desirable to show the hardware, such as early American furniture.

- The butt hinge is used on flush doors when little hardware must show. When it is installed, only the pin of the butt hinge shows when the door is closed. These hinges require a little extra time to install. It is recommended that you recess or mortise the hinge into the wood.
- The offset hinge is used on lipped doors that are made from plywood. The offset hinge comes in various sizes to match the thickness of the plywood, and must be mortised, rather than surface-mounted.
- The semi-concealed hinge is designed for lipped and overlapping doors. This hinge has one leaf exposed on the face of the cabinet and the offset leaf is mortised into the door. Before the door is rabbeted, check the hinge to ensure that you rabbet the door to the proper depth.
- The pivot hinge is used on overlay doors. It is fastened to the top and bottom of the door and to the inside of the case. It is used frequently when there is no face frame on the case. The doors completely cover the face of the case.
- The continuous or piano hinge is a one-piece hinge that usually extends the whole length of the door. It is installed like a butt hinge, and only the hinge pin is exposed. This type of hinge is used when the door is subjected to heavy use.
- The European hinge can be used on overlay or flush doors and is an excellent hinge used for frameless cabinets. This hinge has two leafs—the hinge cup leaf and the adjustable leaf. The hinge cup fits into a 1 3/8-inch hole (use a forstner bit to drill hole) on the cabinet door. The other leaf is screwed to the side panel of the cabinet. This leaf has an oval adjustment screw that allows the hinge to adjust up and down while the center mechanism adjustment has two screws that adjust the hinge left and right.

The number and size of hinges depend on the dimensions of the door. There are two rules to follow:

1. On any door that is longer than 2 feet, install three hinges.
2. The total length of the hinges should equal at least one sixth of the length of the hinged edge.

For example, if the door is 24 inches high, use two 2-inch hinges; if the door is 34 inches, use three 2-inch hinges. When only two hinges are required, they are usually placed one quarter of the way from the top and bottom of the door. When three hinges are required, install the first hinge in the center and the other two hinges 4 to 5 inches from the top and bottom.

### 3.12.1 Catches

Some hinges are self closing; these eliminate the need for installing catches to hold the door closed. Others require catches. There are many kinds of catches available for holding doors.

Catches should be placed in the most out of the way position possible. For instance, they are placed on the underside of shelves instead of on top.

- Magnetic catches are used widely. They are available in single or double magnets of varying holding power. An adjustable magnet is attached to the inside of the case and a metal plate to the door. Other types of catches are the roller type and the friction type.

- Elbow type catches are used to hold one door of a double set. It must be released by reaching in back of the door. These are used when one of the doors is locked against the other.
- Bullet catches are spring loaded and fit into the edge of the door. When the door is closed, the catch fits into a recessed plate mounted on the frame.

## 3.13.0 Laminating Counter Tops

In cabinetwork, the countertops are usually covered with a 1/16 inch layer of high pressure plastic laminate. Although this material is very hard, it does not possess great strength and is serviceable only when it is bonded to plywood, particle board, or wafer wood. This base, or core material, must be smooth and is usually 3/4 inch thick.

Plastic laminate is a very tough material. It is widely used for surfacing counter tops, kitchen cabinets, and many other kinds of cabinetwork. It can be scorched by an open flame but resists heat, alcohol, acids, and stains. Another advantage of plastic laminate is that no finishing is required. It also cleans easily with mild detergent.

Laminates are known by such trade names as *Formica, Micarta, Texolite, Wilson Art, Melamite,* and many others. They are manufactured in many colors and designs including many wood grain patterns. Surfaces are available in gloss, satin, textured, and other finishes. The distributor supplies samples or chips of the different colors and finishes to help the customer decide which to use.

### 3.13.1 Thicknesses

Generally two thicknesses of laminates are used: thick and thin.

Thick laminate is about 1/16 inch thick. It is used on horizontal surfaces such as counter tops, tables, dressers, and desk tops.

Thin laminate is about 1/32 inch thick. It is used on vertical surfaces such as the sides and front of kitchen cabinets. This is because vertical surfaces take less wear than horizontal surfaces. Thin laminate makes a more pleasing appearance because of the thin edge line it presents when trimmed. It is also less expensive than the thick laminate.

A thinner laminate, called backer laminate, is also available. It is used to cover the inside of doors and the underside of tabletops to give a balanced construction to the core.

### 3.13.2 Width and Lengths

Plastic laminate sheets come in widths of 24, 30, 36, 48, and 60 inches and lengths of 5, 6, 8, 10, and 12 feet. Sheets are usually 1 inch wider and longer than the size indicated.

Most distributors cut sheets in half through their width or length. This action increases the range of sizes. Since the material is relatively expensive, it is wise to carefully plan and order the most economical sizes.

### 3.13.3 Inspecting the Surface

Before a counter top is laminated, make sure all surfaces are flush. There should be no indentations where the pilot of the router bit will ride. Check for protruding nail heads and points. Plane or sand surfaces that are not flush. Fill in any holes and sand them smooth. Drive nail heads flush, fill, and sand.

### 3.13.4 Cutting Laminate to Rough Size

There are a number of ways to cut laminate. Whatever method you use, cut the pieces 1/4 to 1/2 inch wider and longer than the surface to be covered. Laminate must be handled carefully because it is very brittle. It may crack if dropped or handled roughly.

One method of cutting laminate is to use a straightedge and a router with a flush trimming bit. This method is used frequently by installers on the job and in the shop. It is easier to run the cutting tool across a larger sheet than to move a large sheet across the cutting tool. Also, the router bit leaves a smooth edge.

The table saw can produce a smooth edge, cut with a 60 tooth, triple chip carbide blade. Laminate may also be cut with a portable circular saw, saber saw, or band saw. These tools will not give a clean, chip free edge, however.

### 3.13.5 Working with Laminates

Plastic laminates can be cut to rough size with a table saw, portable saw, or saber saw. Use a fine tooth blade, and support the material close to the cut. If no electrical power is available, you can use a finish handsaw or a hacksaw. When you cut laminates with a saw, place masking tape over the cutting area to help prevent chipping the laminate. Make cut markings on the masking tape.

Measure and cut a piece of laminate to the desired size. Allow at least 1/4 inch extra to project past the edge of the counter top surface. Next, mix and apply the contact bond cement to the underside of the laminate and to the top side of the counter top surface. Be sure to follow the manufacturer’s recommended directions for application.

### 3.13.6 Adhering Laminates

Allow the contact bond cement to set or dry. To check for bonding, press a piece of waxed brown paper on the cement coated surface. When no adhesive residue shows, it is ready to be bonded. Be sure to lay a full sheet of waxed brown paper across the counter top. This allows you to adjust the laminate into the desired position without permanent bonding. Now you can gradually slide the paper out from under the laminate, and the laminate becomes bonded to the counter top surface.

Be sure to roll the laminate flat by hand, removing any air bubbles and getting a good, firm bond. After the laminate is sealed to the counter top surface, trim the edges by using either a router with a special guide or a small, block plane. If you want to bevel the countertop edge, use a mill file.

## 3.14.0 Adhesives

Seabees use many different types of adhesives in various phases of their construction projects. Glues, which have a plastic base, and mastics, which have an asphalt, rubber, or resin base, are the two major categories of adhesives.

The methods of applying adhesives, their drying times, and their bonding characteristics vary. Some adhesives are more resistant to moisture and to hot and cold temperatures than others.

**⚠ CAUTION ⚠**

Some adhesives are highly flammable; they should be used only in a well-ventilated work area. Others are highly irritating to the skin and eyes. Always follow manufacturer’s instructions when using adhesives.

### 3.14.1 Glues

The primary function of glue is to hold together joints in millwork and cabinetwork. Most modern glues have a plastic base. Glues are sold either as a powder to which water must be added or in liquid form. Many types of glue are available under brand names. Brief descriptions of some of the more popular types of glues are listed below.

- Polyvinyl resin, or white glue, is a liquid that comes in ready to use plastic containers. It does a good job of bonding wood together and it sets up (dries) quickly after being applied. Because white glue is not waterproof, it should not be used on work that will be subject to constant moisture or high humidity.
- Aliphatic resin, or yellow carpenter’s glue, is a liquid that comes in ready to use plastic containers. Yellow glue is somewhat stronger than white glue and is more resistant to moisture, lacquers, and solvents.
- Urea resin is a plastic-based glue sold in powder form. The required amount is mixed with water when the glue is needed. Urea resin makes an excellent bond for wood and has fair water resistance.
- Phenolic resin glue is highly resistant to temperature extremes and water. It is often used for bonding the veneer layers of exterior grade plywood.
- Resorcinol glue has excellent water resistance and temperature resistance, and it makes a very strong bond. Resorcinol resin is often used for bonding the wood layers of laminated timbers.
- Contact cement is used to bond plastic laminates to wood surfaces. This glue has a neoprene rubber base. Because contact cement bonds very rapidly, it is useful for joining parts that cannot be clamped together.

### 3.14.2 Mastics

Mastics are widely used throughout the construction industry. The asphalt, rubber, or resin base of mastics gives them a thicker consistency. Mastics are sold in cans, tubes, or canisters that fit into hand-operated or air-operated caulking guns.

These adhesives can be used to bond materials directly to masonry or concrete walls. If furring strips are required on a wavy concrete wall, the strips can be applied with mastic, rather than by the more difficult procedure of driving in concrete nails. You can also fasten insulation materials to masonry and concrete walls with a mastic adhesive. Mastics can be used to bond drywall (gypsum board) directly to wall studs. They can also be used to bond gypsum board to furring strips or directly to concrete or masonry walls. Because you do not use nails, there are no nail indentations to fill.

By using mastic adhesives, you can apply paneling with very few or no nails at all. Wall panels can be bonded to studs, furring strips, or directly against concrete or masonry walls. Mastic adhesives can be used with nails or staples to fasten plywood panels to floor joists. The mastic adhesive helps eliminate squeaks, bounce, and nail popping. It also increases the stiffness and strength of the floor unit.

## Summary

In this chapter you learned how to set up a Builder shop for your crew to maximize their production, and discovered the different types of Millworking available for use in Builder projects. You also learned how to take an idea from the initial concept, through sketches and drawings, to the completion of a cabinetmaking project.

## Review Questions (Select the Correct Response)

1. **(True or False)** When taking over an established shop, you should NOT make a survey of shop equipment.

   A. True
   B. False

2. **(True or False)** The function of a shop has an important bearing on the space and equipment needed.

   A. True
   B. False

3. You should refer to the Occupational Safety and Health Standards for the Construction Industry, Code of Federal Regulations (29 CFR Part 1910) for what type of information?

   A. Storage of fuels
   B. Shop setup
   C. Shop floor plans
   D. Storage of tools, material, and equipment

4. **(True or False)** You should ensure that your storage facilities are arranged to provide as much working space as possible.

   A. True
   B. False

5. What type of flooring material is unfortunately used most often by industrial shops?

   A. Wood
   B. Ceramic
   C. Concrete
   D. Tile

6. What type of floor material is preferred for shops?

   A. Tile
   B. Ceramic
   C. Concrete
   D. Wood

7. As a general rule, windows should be installed at what minimum height in inches above the floor?

   A. 48
   B. 50
   C. 54
   D. 60

8. What number of feet above the floor is considered the minimum height for the ceiling of a Shop?

   A. 10
   B. 11
   C. 12
   D. 13

9. Shaped items of wood that are usually made from well seasoned kiln-dried lumber (with 4 to 9 percent moisture content) are known by what term?

   A. Millwork
   B. Kilnwork
   C. Dry formwork
   D. Framework

10. Which of the following units is NOT a form of setup millwork?

   A. Prehung doors
   B. Molding
   C. Doorframes
   D. Cabinets

11. Which of the following units are NOT a form of knocked down millwork?

   A. Stairs
   B. Window frames
   C. Doorframes
   D. Cabinets

12. **(True or False)** The Architectural Graphics Standard provides complete information on drawings.

   A. True
   B. False

13. **(True or False)** When developing working drawings, you do NOT have to follow drafting standards closely.

   A. True
   B. False

14. Which of the following units are NOT an example of casework construction?

   A. Desks
   B. Chests
   C. Bookcases
   D. Window frames

15. Which of the following techniques is most often used to strengthen a shelf?

A. Installing strongbacks
B. Adding additional nails
C. Adding thick wood blocks
D. Installing additional face frames

16. The toeboard is usually set back how many inches from the face of a case?

A. 1 1/2 to 2
B. 2 1/2 to 3
C. 3 1/2 to 4
D. 4 1/2 to 5

17. What are the dimensions in inches of a standard kitchen counter top, in height, depth, and thickness?

A. 36 by 25 by 1 1/2
B. 40 by 26 by 1 1/2
C. 42 by 24 by 2 1/2
D. 44 by 36 by 2 1/2

18. Which of the following joints should NOT be used to fasten together the stiles and rails in a cabinet?

A. Dado
B. Rabbet
C. Spline miter
D. Glue

19. After marking the location of a stud in a wall unit, how many inches should you measure in both directions to locate the next studs?

A. 12
B. 14
C. 16
D. 18

20. In addition to the lock shouldered and the square shouldered methods of building drawers, you can also use what other method?

A. Clamping
B. Multiple dovetail
C. Multiple miter
D. Singular dovetail

21. **(True or False)** Drawer dimensions are usually given as width, height, and depth, in that order.

A. True
B. False

22. What type of cabinet door is the most difficult to construct?

  A. Overlay
  B. Flush
  C. Lipped
  D. Sliding

23. If a cabinet door is 36 inches in length, you should attach a total of how many 2-inch hinges?

  A. Two
  B. Three
  C. Four
  D. Five

24. Formica, Micarta, Texolite, Wilson Art, and Melamite are trade names for what type of material?

  A. Laminates
  B. Glues
  C. Bricks
  D. Tiles

25. **(True or False)** Polyvinyl resin (white glue), is stronger than aliphatic resin (yellow glue).

  A. True
  B. False

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Lewis, Gasper J., *Cabinetmaking, Patternmaking and Millwork*, Delmar publishers Inc., Albany, NY, 1981.

*Navy Occupational Safety and Health Program Manual*, OPNAVINST 5100.23, Office of the Chief of Naval Operations, Department of the Navy, Washington, DC, 1994.

*OSHA Standards for the Construction Industry*, 29 CFR, Part 1910, Commerce Clearing House, Inc., 4025 West Peterson Avenue, Chicago, IL, 1991.

*School Shop Development Manual*, Rockwell Manufacturing Company, Pittsburgh, PA, 1966.

Wagner, Willis H., *Modern Carpentry*, The Goodheart-Wilcox Company, Inc., South Holland, IL, 1992.

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(Optional) Correction

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(Optional) Your Name and Address

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

# Chapter 6

# Quality Control

## Topics



To hear audio, click on the box.

## Overview

In previous chapters we covered ways to plan, organize, read plans and specifications, estimate, schedule, manage, and execute construction projects. This chapter will cover how construction projects need to be carried out with quality in mind.

In the Seabee community, quality ranks right along with safety. The customer wants to see a quality project done safely and in a timely manner. Doing quality work for the customer brings job satisfaction to you and increases the chances of the customer returning for more work. Having satisfied customers also leads to getting new customers, which means job security.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Distinguish between Quality, Quality Assurance, and Quality Control, and identify means of establishing quality measures.
2. Identify the responsibilities of the inspector and items checked in inspecting various parts of buildings and other structures.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

To ensure quality workmanship, NAVFAC has developed the following quality management programs:

- Construction Contract Quality Management Program, NAVFAC P-445
- Facilities Support Contract Quality Management Program, MO-327
- Construction Quality Control (CQC) Program, COMSECOND/ COMTHIRDNCBINST 4355.1 (series)

These three programs all deal with quality, but they pertain to certain aspects of quality.

- The NAVFAC P-445 states how the contractor and the government will produce a quality project on time and in compliance with the terms of the contract.
- The MO-327 provides naval shore activity guidance on obtaining quality public works support services through quality assurance.
- The COMSECOND/COMTHIRDNCBINST 4355.1 prescribes the policy, the objectives, and the procedures to ensure that the required quality is achieved on construction projects assigned to NCF units.

Before we cover quality control, let's first define quality and distinguish the differences between quality control (QC) and quality assurance (QA). At times, the construction industry tends to get these terms confused.

- Quality is the state of being excellent and is achieved by acquiring and applying skills. The Navy recognizes quality as individual contribution and team effort in an organization working together to improve the process/system or product. Teamwork is essential.
- Quality assurance is concerned with the quality of the end product, not with the procedures used to get to that product. Surveillance and inspections are the methods used to review performance standards. The receiving officer in charge of construction (ROICC) usually oversees these methods. Surveillance and inspections are covered thoroughly in the NCF/Seabee Petty Officer 1 & C, NAVEDTRA 12543.
- Quality control reviews each step or procedure used in completing tasks on the way to the completed product. Quality control checks are normally performed daily. NMCBs, CBUs, and other construction units run the quality control program.

## A Word about Asbestos

Asbestos is no longer used in new construction in the United States, but when you perform rehab work on older buildings, you may come across old installations of products containing asbestos. Check if there has been a recent Industrial Hygienist (IH) survey, which identifies if there are asbestos products used in the construction. If there has not been an IH survey, especially if the building was constructed before the late 1970s, request one. If there is asbestos in the building materials, any work done in those areas will need to be contracted out to companies that specialize in asbestos removal.

Some of the materials that might have asbestos include these:

- Insulation
- Acoustical plaster
- Resilient flooring
- Built-up roofing
- Skylight frames

# 1.0.0 QUALITY CONTROL

Quality control is a management system of published and enforced standards which ensures that a construction project is completed with a specified minimum quality. A product that falls below minimum standards will not satisfy the customer or its intended purpose, and may require excessive maintenance costs. A product that exceeds the standards generally consumes more resources than planned, but it is better to exceed the standards than to fail to meet the standards.

Quality control is the responsibility of each member in the construction chain of command, who must all be familiar with personnel responsibilities to ensure a quality project. You must remember that plans and specifications are the construction standards and may vary from project to project.

A project which costs a life or serious injury is not a quality project. Safety and good housekeeping are very important elements in obtaining a finished product of acceptable quality.

## 1.1.0 Ensuring Quality

The crew leader must plan quality into and develop a QC plan for each project. This plan ensures that the quality of the construction meets the standards in the plans and specifications. The development and implementation of a QC plan can be broken down into the steps covered in this section.

### 1.1.1 Establish Quality Measures

The first step in ensuring quality is to establish the means of measuring QC progress. The crew leader must review the plans and specifications and identify the required quality criteria. For instance, the quality criteria for reinforcing steel would be the size, placement, anchoring, and distance lapped. Quality measures must be specific. For example, the specifications may require that rebar be at least 1 1/2 inches from inside of the forms and the rebar must be lapped 24 inches at splices.

QC measures must be listed in plain language on the Construction Activity Summary (CAS) sheet. These measures are then transferred to the PC plan. The crew leader, the QC rep, and the inspector (ROICC) should agree in advance on how the various tests are to be performed and exactly what the requirements are. For example, when laying block and the requirement is within 1/4 inch plumb within 10 feet, will this be measured with a string line, a level, or some other method? *Figures 6-1* and *6-2* are samples of project QC plans.

**Project QC Plan**

I. Project Name and Number
II. Project Location
III. Prime Contractor
Subcontractors (a)
(b)
IV. Project Scope
V. Type of Testing Required (soil, concrete, etc.)
VI. Type of Associated Risk (fire, fumes, noise, etc.)
VII. Special Training Requirements
VIII. Special License Required
IX. Engineering Controls (guard rails, welding curtains, etc.)
X. Testing Equipment Required (state how it is to be used)
XI. Personal Protective Equipment Required for Testing

Project Planner: ______________________________

Print name, rate and company/det

QC Chief: Approved/Disapproved ______________________________

Signature

Reason for disapproval ______________________________

**Figure 6-1 – Project QC plan cover sheet.**

## Quality Control Plan

| Project Number _ | | Project Title _ | | Date _ |
|---|---|---|---|---|
| **Activity Number** | **Activity Description** | **Quality Control Requirement** | **Specification Reference** | **Remarks / Results** |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Figure 6-2 – Quality Control plan.**

The second step in ensuring quality is the proper selection of construction methods that are essential to safe, quality construction. Construction methods must be determined very early in the planning stage of the project, as they impact on equipment, tools, and material, labor, training, and safety requirements. Construction methods selected in the planning stage will also, to a great extent, determine the quality of the finished product.

Commonly accepted construction practices have resulted from people doing the same work for many years. This is usually the most effective way to accomplish safe, high quality work. Use these accepted practices where you have the skills and equipment to do so and discuss these methods with the crew, the chain of command, and the QC inspector.

### 1.1.2 Identify Required Training and Equipment

The crew leader must be aware that many activities require specialized training or qualifications. Some activities, such as welding certifications or cable splicing, may be satisfied only through formal instruction. Formal training for a great many activities is simply impractical. It is frequently necessary to identify the skills required and find alternate sources of training. The most common source of informal training is on the job training (OJT). Use OJT when you can identify at least one person who knows how to perform the task correctly (yourself, a crew member, or a QC rep) and schedule enough time to show the remaining crew the proper techniques. Remember that one purpose of projects is to provide training for our people. Teaching your crew the proper methods and techniques should be high on your list of priorities. Besides the required training, the required equipment must also be available to accomplish the task according to the method selected. Finishing a large concrete pad without the use of a power trowel (whirlybird) might prove to be difficult. Renting one with project funds may be an option if you do not have one at the deployment site.

### 1.1.3 Ensure Personnel Awareness

Another important step in the implementation of a QC plan is personnel awareness. Each crew member must understand what the quality measures are and inspect the work of the crew for quality on a daily basis. Before you start work on an activity, all crew members should be briefed about critical measurements, inspection items, potential problems, and each member's responsibility for quality. Remember, quality is everyone's responsibility. If you use the crew briefing checklist shown in *Figure 6-3*, all of these items will be addressed.

**Master Activity Prep List**

Project Number ____________________________

Project Title ____________________________

Activity Number ____________________________

Activity Description ____________________________

Early Start Date ____________________________

Late Finish Date ____________________________

Estimated Duration ____________________________

| Resource check to be completed by the crew leader before commencement of work: | (Y/N) |
|---|---|
| Have the construction methods been clearly described on the CAS sheets? | |
| Are all the materials estimated on the CAS sheets on site, stored properly, and in compliance with the plans and specifications? | |
| Have required shop drawings been prepared? | |
| Has the equipment listed on the CAS sheets been reserved? | |
| Are the tools listed on the CAS sheets on site or being reserved? | |
| Is the safety equipment/personal protective gear listed on the CAS sheets on site or reserved? | |
| Briefing of crew to be completed by the crew leader before commencement of work: | (√) |
| Discuss all required tests and inspections. | |
| Establish levels of quality for each element of the work. | |
| Discuss all other pertinent parts of the specifications. | |
| Discuss each individual's job and establish specific measures of performance. | |
| Define each crew member's responsibility and authority. | |
| Clearly outline the sequence of work activities. | |
| Discuss all safety requirements from the CAS sheets and instruct crew members in the proper use of safety equipment. | |
| Stress the importance of good housekeeping. | |

**Figure 6-3 – Master activity prep list.**

### 1.1.4 Evaluate Completed Work

The last major step in QC plan development is the daily QC inspection report. This daily report is required for all projects. Its purpose is to document the completion of all required checks, tests, and inspections. All work completed or in progress either is or is not done according to the specifications. The daily report is signed by both the QC inspector and the crew leader and then forwarded to the operations officer or detail OIC with a copy to the ROICC office, the company commander, and the crew leader. *Figure 6-4* shows a form for the daily QC report. All checks, tests, and inspections are listed on the back of the CAS sheet. Everyone on the crew should know in advance what the inspections will consist of and what the results are.

<table>
<tr><td colspan="4" rowspan="7">DAILY<br>QUALITY CONTROL<br>INSPECTOR’S REPORT</td><td>Route to:</td><td>Initial</td><td>Date</td><td colspan="2">Remarks</td></tr>
<tr><td>S3</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>S3C</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>S3QC</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>00S</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Prime</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Sub</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Date</td><td colspan="2">Time</td><td colspan="5">Project No.</td><td>Report No.</td></tr>
<tr><td colspan="3">Prime Co.</td><td colspan="6">Project Title</td></tr>
<tr><td colspan="3">Sub Co.</td><td colspan="6">Weather</td></tr>
<tr><td colspan="4">Supervisor</td><td colspan="5">Inspector</td></tr>
<tr><td>Activity</td><td>Rate</td><td colspan="7">Description of Work Performed</td></tr>
<tr><td></td><td></td><td colspan="7"></td></tr>
<tr><td></td><td></td><td colspan="7"></td></tr>
<tr><td></td><td></td><td colspan="7"></td></tr>
<tr><td></td><td></td><td colspan="7"></td></tr>
<tr><td></td><td></td><td colspan="7"></td></tr>
<tr><td colspan="4">Activities Started</td><td colspan="5">Activities Completed</td></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="4">Construction Inspection Plan Items Checked</td><td colspan="5">Results</td></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="4">Delays</td><td colspan="5">Safety Hazards Present</td></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="9">Remarks</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9">Material Received</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="9">Project Supervisor QC Inspector Reviewed (S3QC)<br>Dist: 1. ROICC<br>2. QC File via S3<br>3. Prime Contractor</td></tr>
</table>

**Figure 6-4 – Daily QC Inspector’s Report.**

## 1.2.0 ROICC Interface

The ROICC is responsible for the inspection and surveillance of ongoing NCF projects and for the daily review of QC reports to ensure compliance with the plans and specifications. The ROICC office also has to approve any battalion-recommended field adjustment requests (FARs) or customer requested changes. Scope changes require the approval of the customer's major claimant. Any changes that require 50 or more man-days of additional direct labor or any changes that increase the cost of the project by $500 or more require the approval of COMSECONDNCB/COMTHIRDNCB. The ROICC also conducts the final inspection and accepts only those facilities built according to the plans and specifications. The QC staff provides direct liaison between the battalion and the ROICC on all matters, such as change requests and project specification questions. No field changes can be made without a request being forwarded through the QC staff and being approved in writing by the ROICC. Change requests must include the same level of detail as the original specification. The engineering division can provide assistance on sketches for your change requests. *Figure 6-5* is a sample design change request.

**FIELD ADJUSTMENT REQUEST/**
**DESIGN CHANGE DIRECTIVE**

FAR/DCD # _
Page _ of _
Date _

Project Number:

Project Title: _

Requested By: _

Description of and reason for request: (Include drawings and sheet numbers and attach drawings as necessary for description.)

Estimated additional cost:

Estimated additional man-days:

| | | |
|---|---|---|
| Approved/Disapproved | Prime Contractor | Date _ |
| Approved/Disapproved | Quality Control | Date _ |
| Approved/Disapproved | Engineering | Date _ |
| Approved/Disapproved | Operations | Date _ |
| Approved/Disapproved | ROICC | Date |

As Built Date _
(initial)

Notes:
1. Route original and 3 copies through to ROICC.
2. ROICC return original and 2 copies.

**Figure 6-5 – Design Change Request.**

A log of all design change requests in a format similar to *Figure 6-6* must be kept in folder six of the project package.

| **FIELD ADJUSTMENT REQUEST (FAR) / DESIGN CHANGE DIRECTIVE (DCD) SUBMITTAL LOG** | | | | | | |
|---|---|---|---|---|---|---|
| FAR # | Description | Spec Location | Drawing Number | Date to Ops | Date Returned | Approved/ Disapproved |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Figure 6-6 – Field Adjustment Request Submittal Log.**

# 2.0.0 INSPECTIONS

A Builder who is well qualified and has shown the capability to handle the responsibility of an important position may be selected to serve in the role of QC inspector for the OPS Department of a NMCB. In addition, qualified Builders may find themselves assigned to a Public Works Department where they will serve as project and maintenance inspectors for the facilities at their base. A good guide to use for checking your projects is the *Construction Inspector's Guide,* EP 415-1-261, published by the U.S. Army Corps of Engineers.

In this section, we will cover the responsibilities of the inspector and point out items checked in inspecting various parts of buildings and other structures. Bear in mind that inspections are broad in scope, so every area covered in an inspection is not listed, but the information provides you with the basics of performing an inspection. In addition to the checkpoints given here, other important points could be included in your inspection, based on plans and specifications, local building codes and regulations, manufacturer's specifications, special requirements, and so on. Remember that as crew leaders and project managers, you are also inspectors of your own projects.

## 2.1.1 Inspectors' Responsibilities

As an inspector, your prime function and responsibility is to make certain that the work is performed in every aspect with the drawings and specifications. These requirements are usually, but not always, sufficiently exacting to necessitate high standards of quality in both materials and workmanship. In the case of temporary or emergency construction, you may have to intentionally lower quality requirements; you must be careful to make certain that the work is of the required quality while being equally careful not to demand a quality of work superior to that required. The inspector should also ensure that any construction changes, omissions, or additions are made to the blueprint to show the final, as-built conditions.

In some cases, the specifications for the project or the standard specifications that are included as references may establish definite tolerances over or under the measurements that will be accepted. Then as the inspector, you only have to verify that the work is within the specified limits. However, on most phases of the work, specific tolerances cannot be fixed, and you must show intelligent judgment in interpreting such requirements as plumb, true, level, and perfect. An inspector's intention is that the workmanship be of the most suitable grade for the purpose for which the finished project is to be used. The inspector should have a comprehensive, practical knowledge of the grades of workmanship satisfactory in the various classes of structures and in the various details of the work.

The acceptable degree of accuracy is dependent on many factors. Structural framing may have to be true within one sixteenth of an inch or, in some cases, within one eighth of an inch. Concrete work can seldom be held closer than one eighth of an inch, but in some special types of structures, much larger tolerances must be permitted and allowed.

The inspector must make sure:

- That the principal center line, column lines, and controlling overall dimensions and elevations are correct.
- That minor errors are not permitted to accumulate, but are compensated for continuously.

- That exposed work is visually acceptable.
- That special care is taken when greater than ordinary precision for the type of work is necessary for some special reason.

It is important that the inspector make clear at the outset of the work what will be expected and ensure that the initial portions of the work fulfill these expectations. Invariably, the standards of accuracy established and enforced during the first few days of work will set the pattern for the rest of the work. As an inspector, you must be consistent in the standards you exact. You must be reasonable, but not be too lenient in this respect. Inspections of temporary construction must be limited to assure the work is adequate and safe for the purpose for which it was intended. You must be alert to note any defective construction, unsound materials, possible weaknesses, and hazards and then call them to the attention of your superiors.

Inspectors are responsible for the effective application of the safety program for the projects to which they are assigned. This responsibility covers the prevention of accidents that would cause physical injury or property damage. In the event that you encounter difficulty in correcting an existing hazard or safety violation, or preventing a future hazard, you should immediately report such conditions to a superior for the proper action and/or guidance.

An extremely important and relatively difficult phase of an inspection is in the checking of a project as it nears completion to make sure that every item required for the completion of the project has actually been provided. The use of a check off system is essential for this purpose. You should adopt and initiate this system early enough to allow ample time for delivery and installation of any items that might be overlooked. This is particularly necessary in times of emergency when long lead time between ordering and delivery is encountered for many critical items of material and equipment. Inspectors must maintain a strict watch over cleanup items, particularly where portions of the work may be concealed in later stages. Because of the inherent tendency of construction projects to drag out to a slow finish, you will have to exert greater pressure to obtain full and rapid compliance with the time requirements for completing the project.

Inspectors may be responsible for maintaining accurate and detailed records of performance of their work and of various pertinent matters. Your records and reports should be clear and complete so that no possible misinterpretation of the facts or uncertainty about events may arise.

As an inspector, you have contact with other people and need an understanding of human relations. You must use tact and courtesy in dealing with others. If you give criticism, you should do so constructively and in a manner that will not cause resentment. You must avoid showing any favoritism or partiality. In particular, you must avoid making any statements or taking any action that might discredit any supervisors or foremen when their subordinates are present.

It is imperative that you, as an inspector, conduct yourself at all times in a manner commensurate with the highly responsible position you occupy. You must be absolutely honest in your dealings with others. Integrity is a fundamental requisite. You must be trustworthy, loyal, diligent, and punctual. You must be dignified, steady, and poised in all your actions. When, as an inspector, your job involves supervising others, you must be firm but fair in handling your subordinates. You must maintain your self respect and win the respect of all your associates, always keeping in mind that a harmonious relationship is more successful than one hampered by friction and discord.

The rest of this chapter covers commonly encountered problems in the inspection of construction projects or maintenance of facilities. This chapter is not intended to identify every inspection process or identify new construction technology. For more information, refer to the *Construction Inspector's Guide,* NAVFAC P-456 (series), or the *Construction Inspector's Guide, EP-415-1-261,* U.S. Army Corps of Engineers.

## 2.2.0 Concrete Construction

When assigned to inspect concrete construction, you must have a thorough understanding of the standard specifications and the best techniques and methods for meeting those specifications. Concrete construction must meet the requirements set by the *American National Standards Institute (ANSI),* A10.9, "Safety Requirements for Concrete Construction and Masonry Work."

The standard specifications cover a wide range of possible conditions and allow a choice of types of cement, sizes and types of aggregates, and classes of concrete. The specific requirements for each project must be set forth in a definitive manner in the drawings and specifications for the work. You should verify that all variables and options permitted by the standard specifications are fixed by the project documents and you should call any apparent omissions to the attention of a superior.

### 2.2.1 Preparatory Work

As soon as the batch plant is set up or a local batch plant has been identified for producing and delivering concrete, familiarize yourself with the functional arrangement and transportation, and check all equipment to make sure it is in good working order. You should be present at any trial runs made and make sure that any deficiencies that develop are corrected. If any serious deficiencies are apparent that cannot be readily overcome and that might affect the efficiency of the operations, you should inform your superior of the situation.

Before permitting any concrete to be placed, you must submit a hard card to the ROICC or the OPS Department. A hard card, or Concrete Placement Clearance Form as shown in *Figure 6-7*, is a checklist to be completed before placement of the concrete. This is an excellent checklist for you to ensure yourself and the ROICC that every aspect has been thoroughly covered and your crew is ready to place the concrete.

You must make sure that the formwork complies in all respects with the applicable requirements of the specifications. When old forms are reused, make sure they have been properly repaired and cleaned. If the forms are of considerable height, you must see that openings have been provided as necessary for placing concrete without excessive drop. See Chapter 4 for these requirements. Before placing concrete, you must make sure that all debris has been completely removed from inside the forms and that the contact surfaces of the forms have been wetted, oiled, or coated as specified. Generally, form contact surfaces are oiled before being erected. When used for footings, abutments, and other large sections, the forms should be oiled after erection, but take care to avoid getting oil on the reinforcement.

All reinforcement must be checked in detail to make sure that it is of the specified size, length, type, form, and spacing; is clean and free from loose rust or scale; is firmly secured by approved devices against displacement, and is accurately located to assure that the required cover will be obtained. Splices must be checked for location, length of lap, clearances between bars, and clearance of bars to forms and dirt. When welded butt or lap splices are required or permitted, you must check the quality, size, and amount of weld.

## Concrete Placement Clearance Form

**PART I**

Date ____________

Project Number    Title    Location ____________

Date/Time Desired    QTY    Strength (PSI) ____________

Slump (in)    Max Aggregate Size    Admixtures ____________

Type of Placement    ( ) Roof    ( ) Slab    ( ) Wall    ( ) Other

Finish Required (Type)    Tolerance ( ) +/- 1/4 in.    ( ) Other

| **PART II** Item | Conforms to Requirements N/A | Crew leader | QC Insp | Item | Conforms to Requirements N/A | Crew Leader | QC Insp |
|---|---|---|---|---|---|---|---|
| Subgrade Prep | | | | Electrical | | | |
| Elevation | | | | Conduit inst/stubbed up | | | |
| Dimension | | | | Sleeves (foundations) | | | |
| Compaction | | | | Pull Cords | | | |
| Capillary Barr (sand) | | | | Mechanical | | | |
| Vapor Barrier | | | | Sleeves (foundations) | | | |
| Misc. (insec, drain rack, etc.) | | | | Sub slab piping | | | |
| Forms | | | | - pressure tested | | | |
| Elevation | | | | Floor Drains (elevation & location) | | | |
| Dimensions | | | | Floor Cleanouts (elevation & location) | | | |
| Alignment | | | | Stubups (location, type) | | | |
| Bracing | | | | Placing/Finishing Equipment | | | |
| Condition | | | | Screed Boards Set | | | |
| Keyways | | | | Screed Boards Checked | | | |
| Water Stop | | | | Placing Tools Set | | | |
| Embedded Items | | | | Placing Tools Checked | | | |
| Anchor Bolts | | | | Finishing Tools Set | | | |
| Sleeves | | | | Finishing Tools Checked | | | |
| Misc. | | | | Curing Materials | | | |
| Reinforcing | | | | Testing Materials (cylinders, slump cone, etc.) arranged for on site | | | |
| Size | | | | | | | |
| Location and Spacing | | | | | | | |
| Chairs (meshups) | | | | | | | |
| Bracing | | | | | | | |

Submitted: ____________

Approved: ____________

Crew Leader    Date

Scheduled For: ____________

QC Inspector    Date

Remarks

**Figure 6-7 – Concrete Placement Clearance Form.**

You must be sure that all anchors, inserts, dowels, sleeves, pipes, and similar fixtures that have to be embedded in the concrete are accurately placed and firmly secured to the forms. Before and during placing operations, you must check the concrete mixture for conformity with specifications. This means verifying slump tests and air-entrainment tests, and preparing laboratory test samples for compressive and flexural strength tests.

### 2.2.2 Placing

When ready mixed concrete is to be used, you must ensure the requirements of the specifications for the method of mixing and delivery are fully met. When job mixing at a central plant at the site is adopted, make sure the methods of transporting the concrete assure rapid delivery without segregation or loss of material.

Concrete may be conveyed from the mixer or delivery point to the forms by carts, buckets, chutes, pneumatic methods, pumping, or tremie. You must make sure that the methods and equipment meet with the approval of your superior when so required. You must, in all cases, be satisfied that the concrete, as placed, is acceptable in all respects and require correction of deficiencies in methods or equipment if the concrete is not of acceptable quality.

You must make sure that the concrete does not displace the reinforcement and that construction joints and expansion joints are provided at all required locations and are properly located and formed. If concrete is placed in cold weather by a tremie or under other special circumstances, you must make sure that the special precautions required are taken.

### 2.2.3 Finishing

You must remember the importance of uniformity of the finish and the surface texture. To inspect, you should familiarize yourself with the proper techniques for achieving satisfactory results and with the causes and methods of avoiding the common defects in the finish. Excessive surface water, for example, results from too wet or too sandy a mix or from overworking. Such excess water should be removed by blotting methods or by evaporation, and not by sprinkling dry cement on the surface. Excessive troweling brings laitance to the surface and gives a surface that soon dusts and deteriorates. The drying of concrete too rapidly leads to hair cracks. Placing a topping over dry concrete causes alligator cracking from rapid absorption of water by the base course. You must assure yourself that the methods and techniques used prevent such defects and deficiencies.

### 2.2.4 Curing

Specifications contain specific requirements for the protection and curing of concrete, including special requirements for certain cases. You must determine which requirements are correct for the project. You should give careful attention to the requirements for the length of the curing period required and the length of time forms or supports must be kept in place. You must make sure that the curing methods fully protect the concrete against drying out prematurely. If membrane waterproofing is permitted, make sure that the membrane seal is applied so that no gaps or holidays occur. Likewise, require a second application over uncovered areas.

## 2.3.0 Foundations

Various types of foundations are used in the construction industry today. Because of space limitations, let's consider only two of the main types, mat foundations and spread footings.

### 2.3.1 Mat Foundations

The mat (raft or floating) foundation is a continuous footing that supports a reinforced concrete slab covering a minimum of 75 percent of the total area within the exterior walls. It is normally used when the subsoil is not considered good enough for spread footings. Mat foundations may take the form of a hollow concrete box with intermediate walls or columns to permit taking advantage of the weight of the earth removed in the excavation to partially offset the load imposed on the mat foundations. When inspecting, you must make sure that the subgrade is carefully leveled to the specified elevation so that the concrete will be of full thickness and that special sand or gravel is spread and compacted if called for. Be alert to detect any wide variations in the quality of the subgrade.

### 2.3.2 Spread Footings

The spread footing shown in *Figure 6-8* is the lowest foundation support and is wider at the base than at the rest of the foundation. For example, a common 8 inch concrete retaining wall is placed on a 16 inch footing. Spread footings are designed for a definite load per square foot, based on prior investigations of the site, or on general knowledge of the characteristics of the soil in the area. Usually the drawings indicate both the sizes of the various footings and the load on which they are based, normally twice the size of the foundation wall. Your primary function is simply to make sure the footings are the correct size, with satisfactory concrete reinforcement or other parts, as shown or specified. Be alert to detect any significant variations in the quality of the substrata from that indicated by boring records or assumed designed loads.

**Figure 6-8 – Spread footing with a keyway joint.**

It is essential that anchor bolts be set with the utmost accuracy relative to both position and level. Errors discovered after the concrete has set are extremely expensive to correct. This is particularly vital when sleeves are not specified or permitted to allow for lateral play. Anchor bolts are usually set to a template which is carefully aligned with the building lines and leveled to a definite elevation. You must check the setting and verify beyond question that the template is accurate within permissible tolerances before permitting concreting to proceed. Check the templates periodically during the course of the work to make sure they have not been disturbed. Pay particular attention to the bolt settings to make certain that there is sufficient thread exposed above the top of the steel base plate to permit full engagement of the nuts without excessive projection of the threaded bolt. You must also make sure that the anchor bolts are provided with hooks, L-bends, swaging, or other anchorage devices, as shown or specified. When sleeves are specified, you should make sure that the bolts are centrally located in the sleeves to provide leeway in adjustment in all directions. Ensure that the sleeves are NOT installed in such a manner as to decrease the holding power of the bolts. Later, make sure that the sleeves are properly filled with grout, lead, or sulfur, as the specifications may require, after the steel has been erected and aligned.

## 2.4.0 Concrete Floors

Concrete floors may be built on the ground at grade or on well reinforced overheads. Structural concrete floors may be of flat slab, beam and slab, beam and girder, or steel decking.

On floor construction, you must be sure that forms and supports are designed and installed so that they are readily adjusted to exact grade. Also, ensure that slab forms and beam and girder side forms can be removed after the specified curing period without disturbing the forms under the soffits of beams and girders. You should never permit the removal of soffit forms and supports and reshoring in advance of the time specified. Furthermore, make certain that all forms are accurately and adequately constructed, are adjusted to exact grade, are lined with absorptive lining if specified, and are oiled or otherwise treated as indicated. Take special care to secure clean, true surfaces with straight edges and uniform chamfer strips if the underside of the structural floor will be exposed in the finished work. You must check the work to make sure that all inserts, hangers, anchors, sleeves, and other fittings are provided as required and are accurately located.

You must be sure that curing is performed as shown in the project specifications and that forms and form supports are left in place for the minimum length of time specified for slabs, beam and girder sides, and beam and girder soffits. In addition, you must particularly note concrete that may have been frozen, and report the circumstances and conditions to the proper authority.

## 2.5.0 Concrete Framing

Concrete framing of buildings generally consists of columns, girders, beams, and slabs. Slab construction consists of columns, capitals, plinths, and slabs with girders and beams used only to frame around openings and to support spandrel walls (area of wall between the header of one window and the sill of the window above).

On building construction, you must be sure that all wall ties, anchors, inserts, and other appliances for fastening are installed in the forms in the exact locations needed and that all the openings for pipes, ducts, vents, and other purposes are formed in the correct locations. You must check these thoroughly before giving permission to start concreting to ensures that no item has been overlooked.

On building work, pay special attention to the accuracy of alignment, the trueness of exposed surfaces, and the finish. You must ensure that full compensation is made for the change of floor levels caused by the shrinkage of columns. You must give close attention to the location of construction joints and expansion joints, if required. You must make sure that slab forms are kept in position for the full period specified, that forms under beam and girder soffits are kept in place for the additional period required, and that all concrete is cured in the proper manner for the full period prescribed.

## 2.6.1 Concrete Masonry Unit (CMU) Walls

Concrete masonry units (CMUs) are made with stone, gravel, shale, slag, or cinders as the coarse aggregate. Units usually are made with nominal widths of 3, 4, 6, 8, 10, or 12 inches. Walls and webs usually are 2 inches in nominal thickness, but actual thicknesses may run one fourth to three eighths inch less. Units are made with 2, 3, 4, and 6 cores. They are also manufactured in half units and in special units, such as jamb blocks, end blocks, headers, and double corner units.

In construction involving the use of concrete block, check all material for damage, imperfections, stains, color, size, and marking, and make certain that only material conforming fully with the requirements is used in the work. You should also verify the course heights, bond, color pattern, and similar basic requirements.

You must make sure that all masonry units are handled carefully at all stages of the work to prevent damage and see to it that scaffolds and floors are not overloaded by stacking them too heavily.

You must determine that joints conform to the specifications in materials, type, pointing, and finish. To assure sound watertight construction, you must ensure that joints are:

- Completely filled for their entire length and depth and are free of voids.
- Correctly struck without excessive troweling, with horizontal joints truly level and vertical joints broken, staggered, or patterned as specified or shown.

When inspecting, you must determine that all joints are tooled to the specified form, if indicated. Where pointing is specified, you must ensure that the mortar joints are raked out to the specified depth, saturated with clean water, refilled solidly with mortar, and tooled. You should also require that all surplus mortar and stains be removed as the work progresses. You should ensure that horizontal or bed joints are finished first and then the vertical joints.

In addition, make sure that the exposed surfaces of masonry units are washed with water and brushed with a stiff brush until all mortar stains have been removed. A weak solution of muriatic acid may be used for stubborn stains, but exercise care to require thorough flushing with clean water. Finished terra cotta facing should be cleaned with a stiff brush, using soap powder boiled in water. The brushing should be continued until all stains and dirt are removed. The facing should then be rinsed thoroughly with clean water. Do not permit the use of wire brushes, abrasives, or metal tools because they may damage the surface, color, edges, and joints.

