NONRESIDENT TRAINING COURSE

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BUILDER BASIC

NAVEDTRA 14043A

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Chapter 1

Basic Math

Topics

To hear audio, click on the box.

Overview

Addition, subtraction, multiplication, and division; these are all basic math skills that Builders use every day. A sound understanding of these basics prepares you for the more complex math skills you're likely to use on construction projects, including fractions, ratios, proportions, percentages, square roots, and the metric system. They will also prepare you for measurements and calculations using geometric shapes.

Measuring components for a construction project and figuring the materials needed to complete a project are both tasks that are accomplished using math. Figuring materials needed is a task that people in all construction trades perform, whether it's a mason calculating amounts of block and mortar, or a plumber figuring amounts of pipe and fittings.

Safety can be impacted by calculations you make for your project. Concrete form design relies on math to determine what load the form can carry without failing. Form failure can cause both loss of material and injury. Careful calculations help ensure the best results for all of your projects.

Objectives

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

1. Identify whole numbers.
2. Understand how to work with decimals.
3. Understand how to work with fractions.
4. Understand how to convert fractions to decimals and decimals to fractions.
5. Understand how to work with ratios and proportions.
6. Understand how to work with percentages.
7. Understand how to convert percentages to decimals and decimals to percentages.
8. Understand how to calculate square roots.
9. Understand the metric system.
10. Understand how to use measuring tools, including a standard ruler, a metric ruler, and an architect's scale.
11. Understand construction geometry.

Prerequisites

None

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

Expeditionary Structures	↑	B
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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 PARTS of a WHOLE NUMBER

Whole numbers are made up of ***digits***, which can be any numerical symbol from 0 to 9. Each digit of a whole number represents a ***place value***, as shown in *Figure 1-1*. The number in this example is read as one million two hundred thirty-four thousand five hundred sixty-seven.

1	,	2	3	4	,	5	6	7
Millions		Hundred Thousands	Ten Thousands	Thousands		Hundreds	Tens	Units

Figure 1-1 – Place values in whole numbers.

Every digit has a value that depends on its place, or location, in the whole number. In *Figure 1-1*, the place value of the 1 is one million; the place value of the 5 is five hundred.

Numbers can be positive or negative. ***Positive numbers*** are larger than zero and don't usually have a positive sign (+) before them. ***Negative numbers*** are smaller than zero and always have a negative sign (-) before them. Zero is not positive or negative; it never has a positive or negative sign before it. Any whole number that doesn't have a negative sign in front of it is a positive number.

Test your Knowledge (Select the Correct Response)

1. What number is the same as the words *one thousand three hundred eighty-six*?

   A. 1,068
   B. 1,368
   C. 1,386
   D. 3,186

2.0.0 DECIMALS

Decimals are numbers in the base 10 system, using any numerical symbol from 0 to 9. The place values in decimal numbers are similar to the place values in whole numbers, except that decimal numbers appear to the right of a decimal point and do not use comma separators. Place values in decimal numbers are shown in *Figure 1-2.*

.	1	2	3	4	5	6
Decimal Point	Tenths	Hundredths	Thousandths	Ten Thousandths	Hundred Thousandths	Millionths

Figure 1-2 – Place values in decimal numbers.

Like whole numbers, decimal numbers have values that depend on their place in the number. In the example above, the place value of the 1 is one tenth, the place value of the 3 is three thousandths.

Operations with decimals are very similar to operations with whole numbers. The only difference is that you have to keep track of the decimal point.

2.1.0 Adding Decimals

12.34

+5.678

When you add numbers containing decimals, make sure to keep the decimal points lined up. For example, if you add 12.34 to 5.678, they should look like this when you add them:

Be sure to add each column of numbers, starting with the numbers that are farthest right. In this case, the first number has no digit in the thousandths position, so it can be treated as a zero:

12.340

+5.678

8

As you move left adding the columns, make sure to carry any numbers greater than 10. When you add 4 and 7 in the hundredths column, the sum is 11. Record a 1 in the hundredths column and carry a 1 to the tenths column as shown below:

1

12.340

+5.678

18

When you add the tenths column, you have to add 3 and 6, and the 1 you carried from the sum in the hundredths column. This will give you a sum of 10, so record the 0 in the tenths column and carry a 1 to the units column as shown below:

1

12.340

+5.678

.018

Add the remaining numbers as you would any whole number. Remember to place the decimal point between the units column and the tenths column, as shown below:

12.340

+5.678

18.018

Test your Knowledge (Select the Correct Response)

2. What is the sum of 54.32 and 1.786?

   A. 72.18
   B. 56.106
   C. 64.143
   D. 54.498

2.2.0 Subtracting Decimals

Subtracting decimals is very similar to adding decimals. You need to line up the decimal points as in addition. Subtracting 5.678 from 12.34 looks like this:

12.37

-1.248

Since there are only 2 decimal points after the whole number in 12.34, we need to add a zero at the end so we can subtract the three decimal points in 5.678.

12.370

- 1.248

You subtract columns the same way as you add them, starting with the farthest right column. In this case, you can't subtract 8 from 0, so you need to borrow from the hundredths column to be able to subtract from 10, as shown below:

6

12.3~~7~~^{1}0

- 1.24 8

2

You now have 6 to subtract 4 from, since you borrowed 1 from 7. The rest of the numbers subtract normally, as shown below:

6

12.3~~7~~^{1}0

- 1.24 8

11.122

Test your Knowledge (Select the Correct Response)

3. What is the difference between 65.43 and 2.897?

   A. 36.46
   B. 98.993
   C. 62.533
   D. 65.14

2.3.0 Multiplying Decimals

Multiplying numbers with decimals is a two step process. First, multiply the numbers as if they were whole numbers. Then place the decimal point in the correct location. The example below shows the product of 1.2 and 3.4, before the decimal is placed.

$$\begin{array}{r} 1.2 \\ \underline{\times 3.4} \\ 408 \end{array}$$

To get the correct location for the decimal point, count the number of decimal places in each number and add the number of decimal places. In this case, each number has one decimal place, so the product will have two decimal places. The product of the equation is 4.08.

Test your Knowledge (Select the Correct Response)

4. What is the product of 21.34 and 5.964?

   A. 127.271
   B. 1272.71
   C. 127.422
   D. 1274.22

2.4.1 Dividing Decimals

Dividing numbers with decimals is a four step process.

1. Convert the divisor to a whole number. A divisor of .2 becomes 2.
2. Convert the dividend by the same number of decimal places as the divisor. In this case, 2.34 becomes 23.4.
3. Divide the two numbers as shown below.

$$\begin{array}{r} 117 \\ 2\overline{)23.4} \\ \underline{2} \\ 3 \\ \underline{2} \\ 14 \\ \underline{14} \\ 0 \end{array}$$

4. Place the decimal according to the number of decimal places in the dividend.

$$\begin{array}{r} 11.7 \\ 2\overline{)23.4} \end{array}$$

Test your Knowledge (Select the Correct Response)

5. What is the result of dividing 246.81 by 12.3?

   A. .0498
   B. 4.983
   C. 2.007
   D. 20.07

3.0.0 FRACTIONS

A fraction is a part of a whole. Fractions are usually written as two numbers separated by a slash, such as 1/2. The slash means the same thing as the division sign (÷), so 1/2 = 1 ÷ 2. *Figure 1-3* shows a whole triangle shaded blue and a triangle with one half (1/2) shaded blue.

The bottom number of a fraction is called the ***denominator*** and tells how many parts the whole is being divided into. The top number of a fraction is called the ***numerator*** and tells how many of the parts are being used. In the example of 1/2, 2 is the denominator and 1 is the numerator. The denominator and numerator are also known as the terms of the fraction.

Figure 1-3 – Whole and half triangles.

Equivalent fractions are different fractions which mean the same amount. For example, 1/2 is an equivalent fraction to 2/4, 10/20, and 25/50.

3.1.1 Reducing Fractions to their Lowest Terms

Fractions shown with different numbers can have the same value. Fractions are easier to work with when they are at the lowest terms possible. For example, it is easier to work with the fraction 1/2 than it is to work with the equivalent fraction 17/34. To reduce a fraction to its lowest terms, there are two steps.

1. Determine what the largest number is that will divide evenly into both the numerator and the denominator. If the only number that will divide evenly into both numbers is 1, the fraction is at its lowest terms.

2. Divide both the numerator and denominator by the number you determined in Step 1. For the fraction 8/32, the largest number that evenly divides both the numerator 8 and the denominator 32 is 8. Reducing the fraction to its lowest terms looks like this:

   8/32 ÷ 8/8 = ¼

3.2.1 Comparing Fractions and Finding the Lowest Common Denominator

Comparing fractions is simple if the two fractions have the same denominator. In this case, the fraction with the larger numerator is larger than the fraction with the smaller numerator.

Most fractions that you need to compare won't have the same denominator. You need to convert them to the same denominator to compare them. The simplest way to convert fractions to the same denominator is to multiply their denominators to get a ***common denominator***, and then convert each fraction to the resulting denominator. For example, if you are comparing 3/4 to 5/7, you would convert and compare them as shown below.

1. Find the common denominator.

   4 x 7 = 28

2. Convert each fraction to the common denominator.

   3/4 x 7/7 = 21/28

   5/7 x 4/4 = 20/28

3. Compare the fractions. You find that 3/4 is larger than 5/7.

Just as you can find the lowest terms for single fractions, you can find the ***lowest common denominator*** for multiple fractions.

1. Reduce both fractions to their lowest terms.
2. Determine the lowest common multiple for the denominators. You may find that one denominator is a multiple of the other. For example, if you are comparing 1/4 and 3/8, the denominator 8 is a multiple of the denominator 4.
3. Convert the fractions to equivalent fractions with the common denominator.

   1/4 x 2/2 = 2/8

   3/8 x 1/1 = 3/8

4. Compare the fractions. You find that 1/4 is smaller than 3/8.

3.3.1 Adding Fractions

Sometimes you calculate a number in which the numerator is larger than the denominator. This is called an ***improper fraction.*** You can convert an improper fraction to a whole number and a fraction, which is known as a ***mixed number.*** Start by adding the fractions as you would normally. To add 5/7 to 3/4:

1. Find the common denominator.

   7 x 4 = 28

2. Convert each fraction to the common denominator.

   5/7 x 4/4 = 20/28

3/4 x 7/7 = 21/28

3. Add the numerators of the fractions, and place the sum over the common denominator. Do NOT add the denominators.

   20/28 + 21/28 = 41/28

4. Convert the improper fraction to a mixed number.

   41 ÷ 28 = 1 with a remainder of 13 or 1 13/28

The remainder becomes the numerator for the fraction portion of the mixed number. The resulting mixed number is 1 13/28.

Test your Knowledge (Select the Correct Response)

6. 12/24 + 6/16 =

   A. 18/24
   B. 1 1/8
   C. 7/8
   D. 18/40

3.4.1 Subtracting Fractions

When you need to subtract measurements that include fractions on construction projects, it is very similar to adding fractions. If the denominators of the fractions are the same, subtract the numerators, place the result over the denominator, and reduce the resulting fraction to its lowest terms. If the denominators are not the same, follow these steps.

1. Write out the equation.

   3/4 - 1/8 = x

2. Determine the common denominator for the fractions you need to subtract. For the fractions 3/4 and 1/8, the common denominator is

   4 x 8 = 32

3. Convert the fractions to equivalent fractions with the common denominator.

   3/4 x 8/8 = 24/32

   1/8 x 4/4 = 4/32

4. Subtract the numerators of the fractions, and place the result over the common denominator. Do NOT subtract the denominators.

   24/32 - 4/32 = 20/32

5. Reduce the resulting fraction to its lowest terms.

   20/32 ÷ 4/4 = 5/8

Sometimes you need to subtract a fraction from a whole number. To do this you need to convert the whole number to an equivalent fraction, and then make your subtraction. In this example we'll subtract 5/8 from 1.

1. Write out the equation.

   1 – 5/8 = x

2. Convert the whole number to an equivalent fraction.

   1 x 8/8 = 8/8

3. Subtract the numerators of the fractions, and place the result over the common denominator. Do NOT subtract the denominators.

   8/8 - 5/8 = 3/8

4. Reduce the resulting fraction to its lowest terms. In this case the result is already in its lowest terms.

Test your Knowledge (Select the Correct Response)

7. 5/8 - 3/16 =

   A. 2/12
   B. 1/6
   C. 7/16
   D. 3/8

3.5.1 Multiplying Fractions

Multiplying fractions is fairly simple, since you don't need to worry about finding a common denominator. When you read or hear that you need to find a part of a number, such as 3/8 of 5/6, it means you need to multiply the numbers using the steps below.

1. Write out the equation.

   3/8 x 5/6 = x

2. Multiply the numerators.

   3 x 5 = 15

3. Multiply the denominators.

   8 x 6 = 48

4. Reduce the resulting fraction to its lowest terms.

   15/48 ÷ 3/3 = 5/16

In this case, 3 is the largest number that can be evenly divided into both the numerator and the denominator. You may find it easier to work with the fractions if you reduce them to their lowest terms before you multiply them.

Test your Knowledge (Select the Correct Response)

8. 2/8 x 10/16 =

   A. 20/16
   B. 1 1/4
   C. 5/32
   D. 1 2/8

3.6.1 Dividing Fractions

Dividing fractions is very similar to multiplying fractions, except that you invert or flip the fraction by which you are dividing. Use the following steps to divide 7/8 by 1/4.

1. Write out the equation.
   7/8 ÷ 1/4 = x
2. Invert the fraction you are dividing by.
   1/4 becomes 4/1
3. Convert the division sign (÷) to a multiplication sign (x) and write the new equation.
   7/8 ÷ 1/4 becomes 7/8 x 4/1
4. Multiply the numerators.
   7 x 4 = 28
5. Multiply the denominators.
   8 x 1 = 8
6. Reduce the resulting fraction to its lowest terms.
   28/8 ÷ 4/4 = 7/2
7. Convert the improper fraction to a mixed number.
   3 1/2

Test your Knowledge (Select the Correct Response)

9. 3/8 ÷ 3/6 =

   A. 3/4
   B. 9/48
   C. 3/16
   D. 6/8

4.0.0 CONVERSIONS – FRACTIONS and DECIMALS

There will be times when you need to convert numbers so that all of the numbers you are working with are in the same format. The most common conversions you will work with are from fractions to decimals and from decimals to fractions.

4.1.0 Converting Fractions to Decimals

To convert a number from a fraction to a decimal, divide the numerator by the denominator. The fraction 5/8 can be converted as shown.

```
    .625
8 ) 5.000
   -4.8
     .20
    -.16
     .040
    -.040
        0
```

4.2.1 Converting Decimals to Fractions

There are three steps to convert a decimal to a fraction. The decimal .125 can be converted to a fraction as follows:

1. Place the number to the right of the decimal point in the numerator.

   125/

2. Count the number of decimal places in the number. Place this number of zeros following a 1 in the denominator.

   125/1000

3. Reduce the fraction to its lowest terms.

   125/1000 ÷ 125/125 = 1/8

4.3.1 Converting Inches to Decimal Equivalents in Feet

Sometimes you will need to convert measurements in inches to decimal equivalents in feet. You can calculate what the decimal equivalent in feet would be for 6 inches with the following steps.

1. Show the measurement as a fraction of a foot. Use 12 as the denominator, since there are 12 inches in a foot.

   6/12

2. Reduce the fraction to its lowest terms.

   6/12 ÷ 6/6 = 1/2

3. Convert the fraction to a decimal. Divide the numerator by the denominator.

$$\begin{array}{r} .5 \\ 2\,\overline{)\,1.0} \\ \underline{-1.0} \\ 0 \end{array}$$

The result is that 6 inches converts to .5 foot.

Test your Knowledge (Select the Correct Response)

10. Is 14 inches = 1.17 feet?

    A. Yes
    B. No

5.0.0 RATIOS and PROPORTIONS

5.1.1 Ratios

A ratio is a comparison of two numbers, which can be expressed in three ways. A comparison of the numbers 1 and 2 can be expressed as follows:

1:2

1/2

1 to 2

One place where ratios come into play for Builders is Rule 42 for concrete mixes. This rule specifies a ratio of 1:2:4 for cement, sand, and aggregates.

Ratios can be used to calculate the quantities of materials needed for a project. If your specifications call for a 1:2:4 concrete mix with 2-inch coarse aggregates, you use Rule 42 to figure the material amounts.

1. Add 1:2:4, which gives you 7.
2. Divide 42 by 7 to figure the prime number.

   42 cu ft ÷ 7 = 6 cu ft

3. Compute your material requirements by multiplying the prime number by the ratio as follows:

   1 x 6 = 6 cu ft of cement

   2 x 6 = 12 cu ft of sand

   4 x 6 = 24 cu ft of coarse aggregates

5.2.1 Proportions

A proportion is an equation showing a ratio on each side. The equation shows that the two ratios are equal, as shown below:

1:2 = 2:4

You will usually work with proportions to figure an unknown number on one side of the equation. If you have a ratio of 1:2 and need to figure the equivalent ratio of n:8, there are three steps.

1. Write out the proportion.

   2:4 = n:8

   OR

   2/4 = n/8

2. Use the cross product.

   4 x n = 2 x 8

   4n = 16

3. Solve the proportion.

   n = 16/4

   n = 4

The solved proportion is 2:4 = 4:8.

6.1.1 PERCENTAGES

A percentage is a number expressed as a fraction of 100. You will usually see percentages with the percent sign, as in 35%.

You can calculate the percentage of a material that has been used in two steps.

1. Divide the used amount by the initial amount.
2. Multiply the result by 100.

If you had an initial supply of 300 sheets of plywood and you have used 80 of them, you calculate the percent used as follows:

80/300 = .27

.27 x 100 = 27%

If you need to know what percent you have remaining, you subtract the percent used from 100, as follows:

100 – 27 = 73%

If you have not calculated the percent used, you can still calculate the percent remaining with two steps.

1. Calculate the amount remaining.

   300 – 80 = 220

2. Calculate the percent remaining.

   220/300 = .73

   .73 x 100 = 73%

Test your Knowledge (Select the Correct Response)

11. If you started with 400 concrete masonry units, and you have used 175 of them, what percent have you used?

    A. 2.286%
    B. 22.86%
    C. .4375%
    D. 43.75%

7.0.0 CONVERSIONS – PERCENTAGES and DECIMALS

7.1.0 Converting Percentages to Decimals

Convert a percentage to a decimal by dividing the percent by 100. If you need the decimal equivalent of 37%, perform the following calculation:

37/100 = .37

7.2.0 Converting Decimals to Percentages

Convert a decimal to a percentage by multiplying the decimal by 100**.** If you need the percentage equivalent of .74, perform the following calculation:

.74 x 100 = 74%

8.1.1 SQUARE ROOTS

The square root of a number is a value that, multiplied by itself, gives the original number. In other words, if you have a value x, the square root r is a number such that

$r^2 = x$. A simple example is the square root of 9, which is 3.

There is a table in Appendix I of NAVEDTRA 14139 Mathematics, Basic Math, and Algebra called Squares, Cubes, Square Roots, Cube Roots, Logarithms, and Reciprocals of Numbers that you can use to look up a square root. If that resource or a calculator with a square root function is not available, there are several methods of calculating a square root. The simplest of these methods is called the Babylonian Method, which is repeated until you get as close to the square root as you need to. In this example we will calculate the square root of 8.

1. Estimate a number that you think is close to the square root. The closest squares to 8 are 2 (22 = 4) and 3 (32 = 9). For this example, use 3 as the estimate.
2. Divide the number you are trying to calculate the square root of by your estimate.
   8/3 = 2.67
3. Add that number to your estimate.
   3 + 2.67 = 5.67
4. Divide the sum by 2.
   5.67/2 = 2.835
5. Test your result by multiplying the number by itself. If the result is accurate enough, great! Stop here.
6. If the number is not accurate enough, use the result as your new estimate. In our example, when 2.835 is squared, the result is 8.037225. Using a second round brings us to a possible square root of 2.828, with a result of 7.997584.
7. Repeat these steps until you have as accurate a result as you need.

Test your Knowledge (Select the Correct Response)

12. What is the square root of 10?

    A. 4.0025
    B. 3.1275
    C. 3.1623
    D. 2.9876

9.0.0 METRIC SYSTEM

The metric system is a decimal-based system of units. We will focus on units of weight, length, volume, and temperature.

9.1.0 Units of Weight

The standard metric unit of mass is the gram. *Table 1-1* shows units of mass, their equivalents in grams, and the abbreviations for the units of mass.

Table 1-1 – Metric Units of Mass.

Unit of Mass	Equivalent in Grams	Abbreviation
1 milligram	0.001 gram	mg
1 centigram	0.01 gram	cg
1 decigram	0.1 gram	dg
1 gram	1 gram	g
1 kilogram	1000 grams	kg

Rough equivalent masses of objects you might be familiar with are:

1 gram	paper clip
1 kilogram	liter of water

9.2.0 Units of Length

The standard metric unit of length is the meter. *Table 1-2* shows units of length, their equivalents in meters, and the abbreviations for the units of length.

Table 1-2 – Metric Units of Length.

Unit of Length	Equivalent in Meters	Abbreviation
1 millimeter	0.001 meter	mm
1 centimeter	0.01 meter	cm
1 decimeter	0.1 meter	dm
1 meter	1 meter	m
1 kilometer	1000 meters	km

Rough equivalent lengths of objects you might be familiar with are:

1 meter	a little longer than 1 yard
1 centimeter	nearly the diameter of a dime
1 millimeter	about the thickness of a dime

9.3.0 Units of Volume

The standard metric unit of volume is the liter. *Table 1-3* shows units of volume, their equivalents in liters, and the abbreviations for units of volume.

Table 1-3 – Metric Units of Volume.

Unit of Volume	Equivalent in Liters	Abbreviation
1 milliliter	0.001 liter	ml
1 centiliter	0.01 liter	cl
1 deciliter	0.1 liter	dl
1 liter	1 liter	l
1 kiloliter	1000 liters	kl

Rough equivalent volumes of objects you might be familiar with are:

1 liter	a little more than a quart
5 millimeters	about one teaspoon

9.4.0 Units of Temperature

The standard metric unit of temperature is the degree Celsius. The boiling point of water at sea level is 100°Celsius, or 100°C. The freezing point of water at sea level is 0°Celsius, or 0°C. A day with a temperature of 30°C is considered hot.

9.5.0 Metric Conversion

There will be times when you need to convert to metric equivalents of measurements. *Table 1-4* shows conversions for some of the most common measurements.

Table 1-4 – Conversion to Metric Equivalents.

English Symbol		When You Know	Multiply By	To Find	Metric Symbol
LENGTH	in	inches	25.4	millimeters	mm
	ft	feet	0.305	meters	m
	yd	yards	0.914	meters	m
	mi	miles	1.61	kilometers	km
AREA	in^2	square inches	645.2	square millimeters	mm^2
	ft^2	square feet	0.0903	square meters	m^2
	yd^2	square yards	0.836	square meters	m^2
	ac	acres	0.405	hectares	ha
	mi^2	square miles	2.59	square kilometers	km^2
VOLUME	fl oz	fluid ounces	29.57	milliliters	mL
	gal	gallons	3.785	liters	L
	ft^3	cubic feet	0.028	cubic meters	m^3
	yd^3	cubic yards	0.765	cubic meters	m^3
MASS	oz	ounces	28.35	grams	g
	lb	pounds	0.454	kilograms	kg
	T	short tons (2000 lb)	0.907	Megagrams (“metric ton”)	Mg (or “t”)
TEMP	°F	Fahrenheit	(F-32) x 5/9 Or (F-32)/1.8	Celsius	°C

Test your Knowledge (Select the Correct Response)

13. What is the equivalent in meters of 2 yards?

A. 1828 m
B. 182.8 m
C. 18.28 m
D. 1.828 m

10.0.0 USING MEASURING TOOLS

Measuring tools are a key part of a Builder's toolkit. You will most likely use a ***standard (English) ruler***, an ***architect's scale***, and a ***metric ruler***, as shown in *Figure 1-4*. There are conversions between standard and metric measurements, but you will have better results if you measure with the appropriate ruler, such as a standard ruler when you are working in the United States.

Figure 1-4 – Types of measurement tools.

10.1.0 Using a Standard Ruler

A standard ruler is divided into inches and feet. Inches are divided into fractions of an inch, including halves, fourths, eighths, and sixteenths, as represented in *Figure 1-5*. There are some rulers that are further divided into thirty-seconds and sixty-fourths of an inch.

Figure 1-5 – Inch divided into 16ths.

An English or metric ruler is read from left to right. The arrow in *Figure 1-6* is at 2 and 5/16 inches.

Figure 1-6 – Measuring on an English ruler.

10.2.0 Using the Architect's Scale

An architect's scale is used to read all plans except site plans. It measures interior and exterior dimensions for structures and buildings, including rooms, walls, doors, and windows. *Table 1-5* shows scales that are generally grouped in pairs using the same dual-numbered index line.

Table 1-5 – Common Architect Scale Groupings.

Scale One			Scale Two		
Description	**Abbreviation**	**Ratio Equivalent**	**Description**	**Abbreviation**	**Ratio Equivalent**
Three inches to the foot	3" = 1' 0"	1:4	One and one half inches to the foot	1 1/2" = 1' 0"	1:8
One inch to the foot	1" = 1' 0"	1:12	One half inch to the foot	1/2" = 1' 0"	1:24
Three quarters inch to the foot	3/4" = 1' 0"	1:16	Three eighths inch to the foot	3/8" = 1' 0"	1:32
One quarter inch to the foot	1/4" = 1' 0"	1:48	One eighth inch to the foot	1/8" = 1' 0"	1:96
Three sixteenths inch to the foot	3/16" = 1' 0"	1:64	Three thirty-seconds inch to the foot	3/32" = 1' 0"	1:128

Numbers on architect scales can be read from left to right or right to left, depending on which scale you are using. Unlike standard rulers, the 0 point on an architect's scale is not at the end of the measuring line. Any numbers below 0 represent fractions of one foot.

Determine what scale you need to use from the drawing you are working with. Find the matching scale on one of the ends of the architect's scale you are using. If the scale you need is shown on the left of the architect's scale, measure and read from left to right. If the scale you need is shown on the right of the architect's scale, measure and read from right to left. *Figure 1-7* shows measurement on the 1/8" = 1' 0" scale, *Figure 1*-8 shows measurement on the 1/4" = 1' 0" scale.

Figure 1-7 – Architect’s scale (1/8” = 1’ 0”).

This diagram shows a reading of 21’ 4” on the one eighth inch to the foot scale, reading from left to right. Notice that the numbers for this scale are the top set, reading 0, 4, 8, 12, etc. The feet are measured to the right of the zero on the scale; the inches are measured to the left of the zero on the scale. The numbers in the bottom set, reading 46, 44, 42, 40, etc. are for the one quarter inch to the foot scale.

Figure 1-8 – Architect’s scale (1/4” = 1’ 0”).

This diagram shows a reading of 6’ 2” on the one fourth inch to the foot scale, reading from right to left. Notice that the numbers for this scale are the bottom set, reading 0, 2, 4, 6, etc. The feet are measured to the left of the zero on the scale; the inches are measured to the right of the zero on the scale. The numbers in the top set, reading 56, 60, 64, 72, etc. are for the one eighth inch to the foot scale.

10.3.0 Using a Metric Ruler

A metric ruler is divided into millimeters and centimeters, which makes it fairly easy to read, as shown in *Figure 1-9*.

Figure 1-9 – Metric ruler divided into centimeters and millimeters.

Centimeters are shown as larger lines with numbers; millimeters are shown as smaller lines. One millimeter is 1/10th of a centimeter.

11.0.0 CONSTRUCTION GEOMETRY

Measurements of shapes are a basic part of construction you will use every day. You should be familiar with measuring basic shapes like circles, triangles, squares, and rectangles.

11.1.0 Angles

Two straight lines that meet at a common point form an ***angle***. The point where the lines meet to form the angle is called a ***vertex***. Angles are measured with a tool called a ***protractor*,** using degrees. There are many different types of angles, as shown in *Figure 1-10*.

11.1.1 Acute angle

An acute angle measures between 0 and 90 degrees. Common acute angles measure 30, 45, and 60 degrees as shown in *Figure 1-10*.

Figure 1-10 – Acute angles.

11.1.2 Right Angle

A right angle measures 90 degrees. The two lines that form a right angle are perpendicular to each other as shown in *Figure 1-11*. This is the angle that is used most in construction. It is indicated in drawings by the symbol ∟.

Figure 1-11 – Right angle.

11.1.3 Obtuse Angle

An obtuse angle measures between 90 and 180 degrees. Common obtuse angles are 120, 135, and 150 degrees as shown in *Figure 1-12*.

Figure 1-12 – Obtuse angles.

11.1.4 Straight Angle

A straight angle measures 180 degrees, a flat line, as shown in *Figure 1-13*.

Figure 1-13 – Straight angle.

11.1.5 Adjacent Angles

Adjacent angles are right next to each other; they share a vertex and one side as shown in *Figure 1-14*.

Figure 1-14 – Adjacent angles.

11.1.6 Opposite Angles

Opposite angles are formed by two straight lines that cross; they are always equal as shown in *Figure 1-15*.

Figure 1-15 – Opposite angles.

11.2.0 Shapes

Your work in construction involves common geometric shapes. These shapes include rectangles, squares, triangles, and circles.

11.2.1 Rectangle

A rectangle is a four sided shape with all four angles being right angles. All four angles in a rectangle add up to 360° as shown in *Figure 1-16*. A rectangle has two pairs of parallel sides, which makes a rectangle a parallelogram. In a rectangle, the longer sides define the length of the rectangle; the shorter sides define the width.

Figure 1-16 – Rectangle.

11.2.2 Square

A square is a special rectangle with four right angles and equal length parallel sides as shown in *Figure 1-17*. Each angle in a square is 90°, totaling 360° for all four angles.

Figure 1-17 – Square.

11.2.3 Triangle

A triangle is a basic shape in geometry, with three sides or edges, also known as line segments. A triangle is a polygon with three corners, or vertices. The three angles of a triangle always add up to 180° as shown in *Figure 1-18*.

Figure 1-18 – Triangle.

Types of triangles are classified by the relative lengths of their sides.

Right Triangle – A right triangle has one 90°, or right, angle as shown in *Figure 1-19*. The longest side of the right triangle is opposite the right angle, and is called the hypotenuse. The other two sides of the right triangle are called the legs.

Figure 1-19 – Right triangle.

Equilateral Triangle – An equilateral triangle has all three sides of an equal length; this makes it equilinear. It is also equiangular, which means that all three of its internal angles are the same, 60° as shown in *Figure 1-20*.

Figure 1-20 – Equilateral triangle.

Isosceles Triangle – An isosceles triangle has two sides of equal length as shown in *Figure 1-21*. An isosceles triangle also has two angles equal to each other; the angles opposite the equal sides.

Figure 1-21 – Isosceles triangle.

Scalene Triangle – A scalene triangle has three sides of different lengths as shown in *Figure 1-22*. The angles inside a scalene triangle are also all different.

Figure 1-22 – Scalene triangle.

11.2.4 Circle

A circle is a simple closed curve where every point on the curved line is the same distance from the center. A circle always measures 360° as shown in *Figure 1-23*. There are three measurements you can make of a circle, as shown in *Figure 1-*24. The ***circumference*** of a circle is the outside perimeter of the circle. The ***diameter*** of a circle is a line straight through the circle from one point on the outside to a point directly opposite on the outside. The ***radius*** of a circle is the distance from the center of the circle to a fixed point on the outside of the circle. The radius is half of the diameter of the circle.

Figure 1-23 – Circle.

Figure 1-24 – Measurements of a circle.

11.3.0 Area of Shapes

Area is a measurement of the two-dimensional size of a surface. Calculations for the area of shapes differ according to the type of shape.

11.3.1 Rectangle

The area (A) of a rectangle is the product of its length (L) and its width (W). This is expressed as

$A = L \times W$

If you need to paint a wall that is 12 feet long and 8 feet high, you calculate the area of the wall based on a rectangle with a length of 12 feet and a width of 8 feet.

$A = 12 \text{ feet} \times 8 \text{ feet} = 96 \text{ feet}^2$

Figure 1-25 – Area of a rectangle.

11.3.2 Square

The area of a square is the product of the length (L) of its sides.

$A = L^2$

If you need to tile a counter that is 3 feet square, you calculate the area of the counter based on a 3 foot square.

$A = 3^2 \text{ feet} = 9 \text{ feet}^2$

Figure 1-26 – Area of a square.

11.3.3 Circle

The area enclosed by a circle is the radius of the circle squared multiplied by π. The radius is one half of the diameter of the circle.

$A = R^2 \times \pi$

If you need sealer to cover a circular driveway 16 feet in diameter, you calculate the area of the driveway based on a radius of 8 feet.

$A = 8^2$ feet x 3.14
A = 64 feet x 3.14 = 201 square feet

Figure 1-28 – Area of a circle.

11.3.4 Triangle

The area of a triangle is the base times the height times 0.5.

A = B x H x 0.5

If you need siding to cover a triangular shape 4 feet wide and 3 feet high, you calculate the area of the triangular shape based on a triangle with a base of 4 feet and a height of 3feet.

A = 4feet x 3 feet x 0.5 = 6 $feet^2$

Figure 1-27 – Area of a triangle.

Test your Knowledge (Select the Correct Response)

14. What is the area of a triangle with a base of 5 feet and a height of 8 feet?

    A. 40 square feet
    B. 20 square feet
    C. 32 square feet
    D. 36 square feet

11.4.0 Volume of Shapes

The volume of any solid, liquid or gas is how much three-dimensional space it occupies. Volumes of straight edged and circular shapes are calculated using arithmetic formulae based on length, width, and height. Volume is measured in cubic units, as shown in *Table 1-6*.

Table 1-6 – Cubic Measurements.

Cubic Measure	Full Expression	Abbreviation
Cubic inch	1 inch x 1 inch x 1 inch	$inch^3$
Cubic foot	1 foot x 1 foot x 1 foot	$foot^3$
Cubic yard	1 yard x 1 yard x 1 yard	$yard^3$
Cubic centimeter	1 centimeter x 1 centimeter x 1 centimeter	$centimeter^3$
Cubic meter	1 meter x 1 meter x 1 meter	$meter^3$

11.4.1 Rectangular Shape

The volume of a rectangular shape is the length times the width times the depth.

V = L x W x D

If you need to figure how many cubic yards of concrete to order for a slab 15 feet long and 5 feet wide and 4 inches thick, you calculate the volume of the slab based on a length of 15 feet, a width of 10 feet, and a depth of 4 inches. This will take several steps.

1. Convert inches to feet.

   $4 \text{ inches} \div 12 \text{ inches/foott} = .33 \text{ feet}$

2. Figure the volume.

   V = 15 feet x 10 feet x .33 feet = 49.5 cubic feet

3. Convert cubic feet to cubic yards.

   $49.5 \text{ cubic feet} \div 27 \text{ cubic feet / cubic yard} = 1.83 \text{ cubic yards}$

Figure 1-29 – Volume of a rectangular shape.

11.4.2 Cube

The volume of a cube, which is based on a square, is similar to the volume of a rectangle; it is the length times the width times the depth. The only difference is that all three measurements are the same in a cube.

If you need to figure how many cubic yards of concrete to order for a support member measuring 6 feet cubed, you calculate the volume of the support member based on the length, width, and depth each being 6 feet.

1. Figure the volume.
   V = 6 feet x 6 feet x 6 feet = 216 cubic feet

Figure 1-30 – Volume of a cube.

2. Convert cubic feet to cubic yards.
   216 cubic feet ÷ 27 cubic feet / cubic yard = 8 cubic yard

Figure 1-31 – Volume of a cylinder.

11.4.3 Cylinder

The volume of a cylinder, which is based on a circle, is π times the radius^2 times the height of the cylinder. Another way to think of this is the area of the circle times the height of the cylinder.

If you need to figure how many cubic yards of concrete to order for a column 2 feet in diameter and 12 feet high, you calculate the volume of the column as follows:

1. Figure the area of the circle.

   $A = \pi \times 1$ foot = 3.14 square feet

2. Figure the volume of the cylinder.

   V = 3.14 square feet x 12 feet = 37.68 cubic feet

3. Convert cubic feet to cubic yards.
   37.69 cubic feet $\div$ 27 cubic feet / cubic yard = 1.395 cubic yards

11.4.4 Triangular Shape

The volume of a triangular shape is 0.5 times the base times the height times the depth. Another way to think of this is the area of the triangle times the height of the structure.

If you need to figure how many cubic yards of concrete to order for a triangular shape with a base of 2 feet, a height of 2 feet, and 16 feet long, you calculate the volume of the triangular shape as follows:

1. Figure the area of the triangle.

   A = 0.5 x 2 feet x 2 feet = 2 sq feet

2. Figure the volume of the triangular shape.

   V = 2 square feet x 16 feet = 32 cubic feet

3. Convert cubic feet to cubic yards.
   32 cubic feet $\div$ 27 cubic feet / cubic yard = 1.19 cubic yard

Figure 1-32 – Volume of a triangular shape.

Test your Knowledge (Select the Correct Response)

15. What is the volume of a column 3 feet in diameter and 10 feet tall?

    A. 28.26 square feet
    B. 28.26 cubic feet
    C. 10.47 square feet
    D. 10.47 cubic feet

Summary

Use of math is an integral part of each day on a construction project. You need solid math skills on the job, whether you're cutting wood, applying paint to a wall, or installing plumbing. Basic mathematical operations like addition, subtraction, multiplication, and division are critical skills for any construction crewmember. The ability to measure, mark, and use materials and supplies efficiently makes you a valuable part of your construction crew.

Review Questions (Select the Correct Response)

Based on this description of a number:

Digit in the units place:	3
Digit in the tens place:	5
Digit in the hundreds place:	8
Digit in the thousands place:	2

1. How should the number be written?

   A. 2,853
   B. 3,582
   C. 20,853
   D. 28,053

2. Based on the number 14,607 the numeral 4 is in what place?

   A. Tens
   B. Thousands
   C. Units
   D. Hundreds

3. What is the sum of 23.45 and 687.1?

   A. 92.16
   B. 921.6
   C. 71.055
   D. 710.55

4. What is the difference between 34.56 and 7.982?

   A. 26.578
   B. 54.74
   C. 45.26
   D. 4.526

5. What is the product of 43.12 and 4.695?

   A. 20.2448
   B. 202.448
   C. 2024.48
   D. 20244.8

6. What is the result of dividing 186.42 by 32.1?

   A. 5807
   B. 58.07
   C. 5.807
   D. .5807

For questions 7 and 8, is the fraction on the right the lowest term for the fraction on the left?

7. 6/16 = 2/8

   A. True
   B. False

8. 6/8 = 3/4

   A. True
   B. False

For questions 9 and 10, identify the lowest common denominator for each set of fractions.

9. 2/6 and 3/4

   A. 12
   B. 10
   C. 8
   D. 6

10. 1/4 and 3/16

   A. 12
   B. 14
   C. 16
   D. 18

For questions 11 and 12, add the following fractions. Identify the correct sum in its lowest terms.

11. 2/16 + 1/4 =

   A. 6/16
   B. 4/16
   C. 3/8
   D. 1/8

12. 9/12 + 2/8 =

   A. 11/20
   B. 1
   C. 4/4
   D. 3/4

For questions 13 and 14, subtract the following fractions. Identify the correct difference in its lowest terms.

13. 4/9 - 1/3 =

    A. 3/6
    B. 1/9
    C. 1/2
    D. 3/9

14. 6/8 - 1/4 =

    A. 5/4
    B. 1 1/4
    C. 2/4
    D. 1/2

For questions 15 and 16, multiply the following fractions. Identify the correct product in its lowest terms.

15. 3/4 x 5/8 =

    A. 1 5/8
    B. 1 7/8
    C. 3 3/4
    D. 15/32

16. 8/16 x 32/64 =

    A. 1/4
    B. 256/64
    C. 4
    D. 256/16

For questions 17 and 18, divide the following fractions. Identify the correct quotient in its lowest terms.

17. 5/8 ÷ 1/2 =

    A. 10/8
    B. 5/8
    C. 8/10
    D. 1 1/4

18. On a scale drawing, if 1/4 of an inch represents a distance of 1 foot, what length does a line on the drawing measuring 8 1/2 inches long represent?

    A. 34 feet
    B. 36 feet
    C. 38 feet
    D. 40 feet

19. Is 7/8 = 0.875?

    A. True
    B. False

20. Is 0.67 = 2/5?

    A. True
    B. False

For questions 21 and 22, is the measurement in inches the same as the measurement in feet?

21. 9 inches = .95 feet

    A. True
    B. False

22. 10 inches = .83 feet

    A. True
    B. False

23. If you have 50 Builders (BUs) and 10 Engineering Aids (EAs), what is the ratio of EAs to BUs in simplest terms?

    A. 50:10
    B. 10:50
    C. 5:1
    D. 1:5

24. If you have a ratio of 1:9 Equipment Operators (EOs) to Builders (BUs), when you have 3 EOs, how many BUs do you have?

    A. 27
    B. 18
    C. 12
    D. 9

25. What percent of 8 is 6?

    A. 25%
    B. 33%
    C. 50%
    D. 75%

26. What is 33% of 120?

A. 39.6
B. 40.0
C. 41.2
D. 42.3

For questions 27 and 28, is the decimal on the left the same as the percentage on the right?

27. 0.62 = 62%

A. True
B. False

28. 1.47 = 14.7%

A. True
B. False

For questions 29 and 30, is the percentage on the left the same as the decimal on the right?

29. 12.5% = 1.25

A. True
B. False

30. 72% = 0.72

A. True
B. False

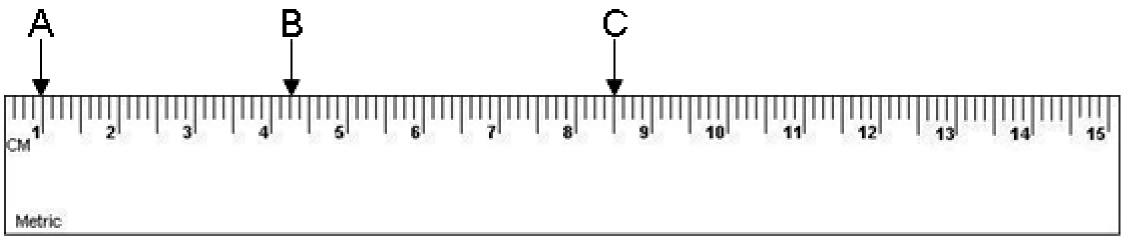
31. What is the square root of 8?

A. 2.835
B. 2.828
C. 2.913
D. 2.924

32. What is the equivalent in liters of 3 gallons?

A. 1.1355 liters
B. 11.355 liters
C. 113.55 liters
D. 1135.5 liters

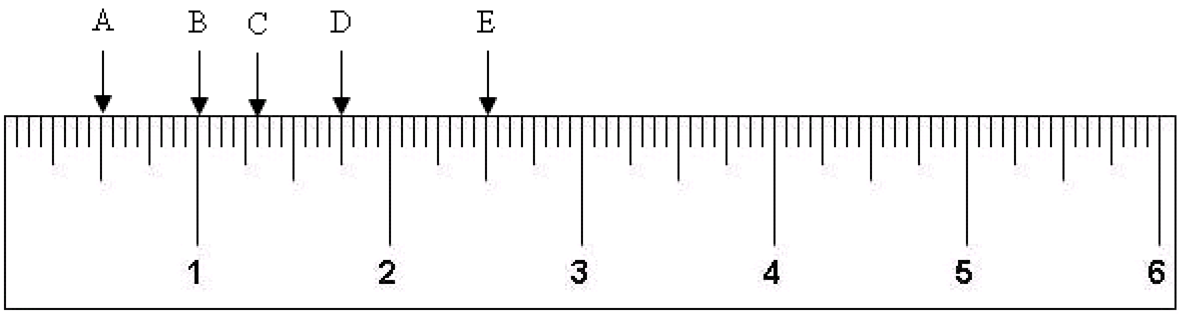
Use the ruler shown below to answer question 33.



33. What mark is the arrow at?

A. 42 cm
B. 4.2 cm
C. 4.2 mm
D. 420 mm

Use the ruler shown below to answer questions 34 and 35.



34. What mark is A at?

A. 1/4 inch
B. 1/2 inch
C. 1/16 inch
D. 1/8 inch

35. What mark is B at?

A. 1/16 inch
B. 5/16 inch
C. 15/16 inch
D. 1 5/16 inch

36. How many degrees are in a right angle?

A. 30º
B. 45º
C. 90º
D. 115º

37. What is the term for a straight line through a circle that runs from one point on the outside of the circle to another point directly on the outside of the circle?

A. Circumference
B. Radius
C. Area
D. Diameter

38. The area of a rectangle that is 8 feet long and 4 feet wide is

A. 12 sq ft
B. 22 sq ft
C. 32 sq ft
D. 36 sq ft

39. The area of a 16 centimeter square is

A. 256 sq cm
B. 265 sq cm
C. 276 sq cm
D. 278 sq cm

40. The area of a circle with a 14-foot diameter is

A. 15.44 sq ft
B. 153.86 sq ft
C. 43.96 sq ft
D. 196 sq ft

41. The area of a triangle with a base of 4 feet and a height of 6 feet is

A. 36 sq ft
B. 32 sq ft
C. 24 sq ft
D. 12 sq ft

42. If a concrete block measures 17 feet square and is 6 inches thick, its volume is

A. 144.5 cu yd
B. 5.35 cu yd
C. 102 cu yd
D. 3.77 cu yd

43. The volume of a 3 centimeter cube is

A. 6 cu cm
B. 9 cu cm
C. 12 cu cm
D. 27 cu cm

44. The volume of a cylinder that is 6 centimeters in diameter and 60 centimeters high is

A. 1130.4 cu cm
B. 1810.6 cu cm
C. 1695.6 cu cm
D. 6728.4 cu cm

45. The volume of a triangular shape that has a 6 inch base, a 2 inch height, and a 4 inch length is

A. 12 sq in
B. 24 cu in
C. 48 sq in
D. 36 cu in

Trade Terms Introduced in this Chapter

Angle — The figure formed by two rays (lines) sharing a common endpoint.

Architect's scale — An architect's scale is a specialized ruler. It is used in making or measuring from reduced scale drawings, such as blueprints and floor plans. It is marked with a range of calibrated scales (ratios).

Circumference — The distance around a closed curve. Circumference is a kind of perimeter.

Common denominator — An integer that is a multiple of the denominators of two or more fractions.

Denominator — The name for the bottom part of a fraction. It indicates how many equal parts make up a whole.

Diameter — Any straight line segment that passes through the center of the circle and whose endpoints are on the circle.

Digit — A symbol used in numerals to represent numbers in positional numeral systems.

Improper fraction — The absolute value of the numerator is greater than or equal to the absolute value of the denominator.

Lowest common denominator — The least common multiple of the denominators of a set of fractions. The smallest positive integer that is a multiple of the denominators.

Metric ruler — A ruler used for measuring with the metric system, generally divided into centimeters and millimeters.

Mixed number — The sum of a whole number and a proper fraction, such as 1 2/3.

Negative number — A number that is less than zero, such as −2.

Numerator — The name for the top part of a fraction. It indicates how many parts of a whole you are working with.

Place value — A numeral system in which each position is related to the next by a constant multiplier, such as 10.

1	,	2	3	4	,	5	6	7
Millions		Hundred Thousands	Ten Thousands	Thousands		Hundreds	Tens	Units

Positive number — A number that is greater than 0, such as 2.

Protractor	A circular or semicircular tool for measuring an angle or a circle. The units of measurement used are generally degrees.
Radius	Any line segment from the center of a circle to its perimeter.
Standard (English) ruler	A ruler used for measuring with the English system, generally divided into inches, 1/2 inches, 1/4 inches, 1/8 inches, and 1/16 inches. Some standard rulers are further divided into 1/32 inches and 1/64 inches.
Vertex	The point where two rays (line segments) begin or meet.

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.

Naval Construction Force Manual, P-315, Naval Facilities Engineering Command, Washington, D.C., 1985.

Seabee Planner's and Estimator's Handbook, NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, Va., 1983.

http://en.wikipedia.org/wiki/Percentage

Operations with Decimals: http://cstl.syr.edu/fipse/Decunit/opdec/opdec.htm

U.S. Metric Association: http://lamar.colostate.edu/~hillger/

CliffsNotes.com. *How do you convert a fraction to a decimal or change a decimal to a fraction?* 5 Jun 2008 http://www.cliffsnotes.com/WileyCDA/Section/id-305405,articleId-7841.html

CliffsNotes.com. *Ratio and Proportion*. 18 Dec 2008 http://www.cliffsnotes.com/WileyCDA/CliffsReviewTopic/topicArticleId-18851,articleId-18809.html

http://www.math.com/school/subject1/lessons/S1U1L9DP.html

The Math League http://www.mathleague.com/

Online Conversion: http://www.onlineconversion.com

Science Made Simple, Inc.: http://www.sciencemadesimple.com/metric_conversion_chart.html

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Chapter 2

Tools

Topics

To hear audio, click on the box.

Overview

Having the appropriate tools is a critical part of completing all construction projects successfully. Using tools correctly keeps you and your fellow crewmembers safe while you perform your construction tasks. Maintaining tools properly gives you good performance and minimizes downtime caused by broken tools.

All types of tools, including hand, power, powder actuated, and pneumatic tools, are essential parts of your trade as a Builder. To be a proficient Builder, you must be able to use and maintain a large variety of field and shop tools effectively. To perform your work quickly, accurately, and safely, you must select and use the correct tool for the job at hand. Without the proper tools and the knowledge to use them correctly, you waste time, reduce efficiency, and may injure yourself or others.

Keep in mind that you are responsible for knowing and observing all safety precautions applicable to the tools and equipment you operate. For additional information on the topics discussed in this chapter, you are encouraged to study *Tools and Their Uses,* NAVEDTRA 10085-B2.

This chapter describes many of the most common tools used by Builders. Their uses, general characteristics, attachments, and safety and operating features, including maintenance, are outlined. Further information on tools specific to particular tasks is included in the sections on those tasks. For example, the various types of trowels used to install and finish masonry are included in the Masonry chapter. To become skilled with any of these tools, you must use them. For additional guidance, you should also study the manufacturer's operator and maintenance guides for each tool you use.

Objectives

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

1. Determine proper use and maintenance of hand tools.
2. Determine proper use and maintenance of power tools.
3. Determine proper use and maintenance of powder actuated tools.
4. Determine proper use and maintenance of pneumatic tools.
5. Identify the types and contents of Builder TOA kits.

Prerequisites

None

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

Expeditionary Structures	↑	B
Finishes		U
Moisture Protection		I
Finish Carpentry		L
Rough Carpentry		D
Carpentry Materials and Methods		E
Masonry		R
Fiber Line, Wire Rope, and Scaffolding		
Concrete Construction		B
Site Work		A
Construction Management		S
Drawings and Specifications		I
Tools		C
Basic Math		

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 HAND TOOLS

A hand tool is a device, used for performing a task, which does not use a motor, but is powered solely by the person using it. Builders use many hand tools; this section covers the main categories of tools.

1.1.1 Measuring and Layout Tools

There are many types of tools used to measure and lay out construction projects. Measuring tools include flat steel rules, measuring tapes, wooden folding rules, digital measuring devices, and measuring wheels. Squares are used to mark, check, and measure components of construction projects. Chalk lines are used to mark straight lines on large surfaces. Plumb bobs are used to check that project components are perfectly upright. Levels are used to check that project components are level and/or plumb. When you consider which of these tools to use, keep in mind the following points:

- The tool must be accurate.
- The tool should be easy to use.
- The tool should be durable.
- Numbers on the tool must be easy to read. Black numbers on a yellow or off-white background work well.

1.1.1 Safety and Maintenance Considerations for Measuring Tools

Be safe with your measuring tools by using the following guidelines:

For all measuring tools:

- Always wear eye protection.

For measuring tapes:

- Keep the case intact. The spring motor is under tension and opening the case can cause injury.
- Protect your hands by retracting the tape slowly. Allowing the tape to retract at full speed can cause injury.
- Keep steel tape measures away from electrified parts during use and storage.
- Keep steel tape free of kinks and twists, which can cause it to break.
- Keep steel tape dry by wiping it to prevent it from rusting.

For digital measuring devices:

- Keep digital measuring devices from getting wet.

For wooden folding rules:

- Maintain a wooden folding rule by occasionally applying a few drops of light oil on the spring joints.

Steel Rule – The flat steel ***rule*** shown in *Figure 2-1* is the simplest measuring tool. It is usually 6 or 12 inches in length but can be longer. Steel rules can be rigid or flexible, thin or wide. It is easier and more accurate to use a thin rule, since it is closer to the work being measured.

Figure 2-1 – Steel rule.

Flat steel rules can have up to four sets of marks, two on each side of the blade. Rules with four sets of marks are set up with divisions of 1/8” and 1/16” on one side, and divisions of 1/32” and 1/64” on the other side. The marks are longer for a division of 1/2”, scaling down in length from 1/4” through 1/64”.

Measuring Tape – A ***measuring tape***, as shown in *Figure 2-2* can come in any length from 6’ to 50’. The most common are 10’, 16’, and 25’. Shorter tapes usually have a curved cross section so they roll easily but stay rigid when extended. Longer tapes are usually flat and should be laid along a surface to avoid sagging in the middle.

Figure 2-2 – Measuring tape.

A locking mechanism, such as a sliding button, keeps the tape locked in place while a measurement is being taken. Other locking mechanisms, such as levers and toggles, allow the tape to be retracted after measuring by simply squeezing them. In any case, a spring mechanism in the case automatically retracts the tape.

1.1.2 How to Use a Measuring Tape

Follow these steps to use a measuring tape properly:

1. Pull the tape out to the desired length.
2. Place the hook over the edge of the material you are measuring.
3. Lock the tape in place.
4. Record or mark the measurement.
5. Unhook the tape from the edge of the material.
6. Release the lock and rewind the tape.

Digital Measuring Devices – Digital measuring devices, as shown in *Figure 2-3*, are similar to conventional measuring devices, but their digital readouts make measurement readings more precise. They give you the ability to convert fractions to decimal or metric equivalents. A useful function of these devices is their ability to compensate for the size of the tape case when making measurements inside a window frame or door jamb. Some devices have a memory function that holds a measurement; others have a voice recorder to keep track of multiple measurements.

Figure 2-3 – Digital measuring device.

Folding Rule – A ***folding rule***, as shown in *Figure 2-4*, is made up of hardwood, steel, or aluminum sections, each measuring 6” to 8”. The sections are connected by spring joints that unfold for measuring distances.

Figure 2-4 – Folding rule.

Measuring Wheel – A measuring wheel, as shown in *Figure 2-5*, is made up of a wheel, handle, odometer, and a reset button to return the counter to zero. It is designed to take lengthy exterior measurements, as long as 10,000 feet. Measuring wheels can have collapsing or telescoping handles, different tread materials, and optional storage cases. Wheel diameters range from 4” to 25”, with the larger wheels suitable for rough terrain.

Figure 2-5 – Measuring wheel.

1.1.3 Squares

Squares are used to mark, check, and measure components of construction projects. Different types of squares are used for different projects. Some of the more common squares are carpenter (framing) squares, try squares, rafter angle squares, T-squares, and combination squares.

1.1.4 Safety and Maintenance Considerations for Squares

Observe the following guidelines when working with squares:

- Wear gloves. The edges can be very sharp.
- When you use a square as a saw guide, use a clamp to hold the square so you can keep both hands on the saw.
- Keep the square dry to prevent it from rusting.
- Use a light coat of oil on the blade. Occasionally clean the blade's grooves and the setscrew (if there is one).
- Use squares for the appropriate purpose and in the correct way. Avoid the following to preserve the integrity of the square, as they are expensive to replace:
  - ∅ Dropping it.
  - ∅ Prying or hammering with it.
  - ∅ Striking it hard enough to change the angle between the blade and the head.
  - ∅ Bending it.
  - ∅ Using it during horseplay.

Carpenter (Framing) Square – The ***carpenter square***, shown in *Figure 2-6*, has a large arm, called the blade, and a small arm, called the tongue. The arms meet in a 90° angle. It has several scales etched onto the surface for quick reference: a diagonal scale, a board foot scale, and an octagonal scale. It has ruler increments etched on the inside and outside edges.

Figure 2-6 – Carpenter (Framing) square.

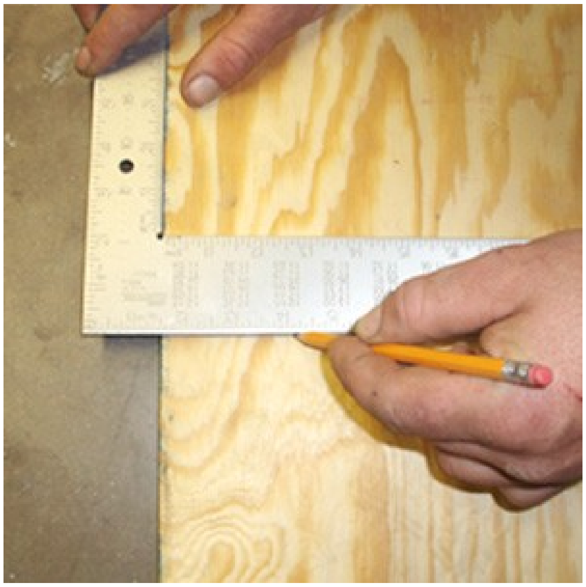


Figure 2-7 – Using a carpenter (framing) square.

1.1.5 How to Use a Carpenter's Square

To mark a line for cutting, use the following steps:

1. Find and mark where the line will be drawn.
2. Line the square up with the bottom of the object to be marked as shown in *Figure 2-7*.
3. Mark the line to be cut, mark an x on the material to be cut away.
4. Cut off the excess material.

Check that joints meet at a 90° angle by placing the blades of the framing square along the two sides of the angle, as shown in *Figure 2-8*. If both blades fit tightly, the material is square. If there is any space between either blade and the side closest to it, the material is not square.

Figure 2-8 – Checking for square.

Try Square – The ***try square***, shown in *Figure 2-9*, is an L- shaped tool used as a guide to lay out 90° cuts with pencil markings. It is also used to check that the edges and ends of boards are square, and whether a board is the same depth along its entire length. A try square has broad blades 6 to 12 inches long set at right angles.

Figure 2-9 – Try square.

Rafter Angle (Speed) Square – The ***rafter angle square*** or ***speed square***, shown in *Figure 2-10*, is a three-sided, triangle-shaped measuring tool. It is used to draw perpendicular lines on boards to be cut, or to lay out angles for rafters, stairs, and other construction projects. It has degree gradations etched onto the surface for quick layout and cutting of lumber so you don't have to perform angle calculations.

Figure 2-10 – Rafter angle square.

T-Square – The ***T-square***, shown in *Figure 2-11*, is used to measure and cut drywall. Some table saws come with a T-square fence attached.

Figure 2-11 – T-square.

Combination Square – The ***combination square***, shown in *Figure 2-12*, has a blade that can be moved through a head, which is marked for 45° and 90° angles. It is used for many purposes in woodworking and metalworking but mainly for measuring the accuracy of a right angle. The combination square may have a small level to check for level and plumb. This square can be used for measuring lengths and widths. It may also have a scratch awl for scribing a mark

Figure 2-12 – Combination square.

on the surface of your material.

Figure 2-13 – Measure a 90° cut with a combination square.

1.1.6 How to Use a Combination Square

Mark a 90° angle using the following steps. *Figure 2-13* shows this process.

1. Set the blade at 90° (a right angle).
2. Place the square so the head fits snugly against the edge of the material to be marked.
3. Use the blade as a straightedge to guide the mark, starting at the edge of the material.

Mark a 45° angle using the following steps. *Figure 2-14* shows this process.

1. Set the blade at a 45° angle.
2. Place the square so the head fits snugly against the edge of the material to be marked.
3. Use the blade as a straightedge to guide the mark, starting at the edge of the material.

Figure 2-14 – Measure a 45° cut with a combination square.

1.1.7 Chalk Lines

A ***chalk line***, shown in *Figure 2-15*, is a piece of string or cord coated with chalk used to mark a straight line on a large surface. It is usually contained in a case with a crank for rewinding the line after use. Some chalk lines have one pointed end so that they can also be used as a plumb bob.

Figure 2-15 – Chalk line.

1.1.8 Safety and Maintenance Considerations for Chalk Lines

- Make sure the chalk line is stored in a dry place. You won't be able to use chalk that is damp or wet.
- Be careful to use appropriate tension on the string. Too much tension on the string can break it.

1.1.9 How to Use a Chalk Line

Follow these steps to use a chalk line properly:

1. Gently shake the container to loosen the chalk and distribute it evenly in the case.
2. Pull the line from the case. Fasten the hook ring to a nail at the starting point or have a partner hold one end of the line at the starting point.
3. Feed the line out to the ending point and stretch the line tightly between the two points.
4. Make sure the line is taut, pull straight away from the work, and then release the line. This marks the surface underneath the line with a straight line of chalk, as shown in *Figure 2-16*.

Figure 2-16 Proper use of a chalk line.

1.1.10 Plumb Bobs

A ***plumb bob***, shown in *Figure 2-17*, is used as a vertical reference line. It is a weight with a pointed tip on the bottom that is suspended from a string. It has been used since ancient times to ensure that constructions are plumb, or perfectly upright.

Figure 2-17 – Plumb bob.

1.1.11 Safety and Maintenance Considerations for Plumb Bobs

Keep the plumb bob from dropping on its point. A bent or rounded point will cause inaccurate readings.

1.1.12 How to Use a Plumb Bob

Follow these steps to use a plumb bob properly:

1. Make sure the line is attached at the exact top center of the plumb bob.
2. Hang the bob from a horizontal member, such as a doorjamb, joist, or beam.
3. When the weight is allowed to hang freely, and stops swinging, the string is plumb (vertical).
4. Mark the point directly below the tip of the plumb bob. This point is precisely below the point where you attached the bob.

1.1.13 Levels

A level, shown in *Figure 2-18*, is an instrument used to indicate how level a horizontal surface is and how plumb a vertical surface is. Levels range from simple spirit levels and torpedo levels to more complex digital levels and laser levels.

Figure 2-18 – Parts of a level.

1.1.14 Safety and Maintenance Considerations for Levels

You are not likely to have any personal injuries from using a level. However, you can damage this sensitive instrument if you don’t handle it carefully. Follow these guidelines:

- Replace the level if any of the vials are cracked or broken.
- Keep the level clean and dry. Keep the level in its case when not in use.
- Use the level properly. Avoid the following:
  - ∅ Bending or applying excessive pressure on the level.
  - ∅ Dropping or bumping the level.

Spirit Level – A ***spirit level***, shown in *Figure 2-19*, is made of a lightweight, durable casing, usually aluminum or magnesium. It includes three vials nearly filled with alcohol, which is why it is called a spirit level. The bubble of air is used to check for level or plumb. Use the center vial to check for level; use the two end vials to check for plumb.

Figure 2-19 – Spirit level.

Torpedo Level – The torpedo level, shown in *Figure 2-20*, is a small level, generally 6 to 9 inches in length. Its name is derived from its boat-like shape, tapered at both ends. It is useful in small spaces where a larger level would not fit.

Figure 2-20 – Torpedo level.

1.1.15 How to Use a Spirit or Torpedo Level

Spirit and torpedo levels are easy to use. All you need is a careful eye to read it correctly.

1. Place the level on the object you need to check. Lay it on a horizontal surface or hold it against a vertical surface.
2. Check the air bubble in the vial. When the bubble is centered between the two lines on the vial, the object you are checking is level if you're checking a horizontal surface or plumb if you're checking a vertical surface.

Digital Level – The digital level shown in *Figure 2-21* has two vials; one to check for level, the other to check for plumb. It also includes a digital readout for

- Degrees of slope
- Inches per foot of rise and run for stairs and roofs
- Percentage of slope for drainage on decks and masonry

Figure 2-21 – Digital level.

Laser Level – A laser level, shown in *Figure 2-22*, is used to level and provide reference lines for tasks such as setting foundation levels, establishing drainage slopes, aligning plumbing and electrical lines, and setting tile. It can be mounted on a tripod, fixed to pipes or framing studs, or suspended from ceiling framing.

Figure 2-22 – Laser level.

1.2.0 Fastening and Prying Tools

Fastening and prying tools are made to either put things together or take things apart. These tools include hammers, screwdrivers, wrenches, pliers, and pry bars.

1.2.1 Hammers

A hammer is a tool used to deliver an impact to an object. Hammers are mostly used to drive nails, fit parts, or break up objects. There are many types of hammers designed for specific uses, which vary in shape and structure. Most hammers include a handle and a head, with most of the weight in the head. The strongest, safest hammers have heads made of tough alloy (two or more metals) or drop-forged steel. The two main types of hammers are claw and ball peen.

1.2.2 Safety and Maintenance Considerations for Hammers

Use the following guidelines when you work with hammers:

- Always use appropriate personal protective equipment (PPE) when working with a hammer, especially safety gloves and eye protection.
- Focus on the work. If you look away from the work while using a hammer, you may accidentally strike yourself or damage the work.
- Always use a hammer the right size and weight for the job.
- Make sure the hammer is in good condition before you use it.
    - Make sure there are no splinters in the handle of the hammer.
    - Make sure the handle is set securely in the head of the hammer.
    - Replace loose, cracked, or broken handles.
    - Discard and replace hammers with cracked claws or eye sections.
    - Discard and replace any hammer with a chipped, cracked, or mushroomed face.
    - Make sure the face of the hammer is clean.
- Hold the hammer properly. Grasp the handle firmly near the end and hit the nail squarely. Avoid glancing blows.
- Use hammers for the appropriate purpose and in the correct way. Avoid the following:
    - ∅ Hitting a hardened steel surface, concrete, or stone with a steel claw hammer. Metal chips from such use can cause injury.
    - ∅ Hitting with the hammer handle or using the hammer as a pry bar. This can split the handle and cause injury.
    - ∅ Hitting a hammer with or against another hammer. This can damage both hammers and cause injury.
    - ∅ Hitting with the cheek or side of the hammer head.

Claw Hammer – The parts of a ***claw hammer*** are shown in *Figure 2-23*. Use the flat head to drive nails, wedges, and dowels. Use the two pronged claw to remove nails from wood.

Figure 2-23 – Parts of a claw hammer.

Bell-faced Hammer – The bell-faced hammer, shown in *Figure 2-24*, has a slightly rounded (convex) face. It takes some practice to become skilled with this hammer, but it can help you drive a nail head flush to the wood without marring the surface of the wood.

Figure 2-24 – Bell-faced hammer.

1.2.3 How to Use a Claw Hammer to Drive a Nail

Follow these steps to use a claw hammer properly when you drive a nail.

1. Hold the nail straight, at a 90° angle to the surface you are nailing.
2. Grip the handle of the hammer, holding the end of the handle even with the lower edge of your palm.
3. Start with the face of the hammer resting on the nail.
4. Pull the hammer back and tap the nail lightly a few times to start it.
5. Move your fingers away from the nail, and then hit the nail firmly with the center of the hammer face. Hold the hammer level with the head of the nail and strike the face squarely. Deliver the blow through your wrist, your elbow, and your shoulder.

To view animation, click on the picture.

Figure 2-25 – Using a claw hammer to strike a nail.

1.2.4 How to Use a Claw Hammer to Pull a Nail

Follow these steps to pull a nail with a hammer claw.

1. Slip the claw of the hammer under the nail head. Pull until the handle is nearly straight up and the nail is partly drawn out of the wood.
2. Pull the nail straight up out of the wood.

Finish Hammer – The finish hammer, shown in *Figure 2-26*, is a claw hammer used for cabinet making, finishing, and general carpentry. It has a lightweight head with a smooth face that keeps it from marring the surface of the wood. It has a curved claw for removing nails from wood.

Figure 2-26 – Claw hammer.

Framing Hammer – The framing hammer, shown in *Figure 2-27*, is a claw hammer with an oversized head used in framing carpentry. The larger, heavier head improves the user's accuracy and decreases the number of blows required to fully drive the nail into the wood. This hammer may leave slight indentations in the surface of the wood, but that is not important in rough carpentry. The claw on a framing hammer is straighter than on a regular claw hammer; it is used to pry apart nailed boards.

Figure 2-27 – Framing hammer.

Framing hammers often have a milled or waffle face as shown in *Figure 2-28*, which helps prevent the hammer from slipping off the nail head if the nail is not struck precisely.

Figure 2-28 – Milled or waffle face.

1.2.5 Ball Peen Hammer

The parts of a ***ball peen hammer*** are shown in *Figure 2-29*. A ball peen hammer is used on metal for tasks like riveting, center punching, and bending or shaping soft metal. The head of this hammer is soft and will dent if used to pound nails.

Figure 2-29 – Parts of a ball peen hammer.

1.2.6 How to Use a Ball Peen Hammer

Using a ball peen hammer is similar to using a claw hammer. Follow these steps:

1. Grip the handle. Keep the end of the handle flush with the lower edge of your palm and the face of the hammer parallel to the work.
2. Use the face for hammering. Use the ball peen for rounding off (peening) rivets and similar jobs.

1.2.7 Specialty Hammers

There are many types of hammers used for specialized tasks. This section describes the most commonly used specialty hammers.

Roofing Hammer – The roofing hammer, shown in *Figure 2-30*, is used to drive roofing nails. It has several special features, including a cutting blade for trimming shingles. A roofing gauge on the hammer is used to assure proper shingle spacing.

Figure 2-30 – Roofing hammer.

Rubber Mallet – The rubber ***mallet*** shown in *Figure 2-31* is used to drive chisels or to hammer joints together. There are various shapes and sizes for accomplishing specific tasks.

Figure 2-31 – Rubber mallet.

Leather Mallet – The leather mallet, shown in *Figure 2-32*, is used for projects that need significant pressure and the final appearance of which would be marred by impact marks.

Figure 2-32 – Leather mallet.

Sledgehammer – The sledge hammer, shown in *Figure 2-33*, is used for projects that need great force, such as breaking up concrete or driving heavy spikes or stakes. A sledgehammer head is made of high-carbon steel, weighs between 2 and 20 pounds, and has a handle 14 to 36 inches long. The shape of a sledgehammer head depends on the job for which it will be used.

Figure 2-33 – Sledgehammer.

Tack Hammer – The tack hammer shown in *Figure 2-34* is used to drive small nails and tacks, as in furniture upholstery. The tack hammer has a magnetic face that can hold small tacks, as well as a regular face for driving tacks.

Figure 2-34 – Tack hammer.

Drywall Hammer – The drywall hammer, shown in *Figure 2-35*, is used to set nails in drywall. It has a blade that can be used for both scoring drywall and cutting small holes. There is a notch in the blade for removing exposed nails.

Figure 2-35 – Drywall hammer.

Masonry Hammer – The masonry hammer, shown in *Figure 2-36*, is used for setting or splitting bricks and for chipping excess mortar from bricks. The striking surface is small, square, and blunt for breaking or setting bricks. The sharp surface is curved and chisel-like, for scoring brick.

Figure 2-36 – Masonry hammer.

Tile Hammer – The tile hammer, shown in *Figure 2-37*, is very similar to a masonry hammer, although it may be smaller. It has a sharp surface for scoring tile and a striking surface for breaking tile.

Figure 2-37 – Tile hammer.

Test your Knowledge (Select the Correct Response)

1. What kind of head do the safest hammers have?

   A. Welded and alloyed
   B. Cast steel and chiseled
   C. Chiseled and drop forged
   D. Alloy and drop-forged steel

1.2.8 Screwdrivers

A ***screwdriver***, shown in *Figure 2-38*, is a device used to insert and tighten screws or to loosen and remove screws. A screwdriver has a head or tip that connects with a screw, a mechanism to apply torque by rotating that tip, and a way to position and support the screwdriver. A typical manual screwdriver is made up of a roughly cylindrical handle, with a shaft fixed to the handle, including a tip shaped to fit a particular type of screw. The handle and shaft support and position the screwdriver, and apply torque when rotated. The blade is made of tempered steel so it will resist wear, bending, and breaking.

Figure 2-38 – Parts of a screwdriver.

There are many different types of screwdrivers, identified by the type of screws they fit. Some of the more common types of screwdrivers are flat head, Phillips head, clutch drive, TORX, Robertson, and Allen (hex).

1.2.9 Safety and Maintenance Considerations for Screwdrivers

When using a screwdriver, you must follow many guidelines for your own safety and that of others, as well as for maintaining your tool. Use the following guidelines when you work with screwdrivers:

- Always use eye protection.
- The plastic handles on screwdrivers should be fire and heat resistant.
- Use the right size screwdriver for the screw you are driving to avoid having the screwdriver slip. Using the wrong size could also damage the screwdriver or the screw head.
- Visually inspect your screwdriver before using it. The handle should not be worn or damaged. The blade's tip should be straight and smooth. If the handle is worn or damaged, the tip is not straight and smooth, or the shaft of the screwdriver is bent, replace the screwdriver.
- Keep the screwdriver free of dirt, grease, and grit so the blade will not slip out of the screw head slot.
- File the blade tip to restore a worn straightedge.
- Place the material with which you're working on a work surface and secure it with a clamp or vise.
- When you're starting the screw, it's easy to hurt your fingers if the blade slips. Work with caution.
- Use screwdrivers for the appropriate purpose and in the correct way. Avoid the following:

  ∅ Using the screwdriver as a punch, chisel, or pry bar.