## 2.7.1 Concrete Finishes

Concrete floor finishes may be either integral with or placed separately from the structural slab and may have coloring pigment or hardening agents incorporated. You must be sure that materials and workmanship conform to the requirements specified for the type required in the project specifications. You must make sure that color pigment or integral hardener is added following the specifications or approved manufacturer's instructions.

If the finish is to be placed integrally, you must see that it is applied within the specified time limit. To do this, you must ascertain whether the number of qualified finishers is adequate to keep pace with the rate of placing of the floor slab.

When a separate finish is required, you must ensure that the surface of the slab is well roughened, thoroughly cleaned of all loose material, and brushed with neat cement grout immediately before the finish is placed. Furthermore, ensure:

- That the finishing concrete is placed at the driest practicable consistency to minimize shrinkage.
- That the dusting on of cement to absorb excess water is not permitted.
- That the surface is floated to a true, even surface, level or slightly pitched as specified.
- That the surface is troweled smooth without voids, exposed aggregate, or other visual defects.
- That troweling is not continued to excess because checking, crazing, and excessive dusting of the finished floor may result.

Make certain that the surface is cured as directed and for the time specified. Then also make certain that surface hardening treatments, if required, are applied after the surface is thoroughly cured, using approved chemicals of the type and in the amounts specified.

Painting of concrete, stucco, and similar surfaces is done primarily for decorative purposes or for damp proofing walls. Paints usually are of white Portland cement base with color but may be oil-based. In an inspection of painting, you must be sure that the materials conform to the project specifications or the referenced standard specifications. You must also determine whether surfaces are clean and free from dust, efflorescence, and other contamination and whether they are adequately cured. When Portland cement paint is used, be certain that the surface is thoroughly wetted. If oil-based paints are used, ensure that the surface is thoroughly cured, pretreated as specified, and thoroughly dry.

## 2.8.0 Steel-Framed Construction

Steel construction is used principally on shop buildings requiring relatively long span construction and on multistory buildings for comparatively light occupancy. In most cases, factory inspection of material, fabrication, and shop assembly will have been made. The inspector must make certain that the steelwork as delivered is correctly identified, sorted, handled, and stored.

### 2.8.1 Steel Floor Framing

In the construction industry today, steel-framed systems continue to gain popularity. The material used most often is light gauge galvanized steel. The steel floor framing methods are similar to the wood framed systems and the two are interchangeable.

As the inspector, you must give special attention to the alignment and plumbing of columns and posts. Joists, beams (usually wide flanged), and girders must be level and set at the prescribed distance below the finished floor. You must ensure that all steel is held and adequately braced by clips, brackets, ties, and anchors until the steel can be riveted or welded. The inspector must be certain that adequate erection bolts are used to hold all joining surfaces tightly together at joints and to hold the assembled steel in alignment. You must also make sure that mismatched holes are drilled or reamed and not drifted.

On welded work, as an inspector you must ensure:

- That suitable electrodes are used, as specified.
- That all base metal at welds is cleaned, brought into correct position, and clamped or backed up as necessary.

- That welds are made in the approved sequence to minimize internal stresses and distortion.
- That welds are of satisfactory quality, length, and size.
- That the parent metal is not damaged.
- That on truss joints lengths of welds are proportioned as indicated so that eccentricity of the welded joint to the line of stress is avoided.
- That all loose slag is removed.
- That special care is taken to make sure that welds made overhead or in awkward or restricted positions are sound and full.
- That the shop coat and welds are touched up as specified and that the specified number of coats of field paint is applied.
- That the paint used is of the type, quality, and color specified. (For more information, consult the *Steelworker Basic NRTC.*)

### 2.8.2 Metal-Framed Walls

Metal-framed walls are similar in design to wood-framed walls. They have channel-shaped studs and C-shaped studs that are fastened to the metal channel that serves as the bottom and top plate. The tops of the door and window openings are supported by channel-shaped headers. Lumber may be used for header material if the plans and specifications specify it. The metal C stud material is available in various sizes. The most popular stud widths are 6, 3 1/2, and 2 1/2 inches, and the header and joist widths are 6, 8, and 10 inches. The thickness of the galvanized steel ranges from 14 to 20 gauge steel. For the double top plate, you may use 2-by material as long as the plans and specifications specify lumber vice metal. When inspecting these metal walls, make sure the proper self-drilling screws are used, check for tolerance and gauge of metal, and be sure the bottom plate is securely fastened to the floor. Also ensure the knockouts are aligned properly for easier runs for the electrical and mechanical lines. There is one mistake commonly made when working with metal framing and that is cutting of the metal. When you cut metal or scratch metal it tends to oxidize, resulting in the creation of rust. How fast the oxidation occurs depends on the climate. To prevent oxidation, coat the cut ends with a galvanized paint or a primer.

## 2.9.0 Wood-Framed Construction

In light-frame construction, buildings are constructed according to the country and local building codes. As the inspector, you must be familiar with these codes and regulations. In some areas of the country, buildings must be constructed with special resistance to wind and rain. In other locations a building is constructed according to other disaster problems, such as locations prone to earthquakes, cold climates, snow loads, and humid climates. All require quality construction and special designs. Structures should be built to reduce the effects of shrinkage and warping, and to resist fire hazards.

This section will not cover all aspects of inspecting light-frame construction, but as an inspector or crew leader, you need to be knowledgeable about what to look for when inspecting this type of construction.

### 2.9.1 Wood Floors

Wood floors for buildings of frame construction usually consist of finished flooring laid on subflooring that is supported by floor joists. Wood floors usually consist of planks surfaced on four sides (S4S), laid on edge with tight joints, and supported by floor beams of dimensional timber spaced at fairly long spans as specified in the drawings and specifications.

As the inspector, you must ensure:

- That all lumber is of the specified grade and type according to specifications.
- That all beams are true.
- That flooring material is resting squarely on the joist.
- That floor joists are the correct size and overall length, and are sound and free from excessive warp.
- That the floor joists are installed bearing on sills or beams or supported by straps or hangers, and are braced with cross bridging and/or with solid bridging, as specified.
- That the tops of floor joists are brought to a true, level plane.
- That subflooring of the specified kind, grade, and size is installed, made tight, and thoroughly nailed.
- That building paper is laid, if prescribed.

Wood floors are frequently installed on steel framing, particularly in light industrial buildings where steel bar joists are used. In some cases, floor joists are installed on the steelwork, and the wood floor construction is the same as for frame construction. In other cases, floor decking, consisting of heavy planking with square, shiplap, or tongue and groove joints, is laid, driven tight, and bolted directly to the steelwork with carriage bolts. You must make sure that all materials and workmanship conform to the requirements of the specifications and that the floor is finished smooth and even.

### 2.9.2 Wood-Framed Walls

Wood (stick) framing is widely used throughout the construction industry, but the cost doubles that of metal framing. It is still the preferred method of construction, particularly for emergency and temporary construction. Quarters and temporary barracks may be of typical frame house construction. Storehouses, particularly of the large one story type, may have frames of wood posts, beams, and joists with wood roof sheathing. Shop buildings may have to be built of wood when steel and concrete are not available. Such structures may require heavy built-up timber columns and trusses, particularly if crane runways have to be provided. Large, wooden hangars have been built, necessitating trusses, with each member consisting of a number of heavy planks.

Structures that require wide span construction have occasionally been framed with laminated wood arches, consisting of a large number of plies of relatively thin planks, glued together with special waterproof, durable glue. You may encounter many other special types of framing. With changing technology, glued laminated beams could be a thing of the past, and plastics may take over--who knows? We just cannot cover every aspect of the construction industry.

As the inspector, you must familiarize yourself fully with the drawings and specifications and the standard specifications used for references. Make sure the framing material is of the specified grade and size, and the surface has been inspected and grade marked.

You must make certain that the nails, bolts, screws, connector rings, and other fastening devices conform to the requirements in type and size. Also ensure that metal ties, straps, hangers, stirrups, joist hangers, and similar accessories are suitable and correctly used. Where numerous plies of lumber are held together by long through-bolts, you should recheck the tightness of the nuts before the project is finally accepted because shrinkage of the lumber may have caused them to loosen. As an inspector, make sure that the wall material conforms to the specifications as to the kind of wood, grade, and manufacture or has been inspected or grade marked. You must ensure that the wall sheathing is tight and covered with a building wrap (vapor barrier) and flashed as necessary for weathertightness. Also make certain that siding is applied carefully so that the lines are straight and true and that laps and exposed faces are correct. In addition, make sure that nails are the specified kind and weight, are driven flush, recessed, or blind, as specified, and that, if recessed, they are filled over with a suitable plastic wood putty.

Wood partitions are used in all frame construction. In most cases, wood partitions are composed of 2 by 4 inch wood studs with sills and plates of the same material. Studs are doubled at openings, and the top plates are usually doubled to provide strong splices.

Headers, encountered in light frame construction, are required at all openings of load-bearing and non-load-bearing walls. Remember, non-load-bearing headers run parallel with the joist, and unless the opening is more than 3 feet wide, a single 2 by 4 (laid flat) is sufficient as a header. Load-bearing headers run perpendicular to the joist and carry the load immediately above the openings. Load-bearing headers should be doubled and laid on edge. If the opening is more than 3 feet in width, the header will need additional strength to carry the load imposed upon it from above. Check the local building codes, plans, and specifications, and *Architectural Graphics Standard* (AGS) for more information on headers.

Wood partitions to be finished on both sides are covered with wood lath, metal lath, plasterboard, or some other base, or may be covered in drywall construction with wallboard of various types. Wood partitions in offices are frequently covered by paneling. This type of construction uses studs spaced fairly wide apart (2 feet) with either tongue and groove panels, wallboard, Masonite, or other material used for wall coverings. Such partitions frequently extend only part way to the ceiling, and the upper panels may be glazed, glass panels, or glass block. In the tropics, wood partitions may be surfaced on one side only, leaving the studding fully exposed on the other side to eliminate all concealed spaces and permit effective control of termites and other vermin.

As the inspector, you must ensure:

- That all partitions are adequately anchored to the floor, walls, and ceiling, as specified, and are adequately braced and stiffened at all splices and corners.
- That studs are set truly plumb and in line, and are well nailed to sills and plates.
- That plaster base or other surfacing or panels and trim are carefully and accurately installed so that a neat, workmanlike finish is obtained. When necessary, make sure that all fastenings are completely concealed behind the trim and that the latter is nailed with finish brads.

### 2.9.3 Wood Roofs

You may have occasion to inspect various types of roofs, including concrete, corrugated metal, wood, and so on. Although this chapter is broad in scope, it does not cover all the different types of roofs. The subject matter is limited here to wood roofs. Built-up roofs are covered in a later section.

When a pitched roof is inspected, as the inspector, you must ensure:

- That all framing is cut accurately to exact length.
- That all framing is beveled or mitered as necessary to assure proper bearing of the cut at all meeting faces, and is securely nailed.
- That all bracing, trusses, collar ties, king posts, and end studs are provided according to the drawings and specifications.
- That sheathing is laid tight and straight and nailed according to the specifications. You should be sure that sheathing on pitched roofs is started at the eaves, with the face grain laid perpendicular to the rafters and the horizontal joints staggered at mid-sheet intervals.

Thickness of plywood is very important to any roof, and this is where local codes tend to differ due to load design, wind resistance, or type of roofing material. Normally 1/2 inch plywood is the minimum, but 7/16 inch oriented stranded board (OSB) is widely used in residential construction.

## 2.10.0 Thermal and Moisture Protection

The material and its installation used in thermal and moisture protection are critical to any construction. In the construction industry, insulation is usually thought of in relation to heat transmission, although sound is an equally important aspect to consider. There are so many different types of thermal and moisture protection, such as waterproofing, damp proofing, vapor and air retarders, fireproofing, various types of insulation (blanket, batt, and loose), and joint sealers. With limited space, we will briefly cover waterproofing, building insulations, and joint sealers.

### 2.10.1 Waterproofing

Waterproofing is the application of material that protects an area, structure, or individual member from the presence of water, whether it is in the form of a liquid or a vapor.

Membrane waterproofing is achieved by placing a moisture-impervious membrane, such as bituminous membrane (felt paper), polyethylene (plastic), or sheet rubber. When a membrane waterproofing material is applied to a surface, that surface must be clean and free from foreign material and kept dry. You must ensure that quality workmanship and proper installation procedures are strictly followed.

### 2.10.2 Insulation

Insulation materials are resistant to the passage of either heat or sound, or both. Typical insulation materials include the following:

- Foamed glass
- Foamed plastics
- Glass fibers
- Cork
- Asbestos fibers
- Granular fibers, such as vermiculite and perlite

Insulating materials are often designed to trap dead air space.

Before installation of these materials, make sure that no moisture has damaged the material due to handling or transporting. Adhere to quality workmanship during installation.

Fiberglass insulation (blanket, batt, or loose) must be inspected for the approved manufacturer's specifications for the proper **R** value and thickness. Fiberglass is usually covered on one or two sides with either a paper backing or foil backing, or wrapped with a plastic wrap. It also may be blown in loose.

When fiberglass insulation is inspected, make sure that the proper procedures are followed according to the specifications or manufacturer's specifications. In the construction industry today, fiberglass is treated with care. Check with your safety officer or environmental officer for the proper handling techniques.

In masonry construction vermiculite and perlite are excellent soundproofing insulation to fill all the hollow cores that are not already filled by concrete. Vermiculite and perlite are also used as an additive to plaster or joint compound to texture the ceilings and for soundproofing.

### 2.10.3 Joint Sealers

The purpose of joint sealers (caulking) is to obtain a watertight structure. In masonry walls, a space about 1/4 inch wide and 1 1/2 inch deep should be allowed around all door and window frames to allow for adequate caulking. When caulking is applied, ensure the joints are clean and filled with the proper backing material, such as oakum, rockwood, styrofoam, or a urethane foam. Open spaces between wood and masonry sills must be caulked. Remember, watertightness is what you are trying to achieve. Air flow loss is very common through window and doorframes due to improper installation of the jambs. The presence of foreign material will prevent a good bond of the caulking material.

## 2.11.0 Ceilings

Due to space limitations, information on ceiling finishes for ceilings is limited to three materials: acoustical tile, acoustical plaster, and drywall. Since drywall is classified as a finish, we will cover it in the next section.

### 2.11.1 Acoustical Tile

Acoustical tiles are available in various materials, such as wood, vegetable, or mineral fiber, perforated metal, or cemented shavings in different thicknesses, shapes, dimensions, textures, perforations, and joint treatments. They may be nailed, clipped, or cemented in place, depending on the ceiling construction.

The inspector must make sure that the tile, hardware for fastening and adhesive cement conform to the project specifications or the standard specifications referenced there. You must make sure that tiles are handled and stored carefully and are not allowed to get wet or even damp. Be sure that all marred, broken, or damaged tiles are culled and not used.

If the tile is installed on suspended ceilings, you must make certain that the furring construction is strong, rigid, and according to the specifications. If wood furring is prescribed, you must be sure that the furring strips are spaced accurately and suited to the tile width. Tiles must be fastened to furring strips by either blind nailing (nail heads that are concealed) or by screwing through the perforations, as specified. If metal furring channels are prescribed, you must ensure that the tiles are fastened to the channels with approved coupling devices and hangers. When tiles are applied to a finished solid surface, they are cemented with special adhesives, usually with five spots per tile, one near each comer and one in the center, applied to the back of the tiles, and pressed into place to a true, level plane. You must make certain:

- That all work is accurate and true to plane and line.
- That all special fitting around pipes, sleeves, and fixtures is neatly done.
- That all tiles adhere tightly to the backing material.

### 2.11.2 Acoustical Plaster

Acoustical plaster is a manufactured product composed usually of asbestos fiber and rock wool fibers, lime or cement binder, and an aerating agent, factory blended, and ready for mixing with water. It is available in white and in light pastel colors.

Acoustical plaster is seldom used in the industry today because the material is composed of asbestos fiber. However, with continuing renovations to our naval facilities, you will encounter ceilings with acoustical plaster. Take the necessary precautions and contact your safety officer and ROICC before the installation or removal of this product.

Acoustical plaster is usually applied over a scratch course of gypsum plaster. The inspector must make certain that this coat is applied as prescribed, cross scratched for bond, and allowed to dry thoroughly. You must be sure:

- That the acoustical plaster is applied in the prescribed number of coats to the specified thickness.
- That the undercoats are each leveled, rodded, and scratched.
- That the finish coat is brought to a true, level surface of uniform texture with a minimum of troweling to avoid reduction in acoustical qualities.
- That the plaster conforms to any special requirements of the specifications, such as porosity, density, or hardness.

## 2.12.0 Finishes

The inspection of finishes for floors, walls and partitions, and ceilings is an important phase of your job. Be sure that each finishing job is properly done and gives a neat, attractive appearance. Now we will cover some items to look for during an inspection of interior and exterior finishes.

### 2.12.1 Interior Finishes

Interior finishes are those materials installed to cover the surfaces of the floors, walls, and ceilings. Because of the broad scope of material on finishes, we will cover this topic by focusing on floor tile, drywall, and wall tile.

#### 2.12.1.1 Floor Finish

Floor finish is any material used as the final surface of a floor. Many different materials are available for this application:

- Wood
- Quarry tile
- Resilient tile

- Glazed tile
- Sheet vinyl
- Carpet
- Block flooring (slat block, laminated block, and solid-unit block)

The Navy tends to use resilient tile as its primary surface because it is easy to apply, durable, and cost effective.

#### 2.12.1.1.1 Resilient Flooring

As the inspector, you must keep in mind that floor tile, especially 9 by 9 inch tile, was commonly made of asbestos fibers until the late 1970s. So if there is any demolition to be done, it is vital to take a sample of the flooring first.

You must ensure that the flooring material is placed starting from the center and working outward, this method ensures that the border tile is of equal size.

**NOTE**

Read the specifications. Usually they call for two coats of wax to be applied to the surface before occupancy.

#### 2.12.1.1.2 Floor Tile

Floor tiles come in several varieties, such as flint tile, unglazed or semi glazed ceramic tile, or quarry tile. Glazed ceramic tile, such as that generally used for a wall finish, is occasionally used. Flint and ceramic tiles are usually small and hexagonal, square, or rectangular shaped, and are delivered with the patterns assembled in panels of about 12 inches square cemented on the face to the paper. These tiles are also available in various square and rectangular sizes and in a variety of colors, shades, and textures.

You must ensure that tiles for both field and borders are of the kind, size, color, texture, and pattern specified and that adequate quantities are on hand to complete each room or area. You must determine that mortar for beds and wire mesh or other reinforcement, if required, conform to the specifications.

Also, make sure that the structural floor is prepared and ready to receive the tile and to assure a true, level, finished floor. If the floor is of wood, you must make certain that the floor joists are leveled at the top and that the subfloor is set down as necessary to provide an adequate mortar bed. If the floor slab is concrete, you must make sure that it is depressed below the finished floor grade as required, roughened to provide bond, thoroughly cleaned, and wetted down immediately before the mortar bed is placed. See to it that the mortar bed is placed and screeded and that tiles are set immediately and tamped level and true with straight, even, uniform joints. You must ensure that tile placed as paperbacked panels is set so that the pattern repeats truly and joints between panels match those established within the panels. You must be particularly careful to determine that the tile is laid parallel to the principal walls and that all special work required to fill in corners and irregular areas is placed so that joints are true and the pattern is faithfully reproduced without offset or other error. Check that all joints are carefully and neatly filled with mortar as specified, and that the floor is cleaned of all mortar. After the mortar has set, check the floor for loose tile, irregularities, or other defects that require correction. Quarry tile may be specified to be set in bituminous mastic or in colored white cement mortar. You must determine that the mortar conforms to the specified requirement and that tiles are set level with even joints and are solidly embedded.

#### 2.12.1.2 Walls and Partitions

Various types of materials are used as finishes for walls and partitions. We will cover only drywall and wall tile.

##### 2.12.1.2.1 Drywall

Drywall construction has replaced the plastering methods for walls and ceilings in the construction industry. More than 80 percent of homes today use some form of gypsum wallboard. It has been developed as an economical finish for walls and ceilings because of the increased cost of plasterwork and the relative scarcity of expert plasterers. Essentially, it consists of panels of wallboard of various types with joints tight, true, and effectively concealed.

As an inspector, you must be sure that the studding on which the wall is to be installed is brought carefully to a plumb, true plane. You must ascertain that all materials required by the specifications are used strictly as specified and that the wallboard is applied accurately (remember the nailing patterns for walls and ceilings). Check the walls for the required number of coats of joint compound, as required, and that the finished wall is true and uniform in texture and appearance with joints substantially invisible.

##### 2.12.1.2.2 Wall Tile

Glazed ceramic tile, glazed vitrified (waterproof) clay tile, and plastic tile are used for wall finishes for baths, galleys, mess halls, hospital rooms, and other applications for which a highly sanitary, easily cleaned, impervious wall finish is required. Tiles are furnished with various types of grooves, ridges, or clincher button heads on the back to assure bond.

You must make sure that the tile furnished conforms to the specifications in kind, quality, size, color, glaze, texture, and grip. You must also make sure that all necessary special tiles, such as base, corners, decorative band, fixtures, and trim, are of a true matching color or of the color or pattern specified.

A good checklist for inspecting the workmanship of tile should include the following:

1. Ensure the mortar scratch coat is applied and allowed to dry, as specified, and that it is ready in all respects to receive the tile.
2. Ensure that the mortar bed for tile is applied in the required thickness and made true.
3. Ensure that the tile is applied and tapped to true, plumb alignment with all joints straight, plumb, or level and of uniform thickness.
4. Ensure that the color schemes and patterns are faithfully followed and correctly arranged and cut around fixtures.
5. Ensure that wainscoting is extended to the specified height.
6. Ensure that bases align correctly with the finished floor and that joints are filled with plaster of Paris, cement, or other mortar as specified.
7. Ensure that all tile walls are cleaned thoroughly without scratching the glazed surface.

### 2.12.2 Exterior Finishes

Exterior finish includes all the exterior materials of a structure, such as walls, roofs, decks, patios, and so on. In this section we will concern ourselves with stucco and built-up roofs, which are common trades that Builders perform.

#### 2.12.2.1 Stucco

Stucco usually is specified as composed of Portland cement, hydrated lime, sand, and water and may have integral waterproofing or coloring pigment added. Painted or galvanized metal lath, expanded metal, or wire mesh is used for the support of stucco, except on masonry walls, and requires nails, staples, and wire for fastenings. The inspector must make certain that all material conforms to the requirements of the project specifications and the referenced standard specifications.

Stucco may be applied on masonry, concrete, or wood frame walls. As the inspector, make sure that the masonry has an unglazed rough surface with joints struck flush and adequate key to assure a good bond. Concrete is often given a dash coat of neat cement and sand before the stucco is applied. If the base is wood frame walls, the inspector must determine whether the lath or wire is securely fastened to the framing and tied together to form a taut, strong support to the stucco. Specifications usually will require application in a three-coat system of scratch, brown, and color coat, in that order.

As an inspector, you must make sure that all masonry joints are filled, struck smooth, and allowed to set before applying the scratch coat. You should then make certain that the scratch coat is pressed thoroughly into the joints for the masonry or into the openings of metal or wire lath to assure adequate key and bond. You must determine:

- That this coat is applied carefully to level and plumb irregularities.
- That it is scored or combed tier to completion to provide good bond.
- That it is permitted to dry for the specified period.

The brown coat is usually of the same composition as the scratch coat. You must ensure:

- That the scratch coat is wetted immediately before the brown coat is started.
- That the brown coat is applied, rodded, and floated to bring all surfaces to true, flat, plumb planes.
- That the surface is combed by fine cross-hatching to provide a bond for the finish coat.
- That the coat is permitted to dry for the prescribed period.

The color coat, also called the finish coat, is a relatively thin coat of special composition to provide the finished surface with texture and color. It is your responsibility to make sure:

- That this coat conforms to the specifications in composition, including colored aggregate, pigment, and integral waterproofing, if prescribed.
- That it is carefully applied to assure true, plane or curved surfaces and sharp edges.
- That on completion it is protected from excessive heat and kept moistened for the specified period to preclude hairline cracks, fading, and checking.

You must also make sure:

- That all surfaces are true.
- That the surface texture conforms to the finish specified and to the approved sample, if any.
- That the color is of a permanent type and after the stucco is dry, matches the color specified or indicated by a previously approved sample.

### 2.12.2.2 Built-Up Roofing

A number of different types of roofing are used on structures. One of the main types found on Navy-built structures is built-up roofing. The following information deals with this type of roofing.

Built-up roofing, as the name implies, is a membrane built up on the job from alternate layers of bitumen-saturated felt and bitumen. Because each roof is custom made, the importance of good workmanship cannot be overemphasized.

In inspecting built-up roofing, you should verify the particular combination of plies, felt, binder, and cover indicated in the project specifications.

You must be sure:

- That the felt conforms to the requirements in kind, grade, weight, and other specified characteristics.
- That the material is not crushed, tom, or otherwise damaged as it is used.
- That the primer and binder furnished are asphalt or tar as described.
- That the material conforms to the specification requirements for the indicated type.
- That it is kept free from water, oil, and dirt.

The standard specifications limit the material used for surfacing to gravel or slag, but the project specifications may permit or require a special material, such as white marble chips. You must verify the types of material required or permitted and ensure that the material furnished conforms and is of suitable size, gradation, and cleanliness. No surfacing is required for roofing that calls for asbestos felt.

Where a wood roof is concerned, you must ensure:

- That the roof deck has been prepared suitably to receive the roofing before permitting the roofing to be started.
- That all large cracks and knotholes have been covered with the tin nailed in place.
- That the roof is suitably smooth, clean, and dry.
- That felt or metal valley lining is installed in all valleys, as required for the type of roofing being used.
- The roof is covered with a layer of unimpregnated felt or resin-sized building paper and then covered with two layers of saturated felt, all lapped, nailed, mopped, and turned up or cut off at junctions with vertical surfaces, as specified.

Where concrete and similar roofs are concerned, as an inspector you must ensure:

- That all cracks, voids, and rough spots are filled level and smooth with grout and are thoroughly dry.
- That all sharp or rough edges are smooth.
- That all loose mortar and concrete are removed and the surface is broom clean.
- That felt or metal valley lining is installed in all valleys, as specified for the type of roofing being used.
- That the roof is covered with a primer of hot pitch or asphalt and then covered with two layers of saturated felt, all lapped, mopped, and turned up or cut off at junctions with vertical surfaces, as indicated. On precast gypsum or nailable concrete roofs, the specifications may require that these first two plies be nailed.

With all roofs, you must be certain that any additional layers of binder and felt are applied as required by the specifications. You must make sure:

- That each lap and layer is mopped full width with the specified quantity of hot binder, without gaps, so that felt nowhere touches felt.
- That the binder is applied at a temperature within the specified range and no burnt tar or asphalt is used.
- That these layers are turned up, as indicated.
- That the entire finished surface is uniformly coated with binder poured on at the specified rate and then covered with the required quantity and kind of covering material.
- That all roofing is free from wrinkles, air or water bubbles, and similar irregularities.
- That all plies are firmly cemented together.

## 2.13.1 Trim

There are basically three types of trim: metal, wood, and plastic. Since plastics and metal are seldom used in the Navy, we will cover only wood trim.

Wood trim or millwork may be of either rare or common varieties of hardwood or softwood. Regardless of species, millwork usually must be thoroughly seasoned; air or kiln dried, free from knots and sap, and of an even, straight grain.

As the inspector, you must make sure:

- That the trim has been factory inspected or grade marked and is of the species, grade, dimensions, pattern, and finish prescribed.
- That molded lines are true and sharp without fuzz, flats, or splintered edges.
- That the material has been suitably dried and is not warped or curled.

You must make certain that the installation of wood trim is made with the specified quality of workmanship. On high grade work, the inspector must ensure:

- That all trim is set plumb with square comers.
- That all corners are miter cut and coped, if necessary, for close fit on internal comers, and provision is made for expansion and shrinkage.

- That where long runs are installed in more than one piece, miter cuts and lap splices are used.
- That where curved bends are needed, the trim is kerfed on the back so that the cuts are invisible from the front and are close enough together to create a smooth, uniform curve without kinks.
- That all trim is nailed securely and that the nails or brads are suitable to avoid splitting.
- That finishing nails are set adequately, but not so deeply as to pull through the wood.
- That all joints and visible seams are sealed with wood filler and that all trim is suitably primed and field painted.

## 2.14.0 Doors

An inspection of structures should include both exterior and interior doors. The following sections provide information on some of the different types of doors used at Navy sites. Items that should be checked in an inspection of specific types of doors also are pointed out.

### 2.14.1 Exterior Doors

Exterior doors are constructed mainly of solid wood, fiberglass, sheet metal, aluminum, or structural glass. Wood doors may be of hardwood or softwood. Metal doors may be of a metal faced frame with an insulated foam core.

Hinged doors are used for most personnel entrances. They may be single leaf or double leaf. Two or more pairs of double leaf doors may be used for main entrances. Hinged doors may be of solid wood, metal faced, filled panel, or rolled metal construction. They vary in style from simple stock patterns to highly ornamental designs in bronze, aluminum, Monel metal, or stainless steel. Hinged doors may have exposed or concealed hinges mounted on the jamb or top and bottom set in the head and threshold. Most screen doors are the hinged type.

You must be sure that hinged doors are of the material, grade, size, type, and design specified and conform to the specifications. Usually, doors will have been factory inspected. You must determine:

- That they are accurately fitted to the frames with minimum clearance at head, jambs, and sill.
- That they are weather-stripped, glazed, and fitted with hardware, as specified.
- That they are painted, varnished, or otherwise finished as required.

Large openings may be closed by horizontal sliding or rolling doors, usually suspended by hangers from rollers that travel on horizontal or slightly inclined tracks and guided by troughs, grooves, or similar devices at the bottom. These doors vary from simple barn doors to the massive, steel framed doors used for airplane hangars. Large doors of this type usually run on wheels mounted in the bottom chord and travel on rails set at grade.

When horizontal sliding or rolling doors are inspected, you must be sure:

- That the doors are plane and free from wind.
- That the doors are mounted so that adequate operating clearance is obtained.

- That suitable weathertight closure is also obtained when they are closed.
- That tracks, rollers, roller suspensions, and operators are accurately aligned and adjusted for smooth operation.

Large shop and storehouse openings are frequently closed by steel rolling doors. These doors consist of a large number of interlocking horizontal slats that can be rolled up on a drum mounted above the head of the door opening. The slats are held loosely in channel guides at the jambs. The doors are counterbalanced by a spring tension device for ease of movement and may be operated either by motor or by hand.

In an inspection of steel rolling doors, you must ensure:

- That the slats are true and undamaged and interlock with adjacent slats, as intended, and that the slat assembly is mounted truly on the roller or drum and is correctly fastened so that the slats roll up smoothly and evenly, maintaining their horizontal position.
- That slat ends are provided with guide castings, as specified or approved, and that these guide castings fit accurately into the side guides with sufficient depth of bearing to assure against their pulling out and with sufficient clearance to assure easy operation.
- That the spring counterbalance or other balancing device is tensioned for the required ratio of the total load and maintains satisfactory tension throughout the operating range.
- That operating machinery is suitably aligned and adjusted, and that all accessories specified are provided and installed.

### 2.14.2 Interior Doors

Interior doors are made of hardwood or softwood, wood veneer, and sheet metal. Hollow core doors are usually filled with a sound-absorbing material that is fire resistant. Most interior doors are of the single leaf hinged type. Double swing doors will be specified for some locations.

Sliding doors may be specified for closets and for large openings between rooms. They usually will be arranged to slide into concealed recesses when opened. Fire doors are frequently arranged to slide or roll down an inclined track automatically when released by the melting of a fusible link in the anchoring device.

You will encounter doors of numerous special types, such as elevator doors, trap doors, clutch doors, lattice and louver doors, incinerator doors, vault doors, and accordion doors.

You must be sure:

- That all doors conform to specifications and are free from any defects that impair their strength, durability, or appearance.
- That all doors are of the prescribed types.
- That doors and door hardware are installed correctly and accurately.
- That doors operate freely and close tightly.
- That sufficient clearance is provided above the finished floor to accommodate floor coverings when necessary.
- That the swing of the doors is in accord with drawings and schedules.

## 2.15.0 Windows and Skylights

Special care is needed in the inspection of windows and skylights. Windows and skylights come in many different sizes and shapes. They are usually preassembled at the factory or millworking shop.

### 2.15.1 Windows

Wood windows usually are of the double hung or casement types. You must be sure that the panels and sashes are of the specified type and grade of wood, that they conform to the requirements for each unit, and that they are carefully handled and fully protected against damage.

As an inspector, you must ensure the following:

- That frames are carefully installed plumb and square, and that sashes are fitted neatly so that they operate freely, but without rattling.
- That sash weights or spring balances are installed and adjusted correctly and that all specified hardware and weather stripping are installed and adjusted satisfactorily.
- That casement sashes are hinged to swing in or out, as required, and that they fit accurately and are suitably weather-stripped.
- That bolts and other hardware are accurately positioned and adjusted.

Steel and vinyl clad windows are available in many types. Among the more common windows are double hung, pivoted, commercially projected, architecturally projected, casement, top hinged, and detention or security types. You must be sure:

- That the windows are of the prescribed type, size, grade, and section of members and conform to the specifications in details and workmanship.
- That the windows installed in each opening conform to the schedule shown or specified.
- That windows are carefully handled and stored and are free from distortion when they are installed.
- That all anchors, bolts, and clips needed for fastening the windows in place are installed.
- That frames are set accurately and truly and are caulked, as specified.
- That ventilators are set accurately and adjusted so that they operate freely and close tightly.
- That all operators and other moving parts are made to operate smoothly and easily without strain.

Most aluminum windows are built of extruded shapes of relatively light sections. They are available in most of the types listed for steel windows in the preceding paragraph, but they are generally of the double hung or casement types. Requirements for inspection are substantially the same as for steel windows. You must be sure that aluminum is of the grade and temper specified. Usually the manufacturers caution that windows must be kept locked and unopened until they are set and glazed. As the inspector, you should insist that this practice is followed. You must determine that care is taken to avoid marring the members during installation because of their relative softness.

### 2.15.2 Skylights

Skylights of the framed type may be constructed of galvanized iron, asbestos-protected metal, copper, aluminum, stainless steel, or Monel metal. You must be sure:

- That the skylights conform to the details shown.
- That all necessary steel supports, base curb, and reinforcement are provided.
- That skylights are flashed to all adjoining work in a watertight manner.
- That bars are provided with suitable shoulders for the support of the glass and with gutters for the collection of condensation.
- That glass is set on felt or in putty, as prescribed.
- That caps are set and adjusted to be watertight without imposing restraint or strain on the glass.

Skylights may be provided by installing corrugated glass in panels on roofs of corrugated types. As the inspector, you must be sure:

- That glass is of the type, thickness, and size specified.
- That the glass is fastened securely but without restraint or strain.
- That the installation is made completely watertight.

## 2.16.0 Glazing

Glass may be clear window, polished plate, processed, rolled figure sheet, figured plate, wire, prism, corrugated, safety, or heat absorbing.

You must make sure that the glass for each location is of the type, grade, thickness, surface finish, color, and size specified and that it conforms to include metalwork and steel structures, woodwork, and concrete work. To inspect different types of jobs, you must know what to look for in each type of surface.

## 2.17.0 Painting

As an inspector, you need a thorough knowledge of paint material, equipment, painting procedures, and disposal. You must also be able to inspect both exterior and interior jobs involving different types of surfaces, such as metalwork, woodwork, and concrete work.

Paints that are on the market today may not be on the market tomorrow. The never-ending advancement in technology and environmental restrictions will result in new paint materials, equipment, and methods. Many products today come either primed for painting or have a baked-on enamel finish, ready to install.

Paint materials have really changed over the years. Technology has gone from lead-based paints to lead-free paints, from enamel to water-based (latex) enamel, which is much safer for the environment, and so on. Remember, if you need to rehab an old building and paint removal is necessary, you are probably looking at a lead-based surface. If this is the case, check with the safety officer, the environmental officer, or the ROICC, so he or she can sample the exterior paint for lead. Also, when painting, make sure the paints are applied at temperatures above 40°F. Preparation is the key to any good paint job.

### 2.17.1 Exterior Painting

The inspection of exterior work includes steel structures and woodwork. To inspect different types of jobs, you must know what to look for in each type of surface.

#### 2.17.1.1 Steel Structures

Thorough preparation of the surfaces to be painted is the most important and the most frequently slighted element of good painting. Preparation of surfaces is of particular importance when paints with synthetic resin vehicles are to be used because they require exceptionally clean, dry surfaces for satisfactory results. As the inspector, you must be sure:

- That steel surfaces are cleaned by wire brushing, sandblasting, gritblasting, flame cleaning, cleaning with solvent, or airblasting, as may be specified.
- That all surface rust, dirt, grease, oil, and loose scale are removed.
- That tight scale is also removed if so specified.

When the use of chemical rust removers is specified or permitted, you must make sure:

- That the preparation is of an approved type and is brushed on thoroughly and allowed to dry.
- That all loose material is brushed off.

Galvanized surfaces must either be treated with diluted muriatic, phosphoric, or ascetic acid, rinsed, or allowed to dry, or be treated with the approved proprietary treating agents, as may be specified.

You must be sure:

- That ready-mixed paint, which tends to settle in the container, is thoroughly remixed to uniform consistency either by hand or power stirring. It is usually necessary to pour off the lighter fluid into another clean container, stir the heavier residue until it is uniform, and then add the lighter liquid gradually with continuous stirring until the paint has been worked to a smooth, even, homogeneous mixture.
- That paints delivered with pigments and vehicles in separate containers are similarly mixed, preferably with power stirrers.
- That thinning is permitted only when specifically authorized.
- That the amount of thinner added is limited to the minimum required for satisfactory application.
- That paint is applied only under satisfactory atmospheric conditions. The specifications usually specify the minimum temperatures at which painting may be done.
- That paint is not applied in a highly humid or rainy atmosphere or under conditions when condensation on the metal surface may occur.
- That the paint surface is visually dry before permitting painting to proceed.

Specifications may prescribe application by brush or spray, or permit either method. When paint is applied by brush, you must be sure:

- That each coat is thoroughly worked with suitable brushes until a smooth, even coat is obtained, free from brush marks, laps, holidays, and drips of excess paint.

- That the paint is worked thoroughly into all joints, cracks, and crevices, and that the coverage obtained and the area covered per gallon are within acceptable limits.
- That each coat is allowed to dry thoroughly before the next coat is applied.
- That the prescribed number of coats, each conforming to the requirements of the specifications, is applied.

Nonferrous metal is usually not painted. When it is prescribed, you must prepare, prime, and paint the surfaces, as specified.

#### 2.17.1.2 Woodwork

You must make sure:

- That surfaces are thoroughly dry and clean and are otherwise suitably prepared for painting before permitting work to proceed.
- That the priming coat is intact and is of suitable consistency to protect the wood, but not so tight that moisture in the wood is prevented from evaporating. For exterior work, sandpapering will not be specified.
- That the wood is smooth enough to assure the continuity and adherence of the paint film.
- That holes and cracks are puttied or filled with wood filler.
- That knots and pitch streaks are sealed with shellac, varnish, or other sealer, as prescribed.
- That the paints are of the specified type and quality.
- That the paints are mixed, colored, and thinned to provide a paint of uniform consistency and color.
- That the paints are applied by brushing, using high quality brushes, until the coat is smooth, even, free from brush marks, and of uniform thickness, texture, and color.
- That all cracks and crevices are sealed.
- That the paint is not brushed too thin to assure satisfactory hiding power.
- That each coat is allowed to dry thoroughly to a firm film before permitting application of the next coat.
- That the specified number of coats is applied.

To stain shingles and trim, use either the dipping or the brushing method. You must be sure:

- That, when dipped, the material is loosened so that the stain reaches all immersed surfaces.
- That it is left immersed until the stain has fully penetrated the grain.
- That excess stain is drained off.
- That stain is replenished and stirred to assure uniformity.

### 2.17.2 Interior Painting

Paint for interior walls and ceilings is usually flat wall paint. For small jobs the specifications may permit the use of approved commercial ready-mixed paints. Interior enamel may be specified where a semi-gloss or gloss washable finish is desired on woodwork or walls. The specifications may require either a standard undercoat for primer under enamel, or they may permit the use of the enamel with thinner. Paint and enamel may be obtained with color added, or color in oil may be added to the white paint on the job.

In general, requirements for inspection of interior painting are the same as those already described for exterior painting. Specifications may require the sanding of interior woodwork or rubbing with steel wool. Priming of plaster surfaces with glue may also be required. You must be sure that finish coats are of uniform gloss and color and are free from suction spots, highlights, brush marks, and other imperfections.

### 2.17.3 Special Work

Aluminum windows, doors, and trim usually will not be painted but will be given an alumilite or other anodic surface treatment at the factory. When painting is specified, the following steps will be necessary:

- Clean the surface thoroughly, so the surface is free from all dust, dirt, oil, and grease.
- Apply a primer of the type specified.
- Apply one or more coats of paint, as required.

Where dissimilar metals are in contact, electrolysis that uses the rapid corrosion of the anodic or positively charged material may occur.

- Magnesium, zinc, and aluminum corrode when in contact with steel.
- Steel and iron corrode when in contact with copper, brass, or bronze.
- Copper and its alloys corrode when in contact with the precious metals.

Zinc coating protects steel at the expense of the zinc coating. You must be sure that aluminum is well isolated from steel and that steel is well isolated from copper by felt, varnish, or other methods, as specified. Cathodic protection by impressed current is another method of resisting galvanic action.

Before paint can be applied successfully to bright galvanized metal, the surface film must be removed and adequate tooth provided by treating the surface with diluted hydrochloric, phosphoric, or acetic acid. A 5 percent solution usually is specified. You must determine that the surface is completely treated and is then rinsed thoroughly with clean water. A small amount of lime sometimes is added to neutralize any residual acid. When dry, surfaces so treated are primed and painted like other metalwork. Refer to the *Paint and Protective Coating Manual*, NAVFAC MO-110 for further information on procedures for painting.

## 2.18.0 Pile Construction

The inspection of pile driving is an extremely important part of an inspector's duties. There is probably no other type of construction work that requires quick, sound decisions to be made on the spot as frequently. Every inspector assigned to supervise pile driving operations needs to be familiar with all aspects, procedures, and details regarding the materials, equipment, and techniques used in pile driving operations.

### 2.18.1 Pile Driving

The accuracy with which piles must be located varies with the nature of the work. Extreme accuracy in positioning is not essential, for example, in a large mat foundation supported on piles at relatively wide centers. Accuracy is important in closely spaced footing clusters, and it is particularly important in bridge bent piers, in which the upper part of the piles is exposed and any misalignment is immediately noticeable and objectionable. The inspector must make sure that piles are positioned with the accuracy required by the circumstances but should avoid arbitrary and unduly burdensome requirements when they are not reasonable. When close tolerances are essential, the specifications may require the use of templates to assure proper centering. In such cases, the inspector must make sure that the templates provided are strong enough to withstand the abuse to which they are subjected and that they are maintained square and rigid.

You must take care to see:

- That the pile is handled without undue strain or shock.
- That the pile is set plumb in the leads.
- That the pile-driver leads are themselves plumb.

Give special attention to the rigging used for lifting precast concrete piles to prevent overstraining and cracking the piles. It is difficult to reposition a pile that has been started slightly out of position, and it is almost impossible to straighten up a pile that has been started crooked.

The inspector must be present during the driving of every pile. A digging permit must be present along with the proper safety procedures for the driving of the pile.

The inspector must make sure that the hammer used is heavy enough to be effective, considering the weight of the pile. The hammer should weigh as much as the pile being driven, and preferably it should be up to twice the weight of the pile. Hammers that are too light waste their energy in impact and inertia effects. In driving the piles down, force is so little that its effectiveness causes gross erroneous indications of bearing capacity, far above what the pile will actually sustain. The hammer must strike the pile squarely, or additional energy will be lost in springing the pile sideways. When batter piles are being driven, as an inspector you must make sure:

- That the leads are set for the proper batter.
- That the piles are held true to top position and batter as they are driven.

If timber piles are being driven, you must make sure:

- That protective rings of proper size are used at the heads of the piles to protect them from splitting.
- That pile shoes of approved design are used and properly secured when called for or required.

Use jetting to facilitate driving piles through many types of soil. As the inspector, follow the specifications insofar as they prescribe specific requirements for jetting. Usually jetting is done by one or more pipes with nozzles hung from the driver and operated independently of the pile. Some precast concrete piles have been used with the jet pipes cast in the piles. Such cast in jets cannot be moved around as needed to obtain the best effectiveness, and their use has been largely discontinued. You should permit the widest latitude possible regarding methods of jetting. However, you must make sure that jetting is discontinued a sufficient distance above the final point elevation of the pile to ensure that the pile base is in undisturbed soil and that the bearing capacity, calculated from the average penetration of the last few blows, is a reliable index.

You must make sure that the piles are driven to the minimum point elevation specified or to the minimum penetration below the ground, bottom of footing, or mud line, as may be specified. If neither point elevation nor minimum penetration is shown or specified, you should make sure that the driving is continued until the penetration per blow is reduced to the limit indicated by the formula for the required bearing capacity. If jetting is permitted, you must make sure that the driving is continued into undisturbed material. If the required bearing capacity is obtained with every short pile, you should report the situation to your superior promptly and request further instructions.

### 2.18.2 Difficulties Encountered in Pile Driving

Various defects are encountered in working with piles. Some of the common defects you may encounter in the inspection of wood and concrete piles are covered next.

#### 2.18.2.1 Wood Piles

As an inspector, you must be alert to detect and take steps to correct deficiencies in equipment and methods which may damage wood piles. You must learn to recognize the indications of such failures and require that the methods be modified, if necessary.