  ∅ Using a screwdriver to score or scrape.

- ∅ Using the screwdriver near live wires or as an electrical tester.
- ∅ Exposing a screwdriver to excessive heat.
- ∅ Pointing the screwdriver blade toward yourself or anyone else.
- ∅ Carrying a screwdriver in your pocket.
- ∅ Using pliers for added turning leverage on the shank of a screwdriver. (A wrench may be used on square-shank screwdrivers.)

1.2.10 How to Use a Screwdriver

Use a screwdriver correctly so you don't damage the screwdriver or strip the screw head. Follow these steps:

1. Choose the right type of blade for the screw head. Different types of screw heads are shown in *Figure 2-39*.

Figure 2-39 – Types of screw heads.

2. Make sure the screwdriver fits the screw correctly as shown in *Figure 2-40. Table 2-1* shows what size screwdriver to use with various sizes of screws.

Figure 2-40 – Using correct size screwdriver.

Table 2-1 Size of screwdrivers to use for different size screws.

Screw # (Size)	Flat Slot Blade Width	Cross Slot Blade
0	3/32”	No. 0
1	1/8”	No. 0
2	1/8”	No. 1
3	1/8”	No. 1
4	5/32”	No. 1
5	3/16”	No. 2
6	3/16”	No. 2
7	7/32”	No. 2
8	1/4”	No. 2
9	1/4”	No. 2
10	5/16”	No. 3
12	3/8”	No. 3
14	3/8”	No. 3
16	3/8”	No. 3
18	1/2”	No. 4
20	1/2”	No. 4
24	1/2”	No. 4
7/16	1/2”	No. 4
1/2	1/2”	No. 4
9/16	1/2”	No. 4

3. Position the shank perpendicular (at a right angle) to your work.
4. Apply firm, steady pressure to the screw head and turn: clockwise to tighten (right is tight); counterclockwise to loosen (left is loose).

Flat (Slot) Head Screwdriver – The flat head screwdriver shown in *Figure 2-41* is used to drive and remove standard slotted screws. It can have a round or square shank and ranges in size from 1/6” to 1/4”. The tip of this screwdriver is flared at the shoulder of the blade so that it is wider than the driver bar.

Figure 2-41 – Flat (slot) head screwdriver.

Phillips® Head Screwdriver – The Phillips® head screwdriver, shown in *Figure 2-42*, is used to tighten and loosen Phillips® head screws. It is the most common type of crosshead screwdriver, and ranges in size from 0 to 4, 0 being the smallest.

Figure 2-42 – Phillips® head screwdriver.

Clutch Drive Screwdriver – The clutch drive screwdriver, shown in *Figure 2-43*, is used to tighten and loosen clutch head screws, which are shaped like an hourglass. The clutch drive screw has extra holding power, especially for use in cars and appliances.

Figure 2-43 – Clutch drive screwdriver.

TORX Screwdriver – The TORX screwdriver, shown in *Figure 2-44*, is used to tighten and loosen six point star head screws. TORX head screws are used in cars, appliances, and lawn and garden equipment.

Figure 2-44 – TORX screwdriver.

Robertson Screwdriver – The Robertson screwdriver, shown in *Figure 2-45*, has a square drive that yields high torque power. It is useful to reach screws sunk below the surface of the material.

Figure 2-45 – Robertson screwdriver.

Allen (hex) Screwdriver – The Allen screwdriver set, shown in *Figure 2-46*, contains several sizes that are attached to and fold into a metal carrying case. It is also known as a hex key or hex wrench and is used on screws with hexagonal slots. It is useful for recessed socket head screws.

Figure 2-46 – Allen (hex) screwdriver.

Test your Knowledge (Select the Correct Response)

2. What makes industrial screwdriver blades safe?

   A. Tempered steel
   B. Torx®
   C. Clutch-driven steel
   D. Fiberglass

1.2.11 Wrenches

A ***wrench*** is a tool used to provide a mechanical advantage when applying torque to hold and turn bolts, nuts, screws, and pipes. Wrenches are divided into two categories; nonadjustable and adjustable. Nonadjustable wrenches are made to work on a particular size bolt, nut, screw, or pipe. Adjustable wrenches are used to tighten or loosen any size bolt, nut, screw, or pipe.

1.2.12 Safety and Maintenance Considerations for Wrenches

Follow these guidelines to use a wrench properly:

- Use the proper size wrench.
- Focus on your work.
- Pull the wrench instead of pushing it.
- Make sure the wrench is properly seated on the nut or bolt. Never tilt the wrench at an angle.
- Brace your stance in case the wrench releases or the fastener slips suddenly.
- When you have to break loose a frozen fastener, use a box wrench with a striking face or a heavy-duty socket wrench with an appropriate size sledge hammer.
- Keep your wrenches clean. Keep the adjusting screw on adjustable wrenches clean and lubricated.
- Use the correct wrench for the appropriate purpose. Avoid the following:
  - ∅ Applying excessive torque on a wrench. This can strip or damage threads on the fastener.
  - ∅ Using extension handles, also known as cheaters, to increase leverage.
  - ∅ Using sockets intended for hand tools on a power tool or impact wrench.
  - ∅ Using a torque wrench as a conventional wrench.
  - ∅ Using the wrench as a hammer.

1.2.13 How to Use a Nonadjustable Wrench

Follow these steps to use a nonadjustable wrench:

1. Find the correct size wrench for the nut or bolt.
2. Pull the wrench toward you. Pushing the wrench away from you can cause injury.

Open End Wrench – The open end wrench, shown in *Figure 2-47*, grips on two sides of the nut or bolt head, with an opening that can access fasteners that a closed, or box, wrench might not reach. It has different size openings on each end. The opening should fit the nut or bolt exactly to prevent mutilating the edges of the fastener. They can come in sets.

Figure 2-47 – Open end wrench.

Box End Wrench – The box end wrench shown in *Figure 2-48* has an enclosed head that provides more leverage by completely enclosing the nut. This wrench also comes in an offset model to give more room for your knuckles or to give clearance over obstructions. Some models have ratcheting capability.

Figure 2-48 – Box end wrench.

Combination Wrench – The combination wrench, shown in *Figure 2-49*, has a box wrench and an open end wrench on opposite sides of the same tool. The two ends are usually the same size.

Figure 2-49 – Combination wrench.

Allen Wrench – The Allen wrench, shown in *Figure 2-50*, is also known as a hex key wrench. It is a short, L-shaped tool designed to turn bolts or screws with hexagonal heads. Allen wrenches usually come in sets of different size wrenches.

Figure 2-50 – Allen wrench.

1.2.14 How to Use an Adjustable Wrench

Follow these steps to use an adjustable wrench:

1. Set the jaw to the correct size for the nut or bolt.
2. Make sure the wrench jaws are fully tightened on the nut or bolt.

3. Pull the wrench toward you as much as you can. If you must push the wrench, keep your hand open to avoid pinching it.
4. Pull so that the force is on the fixed side of the jaw.
5. Make sure there is enough room for your fingers as you turn the wrench.

Pipe (Stillson) Wrench – The pipe wrench, shown in *Figure 2-51*, is also known as a Stillson wrench. It has jaws that bite into the surface of pipe to hold it for turning, and should not be used on plated pipes, since it would mar the surface. It is used to screw pipes into elbows or other threaded items.

Figure 2-51 – Pipe (Stillson) wrench.

Spud Wrench – The spud wrench, shown in *Figure 2-52*, is meant to work on a piece of piping found on older toilets and sinks which is called a “spud”. This wrench is used to tighten and loosen the collar, bolts, and other hardware holding the spud to the toilet or sink. The narrow jaws of the spud wrench are useful in tight spaces.

Figure 2-52 – Spud wrench.

Crescent Wrench – The crescent wrench, shown in *Figure 2-53*, has an adjustable end opening that comes in locking and non-locking styles. The locking style can secure the jaws in the desired position, so when properly adjusted, it won’t slip. The non-locking style requires frequent readjustment and is prone to slipping. The crescent wrench is used to tighten or loosen nuts and bolts, but never on a fastener that has been rounded off. Make sure the movable jaw is located on the side where the rotation will be done.

Figure 2-53 – Crescent wrench.

1.2.15 Pliers

Pliers, as shown in *Figure 2-*54, are a special type of adjustable wrench that are scissor-shaped tools with jaws. The jaws usually have teeth to help grip objects and are adjustable because the two handles move on a pivot. Pliers are made of hardened steel and come with different head styles which determine their use. Pliers are used to hold, cut, and bend wire and soft metals.

Figure 2-54 – Parts of pliers.

1.2.16 Safety and Maintenance Considerations for Pliers

Misuse of pliers can cause injury. Here are guidelines to remember when working with pliers:

- Always wear eye protection.
- Hold pliers close to the end of the handles. This will help avoid pinching your fingers in the hinge.
- Cut at right angles with cutting pliers.
- Use the right length of pliers or cutters for the job. Trying to extend the handles of short pliers can cause injury.
- Maintain pliers occasionally with a drop of oil on the hinge to lengthen the pliers' life and assure easy operation.
- Keep pliers away from excessive heat; it can ruin them.
- Discard any pliers that are cracked, broken, sprung, or have nicked cutting edges.
- Remember that slip joint pliers can slip while in use.
- Use pliers for the appropriate tasks and in the appropriate manner. Avoid the following:
    - ∅ Using pliers on live electric circuits unless they have handles specified as insulated against electric shock.
    - ∅ Cutting hardened wire unless specifically manufactured for that purpose.
    - ∅ Rocking pliers from side to side when cutting wire.
    - ∅ Bending wire back and forth when cutting wire.
    - ∅ Bending stiff wire with light pliers. This can damage the tips, so use a sturdier tool.
    - ∅ Using pliers on nuts or bolts. This can damage the fastener; use a wrench instead.

Slip Joint (Combination) Pliers – Slip joint pliers, as shown in *Figure 2-55*, have adjustable jaws with two settings; one for large materials and one for small materials. They are used to hold and bend wire and to hold objects during assembly operations.

Figure 2-55 – Slip joint pliers.

1.2.17 How to Use Slip Joint Pliers

Use slip joint pliers as follows:

1. Place the jaws on the object you need to hold.
2. Squeeze the handles until the pliers grip the object firmly.

Long Nose Pliers (Needle Nose Pliers) – Long nose pliers, also known as needle nose pliers, are shown in *Figure 2-56*. The pointed nose makes them useful for work in tight places where other pliers can't reach. The jaws and cutting blades meet evenly.

Figure 2-56 – Long nose (needle nose) pliers.

1.2.18 How to Use Long Nose Pliers

Use long nose pliers as follows:

1. If the pliers don't have a spring to keep them open, use your third or little finger to keep them open.
2. Cut wire with the sharp cutter near the pivot.

Lineman's Pliers – Lineman's pliers, shown in *Figure 2-57*, are also known as electrician's pliers; they are used in electrical, communications, and construction work. They are heavy-duty, side-cutting pliers used for cutting wire, with gripping jaws for holding, shaping, and twisting wire.

Figure 2-57 – Lineman's pliers.

1.2.19 How to Use Lineman's Pliers

Use lineman's pliers as follows:

1. When cutting wire, point the loose end of the wire down.
2. Cut at a right angle to the wire.

Tongue and Groove (Channel Lock) Pliers – Tongue and groove pliers, also known as channel lock pliers, are shown in *Figure 2-58*. They have multiple size adjustments that make them good for gripping and applying limited torque to round, square, flat, and hexagonal objects. Their jaws may be straight, smooth, or curved. They are used mostly in plumbing and electrical work.

Figure 2-58 – Tongue and groove (channel lock) pliers.

1.2.20 ow to Use Tongue and Groove Pliers

Use tongue and groove pliers as follows:

1. Open the pliers to their widest position.
2. Place the jaws on the object to be held.
3. Determine which groove gives the best position.
4. Squeeze the handles until the pliers grip the object firmly.

Vise Grip (Locking) Pliers – A vise grip, shown in *Figure 2-59*, is a type of locking pliers. One side of the handle has an adjusting screw used to set the size of the jaws. Some models also include a lever on the opposite side of the bolt to unlock the pliers by pushing the handles apart.

Figure 2-59 – Vise grip (locking) pliers.

1.2.21 How to Use Vise Grip Pliers

Use vise grip pliers as follows:

1. Place the jaws on the object to be held.
2. Turn the adjusting screw until the pliers grip the object.
3. Lock the pliers by squeezing the handles together.
4. To remove the pliers, squeeze the release lever.

Test your Knowledge (Select the Correct Response)

3. What are the best-quality pliers made of?

   A. Fiberglass
   B. Hardened steel
   C. High-carbon steel
   D. Alloys

1.2.22 Pry Bars

A number of tools are made to rip and pry apart woodwork as well as to pull nails. In this section you will learn about ripping bars and nail pullers. *Figure 2-60* shows the parts of a pry bar, which is used for heavy-duty dismantling of woodwork. The forked tip pulls nails out easily. The gooseneck hook end gives you extra leverage for pulling and prying. The chisel end is angled to give you prying leverage.

Figure 2-60 – Parts of a pry bar.

1.2.23 Safety and Maintenance Considerations for Pry Bars

Remember these guidelines when you use a ripping bar or nail puller:

- Use personal protective equipment (PPE), including a hard hat, gloves, and eye protection.
- Use two hands to keep even pressure on your back as you pull.
- When you pull nails, make sure the material holding the nail is braced securely before you pull the nail. This will keep it from hitting you in the face.
- Keep your footing balanced and keep a firm grip on the tool to avoid the tool slipping, which can cause you to fall to the ground.

1.2.24 How to Use Pry Bars

Follow these steps when you use a pry bar:

1. Use the angled prying end to force apart pieces of wood.
2. Use the heavy claw to pull large nails and spikes.

Wrecking Bar – The wrecking bar, shown in *Figure 2-61*, is used for demolition, pulling nails, ripping wood, and other similar tasks. The length of the wrecking bar gives it better leverage for pulling larger and longer nails.

Figure 2-61 – Wrecking bar.

Chisel (Wonder) Bar – The chisel bar, shown in *Figure 2-62*, gets you into tight spots for prying, although it is not designed for heavy-duty prying. It is useful for removing nails with exposed heads and for prying paneling or molding without marring the surface. You can drive it into wood to split and rip apart the pieces.

Figure 2-62 – Chisel (Wonder) bar.

Flat Bar – The flat bar shown in *Figure 2-63* is a small pry bar. It is usually 2” wide and 15” long, with a nail slot at the end to pull nails out from tightly enclosed areas.

Figure 2-63 – Flat bar.

Cats Paw – The cats paw, shown in *Figure 2-64*, is used to pull nails when the nail heads are buried beneath the wood’s surface. Hammer the forked chisel head into the wood surrounding the nail head until the nail head is positioned between the notches, and then pull it from below the wood surface.

Figure 2-64 – Cats paw.

Test your Knowledge (Select the Correct Response)

4. What do you need to be sure to do when you use prying tools?

   A. Keep a balanced footing
   B. Hold the tool loosely
   C. Swing firmly from above
   D. Keep the material loosely braced

1.3.0 Sawing and Cutting Tools

Sawing and cutting tools are made to cut materials down to size. These tools include saws, chisels, and punches.

1.3.1 Hand Saws

Choosing the right saw for the job makes cutting easy. There are many different types of saws, distinguished by the shape, number, and pitch of their teeth. The differences in saws give you the ability to cut across or with the grain of the wood, along curved lines, or through metal, plastic, or wallboard. A saw with fewer points or teeth per inch (tpi) will give you a slower, smoother cut. A typical saw is shown in *Figure 2-65.*

Figure 2-65 – Parts of a saw.

1.3.2 Safety and Maintenance Considerations for Saws

Follow these guidelines when using saws:

- Always wear eye protection, either safety glasses or a face shield.
- Choose a saw that is the right size and design for the type of material being cut.
- Make sure the saw handle keeps your wrist in a natural position, horizontal to the piece being cut.
- Make sure the piece being cut is free of objects, such as screws or nails, that could make the saw buckle.
- Be sure the stock being cut is secured firmly in place.
- When cutting longer stock, be sure the stock is properly supported.
- Brace yourself when you are sawing so the final cut doesn't throw you off balance.
- Make sure the teeth and blades are properly sharpened and set by a qualified professional. Dull teeth can be a safety hazard.
- Make sure the saw blade is cleaned and protected from rust. Use emery cloth to clean the blade and a coat of light machine oil to prevent rust.
- Lay the saw down gently.
- Keep the saw teeth away from contact with stone, concrete, or metal.
- Protect the teeth of any saw when the tool is not in use.

1.3.3 How to Use a Saw

There are several steps you should use with any type of saw:

1. Begin the cut by placing your hand with the thumb in an upright position pressed against the blade.
2. Start sawing slowly at first to prevent the blade from jumping off the cut line.

3. After the blade is engaged, use partial cutting strokes and be sure to set the saw at the proper angle.
4. During the cut, apply pressure only during the down stroke.

Backsaw (Miter Saw) – The backsaw, shown in *Figure 2-66*, is also known as a miter saw. It is a thick-bladed saw with a stiff, reinforced back to provide rigidity for precision cutting. The backsaw can be from 10” to 30” in length and has 7 to 14 teeth per inch. It is used with miter boxes to cut ***miters***.

Figure 2-66 – Backsaw.

Compass Saw (Key Hole Saw) – The compass saw, shown in *Figure 2-67*, has a narrow blade that tapers nearly to a point. This helps it to fit in tight spaces where larger saws would not fit. There are three or four blade styles you can change according to the cutting job. It cuts curves quickly in wood and wallboard.

Figure 2-67 – Compass (key hole) saw.

A key hole saw is a small compass saw with finer teeth, used to cut metal. Keyhole saw blades can come in a turret head model that can be rotated and locked in several positions to ease cutting in tight spots.

Coping Saw – The coping saw, shown in *Figure 2-68*, has a narrow, flexible blade attached to a U-shaped frame. Blade holders at each end of the frame can be rotated so you can cut at any angle. This saw is used for cutting irregular shapes, curves, and intricate decorative patterns.

Figure 2-68 – Coping saw.

Dovetail Saw – The dovetail saw, shown in *Figure 2-69*, is similar to a backsaw with its stiff reinforced back, but it is smaller with finer teeth. It is used for fine finish cuts, such as dovetail joints. It is commonly used for trimming molding and repairing furniture. It can also be used to cut plastics and laminates.

Figure 2-69 – Dovetail saw.

Hacksaw – The hacksaw, shown in *Figure 2-70*, is a fine-toothed saw with the blade held rigidly straight, with relatively high tension, in a steel frame. Many models can be adjusted to hold various blade lengths. Blades come in coarse, medium, fine, and very fine. They are usually used for cutting metal or plastic, but there are rod saw blades available that can cut through spring and stainless steel, chain, brick, glass, and tile.

Figure 2-70 – Hacksaw.

When you use a hacksaw, make sure the blade is secured with the teeth pointing forward, and that the frame is aligned properly. When you cut with a hacksaw, use the full length of the blade in each cutting stroke.

Crosscut Saw – The ***crosscut saw***, shown in *Figure 2-71*, has teeth shaped like knife points to crumble out wood between cuts. It is designed to cut across wood grain and produces a smoother cut than rip saws. They can also be used to cut plywood.

Figure 2-71 – Crosscut saw.

1.3.4 How to Use a Crosscut Saw

The crosscut saw cuts across the grain of the wood, and will cut slowly and smoothly because of the number of points per inch (8 to 14). Follow these steps to use a cross cut saw properly:

1. Mark the cut with a square or other measuring tool.
2. Ensure that the piece is supported well with sawhorses, jacks, or other supports. Support the scrap end as well as the working piece so the wood doesn't split as you get to the end of the cut. You can support the scrap end of a short piece with your hand, but will need other support for longer work.
3. Place the saw teeth on the far edge of the wood, just outside the edge of your cut mark.
4. Start the cut with the part of the blade closest to the handle. Pull the saw toward your body.
5. Use the thumb of the hand not holding the saw to steady the saw and keep it vertical to the work.
6. Place the saw at a 45º angle and pull the saw to make a small groove.
7. Saw slowly and increase the length of the stroke as the ***kerf*** deepens.
8. Keep sawing at a 45º angle to the wood.

Rip Saw – The ***rip saw***, shown in *Figure 2-72*, has large chisel-shaped teeth, usually 5 1/2 per inch. It is designed to cut with the wood grain, with teeth that are cross-filed to ensure the chisel point is set square to the direction of cutting. The ripping action of this saw produces a coarse, ragged cut not desirable for finish work.

Figure 2-72 – Rip saw.

1.3.5 How to Use a Rip Saw

The rip saw cuts along the grain of the wood. It has fewer points per inch (between 5 and 9 tpi) than the cross cut saw. This allows you to cut faster, but gives you a coarser finish. Follow these steps to use a rip saw properly:

1. Mark the cut with a square or other measuring tool.
2. Ensure that the piece is supported well with sawhorses, jacks, or other supports. Support the scrap end as well as the working piece so the wood doesn't split as you get to the end of the cut. You can support the scrap end of a short piece with your hand, but will need other support for longer work.
3. Place the saw teeth on the far edge of the wood, just outside the edge or your cut mark.
4. Start the cut with the part of the blade closest to the handle. Pull the saw toward your body.
5. Use the thumb of the hand not holding the saw to steady the saw and keep it vertical to the work.
6. Place the saw at a 60º angle and pull the saw to make a small groove.
7. Saw steadily and increase the length of the stroke as the kerf deepens.
8. Keep sawing at a 60º angle to the wood.

Test your Knowledge (Select the Correct Response)

5. What do the main differences between types of saws relate to?

   A. Handles
   B. Blades
   C. Frames
   D. Teeth

1.3.6 Chisels

A ***chisel***, as shown in *Figure 2-73,* is used to cut and shape wood, stone, and metal. Chisels are metal tools with a sharpened, beveled edge. Chisels are either wood chisels or cold chisels; we will discuss each type separately.

Figure 2-73 – Parts of a chisel.

1.3.7 Safety and Maintenance Considerations for Chisels

Use these guidelines when you're working with chisels:

- Always use eye protection.
- Plastic guards near the head of the chisel protect your hands against mishits.
- Tip guards protect the sharpened tip of the chisel.
- Keep all chisels sharpened and in good working order. Sharpen the cutting edge of a chisel on an oilstone to produce a keen edge.
    - Make sure the wood chisel blade is beveled at a precise 25° angle so it will cut well.
    - Make sure the cold chisel blade is beveled at a 60° angle so it will cut well.
- Strike cold chisels only with a hand drilling, ball peen, or similar heavy hammer. The face diameter of the hammer should be about 3/8" larger than the chisel head.
- Discard any chisel with a cracked or chipped face.
- Discard any chisel with a head that is mushroomed or flattened.
- Use chisels for the appropriate purpose and in the correct way. Avoid the following:
    - ∅ Using a cold chisel to cut or split stone or concrete.
    - ∅ Using a wood chisel to cut metal, concrete, or stone.
    - ∅ Using a chisel for prying or driving screws.
    - ∅ Placing a chisel of any type in your pocket.

Wood Chisel – The wood chisel, shown in *Figure 2-74*, is used for cutting deeply into wood. It should be used with soft-face hammers.

Figure 2-74 – Wood chisel.

Butt Chisel – The butt chisel, shown in *Figure 2-75*, is a type of wood chisel with a short blade. It gives you good control of your work, especially in tight spaces. It is used to set hardware on doors and door frames.

Figure 2-75 – Butt chisel.

1.3.8 How to Use a Wood Chisel

The wood chisel is used to make openings or notches in wooden material. You can use it to make a recess for butt-type hinges, such as the hinges in a door. Follow these steps to use a wood chisel properly:

1. Use a pencil to outline the opening or recess to be chiseled.
2. Set the chisel at one end of the outline. The edge of the chisel should be on the cross-grain line. The bevel should be facing the recess to be made.
3. Strike the head of the chisel lightly with a mallet.
4. Repeat the process at the other end of the outline, with the bevel of the chisel blade toward the recess.
5. Make a series of cuts about 1/4 inch apart from one end of the recess to the other.
6. Pare (trim away) the notched wood. Hold the chisel bevel-side down to slice inward from the end of the recess, as shown in *Figure 2-76*.

Figure 2-76 – Paring excess material with a chisel.

1.3.9 How to Use a Cold Chisel

A cold chisel is used to cut metal, as long as that metal is softer than the steel that the chisel is made of. You can use it to cut rivets, nuts, and bolts made of brass, bronze, copper, or iron. Follow these steps to use a cold chisel properly:

1. Secure the material you need to cut in a vise.
2. Use a holding tool to place the blade of the chisel where you want to cut the material.
3. Hit the chisel handle with a ball peen hammer to force the chisel into and through the material. Repeat if necessary.

Cold Chisel – The cold chisel, shown in *Figure 2-77*, is used only for cutting and chipping cold metal, such as unhardened steel, cast and wrought iron, aluminum, brass, and copper; never on masonry.

Figure 2-77 – Cold chisel.

Masonry Chisel – The masonry chisel, shown in *Figure 2-78*, is used to cut masonry, such as concrete block and brick. There are also masonry chisels with teeth used for cutting soft stone.

Figure 2-78 – Masonry chisel.

Flooring Chisel – The flooring chisel shown in *Figure 2-79* is used to remove flooring material. It has a larger head to increase the striking area.

Figure 2-79 – Flooring chisel.

1.3.10 Knives

Several types of knives are used in construction. The most commonly used is the utility knife, which has a replaceable razor-like blade. Other types of knives are glass scrapers, glass cutters, and hook bill knives.

1.3.11 Safety and Maintenance Considerations for Knives

Use these guidelines when you work with a utility knife:

- Always wear safety glasses when using utility knives, as blades can snap off unexpectedly.
- Always use sharp blades; replacement blades are very inexpensive.
- Make sure the blades are seated properly in the knife to prevent slippage.
- Lock the blade in the open position before beginning your cut.
- Pull the knife toward you when cutting. Make several passes when cutting thicker materials.
- Place a scrap under the object you are cutting to protect the surface under the object.
- Use knives for the appropriate purpose and in the correct way. Avoid the following:
  - ∅ Use on live electrical wires. A utility knife is **NOT** insulated for such use.
  - ∅ Leaving a utility knife unattended. Keep the blade closed and locked when the knife is not in use.

Utility Knife – The utility knife, shown in *Figure 2-80*, is a general-use tool used to cut material such as drywall, laminates, and plastic. The handle of a utility knife is made of cast iron or plastic in two pieces, held together with a screw. The utility knife blade can usually be locked in one of three positions when in use, depending on the depth of cut needed, and retracts completely for safe storage.

Figure 2-80 – Utility knife.

Glass Scraper – The glass scraper shown in *Figure 2-81* is used to remove coatings, paint, and stickers from glass and mirrors. It has a large ribbed control button for extending and retracting the blade. The track design of this blade minimizes clogging and gumming up from the debris caused by scraping.

Figure 2-81 – Glass scraper.

Glass Cutter – A glass cutter, shown in *Figure 2-82*, is a hand tool used for controlled breaking of flat or sheet glass. The cutting section is a wheel about 5 mm in diameter made of hardened steel or tungsten carbide, with the edge ground to a V-section. The cutter or glass is wetted with oil or paraffin, and then the cutter is pressed tightly to scribe a line where the glass will be split. The ball end of the glass cutter can be used to tap the waste side of the glass to break it. A cleaner break is made by bending the glass along the scribe line.

Figure 2-82 – Glass cutter.

Hook Bill Knife – The hook bill knife shown in *Figure 2-83* is made of fine high carbon steel with an extra heavy blade. It yields accurate, even cuts when you are trimming gypsum board or making odd-shaped cuts.

Figure 2-83 – Hook bill knife.

Test your Knowledge (Select the Correct Response)

6. What does the safest kind of utility knife include?

   A. A leather sheath
   B. A blue blade
   C. At least three blades
   D. A retractable blade

1.4.0 Boring and Clamping Tools

Boring and clamping tools are used to create holes in material and hold materials together. They include punches, nail sets, drills, clamps, and vises.

1.4.1 Punches

A ***punch*** is used to indent metal using the impact of a hammer before you drill a hole. It can also be used to drive pins and to align holes in two parts to be joined. Punches are made of hardened and tempered steel. They come in various sizes.

Three common types of punches are the center punch, the prick punch, and the straight punch. The center and prick punches will make small locating points for drilling holes. The straight punch will punch holes in thin sheets of metal. A typical punch is shown in *Figure 2-84.*

Figure 2-84 – Parts of a punch.

1.4.2 Safety and Maintenance Considerations for Punches and Nail Sets

Use these guidelines when you're working with punches and nail sets:

- Always use eye protection.
- Always strike a punch with a ball peen hammer or a sledgehammer.
- Discard any punch that is bent, cracked, or chipped.
- Discard any punch with a deformed or chipped point.
- Discard any nail set that is bent, cracked, chipped, or shows excessive wear.
- Use punches and nail sets for the appropriate purpose and in the correct way. Avoid the following:
    - ∅ Using a nail set as a punch.
    - ∅ Using a nail hammer to strike a punch or nail set. The hammer face is too small and could chip.

1.4.3 How to Use a Punch

A punch is used to help with drilling by making an impression in wood, plastic, or metal. This marks the area you will drill and acts as a guide so the drill stays in place as it goes through the material. A punch is used with a ball peen hammer or a sledge hammer, with enough force to make an indentation.

1. Use a pencil to mark the location where you need to drill.
2. Determine what size punch to use based on the size of the drill bit you will use. Some common punch sizes are 1/4, 5/16, 3/8, 1/2, and 5/8 inch.
3. Line up the point of the punch with the pencil mark you made.
4. Tap the back of the punch sharply with a ball peen hammer or a sledgehammer.

Center (Nail) Punch – The center punch shown in *Figure 2-85* is used to start holes in wood or metal or to align rivet or bolt holes. It is also used to drive rivets after the rivet heads have been removed. The point of a center punch has a short bevel.

Figure 2-85 – Center (nail) punch.

Prick Punch – The prick punch, shown in *Figure 2-86*, is used to make a very light starter mark that can be enlarged with a different type of punch, such as a center punch. It can also be used to mark layout lines. The point of a prick punch has a long bevel.

Figure 2-86 – Prick punch.

Straight Punch – The straight punch, shown in *Figure 2-87*, is used to punch holes in thin sheets of metal.

Figure 2-87 – Straight punch.

Tapered Punch – The tapered punch, shown in *Figure 2-88*, is used to remove or install pins, shafts, rivets, etc. or to align holes when inserting screws and bolts. It is used with a hammer.

Figure 2-88 – Tapered punch.

Nail Set – The nail set shown in *Figure 2-89* is used to countersink nails before the nail holes are filled with putty, plastic, wood, etc. to create a smooth surface. They range in size from 1/32” to 5/32”; using the correct size nail set avoids enlarging the nail hole. The pointed end of the nail set should be cupped or hollowed out to avoid splitting the nail head.

Figure 2-89 – Nail set.

1.4.4 Hand Drills

There are a number of hand ***drills*** available to create holes in wood. They include augers, push drills, hand drills, and awls.

1.4.5 Safety and Maintenance Considerations for Hand Drills

Use these guidelines when working with hand drills:

- Always wear eye protection.
- When you use hand drills or bit braces, make sure the work piece is clamped securely.
- Hold the hand drill or bit brace vertically.
- Take your time, especially when precision counts. You’ll get better results if you don’t hurry the tool.
- Place a piece of scrap material under the work piece if you can.
- Never place an awl in your pocket.
- Periodically place a drop of light oil on the moving parts of these tools.

Auger – The ***auger***, shown in *Figure 2-90*, is also known as a bit brace; it is used to drill holes in wood. You apply pressure to the head, which is mounted on ball bearings so it can turn freely. You rotate the handle clockwise to create the drilling action. The chuck holds drill bits that have either square or hex shanks. The direction ratchet keeps the tool turning in one direction.

Figure 2-90 – Parts of an auger.

Push Drill – The push drill shown, in *Figure 2-91*, is used to drill holes in wood. You push down on the handle, causing the bit to rotate clockwise and cut the hole in the wood. When you release the pressure, the handle springs up and the bit rotates counterclockwise, clearing the bit as it comes out of the wood.

Figure 2-91 – Push drill.

Hand Drill – The hand drill, shown in *Figure 2-92*, is used to drill holes in wood when you want total control of the drill, particularly in materials that tend to split. You hold the handle and turn the crank, which turns the pinion gears on the shaft. This amplifies the circular motion of the crank into circular motion of the drill chuck and drives the bit into the wood.

Figure 2-92 – Parts of a hand drill.

Awl – The awl, shown in *Figure 2-93*, is used to mark wood. It is a steel spike with its tip sharpened to a fine point. The tip of the spike is drawn across the timber, leaving a shallow groove. It is also used to mark a point by pressing the tip into the timber.

Figure 2-93 – Awl.

1.4.6 Clamps

Clamps are devices for holding work. They come in many sizes based on the maximum opening of the jaw, from 1” to 24”. There are many varieties to use for different purposes.

C Clamp – The C clamp is the most common type of clamp, with a C-shaped frame made of forged steel or cast iron. It is used mostly to clamp metalwork. An adjustable screw changes the jaw opening, controlled by turning a wing nut or a sliding cross-pin handle as shown in *Figure 2-94*. The size of the C clamp is its jaw capacity, which is the largest object the frame can accommodate when the screw is fully extended. The depth of the throat is another important measure which determines how far in from the edge of the material the clamp can be placed.

Figure 2-94 – C clamp.

1.4.7 Safety and Maintenance Considerations for Clamps

Use guidelines when you work with clamps:

- Choose the correct size clamp for the work. Avoid overloading a clamp that is too small so you don’t damage the work or break the clamp.
- Remove clamps as soon as the work is finished, they are meant for temporary holding.
- Store clamps by clamping them to a rack. Storing them in drawers can lead to clamp damage.
- Discard any clamp that has a bent frame, screw, or spindle.
- Use clamps and other tools appropriately.
  - ∅ Never use a C clamp to hoist anything.
  - ∅ Never use a wrench, pipe, hammer, or pliers to tighten most clamps. Use a wrench only on clamps designed to be tightened with a wrench.

1.4.8 How to Use Clamps

Use a clamp as follows:

1. Open the clamp and place it loosely around the work you are clamping.
2. Protect the surface of wood you are clamping by placing pads or thin blocks of wood between the wood surface and the clamp.
3. Tighten the clamp’s pressure mechanism. Take care not to force the clamp past a snug fit.

Locking C Clamp – The locking C clamp, shown in *Figure 2-95*, has wide-opening jaws that give you the versatility to clamp a variety of shapes. You turn the screw to adjust the pressure and fit the work, and it stays adjusted for repetitive use. A guarded release trigger quickly unlocks the clamp and protects your work from accidental release.

Figure 2-95 – Locking clamp.

Spring Clamp – The spring clamp, shown in *Figure 2-96*, is a versatile clamp designed for use with thin materials. It has two metal jaws with a steel spring giving it 1”, 2”, or 3” jaw openings. It can hold round or odd-shaped objects. Use spring clamps when you need only moderate pressure.

Figure 2-96 – Spring clamp.

Hand Screw (Cabinetmaker's) Clamp – The hand screw clamp, shown in *Figure 2-97*, is made up of two hardwood clamping jaws that you adjust to the work by tightening two opposing steel screw spindles. You can adjust the jaws to a variety of angles, with sizes up to 10". The hand screw clamp is used to clamp wood, metal, plastic, and fabric.

Figure 2-97 – Hand screw clamp.

Bar Clamp – The bar clamp, shown in *Figure 2-98*, has a clamping device built on a flat steel bar. The size of the largest object that can be held between the bar clamp jaws is determined by the length of the bar. The final clamping load is applied by screw pressure. Use the bar clamp to clamp large objects.

Figure 2-98 – Bar clamp.

Pipe Clamp – A pipe clamp, shown in *Figure 2-99*, can be mounted to standard threaded or unthreaded pipe. You can clamp from one end or both ends, since you can position the jaws at the ends of the pipe or anywhere along its length. A hardened steel set screw holds the head firmly on the pipe, but you can easily loosen it. Pipe clamps are used to hold boards together while gluing. They can also be quickly converted to use as a spreader.

Figure 2-99 – Pipe clamp.

Web Clamp – The web clamp, also known as a strap or band clamp is shown in *Figure 2-100*. This clamp applies even clamping pressure around irregular shapes or large objects. It uses a spring-loaded locking fixture to hold objects tightly. The web clamp is commonly used on cylinder shapes and to hold chair legs when they've been glued. Inspect a web clamp before using it. If the web is frayed or cut, discard the clamp.

Figure 2-100 – Web clamp.

1.4.9 Vises

The bench vise, shown in *Figure 2-101*, is mounted on a workbench or table, and is used to hold work pieces securely in place between two flat jaws. It is available in stationary or swivel models; the swivel model has a sliding spindle lockdown to hold the vise at different angles. The threaded spindle adjusts the jaw openings when you turn the sliding cross pin handle.

Figure 2-101 – Parts of a bench vise.

1.4.10 Safety and Maintenance Considerations for Vises

Use these guidelines when you work with vises:

- Always wear eye protection when hammering an object held by a vise.
- Secure the vise to the workbench with a bolt in each hole. Use a lock washer under each nut.
- Replace worn jaw inserts and bent sliding cross pin handles.
- Use jaw liners if there is a possibility of marring the work.
- When you hold work in a vise for sawing, saw as close to the jaws as possible.
- When you clamp long work pieces in a vise, make sure the end of the work is properly supported.
- Use a vise appropriately. Avoid the following:
    - ∅ Using an extension (cheater) handle or hammer on the vise handle for extra clamping pressure.
    - ∅ Using a vise that shows the slightest hairline fracture; discard any such vise.

1.4.11 How to Use a Vise

Use a vise as follows:

1. Turn the sliding cross pin handle counterclockwise to open the jaws.
2. Place the work in the open clamp.
3. Turn the sliding cross pin handle clockwise to clamp the work.
4. Turn the sliding cross pin handle counterclockwise to release the work.

Test your Knowledge (Select the Correct Response)

7. **(True or False)** When you saw an object, you should saw as close as possible to the jaws of the vise.

   A. True
   B. False

1.5.0 Smoothing Tools

Smoothing tools are used to smooth wood surfaces so that they can be finished with paint or stain. They include planes, scrapers, files, and rasps.

1.5.1 Planes

Planes are used for smoothing and jointing lumber. There are several types, including jointer and fore planes, jack planes, smooth planes, block planes, and rabbet planes. A typical plane is shown in *Figure 2-102*.

Figure 2-102 – Parts of a plane.

1.5.2 Safety and Maintenance Considerations for Planes

Use the following guidelines when you work with planes:

- Always wear eye protection, especially safety glasses.
- Use the correct plane for the job. A longer plane will straighten edges on longer work pieces.
- Store the plane with the cutting blade retracted. This will prevent injury and avoid wearing out the cutting edge.

1.5.3 How to Use Planes

Use a plane as follows:

1. Place the wood level and firmly in a vice.
2. Rub a little candle wax on the bottom of the plane to help it glide more smoothly across the wood.
3. Plane in the direction of the grain. If the plane sticks while you use it, the grain is probably in the opposite direction. Reverse the wood in the vise and try again.
4. Make sure that a very small portion of the blade sticks out from the bottom of the plane, making adjustments with the depth adjustment screw. This will help you plane small portions at a time, which will give you a better result.
5. Start with the plane at one end of the wood and push it firmly across the entire length of the wood. Lift the plane and move it back to the starting position so you don’t blunt the blade.

6. Keep the plane straight by pressing down on the knob at the beginning of the stroke and pressing down on the handle at the end of the stroke.
7. Always use a sharp blade. Sharpen the blade with a bench grinder.
8. When you are not using a plane, rest it on its side.

Jointer Plane – The jointer plane, shown in *Figure 2-103*, is used to straighten the edges of boards in an operation known as jointing. It is also used to flatten the face of a board. A jointer plane is usually 20 to 24 inches long. A similar but shorter plane about 18 inches long is known as a fore plane.

Figure 2-103 – Jointer plane.

Scrub Plane – The scrub plane, shown in *Figure 2-104*, is used to remove large amounts of wood from the surface of lumber in the first stages of preparing rough stock, or when the thickness of the board needs to be reduced significantly. Unlike most planes, it is used in diagonal strokes across the face of a board.

Figure 2-104 – Scrub plane.

Jack Plane – The jack plane, shown in *Figure 2-105*, is used for general smoothing of edges and sizing of wood. The name comes from the saying “Jack of all trades”, since this plane performs the work of both smooth planes and trying planes. It is usually about 15 inches long with a blade that has a moderately curved edge. When you prepare stock, the jack plane is used after the scrub plane and before the smooth plane.

Figure 2-105 – Jack plane.

Smooth Plane – The smooth plane, shown in *Figure 2-106*, is the last plane used on a wood surface. With proper use, the finish from a smooth plane is much better than you can achieve with sandpaper or scrapers. This smooth finish comes from planing the wood off in strips. The smooth plane is 9 to 10 inches long and is meant to be used with two hands.

Figure 2-106 – Smooth plane.

Block Plane – The block plane, shown in *Figure 2-107*, is a small hand plane with the plane iron set at a much lower angle than that of other planes. It is used to plane across the grain at the ends of boards, otherwise known as blocking in. It is also used to shave thin pieces of wood from small surfaces in awkward areas. This plane is small enough to use with one hand, sometimes at an angle of as much as 45°.

Figure 2-107 – Block plane.

The block plane is a tool with many uses, including cleaning up components to make them fit within fine tolerances. Rounding square edges, otherwise known as chamfering, and removing glue lines are some other uses for this plane.

Figure 2-108 – Rabbet plane.

Rabbet Plane – The rabbet plane, shown in *Figure 2-108*, is used to make rabbet joints on the ends of boards. The blade on this plane protrudes by a very small amount from the sides of the plane so that the plane doesn't bind on the side of the cut. This helps make the side of the rabbet joint perpendicular to the bottom. This plane is used for long grain cutting and is meant to remove large amounts of material quickly.

1.5.4 Scrapers

The ***scrapers*** shown in *Figure 2-109* are woodworking shaping and finishing tools. They are sometimes known as card scrapers, the most common about the size and shape of a postcard. They are also known as cabinet scrapers, because they leave a cleaner finish than sandpaper. Scrapers remove small amounts of material, especially where tricky grains might cause a planer to tear out chunks of material. This prepares the wood for any finish paint or stain.

Figure 2-109 – Scrapers.

1.5.5 Safety and Maintenance Considerations for Scrapers

Use these guidelines when you work with scrapers:

- Eye protection prevents scraped material from flying into your eyes.
- Gloves protect your fingers from sharp edges and from the heat generated by a scraper.

1.5.6 How to Use Scrapers

There is preparation involved in using a scraper. Follow these steps to use a scraper properly:

1. File the edges. Most scrapers are stamped from sheets of steel, which leaves the edges ragged. Keep the file at a 90-degree angle to the body of the scraper for the best results.
2. Smooth the edges. If you are using the scraper for finish work, you need to smooth out the filed edges with a stone. Lay the stone on your work surface and rub the scraper on the side of the stone until the scraper edge is smooth.
3. Draw a burr. Apply a thin layer of lubricant along the blade of the scraper. Hold the scraper in a padded bench vise, and then use a burnishing tool or a screwdriver to bend the scraper slightly along the entire edge. The angle of the burr depends on what you will use the scraper for; fine finishing uses a 5° angle, removing paint and lacquer uses a 10° angle.
4. Use the scraper. This takes practice to get right, but there are a few tips to help you.
   - Work with the grain of the wood to prevent the scraper from gouging the wood.
   - Bend the scraper slightly in the middle. The easiest way to do this is to hold the edges of the scraper with your fingers and apply pressure in the middle with your thumbs.
   - Keep the scraper in good condition. If you notice that the scraper produces dust instead of shaving the wood, it needs to be sharpened.

Test your Knowledge (Select the Correct Response)

8. What should you always do when you use a plane?

   A. Use both hands
   B. Plane across the grain of the wood
   C. Plane with the grain of the wood
   D. Plane around any knots

1.5.7 Files and Rasps

Files and ***rasps*** are used for cutting, smoothing, or shaping materials. Files have slanting rows of teeth and rasps have individual teeth. Both are usually made from a hardened piece of high grade steel. The size of a file or rasp is determined by the length of the body; it does not include the handle. Sizes vary between 4 and fourteen inches. Handles are separate from the file, and can be used interchangeably with different files. A typical file is shown in *Figure 2-110*.

Figure 2-110 – Parts of a file.

The shape of the file or rasp you use is partly determined by the area you want to file. They are available in round, half-round, square, flat, and triangular shapes. Another factor in deciding what file to use is the material you will work on. Files for soft materials have teeth that are very sharp and spaced wide apart. Files for hard materials have teeth that are blunt and spaced close together. Files are classified by how their teeth are cut. *Table 2-2* shows types of files along with their uses.

Table 2-2 – File types and their uses.

Type	Description	Uses
Rasp-cut file	Teeth cut individually, not attached to each other.	Used for aluminum, lead, and other soft metals as well as wood, to remove excess material. These files give you a very rough surface.
Single-cut file	A single set of straight-edged teeth run across the file at an angle.	Used to sharpen edges, like rotary mower blades.
Double-cut file	Two sets of teeth crisscross each other. Three types are available: • Bastad (roughest cut) • Second cut • Smooth	Used to cut fast.

1.5.8 Safety and Maintenance Considerations for Files

Here are the guidelines to remember when working with files and rasps:

- Always use eye protection.
- Always wear a dust mask to prevent inhaling small particles of wood or metal.
- Use the correct file for the material being worked.
- Always put a handle on a file before using it; most files have handle attachments.
- Use two hands on a file.
- Secure the material you're working on with a vise. If the material vibrates, it can dull the file teeth.
- Clean the file after you have used it. Brush the filings from between the teeth with a wire brush, pushing in the same direction as the line of the teeth.
- Store files in a dry place wrapped in cloth.
- Keep files separated from other tools so they don't get chipped or damaged.
- Use the special equipment needed to sharpen a serrated edge. A sharpening stone won't work.

1.5.9 How to Use Files

Follow these steps to use a file properly:

1. Secure the material you are filing in a vise at about elbow height.
2. Stand back from the vise a little with your feet about 24 inches apart. Put your right foot ahead of your left if you are right-handed; your left foot ahead of your right if you are left-handed.
3. If you are right-handed, hold the file with the handle in your right hand, and hold the tip of the blade in your left. If you are left-handed, hold the handle in your left hand and the hold the tip of the blade in your right.
4. For regular work, hold the tip of the file with your thumb on top of the blade and your first two fingers under it. For heavy work, use a full-hand grip on the tip.
5. Apply pressure only on the forward stroke.
6. Raise the file from the work on the return stroke to keep from damaging the file.
7. Keep the file flat on the work, as shown in *Figure 2-111*. Clean it by tapping lightly at the end of each stroke.

Figure 2-111 – Using a file.

Veneer Knife File – The veneer knife file, shown in *Figure 2-112*, is designed for sharpening veneer knives. It has a thin, rectangular shape with 2 round edges.

Figure 2-112 – Veneer knife file.

Square File – The square file, shown in *Figure 2-113*, is handy to use on slots and keyways, both rectangular and square, and for surface work. It has four equal sides, which taper toward the point.

Figure 2-113 – Square file.

Triangle File – The triangle file, shown in *Figure 2-114*, is used for clearing out square corners and filing taps and cutters. It is triangular in cross-section and has fairly sharp corners.

Figure 2-114 – Triangle file.

Flat File – The flat file, shown in *Figure 2-115*, is used by machinists on metal for rapid stock removal. It is a rectangular file tapered in width at the point and lightly tapered in thickness at the point.

Figure 2-115 – Flat file.

Rat-tail File – The rat-tail file, shown in *Figure 2-116*, is used for smoothing wood or metal. It can be used for removing stock from round holes to make the holes larger or smoother. It is a thin round tool with small sharp teeth.

Figure 2-116 – Rat-tail file.

Rasp – The rasp, shown in *Figure 2-117*, is used to shape wood. It has individual teeth that are rougher than those of a file, as it is used for rapid removal of wood stock.

Figure 2-117 – Rasp.

Test your Knowledge (Select the Correct Response)

9. Files are classified by which aspect of their teeth?

    A. Width
    B. Angle
    C. Taper
    D. Cut

1.6.0 Concrete Tools

There are a number of tools used in concrete projects. These include screeds, floats, trowels, edgers, and groovers.

1.6.1 Safety and Maintenance Considerations for Concrete Tools

Remember these guidelines when working with concrete:

- Wear appropriate personal protective equipment when working with concrete. This includes a hard hat, eye protection, and skin protection such as gloves, waterproof boots, long sleeves, and long pants.
- Be careful of the edges of finishing tools, which can be sharp.
- Clean tools after use to avoid concrete build-up.

Vibrator – The concrete ***vibrator*** shown in *Figure 2-118* is used to consolidate concrete after it has been poured. Concrete vibration is important in removing air pockets in the mix. It is performed before the surface is finished.

Figure 2-118 – Concrete vibrator.

Wood Screed Board – The wood ***screed board***, shown in *Figure 2-119*, is used to cut off excess wet concrete to bring the top surface of a slab to the proper grade. It is a straight 2" by 4" board about a foot longer than the width of the area you are working on. Start screeding the concrete as soon as you've finished pouring and vibrating it. Rest the screed board on the concrete forms and use a sawing motion while you pull the screed board toward the end of the poured area. Pour fresh concrete into lower areas and repeat the screeding process.

Figure 2-119 – Wood screed board.

Power Screed – The power screed, shown in *Figure 2-120*, is used to cut off excess concrete from the top surface of a concrete slab. It is useful for screeding large concrete slabs that would be difficult to screed using a wood screed board.

Figure 2-120 – Power screed.

Bull Float – A ***float*** smoothes the surface of freshly laid concrete by applying pressure to the concrete's surface. This pressure levels ridges and fills voids left by the screeding process by pushing the aggregate down and allowing the liquid to rise and dry, leaving behind a smooth surface. The bull float, shown in *Figure 2-121*, is used to float large areas of concrete. A bull float is generally 42" or 48" long and 8" wide. It has handle sections that come in 5' or 6' lengths that can be joined together so they will reach 15' to 20' over a slab.

Figure 2-121 – Bull float.

Darby Float – The darby float, shown in *Figure 2-122*, is used to level concrete on smaller areas, with a surface that is generally less wavy than that created with a bull float. It is usually made of magnesium or aluminum.

Figure 2-122 – Darby float.

Magnesium Float – The magnesium float, shown in *Figure 2-123*, is another option for smoothing smaller areas. They range in length from 12" to 16", with widths from 3 1/8" to 3 1/2".

Figure 2-123 – Magnesium float.

Steel Trowel – A ***trowel*** produces a hard, smooth, dense surface on concrete and is used immediately after floating. The steel trowel, shown in *Figure 2-124*, is used to increase the wear resistance of the concrete. Multiple trowelings allow the worker to apply increasingly greater pressure to make the concrete denser. Each successive troweling should be done with a smaller trowel tipped at a greater angle than the last troweling.

Figure 2-124 – Steel trowel.

Concrete Whirlybird – The concrete whirlybird, shown in *Figure 2-125*, is a walk-behind power trowel. It is useful for troweling large concrete surfaces.

Figure 2-125 – Whirlybird.

Edger – The ***edger***, shown in *Figure 2-126*, is used to round the edge of the slab after the bleedwater disappears from the concrete surface. Edging is done mostly on patios, curbs, sidewalks, and driveways to give a tight, clean-looking edge that resists chipping.

Figure 2-126 – Edger.

Groover – The ***groover***, shown in *Figure 2-127*, is used to cut joints in concrete to control the location of cracks that might form as the slab contracts. The groove sizes range from 1/4” to 1/2” wide and are usually 1/2” deep.

Figure 2-127 – Groover.

Concrete Saw – The concrete saw, shown in *Figure 2-128*, is used much like the groover, to cut joints in concrete to control the location of cracks. It is used for large concrete projects.

Figure 2-128 – Concrete saw.

Test your Knowledge (Select the Correct Response)

10. Why is it important to clean concrete tools immediately after use?

    A. To keep the tools from corroding
    B. To keep the edges sharp
    C. To avoid concrete build-up
    D. To prevent metal tools from rusting

1.7.0 Masonry Tools

There are many tools used in masonry projects. These include trowels, jointers, chisels, and line blocks.

1.7.1 Safety and Maintenance Considerations for Masonry Tools

Remember these guidelines when working with masonry:

- Wear appropriate personal protective equipment when working with concrete. This includes eye protection and gloves.
- Be careful of the edges of finishing tools, which can be sharp.
- Clean tools after use to avoid mortar build-up.
- Cover the tip of a pointing tool to protect the tool and yourself.

Pointing Trowel – The pointing trowel, shown in *Figure 2-129*, is used by bricklayers for pointing up their work, as well as for patch work and for cleaning other tools. The length of pointing trowels ranges from 4 1/2” to 7”.

Figure 2-129 – Pointing trowel.

Mortar Trowel – The mortar trowel, shown in *Figure 2-130*, is used for spreading mortar on a surface before laying brick or block.

Figure 2-130 – Mortar trowel.

Convex Jointer – The ***convex jointer***, shown in *Figure 2-131*, is used to strike joints in brick and block walls, giving the joints a neat, finished appearance. Each end of the jointer is a different size, with popular sizes of 1/2”, 5/8”, 3/4”, and 7/8”.

Figure 2-131 – Convex jointer.

V Jointer – The V jointer, shown in *Figure 2-132*, is similar to the convex jointer. It has one turned up end for easy use.

Figure 2-132 – V jointer.

Slicker – The ***slicker***, shown in *Figure 2-133*, is another type of jointer for finishing mortar. It has a ridge that leaves an even depression in the mortar.

Figure 2-133 – Slicker.

Rake Out Jointer – The rake out jointer, shown in *Figure 2-134*, is used to remove old mortar when you are repointing masonry. It is offset to throw mortar out as you rake the joint. The tab at the end helps you rake the corners.

Figure 2-134 – Rake out jointer.

Mason’s Chisel – The mason’s chisel, shown in *Figure 2-135*, is used to cut masonry such as concrete block and brick. There are also masonry chisels with teeth used for cutting soft stone.

Figure 2-135 – Mason’s chisel.

Line Block – The line block, shown in *Figure 2-136*, is used to hold mason's line to keep masonry construction level.

Figure 2-136 – Line block.

Test your Knowledge (Select the Correct Response)

11. What tool is used to cut brick and concrete block?

    A. Chisel
    B. Jointer
    C. Mortar trowel
    D. Pointing trowel

1.8.0 Interior Finish Tools

There are numerous tools for finishing interiors. These include rasps, saws, drywall tools, sanders, trowels, and various types of cutters.

1.8.1 Safety and Maintenance Considerations for Interior Finish Tools

The diversity of tools used for interior finishing jobs is reflected in the safety and maintenance considerations for these tools. In general, keep the following guidelines in mind:

- Keep the tools clean and dry.
- Keep sharp edges and points covered when the tool is not in use to avoid damage to the tool or injury to anyone handling it.

Drywall Rasp – The drywall rasp, shown in *Figure 2-137*, is used to perform minor trimming on drywall panels that are too tight for the space they are going into. A good drywall rasp is self-cleaning.

Figure 2-137 – Drywall rasp and blade.

Circle Cutter – The ***circle cutter*** shown in *Figure 2-138* marks a round hole to be cut in drywall. This is most commonly used to cut holes for ceiling mounted lighting fixtures.

Figure 2-138 – Circle cutter.

Drywall Saw – The drywall saw, shown in *Figure 2-139*, is used for cutting drywall that has already been placed. It can be easier to place the drywall and then cut out window openings in place. This saw has a sharp point to get the hole started.

Figure 2-139 – Drywall saw.

Keyhole Saw – The keyhole saw, shown in *Figure 2-140*, is used for cutting small openings in drywall, such as openings for electrical boxes, pipes, and lighting fixtures. It is often used in conjunction with a circle cutter.

Figure 2-140 – Keyhole saw.

Drywall Lifter – The drywall lifter shown in *Figure 2-141* is used to lift and hold sheets of drywall into place while it is being attached to the wall or ceiling. You may also hear this tool referred to as a board lifter.

Figure 2-141 – Drywall lifter.

Putty Knife – The ***putty knife*** shown in *Figure 2-142* is used for scraping surfaces or spreading material such as plaster. Widths vary from 1 ¼" to 6" or more, depending on what the putty knife will be used for. Stiff-blade knives, usually .040" thick, are used for scraping. Flexible-blade knives, usually .020" thick, are used for spreading.

Figure 2-142 – Putty knife.

Finish Knife – The finish knife, shown in *Figure 2-143*, is used in drywall work to smooth mud and tape seams. The steel blade makes the tool easy to clean when the job is complete. The handle is usually made of a material such as polypropylene so that it will hold up to exposure to chemical cleaning agents.

Figure 2-143 – Finish knife.

Mud Pan – The mud pan, shown in *Figure 2-144*, is used for mixing and holding mud for drywall taping, texturing, and patching. Mud pans have watertight seams and range in length from 10” to 24”.

Figure 2-144 – Mud pan.

Clinch-On Cornerbead Tool – The clinch-on cornerbead tool, shown in *Figure 2-145*, is used to install cornerbead on walls covered with drywall.

Figure 2-145 – Clinch-on cornerbead tool.

Inside Corner Tool – The inside corner tool, shown in *Figure 2-146*, is used to finish inside corners on drywall installations. It is a one piece, flexible, stainless steel tool with a 103° angle that flexes to 90°.

Figure 2-146 – Inside corner tool.

Outside Corner Tool – The outside corner tool, shown in *Figure 2-147*, is used to finish outside corners on drywall installations. It is a one piece, flexible, stainless steel tool with an 80° angle that flexes to 90°.

Figure 2-147 – Outside corner tool.

Hawk – The hawk, shown in *Figure 2-148*, is used to hold drywall mud right before it is applied. It can carry a larger amount of mud than a trowel can from the mud pan to the wall or ceiling where it will be applied.

Figure 2-148 – Hawk.

Pole Sander – The pole ***sander***, shown in *Figure 2-149*, is used to sand drywall joints. The attached pole helps reach joints that are difficult to reach with a hand sander, such as those on ceilings or high walls.

Figure 2-149 – Pole sander.

Hand sander – The hand sander, shown in *Figure 2-150*, is used to sand drywall joints.

Figure 2-150 – Hand sander.

Mud Masher – The mud masher, shown in *Figure 2-151*, is used for mixing drywall mud. The 24” handle makes this a good tool when you are mixing mud in a 5 gallon bucket.

Figure 2-151 – Mud masher.

Mastic Trowel – The mastic trowel, shown in *Figure 2-152*, is used to apply mastic to walls and floors before ceramic tiling. The smooth edges are used to apply a thin coat of mastic to the surface. The notched edges are used to ridge the mastic for better adhesion to the tile.

Figure 2-152 – Mastic trowel.

Notch Trowel – The notch trowel, shown in *Figure 2-153*, is used to apply mortar to surfaces. The flat side of the trowel is used to apply a skim coat to a surface. The notched side is used to comb the mortar.

Figure 2-153 – Notch trowel.

Rubber Surface Trowel – The rubber surface trowel, shown in *Figure 2-154*, is used in tile grouting.

Figure 2-154 – Rubber surface trowel.

Tile Nipper – The tile nipper, shown in *Figure 2-155*, is used to make circular cuts in ceramic tile. This tool is best used to take small bites, or nips, from the tile; large nips can cause the tile to break. Eye protection is critical, as sharp tile fragments can fly from the cut in any direction.

Figure 2-155 – Tile nipper.

Tile Cutter – The tile cutter, shown in *Figure 2-156*, is used to make straight or angled cuts in ceramic tile. A scoring wheel makes a score across the tile surface, which can then be broken along the score line. Tile cutters come in various sizes to accommodate various tile sizes. The beams holding the scoring wheel can be adjusted for height to accommodate various tile thicknesses.

Figure 2-156 – Tile cutter.

1.9.0 Brushes

Several types of brushes are used in construction, including paintbrushes and wire brushes.

1.9.1 Safety and Maintenance Considerations for Brushes

It is important to keep all brushes clean and dry when they are in storage. Methods of cleaning paintbrushes depend on the type of paint for which they are used.

Paint Brush – The paint brush, shown in *Figure 2-157*, is made up of a handle that holds bristles, which are made of natural or synthetic fibers, and comes in various sizes and shapes. A paint brush is used to apply paint to a surface. Paint brushes in construction are generally used to paint the interior and exterior of houses.

Figure 2-157 – Paint brush.

Wire Brush – The wire brush, shown in *Figure 2-158*, is a tool consisting of a handle and a brush made up of a large number of steel or brass wire bristles. It is an abrasive tool, used to clean rust and remove paint from surfaces. It can also be used to clean wire rope and chain. Wire brushes will leave marks on

Figure 2-158 – Wire brush.

soft surfaces and can transfer oil and dirt if they are not kept clean between uses.

Test your Knowledge (Select the Correct Response)

12. What abrasive tool is used to clean rust and remove paint from surfaces?

    A. Drywall rasp
    B. Finish knife
    C. Wire brush
    D. Mastic trowel

2.0.0 POWER TOOLS

Your duties as a Builder include developing and improving your skills and techniques when working with different power tools. In this section, we'll identify and describe the most common power tools that are in the Builder's workshop or used on the jobsite. We'll also present safety precautions as they relate to each power tool. You must keep in mind and continually stress to your crew that power tools can be dangerous, and that safety is everyone's responsibility.

2.1.0 Shop Tools

As a Builder, you might be assigned to a shop. You will need to know some of the common power tools and equipment found there.

2.1.1 Safety and Maintenance Considerations for Shop Tools

There are a few guidelines that apply to all power tools used in a shop.

- Always use ear and eye protection when operating a power tool.
- Avoid loose clothing, jewelry, and anything that could get caught in the power tool.
- When you replace a blade, make sure it is set to rotate in the proper direction.
- Use the correct blade for the material you are cutting. Keep blades sharp and watch for overheated or vibrating blades.
- Unplug the tool before changing blades or making adjustments.
- Never leave a tool unattended with the power on.

Shop Radial Arm Saw – *Figure 2-159* illustrates a typical shop ***radial arm saw***. This saw has a circular saw blade that cuts by rotating the blade toward the operator. It can make a variety of cuts, including crosscuts, rips, and miters. With accessories, this saw can also make dadoes, sand, shape, saber saw, surface, and route. The length of the top arm limits the length or width of the cut.

The procedures used to operate, maintain, and lubricate any shop radial arm saw are found in the manufacturer's operator and maintenance manuals, along with the safety precautions to be observed. The primary difference between this saw and other saws of this type (field saws) is the location of the controls.

Figure 2-159 – Shop radial arm saw.

Tilt-Arbor Table Saw – The tilt-arbor ***table saw***, shown in *Figure 2-160*, is named for its ability to tilt the saw blade for cutting bevels by tilting the arbor. The arbor, located beneath the table, is controlled by the tilt handwheel.

Figure 2-160 – Tilt-arbor table saw.

2.1.2 Safety and Maintenance Considerations for the Tilt-Arbor Bench Saw

Observe the following safety procedures when operating a tilt-arbor bench saw.

- Make sure the saw blade is sharp, unbroken, and free from cracks before using. Change the blade if it becomes dull, cracked, chipped, or warped.
- Be sure the saw blade is set at the proper height above the table to cut through the wood.
- Stand to one side of the saw to avoid the being hit by materials caused by kickbacks.
- Use a push stick to push short, narrow pieces between the saw blade and the gauge.

- Keep stock and scraps from accumulating on the saw table and in the immediate working area.
- Use the tilt-arbor bench saw appropriately. Avoid the following:
  - ∅ Feeding wood into the saw blade faster than it will cut freely and cleanly.
  - ∅ Reaching over the saw to obtain material from the other side.
  - ∅ Using a ripsaw blade for crosscutting or using a crosscut blade for ripping. If you rip and crosscut frequently, you should install a combination blade to eliminate constantly changing the blade.

2.1.3 How to Use a Tilt-Arbor Bench Saw

To rip stock, remove the cutoff gauges and set the rip fence away from the saw by a distance equal to the desired width of the piece to be ripped off. Place the piece with one edge against the fence and feed through with the fence as a guide.

To cut stock square, set the cutoff gauge at 90° to the line of the saw and set the ripping fence to the outside edge of the table, away from the stock to be cut. Place the piece with one edge against the cutoff gauge, hold it firmly, and feed it through by pushing the gauge along its slot. To cut stock at an angle other than 90°, also known as miter cutting, the process is similar, except that the cutoff gauge is set to bring the piece to the desired angle with the line of the saw.

For ordinary ripping or cutting, the saw blade should extend above the table top 1/8 to 1/4 inch plus the thickness of the piece to be sawed. The vertical position of the saw is controlled by the depth of cut handwheel, shown in *Figure 2-156*. The angle of the saw blade is controlled by the tilt handwheel. Except when its removal is absolutely unavoidable, the guard must be kept in place.

The slot in the table through which the saw blade extends is called the throat. The throat is contained in a small, removable section of the table called the throat plate. The throat plate is removed when it is necessary to insert a wrench to remove the saw blade.

The blade is held on the arbor by the arbor nut. A saw is usually equipped with several throat plates, containing throats of various widths. A wider throat is required when a dado head is used on the saw. A dado head consists of two outside grooving saws, which are much like combination saws, and as many intermediate chisel type cutters (chippers) as required to make up the designated width of the groove or dado. Grooving saws are usually 1/8 inch thick, so one grooving saw will cut a 1/8 inch groove, and two used together will cut a 1/4 inch groove. Intermediate cutters come in various thicknesses.

Compound Miter Saw – The compound miter saw, shown in *Figure 2-161*, is used to provide smooth crosscuts and beveled cuts of wood molding, trim, and other materials. This saw uses a circular blade that is pivoted to the correct angle then dropped onto the material. It has a large compass scale marked in degrees to show the angle of the cut.

Figure 2-161 – Compound miter saw.

Tile Saw – The tile saw, shown in *Figure 2-162*, is used to cut tile and stone. This saw is also know as a wet saw and uses a diamond tipped circular blade cooled by a continuous stream of water contained in a reservoir. It can operate either like a radial arm saw or a table saw.

Figure 2-162 – Tile saw.

Test your Knowledge (Select the Correct Response)

13. Material should be fed to a table saw blade at what speed?

    A. As fast as possible
    B. No faster than you can pull
    C. As slow as you can
    D. As fast as it can cut freely and cleanly

2.1.4 Band Saw

Although the ***band saw***, shown in *Figure 2-163*, is designed primarily for making curved cuts, it can also be used for straight cutting. Unlike the circular saw, the band saw is frequently used for freehand cutting. Sanding attachments and sanding loops are available for sanding on irregular or curved surfaces.

The band saw has a band or loop-like blade that comes in various widths and strengths for various cutting purposes. It has two large wheels on which the band turns, just as a belt is turned on pulleys. The lower wheel, located below the working table, is connected to the motor directly or by means of pulleys or gears, and serves as the driver pulley. The upper wheel is the driven pulley.

The saw blade is guided and kept in line by two sets of blade guides, one fixed set below the table and one set above with a vertical sliding adjustment. The alignment of the blade is adjusted by a mechanism on the backside of the upper wheel. Tightening and loosening of the blade is provided by another adjustment located just back of the upper wheel.

Figure 2-163 – Band saw.

Cutoff gauges and ripping fences are sometimes provided for use with band saws, but you'll do most of your work freehand with the table clear. With this type of saw, it is difficult to make accurate cuts when you use gauges or fences.

The size of a band saw is designated by the diameter of the wheels. Common sizes are 14, 16, 18, 20, 30, 36, 42, and 48 inch diameter wheel machines. The 14 inch size is the smallest practical band saw. With the exception of capacity, all band saws are much the same with regard to maintenance, operation, and adjustment.

A rule of thumb used by many Seabees is that the width of the blade should be one eighth the minimum radius to be cut. If the piece on hand has a 4 inch radius, the operator should select a 1/2 inch blade. This doesn't mean that the minimum radius that can be cut is eight times the width of the blade; the ratio indicates the practical limit for high speed band saw work.

Blades for band saws are designated by points (tooth points per inch), thickness (gauge), and width. The required length of a blade is calculated by adding the circumference of one wheel to twice the distance between the wheel centers. Length can vary within a limit of twice the tension adjustment range.

Band saw teeth are shaped like the teeth in a hand ripsaw blade, which means that their fronts are filed at 90° to the line of the saw. Reconditioning procedures are the same for a hand ripsaw, except that very narrow band saws with very small teeth must usually be set and sharpened by special machines.

2.1.5 Safety and Maintenance Considerations for Band Saws

Observe the following safety procedures when operating a band saw:

- Keep your fingers away from the moving blade.
- Keep the table clear of stock and scraps so your work will not catch as you push it along.

- Keep the upper guide just above the work, not excessively high.
- Ensure that the blade is not cracked. If a blade develops a click as it passes through the work, shut off the power. The click is a danger signal that the blade is cracked and may be ready to break. Shut off the power immediately and wait until the saw blade has stopped moving before you replace the cracked blade with one in proper condition.
- If the saw blade breaks, shut off the power immediately and wait until the machine is completely stopped before you attempt to remove any part of the saw blade.
- Make sure that the blade is working freely through the cut. If the work binds or pinches on the blade, wait until the machine is completely stopped before you attempt to back the work away from the blade; otherwise you may break the blade.
- Take particular care when sharpening or brazing a band saw blade. Make sure the blade is not overheated and the brazed joints are thoroughly united and finished to the same thickness as the rest of the blade. All band saw blades should be butt welded where possible.
- Use the band saw appropriately. Avoid the following:

  ∅ Using a band saw when the temperature is below 45° F. The blade may break from the cold.

  ∅ Using a small saw blade for large work or forcing a wide saw on a small radius. The saw blade should always be as wide as the nature of the work will permit.

  ∅ Stopping a band saw by thrusting a piece of wood against the cutting edge or side of the band saw blade immediately after the power has been shut off. This may cause the blade to break. Band saws with 36 inch wheel diameters and larger should have a hand or foot brake.

Test your Knowledge (Select the Correct Response)

14. A clicking sound develops while you are cutting material with a band saw. The sound is an indication of what blade problem?

    A. Binding
    B. Crack
    C. Pinch
    D. Too small

2.1.6 Drill Press

The ***drill press***, shown in *Figure 2-164*, is an electrically operated power machine originally designed as a metal working tool. Accessories such as jigs and special techniques make it a versatile woodworking tool as well.

The motor is mounted to a bracket at the rear of the head assembly and designed to permit V belt changing for desired spindle speed without removing the motor from its mounting bracket. Four spindle speeds are obtained by locating the V belt on any one of four steps of the spindle driven and motor driven pulleys. The belt tensioning rod keeps proper tension on the belt so it doesn't slip.

Figure 2-164 – Drill press.

The controls of all drill presses are similar. The terms right and left are relative to the operator's position standing in front of and facing the drill press. Forward applies to movement toward the operator. Rearward applies to movement away from the operator. Specific instructions on how to safely use the drill press are found in the manufacturers' documentation. The on/off switch is located in the front of the drill press for easy access.

The spindle and quill feed handles radiate from the spindle and quill pinion feed hub, which is located on the lower right-front side of the head assembly. Pulling forward and down on any one of the three spindle and quill feed handles, which point upward at the time, moves the spindle and quill assembly downward. Release the feed handle and the spindle and quill assembly return to the retracted or upper position by spring action.

The quill lock handle is located at the lower left-front side of the head assembly. Turn the quill lock handle clockwise to lock the quill at a desired operating position. Release the quill by turning the quill lock handle counterclockwise. However, in most cases, the quill lock handle will be in the released position.

The head lock handle is located at the left-rear side of the head assembly. Turn the head lock handle clockwise to lock the head assembly at a desired vertical height on the bench column. Turn the head lock handle counterclockwise to release the head assembly. When operating the drill press, you must ensure that the head lock handle is tight at all times.

The head support collar handle is located at the right side of the head support collar and below the head assembly. The handle locks the head support collar, which secures the head vertically on the bench column, and prevents the head from dropping when the head lock handle is released. Turn the head support collar lock handle clockwise to lock the support to the bench column and counterclockwise to release the support. When operating the drill press, ensure that the head support collar lock handle is tight at all times.

As you face the drill press, the tilting table lock handle is located at the right-rear side of the tilting table bracket. The lockpin secures the table at a horizontal or 45° angle. This allows you to move the table to the side, out of the way for long pieces of wood. The table support collar allows you to raise or lower the table. Turn the tilting table lock handle counterclockwise to release the tilting table bracket so it can be moved up and down or around the bench column. Lock the tilting table assembly at the desired height by turning the lock handle clockwise. When operating the drill press, ensure that the tilting table lock handle is tight at all times.