- Overdriving is usually indicated by bending or staggering the hammer.
- Breaking or shearing is indicated by sudden resumption of easy driving after the pile has apparently been driven to practical refusal. Similar behavior may occur when the pile breaks through a hard crust into a softer stratum.
- Sudden hard driving may indicate that the pile has struck a boulder.
- Sudden change of direction may indicate that the pile has sheared or broken, or that the pile has glanced off a boulder.

You should inform your superior when such difficulties occur and there is doubt as to the cause; damaged piles may endanger the safety of the structure they support.

#### 2.18.2.2 Concrete Piles

Common failures that may occur in precast concrete piles are cracking and spalling or shattering of the head.

Cracking may occur as a result of faulty mixes or curing, but it usually results from carelessness or improper rigging in handling. You should inspect piles frequently and minutely during driving to make sure cracks do not exist. They are particularly dangerous in the portion above the mud line where they may permit corrosion of the reinforcement to occur. When numerous cracks occur, report the situation to your superior so that a fill engineering investigation can be made and the causes corrected.

Spalling or shattering of the heads usually occurs in precast concrete piles because the proper followers and driving blocks are not used. The equipment should be modified if these troubles develop consistently. Piles with badly shattered heads cannot be repaired effectively so that they can be driven with assurance that fill-bearing capacity is obtained. It may, in extreme cases, be necessary to remove and replace the pile. If the pile is not damaged badly enough to warrant rejection, you should require the removal of all unsound concrete and building up to the finished cutoff.

With cast-in-place piles, difficulties are sometimes experienced through tearing of the shells or partial collapse after the mandrel is removed. A customary emergency measure is to drive a second shell inside the damaged shell. Inspect all shells by throwing a beam of light down the shaft with a mirror to determine that they are sound, intact, and tight. Piles that you reject as defective must be filled with concrete to eliminate a hole in the ground that could subsequently decrease the bearing capacity of adjacent piles.

#### 2.18.2.3 Steel Piles

The main difficulties with steel piles are twisting and distortion of the heads. Take special care to see that caps of proper design are provided to prevent this action.

## 2.19.0 Timber Construction

This section covers some of the major items in the inspection of the field construction of timber structures.

### 2.19.1 Delivery and Storage

When timber is delivered to the work site for incorporation into the structure being constructed, as an inspector you must make sure that it has been inspected and grade marked as required by the specifications or as approved by proper authority and that inspection certificates have been furnished by the inspecting agency. These certificates must be properly identified as pertaining to the material delivered, and the tally of material delivered must be correct. If it is treated material, you must make sure that the inspection reports of treatment are received and identified, and that the treatment complies with requirements. If inspection before delivery has been waived for any reason, you must make sure that the timber conforms in species, dimensions, and quality to the requirements of the specifications.

You must make sure that all timber is unloaded with reasonable care so that it is not damaged in handling. Exercise special care when handling timber treated with creosote or other preservatives to preclude damage penetrating the more heavily treated surface layer.

As an inspector you must require:

- That timber be stored in a well drained area so that it will be clear of the ground.
- That it be stacked so that there is good circulation of air through the pile.
- That in stacking, one end be raised so that water will drain off without standing.
- That the layers be adequately supported so that the lower layers will not be crushed by the weight of the material above them.

Preferably, the high end of the stack should be cantilevered forward at the top to provide a cave effect. Kiln dried timber, finish lumber, and millwork must be stored under cover.

### 2.19.2 Fabrication

You must allow latitude on the type and arrangement of plant and equipment to be used on the job, but you must make sure:

- That the plant is adequate for the work.

- That the plant is arranged to minimize interference with others or with station operations.
- That the plant is safe.

The scope of the plant will depend both on the magnitude of the work and on the extent of manufacture and prefabrication before erection.

When a large volume of rework is involved, all cutting, matching, and shaping, and as much prefabrication as possible will generally be done at a central woodworking plant at the site before erection. This procedure assures more accurate work at considerable saving in labor and is to be encouraged as tending to assure a better job. You should give special attention to checking first runs of each production run to make sure that each piece is cut and shaped to correct dimensions and pattern. When required by the project specifications, you must check to see that all fabrication is accomplished before treatment.

Prefabrication or preassembly may be practical on a larger scale if the character of the work permits. You should check all jigs and fixtures used in such processes to make sure that the units are true to exact dimensions within permissible tolerances and that the units are complete in all respects with attachments, holes for field bolts, and grooves for ring connectors, as required. In addition, make sure that handling devices for the completed units are adequate to assure their conveyance without distortion or damage. If the material is treated, make sure that all cuts and holes are given the surface treatment specified.

### 2.19.3 Erection

The erection plant will usually consist of automotive or locomotive cranes or travelers with the necessary slings, strongbacks, and lifting devices. You must ensure:

- That the equipment has satisfied all the weight handling requirements.
- That the equipment is safe to operate.
- That the equipment is in good working order.

Then you must make sure:

- That the erection methods used are safe.
- That the erection methods allow the work to be done effectively.
- That the erection methods are in keeping with the workmanship and quality of the Seabees.

You must then ensure:

- That all members are of the correct dimensions and are cut square or formed to exact shape and that they are fitted together truly with full bearing and without shims or other adjusting devices, except as specifically permitted.
- That bolt holes are round and undersized for drive fit.
- That all members are aligned correctly.
- That the work is adequately braced, guyed, or supported at all times to assure against distortion or collapse.

- That all bolts, driftpins, ring connectors, and other hardware are of the specified dimensions and materials, and galvanized if required, and are properly installed and tightened or driven to proper depth without damaging the timber.

You must reject and require replacement of any timber or hardware damaged during erection. You should make sure:

- That temporary holding or aligning devices are provided and used as necessary to assure tight, accurate work.
- That these devices do not injure or mar the finished work.
- That they are removed upon completion of erection.

On work involving the connection of a number of plies of heavy material, it is essential that ample length of tread bolts is available if the timber shrinks. As an inspector, you must make sure that all other detailed requirements of the specifications are fully met.

## Summary

In this chapter you have learned the difference between Quality, Quality Assurance, and Quality Control. You have also learned how to establish quality measures.

You have learned the responsibilities of the inspector and have been introduced to what you must check when inspecting the following parts of buildings and other structures:

- Concrete Construction
- Foundations
- Concrete Floors
- Concrete Framing
- Concrete Masonry Unit Walls
- Concrete Finishes
- Steel-Framed Construction
- Wood-Framed Construction
- Thermal and Moisture Protection
- Ceilings
- Finishes
- Trim
- Doors
- Windows and Skylights
- Glazing
- Painting
- Pile Construction
- Timber Construction

## Review Questions (Select the Correct Response)

1. NAVFAC has developed three quality management programs to ensure quality workmanship. Which program is NOT one of these NAVFAC programs?

   A. Construction Contract Quality Management
   B. Facilities Support Contract Quality Management
   C. Construction Quality Control
   D. Total Quality Management

2. What quality management program provides guidance to naval shore activities on how to obtain quality public works support services through quality assurance?

   A. Construction Contract Quality Management, P-445
   B. Facilities Support Contract Quality Management, MO-327
   C. Construction Quality Control, MO-435
   D. Total Quality Management, P-415

3. **(True or False)** The Navy recognizes quality as individual contribution and team effort in an organization working together to improve the process/system or product.

   A. True
   B. False

4. Quality control checks should be conducted at what time intervals?

   A. Monthly
   B. Weekly
   C. Daily
   D. Hourly

5. **(True or False)** Quality control is a management system established to ensure a construction project is completed with a specified minimum quality.

   A. True
   B. False

6. Quality control measures are to be listed in “plain language” on what sheet?

   A. QC
   B. CAS
   C. QM
   D. TQL

7. **(True or False)** The first step in ensuring quality is to establish a means for measuring QC progress.

   A. True
   B. False

8. **(True or False)** The Daily QC Inspector's Report is used to document the completion of required checks, tests, and inspections.

   A. True
   B. False

9. What office can approve any battalion recommended field adjustment requests (FARs) or customer requested changes?

   A. CESO
   B. S-7
   C. ROICC
   D. QC

10. Any changes to a project that require 50 or more man-days of additional direct labor or cause an increase in the cost of the project by $500 or more must be approved by whom?

   A. Battalion commander
   B. Operations officer
   C. QC officer
   D. COMSECONDNCB or COMTHIRDNCB

11. What staff provides direct liaison between the battalion and the ROICC?

   A. COMSECOND
   B. Operations
   C. QC
   D. Executive

12. What agency publishes the Construction Inspector's Guide, EP 415-1-261?

   A. COMTHIRDNCB
   B. COMSECONDNCB
   C. BUPERS
   D. U.S. Army Corps of Engineers

13. The primary function of an inspector is to make certain that the work is performed in every aspect in accordance with ________.

   A. drawings and specifications
   B. NAVFAC P-409
   C. local regulations
   D. QC guidelines

14. Concrete construction must meet the requirements set by ________.

   A. the battalion
   B. local regulations
   C. NAVFAC
   D. the American National Standards Institute

15. What type of concrete foundation is used when the subsoil is not considered well enough for spread footings?

    A. Mat (raft or floating)
    B. Triangle
    C. Pillar
    D. Concentric

16. What is the lowest foundation of a concrete structure?

    A. Bottom footing
    B. Substructure footing
    C. Spread footing
    D. Leveling footing

17. What type of bolts is usually set to a template?

    A. Check
    B. Floor
    C. Anchor
    D. L-bend

18. CMUs are usually made with nominal widths of what size, in inches?

    A. 3, 4, 5, or 6
    B. 6, 8, 10, or 12
    C. 3, 4, 6, 8, 10, or 12
    D. 1, 2, 3, 4, or 12

19. What type of construction is used for shop buildings requiring relatively long-span construction?

    A. Concrete
    B. Steel
    C. Wood
    D. Special

20. For information on headers for light-frame construction, you should refer to what publication?

    A. Frame Graphics Guide
    B. Woodworkers Guide
    C. Architectural Graphics Standard (AGS)
    D. Header and Footer Standards Manual

21. **(True or False)** For roofs, oriented stranded board (OSB) is widely used in residential construction.

    A. True
    B. False

22. What type of steel is most often used for steel floor framing?

A. Bessemer
B. Bingham
C. Light-gauge galvanized
D. Heavy gauge

23. If wood framing is used for walls instead of metal framing, the cost is _.

A. the same
B. doubled
C. tripled
D. somewhat less

24. Membrane waterproofing is achieved by the placement of a moisture-impervious membrane. Which materials can be used as membrane waterproofing material?

A. Polytetraflourotylene and cotton
B. Resin and polyurethane
C. Polyvinyl chloride, glycongen, and vinyl compounds
D. Polyethylene, bituminous membrane, and sheet rubber

25. Which material is NOT an example of insulating material?

A. Foamed glass
B. Foamed plastics
C. Glass fibers
D. Bitumen

26. Floor finish is any material used as the final surface of a floor. Which materials are used as floor finish?

A. Stucco and tile
B. Fiberglass and plaster
C. Sheet vinyl, wood, and slat block
D. Vermiculite and perlite

27. Stucco is composed of what ingredients?

A. Clay, sand, and water
B. Bitumen, felt, sand, and oil
C. Portland cement, hydrated lime, sand, and water
D. Lime, sand, and water

28. Stucco can be applied to masonry, concrete, or _ walls.

A. wood-frame
B. steel-frame
C. aluminum-frame
D. iron-frame

29. Built-up roofing is a membrane built up on the job from alternate layers of what materials?

A. Felt and oil
B. Fiberglass and resin
C. Bitumen-saturated felt and bitumen
D. Oil-saturated fibers and asbestos

30. **(True or False)** When inspecting built-up roofing, you should verify the particular combination of plies, felt, binder, and cover indicated in the project specifications.

A. True
B. False

31. Of the three types of trim, which is most often used by the NCF?

A. Metal
B. Wood
C. Plastic
D. Steel

32. Exterior doors are NOT often made of which material?

A. Solid wood
B. Steel
C. Sheet metal
D. Aluminum

33. Interior doors are NOT often made of which material?

A. Hardwood
B. Softwood
C. Sheet metal
D. Aluminum

34. **(True or False)** Skylights may be constructed from Monel metal, aluminum, copper, and galvanized iron.

A. True
B. False

35. You should not paint if the temperature is below what degrees Fahrenheit?

A. 10
B. 20
C. 30
D. 40

36. What type of paint is used for interior walls?

A. Oil-based
B. Lead-based
C. Flat
D. Carbon-based

37. **(True or False)** During pile-driving operations, the inspector must be present during the driving of every pile, and a digging permit must be maintained at the site.

A. True
B. False

38. During pile-driving operations, what condition is indicated by the bending or staggering of the hammer?

A. Broken hammer
B. Shearing of the pile
C. Boulder being hit
D. Overdriving

39. **(True or False)** During timber construction operations, the inspector must ensure the timber is stored with the high end of the stack cantilevered forward at the top to provide a cave effect.

A. True
B. False

40. **(True or False)** During timber operations, the inspector must reject and require replacement of any timber damaged during erection.

A. True
B. False

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*Construction Inspector's Guide,* NAVFAC P456 (series), Naval Facilities Engineering Command, Alexandria, VA, 1985.

*Construction Inspector Guide,* EP 415-1-261, Volumes 1-4, U.S. Army Corps of Engineers, Washington, DC, 1982.

*Construction Quality Control Manual,* NAVFAC P-445, Naval Facilities Engineering Command, Alexandria, VA, 1988.

*Construction Quality Control (CQC) Program,* COSECONDNCBINST/ COMTHIRDNCBINST 4355.1 (series), Commander, Second Naval Construction Brigade, Norfolk, VA, and Commander, Third Naval Construction Brigade, Pearl Harbor, HI, 1985.

*Equipment Operator Basic,* NAVEDTRA 12535, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

*Facilities Support Contract Quality Management Program,* MO-327, Naval Facilities Engineering Command, Alexandria, VA, 1985.

*NCF/Seabee Petty Officer 1 & C,* NAVEDTRA 12543, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

O'Brien, James J., *Construction Inspection Handbook "Quality Assurance and Quality Control,"* 3d cd., Chapman and Hall Publishers, New York, NY, 1989.

*Safety and Health Requirements Manual,* EM 385-1-1, Department of the Army, Washington, DC, 1995.

Wagner, Willis H., *Modem Carpentry,* The Goodheart-Wilcox Company, Inc., South Holland, IL, 1992.

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write or email us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate__ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

____________________________________________________________

____________________________________________________________

____________________________________________________________

(Optional) Correction

____________________________________________________________

____________________________________________________________

____________________________________________________________

(Optional) Your Name and Address

____________________________________________________________

____________________________________________________________

____________________________________________________________

# Chapter 7

# Maintenance Inspections

## Topics



To hear audio, click on the box.

## Overview

A newly constructed building, regardless of how well it is constructed, will immediately start to deteriorate. Proper maintenance and repairs are necessary from time to time to keep any structure in first class condition. An effective maintenance inspection program will disclose whether specific types of maintenance or repairs are needed on buildings or other structures. Such a maintenance program should be designed to do the following:

1. Detect deficiencies and damages promptly
2. Perform economical and workmanlike repairs quickly and efficiently

These requirements are essential in achieving maintenance standards.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify defects and damages associated with building inspection and maintenance, and determine proper procedures for repairs.
2. Identify defects and damages associated with waterfront structure inspection and maintenance, and determine proper procedures for.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

## 1.1.1 INSPECTION of BUILDINGS

Qualified inspectors must carry out frequent and regular inspections. The inspection program should also include emergency inspections to cover contingencies such as the following:

- Before and after unusual and severe storms where high velocity winds, abnormal tides, and heavy wave action have been experienced.
- When heavy snowstorms and extremely low temperatures are anticipated or experienced.
- After the occurrence of any type of operational hazard.

In some instances, an inspection will turn up minor defects that can be corrected promptly and prevent the occurrence of major defects requiring extensive repairs. As a Second or First Class Builder, you may be called upon to conduct maintenance inspections at Navy activities. This is a responsible job and one that should be assigned to well qualified personnel.

The types of structures that you inspect will depend upon the types available at your activity. Consider those discussed here as typical of the many types that you will find at some activities. Let us emphasize that this instruction is not intended to list every item that should be checked during an inspection of a specific type of structure. Additional and more detailed information applicable to the maintenance inspection of structures, roofing, painting, and waterfront facilities can be found in the appropriate MOs, which are published by NAVFAC and listed in the *Index of Naval Facilities Engineering Command,* NAVFAC P-349.

At some activities, forms that provide a checklist may be available showing major items to be covered in the inspection of the structure concerned. These forms may be prepared locally, and may differ from one activity to another. At times forms may not be available and the inspector will have to depend on past experience in building and construction, as well as sound judgment, to determine what to look for in the inspection.

After completing an inspection, you may have to make a written report on your findings. You may also make recommendations on the type and extent of repairs needed to correct certain defects. You must remember that each inspection is important and should be done carefully, thoroughly, and with safety in mind.

Many checkpoints can be covered in a maintenance inspection of buildings, especially when the inspection extends from the basement up to and including the roof. We will not attempt to cover all items that might involve a complete and thorough inspection of an entire building. We will cover some of the primary items of concern to an inspector at Navy activities.

### 1.1.0 Foundations

The foundation of a building transfers the dead and live loads of the superstructure to the soil that has enough bearing capacity to support the structure in a permanent, stable position. Footings are used under foundation components, such as columns and piers, to spread concentrated loads over enough soil area to bring unit pressure within allowable limits. Foundation design is determined not only by the weight of the superstructure but also by occupancy or use of the building or structure and by the load-bearing capacity of the soil at the site. The latter conditions may change and introduce maintenance and repair problems even in initially well designed foundations.

Foundations should be inspected at least annually and more often where climate, soil conditions, or changes in building occupancy or structural use present special problems. Evidence of initial foundation failure may be found during routine inspection of other structural components.

### 1.1.1 Foundation Displacement

A foundation should be checked regularly for proper elevation and alignment. Complete failure in a foundation is rare, but some settling or horizontal displacement may occur.

Some common causes of foundation movement include the following:

- inadequate footings
- overloaded structure
- excessive groundwater that reduces the bearing capacity of the soil
- inadequate soil cover that fails to protect against frost heaving
- adjacent excavations that allow unprotected bearing soil to shift from under foundations to the excavated area

The following conditions may indicate localized foundation displacement:

- cracked walls
- damaged framing connections
- sloping floors
- sticking doors
- leakage through a displaced roof

Corrective actions that can be taken to alleviate foundation displacement include the following:

- Replace any missing or dislodged part of the foundation immediately.
- Repair cracks or open joints in concrete or masonry foundation walls.
- Replace defective wood members.
- Replace unstable fill around the foundation with clean, properly compacted fill.
- Remove growing roots of trees or shrubs that may dislodge footings or foundations.
- Increase bearing area of inadequate footings.
- Maintain enough soil cover to keep footings below the freezing zone.
- Prohibit loads from exceeding the design loads of buildings and structures.
- Isolate foundations from heavy machine operations by providing independent footings and foundations for heavy machines.
- Provide air conditioning equipment, cooling towers, and compressors with cork or rubber isolation mounts to prevent transmission of vibrations to the structural frame of the building.

When excavations are made near the footings of buildings, care must be taken in removing bearing soil under existing structures. Temporary stabilization can be gained by shoring, underpinning, or needling to relieve pressure of the footings on the soil.

Sheetpiling may be driven and supported laterally to contain the bearing stress in the soil under the footings.

When water erosion removes soil from around and under footings, some means of erosion prevention such as ditching or the use of splash blocks must be used.

Footings that fail because of insufficient bearing area must have their bearing area increased. The amount of movement in the wall dictates the repairs necessary. Minor settlement, especially when uniform, may require no repair. If serious settlement occurs, the wall may have to be jacked back to its original elevation, a new footing provided, and repairs made to the wall.

Improved drainage is the basic solution to the most common groundwater problems, as shown in *Figure 7-1*. Moisture in structures caused by a high water table can be drained away from a foundation by the installation of open joint drain tiles surrounded by loose gravel fill. The drains should be laid so as to drain the water away from the footings into a sump with a float-controlled electric pump. Drain tiles should generally be pitched from a high point around the perimeter of the building to a low point below the floor slab where the sump and pump are located. Where roof drainage causes a foundation water problem, gutters and downspouts should be installed, preferably connected to a storm sewer. Gutters that are improperly hung or allowed to become clogged will overflow and lose their effectiveness. Leaks in gutters should be repaired promptly. Splash blocks or drain tiles should be installed in the absence of storm sewer connections to prevent pooling of water below downspouts. The drainage of surface water toward a building can be reversed by sloping the ground surface away from the foundation wall. Where that is not possible, ditching or installing drain tiles will serve the same purpose. The general grade of crawl spaces should not be lower than the surrounding area, which should be graded to drain away from the building.

**Figure 7-1 – Proper drainage for storm water.**

Foundations are subject to deterioration, whether from material or construction deficiencies, or from environmental conditions. The deterioration of foundation materials must be observed directly unless the effects are severe enough to cause foundation settling. Excessive moisture from surface or subsurface sources is a major cause of timber deterioration, providing the necessary condition for wood decay and encouraging insect infestation. Improperly seasoned wood is subject to cracking, splitting, and deflection. Concrete and masonry are subject to cracking, spalling, and settling, particularly under adverse ground and climatic conditions. Steel and other ferrous metals are subject to corrosion in the presence of moisture and sometimes by contact with acid-bearing soils. Signs of corrosion are darkening, rusting, and pitting of the metal.

Corrective actions taken to alleviate the deterioration of the foundation materials given above are covered in detail later in this chapter in the section dealing with the maintenance and repair of waterfront structures.

### 1.1.2 Crawl Spaces

Considerable deterioration extending from the foundation to the building superstructure can be caused by neglect of crawl spaces, especially in climates where it is necessary to enclose the space to maintain comfortable floor temperatures. Unventilated crawl spaces contribute materially to rapid absorption of moisture into structural wood and other materials, and the spaces soon become a natural habitat for fungus growth and termites. Sills, joints, and subflooring may be affected by wood decay. Condensation may occur in the studding spaces above the floor level and cause paint failures.

Crawl spaces should be carefully checked periodically. In checking these spaces, ensure that they are clean, clear, and accessible. An accumulation of rubbish in the space may provide a natural harbor for insects and rodents as well as impede access and possibly interfere with drainage. Scrap wood is a clear invitation to termites.

Look for disorganized storing of any material in crawl spaces. Also check for accumulations of water that may breed mosquitoes, cause fungus growth, and weaken soil bearing under footings.

Ensure that all ventilation openings are covered with suitable hardware cloth or copper screening to prevent entry of birds and rodents. In addition, see that access doors to crawl spaces are provided with a suitable padlock and kept closed.

### 1.1.3 Wood Decay

Wood decay is caused by wood-rotting fungi that grow in damp wood. Fungi attack wood members in contact with damp masonry foundations, moist ground or standing water, and water pipes on which moisture condenses. Poor ventilation around the wood hastens the process of decay. Wood decay is indicated by the following:

- damp, musty odor
- opening or crumbling of the wood
- presence of fine, dusty, reddish brown powder under the building
- hollow sound when the timber is tapped
- easy penetration of timber by a sharp pointed tool

Corrective actions taken to alleviate wood decay include the following:

- Removal of fungus-infested lumber. Spray infested areas with wood preservative.
- Elimination of the source of moisture. Add fill around masonry and grade swales to lead water away from the foundation. Where land contours do not promote runoff, install drain tiles around the foundation and lead them to a storm drain, or provide a dry well at a lower elevation than the water table at the foundation.
- Provision of ventilation to affected areas.
- Replacement of infested lumber with lumber treated with wood preservative.

### 1.1.4 Termite Control

An inspection should include a check, where applicable, for termites. Wood and wood and masonry members are susceptible to termite attack. Subterranean termites become established in wood that is in contact with moist soil. Their presence may be indicated by earthlike shelter tubes leading from the ground to the infested wood. Dry wood termites live all their lives in dry, sound, and seasoned wood. A reliable sign of dry wood termite attack is finding pellets in the immediate area. Among basic methods of preventing termite infestation are soil treatment, use of wood preservatives (such as pentachlorophenol), removal of surplus wood and other debris from the site, preventing contact of lumber with the ground, and covering openings into attic spaces with suitable hardware cloth or copper screening.

### 1.1.5 Moisture Control

In crawl spaces or dead areas under non-basement structures, moisture control problems other than building drainage develop from condensation of moisture rising from damp soil. The ideal method of preventing ground moisture from entering the building is to provide an impermeable vapor barrier on the warm side of insulation in floors and walls. In existing buildings this is not possible unless it is done in the course of major renovation.

The most practical solution is to provide a soil cover of water-resistant material. Fifty-five pound roll roofing has been the most widely used and successful solid cover, but recent tests indicate that 0.006 inch polyethylene plastic sheeting is effective and lighter to handle than roofing paper. The effective life of these plastic covers has not been established when used exposed to the air or under slabs. Soil covers may be rolled out on the soil from foundation wall to wall. It is not necessary to form a complete seal over the soil, but more than 90 percent of the soil should be covered, and cracks should be limited to 1 inch. Removing trash and debris and leveling sharp dips and mounds in the soil will increase the life of the cover.

## 1.2.1 Basic Supporting Members

For inspection purposes, the basic supporting members of wood frame structures are divided into the following three groups:

- sills and beams
- posts and columns
- girders and joists

### 1.2.1 Sills and Beams

Inspection and timely repair of sills and beams set on foundation walls, piers, or columns are important to the general maintenance of a structure. As in the case of uneven settlement of the foundation, severe damage can be done to the basic building by a reduction of the ability of the sill or beam to maintain upper components in their fixed position. Sill and beam defects can lead to many lesser but troublesome and expensive repairs of wall and ceiling cracks and misaligned doors and windows. Wood sills and beams should be inspected periodically for dry rot, and termite and rodent damage.

Sills and beams should be kept to a correct grade by using slate or steel shims and mortar pointing. Reinforcing plates, extra tie downs, or other means should be used to correct misalignment. Timbers exposed to ground moisture or severe weathering must be treated often enough to prevent deterioration, and sufficient ventilation must be assured to avoid rotting.

### 1.2.2 Posts and Columns

To prevent periodic deterioration, all posts and columns in contact with the ground should be thoroughly inspected. They should be treated with a preservative to resist decay and damage by termites. Posts and columns should be maintained plumb and in alignment.

Inspection of posts should include a test for soundness, made by jabbing the post on all sides with an ice pick or other sharp instrument; the amount of penetration indicates the soundness of the wood. In most softwoods, such as pine and fir, the pick should penetrate more than one half inch; in hardwoods, such as gum and oak, penetration should not exceed three eighths inch. Columns are more difficult to inspect in finished buildings, but when there are indications that columns are out of plumb, the covering finish material should be removed and a thorough inspection made. Out of plumb or misaligned columns may be indicated by cracks in plaster or other finish, but the same defects may be caused by failure of other structural components. Repairs and/or replacement work should not be made until the true cause of defects has been established.

If the foundation is not level because of uneven settling, the defect should be corrected before any attempt is made to plumb or align posts or columns. The floor above should then be shored with jacks or other devices and the supporting members plumbed and realigned.

Posts or columns that show signs of failure caused by overloading should be surveyed by an engineer competent to recommend repairs or replacement in terms of overall structural soundness.

### 1.2.3 Girders and Joists

As with the other basic supporting members, periodic inspection and timely repair of girders and joists are important to the general maintenance of a structure. Wood joists and girders are usually of a size that is not easily dried, so it is normal to expect shrinkage and seasoning splits and checks.

Checks and splits should be carefully recorded as to size, location, and depth. If records indicate increase in length or depth, then stitch bolts may be required. Stitch bolts are required in all structural members that have deep checks or splits three eights inch or greater in width and/or have slope of grain greater in width than 1 inch in 14 inches.

In the event of a structural failure, an engineering study should be made to determine whether the failure can be properly patched or if the entire girder or joist should be replaced. Many methods can be used to reinforce girders and joists. The selection of the proper methods should be determined by the loads to be carried, the cost, and clearance and accessibility. When either a permanent or temporary post is placed under a failed girder or joist, consideration of the size of the post and the cap, as well as adequacy of base support under the post, should be considered. Joist repair can be facilitated if the new member is sized one dimension smaller than the original member. Bridging that is removed should be replaced with solid bridging.

## 1.3.0 Floors and Stairs

Floor materials found in shore establishment buildings and structures for various occupancies include wood, concrete, terrazzo, and clay tile. Common floor coverings include asphalt, vinyl tile, and linoleum.

### 1.3.1 Wood Floors

Wood floors should be inspected quarterly for the following:

- loose nails
- warped, cupped, or loose boards
- raised ends
- slivers
- cracks
- loose knots
- raised nails
- water damage
- damage from improper cleaning or condensation
- wood decay

If floor damage requires replacement of strips or planks, the steps for the procedure are as follows:

1. Make two longitudinal cuts in the damaged strip or plank, as shown in *Figure 7-2, View A.*
2. Remove the section between the two cuts by cutting the strip with a chisel at midpoint, as shown in *Figure 7-2, View B.*
3. Remove the remainder of the damaged strip, taking care not to damage the tongues and grooves of adjoining boards, as shown in *Figure 7-2, View C.*
4. Remove the lower part of the groove of the new closure strip or plank, as shown in *Figure 7-2, View D.*
5. Insert the tongue of the closure into the groove of the adjoining board, and nail with two eight penny annular ring finishing nails through the top surface. When possible, the end joints should be located so the nails will enter the joist. In new closure areas of flooring laid in mastic on concrete, remove the existing mastic and apply new mastic of the type recommended by the flooring manufacturer before installing the new closure.
6. Set exposed nails, as shown in *Figure 7-2, View E.*
7. Dress the new portion to the level of the adjacent floor by sanding both areas to a continuous, smooth plane.
8. Dry sweep the area to remove all particles of dust.

**Figure 7-2 – Method of replacing tongue and groove flooring.**

9. On-open grained woods, brush on a paste filler. After the filler has partially dried, rub it into the pores of the wood with a circular motion. Wipe the surface lightly to remove any surplus filler. Inadequate filling is indicated by pockmarks and results from wiping off too much of the filler or from unusual absorption by the wood. Eliminate such deficiencies by repeating the filler application.
10. Seal and wax the floor (two coats).

### 1.3.2 oncrete Floors

Concrete floors should be inspected annually for dusting, spalling, cracking, and settling. Concrete floors of proper composition, installation, and curing require comparatively little maintenance unless they are exposed to conditions such as the following:

- severe abrasion and heavy vehicle loads from industrial traffic
- deteriorating effect of grease, oils, and food acids encountered in galleys, sculleries, and similar food preparation spaces
- caustic soaps and solutions

The corrosive agents in highly acid or alkaline liquids attack concrete floors and cause spalling and pitting. Where trucking is done over concrete floors such as warehouses, trucks should be fitted with wide-faced wheels; if vehicle abrasion and shock continue to raise maintenance demands, the application of a heavy duty topping to the concrete should be considered.

**⚠ CAUTION ⚠**

Do NOT paint concrete floors except for functional requirements, such as marking safety lanes or similar areas. Painting for appearance is unjustified and impractical; traffic areas on painted floors will wear first, making the floor unsightly and presenting a difficult cleaning problem.

One of the more common problem areas with concrete floors is the development of unsightly cracks. These cracks may be caused by shrinkage, temperature changes, settlement, or lack of rigidity of supporting beams or other structural members. When such movements are recurrent and can be eliminated only by major structural changes, little can be done except to keep the cracks filled with a mastic material. In many cases comparatively small cracks may be filled with varnish or resin. Although the cracks will remain visible, they will not leak or gather dirt. When the cause of larger cracks has been determined and corrective measures taken to eliminate further cracking, the cracks can be permanently repaired by filling them with non-shrinking cement mortar.

Patching will not permanently correct cracks in slabs on grade caused by vertical movement resulting from excessive load on the slab, inadequacy of the base, or insufficient bearing capacity of the soil. Slab failure under these circumstances can be corrected only by a major maintenance operation, such as mud jacking. The procedures for repairing concrete floors are covered in detail in the section of this chapter that deals with the maintenance and repair of waterfront structures.

### 1.3.3 Terrazzo Floors

Terrazzo floors should be inspected annually for loose or broken segments and damage from improper cleaning. Terrazzo appears to be dense and very hard, but the cement is sensitive to harsh soaps and cleaners, which can cause pitting, roughen the surface, and make the floor permanently susceptible to dusting and dirt trapping. Repairs to a terrazzo floor should be made according to the specification for new floors. Only floor specialists who are capable of the class of workmanship necessary should be entrusted with the work.

### 1.3.4 Clay Tile Floors

Clay tile floors should be inspected annually for missing, loose, or broken tiles, open joints, and damage from improper cleaning. If floor damage requires replacing broken or badly stained tiles or resetting loose tiles, the steps for the procedure are as follows:

1. Remove the damaged or loose tiles.
2. Clean the mortar from the edges of the surrounding tile.
3. Roughen the concrete underbed to provide a good bond for the new setting cement.
4. Dampen the underbed and edges of the surrounding tile and place the setting mortar mixed in the proportion of 1 part Portland cement to 3 parts sand.
5. Set the tile, tamping it to the level of the finished floor.
6. Fill the joints with grout or pointing mortar, matching the color and finish of the joints of the original floor as closely as possible.

If the mortar in the existing joints has deteriorated, cracked, or crumbled, thoroughly clean the joints of all loose mortar and re-point them with grout or pointing mortar as follows:

- Grout joints one eighth inch or less in width with neat Portland cement grout of the consistency of thick cream.
- Point joints one eighth inch to one fourth inch in width with pointing mortar, consisting of one part Portland cement to one part screened sand.
- Point joints wider than one fourth inch with pointing mortar consisting of one part Portland cement to two parts screened sand.

7. In locations such as galleys and food preparation areas where the floor is directly exposed to the effects of corrosion agents, you should use acid-resistant joint material to fill the joints. The acid-resistant mortars are proprietary products and should be mixed according to the manufacturer's recommendations.

### 1.3.5 silient Floor Coverings

Resilient floor coverings include linoleum, vinyl plastic tile, vinyl asbestos tile, and asphalt tile. Linoleum should be inspected annually for loose seams, buckling, serious indentation, and damage from improper cleaning. Resilient tile should be inspected annually for the following:

- missing, loose, or broken tiles
- open joints
- serious indentations
- damage from improper cleaning

#### 1.3.5.1 Linoleum

Linoleum is repaired using the following steps:

1. Lay out the area along rectangular lines and lay an oversize section of new linoleum over the damaged area.
2. Cut through the two layers simultaneously to ensure a tight fit.
3. Remove the damaged section and clean the exposed underfloor of adhesive, dust, and dirt.
4. Replace the damaged felt lining.
5. Apply a linoleum adhesive to the exposed surface and fit the new linoleum in place.
6. Roll the area with a linoleum roller and place weights of suitable size on the patch to assure proper adhesion.

#### 1.3.5.2 Resilient Tile

Resilient tile is repaired by removing the damaged section and replacing it with new material. Tile is more easily replaced than linoleum because of its smaller size.

1. Remove the damaged tile.
2. Scrape the exposed area level and clean off all mastic, dust, and dirt.
3. Replace the damaged felt lining.
4. Install the new tile in suitable cement or mastic according to the manufacturer's recommendations.

### 1.3.6 Stairways

Stairways should be inspected at least quarterly for adequacy of support and safe condition of components. A good inspection of stairways includes a check for the following conditions:

- Wood framing that has cracked, weathered, or rotted.
- Concrete that has settled, cracked, or spalled.
- Metal supports that are rusted or loose.
- Treads should be inspected for loose or broken tread nosing, excessive wear, paint or tread covering deterioration, and loose, eroded, or slippery tread surfaces. Exterior treads should be sloped or drilled to drain properly.
- Handrails should be inspected for loose fastenings and material deterioration.
- Newel posts and balusters should be checked for looseness and missing parts.
- Squeaks indicate loose treads that can be corrected by driving finishing nails through the treads into the riser or carriages or by removing the molding under the tread overhang, driving wood wedges between the tread and riser, re-nailing the tread tightly, and replacing the molding.
- In open string stairs, a tread that is worn but not split or broken may be removed and reversed.
- Split, broken, or otherwise seriously damaged treads should be replaced with new boards.
- Housed treads that cannot be removed may be repaired by leveling the worn surface with asphaltic mastic or other suitable plastic materials and covering the tread with a suitable floor covering. Plain and nonslip nosing of steel, brass, bronze, aluminum, and molded hard rubber is commercially available and should be applied according to the manufacturer's recommendations.

## 1.4.1 Exterior Walls

Exterior walls fall into three structural categories:

- Load-bearing walls (carrying structural loads)
- Nonbearing walls (carrying only their own weight)
- Supported or enclosed walls, sometimes called curtain walls (with their weight supported by structural members)

Exterior walls are made of a wide variety of materials, including the following:

- Wood (shingles, weatherboard siding, plywood)
- Concrete and masonry (brick, concrete or cinder block, reinforced or non-reinforced concrete, structural clay tile, stone, stucco)
- Metal (corrugated iron or steel, aluminum, enamel coated steel, protected metals)
- Mineral products (asbestos shingles, asbestos cement sheets, and glass block)

### 1.4.1 Wood Exteriors

Wood exteriors should be regularly inspected for damage from wear, accidents, and the elements. They should also be inspected for damage resulting from insect pests. This may be done by tapping the wood with an object. A dull or hollow sound is an indication of damaged wood, which may be the result of insect pests. Painting and surface treatments should be inspected quarterly for deterioration. Exteriors should be inspected for loose, warped, cracked, or broken boards or shingles.

Moisture is the most prevalent cause of failure of exterior walls. Stains, paint deterioration, and rot are usual signs of moisture damage. Condensation within and behind walls is a less obvious but equally damaging factor. Insufficient, loose, or displaced nailing produces separations and cracks that admit moisture and reduce the stability of wood walls.

Foundation settlement or displacement may cause misalignment of framing members and consequent damage to walls, including cracks in siding and breaking or displacement of boards or shingles. Make a careful check to determine that existing structural, functional, and material conditions warrant repair to the existing wall, rather than complete residing, insulating, or other overall repair or rehabilitation. Where existing situations are satisfactory, replace damaged material with like material.

1. Cut back sufficient areas beyond the damaged part to obtain good jointing and sound nailing.
2. Tighten nails in existing material to be left in place.
3. Be sure that material receiving the new nailed pieces or sections is sound and true.
4. Cover replacement wood with treatment and/or paint matching the original design.

When as-built plans are available, it is good to examine the original construction detail for assurance that out of vision construction and utilities will not be damaged. Warped, split, or curled shingles should be removed with a ripper and replaced in a similar manner as roofing shingles. Panel siding should be periodically checked for looseness and faulty caulking. It is usually more economical and satisfactory to replace damaged or deteriorated panels than to attempt patching.

### 1.4.2 Concrete and Masonry Exteriors

Concrete and masonry exteriors such as concrete block, cinder block, and brick require less frequent maintenance than most outside materials, but some failures are common. Exteriors should be inspected quarterly for the following:

- structural cracks
- open mortar joints
- condensation in weep holes
- settlement
- efflorescence
- stains
- deterioration of paint or other surface covering

The most common fault found in block and brick walls is defective mortar joints. These defective joints can be corrected by re-pointing. The steps for the procedure are as follows:

1. Cut out cracked open mortar joints to a depth of at least one half inch. Cutting can be done by hand, but if large areas are involved, it is usually cheaper to use power tools. Take care not to damage brickwork during the cutting process.
2. Remove all dust and loose material with brushes, compressed air, or a water jet. If water is used, no further wetting of the joints may be needed unless the work is delayed.
3. Repair the joints by tuck pointing.
4. Use mortar of about the same density as the original mortar if it can be determined; otherwise, use a prehydrated mortar mix in the following proportions by volume:
   - 1 part of Portland cement
   - 1 part of lime putty or hydrated lime
   - 6 parts of sand
5. Be sure the joints are damp, and then apply the mortar by placing it tightly into the joints in thin layers.
6. Tool the joints to smooth, compact, concave surfaces.

Another problem area easily detected during a routine inspection is efflorescence. Efflorescence usually appears as a light powder or crystallization caused by water soluble salts, deposited as water evaporates within the mortar or the masonry unit. Aside from detracting from the appearance of a wall, efflorescence may indicate the penetration of moisture into the wall to an extent that could cause deterioration of interior wall coverings and finishes. Efflorescence may be removed by vigorous and repeated scrubbing with a stiff fiber or wire brush and clean water. An inspection should be made to determine the source of the stain. If efflorescence appears at the edges and not near the center of the masonry unit, the mortar is probably at fault. If it appears near the center of the unit only, the masonry unit is at fault. The most immediate remedy to prevent recurrence of efflorescence is to check causes of excessive moisture that contacts the wall, such as defective flashings, gutters, downspouts, copings, and mortar joints.

Leakage through concrete walls is caused by cracks in the concrete and, in rare cases, porosity of the concrete. As with brick walls, the cracks may be caused by the following:

- foundation settlement
- excessive floor loadings
- temperature settlement
- contraction in structural members
- poor materials and poor workmanship in the original construction

You may encounter the following types of cracks:

- horizontal movement cracks
- vertical and diagonal movement cracks

- shrinkage cracks

An engineering investigation of the causes of structural defects should govern the nature and extent of major repairs.

### 1.4.2.1 Vertical and Diagonal Movement Cracks

Vertical and diagonal movement cracks generally occur near the ends or offsets of buildings. They may also be found extending from a windowsill to the lintel or a door or window on a lower floor. They vary from one eighth to three eighths of an inch in width and follow the mortar joints, but in some instances, they may break through the bricks or other masonry. A diagonal movement crack is shown in *Figure 7-3*.

### 1.4.2.2 Shrinkage Cracks

Shrinkage cracks are the fine hairline cracks that are found in mortar as well as in concrete walls. The most noticeable ones are those running vertically, but a close examination of a section of a wall that leaks may also show them in the horizontal or bed joints of brick or block walls.

**Figure 7-3 – Diagonal movement crack.**

### 1.4.2.3 Horizontal Movement Cracks

Horizontal movement cracks are usually long, wide cracks in the mortar joints that occur along the line of the floor or roof slab or along the line of lintels over the window. Where these cracks turn the corner of a building, they frequently rack down. *Figure 7-4* shows a typical horizontal movement crack and racked-down corner.

### 1.4.2.4 Racked-Down Corners

Racked-down corners occur where the horizontal movement cracks along the side and end of a building meet. Frequently the horizontal crack not only continues around the corner but forms part of a diagonal crack that takes a downward direction and meets a similar crack from the other side, forming a V. The bricks inside this V are loosened and must be reset.

**Figure 7-4 – Typical horizontal movement and racked-down corner cracks.**

The steps you should follow to repair

racked-down corners are as follows:

1. Remove all the bricks inside the V, including any bricks that have been broken, as shown in *Figure 7-5*. This forms irregular sides and helps to hold or key the brick in place.
2. After the bricks are removed, clean the sound bricks and obtain as many new matching ones as you need to fill the opening.
3. Re-lay the bricks in mortar up to and even with the horizontal crack running along the side and end of the building. If all joints are made the same width as the original joints and the mortar tends to match the old mortar, a very presentable job will result. As the bricks are built up, coat the backup bricks with mortar so that the newly laid bricks will be bonded to them.

**Figure 7-5 – Damaged brick removal.**

4. Partly fill the top joint with mortar that is on line with the horizontal crack. This can be done by pushing the mortar into the joint with a narrow pointing trowel. When about half the depth of the joint is filled, fill the remainder with sealing compound. This system of mortaring only half the joint supports the brick above but forms a weak plane along the top of the racked-down areas. If movement takes place, the mortar joint breaks, but the re-laid bricks remain in place. The sealing compound keeps the joint watertight.

## 1.5.1 Interior Walls, Partitions, and Ceilings

Interior walls are usually made up of gypsum and plaster materials; the most common material is drywall. Other materials include these:

- plywood
- wood paneling
- ceramic tile
- glazed faced masonry

Partitions may be made of the following materials:

- plywood
- drywall
- hard pressed fiberboard (particle board)
- structural clay tile
- gypsum block
- metal
- glass

Ceilings are usually made up of these materials:

- drywall
- acoustical materials
- plaster

Some of the major defects to look for when inspecting the more common types of interior walls, partitions, and ceilings are given in the following sections.

### 1.5.1 Plastered Surfaces

Cracks, holes, and looseness in plastered surfaces are signs of excessive internal or external stresses, and may be caused by the following:

- poor workmanship, such as improper proportions or application of the plaster
- imperfect lathing
- poor atmospheric conditions during plastering
- moisture infiltration or an excess of moist air generated inside a building
- settling or other movement of some part of the building frame

External stresses that cause plaster damage should be investigated and corrected before repairs are made to the plastered surfaces themselves.

#### 1.5.1.1 Structural Cracks

Structural cracks are easily identified because they are usually large and well defined, extending across the surface and entirely through the plaster. They generally develop during the first year after completion of construction and in most cases can be successfully and permanently repaired. Before repairs are initiated, the cause of the failure should be determined from an engineering standpoint and necessary precautions taken to prevent recurrence of the failure. Structural cracks may do the following:

- extend diagonally from the corners of door and window openings
- run vertically in corners where walls join
- run horizontally along the junction of walls and ceilings
- occur in walls where two unlike materials join

To repair a structural crack:

1. Use a linoleum knife or chisel to cut out and remove loose material. The crack must be formed to a V shape to provide adequate keying action by making the surface opening narrower than the bottom of the crack. Exercise care to widen the crack only enough to ensure a good bond between patching plaster, old plaster, and lath.
2. Clean the expanded metal or wire lath and open the mesh, so when patching plaster is forced into the opening, a good key is formed.
3. Break out the key between wood laths so that a new key is formed when patching material is forced into place.
4. Thoroughly wet wood lath before applying patching plaster. Brush out all loose material, remove all grease or dirt from surrounding surface areas, and wet the edges of the groove.

5. Press the first coat of patching plaster firmly into place, filling the groove nearly to the surface.
6. Allow it to set until nearly dry but not hard.
7. Complete the patch by applying a coat of finished plaster, striking off flush, and troweling smooth.

If the edges of the old plaster and the wood lath are not thoroughly wetted, they serve as a wick to draw the water from the fresh plaster, causing it to dry out, remain chalky, and crack around the edges of the patch. Give special attention to the edges of the patch when applying the patching plaster to ensure a firm, solid bond between old and new plaster.

### 1.5.1.2 Loose Plaster

Loose plaster is indicated by the bulging and cracking of large areas of the plaster surface. The extent of loosened plaster can be determined by lightly tapping the surface with a small hammer, with the resultant sounds indicating the extent of the loose area. Loose plaster may result from excessive moisture caused by one of these:

- leaks in the roof
- seepage through an exterior wall
- plumbing leaks
- heavy condensation

This excessive moisture causes the plaster to become soft, which destroys the bond to the base, causing the plaster to loosen. In some cases, the plaster may bulge or sag but continue to hang in this condition quite a long time before falling, being held together only by the hair or fiber in the base coat. Occasionally moisture causes the fastenings holding the lath to the structural frame to corrode, permitting both the lath and plaster to bulge or sag. Another cause of bulging plaster is the use of incompletely hydrated lime in the plaster mix. In localities where high humidity is prevalent, moisture causes a continued hydration of the lime that weakens the plaster and destroys the bond between plaster and base. This condition usually occurs in the spring and summer months, starting from the first to third year after plastering and continuing indefinitely.

Before the damaged plaster is repaired, it is necessary to locate and eliminate any source of moisture. Temporary repair to prevent loose plaster from falling until permanent repair can be done may be made by securing the loose plaster with a section of wallboard nailed securely to the wall or ceiling over the area affected. Nails should be long enough to penetrate the plaster and obtain a firm bearing in the studs or joists. Repairs of a permanent nature should be made as soon as possible.

1. Remove all loose plaster around the break, working well back in the surrounding area to a point where solid plaster (well keyed to the lath, which in turn is solidly secured to the structural frames) is obtained.
2. Remove the defective lath and replace it with suitable plaster backing, such as metal lath or plasterboard.
3. Securely refasten all lath that has become loosened.

### 1.5.2 Drywall and Partitions

Maintenance and repair of interior wallboard generally requires that nails, screws, and other fasteners be kept in a secure condition.

- Cracks in gypsum type of boards may be repaired similarly to cracks in plaster.
- Joints in drywall construction that fail must be re-cemented and taped.
- Broken sections of interior wallboard are generally best corrected by replacement of an entire panel.
- Wood paneling that develops cracks may be sealed with plastic wood or putty.
- Broken panels or siding usually are best repaired by replacement of a complete section, panel, or board.

When repairs are completed, the repaired area should be finished to match the adjoining area. All fastening, such as nailing, screwing, or gluing, must be at least equal to the as-built construction. Non-load bearing partitions should be inspected periodically for marks, dents, scratches, cracks, or other surface damage. Non-load bearing partitions may be repaired or replaced without regard to the structural frame or ceiling and may be relocated to provide other interior arrangements of space.

### 1.5.3 Doors

Exterior doors are more subject to abuse and to weathering than interior doors. In general though, defects encountered in inspecting both exterior and interior doors are similar. Doors should be inspected quarterly for defects, such as the following:

- poor fitting
- deteriorated or damaged frames
- paint deterioration
- material damage, such as cracked or broken glass, split or cracked wood panels, warped or dented metal, and warped or broken screening
- broken or inoperative hardware, such as locks, hinges, and slides

Check all doorstops, thresholds, and weather stripping for cracks, looseness, and workability, where applicable.

#### 1.5.3.1 Wood Doors

Mechanical injury to mullions, headers, jambs, or hardware usually causes trouble with large wood framed and braced doors. Decay resulting from exposure to weather or shrinkage of door members also causes distortion or failure. Frequently the free edge of the door sags and causes the door to bind at the bottom and to open at the top. When inspecting these doors, you should check the following:

- jamb opening to ensure that the hinge and lock sides are plumb and parallel
- door head to ensure that it is level
- anchorage of the jamb and the hinges
- lock faceplates for projection beyond the face of the door

Settling of the foundation or shrinkage and deflection of framing members often causes trouble at door openings.

- When the greatest settlement is on the hinge side of a door, the door will tend to become floor-bound at the lock side.

- When settlement is greatest on the lock side, the door will bind at the head jamb. As a result, the bolt in the lock will not be in alignment with the strike plate, making it impossible to lock the door securely.
- Vertical settlement and horizontal deflection will cause the jamb opening to become out of square.

On most wood doors the simple correction is to plane as required at either the top or bottom for proper clearance. When the door itself has shrunk or is warped, swollen, or sagged, the procedures for corrective action are as follows:

1. When a door shrinks, remove the hinge leaves and install filler, such as cardboard or metal shim, at the outer edge of the jamb and hinge mortise. This forces the door closer to the jamb at the lock edge, and if the hinge pins do not bend, the door should then operate satisfactorily. Each hinge should be shimmed equally to prevent the door from becoming hinge-bound. When the door has swelled, place shims in the inner edge of the hinge mortise, as shown in *Figure 7-6*.

**Figure 7-6 – Hinge adjustment for binding or sticking doors.**

2. Restore a warped door to its normal shape by removing it and laying it flat. Weighing it down may also be necessary. If it is still warped after a reasonable length of time, battens can be screwed to the door to restore it to true plane. Screw eyes, rods, and turnbuckles help straighten a door by gradually pulling it into place.
3. Install a diagonal batten brace from the top of the lock side to the bottom of the hinge side to repair a sagging door permanently. The diagonal brace must cover the joint between the rail and the stile and be securely fastened to both members at the top and bottom and at other intermediate rail members. Make a temporary repair by installing a wire stay brace equipped with turnbuckles and placed diagonally in the reverse direction from a batten brace.
4. Doors or door members may require rebuilding because of neglect or abuse. Remove the door to a flat surface and replace the damaged member. Carpenter’s clamps assist in holding door members square while nails or screws are driven.

5. Trim the door when the preceding methods fail to correct the trouble. Do not cut the doors immediately following rain or damp weather. When the door is dry, it may fit too loosely.

Failures in panel doors are similar to those in large wood doors. In addition, panel doors are subject to binding at the hinge edge, as well as to friction between the dead bolt and strike plate or between the latch bolt and strike plate.

### 1.5.3.2 Metal Doors

Metal doors, commonly used in warehouses, hangars, stockrooms, galleys, and other areas where hard service or other operations require them, are of various types: metal-clad, hollow metal, and solid metal, with variations including interchangeable glass and screen panels.

Because most metal doors and fittings are shop designed and fabricated, it can be assumed that they will maintain their shape and mechanical operating ability provided hinges, locks, and other fittings remain secure in their fastenings. This is done by checking screens, nuts and bolts, and special fasteners and operating devices regularly, keeping them tight and in good order. Building settlement, mechanical failure, and collision may require investigation and corrective measures for a basic cause of misalignment in the structure framing itself. Frames must be plumb and corners square, so the door fits the opening with proper clearances. Weatherproofing and caulking must be maintained in a workmanlike manner. Mechanically operated doors must be removed and straightened, repaired, or replaced. Repair material and finishing should match the existing material. Shop repair of metal doors should meet acceptable standards for welding, riveting, and sightliness. Replacement of surface metal on fireproof metal clad wood doors must be weathertight and of material of the same gauge as originally provided. Service doors in galleys, stockrooms, and other areas where personnel pass in and out frequently with arms loaded should be provided with kick plates and with bumper protection to prevent slamming against walls.

### 1.5.4 Windows

Both wood and metal windows are found in structures at Navy activities, and the inspector should be alert to detect any defects present in either type. Windows should be inspected quarterly, as appropriate, for the following:

- loose fitting or damaged frames
- ill fitting or broken sashes
- cracked or broken glass
- deteriorated putty or caulking
- broken or worn sash balances
- missing or broken hardware

Window failures may result from various causes, the most common of which is weathering. Weathering causes loss of putty, paint, and caulking, and this leads to deterioration and rotting in wood windows and rusting in metal windows. If atmospheric conditions cause ordinary putty to deteriorate quickly, plastic glazing compound should be substituted. Caulking around window frames must be maintained in good order, as shown in *Figure 7-7*, to prevent leakage of moisture and air.

**Figure 7-7 – Required caulking around window frames.**

Rust spots on metal sash and frames should be wire brushed or sanded, cleaned with a rag saturated with mineral spirits, and then painted. Problems of alignment caused by building settlements must be adjusted in conjunction with overall corrective measures, which may involve stabilizing the foundation and framing.

## 1.6.1 Roofs

Roof structures can be classified according to their shapes and structural limitations, such as one of the following:

- flat
- pitched
- sloped, such as shed or lean-to types
- curved, such as provided by bowstring trusses or circular arches
- mansard, which is a combination of a steep pitched and a shallow pitched roof

Roofs that are supported on exterior walls and at a ridge or bearing at some intermediate point are usually referred to as frame roofs. Those that are truss or arch supported only at the exterior walls or other trusses or columns are referred to as trussed roofs. Rafters are the structural members of a frame roof.

### 1.6.1 Frame Roofs

Rafters are generally more accessible to inspection than other structural members of a frame building. They are usually uncovered on the underside, so defects and failures can be visually detected.

- Warped, twisted, or broken rafters can be replaced, or if the roof surface is sound, they may be repaired.
- Warped and twisted rafters can be straightened by the addition of solid bridging and bracing, and broken pieces can be scabbed without harm to the roof covering.
- Railers, sheathing, and other roof framing members that are damaged by decay must be replaced.

A prevalent cause of the need for extensive roof maintenance is failure of the roof covering. Leaky roofs no longer protect the framing, thus allowing weathering and eventual decay.

### 1.6.2 Trussed Roofs

Trusses should be inspected at least once a year to check for the existence of problems such as the following:

- failure in upper and lower chord or web members
- bowing of overstressed compression members
- evident separation of joints caused by shrinkage
- development of splits along lines of bolts
- development of splits in ends of web members and chord splices
- pronounced sagging of trusses

Normally, if an actual failure has occurred in a chord member, that member should be replaced.

1. Shore the truss at the panel points along the bottom chord.
2. Remove the damaged member.
3. Using the damaged member as a template, fabricate and install the new member.

The replacements should be of the same material as the truss and of the same moisture content, if possible. To replace any truss member is usually a costly operation. Unless the building is for permanent use, the member should be repaired or augmented rather than replaced.

Checking and splitting are normal reactions in most timber as it dries out. The checking and splitting are more pronounced when unseasoned lumber is used. If the split passes through the bolt holes and continues beyond into the member, it will require attention. The recommended remedy for splitting and checking is the installation of stitch bolts.

*Figure 7-8* shows the use of stitch bolts in repairing scabs in which end splits have developed. Also shown is stitch bolt repair to wood columns in which splitting and deep checking along the grain have occurred. The bolts used for this purpose are 1/2 inch bolts, threaded on both ends. To repair scabs:

1. Drill 1/2 inch holes 2 or 4 inches from the end of the split member and perpendicular to the axis of the member.
2. Insert the bolt.
3. Place a 2-inch square cut washer at each end
4. Tighten the nuts.

Installing the stitch bolts before tightening the bolted connection is advisable.

**Figure 7-8 – Repair of minor splits using stitch bolts.**

## 1.7.0 Roofing

Failures to inspect for recognize, and correct minor defects and deterioration in its earliest stages is probably the greatest cause of premature roof failure. All roofing materials deteriorate on exposure to weather, and the rate of deterioration is affected largely by the kind of material involved and the conditions of exposure.

In inspecting structures, you will probably inspect different types of roofing such as built-up, asphalt shingle, wood, metal, tile, and slate. No attempt is made here to cover in detail the many types of roofing materials and their component accessories produced by numerous manufacturers, but rather to discuss in general terms the inspection and preventive maintenance procedures peculiar to built-up and metal roofing.

### 1.7.1 Built-Up Roofing

Built-up roofing is exactly what the name implies, a membrane built up on the job from alternate layers of bituminous saturated felt and bitumen. The bitumen used to saturate the felt and used as a plying cement and coating for the saturated felts may be asphalt or coal tar pitch. These can usually be distinguished by their odors. Asphalt has a distinctly oily odor, and coal tar pitch a somewhat pungent odor. These odors can be detected best with freshly broken specimens or from fumes of specimens that have been ignited and freshly extinguished. You must determine the type of the existing bituminous material before making or recommending repairs because asphalt and coal tar pitch are not compatible, and contact between the two should be avoided. If you are in doubt, perform a solubility test.

Perform the solubility test by pouring white gasoline into a container to which you have added a small amount of unknown bituminous material. The amount that will stick to the head of a nail is sufficient. Agitate the mixture to determine the volubility of the unknown material. If the material mixes readily, giving a homogeneous mixture, it is asphalt cement. If a mixture with stringy particles in suspension results, it is a tar, since tars are insoluble. If the unknown material is not readily soluble but forms black globules (balls), it is an asphalt emulsion. Built-up roofing should be inspected semiannually for (1) cracking, alligatoring, low spots, and water pending, (2) exposed bituminous coatings, and (3) exposed, disintegrated, blistered, curled, or buckled felts.

#### 1.7.1.1 Cracking and Alligatoring

Smooth surfaced, asphalt built-up roofs on which the surface mopping is relatively thin usually show definite alligatoring of the surface coating within 3 to 5 years. Alligatoring is always most severe where the asphalt coating is thickest. If allowed to proceed, alligatoring will develop into cracking, as shown in *Figure 7-9*. Once the surface coating is cracked, water penetrates the membrane, and the roof deteriorates rapidly. Consequently, maintenance is necessary to prevent cracking.

**Figure 7-9 – Cracking and alligatoring.**

The type and extent of maintenance depends on the future use of the structure. On smooth surfaced, organic felt roofs of relatively brief expected use (4 years or less):

1. Remove all dust and dirt by sweeping, vacuuming, or air blasting.
2. Apply a thin coat of asphalt primer.
3. After the primer is dry, apply one or two coating materials (asphalt or asphalt emulsion) by brushing or spraying at a rate of 3 gallons per square (100 square feet).

If the asphalt coating is alligatored but not cracked and the felts are not exposed, the primer may be omitted. If an asphalt emulsion coating is to be applied to such surfaces, dust and dirt may be washed off with a stream of water from a hose. The emulsion can be applied to a damp but not a wet surface.

On organic (rag) felt roofs intended for prolonged use (over 4 years):

1. Perform cleaning and priming the same as for roofs of relatively brief expected use.
2. After the primer has dried, apply one coat of asphalt emulsion at a rate of 2 gallons per square.
3. Immediately after applying the emulsion while it is still wet, embed strips of fibrous glass mesh (woven or non-woven) in the emulsion, lapping the strips 2 inches.
4. While the first coat of emulsion is still wet, apply a second coat of emulsion at a rate of 1 gallon per square over the fibrous glass strips.
5. After the second coat of emulsion has set firmly, apply a final coat of emulsion at a rate of 2 gallons per square.

If the asphalt surface is alligatored but not cracked and the felts are not exposed, the primer may be omitted.

#### 1.7.1.2 Exposed Bituminous Coating

When the bituminous coating on a mineral surfaced built-up roof is exposed, as shown in *Figure 7-10*, repair it as follows:

1. Brush loose gravel or slag from the bare area.
2. Cover the bare area with hot bitumen poured at a rate of 70 pounds per square.
3. Embed fresh gravel or slag.
4. Old gravel or slag may be reapplied when the dirt and dust have been screened from it.

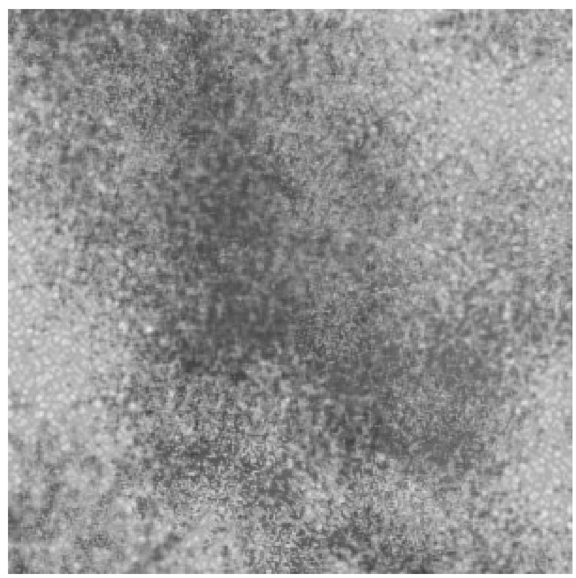


**Figure 7-10 – Exposure of bituminous coating.**

#### 1.7.1.3 Exposed Felts

Smooth surfaced, asbestos felt built-up roofs may be surfaced originally with hot asphalt or with a cold applied asphalt emulsion. After 4 or 5 years of exposure, sometimes earlier with cold applied coatings, light gray or even white areas appear, indicating that the felts are partly exposed. Because the asbestos felts are constructed mainly of inorganic materials, exposure to the weather is much less serious than with organic felts. For an expected use of not more than 4 years, no treatment is necessary. Manufacturers of asbestos felts usually do not recommend recoating asbestos felt roofs at any time. Recoating these roofs with asphalt emulsion at a rate of 3 gallons per square at intervals of 4 or 5 years will prolong their usefulness indefinitely.

On mineral surface built-up roofs, use this method to repair exposed felts:

1. Remove all dust and dirt from the exposed area.
2. In the case of asphalt roofs, apply one thin coat of asphalt primer.
3. When the primer is dry, treat as described for exposed bituminous coating.

Coal tar pitch roofs are treated similarly, except that no primer is required before the coal tar pitch is applied.

On organic felt, smooth surfaced built-up roofs, make repairs to exposed felts as described for those on mineral surfaced roofs, except that 20 or 25 pounds of asphalt should be mopped per square and the mineral surface omitted.

### 1.7.1.4 Disintegrated Felts

To repair felts that have been exposed and partially disintegrated:

1. Scrape off all surfacing material to at least 2 1/2 feet beyond the area of disintegrated felts.
2. Remove disintegrated felt layers.
3. Replace them with new 15-pound, bituminous saturated felts of approximately the same size, mopped in place with hot bitumen.
4. Apply at least two additional layers of 15-pound saturated felt, mopped on with hot bitumen and extending at least 12 inches beyond the area covered by the replacement felts.
5. Apply a pouring of hot bitumen to the repaired area at a rate of 70 pounds per square.
6. While hot, embed fresh gravel or slag into it.

As mentioned earlier, asphalt and coal tar pitch are not compatible. Asphalt and asphalt- saturated felt should always be used in the maintenance of asphalt built-up roofs, and coal tar pitch- and coal tar-saturated felt in the maintenance of coal tar pitch built-up roofs.

### 1.7.2 Metal Roofing

Galvanized steel and aluminum roofing should be inspected semiannually for the following:

- holes
- looseness
- punctures
- broken seams
- inadequate side and end laps
- inadequate expansion joints
- rust or corrosion
- damage resulting from contact of dissimilar metals

Because the different metal roofing materials normally require different preventive maintenance, they are considered separately in this chapter. Copper, terne, and aluminum roofs have one thing in common: When they have been well applied and adequately maintained, reroofing is seldom required.

### 1.7.2.1 Galvanized Steel Roofing

Corrugated galvanized roofing is the lowest in cost of all types of metal roofing, and when properly applied and maintained, it renders satisfactory service. This type of galvanized roofing is used most frequently on warehouses and sheds and is representative of the galvanized metal roofings. The most frequent causes of failure in galvanized roofs are improper application and lack of maintenance painting. Leaks at seams and fasteners are evidence of improper application.

Inadequate laps in galvanized steel roofing may be repaired by caulking or, in severe cases where caulking is not possible, by covering the laps with a membrane such as asphalt-saturated cotton fabric or lightweight smooth surfaced roll roofing. When making repairs, the procedure requires the following steps:

1. Apply an asphalt roof coating to the seams in strips approximately 6 inches wide. Use approximately 1 gallon of coating material to 80 linear feet of seam.
2. Cut the roll roofing or saturated fabric into 4-inch strips approximately 12 feet long. Embed the membrane strip in the asphalt roof coating, pressing it firmly into the coating until it lies flat without wrinkles or buckles. The center of the strip must be directly over the exposed edge of the roofing.
3. Apply another coating directly over the membrane strip so that the membrane is completely covered and the first and second coatings are continuous.

Roof coating materials vary considerably in consistency, composition, and setting time. In some cases it may be desirable to allow the first coating to become tacky before applying the membrane material or to allow the first coating with the membrane embedded in it to remain for some time before applying the second coating.

You should realize that repairs of this kind cannot be expected to last as long as the galvanized sheets. Seams treated by this method should be maintained by recoating them periodically with an asphalt coating of the type used in the original treatment. In warm, humid locations, recoating will probably be necessary after 18 months to 2 years, in other locations after 2 1/2 to 3 years.

### 1.7.2.2 Aluminum Roofing

Aluminum roofing properly applied does not normally require maintenance. Failures in aluminum roofing that result from improper application are essentially the same as those encountered with galvanized steel roofing and are repaired similarly.

### 1.7.3 Flashing

Failures to roofs are usually attributed to the roofing material, but frequently failures are actually due to improper installation of the flashing material. These areas are the first you should inspect when leaks in a structure are reported. A good procedure to follow is to make a careful inspection of the roofing material near the flashings for signs of moisture. Punctures, broken laps or seams, separation of flashing from vertical surfaces, and deterioration from weather are causes of failure.

If a separation occurs between the base flashing and a wall:

1. Refasten the base flashing to the vertical surface by nailing or cementing.
2. Recoat it with plastic flashing cement.
3. Replace with the correct counterflashing.

Leaks sometime occur around vent flashing. Most vents are constructed of metal and are subject to expansion and contraction. For this reason, it is poor practice to attempt to flash up the sides of such projections because this type of flashing is subject to early failure. Vents are usually of two types, the flat flange vent and the curb flange vent. The flat flange vent is placed directly upon the last ply of roofing, where the curb vent is constructed to fit over a wooden or concrete curb.

When exposed nails that hold a flashing flange to a roof work loose, as shown in *Figure 7-11*:

1. Raise the flashing flange high enough to force plastic cement beneath it.
2. Replace the loose nails.
3. Apply two plies of felt or fabric cemented to each other and to the flange with asphalt, pitch, or plastic cement. The outer edge of the first ply of felt or fabric should extend not less than 3 inches beyond the flange and that of the second ply of felt or fabric not less than 6 inches.

**Figure 7-11 – Separation of metal flashing.**

4. Apply the finished surfacing similar to existing roof surfacing.

### 1.7.4 Drainage Systems

Drainage areas should be kept free from debris that will interfere with proper drainage. Many roof failures can be traced to inadequately maintained drainage systems. If during a semiannual roof inspection you notice the accumulation of debris in gutters and around drains, take action to make sure that all debris is removed to prevent subsequent roof failure.

## 1.8.0 Painted Surfaces

Paints are not indestructible. Even properly selected protective coatings properly applied on well prepared surfaces will gradually deteriorate and eventually fail. The rate of deterioration under such conditions is slower than when improper painting operations are carried out. Inspectors and personnel responsible for maintenance painting must be familiar with the signs of various stages of deterioration to establish an effective and efficient system of inspection and programmed painting. Repainting at the proper times prevents the problems resulting from painting either too soon or too late.

Painting scheduled before it is necessary is uneconomical and eventually results in a heavy film buildup leading to abnormal deterioration of the paint system. Painting scheduled too late results in costly surface preparation and may cause damage to the structure, which may then require expensive repairs.

### 1.8.1 Inspection of Painted Surfaces

All painted surfaces should be inspected at definite intervals, semiannually in exterior and corrosive environments, in areas where heavy traffic may cause rapid wear (floor finishes), and in areas where sanitation is important; other areas should be inspected annually. As inspector, you should observe their condition for the type and stage of deterioration, and make recommendations for spot painting, repainting, or more frequent inspection.

The frequency of repainting can be determined by periodic inspection of all coatings. It is important to check on a systematic basis so that painting can be scheduled in advance, at a time when the coating is thin enough, yet has not degraded to the point of disintegration. Little surface preparation will be required, and only one or two coats of paint may be necessary.

### 1.8.2 Stages of Paint Deterioration

Paints which are exposed outdoors normally proceed through two stages of deterioration, generally a change in appearance followed by a gradual degradation. If repainting is not done in time, disintegration of the paint then takes place followed ultimately by deterioration of the substrate (basic surface). Interior coatings generally change slowly in appearance with time but do not usually degrade to any significant extent otherwise.

The first stage of deterioration shows up as a change in appearance of the coating with no significant effect on its protective qualities. This change in appearance may result from soiling, fading, or flattening, depending on the type and color of the paint used and the conditions of exposure.

The second stage of normal deterioration occurs after continued exposure. The coating begins to break down, first at the surface, then unless repainted, gradually through the coating and down to the substrate. Two types of degradation may take place, either chalking or checking and cracking, the degree of either depending on the type of paint and the severity of exposure. When large areas of substrate become exposed, the coating has reached the point of complete deterioration and is in a state of neglect. Such surfaces require extensive and difficult preparation before repainting. All of the old coating may have to be removed for you to ensure that it does not create problems by continuing to lose adhesion, taking the new coating with it. Complete priming of the exposed substrate will also be required, adding to cost and time. Continued neglect may also lead to deterioration of the structure, resulting in expensive repairs in addition to paint costs.

It is assumed that, through study and experience, you are familiar with the defects resulting from the various stages of deterioration mentioned above and can readily identify them. Therefore the defects are not described here.

## 2.1.1 WATERFRONT STRUCTURES

As with buildings, the maintenance inspection of waterfront structures should be designed to include the following:

- prompt detection of deficiencies or damages
- expeditious performance of repairs, consistent with requirements, in an economical and workmanlike manner

Deterioration of waterfront structures is caused by the destructive forces to which they are exposed, such as the following:

- attack by marine organisms
- rust, corrosion, and decay

- mechanical damage, including the impact and pressure of ships, and the abrasive action of sand and debris
- wave action and erosion

To determine the extent of maintenance and repair work required, an inspection should be made annually of all basic structures such as piers, wharves, quay walls, bulkheads, and retaining walls; and semiannually for fenders and movable equipment, such as brows and camels. More frequent inspections than those specified may be necessary under certain circumstances, such as tidal waves, high tides, earthquakes, and action by destructive forces of nature. Inspections may be made from the structures, from a boat afloat, or from below the waterline by divers. Cameras are often used in visual inspections.

Some of the major defects that can be seen by visual inspection are as follows:

- Spans, cracks, and breaks in concrete work
- Rusting of structural steel and exposed reinforcing steel in concrete
- Decay in wood
- Mechanical damage, resulting in broken or bent structural members
- Damage by wave action and water erosion, including the washing out of fill through defective sheet-piling
- Shrinkage of timbers around bolts and cracks around loose bolts that allow water to enter, conditions usually found in pier curb rails, stringers, wales, pile caps, and other members above the tidal range
- Deterioration of decking
- Loose spikes and bolts, worn, cracked or broken rails, and deteriorated ties
- Deterioration of service lines, terminal boxes, outlets, broken brackets, loose insulation, corroded piping, and broken seals

Concealed damages are often overlooked in a visual inspection. It is often necessary to resort to special methods or tests. When underwater damage is suspected, divers are generally required. Some of the methods used to discover concealed damages are tapping with a hammer and probing with a chisel, a screwdriver, or a sharp pointed instrument to detect deterioration or decay. This type of inspection will usually indicate whether further examination is necessary. Any evidence of damage or deterioration affecting the structural stability of any structure should be the subject of an immediate engineering study.

Waterfront structures for the most part contain one or more of the following materials:

- concrete
- metal
- wood
- stone
- earth
- masonry units

The following sections describe the maintenance and repair procedures unique to each of these materials in general, with specific procedures when they apply to certain types of structures.

## 2.1.0 Concrete Structures

Concrete is a fairly permanent construction material, but local conditions can produce defects that require corrective measures. You should be familiar with common types of defects that occur in concrete and know what measures to take to correct these defects.

### 2.1.1 Repairing Concrete

When concrete that covers reinforcing steel is deteriorated, spalled, or cracked, the reinforcing steel begins to rust and repairs should be made promptly to avoid excessive damage.

1. Remove all loosened materials and cut back the concrete to sound material.
2. Cut the areas to be patched a minimum of 1 inch and at right angles to the surface.
3. If the reinforcing steel is seriously damaged by rust, cut the concrete back far enough to replace the damaged steel with new reinforcing. New reinforcing bars should match the original bars in size and grade of steel and should be lapped at each end for a length of not less than 30 diameters of the original bars or as directed by higher authority.
4. Securely wire or weld the new bars to the old before patching.
5. Clean exposed reinforcing steel that is not seriously damaged by rust by brushing or sandblasting to make a firm bond with the new concrete.
6. Cover the reinforcing steel with a minimum of 3 inches of concrete if at all possible.

### 2.1.2 Superstructure Repairs

Repairs to superstructures will include filling surface cracks, replacing structural members, cutting and filling expansion joints, and resurfacing decks.

#### 2.1.2.1 Surface Cracks

Surface cracks that are not structural defects must be promptly filled to avoid the entrance of water.

1. Thoroughly clean the crack with a high pressure water jet to remove all foreign matter. Edges of the crack should be moistened, but not wet.
2. Fill the crack with a thin grout of cement and water or an epoxy-based material, using a brush, if necessary, to push the grout in the crack. For wider cracks, use a mortar of cement, sand, and water instead of cement grout. If such cracks are too narrow to permit placement of filler material, they should be cut out before cleaning.
3. After filling the crack, cover with burlap or sand and keep the covering moist for at least 3 days. Asphalt, tar, and certain other materials may also be used with satisfactory results for sealing random cracks in concrete decks and curbs.

### 2.1.2.2 Patching and Replacement

Patching and replacement forms are usually required except for minor patches on top of a slab and for pressure-applied concrete or epoxy-based material. Forms may be of pipe, sheet metal, or wood and either left in place or stripped. They should be strong, well braced and, if they are to be stripped, designed so they can be removed without damaging the concrete. Pressure-applied concrete is generally used to repair spalling on the underside of a deck or beam.

1. Cut back the spalled area to sound concrete.
2. Replace reinforcement as described earlier.
3. Repair or rebuild to the original section with pressure-applied concrete. Slabs or other structural members that are broken or severely damaged must be replaced.

The assistance of qualified engineers should be obtained to analyze such cases to determine the cause of failure and to furnish an adequate design of replacement members. Methods of patching deck slabs of reinforced concrete piers are shown in *Figures 7-12* and *7-13*. Slabs may be broken through by overloading. If this is a relatively small area and near the center of a span, it can be repaired by cutting out the deck and reconcreting, as shown in *Figure 7-13*.

**Figure 7-12 – Repair of deck at center of span.**

**Figure 7-13 – Repair to damaged edge of slab.**

To repair a hole:

1. Bevel the concrete, as shown in *Figure 7-14*, or in addition to beveling, the area to be removed may first be scored along the break line using a saw, to a depth of 1 1/2 inches. The depth must be adjusted where reinforcing is encountered. No joint in the slab should be made either adjacent to or at the edge of a supporting beam, or at or near the ends of reinforcing bars.
2. If the slab must be cut back to the supporting beams or replaced, cut a seat into the beam to the depth of the slab and one quarter to one third of the width of the beam.

**Figure 7-14 – Heaving of concrete deck.**

3. If deck slabs have been damaged by heaving (lateral or upward movement resulting from freeze/thaw cycles), they must be replaced. Make provisions for an adequate expansion joint in the new slab.
4. If two or more adjacent slabs have heaved, you will often find that piles have been pulled up with the slabs. When this occurs, re-drive the piles to a firm bearing and make necessary repairs to concrete caps, as shown in *Figure 7-15*.

**Figure 7-15 – Piles pulled by heaving deck.**

### 2.1.2.3 Expansion Joints

If expansion joints have proven inadequate in number or are not functioning properly, heaving will result. Where joints are too far apart, cut additional joints with a concrete saw and fill them with an approved type of joint sealer. Asphalt, tar, and certain other materials may be used with satisfactory results for sealing joints. Sealing material should adhere to the concrete and should remain plastic at all temperatures. It should not become hard and brittle in low temperatures, or so soft that it flows from the joint during intense heat or so tacky that it is picked up by vehicle tires.

#### 2.1.2.4 Resurfacing

Resurfacing concrete pier decks that have widespread surface deterioration may be restored by resurfacing with asphalt. The existing slab must be properly prepared before placement of the new asphalt surface course.

1. Clean all loose, scaled, and foreign matter down to sound concrete, using power wire brooms and compressed air.
2. Flush with high pressure fresh water to remove salt if near seawater.
3. Cut all cracks to a clean rectangular trench, usually not less than 1/2 inch wide by 1 1/2 inches deep; adjust depth to suit reinforcing steel.
4. Fill the trench to within one half inch of the top with a high-softening-point asphalt mastic or joint filling compound.
5. Paint the surface of the concrete for 3 to 4 inches on both sides of the trench with asphalt emulsion and cover with 30-pound asphalt-impregnated felt 4 inches wider than the trench.

It is very important to seal the cracks properly to eliminate reflection cracking and subsequent premature failure of the new asphalt surface cover. Apply liquid asphalt to the surface of the Portland cement surface as a primer, and lay a dense graded mix of asphalt concrete or sheet asphalt as a surface according to a predetermined design. A partial remedy to protect concrete from chemical deterioration is to apply a layer of dense impervious concrete properly anchored to the old work or some of the newer materials, such as epoxy resin formulations.

### 2.1.3 Substructure Repair

Free-standing components of structures damaged or deteriorated by such means as spalling or longitudinal or horizontal cracks in tiles and bracing can be repaired above the waterline. Pressure-applied mortar, epoxy formulations, normal Portland cement concrete, or grout are the materials used. Encasement of damaged portions in reinforced concrete is the conventional method of repairing piling. It is always preferable to place concrete in air if economical and feasible, but this requires the use of cofferdams, and is not always an economical solution. When the solution dictates, concrete can be placed under water. Forms may be used, as shown in *Figures 7-16* and *7-17*.

**Figure 7-16 – Encasement of damaged piles in a wood form.**

1. Place additional reinforcing, in the form of rods or mesh, around the damaged pile, and use sectional forms to hold the concrete in place until it cures. Forms may be made of pipe, sheet metal, or wood and are split in half vertically so that they can be placed around the pile and bolted together above the water.
2. Slide each section into place and add new sections until the desired length is obtained.
3. Fill the form with concrete.
4. Forms may be left in place or removed for reuse.

**Figure 7-17 – Encasement of damaged piles in a metal form.**

Where only a section of the pile is to be encased in concrete and the forms do not extend to the mud line, the lowest section of the forms must be closed to hold the concrete or aggregate and grout in place, as shown in *Figure 7-17*.

Pressure-applied concrete may be used to make sectional forms. These are built upon cylinders of expanded metal laths shaped to fit around the pile. Wire mesh reinforcement may be used outside of the metal lath where additional strength is required. Pressure-applied concrete is used to make a sectional form 1 or 2 inches thick, and the concrete is allowed to set. This form is then dropped into place and filled with concrete.

## 2.2.1 Steel Structures

Inspections of corroded, weakened, or damaged areas are essential for determining the best methods or needs for repair coating or replacement of steel members in the various structures. Main members are normally replaced when 30 percent or more of the section has been removed by corrosion or when seriously deformed. In the planning of replacements, you must consider the rate of corrosion or actual decrease in section. If adjacent members show signs or serious deterioration, it may be best to replace whole frames or bents.

Never remove a stressed member until the stress has been relieved by temporary bracing, shoring, or jacking because, if the stress is not removed, the member may sprint out of place when loosened, making it very difficult to replace the member. In the replacement of piles, the load should be shifted temporarily to adjacent piles by means of temporary beams or jacks. The replacement of wales on bulkheads may require the excavation of the fill to relieve the lateral loads. The structures must retain their structural stability at all times. In most cases, the maintenance and repair of metal structures will be handled by the Steelworkers (SWs). At times, though, the BUs may be working with the SWs in these operations, so let us consider some of the common methods of maintenance and repair.

1. Make sure that new members are accurately fabricated to match the old work and that all bolt and rivet holes line up with original members.
2. Before the placement of the new member, remove all old rivets or bolts in the most expeditious manner by using hand or pneumatic chisels, saws, and wrenches, or by burning them off before removing the old member.
3. Place the new member in position and line up all holes by adjusting the jacks or the bracing as necessary.
4. Place a few bolts to hold the member, and then fasten securely in place by riveting, placing additional bolts, or welding.

In the replacement of bearing piles, the new pile is generally driven alongside the old one at a slight angle. It is then cut off at the proper elevation, capped, usually by welding on a steel plate, and pulled into position by block and tackle. If the old pile is pulled and a new one driven, care must be taken to transfer the load temporarily until the new pile can assume the load. Care must also be taken to bore or punch the bolt holes in the cap to conform with the holes in the floor beam or stringer.

Precautions may be necessary when replacing wales and sheet metal bulkheads because they often retain materials that have a low angle of repose. The old wales are left in place or at least until new wales are installed just above or below the originals. Occasionally they can be connected to existing tie rods, but in most cases new tie rods and deadmen should be installed.

Badly deteriorated sheetpiling is generally protected by new sheetpiling being driven outside the old piling and provided with new wales, rods, and deadmen. The space between the piles must be filled with well tamped earth, sand, gravel, or concrete, depending upon conditions at the site.

Steel members that have corroded in only limited areas may be repaired by welding fishplates onto the flanges and the web.

1. Thoroughly clean the corroded area
2. Burn off the featheredges back to a point where the metal is of sufficient thickness to hold a weld.
3. Ensure that fishplates are of sufficient cross-sectional areas to develop the full strength of the original section. They should extend beyond the top and bottom of the corroded zone.

Another method is to encase the corroded section in reinforced concrete.

1. Clean the corroded area.
2. Cut back the corroded edges.
3. Weld the reinforcing bars to the flanges and the web.
4. Place a form around the corroded section and fill it with concrete.

*Figure 7-18* shows this procedure for a steel H-pile. The same system can be used for other structural members.

**Figure 7-18 – Concrete encasement of steel pile.**

### 2.2.1 Sheetpiling Repair

Sheetpiling usually serves as a bulkhead to retain earth or other fill. Holes in the bulkhead will result in loss of materials and settlement behind the bulkhead. Local damage or holes can be repaired by welding on plates or more sections of steel sheetpiling. If the holes are small, wooden plugs can be used to fill the holes. Usually it is necessary to install new sheetpiling in the deteriorated areas, but it may be economically feasible to protect the damaged sheetpiling with a concrete facing, as shown in *Figure 7-19*.

**Figure 7-19 – Concrete encasement of steel sheet pile.**

1. Remove all rust, scale, and marine growth before placing concrete.
2. Make sure concrete covers applied to the exposed exterior face of the piling are at least 6 inches in thickness and extend well beyond the area of corrosion, damage, or deterioration.
3. Make formwork of wood and support it in place with stud bolts that are welded to the sheetpiling. Use heavy zinc-coated bolts and nuts.
4. Leave the wood forms in place because they will provide protection against damage from floating debris and erosion for some time.
5. Where the back of the bulkhead can be easily exposed, it may be advisable to encase the sheetpiling completely in concrete. Minimum thickness of concrete facing where the piling is completely encased in concrete should be 3 inches.
6. Take care in replacing the backfill when the sheet pile has been encased. Granular materials are preferable. Fill should be placed in layers and well compacted.

### 2.2.2 Tie Rod Repair

Deteriorated tie rods will allow the top of a bulkhead to move outward.

1. Remove the fill to expose the tie rods and turnbuckles by starting the excavation at the back face of the bulkhead, and progress to the shore in as narrow a trench as possible along the tie rod to the deadmen.
2. Thoroughly clean the tie rods and turnbuckle by removing rust and corrosion.
3. Make repairs by welding new rods onto the corroded area, as shown in *Figure 7-20*, or by installing new rods from the turnbuckle to the face of the wall or outside of the wales.
4. Check the condition of the deadmen and either make necessary repairs or strengthen them as required.
5. Tie rods should be replaced or repaired one at a time. Coat new work with bituminous material, wrap with fabric tape, and apply another coating of bituminous material over the tape.
6. When repairs are complete, backfill the trench.

**Figure 7-20 – Repair of tie rods.**

## 2.3.0 Wood Structures

Wood pile and timber structures in a marine environment are susceptible to infestation and attack by marine organisms or wood rot spores. Unless there is a specific reason for doing otherwise, use treated piles and timbers in the repair or replacement of such members in structures on the basis of the economic expected life. Southern yellow pine, Douglas fir, and oak have been found to be most suitable for waterfront structures, but hemlock, larch, spruce, cedar, and tamarack can be used. Bolts, washers, spikes, driftpins, and other hardware used in repair of timber members must be heavily galvanized.

### 2.3.1 Decking

Creosote-treated lumber is not recommended for wood decking. Deck surfaces drain rapidly and, being well ventilated, dry rapidly so the principal concern is not the same as it is for covered, inaccessible structural framing. Usage and wear from traffic is generally the cause of deck repair and replacement. Top surface decking over which vehicular and pedestrian traffic passes should be replaced when the top surface becomes excessively uneven, hazardous, or worn to a point of possible failure of the decking.

1. Replace decking with edge grain timber, surfaced on four sides.
2. Lay decking with 1/2 inch to 3/8 inch spaces between each plank to permit ventilation and drainage.
3. The top surface should be reasonably smooth and level, particularly where repaired areas meet existing decking.
4. Stagger end joints where existing and new decking meet.
5. Nail decking securely at every stringer with 6-inch spikes for 3-inch decking and 7- or 8-inch spikes for 4-inch decking. Drive spikes flush with the top deck planking.
6. Take care to rebuild openings or access for underpier fire fighting nozzles or sprayers and for access to piping, valves, and fittings in the repaired decking area.
7. Decking for relieving platforms that have an earth fill should be a double layer of pressure-treated lumber laid without spacing between planks.

### 2.3.2 Stringers

Stringers that have rotted or have been damaged should be replaced.

- Replacement stringers should be tightly bolted where they lap with existing stringers that are to remain, and they should be pinned or bolted down to caps.
- Stringers that extend continuously for the length of the pier may be replaced in part by splicing to sound parts of the timber.
- Splices should be placed directly over pile caps, and the splices in adjacent stringers should be staggered where possible. A typical splice for a 12-inch by 12-inch stringer or cap is shown in *Figure 7-21*.

**Figure 7-21 – Stringer splice.**

### 2.3.3 Pile Caps

Pile caps that require replacement because of rot or damage should be completely replaced between the splices of the original structure. Bolt holes in new caps should be carefully made to align properly with bolt holes in existing caps. It is preferable to use new fishplates, particularly if they are of timber.

#### 2.3.4 Braces

Diagonal and sash braces that have rotted or that have been broken or weakened by marine borer attack should be replaced.

- Replace each brace completely, rather than splicing them.
- Carefully place bolt holes for proper alignment.
- When wood braces are fastened to piling, do not cut the pile to obtain a flush fit.
- Bolt the braces, if possible, above the high waterline.
- After bolt holes have been drilled, treat them with preservative, preferably with a specially designed bolt hole that forces the preservative into the hole under pressure.

Where decking has been removed for repairs, it is often possible to drive brace piles to provide lateral stiffness. This eliminates all bolt holes except at the top of the structure immediately under the decking.

#### 2.3.5 Fire Curtain Walls

Fire curtain walls that have rotted or that have been damaged or severely attacked by marine borers should be restored to the original condition.

- When damaged timbers are replaced, they may be spliced out.
- Do not make splices in the same location on both sides of the wall because an open crack would remain.
- The curtain wall should be as airtight as possible after repairs are completed.
- Wood fire curtains are usually made of two layers of timber, the joints in one layer running diagonally to the joints in the other. It is important that the joints be tight and that both sides of the wall be completely repaired.

#### 2.3.6 Wood Piles

The decayed top of wood bearing piles can be repaired as follows:

1. Cut off the damaged portion
2. Build it up to the proper height with sound timber, as shown in *Figure 7-22*.
3. Drive driftpins through the cap and down through the new section of pile. This involves removing some of the deck planking.
4. In every case, use fishplates of metal or treated wood to hold the new section in place. Fasten the fishplates securely with spikes, lag **screws**, or bolts.

**Figure 7-22 – Replacing top of piles.**

Where all the piles in a bent have decayed tops but there is less than a foot of unsound piling, use the method shown in *Figure 7-23*.

1. Cut off the top of each pile in the bent to allow installation of an additional 12-inch by 12-inch cap under the existing cap.
2. Drive the driftpins through the caps into the piles to hold the tops in place.
3. In most cases, the connection of the caps to the piles should be further strengthened by bolting them together with 1-inch bolts and 12 1/2-inch by 3/8-inch steel straps. Use 1-inch bolts for bolting the two caps together.

**Figure 7-23 – Repair of top of piles.**

Piles that are broken or badly damaged, as shown in *Figure 7-24*, should be replaced.

1. Pull the old pile and drive a new one in its place.
2. Where old piles cannot be pulled or where they break off, cut off the old pile as far down as possible and drive a new pile alongside of it.
3. After driving, pull the head of the new pile into place and fasten it to the cap with a driftpin or with fishplates, as shown in *Figure 7-25*.
4. Use treated replacement piles for all structural pier piles, but on major operations and supply piers where the life expectancy of the fender system is relatively short because of its continued exposure to the berthing of major ships, using untreated, unskinned piles may be considered structurally suitable and economically sound.