The adjustable locknut is located on the depth gauge rod. The purpose of the adjustable locknut is to regulate depth drilling. Turn the adjustable locknut clockwise to decrease the downward travel of the spindle. The locknut must be secured against the depth pointer when operating the drill press. The depth of the hole is shown on the depth scale.

2.1.7 Safety and Maintenance Considerations for Drill Presses

Observe the following safety precautions when operating a drill press:

- Make sure that the drill is properly secured in the chuck and that the chuck key is removed before starting the drill press.
- Make sure your material is properly secured.
- Operate the feed handle with a slow, steady pressure to make sure you don't break the drill bit or cause the V-belt to slip.
- Make sure all locking handles are tight and that the V-belt is not slipping.
- Make sure the electric cord is securely connected and in good shape.
- Make sure you are not wearing hanging or loose clothing.
- Listen for any sounds that may be signs of trouble.
- After you have finished operating the drill press, make sure the area is clean.

Test your Knowledge (Select the Correct Response)

15. On a drill press, which of the following features allows you to regulate drilling depth?

    A. Table lock handle
    B. Head lock handle
    C. Adjustable locknut
    D. Head support collar handle

2.1.8 Woodworking Lathe

The ***woodworking lathe*** is, without question, the oldest of all woodworking machines. In its early form, it consisted of two holding centers with the suspended stock rotated by an endless rope belt. It was operated by having one person pull on the rope hand over hand while the cutting was done by a second person holding crude hand tools on an improvised beam rest.

The actual operations of woodturning performed on a modern lathe are still done to a great degree with woodturner's hand tools. Machine lathe work is coming more and more into use with the introduction of newly designed lathes for that purpose.

The lathe is used in turning or shaping round drums, disks, and any object that requires a true diameter. The size of a lathe is determined by the maximum diameter of the work it can swing over its bed. There are various sizes and types of wood lathes, ranging from very small sizes for delicate work to large surface or bull lathes that can swing jobs 15 feet in diameter.

Figure 2-165 illustrates a type of lathe that you may find in your shop. It is made in three sizes to swing 16, 20, and 24 inch diameter stock. The lathe has four major parts; bed, headstock, tailstock, and tool rest.

The lathe shown in *Figure 2-165* has an iron bed and comes in assorted lengths. The bed is a broad, flat surface that supports the other parts of the machine.

Figure 2-165 – A woodworking lathe with accessories.

The headstock is mounted on the left end of the lathe bed. All power for the lathe is transmitted through the headstock. It has a fully enclosed motor that gives variable spindle speed. The spindle is threaded at the front end to receive the faceplate. A faceplate attachment to the motor spindle is furnished to hold or mount small jobs having large diameters. There is also a flange on the rear end of the spindle to receive large faceplates, which are held securely by four stud bolts.

The tailstock is located on the right end of the lathe and is movable along the length of the bed. It supports one end of the work while the other end is being turned by the headstock spur. The tail center can be removed from the stock by simply backing the screw. The shank is tapered to center the point automatically.

Most large lathes are provided with a power-feeding carriage. A cone-pulley belt arrangement provides power from the motor, and trackways are cast to the inside of the bed for sliding the carriage back and forth. All machines have a metal bar that can be attached to the bed of the lathe between the operator and the work. This serves as a hand tool rest and provides support for the operator in guiding tools along the work. It may be of any size and is adjustable to any desired position.

2.1.9 Safety and Maintenance Considerations for a Woodworking Lathe

Lathe turning can be extremely dangerous. You must use particular care in this work. Observe the following safety precautions:

- When starting the lathe motor, stand to one side. This helps you avoid the hazard of flying debris in the event of defective material.
- You must use the tool rest when milling stock.
- Adjust and set the compound or tool rest for the start of the cut before turning the switch on.
- Take very light cuts, especially when using hand tools.

- Never attempt to use calipers on interrupted surfaces while the work is in motion.

In lathe work, wood is rotated against the special cutting tools illustrated in *Figure 2-169*. These tools include turning gouges, skew chisels, parting tools, round nose, square nose, and spear point chisels. Other cutting tools are toothing irons and auxiliary aids, such as calipers, dividers, and templates.

Figure 2-166 – Lathe cutting tools.

Turning gouges are used chiefly to rough out nearly all shapes in spindle turning. The gouge sizes vary from 1/8 to 2 or more inches, with 1/4, 3/4, and 1 inch sizes being the most common.

Skew chisels are used for smoothing cuts to finish a surface, turning beads, trimming ends or shoulders, and for making V cuts. They are made in sizes from 1/8 to 2 1/2 inches in width and in right handed and left handed pairs.

Parting tools are used to cut recesses or grooves with straight sides and a flat bottom, and also to cut off finished work from the faceplate. These tools are available in sizes ranging from 1/8 to 3/4 inch.

The toothing iron, shown in *Figure 2-167*, is basically a square nose turning chisel with a series of parallel grooves cut into the top surface of the iron. These turning tools are used for rough turning of segment work mounted on the faceplate. The points of the toothing iron created by the parallel grooves serve as a series of spear point chisels. The toothing iron is made with coarse, medium, and fine parallel grooves and varies from 1/2 to 2 inches in width.

Figure 2-167 – Toothing iron lathe tool.

Test your Knowledge (Select the Correct Response)

16. When operating a woodworking lathe, which of the following practices is safe?

    A. Standing to one side when starting the motor
    B. Making adjustments with the motor running
    C. Using calipers on irregular surfaces while the lathe is in motion
    D. Milling stock freehand

2.1.10 Jointer

The ***jointer***, shown in *Figure 2-168*, is a machine for power planing stock on faces, edges, and ends. The size of a jointer is designated by the width in inches of the cutterhead, sizes range from 4 to 36 inches.

Figure 2-168 – Six inch jointer.

The planing is done by a revolving cutterhead equipped with two or more knives as shown in *Figure 2-169*. Tightening the set screws forces the throat piece against the knife for removal.

Figure 2-169 – Four-knife cutterhead for a jointer.

The principle on which the jointer functions is illustrated in *Figure 2-170*. The table consists of two parts on either side of the cutterhead. The stock is started on the infeed table and fed past the cutterhead onto the outfeed table. The surface of the outfeed table must be exactly level with the highest point reached by the knife edges. The surface of the infeed table is depressed below the surface of the outfeed table an amount equal to the desired depth of cut. The usual depth of cut is about 1/16 to 1/8 inch.

Figure 2-170 – Operating principle of a jointer.

2.1.11 Safety and Maintenance Considerations for a Jointer

The jointer is one of the most dangerous machines in the woodworking shop. Only experienced and responsible personnel should be allowed to operate it, using the following basic safety precautions:

- Always plane with the grain. A piece of wood planed against the grain on a jointer may be kicked back.
- Never place your hands directly over the inner cutterhead. Should the piece of wood kick back, your hands will drop on the blades. Start with your hands on the infeed bed. When the piece of wood is halfway through, reach around with your

left hand and steady the piece of wood on the outfeed bed. Finish with both your hands on the outfeed bed.

- Never feed a piece of wood with your thumb or finger against the end of the piece of wood being fed into the jointer. Keep your hands on top of the wood at all times.
- Avoid jointing short pieces of wood whenever possible. Joint a longer piece of wood and then cut it to the desired size. If you must joint a piece of wood shorter than 18 inches, use a push stick to feed it through the jointer.
- Never use a jointer with dull cutter blades. Dull blades have a tendency to kick the piece, and a kickback is always dangerous.
- Keep the jointer table and the floor around the jointer clear of scraps, chips, and shavings. Always stop the jointer before brushing off and cleaning up the scraps, chips, and shavings.
- Never joint a piece of wood that contains loose knots.
- Keep your eyes and undivided attention on the jointer as you are working. Do not talk to anyone while operating the jointer.

The level of the outfeed table must be checked frequently to ensure the surface is exactly even with the highest point reached by the knife edges. If the outfeed table is too high, the cut will become progressively shallower as the piece is fed through. If the outfeed table is too low, the piece will drop downward as it leaves the infeed table, and the cut for the last inch or so will be too deep.

To set the outfeed table to the correct height:

1. Feed a piece of waste stock past the cutterhead until a few inches of it lie on the outfeed table.
2. Stop the machine and look under the outfeed end of the piece. If the outfeed table is too low, there will be a space between the surface of the table and the lower face of the piece. Raise the outfeed table until this space is eliminated. If no space appears, lower the outfeed table until a space does appear.
3. Run the stock back through the machine. If there is still space, raise the table just enough to eliminate it.

Note that the cutterhead cuts toward the infeed table. To cut with the grain you must place the piece with the grain running toward the infeed table. A piece is edged by feeding it through on edge with one of the faces held against the fence. A piece is surfaced by feeding it through flat with one of the edges against the fence. This operation should be limited to straightening the face of the stock. The fence can be set at 90° to produce squared faces and edges or at any desired angle to produce beveled edges or ends.

Only use sharp and evenly balanced knives in a jointer cutting head. The knives must not be set to take too heavy a cut because a kickback is almost certain to result, especially if there is a knot or change of grain in the stock. You must be securely refasten the knives after the machine has been standing in a cold building over the weekend.

Each hand fed jointer should be equipped with a cylindrical cutting head, the throat of which should not exceed 7/16 inch in depth or 5/8 inch in width. It is strongly recommended that no cylinder be used in which the throat exceeds 3/8 inch in depth or 1/2 inch in width.

Each hand fed jointer should have an automatic guard that covers all the sections of the head on the working side of the fence or gauge. The guard should automatically adjust horizontally for edge jointing and vertically for surface work, and it should remain in contact with the material at all times.

Test your Knowledge (Select the Correct Response)

17. Setting jointer knives at too heavy a cut can cause which of the following problems?

    A. The jointer to stop
    B. Gaps in the spindle
    C. Kickback
    D. A sharp edge to form on the outfeed table

2.1.12 Surfacer

A single ***surfacer***, also called a single planer, is shown in *Figure 2-171*. This machine surfaces stock on one face, the upper face, only. Double surfacers, which surface both faces at the same time, are used only in large planing mills.

The single surfacer cuts with a cutterhead like the one on the jointer, but on the single surfacer, the cutterhead is located above instead of just below the drive rollers. The part adjacent to the cutterhead is pressed down against the feed bed by the chip breakers just ahead of the cutterhead and the pressure bar just behind the cutterheads. The pressure bar temporarily straightens out any warp a piece may have; a piece that goes into the surfacer warped will come out still warped. This is not a defect in the machine; the surfacer is designed for surfacing only, not for truing warped stock.

Figure 2-171 – Single surfacer.

If you desire true plane surfaces, one face of the stock, the face that goes down in the surfacer, must be trued on the jointer before feeding the piece through the surfacer. If the face that goes down in the surfacer is true, the surfacer will plane the other face true.

2.1.13 Safety and Maintenance Considerations for a Surfacer

Observe the following safety precautions when operating a surfacer:

- The cutting head should be covered by metal guards.
- Feed rolls should be guarded by a hood or a semicylindrical guard.
- Never force wood through the machine.
- If a piece of wood gets stuck, turn off the surfacer and lower the feed bed.

Test your Knowledge (Select the Correct Response)

18. A piece of material becomes stuck during surfacing. Which of the following procedures should you follow to remove it?

    A. Stop the surfacer and lower the feed bed
    B. Stop the surfacer and push out the material
    C. Keep the surfacer running and pull out the material
    D. Keep the surfacer running and use another piece of stock to push out the material

2.1.14 Shaper

The ***shaper*** is designed primarily for edging curved stock and for cutting ornamental edges, as on moldings. It can also be used for rabbeting, grooving, fluting, and beading.

For shaping the side edges on a rectangular piece, a light-duty shaper has an adjustable fence, like the one shown on the shaper in *Figure 2-172*. For shaping the end edges on a rectangular piece, a machine of this type has a sliding fence similar to the cutoff gauge on a circular saw. The sliding fence slides in the groove shown in the table top.

Figure 2-172 – Light-duty shaper with adjustable fence.

On larger machines, the fence consists of a board straightedge, clamped to the table with a hand screw, as shown in *Figure 2-173*. A semicircular opening is sawed in the edge of the straightedge to accommodate the spindle and the cutters. Whenever possible, a guard of the type shown in the figure should be placed over the spindle.

For shaping curved edges, there are usually a couple of holes in the table, one on either side of the spindle, into which vertical starter pins can be inserted. When a curved edge is being shaped, the piece is guided by and steadied against the starter pin and the ball bearing collar on the spindle.

Figure 2-173 – Heavy-duty shaper with fence and guard.

Figure 2-174 shows a flat cutter for a shaper. When it is in use, the cutter is mounted on a vertical spindle and held in place by a hexagonal spindle nut. A grooved collar is placed below and above the cutter to receive the edges of the knives. Ball bearing collars are available for use as guides on irregular work where the fence is not used. The part of the edge that is to remain uncut runs against a ball bearing collar underneath the cutter. Cutters come with cutting edges in a great variety of shapes.

Figure 2-174 – Three-wing cutter for a shaper.

2.1.15 Safety and Maintenance Considerations for a Shaper

When operating a shaper, observe the following safety precautions:

- Like the jointer and surfacer, the shaper cuts toward the infeed side of the spindle; this is against the rotation of the spindle.
- Make sure the cutters are sharp and well secured.

- If shaping curved or irregularly shaped edges, place the stock in position and make sure the collar will rub against part of the edge, which you should not remove.
- Whenever the straight fence cannot be used, always use a starting pin in the table top.
- Never make extremely deep cuts.
- Make sure the shaper cutters rotate toward the pressure bar, hold down, or holding jig.
- If possible, place the cutter on the shaper spindle so that the cutting will be done on the lower side of the stock.
- Do not attempt to shape small pieces of wood.
- Check all adjustments before turning on the power.

CAUTION

The spindle shaper is one of the most dangerous machines used in the shop. Use extreme caution at all times.

2.2.0 Portable Hand Tools

In addition to using power shop tools, you will be required to operate different types of portable hand tools in the field. You need to understand the safety precautions associated with them.

2.2.1 Portable Power Drills

Portable ***power drills*** have generally replaced hand tools for drilling holes because they are faster and more accurate. With variable speed controls and special clutch drive chucks, they can also be used as electric screwdrivers. More specialized power driven screwdrivers are also available; these have greatly increased the efficiency of many fastening operations in construction work.

The two basic designs for portable electric drills are the spade design for heavy-duty construction, shown in *Figure 2-175*, and the pistol grip design for lighter work, shown in *Figure 2-176*. Sizes of power drills are based on the diameter of the largest drill shank that will fit into the chuck of the drill.

Figure 2-175 – Heavy duty portable power drill.

Figure 2-176 – Light duty portable power drill.

2.2.2 Safety and Maintenance Considerations for Portable Power Drills

Use the following guidelines when working with portable power drills:

- Make sure that the drill or bit is securely mounted in the chuck.
- Hold the drill firmly as prescribed by the manufacturer of the drill.
- When feeding the drill into the material, vary the pressure you apply to accommodate the different kinds of stock. Be careful not to bind the drill or bit.
- When drilling a deep hole, withdraw the drill several times to clean the drill bit.

The right angle drill, shown in *Figure 2-177*, is a specialty drill used in plumbing and electrical work. It allows you to drill holes at a right angle to the drill body.

Figure 2-177 – Right angle drill.

2.2.3 Portable Electric Circular Saw

The portable electric ***circular saw*** is used chiefly as a great labor saving device in sawing wood framing members on the job. The size of a circular saw is determined by the diameter of the largest blade it can use. The most commonly used circular saws are the 7 1/4 inch and 8 1/4 inch saws. There are two different types of circular saws*;* the side drive shown in *Figure 2-178,* and the worm drive shown in *Figure 2-179*.

Figure 2-178 – Side drive circular saw. **Figure 2-179 – Worm drive circular saw.**

Circular saws can use many different types of cutting blades, some of which are shown in *Figure 2-180*.

Combination Crosscut and Rip Blades – Combination blades are all purpose blades for cutting thick and thin hardwoods and softwoods, both with or across the grain. They can also be used to cut plywood and hardboard.

Crosscut Blades – Crosscut blades have fine teeth that cut smoothly across the grain of both hardwood and softwood. These blades can be used for plywood, veneers, and hardboard.

Rip Blades – Rip blades have bigger teeth than combination blades, and should be used only to cut with the grain. A rip fence or guide will help you make an accurate cut with this type of blade.

Hollow-Ground Blades – Hollow ground blades have no set. They make the smoothest cuts on thick or thin stock. Wood cut with these blades requires little or no sanding.

Abrasive Blades – Abrasive blades are used for cutting metal, masonry, and plastics. These blades are particularly useful for scoring bricks so they can be easily split.

Figure 2-180 – Circular saw blades.

Make sure that the abrasive blade you choose has an RPM rating at or above the RPM rating of the saw. If the blade RPM rating is lower than the RPM rating of the saw, the blade can shatter or break, possibly causing injury or damage.

2.2.4 Safety and Maintenance Considerations for Portable Electric Circular Saws

Observe the following safety precautions when operating a circular saw:

- Wear goggles or face shields while using the saw and while cleaning up debris afterward.
- Before using the saw, carefully examine the material to be cut and free it of nails or other metal objects. Avoid cutting into or through knots, if possible.

- Inspect daily the electric cords that you use to make sure there are no cuts or breaks. Before cutting boards, make sure the cord is not in the way of the blade.
- Make sure all circular saws are equipped with guards that automatically adjust themselves to the work when in use so that none of the teeth protrude above the work. Adjust the guard over the blade so that it slides out of its recess and covers the blade to the depth of the teeth when you lift the saw off the work.
- Disconnect the saw from its power source before making any adjustments or repairs to the saw. This includes changing the blade.
- Grasp the saw with both hands and hold it firmly against the work. Take care to prevent the saw from breaking away from the work and thereby causing injury.
- Avoid forcing the saw through heavy cutting stock. You may overload the motor and damage it.
- Inspect the blade at frequent intervals and always after it has locked, pinched, or burned the work. Disconnect the saw from the power source before performing this inspection.

Figure 2-181 shows how versatile the circular saw can be. To make an accurate ripping cut (*A*), set the ripping guide a distance away from the saw equal to the width of the strip to be ripped off. Then place it against the edge of the piece as a guide for the saw. To make a bevel angle cut up to 45° (*B*), just set the bevel adjustment knob to the angle you want and cut down the line. To make a pocket cut (*C and D*), a square cut in the middle of a piece of material, retract the guard back and tilt the saw so that it rests on the front of the base. Then, lowering the rear of the saw into the material, hold it there until it goes all the way through the wood. Then, follow your line.

Figure 2-181 – Different ways to use a circular saw.

Test your Knowledge (Select the Correct Response)

19. When cutting materials with a portable electric circular saw, you should use which of the following procedures?

    A. Hold the saw with the right hand and guide the work with the left hand
    B. Hold the saw with both hands firmly against the work
    C. Hold the saw with both hands after removing the blade guard
    D. Hold the saw with both hands lightly against the work

2.2.5 Saber Saw

The ***saber saw***, shown in *Figure 2-182*, is a power-driven ***jigsaw*** that cuts smooth and decorative curves in wood and light metal. Most saber saws are light-duty machines and are not designed for extremely fast cutting.

Figure 2-182 – Saber saw.

There are several different, easily interchangeable blades, as shown in *Figure 2-183*, designed to operate in the saber saw. Some blades are designed for cutting wood and some for cutting metal.

Figure 2-183 – Saber saw blades.

The best way to learn how to handle this type of tool is to use it. Before trying to do a finished job with the saber saw, clamp down a piece of scrap plywood and draw some curved as well as straight lines to follow. You will develop your own way of gripping the tool, which will be affected somewhat by the particular tool you are using. On some tools, for example, you will find guiding easier if you apply some downward pressure on the tool as you move it forward. If you don't use a firm grip, the tool will tend to vibrate excessively and roughen the cut. Do not force the cutting faster than the design of the blade allows or you will break the blade.

You can make a pocket cut with a saber saw just like you can with a circular saw, although you need to drill a starter hole to begin work. A saber saw can also make bevel-angle and curve cuts.

2.2.6 Safety and Maintenance Considerations for a Saber Saw

Observe the following safety precautions when operating the saber saw:

- Before working with the saber saw, be sure to remove your rings, watches, bracelets, and other jewelry.
- If you are wearing long sleeves, roll them up.
- Be sure the saber saw is properly grounded.
- Use the proper saw blade for the work to be done, and ensure the blade is securely locked in place.
- Be sure the material to be cut is free of any obstructions.
- Keep your full attention on the work being performed.
- Grip the handle of the saw firmly. Control the forward and turning movements with your free hand on the front guide.
- To start a cut, place the forward edge of the saw base on the edge of the material being worked, start the motor, and move the blade into the material.

2.2.7 Portable Reciprocating Saw

The portable ***reciprocating saw*** (sawzall), shown in *Figure 2-184*, is a heavy duty power tool used for a variety of woodworking maintenance work, remodeling, and roughing in jobs. You can use it to cut rectangular openings, curved openings, along straight or curved lines, and flush.

Blades for reciprocating saws are made in a great variety of sizes and shapes. They vary in length from 2 1/2 to 12 inches and are made of high speed steel or carbon steel. They have cutting edges similar to those shown in *Figure 2-183*.

Figure 2-184 – Reciprocating saw.

2.2.8 Safety and Maintenance Considerations for Reciprocating Saws

Observe the following safety precautions when operating a reciprocating saw:

- Disconnect the saw when changing blades or making adjustments.
- Place the foot of the saw firmly on the stock before starting to cut.

- Use the reciprocating saw appropriately. Avoid the following:
  - ∅ Cutting curves sharper than the blade can handle.
  - ∅ Cutting electrical wires when you cut through a wall.

Before operating this saw, be sure you are using a blade that is right for the job. The manufacturer's instruction manual shows the proper saw blade to use for a particular material. The blade must be pushed securely into the opening provided. Rock it slightly to ensure a correct fit, and then tighten the setscrew.

To start a cut, place the saw blade near the material to be cut. Then, start the motor and move the blade into the material. Keep the cutting pressure constant, but do not overload the saw motor. Never reach underneath the material being cut.

2.2.9 Router

The ***router*** is a versatile portable power tool that can be used free hand or with jigs and attachments. *Figure 2-185* shows a router typical of most models. It consists of a motor containing a chuck into which the router bits are attached. The motor slides into the base in a vertical position. By means of the depth adjustment ring, easy regulation of the depth of a cut is possible. Routers vary in size from 1/4 to 2 1/2 horsepower, and the motor speed varies from 18,000 to 27,000 rpm.

Figure 2-185 – Portable router with edge guide.

One of the most practical accessories for the router is the edge guide. It is used to guide the router in a straight line along the edge of the board. The edge guide is particularly useful for cutting grooves on long pieces of lumber. The two rods on the edge guide slip into the two holes provided on the router base. The edge guide can be adjusted to move in or out along the two rods to obtain the desired lateral depth cut.

2.2.10 Safety and Maintenance considerations for a Router

Observe the following safety precautions when operating a router:

- Before operating a router, be sure the work piece is well secured and free of obstruction.
- Make sure the router is disconnected from the power source before making any adjustment or changing bits.
- Use both hands to hold the router when cutting material.
- Avoid overloading the router when cutting the material.

There are two classifications of router bits. Built in, shank type bits fit into the chuck of the router. Screw type bits have a threaded hole through the center of the cutting head, which allows the cutting head to be screwed to the shank. *Figure 2-186* shows a few of the most common router bits.

Figure 2-186 – Router bits.

2.2.11 Portable Power Plane

The portable electric power plane, shown in *Figure 2-187*, is widely used for trimming panels, doors, frames, and so forth. It is a precision tool capable of exact depth of cut up to 3/16 inch on some of the heavier models. The maximum safe depth of cut on any model is 3/32 inch in any one pass. The power plane is a high speed motor that drives a cutter bar, containing either straight or spiral blades, at high speed.

Figure 2-187 – Portable electric power plane.

2.2.12 Safety and Maintenance Considerations for a Power Plane

Observe the following safety precautions when operating a portable power plane:

- Make sure that the plane is turned off before plugging it in.
- Make sure you disconnect the plug before making any adjustment.
- Always clamp your work securely in the best position to perform the planing.
- Use both hands to operate the power plane.
- Make sure you disconnect the power cord when you are finished planing.

2.2.13 How to Use a Power Plane

Operating the power plane is a matter of setting the depth of cut and passing the plane over the work.

1. Make careful measurements of the piece and where it is to fit, and determine how much material has to be removed.
2. The stock being planed should be held in a vise, clamped to the edge of a bench, or otherwise firmly held.
3. Check the smoothness and straightness of all the edges.

If a smoothing cut is desired, make that cut first and then recheck the dimensions. Make as many passes as necessary with the plane to reach the desired dimensions. Check frequently so you don’t remove too much material. The greater the depth of the cut, the more slowly you must feed the tool into the work. Feed pressure should be enough to keep the tool cutting, but not so much as to slow it down excessively. Keep wood chips off the work because they can mar the surface of the stock as the tool passes over them. Keep your hands away from the cutterhead or blades when a cut is finished.

The L shaped base, or fence, of the plane should be pressed snugly against the work when planing; assuring that the edge will be cut square. For bevel cuts, loosen the setscrew on the base, set the base at the desired bevel, and then retighten the setscrew.

2.2.14 Portable Sanders

There are three types of portable sanders: belt, disk, and finish sanders. When using a belt sander like the one shown in *Figure 2-188*, be careful not to gouge the wood. The size of a belt sander is usually identified by the width of its sanding belt. Belt widths on heavier duty models are usually 3 or 4 inches. Depending on the make and model, belt lengths vary from 21 to 27 inches. Different grades of abrasives are available.

Figure 2-188 – Belt sander.

The ***disk sander***, shown in *Figure 2-189*, is a useful tool for removing old finish, paint and varnish from siding, wood flooring, and concrete. For best results with a disk sander, tip the machine lightly with just enough pressure to bend the disk. Use a long, sweeping motion, back and forth, advancing along the surface. When using a disk sander, always operate it with both hands.

Figure 2-189 – Portable disk sander.

Finish sanders are used for light and fine sanding. Two kinds of finish sanders are available. One operates with an orbital (circular) motion as shown in *Figure 2-190*; the other has an oscillating (back and forth) movement as shown in *Figure 2-191*. Finish sanders use regular abrasive paper (sandpaper) cut to size from full sheets.

2.2.15 Safety and Maintenance Considerations for Portable Sanders

Observe the following safety tips when operating portable sanders:

- Make sure the sander is off before plugging it in.
- Make sure the sander is disconnected when changing sandpaper.
- Make sure that you use two hands when using the belt sander.
- Use light pressure on the sander. The weight of the sander is enough to sand the material.
- Keep the electrical cord away from the area being sanded.

Figure 2-190 – Orbital finish sander.

Figure 2-191 – Oscillating finish sander.

3.0.0 POWDER ACTUATED TOOLS

Powder actuated tools are used in construction to join materials to hard substrates such as concrete and steel; they are also known as direct fastening tools. Each of these tools hold a charge of gunpowder, which is ignited and blows the fastener into place.

Powder-actuated tools come in either low-velocity or high-velocity types. Low-velocity tools introduce a piston into the chamber. The propellant acts on the piston, which then drives the fastener into the substrate. A powder-actuated tool is considered to be low-velocity if the average test velocity of the fastener does not exceed 492 feet per second. In high-velocity tools, which are now illegal to manufacture and/or sell in the United States, the propellant acts directly on the fastener, very similar to how a firearm works. Although high-velocity tools are now illegal to manufacture and sell, some that were made decades ago are still in use in the shipbuilding and steel industries.

Powder-actuated fasteners are usually nails made of high-quality, hardened steel, although there are many specialized fasteners designed for specific applications in the construction and manufacturing industries. Powder actuated fastening is a unique and very cost-efficient method used in a variety of construction situations from home building to large urban structures.

Powder-actuated technology was developed for commercial use during the Second World War, when high-velocity fastening systems were used to temporarily repair damage to ships. In the case of hull breach, these tools would be used to fasten a plate of steel over the damaged area.

3.1.1 Safety and Maintenance Considerations for Powder Actuated Tools

Powder actuated tools are very dangerous, and it is critically important that they are used properly and safely. OSHA requires that safety training be completed by any user before they work with powder actuated tools. A summary of OSHA requirements follows:

- Powder actuated fastening tools shall be tested each day before loading to ensure that the safety devices are in proper working condition. Any tool found not to be in proper working order shall be immediately removed from service until repairs are made.
- Powder actuated fastening tools shall not be used in an explosive or flammable atmosphere.
- All tools shall be used with the type of shield or muzzle guard appropriate for a particular use.
- Fasteners shall not be driven into very hard or brittle materials such as cast iron, glazed tile, surface hardened steel, glass block, live rock, face brick or hollow title.
- Fasteners shall not be driven into soft materials unless such materials are backed by a substance that will prevent the pin or fastener from passing completely through and creating a flying missile hazard on the opposite side.

- Unless a special guard, fixture or jig is used, fasteners shall not be driven directly into materials such as brick or concrete within 3 inches of the unsupported edge or corner, or into steel surfaces within 1/2 inch of the unsupported edge or corner. When fastening other material, such as 2 x 4 inch lumber to a concrete surface, fasteners of greater than 7/32 inch shank diameter shall not be used and fasteners shall not be driven within 2 inches of the unsupported edge or corner of the work surface.
- Fasteners shall not be driven through existing holes unless a positive guide is used to secure accurate alignment.
- No attempt shall be made to drive a fastener into a spalled area caused by an unsatisfactory fastening.
- Seabees using powder actuated fastening tools shall be protected by personal protective equipment in accordance with the requirements of subpart I of this part.
- Before Seabees are permitted to use powder actuated tools, they shall have been thoroughly instructed by a competent person in the safe use of such tools as follows:
  - Before using a tool, the operator shall inspect it to determine that it is clean, that all moving parts operate freely, and that the barrel is free from obstructions.
  - When a tool develops a defect during use, the operator shall immediately cease to use it and shall notify his supervisor.
  - Tools shall not be loaded until just prior to the intended firing time and the tool shall not be left unattended while loaded.
  - The tool, whether loaded or empty, shall not be pointed at any person, and hands shall be kept clear of the open barrel end.
  - In case of a misfire, the operator shall hold the tool in the operating position for at least 15 seconds and shall continue to hold the muzzle against the work surface during disassembly or opening of the tool and removal of the powder load.
  - Neither tools nor powder charges shall be left unattended in places where they would be available to unauthorized persons.

The Powder Actuated Tool Manufacturers' Institute, Inc. (PATMI) is an association that provides a common industry voice for manufacturers of powder actuated fastening systems. With operator safety as the primary goal of the organization, PATMI stresses training, certification, and safety awareness.

A few powder actuated tools available for building construction are shown in *Figure 2-192*.

Figure 2-192 – Powder actuated tools.

Test your Knowledge (Select the Correct Response)

20. **(True or False)** Powder actuated tools can be used in an explosive or flammable atmosphere.

    A. True
    B. False

4.0.0 PNEUMATIC TOOLS

Pneumatic tools are driven by gas, usually compressed air supplied by a gas canister or compressor. The amount of pneumatic, or air, pressure required to operate the tool depends on the size of the tool and the type of operation you are performing. Check the manufacturer's manual for the proper air pressure to operate the tool.

Pneumatic tools can also run on compressed carbon dioxide (CO_2) stored in small canisters, which allows for greater portability. Pneumatic tools are generally cheaper and safer to run and maintain than the equivalent electric power tool. They have a higher power to weight ratio, allowing a smaller, lighter tool to accomplish the same task. The most common pneumatic tools used in construction are nailers and staplers.

4.1.1 Safety and Maintenance Considerations for Power Nailers and Staplers

The power nailer and power stapler are great timesaving tools, but they are also very dangerous tools. Observe the following safety precautions when using them:

- Use the correct air pressure for the particular tool and job.
- Use the right nailer or stapler for the job, along with the correct nails or staples.
- Keep the nose of the tool pointed away from your body or other people.
- When you are not using a nailer or stapler or if you are loading one, disconnect the air supply.

4.1.2 Power Nailers and Staplers

There is a wide variety of power nailers and staplers available. A heavy duty nailer, shown in *Figure 2-193*, is used for framing or sheathing work, finish nailers are used for paneling or trimming.

Figure 2-193 – Heavy duty nailer.

There is also a wide variety of staplers, like the one shown in *Figure 2-194*, that you can use for jobs, such as fastening sheeting, decking, or roofing.

Figure 2-194 – Heavy duty stapler.

5.0.0 BUILDER TOA KITS

The Naval Construction Battalion Table of Allowances (NMCB TOA-01) lists the various kits available for Seabee projects. *Table 2-3* below lists some of the more commonly used Seabee tool kits. You can check what is currently included in each kit on the internet on the Advanced Base Functional Component (ABFC View) of the Naval Facilities Engineering Command's Expeditionary Logistics Center (NAVFAC). Keep in mind that this is a view only version, updates to the kit contents are made by NFELC.

Table 2- 3 Seabee Tool Kits.

Kit Number	Kit Description
80010	Kit Surveyors Equipment
80010M	Kit Surveyors Equipment
80019	Kit Carpenters Tools F/4 Men
80019MDSU	Mobile Diving and Salvage Unit (MDSU) Carpenters Equipment
80019UCT	Underwater Construction Team (UCT) Carpenters Kit
80019V	Kit Carpenters Tools F/4 Men
80020	Kit Mason Tools F/4 Men
80026	Kit Soils
80041	Kit Heavy Timber Construction Tools F/4 Men
80051	Kit Pioneer and Rigging Tools
80056	Kit Concrete Placement
80056V	Kit Concrete Placement
80063	Kit Construction Tools Mini
80063UCT	Underwater Construction Team (UCT) Construction Tools
80064UCT	Underwater Construction Team (UCT) Engineering Aid Mini Kit
80065	Kit Carpenters Power Tools Cordless
80065V	Kit Carpenters Power Tools Cordless
80086	Kit Nailer Fuel Cell
80094	Kit Carpenters F/2 Men
80099	Survey Instruments Total Station

80110	Kit Planning and Estimating (P&E)
80122	Kit Carpenter for *Power Supply Unit or Primary Sampling Unit* (PSU)
80127	Kit Concrete Testing (Supplements Kit 80026)
80129	Kit Small Tools
80175V	Kit Carpenters Squad F/4 Person Tool
80176V	Kit Nailer Pneu w/ Compressor 2/Person Tool
80177V	Kit Multi Saw and Drill (1/2 inch) Tool
80181V	Kit Cordless 36Volt Multi Tools

Navigate to the ABFC View on NAVFAC using the following instructions:

1. Link to the Review Assembly page: 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 2-195*.

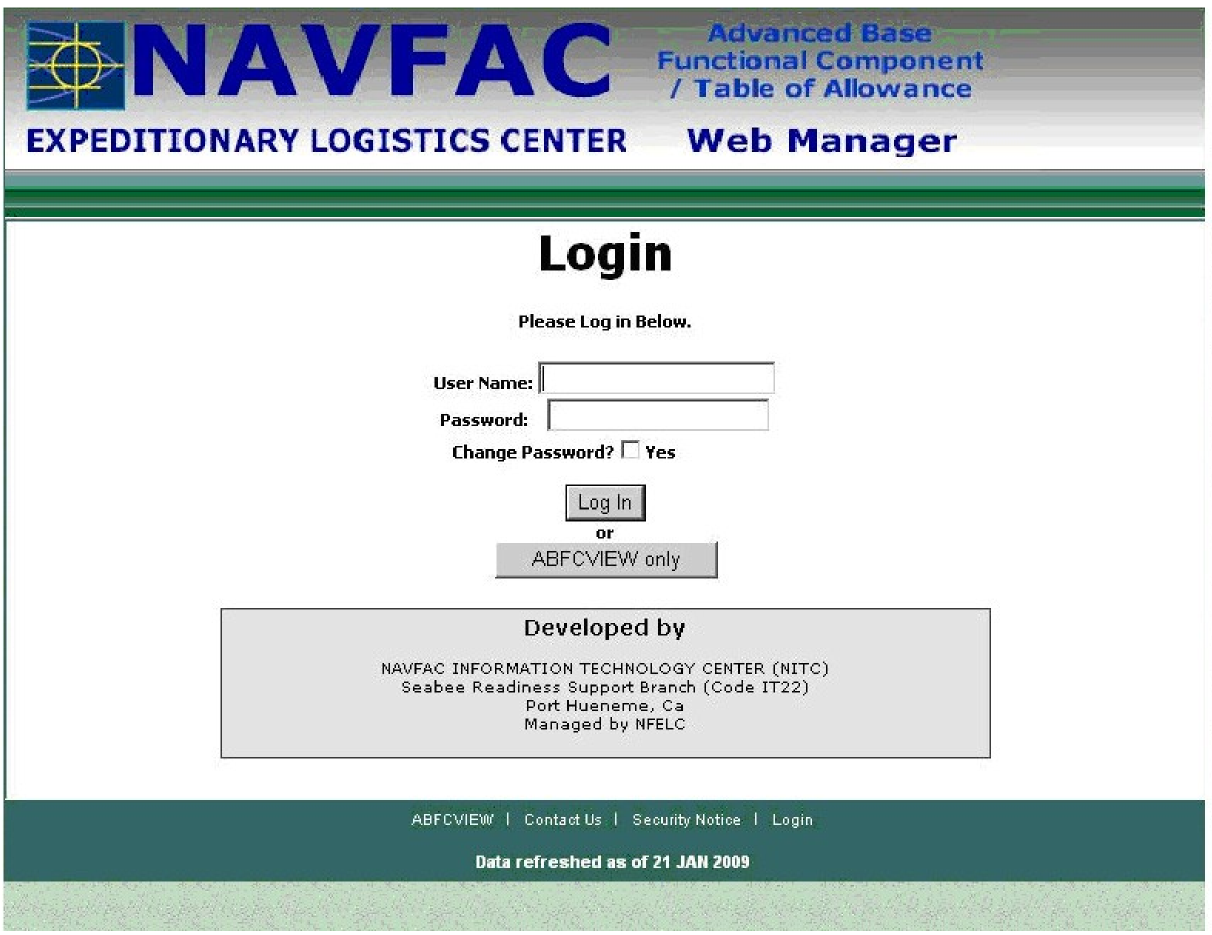


Figure 2-195 – ABFC login screen.

2. Click on 

.

You will see the About ABFC/TOA Planning Information screen shown in *Figure 2-196*.

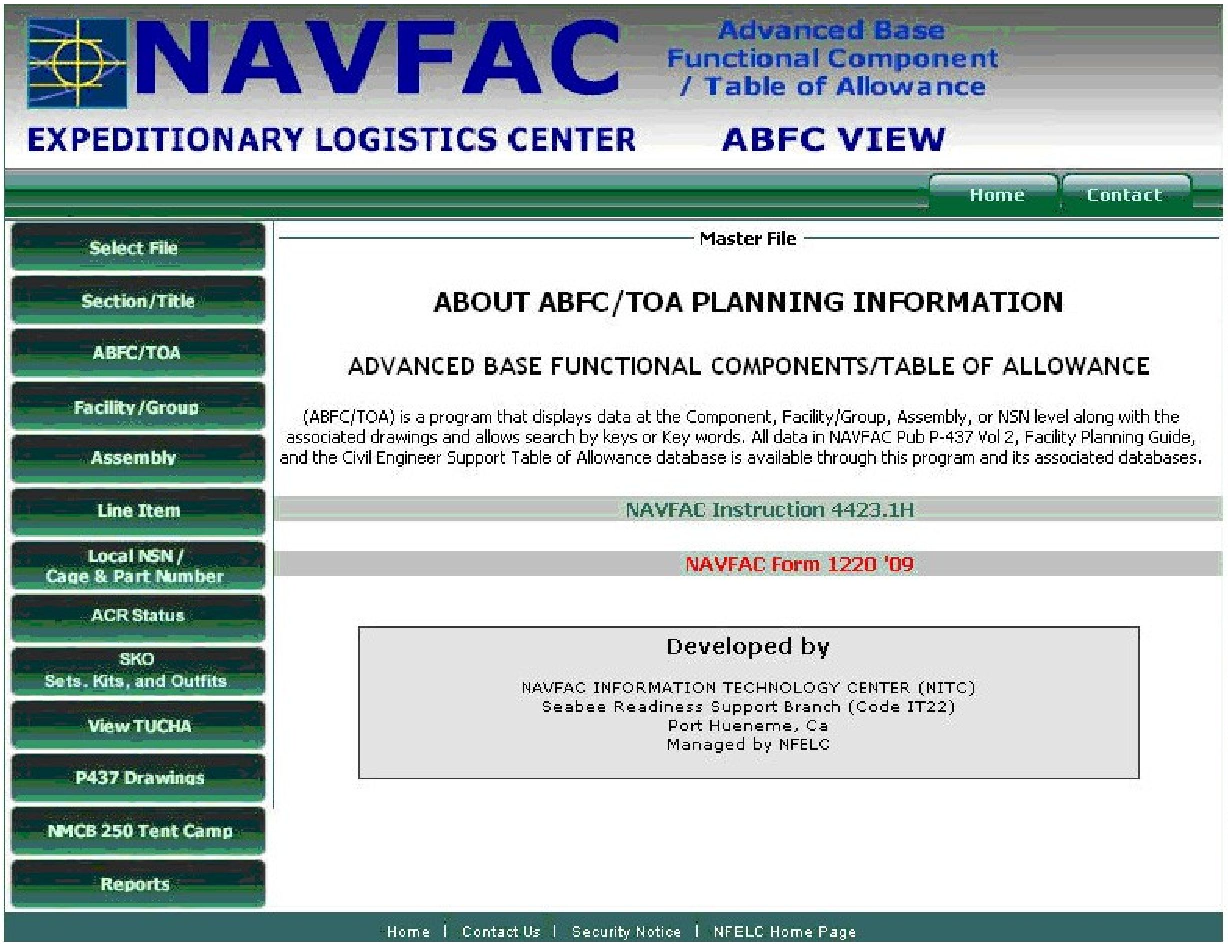


Figure 2-196 – About ABFC/TOA Planning Information screen.

3. Select the  option.

You will see the ABFC Assembly screen shown in *Figure 2-197*.

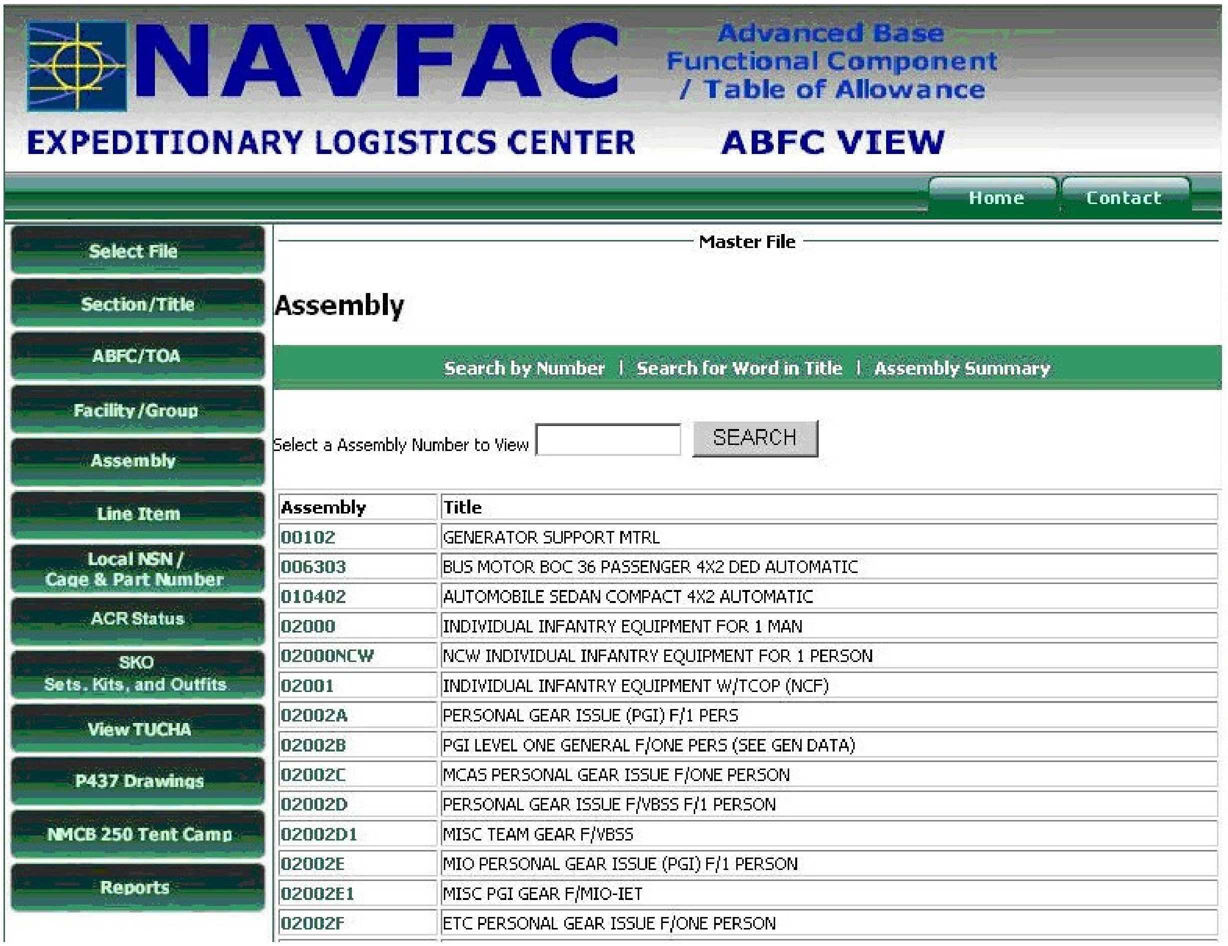


Figure 2-197 – ABFC Assembly screen.

4. You can use several methods to search for the kit you need. If you know the kit number, enter the kit number from *Table 2-3* in the input box. *Figure 2-198* shows how to search for Kit 19.

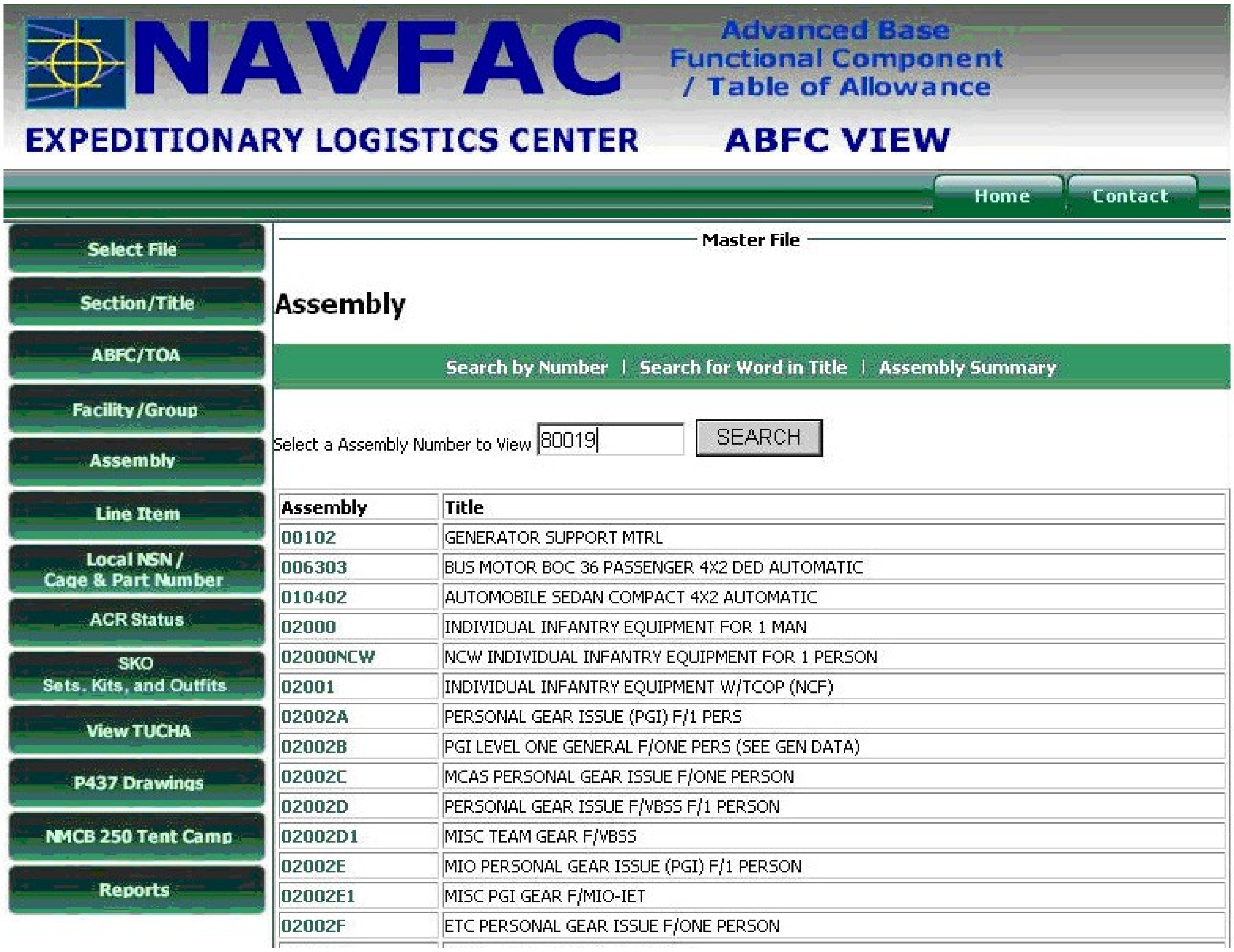


Figure 2-198 – Using the ABFC Assembly screen to search by number.

5. Click on SEARCH.

There are several other options for searching:

- Select from List
  - o Scroll down the screen.
  - o Select the kit number you want from the Assembly Number column.
- Search for Word in Title
  - o Select "Search for Word in Title".
  - o Enter the word you want to search for in the Title Search Words box shown in *Figure 2-199*. In this case we are searching for concrete.

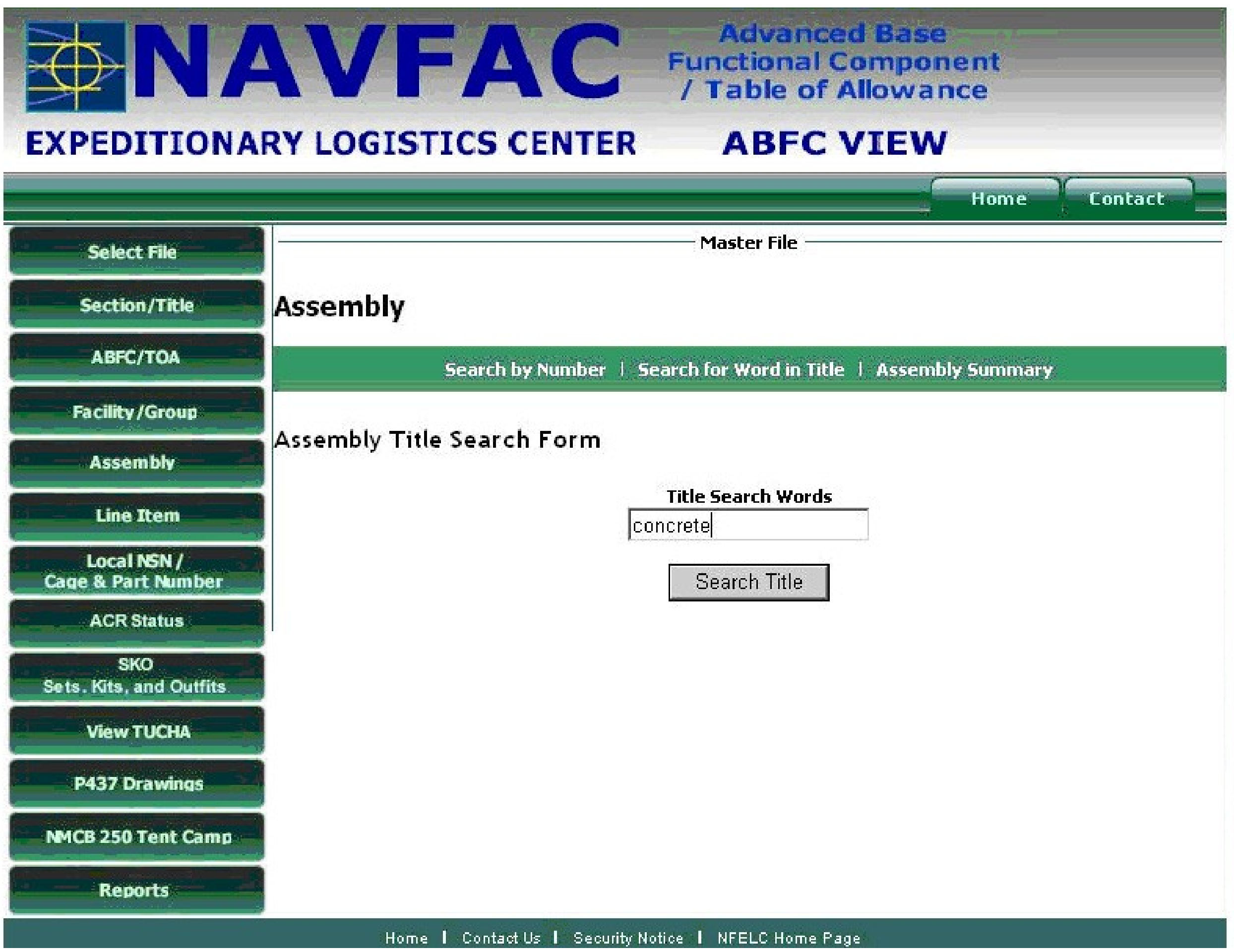
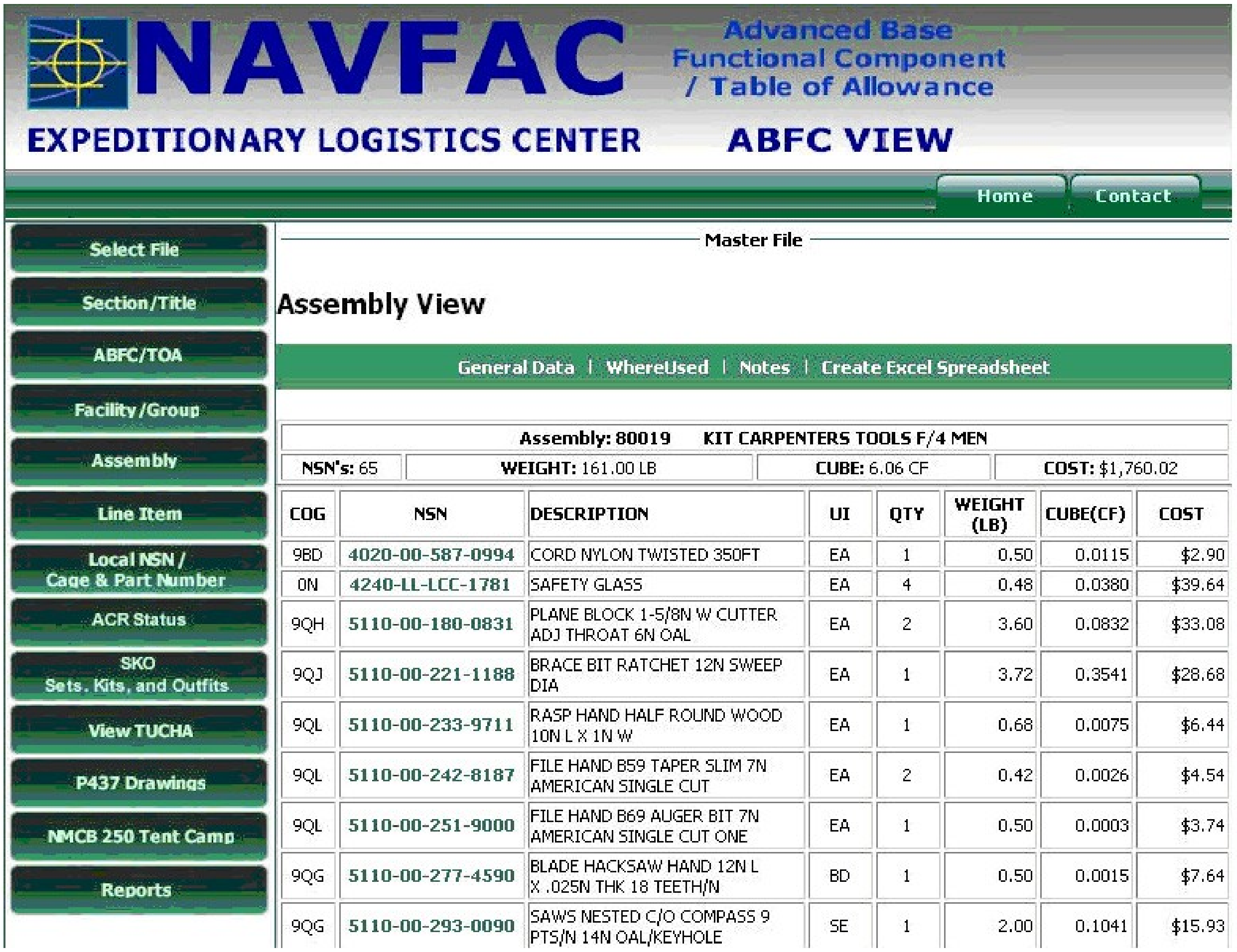


Figure 2-199 – Using the ABFC Assembly screen to search by a word in the title.

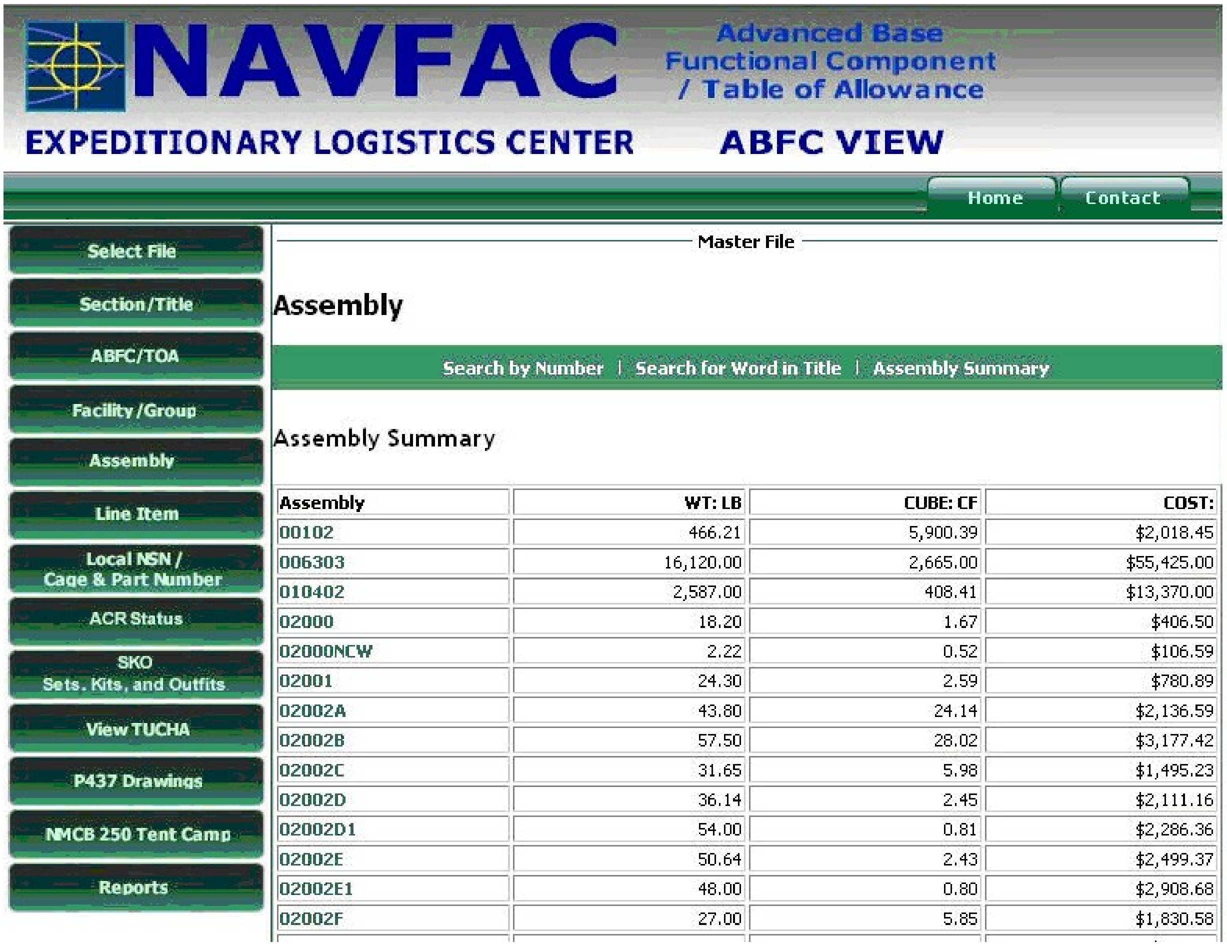
No matter which search option you use, eventually you will see the Assembly View screen shown below. *Figure 2-200* shows you the details of what is included in the kit. You can scroll through this screen to see all of the components of the kit.



COG	NSN	DESCRIPTION	UI	QTY	WEIGHT (LB)	CUBE(CF)	COST
9BD	4020-00-587-0994	CORD NYLON TWISTED 350FT	EA	1	0.50	0.0115	$2.90
0N	4240-LL-LCC-1781	SAFETY GLASS	EA	4	0.48	0.0380	$39.64
9QH	5110-00-180-0831	PLANE BLOCK 1-5/8N W CUTTER ADJ THROAT 6N OAL	EA	2	3.60	0.0832	$33.08
9QJ	5110-00-221-1188	BRACE BIT RATCHET 12N SWEEP DIA	EA	1	3.72	0.3541	$28.68
9QL	5110-00-233-9711	RASP HAND HALF ROUND WOOD 10N L X 1N W	EA	1	0.68	0.0075	$6.44
9QL	5110-00-242-8187	FILE HAND B59 TAPER SLIM 7N AMERICAN SINGLE CUT	EA	2	0.42	0.0026	$4.54
9QL	5110-00-251-9000	FILE HAND B69 AUGER BIT 7N AMERICAN SINGLE CUT ONE	EA	1	0.50	0.0003	$3.74
9QG	5110-00-277-4590	BLADE HACKSAW HAND 12N L X .025N THK 18 TEETH/N	BD	1	0.50	0.0015	$7.64
9QG	5110-00-293-0090	SAWS NESTED C/O COMPASS 9 PTS/N 14N OAL/KEYHOLE	SE	1	2.00	0.1041	$15.93

Figure 2-200 – ABFC Assembly View screen.

There is a way to get a summary of the TOA kits, showing the assembly number, weight in pounds, volume in cubic feet, and cost in dollars. This is done by selecting "Assembly Summary". The results of this selection are shown in *Figure 2-201*.



Assembly	WT: LB	CUBE: CF	COST:
00102	466.21	5,900.39	$2,018.45
006303	16,120.00	2,665.00	$55,425.00
010402	2,587.00	408.41	$13,370.00
02000	18.20	1.67	$406.50
02000NCW	2.22	0.52	$106.59
02001	24.30	2.59	$780.89
02002A	43.80	24.14	$2,136.59
02002B	57.50	28.02	$3,177.42
02002C	31.65	5.98	$1,495.23
02002D	36.14	2.45	$2,111.16
02002D1	54.00	0.81	$2,286.36
02002E	50.64	2.43	$2,499.37
02002E1	48.00	0.80	$2,908.68
02002F	27.00	5.85	$1,830.58

Figure 2-201 – ABFC Assembly Summary screen.

Summary

Determining the right tool for the job is an important skill. Whether you and your crew are working with stationary power tools in the shop or with hand tools in the field, using and maintaining tools properly is critical to the safety of all crewmembers.

A hand tool is a device for performing a task that is powered solely by the person using it. Builders use many hand tools; the main categories are measuring and layout tools, fastening and prying tools, sawing and cutting tools, boring and clamping tools, and smoothing tools. Hand tools, as well as power tools, are included in concrete tools, masonry tools, and interior finish tools.

You will also work with different power tools, including shop tools and portable tools. Shop tools include table saws, band saws, drill presses, lathes, jointers, surfacers, and shapers. Portable tools include circular saws, saber saws, reciprocating saws, routers, power planes, and sanders.

Many fastening tasks are now performed by powder actuated tools, which are used to join materials to hard substrates such as concrete and steel; they are also known as direct fastening tools. Each of these tools hold a charge of gunpowder which is ignited and blows the fastener into place.

Some fastening tasks are performed with pneumatic tools. These tools are driven by gas, usually compressed air supplied by a gas canister or compressor. The amount of pneumatic, or air, pressure required to operate the tool depends on the size of the tool and the type of operation you are performing.

The Naval Construction Battalion Table of Allowances (NMCB TOA-01) lists the various kits available for Seabee projects. You can check what is currently included in each kit on the internet on the Advanced Base Functional Component (ABFC View) of the Naval Facilities Engineering Command's Expeditionary Logistics Center (NAVFAC).

Review Questions (Select the Correct Response)

1. What is the simplest, most common measuring tool?

   A. Digital measuring device
   B. Flat steel rule
   C. Measuring tape
   D. Wooden folding rule

2. What is the main use for a carpenter's square?

   A. Squaring up sections of work
   B. Placing nails along a beam
   C. Measuring 360-degree angles
   D. Reaching areas where hammers won't fit

3. What is a combination square used for?

   A. Test work for squareness
   B. Measure lengths, width, and angles
   C. Check level and plumb surfaces
   D. All of the above

4. What is it the term for something that is plumb?

   A. Vertical
   B. Horizontal
   C. At a 30-degree angle
   D. Bobbed

5. When you check whether a surface is level, what do you gauge?

   A. Amount of bubbles
   B. Horizontal surface
   C. Spirit
   D. Vertical surface

6. What does the shape of a sledgehammer head depend on?

   A. The torque of the sledgehammer
   B. Whether the sledgehammer is single-face or double-face
   C. The composition of the head
   D. The job the sledgehammer is intended to do

7. What is a screwdriver identified by?

   A. The length of its handle
   B. Its torque
   C. The type of screw it fits
   D. The width of its tip

8. What might happen if you use the wrong size screwdriver head for the job? You might

   A. Strike a live wire
   B. Strip the screw threads
   C. Twist the shank of the screwdriver
   D. Damage the screw head

9. What are wrenches used for?

   A. Pound nails into wood
   B. Turn screws, nuts, bolts, and pipes
   C. Pry open fittings on drains
   D. Strip threaded pipe

10. What are pliers generally used for?

   A. To pry open objects that are stuck together
   B. To turn nuts or bolt heads
   C. To hold, cut, and bend wire and soft metals
   D. To substitute for wrenches in tight spaces

11. Why should pliers NOT be used on a nut or bolt?

   A. They will round off the edges of the hex head.
   B. They are not strong enough.
   C. They are designed only for tightening.
   D. Their jaws will not open wide enough.

12. What is the wrecking bar used for?

   A. Gripping large metal objects for demolition
   B. Heavy-duty dismantling of woodwork
   C. Hammering nails
   D. Breaking up concrete

13. What can you use a chisel bar for?

   A. To pry apart steel beams
   B. To split and rip apart pieces of wood
   C. To break apart concrete
   D. To make ridges in wood beams

14. What saw would you choose if you wanted to cut metal?

   A. Ripsaw
   B. Compass saw
   C. Hacksaw
   D. Crosscut saw

15. What type of saw cuts *with* the grain of the wood?

   A. Dovetail saw
   B. Rip saw
   C. Crosscut saw
   D. Hacksaw

16. If a chisel is going to cut metal, how must the metal you are cutting relate to the metal of the chisel?

   A. It must be softer
   B. It must be harder
   C. It must be colder
   D. It must be warmer

17. When you use a utility knife, why do you place a scrap under the object you are cutting?

   A. See the object more clearly
   B. Keep the blade sharp
   C. Protect the surface under the object
   D. Automatically unlock the knife blade

18. What is a punch used for?

   A. Cut metal
   B. Cut wood
   C. Indent metal
   D. Indent oilstone

19. A bit brace is also known as

   A. An auger
   B. A push drill
   C. A hand drill
   D. An awl

20. A sharpened steel spike used to mark wood is

   A. An auger
   B. A push drill
   C. A hand drill
   D. An awl

21. What are clamps sized by?

   A. Length of the handles
   B. Distance between the metal bar and the shoe
   C. Maximum opening of the jaw
   D. Kind of pad you insert to protect the work

22. What do you need to use to protect the work when you are clamping soft materials?

A. A web
B. Pads
C. A rack
D. Pipes

23. What kind of tool is a vise?

A. Measuring and gauging
B. Holding and gripping
C. Slicing and sawing
D. Ripping and prying

24. When you use a bench vise, which way do you turn the sliding T-handle screw to clamp the object?

A. Clockwise
B. Counterclockwise
C. Downward
D. Upward

25. Besides smoothing lumber, what is a plane used for?

A. Reducing
B. Shaping
C. Seaming
D. Jointing

26. What is a scraper used for?

A. To remove large amounts of material at one time
B. To smooth wood before a finish is applied
C. To remove paint from windows only
D. To rough up the surface of wood

27. Files have slanting rows of teeth; what type of teeth do rasps have?

A. Smooth
B. Individual
C. Coarse
D. Wire

28. What do you need to do when you clean files?

A. Brush in the opposite direction of the line of teeth
B. Use an old toothbrush
C. Brush in the same direction as the line of teeth
D. Use soap and water

29. What tool is used to consolidate concrete after it has been poured?

A. Screed board
B. Float
C. Vibrator
D. Whirlybird

30. What is a screed used for?

A. Consolidating concrete
B. Cutting off excess concrete
C. Smoothing the surface of concrete
D. Rounding the edge of concrete

31. What is a line block used for?

A. Aligning block at corners
B. Holding mason's line to keep masonry level
C. Blocking off excess mortar
D. Lining block to keep it waterproof

32. What is a drywall rasp used for?

A. Smoothing the surface of drywall seams
B. Roughing the surface of drywall to make finishes adhere
C. Minor trimming on drywall panels to make them fit tight spaces
D. Cutting holes in drywall panels for electrical boxes

33. Which tool is used to hold drywall mud right before it is applied?

A. Mud pan
B. Inside corner tool
C. Hawk
D. Mud masher

34. On a tilt-arbor bench saw, the saw blade for ordinary ripping and cutting should extend how far above the table top?

A. 1/32 to 1/16 inch plus thickness of material
B. 1/16 to 1/8 inch plus thickness of material
C. 1/8 to 1/4 inch plus thickness of material
D. 1/4 to 3/8 inch plus thickness of material

35. Which combination of grooving saws and chisel-type cutters makes up a dado head?

A. One saw and one cutter
B. One saw and two cutters
C. Two saws and one or more cutters
D. Three saws and two cutters

36. The band saw is primarily designed for which of the following cuts?

A. Freehand
B. Curved
C. Straight
D. Miter

37. How is the size of a band saw designated?

A. Tooth points per inch
B. Width and gauge of the blade
C. Diameter of the wheels
D. Cutoff gauges and gears

38. How is drill press speed changed?

A. By a two-speed control switch
B. By the location of the V-belt
C. By a variable speed control knob
D. By changing the drive pulley

39. At what maximum angle from horizontal can you tilt a drill press table?

A. 10°
B. 25°
C. 30°
D. 45°

40. The size of a wood lathe is determined by what factor?

A. The diameter of the stock that the lathe will accommodate
B. The circumference of the stock that the lathe will accommodate
C. The length of stock that can be mounted on the lathe
D. The horsepower of the lathe motor

41. When a jointer makes a cut deeper at the beginning of the cut than at the end, you should adjust the jointer by

A. Raising the infeed table
B. Lowering the infeed table
C. Raising the outfeed table
D. Lowering the outfeed table

42. The fence on a jointer can be set to produce beveled edges at which of the following angles?

A. 45° only
B. 60° only
C. 75° only
D. Any desired angle

43. How should you true a warped board and plane its top surface if the available tools include a jointer and a single surfacer?

A. Simply feed the board once through the surfacer
B. Feed the board through the surfacer, then turn over the board and feed it through again
C. True one face of the board on the jointer, then feed the board through the surfacer with the true face down
D. True one face of the board on the jointer, then feed the board through the surfacer with the trued face up

44. When shaping an edge on a shaper, how should you feed the stock to the cutter head?

A. Feed stock in the same direction as the spindle is rotating only
B. Feed stock against the rotation of the spindle only
C. Feed stock in the same direction as the spindle is rotating, then reverse and feed against the rotation of the spindle
D. Feed the stock through in either direction

45. If turned or irregular edges are to be shaped, you should remove the straight fence and replace it with what component?

A. A starting pin placed in the table top
B. A C-clamp with a hand screw
C. A three-wing cutter
D. A straightedge board

46. Which of the following characteristics distinguishes a standard drill from a specialty drill?

A. Spade design
B. Pistol-grip design
C. Right-angle
D. Variable speed

47. The size of a circular saw is determined by what factor?

A. The size of the motor
B. The size of the smallest blade
C. The size of the largest blade
D. The size of the guard

48. **(True or False)** Hollow-ground blades have no set and make the smoothest cuts on thick or thin stock.

A. True
B. False

49. If you do not maintain a firm grip on a saber saw during cutting, the saw will tend to

A. Burn the wood
B. Overheat
C. Excessively vibrate
D. Stop cutting

50. To start a cut with a saber saw, what technique should you use?

A. Press the blade into the material and start the motor
B. Pull back on the blade and start the motor
C. Start the motor and push the material into the blade
D. Start the motor and push the blade into the material

51. Which of the following router features allows you to guide the router in a straight line and is particularly useful for cutting grooves on long pieces of lumber?

A. The depth setscrew
B. The depth ring
C. The chuck nut
D. The edge guide

52. Safe operation of any portable power plane requires a single pass cut to be less than what maximum depth?

A. 1/8 in
B. 1/16 in
C. 3/32 in
D. 1/4 in

53. To get a bevel cut using a portable power plane, what action should you take?

A. Loosen the base, set base at desired level, then retighten
B. Tilt the planer to the desired angle
C. Tilt the material to the desired angle
D. Adjust the blade to the desired angle

54. Which of the following sander types is ideal for removing old finishes from wood flooring, siding, and concrete?

A. Belt
B. Disk
C. Orbital
D. Oscillating

55. When using a disk sander to remove old paint, what method should you use?

A. Lay the disk flat on the surface and apply light pressure
B. Lay the disk flat and apply heavy pressure
C. Lay the disk on its edge and apply enough pressure to bend it at a 45° angle
D. Tip the machine slightly and apply just enough pressure to bend the disk slightly

56. **(True or False)** Powder actuated tools can be used by any Seabee with no special training.

A. True
B. False

57. In case of a misfire with a powder actuated tool, what should you do?

A. Turn the tool over and check the barrel
B. Have the crew leader check the barrel
C. Hold the tool in the operating position for at least 15 seconds
D. Remove the tool from the work surface

58. **(True or False)** All air-powered nailers use the same air pressure.

A. True
B. False

59. Which of the following is NOT a safety consideration for pneumatic tools?

A. Use the correct air pressure.
B. Use any size fastener that you have.
C. Point the nose of the tool away from your body and other people.
D. Disconnect the air supply when you load the tool.

60. **(True or False)** The Naval Construction Battalion Table of Allowances lists tool kits available for Seabee projects.

A. True
B. False

Trade Terms Introduced in this Chapter

Auger	(1) A carpenter's hand tool used for boring holes in wood. (2) A hand-held or rotary-powered tool with a helical cutting edge used for drilling holes in soil. Augers are used for taking soil samples, drilling for caissons, or drilling for cast-in-place piles.
Ball peen hammer	A hammer having a hemispherical peen on one end, used by metal workers, stonemasons, and mechanics.
Band saw	A power saw consisting of a continuous piece of flexible steel that runs around two pulleys and has teeth on one or both sides. Used to cut logs into cants, to rip lumber, and to cut curved shapes.
Carpenter square	A flat, metal, L-shaped tool that constitutes an accurate right angle and is engraved with divisions and markings useful to a carpenter laying out and erecting framing. Also known as a framing square.
Chalk line	(1) A light cord that has been surface-coated with chalk (usually blue) that is used for marking. (2) The line left by a chalked string.
Chisel	A metal tool with a cutting edge at one end, used in dressing, shaping, or working wood, stone, or metal. A chisel is usually tapped with a hammer or mallet.
Circle cutter	A tool used primarily to score a circular pattern in drywall in order to fit over recessed electrical components in a wall or ceiling. The tool consists of a square shank with a sliding pivot that is locked into the desired location with a turn knob. One end of the shank has a fixed cutter wheel that scores a fine line in the drywall.
Circular saw	A thin steel-toothed disk that rotates on a power-driven spindle. Can be used as a hand tool or mounted on a table.
Clamps	Mechanical devices used to hold items together or firmly in place while other operations are being performed. The clamping force may be applied by screws, wedges, cams, or a pneumatic/hydraulic piston.
Claw hammer	A hammer with a hardened face on one end of the head for driving nails, and curved, forked tines on the other end for pulling out nails.
Combination square	A carpenter's hand tool with a head that slides along a metal rule and may be locked at any location. The head has 90° and 45° angle surfaces, a bubble level, and a scribe pin.

Convex Jointer	An offset metal tool used to smooth or indent mortar joints in masonry.
Crosscut saw	A saw with its teeth filed and set to cut across the grain of a piece of wood.
Disk sander	A hand held power tool that has a rotating, circular abrasive disk used for smoothing or polishing a surface.
Drills	(1) Hand-held, manually operated or power-driven rotary tools for boring holes in construction materials. (2) Large machines capable of drilling 4" diameter blast holes 100' deep in rock cuts or quarries. (3) Machines capable of taking core samples in rock or earth.
Drill press	A rotary drill, mounted on a permanent stand, which operates along a vertical shaft.
Edger	A tool used to fashion finishing edges or round corners on fresh concrete or plaster. Also known as an edging trowel.
Files	Hand-held steel tools with teeth or raised oblique ridges, used for scraping, redressing, or smoothing metal or wood.
Float	A tool usually of wood, aluminum, magnesium, rubber, or sponge, used in concrete or tile finishing operations to impart a relatively even but still open texture to an unformed fresh concrete surface.
Folding rule	A rule made of lengths that are joined by pivots so it can be folded when not in use.
Groover	A tool for creating grooved joints in unhardened concrete slabs.
Jigsaw	An electrically powered table mounted saw having a small, thin, narrow, vertically reciprocating blade which is capable of cutting a tighter radius than a band saw.
Jointer	A power driven woodworking tool or long, hand operated bench plane. Used to square the edges of lumber or panels.
Kerf	A saw-cut in wood, stone, etc. which is usually performed crosswise and usually not completely through the member.
Woodworking lathe	A machine used to shape circular pieces of wood, metal, or other material. The stock is rotated on a horizontal axis while a stationary tool cuts away the unwanted material or creates ornamental turned work.
Mallet	A small wooden hammer used to drive another tool, such as a chisel or gouge.

Measuring tape	A flexible measuring strip of fabric or steel marked off with lines similar to the lines of a carpenter's rule, usually contained in a case to allow rewinding or retracting after use.
Miters	Miter joints are made by beveling each of two parts to be joined to form a corner. The parts to be joined are usually beveled at a 45° angle. The resulting corner is usually a 90° angle.
Planes	Tools used to smooth or shape wood.
Pliers	Hand tools, designed primarily for gripping objects by using leverage. Pliers are designed for numerous purposes and sometimes require different jaw configurations to grip, turn, pull, or crimp a variety of things. They are a tool common to many dexterous trades and occupations. Many types of pliers also include jaws for cutting.
Plumb bob	A cone-shaped metal weight, hung from a string, used to establish a vertical line or as a sighting reference to a surveyor's transit.
Power drills	Electric powered hand-held drills, activated by pressing a trigger-like switch.
Punch	(1) A small pointed tool which is struck with a hammer and used for centering and starting holes. (2) A steel tool, usually cylindrical, with sharpened edges used in a hydraulic machine to make holes through metal.
Putty knife	A knife, with a broad flexible blade with a flat end, used to apply putty.
Radial arm saw	A circular saw suspended above the table on a cantilevered arm. The material remains stationary while the saw is free to move along its projecting beam.
Rafter angle square	A three-sided measuring tool in the shape of a triangle marked with degree gradations. Speed squares are used to quickly lay out and cut lumber without performing complex trigonometry calculations. Also known as a speed square.
Rasps	Files with projecting teeth for rough work.
Reciprocating saw	A saw operated in a back and forth or up and down motion extending from an engine or other power source, such as a saber saw.
Rip saw	A coarse-toothed saw used for cutting wood in the direction of the grain.
Router	An electrically driven device with various bits for cutting grooves or channels in wood.

Rule	(1) A straightedge with gradations used for measuring, laying out lengths, or drawing straight lines. (2) A straightedge for working plaster to a plain surface. Also known as a ruler.
Saber saw	A hand-held power saw with a reciprocating blade extending through the base of the saw.
Sander	A machine designed to smooth wood and remove saw or lathe marks and other imperfections. Sanders range in size from hand-held to large drums or belts capable of surfacing a full-size panel.
Scrapers	Scrapers prepare wood for finish paint or stain by removing small amounts of material.
Screed board	A tool for striking off the concrete surface sometimes referred to as a strikeoff.
Screwdriver	A hand tool with the shank's tip shaped to fit the recess of a screw; used to drive or remove the screw.
Shaper	(1) A woodworking machine with a vertically revolving cutter for cutting irregular outlines, moldings, etc., in wood placed on a table below the cutter. (2) A metalworking machine similar to a planer, except that the cutting tool is moved back and forth across the surface.
Slicker	A type of jointer for finishing mortar which has a ridge that leaves an even depression in the mortar.
Spirit level	A device used to set an instrument to true horizontal or true vertical, consisting of a glass tube nearly filled with liquid so a traveling air bubble is formed. Cheap levels are bent concave; better levels are ground internally to an overall concave shape.
Surfacer (surface planer)	A machine used to plane and smooth the surface of materials such as wood, stone, or metal.
T-square	A guide, in the shape of a T, used in engineering and architectural drawing. The short arm slides along the edge of a drawing board, keeping the long arm in a parallel state.
Table saw	A power saw, with a circular blade set below a table. The blade projects above the table through a slot, with the projection height adjustable to suit the work.
Trowel	(1) A flat, broad-blade, steel hand tool used in the final stages of finishing operations to impart a relatively smooth surface to concrete floors and other unformed concrete surfaces. (2) A flat, triangular-blade tool used for applying mortar to masonry.

Try square A normally graduated square, the legs of which are at 90°.

Vibrator An oscillating machine used to agitate fresh concrete so as to eliminate gross voids, including entrapped air, but not entrained air, and to produce intimate contact with form surfaces and between embedded materials.

Wrench A hand tool consisting of a handle and a jaw at one end; used to turn or hold a bolt, nut, pipe, or fitting. The jaw may be shaped for a specific-sized object or may be adjustable.

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.

Carpentry I, Headquarters, EN5155, U.S. Army Engineer School, Fort Belvoir, Va., 1988.

Carpentry III, Headquarters, EN0533, U.S. Army Engineer School, Fort Belvoir, Va., 1987.

Tools and Their Uses, NAVEDTRA 14256, Naval Education and Training Professional Development and Technology Center, Pensacola, Fla., 1992.

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http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10265 (Powder Actuated Tools (OSHA))

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Chapter 3

Drawings and Specifications

Topics

To hear audio, click on the box.

Overview

By this time in your Navy career, you have probably worked as a crewmember on various building projects. You probably did your tasks without thinking much about how to lay out structures to conform to location, size, shape, and other building features. In this chapter, you will learn how to extract this information from ***drawings*** and specifications. This chapter will cover basic print reading skills and the symbols, abbreviations, and conventions that show and describe building materials. You will learn how to draw, read, and work from simple ***shop drawings*** and ***sketches***. If you are using an electronic version of this rating manual, you will also learn to read and manipulate electronic drawings.

Project drawings and specifications thoroughly detail everything that your crew will need to estimate, plan, and construct a building; in addition to developing a Material Take Off (MTO)/***Bill of Material*** (BM). You can bring projects in at or below cost by producing complete MTO/BM that conveys an adequate level of detail.

Objectives

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

1. Identify different types of structural members.
2. Recognize different types of drawings and their uses.
3. Interpret sectional views.
4. Interpret building schedules.
5. Interpret written construction specifications.
6. View and manipulate electronic drawings.

Prerequisites

None

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

Expeditionary Structures	↑	B
Finishes		U
Moisture Protection		I
Finish Carpentry		L
Rough Carpentry		D
Carpentry Materials and Methods		E
Masonry		R
Fiber Line, Wire Rope, and Scaffolding		
Concrete Construction		B
Site Work		A
Construction Management		S
Drawings and Specifications		I
Tools		C
Basic Math		

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 DESIGN OF STRUCTURAL MEMBERS

From the Builder's standpoint, building designs and construction methods depend on many factors. No two building projects are alike. The factors usually considered before a structure is designed are its geographical location and the availability of construction materials.

It is easy to see why geographical location is important to the design of a structure, especially its main parts. In a northern temperate zone, for example, the roof of a structure must be sturdy enough to avoid collapsing under the weight of snow and ice. Also, the foundation walls have to extend below the ***frost line*** to guard against the effects of freezing and thawing. In the tropics, a structure should have a low-pitch roof and be built on a concrete slab or have shallow foundation walls.

Likewise, the availability of construction materials can influence the design of a structure. This happens when certain building materials are scarce in a geographical location, and the cost of shipping them is prohibitive. In such a case, particularly overseas, the structure is likely to be built with materials purchased locally. This can affect the way you use construction materials; it means working with foreign drawings and metric units of weights and measures.

By comparing the designs of the two structures shown in *Figures 3-1* and *3-2*, you can see that each is designed according to its function.

Figure 3-1 – Typical light frame construction.

For example, light frame construction is usually found in residential buildings that require a number of small rooms.

Figure 3-2 – Typical concrete masonry and steel structure.

Concrete masonry and steel construction is used for warehouse type facilities, which require large open spaces. You should study these figures carefully and learn the terminology. Depending on the use of the structure, you may use any combination of structural ***members***.

1.1.0 Dead and Live Loads

The main parts of a structure are the load-bearing members. These support and transfer the loads on the structure while remaining equal to each other. The places where members are connected to other members are called joints. The total sum of the load supported by the structural members at a particular instant is equal to the total dead load plus the total live load.

The total ***dead load*** is the total weight of the structure, which gradually increases as the structure rises and remains constant once it is complete. The total ***live load*** is the total weight of movable objects, such as people, furniture, and bridge traffic, the structure happens to be supporting at a particular instant.

A structure transmits live loads through the various load-bearing structural members to the ultimate support of the earth. First, horizontal members provide immediate or direct support for the live loads. Vertical members, in turn, support the horizontal members. Finally, the vertical members are supported by foundations or ***footings***, which are supported by the earth. Look at *Figure 3-1*, which illustrates both horizontal and vertical members of a typical light frame structure. The weight of the roof material is distributed over the top supporting members and transferred through all joining members to the soil.

The ability of the earth to support a load is called its soil-bearing capacity. This varies considerably with different types of soil. A soil of a given ***bearing capacity*** bears a heavier load on a wide foundation or footing than on a narrow one.

Loads are covered in much greater detail in the Builder Advanced rate training manual. This section is meant to be a brief introduction to the concept of load.

1.2.0 Vertical Structural Members

In heavy construction, vertical structural members are high-strength ***columns***. In large buildings, these are called ***pillars***. Outside wall columns and inside bottom floor columns usually rest directly on footings. Outside wall columns usually extend from the footing or foundation to the roof line. Inside bottom floor columns extend upward from footings or foundations to the horizontal members, which, in turn, support the first floor or roof, as shown in *Figure 3-2*. Upper floor columns are usually located directly over lower floor columns.

In building construction, a ***pier***, sometimes called a short column, rests either directly on a footing, as shown in the lower center of *Figure 3-3*, or is simply set or driven into the ground. Building piers usually support the lowermost horizontal structural members.

Figure 3-3 – Exploded view of a typical light frame house.

The chief vertical structural members in light frame construction are called ***studs***, shown in *Figures 3-1 and 3-3*. They are supported by horizontal members called ***sills*** or ***soleplates***, shown in *Figure 3-3*. ***Corner posts*** are enlarged studs located at the building corners. At one time, in full frame construction, a corner post was usually a solid piece of larger timber. Most modern construction uses built-up corner posts. These consist of various members of ordinary studs nailed together in various ways.

In bridge construction, a pier is a vertical member that provides intermediate support for the bridge ***superstructure*,** as shown in *Figure 3-4*.

Figure 3-4 – Pier supporting bridge superstructure.

1.3.0 Horizontal Structural Members

Any horizontal load-bearing structural member that spans a space and is supported at both ends is considered a ***beam***. A member fixed at only one end is called a ***cantilever*** beam. A ***joist*** is a horizontal supporting member generally smaller than a beam. Steel members that consist of solid pieces of regular structural steel are referred to as structural shapes. The ***girder***, shown in *Figure 3-2*, is a structural shape. Other prefabricated, open-web, structural-steel shapes are called ***bar joists***, also shown in *Figure 3-2*.

Horizontal structural members that support the ends of floor beams or joists in wood-frame construction are called sills or girders, shown in *Figures 3-1* and *3-3*, depending on the type of framing and the location of the member in the structure. Horizontal members that support studs are called soleplates. They may also have other names, depending on the type of framing. Horizontal members that support the wall ends of ***rafters*** are called ***rafter plates***. Horizontal members that assume the weight of concrete or masonry walls above door and window openings are called ***lintels***, shown in *Figure 3-2*.

The horizontal or inclined members that provide support to a roof are called rafters, shown in *Figure 3-1*. The lengthwise member at a right angle to the rafters, which supports the peak ends of the rafters in a roof, is called the ***ridge***. The ridge may be called a ***ridgeboard***, the ridge piece, or the ***ridgepole***. Lengthwise members other than ridges are called purlins. In wood frame construction, the wall ends of rafters are supported on horizontal members called rafter plates, which are in turn supported by the outside wall studs. In concrete or masonry construction, the wall ends of rafters may be anchored directly on the walls or on plates bolted to the walls.

A beam of given strength, without intermediate supports below; can support a given load over only a specific maximum span. When the span is wider than this maximum space, the beam requires intermediate supports such as columns. Sometimes it is either not feasible or impossible to increase the beam size or to install intermediate supports. In such cases, a ***truss*** provides the required support. A truss is a combination of members, such as beams, bars, and ties, usually arranged in triangular units, that forms a rigid framework for supporting loads over a span.

The basic components of a roof truss are the top and bottom ***chords*** and the web members. The top chords serve as roof rafters. The bottom chords act as ceiling joists. The web members run between the top and bottom chords. The truss parts are usually made of 2 by 4 inch or 2 by 6 inch material and tied together with metal or plywood ***gusset plates***, shown in *Figure 3-5*.

Figure 3-5 – A truss rafter.

Roof trusses come in a variety of shapes and sizes. The most commonly used roof trusses for light frame construction are the king-post, the W-type, and the scissors trusses, shown in *Figure 3-6*.

Figure 3-6 – The most commonly used roof trusses.

The simplest type of truss used in frame construction is the king-post truss. It is mainly used for spans up to 22 feet. The most widely used truss in light frame construction is the W-type truss. The W-type truss can be placed over spans up to 50 feet. The scissors truss is used for buildings with sloping ceilings. Generally, the slope of the bottom chord equals one half the slope of the top chord. It can be placed over spans up to 50 feet.

Test your Knowledge (Select the Correct Response)

1. At any given time, building structural members must be able to support which of the following loads?

   A. Dead loads only
   B. Live loads only
   C. Total dead plus total live loads
   D. Dead load minus live load

2.0.0 DRAWINGS

The building of any structure is described by a set of related drawings that give the Builder a complete, sequential, graphic description of each phase of the construction process. In most cases, a set of drawings begins by showing the location, boundaries, contours, and outstanding physical features of the construction site and its adjoining areas. Succeeding drawings give instructions for the excavation and disposition of existing ground; construction of foundations and superstructure; installation of utilities, such as plumbing, heating, lighting, air conditioning, interior and exterior finishes; and whatever else is required to complete the structure.

The engineer works with the architect to decide what materials to use in the structure and the construction methods to follow. The engineer determines the loads that supporting members will carry and the strength qualities the members must have to bear the loads. The engineer also designs the mechanical systems of the structure, such as the lighting, heating, and plumbing systems. The end result is the architectural and engineering design sketches. These sketches guide draftsmen in preparing the ***construction drawings***.

Any field adjustments to the designs have to be approved by the designer. Submit a Field Adjustment Request (FAR) to request any adjustments.

2.1.1 Construction Drawings

Generally, construction or working drawings furnish enough information for the Builder to complete an entire project and incorporate all five main groups of drawings listed below:

Architectural – A

- Site Plan
- Foundation Plan
- Floor Plans
- Interior/Exterior Elevations
- Sections
- Details
- Schedules

Structural – S

Plumbing – P

Mechanical – M

Electrical – E

In drawings for simple structures, this grouping may be hard to discern because a single drawing may contain both the electrical and mechanical layouts. In complicated structures, a combination of layouts is not possible because of overcrowding. In this case, the floor plan may be traced over and over for separate drawings for the electrical and mechanical layouts.

All or any one of the five types of drawings gives you enough information to complete a project. The specific one to use depends on the nature of construction involved. The construction drawing furnishes enough information for the particular tradesman to complete a project, whether architectural, structural, plumbing, mechanical, or electrical. Normally, construction drawings include the detail drawings, assembly drawings, and the specifications in order to develop a complete MTO/BM.

Construction drawings consist mostly of right angle and perpendicular views prepared by draftsmen using standard technical drawing techniques, symbols, and other designations as stated in military standards (MIL-STDS). The first section of the construction drawings consists of the ***site plan***, ***plot plan***, ***foundation plans***, ***floor plans***, and ***framing plans***. General drawings consist of plans (views from above) and elevations (side or front views) drawn on a relatively small scale. Both types of drawings use a standard set of architectural symbols. *Figures 3-7 and 3-8* show some examples of construction drawings.

Figure 3-7 – Construction drawings – architecture.

Figure 3-8 – Construction drawing – plot plan.

A detail drawing shows a particular item on a larger scale than that of the general drawing in which the item appears. Or, it may show an item too small to appear at all on a general drawing.

An assembly drawing is either an exterior or a ***sectional view*** of an object showing the details in proper relationship to one another. Assembly drawings are usually drawn to a smaller scale from the dimensions of the detail drawings. This provides a check on the accuracy of the design drawings and often discloses errors.

The title block shown in *Figure 3-9* is the logical place to begin reading a set of prints. Information in the title block includes:

- Name and number of the project
- Project location
- Architect and engineer names
- Drafter
- Number of sheets
- Name of sheets and revisions (if applicable)

Figure 3-9 – Title block.

Construction drawings use many symbols. *Figure 3-10* illustrates the conventional symbols for the more common types of material used on structures.

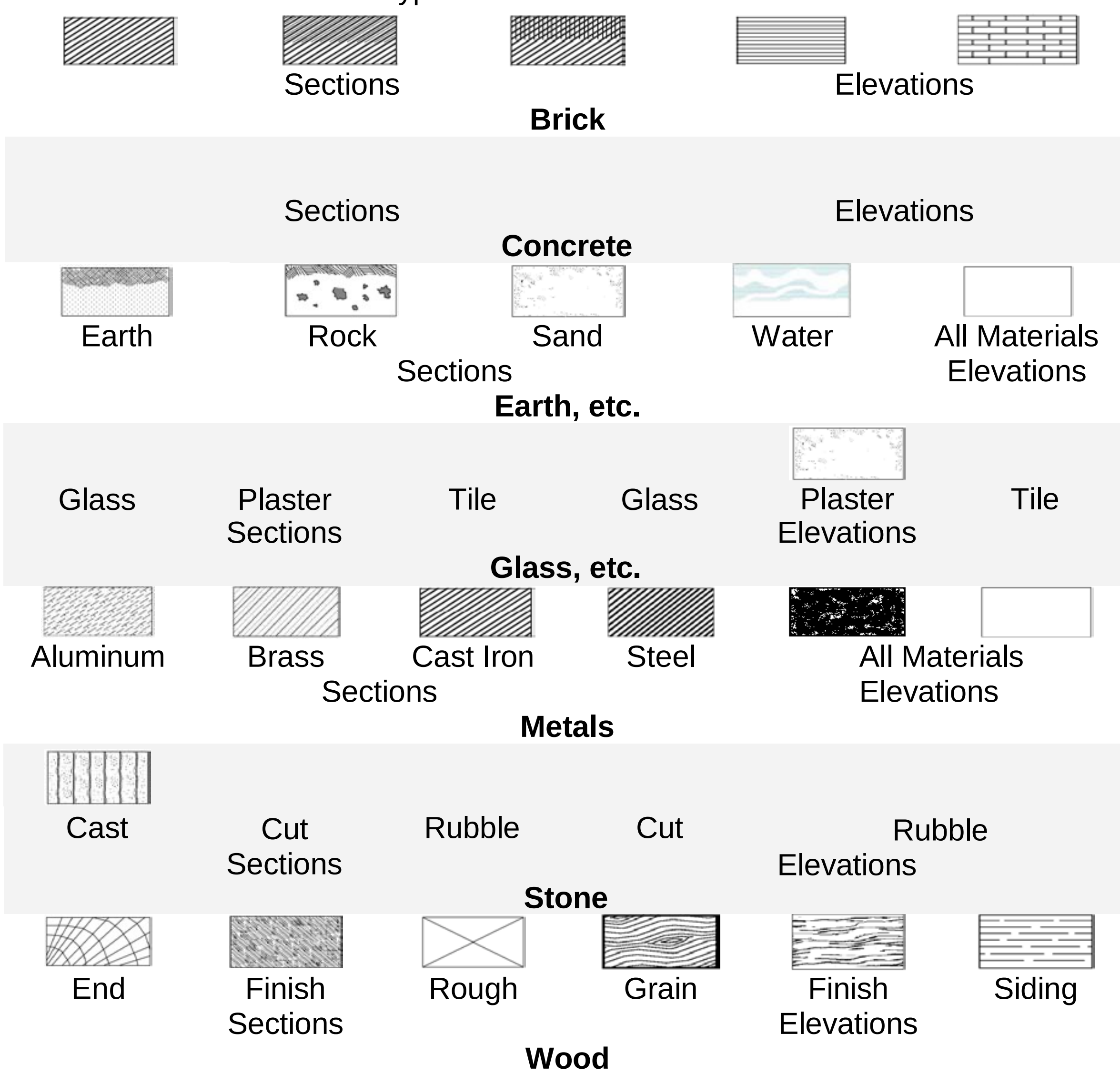

Figure 3-10 – Architectural symbols for plans and elevations.

Figure 3-11 shows topographic symbols used in site plans and plot plans.

Figure 3-11 – Topographic symbols.

Figure 3-12 shows Steel Structural Shapes and Designations.

Figure 3-12 – Steel Structural Shapes and Designations.

Figure 3-13 shows basic weld symbols.

Figure 3-13 – Basic weld symbols.

Figure 3-14 shows contour symbols for welds.

Figure 3-14 – Contour symbols for welds.

Figure 3-15 shows line standards for welds.

Figure 3-15 – Line standards for welds.

Figure 3-16 shows symbols for HVAC components.

Figure 3-16 – HVAC symbols.

Figure 3-17 shows symbols for electrical components.

Figure 3-17 – Electrical symbols.

Figure 3-18 shows symbols for plumbing and piping.

Figure 3-18 – Plumbing and piping symbols.

Figure 3-19 shows the more common symbols used for doors and windows.

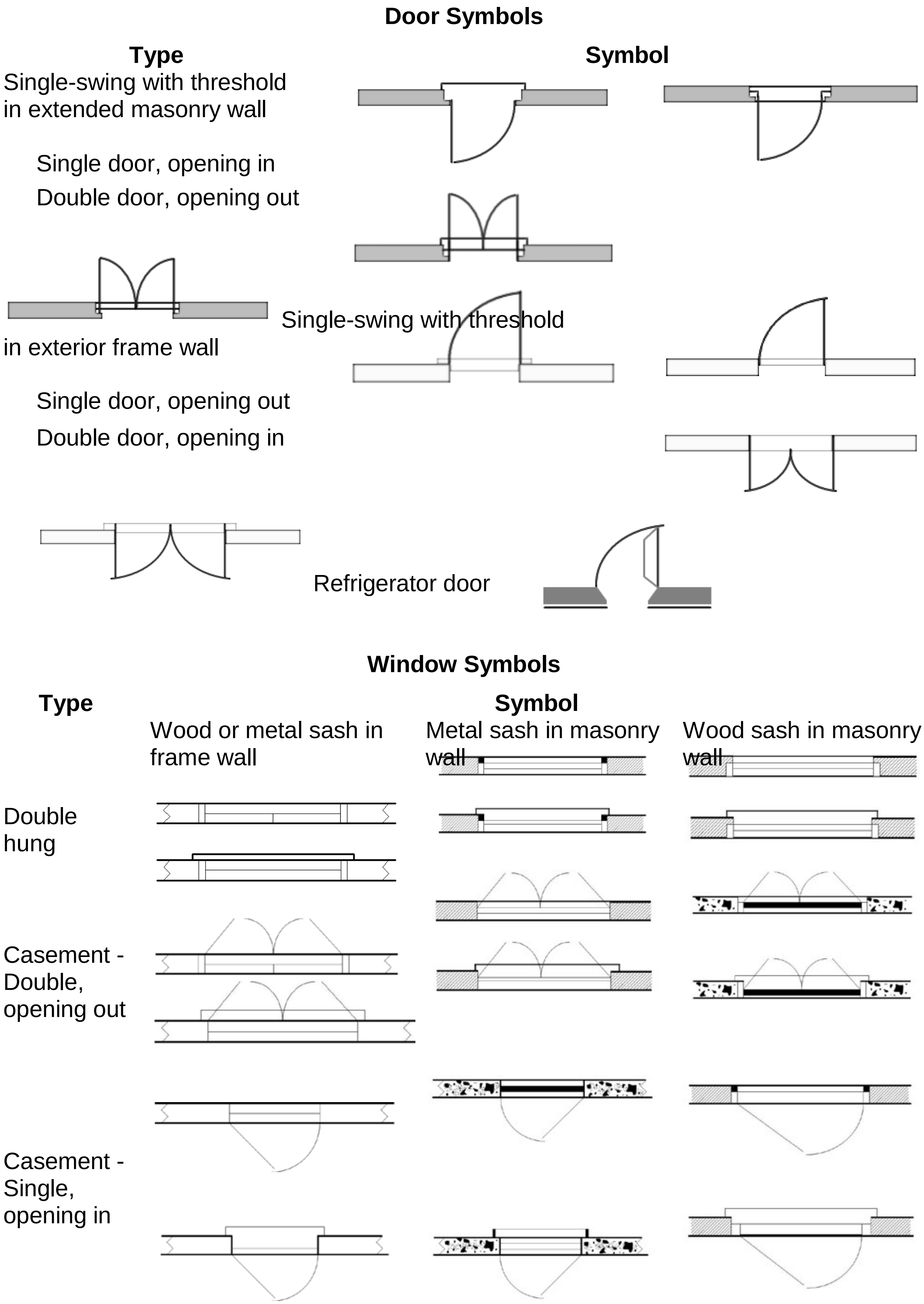

Figure 3-19 – Architectural symbols for doors and windows.

The architect's scale shown in *Figure 3-20* provides a way to translate construction measurements to a smaller scale. This allows for detail drawings of construction projects in a manageable size.

Figure 3-20 – Architect's scale.

2.1.1 Site Plan

The site plan shown in *Figure 3-21* shows the contours, boundaries, roads, utilities, trees, structures, and any other significant physical features on or near the construction site. It shows the locations of proposed structures in outline. This plan also shows corner locations relative to reference lines, shown on the plot, that can be located at the site. By showing both existing and finished contours, the site plan furnishes essential data for the graders.

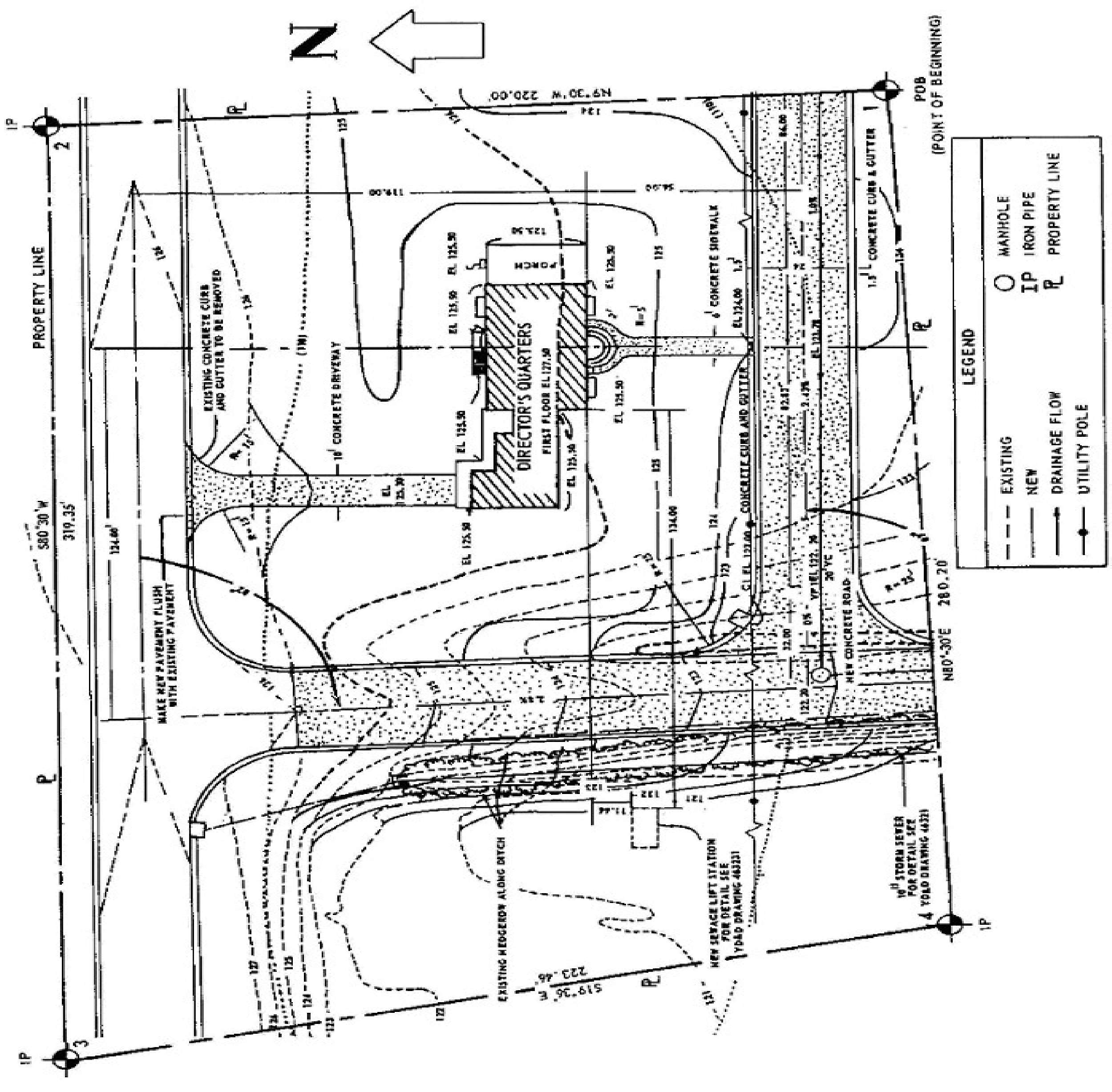

Figure 3-21 – Site plan.

2.1.2 Plot Plan

The plot plan shows the survey marks, including the ***bench mark*** (BM), with the elevations and the grading requirements. Engineering Aids use the plot plan shown in *Figure 3*-22 to set up the corners and perimeter of the building using ***batter boards*** and line stakes. The plot plan furnishes the essential data for laying out the building.

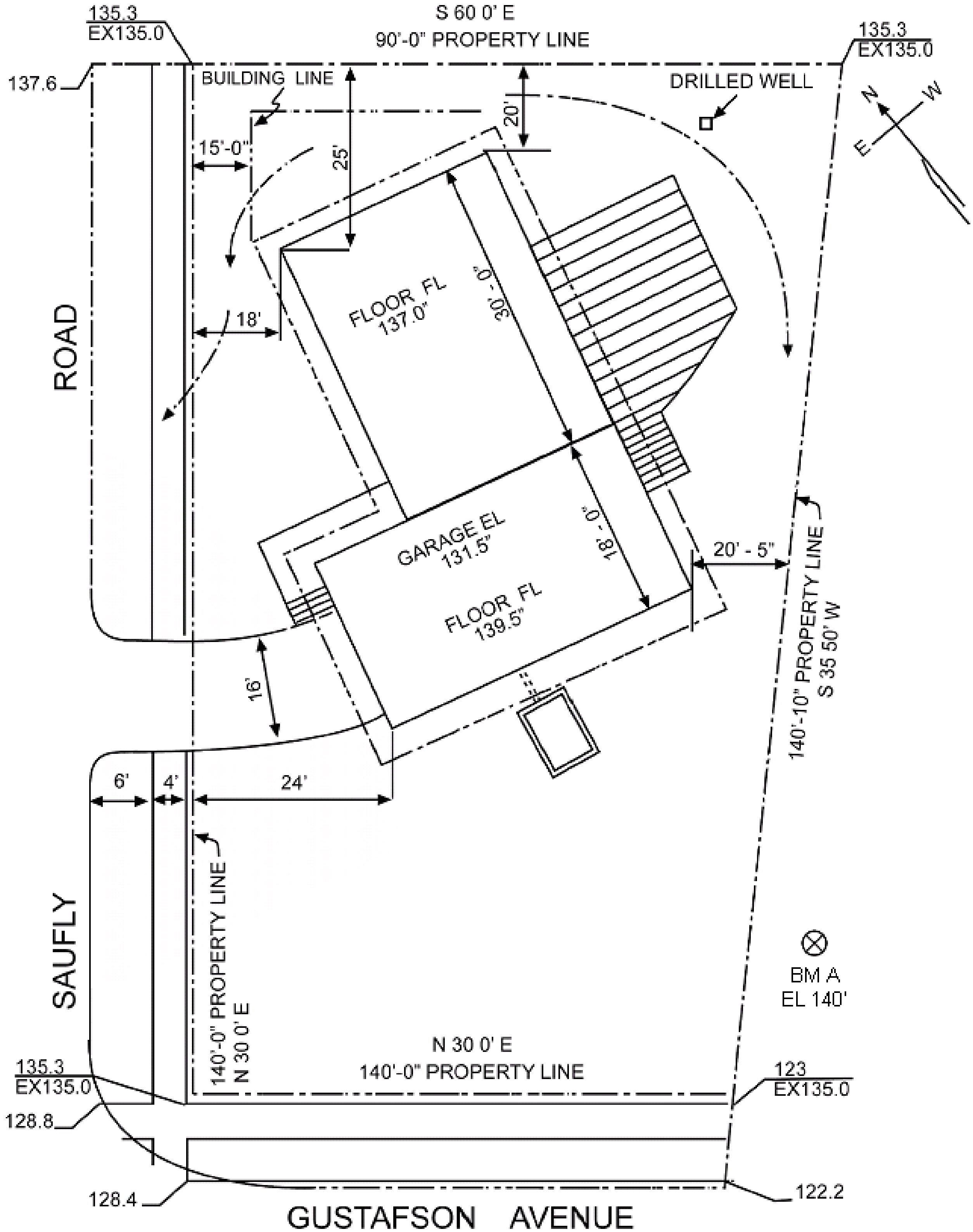

Figure 3-22 – Plot plan.

2.1.3 Foundation Plan

A foundation plan is a plane view of a structure. That is, it looks as if it were projected onto a horizontal plane and passed through the structure. In the case of the foundation plan, the plane is slightly below the level of the top of the foundation wall. The plan in *Figure 3-23* shows that the main foundation consists of 12 inch and 8 inch concrete masonry unit (CMU) walls measuring 28 feet lengthwise and 22 feet crosswise. The lower portion of each lengthwise section of wall is to be 12 inches thick to provide a concrete ledge 4 inches wide.

A girder running through the center of the building will be supported at the ends by two 4 by 12 inch concrete ***pilasters*** butting against the end foundation walls. Intermediate support for the girder will be provided by two 12 by12 inch concrete piers, each supported on 18 by 18 inch ***spread footings***, which are 10 inches deep. The dotted lines around the foundation walls indicate that these walls will also rest on spread footings.

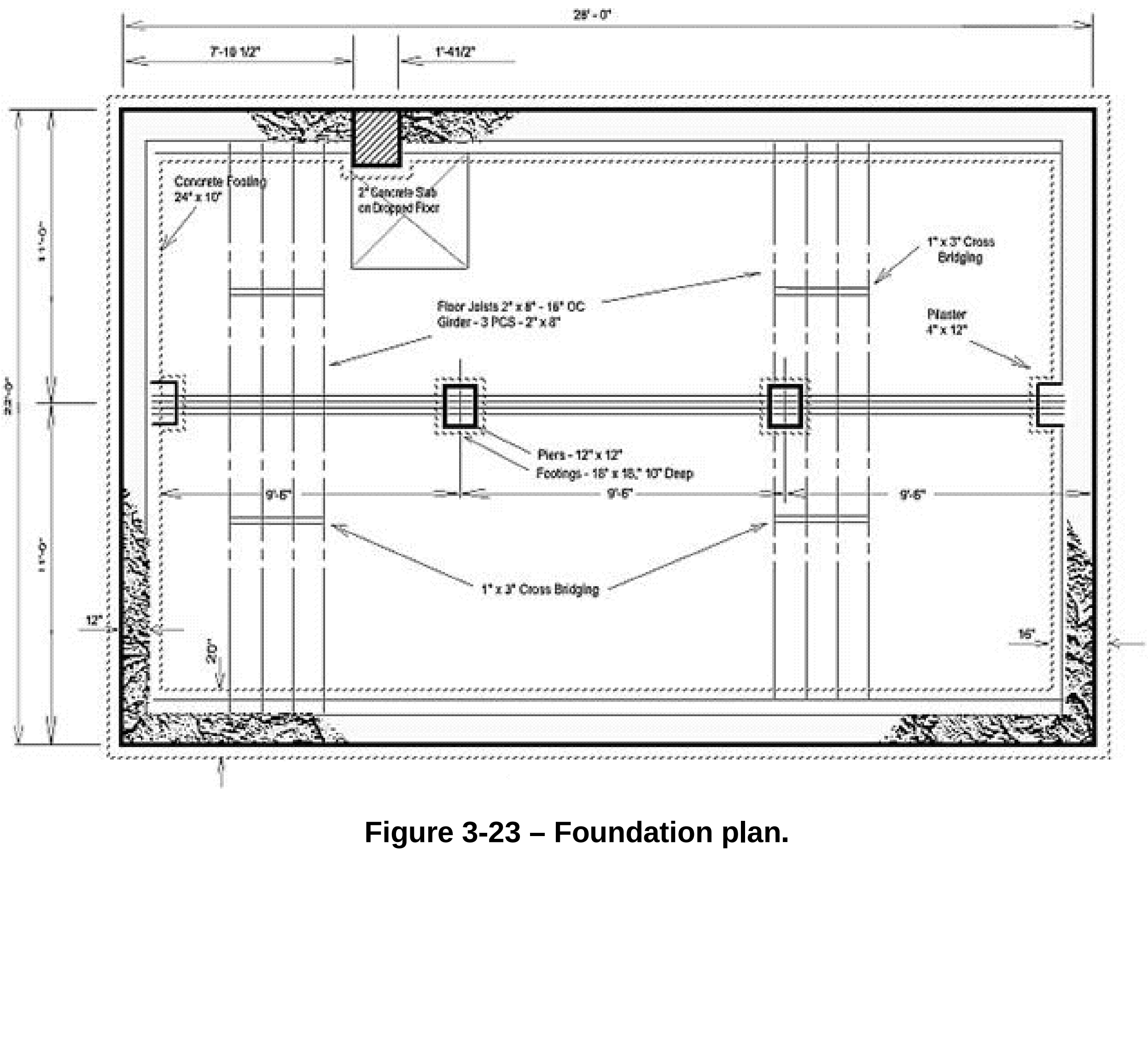

Figure 3-23 – Foundation plan.

2.1.4 Floor Plan

Floor plans are views of a building as though cutting planes were made through the building horizontally. The cutting plane is generally taken 5'-0" above the floor being shown.

Figure 3-24 shows the way a floor plan is developed from elevation, to cutting plane, to floor plan. An architectural or structural floor plan shows the structural characteristics of the building at the level of the plane of projection. A mechanical floor plan shows the plumbing and heating systems and any other mechanical components other than those that are electrical. An electrical floor plan shows the lighting systems and any other electrical systems.

Figure 3-24 – Floor plan development.

Figure 3-25 is a floor plan showing the lengths, thicknesses, and character of the outside walls and partitions at the particular floor level. It also shows the number, dimensions, and arrangement of the rooms, the widths and locations of doors and windows, and the locations and character of bathroom, kitchen, and other utility features. You should carefully study *Figure 3-25*. In dimensioning floor plans, it is very important to check the overall dimension against the sum of the partial dimensions of each part of the structure.

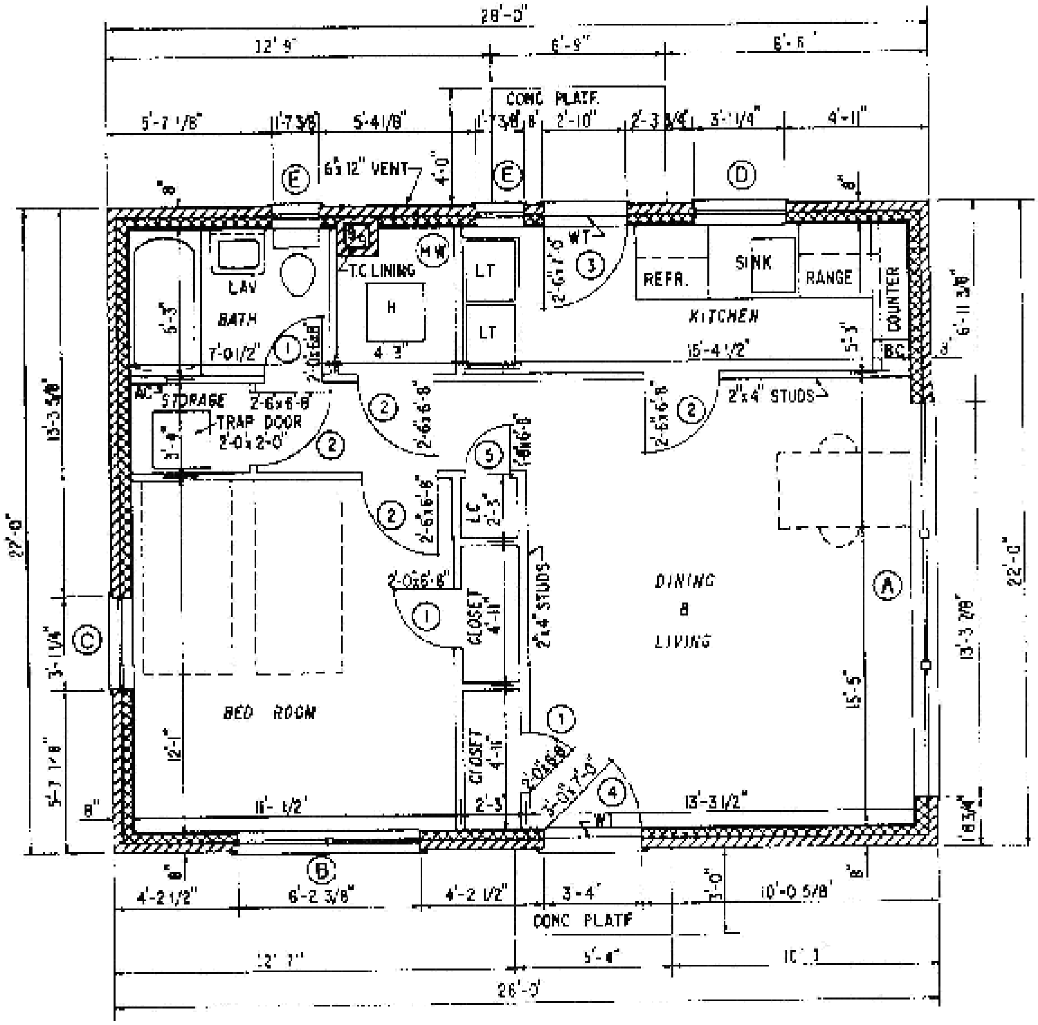

Figure 3-25 – Floor plan.

2.1.5 Elevations

Elevations show the front, rear, and sides of a structure, as they would appear projected on vertical planes. Studying the elevation drawing gives you a working idea of the appearance and layout of the structure.

Figure 3-26 shows elevations for a small building. Note that the wall surfaces of this house will consist of brick and the roof covering of composition shingles. The top of the rafter plate will be 8 feet 2 1/4 inches above the level of the finished first floor, and the tops of the finished door and window openings 7 feet 1 3/4 inches above the same level. The roof will be a gable roof with 4 inches of rise for every 12 inches length. Each window shown in the elevations is identified by a capital letter that goes with the window schedule, which we'll discuss later in this chapter.

Figure 3-26 – Elevations.

2.1.6 Framing Plans

Framing plans show the size, number, and location of the structural members (steel or wood) that make up the building framework. Separate framing plans may be drawn for the floors, walls, and roof. The floor framing plan must specify the sizes and spacing of joists, girders, and columns used to support the floor. When detail drawings are necessary, they must show the methods of anchoring joists and girders to the columns and foundation walls or footings. Wall framing plans show the location and method of framing openings and ceiling heights so that studs and posts can be cut. Roof framing plans show the construction of the rafters used to span the building and support the roof. They also show size, spacing, roof slope, and all details.

Floor Plans - Framing plans for floors are basically plane views of the girders and joists. *Figure 3-27* is an example of a typical floor framing plan.

Figure 3-27 – Floor framing plan.

The unbroken double line symbol is used to indicate joists, which are drawn in the positions they will occupy in the completed building. This type of plan also shows double framing around openings and beneath bathroom fixtures where used. ***Bridging*** is shown by a double-line symbol that runs perpendicular to the joists. The span of the joists controls the number of rows of cross bridging. They should not be placed more than 7 or 8 feet apart. A 14 foot span needs only one row of bridging, but a 16 foot span needs two rows.

Notes identify floor openings, bridging, and ***girts*** or plates. Nominal sizes are used in specifying lumber. Dimensions need not be given between joists. Such information is given along with notes. For example,

1” x 6” joists @ 2’ 0” o.c.

indicates that the joists are to be spaced at intervals of 2 feet 0 inches from center to center. Framing plans might not indicate lengths. If you find this to be the case, the overall building dimensions and the dimensions for each bay or distances between columns or posts provide such information.

Roof Plans – Framing plans for roofs are drawn in the same manner as floor framing plans. A Builder should visualize the plan as looking down on the roof before any of the roofing material (sheathing) has been added. Rafters are shown in the same manner as joists.

2.1.7 Shop Drawings

Shop drawings are sketches, schedules, diagrams, and other information Builders prepare to illustrate some portion of the work. As a Builder, you will have to make shop drawings for minor shop and field projects. These may include shop items such as doors, cabinets, and small portable buildings forming plans; prefabricated berthing quarters; and modifications of existing structures.

Shop drawings are prepared from portions of design drawings, or from freehand sketches based on the Builder's past building experience. They must include enough information for the crew to complete the job. Normally, the Builder bases the amount of required detailing on the experience level of the crew expected to complete the project. When an experienced building crew will be doing the work, it is not necessary to show all the fine standard details.

When you make actual drawings, use any available templates for standard symbols. Standard technical drawing techniques are recommended but not mandatory. For techniques in the skill of drawing, refer to *Blueprint Reading and Sketching,* NAVEDTRA 10077.

2.1.8 Freehand Sketches

Builders must be able to read and work from drawings and specifications and make quick, accurate sketches to convey technical information or ideas. You may prepare sketches for your own use or for use by other crewmembers. One of the main advantages of sketching is that it requires few materials. Basically, pencil and paper are all you need. The type of sketch prepared and personal preference determine the materials you use.

You will do most of your sketches on some type of scratch paper. The advantage of sketching on tracing paper is the ease with which sketches can be modified or redeveloped simply by placing transparent paper over previous sketches or existing drawings. You may use cross-sectional or graph paper to save time when you need to draw sketches to scale. For making dimensional sketches in the field, you will need a measuring tape or pocket rule, depending on the extent of the measurements taken. In freehand pencil sketching, draw each line with a series of short strokes instead of with one stroke. Strive for a free and easy movement of your wrist and fingers. You don't need to be a draftsman or an artist to prepare good working sketches.

Freehand sketches are prepared by the crew leader responsible for the job. He or she may include any information that will make the project more understandable, although sketches needn't be prepared in great detail.

Test your Knowledge (Select the Correct Response)

2. Of the following types of drawings, which is NOT one of the five main drawing groups?

   A. Architectural
   B. Mechanical
   C. Detail
   D. Electrical

3.0.0 SECTIONAL VIEWS

Sectional views, or sections, provide important information about the height, materials, fastening and support systems, and concealed features of a structure. *Figure 3-28* shows the initial development of a section and how a structure looks when cut vertically by a cutting plane. The cutting plane is not necessarily continuous, but, as with the horizontal cutting plane in building plans, may be staggered to include as much construction information as possible. Like elevations, sectional views are vertical projections. They are also detail drawings drawn to large scale. This aids in reading, and provides information that cannot be given on elevation or plan views. Sections are classified as typical and specific.

Figure 3-28 – Development of a sectional view.

Typical sections represent the average condition throughout a structure and are used when construction features are repeated many times. *Figure 3-29* shows typical wall section A-A of the foundation plan in *Figure 3-18*. You can see that it gives a great deal of information necessary for those constructing the building. Let's look at these a little more closely.

Figure 3-29 – A typical section of a masonry building.

The foundation plan shown in *Figure 3-23* specifies that the main foundation of this structure will consist of a 22 by 28 foot concrete block rectangle. *Figure 3-29*, which is section A-A of the foundation plan, shows that the front and rear portions of the foundation (28 foot measurements) are made of 12 by 8 by 16 inch CMUs centered on a 10 by 24 inch concrete footing to an unspecified height. These are followed by 8 inch CMUs, which form a 4 inch ledger for floor joist support on top of the 12 inch units. In this arrangement, the 8 inch CMUs serve to form a 4 inch support for the brick. The main wall is then laid with standard 2 l/2 by 4 by 8 inch face brick backed by 4 by 8 by 16 inch CMUs.

Section B-B, shown in *Figure 3-30* of the foundation plan, shows that both side walls (22 foot measurements) are 8 inches thick centered on a 24 inch concrete footing to an unspecified height. It also illustrates the pilaster, a specific section of the wall to be constructed for support of the girder. It shows that the pilaster is constructed of 12 by 8 by 16 inch CMUs alternated with 4 by 8 by 16 inch and 8 by 8 by 16 inch CMUs. The hidden lines (dashed lines) on the 12 inch wide units indicate that the thickness of the wall beyond the pilaster is 8 inches. Note how the extra 4 inch thickness of the pilaster provides a center support for the girder, which will support the floor joists.

Figure 3-30 – A specific section of a concrete masonry wall.

Details are large-scale drawings that show the builders of a structure how to connect and place its various parts. Although details do not use the cutting plane indication, they are closely related to sections. Detail drawings of buildings customarily show the construction of doors, windows, and eaves. Typical door and window details are shown in *Figure 3-31 and 3-32*. Detail drawings are used whenever the information provided in elevations, plans, and sections is not clear enough for the constructors on the job. These drawings are usually grouped so that references may be made easily from the general drawing.

Figure 3-31 – Door details - section through head jamb.

Figure 3-32 – Upper and lower corner details of window frame.

4.0.0 SCHEDULES

A schedule is a group of general notes, usually grouped in a tabular form, according to materials of construction. "General notes" refers to all notes on the drawing not accompanied by a leader and an arrowhead. Item schedules for doors, rooms, footings, and so on, are more detailed. Typical door and window finish schedule formats are presented in the next section.

4.1.0 Door Schedule

A plan may identify doors by size, type, and style with code numbers placed next to each symbol in the plan view. This code number, or mark, is then entered on a line in a door schedule, and the principal characteristics of the door are entered in successive columns along the line. The Amount Required column allows a quantity check on doors of the same design as well as the total number of doors required. By using a number with a letter, you will find that the mark serves a double purpose; the number identifies the floor on which the door is located, and the letter identifies the door design. The Remarks column allows identification by type (panel or flush), style, and material. The ***door schedule*** is a convenient way of presenting pertinent data without making the Builder refer to the specification. *Table 3*-1 shows a typical door schedule.

Table 3-1 – Door Schedule

MARK	SIZE	AMOUNT REQUIRED	REMARKS
1	2'0" x 6'8" x 1 3/8"	3	Flush door
2	2'6" x 6'8" x 1 3/8"	4	Flush door
3	2'6" x 6'8" x 1 3/8"	1	Ext flush door, 1 light
4	3'0" x 7'0" x 1 3/4"	1	Ext flush door, 4 lights
5	1'8" x 6'8" x 1 3/8"	1	Flush door

4.2.0 Window Schedule

A ***window schedule*** is similar to a door schedule in that it provides an organized presentation of the significant window characteristics. The mark used in the schedule is placed next to the window symbol that applies on the plan view of the elevation view as shown in *Figure 3-21*. A similar window schedule is shown in *Table 3-2*.

Table 3-2 – Window Schedule

MARK	SIZE	AMOUNT REQUIRED	REMARKS
A	4'5 1/8" x 4'2 5/8"	3	Metal frame
B	3'1 1/8" x 4'2 5/8"	2	Metal frame
C	3'1" x 4'2 5/8"	1	Metal frame
D	3'1" x 4'2 5/8"	1	Metal frame
E	1'7 5/8"	2	Metal frame

4.3.0 Finish Schedule

A ***finish schedule*** specifies the interior finish material for each room and floor in the building. The finish schedule provides information for the walls, floors, ceilings, baseboards, doors, and window trim. *Table 3*-3 shows an example of a finish schedule.

Table 3-3 – Finish Schedule

ROOM	FLOOR	WALLS	CEILING	BASEBOARD	TRIM
Dining & living	1” x 3” oak	½” Drywall paint white	½” Drywall paint white	Wood	Wood
Bedroom	1” x 3” oak	½” Drywall paint white	½” Drywall paint white	Wood	Wood
Bathroom	Linoleum-tan	½” Drywall paint white	½” Drywall paint white	Lino-cove	Wood
Kitchen	Linoleum-tan	½” Drywall paint white	½” Drywall paint white	Lino-cove	Wood
Utility room	Linoleum-tan	½” Drywall paint white	½” Drywall paint white	Lino-cove	Wood
Hall	1’ X 3” oak	½” Drywall paint white	½” Drywall paint white	Wood	Wood

4.4.0 Notes on Schedules

Notes are generally placed a minimum of 3 inches below the Revision block on the right-hand side of the first sheet. The purpose of these notes is to give additional information that clarifies a detail or explains how a certain phase of construction is to be performed. You should read all notes, along with the specifications, while you are planning a project.

5.0.0 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, how can anyone show on a drawing the quality of workmanship required for the installation of doors and windows? Or, who is responsible for supplying the materials? 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.

The design engineer usually has the responsibility of preparing 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 they use.

5.1.0 NAVFAC Specifications

NAVFAC specifications are prepared by Naval Facilities NAVFAC, which sets standards for all construction work performed under its jurisdiction. This includes work performed by the Seabees. There are three types of NAVFAC specifications.

5.1.1 Unified Facilities Guide Specifications

Unified Facilities Guide Specifications (UFGS) consolidate specifications for USACE, NAVFAC, AFCESA, and NASA, and are the primary basis for preparing specifications for construction projects. These specifications define and establish 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, has been written to encompass a wide variety of different materials, construction methods, and circumstances. They must also be tailored to suit the work actually required by the specific project.

To better explain this, let's look at *Figure 3-27*, which is part of a page taken from a United Facilities guide specification.

****

USACE / NAVFAC / AFCESA / NASA **UFGS-07 31 13 (April 2006)**

Preparing Activity: NAVFAC **Replacing without change UFGS-07311 (February 2003)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2008

****

3.3 APPLICATION

Apply roofing materials as specified herein unless specified or recommended otherwise by shingle manufacturer's written instructions [or by NRCA 0408].

3.3.1 Underlayment

****

NOTE: Select the applicable paragraph(s) from the following.

****

The installation of asphalt strip shingles at maximum exposure is not recommended on roofs having a slope of less than 1:4. In locations where the January mean temperature is minus one degree C (30 degrees F) or less, a leak barrier underlayment membrane should be used. The leak barrier underlayment membrane may consist of: two plies of No. 15 asphalt saturated felt, one nailed to the deck and the second set in Type III or Type IV hot asphalt or asphalt lap cement; a heavyweight coated base sheet nailed to the deck and another felt ply or plysheet set in hot asphalt or asphalt lap cement; or a self adhering modified bitumen membrane.

****

NOTE: In locations where the average daily January temperature is minus 4 degrees C 25 degrees F or below, use the second optional paragraph instead of the first optional paragraph.

****

[Provide for roof slopes one in three 4 inches per foot and greater. Apply one layer of shingle underlayment to roof deck. Lay underlayment parallel to roof eaves, starting at eaves. Provide minimum 50 mm 2 inch head laps, 100 mm 4 inch end laps, and 150 mm 6 inch laps from both sides over hips and ridges. Nail sufficiently to hold until shingles are applied. Turn up vertical surfaces a minimum of 100 mm 4 inches.]

****

Figure 3-27 – Sample from a United Facilities Guide Specification.

In this figure, you can see that there are options that indicate that the spec writer must choose the paragraph that best suits the particular project for which he is writing the specification. You can see that some of the information in *Figure 3-27* is enclosed in brackets ([ ]). This indicates there are choices that the spec writer must make. Guide specifications should be modified and edited to reflect the latest proven technology, materials, and methods.

5.1.2 NAVFAC Regional Specifications

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

5.1.3 Standard Specifications

Standard specifications are written for a small group of specialized structures that must 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

5.2.0 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.

5.2.1 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 pertinent to Seabee construction.

Military specifications are those specifications the Department of Defense has developed. Like federal specifications, they also cover the characteristics of materials. They are identified by DOD or MIL preceding the first letter and serial number.

5.2.2 Technical Society and Trade Association Specifications

Project specifications should reference technical society 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.

5.2.3 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 preparing project specifications.

5.3.0 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.

The drawings, together with the project specifications, define the project in detail and show exactly how to construruct it. Usually, drawings for an important project 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, or they further clarify details that are not covered amply by the drawings and notes on the drawings. When you are preparing project specifications, it is important that you closely coordinate the specifications and drawings in order to minimize discrepancies and ambiguities. Whenever there is conflicting information between the drawings and project specs, the specifications take precedence over the drawings.

5.3.1 Organization of Specifications

For consistency, the Navy has organized the format of specifications into 17 basic ***divisions***. These divisions, used throughout the military, are listed in order as follows:

General Requirements include information that is of a general nature to the project, such as inspection requirements and environmental protection.

Site Work includes work performed on the site, such as grading, excavation, compaction, drainage, site utilities, and paving.

Concrete Construction includes precast and cast-in-place concrete, formwork, and concrete reinforcing.

Masonry includes concrete masonry units, brick, stone, and mortar.

Metals includes 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.

Carpentry includes wood and wood framing, rough and finish carpentry, foamed plastics, fiberglass reinforced plastics, and laminated plastics.

Moisture Protection includes such items as waterproofing, dampproofing, insulation, roofing materials, sheet metal and flashing, caulking, and sealants.

Doors, Windows, and Glass includes doors, windows, finish hardware, glass and glazing, storefront systems, and similar items.

Finishes includes such items as floor and wall coverings, painting, lathe, plaster, and tile.

Specialties includes prefabricated products and devices, such as chalkboards, moveable partitions, fire fighting devices, flagpoles, signs, and toilet accessories.

Architectural Equipment includes such items as medical equipment, laboratory equipment, food service equipment, kitchen and bath cabinetwork, and counter tops.

Furnishings includes prefabricated cabinets, blinds, draperies, carpeting, furniture, and seating.

Special Construction includes such items as prefabricated structures, integrated ceiling systems, and swimming pools.

Conveying Systems includes dumbwaiters, elevators, moving stairs, material handling systems, and other similar conveying systems.

Mechanical Construction includes plumbing, heating, air conditioning, fire protection systems, and refrigeration systems.

Electrical Construction includes electrical service and distribution systems, electrical power equipment, electric heating and cooling systems, lighting, and other electrical items.

Expeditionary Structures includes tension fabric structures and K-span buildings.

Each of the above divisions is further divided into sections. You can find a listing of the sections in the *Seabee Crewleader's Handbook*.

5.3.2 Guidance

Usually, the engineer or spec writer prepares each section of a specification based on the appropriate guide specification listed in the Design Guidance page of the Whole Building Design Guide, which can be found at http://www.wbdg.org/design/index.php.

As discussed earlier, when writing the specifications for a project, you must modify the guide specification you are using to fit the project. Delete portions of guide specifications that concern work not included in the project. When portions of the required work are not included in a guide specification, then you must prepare a suitable section to cover the work, using language and form similar to that of the guide specification. Do not combine work covered by various guide specifications into one section unless the work is minor in nature. Do not reference the guide specification in the project specifications. You must use the guide spec only as a manuscript that can be edited and incorporated into the project specs.

The preceding discussion provides only a brief overview of construction specifications. For additional guidance regarding specification preparation, refer to *Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications,* MIL-STD-3007.

Test your Knowledge (Select the Correct Response)

3. **(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

Summary

An important skill for Builders is knowing how to lay out structures so they will conform to their location, size, shape, and other building features. You learned how to extract this information from drawings and specifications. You also learned how to draw, read, and work from simple shop drawings and sketches.

Schedules of materials to be used in a project are an important component of the project plans. Project plans also incorporate specifications, written notes that supplement construction drawings with detailed written instructions. You must also be familiar with the various types of federal, military, and nongovernmental reference specifications used in preparing project specifications.

Review Questions

1. Which of the following building structural members provide immediate support for live loads?

   A. Footings
   B. Horizontal members
   C. Vertical members
   D. Diagonal members

2. Which of the following statements best applies to an outside wall column?

   A. It is usually located directly over the inside lower floor columns.
   B. It rests on the ground and extends to the roof line.
   C. It is a high-strength horizontal structural member.
   D. It is a high-strength vertical structural member usually extending from the footing to the roof line.

3. What type of column is used to support the lowest horizontal building member?

   A. Bottom floor inside
   B. Outside-wall
   C. Upper floor
   D. Short

4. The building components supporting the chief vertical structural members (studs) are known as

   A. Piers
   B. Sills or soleplates
   C. Beams
   D. Bar joists

5. The building component above the wall studs and supporting roof framing members is called a

   A. Header
   B. Rafter plate
   C. Stud
   D. Sill

6. **(True of False)** Rafters are horizontal or inclined members providing roof support.

   A. True
   B. False

7. The peak ends of rafters are supported by

   A. Purlins
   B. Rafter plates
   C. A ridgeboard
   D. Studs

8. A load on a beam is too great for structural integrity and supports cannot be used under the beam. What other structural member can be used to adequately support the load?

   A. Pier
   B. Truss
   C. Suspension cable
   D. Rafter

9. In light frame construction, which of the following trusses is the simplest type used?

   A. W-type
   B. Scissors
   C. Hip
   D. King-post

10. Engineering and architectural design sketches are combined to form what type of drawings?

   A. Construction
   B. Perspective
   C. Combination
   D. Symbol

11. Drawings that are adequate for a Builder to complete a project are known as

   A. Assembly drawings
   B. Working drawings
   C. Detail drawings
   D. A bill of materials

12. Where are you most likely to find information on items too small to appear on general drawings?

   A. Detail drawings
   B. Assembly drawings
   C. Bill of material
   D. Specifications

13. What type of drawing is either an exterior or sectional view of an object showing details in proper relationship to one another?

A. Design
B. Construction
C. Assembly
D. General

14. The contours, boundaries, utilities, structures, and other significant physical features of a piece of property are shown on what type of plan?

A. Plot
B. Site
C. General
D. Elevation

15. What plan should be used to set batter boards and line stakes?

A. Plot
B. Site
C. Detail
D. General

16. For a footing, the material used and the depth are shown on what type of plan?

A. Floor
B. Site
C. Foundation
D. Elevation

17. The dimensions, number, and arrangement of structural members in wood-frame or steel construction are shown in what type of plan?

A. Foundation
B. Floor
C. Framing
D. Detail

18. To check the overall height of finished floors, doors, and windows, you should consult what plan?

A. Plot
B. Elevations
C. Section
D. Floor

19. What plan shows the type of wall and roof covering required?

A. Elevation
B. Floor
C. Plot
D. Foundation

20. What plan specifies the sizes and spacing of joists, girders, and columns used to support the floor?

    A. Plot
    B. Floor framing
    C. Section
    D. Elevations

21. **(True or False)** Sectional views, or sections, provide important information about the height, materials, fastening and support systems, and concealed features of a structure.

    A. True
    B. False

22. Detail drawings give construction information about which of the following items?

    A. Doors
    B. Windows
    C. Eaves
    D. All of the above

23. **(True or False)** A schedule is a table or list of working drawings giving number, sizes, and placement of similar items.

    A. True
    B. False

24. Which of the following items supplement construction drawings with detailed written instructions?

    A. Specifications
    B. Notes
    C. Revisions
    D. Details

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

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

26. Which of the following NAVFAC specifications are written for a small group of specialized structures that must have uniform construction to meet rigid operational requirements?

    A. NAVFACENGCOM guide specifications
    B. EFD regional guide specifications
    C. Standard specifications
    D. Other specifications

27. Which of the following specifications do NOT cover installation or workmanship for a particular project?

    A. Technical society and trade association specifications
    B. Federal and military specifications
    C. Manufacturer’s specifications
    D. Project specifications

28. 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. Manufacturer’s specifications
    D. Project specifications

29. Which of the following specifications divisions provides information on concrete masonry units, brick, stone, and mortar?

    A. Concrete
    B. Masonry
    C. Site work
    D. General requirements

30. Which of the following specifications provides information on prefabricated cabinets, blinds, draperies, carpeting, furniture, and seating?

    A. Finishes
    B. Furnishings
    C. Special Construction
    D. Specialties

Trade Terms Introduced in this Chapter

Bar joists	Light steel joists of open-web construction with a single zigzag bar welded to upper and lower chords at the points of contact. Used as floor and roof supports.
Batter boards	Pairs of horizontal boards nailed to wood stakes adjoining an excavation. Used with strings as a guide to elevation and to outline a proposed building. The strings strung between boards can be left in place during excavation.
Beam	A horizontal structural member, such as a girder, rafter, or purlin, which transversely supports a load and transfers the load to vertical members, such as columns and walls.
Bearing capacity	The maximum unit pressure that soil or other material can withstand without failure or excessive settlement.
Bench Mark	A mark made by a surveyor or general contractor to be used as a reference point when measuring the elevation or location of other points.
Bill of Material	A detailed analysis of material and equipment required to construct a project.
Bridging	A method of lateral bracing between joists for stiffness, stability, and load distribution.
Cantilever	A structural member supported at one end only.
Chords	The top or bottom members of a truss (typically horizontal), as distinguished from the web members.
Columns	Long, relatively slender, supporting pillars. Columns are usually loaded axially in compression.
Concrete masonry	(1) Concrete blocks laid with mortar or grout in a manner similar to bricks. (2) Concrete that may be poured in place or as special tilt-up building walls.
Construction drawings	The portion of the contract documents that provide the requirements of a construction project.
Corner posts	Vertical members located at the corners of a timber structure.
Dead load	A calculation of the weight of a building’s structural components, fixtures, and permanently attached equipment (used in designing a building and its foundations).
Details	Large scale architectural or engineering drawings indicating specific configurations and dimensions of construction elements. If the large scale drawing differs from the general drawing, it is the architect’s or engineer’s intention that the large scale drawing be used to clarify the general drawing.

Divisions	One of the standard sixteen major Uniform Construction Index (CSI) classifications used in specifying, pricing, and filing construction data.
Door schedule	A table in the contract documents listing all the doors by size, specifications, and location.
Drawings	Graphic illustrations depicting the dimensions, design, and location of a project. Generally including plans, elevations, details, diagrams, schedules, and sections.
Electrical drawing	A drawing that includes the complete power layout for a construction project.
Elevations	Views or drawings of the interior or exterior of a structure as if projected onto a vertical plane.
Finish schedule	A listing that provides information on finishes for the walls, floors, ceilings, baseboards, doors, and window trim.
Floor plans	Drawings showing the outline of a floor, or part of a floor, interior and exterior walls, doors, windows, and details such as floor openings and curbs. Each floor of a building has its own floor plan.
Footings	Enlargements at the lower end of a wall to distribute the load to a wider area of supporting soil.
Foundation plans	Drawings of plane views of a structure. The plane in this case is slightly below the top of the foundation wall.
Framing plans	Drawings of each floor of a building showing exact locations of framing members and their connections. May include wall elevations and details.
Frost line	The depth to which frost penetrates the ground. This depth varies from one part of the country to another. Footings should be placed below the frost line to prevent shifting.
Girder	A large principal beam of steel, reinforced concrete, wood, or a combination of these, used to support other structural members at isolated points along its length.
Girts	Horizontal braces used on outside walls covered with vertical siding.
Gusset plates	Plates fastened across a joint, as in wood or steel framework members.
Joist	A horizontal supporting member that runs from wall to wall, wall to beam, or beam to beam to support a ceiling, roof, or floor.
Lintels	Horizontal supporting members, installed above an opening such as a window or door, which serve to carry the weight of the wall above it.