**Figure 7-24 – Broken wood piles.**

**Figure 7-25 – Wood pile replacement.**

Piles that have been weakened by marine borers can be strengthened and protected by encasing them in concrete jackets. Use steel reinforcing in the concrete jacket, either in the form of bars or wire mesh.

**Figure 7-26 – Concrete encasement of short section of wood pile.**

Concrete encasement may be used to cover a short section of the pile where damage is limited, as shown in *Figure 7-26*. It may be extended well below the waterline, as shown in *Figure 7-27*.

**Figure 7-27 - Extensive concrete encasement of wood pile.**

1. Scrape the damaged surface of the pile to sound wood.
2. Use either metal or wood forms. For wood forms, use a 2-inch creosoted tongue and groove material and leave it in place.

Fender piles that are broken between the top and bottom wales, as shown in *Figure 7- 28*, can be repaired as follows:

1. Cut off the pile just below the break.
2. Install a new section of pile and fitting.
3. Place and bolt a pile section or timber section directly behind the fender pile from the top to the bottom wales.
4. Spike a metal wearing strip to the wearing edge of the pile.

**Figure 7-28 – Fender pile repair.**

Piers and quay walls may have a bulkhead of wood sheetpile to retain the fill on the shoreside. Riprap is usually placed at the foot of the sheetpiling for strengthening. Extensive deterioration of the bulkhead will result in the loss of fill and settlement above the affected area.

- Repairs usually require driving sheetpiling to form a new bulkhead a minimum of 1 foot inside the old one to avoid the driving frames or wales attached to the old bulkhead.
- New sheetpiling may be pressure-treated wood, concrete, or sheet steel.
- Steel sheetpiling is normally used for the new bulkhead because often the work must be done inside a pier shed. In this case, steel piling is driven in the maximum lengths possible and additional lengths welded on successively.
- The new sheetpile should extend to a minimum of 3 feet below the top of the deteriorated wood sheeting.
- The fill at the inside edge of the old bulkhead is normally removed before driving the new sheetpiling. When this is done, place a concrete cap over the new sheeting to form a seal with the existing construction.

### 2.3.8 olphins

Maintenance of dolphins includes the replacement of fastenings and any wire rope wrapping that has become ineffective through corrosion or wear. If dolphins are connected by a catwalk, maintenance of the catwalk includes the following:

- replacement of damaged or deteriorated timbers
- cleaning and painting or replacement of steel members

Repairs of dolphins include the following:

- replacement of piles

- replacement of wire rope wrappings
- replacement of blocking

If any piles have to be replaced, remove the fastenings only as far as necessary to release the piles that are damaged.

1. Take care to drive the new piles at the proper angle so they will not have to be pulled too far to fit them in place.
2. Carefully note the size of piles to be replaced, particularly at the head or intermediate point where they are fitted together with the other piles. Selecting piles with the proper size head helps to avoid the trouble of cutting and fitting the replacement piles.
3. Drive all of the replacement piles before any are brought together.
4. After all of the piles are driven, bring the center cluster together first and then fit, chock, bolt, and pin them. Then wrap them with wire rope.
5. Thoroughly field treat with creosote all cuts in piles for fittings, bolts, and wrappings.

Frequently it is more economical to build a new dolphin than to repair an existing one.

## 2.4.0 Stone, Masonry, and Earth Structures

Some structures, such as breakwaters and seawalls, depend upon their mass for stability against wave action and currents. Materials commonly used for such structures are stone, blocks of concrete, cast-in-place concrete, and earth. Earth structures are usually covered with a protective coating such as riprap to hold them in place.

The most common cause of deterioration and damage to mass structures is wave action, particularly during storm conditions. Severe wave action may move stones out of place when built into a wall or move others by washing out sections of a breakwater or causeway. This damage makes the structure more susceptible to additional damage. Repairs should be made as soon as possible.

### 2.4.1 Stone Structures

Stone structures are those constructed of stone, blocks of concrete or special concrete shapes, such as tetrahedrons, piled up or distributed in a random fashion. Some structures may have an earth core retained in place by stone, composing the area that is exposed to wave action. In repair of the damage, consider the following:

- cause of damage, such as an unusually severe storm
- need for strengthening of the structure
- side slopes that are too steep

Unless it is evident after study by design engineers that changes in design are required, the structural damage should be repaired with the same materials used in the original to restore the structure to its original strength, elevation, and cross section. Depressions washed out of the bottom in the vicinity of structures should be replaced with sand or granular materials up to the original level before replacing stone. You can do this either by dumping from the undamaged part of the structure or by placing the materials from a barge or floating derrick.

### 2.4.2 Masonry Structures

Masonry structures are structures made of cut stone and cast concrete, made into shapes and fitted up tightly together, or laid up with mortar or similar material. Units may be bonded together by one of these:

- overlapping
- metal clamps
- dowels
- bed plugs
- shapes of the blocks, as shown in *Figure 7-29*

**Figure 7-29 – Anchoring masonry blocks.**

All metal fastenings should be zinc-coated and well bedded in mortar. Sections of masonry that have washed out or have been damaged should be completely rebuilt, bonding the units to each other or using metal fastenings as necessary. Masonry walls that have cracked because of unequal settlement can be rebuilt, adding reinforcing bars, as shown in *Figure 7-30*.

Repair of cracked walls should be delayed until settlement is complete, if possible. Where sections of walls have been displaced by sliding, an investigation should be made to determine the cause before it is rebuilt.

**Figure 7-30 – Repair to cracked masonry walls.**

If water builds up in back of the walls, the weep holes should be cleaned and new ones installed to relieve the pressure. Walls that fail because they are inadequate should be redesigned before they are rebuilt. It is advisable to provide clamps for reinforcement where the displacement of a wall is minor. If it is not necessary to rebuild the wall, it can be reinforced, as shown in *Figure 7-31*:

1. Drill holes down through the wall at the rear of the displacement and a short distance beyond.
2. Insert steel rods in the holes.
3. Fill the holes with cement mortar.

**Figure 7-31 – Reinforcing vertical walls.**

### 2.4.3 Earth Structures

The use of earth for waterfront structures is confined largely to dikes and levees. It is also used as the following:

- the interior of structures such as causeways, moles, and breakwaters
- backfill for quay walls and similar structures
- fill for caissons and cellular structures

Earth that is exposed to wave action must usually be protected by riprap, cut stones, concrete blocks, or similar materials. The washing away of this protection exposes the earth to erosion by rain, waves, and currents.

- When the earth is eroded, it should be replaced and well compacted before replacing the protecting material.
- Where earth fill is supported by a bulkhead, cell, caisson, or similar structure, the supporting structure should be repaired and the fill replaced in layers with the coarser materials next to the bulkhead and the finer materials inboard. Layers must be compacted and consolidated.
- All materials for dikes and levees should be impermeable to prevent water from working through the structure.
- Vegetative covering is usually grown on the sides and top of earth structures to prevent erosion. Areas where vegetation has died or been damaged should be replanted.

This chapter does not attempt to give you all the tools necessary to inspect facilities and structures, but the information given you and the references listed below are what you need to provide proper maintenance procedures in the construction industry.

## Summary

You have learned how to inspect buildings and waterfront structures and how to determine what maintenance and repairs are necessary to keep the structures in first class condition. You have also learned how to develop an effective maintenance inspection program designed to promptly detect deficiencies and damages and to perform economical and workmanlike repairs.

## Review Questions (Select the Correct Response)

1. Foundations should be inspected at what time intervals?

   A. Monthly
   B. Quarterly
   C. Every four months
   D. Yearly

2. What structures are used under foundations to spread loads over enough soil area to bring unit pressure to allowable limits?

   A. Footings
   B. Separators
   C. Substructures
   D. Levels

3. Which of the following conditions does NOT indicate localized displacement of a foundation has occurred?

   A. Cracked walls
   B. Sloping floors
   C. Stable fill
   D. Sticking doors

4. **(True or False)** Unventilated crawl spaces do NOT provide a natural habitat for fungus and termites.

   A. True
   B. False

5. Pentachlrophenol is a wood preservative that is used to prevent infestation of what pest?

   A. Termites
   B. Wasps
   C. Rodents
   D. Birds

6. The basic supporting members of wood frame structures are divided into three groups for inspection purposes: sills and beams, posts and columns, and

   -          _.

   A. stairways and steps
   B. girders and joists
   C. roofs and chimneys
   D. doors and floors

7. **(True or False)** Asphalt, vinyl tile, and linoleum are the most often used types of floor covering.

   A. True
   B. False

8. Wood floors should be inspected at least once each ________.

   A. month
   B. quarter
   C. year
   D. decade

9. **(True or False)** Concrete floors should be painted at least every two years.

   A. True
   B. False

10. What is the primary factor that makes tile flooring easier to replace than linoleum?

    A. Tile is larger.
    B. Tile has a felt lining.
    C. Tile has an adhesive backing.
    D. Tile is smaller.

11. Stairways and doors should be inspected each ________.

    A. week
    B. month
    C. quarter
    D. year

12. Which type of wall is NOT a category of exterior wall?

    A. Load-bearing
    B. Nonbearing
    C. Curtain
    D. Non-reinforced

13. Which type of crack is NOT a category of wall cracks?

    A. Horizontal movement cracks
    B. Shrinkage cracks
    C. Racked-down corners
    D. Stretcher cracks

14. **(True or False)** Efflorescence may indicate the penetration of moisture into an exterior wall to an extent that could cause deterioration of interior wall coverings.

A. True
B. False

15. What material is most often used to make interior walls?

A. Glass
B. Fiberboard
C. Drywall
D. Tile

16. **(True or False)** When conducting the required quarterly inspection of windows, you can expect weathering to be the most common cause of window failures.

A. True
B. False

17. The recommended remedy for splitting and checking of dry timber is to install what type of bolts?

A. Roofing
B. Form
C. Stitch
D. Anchor

18. **(True or False)** Asphalt and coal-tar pitch are NOT compatible, and contact between the two should be avoided.

A. True
B. False

19. Of all types of metal roofing, what type has the lowest cost?

A. Aluminum
B. Corrugated, galvanized steel
C. Non-corrugated, galvanized steel
D. Monel

20. **(True or False)** One of the most frequent causes of failure of galvanized roofs is the lack of maintenance painting.

A. True
B. False

21. **(True or False)** Many roof failures are the result of inadequately maintained drainage systems.

A. True
B. False

22. Inspection of painted surfaces that are in exterior environments should be conducted at what time intervals?

A. Monthly
B. Quarterly
C. Semiannually
D. Annually

23. When repairing concrete structures, you should cover the reinforcing steel with a minimum of how many inches of concrete?

A. 1
B. 2
C. 3
D. 4

24. **(True or False)** Deck slabs that have been damaged by heaving movements should be replaced.

A. True
B. False

25. Main members of steel structures are removed when the section becomes seriously deformed or when corrosion has caused the removal of what percentage of the section?

A. 10
B. 20
C. 30
D. 40

26. What types of timber have proven to be best suited for waterfront structures?

A. Spruce and tamarack
B. Hemlock and larch
C. Knotted pine and cedar
D. Southern yellow pine, Douglas fir, and oak

27. **(True or False)** The use of creosote-treated lumber for wood decking is NOT recommended.

A. True
B. False

28. To permit drainage and ventilation, decking should be laid with what size spaces between each plank?

    A. Between 1 1/2 to 2 inches
    B. Between 3/8 inch to 1/2 inch
    C. 3/6 inch
    D. 1/8 inch

29. Piles that have been weakened by marine borers can be strengthened and protected by encasing them in _______ jackets.

    A. leather
    B. aluminum
    C. steel
    D. concrete

30. **(True or False)** Structures made of cut stone and cast concrete and laid up with mortar or similar materials are considered masonry structures.

    A. True
    B. False

31. **(True or False)** The use of earth for waterfront structures is confined largely to dikes and levees.

    A. True
    B. False

32. **(True or False)** Vegetative covering is usually grown on the sides and top of earth structures to prevent erosion.

    A. True
    B. False

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*Construction Inspector's Guide,* EP 415-1-261, Volumes 1-4, U.S. Army Corps of Engineers, Washington, DC, 1982.

*Construction Inspector Guide,* NAVFAC P-456 (series), Naval Facilities Engineering Command, Alexandria, VA, 1985.

*Construction Quality Control Manual,* NAVFAC P-445, Naval Facilities Engineering Command, Alexandria, VA, 1988.

*Construction Quality Control (CQC) Program,* COMSECONDNCBI COMTHIRDNCBINST 4355.1 (series), Commander, Second Naval Construction Brigade, Norfolk, VA, and Commander, Third Naval Construction Brigade, Pearl Harbor, HI, 1985.

*Equipment Operator Basic,* NAVEDTRA 12535, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

*Facilities Support Contract Quality Management Program,* MO-327, Naval Facilities Engineering Command, Alexandria, VA, 1985.

O'Brien, James J., *Construction Inspection Handbook,* "Quality Assurance and Quality Control," 3d cd., Chapman and Hall Publishers, New York, NY, 1989.

*NCF/Seabee Petty Officer 1 & C,* NAVEDTRA 12543, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

*Safety and Health Requirements Manual,* EM 385-1-1, Department of the Army, Washington, DC, 1992.

*Seabee Planner's and Estimator Handbook,* NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

*Steelworker,* NAVEDTRA 12530, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1996.

Wagner, Willis H., *Modern Carpentry,* The Goodheart-Wilcox Company, Inc., South Holland, IL, 1992.

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

____________________________________________

____________________________________________

____________________________________________

(Optional) Correction

____________________________________________

____________________________________________

____________________________________________

(Optional) Your Name and Address

____________________________________________

____________________________________________

____________________________________________

# Chapter 8

# Heavy Construction

## Topics



To hear audio, click on the box.

## Overview

As a Builder, you may perform various construction operations involving heavy structures. Since heavy construction is hazardous work, the use of safe working practices at all times can prevent injuries to personnel and damage to equipment. This chapter describes equipment, terminology, and techniques of heavy construction and explains the methods of constructing heavy timber structures and waterfront structures in terms of contingency operations.

Heavy construction refers to the type of construction in which large bulks of materials (over 5 inches thick) and extra heavy structural members are used, such as steel, timber, concrete, or a combination of these materials. In the Naval Construction Force (NCF), heavy construction includes the construction of bridges, shoring operations, waterfront structures, and steel frame structures.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the procedures for erecting heavy timber bridges.
2. Describe the procedures for erecting shoring.
3. Describe the procedures for pile construction, identify the different types of pile driving equipment and types of piles, and understand the many safety hazards associated with pile driving.
4. Describe the procedures for erecting waterfront structures.
5. Identify the different types of timber fasteners and connectors.
6. Describe the procedures for erecting steel frame structures.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | BUILDER ADVANCED |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.0.0 BRIDGE CONSTRUCTION

A bridge is a structure used to carry traffic over a depression or an obstacle, generally consisting of two principal parts: the lower part, or substructure, and the upper part, or superstructure. When a bridge is supported only at its two end supports, or abutments, it is called a single span bridge. A bridge with one or more intermediate supports, as shown in *Figure 8-1*, is known as a multi-span bridge.

**Figure 8-1 – A multi-span (trestle-bent) bridge.**

Although bridges may be either fixed or floating, only fixed bridges are covered in this chapter. The following information covers the components of a fixed bridge.

## 1.1.0 Substructure

The substructure supports the superstructure and consists of abutments, footings, sills, posts, bracing, and caps.

### 1.1.1 Abutments

There are different types of fixed bridge abutments. First, let's cover the footing type of abutment. In *Figure 8-2*, *Views A* and *C* show two types of footing abutments. *View A* shows a timber-sill abutment, and *View C* shows a timber-bent abutment. By studying both of these views, you will see that three elements are common to a footing type of abutment. Each type has a footing, a sill, and an end dam.

Notice that the timber-sill abutment shown in *Figure 8-2, View A* is the same footing type of abutment shown for the bridge in *Figure 8-1*.

**Figure 8-2 – Types of fixed bridge abutments.**

In this type of abutment, loads are transmitted from the bridge stringers to the sill, which distributes the load to the footing. The footing then distributes the combined load over a sufficient area to keep the support from sinking into the ground. The end dam is a wall of planks that keeps the approach road backfill from caving in between the stringers. The timber-sill abutment should not be more than 3 feet high. It can be used to support spans up to 25 feet long.

The timber-bent abutment shown in *Figure 8-2,View C* can be used with timber or steel stringers on bridges with spans up to 30 feet. The deadman is used to provide horizontal stability. These abutments do not exceed 6 feet in height.

Other types of fixed bridge abutments are pile abutments and concrete abutments. Timber or steel pile abutments can support spans of any length, can be used with steel or timber stringers, and can reach a maximum height of 10 feet. A timber-pile abutment is shown in *Figure 8-2; View B*. Concrete abutments are the most permanent type and may be:

- Mass or reinforced concrete
- Used with spans of any length
- As high as 20 feet.

These abutments are used with either steel or timber stringers.

### 1.1.2 Foundations

That part of a building or structure located below the surface of the ground is called the foundation. Its purpose is to distribute the weight of the building or structure and all live loads over an area of subgrade large enough to prevent settlement and collapse.

In general, all foundations consist of the following three essential parts:

- Foundation bed, which consists of the soil or rock upon which the building or structure rests.
- Footing, which is normally widened and rests on the foundation bed.
- Foundation wall, which rises from the foundation to a location somewhere above the ground.

The foundation wall, contrary to its name, may be a column or a pedestal instead of a wall. When it is a wall, it forms what is known as a continuous foundation. *Figure 8-3* shows common types of wall and column foundations.

**Figure 8-3 – Common wall and column foundations.**

The continuous foundation is the type most commonly used for small buildings. The size of the footing and the thickness of the foundation wall are specified based on the type of soil at the site. Most building codes require that the bottom of the footing be horizontal and that any slopes be compensated for by stepping the bottom of the footing.

Another type of foundation is the grade beam foundation. A grade beam is a reinforced concrete beam located at grade level around the entire perimeter of a building, and it is supported by a series of concrete piers extending into undisturbed soil. The building loads are supported by the grade beam, which distributes the load to the piers. The piers then distribute the load to the foundation bed.

A spread foundation, shown in *Figure 8-4*, is often required where heavily concentrated loads from columns, girders, or roof trusses are located. This type of foundation may be located under isolated columns or at intervals along a wall where the concentrated loads occur. Spread footings are generally reinforced with steel. They may be flat, stepped, or sloped, as shown in *Figure 8-3*.

**Figure 8-4 – Plan and section of a typical spread footing.**

*Figure 8-5* shows the plan and section of a typical mat foundation. In this type of foundation, a heavily reinforced concrete slab extends under the entire building and distributes the total building load over the entire site. This minimizes problems created by unequal settlement when the subsoil conditions are uneven.

**Figure 8-5 – Plan and section of a mat foundation.**

### 1.1.3 Intermediate Supports

Bents and piers provide support for the bridge superstructure at points other than the bank ends. A bent consists of a single row of posts, or piles, while a pier consists of two or more rows of posts, or piles.

The pile bent, shown in *Figure 8-6*, consists of the bent cap, which provides a bearing surface for the bridge stringers, and the piles, which transmit the load to the soil. The support for the loads may be derived either from column action, when the tip of the pile bears on firm stratum, such as rock or hard clay, or from friction between the pile and the soil into which it is driven. In both cases, earth pressure must provide some lateral support, but transverse bracing is often used to brace the bent laterally.

A timber pile bent consists of a single row of piles with a pile cap. It is braced to the next bent or to an abutment to reduce the unbraced length and to provide stability. This bent will support a combined span of 50 feet.

**Figure 8-6 – Typical pile bent.**

The trestle bent, shown in *Figure 8-7*, is similar to the pile bent, except the post takes the place of the piles and transmits the load from the cap to the sill. The sill transmits the load to the footings, and the footings transmit the load to the soil. Timber trestle bents are normally constructed in dry, shallow gaps where the soil is firm. They are not suitable for use in soft soil or in swift or deep streams. The bent can support a combined span length of up to 30 feet and can be 12 feet high.

A trestle bent pier is the same as the pile bent pier, except it has sills and footings to transmit the load to the soil, as shown in *Figure 8-7*. This bent is designed to carry vertical loads only, and is used to support spans up to a combined 60 feet and ground to grade heights of up to 18 feet.

**Figure 8-7 – Timber trestle bent.**

The pile bent pier, shown in *Figure 8-8*, is composed of two or more pile bents. In this figure, notice the common cap. The cap transmits the bridge load to the corbels which transmits the combined load to the individual bent caps. Piers are usually provided with cross bracing that ties the bents together and provides rigidity in the longitudinal direction.

### 1.1.4 Bracing

Longitudinal bracing and transverse bracing are the two types commonly used to support the substructure in heavy timber construction, as shown in *Figure 8-8*. Longitudinal bracing is used to provide stability in the direction of the bridge center line. Transverse bracing, sometimes called lateral bracing, provides stability at right angles to the center line.

Sometimes a third type of bracing, called a diaphragm, is used. This bracing is used between the stringers to prevent buckling, which is deflecting laterally under load.

**Figure 8-8 – Typical pile pier.**

## 1.2.1 Superstructure

The superstructure of a bridge consists of the stringers, flooring (decking and treads), curbing, walks, handrails, and other items that form the part of the bridge above the substructure. *Figure 8-9* is an illustration of a superstructure.

**Figure 8-9 – Details of a superstructure of a timber trestle.**

As shown in *Figure 8-9*, the structural members that rest on and span the distance between the intermediate supports or abutments are called stringers. The stringers are the main load-carrying members of the superstructure. They receive the load from the flooring and transmit it to the substructure. The flooring system includes these sections:

- Deck
- Wearing surface, or tread, that protects the deck
- Curb and handrail system

The plank deck is the simplest to design and construct, and it provides considerable savings in time compared to other types of decks. Plank decking is normally placed perpendicular to the bridge center line (direction of traffic) for ease and speed of construction. A better arrangement is provided when the decking is placed at about a 30 to 60 degree skew to the center line. Spacing of approximately 1/4 inch between the planks allows for swelling, provides water drainage, and permits air circulation. The minimum thickness of decking is 3 inches in all cases, but when the required thickness of plank decking exceeds 6 inches, a laminated type of decking is used.

# 2.0.0 TYPES of MODULAR BRIDGES

There are several types of modular bridges available to the Navy. These include the Bailey bridge, shown in *Figure 8-10*, the Mabey bridge, also known as the Mabey Johnson or Johnson bridge, and the medium girder bridge.

**Figure 8-10 – Bailey M2 bridge.**

## 2.1.0 Bailey Bridge

At the outset of World War II, the US Army sought a versatile bridge that could span a variety of gaps and be quickly assembled by manpower alone. We adopted the design for the British prefabricated Bailey bridge, US nomenclature M1. We revised the design to provide a greater roadway width of 12 feet and designated it the panel bridge, Bailey M2, shown in *Figure 8-11*. The Bailey bridge is a through-type truss bridge, with the roadway carried between two main girders. The trusses in each girder are formed by 10- foot panels pinned end to end. In this respect, the Bailey bridge is often referred to as the panel or truss bridge.

**Figure 8-11 – Parts of a Bailey M2 panel bridge.**

### 2.1.1 Advantages

Some of the characteristics that make the Bailey bridge valuable in the field are the following:

- It is easy to install. Each part of the Bailey bridge is a standard machine-made piece and is interchangeable among spans. In most cases, no heavy equipment is required to assemble or launch a Bailey bridge; only basic pioneer skills and equipment are needed.
- It is highly mobile. All parts of the bridge can be transported to and from the bridge site by 5-ton dump trucks and trailers.
- It is versatile. Standard parts are used to assemble seven standard truss designs for efficient single spans up to 210 feet long and to build panel crib piers supporting longer bridges. With minor nonstandard modifications, the expedient uses of bridge parts are limited only by the user’s imagination.

### 2.1.2 Construction

Transverse floor beams, called transoms, are clamped to the bottom chords of the trusses and support stringers and decking. Sway braces between the girders provide horizontal bracing. Rakers between the trusses and transoms keep the trusses upright. Bracing frames and tie plates between the trusses provide lateral bracing within each girder.

#### 2.1.2.1 Main Girders

The main girders on each side of the centerline of the bridge can be assembled from a single truss or from two or three trusses side by side. For greater strength, a second story of panels can be added to the trusses. The upper stories are bolted to the top chord of the lower story. For greatest strength, a third story is added. These three basic types are shown in *Figure 8-12*.

**Figure 8-12 – Single, double, and triple truss assemblies.**

The types of possible truss assemblies are given in *Table 8-1*. A single truss, double or triple story bridge is never assembled because it would be unstable. All triple story bridges with the deck in the bottom story are braced at the top by transoms and sway braces which are fastened to overhead bracing supports bolted to the top chords.

**Table 8-1 – Abbreviations for Bailey Type M2 Single Lane Panel Bridges.**

| Type | | Usual Nomenclature | Abbreviation |
|---|---|---|---|
| Truss | Story | | |
| Single | Single | Single single | SS |
| Double | Single | Double single | DS |
| Triple | Single | Triple single | TS |
| Double | Double | Double double | DD |
| Triple | Double | Triple double | TD |
| Double | Triple | Double triple | DT |
| Triple | Triple | Triple triple | TT |

#### 2.1.2.2 Materials

The decking, called chess, is wood. Panels, end posts, transoms, and ramps are a low alloy, high tensile steel. All other parts are carbon structural steel. All joints in the parts are welded.

#### 2.1.2.3 Deck

The clear roadway between curbs, called ribbands, is 12 feet 6 inches wide. The transoms supporting the roadway are normally set on the bottom chords of the bottom story. Footwalks can be carried on the transoms outside of the main trusses on each side of the bridge.

#### 2.1.2.4 Bearings

End posts pinned to the end of each truss sit on cylindrical bearings which rest on a steel base plate. On soft soil, timber grillage is used under the base plates to distribute the load. The bridge can be assembled between banks of different elevations, but the slope should not exceed 30 to 1.

### 2.1.3 Types of Structures

Panel bridge equipment can be used to assemble fixed bridges and panel crib piers and towers. Other special structures, such as floating bridges, suspension bridges, retractable bridges, and mobile bridges, can be assembled using special parts. Panel bridge equipment is normally used to assemble fixed simple span, through-type bridges from 30 to 210 feet long. The bridge can be assembled to meet varying conditions of span and load. Bridge weight per bay is given in *Table 8-2*.

**Table 8-2 – Weight of M2 Panel Bridge in Tons per Bay.**

| Type of Construction | | SS | DS | TS | DD | TD | DT | TT |
|---|---|---|---|---|---|---|---|---|
| Bridge Bays | | 2.76[1] | 3.41[1] | 4.01[1] | 4.66[1] | 5.88[1] | 6.46[1,2] | 8.29[1,2] |
| Launching-nose Bays | | 1.00 | 1.64 | | 2.90 | | | |
| Decking | Chess and steel ribbands | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 |
| | Stringer only | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| | Wear treads (four 3" x 12" panels on each side) | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| Miscellaneous | Footwalks | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| | Overhead bracing (supports, transoms, sway bracing, and chord bolts) | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |

[1] Footwalks and wear treads not included.

[2] Overhead bracing included.

Information on planning, preparing for, and constructing a Bailey bridge is available in *Field Manual 5-277 Bailey Bridge* from the Department of the Army.

## 2.2.1 Mabey Bridge

The Mabey Universal panel bridging system, also known as a Johnson bridge, is capable of clear spans up to 266 feet and road widths suitable for single, double, and triple lane traffic. Originally developed in England by Mabey & Johnson Ltd., it was introduced worldwide in 1974. The versatility of the equipment, together with the ease of construction, enables bridges to be built with high load-carrying capacity in a minimum of time. Bridges of varying spans and capacities can be built from a stockpile of standard, interchangeable elements.

- Once the required span and load capacity are known, the necessary construction of the bridge can be automatically calculated or read from tables.
- Bridges can be built quickly with unskilled labor with an engineer supervising.
- With easily transported parts, simple foundations, and minimized on-site time, Mabey Universal bridges can be in service in a very short time.
- Bridges can be launched into position over the gap, and neither temporary supports nor special plants are required.
- With all parts galvanized for minimum maintenance and steel decking which can be coated with an anti-skid surface if required, Mabey Universal bridges are particularly suitable for permanent applications.

### 2.2.1 Bridge Elements

The panel is the basic unit from which the main girders are formed. Measuring 14' 9" by 7' 9", the Mabey Universal panel is longer and stronger than any other of this type. The panel size has been deliberately designed to permit all the spans normally encountered to be in a single panel height construction.

The effective bending moment capacity of the truss is increased by introducing reinforcement in the form of identical panel chords. Bolted top and bottom to a single panel, the bending moment capacity is doubled. Introducing further panel lines increases both bending and shear capacity. The Mabey Universal is a through-type bridge; the roadway is carried between the main girders, as shown in *Figure 8-13*.

**Figure 8-13 – Parts of a Mabey bridge, single bay of two-lane roadway.**

The simplest construction is made up of the following parts:

- Panels, which are pinned end to end to form the main girders
- Transoms, the cross beams which connect the main girders and support the roadway
- Rakers, which link transoms and panels, completing the structure and stabilizing the top compression chord of the panel
- Sway braces, which connect diagonally between the transoms, forming a horizontal truss with the transoms and bottom chords of the panels to resist wind and sway forces
- Vertical bracing, which connects diagonally between the top and bottom of the transom webs, acting in tension to stabilize the transoms
- Deck units, which are self-locating on the transoms and provide the running surface of the bridge

### 2.2.2 Roadway Decking

The deck systems are categorized according to roadway width and load capacity. With the Universal bridge, transoms (cross girders) are fitted at the panel junctions and the mid-panel positions. They vary in depth and length to cater to different roadway widths and loadings.

The configuration is described as two transoms per bay. The transoms support either steel deck units or, on single roadway bridges, stringers which can take timber decking. All the roadways will carry most standard highway loadings. For areas of high traffic density, the steel deck will accept a factory-applied, anti-skid bi-mark wearing course.

The standard ranges of bridge constructions are shown in *Figure 8-14*.

**Figure 8-14 – Mabey bridge truss constructions.**

*Table 8-3* defines the abbreviations.

**Table 8-3 – Key to Abbreviations.**

| Abbreviation | Name | Description |
|---|---|---|
| SSH | Single Single | Each truss has a single panel line in a single story format. |
| SSHRH | Single Single Reinforced | Each truss has a single panel line in a single story format, with a reinforcing chord attached to both the bottom and top of the panel. * |
| DSH | Double Single | Each truss has two panel lines in a single story format. |
| DSHR1H | Double Single Reinforced One | Each truss has two panel lines in a single story format with a reinforcing chord attached to both the bottom and the top of the inner panel of each truss only. * |
| DSHR2H | Double Single Reinforced Two | Each truss has two panel lines in a single story format with a reinforcing chord attached to both the bottom and top of each panel. * |
| TSH | Triple Single | Each truss has three panel lines in a single story format. |
| TSHR2H | Triple Single Reinforced Two | Each truss has three panel lines in a single story format with a reinforcing chord attached to both the bottom and the top of the inner and outer panels of each truss only. * |
| TSHR3H | Triple Single Reinforced Three | Each truss has three panel lines in a single story format with a reinforcing chord attached to both the bottom and the top of all the panels. * |
| DDH | Double Double | Each truss has two panel lines in a double story format. |
| DDHR1H | Double Double Reinforced One | Each truss has two panel lines in a double story format with a reinforcing chord attached to both the bottom of the lower inner panel and the top of the upper inner panel of each truss only. |
| DDHR2H | Double Double Reinforced Two | Each truss has two panel lines in a double story format with a reinforcing chord attached to both the bottom and top of each lower and upper panel. * |
| TDH | Triple Double | Each truss has three panel lines in a double story format. |
| TDHR2H | Triple Double Reinforced Two | Each truss has three panel lines in a double story format with a reinforcing chord attached to both the bottom of the lower inner and outer panel and the top of the upper inner and outer panel of each truss only. |
| TDHR3H | Triple Double Reinforced Three | Each truss has three panel lines in a double story format with a reinforcing chord attached to both the bottom and top of each lower and upper panel. * |
| H | The letter H is used after either the panel configuration or the chord reinforcement configuration to signify that super panels or super chords are used to form the bridge trusses, instead of standard panels or standard chords. If standard panels are available, they should not be used in conjunction with super panels. | |
| * | Note that the final bay at each end of the span is always of unreinforced construction. | |

### 2.2.3 Bridge Weights

*Table 8-4* shows the weight in metric tons of Mabey bridge bays.

**Table 8-4 – Weights per Bay of Bridge Bays (Metric Tons).**

| Truss Construction | Fully Decked | No Deck |
|---|---|---|
| DSH | 9.501 | 5.856 |
| DSHR1H | 10.427 | 6.782 |
| DSHR2H | 11.332 | 7.687 |
| TSH | 10.843 | 7.198 |
| TSHR2H | 12.672 | 9.027 |
| TSHR3H | 13.588 | 9.943 |
| DDH | 12.376 | 8.731 |
| DDHR1H | 13.290 | 6.646 |
| DDHR2H | 14.205 | 10.560 |
| TDH | 15.091 | 11.446 |
| TDHR2H | 16.921 | 13.276 |
| TDHR3H | 17.836 | 14.191 |

**Notes:**

1. The weights tabulated above are in tons per 4.500 m long bay and are based upon theoretical component weights with an allowance of 2.5% for galvanizing.
2. The fully decked weights are with all steel deck fitted. The no deck weights are with neither steel deck units nor kerbs fitted.
3. The final bay at each end of a bridge span is always of an unreinforced truss construction, even when the bridge is otherwise of a reinforced construction.

Information on planning, preparing for, and constructing a Mabey bridge is available in the *Mabey Universal Bridge System Bridge Manual* from the manufacturer.

## 2.3.1 Medium Girder Bridge

The medium girder bridge (MGB) is a two girder deck bridge. The wide upper surfaces of the girders and the deck units laid between them form a roadway 13 feet 2 inches wide. The girders can be constructed to form a shallow single story construction, as shown in *Figure 8-15.* The two girders are constructed from a number of panels pinned together, and are separated by two bankseat beams, one pinned to each of the girders. The roadway is formed by hanging deck units between the girders and connecting ramps to each end. Curbs and guide markers are placed at the outside edges of the girders to mark the edge of the bridge. The single story bridge is used for light loads.

**Figure 8-15 – Medium girder bridge - shallow single story.**

The girders can also be constructed to form a deeper double story construction, as shown in *Figure 8-16*. A double story bridge (DSB) uses all of the parts of a single story bridge (SSB) which are pinned on top of triangular bottom panels, with junction panels and end taper panels at each end. These parts make the bridge stronger.

**Figure 8-16 – Medium girder bridge – double story.**

The double story can be reinforced by adding components of the Link Reinforcement Set (LRS), as shown in *Figure 8-17*; this permits longer Military Load Class (MLC) 70 bridges to be constructed. The Link Reinforcement Set (LRS) extends the single-span capability of the MLC 70 MGB. The set contains all the components needed for use with two bridge sets to construct any length of reinforced MLC 70 (Tracked) MGB up to 150 feet and MLC 60 (Tracked) up to 162 feet (49.4 m). The LRS consists of reinforcing links 12 feet and 6 feet long which are connected to form a pair of link chains, one beneath each bridge girder. The 6-foot links are provided for use in bridges that have an odd number of bays.

**Figure 8-17 – Medium girder bridge - link reinforced.**

The maximum load capabilities of single story, double story and link reinforced MGB are given in *Table 8-5*.

**Table 8-5 – Bridge Length v Maximum Load Capability.**

| Bridge | MLC (Note 1) | Bridge Length in Feet (Meters) (Note 2) | Maximum Transverse Slope Unloaded | Maximum Full Load Crossings (Note 2) |
|---|---|---|---|---|
| Single Story | 60 | 32 (9.8) | 1/10 | 10,000 |
| | 70 (Tracked) | 32 (9.8) | 1/20 | 5,000 |
| | 100 (Wheeled) | 32 (9.8) | 0 | 7,500 |
| Double Story | 60 | 102 (31.1) | 1/20 | 10,000 |
| | 60 (Tracked) | 108 (32.9) | 1/20 | 7,500 |
| | 70 (Tracked) | 102 (31.1) | 1/20 | 5,000 |
| | 100 (Wheeled) | 90 (27.4) | 0 | 3,000 |
| Link Reinforced | 60 | 162 (49.4) | 1/20 | 10,000 |
| | 70 (Tracked) | 150 (45.7) | 1/20 | 10,000 |
| | 70 (Tracked) | 162 (49.4) | 0 | 5,000 |
| | 100 (Wheeled) | 102 (31.1) | 0 | -- |

**NOTES:**

1. Deck width is 13 feet 2 inches (4 meters). In MLC 70 (Tracked) and MLC 100 (Wheeled) configurations the bridge width should be indicated by a sign.
2. MLC 100 (Wheeled) span has yet to be confirmed by tests.

Information on planning, preparing for, and constructing a medium girder bridge is available in the *Operator's Manual – Medium Girder Bridge* from the Department of the Army and Headquarters U.S. Marine Corps.

## 3.1.1 SHORING EXCAVATION

One of the inherently hazardous parts of construction operations is excavating. The main hazards of excavation work are as follows:

1. Collapse or failure of excavation walls, burying workers and equipment
2. Materials, tools, and equipment falling into holes and striking workers below
3. Hazards involving public utilities, such as electricity, water, gas, or natural gases and an oxygen-deficient atmosphere
4. Wet, muddy conditions, causing slips, trips, or falls, complicated by limited spaces in which personnel work

Take precautions to make sure the excavation banks do not collapse and cause injury or death to persons working in the excavation. The method used to protect excavation banks from collapsing depends on these conditions:

- Type of soil in the area
- Depth of the excavation
- Type of foundation being built
- Space around the excavation

Before beginning the excavation, the Builder must secure all possible information regarding any underground installations in the area, including sewer, water, fuel, and electrical lines. As a Builder, you must also take precautions NOT to disturb or damage any utility while digging and to provide adequate protection after any such exposure. Make sure you have a digging permit on the jobsite and that you follow its guidelines.

Many safety codes also require that the excavation be inspected by a qualified person (ROICC or safety officer) after a rainstorm or any other hazardous natural occurrence. Avert earth bank cave-ins or landslides by increasing the amount of shoring and other means of protection.

Provide convenient and safe access to excavated areas for your crew. Such access may consist of stairways, ladders, or securely fastened ramps.

During excavation some soil types pose greater problems than others. Sandy soil is always considered dangerous even when it is allowed to stand for a period of time after a vertical cut. Instability can be caused by moisture changes in the surrounding air or changes in the water table. Vibration from blasting, traffic movement, and material loads near the cut can also cause earth to collapse in sandy soil.

Clay soils present less risk than sand, but soft clay can also be dangerous. You can do a simple test of clay conditions by pushing a 2 by 4 into the soil. If the 2 by 4 is easily pushed into the ground, it indicates that the clay is soft and may collapse. Silty soils, a combination of sand and clay, are also unreliable and require the same precautions as sand.

## 3.1.0 Sloping

When there is sufficient space around the construction site, slope the earth banks as necessary to prevent collapse. The Occupational Safety and Health Administration (OSHA) code regulations for the construction industry recommend a 45-degree slope for excavations with average soil conditions. Solid rock, shale, or cemented sand and gravel may require less slope. Compacted sharp sand or well rounded loose sand may require more than a 45-degree slope.

## 3.2.0 Shoring Vertical Walls

Shoring (supporting) the vertical walls of an excavation is required when sloping is considered unsafe or inadequate. Soil types such as clays, silts, loams, or non-homogenous soils usually require shoring. Shoring may also be required where there is insufficient room for sloped banks. This is particularly true in industrial and commercial areas where new construction is right next to existing buildings. In addition to preventing injury from collapse of excavation banks, stability of the foundation walls of adjoining buildings must be protected. A civil engineer supervises shoring for high vertical walls, and qualified personnel supervise the installation. Do not remove the shoring system until the construction in the excavated area is completed and all the necessary steps are taken to safeguard workers. Two methods commonly used to shore high vertical excavation banks are interlocking sheetpiling, shown in *Figure 8-18*, and soldier piles, shown in *Figure 8-19*.

**Figure 8-18 – Types of interlocking sheet piles.**

### 3.2.1 Interlocking Sheet Piles

Interlocking sheet piles consist of steel pilings that can be reused many times and offer the additional advantage of being watertight. Each individual sheetpiling is lowered by crane into a template that holds it in position. Then the piling is driven into place with a pile driver. Install braces to help support the metal sheets.

### 3.2.2 Soldier Pile Systems

Soldier piles are H-shaped piles that are driven into the ground with a pile driver and are spaced between 3 and 10 feet apart. Refer to the plans and specifications for spacing requirements. Three-inch thick wood planks, called lagging**,** are placed between the flanges or directly against the front of the piles. You may use 2-inch blocks for spacing between each plank or butt the planks together depending on the specifications. Soil conditions and the depth of the excavation may require tie-backs that consist of steel strand cables placed in holes drilled horizontally into the banks of the excavation. The holes are drilled into the banks of the excavation with a power auger and are often 50 feet or more in length. The tie-back cables are inserted through an opening in the pile and are secured in the earth by power grouting the hole. After the grout has set up, a strand-gripping device, consisting of a gripper and gripper casing, is placed over the cables. A hydraulic tensioning jack is used to tighten the cables. When the jack releases the cables, the gripping device holds them and maintains the required tension against the pile. The number of tie-backs required should be determined by an engineer whose decision will be based on soil conditions and the depth of the excavation. Some soldier pile systems may also include a heavy horizontal steel waler held in place with tie-backs. This technique is similar to constructing a single waler system for concrete; it is the same basic principle.

**Figure 8-19 – Soldier pile systems.**

In many instances, the excavation for a new building must be carried right up to the foundation of an existing one. This presents a problem if the new excavation is to be deeper than the footings of the existing building. Part of the support for those footings will be removed, and it is the BU's responsibility to protect the building against movement caused by settlement during and after construction of the new building. Temporary support may be provided by shoring or needling, while permanent support is provided by underpinning, extending the old foundation to the level of the new one.

A common method of support for adjacent structures is by the use of 12 by 12 timbers, called shores, inclined against the wall to be supported and extending across the excavation to a temporary footing consisting of a framework or mat of timbers laid on the ground. Fit the upper ends of the shores into openings cut in the wall, or butt them against a timber bolted to the wall. Place steel saddles in openings cut in concrete or masonry walls to support lifting or to steady the shores.

As a good practice, set the shores as vertical as possible to reduce lateral thrust against the wall. Whenever possible, locate the heads at floor level to minimize the danger of pushing the wall in.

Make the provision for inducing a lift or thrust in the shores by inserting jacks between the bases of the shores and the footing. Use a standard steel screw jack with the capability to lift as much as 100 tons for the shores. When a single screw jack is used with a shore, bore a hole in the base of the shore to admit the threaded portion of the jack, in an arrangement called a pump. For a larger lifting effect, attach a pair of jacks to a short timber called a crosshead. An advantage of crosshead arrangements is that after the lift has been applied, the crosshead can be blocked and the jacks removed for use elsewhere.

# 4.0.0 PILE CONSTRUCTION

As a Builder, you will coordinate and direct pile driving operation crews. Piles include many different types and materials. The more common types are covered next.

## 4.1.0 Bearing Piles

Bearing piles are vertical posts that carry the weight of a foundation. They transmit the load of a structure to the bedrock or subsoil.

### 4.1.1 Timber Bearing Piles

Timber bearing piles are usually straight tree trunks with the limbs and bark removed; they must be pressure treated. These piles, if kept continuously wet, will last for centuries, but they are used for low design loads because of their vulnerability to damage while they are being driven into the ground. The small end of the pile is called the tip, and the larger end is called the butt. Timber piles range from 16 to 90 feet in length with a tip diameter of at least 6 inches. The butt diameter is seldom less than 12 inches.

### 4.1.2 Steel Bearing Piles

Steel bearing piles are usually H piles, with an H-shaped cross section. These piles are usually used for driving through bedrock or until refusal. A steel pile can also be a pipe pile with a circular cross section. A pipe pile can be either an open end pile or a closed end pile, depending on whether the bottom end is open or closed.

### 4.1.3 Concrete Piles

Concrete piles, shown in *Figure 8-20*, may be either precast or cast-in-place. Most precast piles used today are pretensioned and are manufactured in established plants. These piles are made in square, cylindrical, or octagonal shapes. When driven into soft soil or mucky soil, they are usually tapered. Cast-in-place piles are cast on the jobsite and are classified as shell type or shell-less type. The shell type is formed when the hollow steel tube (shell) with a closed end is driven into the ground and filled with concrete. The shell-less type is formed when first a casing and core are driven to the required depth. The core is removed, and the casing is filled with concrete. The casing is then removed, leaving the concrete in contact with the earth.

**Figure 8-20 – Types of concrete piles.**

## 4.2.1 Sheet Piles

Sheet piles made of wood, steel, or concrete are equipped or constructed for edge joining so they can be driven edge to edge to form a continuous wall or bulkhead. A few common uses of sheet piles are as follows:

1. To resist lateral soil pressure as part of a temporary or permanent structure, such as a retaining wall.
2. To construct cofferdams or structures built to exclude water from a construction area.
3. To prevent slides and cave-ins in trenches or other excavations.

The edges of steel sheetpiling shown in *Figure 8-18* are called interlocks because they are shaped for locking the piles together edge to edge. The part of the pile between the interlocks is called the web.

## 4.3.1 Pile Driving Operation

Almost all pile driving is done with a crawler or with truck-mounted cranes rigged with pile-driving attachments, as shown in *Figure 8-21*. The main parts of pile-driving attachments are as follows:

- The leads come in 10-, 15-, and 20-foot sections bolted together to form various lengths.
- The catwalks, also called the lead brace or spotters, can be extended or telescoped to various lengths. These can be set to hold the leads vertical for driving bearing piles or to hold them at an angle for driving batter piles.

**Figure 8-21 – Typical pile-driving operation.**

Steps in rigging pile-driving attachments on a crane are as follows:

1. Assemble the lead sections on the ground, as shown in *Figure 8-22*. Line the crane up with the leads, and lower the boom until its head is in line with the tops of the leads, as shown in *Figure 8-22*.
2. Remove the cotter pins on the ends of the boom point pin, install the adapters, and reinstall the cotter pins.
3. Bolt the adapters to the ends of the leads, as shown in *Figure 8-23*. To avoid trouble, bolt on one adapter, and swing the boom enough to align the bolt holes with the adapter and leads. Attach the tops of the leads to the head of the boom.

**Figure 8-22 – Assembly of 10- and 20-foot sections.**

**Figure 8-23 – Lead adapters connected to the boom tip.**

4. The lines that handle the piles and the hammer are called the pile whip and the hammer whip. Reeve (pass) them over the sheaves at the head of the boom, bring down the ends to the foot of the leads, and lash them. Reeve through enough slack in each whip to ensure that the boom can be topped up to the vertical height of the leads without also straining the sheaves.
5. Raise the leads by topping up the boom.
6. When the leads are raised to the vertical position, attach lead braces or spotters (catwalks).
7. Place the hammer in the leads, as shown in *Figure 8-24*. Raise the leads off the ground by topping the boom, place the hammer under them, lower the leads onto the hammer, and attach the hammer whip line to the pin on top of the hammer.

**Figure 8-24 – Placing hammer in leads.**

**Figure 8-25 – Placing pile cap in leads.**

8. The driving cap or follower block is a cap that rests on the top of the pile being driven. It slides freely in the leads to steady the pile and to receive and transmit the impact of the hammer. The cap, shown in *Figure 8-25*, has a sling of wire rope, so the cap and the hammer may be drawn to the top of the leads out of the way when a pile is being positioned for driving.

### 4.3.1 Pile-Driving Hammers

The three main types of pile-driving hammers are the drop hammer, the steam, or pneumatic, hammer, and the diesel hammer.

A drop hammer is a block of metal run up to a specified height and then dropped on a cap placed on the butt or head of the pile. Drop hammers weigh from 1,200 to 3,000 pounds.

The steam, or pneumatic, hammer has basically replaced the drop hammer. This hammer, shown in *Figure 8-26*, consists of a cylinder that contains a steam-driven or air-driven ram. The ram consists of a piston equipped with a striking head. The hammer is rested on the butt or head of the pile for driving.

With a single-action steam, or pneumatic, hammer, the power drive serves only to lift the ram; the downward blow of the ram results from the force of gravity only. In a double-action hammer, the ram is both lifted and driven downward by the power drive. A double-action hammer weighs from 5,000 to 14,000 pounds and a single-action hammer weighs about 10,000 pounds.

The blow of the double-action hammer is lighter but more rapid than that of the single-action hammer. The double-action hammer generally drives lightweight or average weight piles into soils of average density; its rapid blows tend to keep the pile in motion, which reduces the resistance of inertia and friction. For heavy piles in hard or dense soil, the resistance from inertia and friction, together with the rapid, high velocity blows of the double-action hammer, tend to damage the butt or head of the pile.

**Figure 8-26 – Steam, or pneumatic, pile hammers.**

The single-action hammer generally drives heavy piles into hard or dense soil; its heavy ram, striking at lower velocity, allows more energy to be transferred into the motion of the pile, reducing impact and damage to the butt or head of the pile.

The diesel pile hammer, shown in *Figure 8-27*, is the most common hammer used in the NCF. This hammer is made up of a cylinder, a ram piston, a fuel pump, a built-in fuel tank, a lubricant oil tank, and an inertia oil pump that lubricates mechanically during operation.

The diesel pile hammer is about twice as fast as a conventional pneumatic, or steam, hammer of like size and weight. A conventional pneumatic hammer requires a 600 cubic foot per minute compressor to operate, while the diesel is a self-contained unit constructed in sizes that deliver up to 43,000 foot pounds of energy per blow.

**Figure 8-27 – Diesel pile hammer.**

### 4.3.2 Pile-Driving Caps

A pile-driving cap is a block, usually a steel block, that rests on the butt or head of the pile and protects it against damage by receiving and transmitting the blows of the hammer or ram. In the steam, or pneumatic, hammer, the cap is a part of the hammer. The cap with a drop or diesel hammer is a separate casting, with the lower part recessed to fit the head or butt of the pile, and the upper part recessed to contain a hardwood block which receives the blows of the hammer. The cap is fitted with a wire rope sling so that the cap, as well as the hammer, may be raised to the top of the leads when positioning a pile in the leads. Pile caps are available for driving timber, concrete, sheet, and H beam piles. *Figure 8-28* shows an example of a steel H pile and a special cap for driving.

**Figure 8-28 – H beam pile-driving cap.**

### 4.3.3 Crane Safety

As the project supervisor of a pile-driving operation, you must be aware of the safety precautions and procedures involved when working with and around cranes.

Statistics on accidents show that a free-moving power crane is one of the most destructive machines used in the Navy, as well as in private industry. Over one-third of the victims of crane accidents are operators, and more than one-fourth are crew members other than operators. Ironically, the people who sustain the most injuries from cranes are the very ones who can do the most to prevent injuries. Most crane accidents are preventable simply because they are caused by situations, conditions, or actions under the control of the operating crew. The term “preventable accident” is illogical; if an accident were preventable, it would not be an accident, but an act of omission or commission by somebody.

Most crane work is, or should be, a coordinated activity of a team of skilled technicians and workers. The lives and well-being of the whole team are in the hands of each member of the team during a continually shifting scene requiring constant judgment and responsibility. The pile-driving crew is usually made up of the following personnel:

- Rig operator
- Signalman
- Loftman
- Hoisting engineer
- Hook-on person

During any pile-driving operation, the signalman is the boss of the rig and is normally the only person giving signals to the operator. The only signal any other person may give that the operator will obey is the emergency stop signal. Refer to the *Equipment Operator Basic NRTC* for more information regarding crane safety.

### 4.3.4 Pile-Driving Safety

Standard safety and accident prevention procedures developed to govern general construction operations apply also to pile-driving operations. Pile driving is hazardous, and personnel should take adequate care to be protected from injury. Close cooperation between the Equipment Operators and crew members (Builders/Steelworkers) is essential to avoid accidents.

- Apply normal safety precautions to hand power tools used to prepare piles for driving and in cutting off, straightening, and aligning piles after they are driven.
- Wear safety shoes.
- Be sure you and all your crew are wearing hard hats. Mill scale may fly from a steel pile while it is being driven.
- During the first few feet of driving a pile, keep personnel out of the way as much as possible so that if the tip of the pile were to strike an obstacle and slide out of line, no one would be struck by the pile.
- During actual pile driving, protect your ears.
- When working over water, wear a life jacket and make sure crew members do likewise.
- Use safety belts as required.

### 4.3.5 Characteristics of Different Piles

As a Builder, you will be most concerned with timber piles. Steel piling ranks next in importance, especially where the construction must accommodate heavy loads or the foundation is expected to be used over a long period of time. Steel is best suited for use as bearing piles when piles are longer than 80 feet and column strength exceeds the compressive strength of timber. Steel is also best suited where piles must be driven under the following conditions:

- To reach bedrock for maximum bearing surface through overlying layers of partially decomposed rock.

- To penetrate layers of coarse gravel or soft rock, such as coral.
- To attain greater depth of penetration for stability.

Concrete and composite piles are seldom used because they require material and equipment that is not normally available through military supply channels. They are likely to be used in cases where local materials are readily available, whereas standard military piling would have to be received in large quantities from CONUS. Interlocking steel sheet piling is often used in military construction, but concrete-steel piling can be manufactured in the field when local material is available.

### 4.3.6 Precautions During Pile Driving

Be careful during driving to avoid damage to the pile, the hammer, or both. If the pile driver shifts position during driving, the blows of the hammer will be out of line with the axis of the pile and both the pile and the hammer may be damaged.

Watch the piles carefully for any sign of a split or break below ground. When you are driving a pile and it suddenly becomes easier to drive or the pile suddenly changes direction, a break or split has probably occurred. When this happens, pull the pile as soon as possible, because further driving is useless.

Springing means that the pile vibrates too much laterally. Springing may occur when a pile is crooked, when the butt has not been squared off properly, or when the pile is not in line with the fall of the hammer. In all pile driving, make sure the fall of the hammer is in line with the pile axis; otherwise the head of the pile and the hammer may be damaged severely and much of the energy of the hammer blow lost.

Excessive bouncing may come from a hammer that is too light. It usually occurs when the butt of the pile has been crushed or broomed, when the pile has met an obstruction, or when it has penetrated to a solid footing. When a double-action hammer is being used, bouncing may result from too much steam or air pressure. With a closed end diesel hammer, if the hammer lifts on the upstroke of the ram piston, the throttle setting is probably too high. Back off on the throttle and control just enough to avoid this lifting. If the butt of the timber pile has been crushed or broomed more than an inch or so, cut it back to sound wood before you drive it any more.

When a pile has reached a level where 6 blows of a drop hammer, 20 blows of a steam or air hammer, or 10 blows of a diesel hammer per inch will not drive it more than an average of one eight inch per blow, the pile has either hit an obstruction or has been driven to refusal. In either case, further driving is likely to break or split the pile. If the lack of penetration seems to be caused by an obstruction, try 10 or 15 blows of less than maximum force; they may cause the pile to displace or penetrate the obstruction. For obstructions which cannot be disposed of in this manner, it is often necessary to pull or extract the pile (see the Extracting Piles section) and blast out the obstruction with an explosive lowered to the bottom of the hole.

A pile is at the point of refusal when it has been driven to a depth where deeper penetration is prevented by friction. A pile supported by skin friction alone is called a friction pile. A pile supported by bedrock or an extra dense layer of soil at the tip is called an end bearing pile. A pile supported partly by skin friction and partly by substratum of extra dense soil at the tip is called a combination end bearing and friction pile.

It is not always necessary for you to drive a friction pile to refusal; such a pile needs to be driven only to the depth where friction develops the required load-bearing capacity.

When bearing piles are driven on land, the position of each pile is usually located by the Engineering Aid and marked with a stake. A common method of locating the positions of a series of pile bents driven in water is by use of a wire rope long enough to stretch between the abutments and marked with pieces of tape, spaced according to the prescribed or calculated distance between bents.

After driving the first bent, use a floating template when driving subsequent bents like the one shown in *Figure 8-29*. Space pairs of battens according to a specified spacing between piles in a bent and nail them across each pair of timbers. Hinge the parts of each batten lying beyond the timbers for raising. Lash the template to the outer piles in the bent already driven by means of a pair of wire ropes equipped with turnbuckles, as shown. After driving the piles in the new bent, raise the hinged parts of the battens, let the wire ropes go, and float the template out from between the bents.

**Figure 8-29 – Floating template for positioning piles.**

Piles can be driven either tip or butt down; they may be driven butt first if a large bearing area is required or if the pile is to resist an upward force.

### 4.3.7 Lagging

Lagging is used to increase the resistance of a friction pile. Before driving the pile, lag screw long, narrow strips of wood or steel to the pile, as shown in *Figure 8-30*. Attach these to the lower part of the pile from approximately 12 inches above the tip to the limits of the depth that the pile is expected to penetrate. The extra surface area increases the load-carrying capacity of the pile but tends to make it more difficult to drive.

**Figure 8-30 – Lagging of a timber friction pile.**

## 4.4.0 Constructing a Pile Bent

After the piles in a pile bent have been driven, the remaining steps in constructing the bent are aligning, cutting, capping, and bracing the piles.

### 4.4.1 Aligning Piles in a Bent

Straighten the piles in a bent with tackles and bring them into alignment with an aligning frame, as shown in *Figure 8-31*.

**Figure 8-31 – Straightening frame.**

After the frame has been put on, a working platform, like the one shown in *Figure 8-32*, is usually erected to support the personnel who will cut, cap, and brace the piles.

**Figure 8-32 – Cutting timber pile bent to final height.**

### 4.4.2 utting Piles in a Bent

A timber pile selected for a bent should be long enough to leave 2 or 3 feet extending above the specified elevation of the bottom of the cap after the pile has been driven to the specified penetration. The piles are then cut to the specified elevation with a chain saw or a crosscut saw.

Because the cap must bear evenly on all the piles in the bent, it is important that they all be cut exactly the same elevation. Ensure this by the use of the cutting guide or the sawing guide, as shown in *Figure 8-32*. Determine the position for the cutting guide by locating the correct elevation of the bottom of the cap and using an engineer's level on the two outside piles in the bent.

### 4.4.3 pping Piles in a Bent

After the timber piles in a bent are straightened, aligned, and cut, the piles are usually capped. Set the cap in place, bore a hole for a driftbolt through the cap into the top of each pile, and drive the driftbolts. Then put on the transverse and longitudinal bracing. Sometimes the bracing may be installed before the piles are capped.

## 4.5.0 Placing Piles by Jetting

Jetting often makes pile penetration easier. Jetting is the process of forcing water under pressure around and under the pile to lubricate and/or displace the surrounding soil, as shown in *Figure 8-33*. In soils other than fairly coarse, dense sands, jetting is not necessary or advisable. Jetting equipment consists of a water pump, a length of flexible hose, and a metal jet pipe; jet pipes run from 2 1/2 to 3 inches in diameter.

**Figure 8-33 – Jetting with a single jet pipe.**

Use a single jet pipe as follows. Set the pile in position with the hammer resting on it for extra weight, and manipulate the jet pipe to loosen and wash away the soil from under the tip, as shown in *Figure 8-33*. As the soil is washed away, the pile sinks under its own weight and that of the hammer. Strike a few hammer blows occasionally to keep the pile moving downward. When it is 3 feet above the final tip elevation, withdraw the jet pipe and drive the pile the rest of the way with the hammer.

The action of a single jet pipe on one side of a pile tends to send the pile out of plumb. Whenever possible, use two pipes and lash them to the pile on opposite sides, as shown in *Figure 8-34*.

**Figure 8-34 – Jetting with two jet pipes.**

## 4.6.0 Extracting Piles

A pile that has met an obstruction, has split or broken in driving, or is to be salvaged (steel sheet piles are frequently salvaged for reuse) is usually pulled (extracted). Pull the pile as soon as possible after driving it; the longer the pile stays in the soil, the more compact the soil becomes, and the greater will be the resistance to pulling. Methods of pulling piles are direct lift and tidal lift.

### 4.6.1 Direct Lift

In the direct lift method, a crane is used to pull the pile. The crane whip is slung to the pile, and a gradually increased pull is applied up to just a little less than the amount that is expected to start it. Lateral blows from a headache ball, a heavy steel ball swung on a crane whip to demolish walls, or a few light blows on the butt or head with a driving hammer are given to break the skin friction. The crane pull is then increased to maximum capacity. If the pile still will not start, it maybe loosened by jetting or the lift of the crane may be supplemented by the use of hydraulic jacks.

The 5,000-pound double-action hammer may be used in an inverted position to pull piles. Turn the hammer over, pass a wire rope sling over it and attach it to the pile, as shown in *Figure 8-35*. Heave the hammer whip taut; the upward blows of the hammer ram on the sling plus the pull of the hammer whip are usually enough to pull the pile.

**Figure 8-35 – Wire rope sling used with 5,000-pound airstream hammer to pull piles.**

#### 4.6.2 Tidal Lift

Tidal lift is used often to pull piles driven in tidewater. Attach slings on the piles to barges or pontoons at low tide; the rising tide pulls the piles as it lifts the barges or pontoons. To avoid the danger of tipping barges over, place a barge on each side of the pile with the lifting force transmitted by girders extending across the full width of both barges.

### 4.7.1 Planning and Estimating Pile-Driving Operations

So far, you have acquired a thorough understanding of the materials, principles, and capabilities of pile driving. Although preparing estimates, such as for man-days and equipment, is usually left up to the Equipment Operators (EOs), you should have no problem doing so as well.

Manpower estimates for driving piles, shown in *Figure 8-36*, are based on a typical crew consisting of the following members:

- One crew leader
- One crane operator
- Four crew members to place the piles in the leads
- One or two crew members to prepare the piles

This is based on the further assumption that the pile driver can pick up and place the piles in the leads. If this cannot be done because of the location of the undriven piles, you must allow for an additional crane and increase the total man-days required by 15 percent.

| Work Element Description | Unit | Man-Hours Per Unit |
|---|---|---|
| | | |
| 25 Foot Wood Piling | Each | 3.5 |
| 50 Foot Wood Piling | Each | 6.5 |
| 75 Foot Wood Piling | Each | 9.6 |
| | | |
| 25 Foot Steel Piling | Each | 4.0 |
| 50 Foot Steel Piling | Each | 7.2 |
| 75 Foot Steel Piling | Each | 12.0 |
| | | |
| 40 Foot Precast Concrete Piling | Each | 13.2 |
| 60 Foot Precast Concrete Piling | Each | 18.0 |
| 80 Foot Precast Concrete Piling | Each | 24.0 |
| | | |
| Steel Sheetpiling | 1,000 SF | 102.0 |
| | | |
| Assemble and Rig Leads and Hammer | Each | 48.0 |
| | | |
| Dismantle Leads and Hammer | Each | 32.0 |
| | | |
| Suggested Crew Size: Two EOs, two EAs, six to ten BUs. | | |
| NOTES: | 1. Man-hour figures are preliminary estimate only. The many variables of this work require on-site determination for accurate estimates.<br>2. Factors of importance are: Design, soil, equipment and method used, tides, access to site, currents, materials storage, etc.<br>3. For concrete filled, fluted hollow steel piling and pipe piling for spudding pontoon small craft finger piers, use the steel bearing pile figures. | |

**Figure 8-36 – Table from P-405.**

The time in man-days required to drive each pile depends on the type of pile and its length. Precast concrete bearing piles drive slower than wood or steel ones, and logically, the use of a longer pile usually means that you plan to drive it deeper, which will take more time. Under average conditions, the following estimates apply:

- 3.0 man-hours to drive a 25-foot wood pile
- 4.0 man-hours to drive a steel pile
- 13.2 man-hours to drive a precast concrete pile

These estimates take into account pile preparation, placing it in the leads, driving, and cutoff, if required.

When estimating the man-days required to complete a pile-driving operation, you cannot forget to include time for assembling the leads and hammer, preparing the equipment for driving, cutting holes in steel piling to facilitate handling, and disassembling the equipment upon completion, if required. You must also allow time for pile extraction if it is a required part of the project.

# 5.1.1 WATERFRONT STRUCTURES

Waterfront structures may be broadly divided into three types:

1. Harbor shelter structures
2. Stable shoreline structures
3. Wharfage structures

## 5.1.0 Harbor Shelter Structures

Harbor shelter structures are offshore structures designed to create a sheltered harbor. Various types of these structures are covered next.

### 5.1.1 Breakwater and Jetty

A breakwater is an offshore barrier erected to break the action of the waves and thereby maintain an area of calm water inside the breakwater. A jetty is a similar structure, except its main purpose is to direct the current or tidal flow along the line of a selected channel.

The simplest type of breakwater or jetty is the rubble mound (also called rock mound) type, shown in *Figure 8-37*.

**Figure 8-37 – Rubble mound breakwater or jetty.**

The width of its cap may vary from 15 to 70 feet. The width of its base depends on the width of the cap, the height of the structure, and the slopes of the inner and outer faces.

For a deepwater site or for one with an extra high tide range, a rubble mound breakwater may be topped with a concrete cap structure, as shown in *Figure 8-38*. A structure of this type is called a composite breakwater or jetty. In *Figure 8-38*, the cap structure is made of a series of precast concrete boxes called caissons, each of which is floated over its place of location and then sunk into position. A monolithic (single piece) concrete cap is then cast along the tops of the caissons.

**Figure 8-38 – Composite breakwater or jetty.**

Sometimes breakwaters and jetties are built entirely of caissons, as shown in *Figure 8-39*.

**Figure 8-39 – Caisson breakwater or jetty.**

### 5.1.2 Groin

A groin is a structure similar to a breakwater or jetty, but it serves a third purpose. It is used in a situation where a shoreline is subject to along-shore erosion caused by wave or current action parallel or oblique to the shoreline. The groin is run out from the shoreline (usually there is a succession of groins at intervals) to check the along-shore wave action or deflect it away from the shore.

### 5.1.3 Mole

A mole is a breakwater that is paved on the top for use as a wharfage structure. To serve this purpose, it must have a vertical face on the inner side, or harborside. A jetty may be similarly constructed and used, but it is still called a jetty.

## 5.2.0 Stable Shoreline Structures

These structures are constructed parallel with the shoreline to protect it from erosion or other wave damage. They are covered next.

### 5.2.1 Seawall

A seawall is a vertical or sloping wall that offers protection to a section of the shoreline against erosion and slippage caused by tide and wave action. A seawall is usually a self-sufficient type of structure, such as a gravity type retaining wall. Seawalls are classified according to the types of construction and may be made of riprap or solid concrete. Several types of seawall structures are shown in *Figure 8-40*.

**Figure 8-40 – Various types of seawalls.**

### 5.2.2 Bulkhead

A bulkhead serves the same general purpose as a seawall, namely, to establish and maintain a stable shoreline. However, while a seawall is self-contained, relatively thick, and supported by its own weight, the bulkhead is a relatively thin wall. Bulkheads are classified according to types of construction, such as the following:

- Pile and sheathing bulkhead
- Wood sheet pile bulkhead
- Steel sheet pile bulkhead
- Concrete sheet pile bulkhead

Most bulkheads are made of steel sheet piles, as shown in *Figure 8-41*, and are supported by a series of tie wires or tie rods that are run back to a buried anchorage (or deadman). The outer ends of the tie rods are anchored to a steel wale that runs horizontally along the outer or inner face of the bulkhead. The wale is usually made up of pairs of structural steel channels that are bolted together back to back.

**Figure 8-41 – Steel sheet pile bulkhead.**

In stable soil above the groundwater level, the anchorage for a bulkhead may consist simply of a buried timber, a concrete deadman, or a row of driven and buried sheet piles. A more substantial anchorage for each tie rod is used below the groundwater level. Two common types of anchorages are shown in *Figure 8-42*. In *View A*, the anchorage for each tie rod consists of a timber cap supported by a batter pile, which is bolted to a bearing pile. In *View B*, the anchorage consists of a reinforced concrete cap supported by a pair of batter piles. As shown in the figure, tie rods are supported by piles located midway between the anchorage and the bulkhead.

**Figure 8-42 – Two types of tie-rod anchorages for bulkheads.**

Bulkheads are constructed from working drawings like those shown in *Figure 8-43*. The detail plan for the bulkhead shows that the anchorage consists of a row of sheet piles to which the inner ends of the tie rods are anchored by means of a channel wale.

The section view shows that the anchorage will lie 58 feet behind the bulkhead. This view also suggests the order of construction sequence. First, excavate the shore and bottom to the level of the long, sloping dotted line. Then drive the sheet piles for the bulkhead and anchorage. Drive the intervening supporting piles at intervals of 19 feet 4 inches to hold up the tie rods. Drive the piles next, and then set the tie rods in place. Bolt on the wales, and tighten the tie rods moderately with turnbuckles.

Begin backfilling to the bulkhead. The first backfilling operation consists of filling over the anchorage out to the sloping dotted line. Then set up the turnbuckles on the tie rods to bring the bulkhead plumb. Then put in the remaining fill out to the bulkhead. Finally, outside the bulkhead, dredge the bottom to a depth of 30 feet.

**Figure 8-43 – Working drawings for steel sheet pile bulkhead.**

Fit the fender piles with a timber cap, as shown in *Figure 8-44*, to make it possible for ships to come alongside the bulkhead. These piles, installed at proper intervals, provide protection against the impact of ships and protect the hulls of ships from undue abrasion.

**Figure 8-44 – Cap and fender pile for bulkhead.**

## 5.3.0 Wharfage Structures

Wharfage structures are designed to allow ships to dock alongside them for loading and discharge. *Figure 8-45* shows various plan views of wharfage structures. Any of these may be constructed of fill material, supported by bulkheads.

**Figure 8-45 – Types of wharfage structures.**

### 5.3.1 Pier

A pier or marginal wharf usually consists of a timber, steel, or concrete superstructure supported on a substructure of timber, steel or concrete pile bents.

Working drawings for advanced base piers are found in the ABFC system. You access them by clicking on the P437 Diagrams button. *Figures 8-46*, *8-47*, and *8-48* are portions of the advanced base drawing for a 40-foot timber pier. The Advanced Base Functional Components chapter provides further information on the advanced base functional components (ABFC).

**Figure 8-46 – General plan of an advanced base 40-foot timber pier.**

Each part of a pier lying between adjacent pile bents is called a bay, and the length of a single bay is equal to the on-center spacing of the bents. In the general plan shown in *Figure 8-47*, the 40-foot pier consists of one 13-foot outboard bay, one 13-foot inboard bay, and 12-foot interior bays as needed to meet the length requirements for the pier.

**Figure 8-47 – Part plan of an advanced base timber pier.**

The cross section shown in *Figure 8-48* shows that each bent consists of six bearing piles. The bearing piles are braced transversely by diagonal braces. Additional transverse bracing for each bent is provided by a pair of batter piles. The batter angle is specified as 5 in 12. One pile of each pair is driven on either side of the bent, as shown in the general plan. The butts of the batter piles are joined to 12 by 12-inch by 14- foot longitudinal batter pile caps, each of which is bolted to the undersides of two adjacent bearing pile caps in the positions shown in the part plan. The batter pile caps are placed 3 feet inboard of the center lines of the outside bearing piles in the bent. They are backed by 6 by 14-inch batter pile cap blocks, each of which is bolted to a bearing pile cap. Longitudinal bracing between bents consists of 14-foot lengths of 3 by 10-inch planks bolted to the bearing piles.

**Figure 8-48 – Cross section of an advanced base timber pier.**

The superstructure shown in *Figure 8-48* consists of a single layer of 4 by 12 planks laid on 19 inside stringers measuring 6 inches by 14 inches by 14 feet. The inside stringers are fastened to the pile caps with driftbolts. The outside stringers are fastened to the pile caps with bolts. The deck planks are fastened to the stringers with 3/8 by 8-inch spikes. After the deck is laid, 12-foot lengths of 8 by 10 are laid over the outside stringers to form the curbing. The lengths of curbing are distributed as shown in the general plan. The curbing is bolted to the outside stringers.

The pier is equipped with a fender system to protect it against shock caused by contact with vessels coming or docked alongside of it. Fender piles, spaced as shown in the part plan, are driven along both sides of the pier and bolted to the outside stringers. The heads of these bolts are countersunk below the surfaces of the piles. An 8 by 10 fender wale is bolted to the backs of the fender piles. Lengths of 8 by 10 fender pile chocks are cut to fit between the piles and bolted to the outside stringers and the fender wales. The spacing for these bolts is shown in the part plan. As shown in the general plan, the fender system also includes two 14 pile dolphins, located 15 feet beyond the end of the pier.

### 5.3.2 olphin

A dolphin, shown in *Figure 8-49*, is an isolated cluster of piles.

## 6.0.0 TIMBER FASTENERS and CONNECTORS

As a Builder, be aware that it is usually unnecessary in working drawings to call out the types of fasteners used for light frame construction. However, this is not the case for heavy timber construction. To prepare drawings or estimate materials for timber structures, you need a working knowledge of timber fasteners and connectors and the manner in which they are used. The following discussion covers the more common types.

**Figure 8-49 – Typical dolphin plan.**

### 6.1.0 Timber Fasteners

Bolts used to fasten heavy timbers usually come in 1/2-, 3/4-, and 1-inch diameters and have square heads and nuts. In use, the bolts are fitted with round steel washers under both the bolt head and the nut. The bolts are then tightened until the washers bite well into the wood to compensate for future shrinkage. Bolts should be spaced a minimum of 9 inches on center and should be no closer than 2 1/2 inches to the edge or 7 inches to the end of the timber.

### 6.1.1 ftbolts

Driftbolts, also called driftpins, are used primarily to prevent timbers from moving laterally in relation to each other, rather than to resist pulling apart. They are used more in dock and trestle work than in trusses and building frames. A driftbolt is a long threadless rod that is driven through a hole bored through the member and into the abutting member. The hole is bored slightly smaller than the bolt diameter and about 3 inches shorter than the bolt length. Driftbolts are from 1/2 to 1 inch in diameter and 18 to 26 inches long.

### 6.1.2 Scabs

Butt joints are customarily connected using driftbolts; however, another method of making butt joint connections is to use a scab. A scab is a short length of timber that is spiked or bolted to the adjoining members, as shown in *Figure 8-50*.

**Figure 8-50 – Scabs.**

## 6.2.0 Timber Connectors

A timber connector is any device used to increase the strength and rigidity of bolted lap joints between heavy timbers.

### 6.2.1 Split Ring

For example, the split ring shown in *Figure 8-51* is embedded in a circular groove. These grooves are cut with a special bit in the faces of the timbers that are to be joined. Split rings come in diameters of 2 1/2 and 4 inches. The 2 1/2-inch ring requires a 1/2-inch bolt, and the 4-inch ring uses a 3/4-inch bolt.

**Figure 8-51 – Split ring and split ring joints.**

### 6.2.2 Shear Plates

Shear plates are shown in *Figure 8-52*. These connectors are intended for wood to steel connections, as shown in *View B*. But when used in pairs, they may be used for wood to wood connections, as shown in *View C*. When making a wood to wood connection, the fabricator first cuts a depression into the face of each of the wood members. These depressions are cut to the same depth as the shear plates. Then a shear plate is set into each of the depressions so that the back face of the shear plate is flush with the face of the wood members.

Finally, the wood members are slid into place and bolted together. Because the faces are flush, the members easily slide into position, which reduces the labor necessary to make the connection. Shear plates are available in 2 5/8- and 4-inch diameters.

**Figure 8-52 – Shear plate and shear plate joints.**

### 6.2.3 Toothed Rings

For special applications, toothed rings and spike grids are sometimes used. The toothed ring connector, shown in *Figure 8-53*, functions in much the same manner as the split ring but can be embedded without the necessity of cutting grooves in the members. The toothed ring is embedded by the pressure provided from tightening a high tensile strength bolt, as shown in *Figure 8-54*. The hole for this bolt is drilled slightly larger than the bolt diameter so that the bolt may be extracted after the toothed ring is embedded.

**Figure 8-53 – Toothed ring and toothed ring joints.**

**Figure 8-54 – Embedding toothed rings.**

A spike grid is used as shown in *Figure 8-55*. A spike grid may be flat for joining flat surfaces, single curved for joining a flat and a curved surface, or double curved for joining two curved surfaces. A spike grid is embedded in the same manner as a toothed ring.

**Figure 8-55 – Spike grids and spike grid joints.**

**Figure 8-56 – Trailer-mounted radial overarm field saw (front view and side view).**

Tools used in heavy construction are covered in the Use *and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085. In the Table of Allowance (TOA), you will find certain kits that can be used, such as the following:

- Kit assembly 80041 – Heavy Construction Tools F/4
- Kit assembly 82072 – Saw, Radial Arm (Field), shown in *Figure 8-56*
- Kit assembly 85025 – Saw, Chain 36N, GEN, 2 man
- Kit assembly 80019 – Carpenters Tools F/4

These are just a few of the kits that can be used from the TOA. Refer to *NAVFAC P-405* for a list of the assemblies by number.

# 7.0.0 STEEL FRAME STRUCTURES

The construction of a framework of structural steel involves two principal operations: fabrication and erection. Fabrication involves the processing of raw materials to form the finished members of the structure. Erection includes all rigging, hoisting, or lifting of members to their proper places in the structure, and making the finished connections between members.

A wide variety of structures are erected using structural steel. Basically, they can be listed as buildings, such as PEBs, bridges, and towers; most other structures are modifications of these three.

## 7.1.1 Steel Buildings

Three basic types of steel construction are used today, designated as follows:

- Wall-bearing construction
- Skeleton construction
- Long span construction

### 7.1.1 Wall-Bearing Construction

In wall-bearing construction, exterior and interior masonry walls are used to support structural members, such as steel beams and joists, which carry the floors and roof. Note that while this section of your manual covers steel structures, wall-bearing construction is applicable to non-steel structures as well. Wall-bearing construction is one of the oldest and most common methods in use. Although modem developments in reinforced concrete masonry make the use of this method feasible for high rise structures, wall-bearing construction is normally restricted to relatively low structures, such as residences and light industrial buildings.

### 7.1.2 Skeleton Construction

A tall building with a steel frame, as shown in *Figure 8-57*, is an example of skeleton construction.

**Figure 8-57 – Structural and skeleton construction.**

In this type of construction, all live and dead loads are carried by the structural frame skeleton. For this reason, the exterior walls are nonbearing curtain walls. Roof and floor loads are transmitted to beams and girders, which are, in turn, supported by columns. The horizontal members or beams that connect the exterior columns are called spandrel beams. If you add additional rows of columns and beams, there is no limitation to the area of floor and roof that can be supported using skeleton construction. One limitation of using skeleton construction, however, is the distance between columns.

### 7.1.3 Long Span Construction

Often large structures, such as aircraft hangars, may require greater distances between supports than can be spanned by the standard structural steel shapes. In this case, one of several methods of long span steel construction is used. One method uses built-up girders to span the distances between supports.

Two types of built-up girders are shown in *Figure 8-58*. As shown in the figure, the built-up girder consists of steel plates and shapes that are combined to meet the necessary strength. The individual parts of these girders are connected by welding or riveting.

**Figure 8-58 – Typical built-up girders.**

Another method, usually more economical, is the use of a truss to span large distances. A truss is the framework of a structural member consisting of a top chord, a bottom chord, and diagonal web members that are usually placed in a triangular arrangement. *Figure 8-59* shows many different types of trusses that can be fabricated to conform to the shape of nearly any roof system.

**Figure 8-59 – Typical steel trusses.**

A third long span method, although not as versatile as trusses, is the use of bar joists. Bar joists are much lighter than trusses and are fabricated in several different types. One type is shown in *Figure 8-60*. Prefabricated bar joists, designed to conform to specific load requirements, are obtainable from commercial companies. Other long span construction methods involve several different types of framing systems, which include steel arches, cable-hung frames, and other types of systems. These methods, however, are beyond the scope of this manual.

**Figure 8-60 – Clear span bar joists.**

## 7.2.0 Pre-Engineered Metal Structures

Pre-engineered metal structures are commonly used in military construction. These structures are usually designed and fabricated by civilian industry to conform to specifications set forth by the military. Rigid-frame buildings, steel towers, communications antennas, and steel tanks are some of the most commonly used structures, particularly at overseas advanced bases. Pre-engineered structures offer an advantage in that they are factory-built and designed to be erected in the shortest amount of time possible. Each structure is shipped as a complete kit, including all the materials and instructions needed to erect it.

Of the pre-engineered metal structures available, the one that is perhaps most familiar to the Seabees is the pre-engineered metal building (PEB), shown in *Figures 8-61* and *8-62*. *Figure 8-62* shows the nomenclature of the various parts of the PEB. For definition of this nomenclature, erection details, and other important information regarding the PEB, you should refer to the Steelworker Basic rate training manual.

**Figure 8-61 – Completed 40’ x 100’ x 14’ pre-engineered metal building.**

**Figure 8-62 – Structural members of a pre-engineered metal building.**

## Summary

This chapter presented information on various construction operations involving heavy structures, and the importance of safe working practices to prevent injuries to personnel and damage to equipment. You learned about the equipment, terminology, methods, and techniques of heavy construction and the methods of constructing heavy timber structures and waterfront structures in terms of contingency operations.

You now understand how large bulks of materials (over 5 inches thick) and extra heavy structural members are used, including steel, timber, concrete, and a combination of these materials. You discovered that heavy construction in the Naval Construction Force includes the construction of bridges, shoring operations, waterfront structures, and steel frame structures.

## Review Questions (Select the Correct Response)

1. The lower part of a bridge is known by what term?

   A. Foundation unit
   B. Substructure
   C. Superstructure
   D. Trough

2. What part of a building is located below the surface of the ground?

   A. Deadman
   B. Foundation
   C. Substructure
   D. Superstructure

3. What part of a building rises from the foundation to a location above the ground?

   A. Footing
   B. Foundation wall
   C. Grade beam
   D. Pile bent

4. What type of foundation is most often used for small buildings?

   A. Continuous
   B. Grade beam
   C. Mat
   D. Spread

5. What type of foundation is located at grade level around the entire perimeter of a building?

   A. Continuous
   B. Foundation wall
   C. Grade beam
   D. Spread

6. What type of foundation is located under isolated columns or at intervals along a wall?

   A. Continuous
   B. Grade beam
   C. Mat
   D. Spread

7. What total number of rows of posts or piles does a bent contain?

A. 1
B. 2
C. 3
D. 4

8. A timber pile bent can support a span of how many feet?

A. 25
B. 50
C. 75
D. 90

9. A trestle bent can support a combined span length of what maximum length, in feet?

A. 30
B. 40
C. 50
D. 60

10. The pile bent pier is composed of what minimum number of pile bents?

A. 1
B. 2
C. 3
D. 4

11. A trestle bent pier is specifically designed to carry what type of loads?

A. Horizontal
B. Vertical
C. Longitudinal
D. Transverse

12. What type of bracing provides stability at right angles to the center line of the superstructure of a bridge?

A. Bent
B. Diaphragm
C. Longitudinal
D. Transverse

13. Which structure is NOT a part of the superstructure of a bridge?

A. Flooring
B. Handrails
C. Stringers
D. Trestle bent

14. What members of the superstructure of a bridge are the main load-carrying members?

    A. Bents
    B. Diaphragms
    C. Stringers
    D. Treads

15. What part of the flooring system protects the deck?

    A. Bent
    B. Diaphragm
    C. Stringer
    D. Tread

16. For excavations in average soil, OSHA recommends a slope of what angle, in degrees?

    A. 15
    B. 20
    C. 30
    D. 45

17. **(True or False)** Before beginning an excavation, you must have a digging permit.

    A. True
    B. False

18. Which of the following situations does NOT require shoring?

    A. When new construction is next to buildings in industrial or commercial areas
    B. When sloping is considered adequate
    C. When there is insufficient room for sloped banks
    D. When using clay, silt, loam, or non-homogeneous types of soil

19. What two methods are most often used to shore high vertical excavation banks?

    A. Interlocking sheetpiling and soldier piles
    B. Needling and sheet piles
    C. Saddling and underpinning
    D. Sloping and footing

20. What type of pile is H-shaped and is driven into the ground with a pile driver?

    A. Bearing
    B. Code H
    C. Interlocking sheet
    D. Soldier

21. What type of pile is watertight?

A. Bearing
B. Code W
C. Interlocking sheet
D. Soldier

22. What type of pile is usually a straight tree trunk with the limbs and bark removed?

A. Code T
B. Interlocking sheet
C. Soldier
D. Timber bearing

23. What type of pile is usually H pile?

A. Concrete
B. Shell
C. Steel bearing
D. Timber bearing

24. What type of pile can be either precast or cast-in-place?

A. Concrete
B. Drop
C. Steel bearing
D. Timber bearing

25. Which is NOT one of the three main types of pile-driving hammers?

A. Diesel
B. Drop
C. Hydraulic
D. Pneumatic

26. For driving heavy piles into hard or dense soil, what pile-driving hammer provides the best results?

A. Diesel
B. Drop
C. Pneumatic single-action
D. Steel double-action

27. What type of pile-driving hammer is most often used?

A. Diesel
B. Drop
C. Hydraulic
D. Pneumatic

28. What part of a pile-driving hammer protects it from damage by receiving and transmitting the blow of the hammer or ram?

A. Catwalk
B. Cap
C. Hammer guide grove
D. Lead

29. The pile-driving crew is usually made up of people manning which positions?

A. Driver and loftman
B. Rig operator and signalman
C. Safety advisor and signal maker
D. Safety supervisor and rigger

30. During a pile-driving operation, what individual is the boss and normally the only person giving signals to the operator?

A. Hoisting engineer
B. Hook-on person
C. Loftman
D. Signalman

31. A pile supported by skin friction alone is referred to as what type of pile?

A. Combination pile
B. End bearing
C. Friction
D. Sliding

32. A pile supported by bedrock or an extra dense layer of soil at the tip is known as what type of pile?

A. Combination
B. End bearing
C. Friction
D. Substratum-friction

33. What type of piling is most often used in military construction?

A. Precast concrete
B. Steel sheet pile
C. Timber pile
D. Z pile

34. When a pile changes direction or becomes easier to drive, you should take what corrective action?

A. Drive a supporting pile next to it
B. Drive faster
C. Drive slower
D. Pull the pile

35. Which condition does NOT cause bouncing?

A. Crooked pile
B. Crushed pile butt
C. Hammer that is too light
D. Obstruction

36. Which is not a pile supported partly by skin friction and partly by a substratum of extra dense soil at the tip.

A. Combination
B. End bearing
C. Friction
D. Substratum-friction

37. Which action is NOT a necessary step for constructing a bent?

A. Aligning
B. Capping
C. Cutting
D. Hammering

38. When selecting a timber pile to build a bent around, the timber pile should be long enough to leave what minimum amount of space?

A. 1 foot
B. 2-3 feet
C. 5 feet
D. 6-7 feet

39. Jetting equipment includes all these except which one?

A. Hydraulic pump
B. Length of flexible hose
C. Metal jet pipe
D. Water pump

40. **(True or False)** In the direct lift method, a crane is used to pull the pile.

A. True
B. False

41. **(True or False)** The tidal lift method is used to pull piles driven in tidewater.

A. True
B. False

42. A typical crew for bearing piles will NOT include which personnel?

A. Crane operator
B. Crew leader
C. Hoisting engineer
D. 5 or 6 crew members

43. The time in man-days required to drive a pile depends on what two factors?

A. Length and circumference of the pile
B. Length and weight of the pile
C. Type and length of the pile
D. Weight and circumference of the pile

44. Waterfront structures are divided into what total number of categories?

A. 1
B. 2
C. 3
D. 4

45. **(True or False)** A mole is run out from the shoreline to check the along-shore wave action or deflect it away from the shore.

A. True
B. False

46. A breakwater that is paved on the top for use as a wharfage structure is known by what term?

A. Level top
B. Groin
C. Mole
D. Jetty

47. Bulkheads are NOT constructed to fall into which classification?

A. Groin
B. Pile and sheathing
C. Steel sheet pile
D. Wood sheet pile

48. Which type of construction is NOT a type of steel construction used today?

A. Long-span
B. Skeleton
C. Tilt-up
D. Wall-bearing

49. What publication contains drawings for advanced-base piers?

A. NAVFAC P-72
B. NAVFAC P-405
C. NAVFAC P-437, Vol. 1
D. NAVFAC P-437, Vol. 2

50. What part of a pier is located between pile bents?

A. Bay
B. Dolphin
C. Fender
D. Wharf

51. Which attachments prevent timbers from moving laterally?

A. Driftpins
B. Anchor bolts
C. Split rings
D. Scabs

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Advanced Base Functional Components (ABFC), NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, VA, 1991.

Engineering Aid Intermediate/Advanced, NAVEDTRA 12540, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Equipment Operator Basic, NAVEDTRA 12535, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Field Manual 5-277 Bailey Bridge, Headquarters, Department of the Army, Washington, D.C., and 9 May 1986.

Mabey Universal Bridge System Bridge Manual: 7.35m Roadway, Publication Reference 9U02, Mabey & Johnson Ltd, Floral Mile, Twyford, Reading RG10 9SQ, England.

NCF/Seabee Petty Officer 1 & C, NAVEDTRA 12543, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

NMCB Operations Officer’s Handbook, COMSECONDNCB/COMTHIRDNCBINST 5200.2, Naval Facilities Engineering Command, Alexandria, VA, 1988.

Operator’s Manual – Medium Girder Bridge, Army TM 5-5420-212-10-1 and Marine Corps TM 08676A-10/1-1, Headquarters, Department of the Army and Headquarters U.S. Marine Corps, 16 FEB 1993.

Pile Construction, FM 5-134, Department of the Army, Washington, DC, 1985.

Seabee Planner’s and Estimator Handbook, NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

Safety and Health Requirements Manual, EM 385-1-1, Department of the Army, Washington, DC, 1991.

Steelworker, NAVEDTRA 12530, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1996.

Use and Care of Hand Tools and Measuring Tools, NAVEDTRA 12085, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1992.

## CSFE Nonresident Training Course – User Update

CSFE makes every effort to keep their manuals up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this manual, or if you find an error, a typographical mistake, or an inaccuracy in CSFE manuals, please write us, using this form or a photocopy. Be sure to include the exact chapter number, topic, detailed description, and correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Write: CSFE N7A
3502 Goodspeed St.
Port Hueneme, CA 93130

FAX: 805/982-5508

E-mail: CSFE_NRTC@navy.mil

Rate_ Course Name_

Revision Date_ Chapter Number_ Page Number(s)_

Description

________________________________________

________________________________________

________________________________________

(Optional) Correction

________________________________________

________________________________________

________________________________________

(Optional) Your Name and Address

________________________________________

________________________________________

________________________________________

# Chapter 9

# Advanced Base Functional Components and Field Structures

## Topics



To hear audio, click on the box.

## Overview

As a Seabee in the Naval Construction Force (NCF), your primary mission is to support the Navy and Marine Corps during contingency operations. As a Builder, you are usually the prime contractor on any vertical construction project, as covered in Chapter 3 of this manual. This means you have to be knowledgeable about contingency operations. Remember, the primary reason Seabees exist is to provide construction support in any contingency operation and to train everyone accordingly.

Contingency means an amount included in the construction budget to cover the cost of unforeseen factors related to construction. Contingency operations, such as the Vietnam War, Persian Gulf War, Operation Restore Hope in Somalia, the peace-keeping mission in Bosnia, Typhoon O'Mara in Guam, Hurricane Andrew in Florida, the Mt. Pinatubo eruption in Philippines, and many more humanitarian assignments, are what Seabees are trained to do.

As a crew leader and project manager, your understanding of how the Advanced Base Functional Component (ABFC) system works and what types of field structures you will be dealing with is critical to contingency operations.