Live load	The load superimposed on structural components by the use and occupancy of the building, not including the wind load, earthquake load, or dead load.
Mechanical drawing	Plans showing the HVAC and plumbing layout of a building.
Members	A general term for structural components of a building, such as a beam or column.
Pier	A short column to support a concentrated load. Also known as ashort column.
Pilasters	Columns built within a wall, usually projecting beyond the wall.
Pillars	Posts or columns.
Plot plan	A ground plan of a building and adjacent land.
Purlins	Horizontal structural members that support roof loads and transfer them to roof beams.
Rafters	A series of sloping parallel beams used to support a roof covering.
Rafter plates	Plates used to support the lower ends of rafters and to which they are fastened.
Ridge	The horizontal line formed by the upper edges of two sloping roof surfaces.
Ridgeboard	The longitudinal board set on edge used to support the upper ends of the rafters. Also known as a ridgepole.
Ridgepole	The longitudinal board set on edge used to support the upper ends of the rafters. Also known as a ridgeboard.
Sectional views	Drawings of an object or construction member cut through to show the interior makeup. Also known as a section.
Shop drawings	Drawings that illustrate construction, materials, dimensions, installation, and other pertinent information for the incorporation of an element or item into the construction.
Sills	The lowest members of the frame of the structure, resting on the foundation and supporting the frame.
Site plan	A plan that shows the contours, boundaries, roads, utilities, trees, structures, and other significant physical features on or near the construction site.
Sketches	Hasty or undetailed drawings often made as a preliminary study.
Soleplates	A solepiece or shoe that serves as a base for studs in a core of solid wood or mineral composition, as opposed to a partition.

Spread footings	Generally rectangular prisms of concrete, larger in lateral dimensions than the column or wall they support; used to distribute the load of a column or wall to the subgrade.
Studs	Framing members, usually cut to a precise length at the mill, designed to be used in framing building walls with little or no trimming before being set in place. Studs are most often 2” x 4”, but 2” x 3”, 2” x 6”, and other sizes are also included in the stud category. Studs may be of wood, steel, or composite material.
Superstructure	The part of a bridge above the beam seats or the spring line of an arch.
Truss	A structural component composed of a combination of members, usually in a triangular arrangement, to form a rigid framework; often used to support a roof.
Window schedule	A tabulation, usually on a drawing, listing all windows on a project; and indicating sizes, number of lights, type of sash and frame, and hardware required.

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.

Blueprint Reading and Sketching, NAVEDTRA 14040, Naval Education and Training Professional Development and Technology Center, Pensacola, Fla., 2003.

Engineering Aid 3, NAVEDTRA 14069, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1995.

Whole Building Design Guide*,* Design Guidance page: http://www.wbdg.org/design/index.php.

Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications, MIL-STD-3007, Naval Facilities Engineering Command-Engineering Innovation and Criteria Office, Norfolk, VA, 2002.

Proctor, Thomas E., *Building Trades Printreading – Parts 1 and 2 – Residential and Light Commercial Construction*, 3rd ed. Homewood, I.: American Technical Publishers, Inc., 2000.

Carpentry Framing and Finishing – Level Two, 4th ed., Prentiss Hall, Upper Saddle River, NJ, 2007.

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Chapter 4

Construction Management

Topics

1.0.0 Definitions

2.0.0 Planning

3.0.0 Estimating

4.0.0 Scheduling

5.0.0 Execution

6.0.0 Administration

7.0.0 Safety

8.0.0 Operational Risk Management

9.0.0 Quality Control

To hear audio, click on the box.

Overview

As a candidate for Petty Officer Third or Second Class, you are an emerging leader who will provide critical support to sustain the U.S. Navy's mission throughout the world. When you have achieved Petty Officer Third Class, you will have the responsibility, authority, and accountability to manage the sailors working for you, always maintaining safe work practices.

The first and most important thing for any Seabee project is ***planning***, ***estimating***, and scheduling. Proper execution of these tasks ensures the correct amount of the appropriate materials is on site at the right time. This also ensures that the right staff is available for the work when needed. Before the project begins, and while it is being executed, good administration helps keep it on track. Safety is a major responsibility of the crewleader; operational risk management can help identify and correct potential safety concerns. Quality control is another crewleader responsibility, in coordination with the Quality Control Division.

Objectives

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

1. Identify basic planning, estimating, and scheduling terms.
2. Give documentation requirements necessary in planning a construction project.
3. Explain estimating requirements for a construction project.
4. Explain the scheduling requirement for a construction project.
5. Explain the responsibilities of the various project management levels for executing a construction project.
6. Explain the administrative responsibilities of the crewleader.
7. Explain the safety responsibilities of the crewleader.
8. Explain the five step Operational Risk Management process.
9. Explain the responsibilities of the crewleader for Quality Control.

Prerequisites

None

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

Expeditionary Structures	↑	B
Finishes		U
Moisture Protection		I
Finish Carpentry		L
Rough Carpentry		D
Carpentry Materials and Methods		E
Masonry		R
Fiber Line, Wire Rope, and Scaffolding		
Concrete Construction		
Site Work		B
Construction Management		A
Drawings and Specifications		S
Tools		I
Basic Math		C

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 italicized instructions 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 DEFINITIONS

In planning any project, you must be familiar with the vocabulary commonly associated with planning, estimating, and scheduling. Here, we'll define a number of terms you need to know as a Builder.

1.1.1 Planning

Planning is the process of determining requirements and devising and developing methods and action for constructing a project. Good construction planning is a combination of many elements:

- the ***activity***, material, equipment, and manpower estimates
- project layout
- project location
- material delivery and storage
- work schedules
- quality control
- special tools required
- environmental protection
- safety
- progress control

All of these elements depend upon each other. You must consider them all in any well-planned project.

1.2.0 Estimating

Estimating is the process of determining the amount and type of work to be performed, quality and the quantities of material, equipment, and labor required. Lists of these quantities and types of work are called estimates. There are a number of estimates you will work with, including ***preliminary estimates***, detailed estimates, activity estimates, material estimates, equipment estimates, and manpower estimates.

1.2.1 Estimator

An ***estimator*** is a person who evaluates the requirements of a task. A construction estimator must be able to mentally picture the separate operations of the job 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 when determining what factors and conditions have effects on construction projects and what allowances to make for each of them. The estimator must be able to do accurate work. A Seabee estimator must have access to information about the material, equipment, and labor to perform various types of work under any conditions encountered on 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 must frequently review the information.

1.3.0 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, and 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.

Manpower schedules coordinate the manpower requirements of a project and show the number of personnel required for each activity. In addition, it 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.

2.1.1 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 don’t plan sequentially, you will end up with steps out of sequence and may substantially delay the project. Everyone concerned should know precisely the following aspects of a project:

1. What it is
2. Its start and finish points
3. Its external factors, such as the schedule dates and requirements of other trade groups
4. The availability of resources, such as manpower and equipment
5. What you need to make up the project planning files

Test your Knowledge (Select the Correct Response)

1. **(True or False)** In analyzing a project, scheduling always precedes planning.

   A. True
   B. False

2.1.0 Planning Documentation – Seabee Project Package

2.1.1 Instructions for the Seabee Project Package

Listed below are the instructions needed to complete a typical Seabee project package. There are five main sections, each containing forms for that section. Those forms marked with an asterisk (*) are mandatory on all projects. In a contingency operation, requirements for forms marked with a double asterisk (**) may be waived. Small projects of short duration or Advanced Base Functional Component (ABFC) projects may require only the mandatory forms. Other forms are used as needed. Forms may be computer generated but must have the content shown. Details on the forms are in Chapter 15 of the *Seabee Crewleader's Handbook.*

A. Seabee 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 crewleader 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 manday totals recorded on this form. All numbers will match Level III calculations. Horizontal and vertical totals will match exactly.

   b. *Two week Schedule: The crewleader will complete this each week. The company will present it to Ops at the weekly Ops meeting. The crewleader 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 barchart 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 mandays and duration.

   d. Two Week Labor Summary: The crewleader 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. Crewleader 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: Crewleader 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 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:

Test your Knowledge (Select the Correct Response)

2. A Seabee project package contains what total number of main sections?

   A. 3
   B. 5
   C. 7
   D. 9

2.2.0 Project Planning Steps and Flowcharts

There are numerous steps to take in planning a project. Some of them are usually completed by the Company Commander or Operations Chief, as shown below.

A. Preliminary Project Planning Steps

1. Obtain and review plans and specifications.
2. Write scope paragraph.
3. Develop master activities.
4. Place master activities into logical connection sequence (Logic Network).
5. Rough manday estimate for master activities (crew size x duration).
6. Select construction methods.
7. Identify long lead time materials.
8. Visit site, if practical.

Other steps are usually completed by the Crewleader, as shown below.

B. Detailed Project Planning Steps

1. Develop construction activities.
2. Place construction activities into Logic Network.
3. Identify training required and ensure it is provided.
4. Write quantity estimates for detailed activities:
   - permanent material
   - construction support
   - material (consumables)
   - crew size and ratings
   - tools and equipment
   - durations
   - mandays
5. Complete CAS sheets for each construction activity.
6. Compare Material Take Off to BM.
7. Make or request shop drawings in conjunction with the estimate.
8. Revise scope or methods, based on site visit.
9. Develop Safety and Quality Control plans.
10. Monitor message traffic, Situation Reports and correspondence.

11. Obtain deployment calendar.

12. Enter project into computer.

13. Level resources and reschedule.

14. Identify any restraints on start/finish.

15. Supply Required Delivery Dates for material to cognizant regiment.

16. Develop Level II barchart.

A summary of project planning steps is shown in *Figure 4-1*.

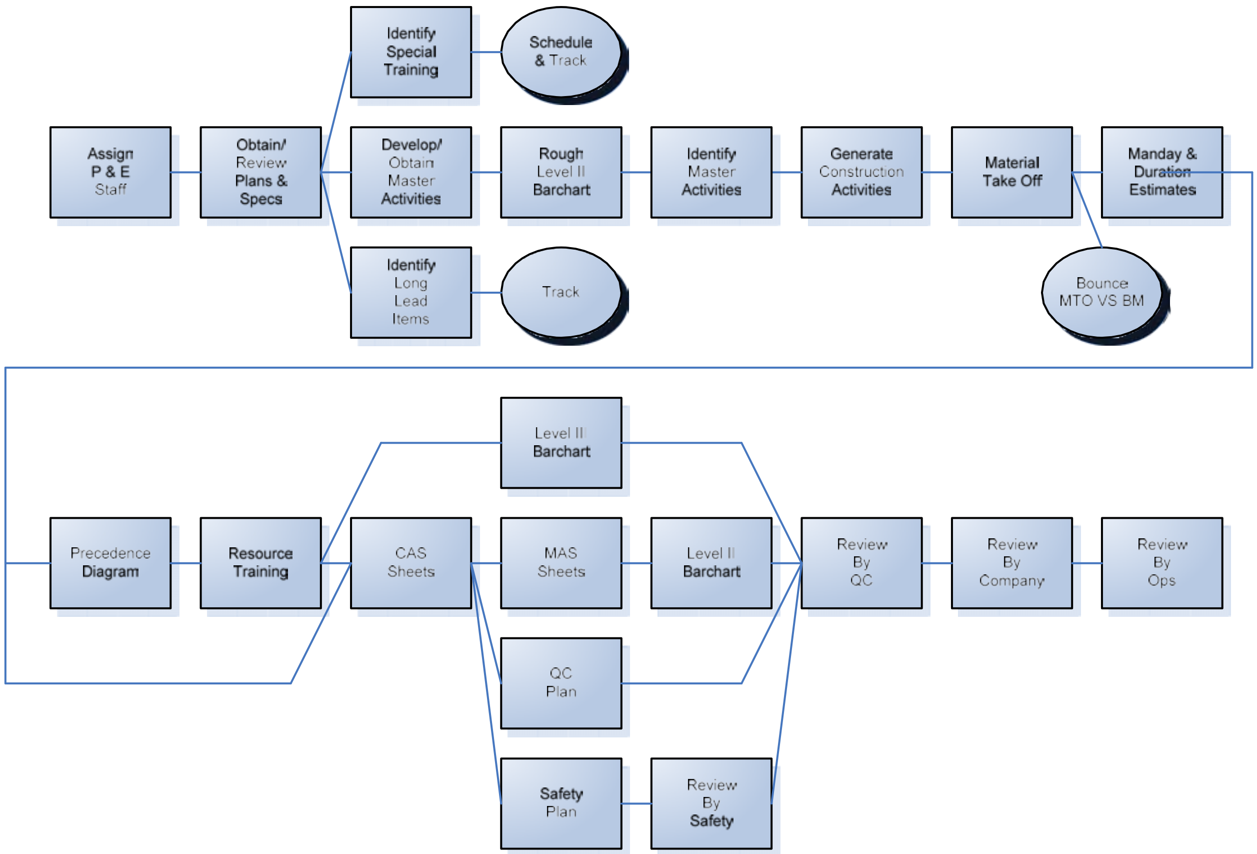

Figure 4-1 – Project planning flowchart.

2.3.0 Using Blueprints

Construction drawings are your main basis for defining the required activities for measuring the quantities of material. Accurate estimating requires a thorough examination of the drawings. Carefully read all notes and references and examine all details and reference drawings. Carefully check the orientation of sectional views. Dimensions shown on drawings or computed figures shown from those drawings take precedence over those obtained by scaling distances.

Check the Revision section near the title section to ensure that the indicated changes were made in the drawing itself. You must ensure that the construction plan, the specifications, and the drawings are for the same project. When there are inconsistencies between general drawings and details, follow the details. If there is a controversy, request an RFI for further clarification. When there are inconsistencies between drawings and specifications, follow the specifications.

As an estimator, you must first study the specifications and then use them with the drawings when preparing quantity estimates. Become thoroughly familiar with all the requirements stated in the specifications. Some estimators may have to read the specifications more than once to understand these requirements in their mind. You are encouraged to make notes as you read the specifications. These notes will be helpful to you later as you examine the drawings and prepare your CAS sheet and MTOs. In the notes, list any unusual or unfamiliar items of work or materials and reminders for use during examination of the drawings. A list of activities and materials described or mentioned in the specifications is helpful in checking quantity estimates.

The tables and diagrams in the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405, should save you time in preparing estimates and, when used properly, provide accurate results. The tables and the 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. A thorough knowledge of the project drawings and specifications makes you alert to the various areas where errors may occur.

One way to reduce errors is to keep track of the drawings and specifications for which you have already created estimates. Use highlighters to mark each section of the prints as you complete the estimate for it.

2.3.1 Accuracy as a Basis for Ordering and Scheduling

Quantity estimates are used as a basis for purchasing materials, determining equipment, and determining manpower requirements. They are also used in scheduling progress, which provides the basis for scheduling material deliveries, equipment, and manpower. Accuracy in preparing quantity estimates is extremely important; 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. For example, concrete ingredients, lumber, reinforcing materials, and everything else involved in mixing and placing the concrete, including equipment time, material, manpower, and man-hours, will be seriously underestimated and under-ordered.

2.3.2 Checking Estimates

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

2.3.3 Error Sources

Failure to read all 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. Although not recommended but sometimes required take care in scaling drawings so that you 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, some drawings are not drawn to scale. Since these cannot be scaled for dimensions, you must obtain dimensions from other sources.

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. If drawings are revised after material takeoff, new issues must be compared with the copy used for takeoff and appropriate revisions made 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.

2.4.0 Master Activities

Projects are broken down into master activities representing large, functional parts of the project. A good narrative description of each master activity clearly shows where each section of the project falls. This helps reduce the chance of omitting any items of work when estimating.

The standard master activities Seabees use are listed in *Table 4-1*. These are based on the same numbering system format used for the 16 divisions established by the Construction Specification Institute (CSI). Division 17 (Expeditionary Structures) was established specifically by NAVFAC.

Table 4-1 – Standard 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 Construction
16XX	Electrical Construction
17XX	Expeditionary Structures

Each master activity is further broken down into construction activities identifying functional parts of the facility, often tied to a particular company or rating.

2.5.0 Construction Activity

The crewleader breaks the master activity down into construction activities. A typical NMCB project might have between fifteen and fifty construction activities. Construction activity numbers are four digits. The standard construction activities the Seabees use are listed in *Table 4-2*. The first two digits identify the master activity and the second two digits show a specific construction activity within a master activity.

Table 4-2 – Standard Construction Activities.

01 General			
010X	Overhead	015X	Site Facilities & Temporary Controls
013X	Submittals	016X	Material & Equipment
014X	Quality Control	017X	Job Close Out

02 Site Work			
020X	Subsurface & Demolition	025X	Paving & Surfacing
021X	Site Preparation	026X	Piped Utilities
022X	Earthwork	027X	Sewerage & Drainage
023X	Tunneling, Piles, & Caissons	028X	Site Improvements
024X	Railroad & Marine Work	029X	Landscaping
03 Concrete Construction			
031X	Concrete Formwork	034X	Precast Concrete
032X	Concrete Reinforcement	035X	Cementitious Decks
033X	Cast-in-Place Concrete		
04 Masonry			
041X	Mortar & Masonry Accessories	044X	Stone
042X	Unit Masonry	045X	Masonry Restoration & Cleaning
05 Metals			
050X	Metal Materials, Finishes, & Fastenings	053X	Metal Decking
051X	Structural Metal Framing	055X	Metal Fabrications
052X	Metal Joists	058X	Expansion Control
06 Carpentry			
060X	Fasteners & Adhesives	063X	Wood Treatment
061X	Rough Carpentry	064X	Architectural Woodwork
062X	Finish Carpentry		
07 Moisture Protection			
071X	Waterproofing & Dampproofing	076X	Flashing & Sheet Metal
072X	Insulation	077X	Roof Specialties & Accessories
073X	Shingles & Roofing Tiles	078X	Skylights
074X	Preformed Roofing & Siding	079X	Joint Sealers
075X	Membrane Roofing		
08 Doors, Windows, & Glass			
081X	Metal Doors & Frames	086X	Wood & Plastic Windows
082X	Wood & Plastic Doors	087X	Hardware
083X	Special Doors	088X	Glazing
084X	Entrances & Storefronts	089X	Glazed Curtain Wall
085X	Metal Windows		

09 Finishes			
091X	Metal Support Systems	096X	Flooring & Carpet
092X	Lath, Plaster, & Gypsum Board	097X	Special Flooring & Floor Treatment
093X	Tile	098X	Special Coating
094X	Terrazzo	099X	Painting & Wall Coverings
095X	Acoustical Treatment & Wood Flooring		
10 Specialties			
101X	Chalkboards, Compartments, & Cubicles	106X	Partitions & Storage Shelving
102X	Louvers, Corner Protection, & Access Flooring	107X	Telephone Specialties
103X	Fireplaces, Exterior Specialties, & Flagpoles	108X	Toilet & Bath Accessories & Scales
104X	Signs	109X	Wardrobe & Closet Accessories
105X	Lockers, Protective Covers, & Postal Specialties		
11 Architectural Equipment			
110X	Equipment	115X	Industrial & Process Equipment
111X	Mercantile & Commercial Equipment	116X	Lab, Planetarium, & Observatory Equipment
114X	Food Service, Residential, Darkroom, & Athletic Equipment	117X	Medical Equipment
12 Furnishings			
123X	Manufactured Casework	127X	Multiple Seating
125X	Window Treatment	128X	Interior Plants & Planters
126X	Furniture & Accessories		
13 Special Construction			
130X	Special Construction	133X	Utility Control Systems
131X	Preengineered Structures, Pools, & Ice Rinks	135X	Recording & Transportation Control Instrumentation
132X	Tanks, Tank Covers, & Filtration Equipment		
14 Conveying Systems			
141X	Dumbwaiters	144X	Lifts
142X	Elevators	145X	Material Handling Systems
143X	Moving Stairs & Walks		

15 Mechanical Construction			
151X	Pipe & Fittings	155X	Heating
152X	Plumbing Fixtures	156X	HVAC Piping Specialties
153X	Plumbing Appliances	157X	Air Conditioning & Ventilating
154X	Fire Extinguishing System		
16 Specialties			
160X	Raceways	165X	Power System & Capacitors
161X	Conductors & Grounding	166X	Lighting
162X	Boxes & Wiring Devices	167X	Electric Utilities
163X	Starters, Boards, & Switches	168X	Special Systems
164X	Transformers & Bus Ducts		
17 Expeditionary Structures			
Construction activity numbers may be assigned as needed under this master activity.			

According to the list of master activities in *Table 4-1* and the list of construction activities in *Table 4-2*, a project with a construction activity for "Install Footing RST" would be numbered 0325. The 03 represents the "Concrete Construction" master activity and the 25 distinguishes "Install Footing RST" from other construction activities in that master activity. 5 replaces the "X" in the standard construction activity "Concrete Reinforcement".

2.6.0 Work Element

Construction activities are further broken down into work elements. A specific construction activity could have one or several work elements. A construction activity such as "Fabricate Forms for Footings" could require only one work element. A construction activity such as "Install PVC Pipes" could require several work elements depending on the different types of fittings involved. These work elements are placed on the back of the CAS sheet as line items in the construction comments block. NAVFAC P-405 uses the term "work element". Other estimating guides use different terms, but the concept is the same. *Figure 4-2* shows the front of a blank Construction Activity Summary sheet.

CONSTRUCTION ACTIVITY SUMMARY SHEET

PROJECT NUMBER:_
TITLE:_
BM CODE:_ _ **PREPARED BY:_ _** **CHECKED BY:_ _**
START SCHEDULED:_ FINISH SCHEDULE:_ _
ACTUAL:_ ACTUAL:_

ACT. NO.:_ _ **MASTER ACTIVITY:_**
ACT. TITLE:_

DESCRIPTION OF WORK METHOD:_

DURATION: ESTIMATED_ **MANDAYS:** ESTIMATED_
ACTUAL_ ACTUAL_ _
Production Efficiency Factor:_ Resulting Delay Factor:_ _
Travel Time:_ _ Manday Equivalent:_

LABOR RESOURCES:

NO.	DESCRIPTION	QTY.	NO.	DESCRIPTION	QTY.

EQUIPMENT/TOOL RESOURCES:

NO.	DESCRIPTION	QTY.	NO.	DESCRIPTION	QTY.

MATERIAL RESOURCES:

NO.	DESCRIPTION	QTY.	NO.	DESCRIPTION	QTY.

ASSUMPTIONS:_ _

ACTIVITY NUMBER:_ ACTIVITY DESCRIPTION:_ _

Figure 4-2 – Construction Activity Summary Sheet.

3.0.0 ESTIMATING

The construction activities provide a basis for preparing the estimates of material, equipment, and manpower requirements. A construction activity might call for rough-in piping in a floor slab. In a material estimate, your immediate concern is to identify the material necessary to do the task; pipe, fittings, joining materials, and so forth. The equipment estimate for this activity should consider vehicles for movement of material and special tools; such as portable power tools, kits, a threader, and a power vise. From the scope of the activity and the time restraints, you can estimate the manpower required. The information shown in the construction activity is also useful in scheduling progress and in providing the basis for scheduling deliveries of material, equipment, and manpower to the jobsite.

Before doing anything, become knowledgeable about the project by studying the drawings. Read the specifications and examine all available information concerning the site and local conditions. Only after becoming familiar with the project are you ready to identify individual activities. Here are two ideas that will help you make good estimates.

First, define activities. They may vary depending on the scope of the project. An activity is a clearly definable quantity of work. For estimating and scheduling, an activity for a single building or job should be a specific task or work element done by a single trade. For scheduling of large-scale projects, however, a complete building may be defined as an activity. For estimating, it should remain at the single-task, single-trade level.

Second, after becoming familiar with the project and defining its scope, proceed with identifying the individual activities required to construct the project. To identify activities, be sure each activity description shows a specific quantity of work with clear, definite limitations or cutoff points that everyone concerned with the project can readily understand. Prepare a list of these activities in a logical sequence to check for completeness.

As project estimator, you will need to assemble information about various conditions affecting the construction of the project. This enables you to prepare a detailed and accurate estimate. Drawings should be detailed and complete. Specifications should be exact and leave no doubt as to their intent. Information should be available about local material, such as quarries, gravel pits, spoil areas, types of soil, haul roads and distances, foundation conditions, the weather expected during construction, and the time allotted for completion. You should know the number and types of construction equipment available. Consider all other items and conditions that might affect the production or the progress of construction.

Test your Knowledge (Select the Correct Response)

3. When identifying an activity for an activity estimate, you must ensure that the

   A. Description is not complicated
   B. Description includes all trades required to do the task
   C. Manpower is available to accomplish the task
   D. Description identifies a specific quantity of work

3.1.0 Material Estimates

A material estimate consists of a listing and description of the various materials and the quantities required to construct a given project. Information for preparing material estimates is obtained 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.

Material estimates are used to procure construction material and to determine whether sufficient material is available to construct or complete a project. The sample forms shown in *Figures 4-3, 4-4, and 4-5* may be used in preparing material estimates. The forms show one method of recording the various steps taken in preparing a material estimate. Each step can readily be understood when the work sheets are reviewed. A work sheet must have the following headings: Project Title, Project Location, Drawing Number, Sheet Number, Project Section, Prepared By, Checked By, and Date Prepared.

ESTIMATING WORK SHEET					
Prepared By:	Proj Location Diego Garcia	Sheet _1_ of _5_	Drawing No 1,337,494/7,604,980		Proj Title Cantonnment Area Interim Water System Bldg.
Checked By:	Proj Section Architectural	Activity No Node _71_ to Node _64	BM No. DIW-112	MTO No.	Date Prepared 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 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 4-3 – Typical estimating work sheet.

3.1.1 Estimating Work Sheet

The Estimating Work Sheet shown in *Figure 4-3*, 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, a material description, and the cost, the unit of issue, the waste factors, the total quantities, and the remarks. The field supervisor should keep the Estimating Work Sheets during construction to ensure the use of the material as planned.

3.1.2 Material Takeoff Sheet

The Material Takeoff Sheet (MTO) is shown in *Figure 4-4*. In addition to containing some of the information on the Estimating Work Sheet, the MTO also contains the suggested vendors or sources, supply status, and the required delivery date.

<table>
<tr><td colspan="6">MATERIAL TAKEOFF WORKSHEET</td><td>Page _1 of _5</td></tr>
<tr><td>Project Location:
Diego Garcia</td><td colspan="2">Project Title:
Cantonment Area, Interim Water Sys Bldg</td><td colspan="2">Project Number:
1938.97</td><td>BM Number:
DIW-112</td><td>Date Prepared:
19 FEB ‘92</td></tr>
<tr><td>Project Section:
Architectural</td><td>Master Activity Number:</td><td>Drawing Number:
1,337,494/7,604,980</td><td colspan="2">Prepared By:</td><td colspan="2">Checked By:</td></tr>
<tr><td rowspan="2">Construction Activity Number</td><td colspan="2" rowspan="2">Description/Calculations</td><td colspan="2">MTO</td><td colspan="2" rowspan="2">Remarks:</td></tr>
<tr><td>U/I</td><td>Qty</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td colspan="2"></td></tr>
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</table>

Figure 4-4 – Typical material takeoff (MTO) worksheet.

3.1.3 Bill of Material

The Bill of Material (BM) sheet shown in *Figure 4-5* is similar in content to the Material Takeoff Sheet. Here 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.

Between procurement and final installation, construction material is subject to loss and waste. This loss may occur during shipping, handling, 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, however, 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, appendix C.

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"x4"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 4-5 – Sample bill of material (BM) sheet.

3.1.4 Checklists

Use checklists to eliminate any omissions from the material estimates. Prepare a list for each individual project when you examine the drawings, specifications, and activity estimates. This is the practical way to prepare a listing for the variety of material used in a project. The listing applies only to the project for which it has been prepared. If no mistakes or omissions have been made in either the checklist or estimate, the material estimate will contain a quantity for each item on the list.

3.1.5 Long Lead Times

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 nonshelf items, such as steam boilers, special door and window frames, items larger than the standard issue, and electrical transformers for power distribution systems. Identify and order these items early. Make periodic status checks of the orders to avoid delays in completing the project.

3.1.6 Preparing Material Estimates

There are several steps for preparing a material estimate. First, determine the activity by using the activity description with the detailed information furnished by the drawings and plans to provide a quantity of work. Convert this quantity to the material required. Next, enter the conversion on a work sheet to show how each quantity was computed, as shown in *Figure 4-3*. Include sufficient detail; work sheets need to be self-explanatory. Anyone examining them should be able to determine how the quantities were computed without having to consult the estimator. Allowances for waste and loss are added after determining the total requirement. All computations should appear on the estimate work sheet, as must all notes related to the reuse of the material. Material quantities for similar items of a project are entered on the Material Takeoff Sheet or Bill of Material. *Figures 4-4 and 4-5* become the material estimate for the project.

Test your Knowledge (Select the Correct Response)

4. **(True or False)** When ordering construction materials, long lead items are readily available through the supply system.

   A. True
   B. False

3.2.0 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. In the past, estimators used the posted speed limit as an average rate for moving material. This was wrong. Equipment speed usually averages between 40 to 56 percent of the posted speed limit. Factors such as road conditions, number of intersections, amount of traffic, and hauling distances, affect the percentage of the posted speed limit for moving material. You should consider the types of material hauled; damp sand or loam, for example, is much easier to handle than clay. Safety (machine limitations), operator experience, condition of the equipment, work hours, and the local climate are other factors.

You must 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. To estimate the production rate per day for each piece of equipment, consider the factors discussed above, along with information obtained from NAVFAC 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 to perform the work. 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.

3.2.1 Estimate Sheets

After the reviews and revisions, prepare a list of equipment required. The list must include anticipated downtime. Add sufficient reserve pieces to cover any downtime.

To aid you in preparing the equipment estimate schedule, use such forms as those shown in *Figure 4-6*. 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.)

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.

Sheet 2 of 2

Figure 4-6 – Sample equipment estimate.

3.2.2 TOA and Equipment Characteristics

The ***table of allowance*** (TOA) of the Naval Mobile Construction Battalion (NMCB) contains specific information on the quantities and characteristics of construction equipment available to the NMCBs. *Table 4-3* contains an abbreviated listing of such equipment.

Table 4-3 – NMCB Construction Equipment Characteristics.

QUANTITY	EQUIPMENT DESCRIPTION
	TRUCKS
12	Dump, 6 x 6, 5 ton, 5 cu. Yd. capacity
8	Dump, 6 x 4, 15 ton, 10 cu. Yd. capacity
	GRADERS
6	Motor, road, 12 ft. blade, 6 x 4, with scarifier
	LOADERS
4	Scoop, full tracked, 1 ½ cu. yd. multipurpose bucket
2	Scoop, wheeled, 4 x 4, 2 ½ cu. yd. std. bucket with forks
2	Scoop, wheeled 4 x 2, 2 ½ cu. yd. std. bucket with forks backhoe, crane, dozer blade
	ROLLERS
2	Oscillating, self-propelled, 9 wheel, pneumatic tired
3	Vibrating, self-propelled, pneumatic tired, single drum
	SCRAPERS
6	Tractor, wheeled, 14 to 20 cu. yd., hydraulic
	TRACTORS
5	Crawler, hydraulic semi-U-tilt dozer
2	Crawler, hydraulic angle dozer, winch
1	Crawler, hydraulic semi-U dozer, hydraulic ripper
	CRANES
2	Truck, mounted, 8 x 4, 35 ton, 60 ft. boom with extension
1	Truck, mounted, 8 x 4, 25 ton, hydraulic
1	Tractor, wheel mounted, 4 x 4, 12 ½ ton, telescoping boom, hydraulic
	SPECIALIZED EQUIPMENT
1	Distributor, bituminous material, truck mounted, 6 x 4, 2,000 gal. capacity
2	Distributor, water, truck mounted, 6 x 6, 2,000 gal. capacity
2	Distributor, water, wagon mounted, 8,000 gal. capacity
2	Ditching machine, ladder type, 8 to 24 in. width by 7 ft. depth, crawler
2	mounted
2	Excavator, multipurpose, hydraulic, 6 x 6, 11 ft. 1 in. digging depth,
8	mounted
	Auger, earth, truck mounted
	Truck, forklift, rough terrain, 6,000 lb. capacity, pneumatic tired

Test your Knowledge (Select the Correct Response)

5. Where can an estimator locate information on the quantities and characteristics of construction equipment?

   A. SAMM program
   B. NMCB TOA
   C. NAVFAC P-405
   D. NAVFAC P-437

3.3.0 Labor and Manday Estimates

The manpower estimate consists 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 to determine the number of personnel and the ratings required on a deployment. They also provide the basis for scheduling manpower in relation to construction progress.

In the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405, a man-day is a unit of work performed by one person in one 8-hour day or its equivalent. One man-day is equivalent to a 10-hour day for contingency operations in the *Facilities Planning Guide,* NAVFAC P-437.

Battalions set their own schedules, as needed, to complete their assigned tasks. In general, the work schedule of the battalion is based on an average of 55 hours per person per week. The duration of the workday is 10 hours per day, which starts and ends at the jobsite. This includes 9 hours for direct labor and 1 hour for lunch. There are situations where travel to and from the job site is included in the 10 hours.

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 overhead labor and indirect labor. Overhead labor is considered productive labor that does not contribute directly or indirectly to the product, for example administrative tasks such as time cards and evaluations. It includes all labor that must be performed regardless of the assigned mission. Indirect labor includes labor required to support construction operations but that does not, in itself, produce an end product, for example toolkit inventories.

There are two types of labor estimates; preliminary manpower estimates and detailed manpower estimates.

Test your Knowledge (Select the Correct Response)

6. When filling out a time card, what code should you give labor required to support construction operations but that does not itself produce an end product?

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

3.3.1 Preliminary

Use preliminary manpower estimates to establish budget costs and the project manpower 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.

3.3.2 Detailed

Use detailed manpower estimates to determine the manpower requirements for constructing a given project and the total direct labor requirements of a deployment. Take the individual activity quantities from the activity work sheet to prepare detailed estimates. Then, select the man-hours per unit figure from the appropriate table in NAVFAC P-405 and multiply it by the quantity to obtain the total man-hours required. When preparing the activity estimates in the format discussed earlier, you may use a copy of the activity estimates as a manpower 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 on another format, in sufficient detail to provide the degree of progress control desired. For example, the work sheets should show the information as in *Figure 4-7*.

DESCRIPTION	QUANTITY	MAN-HOURS* PER UNIT	TOTAL MAN-DAYS
Install 12 inch diameter concrete pipe	2,500 feet	20/100	62.5
Install 30 inch diameter concrete pipe	2,500 feet	80/100	250.0
TOTALS	5,000 feet		312.5
* 8 man-hours equal 1 man-day.			

Figure 4-7 – Sample worksheet.

If the control is to be exercised only on concrete pipe installation without regard to detail, the manpower estimate should show the following information on the summary sheet, as shown in *Figure 4-8*.

DESCRIPTION	QUANTITY	MAN-HOURS* PER UNIT	TOTAL MAN-DAYS
Install concrete pipe	5,000 feet	50/100	312.5

Figure 4-8 – Sample manpower worksheet.

The man-hours per unit on the work sheet is obtained by dividing the total man-days shown in the detail estimate by the total feet of concrete pipe times the unit to obtain the average man-hours. Use the man-hours per unit for checking actual progress. Check manpower estimates against the activity estimate to ensure that no activities have been omitted. NAVFAC P-405 also provides labor estimates for the various projects undertaken by the Engineering Aids.

The *Facilities Planning Guide,* NAVFAC P-437, volumes 1 and 2, is an excellent source for preliminary estimates. Use it to find estimates for a wide range of facilities and assemblies commonly constructed. The P-437 not only gives the man-hours required, but it also gives a breakdown of the construction effort by rating (BU, CE, UT, and so forth) as well as lapsed day estimates.

You must bear in mind that the lapse time from the P-437 is calculated using the contingency norm of a 10 hour man-day instead of the 8 hour man-day used in the P-405. For example, a specific task from the P-437 requires 100 man-hours (MH) of effort by the Utilitiesman. The optimum crew size is four UTs. This yields the following lapse time:

$$100 \quad \frac{MH}{4\ UTs \times 10\ hr} = 2.5\ days\ (lapse\ time)$$

Using the P-405 and an 8-hour man-day, you will find that the same task yields the following:

$$100\ \frac{MH}{4\ UTs \times 8\ hr} = 3.1\ days\ (lapse\ time)$$

In preparing manpower estimates, weigh the various factors affecting 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. The production efficiency guide chart shown in *Table 4-4* lists eight elements that directly affect production.

Table 4-4 – Production Efficiency Guide Chart.

ELEMENTS	**LOW PRODUCTION**	**AVERAGE PRODUCTION**	**HIGH PRODUCTION**
	Production Elements in Percent		
	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 requirement low
2. Site Area	Cramped working area, no area for material storage, work restricted to design, poor job layout	Work area limited slightly, partial material storage, some variation from design, average job layout	Large work are, adequate material storage, wide latitude from design, good job layout
3. Labor	Poorly trained, low strength, low morale, high sick call	Average trained, normal strength, fair morale, normal sick call	Highly trained, over strength, high morale, low sick call
4. Supervision	Poor management, poorly trained personnel, low strength	Average management, average trained personnel, normal strength	Efficient management, highly trained personnel, over strength
5. Job Conditions	High quality work required, unfavorable site materials, short time operations, insect annoyance high	Average work required, average site materials, reasonable operation time, insect annoyance normal	Passable work required, good site materials, long time operations, no insect annoyance
6. Weather	Abnormal rain, abnormal heat, abnormal cold	Moderate rain, moderate heat, moderate cold	Some rain, occasional heat, occasional cold
7. Equipment	Improper job application, equipment in poor condition, repair and maintenance inadequate	Fair job application, equipment in average condition, repair and maintenance average	Efficient job application, equipment in good condition, efficient repair and maintenance
8. Tactical and Logistical	Slow supply delivery, frequent tactical delays	Normal supply delivery, occasional tactical delays	Prompt supply delivery, no tactical delays

Each production element is matched with three areas for evaluation. Each element contains two or more foreseen conditions from which to select 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 in *Figure 4-9*.

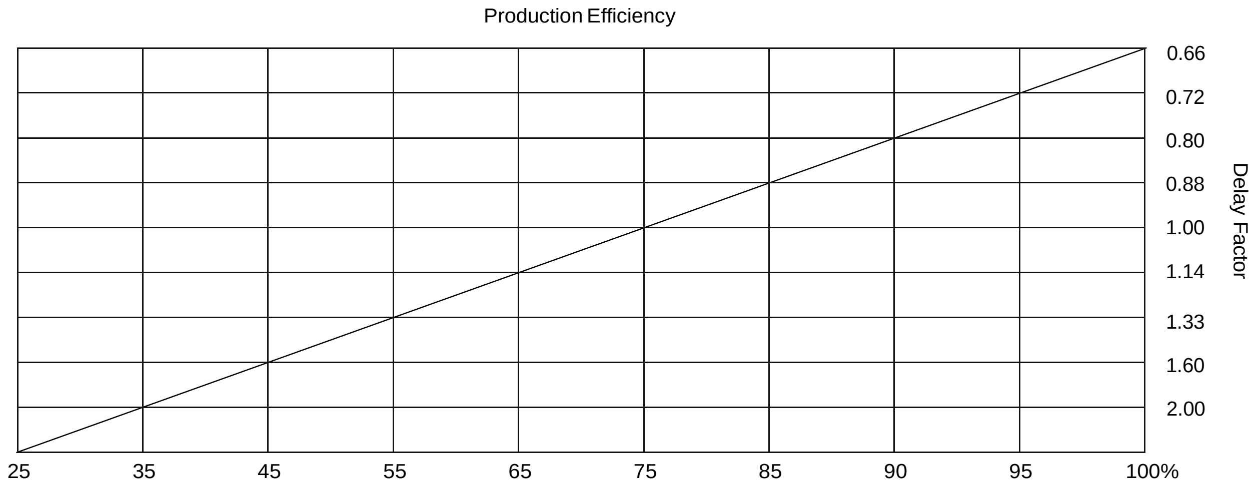


Figure 4-9 – Production efficiency graph.

It is strongly recommended that the field or project supervisors reevaluate the various production elements and make the necessary adjustments to man-day figures based on actual conditions at the jobsite.

NOTE

The estimate of average Seabee production used in the NAVFAC P-405 tables falls at 67 percent production efficiency on the graph shown in *Figure 4-9*. As you see, this represents a delay factor of 1.00. A delay factor of 0.66 represents peak production efficiency, equivalent to 100 percent.

Note that on the graph 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 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 a given unit of work requires 6 man-hours. 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 1.80. You find the adjusted man-hour estimate by multiplying this delay factor by the man-hours from the estimating tables *(6MH* x 0.8 = 4.8 as the adjusted man-hour estimate).

The man-hour labor estimating tables are arranged and grouped together into the 17 major divisions of work. This is the same system used to prepare government construction specifications. The 17 major divisions of work are as follows:

1. General
2. Site sork
3. Concrete
4. Masonry
5. Metal
6. Carpentry
7. Moisture protection
8. Doors, windows, glass
9. Finishes
10. Specialties
11. Architectural equipment
12. Furnishings
13. Special construction
14. Conveying systems
15. Mechanical
16. Electrical
17. Expeditionary Structures

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 herein, 1 man-day equals 8 man-hours of direct labor. Man-day figures do not include overhead items, such as dental or personnel visits, transportation to and from the jobsite, or inclement weather.

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 shown in *Table 4-6 and Figure 4-7* 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. When using the *Seabee Planner's and Estimator's Handbook* for manpower estimates, a man-day is equal to what hour work day?

   A. 7
   B. 7 1/2
   C. 8
   D. 10

4.0.0 SCHEDULING

After World War II, the construction industry experienced the same critical examination that the manufacturing industry had experienced 50 years before. Large construction projects came under the same pressures of time, resources, and cost that prompted studies in scientific management in the factories.

The emphasis, however, was not on actual building methods, but upon the management techniques of programming and scheduling. The only planning methods being used at that time were those developed for use in factories. Management tried to use these methods to control large construction projects. These techniques suffered from serious limitations in project work. The need to overcome these limitations led to the development of network analysis techniques.

4.1.0 Basic Concepts

In the late 1950s, this 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 samples of about 50 different approaches. The basis of each of these approaches is the analysis of a network of events and activities. For this reason, the generic title covering the various networks is network analysis.

Network analysis techniques are now the accepted method of construction planning in many organizations. They form the core of project planning and control systems.

4.1.1 Advantages and Disadvantages

There are many advantages of network analysis. As a management tool, it readily separates planning from scheduling of time. The analysis diagram, a pictorial representation of the project, enables you to see the interdependencies between events and the overall project to prevent unrealistic or superficial planning. Resource and time constraints are easily detachable, to permit adjustments in the plan before its evaluation.

Because the system splits the project into individual events, estimates and lead times are more accurate. Deviations from the schedule are quickly noticed. Manpower, material, and equipment resources are easily identifiable. Since the network remains constant throughout its duration, it is also a statement of logic and policy. Modifications of the policy are allowed, and the impact on events is assessed quickly.

Identification of the critical path is useful when you have to advance the completion date. Attention can then be concentrated toward speeding up those relatively few critical events. The network allows you to accurately analyze critical events and provides an effective basis for the preparation of charts. This results in better control of the entire project.

The main disadvantage of network analysis as a planning tool is that it is a tedious and exacting task when attempted manually. Depending upon what the project manager wants as output, the number of activities that can be handled without a computer varies.

Calculations are made in terms of the sequence of activities. Now, a project involving several hundred activities may be attempted manually. However, the chance for error is high. Suppose the jobs are to be sorted by rating, so jobs undertaken by Utilitiesmen are together, as are those for Equipment Operators or Construction Electricians. The time required for manual operation would become costly.

On the other hand, standard computer programs for network analysis can handle project plans of 5,000 activities or more and can produce output in various forms. However, a computer assists only with the calculations and print plans of operations sorted into various orders. The project manager, not the computer, is responsible for planning and must make decisions based on information supplied by the computer. Also, computer output is only as accurate as its input, supplied by people. The phrase “garbage in, garbage out” applies.

4.1.2 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.

4.2.0 Precedence Diagramming

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 4-10*.

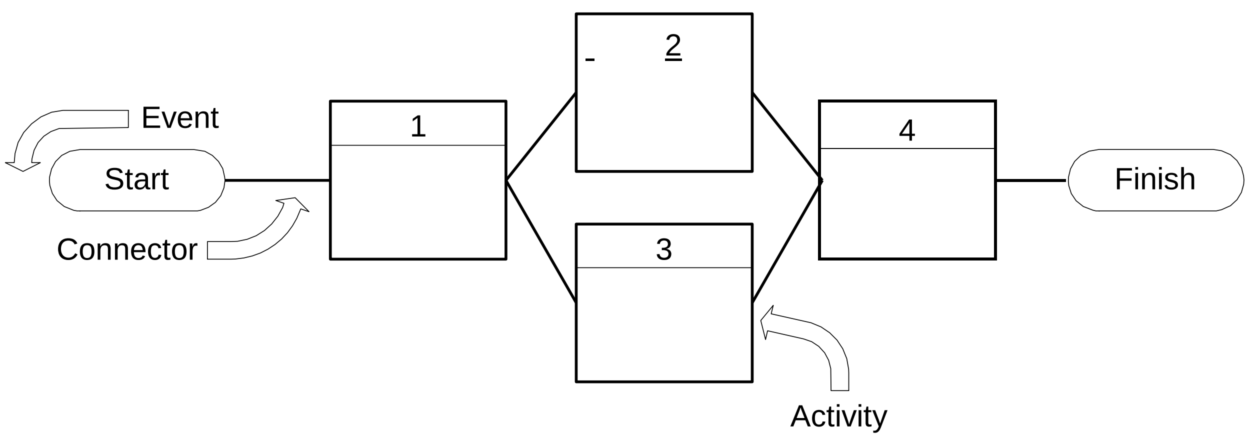


Figure 4-10 – Precedence diagram.

Precedence diagramming does not require the use of dummy activities. It is also easier to draw, and has greater applications and advantages when networks are put in the computer. In precedence diagrams, the activity is “on the node.”

Test your Knowledge (Select the Correct Repsonse)

8. The basic concept behind precedence scheduling is known as

   A. CPM
   B. PERT
   C. SAMM
   D. ADM

4.2.1 Activities and Events

To build a flexible CPM network, the manager needs a reliable means of obtaining the 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 left side of the activity box represents the start of the activity. The right side represents the completion. Lines linking the boxes are called connectors. The general direction of flow is evident in the connectors themselves.

Activities may be divided into three distinct groups:

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, are not normally drawn to scale. They only reflect the logical sequence of events.

Milestone Events – The network may also contain certain precise, definable points in time, called events. Examples of events are the start and finish of the project as a whole. Events have no duration and are represented by oval boxes in a network, as shown in *Figure 4-10*.

Milestones are intermediate goals within a network. For instance, "ready for print" is an important event that represents a point in time but has no time duration of its own. To reach this particular activity, all activities leading up to it must be completed.

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, known as the critical path, which controls the project finish date. The critical path is determined after the forward and backward pass analysis is complete. Slashes drawn through an activity connector, as shown in *Figure 4-11*, denote a critical path.

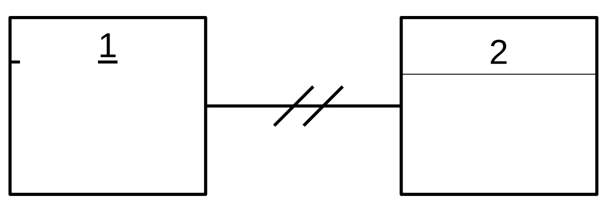


Figure 4-11 – Designations of a critical path.

The rule governing the drawing of a network is that the start of an activity normally 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 4-10*, 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.

Test your Knowledge (Select the Correct Response)

9. **(True or False)** The longest path through a network is the critical path.

   A. True
   B. False

4.2.2 Use of Diagram Connectors

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

Representing a Delay – In certain cases, there may be a ***delay*** between the start of one activity and the start of another. In this case, the delay maybe indicated on the connector itself, preceded by the letter *d* as in *Figure 4-12*. Here, Activity 2 may start as soon as Activity 1 is complete, but Activity 3 must wait 2 days. The delay is stated in the basic time units of the project, so the word days can be omitted.

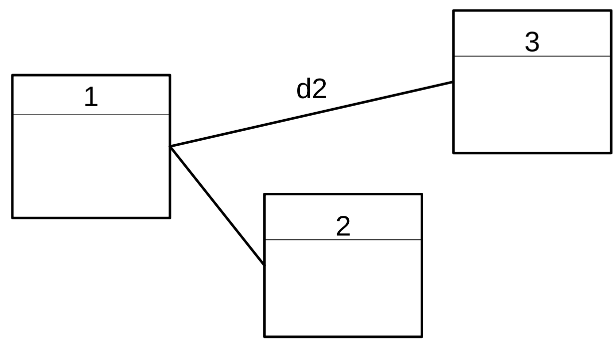


Figure 4-12 – Representation of delay.

Representing a Parallel Activity – Some activities may parallel others. This can be represented in precedence diagrams without increasing the number of activities. For instance, it is possible to start laying a long pipeline before the excavations are completed. This type of overlap is known as a lead. It is also possible to start a job independently, but to not complete it before another is completed. This type of overlap is known as a lag. It is also a common occurrence that both the start and the finish of two activities may be linked, but, in this case, they are accommodated by a combination of lead and lag.

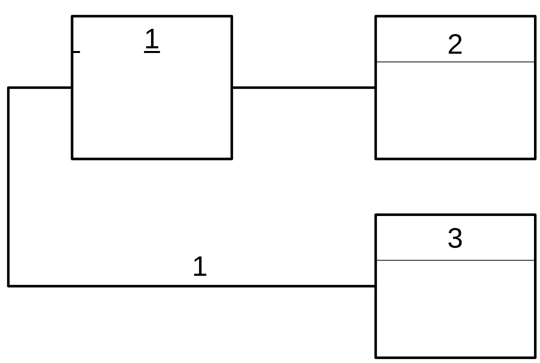


Figure 4-13 – Lead on start of preceding activity.

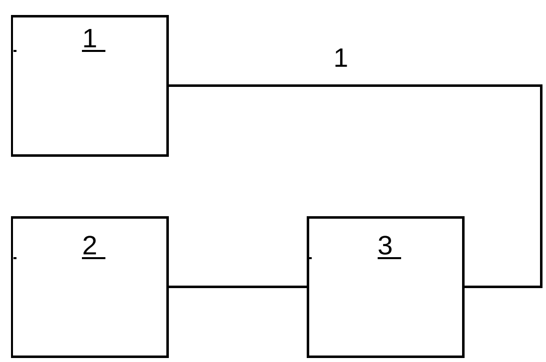


Figure 4-14 – Lag on finish of a following activity.

As seen in *Figure 4-13*, a lead or partial start is indicated by drawing the connector from the start of the preceding activity (1). In *Figure 4-14*, a lag or partial finish is indicated by drawing the connector from the end of the following activity (3). The values may be given in the basic time units of the project, as with a delay, or as a percentage of overlap. In certain circumstances, they can be stated as quantities if the performance of the activity can be measured on a quantitative basis. The indication of the type and amount of delay, lead, or lag is generally referred to as a lag factor.

In *Figure 4-13*, Activity 3 may start when Activity 1 is 1-day completed, although Activity 2 must wait for the final completion of Activity 1. In *Figure 4-14*, Activity 3 may start when Activity 2 is completed but will still have 1 day to go when Activity 1 is completed.

The last phase of Activity 3 may not begin until Activity 1 has been completed. In *Figure 4-15*, Activity 2 may start when Activity 1 is advanced 3 days but will still have 4 days of work left when Activity 1 is completed.

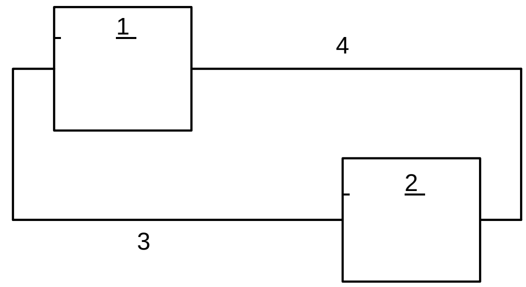


Figure 4-15 – Start and finish lags on same activity.

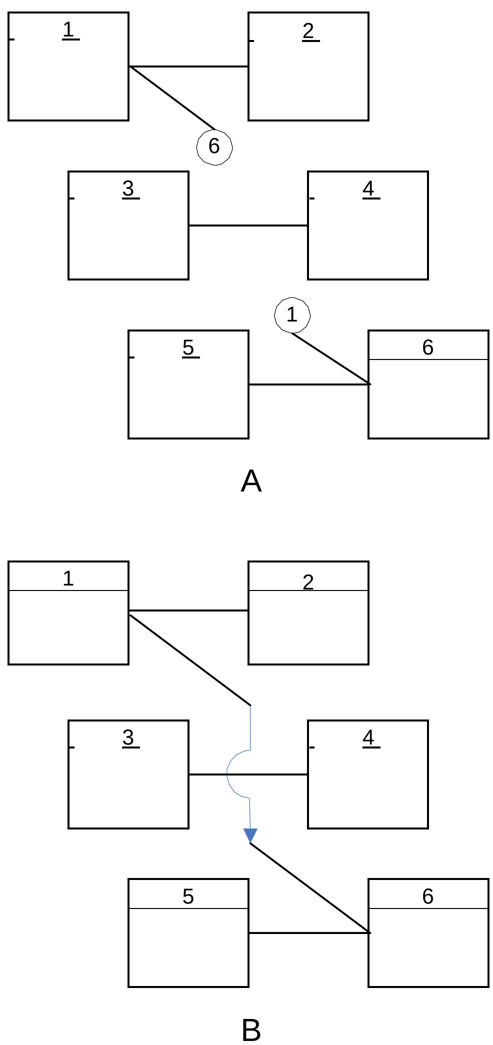


Figure 4-16 – Splitting connectors and line jumps.

Splitting Connectors – The number of sequencing connectors becomes large when a network is of a great size. When two activities are remote from each other 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 4-16*, *view A*, both Activities 2 and 6 are dependent upon Activity 1.

Splitting connectors can also be represented as a line jump, shown in *view B*. Computer printouts will show a line jump as in *view B* rather than a splitting connector as in *view A*.

Direct Linking Using an Event – When the number of common preceding and succeeding activities in a particular complex is large, as in *Figure 4-17*, a dummy event or focal activity of zero duration may be introduced to simplify the network. The use of such a dummy event is shown in *Figure 4-18*, which is a simplification of *Figure 4-17*.

Although the effect in terms of scheduling is the same, the introduction of the dummy improves the clarity of the diagram.

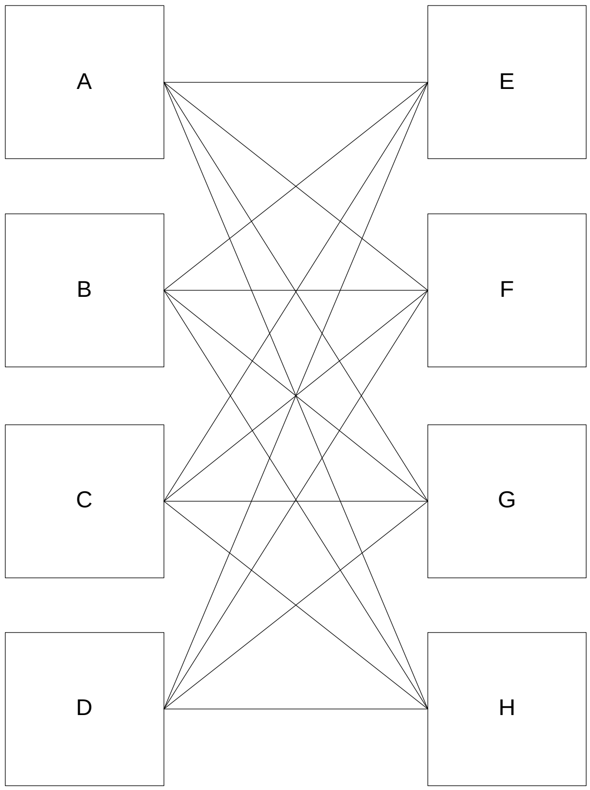


Figure 4-17 – Multiple predecessors and successors (direct linking).

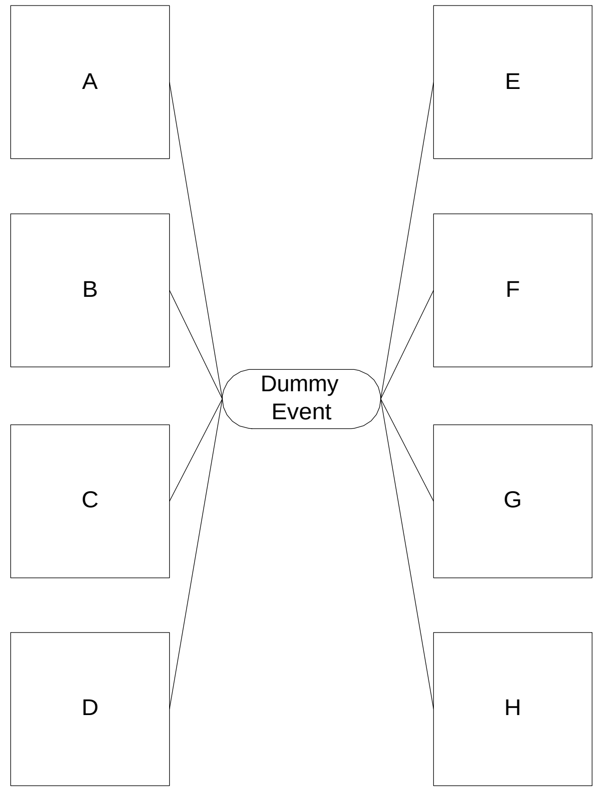


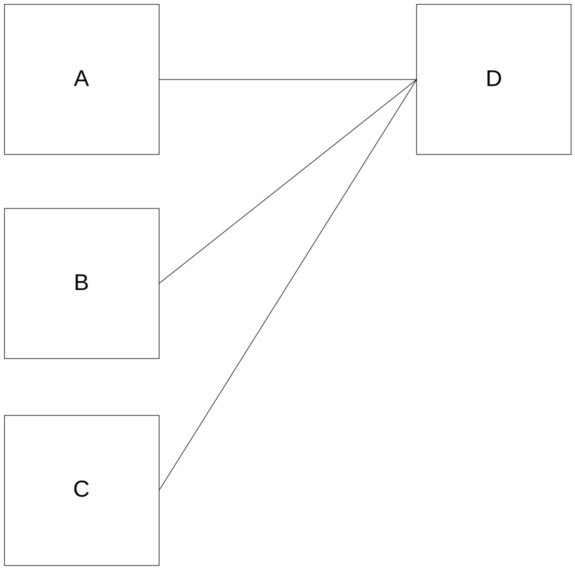
Figure 4-18 – Multiple predecessors and successors (using dummy collector).

Test your Knowledge (Select the Correct Response)

10. The general flow of a precedence diagram is represented by

    A. An alphabetical sequence
    B. A numerical sequence
    C. Arrows
    D. Connectors

Joining Connectors – In many instances, there are opportunities to join several connectors going to a common point to reduce congestion in the drawing. This practice is, however, discouraged. The diagrams in *Figures 4-19* and *4-20* have precisely the same interpretation. The danger with the form of representation is evident in *Figure 4-20*, where several connectors have been joined. When the network is coded for the computer, you may lose sight of the fact that Activity D has three preceding activities since only one line actually enters Activity D.



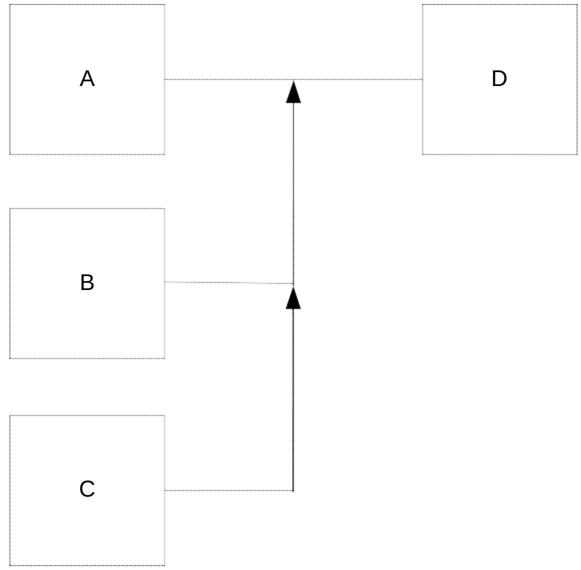


Figure 4-19 – Direct representation of dependencies.

Figure 4-20 – Indirect linking of dependencies.

4.3.0 Precedence Diagrams

Scheduling involves putting the network on a working timetable. Information relating to each activity is contained within an activity box, as shown in *Figure 4-21*.

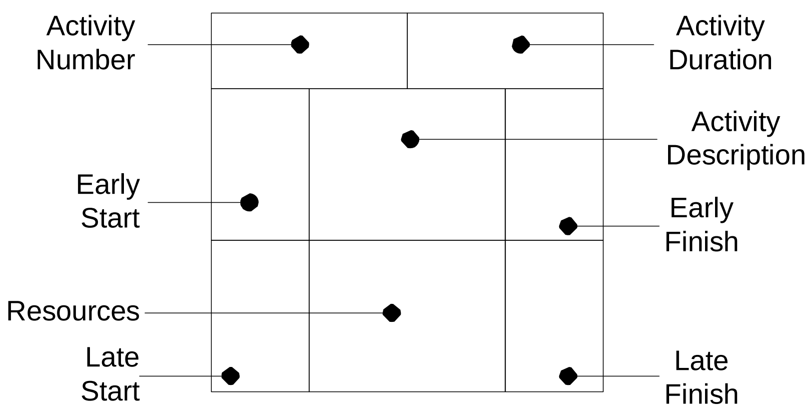


Figure 4-21 – Information for a precedence activity.

4.3.1 Forward and Backward Pass Calculations

To place the network on a timetable, you must make time and duration computations for the entire project. These computations establish the critical path and provide the start and finish dates for each activity. Each activity in the network can be associated with four time values:

- ***Early Start (ES)*** – Earliest time an activity may be started
- ***Early Finish (EF)*** – Earliest time an activity may be finished
- ***Late Start (LS)*** – Latest time an activity may be started and still remain on schedule

- ***Late Finish (LF)*** – Latest time an activity may be finished and still remain on schedule

The main objective of forward pass computations is to determine the duration of the network. The forward pass establishes the early start and finish of each activity and determines the longest path through the network (critical path).

The common procedure for calculating the project duration is to add activity durations successively, as shown in *Figure 4-22*, along chains of activities until you find a merge. At the merge, take the largest sum entering the activity at the start of succeeding activities. Continue the addition to the next point of merger, and repeat the step.

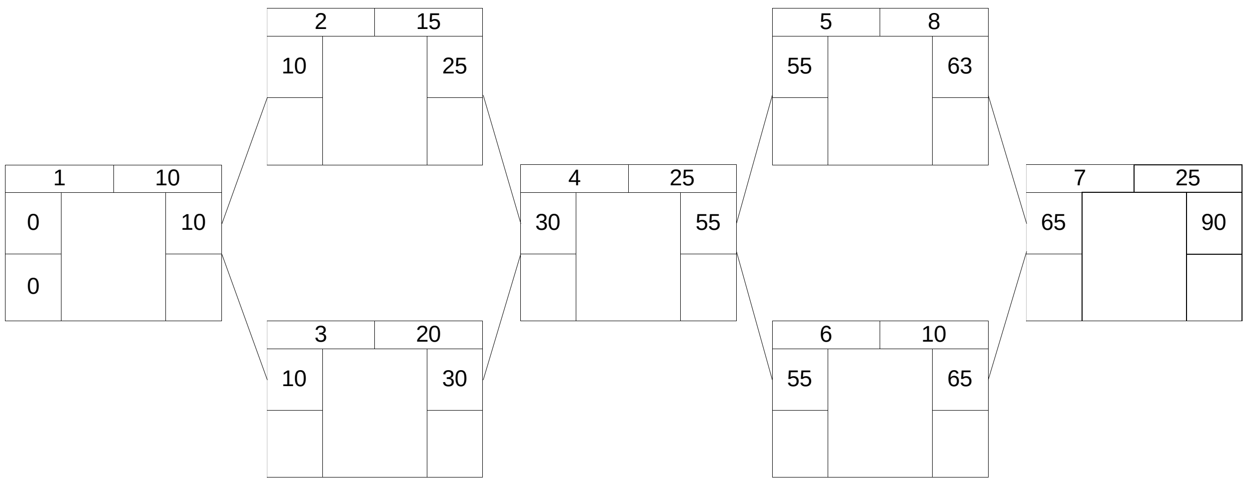


Figure 4-22 – Example of forward pass calculations.

The formula for forward pass calculations is as follows:

ES = EF of preceding activity
EF = ES + activity duration

The backward pass latest possible start and computations provide the finish times that may take place without altering the network relationships. Obtain these values by starting the calculations at the last activity in the network and working backward, subtracting the succeeding duration of an activity from the early finish of the activity being calculated. When you encounter a “burst” of activities emanating from the same activity, calculate each path. Record the smallest or multiple value as the late finish.

The backward pass is the opposite of the forward pass. During the forward pass, add the early start to the activity duration to derive the early finish of that activity. During the backward pass, subtract the activity duration from the late finish to provide the late start time of that activity. This late start time then becomes the late finish of the next activity within the backward flow of the diagram.

LS = LF – activity duration

Figure 4-23 shows a network with forward and backward pass calculations entered.

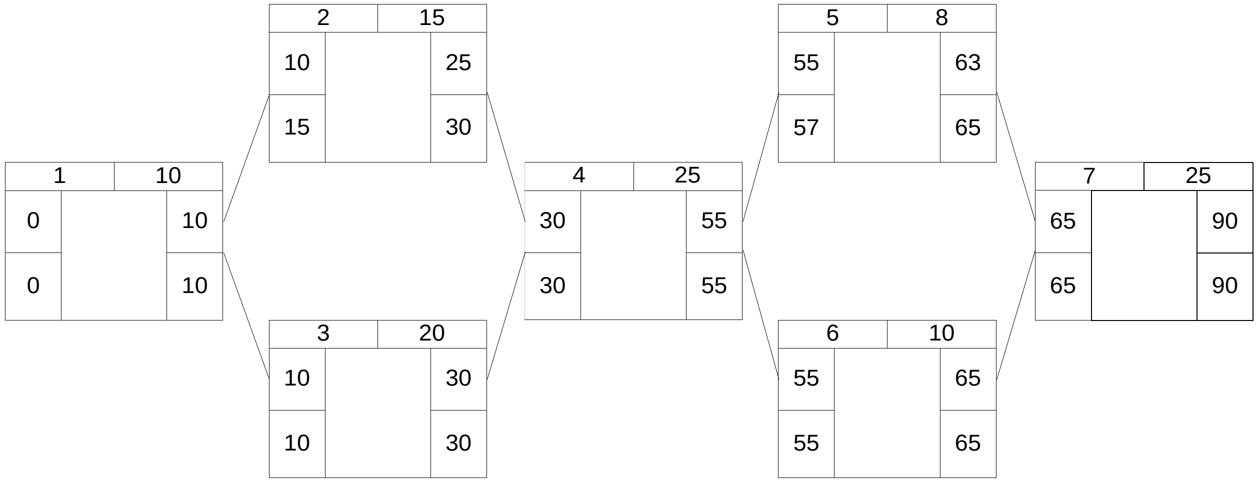


Figure 4-23 – Example of forward and backward pass calculations.

The free and ***total float*** times are the amount of scheduled leeway allowed for a network activity, and are referred to as float or slack. For each activity, it is possible to calculate two float values from the results of the forward and backward passes.

Total Float – The accumulative time span in which the completion of all activities may occur and not delay the termination date of the project is the total float. If the amount of total float is exceeded for any activity, the project end date extends to equal the exceeded amount of the total float.

Calculating the total float consists of subtracting the earliest finish (EF) date from the latest finish (LF) date, that is:

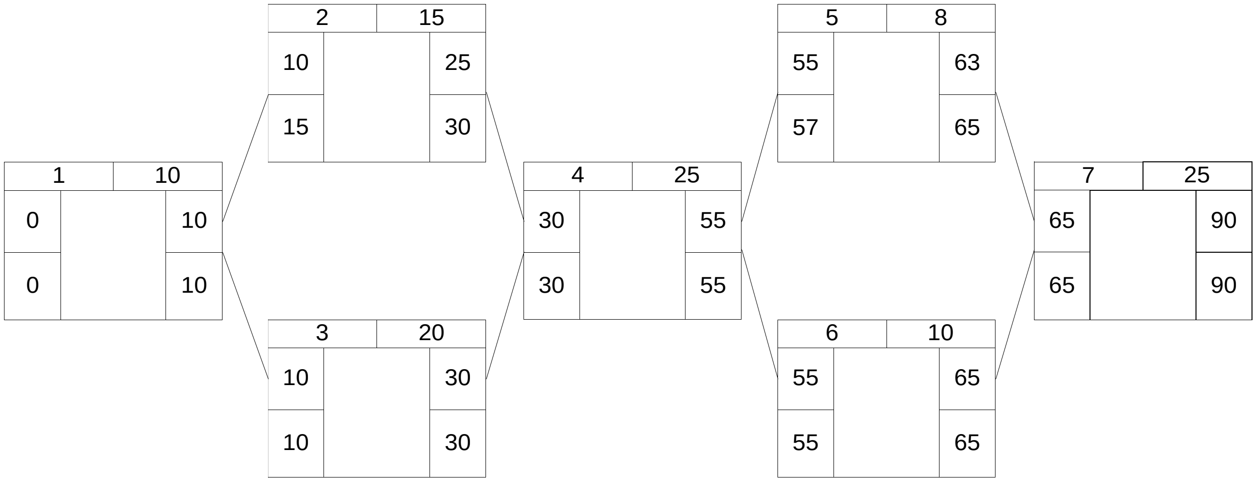
Total float = LF – EF

Free Float – The time span in which the completion of an activity may occur and not delay the finish of the project or the start of a successor activity is the free float. If this value is exceeded, it may not affect the project end date but will affect the start of succeeding, dependent activities.

Calculating the free float consists of subtracting the earliest start (ES) date from the latest start (LS) date, or:

Free float = LS – ES

Figure 4-24 is an example of an activity-on-node precedence diagramming method (PDM) network with total and free float calculations completed.



ACTIVITY	DUR	ES	EF	LS	LF	FF	TF	
1	10	0	10	0 10 0			0	Critical
2 15		10	25	15	30	5	5	
3 20		10	30	10	30	0	0	Critical
4 25		30	55	30	55	0	0	Critical
5 8		55	63	57	65	2	2	
6 10		55	65	55	65	0	0	Critical
7 25		65	90	65	90	0	0	Critical

Figure 4-24 – PDM network with total and free float calculations.

Independent Activity – An independent activity is an activity that is not dependent upon another activity to start. Activity 1, diagramed in *Figure 4-25*, is an example of an independent activity.

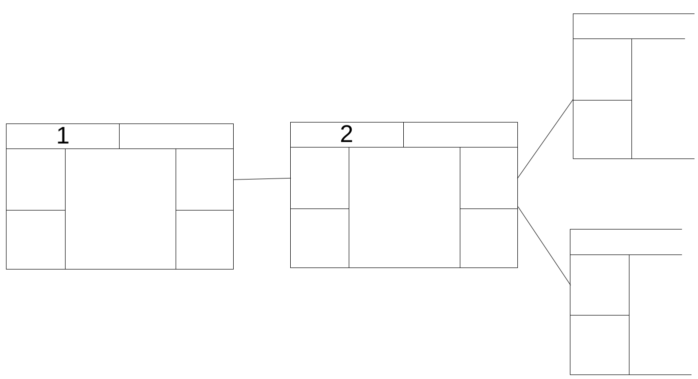


Figure 4-25 – Independent activity.

Dependent Activity – A dependent activity is dependent upon completion of one or more preceding activities before it can start. The relationship in *Figure 4-26* states that the start of Activity 2 is dependent upon the finish of Activity 1.

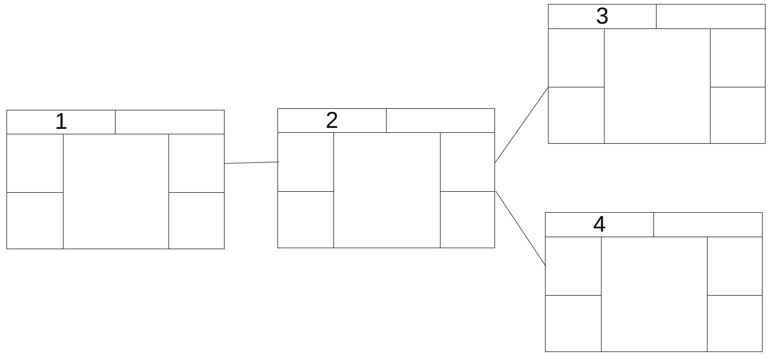


Figure 4-26 – Dependent activity.