## Objectives

When you have completed this chapter, you will be able to do the following:

1. Recognize the principles involved in the use of the Advanced Base Functional Component system.
2. Identify procedures used to construct field structures.
3. Identify procedures used in natural disaster recovery operations.
4. Identify procedures used in war damage repair.

## Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Advanced Base Functional Components and Field Structures | ↑ | B U I L D E R A D V A N C E D |
| Heavy Construction | | |
| Maintenance Inspections | | |
| Quality Control | | |
| Shop Organization and Millworking | | |
| Masonry Construction | | |
| Concrete Construction | | |
| Planning, Estimating, and Scheduling | | |
| Technical Administration | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review.  When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.1.1 ADVANCED BASE FUNCTIONAL COMPONENT SYSTEM

The Advanced Base Functional Component (ABFC) system provides support facilities to the constantly changing tactical and strategic situations using a modular or building block concept. Components were needed to incorporate personnel, materials, equipment, and facilities. These components were designed and developed to fulfill specific functions, no matter where the components were placed. The Navy ABFC system is based on early experiences in advanced base planning and shipment used in World War II. Additional improvements were adopted from experiences learned in Korea, Vietnam, and the Persian Gulf, as well as many other small conflicts.

ABFCs are normally complete entities. There are three basic groupings of the ABFC system:

- Component, a complete unit
- Facility, a portion of a complete component
- Assembly, a portion of a facility

ABFCs, though normally complete, may not be supplied with housing, messing, medical facilities, maintenance facilities, defensive ordnance, communication equipment, and utilities with each component. These service components or facilities are to be integrated into an overall base development or augmentation plan. The ABFC system consists of two resources. The first resource is the *Table of Advanced Base Functional Components with Abridged Initial Outfitting Lists,* OPNAV 41P3A, which is part of OPNAVINST 4042.1 The second resource is an online NAVFAC system, the Advanced Base Functional Component/Table of Allowances system, which replaces the *Facilities Planning Guide,* NAVFAC P-437.

To facilitate reference, ABFCs are assigned descriptive names to indicate their functions and alphanumeric designators. A detailed advanced base initial outfitting list (ABIOL) is an itemized line-item printout of the material in each ABFC. Each command or bureau of the system is responsible for maintaining a detailed listing of that part of the ABIOL assigned to it.

## 1.1.1 Advanced Base Functional Component/Table of Allowances System

When you are tasked to assist in planning the construction of an advanced base, consult the Advanced Base Functional Component/Table of Allowances online system. This online system, which identifies the structures and supporting utilities of the Navy ABFC system, was developed to make pre-engineered facility designs and corresponding material lists available to planners at all levels. While these designs relate primarily to the expected needs at advanced bases and to the Navy ABFC system, they also can be used to satisfy peacetime requirements. Facility, logistic, and construction planners will find the information required to select and document the materials necessary to construct facilities.

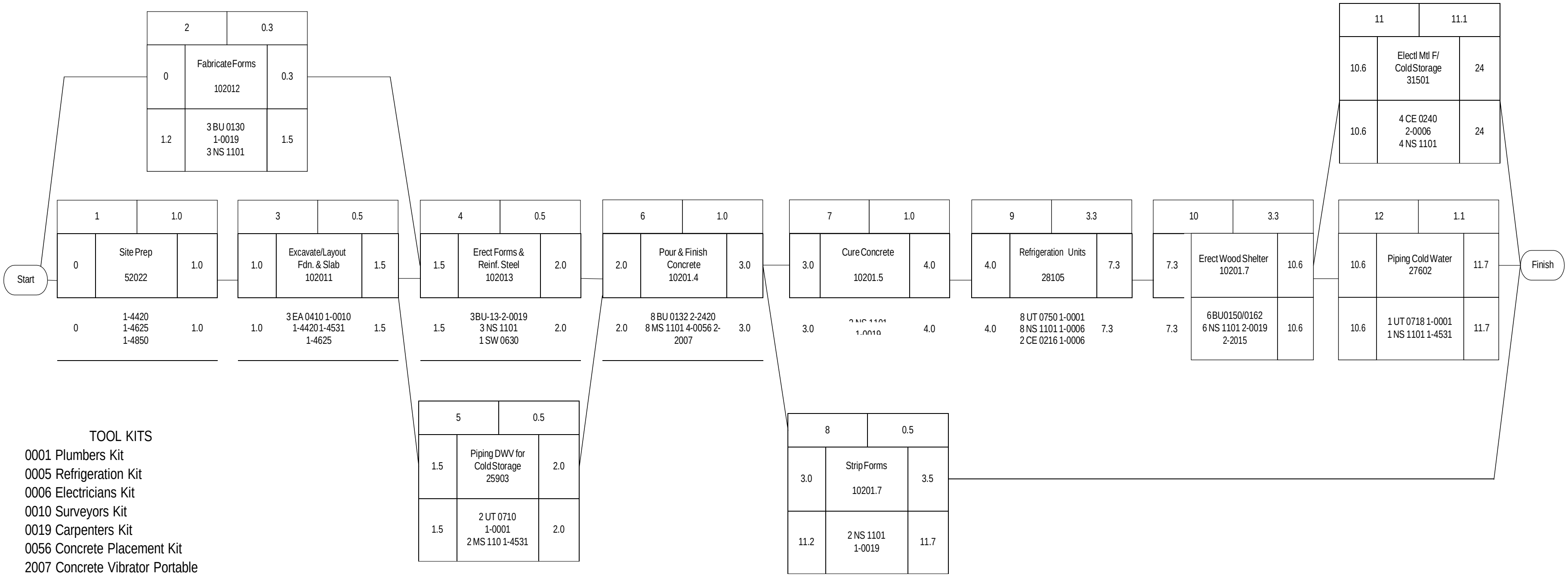
The ABFC/TOA system consists of multiple sections. The P437 Drawings section contains reproducible engineering drawings, which is organized as follows:

- Component Site Plans are indexed by component and ABFC designation.
- Facility Drawings are indexed by facility number and DoD category code.

- Assembly Drawings contain assembly information and are indexed by assembly number.

Each drawing is a detailed construction drawing that describes and lists the facilities, the assemblies, or the line items required to complete it. A summary of logistic, construction, and cost data is provided for each component, facility, and assembly of the ABFC system. A component is defined as a grouping of personnel and material that has a specific function or mission at an advanced base. Whether it is located overseas or in CONUS, a component is supported by facilities and assemblies.

A construction network is included in each facility of the ABFC system as part of the design package, as shown in *Figure 9-1*.




# Figure 9-1 – Construction Network.

TOOL KITS

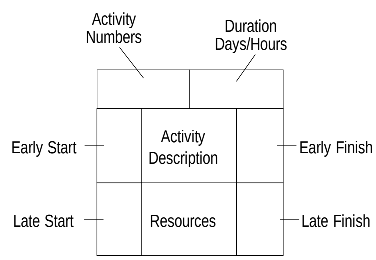
0001 Plumbers Kit
0005 Refrigeration Kit
0006 Electricians Kit
0010 Surveyors Kit
0019 Carpenters Kit
0056 Concrete Placement Kit
2007 Concrete Vibrator Portable
2015 Drill Portable ¾"

EQUIPMENT

2420 Transit Mixer
4420 Motor Grader
4531 Front End Loader
4625 Roller Vibrating
4850 Crawler Tractor

SKILLS

0130 BU Forming and Reinforcing
0132 BU Concrete Work
0150 BU Light Frame Construction
0162 BU Roofing
0216 CE Elec Motors & Control
0240 CE Interior Wiring
0410 EA Surveying
0630 SW Steel Reinforcing
0710 UT Plumbing
0760 UT Air Con & Refrigeration




NOTES

1. Equipment comes with the operator.
2. One manday equals ten manhours.
3. When this network is used in a CMS program[Ch5], it adds 0.9 day duration to the project.

Users of this drawing are requested to note discrepancies and recommended revisions on a blue print copy and mail to

Commanding Officer (Code 155)
Naval Construction Battalion Center
Port Hueneme, CA

The network includes information on tool kits, equipment, and skills required for each facility. You can save time and effort by using the construction networks that were developed for each facility in the ABFC system. To benefit from the construction networks, you must have an understanding of the basic principles and assumptions the networks are based on. Network analysis procedures for precedence diagramming are covered in Chapter 5 of the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405, and Chapter 2 of this manual.

Separate sections of the ABFC/TOA system contain the detailed data display for each component, facility, and assembly. (Except for earthwork, material lists in the system are complete bills of material.) Sections are arranged as follows:

- Facility/Group lists and describes by DoD category code the facilities requirement for each component.
- Assembly lists and describes by assembly number the assembly requirement for each facility.
- Local National Stock Number/Cage & Part Number lists line-item requirements by NSN for each assembly.

The ABFC/TOA system also contains other useful information for planners, such as crew sizes, man-hours by skill, land areas, amounts of fuel necessary to make a component, facility, or assembly operational, and information about predesigned facilities and assemblies that are not directly related to components shown in the ABFC table (OPNAV 41P3). These predesigned facilities and assemblies give the planner alternatives for satisfying contingency requirements when the callout of a complete component is not desired. To make the ABFC/TOA system compatible with DoD planning guides, a related publication, *Category Codes Facilities,* NAVFAC P-72, establishes the category codes, the nomenclature, and the required units of measure for identifying, classifying, and quantifying real property. These are the cardinal category codes:

100 Operations and Training

200 Maintenance and Production

300 Research, Development, and Evaluation

400 Supply

500 Hospital and Medical

600 Administrative

700 Housing and Community Support

800 Utilities and Ground Improvement

900 Real Estate

If a facility is required for enlisted personnel quarters, for example, it will be found in the 700 series (Housing and Community Support). The assemblies within each facility consist of a grouping of line items at the NSN level which, when assembled, will perform a specific function in support of the facility. An assembly is functionally grouped in such a way that the assembly number relates to the Occupational Field 12 skill required to install it. The groupings are numbered, as shown in *Table 9-1*.

| Table 9-1 – Assembly Sequence Numbers. | | |
|---|---|---|
| **Description** | **Number Start** | **Sequence Stop** |
| Builder (BU) oriented | 10,000 | 19,999 |
| Utilitiesman (UT) oriented | 20,000 | 29,999 |
| Construction Electrician (CE) oriented | 30,000 | 39,999 |
| Steelworker (SW) oriented | 40,000 | 49,999 |
| Equipment Operator (EO) oriented | 50,000 | 54,999 |
| Waterfront equipment | 55,000 | 57,999 |
| Underwater construction and diving equipment | 58,000 | 59,999 |
| Operational supplies | 60,000 | 62,499 |
| Operating consumables | 62,500 | 64,999 |
| NBC warfare | 65,000 | 67,499 |
| Personnel related supplies | 67,500 | 69,999 |
| Unassigned at present | 70,000 | 79,999 |
| Shop equipment including maintenance tools | 80,000 | 80,999 |
| Unique ABFC tool kits | 81,000 | 81,999 |
| Naval Construction Force (NCF) Table of Allowance (TOA) construction tools and kits (power tools) | 82,000 | 82,099 |
| NCF TOA construction tools and kits (electrical) | 82,500 | 82,599 |
| NCF TOA construction tools and kits (miscellaneous) | 83,000 | 83,199 |
| NCF TOA construction tools and kits (rigging) | 84,000 | 84,099 |
| Shop equipment (ABFC unique) | 85,000 | 87,499 |

### 1.1.1 Tailoring Components and Facilities

When you use the ABFC system, remember to tailor it to your specific needs. Know your exact mission and its requirements. Choose the components, the facilities, or the assemblies that best fit or can be tailored to meet your desired goals. Develop modular elements to serve similar functions in various locations. The exact requirements for a specific base cannot be defined, economically designed, nor supported within the general system. However, the base development planner knows the specific location, mission, unit composition, and availability of other assets. The planner can then select from the ABFC system the components or facilities that satisfy these specific requirements. Tailor the preplanned ABFC assets to come up with what is needed.

Tailor components or facilities by one or both of these:

1. Deleting or adding facilities or assemblies
2. Specifying requirements for the Tropical or North Temperate Zone

Tropical temperate zone information is indicated by the abbreviation “Trop.” North temperate zone information is indicated by the word “North.”

### 1.1.2 and Application of the ABFC/TOA System

Although a listing in the ABFC/TOA system may help you order individual items in general supply, it does NOT replace stock lists of systems commands or bureaus, offices, single managers, or inventory control points. Stock numbers and descriptions can be verified through appropriate stock lists. You are responsible for verifying stock numbers when ordering a component, a facility, or an assembly. Navigate to the ABFC/TOA system on NAVFAC as follows:

Link to the ABFC/TOA system: https://abfcview.navfac.navy.mil/login.cfm.
You will be asked to verify your CAC code.
You will see the ABFC TOA Web Manager screen shown in *Figure 9-2*.

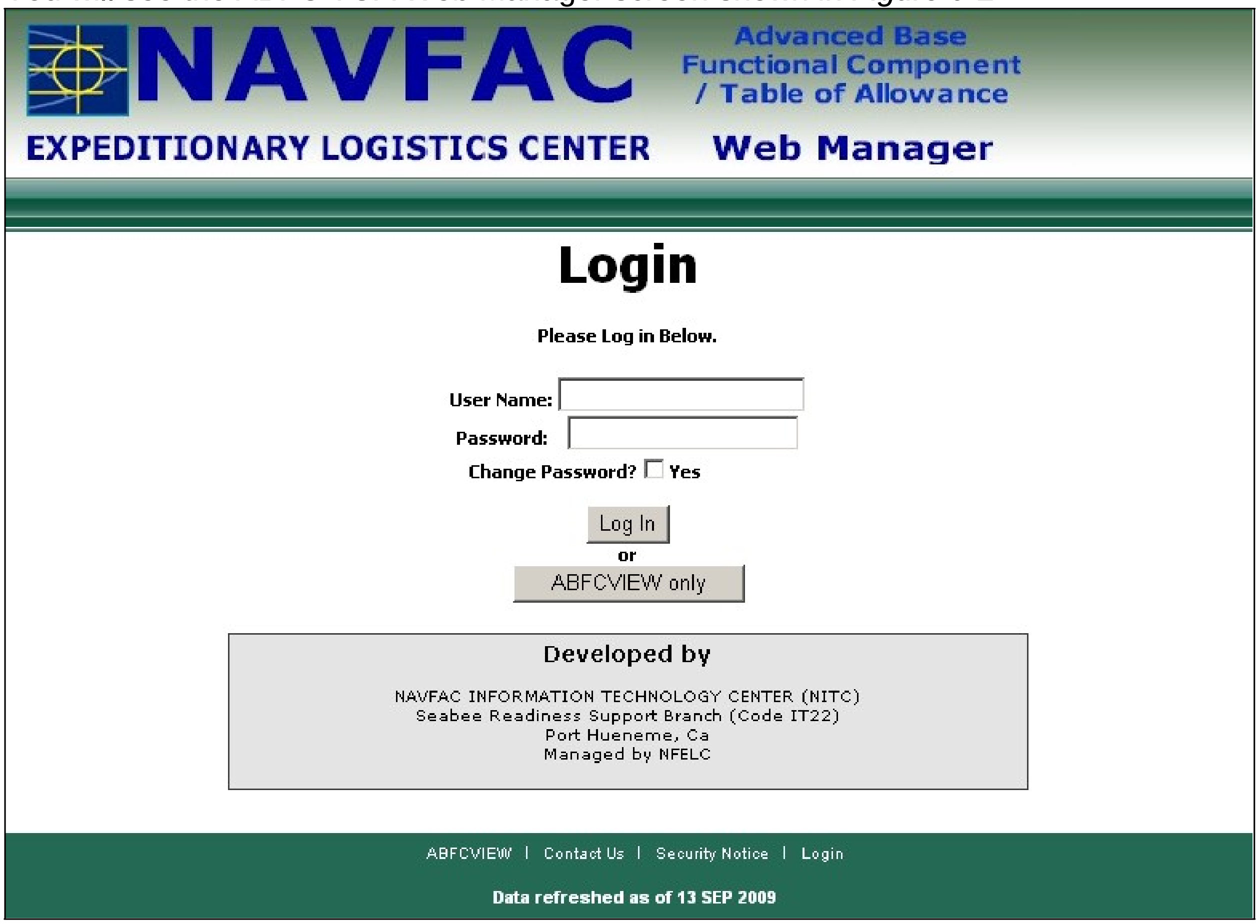
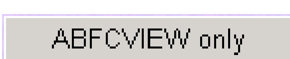



**Figure 9-2 – ABFC login screen.**

Click on 

.

You will see the About ABFC/TOA Planning Information screen shown in *Figure 9-3*.


**Figure 9-3 – About ABFC/TOA Planning Information screen.**

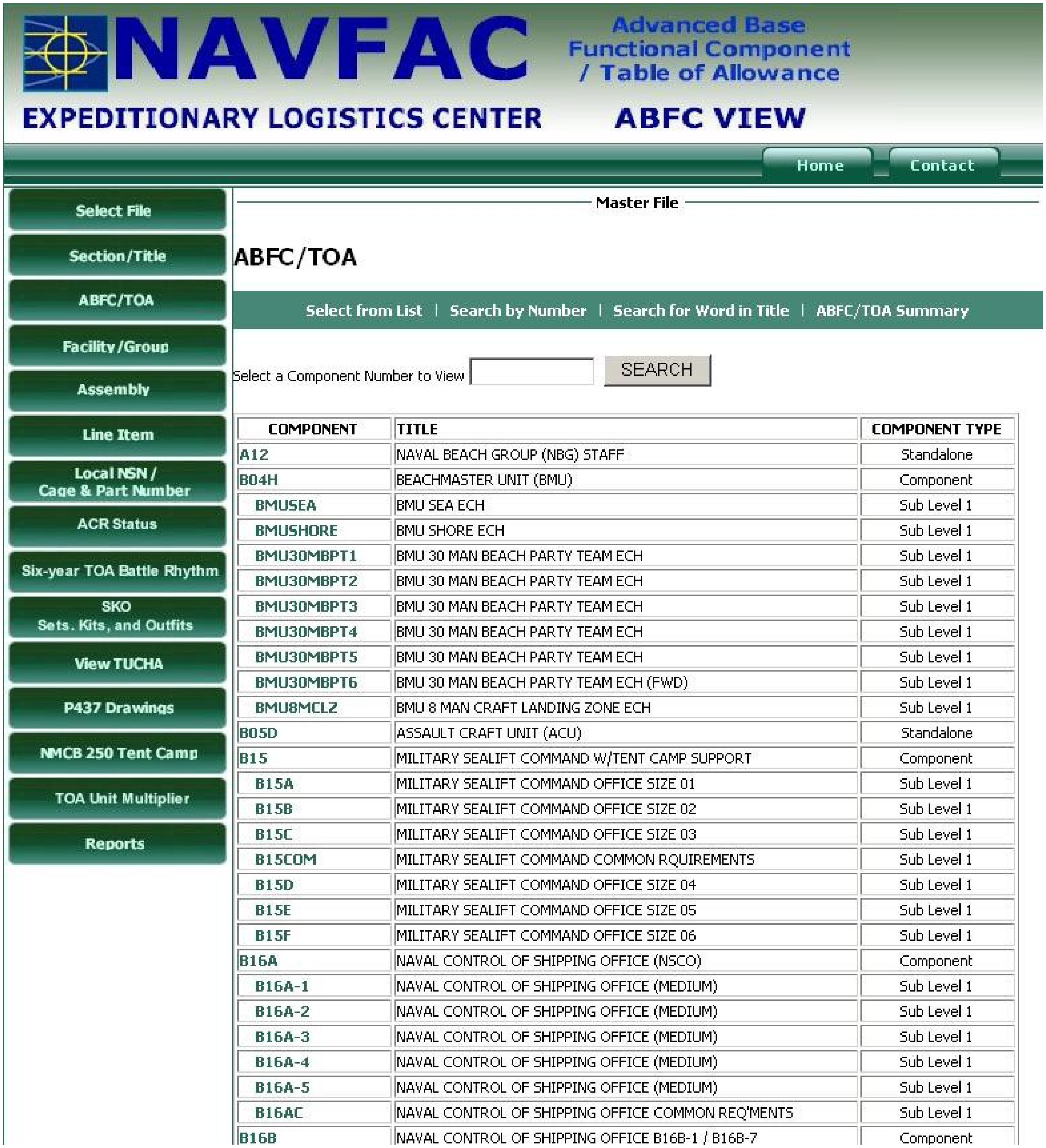
### 1.1.2.1 2.1 Component

There are a number of screens showing information on components. These screens are accessed as follows:

Click on 

.

You will see the ABFC/TOA component search screen shown in *Figure 9-4*.




| COMPONENT | TITLE | COMPONENT TYPE |
|---|---|---|
| A12 | NAVAL BEACH GROUP (NBG) STAFF | Standalone |
| B04H | BEACHMASTER UNIT (BMU) | Component |
| BMUSEA | BMU SEA ECH | Sub Level 1 |
| BMUSHORE | BMU SHORE ECH | Sub Level 1 |
| BMU30MBPT1 | BMU 30 MAN BEACH PARTY TEAM ECH | Sub Level 1 |
| BMU30MBPT2 | BMU 30 MAN BEACH PARTY TEAM ECH | Sub Level 1 |
| BMU30MBPT3 | BMU 30 MAN BEACH PARTY TEAM ECH | Sub Level 1 |
| BMU30MBPT4 | BMU 30 MAN BEACH PARTY TEAM ECH | Sub Level 1 |
| BMU30MBPT5 | BMU 30 MAN BEACH PARTY TEAM ECH | Sub Level 1 |
| BMU30MBPT6 | BMU 30 MAN BEACH PARTY TEAM ECH (FWD) | Sub Level 1 |
| BMU8MCLZ | BMU 8 MAN CRAFT LANDING ZONE ECH | Sub Level 1 |
| B05D | ASSAULT CRAFT UNIT (ACU) | Standalone |
| B15 | MILITARY SEALIFT COMMAND W/TENT CAMP SUPPORT | Component |
| B15A | MILITARY SEALIFT COMMAND OFFICE SIZE 01 | Sub Level 1 |
| B15B | MILITARY SEALIFT COMMAND OFFICE SIZE 02 | Sub Level 1 |
| B15C | MILITARY SEALIFT COMMAND OFFICE SIZE 03 | Sub Level 1 |
| B15COM | MILITARY SEALIFT COMMAND COMMON RQUIREMENTS | Sub Level 1 |
| B15D | MILITARY SEALIFT COMMAND OFFICE SIZE 04 | Sub Level 1 |
| B15E | MILITARY SEALIFT COMMAND OFFICE SIZE 05 | Sub Level 1 |
| B15F | MILITARY SEALIFT COMMAND OFFICE SIZE 06 | Sub Level 1 |
| B16A | NAVAL CONTROL OF SHIPPING OFFICE (NSCO) | Component |
| B16A-1 | NAVAL CONTROL OF SHIPPING OFFICE (MEDIUM) | Sub Level 1 |
| B16A-2 | NAVAL CONTROL OF SHIPPING OFFICE (MEDIUM) | Sub Level 1 |
| B16A-3 | NAVAL CONTROL OF SHIPPING OFFICE (MEDIUM) | Sub Level 1 |
| B16A-4 | NAVAL CONTROL OF SHIPPING OFFICE (MEDIUM) | Sub Level 1 |
| B16A-5 | NAVAL CONTROL OF SHIPPING OFFICE (MEDIUM) | Sub Level 1 |
| B16AC | NAVAL CONTROL OF SHIPPING OFFICE COMMON REQ'MENTS | Sub Level 1 |
| B16B | NAVAL CONTROL OF SHIPPING OFFICE B16B-1 / B16B-7 | Component |

**Figure 9-4 –ABFC/TOA component search screen.**

Enter the number of the component you need, and then click on SEARCH. From the list, select the component you need. You will see the ABFC/TOA Component View screen shown in *Figure 9-5*.

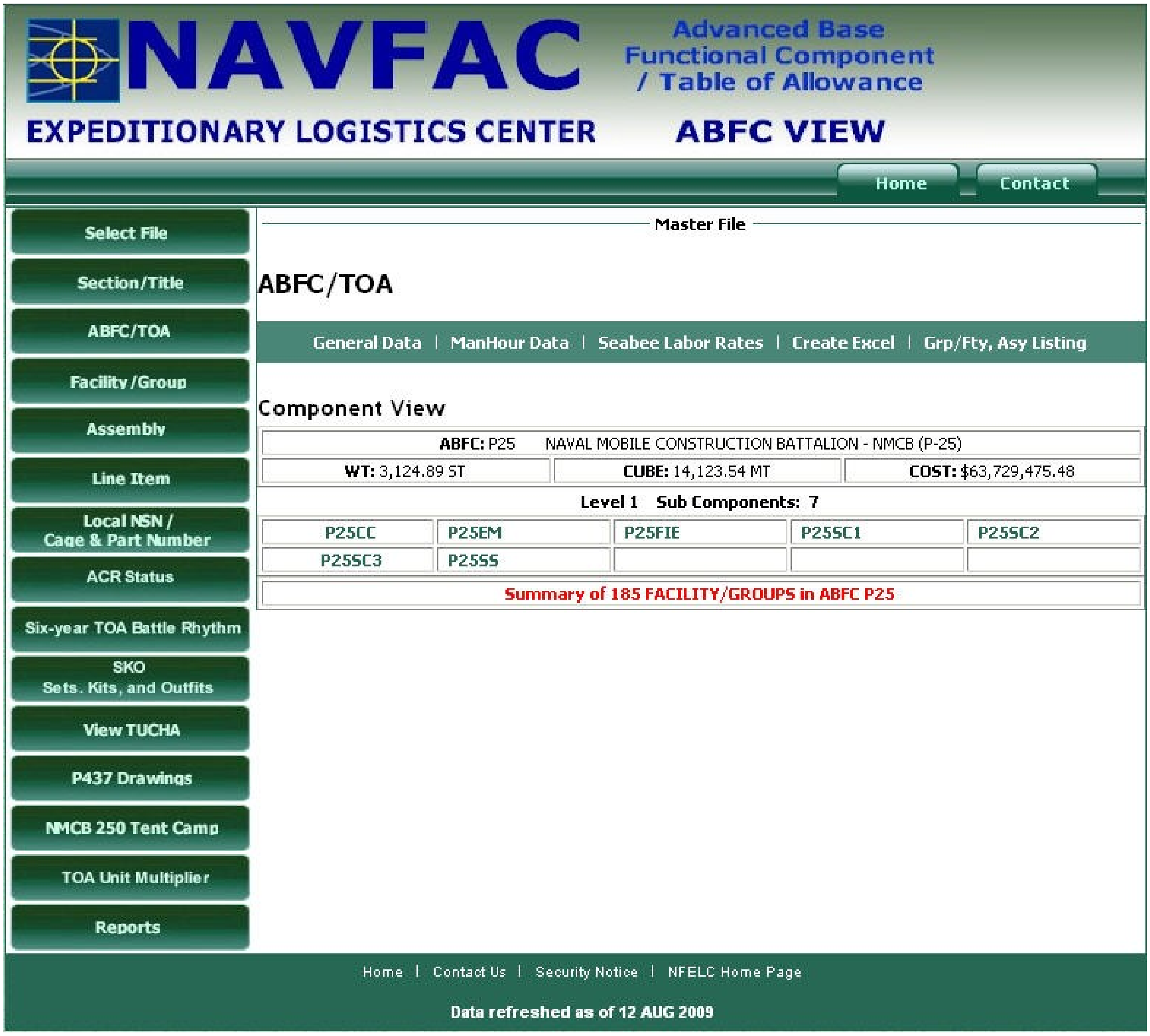
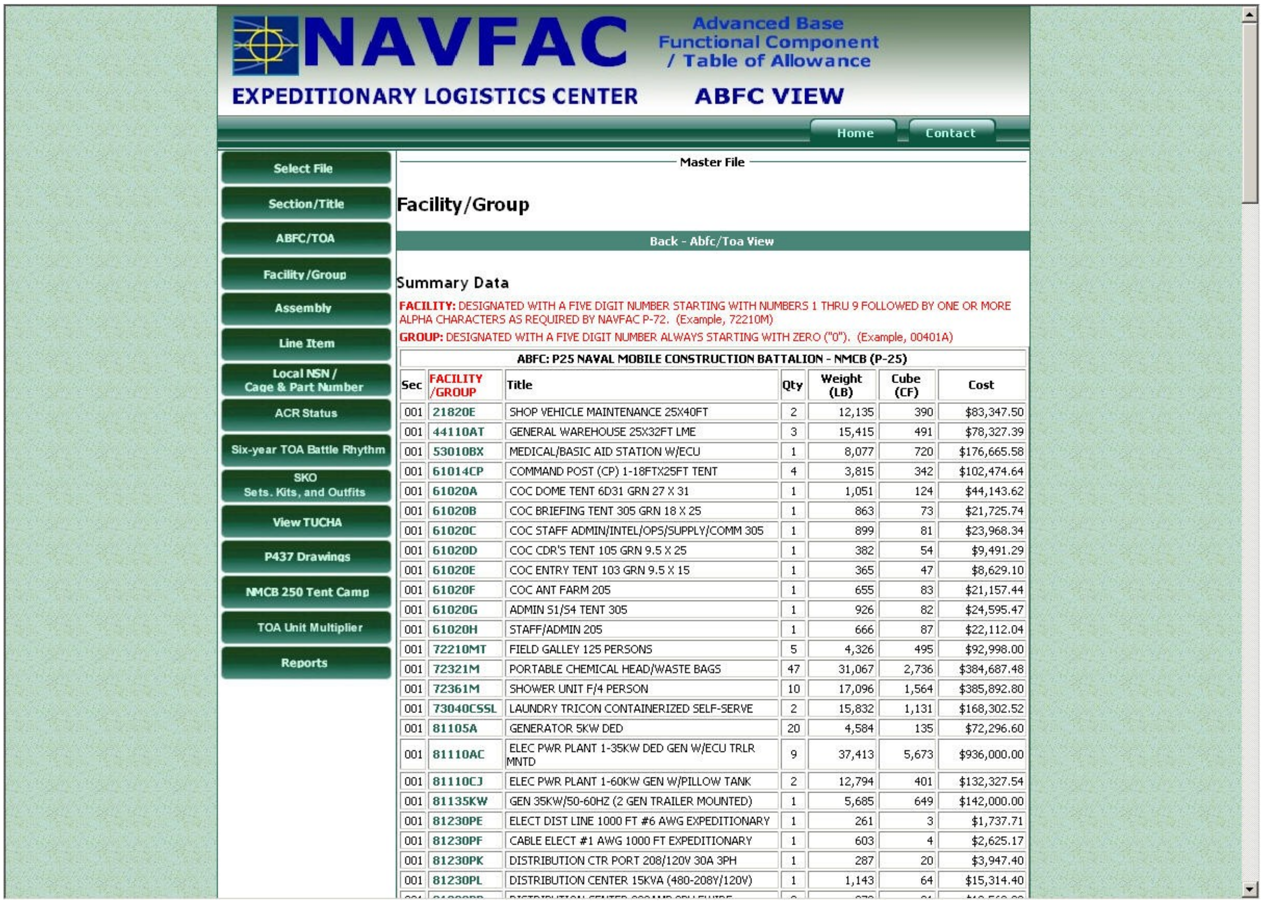



**Figure 9-5 – ABFC/TOA component view screen.**

This is the main screen for component P25. It displays the weight, cubic feet, and cost of the component. It also lists the sub components included in this component. To view the subcomponents, click on the red Summary option. You will see the ABFC/TOA Summary Data screen, as shown in *Figure 9-6*, which shows a typical component breakdown of the P-25.




ABFC: P25 NAVAL MOBILE CONSTRUCTION BATTALION - NMCB (P-25)

| Sec | FACILITY /GROUP | Title | Qty | Weight (LB) | Cube (CF) | Cost |
|---|---|---|---|---|---|---|
| 001 | 21820E | SHOP VEHICLE MAINTENANCE 25X40FT | 2 | 12,135 | 390 | $83,347.50 |
| 001 | 44110AT | GENERAL WAREHOUSE 25X32FT LME | 3 | 15,415 | 491 | $78,327.39 |
| 001 | 53010BX | MEDICAL/BASIC AID STATION W/ECU | 1 | 8,077 | 720 | $176,665.58 |
| 001 | 61014CP | COMMAND POST (CP) 1-18FTX25FT TENT | 4 | 3,815 | 342 | $102,474.64 |
| 001 | 61020A | COC DOME TENT 6D31 GRN 27 X 31 | 1 | 1,051 | 124 | $44,143.62 |
| 001 | 61020B | COC BRIEFING TENT 305 GRN 18 X 25 | 1 | 863 | 73 | $21,725.74 |
| 001 | 61020C | COC STAFF ADMIN/INTEL/OPS/SUPPLY/COMM 305 | 1 | 899 | 81 | $23,968.34 |
| 001 | 61020D | COC CDR'S TENT 105 GRN 9.5 X 25 | 1 | 382 | 54 | $9,491.29 |
| 001 | 61020E | COC ENTRY TENT 103 GRN 9.5 X 15 | 1 | 365 | 47 | $8,629.10 |
| 001 | 61020F | COC ANT FARM 205 | 1 | 655 | 83 | $21,157.44 |
| 001 | 61020G | ADMIN S1/S4 TENT 305 | 1 | 926 | 82 | $24,595.47 |
| 001 | 61020H | STAFF/ADMIN 205 | 1 | 666 | 87 | $22,112.04 |
| 001 | 72210MT | FIELD GALLEY 125 PERSONS | 5 | 4,326 | 495 | $92,998.00 |
| 001 | 72321M | PORTABLE CHEMICAL HEAD/WASTE BAGS | 47 | 31,067 | 2,736 | $384,687.48 |
| 001 | 72361M | SHOWER UNIT F/4 PERSON | 10 | 17,096 | 1,564 | $385,892.80 |
| 001 | 73040CSSL | LAUNDRY TRICON CONTAINERIZED SELF-SERVE | 2 | 15,832 | 1,131 | $168,302.52 |
| 001 | 81105A | GENERATOR 5KW DED | 20 | 4,584 | 135 | $72,296.60 |
| 001 | 81110AC | ELEC PWR PLANT 1-35KW DED GEN W/ECU TRLR MNTD | 9 | 37,413 | 5,673 | $936,000.00 |
| 001 | 81110CJ | ELEC PWR PLANT 1-60KW GEN W/PILLOW TANK | 2 | 12,794 | 401 | $132,327.54 |
| 001 | 81135KW | GEN 35KW/50-60HZ (2 GEN TRAILER MOUNTED) | 1 | 5,685 | 649 | $142,000.00 |
| 001 | 81230PE | ELECT DIST LINE 1000 FT #6 AWG EXPEDITIONARY | 1 | 261 | 3 | $1,737.71 |
| 001 | 81230PF | CABLE ELECT #1 AWG 1000 FT EXPEDITIONARY | 1 | 603 | 4 | $2,625.17 |
| 001 | 81230PK | DISTRIBUTION CTR PORT 208/120V 30A 3PH | 1 | 287 | 20 | $3,947.40 |
| 001 | 81230PL | DISTRIBUTION CENTER 15KVA (480-208Y/120V) | 1 | 1,143 | 64 | $15,314.40 |

**Figure 9-6 – ABFC/TOA component summary data screen.**

The facilities required to make the component operative are listed in numerical sequence by DoD category code. The alpha suffix for each facility designator indicates differences between sizes, types, or layouts of facilities with the same functional purpose. Facility capacity is expressed in terms of the units of measure used in the *Category Codes Facilities,* NAVFAC P-72. The component capacity is figured by multiplying the facility capacity and the quantity. Weight and cube are measured in normal units for export packing.

Access general data about the component by first returning to the ABFC/TOA Component View screen. Select Back – ABFC/TOA View from the banner, and then select General Data.

*Figure 9-7* shows the general data for the P-25. In this screen, notice that the Weight, Cube, and Cost are shown for both Tropical and North temperate zones. The site plan pertaining to each component is shown by a NAVFAC drawing number. The word *NONE* appears for components that have no site plans.

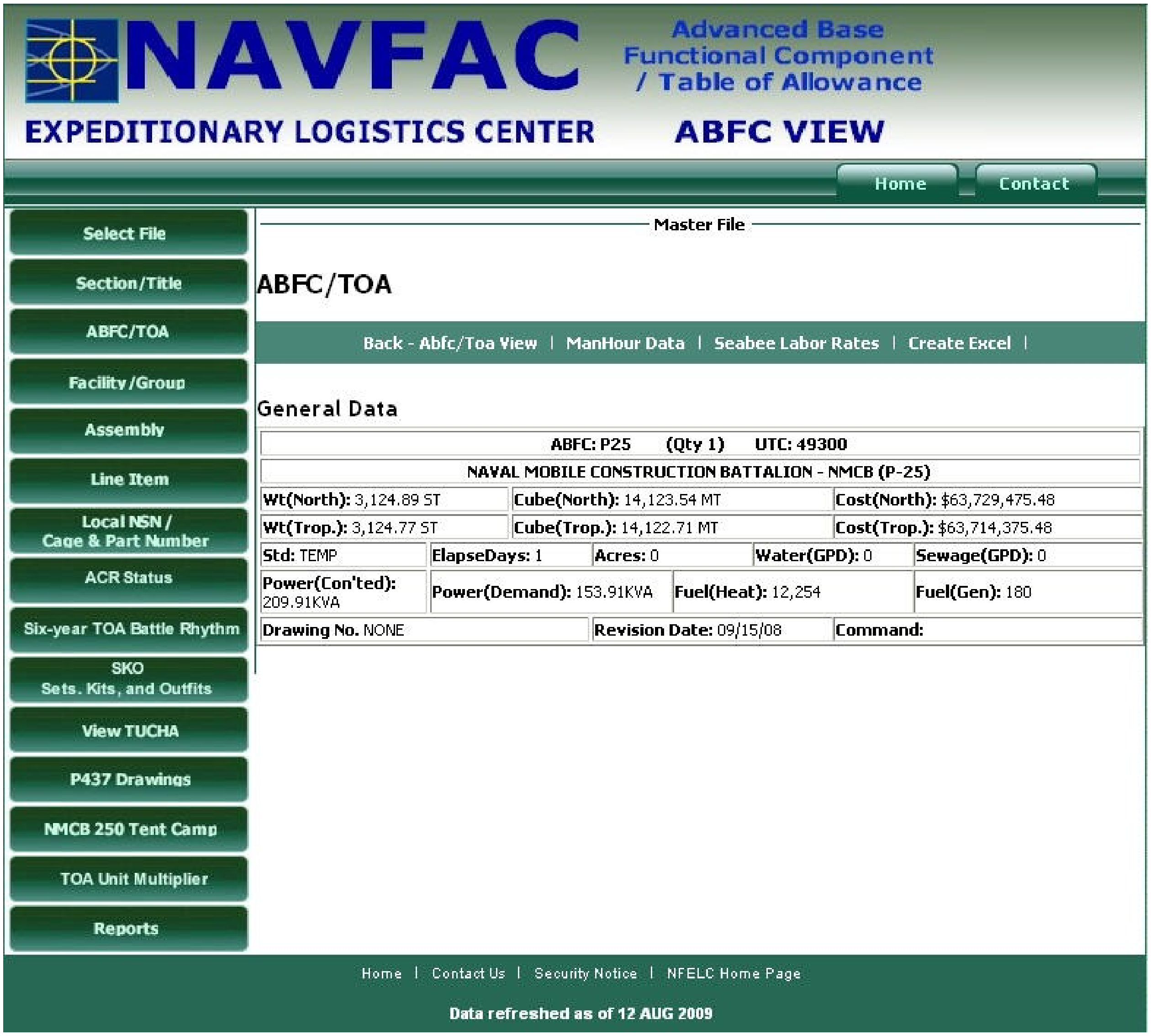


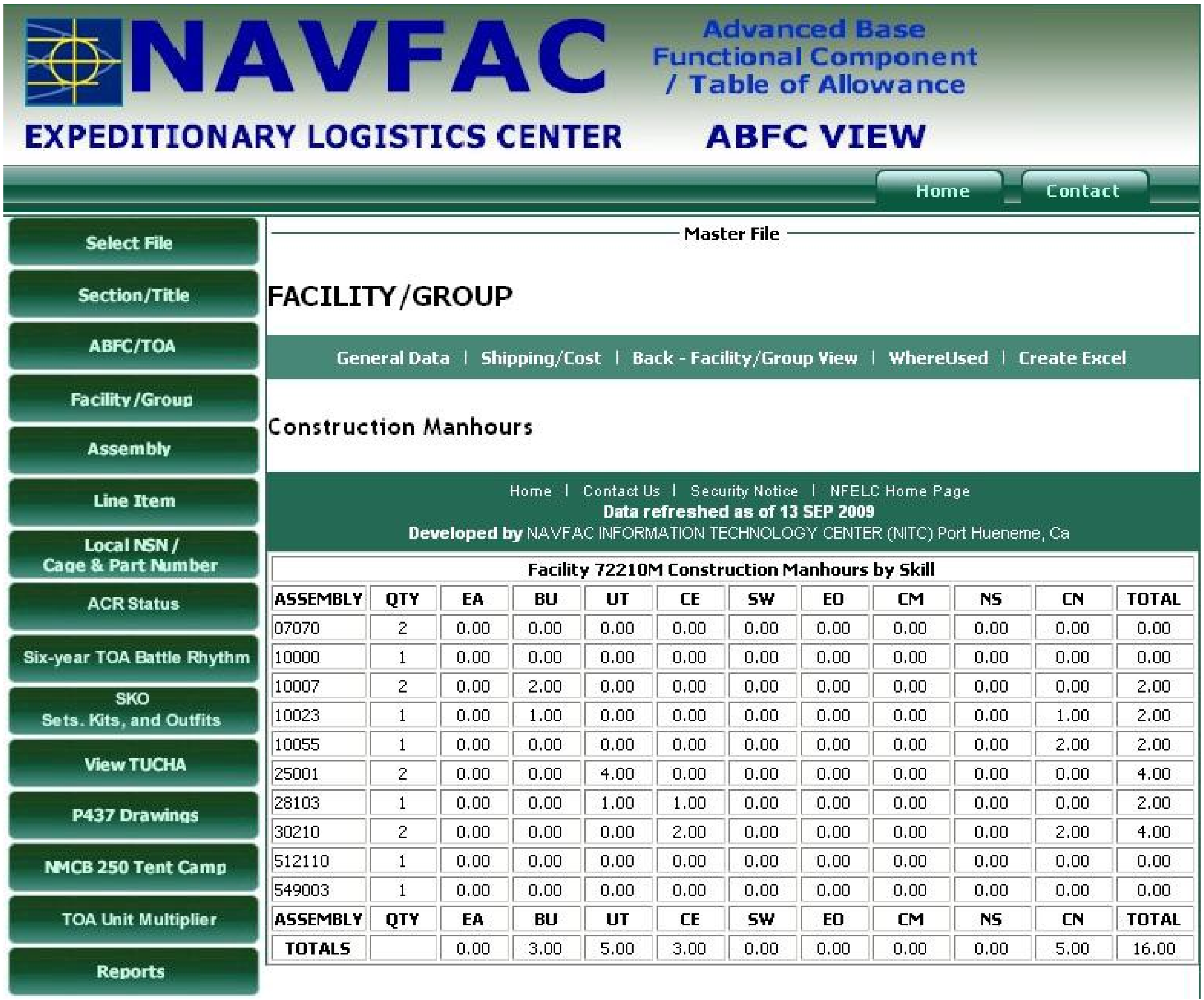

**Figure 9-7 – ABFC/TOA component general data screen.**

Summary data, located below the Weight, Cube, and Cost, provides information on the following:

1. Construction standards (Std), taken from *Joint Chiefs of Staff (JCS),* publication 3, are grouped into two classifications: Initial and Temporary Initial (INIT) is a duration requirement of less than 6 months Temporary (TEMP) is a duration requirement of 6 to 60 months.
2. Days of construction duration (ElapseDays) are based on job requirements, optimum construction crew size, and full-material availability.
3. Often the land requirements (Acres), based on the assumed plot plan, will not be followed exactly because of terrain or existing buildings. The idealized plot plan was developed to design supporting utility systems. The information contained in the utility facilities has been increased to allow for variation in terrain.
4. Water and sewage (GPD) are based on ABIOL or TOA contents and the utility systems designed to these criteria.

5. The connected electrical load [Power (Con'ted)] has been computed based on knowledge of ABIOL or TOA contents. A load diversity factor has been applied to compute the kVA demand [Power (Demand)].
6. Fuel usage is computed on 30-day requirements for installed fuel-fired [Fuel (Heat)] or engine-driven [Fuel (Gen)] equipment only. No allowance for automotive, construction, weight handling, and other jobsite support equipment fuel is included. Fuel is not provided when facilities or assemblies are shipped. NAVSUP provides fuel as a contribution when whole components are shipped.

Access the skill requirements by selecting ManHour Data from the banner. *Figure 9-8* shows the Construction Manhours screen.




| ASSEMBLY | QTY | EA | BU | UT | CE | SW | EO | CM | NS | CN | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 07070 | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10000 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10007 | 2 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 |
| 10023 | 1 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 2.00 |
| 10055 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 |
| 25001 | 2 | 0.00 | 0.00 | 4.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.00 |
| 28103 | 1 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 |
| 30210 | 2 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 4.00 |
| 512110 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 549003 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ASSEMBLY | QTY | EA | BU | UT | CE | SW | EO | CM | NS | CN | TOTAL |
| TOTALS | | 0.00 | 3.00 | 5.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 16.00 |

**Figure 9-8 – ABFC/TOA screen.**

The skill requirements are designated by Seabee (OF- 13) ratings and are expressed in man-hours, as computed for each assembly. The total man-hours are also shown for the component.

### 1.1.2.2 Facility

Access the Facility/Group View screen by clicking on 

.