Frequently, an activity cannot start until two or more activities have been completed. This appears in the diagram as a merge or junction. In *Figure 4-27*, Activities 3 and 4 must be completed before the start of Activity 5.

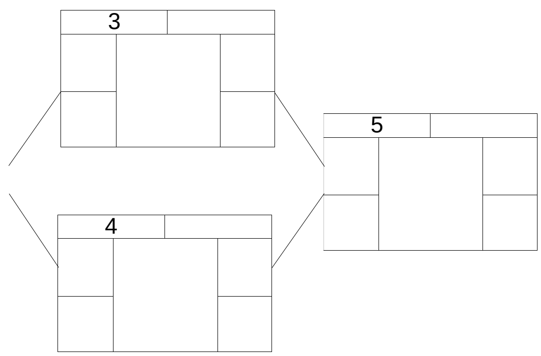
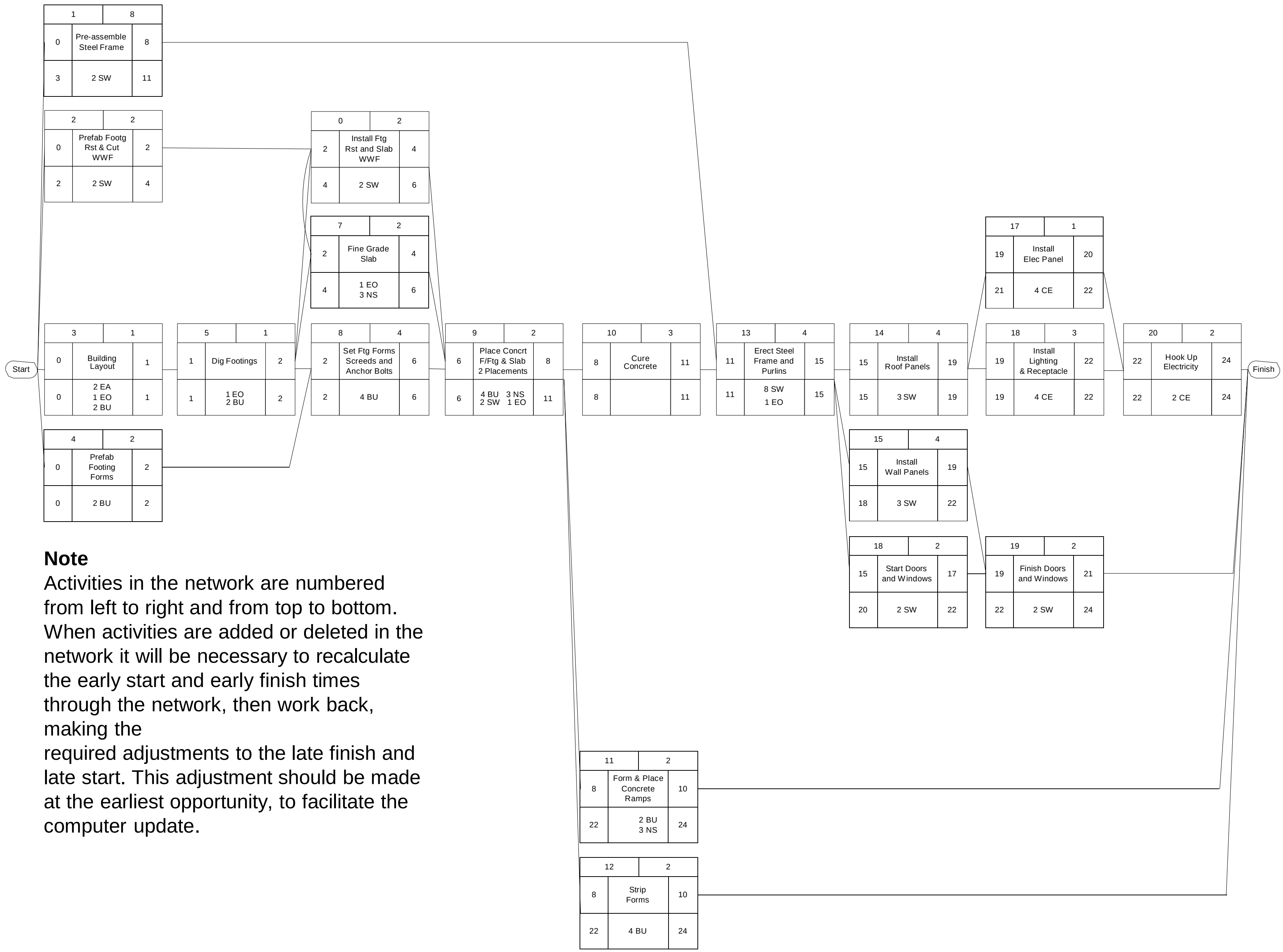


Figure 4-27 – Merge.

Earlier we mentioned a “burst” of activities. A burst is similar to a merge. A burst exists when two or more activities cannot be started until a third activity is completed. In *Figure 4-26*, when Activity 2 is finished, Activities 3 and 4 may start.

4.3.2 Advantages of Diagramming

Precedence networks are easy to draw because the estimator can place all the activities on small cards, lay them out on a flat surface, and easily manipulate them until achieving a realistic logic. It is also easy to show the interrelationships and forward progress of the activities. Just draw connector lines. *Figure 4-28* shows a 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.

Figure 4-28 – Typical precedence diagram for a 40 by 100 foot rigid frame building.

5.0.0 EXECUTION

Construction management in the Seabees is comprised of three levels shown in *Figure 4-29*.

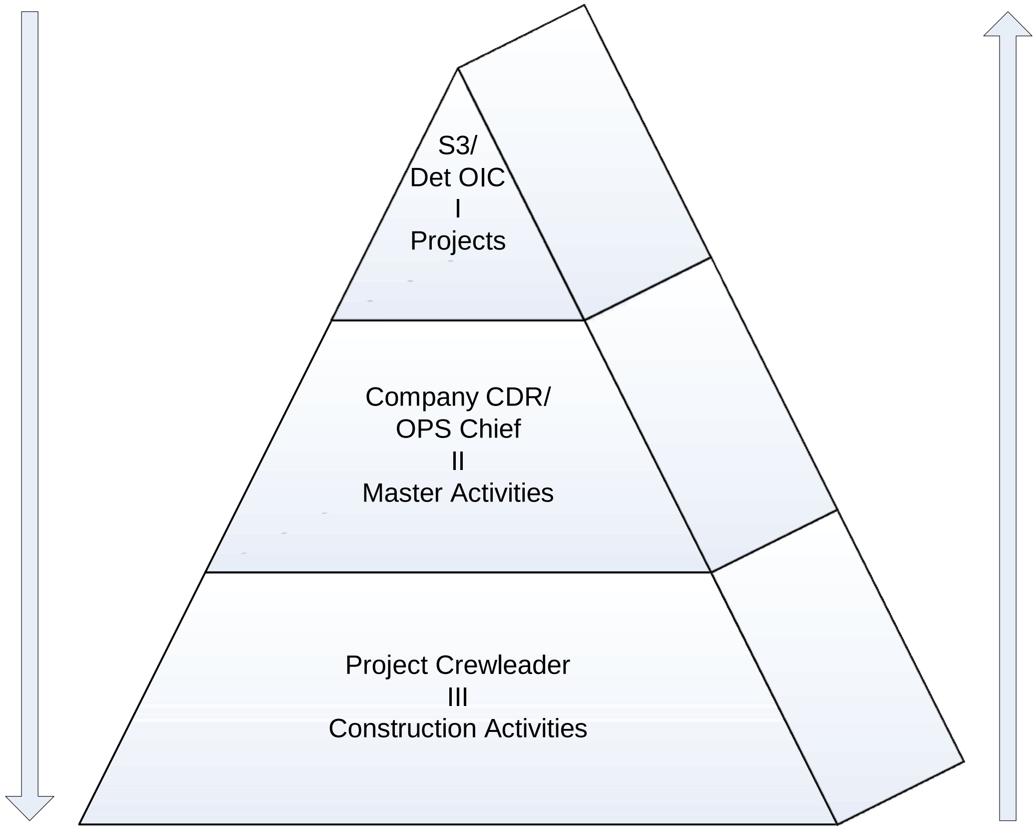


Figure 4-29 – Seabee multi-level construction management.

Planning is done in a top-down, bottom-up cycle as signified by the arrows in *Figure 4-29*. All three levels are eventually summarized on a barchart with a timeline shown horizontally across the top and a list of line items down the left hand side.

5.1.0 Level I

Level I construction management is used at the Operations Officer's (S3) or detail Officer in Charge's (OIC's) level. The primary concern of S3 is management of the overall unit's tasking. The timeline for a Level I barchart will show months of the deployment and the line items will be individual projects.

5.2.0 Level II

Level II construction management is used at the company level. Each company may have several projects to manage. The easiest way for the company commander to manage these projects is with a Level II barchart. The timeline for a Level II barchart will show weeks, and the line items will be master activities for that particular project.

5.3.0 Level III

Level III construction management is used at the crewleader's level. The crewleader's focus is on his/her particular project. He/she manages the day-to-day activity of that project. The timeline for a Level III barchart will show days, and the line items will be construction activities.

6.0.0 ADMINISTRATION

Being a petty officer carries many inherent responsibilities. These include your personal obligation to be a leader, an instructor, and an administrator in all the areas of your rating; military, technical, and safety.

As a petty officer, you need to develop an ability to control the work performed by your workers, as well as to lead them. As you gain experience as a petty officer and increase your technical competence as a Builder, you begin to accept a certain amount of responsibility for the work of others. With each advancement, you accept an increasing responsibility in military matters and in matters relating to the professional work of your rate. As you advance in rank, you will have not only increased privileges but also increased responsibilities. You begin to assume greater supervisory and administrative positions.

The proper administration of any project, large or small, is as important as the actual construction. This chapter will provide you with information to help you use and prepare the administrative paperwork that you encounter as a crew leader.

6.1.0 Planning Work Assignments

Planning means the process of determining requirements and developing methods and schemes of action for performing a task. Proper planning saves time and money and ensures a project is completed in a professional manner. We'll look at some, but not all, of the factors you need to consider.

When you get a project, whether in writing or orally, make sure you clearly understand what is to be done. Study the plans and specifications carefully. If you have any questions, find the answers from those in a position to supply the information you need. Make sure you understand the priority of the project, the expected time of completion, and any special instructions.

Consider the capabilities of your crew. Determine who is to do what and how long it should take. Consider the tools and equipment you will need. Arrange to have them available at the jobsite at the time the work is to get under way. Determine who will use the tools and make sure they know how to use them properly and safely.

To help ensure that the project is completed properly and on time, determine the best method of getting it done. If there is more than one way of doing a particular assignment, analyze the methods and select the one most suited to the job conditions. Listen to suggestions from others. If you can simplify a method to save time and effort, do it.

Establish goals for each workday and encourage your crew to work as a team in meeting these goals. Set goals that keep your crewemployed, but make sure they are realistic. Discuss the project with the crew so they know what you expect from them. Daily briefings of this type cannot be overemphasized.

During an emergency, most crewmembers will make an all-out effort to meet a deadline. Don't expect them to work continuously at an excessively high rate when there is no emergency.

6.2.0 Directing Work Teams

After properly planning a job, you must carefully direct the job. This ensures it is completed on time and with the quality that satisfies both the customer and the crew.

Make sure the crew knows what is expected before starting a project. Give instructions and urge the crew to ask questions on all points that are not clear. Be honest in your answers. If you don't have an answer, say so; then find the answer and get back to the crew. Don't delay in getting solutions to the questions asked. Timely answers keep projects moving forward. They also show the crew your concern for the project is as genuine as theirs.

Spot check to ensure that the work is progressing satisfactorily while a job is under way. Determine whether the proper methods, materials, tools, and equipment are being used. Determine the initial requirements early enough so there are no delays. If crewmembers are performing a task incorrectly, stop them and point out the correct procedures. When you check crewmembers' work, make them feel the purpose of checking is to teach, guide, or direct; not to criticize or find fault.

Make sure the crew complies with applicable safety precautions and wear safety apparel when required. Watch for hazardous conditions, improper use of tools and equipment, and unsafe work practices. These can cause mishaps and possibly result in injury to personnel. There are no excuses for unsafe practices. Proper safety instructions and training eliminate the desire to work carelessly. Practice what you preach when directing construction crews.

Rotate crewmembers on various jobs when time permits. Rotation gives you the opportunity to teach. It also gives each crewmember an opportunity to increase personal skill levels.

As a crew leader, you need to ensure that your crew works together in getting the job done. Develop an environment where each crewmember feels free to seek your advice when in doubt about any phase of the work. Emotional balance is especially important. Don't panic in view of your crew or be unsure of yourself when faced with a conflict.

Be tactful and courteous in dealing with your crew. It sounds obvious, but don't show any partiality. Keep every crewmember informed on both work and personal matters that affect his or her performance. Try to maintain a high level of morale. Low morale has a definite effect on the quantity and quality of a crew's work.

As you advance in rate, you spend more and more time supervising others. You have to learn as much as you can about supervision. Study books on both supervision and leadership. Watch how other supervisors, both good and bad, operate. Don't be afraid to ask questions.

Test your Knowledge (Select the Correct Response)

11. Which of the following actions will aid you, as a crew leader, in developing teamwork?

    A. Rotating crewmembers on various phases of the job
    B. Developing an environment where the crewmembers feel free to seek you out for advice
    C. Maintaining a high level of morale
    D. All of the above

6.3.0 Tool Management

Good tool management is a key ingredient to a successful project. Crewleaders must know tool availability, application, accountability and maintenance. Without the tools, the job can't be done. With the correct tools, the job gets done right and more efficiently.

6.3.1 Planning

Early in the planning process, the Crewleader should look for efficiencies in the construction by choosing the right tools for the task (i.e. Choose a power-nailer over a roofing hammer for 3-tab shingling of a roof). Ensure the tables referenced in the P-405, Seabee Planner's and Estimator's Handbook, apply for the tasks you plan to use. Crewleaders must be familiar with the unit's table of allowance (TOA) to know what to expect for tool availability at the deployment site. Additionally, the Crewleader must communicate with the on-site unit to verify tool condition and availability. All the deployment sites have extra tools that augment the TOA to add flexibility and enhance their construction capability. If required tools are not on site, they may be available elsewhere in the NCF, such as on another detail site or homeport regiment. Tools may be available from local Public Works/self-help shops. Also, if enough project funds are available, they may be rented or purchased.

6.3.2 Tool Kit Inventory

Tool kits contain all the craft hand tools required by one four-member construction crew or fire team of a given rating to pursue their trade. The kits may contain additional items required by a particular assignment. The types of items should not be reduced and should have 100 percent of kit assembly allowance at all times.

As a crew leader, you can order and are responsible for all the tools required by the crew. This incurs the following responsibilities:

- Maintaining complete tools kits at all times
- Assigning tools within the crew
- Ensuring proper use and care of assigned tools by the crew
- Preserving tools not in use
- Securing assigned tools
- Ensuring that all electrical tools and cords are inspected on a daily basis

6.3.3 Accountability

Crewleaders must maintain accountability for all tools on the jobsite. To make sure tools are maintained properly, the operations officer and the supply officer establish a formal tool kit inventory and inspection program. Tool inventories must be completed bi-weekly. Tools requiring routine maintenance are turned in to the central tool room (CTR) for repair and reissue. Damaged or worn tools should be returned to the CTR for replacement. You must submit requisitions for replacement items. Tool management is further specified in instructions issued by Commander, First Naval Construction Division (1NCD) and in the Crewleader Handbook.

The Crewleader should sub-custody tool kits to crewmembers to ensure proper chain of custody and safekeeping. Lost tools are charged to the Seabee who had custody using a pay-checkage form. At times there are also tools that require special attention. These are called Project Tools and are bought with the customer's/project funds for use on that project. The customer owns these tools and will be offered them at the completion of the project.

6.3.4 Maintenance

Crewleaders must exercise proper maintenance and care to ensure safety and long tool life. A good time to visually inspect every tool is during the bi-weekly tool kit inventory. Look for wear and tear, cracks, lack of lubrication, frayed cords, etc. Pay close attention to safety devices and guards, ensuring that they are in proper working order and that crewmembers know the correct way to use them. Taking good care of the tools will prevent construction delays and facilitate good quality construction.

6.4.0 Material Management

Material management and accountability are the crewleader's responsibility. The Material Liaison Office (MLO) is merely a tool used to buy materials for the job. You have already learned that all materials are tied to master activities and identified on the CAS sheets. In this chapter you will learn how to identify hard-to-get materials, how to track them through homeport and on deployment, and how to maintain accountability of the project's money and materials.

6.4.1 Preparing the Requisition

As a crewleader, you must become familiar with the forms used to request material or services through the Navy Supply System. Printed forms are available that provide all the information necessary for the physical transfer of the material and accounting requirements. NAVSUP Form 1250, shown in *Figure 4*-30, is used most often.

Figure 4-30 – NAVSUP 1250.

Crewleaders are not usually required to complete the entire form. The Crewleader must list the stock number of the item, when available, the quantity required, and the name or description of each item needed. Turn this form in to the expediter, who checks it, fills in the remaining information, and signs it. The form then goes to the material liaison officer (MLO) or supply department for processing.

In ordering material, the Crewleader needs to know about the national stock number (NSN) system. Information on the NSN system and other topics about supply is given in *Military Requirements for Petty Officer Third Class,* NAVEDTRA 12044.

6.4.2 Storing Materials at the Job Site

Material receipt, storage and use are very important considerations for setting up the job site. The customer pays for all the materials on Seabee construction projects. The customer expects all U.S. Seabees to protect project materials from theft, misuse, abuse, and damage by handling, weather, or vandalism.

Is there easy access for material delivery and handling? Can you safely store material on your job site? How big an area do you have to store material on site? Has the activity Public Works organization approved a lay-down site? Can the material be secured? Has the activity Security organization been informed of the lay-down site? In some cases the battalion will submit this information for the ROICC to coordinate, or they will go directly to Public Works and Security for information and approval. These items may also be discussed at the Pre-construction Meeting. In either case, you will normally need to prepare a rough drawing of the limits of the areas, and provide all information regarding potential impact to buildings, sites, and personnel adjacent to the construction and lay-down areas. Are materials exposed to the weather? How much material do you need on site? Is the material stored properly? Do you have ***Material Safety Data Sheets*** (MSDS) on hazardous materials, and is it the right material? You should not store more than two weeks of material on the job. If you don't need it now, don't draw it. If you have to build a material storage area, try to place it in an area that is not going to be in the way of construction. You should inspect the material at MLO before you draw it so you will know what to consider for receipt and storage on the job site. Pay particular attention to hazardous material. There are many important considerations for setting up the job site. Items to consider include noise and access impacts. See Appendix 4-A of the *Seabee Crewleader's Handbook* for more specific guidance.

Requisition only the materials you will use for the next two weeks. Take into account pickup/delivery time. Materials required to complete the two week schedules are a good measure of this. Once materials are on the job, the crewleader must protect them from pilferage, weather and job site damage. They will be stored indoors if possible and off the ground outdoors. Lock up high value items that are easily pilfered. With a little prior planning (using the two week schedules) the crewleader can have the materials needed, when they are required, and not worry about them being damaged or stolen. Material management is very important. Copies of manufacturer's installation instructions should be protected and stored in the project folder or elsewhere on the site. These instructions and manuals will need to be turned over to the ROICC at the end of the project, and should be available on site for inspection by QC and ROICC personnel at any time. Material waste by improper installation, poor construction, and damage onsite are the main reason materials are reordered. This is poor construction management and very unprofessional. In extreme cases the crewleader could be responsible under the UCMJ.

6.4.3 Hazardous Material

If project material is hazardous, the crewleader must ensure that MLO supplies a copy of the Material Safety Data Sheet (MSDS). Follow all guidelines listed on the MSDS. The MSDS is explained in Chapter 11 of the *Seabee Crewleader's Handbook*.

6.5.0 Equipment Management

As crewleader you must be familiar with the proper care and maintenance of the equipment your personnel are using. This chapter covers first echelon maintenance, preventive maintenance, and general requirements of the current version of *COMFIRSTNCD Instruction 11200*.

6.5.1 Scheduling

Coordinating equipment requirements between several companies and many projects takes a lot of communication. ALFA Company tracks their workload based on original schedules and weekly goals. When revisions to the schedules are necessary, it takes accurate forecasts on the part of the crewleader several weeks in advance. If the crewleader can see an activity requiring ALFA Company support is going to slip, the crewleader must contact the chain of command immediately to let them know they are not going to be ready and to re-schedule the equipment. The equipment requirements for the projects should be forwarded to ALFA Company as early as possible. This will enable ALFA Company to consolidate all equipment requirements and identify/resolve any constraints.

6.5.2 Planned Maintenance System/PMS Program

PMS was developed to provide the organizational level with the tools to plan, schedule, and control planned maintenance effectively. The maintenance procedures developed in accordance with Reliability-Centered Maintenance (RCM) principles for planned maintenance are the <u>minimum</u> required to maintain equipment within specifications.

PMS is standard in concept and procedure, but flexible enough to be adjusted by the organization to be compatible with operational and other schedules.

PMS supercedes all previous planned or preventive maintenance systems or programs. Where a difference betweenm the requirements and/or procedures of PMS and other technical publications or systems exists, PMS requirements will prevail. Differences shall be reported using PMS feedback reporting procedures.

Equipment not supported by PMS will continue to be maintained per existing procedures of the manufacturers, System Commands (SYSCOM) and/or Bureau of Medicine and Surgery's (BUMED) technical manuals, until PMS is developed and installed. The Fleet Technical Support Centers, Atlantic/Pacific (FTSCLANT/FTSCPAC) function as PMS coordinating activities and are responsible for the accountability and distribution of PMS documentation. The PMS is explained in the current version of NAVSEA Instruction 4790.8B.

6.6.1 Time Cards

The techniques used to evaluate the status of a project and compare the actual progress to the scheduled progress are called Project Monitoring. In order to monitor a project's progress, crewleaders **MUST** be knowledgeable about completing time cards, figuring WIP, updating bar charts, submitting SITREP input and arranging project photos. This chapter will explain the techniques used to monitor a construction project.

Time cards are the most accurate way to record actual mandays on a construction project. They allow you to monitor the efficiency and accountability of your crew. They are the basis of your SITREP input, therefore it is imperative that time cards are filled out correctly and accurately. The current version of COMFIRSTNCD Instruction 5312 is the instruction that governs time keeping for the Seabees. Each crewleader should obtain a copy of it and become familiar with time keeping procedures. The standard form used for time keeping is shown in *Figure 4-31*.

<table>
<tr><th colspan="20">PRIME TIME CARD</th></tr>
<tr><td>Crewleader:</td><td colspan="8">Signature:</td><td colspan="3">Company:</td><td colspan="3">Crew Size:</td><td colspan="5">Transfers This Date:</td></tr>
<tr><td>Project Number:</td><td colspan="14">Project Title:</td><td colspan="5">Date:</td></tr>
<tr><td rowspan="2">Crew Member's Rate/Name</td><td colspan="9">Direct Labor by Construction Activity Number</td><td colspan="5">Indirect</td><td colspan="5">Readiness and Training</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Total</td><td></td><td></td><td></td><td></td><td>Total</td><td></td><td></td><td></td><td></td><td>Total</td></tr>
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Figure 4-31 – Sample prime time card.

Crewleaders will prepare time cards each day to reflect actual mandays by all personnel assigned to them. Crewleaders should be honest when recording actual mandays on the projects. Regardless of whether the crew worked 5 hours or 14 hours on the project, it should be recorded on the time cards. This is the only way to track the projects properly. Subcontractor crewleaders will use the time card in Appendix 9-E in lieu of the standard time card. The sub crewleader will fill out the time card in duplicate while on the project. The time card will reflect all subcontractor labor and will be signed by both the prime and the sub crewleaders. The prime will keep a copy and turn it in with the time card for prime personnel. The sub will turn in the original to his company time keeper. This method will allow the prime crewleader and his chain of command to monitor the effort being expended by the subs and the time being charged against the project. Record all labor to the nearest whole manhour. If more than one labor category applies to a specific manhour, the dominant category shall be used for reporting. Mandays are computed on the basis of an eight-hour day, regardless of the length of the scheduled workday. The reported mandays, therefore, are equal to the total hours worked by an individual divided by eight. Prior to submitting the time cards to the company, the crewleader will transfer the totals from both time cards to a Two Week Labor Summary. This will be used by the crewleader when completing the SITREP feeders. It can also be used to track actual mandays and crew availability. Maintain time cards on file in the company office for the duration of the deployment. Following is a list of labor accounting categories:

a. **Direct Labor.** Direct labor includes all actual mandays expended directly on an assigned construction task, either in the field or in the shop, which contributes directly to the completion of the project. All tasked projects are normally assigned a project number. Labor expended on a specific project will be reported under that project's number. Record direct labor by construction activity number.

b. **Indirect Labor.** Indirect Labor includes actual mandays expended to support construction operations but which does not produce an end product in itself. Therefore, this time is not reported/recorded under a project number but under an indirect labor code. The codes are as follows:

X01 Equipment, Repair and Records: Work in this code includes:

- Maintenance or Repair
- All Common and Automotive Spare Parts Functions
- Record Keeping to Support Maintenance or Repair

X02 Project and Camp Maintenance Support: Work in this code includes:

- Planning and Estimating, and Material Take Offs
- Operation of the Trouble Desk
- Project Planning and Scheduling

X03 Project Management: Work in this code includes:

- Project and Shop Supervision
- Project Coordination and Management Functions such as:

  Arranging for:

  - Equipment and Tools
  - Scheduling Utility Outages
  - Coordinating with Other Crews

- o Inspections, Meetings, and Turnover Functions

X04 Location Moving: Work in this code includes:

- Mobilization/Demobilization of Equipment, Tools, Field Offices, etc. To and From Project Sites
- Motor Pool Operations
- Taxi Drivers and Road Master

X05 Project Travel: Work in this code includes:

- All Travel Time To and From Project Sites (as it pertains to Direct Labor Personnel)

X06 Material Support: Work in this code includes:

- Receipt, Storage, Inventory, Issue and Delivery of Materials

X07 Tools: Work in this code includes:

- All Tool Maintenance and Repair
- Inventory Control
- Ordering Replacement Parts and Rental Equipment

X08 Administration and Personnel: Work in this code includes:

- Legal, DAPA, Career Counselor, Counseling with Chaplain, Driver's License Examiner ESO, PAO, Post Office, Special Services, Supply, Disbursing, Security
- Military Sports Competition
- Armed Forces Police, Court Witness
- TAD Personnel not Covered Under Productive Labor
- Medical and Dental
- Leave and Liberty, Personnel Affairs
- Timekeeping

X09 Lost Time: Work in this code includes:

- Lost Time Due To:
  - Inclement Weather
  - Awaiting Transportation
  - Shortage of Tools and Materials
  - Unauthorized Absence and Confinement

X10 Other: Work in this code includes:

- All Indirect Labor Expended in Areas Not Specifically Addressed Elsewhere in This Category

c. **Readiness and Training.** Readiness and training are comprised of all functions related to preparation for and execution of military exercises, disaster preparedness, mobility, and technical training. Training includes attendance at service schools, factory and industrial training courses, fleet-type training, special Seabee training courses, safety training, military training, and any organized training conducted within the battalion. Report/record these manhours under a specific name.

6.6.1 Crewleader's Logbook

Update all project documents daily. If for some reason this is not possible, the crewleader should keep a daily logbook of everything that transpires on the job site. If the crewleader relies on memory only, some items will be forgotten as time passes. The crewleader's logbook is the best way to track the project's daily activities. *Figure 4-32* is a sample completed entry for a crewleader's logbook.

May 21, Saturday

0700	Act. 03100, 2-Bus Act. 03200, 1-SW, 1-CE Act. 02200, 1-EO, 1-UT *BUCN, UA*
1000	QC/Safety arrive, concerns of worn out GFCIs, CTR has new ones, change them out tonight
1025	QC/Safety depart
1100	BUC arrives with BUCN, Put him on Act. 03100
1115	BUC departs with EO3, he is still sick
1300	BU1 on Act. 03200
1400	Ops arrives
1430	Ops departs
1700	Job site secured

Construction Activity	Total Work	Work Complete	% WIP
03100	1248 sf	1073 sf	86%
03200	1120 pcs	1120 pcs	100%
02200	2700 sf	1800 sf	67%

Material Received

03100	Form release	5 gal
03310	Cement type 1	3 bags
	Sand, washed	6 cubic ft
	3/8" Minus	12 cubic ft
	11S Mixer	1 ea

Typical time card

Crew	Construction Activity No.			Indirect			Readiness and Training		
	03100	03200	02200	X03	X08	X09			
BU1		3		6					
BU2	9								
BU3	9								
BUCN	4					5			
CE3			9						
SW3		9							
EO3			4		5				
UT2		8	9						
Total	22	29	13	6	5	5			

Figure 4-32 – Sample crewleader's logbook entry.

6.6.2 SITREP Input

The battalion sends out a monthly SITREP to higher headquarters to report on the progress of construction tasking. SITREP accuracy is a reflection on how well the crewleaders have documented labor expended on the projects and the quality of the input provided by the crewleaders/companies. The crewleader will forward a SITREP feeder to Ops on a biweekly basis. A sample SITREP feeder is in the *Seabee Crewleader's Handbook* Chapter 15 page 15-44. *Figure 4-33* shows a completed portion of a SITREP feeder and describes each part.

			a	b	a x b		
Master Activity		Original MD Est	Weighted Percent	Master Activity % Comp (WIP)	Project % Complete	Mandays Remaining	Mandays Actual
#	Description						
01	General	20	4	30	1.2	14	22
02	Site Work	47	10	55	5.5	21	24
03	Conc. Const.	140	30	69	20.7	44	105
04	Masonry	32	7	100	7	0	30
05	Metals	9	2	0	0	9	0
06	Carpentry	8	8	0	0	8	0
07	Moist. Protect.	16	4	0	0	16	0
08	Doors/Wind./Glass	10	2	0	0	10	0
09	Finishes	66	15	0	0	66	0
10	Specialties	4	1	0	0	4	0
15	Mech. Const.	44	10	32	3.2	30	16
16	Elect. Const.	30	7	13	.9	26	5
	TOTALS	454	100		38.5	248	202

Figure 4-33 – Sample SITREP feeder – master activities.

Weighted Percent – The weighted percent for each master activity in the table above is simply the mandays estimated for that master activity divided by the total project mandays. For master activity 01, General, the manday estimate was 20 and 20 divided by 454 is .04. Take .04 and multiply it by 100 to change the decimal to a percentage. .04 x 100 = 4%. The weighted percent column must total 100. If the total does not, go to the highest percent and add or subtract to get the total to be 100. For example, when calculating master activity 03, 140 ÷ 454 = .31 x 100 = 31%. The total of the weighted percent column would have been 101%. Master activity 03 was changed to .30 in order for the total to equal 100%. The weighted percent can only be changed at the 45-day review, during the project joint turnover, or when specifically approved by higher headquarters.

Master Activity % Complete by Work-in Place (WIP) – Obviously for master activities not started the percent WIP is zero and for completed master activities the percent WIP is 100. For master activities that are partially complete the crewleader must look at the status of individual construction activities. Refer to *Figure 4-34* for master activity 03 (Concrete Construction):

			a	b	a x b		
Construction Activity		Manday Estimate	Weighted Percent	CA % Complete	MA % Complete	Mandays Remaining	Mandays Actual
#	Description						
03100	PF Forms F/S	8	6	100	6	0	10
03110	Set Forms F/S	11	8	100	8	0	9
03120	Strip Forms F/S	3	2	100	2	0	3
03130	PF Lintel Forms	5	4	100	4	0	5
03140	PF Forms B/C	32	22	100	22	0	35
03150	Set Forms B/C	25	18	50	9	13	14
03160	Strip Fms B/C Ext	3	2	0	0	3	0
03170	Strip Fms B/C Int	2	1	0	0	2	0
03200	PF RST F/S	7	5	100	5	0	8
03210	Set RST F/S	4	3	100	3	0	5
03220	PF RST B/C	7	5	100	5	0	7
03230	Set RST B/C	7	5	0	0	7	0
03300	Place Conc. F/S	5	4	100	4	0	6
03310	Place Conc. Lintels	2	1	100	1	0	3
03320	Place Conc. B/C	5	4	0	0	5	0
03400	Set Roof Panels	14	10	0	0	14	0
	TOTALS	140	100		69	44	105

Figure 4-34 – Sample construction activities.

In evaluating the progress on master activity 03, we can see that we have completed the following construction activities: 03100, 03110, 03120, 03130, 03140, 03200, 03210, 03220, 03300, and 03310. These construction activities represent 60 percent of master activity 03 (6 + 8 + 2 + 4 + 22 + 5 + 3 + 5 + 4 + 1 = 60). We obtained these percents by multiplying the CA % Complete by the Weighted Percent. For construction activity 03150 (Set Forms Beams and Canopy) we obtained the 50% complete by actual measurement. In this case we measured and determined that one half of the forms have already been set. Activity 03150 represented 18% of the master activity. Since we are half done we get credit for 9%. 9 plus the previous 60 gives us a total 69% complete for master activity 03.

Project % Complete – Project % complete represents the percentage that the work completed on that master activity contributes to the overall project completion. We get the project % complete by multiplying the weighted percent by the master activity % complete (WIP) for each activity. For master activity 02, Site Work, the project % complete was determined by multiplying the weighted percent of .10 times the percent WIP of 55 to get a project % complete of 5.5 (.10 x 55 = 5.5).

Actual Percent Complete – Actual percent complete for the project is the total of the project % complete column. For the example above the actual percent complete for this project is 38.5%. We also put the scheduled percent complete at the top of the SITREP feeder. We need to compare the actual progress to the scheduled progress. The scheduled percent complete comes from the Level II barchart in either the Deployment Execution Plan (within the first 45 days of the deployment) or the Revised Deployment Execution Plan (after the 45 day review). The allowable percent deviations between actual WIP and scheduled WIP are listed in *Table 4-5*.

Table 4-5 – Allowable Percent Deviations.

Total Project Manday Range	Allowable % Deviation Between Actual WIP vs. Scheduled WIP
0-1000 MD	10%
1000-2000 MD	5%
2000 & above MD	2.5%

If the actual WIP is less than the scheduled WIP by more than the percentage shown in *Figure 4-35*, the battalion must advise higher headquarters by message. The message will include a plan to get the project back on track and request approval for any required changes to battalion Level I barchart or the project Level II barchart in the Revised Deployment Execution Plan.

Mandays Remaining – Mandays remaining are a reflection of how much work remains to be done on the project and has nothing whatsoever to do with how many mandays have been expended. For master activities that are complete (see master activity 04 in Figure 4-33) the mandays remaining is zero. For master activities not started, the mandays remaining will equal the original manday estimate for that master activity. For master activities under construction we must evaluate the completion status of the individual construction activities. Construction activities that are 100% complete have zero mandays remaining; construction activities that have not begun have mandays remaining equal to the original manday estimate. If a construction activity with an original estimate of 20 mandays is 25% complete the mandays remaining are 15 because 75% of the work is left to be done and (.75 x 20) is 15.

Actual Mandays – Actual mandays have nothing to do with percent complete and are not included in the SITREP when it leaves the battalion. It is included on the feeder so the company staff and Ops can see where your mandays have gone. It may provide insight on why a particular project is behind. The total actual mandays are also needed to update the Level II barchart with actual progress and mandays actual.

Comments Line – The SITREP feeder also has a line for comments. This is for the crewleader's draft input for the SITREP. The battalion must include in its SITREP brief comments describing work performed since the last SITREP. If actual WIP is less than scheduled WIP, the delay must be explained and a plan for getting the project back on schedule must be included.

Mandays Earned – Mandays earned is another method of calculating the actual project percent complete. Refer to Figure 4-35 for master activity 03. For construction activities that are completed, we get credit in mandays earned for all of the original manday estimates, as is the case with construction activity 0310 Prefab Forms Foundation/Slab. For activities not started, we do not get credit for any mandays earned, as is the case with construction activity 0316 Strip Forms Beams/Canopy Exterior. For activities in progress, we get credit in earned mandays for the percentage of the activity that is complete. Construction activity 0315, Set Forms Beams/Canopy is 50 percent complete. .50 x 25 = 12.5 or 13. The total mandays earned for master activity 03 is 140. To calculate the percent complete for the master activity we divide total mandays earned by the total manday estimate (97 ÷ 140 = .69 or 69%).

		a	b	a x b
Construction Activity		Manday	CA % Complete	Mandays Earned
#	Description			
03100	PF Forms F/S	8	100	8
03110	Set Forms F/S	11	100	11
03120	Strip Forms F/S	3	100	3
03130	PF Lintel Forms	5	100	5
03140	PF Forms B/C	32	100	32
03150	Set Forms B/C	25	50	13
03160	Strip Fms B/C Ext	3	0	0
03170	Strip Fms B/C Int	2	0	0
03200	PF RST F/S	7	100	7
03210	Set RST F/S	4	100	4
03220	PF RST B/C	7	100	7
03230	Set RST B/C	7	0	0
03300	Place Conc. F/S	5	100	5
03310	Place Conc. Lintels	2	100	2
03320	Place Conc. B/C	5	0	0
03400	Set Roof Panels	14	0	0
	TOTALS	140		97

Figure 4-35 – Sample mandays earned – construction activities.

Use the same process to calculate earned mandays for the entire project. Referring to *Figure 4-36*, we see that master activity 04 is complete and we get credit for 32 earned mandays. Master activities 05 through 10 have not started, and we do not get credit for any earned mandays. Master activity 01 is 30 percent complete. .30 x 20 = 6 earned mandays. Master activity 02 is 55 percent complete. .55 x 47 = 25.85 or 26 earned mandays. Master activities 03, 15, and 16 were calculated in the same manner. The total actual percent complete on the project is 39.4 percent (179 ÷ 454 = .394 or 39.4 %). The project percent complete will vary slightly between the WIP and Earned Mandays methods of calculation. This results from rounding to whole mandays. Either method is acceptable. Consult with your chain of command on which method to use.

		a	b	a x b
Master Activity		Original MD Est	Master Activity % Comp Earned MDs	Mandays Earned
#	Description			
01	General	20	30	6
02	Site Work	47	55	26
03	Conc. Const.	140	69	97
04	Masonry	32	100	32
05	Metals	9	0	0
06	Carpentry	8	0	0
07	Moist. Protect.	16	0	0
08	Doors/Wind./Glass	10	0	0
09	Finishes	66	0	0
10	Specialties	4	0	0
15	Mech. Const.	44	32	14
16	Elect. Const.	30	13	4
	TOTALS	454		179

Figure 4-36 – Sample mandays earned – master activities.

Master Activity Status Sheet (MASS) – The MASS in the Seabee Crewleader's Handbook Appendix 9-C-1 is used to aid the crewleader in completing the SITREP feeder. MASSs need only be completed for activities underway. The crewleader does not have to be concerned with activities that are 0% or 100% complete. The MASS combines all that we have discussed previously in this section. The step-by-step instructions for completing the MASS are as follows:

a. Construction Activity, Description and Estimated Mandays come from the CA

b. The Weighted Percent (WT%) is equal to the construction activity manday estimate divided by the total master activity manday estimate.

c. The Total Work is equal to the number of linear feet, square feet, cubic yards, etc. of work to be done.

d. The Work Completed is equal to the number of linear feet, square feet, cubic yards, etc. of work actually completed.

e. The Construction Activity Percent Complete (CA % COMP.) is equal to the amount of Work Completed divided by the Total Work.

f. The Master Activity Percent Complete (MA % Comp.) is equal to the Construction Activity Percent Complete Multiplied by the Weighted Percent.

g. The Mandays Actual (MDs Act.) comes from the time cards.

h. The Mandays Remaining (MDs Rem.) is equal to the percentage of work remaining to be completed multiplied by the original manday estimate.

i. The Estimated Mandays, the Weighted Percent, the Master Activity Percent Complete, the Mandays Expended and the Mandays Remaining are then totaled at the bottom of the page.

The following step-by-step instructions will help you complete the SITREP feeder:

a. The % Complete Scheduled, Master Activity # and Description and the Original MD Estimate come from the project Level II barchart.

b. The Weighted Percent (WT%) is equal to the master activity manday estimate divided by the total project manday estimate.

c. The Master Activity % Complete (WIP), if other than 0% or 100% comes from the MASS.

d. The Project % Complete is equal to the Weighted Percent multiplied by the Master Activity % Complete (WIP).

e. The Mandays Remaining and Mandays Actual come from the MASS.

6.7.0 Two Week Schedules

Successful crewleaders must manage their project on three different planes. They must directly supervise the construction effort underway, they must look at activities scheduled for the next two weeks to ensure an uninterrupted flow of resources to the project and they must keep an eye on any long lead items which, if not tracked continuously, could eventually cause a work stoppage or delay. Long lead items should be tracked at least weekly. The two week schedule consists of 3 parts, as shown in *Figure 4-37*.

Part 1 includes the work scheduled for a 14 day period. The items of work listed on the two week schedules must be clear and measurable. The two week schedules must show the work shown on the Level III barchart for that period. If you are behind schedule, the two week schedules must also reflect why you are behind and how you are going to get back on track.

Part 2 lists the tool and equipment requirements for the two week period.

Part 3 lists the material requirements for the two week period. This tool is used primarily by the crewleader to ensure that all materials, equipment and tools required are either on the job site or requested with sufficient lead time to ensure availability.

The two week schedules will be used in the crew briefings described below, provide ongoing project status to the chain of command, and give heads up to MLO and the subcontractors. The two week schedules are normally submitted to Ops at the weekly Operations meeting. They typically cover a two week period and are revised weekly. Higher headquarters will look for these during visits, and they must be useful and accurate. Two week schedules are also referred to as weekly goals.

TWO WEEK SCHEDULE
(Part 1)

Project Title:

Project Number:

Company/Det: Period Covered: ________________ to ________

Date: Page of

Codes
O = Off
S = Start
P = In Progress
C = Complete
SC = Start/Complete in 1 day

Construction Activity		DATES														Crew Size	Remarks
No.	Title																

Assumptions:

____

____

(Part 2)

Activity No.	Tool Requirements	Equipment Requirements	Remarks

(Part 3)

Activity No.	BMLI No.	Description	Unit of Issue	BM Qty.	On Hand Qty.	Needed Qty.	Date Reqd.	Remarks

Figure 4-37 – Sample schedule.

Figure 4-38 is part 1 of a sample completed two week schedule.

TWO WEEK SCHEDULE
(Part 1)

Codes
O = Off
S = Start
P = In Progress
C = Complete
SC = Start/Complete in 1 day

Project Title: Admin Building

Project Number: EL8-830

Company/Det: C Period Covered: 17 May 2005 to 27 May 2005

Date: 12 Apr 2005 Page 1 of ?

Construction Activity No.	Title	Dates 17	18	19	20	21	22	23	24	25	26	27	28	29	30	Crew Size	Remarks
01600	Move In	SC														7	
02100	Clear & Grub		S	C												2	
03100	PF Forms Fd./Sl.		S	P	C											2	
03200	PF RST Fd./Slab		S	P	P	C										3	
02200	Subgrade F & C				S	P	O	C								2	
03130	PF Lintel Forms					S	O	P	C							2	
03140	PF Forms B & C							S	P	P	P	P	O	P	O	3	
02110	Layout Bldg.								SC							2	
02210	Exc. Ftg. U/S Utl.									SC						2	
03310	Place Conc. Lint.										SC					2	
02240	Level/comp. U/S										SC					2	
03110	Set Frms Fd./SL.											S				4	

Assumptions:

Figure 4-38 – Part 1 of two week schedule.

7.0.0 SAFETY

Safety responsibility falls to the crewleader. Any resources the crewleader needs, he/she can obtain through the Safety Office (equipment, material, education, training, etc.). The safety responsibilities for various levels in the chain of command are listed in the NCF Safety and Health Manual.

7.1.0 Safety Organization

The NMCB's safety organization provides for the establishment of safety policy and control and reporting. As illustrated in *Figure 4-39*, the battalion safety policy organization contains several committees: policy; supervisors'; and equipment, shop, and crew.

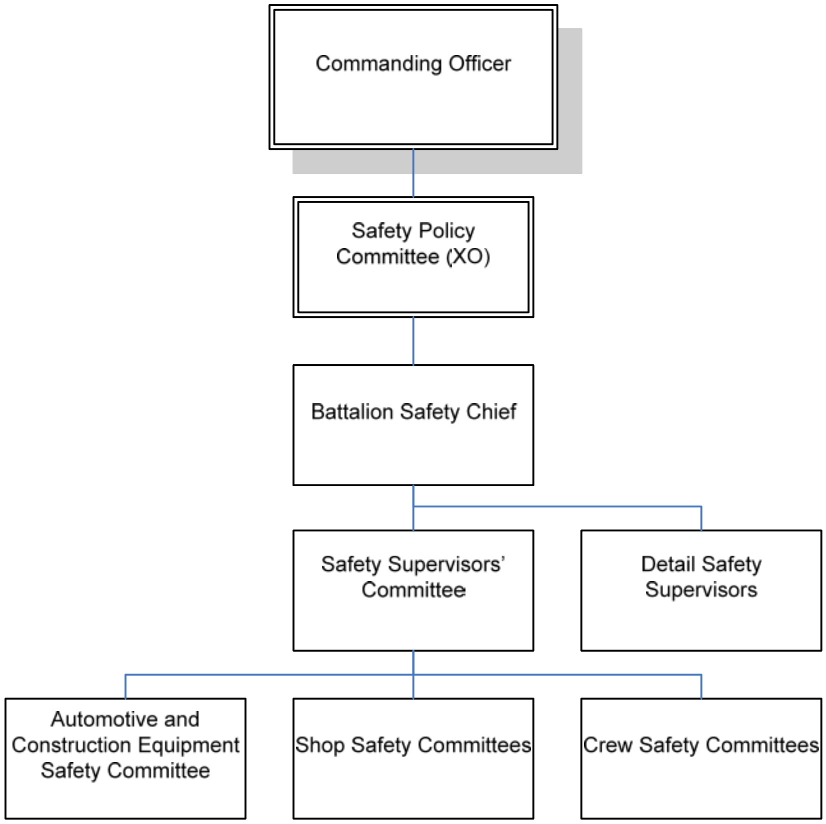

Figure 4-39 – Safety organization.

The executive officer presides over the safety policy committee. Its primary purpose is to develop safety rules and policy for the battalion. This committee reports to the commanding officer, who approves all changes in safety policy.

The battalion safety officer presides over the safety supervisors' committee. This committee includes safety supervisors assigned by company commanders, project officers, or officers in charge of a detail. It helps the safety officer manage an effective overall safety and health program. The committee provides a convenient forum for work procedures, safe practices, and safety suggestions. Its recommendations are sent to the policy committee.

The equipment, shop, and crew committees are assigned as required and are usually presided over by the company or project safety supervisor. The main objective of this committee is to propose changes in the battalion's safety policy to eliminate unsafe working conditions or to prevent unsafe acts. It is your contact for recommending changes in safety matters. The equipment committee reviews all vehicle mishap reports, determines the cause of each mishap, and recommends corrective action. As a crew leader, you can expect to serve as a committee member. Each committee forwards reports and recommendations to the safety supervisors' committee.

7.2.1 Crewleader's Responsibilities

Crewleaders and other supervisors are the Key People in a successful and aggressive safety program. Responsibilities include but are not limited to:

- Familiarity with safety rules and regulations for jobs and facilities in his/her area, and acting in a safe manner.
- Enforcing safety rules and correcting unsafe acts.
- Inspecting jobs and work areas for hazards and taking corrective actions.
- Educating and training personnel in safe work procedures and rules.
- Reporting all mishaps and near misses to the Safety Office promptly and ensuring personnel receive immediate medical treatment.
- Investigating all mishaps or near misses in his/her area, determining basic causes, taking corrective action, and requesting assistance from the Safety Office when necessary.
- Reviewing safety and health records on employees and facilities in his/her area as required.
- Taking corrective action on hazards reported by employees without reprisal for their reporting of the hazard.
- Ensuring that correct personal protective equipment is provided to personnel and that they wear and maintain the equipment properly.
- Obtaining advice and assistance from the Safety Office in the positive implementation of the NAVOSH Program.
- Knowing the limitation of subordinate personnel and avoiding assignment of hazardous jobs to personnel who are not physically and mentally capable of performing work assignments in a safe manner.
- Removing from service any defective machinery, material, or tools until repairs can be made to ensure safe operation.
- Posting appropriate safety precaution signs in conspicuous areas near or on equipment, material, stowage areas and other designated hazards or hazardous areas.

Test your Knowledge (Select the Correct Response)

12. A crewmember is incorrectly doing a job. As crew leader, what action should you take?

    A. Place the crewmember on report
    B. Assign extra work to the crewmember
    C. Stop the crewmember and give correct job procedures
    D. Transfer the crewmember to another crew

7.2.1 Safety Duties

As a crew leader you report to the safety chief, who directs the safety program of a project. The safety chief is inherently responsible for all personnel assigned to that shop or project. Some of the duties include indoctrinating new crewmembers, compiling mishap statistics for the project, reviewing mishap reports submitted to the safety office, and comparing safety performances of all crews.

The crew leader is responsible for carrying out safe working practices. This is done under the direction of the safety supervisor or others in positions of authority, such as the project chief, project officer, or safety officer. You, as the crew leader, ensure that each crewmember is thoroughly familiar with these working practices, has a general understanding of pertinent safety regulations, and makes proper use of protective clothing and safety equipment. You should be ready at all times to correct every unsafe working practice you observe, and report it immediately to the safety supervisor or the person in charge. When an unsafe condition exists, any crew or shop member can stop work until the condition is corrected.

In case of a mishap, make sure injured personnel get proper medical care as quickly as possible. Investigate each mishap involving crewmembers to determine its cause. Remove or permanently correct defective tools, materials, and machines. Do the same for environmental conditions contributing to a mishap. Afterward, submit required reports.

7.3.0 Safety Training/Lectures

The battalion Safety Office oversees and monitors project safety plans, and ensures compliance to safety regulations. It's your job as the crewleader to ensure safety on your job site. According to the NCF Occupational Safety and Health Manual, the current version of COMFIRSTNCD Instruction 5100, the battalion Safety Office administers the battalion safety program and provides technical guidance, but it is the crewleader, the project supervisor, the company chief, the company commander, S3 and the Commanding Officer who are 100% responsible for safety on the job site. If you have any questions concerning safety on the project you are planning or executing, the battalion Safety Office is a good place to go to get your questions answered. The Safety Office can't always prevent you from doing something you know is unsafe. They do not have the staff to be present on the job site at all times. 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.

7.3.1 Safety Training

New methods and procedures for safely maintaining and operating equipment are always coming out. You must keep up to date on the latest techniques in maintenance and operation safety and pass them on to your crewmembers. One method of keeping your crewmembers informed is by holding stand-up safety meetings before the day's work starts. You, as crew leader, are responsible for conducting each meeting and passing on material from the safety supervisor. Information such as the type of safety equipment to use, where to obtain it, and how to use it is often the result of safety suggestions received by the safety supervisors' committee. Encourage your crew to submit ideas or suggestions. Don't limit yourself to just the safety lecture in the morning. Discuss minor safety infractions when they occur or at appropriate break. You must impress safe working habits on your crewmembers through proper instructions, constant drills, and continuous supervision.

You may hold group discussions on specific mishaps to guard against. Be sure to give plenty of thought to what you are going to say beforehand. Make the discussion interesting and urge the crew to participate. The final result should be a group conclusion as to how the specific mishap can be prevented.

Your stand-up safety meetings also give you the chance to discuss prestart checks, and the operation or maintenance of automotive vehicles assigned to a project. Vehicles are used for transporting crewmembers as well as cargo. It is important to emphasize how the prestart checks are made and how to care for the vehicles.

You can use a stand-up safety meeting to solve safety problems arising from a new procedure. An example might be starting a particular piece of equipment just being introduced. First show the safe starting procedure for the equipment. Then have your crewmembers practice the procedure.

There are a variety of vehicles that may be assigned to a project, which means there are too many operating procedures for one person to remember. You need to know where to look for these procedures and other information on each vehicle. For specific information on prestart checks, operation, and maintenance of each vehicle assigned, refer to the manufacturer's operator/maintenance manuals. Personnel from Alfa Company, the equipment experts, will instruct all personnel in the proper start-up procedures for new equipment.

In addition to stand-up safety meetings, conduct day-to-day instruction and on-the-job training. Although it is beyond the scope of this chapter to describe teaching methods, a few words on your approach to safety and safety training at the crew level are appropriate. Getting your crew to work safely, like most other crew leader functions, is essentially a matter of leadership. Don't overlook the power of personal example in leading and teaching your crewmembers. They are quick to detect differences between what you say and what you do. Don't expect them to measure up to a standard of safe conduct that you do not. Make your genuine concern for the safety of your crew visible at all times. Leadership by example is one of the most effective techniques you can use.

7.3.2 Required Safety Training

The safety training below is required by the NCF Safety and Health Manual for the identified crew personnel:

Safety Supervisors – Each Seabee unit will designate in writing a safety supervisor responsible for the Company/Department/Project. This individual will report to the Safety Office for all matters pertaining to the Occupational Safety and Health Program. Required minimum training is outlined in Appendix 11-A of the *Seabee Crewleader's Handbook*.

NAVOSH Training – All personnel assigned to an Seabee unit are required to attend the initial and annual NAVOSH training outlined in Appendix 11-B of the *Seabee Crewleader's Handbook*. This will be taught by the battalion's Safety Office personnel during indoctrination.

Seabee Specific Training – All officers and enlisted personnel who may be assigned to work in a hazardous area will attend the Seabee specific training outlined in Appendix 10-B of the *Seabee Crewleader's Handbook*. The battalion's Safety Office personnel will teach this.

7.3.3 Electrical Safety

All job site electrical supplies are temporary power sources, even existing outlets in buildings being renovated. All temporary power sources must be inspected, certified safe, and tagged with the inspector's name, company, and date prior to first use. Recertifications are required every two weeks thereafter. Ground Fault Circuit Interrupters (GFCIs) shall be used with all power tools, whether double insulated or not. GFCIs will be checked on a monthly basis with a representative from CTR and a proper record maintained. All electrical portable tools, extension cords, small gasoline, pneumatic and powder actuated tools (including those borrowed from other units) shall be visually inspected every day prior to their first use. These inspections will then be documented with the monthly tool inventory. Equipment or circuits that are de-energized shall be rendered inoperative and have tags attached at all points where such equipment or circuits can be energized. Ensure compliance with prescribed lockout/tagout procedures established in the *NAVOSH Ashore Manual (OPNAVINST 5100.23)* and the *NCF Safety and Health Manual*.

7.3.4 Asbestos Operations

Seabees do not normally conduct asbestos removal. The *NCF Safety and Health Manual* gives detailed guidance on the NCF asbestos policy and procedures.

7.3.5 Respiratory Protection

All of the following requirements must be met prior to the use of respirators:

- Correct equipment identified by the local Respiratory Protection Program Manager.
- Medical evaluation of potential users.
- Fit test performed by competent personnel.
- Respiratorypprotection training for all potential users.
- A written SOP developed for the job site, including emergency and rescue guidance, and posted on the job site.

7.3.6 Hazardous Materials

Crewleaders must recognize the threat that hazardous materials pose to all personnel present on the job site and take action to prevent mishaps. Listed below are basic measures in effect to minimize the risk of injury or mishap:

Material Safety Data Sheets (MSDS) – Upon drawing any hazardous material, MLO will provide the crewleader with an MSDS. The MSDS will identify any hazards associated with exposure to that specific material. It will also identify any personal protective equipment or other safety precautions required as well as first aid or medical treatment required for exposure. The crewleader is required by federal law to inform crewmembers of the risks and all safety precautions associated with any hazardous material present on the job site. This should be done during each daily safety lecture. Additionally, the MSDS must be posted conspicuously on the job site.

Hazardous Material Storage – The safest practice concerning hazardous material is not to draw any more material than can be used in a reasonable amount of time. Storing hazardous materials on the job site requires the use of approved storage containers. Consult with the battalion Safety Office, as many hazardous materials require separate storage containers (for example, corrosives and flammables cannot be stored together).

Hazardous Material Turn-in – Any excess material must be disposed of through an authorized hazardous material disposal facility. Check with the battalion MLO staff or Safety Office for procedures.

7.3.7 Safety Items Required on the Job Site

The following safety items are required on all project sites. See the 29 CFR 1926 for additional information.

Transportation/Communication – Required in order to have a rapid response in case of a mishap.

Emergency Plans – Each job site must have posted the location of the nearest phone, the telephone numbers and reporting instructions for ambulance, hospital, physician, police, and fire department personnel.

First Aid Qualified Personnel – If a medical facility is not readily accessible (due to time or distance) a crewmember must be first aid qualified and available on the job site.

First Aid Kits – First aid kits will be readily available and must be checked weekly for consumed items.

Toilet Facilities – If toilet facilities are not readily available, portable facilities must be provided.

Drinking Water – Water must be provided from an approved source and labeled for drinking only and not be used for other purposes. Common cups are not allowed.

Temporary Fencing/Barricades – Required if job site is in an area actively used by the public.

Warning Signs – Red for immediate hazards, yellow for potential hazards.

Eyewash Facility – Required where personnel are exposed to or handling poisons, acids, caustics or toxic chemicals.

Fire Extinguishers – One for every 3000 square feet (or major fraction thereof) of building space. Travel distance from any point to the nearest extinguisher will not exceed 100 feet.

Material Safety Data Sheets – For any hazardous material on the job site.

Hazardous Material Inventory Sheet – For any hazardous material on the job site.

Safety and Health Manual **–** The 29 CFR 1926 is required to be kept on the job site.

7.4.0 Safety Plan

For each construction activity, all hazards and corrective actions identified will be listed on the back of the CAS sheet. The project safety plan shown in *Figure 4-40* is then drawn up listing the hazards and corrective action from the back of the CAS sheets.

SAFETY PLAN					
Project Number:		Project Title:		Date:	
Activity Number	Activity Description	Hazard	Ref.	Page Number	Action Required

Figure 4-40 – Project safety plan.

The cover sheet shown in *Figure 4-41* is made up for the safety plan summarizing the training and equipment requiring review by the chain of command. The Chain of command will approve a Safety Plan for each project before any work starts. The project safety plan must be posted on the job site.

PROJECT SAFETY PLAN

Project Number and Title:

Project Location:

Prime Contractor:

Subcontractor: (a)

(b)

Project Scope:

Type of Inherent Risks (electrical, welding, etc.):

Type of Associated Risk (fire, fumes, noise, etc.):

Special Training Requirements:

Special License Required:

Engineering Controls (guard rails, welding curtains, shoring, etc.):

Administrative Controls (policies, procedures, SOPs, etc.):

Special Safety Equipment Required (state how it is to be used):

Personal Protective Equipment Required:

Safety Standards/Restrictions pertaining to Project Scope:

Project Planner: -

Print name, rate and company/det

Safety Officer: Approved/Disapproved

Signature

Reason for disapproval: -

Figure 4-41 – Project safety plan cover sheet.

Safety Office personnel will perform a daily job site safety inspection using a form such as the one shown in *Figure 4-42*.

DAILY SAFETY INSPECTOR'S REPORT				Route to:	Initials:	Date
INSTRUCTIONS				CO Cdrs		
Form must be returned within 3 working days with the "Action Taken" section filled out correcting the hazards/deficiencies. Company Commanders will initial "Route To" prior to returning to S3C				S3C		
				S3A		
Date: Time:		Project Number:	Project Title:	S3		
				00S		
Prime Contractor:	Subcontractor:	Weather:		Section # 4		
Project Supervisor:	Project Safety Supervisor:			Safety Inspector:		

Rates:		**Description of Work:**
BU	EO	
CE	SW	
CM	UT	
EA	Other	

Safety Inspection Plan Items:	**Results:**

	ITEM N	/A	YES	16		Ladders/Scaffolding: Safe cond/use?	N/A YE	S	NO
1	Safety Talk given? Subj:				17	Are wall/floor openings guarded?			
2	GFCI protection on project and used?				18	Is good housekeeping observed?			
3	Req'd PPE in use?				19	Tool Storage Area: Properly stored?			
4	Hazmat/Hazflam inventory current?				20	Hand Tools: Usable condition?			
5	Material Safety Data Sheets available?				21	Is good area sanitation being observed?			
6	Flammable liquids stored properly?				22	Water jugs maintained IAW SOP?			
7	Eyewash/shower maintained IAW SOP?				23	Fire extinguishers charged/current tags?			
8	Lockout/tagout required and used?				24	First aid kits on project?			
9	Electrical boxes secured and labeled?				25	Equipment Pre-start done?			
10	Temporary power inspected and tagged?				26	Are backup guides being utilized?			
11	Are construction signs in place?				27	Are parked vehicles being chocked?			
12	Excavation: Permits/shoring approved?				28	Respirator protection IAW SOP?			
13	Crewleader using safety plan?				29	Equipment Operators licensed?			
14	Review daily safety report for trends?				30	Fall protection correctly in place?			
15	Welding: Cutting and permits required?				30	Fall protection correctly in place?			

SAFETY HAZARD/DEFICIENCY	**ACTION TAKEN TO CORRECT HAZARD/DEFICIENCY**

Project Supervisor	Project Safety Supervisor	Battalion Safety Inspector
DISTRIBUTION: WHITE; ROUTING CHAIN	YELLOW: TEMPORARY FILE	PINK: PROJECT

Figure 4-42 – Daily Safety Inspector's report.

8.0.0 OPERATIONAL RISK MANAGEMENT (ORM)

ORM is a decision making tool used by people at all levels to increase operational effectiveness by anticipating hazards and reducing the potential for loss. This increases the probability of a successful mission.

The five step ORM process is a standardized tool that will help you operate successfully in high risk environments. As military personnel, we have a responsibility at every level to identify hazards, take measures to reduce the associated risk, and accept risk only when the benefits of the operation exceed the accepted risk.

The goal is to make ORM part of our daily operations. This simple, logical process will help save lives, protect people, and preserve assets while we accomplish our missions efficiently and effectively.

8.1.1 Five Step Process

The five step process has a mnemonic, or memory acronym, to help you remember the steps; **I AM IS**

1. **I**dentify Hazards
2. **A**ssess Hazards
3. **M**ake Risk Decisions
4. **I**mplement Controls
5. **S**upervise

8.2.1 ORM in BAMCIS

One way to look at the five steps of ORM is that they are performed within, not instead of, BAMCIS (Begin the planning, Arrange for reconnaissance, Make reconnaissance, Complete the planning, Issue the order, Supervise), as shown in *Table 4-6*. Any time a new hazard is identified it triggers the remaining ORM steps.

Table 4-6 – ORM in BAMCIS.

BAMCIS ORM	
Begin Planning	Identify Hazards
Arrange Recon	
Make Recon	Assess the Hazards
Complete the Plan	Make Risk Decisions
Issue the Order	Implement Controls
Supervise Supervise	

Here is a breakdown of the five steps of ORM.

Step 1 Identify Hazards

- Conduct an Operational Analysis
    - List major steps of the operation
- Conduct a Preliminary Hazard Analysis

- List the hazards associated with each step
- List the possible causes of the hazards

Step 2 Assess Hazards

- Determine the degree of risk for each hazard in terms of severity and probability.
  - Use of a matrix is recommended but not required. A matrix provides a consistent framework for evaluation and shows the relative perceived risk between hazards and prioritizes which hazards to control first.
  - Any Matrix that supports the specific application may be used; an example is shown in *Table 4-7*.

Table 4-7 – Risk matrix.

RAC Matrix		**Mishap Probability**			
		Likely	Probably	May	Unlikely
Hazard Severity	Critical	1	1	2	3
	Serious	1	2	3	4
	Moderate	2	3	4	5
	Minor	3	4	5	5

Risk Assessment Code (RAC)

The risk matrix in *Table 4-7* includes five classifications, as shown below.

1. Critical
2. Serious
3. Moderate
4. Minor
5. Negligible

Hazard Severity

The hazard severity shown in *Table 4-7* has four levels, which are defined below.

- Critical – May cause death, loss of facility/asset, or grave damage to national interests.
- Serious – May cause severe injury, illness, property damage; or damage to national or service interests.
- Moderate – May cause minor injury, illness, property damage; or damage to national, service, or command interests.
- Minor – Minimal threat.

Mishap Probability

The mishap probability shown in *Table 4-7* has four levels, which are defined below.

- Likely – Likely to occur immediately or in a short period of time. Expected to occur several times to an individual item or person, or continuously to a group.
- Probably – Probably will occur in time. Reasonably expected to occur some time to an individual item or person, or continuously to a group.

- May – May occur in time. Reasonably expected to occur some time to an individual item or person, or several times to a group.
- Unlikely – Unlikely to occur.

Step 3 Make Risk Decisions

- Develop controls for each hazard to eliminate the hazard or reduce the risk until the Benefit is greater than the Risk.
    - Develop controls for the most serious hazards first! You may not have time to control every hazard – so control the worst hazards first. Conduct a Preliminary Hazard Analysis
- Develop residual risk.
    - Assess each hazard's risk again (step 2 repeated) with the controls in place to determine residual risk.
- Make Risk Decision – With the controls in place is the Benefit greater than the Risk?
    - Accept the risk if the Benefit > Risk.
    - Communicate with higher authority if
        - Risk is greater than the Benefit
        - Risk exceeds the Commander's stated intent
        - Help is needed to implement controls

Step 4 Implement Controls

- Incorporate selected controls into:
    - SOPs
- Orders, Briefs, Training, and Rehearsals
- Communicate selected controls to the lowest level. Who will do what by when?
- Implementation goes wrong for the following reasons:
    - Wrong control for the problem
    - Operators dislike it
    - Leaders dislike it
    - It's too costly
    - It's overmatched by other priorities
    - It's misunderstood
    - Nobody measures until it's too late

Step 5 Supervise

- Enforce standards and controls.
  - o Ensure crewmembers are performing tasks to standard.
  - o Ensure controls are in place and having the desired effect.
- Remain alert for changes and unexpected developments that require Time Critical or Deliberate ORM.
- Take corrective action when necessary.

9.0.0 QUALITY CONTROL

The purpose of the NCF Quality Control Program COMSECONDNCB/ COMTHIRDNCBTINST 4355.1 is to prevent discrepancies where the quality of workmanship and materials fail to match the requirements in the plans and specifications. The responsibility for quality construction rests with the crewleader and the chain of command. The Quality Control Division is responsible for conducting tests and inspections to ensure compliance with the plans and specification. The Quality Control (QC) inspectors and crewleaders provide Contractor Quality Control (CQC). The battalion has the responsibility to control construction and inspect the work. Control is an ongoing and continual system of planning future activities. Inspection is the process by which ongoing and completed work is examined. Inspection is “after-the-fact” while control is “preventive”. The objectives of control are to insure that the crewleader is adequately prepared to begin a phase of work, to eliminate deficiencies, and to follow through in accomplishing the work in accordance with plans and specifications. The objective of inspection is to ensure that the work has been accomplished in accordance with plans and specifications. The crewleader will plan quality into the project and avoid discrepancies before the QC inspectors perform their inspections. Discrepancies identified by the QC inspector represent failures in the crewleader’s QC plan.

9.1.0 Three Phases of the Quality Control Program

QC is accomplished in three phases. The primary responsibility for these phases rests with the crewleader. The crewleader is the on-site quality control “manager” and as such “controls” the quality. The QC inspector, as the name implies, “inspects” the quality. The three phases, preparatory phase, initial phase, and follow up phase, are described below.

9.1.1 Preparatory Phase

Prior to starting the project and before the start of each construction activity, the crewleader will hold a QC preparatory phase meeting. The purpose of this meeting is to inform all personnel involved with the activity what the QC requirements are. The meeting will also address all items needed to accomplish the activity such as correct material on hand, correct tools, correct equipment, etc. The QC inspectors should attend these meetings if possible. Use NAVFAC P- 445, Construction Quality Management Program, for guidance in implementing the three-phase quality control program. Forms used for documentation are available at this website: http://navfacilitator.navfac.navy.mil/docs/default.cfm?type=1. A sample is shown in *Figure 4-43*. This form is two pages in length.

PREPARATORY PHASE CHECKLIST (Continued on second page)		Spec Section	Date (DD/MMM/YY)
Contract No	Definable Feature of Work	Schedule Act No	Index #

PERSONNEL PRESENT	Government Rep Notified - Hours in Advance	Yes ☐	No ☐
	Name Position		Company/Government
SUBMITTALS	Review submittals and/or submittal register. Have all submittals been approved?	Yes ☐	No ☐
	If No, what items have not been submitted?		
	Are all materials on hand?	Yes ☐	No ☐
	If No, what items are missing?		
	Check approved submittals against delivered material. (This should be done as material arrives.)		
	Comments:		
MATERIAL STORAGE	Are materials stored properly?	Yes ☐	No ☐
	If No, what action is taken?		
SPECIFICATIONS	Review each paragraph of specifications.		
	Discuss procedure for accomplishing the work.		
	Clarify any differences.		
PRELIMINARY WORK & PERMITS	Ensure preliminary work is correct and permits are on file.		
	If not, what action is taken?		

First page

TESTING	Identify test to be performed, frequency, and by whom. When required? Where required? Review testing plan. Have test facilities been approved?
SAFETY	Activity hazard analysis approved? Yes ☐ No ☐ Review applicable portion of EM 385-1-1.
MEETING COMMENTS	Navy/ROICC comments during meeting.
OTHER ITEMS OR REMARKS	Other items or remarks:

OC Manager Date

Second page

Figure 4-43 – Form for a Preparatory Phase Checklist.

9.1.2 Initial Phase

As soon as construction has started on an activity, the QC inspector and crewleader will inspect the work. The purpose of this inspection is to ensure that the work is being done correctly before too much time has elapsed. Any discrepancies can be corrected before we have a large rework problem. *Figure 4-44* is a sample of an Initial Phase Checklist.

INITIAL PHASE CHECKLIST		Spec Section	Date (DD/MMM/YY)
Contract No	Definable Feature of Work	Schedule Act No	Index #
PERSONNEL PRESENT	Government Rep Notified - Hours in Advance	Yes ☐ No ☐	
	Name Position		Company/Government
PROCEDURE COMPLIANCE	Identify full compliance with procedures identified at preparatory. Coordinate plans, specifications, and submittals. Comments:		
PRELIMINARY WORK	Ensure preliminary work is complete and correct. If not, what action is taken?		
WORKMANSHIP	Establish level of workmanship. Where is work located?		
	Is sample panel required? Yes ☐ No ☐ Will the initial work be considered as a sample? Yes ☐ No ☐ (If Yes, maintain in present condition as long as possible and describe location of sample.)		
RESOLUTION	Resolve any differences. Comments:		
CHECK SAFETY	Review job conditions using EM 385-1-1 and Job Hazard Analysis. Comments:		
OTHER	Other items or remarks:		
OC	Manager		Date

Figure 4-44 – Form for an Initial Phase Checklist.

9.1.3 Follow up Phase

The crewleader will conduct continual inspection of the activities in progress. The QC inspectors will conduct spot checks during this phase. This will ensure that all work is done in accordance with plans and specifications. A sample of a Contractor Quality Control Checklist is shown in *Figure 4-45*.

CONTRACTOR QUALITY CONTROL REPORT (Attach additional sheets if necessary)			Date (DD/MMM/YY) Report No	
Phase	Contract No	Contract Title (Title and Location of Construction Contract)		
PEPREPARATORY	Was preparatory phase work performed today? If Yes, fill out and attach supplemental preparatory phase checklist.		Yes ☐	No ☐
	Schedule Activity No	Definable Feature of Work		Index #
INITIAL	Was initial phase work performed today? If Yes, fill out and attach supplemental initial phase checklist.		Yes ☐	No ☐
	Schedule Activity No	Definable Feature of Work		Index #
FOLLOW-UP	Work complies with contract as approved during initial phase? Work complies with safety requirements?		Yes ☐ Yes ☐	No ☐ No ☐
	Schedule Activity No	Description of Work, Testing Performed & By Whom, Definable Feature of Work, Specification Section, Location and List of Personnel Present		Index #

Rework items identified today (not corrected by close of business)		Rework items corrected today (from rework items list)	
Schedule Activity No	Description	Schedule Activity No	Description

Remarks (Also explain any follow-up phase checklist from above that was answered No), Manuf. Rep on-site, etc.	
Schedule Activity No	Description

On behalf of this contractor, I certify that this report is complete and correct and equipment and material used and work performed during this reporting period is in compliance with the contract drawings and specifications to the best of my knowledge except as noted in this report.	Authorized OC Manager at Site	Date

GOVERNMENT QUALITY ASSURANCE REPORT	Date
Quality Assurance Representative's Remarks and/or Exceptions to the Report	
Schedule Activity No	Description
Authorized OC Manager at Site	Date

Figure 4-45 – Form for a Contractor Quality Control Checklist.

9.2.0 Quality Control Organization

The Quality Control Inspector is responsible for ensuring quality control during the preparatory, initial, and follow-up phases of the project. If the QC Inspector lacks expertise in an area of the project that needs to be inspected, he or she can bring in a consultant who is more expert in that field. *Figure 4-46* below shows this.

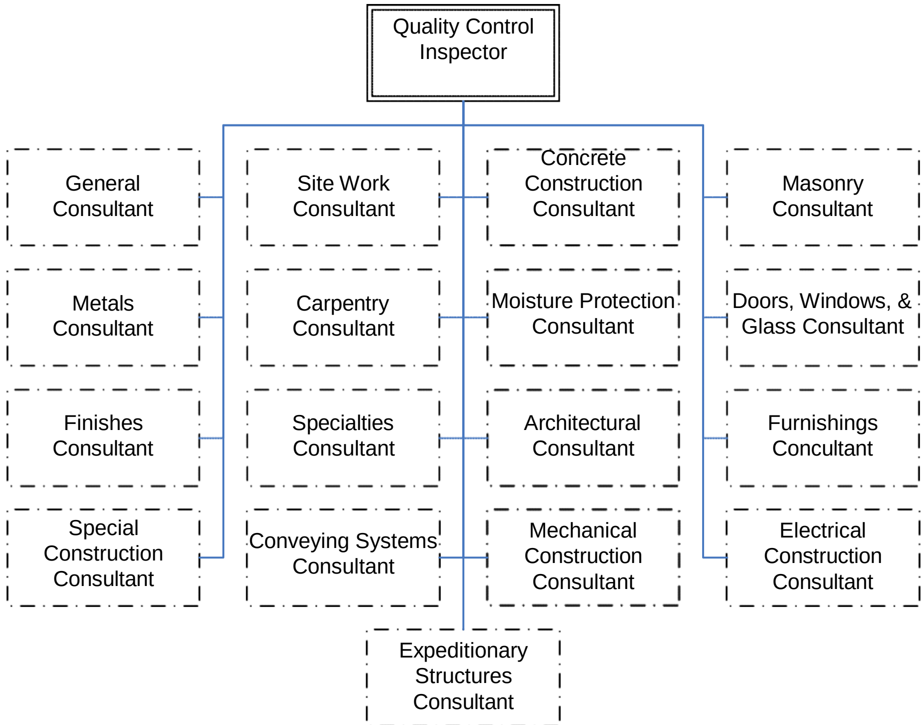

Figure 4-46 – Quality Control organization chart.

9.3.0 Change Requests and Project Specifications Questions

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 forwarding a request through QC and approval 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.

9.3.1 Field Adjustment Request

There will be times when adjustments to projects need to be made from the field. The battalion recommends such changes to the Resident Officer-in-Charge of Construction (ROICC) using a Field Adjustment Request (FAR), as represented in *Figure 4-47*.

FIELD ADJUSTMENT REQUEST (FAR)				
FAR Number:				Page of
Project Number:				Project Title:
Submitted By:				Date:
Description of and reason for request: (Include drawing and sheet numbers and attach drawings as necessary for description.)				
Route to:	Approved: (Initial)	Disapproved: (Initial)	Date:	Estimated Additional Cost:
Prime Co.				
QC				Estimated Additional Mandays:
Eng.				
S3				As Built: Date: (Initial)
ROICC				
ROICC Signature:				
Notes: 1. Route original and 3 copies to ROICC. 2. ROICC return original and 2 copies.				

Figure 4-47 – Form for a Field Adjustment Request (FAR).

A log of all FARs in the format shown in *Figure 4-48* must be kept in the project package.

FIELD ADJUSTMENT REQUEST (FAR) SUBMITTAL LOG						
FAR #	Description	Spec. Section	Drawing Number	Date to Ops	Date Returned	Approved/ Disapproved

Figure 4-48 – Form for a Field Adjustment Request (FAR) Submittal Log.

9.3.2 Request for Information (RFI)

Clarification of prints or specifications may be directed to ROICC on a Request for Information (RFI) form, represented in *Figure 4-49*.

<table>
<tr><th colspan="5">REQUEST FOR INFORMATION (RFI)</th></tr>
<tr><td rowspan="2">RFI Number:</td><td rowspan="2">Page _ of _</td><td>Route to</td><td>Initial:</td><td>Date:</td></tr>
<tr><td>Prime Co.</td><td></td><td></td></tr>
<tr><td rowspan="2">Project Number:</td><td rowspan="2">Project Title:</td><td>QC</td><td></td><td></td></tr>
<tr><td>Eng.</td><td></td><td></td></tr>
<tr><td rowspan="2">Submitted By:</td><td rowspan="2">Date:</td><td>S3</td><td></td><td></td></tr>
<tr><td>ROICC</td><td></td><td></td></tr>
<tr><td colspan="5">Description of and reason for request: (Include drawing and sheet numbers and attach drawings as necessary for description.)

Signature/printed name of requestor   Date</td></tr>
<tr><td colspan="5">Clarification from ROICC:

Signature/printed name of approving official   Date</td></tr>
</table>

Figure 4-49 – Form for a Request for Information.

A log of all RFIs in the format shown in *Figure 4-50* must be kept in the project package.

REQUEST FOR INFORMATION (RFI) SUBMITTAL LOG					
RFI #	Description	Spec. Section	Drawing Number	Date to Ops	Date Returned

Figure 4-50 – Form for a Request for Information (RFI) Submittal Log.

9.3.3 Design Change Directive (DCD)

Any ROICC directed changes are forwarded to the battalion on a Design Change Directive (DCD). Scope changes require the approval of the customers' major claimant. Changes that require 50 or more mandays of additional direct labor, or increase the cost of the project by $500 or more require approval of higher headquarters. All DCDs must be kept in the project package.

Summary

Planning, Estimating, and scheduling are key components of any well executed Seabee project.

Planning is the process of determining requirements, and devising and developing methods and action for constructing a project. Many elements must be considered in any well-planned project; including the activity, material, equipment, and manpower estimates; project layout, project location, material delivery and storage, work schedules, quality control, special tools required, environmental protection, safety, and progress control.

Estimating is the process of determining the amount and type of work to be performed and the quantities of material, equipment, and labor required.

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

Seabee construction projects are managed at three levels. Level I is used at the Operations Officer's or detail OIC's level. Level II is used at the Company level. Level III is used at the Crewleader's level.

The proper administration of any project, large or small, is as important as the actual construction. You now have information to help you use and prepare the administrative paperwork that you encounter as a crewleader.

Safety responsibility falls with the crewleader; it is up to you to conduct a successful and aggressive safety program. Resources, including equipment, material, education, and training, are available through the Safety Office.

Operational Risk Management (ORM) is used to anticipate hazards and reduce the potential for loss, increasing the probability of a successful mission. As military personnel, we have a responsibility at every level to identify hazards, take measures to reduce the associated risk, and accept risk only when the benefits of the operation exceed the accepted risk.

The Quality Control Program is meant to prevent discrepancies where the quality of workmanship and materials fail to match the requirements in the plans and specifications. The responsibility for quality construction rests with the crewleader and the chain of command.

Review Questions (Select the Correct Response)

1. The process of determining requirements, and devising and developing methods for constructing a project is called

   A. Estimating
   B. Scheduling
   C. Planning
   D. Production standardization

2. The process of determining the amount and type of work to be performed and the quantities of material, equipment, and labor required is called

   A. Estimating
   B. Scheduling
   C. Planning
   D. Production standardization

3. The individual who evaluates a job, has a working knowledge of all phases of construction, and can mentally picture separate operations of the project as it progresses is called the

   A. Scheduler
   B. Estimator
   C. Planner
   D. Builder

4. The process of determining when an action must be taken and when material, equipment, and manpower are required is called

   A. Estimating
   B. Planning
   C. Scheduling
   D. Coordination

5. What type of schedule is used to coordinate the manpower requirements of a project and show the number of personnel required for each activity?

   A. Progress
   B. Equipment
   C. Material
   D. Manpower

6. When using blueprints, what section should you check to ensure changes were recorded?

   A. Revisions
   B. Notes
   C. Specifications
   D. Construction drawings

7. On specifications, a list of unusual or unfamiliar items of work or materials is called

   A. Revisions
   B. Quantity estimates
   C. Notes
   D. Statistics

8. Which of the following procedures is the best way to check your estimates?

   A. Have another person check the measurements
   B. Have another person make an independent estimate and compare the two
   C. Have another person initial the estimates as you complete them
   D. Have a crewmember sign the estimate

9. Which of the following problems can lead to omissions in your quantity estimates?

   A. Failure to read all notes on drawings
   B. Errors in scaling
   C. Failure to allow for waste and loss of construction material
   D. All of the above

10. What should an experienced estimator do if he finds that details on a drawing are not drawn to scale?

   A. Approximate to dimensions
   B. Use the same scale that was used elsewhere on the drawings
   C. Assume an approximate scale
   D. Obtain the dimensions from another source

11. What type of estimate is used as a basis for purchasing materials, and determining equipment and manpower requirements?

   A. Activity
   B. Equipment
   C. Quantity
   D. Material

12. Which of the following activities provides information of material, equipment, and manpower requirements?

   A. Planning activities
   B. Scheduling activities
   C. Construction activities
   D. Specifications and drawings

13. For estimating purposes, how should an activity be defined?

A. Single-task, single-trade
B. Single-task, multi-trade
C. Multi-task, multi-trade
D. Multi-task, single-trade

14. Material estimates have which of the following uses?

A. Procurement and determination of availability of materials
B. Justification for and procurement of material
C. Scheduling of equipment for projects
D. Planning manpower needs

15. When estimating, which of the following forms should be used to list the required materials needed to complete each individual activity?

A. Bill of material
B. Material takeoff
C. Estimating worksheet
D. Material estimate

16. Which of the following NAVFAC publications contains conversion and waste factors for construction materials?

A. P-405, App C
B. P-437, Vol I
C. P-458, Vol II
D. DM-4.3

17. The average rate of speed for a vehicle moving materials over roadways is computed by using what percentage of the posted speed limit?

A. 10% to 15%
B. 20% to 30%
C. 40% to 56%
D. 60% to 76%

18. Which type of estimate consists of a listing of the number of direct labor man-days required to complete the various activities of a specific project?

A. Activity
B. Construction
C. Manpower
D. Equipment

19. Which type of 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?

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

20. The man-hour estimating tables in NAVFAC P-405 are arranged into how many divisions of work?

A. 11
B. 13
C. 15
D. 17

21. **(True or False)** The work schedule of a deployed Seabee battalion is based on an average of 65 hours per man per week.

A. True
B. False

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

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

23. Placing underslab conduit runs before pouring concrete is considered what type of dependency?

A. Soft
B. Continuing
C. Flexible
D. Hard

24. In precedence diagrams, how are activities represented?

A. An octagon box
B. A rectangular box
C. A start and finish node
D. A round node

25. In a precedence diagram, what information about an activity can be found on the right side of an activity box?

A. The completion
B. The start
C. The man-hours
D. The critical event

26. In a precedence diagram, activities may be divided into how many distinct groups?

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

27. In a precedence diagram, intermediate goals with no time duration relate to what kind of activities?

A. Working
B. Milestone
C. Critical
D. Support

28. How are critical activities in a precedence diagram identified?

A. By arrows
B. By slash marks through the activity box
C. By a red circle around the activity
D. By slash marks through the activity connector

29. Which of the following rules governs the drawing of a network?

A. Activities must be numbered in sequence
B. The start of an activity must be linked to the ends of all completed activities before the start may take place
C. Activities taking place at the same time must be linked before the start may take place
D. Only critical path activities may be linked to each other

30. When two network activities are remote from each other but must be connected to show dependency, what type of connector should be used?

A. Direct
B. Joining
C. Splitting
D. Parallel

31. In a network, what is the main objective of the forward pass?

A. To determine the number of activities
B. To allow for material delays
C. To establish the late start and late finish of each activity
D. To determine the duration of the network

32. What term identifies the amount of scheduled leeway allowed in a network?

A. Free play
B. Allowance of time
C. Float or slack
D. Dead time or null time

33. When you become a Builder petty officer, you automatically assume which of the following additional responsibilities?

A. Company clerk
B. Project manager
C. Project estimator
D. Crew leader

34. **(True or False)** When planning a project, you must consider both the tools and equipment you will need and the capability of the crew.

A. True
B. False

35. To ensure a job is completed on schedule, you should take which of the following actions?

A. Order extra equipment
B. Conduct disaster control training
C. Demand quality work
D. Encourage teamwork and establish goals

36. A standard Builder tool kit contains the hand tools required for what maximum size crew?

A. Five persons
B. Two persons
C. Six persons
D. Four persons

37. **(True or False)** As a crew leader, you are NOT authorized to draw the tools required by the individual crewmembers.

A. True
B. False

38. What form should a crew leader use to order materials?

   A. DD 1148
   B. DD 1250
   C. NAVSUP 1149
   D. NAVSUP 1250

39. Information on the National Stock Number system is found in which of the following RTMs?

   A. *Tools and Their Uses*
   B. *Military Requirements for Petty Officer 3 & 2*
   C. *Blueprint Reading and Sketching*
   D. *Constructionman TRAMAN*

40. Labor that includes actual mandays expended to support construction operations but which does not produce an end product in itself is what type?

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

41. **(True or False)** As a petty officer, you must be familiar with the safety program at your activity.

   A. True
   B. False

42. The safety policy committee is presided over by what person?

   A. The safety officer
   B. The company chief
   C. The administrative officer
   D. The executive officer

43. What is the primary purpose of the safety policy committee?

   A. Develop safety rules and policy for the battalion
   B. Discipline personnel who are involved in accidents
   C. Elect a battalion safety chief and committee
   D. Review all vehicle accident reports and determine the causes of accidents

44. What is the primary purpose of the safety supervisors' committee?

   A. Establish work procedures
   B. Encourage safe practices
   C. Review safety suggestions
   D. All of the above

45. Which of the following committees reviews vehicle mishaps?

A. The safety supervisors' committee
B. The safety policy committee
C. The responsible crew
D. The equipment committee

46. **(True or False)** As a crew leader, you are NOT responsible for the safe working practices of individual crewmembers.

A. True
B. False

47. When an unsafe working condition exists, which of the following individuals can stop the work until the unsafe condition is corrected?

A. The crewmember
B. The crew leader
C. The project safety supervisor
D. Any of the above

48. Who among the following individuals is responsible for conducting stand-up safety lectures?

A. The safety chief
B. The safety officer
C. The crew leader
D. The company commander

49. Of the following, which is the best safety technique a crew leader can apply?

A. Stand-up meetings
B. Reprimanding violators in view of their peers
C. Designating a crewmember as the safety representative
D. Leadership by example

50. **(True or False)** The first step in Operational Risk Management (ORM) is to identify hazards.

A. True
B. False

51. Which of the following is part of the Assess Hazards step of ORM?

A. Risk Assessment Code
B. Hazard Severity
C. Mishap Probability
D. All of the above

52. Which of the following is part of the Supervise step of ORM?

A. Develop residual risk
B. Incorporate selected controls into SOPs
C. Enforce standards and controls
D. All of the above

53. Which of the following is a phase of Quality Control?

A. Preparatory phase
B. Initial phase
C. Follow up phase
D. All of the above

54. Who is responsible for ensuring quality control during the phases of a project?

A. Crew Leader
B. Quality Control Inspector
C. Executive Officer
D. Company Chief

55. Which form is used when the battalion recommends changes from the field to the Resident Officer-in-Charge of Construction (ROICC)?

A. Field Adjustment Request
B. Request for Information
C. Design Change Directive
D. RFI Submittal Log

Trade Terms Introduced in this Course

Activity	In Critical Path Method (CPM) scheduling, a task or item of work required to complete a project.
Critical path	A term used to describe the order of events (each of a particular duration) that results in the least amount of time required to complete a project.
Delay	An event or condition that results in work activity starting, or the project being completed, later than originally planned.
Early finish (EF)	In Critical Path Method (CPM) scheduling, the first day of a project on which no work is to be done for an activity, assuming work began on its early start time.
Early start (ES)	In Critical Path Method (CPM) scheduling, the first day of a project on which work on an activity can begin if all preceding activities are concluded as early as possible.
Estimating	The process of determining the anticipated cost of materials, labor, and equipment of a proposed project.
Estimator	One who is capable of predicting the probable cost of a building project.
Free float	A term used in project management, planning, and scheduling methods such as PERT and CPM. The free float of an activity is the amount by which the completion of that activity can be deferred without delaying the start of the following activities or affecting any other activity in the network.
Late finish	In the Critical Path Method of scheduling, a completion deadline for a particular activity. Work performed after this date will result in project delay.
Late start	In the Critical Path Method of scheduling, the deadline for starting a particular activity. A late start will throw off the schedule and delay the project.
Material Safety Data Sheets	A form containing data regarding the properties of a particular substance which is intended to give workers and emergency personnel procedures for handling or working with that substance in a safe manner.
Planning	The process of developing a scheme of a building or group of buildings by studying the layout of spaces within each building, and of building and other installations in an open space.
Preliminary estimates	Rough estimates made in an early stage of the design work, prior to receipt of firm bids.
Specifications	Detailed and exact statements of particulars, especially a statement prescribing materials, dimensions, and workmanship for something to be built or installed.

Table of allowance An equipment allowance document which prescribes basic allowances of organizational equipment.

Total float In Critical Path Method terminology, the difference between the time available to accomplish an activity and the estimated time required.

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.

Facilities Planning Guide, NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, Va., 1982.

Operations Officer's Handbook, COMCBPAC/COMCBLANTINST 5200.2A, Commander, Naval Construction Battalions, U.S. Pacific Fleet, Pearl Harbor, Hawaii, and Commander, Naval Construction Battalions, U.S. Atlantic Fleet, Norfolk, Va., 1988.

Seabee Planner's and Estimator's Handbook, NAVFAC P-405, Chapter 5, Naval Facilities Engineering Command, Alexandria, Va., 1983.

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Chapter 5

Site Work

Topics

To hear audio, click on the box.

Overview

Your job as the Builder petty officer is to direct your crewmembers in preparing the construction site before pouring foundations or erecting walls. Your work begins with site surveys using specialized surveying equipment and methods. You will pull building permits for various aspects of the project, working closely with local authorities. Once that work is underway, begin site and building layout. ***Leveling*** and grading are key components in building sound structures, with competent work taking into account the types of soils with which you are working. Soils testing can help you determine whether you need to perform any soil stabilization before construction begins.

This chapter introduces you to the concepts of site surveys, including construction surveys, bench marks, datum, and mean sea level. You will learn about earthwork operations, including pioneering, grubbing, stripping, and drainage. You will get an introduction to permits that need to be coordinated with local agencies for construction projects, including utility interruption requests, excavation requests, and road closure requests.

This chapter describes the common types of leveling instruments; including their principles, uses, procedures of establishing ***elevations***, and techniques of laying out building lines. As a Builder, you will find the information especially useful in performing such duties as setting up a level, reading a ***leveling rod***, interpreting and setting ***grade*** stakes, and setting batter boards.

Information on classifying and testing soils is included in this chapter. You will learn about practices and measures to stabilize soil on construction sites, which can also help prevent slides and cave-ins at excavation sites.

Objectives

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

1. Explain types of site surveys and their components, including construction surveys, bench marks, datum, and mean sea level.
2. Explain types of earthwork operations, including pioneering, grubbing, stripping, and drainage.
3. Describe types of leveling instruments and their uses.
4. Interpret readings from a leveling rod.
5. Determine elevations in the field to locate points at specified elevations.
6. Determine boundaries of building layout.
7. Determine classes of soils through soils testing.
8. Determine soil stabilization strategies.

Prerequisites

None

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

Expeditionary Structures	
Finishes	BUILDER
Moisture Protection	
Finish Carpentry	
Rough Carpentry	
Carpentry Materials and Methods	
Masonry	
Fiber Line, Wire Rope, and Scaffolding	
Concrete Construction	
Site Work	BASIC
Construction Management	
Drawings and Specifications	
Tools	
Basic Math	

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 italicized instructions 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 SITE SURVEY

There are a number of concepts used in surveying a site for a construction project. Construction surveys, sometimes called engineering surveys, are conducted to obtain data essential for planning, estimating, locating, and layout for the various phases of construction activities or projects. Surveys rely on Bench Marks (BM) to establish a known elevation on a construction site. Construction projects on the edge of or in the water utilize tidal datum and mean sea level measurements when sites are established.

Earthwork operations are some of the earliest operations that occur on a construction site. Pioneering, the earliest process makes the area accessible to the equipment that will be used on the project. Clearing is the next step, which consists of cleaning the site surface of vegetation, boulders, and rubbish. Clearing may include grubbing, which is removing roots and stumps, as well as stripping the site of sod and poor topsoil. All of this preparation needs to be done while maintaining or improving the drainage of the site.

1.1.1 Construction Survey

Construction surveys include reconnaissance, preliminary, location, and layout surveys. The objectives of engineering or construction surveying include the following:

1. Gathering reconnaissance information and preliminary data engineers require for selecting suitable routes and sites and for preparing structural designs
2. Defining selected locations by establishing a system of reference points
3. Guiding construction forces by setting stakes or otherwise marking lines, grades, and principal points and by giving technical assistance
4. Measuring construction items in place for the purpose of preparing progress reports
5. Dimensioning structures for preparation of as-built plans

All of the above objectives are called engineering surveys by the American Society of Civil Engineers (ASCE). The term construction surveys is applied to the last three objectives only. The Army Corps of Engineers, on the other hand, generally applies the term construction surveying to all of the objectives listed above.

Engineering and/or construction surveys form part of a series of activities leading to the construction of a man-made structure. The term structure is usually confined to something, such as a building or a bridge that is built of structural members. It is used here in a broader sense, however, to include all man-made features, such as graded areas; sewer, power, and water lines; roads and highways; and waterfront structures.

Construction surveys normally cover areas considered small enough to use plane surveying methods and techniques.

1.2.0 Bench Mark

A Bench Mark (BM) is a relatively permanent object, natural or artificial, bearing a marked point whose elevation is known. BMs are established over an area to serve as (1) starting points for leveling operations so the topographic parties can determine other unknown elevation points and (2) reference marks during later construction work. BMs are classified as Permanent or Temporary. Generally, BM indicates a permanent bench mark, and TBM a temporary bench mark. TBMs are established for a particular job and retained for the duration of that job. Throughout the United States, a series of BMs has been established by various government agencies. These identification markers are set in stone, iron pipe, or concrete, and are generally marked to show the elevation above sea level. When the elevation is not marked, you can find out what it is by contacting the government agency that originally set the BM. Be sure you give them the identification number on the marker.

Bench Marks may be constructed in several ways. *Figure 5-1* shows brass shaft stocks in the tops of permanent horizontal control points, also known as monuments. Monuments of this type are sometimes also used for vertical control BMs. Original BMs may be constructed in the same manner. When regular BM disks are not available, brass, not steel, 50-caliber empty shell casings may be used. The shank of the empty shell casings should be drilled crosswise and a nail inserted to prevent its being pulled out or forced out by either expansion or contraction.

Figure 5-1 – Horizontal control points used also as bench marks.

For short lines and a level circuit of a limited area, any substantial object may be used for vertical control BMs. The remark in the field notes should bear the proper identification of the BMs used.

Figure 5-2 shows a mark like those commonly used on tops of concrete walls, foundations, and the like. Lines are chiseled out with a cold chisel or small star drill and then marked with paint or keel. The chiseled figures should be about the same size as the base area of the rod. They should be placed on some high spot on the surface of the concrete structure.

Figure 5-2 – Points on existing structures used as bench marks.

A spike may be driven into the root of a tree or placed higher up on the trunk of the tree when the limb clearance allows higher rod readings. *Figure 5-3* shows the recommended way to do this. Hold the rod on the highest edge of the spike, and mark the elevation on the blazed portion of the tree.

Figure 5-3 – Spikes used as bench marks on trees and roots.

Figure 5-4 shows a spike driven on a pole or post that also represents a BM. Drive the spike in horizontally on the face of the post in line with the direction of the level line. For the reading, hold the rod on the uppermost edge of the spike. After figuring the elevation, mark it on the pole or post for future reference.

Stakes driven into the ground can also be used as TBMs, especially if no frost is expected before they are needed. A detailed description of these points is just as important as one for a monument station.

Figure 5-4 – Spikes used as bench marks on poles or posts.

In most permanent military installations, monument BMs are established in a grid system approximately one-half mile apart throughout the base to have a ready reference for elevations of later construction in the station. These BMs are generally fenced to mark their locations. The fence also serves to protect them from being accidentally disturbed.

BM systems or level nets consist of a series of BMs established within a prescribed order of accuracy along closed circuits and tied to a datum. These nets are adjusted by computations that minimize the effects of accidental errors and are identified as being of a specific order of accuracy.

In certain areas, Tidal Bench Marks must be established to obtain the starting datum plane or to check previously established elevations. Tidal bench marks are permanent BMs set on high ground and are tied to the tide station near the water surface.

Tide stations are classified as primary and secondary. Primary stations require observations for periods of nineteen years or more to derive basic tidal data for a locality. Secondary stations are operated over a limited period, usually less than one year, and for a specific purpose, such as checking elevations. The secondary station observations are always compared to, and computed from, data obtained by primary stations.

A tide station is set up, and observations are made for a period that is determined by a desired accuracy. These observations are compared with a primary tide station in the area then furnished with a mean value of sea level in the area.

A closed loop of spirit levels is run from the tide station over the tidal BMs and is tied back to the tide station. The accuracy of this level line must be the same as or higher than the accuracy required for the BMs.

For permanency, tidal BMs usually are set in sets of three and away from the shoreline where natural activity or future construction will not disturb or destroy them.

1.3.0 Datum

Tidal datums are specific tide levels that surveyors (?) use as surfaces of reference for depth measurements in the sea and as a base for determining elevations on land. In leveling operations, the tidal datum most commonly used is the Mean Sea Level.

Surveyors (?) sometimes use other datums, such as mean low water, mean lower low water, mean high water, and mean higher high water, depending upon the purpose of the survey. Still other datums have been used in foreign countries. When conducting leveling operations overseas, check into this matter carefully to avoid mistakes.

1.4.0 Mean Sea Level

Mean sea level (MSL) is the average height of the sea for all stages of the tide after long periods of observations. It is obtained by averaging the hourly heights as they are tabulated on a form similar to that shown in *Figure 5-5*.

Day & Mo		1 Mar	2	3	4	5	6	7	Sum	Remarks:
Hour	0	15.1 Ft.	15.5 Ft.	15.4 Ft.	13.9 Ft.	12.0 Ft.	9.0 Ft.	6.6 Ft.	87.5 Ft.	Tides: Hourly Heights
	1	14.4	15.7	16.6	15.9	14.8	12.1	9.5	99.0	Station: Portsmouth
	2	13.5	15.4	17.0	17.3	17.1	15.1	12.8	108.2	Lat. 44° 50' N
	3	12.5	14.8	16.9	17.9	19.2	19.0	18.0	116.2	Long. 68° 10' W
	4	11.7	14.0	16.5	17.8	19.2	19.0	18.0	116.2	Party Chief EA2 Long
	5	11.6	13.3	15.7	17.3	19.1	19.6	19.4	116.0	Tide Gauge No. 85
	6	12.3	13.2	14.9	16.4	18.5	19.5	19.8	114.6	Scale 1:24
	7	13.7	13.7	14.6	15.5	17.4	18.7	19.5	113.1	Tabulated by EA2 Smith
	8	15.4	15.0	15.0	15.0	16.3	17.6	18.6	112.9	
	9	17.6	16.5	15.9	15.2	15.6	16.3	17.1	114.2	
	10	19.2	18.2	17.2	16.0	15.8	15.6	15.9	117.9	
	11	20.1	19.4	18.5	17.2	16.6	15.6	15.1	122.5	
	12	19.9	19.8	19.4	18.4	17.7	16.3	15.4	126.9	
	13	19.0	19.3	19.7	19.2	18.7	17.5	16.2	129.6	
	14	17.3	18.0	18.9	19.2	19.5	18.4	17.3	128.6	
	15	15.0	15.9	17.3	18.2	19.4	19.0	18.3	123.3	
	16	12.2	13.1	14.8	16.3	18.1	18.6	18.9	112.0	
	17	10.3	10.5	11.8	13.6	15.9	17.1	18.4	97.7	
	18	9.5	8.5	9.2	10.5	13.0	14.7	16.8	82.2	
	19	9.7	7.8	7.4	7.8	9.8	11.5	14.1	68.1	
	20	10.5	8.3	6.7	6.1	7.0	8.1	10.9	57.6	
	21	11.8	9.5	7.5	5.8	5.3	5.6	7.8	53.3	
	22	13.4	11.4	9.1	7.0	5.1	4.2	5.4	55.6	
	23	14.8	13.6	11.4	9.1	6.6	4.6	4.2	64.3	
Sum		340.5	340.4	347.5	346.6	357.1	351.2	352.0	2435.3	

Figure 5-5 – Sample format showing hourly heights of tide required for computing average mean sea level (MSL).

The heights on this form are added both horizontally and vertically. Enter the total sum covering seven days of record in the lower right-hand corner of the page. Find the mean for each calendar month by combining all daily sums for the month and dividing by the total number of hours in the month. Enter the monthly mean, to two decimal places, on the sheet that includes the record for the last day of the month. Yearly means are determined from the monthly means, and a mean is taken of all yearly means for the period of record. Use three or more years of records for a good determination of sea level. The actual value varies somewhat from place to place, but this variation is small.

For MSL determinations, use a station on the open coast or on the shore of bays or harbors having free access to the sea. Stations on tidal rivers at some distance from the open sea will have a mean river level that is higher than mean sea level because of the river slope. Note that mean sea level is NOT identical with mean tide level (MTL). The latter is derived from the mean of all high and low points on the tidal curve. But MSL is derived from the mean of a much larger number of points taken at hourly intervals along the tidal curve.

The datum universally used in leveling is mean sea level (MSL), and it is the zero unit. The vertical distance of a given point above or below this datum then becomes the elevation of that point.

1.5.0 Earthwork Operations

Pioneering refers to the first working over of an area that is overgrown or rough. This makes the area accessible for the equipment needed for the project.

In pioneering, the operations of clearing, stripping, grading, and drainage are all done essentially at the same time, rather than performed as separate operations. A dozer starts out along a predetermined route and leaves a road behind it. This may be a haul road which trucks and equipment will use in later operations.

Suppose you, as a dozer operator, get the job of cutting a road on the side of a mountain to be used for access to a proposed airstrip or to reach a mountain stream to be developed into a water supply system. Where should you start and how should you proceed? A survey party will stake out the route your mountain road is to follow. Start your road at the highest point possible and let the force of gravity help the dozer.

In clearing on sidehill cuts, cast brush and trees far enough to the side of the road that they will not be covered with the earth. It is even better if you can cast them over the edge with an angle blade of the dozer when the road is cut. When cutting the road, do not watch the grade stake immediately ahead or you will find yourself below grade. Instead, watch the third or fourth stake down.

NOTE

It is better to be above grade and come back and cut down to grade than to be below grade and have to come back and fill.

Clearing is a construction operation consisting of cleaning a designated area of trees, timber, brush, other vegetation, and rubbish; removing surface boulders and other material embedded in the ground; and disposing of all material cleared.

Clearing, grubbing, and stripping are different in every climatic zone because each has different types of forests and vegetation. The nature of a forest can be determined from records of the principal climatic factors, including precipitation, humidity, temperature, sunlight, and the direction of prevailing winds. The types of forests can be generally classified as temperate, rain, monsoon, or dry, according to the climates in which they exist.

Clearing usually consists of pushing uprooted trees, stumps, and brush in both directions from the center of the area to be cleared. Clear so that you place debris, also known as spoil material, in a designated spot with only one handling. In clearing landing strips, for example, it is generally necessary to dispose of material along each side of the strip outside the construction site. If the site permits burning, you can reduce the haul distance by piling brush, stumps, and trees on the site and burning them. Production in this field must be estimated, rather than calculated.

Grubbing is uprooting and removing roots and stumps. In grubbing, burn or blast stumps that are difficult or impossible to pull out, even with winches. Your supervisor will decide the method. If the stumps are to be removed by blasting, call upon a qualified blaster to do the job. If they are to be burned, you may be assigned the task. Green stumps require continuous application of heat before they catch fire. Check with your supervisor about safety measures to keep the fire from getting out of control if you have to do any stump burning. Remember, it may take as long as three or four days for a stump to burn out. Keep a check on the burning during this period. If a project has a high priority and time must be saved, you will probably blast stumps, rather than burn them. After removing stumps, fill the holes and level the area to prevent the accumulation of water.

Stripping is removing and disposing of objectionable topsoil and sod. It may either follow or be done with clearing and grubbing. Actual earthmoving begins with stripping; surface soil and rocks are removed from the area to be excavated. Deeply embedded rocks and large boulders may have to be blasted before they can be removed.

The material removed by stripping is called spoil. Unless otherwise directed, dump spoil along the area to be excavated within range of the earthmoving equipment. If the spoil will not be put to some use like turfing or finishing the shoulder of a road or runway, waste it along the edges of the project, as shown in *Figure 5-6*. Take care not to disturb necessary drainage.

Figure 5-6 – Stripping.

Equipment commonly used in stripping consists of a dozer, a scraper, and a grader. As mentioned earlier, the dozer is the most often used when removing trees. Dozers can handle all short-haul excavations up to 300 feet. For long-haul excavations over 300 feet, use scrapers. You may also use a scraper on fine soils for shallow stripping. Use a grader mainly for shaping and finishing a stripped surface. It is adaptable also for ditching, side casting, and sloping banks.

Drainage is the construction of facilities needed to allow excess surface and subsurface water to flow from the construction site. Properly designed and constructed drainage systems are one of the most important parts of a construction project. Without proper drainage, rainwater and water running off the surrounding ground could turn the area into a lake. It is also necessary to drain off surface water that would soak down and wet the subgrade.

The elements determining drainage needs for a road or project site are the amount of annual rainfall in the area and the routes or areas that can be used to collect or channel excess surface and subsurface water. These areas include lakes, ponds, streams, or voids such as gullies.

The type of soil is critical to the design and construction of a road. It is poor judgment to construct a road over or through clay, sand, or other undesirable material if it cannot be properly compacted. Bypassing this type of material is best.

If a road surface is to endure continued use for years, it must have firm support from the subgrade. Remove all organic materials, such as living or decayed vegetation, from the area of the subgrade unless the road is for emergencies or is temporary, such as a detour or military road. In designing and building a road, consider the type of drainage, the type of soil, and the amount of clearing or grubbing necessary.

To facilitate drainage, excavate diversion ditches to conduct all surface water into natural channels or outfall ditches. Construct outfall ditches to drain low or boggy spots. At the point or the end of the system where the accumulated runoff discharges into the disposal point, the runoff is technically known as discharge**.** The discharge point in the system is called the outfall**.** This preliminary drainage work is done at the same time the area is cleared and grubbed.

The finished drainage system usually consists of ground slopes, ditches, culverts, gutters, storm drains, and underground water drains. Use open channels to intercept or control surface water. These should be dug by bulldozers, scrapers, backhoes, or motor graders, depending on the circumstances. Construct culverts to drain water across a construction site. Subdrains to drain groundwater are usually excavated with ditchers or backhoes. The drains used are French drains, which are perforated or open-joint tile pipes. *Figure 5-7* shows typical covered and French drains.

Figure 5-7 – Typical sections of covered and French drains.

Remove runoff water from rain or melted snow from the area by constructing an adequate transverse slope or crown. This runoff collects in ditches and drains into the nearest natural drainage channel. Drainage for construction sites can be provided by building the ends of the site sloping towards the middle or sloping from one end to the other. These types of drainage construction are shown on the runways in *Figure 5-8*.

Figure 5-8 – Longitudinal drainage of runways.

2.0.0 PERMITS

Construction projects require pulling of permits at many stages. These permits include the Utility Interruption Request shown in *Figure 5-9*, the Excavation Request shown in *Figure 5-10*, and the Road Closure Request shown in *Figure 5-11*.

Date:

From: Naval Mobile Construction Battalion
To: Public Works Department

Subj: UTILITY INTERRUPTION REQUEST

1. Request authorization for a scheduled utility interruption involving the following utilities:

_ Electric Water
_ Steam Sewerage
_ Communication Other

2. Location:_

3. Planned start date/time: _

4. Planned completion date/time: _

5. The interruption is for project _ and is required to:_

6. Point of contact: _ Phone no. _

Signature/printed name of requestor

INTERNAL PUBLIC WORKS ROUTING

Code		Work Center		Approved/ Disapproved		Signature		Date		Phone		Remarks
		Line Crew										

PUBLIC WORKS DEPARTMENT ENDORSEMENT

From: Public Works Department
To: Naval Mobile Construction Battalion

1. Returned APPROVED/DISAPPROVED

Signature/printed name of approving official

Figure 5-9 – Form for a Road Closure Request.

Date:

From: Naval Mobile Construction Battalion
To: Public Works Department

Subj: EXCAVATION REQUEST

1. Request authorization to excavate for the purpose of (describe excavation):

2. Method of excavation:_

3. Planned start date:

4. Planned completion date (including backfill, compaction, ground cover, paving repair, etc.):

5. The excavation is for project and is required to:_

6. Point of contact: Phone no._

7. Sketch showing location of planned excavation is attached (mandatory).

Signature/printed name of requestor

INTERNAL PUBLIC WORKS ROUTING

Code	Work Center	Approved/ Disapproved	Signature	Date	Phone	Remarks
	Line Crew					
	Water Crew					
	Engineering					

PUBLIC WORKS DEPARTMENT ENDORSEMENT

From: Public Works Department
To: Naval Mobile Construction Battalion

1. Returned APPROVED/DISAPPROVED

Signature/printed name of approving official

Figure 5-10 – Form for an Excavation Request.

Date:

From: Naval Mobile Construction Battalion
To: Public Works Department

Subj: ROAD CLOSURE REQUEST

1. Request permission for closure/partial closure of: ____

2. This closure is for project and is required to: ____

3. Planned closure date/time:

4. Planned reopening date/time:

5. Point of contact: Phone no.

____
Signature/printed name of requestor

INTERNAL PUBLIC WORKS ROUTING

Code		Work Center		Approved/ Disapproved		Signature		Date		Phone		Remarks
		Line Crew										
		Water Crew										
		Engineering										

PUBLIC WORKS DEPARTMENT ENDORSEMENT

From: Public Works Department
To: Naval Mobile Construction Battalion

1. Returned APPROVED/DISAPPROVED

____
Signature/printed name of approving official

Figure 5-11 – Form for an Excavation Request.

3.0.0 SURVEYING INSTRUMENTS

The engineer's level, often called the ***dumpy level***, is the instrument most commonly used to attain the level line of sight required for differential leveling, which is defined later. The dumpy level and the self-leveling level can be mounted for use on a tripod, usually with adjustable legs, shown in *Figure 5-12*.

Mount the level by engaging threads at the base of the instrument, called the footplate, with the threaded head on the tripod. These levels are the ones most frequently used in ordinary leveling projects. For rough leveling, use the ***hand level***.

Figure 5-12 – Tripod.

3.1.0 Dumpy Level

Figure 5-13 shows a dumpy level and its nomenclature. Notice that the telescope is rigidly fixed to the supporting frame.

Inside the telescope is a ring, or diaphragm, known as the reticle, which supports the cross hairs. The cross hairs are brought into exact focus by manipulating the knurled eyepiece focusing ring near the eyepiece, or the eyepiece itself on some models. If the cross hairs get out of horizontal adjustment, they can be made horizontal again by slackening the reticle adjusting screws and turning the screws in the appropriate direction. Only trained personnel should perform this adjustment.

Figure 5-13 – Dumpy level.

The object to which you are sighting, regardless of shape, is called a target. Bring the target into clear focus by manipulating the focusing knob shown on top of the telescope. The telescope can be rotated only horizontally, but before it can be rotated, release the azimuth clamp. Train the telescope as nearly on the target as you can, and then tighten the azimuth clamp. Bring the vertical cross hair into exact alignment on the target by rotating the azimuth tangent screw.

The level vial, leveling head, leveling screws, and footplate are all used to adjust the instrument to a perfectly level line of sight once it is mounted on the tripod.

3.2.0 Self-Leveling Level

The self-leveling, or automatic, level, shown in *Figure 5-14* is a precise, time-saving development in leveling instruments. It did away with the tubular spirit level, whose bubble takes time in centering as well as in resetting to its correct position from time to time during operation.

The self-leveling level is equipped with a small bull's-eye level and three leveling screws. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull's-eye level approximately. The line of sight automatically becomes horizontal and remains horizontal as long as the bubble remains approximately centered. A prismatic device called a compensator makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that defines a horizontal sight. The level maintains this horizontal line of sight despite a slight out of level of the telescope or even when a slight disturbance occurs on the instrument.

Figure 5-14 – Self-leveling level.

3.3.0 Hand Level

The hand level, like all surveying levels, combines a level vial and a sighting device. *Figure 5-15* shows the ***Locke level***, a type of hand level. A horizontal line, called an index line, is provided in the sight tube as a ***reference line***. The level vial is mounted atop a slot in the sighting tube in which a reflector is set at a 45° angle. This permits the observer sighting through the tube to see the object, the position of the level bubble in the vial, and the index line at the same time.

To get the correct sighting through the tube, stand straight, using the height of your eye, if known, above the ground to find the target. When your eye height is not known, you can find it by sighting the rod at eye height in front of your body. Since the distances over which you sight a hand level are rather short, no magnification is provided in the tube.

Figure 5-15 – Locke level.

3.4.1 Setting Up a Level

After you select the proper location for the level, your first step is to set up the tripod.

1. Spread two of the legs a convenient distance apart and then bring the third leg to a position that will bring the protector cap, which covers the tripod head threads, about level when the tripod stands on all three legs.
2. Unscrew the protector cap, exposing the threaded head, and place it in the carrying case where it will not get lost or dirty. The tripod protective cap should be in place when you are not using the tripod.
3. Lift the instrument out of the carrying case by the footplate, not by the telescope.
4. Set the instrument squarely and gently on the tripod head threads and engage the head nut threads under the footplate by rotating the footplate clockwise. If the threads will not engage smoothly, they may be cross threaded or dirty. Do not force them if you encounter resistance; instead, back off, and, after checking to see that they are clean, square up the instrument, and then try again gently.
5. Screw the head nut up firmly, but not too tightly. Screwing it too tightly causes eventual wearing of the threads and makes unthreading difficult.
6. After you have attached the instrument, thrust the leg tips into the ground far enough to ensure that each leg has stable support, taking care to maintain the footplate as nearly level as possible.
7. With the instrument mounted and the legs securely positioned in the soil, firmly tighten the thumbscrews at the top of each leg to prevent any possible movement.

Quite frequently, you must set up the instrument on a hard, smooth surface, such as a concrete pavement. When you do, you must take steps prevent the legs from spreading. *Figure 5-16* shows two good ways of doing this. In *View A*, the tips of the legs are inserted in joints in the pavement. In *View B*, the tips are held by a wooden floor triangle.

Figure 5-16 – Methods of preventing tripod legs from spreading.

3.5.0 Leveling a Level

To function accurately, the level must provide a perfectly horizontal line of sight in any direction you train the telescope. To ensure this, you must level the instrument as discussed in the next paragraphs.

When you first set up the tripod and instrument, make the footplate as nearly level as possible.

1. Train the telescope over a pair of diagonally opposite leveling screws, and clamp it in that position.
2. Manipulate the leveling thumbscrews, as shown in *Figure 5-17,* to bring the bubble in the level vial exactly into the marked center position. Manipulate the thumbscrews by simultaneously turning them in opposite directions. This shortens one spider leg, the threaded member running through the thumbscrew, while it lengthens the other. It is helpful to remember that the level vial bubble will move in the same direction that your left thumb moves while you rotate the thumbscrews. In other words, when your left thumb pushes the thumbscrew clockwise, the bubble will move towards your left hand; when you turn the left thumbscrew counterclockwise, the bubble moves toward your right hand.
3. After leveling the telescope over one pair of screws, train it over the other pair and repeat the process. As a check, set the telescope in all four possible positions and be sure that the bubble centers exactly in each.

Figure 5-17 – Manipulating leveling thumbscrews.

Various techniques for using the level will develop with experience. In this section, we will discuss only the techniques we believe essential to the Builder rating.

3.6.0 Care of Levels

An engineer's level is a precision instrument containing many delicate and fragile parts. Handle it gently and with the greatest care at all times; never subject it to shock or jar. Movable parts, if not locked or clamped in place, should work easily and smoothly. If a movable part resists normal pressure, something is wrong. Forcing the part to move will probably damage the instrument. Tightening clamps and screws excessively will also cause wear or damage.

The only proper place to stow the instrument when it is detached from the tripod is in its own carrying box or case. The carrying case is designed to reduce the effect of jarring to a minimum. It is strongly made and well padded to protect the instrument from damage. Before stowing, slightly tighten the azimuth clamp and leveling screws to prevent movement of parts inside the box. When transporting it in a vehicle, place the case containing the instrument as near as possible midway between the front and rear wheels. This is the point where jarring of the wheels has the least effect on the chassis.

Never lift the instrument out of the case by grasping the telescope. Wrenching the telescope in this manner will damage a number of delicate parts. Lift it out by reaching down and grasping the footplate or the level bar.

When you attach the instrument to the tripod and carry it from one point to another, set up the azimuth clamp and level screws tightly enough to prevent part motion during the transport but loosely enough to allow give in case of an accidental bump against some object. When you are carrying the instrument over terrain that is free of possible contacts, such as across an open field, you may carry it over your shoulder like a rifle. When there are obstacles around, carry it as shown in *Figure 5-18*. Carried in this manner, the instrument is always visible to you, and this makes it possible for you to avoid striking it against obstacles.

Figure 5-18 – Safest carrying position for instrument when obstacles may be encountered.

3.7.0 Leveling Rods

A leveling rod is a vertically supported tape used to measure vertical distance, which is the difference in elevation, between a line of sight and a required point above or below it. Although there are several types of rods, the most popular and frequently used is the ***Philadelphia rod***. *Figure 5-19* shows the face and back of this rod.

Figure 5-19 – Back and face of Philadelphia leveling rod.

The Philadelphia rod consists of two sliding sections, which can be fully extended to a total length of 13.10 feet. When the sections are entirely closed, the total length is 7.10 feet. For direct readings, or readings on the face of the rod, of up to 7.10 and 13.10 feet, the rod is used extended and read on the back by the rodman. If you are in the field and don’t have a Philadelphia rod, you can use a 1 by 4 with a mark or a 6 foot wooden ruler attached to a 2 by 4.

In direct readings, the person at the instrument reads the graduation on the rod intercepted by the cross hair through the telescope. In target readings, the rodman reads the graduation on the face of the rod intercepted by a target. In *Figure 5-19* the target does not appear; it is shown in *Figure 5-20*. It is a sliding, circular device that can be moved up or down the rod and clamped in position. The rodman places it on signals from the instrumentman.

Figure 5-20 – Philadelphia rod set for target reading of less than 7,000 feet.

The rod shown in the figures is graduated in feet and hundredths of a foot. Each even foot is marked with a large red numeral. Between each pair of adjacent red numerals, the intermediate tenths of a foot are marked with smaller black numerals. Each intermediate hundredth of a foot between each pair of adjacent tenths is indicated by the top or bottom of one of the short, black dash graduations.

3.7.1 Direct Readings

As the levelman, you can make direct readings on a self-reading rod held plumb on the point by the rodman. If you are working to tenths of a foot, it is relatively simple to read the footmark below the cross hair and the tenth mark that is closest to the cross hair. If greater precision is required, and you must work to hundredths, the reading is more complicated, as shown in *Figure 5-21*.

For example, suppose you are making a direct reading that should come out to 5.67 feet. If you are using a Philadelphia rod, the interval between the top and the bottom of each black graduation and the interval between the black graduations each represent 0.01 foot.

Figure 5-21 – Philadelphia rod marking.

This is shown in *Figure 5-22*, where each graduation represents 0.01 foot. For a reading of 5.76 feet, there are three black graduations between the 5.70 foot mark and the 5.76 foot mark. Since there are three graduations, a beginner may have a tendency to misread 5.76 feet as 5.73 feet.

Neither the 5 foot mark nor the 6 foot mark is shown in *Figure 5-22*. Sighting through the telescope, you might not be able to see the foot marks to which you must refer for the reading. When you cannot see the next lower foot mark through the telescope, it is a good idea to order the rodman to "raise the red"**.** On the Philadelphia rod, whole feet numerals are in red. Upon hearing this order, the rodman slowly raises the rod until the next lower red figure comes into view.

Figure 5-22 – Direct reading of 5.76 feet on a Philadelphia rod.

3.7.2 Target Readings

For more precise vertical measurements, level rods may be equipped with a rod target that can be set and clamped by the rodman at the direction of the instrumentman. When the engineer's level rod target and the vernier scale are being used, it is possible to make readings of one thousandth of a foot (0.001), which is slightly smaller than one sixty-fourth of an inch. Either the rodman or the instrumentman can read the indicated reading of the target. In *Figure 5-23*, you can see that the 0 on the vernier scale is in exact alignment with the 4 foot mark. If the position of the 0 on the target is not in exact alignment with a line on the rod, go up the vernier scale on the target to the line that is in exact alignment with the hundredths line on the rod, and the number located will be the reading in thousandths.

Figure 5-23 – Target.

There are three situations in which target reading, rather than direct reading, is done on the face of the rod:

- When the rod is too far from the level to be read directly through the telescope.
- When a reading to the nearest 0.001 foot, rather than to the nearest 0.01 foot, is desired. A vernier on the target or on the back of the rod makes this possible.
- When the instrumentman wants to ensure against the possibility of reading the wrong foot designation on the rod, indicated by a large red number.

For target readings up to 7.000 feet, the rod is used fully closed, and the rodman, on signals from the instrumentman, sets the target at the point where its horizontal axis is intercepted by the cross hair, as seen through the telescope. When the target is located, it is clamped in place with the target screw clamp, shown in *Figure 5-20*. When a reading to only the nearest 0.01 foot is desired, the graduation indicated by the target's horizontal axis is read; in *Figure 5-20*, this reading is 5.84 feet.

If reading to the nearest 0.001 foot is desired, the rodman reads the vernier, the small scale running from 0 to 10, on the target. The 0 on the vernier indicates that the reading lies between 5.840 feet and 5.850 feet. To determine how many thousandths of a foot over 5.840 feet, examine the graduations on the vernier to determine which one is most exactly in line with a graduation, the top or bottom of a black dash, on the rod. In *Figure 5-20*, this graduation on the vernier is the 3; so the reading to the nearest 0.001 foot is 5.843 feet.

For target readings of more than 7.000 feet, the procedure is a little different. If you look at the left-hand view of *Figure 5-19* showing the back of the rod, you will see that only the back of the upper section is graduated and that it is graduated downward from 7.000 feet at the top to 13.09 feet at the bottom. You can also see there is a rod vernier fixed to the top of the lower section of the rod. This vernier is read against the graduations on the back of the upper section.

For a target reading of more than 7.000 feet, the rodman first clamps the target at the upper section of the rod. Then, on signals from the instrumentman, the rodman extends the rod upward to the point where the horizontal axis of the target is intercepted by the cross hair. The rodman then clamps the rod, using the rod clamp screw shown in *Figure 5-24*, and reads the vernier on the back of the rod, also shown in that figure. In this case, the 0 on the vernier indicates a certain number of thousandths more than 7.100 feet. Remember that in this case, you read the rod and the vernier down from the top, not up from the bottom. To determine the thousandths, determine which vernier graduation lines up most exactly with a graduation on the rod. In this case, it is the 7, so the rod reading is 7.107 feet.

Figure 5-24 – Philadelphia rod target reading of more than 7,000 feet.

3.7.3 Rod Levels

A rod reading is accurate only if the rod is perfectly plumb, or vertical, at the time of the reading. If the rod is out of plumb, the reading will be greater than the actual vertical distance between the height of instrument (HI) and the base of the rod. On a windy day, the rodman may have difficulty holding the rod plumb. In this case, the levelman can have the rodman wave the rod back and forth, allowing the levelman to read the lowest reading touched on the engineer's level cross hairs.

The use of a rod level ensures a vertical rod. A bull's-eye rod level is shown in *Figure 5-25*. When it is held as shown and the bubble is centered, the rod is plumb. Note that the rod is held on a part of the rod where readings are not being taken to avoid interference with the instrumentman's view of the scale.

A vial rod level has two spirit vials, each of which is mounted on the upper edge of one of a pair of hinged metal leaves. The vial level is used like the bull's-eye level, except that two bubbles must be watched instead of one.

Figure 5-25 – Bull's eye rod level.

3.7.4 Care of Leveling Rods

A leveling rod is a precision instrument and must be treated as such. Most rods are made of carefully selected, kiln dried, well seasoned hardwood. Scale graduations and numerals on some are painted directly on the wood; on most rods they are painted on a metal strip attached to the wood. Unless a rod is handled at all times with great care, the painted scale will soon become scratched, dented, worn, or otherwise marked and obscured. Accurate readings on a damaged scale are difficult.

Allowing an extended sliding section rod to close on the run by permitting the upper section to drop may jar the vernier scale out of position or otherwise damage the rod. Always close an extended rod by easing the upper section down gradually.

A rod will read accurately only if it is perfectly straight. Anything that might bend or warp the rod must be avoided. Do not lay a rod down flat unless it is supported throughout, and never use a rod for a seat, lever, or pole vault. In short, never use a rod for any purpose except the one for which it is designed.

Store a rod that is not in use in a dry place to avoid warping and swelling caused by dampness. Always wipe off a wet rod before putting it away. If there is dirt on the rod, rinse it off, but do not scrub it off. If you must use a soap solution; to remove grease, for example; use a very mild one. A strong soap solution will soon cause the paint on the rod to degenerate.

Protect a rod as much as possible against prolonged exposure to strong sunlight. Such exposure causes paint to chalk, to degenerate into a chalk-like substance that flakes from the surface.

4.0.0 DIFFERENTIAL LEVELING

The most common procedure for determining elevations in the field, or for locating points at specified elevations, is known as differential leveling. This procedure is finding the vertical difference between the known or assumed elevation of a bench mark (BM) and the elevation of the point in question. Once the difference is measured, it can be added to or subtracted from the bench mark elevation to determine the elevation of the new point.

4.1.0 Elevation and Reference

The elevation of any object is its vertical distance above or below an established height on the earth’s surface. This established height is called either a reference plane or a simple reference. The most commonly used reference plane for elevations is mean, or average, sea level, which has been assigned an assumed elevation of 000.0 feet. The reference plane for a construction project is usually the height of some permanent or semi-permanent object in the immediate vicinity, such as the rim of a manhole cover, a rod, or the finish floor of an existing structure. This object may be given its relative sea level elevation, if it is known; or it may be given a convenient, arbitrarily assumed elevation, usually a whole number, such as 100.0 feet. An object of this type, which is used to determine the elevations of other points with a given, known, or assumed elevation, is called a bench mark.

4.1.1 Principles of Differential Leveling

Figure 5-26 illustrates the principle of differential leveling. The instrument shown in the center is an engineer's level. This optical instrument provides a perfectly level line of sight through a telescope, which can be trained in any direction. Point A in the figure is a bench mark having a known elevation of 365.01 feet. It could be a concrete monument, a wooden stake, a sidewalk curb, or any other object. Point B is a ground surface point whose elevation needs to be determined.

Figure 5-26 – Procedure for differential leveling.

The first step in finding the elevation point of point B is to determine the elevation of the line of sight of the instrument. This is known as the height of instrument and is often written and referred to simply as HI.

1. To determine the HI, take a backsight on a level rod held vertically on the bench mark (BM) by a rodman. A backsight (BS) is always taken after setting up a new instrument position by sighting back to a known elevation to get the new HI. A leveling rod is graduated upward in feet, from 0 at its base, with appropriate subdivisions in feet.

   In *Figure 5-25*, the backsight reading is 11.56 feet. The elevation of the line of sight (HI) must be 11.56 feet greater than the bench mark elevation, point A. The HI is 365.01 feet plus 11.56 feet, or 376.57 feet as indicated.
2. Train the instrument ahead on another rod; or more likely, on the same rod carried ahead, held vertically on B. This is known as taking a foresight. After reading a foresight (FS) of 1.42 feet on the rod, you see that the elevation at point B must be 1.42 feet lower than the HI. The elevation of point B is 376.57 feet minus 1.42 feet, or 375.15 feet.

5.0.0 SITE / BUILDING LAYOUT

Before foundation and footing excavation for a building can begin, the building lines must be laid out to determine the boundaries of the excavations. Points shown on the plot plan, such as building corners, are located at the site from a system of horizontal control points established by the battalion engineering aids. This system consists of a framework of stakes, driven pipes, or other markers located at points of known horizontal location. A point in the structure, such as a building corner, is located on the ground by reference to one or more nearby horizontal control points.

5.1.0 Locating Corner Points

We cannot describe here all the methods of locating a point with reference to a horizontal control point of a known horizontal location. We will take the situation shown in *Figure 5-25* as an example. This figure shows two horizontal control points, consisting of monuments A and B. The term monument doesn't necessarily mean an elaborate stone or concrete structure. In structural horizontal control, it simply means any permanently located object, either artificial, such as a driven length of pipe, or natural, such as a tree, of known horizontal location.

In *Figure 5-27*, the straight line from A to B is a control base line from which you can locate the building corners of the structure. You can locate corner E, for example, by first measuring 15 feet along the base line from A to locate point C; then measuring off 35 feet on CE, laid off at 90° to, or perpendicular to, AB. By extending CE another 20 feet, you can locate building corner F. Corners G and H can be similarly located along a perpendicular run from point D, which is itself located by measuring 55 feet along the base line from A.

Figure 5-27 – Locating building corners.

5.1.1 Perpendicular by Pythagorean Theorem

The easiest and most accurate way to locate points on a line or to turn a given angle, such as 90°, from one line to another is to use a surveying instrument called a transit. If you do not have a transit, you can locate the corner points with tape measurements by applying the Pythagorean Theorem.

1. Stretch a cord from monument A to monument B.

2. Locate points C and D by tape measurements from A.

3. If you examine *Figure 5-25*, you will observe that straight lines connecting points C, D, and E form a right triangle with one side 40 feet long and the adjacent side 35 feet long. By the Pythagorean Theorem, the length of the hypotenuse of this triangle, the line ED, is equal to the square root of $35^2 + 40^2$, which is approximately 53.1 feet. Because figure EG DC is a rectangle, the diagonals both ways, ED and CG, are equal. The line from C to G should also measure 53.1 feet.

4. Have one person hold the 53.1 foot mark of a tape on D, have another hold the 35 foot mark of another tape on C, and have a third person walk away with the joined 0 foot ends. When the tapes come taut, the joined 0 foot ends will lie on the correct location for point E. The same procedure, but this time with the 53.1 foot length of tape running from C and the 35 foot length running from D, will locate corner point G. Corner points F and H can be located by the same process, or by extending CE and DG 20 feet.

The equation for the Pythagorean Theorem is as follows:

$$C^2 = A^2 + B^2$$

C is the hypotenuse that you are solving for. A and B are the lengths of the two known sides. When you solve for C, you get the following formula:

$$C = \sqrt{A^2 + B^2}$$

5.1.2 Perpendicular by 3:4:5 Triangle

If you would rather avoid the square root calculations required in the Pythagorean Theorem method, you can apply the basic fact that any triangle with sides in the proportions of 3:4:5 is a right triangle. In locating point E, you know that this point lies 35 feet from C on a line perpendicular to the base line. You also know that a triangle with sides 30 and 40 feet long and a hypotenuse 50 feet long is a right triangle.

1. To get the 40 foot side, measure off 40 feet from C along the base line. In *Figure 5-25*, the segment from C to D happens to measure 40 feet.

2. Run a 50 foot tape from D and a 30 foot tape from C. The joined ends will lie on a line perpendicular from the base line, 30 feet from C.

3. Drive a hub at this point.

4. Extend the line to E, 5 more feet, by stretching a cord from C across the mark on the hub.

5.2.0 Batter Boards

Hubs driven at the exact locations of building corners will be disturbed as soon as the excavation for the foundation begins. To preserve the corner locations, and to provide a reference for measurement down to the prescribed elevations, erect batter boards as shown in *Figure 5-28*.

Figure 5-28 – Batter boards.

Nail each pair of boards to three 2 by 4 corner stakes as shown. Drive the stakes far enough outside the building lines so that they will not be disturbed during excavation. The top edges of the boards are located at a specific elevation, usually some convenient number of whole feet above a significant prescribed elevation, such as the top of the foundation. Nail to the batter boards cords located directly over the lines through corner hubs, placed by holding plumb bobs on the hubs. *Figure 5-28* shows how to locate a corner point in the excavation by dropping a plumb bob from the point of intersection between two cords.

In addition to their function in horizontal control, batter boards are also used for vertical control. Place the top edge of a batter board at a specific elevation. You can locate elevations of features in the structure, such as foundations and floors, by measuring downward or upward from the cords stretched between the batter boards.

Always make sure that you have complete information as to exactly what lines and elevations are indicated by the batter boards. Emphasize to your crewmembers that they must exercise extreme caution while working around batter boards. If the boards are damaged or moved, additional work will be required to replace them and relocate reference points.

5.3.0 Utilities Stakeout

Utilities is a general term applied to pipelines, such as sewer, water, gas, and oil pipelines; communications lines, such as telephone or telegraph lines; and electric power lines.

5.3.1 Aboveground Utilities

For an aboveground utility, such as a pole mounted telephone, telegraph, or power line, the survey problem consists simply of locating the line horizontally as required and marking the stations where poles or towers are to be erected. Often, the directions of guys and anchors may be staked as well, and sometimes pole height for vertical clearance of obstructions is determined.

5.3.2 nderground Utilities

For an underground utility, you will often need to determine both line and grade. For pressure lines, such as water lines, it is usually necessary to stake out only the line, since the only grade requirement is maintaining the prescribed depth of soil cover. However, staking elevations may be necessary for any pressure lines being installed in an area that (1) is to be graded downward or (2) is to have other, conflicting underground utilities.

Gravity flow lines, such as storm sewer lines, require staking for grade to be sure the pipe is installed at the design elevation and at the gradient, or slope, the design requires for gravity flow through the pipe.

Grade for an underground sewer pipe is given in terms of the elevation of the invert. The invert of the pipe is the elevation of the lowest part of the inner surface of the pipe. *Figure 5-29* shows a common method of staking out an underground pipe.

Figure 5-29 – Use of batter boards (with battens) for utility stakeout.

Notice that both alignment and elevation are facilitated by a line of batter boards and battens, or small pieces of wood, set at about 25 to 50 foot intervals. The battens, nailed to the batter boards, determine the horizontal alignment of the pipe when placed vertically on the same side of the batter boards and with the same edges directly over the center line of the pipe. As the work progresses, check the alignment of these battens frequently. A sighting cord, stretched parallel to the center line of the pipe at a uniform distance above the invert grade, is used to transfer line and grade into the trench. The center line of the pipe, therefore, will be directly below the cord, and the sewer invert grade will be at the selected distance below the cord. A measuring stick, also called a grade pole, is normally used to transfer the grade from the sighting cord to the pipe, as shown in *Figure 5-29*. The grade pole, with markings of feet and inches, is placed on the invert of the pipe and held plumb. The pipe is then lowered into the trench until the mark on the grade pole is on a horizontal line with the cord.

Figure 5-30 – Batter boards (without battens) for utility stakeout.

Figure 5-30 shows another method of staking out an underground sewer pipe without the use of battens. Drive nails directly into the tops of the batter boards so that a string stretched tightly between them will define the pipe center line. Keep the string or cord taut by wrapping it around the nails and hanging a weight on each end. Similarly, the string, or cord, gives both line and grade.

5.4.0 Grade Stakes

Grade work is the plotting of irregularities of the ground, making cuts or fills, to a definite limit of grade, or elevation, and alignment. This is performed by reading information placed on construction, or grade, stakes.

5.4.1 Construction Stakes

Construction stakes, sometimes referred to as grade stakes, are the guides and reference markers for earthwork operations to show cuts, fills, drainage, alignment, and boundaries of the construction area. The number of stakes and the information contained on them will vary with the project as to whether they are temporary or permanent. Stakes are usually placed by a three- to five-person survey party using a level, a level rod, a tape, and range poles.

A stake is defined as any wooden lath, stake, or hub. Hub stakes are 2 inches by 2 inches by approximately 12 inches and are used primarily for well-defined surveyors' reference points, with the red and blue tops used in finished grade work. Stakes will vary in shape and size according to their use and the materials available for their manufacture. Several stakes are shown in *Figure 5-31*. Stakes range in size from the ordinary rough plaster lath to 1- by 2- by 3-inch cross-sectional lumber with lengths varying from 18 inches to 48 inches.

Figure 5-31 – Types of stakes.

All reference hubs, markers, and bench marks established by the Engineering Aids (EAs) for project control or alignment are protected by guard stakes. Guard stakes are used as a means of locating the points needed. Some color of bunting or flagging, a narrow strip of cloth or plastic, may be tied around the top of the stake. Station identification is placed on the front of the stake and any other pertinent data on the back.

In some situations, the survey crew will establish grades only on the centerline stakes, while edge-of-road and slope stakes are set by the project supervisor and helpers. Alignment, shoulder, and slope stakes should be 1 inch by 2 inches in cross section, smooth on four sides, and about 2 feet in length. Actual grade desired is indicated by a reference mark, called a crowfoot, and numbers to show the amount of cut or fill.

These stakes should be marked with the following information:

- The stationing or location of any part of the road, runway, or taxiway relative to a starting point or reference
- The amount of cut and fill from the existing ground surface or reference mark on the stake

- The distance from the center line to the stake location and from the center line to the ditch line

In most earthworks, measurements are made and written by the decimal system as used in construction engineering. Most markings on construction stakes will be in feet and tenths of a foot. A stake marked C35 means that a cut must be made 3.5 feet. To convert .5 foot to inches, multiply the decimal fraction by 12. For example: .5 x 12 inches = 6 inches; .25 x 12 inches = 3 inches.

5.4.2 Starting Point

The starting point of a survey is also called the starting station and is numbered 0 + 00. The next station is 100 feet farther away and is numbered 1 + 00. The next station, which is 200 feet beyond the starting point, is then numbered 2 + 00, and so forth. All stations that end with 00 are called full stations**.** *Figure 5-32* shows that stations may be abbreviated STA on the stakes.

On sharp curves or on rough ground, the stakes may be closer together than on the straightaway. Stations located at a distance shorter than 100 feet from the preceding station are known as plus stations, such as 3 + 25, 3 + 53, and 3 + 77. These examples are plus stations of station 3 + 00.

Figure 5-32 – Starting point.

5.4.3 Line Stakes

Line (or alignment) stakes – Line (or alignment) stakes mark the horizontal location of the earthwork to be completed and give the direction of the proposed construction. Running over stakes or otherwise damaging them before they have served their purpose results in many hours of extra work to replace them and delays the completion of the project.

Rough alignment stakes are placed far ahead of the clearing crew to mark boundaries of the area to be cleared and grubbed. These stakes, or markers, are not of a control nature and their loss is expected. On some stakes, the alignment information and the grade requirement are combined on the same stake, as shown in *Figure 5-33*.

Figure 5-33 – Combined alignment and grade stakes.

Centerline Stakes **–** Centerline stakes are set along the center line of a project and are identified by letters, shown in *Figure 5-34*. Most stakes are marked on both the front and back.

On centerline stakes, the station number is written on the front of the stake, such as the 0 + 00, 1 + 00, 4 + 75, and 5 + 25 shown in *Figure 5-35*.

Figure 5-34 – Centerline stake.

Figure 5-35 – Station numbers.

The required grade is always established at the center line of the project. The amount of change in elevation is written on the back of the centerline stake with a cut or fill symbol, which is known as the crowfoot, shown in *Figure 5-36*. The crowfoot is the reference point of the vertical measure or grade.

Figure 5-36 – Cut and fill crowfoot symbol.

Shoulder Stakes – Stakes that are set on a line parallel, in the same direction and interval with the center line are called shoulder stakes and are identified by the symbol SH at the top of the stake, as shown in *Figure 5-37*.

Figure 5-37 – Shoulder stake symbol.

Shoulder stakes mark the outer edge of the shoulders and are set with the broad side facing the center line of the road on the shoulder line. Shoulder stakes carry the same station number as the centerline stake to which they are set, but the station number is placed on the back of the stake, the side facing away from the center line. The amount of cut or fill is marked on the side of the shoulder stake facing the center line, the front, and represents the amount of cut or fill required at that location. The horizontal distance from the shoulder stake to the center line is sometimes placed beneath the cut-or-fill figure.

The basic difference between centerline stakes marked with the symbol and shoulder stakes marked SH is (1) centerline stakes are set along the center line of the project and (2) shoulder stakes are set parallel with the center line, defining the shoulder of the road or runway, and face the center line as shown in *Figure 5-38*.

Cut-and-Fill Stakes – Lowering the elevation of a grade is known as making a cut. Cut stakes are designated by the letter C written on the stake. The numerals following the letter C indicate the amount of ground to be cut to obtain the desired grade and are measured from the crowfoot down.

Figure 5-38 – Center line and shoulder stakes.

Raising the elevation of the ground is known as making a fill. A fill stake is designated by the letter F written on the stake. The numerals that follow the letter F indicate the amount of ground material needed to bring the existing ground to the desired grade and are measured from the crowfoot mark on the stake up.

In going from a cut to a fill or vice versa, there may be one or more stakes representing points on the desired grade, as shown in *Figure 5-39*. These stakes are marked with GRADE**,** or GRD and a crowfoot mark even with the desired grade.

Figure 5-39 – Cut, fill, and on-grade stakes.

Basically, the difference in cut, fill, or on-grade stakes is as follows:

- Cut stakes indicate lowering the ground or elevation.
- Fill stakes indicate raising the ground or elevation.
- On-grade stakes indicate the ground is at the desired grade and does not need a cut or fill.

Offset Stakes – After a survey of a project has been completed and the stakes are set and marked, the required amount of work needed to complete the job is determined by using the information on these stakes. Since this information has to be used often during construction and the original stakes can be destroyed or covered up by carelessness or inexperienced operators, it is necessary to document this information.

To prevent the loss of reference information, transfer the required information from the stake located in the immediate area of construction to a new stake. Set this stake far enough away so that it will not be damaged or destroyed by equipment being operated in the construction area. This new stake is called an offset stake and is identified by the symbol OF or an O as shown in *Figure 5-40*.

Figure 5-40 – Reference information found on an offset stake.

You should note the number of linear feet that separates the offset stake from the original reference stake. This is written on the offset stake below the OF or within the circle, followed by the amount of cut or fill, in feet, which may be required. A stake marked OF 35'CL C-1° means that the stake is offset 35 feet from the centerline stake and that a cut of 1 foot is required to attain the desired final grade.

The difference in elevation must be noted on the offset stake. The symbol, representing the stake from which the information was originally transferred, is also noted on the offset stake. If the offset stake is offset from a shoulder stake, the symbol is SH instead of CL.

The amount of cut or fill, if any, must be noted on the offset stake. However, because of existing terrain, this information on the offset stake may not be the same as that on the original stake. In *Figure 5-41*, you can see that the offset stake reads for a cut to be made to reach a desired elevation at the center line, while a centerline stake would be marked for a fill to reach the same elevation.

Figure 5-41 – Difference in elevation between the offset stake crowfoot and desired grade at center stake.

Slope Stakes – The identification markings on slope stakes may vary according to survey parties, the symbol SS is the most commonly used slope stake symbol. The information normally found on a slope stake, shown in *Figure 5-42*, is any cut or fill requirements, the distance from the center line, and the slope ratio. When it becomes necessary to offset the slope stake, the offset distance from where the slope stake should be is written at the bottom of the offset stake. Slope stakes indicate the intersection of the cut-or-fill slope with the existing natural groundline and limit of earthwork on each side of the center line shown in *Figure 5-43*.

Figure 5-42 – Slope stake.

Figure 5-43 – Slope stakes set in existing natural groundline.

Right-of-Way Stakes – Stakes set on the property line of a construction site are known as right-of-way stakes**.** These stakes mark the boundaries of the site or project. You must not operate equipment outside the property line defined by the right-of-way stakes. The right-of-way stakes are usually marked by with colored cloth, called bunting, or flagging. Occasionally right-of-way stakes may be marked with the symbol R/W shown in *Figure 5-44*.

Figure 5-44 – Right-of-way stake.

Finish Grade Stakes – When performing final grading, you are likely to work with stakes called blue tops**.** These are hub stakes which are usually 2 inches by 2 inches by 6 inches. These hubs are driven into the ground until the top is at the exact elevation of the finished grade as determined by the surveying crew. They are colored with a blue lumber crayon, or keel, to identify them as finish grade stakes. Red crayon is normally used to indicate the subgrade elevation. Blue top stakes are placed when the existing grade is within 0.2 feet, or 2.4 inches, above the final or desired grade. The desired grade is obtained by lowering or raising the compacted grade with a grader until it is flush or even with the top of the hub, as shown in *Figure 5-45*.