*Figure 9-9* shows a typical facility/group view--in this example, facility #72210M, the 100-man galley. The header shows the facility number and briefly describes the basic capability of the facility. Adjacent to the facility number, the heading shows the JCS planning factor applied (10 SF/MN), which means 10 square feet per person. This planning factor is based on *Planning Factors for Military Construction in Contingency Operations,* Joint Staff Memorandum (MJCS) 235-86.

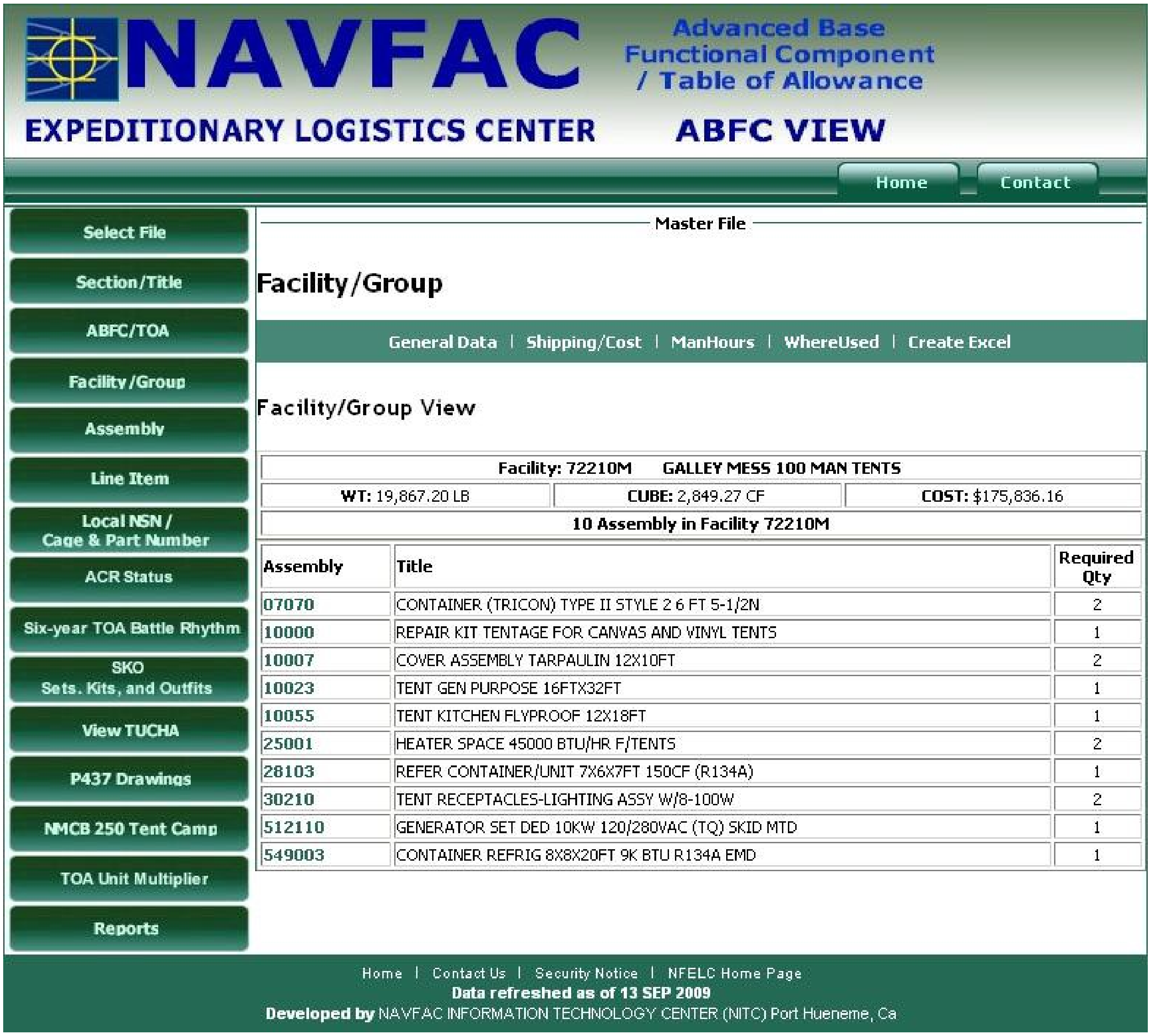
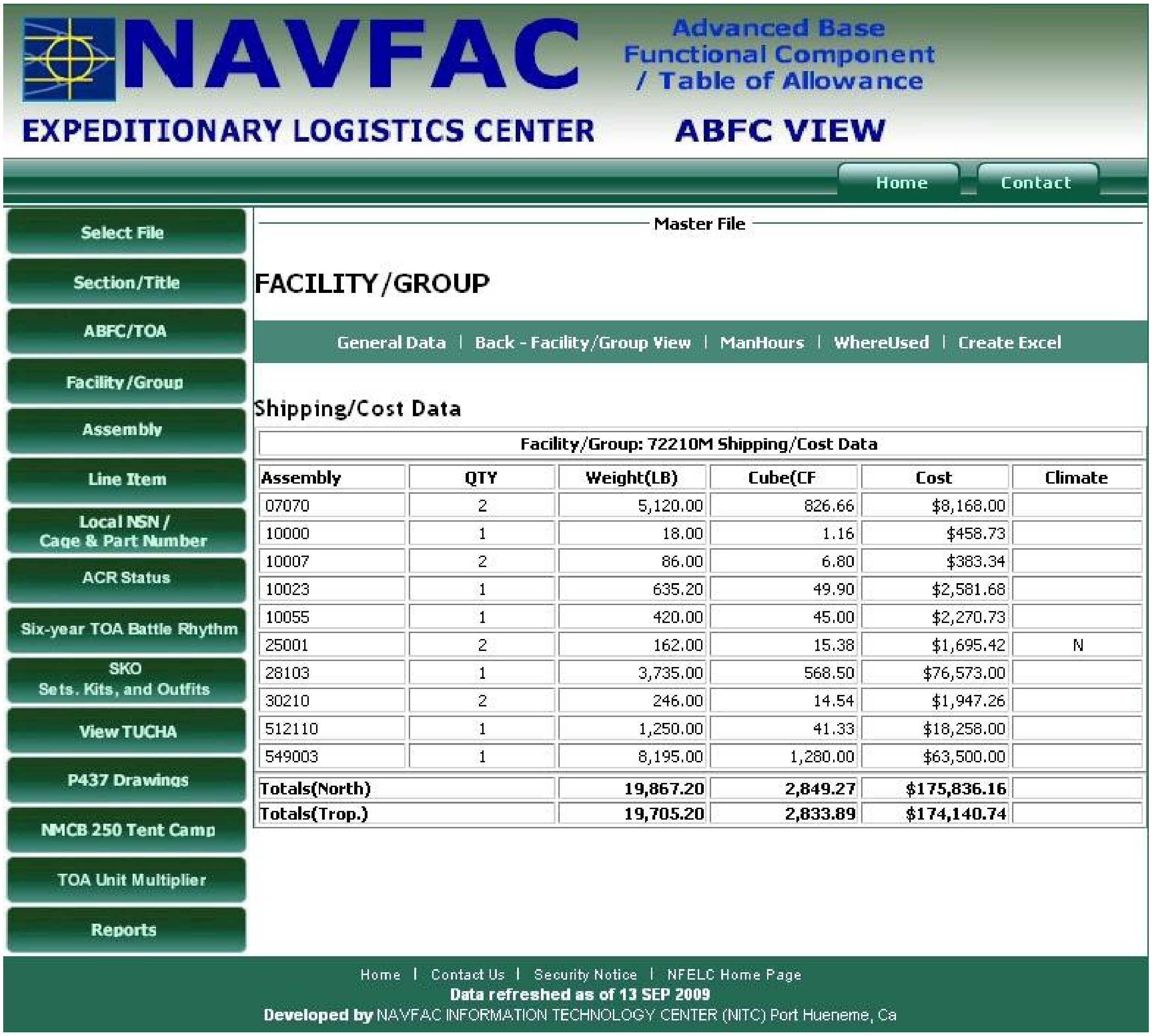



**Figure 9-9 – ABFC/TOA facility/group view screen.**

The Weight, Cube, and Cost for the facility display below the header. The assemblies required to make the facility functionally operational are listed in assembly number sequence. These numbers were derived from the prime trade involved in the construction. The 10,000 series indicates the Builders.

A brief description appears in the next column. This is followed by the required quantity for each assembly in the facility. The required quantity is used as a multiplier, indicating the number of assemblies to be ordered.

Access the shipping/cost data screen by selecting Shipping/Cost from the banner. *Figure 9-10* shows the Shipping/Cost Data screen for Facility/Group 72210M.




| Assembly | QTY | Weight(LB) | Cube(CF | Cost | Climate |
|---|---|---|---|---|---|
| 07070 | 2 | 5,120.00 | 826.66 | $8,168.00 | |
| 10000 | 1 | 18.00 | 1.16 | $458.73 | |
| 10007 | 2 | 86.00 | 6.80 | $383.34 | |
| 10023 | 1 | 635.20 | 49.90 | $2,581.68 | |
| 10055 | 1 | 420.00 | 45.00 | $2,270.73 | |
| 25001 | 2 | 162.00 | 15.38 | $1,695.42 | N |
| 28103 | 1 | 3,735.00 | 568.50 | $76,573.00 | |
| 30210 | 2 | 246.00 | 14.54 | $1,947.26 | |
| 512110 | 1 | 1,250.00 | 41.33 | $18,258.00 | |
| 549003 | 1 | 8,195.00 | 1,280.00 | $63,500.00 | |
| **Totals(North)** | | **19,867.20** | **2,849.27** | **$175,836.16** | |
| **Totals(Trop.)** | | **19,705.20** | **2,833.89** | **$174,140.74** | |

**Figure 9-10 – ABFC/TOA facility/group shipping cost screen.**

Weight and cubic feet are measured in normal terms for export packing. Weight, cubic feet, and dollar value reflect totals for each line. Climate shows which zone the assembly is rated for, indicated by N for the North Temperate Zone or T for the Tropical Zone. Only assemblies required for arctic operation are designated code N. Other facilities or assemblies are designed for use in both North and South Temperate Zones and Tropical Zones.

Construction estimates are computed in the same manner as components except for the addition of the primary facility capacity and the secondary capacity, as described in the NAVFAC P-72. This is used, for example, in the 700 series of facilities where the primary capacity is expressed in personnel and the secondary is expressed in square feet.

The recoverability code is a broad indication of the relocatability or recoverability of the facility. The code A indicates total recoverability, and D indicates a disposable facility. More details are found in *Table 9-2*, Recoverability Code.

| Table 9-2 – Recoverability Code | |
|---|---|
| A. Relocatable: | Designed for the specific purpose of being readily erected, disassembled, stored, and reused. Includes tentage. |
| B. Pseudo-relocatable: | Not specifically designed to be dismantled and relocated, but could be, with considerable effort and loss of parts. Rigid-frame building included. |
| C. Nonrecoverable: | A structure not designed to provide relocatability features or one where the cost of recovery of the shelter exceeds 50% of the initial procurement cost. |
| D. Disposable | Those temporary structures having low acquisition and erection costs, which are not designed for relocation and reuse and may be left on site or destroyed, such as SEAHUTS. |

### 1.1.2.3 Assembly

Search for assemblies by first clicking on 

. This brings up the Assembly search screen shown in *Figure 9-11*.


**Figure 9-11 – ABFC/TOA assembly search screen.**

Enter the assembly you are searching for and press SEARCH .

*Figure 9-12* shows a typical entry for an assembly which provides the necessary material required to build this assembly.

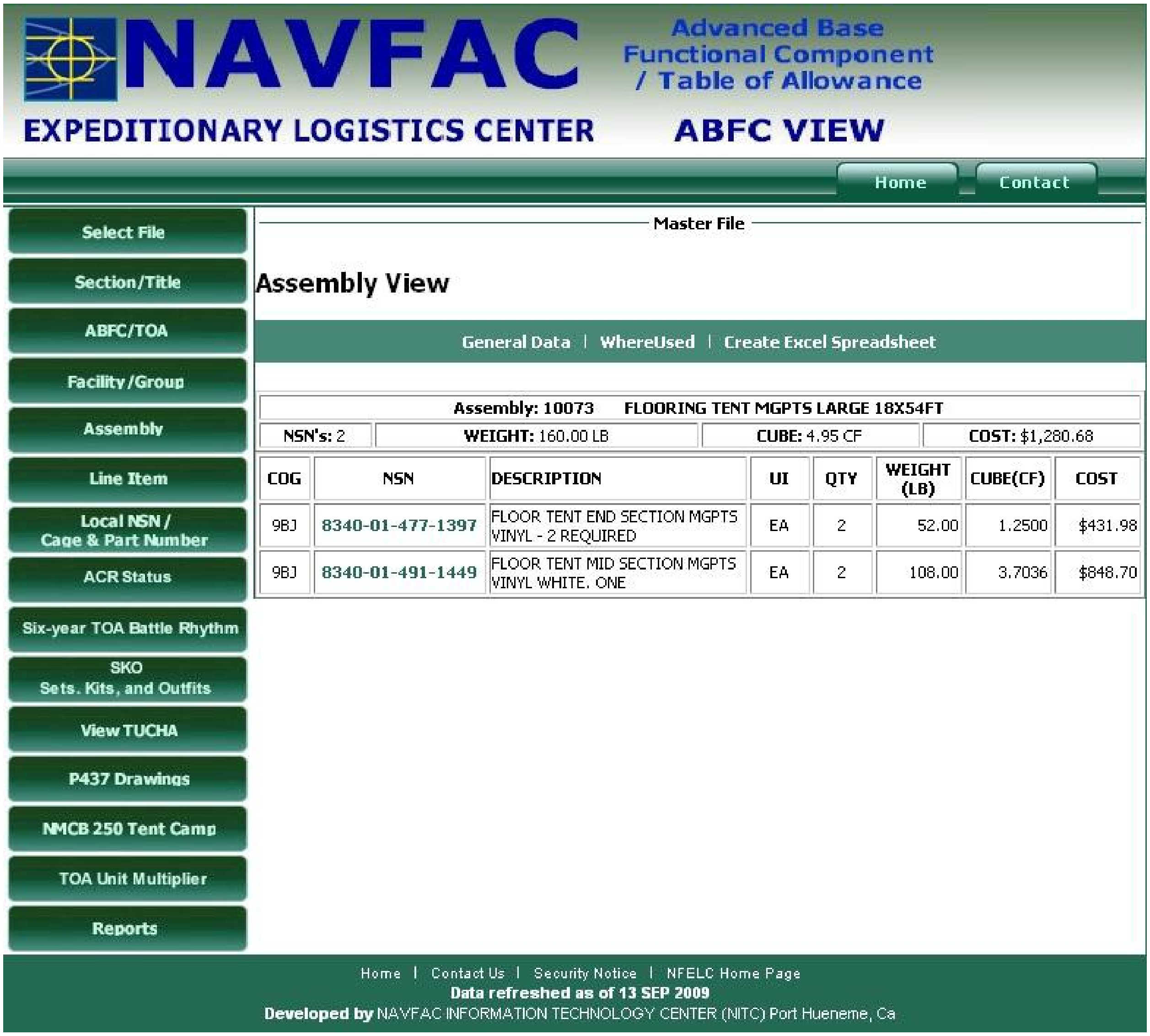



**Figure 9-12 – ABFC/TOA assembly view screen.**

Header information is the same as that for a facility. Assembly line-item requirements are listed by cognizance symbol and NSN. The unit of issue, weight, cubic feet, and dollar value are extracted from supply files once the requirement data is entered. This data changes often, and is updated in the system as the need arises. Access the manpower information for this assembly by selecting General Data from the banner. *Figure 9-13* shows a typical entry for an assembly which provides the estimated manpower required to build this assembly.

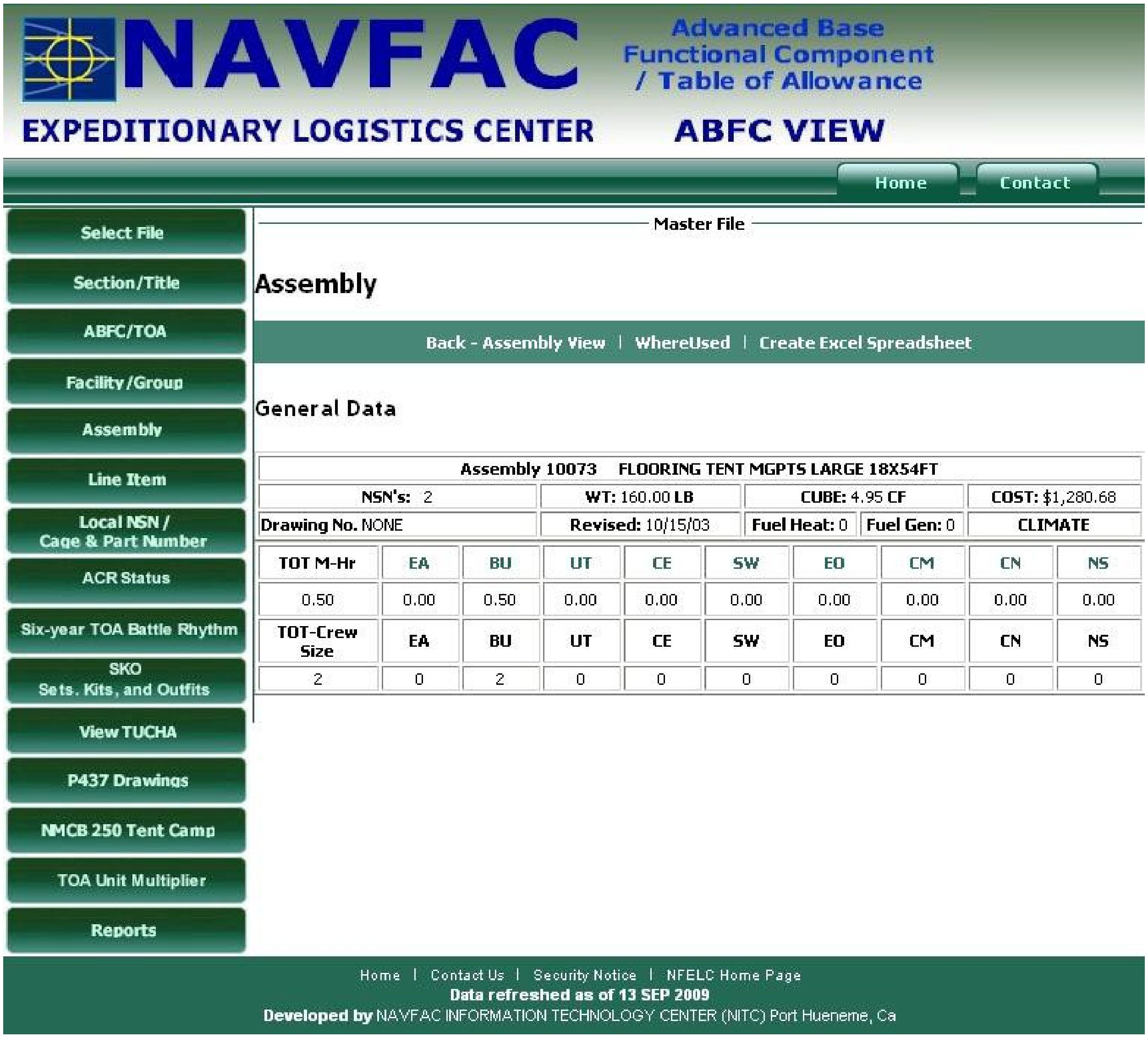



**Figure 9-13 – ABFC/TOA assembly general data screen.**

*Figure 9-14* shows a typical entry for an assembly, but this assembly is not associated with any facility. Assembly 11900 is an augment assembly tailored specifically for contingency operations. The 16 by 32-foot tent frame (strongback) is the most versatile tent assembly used throughout the NCF.

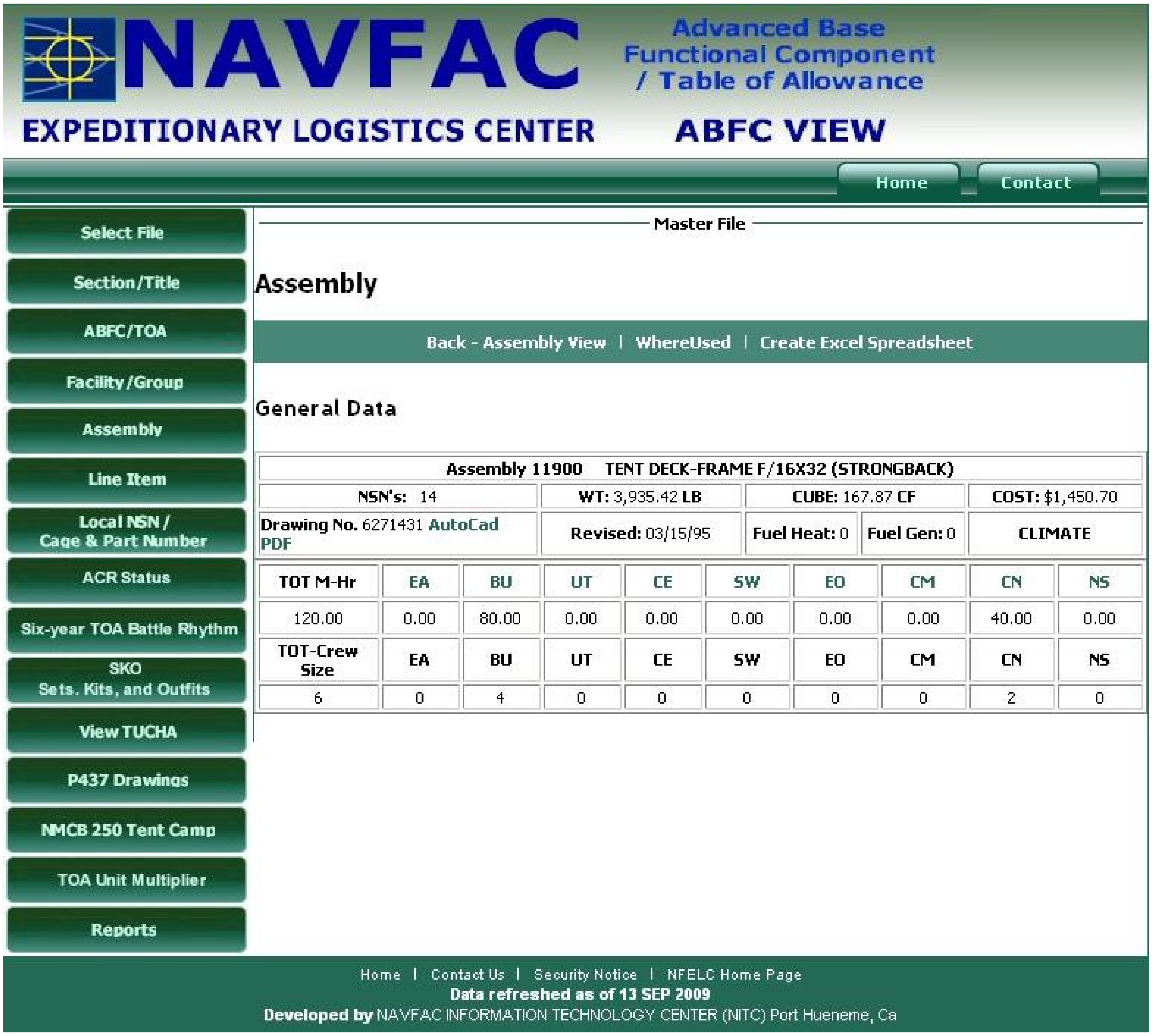



**Figure 9-14 –Strongback tent assembly.**

### 1.1.3 Index of Facilities

Suppose you have a requirement for an electrical distribution system underground. To determine what is available in the ABFC system to satisfy the requirement, click on 

.

*Figure 9-15* shows the ABFC/TOA Facility/Group search screen.


**Figure 9-15 – ABFC/TOA Facility/Group search screen.**

Scroll down to the 800 series (Utilities and Ground Improvements) or enter 8 in the search box and click on 

.

Scroll through the entries until you find an approximate 11,000-foot system. In this case, facility 81230B can be used. Click on the entry for facility 81230B.

*Figure 9-16* shows the facility/group view screen that gives the basic information you need to fulfill the requirement for an underground electrical distribution system.

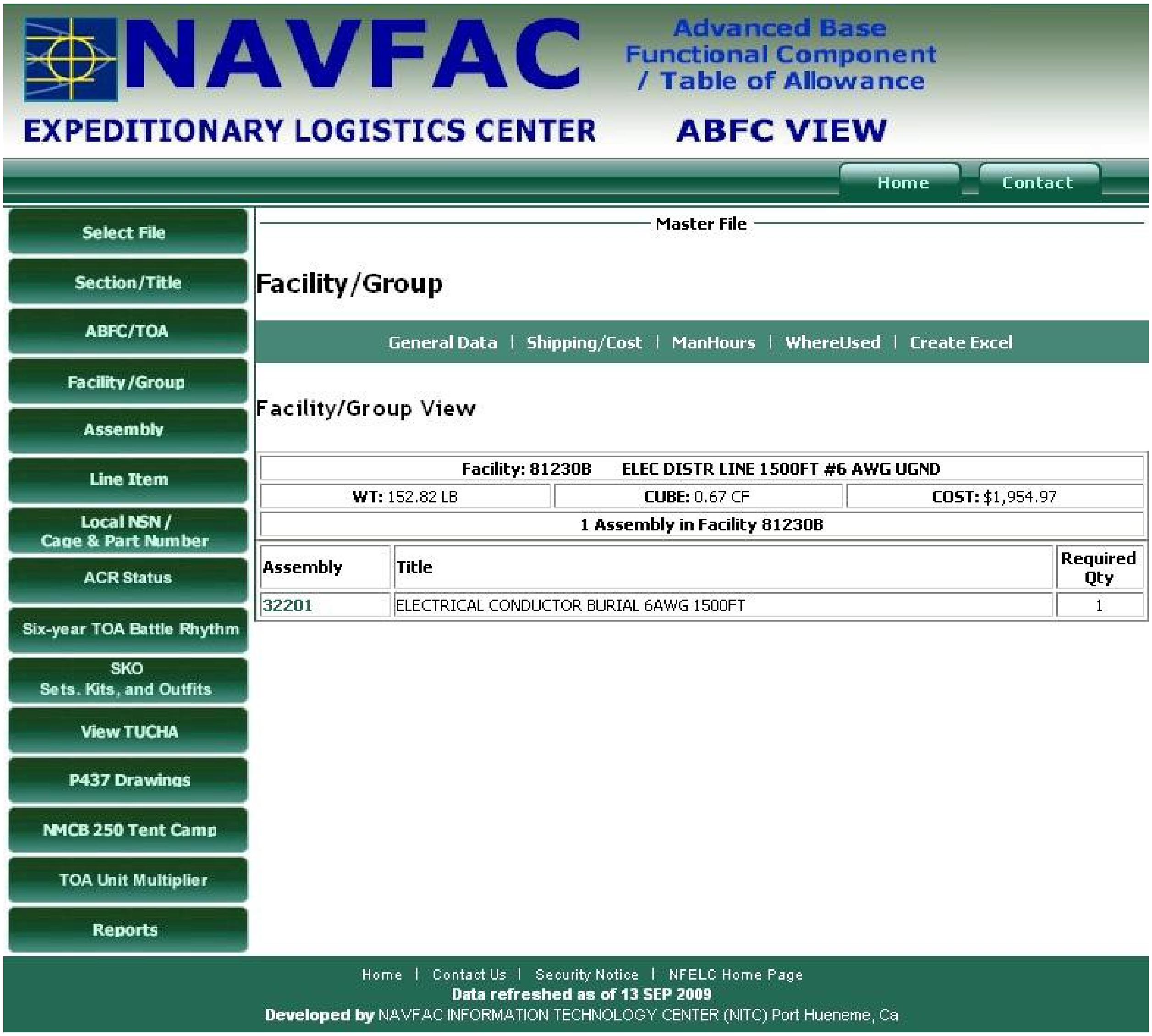



**Figure 9-16 – ABFC/TOA Facility/Group view screen.**

Access more detailed information on the facility by selecting General Data from the banner. *Figure 9-17* shows the general data screen for facility 81230B.

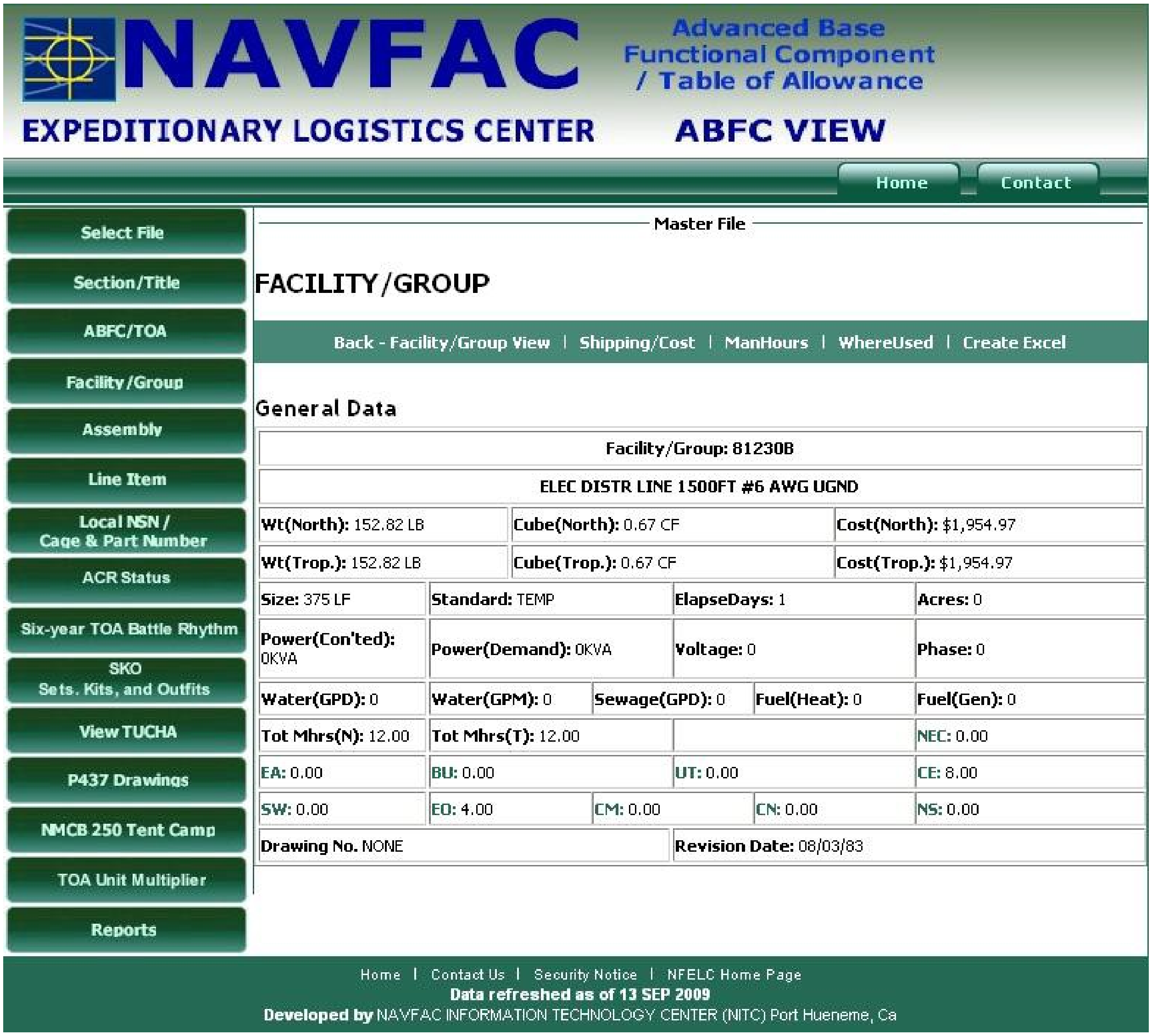



**Figure 9-17 – ABFC/TOA Facility/Group general data screen.**

Certain installed equipment or collateral equipment, such as furniture and fixtures contributed by others, is not furnished with the facilities or the assemblies listed in the ABFC/TOA system. You must request this equipment separately. The assembly listings indicate what is installed or what NAVFAC collateral equipment is provided.

# 2.0.0 FIELD STRUCTURES

This section covers the procedures for the erection of the K-SPAN, towers, and bunkers. Other field structures commonly used are the 40 by 100-foot Pre-Engineered Building (PEB), the 20 by 48-foot PEB, the 16 by 32-foot strongback tent, and heavy timber structures, all of which are covered throughout this manual and in Chapter 6 of this manual.

## 2.1.0 K-Span Building

K-SPAN buildings, shown in *Figure 9-18*, are a newer form of construction within the Seabee community. The intended use of these buildings is for open storage, but they can be designed for use as office spaces, hangars, supply buildings, medical facilities, and more permanent structures.

**Figure 9-18 – Typical K-SPAN building.**

K-SPAN buildings are created using a self-contained, metal building manufacturing plant (Automatic Building Machine) mounted on a trailer, a type of mobile factory. There are two types of K-SPAN building machines. *Figure 9-19* shows the MIC 120 (K-SPAN).

**Figure 9-19 – Automatic Building Machine 120.**

*Figure 9-20* shows the MIC 240 (Super Span).

**Figure 9-20 – Automatic Building Machine 240.**

An interesting aspect of these machines is that they can be easily transported by air anywhere in the world. The ABM System has already been certified for air transport by the U.S. Air Force in C-130, C-141, and C-5 aircraft.

### 2.1.1 Training

Training personnel in the operation of all related K-SPAN equipment is essential. The formal training of K-SPAN construction is held at both NCRs. Crew members and leaders, once trained, can instruct other members of the crew in the safe fabrication and erection of a K-SPAN. Each regiment has personnel certified by MIC Industries to instruct this training.

The training provided to you is not to be taken as the absolute and only way to construct the K-SPAN. As in the case of most construction procedures, there are several different ways to accomplish the task. Crew size, experience, and type of equipment available may alter the way you perform the task; however, you should achieve the same end results. *Table 9-3* shows the personnel and skills required to erect this building.

| Table 9-3 – Personnel and Skill Requirements | |
|---|---|
| **Personnel** | **Skill Requirements** |
| Engineer | (Not required on a full-time basis.)<br>May be required to engineer and design foundation and special applications. |
| Project Manager or Crew Leader | Oversees all phases of construction including machinery transportation and operations.<br>Maintains working knowledge of all tools, equipment, and building construction.<br>Must also be familiar with the ABM machinery.<br>Knows and enforces all SAFETY rules and regulations. |
| Truck/Crane Operator | Loads material onto machine and transport equipment.<br>Places arched panels on foundations.<br>Tows machinery between job sites.<br>Makes sure machinery is in proper working order and is certified in crane operations.<br>Complies with all SAFETY procedures. |
| Welder | Must have a working knowledge of welding, cutting, and fabrication of light steel.<br>Must be familiar with welder/generator operations and maintenance. |
| Construction Mechanic | Successfully undergoes special training on the ABM (training should be conducted by either Regiments or by the Manufacturer).<br>Must be thoroughly familiar with the Operating Manual. |
| General Laborer | Should be familiar with general construction techniques.<br>Must OBEY all safety rules and regulations.<br>To determine the amount of laborers required for the job, divide the weight of steel by 50. See *Figure 9-34*. |

**Figure 9-21 – Determining crew size for ABM 120.**

**Table 9-4 – Chart for determining crew size for ABM 120**

| Loads | | Steel Required | | Maximum Forces in Arch | | Maximum Arch Reactions per Foot at Foundation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Live | Wind | Thickness & Grade | | Axial | Moment | Horizontal (Lb) | | Vertical (Lb) | | Moment (In-Lb) | |
| | | Top | End | (Lb) | (In-Lb) | + | - | + | - | + | - |
| 0 | 70 | .035C | .023C | 241 | -13569 | 248 | -61 | 184 | -96 | 1313 | -13569 |
| 0 | 80 | .041D | .023C | 323 | -17876 | 329 | -85 | 250 | -113 | 1539 | -17876 |
| 0 | 90 | .045D | .023C | 419 | -22801 | 424 | -116 | 331 | -124 | 1689 | -22801 |
| 0 | 100 | – | – | – | – | – | – | – | – | – | – |
| 10 | 70 | .035C | .023C | -306 | -13569 | 248 | -201 | 184 | -256 | 7250 | -13569 |
| 10 | 80 | .041D | .023C | 323 | -17876 | 329 | -210 | 250 | -273 | 7479 | -17876 |
| 10 | 90 | .045D | .023C | 419 | -22801 | 424 | -216 | 331 | -284 | 7625 | -22801 |
| 10 | 100 | – | – | – | – | – | – | – | – | – | – |
| 20 | 70 | .035C | .023C | -521 | -13569 | 350 | -350 | 184 | -416 | 13186 | -13569 |
| 20 | 80 | .041D | .023C | -537 | -17876 | 369 | -359 | 250 | -433 | 13418 | -17876 |
| 20 | 90 | .045D | .023C | -547 | -22801 | 424 | -365 | 331 | -444 | 13562 | -22801 |
| 20 | 100 | – | – | – | – | – | – | – | – | – | – |
| 30 | 70 | .035C | .023C | -739 | 19125 | 500 | -500 | 184 | -576 | 19122 | -13569 |
| 30 | 80 | .041D | .023C | -754 | 19358 | 509 | -509 | 250 | -593 | 19358 | -17876 |
| 30 | 90 | .045D | .023C | -763 | -22801 | 515 | -515 | 331 | -604 | 19498 | -22801 |
| 30 | 100 | – | – | – | – | – | – | – | – | – | – |
| 40 | 70 | .045D | .023C | -981 | 25442 | 664 | -664 | 163 | -764 | 25434 | -25442 |
| 40 | 80 | .045D | .023C | -981 | 25442 | 664 | -664 | 242 | -764 | 25434 | -25442 |
| 40 | 90 | .045D | .023C | -981 | 25442 | 664 | -664 | 331 | -764 | 25434 | -25442 |
| 40 | 100 | – | – | – | – | – | – | – | – | – | – |

| Steel Weights (Lb) | | | | | | |
|---|---|---|---|---|---|---|
| Thickness (inch) | .023 | .016 | .029 | .035 | .041 | .045 |
| Arch weight* (lb) | 126 | 143 | 159 | 193 | 226 | 248 |
| End wall weight | 1367 | 1546 | 1724 | 2081 | 2437 | 2675 |

**NOTE**

The arch weight shown above can be divided by 50 pounds (22.7 kg) carrying load per person to determine the number of workers required to transport each arch from the curved runout tables to the pre-staging area.

### 2.1.2 Operating Instructions

The main component of the K-SPAN system is the trailer-mounted building machine shown in *Figure 9-22*. This figure shows the main components of the trailer and general operating instructions. The primary position of the operator's station is located at the rear of the trailer. The crew member selected for this position must have a thorough understanding of the machine operations and manuals. From that position, the operator controls all the elements required to form the panels. The operator must remain at the controls at all times. From the placement of the trailer on site to the completion of the curved panel, attention to detail is paramount as with all aspects of construction.

**Figure 9-22 – Trailer-mounted machinery.**

As you operate the machine, you will be adjusting the various machine-operating components. Adjustments for the thickness, the radius, and the curving machine **MUST** be made according to the manuals. **Do not permit shortcuts in adjustments.** Any variations in adjustments or disregard for the instructions found in the operating manuals will leave you with a pile of useless material or an inconsistent building.

### 2.1.3 Foundations

The design of the foundation for a K-SPAN building depends on the size of the building (MIC 120 or MIC 240), the existing soil conditions, and the wind load. The foundation must be approved by a certified engineer.

The foundations for the buildings are easy to construct when you have the right equipment and crew. The roof and wall loads are transferred to the foundation through the base of each arch. Therefore, all loads are uniformly carried down each sidewall by continuous strip footing. The foundations are more economical than foundations of more conventional buildings.

The concrete forms and accessories provide sufficient material to form the foundations for a building 100 feet long by 50 feet wide. When a different configuration is required, forms are available from the manufacturer.

The actual footing construction is based, as with all projects, on the plans and specifications. The location of the forms, the placement of the steel, and the pounds per square inch (psi) of the concrete are critical. The building panels are welded to the angle in the footer before concrete placement. Because of this operation, all aspects of footer construction must be completely checked for alignment and squareness. Once concrete is placed, there is no way to correct errors.

As mentioned above, forms are provided for the foundation. Using *Table 9-5* as a guide, *Figure 9-23* gives you a simple foundation layout by parts designation.

**Table 9-5 – Concrete Forms Included in Kit.**

| **Description**<br>(Each set of forms is sufficient to erect a building 100 feet long by 50 feet wide.) | **Part Number** |
|---|---|
| Side form panels, 1' x 10', 12 gauge steel | F-1 |
| Transition panels, 1' x 12", 12 gauge steel | F-2 |
| Transition panels, 1' x 28", 12 gauge steel | F-3 |
| End wall caps, 1' x 15", 12 gauge steel | F-4 |
| Side wall caps, 1' x 19", 12 gauge steel | F-5 |
| Filler form, 1' x 12', 12 gauge steel | F-6 |
| Sidewall inside stop, 1' x 12", 12 gauge steel | F-7 |
| End wall inside stop, 1' x 12", 12 gauge steel | F-8 |
| Stakes, 1/4" diameter, bar steel | F-9 |
| All thread rod, 1/2-13 x 18" | F-10 |
| Hex nuts, 1/2-13 | F-11 |
| Hex bolts, 1/8-16 x 1-1/2" | F-12 |
| Hex nuts, 3/8-`6 | F-13 |
| Flat washers, 1/8" SAE | F-14 |
| Corner angles, 2" x 2" x 12", steel angle | F-15 |

As noted in *Figure 9-23*, the cross pipes are not provided in the kit. They must be ordered when the project is being planned and estimated.

**Figure 9-23 – Simple form assembly.**

### 2.1.4 Building Erection

With the placement of the machinery and forming of the building panels in progress, your next considerations are the placement and the weight-lifting capabilities of the crane. Check the weight-lifting chart of the crane for its maximum weight capacity. This dictates the number of panels (recommend 5/ABM 120 and 3/ABM 240) you can safely lift at the operating distance. As with all crane operations, attempting to lift more than the rated capacity can cause the crane to turn over.

Attaching the spreader bar to the curved formed panels, as shown in *Figure 9-24,* is a critical step; failure to clamp the panels tightly can cause the panels to slip and fall with potential harm to personnel and damage to the panels.

**Figure 9-24 – Spreader bar attachment.**

With the guide ropes attached, as shown in *Figure 9-25*, and personnel manning these ropes, lift the panels for placement. When the panels are lifted, lift only as high as necessary, position two personnel at each free end to guide the panels in place, and remind crew members to keep their feet from under the ends of the arches. You must never attempt to lift sets of panels in winds exceeding 20 mph.

**Figure 9-25 – Guide rope diagram.**

Place the first set of panels on the attaching angle of the foundation and position them so there will be room for the end-wall panels. After the first set of panels is positioned, clamp them to the angle, plumb with guide ropes, and secure the ropes to previously anchored stakes. Detach the spreader bar and continue to place the panel sets. Seam each set to the standing panels before detaching the spreader bar.

After about 15 panels (three sets) are in place, measure the building length at both ends (just above forms) and at the center of the arch. This measurement will seldom be exactly 1 foot per panel (usually slightly more), but should be equal for each panel. Adjust the ends to equal the center measure. Panels are flexible enough to adjust slightly. Check these measurements periodically during building construction. Since exact building lengths are difficult to predict, the end wall attaching angle on the finishing end of the building should not be put in place until all panels are set.

After the arches are in place, set the longest end-wall panel in the form, then plumb and clamp it in place. Work from the longest panel outward and be careful to maintain plumb.

When all the building panels are welded to the attaching angle at 12 inches on center, as shown in *Figure 9-26*, you are ready to place the concrete. When the concrete is placed, remember that it is extremely important that it is well-vibrated. This helps eliminate voids under all embedded items.

**Figure 9-26 – Building foundation concept.**

As the concrete begins to set, slope the top exterior portion of the concrete cap about 5 inches, as shown in *Figure 9-27*, to allow water to drain away from the building. The elevation and type of interior floor are not relevant as long as the finish of the interior floor is not higher than the top of the concrete cap.

**Figure 9-27 – Concrete foundation.**

### 2.1.5 Construction Details

The K-SPAN building system is similar to other types of pre-engineered or prefabricated buildings in that windows, doors, and roll-up doors can be installed only when erection is completed. When insulation of the building is required, insulation boards (usually 4 by 8 feet) may be of any semi-rigid material that can be bent to match the radius of the building. The insulation is installed using clips, as shown in *Figure 9-28*.

**Figure 9-28 – Insulation.**

When the integrity of the end-wall panels is continuous from the ground to the roof line, the end walls become self-supporting. The installation of windows, as shown in *Figure 9-29*, and aluminum doors, as shown in *Figure 9-30*, presents no problem since the integrity of the system is not interrupted.

**Figure 9-29– Aluminum window installation.**

**Figure 9-30 – Aluminum door installation.**

The installation of the overhead door, as shown in *Figure 9-31*, does present a problem in that it does interrupt the integrity of the wall system. This situation is quickly overcome by the easily installed and adjustable (height and width) doorframe package that supports both the door and end wall. This doorframe package is offered by the manufacturer.

**Figure 9-31 – Overhead door frame.**

### 2.1.6 Finish of Project

When all the panels are in place and secured to the base angle, the next step is optional. Apply a rubberized coat of paint to the base of the panels (interior/exterior) to a height slightly above the finish concrete. This gives added protection to the metal panels exposed to the concrete.

Finally, place the concrete into the above-ground foundation forms, as shown in *Figure 9-32*. Take care not to splash excessive amounts of concrete above the rubberized paint line.

**Figure 9-32 – Placement of concrete foundation.**

*Figure 9-33* shows the fundamental steps in constructing a K-SPAN from start to finish.