Figure 5-45 – Finish grade stake.

6.0.0 CLASSIFYING SOILS

The Unified Soil Classification System (USCS) is a common soil classification reference or system that has a universal interpretation. In this system, all soils are divided into three major divisions, including coarse-grained soils, fine-grained soils, and highly organic soils.

Coarse-grained soils are those in which at least half of the material, by weight, is larger than, or retained on, a No. 200 sieve. This division is further divided into gravels and sands. If more than half of the coarse fraction, by weight, is retained on a No. 4 sieve, it is classified as a gravel. If less than half is retained on a No. 4 sieve, then it is a sand. Gravels and sands are further subdivided into additional categories dependent upon the amount and characteristics of any plastic fines the soil sample contains.

Fine-grained soils are those in which more than half of the material, by weight, is smaller than, or passes, a No. 200 sieve. The fine-grained soils are not classified on the basis of grain size distribution but according to plasticity and compressibility.

Highly organic soils are those organic soils, such as peat, that have too many undesirable characteristics from the standpoint of their behavior as foundations and their use as construction materials. A special classification is reserved for these soils, and no laboratory criteria are established for them. Highly organic soils can generally be readily identified in the field by their distinctive color and odor, spongy feel, and frequently fibrous textures. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils.

7.0.0 SOILS TESTING

Soil compaction and density testing are two of the most common and important soils tests that an Engineering Aid (EA) must learn to perform. Those tests, as well as the California bearing ratio test and hydrometer analysis, are discussed in this section.

7.1.0 Compaction Test

Compaction is the process of increasing the density, or the amount of solids per unit volume, of soil by mechanical means to improve such soil properties as strength, permeability, and compressibility. Compaction is a standard procedure used in the construction of earth structures, such as embankments, subgrades, and bases for road and airfield pavement.

In the field, compaction is accomplished by rolling or tamping the soil with special construction equipment. In the laboratory, compaction can be accomplished by the impact of hammer blows, vibration, static loading, or any other method that does not alter the water content of the soil. Usually, however, laboratory compaction is accomplished by placing the soil into a cylinder of known volume and dropping a tamper of known weight onto the soil from a known height for a given number of blows. The amount of work done to the soil per unit volume of soil is called compactive effort.

For most soils and for a given compactive effort, the density of the soil will increase to a certain point as the moisture content is increased. That point is called the maximum density. After that point, the density will start to decrease with any further increase in moisture content. The moisture content at which maximum density occurs is called the optimum moisture content (OMC). Each compactive effort for a given soil has its own OMC. As the compactive effort increases, the maximum density generally increases and the OMC decreases.

7.2.0 Density Tests

From the preceding discussion, you know that compaction testing is performed to determine the OMC and the maximum density that can be obtained for a given soil at a given compactive effort. You also know that, using the maximum density, you can determine a range of densities and moisture contents that will satisfy the compaction requirements for a project. During the construction of that project, a control must be in place to measure whether or not the compaction requirements have been met. That control is density testing. If the results of the density test determine that the compaction process has produced a density within the range specified, then the compaction is complete. If the test results reflect densities that are not within the specified range, additional rolling may be necessary or the moisture content may have to be adjusted.

Several different methods are used to determine the in-place density of a soil; however, the methods that EAs are most apt to use are the sand-displacement method and the nuclear moisture-density meter method.

7.2.1 Sand-Displacement Method

A full discussion of the procedures used in the sand-displacement method can be found in *Test Method for Pavement Subgrade, Subbase, and Base-Course Material,* MIL-STD-621A, and in NAVFAC MO-330. This method, often called the sand-cone method, may be used for both fine-grained and coarse-grained materials. In general, the test consists of digging out a sample of the material to be tested, using calibrated sand to determine the volume of the hole from which the sample was removed and the dry unit weight of the sample.

7.3.0 Bearing Tests

The bearing capacity of a soil is expressed in terms of shear resistance, which means the capacity of the load-bearing portion of a material or member to resist displacement in the direction of the force exerted by the load.

There are various types of load-bearing tests. For description purposes we will briefly discuss the California bearing ratio (CBR) test. The California bearing ratio is a measure of the shearing resistance of a soil under carefully controlled conditions of density and moisture. The CBR is determined by a penetration shear test and is used with empirical curves for designing flexible pavements.

The test procedure used to determine the CBR consists of two principal steps. First, the soil test specimens are prepared; second, a penetration test is performed upon the prepared soil samples. Although one standardized procedure has been established for the penetration portion of the test, it is not possible to establish one procedure for the preparation of test specimens since soil conditions and construction methods vary widely. The soil test specimens are prepared to duplicate the soil conditions existing, or expected to occur later, in the field. Although penetration tests are most frequently performed on laboratory-compacted test specimens, they may also be performed upon undisturbed soil samples or in the field upon the soil in place. Detailed procedures for preparing the test samples and performing the test can be found in NAVFAC MO-330.

7.4.0 Hydrometer Analysis

A soil is considered susceptible to frost when it contains 3 percent or more by weight of particles smaller than 0.020 mm in diameter. To determine whether or not a soil contains an excessive amount of that size particle, you must perform a particle-size analysis of the materials passing the No. 200 (0.074-mm) sieve. Do this by hydrometer analysis. For a full discussion of the procedures, refer to NAVFAC MO-330 or to ASTM D 422.

8.1.1 SOIL STABILIZATION

There are three purposes for soil stabilization. The first one is strength improvement. This increases the strength of the existing soil to enhance its load-bearing capacity. The second purpose is for dust control. This is done to eliminate or alleviate dust generated by the operation of equipment and aircraft during dry weather or in arid climates. The third purpose is soil waterproofing, which is done to preserve the natural or constructed strength of a soil by preventing the entry of surface water.

There are two methods of applying soil stabilization materials. The first is the admix way. Use this method where it is necessary to combine two different soils together for stabilization. Do this as follows:

- In-place mixing: blend soil and stabilization materials on the jobsite.
- Off-site mixing: use stationary mixing plants.
- Windrow mixing: mix the materials using a grader.

The second way is the surface penetration application, which is accomplished by placing a soil treatment material directly to the existing ground surface by spraying or other means of distribution. Some of the additives used in soil stabilization are cement, lime, bituminous products, and calcium chloride. Cement-treated bases are the most commonly used for the purpose of upgrading a poor quality soil. Soil-cement is a mixture of pulverized soil and measured amounts of Portland cement and water, compacted to a high density.

There are three types of soil-cement. The first is compacted soil-cement that contains sufficient amounts of cement to harden the soil and enough moisture for both compaction and hydration of the cement. The second is cement modified soil which is an unhardened or semi-hardened mixture of soil and cement. Only enough cement is used to change the physical properties of the soil. The third is plastic soil-cement. It is a hardened mixture of soil and cement that contains enough water at the time of placing to produce a consistency similar to that of plastering mortar. The three basic materials needed when working with soil-cement are soil, Portland cement, and water. The soil can be almost any combination of gravel, sand, silt, or clay.

The three major control factors when working with soil-cement are as follows:

1. The proper cement content is needed. A rule of thumb: use one 50-pound bag per square yard.
2. Proper moisture content. A soil sample, should make a firm cast when squeezed in your hand without squeezing out any water.
3. Adequate compaction. The principles of compacting soil-cement are the same for compacting the same soils without cement treatment. Compact the soil-cement mixture at optimum moisture content to maximum density and finish it immediately. Moisture loss by evaporation during compaction, as indicated by the graying of the surface, should be replaced with light applications of water.

Occasionally during compaction, the treated area may yield under the compaction equipment. This may result from one or more of the following causes: (1) the soil-cement mix is much wetter than optimum moisture content, (2) the soil may be too wet and unstable, and (3) the roller may be too heavy for the soil. If the soil-cement mix is too damp, aerate it using the scarifier on the grader. After it has dried to near optimum moisture content, then compact it.

Summary

You learned concepts important to surveying a site for a construction project. Construction surveys are made to help with planning, estimating, locating, and layout for construction projects. Surveys rely on Bench Marks (BM) to establish a known elevation on a construction site. Earthwork operations are some of the earliest operations that occur on a construction site. These operations include pioneering, clearing, grubbing, and stripping. Drainage of the site is important to maintain.

You will work closely with local agencies while planning and executing construction projects. Permits needed for each construction project might include Utility Interruption Requests, Excavation Requests, and Road Closure Requests.

You have been introduced to the common types of leveling instruments, including levels, the tripods that support them, and leveling rods. You should be familiar with their principles and uses, as well as procedures of establishing elevations, and techniques of laying out building lines. As a Builder, you will find the information especially useful in performing such duties as setting up a level, reading a leveling rod, interpreting and setting grade stakes, and setting batter boards.

The types of soil on a site can affect how the construction project will proceed. It is important to perform appropriate soils testing to determine if any soil stabilization strategies will be needed.

Review Questions (Select the Correct Response)

1. Construction surveys include which of the following?

   A. Reconnaisssance
   B. Location
   C. Layout
   D. All of the above

2. **(True or False)** A Bench Mark is a relatively permanent object bearing a marked point whose elevation is known.

   A. True
   B. False

3. The average height of the sea for all stages of the tide after long periods of observations is known as

   A. Mean tide level
   B. Mean sea level
   C. Mean high water
   D. Tidal datum

4. Clearing, stripping, grading, and drainage are done essentially at the same time as part of which earthwork operation?

   A. Grading
   B. Grubbing
   C. Pioneering
   D. Spoiling

5. During which earthwork operation are roots and stumps uprooted and removed?

   A. Grading
   B. Grubbing
   C. Pioneering
   D. Spoiling

6. During which earthwork operation are objectionable topsoil and sod removed and disposed of?

   A. Grading
   B. Grubbing
   C. Pioneering
   D. Stripping

7. What is the construction of facilities to allow excess surface and subsurface water to flow from the construction site?

   A. Drainage
   B. Grading
   C. Grubbing
   D. Spoiling

8. **(True or False)** Permits are only pulled before a construction project begins.

   A. True
   B. False

9. To correct an engineer's level that is not quite horizontal, what action should you take first?

   A. Rotate the azimuth tangent screw
   B. Manipulate the focusing knob
   C. Release the azimuth clamp
   D. Slacken the reticle adjusting screws

10. You can bring the vertical cross hair of the dumpy level into exact alignment by rotating which of the following components?

    A. Leveling screws
    B. Leveling head
    C. Azimuth head
    D. Azimuth tangent screw

11. What type of level was designed to eliminate the use of the tubular spirit level?

    A. Wye
    B. Dumpy
    C. Self-leveling
    D. Hand

12. A self-leveling level automatically gives a level line of sight when the level bubble is approximately within the center of the

    A. tripod
    B. level
    C. bull's eye
    D. cross hair

13. What type of level is used for short distance sighting and has no magnification device?

    A. Hand
    B. Wye
    C. Automatic
    D. Dumpy

14. When removing a level from its case, you should grip what part?

A. The telescope
B. The level bar
C. The footplate
D. The leveling plate

15. **(True or False)** An engineering level should be stowed in its carrying case when not in use.

A. True
B. False

16. In the target reading method of surveying, who reads the rod?

A. The chairman
B. The instrumentman
C. The flagman
D. The rodman

17. On a Philadelphia rod, the large numerals indicating foot markings are in what color?

A. Red
B. White
C. Black
D. Yellow

18. When the instrumentman is unable to read the foot markings on a Philadelphia rod, he gives the command RAISE THE RED. What should the rodman do?

A. Read the rod
B. Lower the rod
C. Raise the rod
D. Wave the rod

19. On a Philadelphia rod, the vernier scale helps you make readings as small as what fraction of a foot?

A. 1/10
B. 1/12
C. 1/100
D. 1/1,000

20. **(True or False)** When the rodman finds it difficult to hold the rod perfectly plumb, it should be waved back and forth to allow the levelman to read the lowest reading touched by the crosshair.

A. True
B. False

21. Differential leveling has what purpose?

A. Finding the line of sight between two points
B. Finding the horizontal difference between two points
C. Finding the vertical difference between two points
D. Finding the radius of horizontal curves

22. What is the term in structural horizontal control for any permanently located object of known horizontal location?

A. Monument
B. Gradient
C. Horizon
D. Benchmark

23. Building corners should be laid out with reference to which of the following features?

A. A control base line
B. Contour lines
C. Batter boards
D. Horizontal control points

24. Batter boards have what function?

A. Protect stakes from being knocked over
B. Prevent cave-ins at excavation corners
C. Provide a means for reestablishing building lines when the stakes have been disturbed
D. Mark the outside dimensions of excavations

25. **(True or False)** Batter boards are used for both horizontal and vertical control in maintaining specific elevations.

A. True
B. False

26. What kinds of stakes are set along the center line of a project?

A. Construction
B. Grade
C. Centerline
D. Shoulder

27. Which of the following is a soil classification under the Unified Soil Classification System?

A. Coarse-grained soils
B. Fine-grained soils
C. Highly organic soils
D. All of the above

28. What is the process of increasing the density of soil by mechanical means?

A. California bearing ratio test
B. Compaction
C. Density test
D. Hydrometer analysis

29. **(True or False)** Optimum moisture content is the moisture content at which maximum density occurs.

A. True
B. False

30. Which is a purpose of soil stabilization?

A. Strength improvement
B. Dust control
C. Soil waterproofing
D. All of the above

Trade Terms Introduced in this Chapter

Dumpy level	A surveying instrument consisting of a telescope rigidly attached to a vertical spindle. Used to determine relative elevation.
Elevations	Vertical distance relative to a reference point.
Grade	(1) The surface or level of the ground. (2) The existing or proposed ground level or elevation on a building site or around a building.
Hand level	In surveying, a hand-held sighting level having limited capability.
Leveling	The procedure used in surveying to determine differences in elevation.
Leveling rod	A graduated straight rod used in construction with a leveling instrument to determine differences in elevation. The rod is marked in feet and fractions of feet, and may be fitted with a movable target or sighting disc.
Locke level	A hand level.
Philadelphia rod	A leveling rod in two sliding parts with color-coded graduations. The rod can be used as a self-reading leveling rod.
Reference line	A series of two or more points in line to serve as a reference for measurements.

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 Aid 3 & 2, Vol. 3, NAVEDTRAA 10629-1, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1987.

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Chapter 6

Concrete Construction

Topics

To hear audio, click on the box.

Overview

More concrete is used than any other man-made material in the world. As of 2006, about seven billion cubic meters of concrete are made each year – more than one cubic meter for every person on Earth.

Concrete is one of the most important construction materials. It is comparatively economical, easy to make, offers continuity and solidity, and will bond with other materials. The keys to good quality concrete are the raw materials required to make it and the mix design specified in the project specifications. The final strength and appearance of concrete depends on the quality control and placement of the concrete. Proper placement methods must be used to prevent ***segregation*** of the concrete.

This chapter covers the characteristics of concrete, its ingredients, its mix designs, and how to mix it, as well as the forming, placement, ***finishing***, and ***curing*** of concrete. It also covers the placement of reinforcing steel and the types of ***ties*** required to ensure that the reinforcing doesn't move once positioned. Concrete ***construction joints*** and the concrete saw are also covered.

We'll conclude the chapter with a discussion of precast and ***tilt-up concrete***. At the end of the discussion, we provide helpful references. You are encouraged to study these references, as required, for additional information on the topics discussed.

Objectives

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

1. Define characteristics of concrete.
2. Identify ingredients essential for good concrete.
3. Calculate concrete mix designs.
4. Determine methods and mixing times of concrete.
5. Describe the types of concrete forms and their construction.
6. Determine the types of ties for and placement of reinforcing steel.
7. Determine the location of construction joints.
8. Determine proper occasions for using the concrete saw.
9. Describe the proper procedures for placing concrete.
10. Describe the methods available for consolidating concrete.
11. Describe the finishing process for the final concrete surface.
12. Determine projects suitable for and lifting methods necessary for precast and tilt-up construction.

Prerequisites

None

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

Expeditionary Structures	↑	B U I L D E R
Finishes		
Moisture Protection		
Carpentry		
Masonry		
Fiber Line, Wire Rope, and Scaffolding		
Concrete Construction		
Site Work		B A S I C
Construction Management		
Drawings and Specifications		
Tools		
Basic Math		

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 CONCRETE CHARACTERISTICS

Concrete is a synthetic construction material made by mixing ***cement***, fine ***aggregate*** (usually sand), coarse aggregate (usually gravel or crushed stone), and water in the proper proportions. The product is not concrete unless all four of these ingredients are present.

1.1.0 Constituents of Concrete

The fine and coarse aggregates in a concrete mix are the inert, or inactive, ingredients. Cement and water are the active ingredients. The inert ingredients and the cement are first thoroughly mixed together. As soon as the water is added, a chemical reaction begins between the water and the cement. The reaction, called hydration, causes the concrete to harden. This is an important point.

The hardening process occurs through hydration of the cement by the water, not by water drying out of the mix. Instead of being dried out, concrete must be kept as moist as possible during the initial hydration process. Drying out causes a drop in water content below that required for satisfactory hydration of the cement. The fact that the hardening process does not result from drying out is clearly shown by the fact that concrete hardens just as well underwater as it does in air. The proportions of the constituents in concrete are illustrated in *Figure 6-1*.

Figure 6-1 – Proportions of constituents of concrete.

1.2.0 Concrete as Building Material

Concrete may be cast into bricks, blocks, and other relatively small building units which are used in concrete construction. Concrete has a great variety of applications because it meets structural demands and lends itself to architectural treatment. All important building elements, foundations, columns, walls, slabs, and roofs, are made from concrete. Other concrete applications are in roads, runways, bridges, and dams.

1.3.0 Strength of Concrete

The ***compressive strength*** of concrete, its ability to resist compression, is very high, but its tensile strength, its ability to resist stretching, bending, or twisting, is relatively low. Concrete which must resist a good deal of stretching, bending, or twisting; such as concrete in beams, girders, walls, columns, and the like must be reinforced with steel. Concrete that must resist only compression may not require reinforcement. As you will learn later, one of the most important factors controlling the strength of concrete is the water cement ratio, or the proportion of water to cement in the mix. Another important factor is quality control during the placement of the concrete.

1.4.0 Durability of Concrete

The durability of concrete refers to the extent to which the material is capable of resisting deterioration from exposure to service conditions. Concrete is also strong and fireproof. Ordinary structural concrete to be exposed to the elements must be watertight and weather resistant. Concrete subject to wear, such as floor slabs and pavements, must be capable of resisting abrasion.

The major factor controlling the durability of concrete is its strength. The stronger the concrete, the more durable it is. As we just mentioned, the chief factor controlling the strength of concrete is the water cement ratio. The character, size, and grading i.e., distribution of particle sizes between the largest permissible coarse and the smallest permissible fine, of the aggregate also have important effects on both strength and durability. Maximum strength and durability will still not be attained unless the sand and coarse aggregate you use consist of well graded, clean, hard, and durable particles free of undesirable substances. The relationship of these properties is shown in *Figure 6-2*.

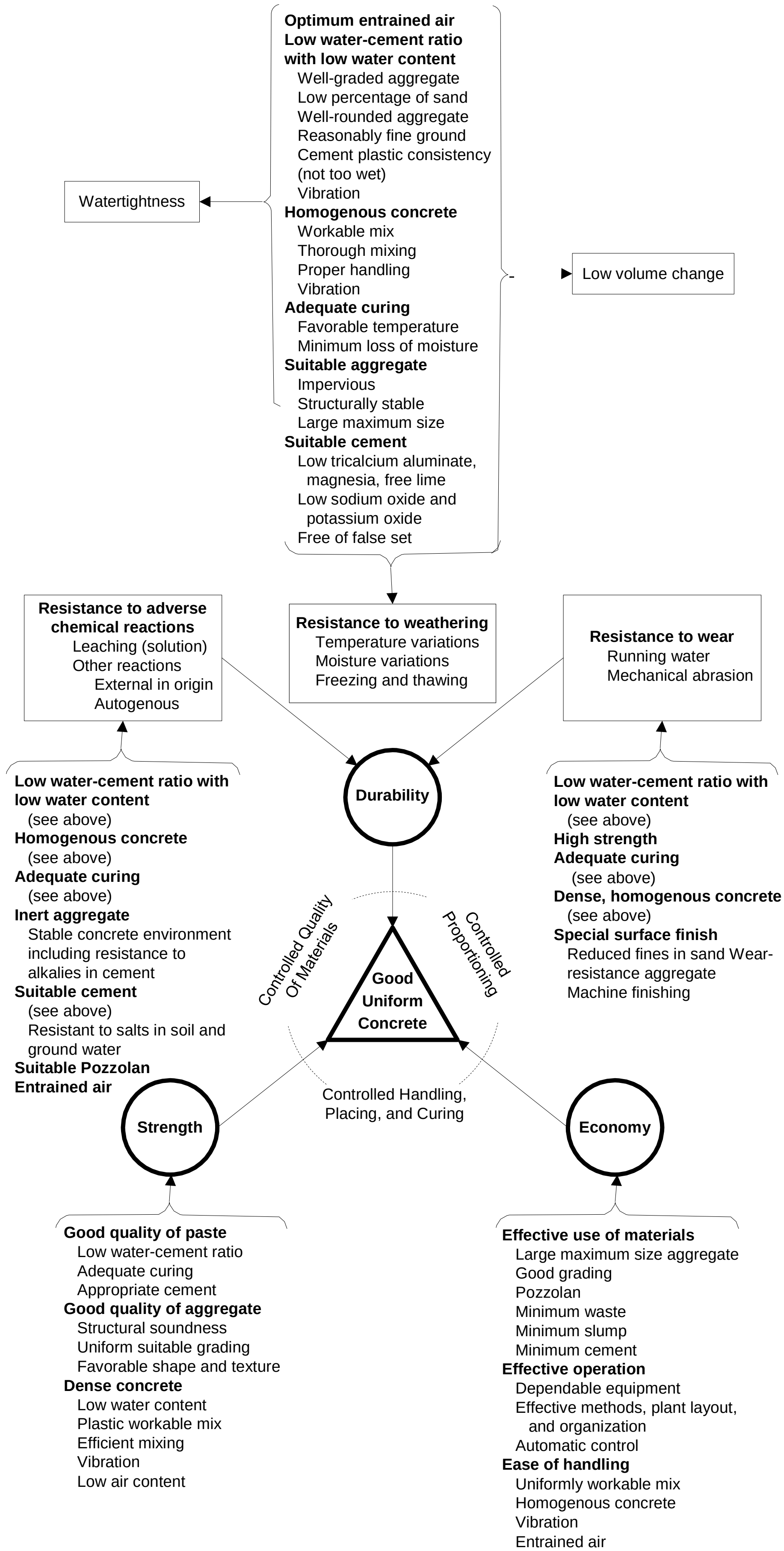

Figure 6-2 – The principal properties of good concrete.

1.5.0 Watertightness of Concrete

The ideal concrete mix is one with just enough water required for complete hydration of the cement, but this results in a mix too stiff to pour in ***forms***. A mix fluid enough to be poured in forms always contains a certain amount of water over and above that which will combine with the cement. This water eventually evaporates, leaving voids, or pores, in the concrete. Penetration of the concrete by water is still impossible if these voids are not interconnected. They may be interconnected as a result of slight sinking of solid particles in the mix during the hardening period. As these particles sink, they leave water filled channels that become voids when the water evaporates. The larger and more numerous these voids are, the more the watertightness of the concrete is impaired. The size and number of the voids varies directly with the amount of water used in excess of the amount required to hydrate the cement.

To keep the concrete as watertight as possible, you must not use more water than the minimum amount required to attain the necessary degree of ***workability***. You may want to make the concrete mix as wet as possible to reduce the labor of placing the concrete. This is not a good idea because adding water can result in more ***shrinkage*** and lower strength concrete, which may not meet the specifications for the project. You might also end up delaying when finishing work can begin.

The quality of ***troweling*** can impact the watertightness of concrete. Troweling is one of the final stages of finishing concrete, completed after the surface of the concrete has been floated and the bleed water has evaporated. Troweling makes the surface of concrete hard and dense, which contributes to its watertightness.

1.6.0 General Requirements for Good Concrete

The first requirement for good concrete is to use a cement type suitable for the work at hand and have a satisfactory supply of sand, coarse aggregate, and water. Everything else being equal, the mix with the best graded, strongest, best shaped, and cleanest aggregate makes the strongest and most durable concrete.

Second, the amount of cement, sand, coarse aggregate, and water required for each ***batch*** must be carefully weighed or measured according to project specifications.

Third, even the best designed, best graded, and highest quality mix does not make good concrete if it is not workable enough to fill the form spaces thoroughly. On the other hand, too much fluidity also results in defects. Also, improper handling during the overall concrete making process, from the initial aggregate handling to the final placement of the mix, causes segregation of aggregate particles by sizes, resulting in nonuniform, poor quality concrete.

Finally, the best designed, best graded, highest quality, and best placed mix does not produce good concrete if it is not properly cured, that is, properly protected against loss of moisture during the earlier stages of setting.

Test your Knowledge (Select the Correct Response)

1. What causes concrete to harden?

   A. The active ingredients dry out.
   B. The inert ingredients dry out.
   C. The active ingredients combine chemically.
   D. The inert ingredients combine chemically.

2.0.0 CONCRETE INGREDIENTS

The essential ingredients of concrete are cement, aggregate, and water. A mixture of only cement and water is called cement paste. In large quantities, cement paste is prohibitively expensive and too weak for most construction purposes.

2.1.0 Portland Cement

Most cement used today is Portland cement. This is a carefully proportioned and specially processed combination of lime, silica, iron oxide, and alumina. It is usually manufactured from limestone mixed with shale, clay, or marl. Properly proportioned raw materials are pulverized and fed into kilns where they are heated to a temperature of 2,700°F and maintained at that temperature for a specific time. The heat produces chemical changes in the mixture and transforms it into clinker, a hard mass of fused clay and limestone. The clinker is then ground to a fineness that will pass through a sieve containing 40,000 openings per square inch.

2.1.1 Types of Cement

There are five types of Portland cement covered under Standard Specifications for Portland Cement. The American Society for Testing and Material (ASTM) types govern these specifications. Separate specifications, such as those required for air-entraining Portland cements, are found under a separate ASTM. The type of construction, chemical composition of the soil, economy, and requirements for use of the finished concrete are factors that influence the selection of the kind of cement to use.

Type I – Type I cement is general purpose cement for concrete that does not require any of the special properties of the other types. In general, type I cement is intended for concrete that is not subjected to sulfate attack or damage by the heat of hydration. Type I Portland cement is used in pavement and sidewalk construction, reinforced concrete buildings and bridges, railways, tanks, reservoirs, sewers, culverts, water pipes, masonry units, and soil-cement mixtures. Generally, it is more available than the other types. Type I cement reaches its design strength in about 28 days.

Type II – Type II cement is modified to resist moderate sulfate attack. It also usually generates less heat of hydration and at a slower rate than type I. A typical application is for drainage structures where the sulfate concentrations in either the soil or groundwater are higher than normal but not severe. Type II cement is also used in large structures where its moderate heat of hydration produces only a slight temperature rise in the concrete. The temperature rise in type II cement can be a problem when concrete is placed during warm weather. Type II cement reaches its design strength in about 45 days.

Type III – Type III cement is high early strength cement that produces design strengths at an early age, usually 7 days or less. It has a higher heat of hydration and is more finely ground than type I. Type III permits fast form removal and, in cold weather construction, reduces the period of protection against low temperatures. Richer mixtures of type I can obtain high early strength, but type III produces it more satisfactorily and economically. Use it cautiously in concrete structures having a minimum dimension of 2 1/2 feet or more. While there is no set minimum dimension, take caution with massive placements of concrete, as they will produce more heat. The high heat of hydration can cause shrinkage and cracking.

Type IV – Type IV cement is a special cement. It has a low heat of hydration and is intended for applications requiring a minimal rate and amount of heat of hydration. Its strength also develops at a slower rate than the other types. Type IV is used primarily in very large concrete structures, such as gravity dams, where the temperature rise from the heat of hydration might damage the structure. Type IV cement reaches its design strength in about 90 days.

Type V – Type V cement is sulfate resistant and should be used where concrete is subjected to severe sulfate action, such as when the soil or groundwater contacting the concrete has a high sulfate content. Type V cement reaches its design strength in about 60 days.

2.1.2 Air-Entrained Cement

Air-entrained Portland cement is special cement that can be used with good results for a variety of conditions. It has been developed to produce concrete resistant to freeze thaw action and to scaling caused by chemicals applied for severe frost and ice removal. In this cement, very small quantities of air-entraining materials are added as the clinker is ground during manufacturing. Concrete made with this cement contains tiny, well distributed and completely separated air bubbles. The bubbles are so small that there may be millions of them in a cubic foot of concrete. The air bubbles provide space for freezing water to expand without damaging the concrete. ***Air-entrained concrete*** has been used in pavements in the northern United States for about 25 years with excellent results. Air-entrained concrete also reduces both the amount of water loss and the capillary/water channel structure.

An air-entrained ***admixture*** may also be added to types I, II, and III Portland cement. The manufacturer specifies the percentage of air entrainment that can be expected in the concrete. An advantage of using air-entrained cement is that it can be used and batched like normal cement. The air-entrained admixture comes in a liquid form or mixed in the cement. To obtain the proper mix, add the admixture at the batch plant. More information on admixtures is included later in this chapter.

2.2.0 Aggregates

The material combined with cement and water to make concrete is called aggregate. Aggregate makes up 60 to 80 percent of concrete volume. It increases the strength of concrete, reduces the shrinking tendencies of the cement, and is used as economical filler.

2.2.1 Types

Aggregates are divided into fine, usually consisting of sand, and coarse categories. For most building concrete, coarse aggregate consists of gravel or crushed stone up to 1 1/2 inches in size. In massive structures such as dams, the coarse aggregate may include natural stones or rocks ranging up to 6 inches or more in size.

2.2.2 Purpose of Aggregates

The large, solid coarse aggregate particles form the basic structural members of the concrete. The voids between the larger coarse aggregate particles are filled by smaller particles. The voids between the smaller particles are filled by still smaller particles. Finally, the voids between the smallest coarse aggregate particles are filled by the largest fine aggregate particles. In turn, the voids between the largest fine aggregate particles are filled by smaller fine aggregate particles, the voids between the smaller fine aggregate particles by still smaller particles, and so on. Finally, the voids between the finest grains are filled with cement. You can see from this that the better the aggregate is graded; that is, the better the distribution of particle sizes, the more solidly all voids will be filled, and the denser and stronger the concrete will be.

The cement and water form a paste that binds the aggregate particles solidly together when it hardens. In a well graded, well designed, and well mixed batch, each aggregate particle is thoroughly coated with the cement-water paste. Each particle is solidly bound to adjacent particles when the cement-water paste hardens.

Aggregate Sieves – The size of an aggregate sieve is designated by the number of meshes to the linear inch in that sieve. The higher the number, the finer the sieve. Any material retained on the No. 4 sieve can be considered either coarse or fine. Aggregates larger than No. 4 are all coarse; those smaller are all fines. No. 4 aggregates are the dividing point. The finest coarse aggregate sieve is the same No. 4 used as the coarsest fine aggregate sieve. With this exception, a coarse aggregate sieve is designated by the size of one of its openings. The sieves commonly used are 1 1/2 inches, 3/4 inch, 1/2 inch, 3/8 inch, and No. 4. Any material that passes through the No. 200 sieve is too fine to be used in making concrete.

Particle Distribution – Experience and experiments show that for ordinary building concrete, certain particle distributions consistently seem to produce the best results. For fine aggregate, the recommended distribution of particle sizes from No. 4 to No. 100 is shown in *Table 6-1*.

Table 6-1 – Recommended Distribution of Particle Sizes

Sieve Size	Percent passing, by weight		
	Normal Weight Aggregate	Lightweight Aggregate	Heavy-duty Toppings
3/8"	100	100	95
No. 4	95-100	85-100	95-100
No. 8	80-90	-	65-80
No.16	50-75	40-80	45-65
No. 30	30-50	30-65	35-45
No. 50	10-20	10-35	5-15
No. 100	2-5	5-20	0-5

Determine the distribution of particle sizes in aggregate by extracting a representative sample of the material, screening the sample through a series of sieves ranging in size from coarse to fine, and determining the percentage of the sample retained on each sieve. This procedure is called making a sieve analysis. For example, suppose the total sample weighs 1 pound. Place this on the No. 4 sieve, and shake the sieve until nothing more goes through. If what is left on the sieve weighs 0.05 pound, then 5 percent of the total sample is retained on the No. 4 sieve. Place what passes through on the No. 8 sieve and shake it. Suppose you find that what stays on this sieve weighs 0.1 pound. Since 0.1 pound is 10 percent of 1 pound, 10 percent of the total sample was retained on the No. 8 sieve. The cumulative retained weight is 0.15 pound. By dividing 0.15 by 1.0 pound, you will find that the total retained weight is 15 percent.

The size of coarse aggregate is usually specified as a range between a minimum and a maximum size; for example, 2 inches to No. 4, 1 inch to No. 4, 2 inches to 1 inch, and so on. The recommended ***particle size distributions*** vary with maximum and minimum nominal size limits, as shown in *Table 6-2*.

Table 6-2 – Recommended Maximum and Minimum Particle Sizes.

Size of Coarse Aggregate, In Inches	Percentages by Weight Passing Laboratory Sieves Having Square Openings										
	4 in.	3 1/2 in.	3 in.	2 1/2 in.	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4
1.5	–	–	–	–	100	95-100	–	35-70	–	10-30	0-5
2	–	–	–	100	95-100	–	35-70	–	10-30	–	0-5
2.5	–	–	100	90-100	–	35-70	–	10-40	–	0-15	0-5
3.5	100	90-100	–	45-80	–	25-50	–	10-30	–	0-15	0-5

A blank space in *Table 6-2* indicates a sieve that is not required in the analysis. For example, for the 2 inch to No. 4 nominal size, there are no values listed under the 4 inch, the 3 1/2 inch, the 3 inch, and the 2 1/2 inch sieves. Since 100 percent of this material should pass through a 2 1/2 inch sieve, there is no need to use a sieve coarser than that size. For the same size designation, 2 inch size aggregate, there are no values listed under the 1 1/2 inch, the 3/4 inch, and the 3/8 inch sieves. Experience has shown that it is not necessary to use these sieves in making this particular analysis.

2.2.3 Quality Standards

Since 66 to 78 percent of the volume of the finished concrete consists of aggregate, the aggregate must meet certain minimum quality standards. It should consist of clean, hard, strong, durable particles free of chemicals that might interfere with hydration. The aggregate should also be free of any superfine material, which might prevent a ***bond*** between the aggregate and the cement-water paste. The undesirable substances most frequently found in aggregate are dirt, silt, clay, coal, mica, salts, and organic matter.

Most of these can be removed by washing. Aggregate can be field tested for an excess of silt, clay, and the like using the following procedure:

1. Fill a quart jar with the aggregate to a depth of 2 inches.
2. Add water until the jar is about three-fourths full.
3. Shake the jar for 1 minute, then allow it to stand for 1 hour.
4. If, at the end of 1 hour, more than 1/8 inch of sediment has settled on top of the aggregate, shown in *Figure 6-3*, the material should be washed.

Figure 6-3 – Quart jar method of determining silt content of sand.

*Figure 6-*4 shows an easily constructed rig for washing a small amount of aggregate.

Figure 6-4 – Field-constructed rig for washing aggregate.

Weak, friable (easily pulverized), or laminated (layered) aggregate particles are undesirable. Especially avoid shale, stones laminated with shale, and most varieties of chert (impure flint-like rock). For most ordinary concrete work, visual inspection is enough to reveal any weaknesses in the coarse aggregate. For work in which aggregate strength and durability are of vital importance, such as paving concrete, aggregate must be laboratory tested.

Table 6-3 – Harmful Substances in Aggregates (from ASTM C 33).

Item	Fine Aggregate	Coarse Aggregate
Clay lumps and friable particles	Unsound particles may affect durability and workability, cause popouts, increase water demand of mix	
Coal and lignite	Affect surface appearance; cause popouts and difficulty in air entrapment	
Material finer than No. 200 sieve	Affects bond of paste to aggregate and increases the mix water demand	Can cause trouble when it exists as a coating on coarse aggregate
Soft particles	-	Reduce durability and surface hardness
Lightweight chert (specific gravity less than 2.40)	-	Reduces durability; a main cause of popouts

Figure 6-5 shows a popout, which occurs when internal pressure causes a small part of the concrete surface to break away. This usually leaves a cone-shaped hole, ranging in size from 1/4 inch or less to 2 inches or more. (Photo courtesy of http://www.all-things-concrete.com.)

Figure 6-5 – Popout.

2.2.4 Handling and Storage

A mass of aggregate containing particles of different sizes has a natural tendency toward segregation. Segregation refers to particles of the same size tending to gather together when the material is loaded, transported, or otherwise disturbed. Always handle and store aggregate by a method that minimizes segregation.

Do not build up stockpiles in cone shapes, formed by dropping successive loads at the same spot. This procedure causes segregation. Build a pile up in layers of uniform thickness, each made by dumping successive loads alongside each other.

If aggregate is dropped from a clamshell, bucket, or conveyor, some of the fine material may be blown aside, causing segregation of fines on the side of the pile away from the wind. Discharge all conveyors, clamshells, and buckets in contact with the pile.

When ***charging*** (filling) a bin, drop the material from a point directly over the outlet. Material chuted in at an angle or material discharged against the side of a bin will segregate. Since a long drop will cause both segregation and the breakage of aggregate particles, minimize the length of a drop into a bin by keeping the bin as full as possible at all times. The bottom of a storage bin should always slope at least 50˚

toward the central outlet. If the slope is less than 50˚, segregation will occur as material is discharged out of the bin.

2.3.0 Water

The two principal functions of water in a concrete mix are to effect hydration and improve workability. For example, a mix to be poured in forms must contain more water than is required for complete hydration of the cement. Too much water causes a loss of strength by upsetting the water-cement ratio. It also causes water gain on the surface, a condition that leaves a surface layer of weak material called ***laitance***. As previously mentioned, an excess of water also impairs watertightness of the concrete.

Water used in mixing concrete must be clean and free from acids, alkalis, oils, or organic materials. Most specifications recommend that the water used in mixing concrete be suitable for drinking (potable), if such water is available.

Seawater can be used for mixing unreinforced concrete if there is a limited supply of fresh water. Tests show that the compressive strength of concrete made with seawater is 10 to 30 percent less than that obtained using fresh water. Seawater is not suitable for use in making steel reinforced concrete because of the risk of corrosion of the reinforcement, particularly in warm and humid environments.

2.4.0 Admixtures

Admixtures include all materials added to a mix other than Portland cement, water, and aggregates. 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 the heat of hydration, entrain air, and accelerate or retard setting and hardening.

We should note that 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 or convenient. Seabees rely on local suppliers for appropriate basic concrete mixes. Add any admixture according to current specifications determined by the Engineering Aid and upon approval of the Quality Control department.

2.4.1 Workability Agents

Materials such as hydrated lime and bentonite improve workability. These materials increase the fines in a concrete mix when an aggregate is tested deficient in fines, i.e., lacking sufficient fine material.

2.4.2 Air-Entraining Agents

The deliberate adding of millions of minute disconnected air bubbles to cement paste, if those bubbles are evenly diffused, changes the basic concrete mix and increases durability, workability, and strength. The acceptable amount of entrained air in a concrete mix, by volume, is 3 to 7 percent. ***Air-entraining agents***, used with types I, II, or III cement, are derivatives of natural wood resins, animal or vegetable fats, oils, alkali salts of sulfated organic compounds, and water soluble soaps. Most air-entraining agents are in liquid form for use in the mixing water.

2.4.3 Accelerating admixtures

Accelerating admixtures speed up the setting and hardening of concrete. They are especially useful in cold weather because concrete hardens slowly at temperatures below about 50°F. In the past, the most common of these admixtures was calcium chloride. However, calcium chloride in concrete increases the potential for corrosion of reinforcing steel and some other metals. When required by the specifications, non-chloride ***accelerators*** are available.

2.4.4 Retarders

The accepted use for ***retarders*** is to reduce the rate of hydration. They are often used in warm weather to keep the concrete from setting before it can be placed and finished. Agents normally used are fatty acids, sugar, and starches.

2.5.0 Cement Storage

Portland cement is packed in cloth or paper sacks, each weighing 94 pounds. A 94 pound sack of cement amounts to about 1 cubic foot by loose volume.

Cement will retain its quality indefinitely if it does not come in contact with moisture. If allowed to absorb appreciable moisture in storage, it sets more slowly and its strength is reduced. Store sacked cement in warehouses or sheds made as watertight and airtight as possible. Close all cracks in roofs and walls, and ensure there are no openings between walls and roof. The floor should be above ground to protect the cement against dampness. Keep all doors and windows closed.

Stack sacks against each other to prevent circulation of air between them, but do not stack them against outside walls. If stacks are to stand undisturbed for long intervals, cover them with tarpaulins.

When shed or warehouse storage is not available, sacks that must be stored in the open should be stacked on raised platforms and covered with waterproof tarps. The tarps should extend beyond the edges of the platform to deflect water away from the platform and the cement.

Cement sacks stacked in storage for long periods sometimes acquire a hardness called warehouse pack. You can usually loosen this by rolling the sack around. Do not use cement that has lumps or is not free flowing.

Test your Knowledge (Select the Correct Response)

2. When a field test for cleanliness of aggregate shows 1/8 inch of sediment on a sample, the aggregate should be washed because this amount of sediment

   A. decreases the workability of the concrete
   B. prevents the aggregate from becoming friable
   C. may obstruct hydration and bonding of the cement to the aggregate
   D. will detract from the appearance of the concrete

3.0.0 CONCRETE MIX DESIGN

Before proportioning a concrete mix, you need information concerning the job, such as size and shapes of structural members, required strength of the concrete, and exposure conditions. The end use of the concrete and conditions at time of placement are additional factors to consider.

3.1.0 Ingredient Proportions

The ingredient proportions for the concrete on a particular job are usually set forth in the specifications under CONCRETE - General Requirements. See *Table 6-4* for examples of normal concrete mix design and the number of bags of cement used in the mixing specifications according to NAVFAC.

In *Table 6-4*, one of the formulas for 3,000 psi concrete is 5.80 bags of cement per cubic yard, 233 pounds of sand (per bag of cement), 297 pounds of coarse aggregate (per bag of cement), and a water-cement ratio of 6.75 gallons of water to each bag of cement. These proportions are based on the assumption that the inert ingredients are in a saturated surface dry condition, meaning that they contain all the water they are capable of absorbing, but no additional free water over and above this amount.

Table 6-4 – Normal Concrete.

Figures Denote Size of Coarse Aggregate in Inches	Estimated 28 Day Compressive Strength (Pounds per Square Inch)	Cement Factor Bags (94 Pounds) of Cement per Cubic Yard of Concrete Freshly Mixed	Maximum Water (Gallons) per Bag (94 Pounds) of Cement	Fine Aggregate Range in Percent of Total Aggregate by Weight	Approximate Weights of Saturated Surface Dry Aggregates per Bag (94 Pounds) of Cement	
					Fine Aggregate Pounds	Coarse Aggregate Pounds
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	1,500	4.10	9.50	42-52	368	415
1-1.5	1,500	3.80	9.50	38-48	376	498
2	1,500	3.60	9.50	35-45	378	567
2.5	1,500	3.50	9.50	33-43	373	609
3.5	1,500	3.25	9.50	30-40	378	702
1	2,000	4.45	8.75	41-51	329	387
1.5	2,000	4.10	8.75	37-47	338	467
2	2,000	3..90	8.75	34-44	338	529
2.5	2,000	3.80	8.75	32-42	332	565
3.5	2,000	3.55	8.75	29-39	334	648
0.5	2,500	5.70	7.75	50-60	282	231
0.75	2,500	5.30	7.75	45-55	288	288
1	2,500	5.05	7.75	40-50	279	341
1.5	2,500	4.65	7.75	36-46	287	413
2	2,500	4.40	7.75	34-42	288	471
2.5	2,500	4.25	7.75	32-40	287	509
3.5	2,500	4.00	7.75	29-37	285	578
0.5	3,000	6.50	6.75	50-58	238	203
0.75	3,000	6.10	6.75	45-53	240	249
1	3,000	5.80	6.75	40-48	233	297
1.5	3,000	5.35	6.75	36-44	239	359
2	3,000	5.05	6.75	33-41	241	410
2.5	3,000	4.90	6.75	31-39	238	441
3.5	3,000	4.60	6.75	28-36	237	503
0.375	3,500	7.70	6.00	56-64	210	140
0.5	3,500	7.35	6.00	48-56	198	183
0.75	3,500	6.85	6.00	43-51	201	226
1	3,500	6.50	6.00	38-46	195	270
1.5	3,500	6.00	6.00	34-42	200	325
2	3,500	5.70	6.00	31-29	199	369
2.5	3,500	5.50	6.00	29-37	197	400
3.5	3,500	5.20	6.00	27-35	200	444
0.25	4,000	8.95	5.50	100	281	–
0.375	4,000	8.40	5.50	55-63	186	129
0.5	4,000	8.00	5.50	47-55	175	168
0.75	4,000	7.45	5.50	42-50	178	209
1	4,000	7.10	5.50	37-45	172	247
1.5	4,000	6.55	5.50	33-41	175	299
2	4,000	6.20	5.50	30-38	175	340
2.5	4,000	6.00	5.50	28-36	173	368
3.5	4,000	5.65	5.50	26-34	176	411
0.25	5,000	11.50	4.25	100	202	–
0.375	5,000	10.80	4.25	53-61	130	98
0.5	5,000	10.35	4.25	45-53	121	126
0.75	5,000	9.65	4.25	40-48	123	157
1	5,000	9.20	4.25	35-43	119	186
1.5	5,000	8.45	4.25	31-39	122	228
2	5,000	8.00	4.25	28-36	122	260

A saturated surface dry condition almost never exists in the field. The amount of free water in the coarse aggregate is usually small enough to be ignored, but always adjust the ingredient proportions set forth in the specs to allow for the existence of free water in the fine aggregate. Furthermore, since free water in the fine aggregate increases its measured volume or weight over that of the sand itself, the specified volume or weight of sand must be adjusted to offset the volume or weight of the water in the sand. Finally, reduce the number of gallons of water used per sack of cement to allow for the free water in the sand. The amount of water actually added at the mixer must be the specified amount per sack, less the amount of free water that is already in the ingredients in the mixer.

Except as otherwise specified in the project specifications, concrete is proportioned by weighing and must conform to NAVFAC specifications. See *Table 6-4* for normal concrete.

3.2.0 Material Estimates

When tables such as *Table 6-4* are not available for determining quantities of material required for 1 cubic yard of concrete, a rule of thumb known as rule 41 or 42 may be used for a rough estimation. According to this rule, it takes either 41 or 42 cubic feet of the combined dry amounts of cement, sand, and aggregates to produce 1 cubic yard of mixed concrete. Rule 41 is used to calculate the quantities of material for concrete when the size of the coarse aggregate is not over 1 inch. Rule 42 is used when the size of the coarse aggregate is over 1 inch but not larger 2 1/2 inches. Here is how it works.

As we mentioned earlier, a bag of cement contains 94 pounds by weight, or about 1 cubic foot by loose volume. A batch formula is usually based on the number of bags of cement used in the mixing machine.

For estimating the amount of dry materials needed to mix 1 cubic yard of concrete, rules 41 and 42 work in the same manner. The decision on which rule to use depends upon the size of the aggregate. Let’s say your specifications call for a 1:2:4 mix with 2-inch coarse aggregates, which means you use rule 42. First, add 1:2:4, which gives you 7. Then compute your material requirements as follows:

42 ÷ 7 = 1 x 6 = 6 cu ft of cement;

6 x 2 = 2 x 6 = 12 cu ft of sand;

6 x 4 = 4 x 6 = 24 cu ft of coarse aggregates.

Adding your total dry materials, 6 + 12 + 24 = 42, so your calculations are correct.

Frequently, you will have to convert volumes in cubic feet to weights in pounds. In converting, multiply the required cubic feet of cement by 94 since 1 cubic foot, or 1 standard bag of cement, weighs 94 pounds. When using rule 41 for coarse aggregate, multiply the quantity of coarse gravel in cubic feet by 105 since the average weight of dry compacted fine aggregate or gravel is 105 pounds per cubic foot. By rule 42, multiply the cubic feet of rock (1 inch size coarse aggregate) by 100 since the average dry compacted weight of this rock is 100 pounds per cubic foot.

Include a handling loss factor in ordering materials for jobs. Add an additional 5 percent for jobs requiring 200 or more cubic yards of concrete, and 10 percent for smaller jobs. This loss factor is based on material estimates after the requirements have been calculated. You may add additional loss factors where conditions indicate the necessity for excessive handling of materials before batching.

3.2.1 Measuring Water

The water measuring controls on a machine concrete mixer are described later in this chapter. Water measurement for hand mixing can be done with a bucket, marked off on the inside in gallons, half gallons, and quarter gallons.

Never add water to the mix without carefully measuring the water, and always remember that the amount of water actually placed in the mix varies according to the amount of free water already in the aggregate. This means that if the aggregate is wet by a rainstorm, you may have to change the proportion of water in the mix.

3.2.2 Measuring Aggregate

The accuracy of aggregate measurement by volume depends upon the accuracy with which the amount of bulking, caused by moisture in the aggregate, can be determined. The amount of bulking varies not only with different moisture contents but also with different gradations. Fine sand, for example, is bulked more than coarse sand by the same moisture content. Furthermore, moisture content itself varies from time to time, and a small variation causes a large change in the amount of bulking. For these and other reasons, aggregate should be measured by weight rather than by volume whenever possible.

Store and measure coarse aggregate from separate piles or hoppers. This will make grading easier, keep segregation low, and ensure that each batch is uniform. The ratio of maximum to minimum particle size should not exceed 2:1 for a maximum nominal size larger than 1 inch. The ratio should not exceed 3:1 for a maximum nominal size smaller than 1 inch. A mass of aggregate with a nominal size of 1 1/2 inches to 1/4 inch, for example, should be separated into one pile or hopper containing 1 1/2 inch to 3/4 inch aggregate, and another pile or hopper containing 3/4 inch to 1/4 inch aggregate. A mass with a nominal size of 3 inches to 1/4 inch should be separated into one pile or hopper containing 3 inch to 1 1/2 inch aggregate, another containing 1 1/2 inch to 3/4 inch aggregate, and a third containing 3/4 inch to 1/4 inch aggregate.

3.2.3 Water-Cement Ratio

The major factor controlling strength, everything else being equal, is the amount of water used per bag of cement. Maximum strength is obtained by using just the amount of water, and no more, required for complete hydration of the cement. As previously mentioned, a mix of this type may be too dry to be workable. Concrete mix always contains more water than the amount required to attain maximum strength. The point to remember is that the strength of concrete decreases as the amount of extra water increases.

The specified water-cement ratio is the happy medium between the maximum possible strength of the concrete and the necessary minimum workability requirements. The strength of building concrete is expressed in terms of the compressive strength in pounds per square inch (psi) reached after a 7 or 28 day set. This is usually referred to as probable average 7 day strength and probable average 28 day strength.

3.3.0 Slump Testing

Slump testing is a means of measuring the consistency of concrete using a slump cone. The cone is made of galvanized metal with an 8 inch diameter base, a 4 inch diameter top, and a 12 inch height. The base and the top are open and parallel to each other and at right angles to the axis of the cone, shown in *Figure 6-6*. A ***tamping*** rod 5/8 inch in diameter and 24 inches long is also needed. The tamping rod should be smooth and bullet pointed. Do not use a piece of reinforcing bar (***rebar***).

Take samples of concrete for test specimens at the mixer or, in the case of ***ready mixed concrete***, from the transportation vehicle during discharge.

The sample of concrete from which test specimens are made should be representative of the entire batch. Obtain these samples by repeatedly passing a scoop or pail through the discharging stream of concrete, starting the sampling operation at the beginning of discharge, and repeating the operation until the entire batch is discharged. To counteract segregation when a sample must be transported to a test site, remix the concrete with a shovel until it is uniform in appearance. The job location from which you take the sample should be noted for future reference. In the case of paving concrete, you may take samples from the batch immediately after depositing it on the subgrade. Take at least five samples at different times, and these samples should be thoroughly mixed to form the test specimen.

Figure 6-6 – Slump cone and tamping rod.

When making a ***slump test***, dampen the cone and place it on a flat, moist, nonabsorbent surface. From the sample of concrete obtained, immediately fill the cone in three layers, each approximately one third the volume of the cone. In placing each scoop full of concrete in the cone, move the scoop around the edge of the cone as the concrete slides from the scoop. This ensures symmetrical distribution of concrete within the cone. Then rod in each layer with 25 strokes. Distribute the strokes uniformly over the cross section of the cone and penetrate 1" into the underlying layer. Rod the bottom layer throughout its depth.

If the cone becomes overfilled, use a straightedge to strike off the excess concrete flush with the top. Immediately remove the cone from the concrete by raising it carefully in a vertical direction. Measure the slump immediately after removing the cone.

Determine the slump by measuring the difference between the height of the cone and the height of the specimen as shown in *Figure 6-7*. The slump should be recorded to the nearest 1/4" in terms of inches of subsidence of the specimen during the test.

After completing the slump measurement, gently tap the side of the mix with the tamping rod. The behavior of the concrete under this treatment is a valuable indication of the cohesiveness, workability, and placeability of the mix. In a well proportioned mix, tapping only causes it to slump lower. It doesn't crumble apart or segregate by dropping larger aggregate particles to a lower level in the mix. If the concrete crumbles apart, it is oversanded.

Figure 6-7 – Measuring the slump.

If it segregates, it is undersanded.

3.4.1 Test Cylinders

There are two reasons to make and test cylinders:

1. Determine if the concrete meets the design requirements for specified compressive strength, known as **design strength check**.
2. Determine if the concrete that has been placed is of sufficient strength for the forms to be removed or for the concrete to be put into service, known as **construction site control**.

3.4.1 Making Test Cylinders

Specifications usually require at least two cylinder breaks to be averaged and reported as one “test” to provide compressive strength results, giving a better indication of the strength of the concrete. If you need to test at 7 days and 28 days, you will need to make at least 6 cylinders. You will also need one or more *hold cylinders* as backups in case the 28-day cylinders are damaged or do not come up to strength.

Most concrete test cylinders made in the United States are 6 inches in diameter and 12 inches high and are known as 6 x 12 cylinders. Sometimes other sizes such as 4 x 8 inches and 3 x 6 inches are used, but these require adjustments of the test results to equate to the 6 x 12 cylinder strengths.

There are several kinds of cylinder molds, including heavy steel molds, sheet metal molds also known as tin can molds, plastic molds, and waxed cardboard molds. Tin can, cardboard, and some plastic molds are single use molds. Heavy steel molds and some sheet metal and plastic molds are reusable, but you must be clean and oil them after each use.

After obtaining a sample of concrete according to ASTM C 172, the procedure to create test cylinders is:

Figure 6-8 – Filling test cylinders.

1. Make sure the cylinder molds have been cleaned and oiled as needed.
2. Place the cylinder molds on a solid base such as a concrete slab or a sheet of plywood, as shown in *Figure 6-8*.
3. For slumps greater than 3 inches: Fill each mold in three equal layers and use a standard tamping rod to rod each layer 25 times. The rod should penetrate all the way through each layer and into the previous layer about 1 inch. Tap the sides of the mold lightly to close any voids created by ***rodding***.

4. Mark each cylinder so it can be matched with the concrete in the corresponding part of the project. Make sure to record the time and date that the concrete was placed.

5. For slumps less than 1 inch: Fill each mold in two equal layers. Use an internal vibrator with a diameter of 3/4 inch to 1 1/2 inches, and insert it into the concrete at three locations. Leave the vibrator in the concrete long enough at each location to allow entrapped air to escape. Raise the vibrator slowly and tap the sides of the mold lightly.

6. For slumps between 1 and 3 inches: Fill the mold and compact the concrete either by rodding or vibrating, as described in step 3 or 4.

7. Strike off and smooth the surface of each cylinder. Cover the top surface of each cylinder with a plate or sheet of impervious plastic as shown in *Figure 6-9*.

Figure 6-9 – Test cylinder on site.

3.4.2 uring and Protecting Test Cylinders

Store test cylinders made for **design strength check** in a moist environment with a temperature of 60° to 80° F for up to 48 hours. ASTM C 31 suggests several ways to maintain the required moisture and temperature.

If the test cylinders will not be transported to the lab within 48 hours, remove the cylinders from their molds within 16 to 32 hours and keep them moist at 70° to 76° F until the time of the test. If the test cylinders are to be sent to the laboratory for standard curing within 48 hours, make sure they remain in the molds and are kept moist until they reach the lab. When the test cylinders reach the lab, the molds are removed and the specimens are placed in standard curing until the time of the test.

Accurate test results rely on care taken in handling, shipping, and storage of test cylinders. ASTM C 31 says that test cylinders must be protected from freezing and moisture loss during transportation and cushioned to prevent them from jarring. Several suggestions are to wrap the specimens in plastic or surround them with wet sand or wet sawdust. Travel time should not exceed 4 hours. Any test cylinders that are prematurely moved, accidentally dropped or kicked, or left in the field too long at the wrong temperature must be discarded.

Keep test cylinders made for **construction site control** at the jobsite temperature and give them the same curing as the concrete they represent. Specimens made to determine when a structure can be put into service should be removed from their molds at the same time the ***formwork*** is removed from the project. Test these specimens in the moisture condition resulting from the jobsite storage. Careful handling and transportation for testing are important for these test cylinders as well.

3.4.3 Testing the Cylinders

Compression tests of concrete cylinders are specified in ASTM C 39. The ends of the test cylinders are ground or capped in accordance with ASTM C 617. The ends of each test cylinder must be smooth, plane surfaces to assure even loading and accurate test results. Various commercial materials are available to cap compressive test specimens. Building codes usually define a **strength test** as the average of the results of breaking **two cylinders** made from the same sample and tested at the same designated age.

Job specifications usually require that concrete reach at least 3000 psi, 4000 psi, or some other minimum strength at 28 days. This specified compressive strength is commonly referred to as f_c'. Always use a 28-day strength test unless specifications definitely specify otherwise. Cylinders made, cured, and transported according to ASTM C 31 and tested according to ASTM C 39 must average at least as strong as the specified strength for the project.

When the test cylinders reach the age specified for test, place them in a calibrated hydraulic testing machine which applies load at a uniform rate to the flat ends. Increase the load until the cylinder fails under load. Calculate the strength of the concrete by dividing the maximum load by the area of the flat surface. If the cylinder is 6 inches in diameter and 12 inches high, and the maximum load is 90,000 pounds (lb), the strength is calculated as:

$$\text{strength} = \frac{\text{maximum load}}{\text{loaded area}}$$

Since the loaded area for a 6 inch diameter circle is 28.3 square inches (sq in):

$$\text{strength} = \frac{\text{90,000 pounds}}{\text{28.3 square inch}}$$

$$\text{strength} = \text{3180 pounds per square inch}$$

3.5.1 Rebound Hammer Test

Nondestructive and in-place test methods are valuable in overall quality assurance of concrete. They cannot be used to evaluate strength until laboratory studies develop correlations with traditional strength test results on concretes made with the same materials and mix proportions. Without such correlations, the nondestructive tests can serve to evaluate relative strengths of hardened concretes.

A widely used in-place test is done with a rebound hammer, frequently referred to as a Schmidt hammer, shown in *Figure 6-10*. It is a spring-controlled hammer that slides on a plunger.

Figure 6-10 – Rebound hammer.

When you press the plunger of the hammer against a concrete surface, the hammer retracts against the force of the spring. When the hammer retracts completely, the spring automatically releases. The hammer impacts the shoulder area of the plunger, and the spring-controlled mass rebounds. The rebound distance, known as the "rebound number," is measured on a scale attached to the instrument.

The results of a Schmidt rebound hammer test performed according to ASTM C 805 are affected by surface smoothness; size, shape, and rigidity of the specimen; the type of coarse aggregate, and the carbonation of the concrete surface. When you recognize these limitations and calibrate the hammer for the particular materials used in the concrete, this instrument is useful to determine the relative compressive strength and uniformity of concrete in the structure.

Although rebound numbers are not a precise indication of the concrete strength, higher numbers mean greater strength compared to concretes made of the same materials and placed at about the same time.

Using the impact rebound hammer seems simple, but it is easy to get misleading readings. There are three main steps to this test procedure:

1. Press the plunger against the concrete surface until the hammer impacts.
2. Press the button to lock the plunger.
3. Read the scale.

The operator must take the following precautions:

- The concrete surface must be dry and smooth. Use an abrasive stone or a grinder to smooth a rough surface.
- Keep the plunger at right angles to the surface.
- Take and record ten readings. No two test points should be closer together than 1 inch.
- Calculate the average reading as follows:
    1. Average the ten readings.
    2. Discard any readings that vary from the average by more than 7.
    3. Average the remaining readings.

If more than two readings vary by more than 7 from the average, discard all 10 readings and repeat the procedure.

3.6.0 Workability

A mix must be workable enough to fill the form spaces completely with the assistance of a reasonable amount of shoveling, spading, and vibrating. Since a fluid or runny mix does this more readily than a dry or stiff mix, you can see that workability varies directly with fluidity. The workability of a mix is determined by the slump test. The amount of the slump, in inches, is the measure of the concrete's workability; the more the slump, the higher the workability.

The slump can be controlled by a change in any or all of the following: gradation of aggregates, proportion of aggregates, moisture content. If the moisture content is too high, add more cement to maintain the proper water-cement ratio.

Attain the desired degree of workability by running a series of trial batches, using various amounts of fine to coarse aggregate, until producing a batch with the desired slump. Once you determine the amount of increase or decrease in fines required to produce the desired slump, alter the aggregate proportions, not the water proportion, in the field mix to conform. If the water proportion is changed, the water-cement ratio will be upset.

Never yield to the temptation to add more water without making the corresponding adjustment in the cement content. Also, make sure that crewmembers who are spreading a stiff mix by hand do not ease their labors by this method without telling you.

As you gain experience, you will discover that adjustments in workability can be made by making very minor changes in the amount of fine or coarse aggregate. Generally, everything else remaining equal, an increase in the proportion of fines stiffens a mix, whereas an increase in the proportion of coarse loosens a mix.

NOTE

Before you alter the proportions set forth in a specification, you must find out from higher authority whether you are allowed to make any such alterations and, if you are, the permissible limits beyond which you must not go.

3.7.0 Grout

As previously mentioned, concrete consists of four essential ingredients: water, cement, sand, and coarse aggregate. The same mixture without coarse aggregate is mortar. Mortar, which is used chiefly for bonding masonry units together, is discussed in a later chapter. ***Grout*** refers to a water-sand-cement mixture. This mixture is used to plug holes or cracks in concrete, to seal joints, to fill spaces between machinery bedplates and concrete foundations, and for similar plugging or sealing purposes. The consistency of grout may range from stiff (about 4 gallons of water per sack of cement) to fluid (as many as 10 gallons of water per sack of cement) depending upon the nature of the grouting job at hand.

3.8.0 Batching

When bagged cement is used, the field mix proportions are usually given in terms of designated amounts of fine and coarse aggregate per bag (or per 94 pounds) of cement. The amount of material mixed at a time is called a batch. The size of a batch is usually designated by the number of bags of cement it contains, such as a four-bag batch, a six-bag batch, and so on.

The process of weighing out or measuring out the ingredients for a batch of concrete is called batching. When mixing is done by hand, the size of the batch depends on the number of people available to turn it with hand tools. When a machine does the mixing, the size of the batch depends on the rated capacity of the mixer. The rated capacity of a mixer is given in terms of cubic feet of mixed concrete, not of dry ingredients.

On large jobs, the aggregate is weighed out in an aggregate batching plant, usually shortened to batch plant, like the one shown in *Figure 6-11*. Whenever possible, a batch plant is located near and used in conjunction with a crushing and screening plant. A crushing and screening plant crushes stone into various particle sizes, then screens them into separate piles. In a screening plant, the aggregate in its natural state is screened by size into separate piles.

The batch plant, which is usually portable and can be taken apart and moved from site to site, is generally set up adjacent to the pile of screened aggregate. The plant may include separate hoppers for several sizes of fine and coarse aggregates, or only one hopper for fine aggregate and another for coarse aggregate. It may have one or more divided hoppers, each containing two or more separate compartments for different sizes of aggregates.

Figure 6-11 – Aggregate batching plant.

Each storage hopper or storage hopper compartment can be discharged into a weigh box, which can, in turn, be discharged into a mixer or a batch truck. When a specific weight of aggregate is called for, the operator sets the weight on a beam scale. The operator then opens the discharge chute on the storage hopper. When the desired weight is reached in the weigh box, the scale beam rises and the operator closes the storage hopper discharge chute then opens the weigh box discharge chute, and the aggregate discharges into the mixer or batch truck. Batch plant aggregate storage hoppers are usually loaded by clamshell equipped cranes.

Test your Knowledge (Select the Correct Response)

In answering question 3, refer to *Table 6-4*.

3. Your specifications for a driveway call for a 3,000 psi concrete using 1 inch coarse aggregate. How many bags of cement per cubic yard will you need?

    A. 8.4
    B. 7.1
    C. 6.5
    D. 5.8

4. Which of the following units is the most accurate way to measure aggregate?

A. Cubic feet
B. Pounds
C. Cubic Yards
D. Gallons

4.0.0 MIXING CONCRETE

Concrete is mixed either by hand or machine. No matter which method you use, you must follow well established procedures if you expect finished concrete of good quality. An oversight in proper concrete mixing, whether through lack of competence or inattention to detail, cannot be corrected later.

4.1.1 Mixing by Hand

A batch to be hand mixed by a couple of crewmembers should not be much larger than 1 cubic yard. The equipment required consists of a watertight metal or wooden platform, two shovels, a metal lined measuring box, and a graduated bucket for measuring the water.

The mixing platform does not need to be made of expensive materials. It can be an abandoned concrete slab or parking lot that can be cleaned after use or a wooden platform having tight joints to prevent the loss of paste. Whichever surface you use, ensure that it is cleaned prior to use and level.

Let’s say your batch consists of two bags of cement, 5.5 cubic feet of sand, and 6.4 cubic feet of coarse aggregate. Mix the sand and cement together first, using the following procedure:

1. Dump 3 cubic feet of sand on the platform first, spread it out in a layer, and dump a bag of cement over it.
2. Spread out the cement and dump the rest of the sand (2.5 cubic feet) over it.
3. Dump the second sack of cement on top of the lot.

This use of alternate layers of sand and cement reduces the amount of shoveling required for complete mixing.

Personnel doing the mixing should face each other from opposite sides of the pile and work from the outside to the center. They should turn the mixture as many times as necessary to produce a uniform color throughout. When the cement and sand are completely mixed, the mixers should level off the pile and add the coarse material and mix them by the same turning method.

Next, they should trough the pile in the center. The mixing water, after being carefully measured, should be poured into the trough. The dry materials should then be turned into the water, with great care taken to ensure that none of the water escapes. When all the water has been absorbed, the mixing should continue until the mix is of a uniform consistency. Four complete turnings are usually required.

4.2.0 Mixing by Machine

The size of a concrete mixer is designated by its rated capacity. As mentioned earlier, the capacity is expressed in terms of the volume of mixed concrete, not of dry ingredients the machine can mix in a single batch. Rated capacities run from as small as 2 cubic feet to as large as 7 cubic yards (189 cubic feet.) In the Naval Construction Forces (NCFs), the most commonly used mixer is the self-contained Model 11-S, shown in *Figure 6-12*, with a capacity of 16 cubic feet (plus a 10 percent overload.)

Figure 6-12 –Model 11-S concrete mixer.

The production capacity of the 11-S mixer varies from 5 to 10 cubic yards per hour, depending on the efficiency of the personnel. Aggregate larger than 3 inches will damage the mixer. The mixer consists of a frame equipped with wheels and towing tongue (for easy movement), an engine, a power loader skip, mixing drum, water tank, and an auxiliary water pump. The mixer may be used as a central mixing plant.

4.2.1 Charging the Mixer

Concrete mixers may be charged by hand or with the mechanical skip. Before loading the mechanical skip, remove the towing tongue. Then load cement, sand, and gravel and dump them into the mixer together while the water runs into the mixing drum on the side opposite the skip. A storage tank on top of the mixer measures the mixing water into the drum a few seconds before the skip dumps. This discharge also washes down the mixer between batches. Place the coarse aggregate in the skip first, the cement next, and the sand on top to prevent excessive loss of cement as the batch enters the mixer.

4.2.2 ng Time

It takes a mixing machine with a capacity of 27 cubic feet or larger 1 1/2 minutes to mix a 1 cubic yard batch. Allow another 15 seconds for each 1/2 cubic yard or fraction thereof. Start the water into the drum for a few seconds before the skip begins to dump, so that the inside of the drum gets a washout before the batched ingredients go in. Measure the mixing period from the time all the batched ingredients are in, provided that all the water is in before one fourth of the ***mixing time*** has elapsed. The time elapsing between the introduction of the mixing water to the cement and aggregates and the placing of the concrete in the forms should not exceed 1 1/2 hours.

4.2.3 Discharging the Mixer

When the material is ready for discharge from the mixer, move the discharge into place to receive the concrete from the drum of the mixer. In some cases, stiff concrete has a tendency to carry up to the top of the drum and not drop down in time to be deposited on the chute. Very wet concrete may not carry up high enough to be caught by the chute. Correct this condition by adjusting the speed of the mixer. For very wet concrete, increase the speed of the drum. For stiff concrete, slow down the drum.

4.2.4 eaning and Maintaining the Mixer

The mixer should be cleaned daily when it is in continuous operation or following each period of use if it is in operation less than a day. If the outside of the mixer is kept coated with oil, the cleaning process can be speeded up. Wash the outside of the mixer with a hose, and knock off all accumulated concrete. If the blades of the mixer become worn or coated with hardened concrete, the mixing action will be less efficient. Replace badly worn blades. Do not allow hardened concrete to accumulate in the mixer drum. The mixer drum must be cleaned out whenever it is necessary to shut down for more than 1 1/2 hours. Place a volume of coarse aggregate in the drum equal to half the capacity of the mixer and allow it to revolve for about 5 minutes. Discharge the aggregate and flush out the drum with water. Do not pound the discharge chute, drum shell, or the skip to remove aggregate or hardened concrete. Concrete will readily adhere to the dents and bumps created by such pounding. For complete instructions on the operation, adjustment, and maintenance of the mixer, study the manufacturer’s manual.

All gears, chains, and rollers of mixers should be properly guarded. All moving parts should be cleaned and properly serviced to permit safe performance of the equipment. When the mixer drum is being cleaned, the switches must be open, the throttles closed, and the control mechanism locked in the OFF position. The area around the mixer must be kept clear.

Skip loader cables and brakes must be inspected frequently to prevent injuries caused by falling skips. When work under an elevated skip is unavoidable, shore up the skip to prevent it form falling in the event the brake fails or is accidentally released. The mixer operator must never lower the skip without first making sure that there is no one underneath.

Dust protection equipment must be issued to the crew engaged in handling cement, and the crew must wear the equipment when so engaged. Crewmembers should stand with their backs to the wind, whenever possible. This helps prevent cement and sand from being blown into their eyes and faces.

4.3.0 Handling and Transporting Concrete

When ready mixed concrete is carried by an ordinary type of carrier, such as a wheelbarrow or buggy, jolting of the carrier increases the natural tendency of the concrete to segregate. Carriers should be equipped with pneumatic tires whenever possible, and the surface over which they travel should be as smooth as possible.

A long free fall also causes concrete to segregate. If the concrete must be discharged at a level more than 4 feet above the level of placement, it should be dumped into an elephant trunk similar to the one shown in *Figure 6-13*.

Figure 6-13 – Chute, or down pipe, used to check free fall of concrete.

Segregation also occurs when discharged concrete is allowed to glance off a surface, such as the side of a form or chute. Wheelbarrows, buggies, and conveyors should discharge so that the concrete falls clear.

Concrete should be transported by chute only for short distances. It tends to segregate and dry out when handled in this manner. For a mix of average workability, the best slope for a chute is about 1 foot of rise to 2 or 3 feet of run. A steeper slope causes segregation, whereas a flatter slope causes the concrete to run slowly or not at all. The stiffer the mix, the steeper the slope required. All chutes and spouting used in concrete pours should be clean and well supported by proper ***bracing*** and guys.

When spouting and chutes run overhead, the area beneath must be cleared and barricaded during placing. This eliminates the danger of falling concrete or possible collapse.

4.4.0 Ready Mixed Concrete

On some jobs, such as large highway jobs, it is possible to use a batch plant that contains its own mixer. A plant of this type discharges ready mixed concrete into transit mixers, which haul it to the construction site. The truck carries the mix in a revolving chamber much like the one on a mixer. Keeping the mix agitated en route prevents segregation of aggregate particles. A ready mix plant is usually portable so that it can follow the job along. It must be certain, of course, that a truck will be able to deliver the mix at the site before it starts to set. Discharge of the concrete from the drum should be completed within 1 1/2 hours.