Online Continuing Education for Professional Engineers
Since 2009

Basics of Concrete Construction

PDH Credits:

6 PDH

Course No.:

CNC101

Publication Source:

US NAVY

Engineering Aid Basics
"Chapter 3 – Concrete Construction"
Pub. # NAVEDTRA 14045A

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Chapter 3

Concrete Construction

Topics

1.0.0 Concrete Safety

2.0.0 Formwork

3.0.0 Reinforced Concrete

4.0.0 Design of Concrete Mixtures

5.0.0 Precast and Tilt-Up Construction

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Overview

Concrete construction, once confined largely to paving and foundations, has been developed to the point where both large and small buildings are now constructed entirely of concrete with concrete joists (usually called floor or grade beams), concrete studs (usually called columns), concrete walls, concrete floors, and concrete roofs.

This chapter explains some of the major factors in the design of concrete forms, as well as the various methods by which you can select the proportions for quality concrete mixtures and adjust these mixtures to suit job requirements. We also cover types and uses of admixtures and slump testing procedures. We point out some of the types of equipment you are likely to encounter in concrete construction. A brief discussion is also included on precast construction.

Objectives

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

1. Understand potential hazards in working with concrete and identify ways to safely work with concrete.
2. Understand and be able to apply the principle objectives of using formwork; economy, quality, and safety.
3. Identify the different types of reinforcing steel and understand the uses of each type.
4. Determine the correct amount of cement, water, and coarse and fine aggregates for concrete mixtures. Understand the effects of admixtures.
5. Identify precast and tilt-up construction. Understand methods for fabricating and placing precast members.

1.0.0 CONCRETE SAFETY

Concrete construction, like all types of construction, involves a certain degree of danger. To help you do your concrete work safely, we will discuss the various safety precautions concerning concrete.

- Form construction and concrete placement have peculiarities in each job; however, certain natural conditions will prevail in all situations. Wet concrete will always develop hydrostatic pressure and strain on the forms. Therefore, be sure to properly secure and inspect all stakes, braces, and other supporting members before placing the concrete.
- All formwork, shoring, and bracing should be designed, fabricated, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that might be applied until the structure can support loads.
- Correctly place and secure all nailing according to the plans and specifications. Careless nailing and exposed nails in formwork are a major cause of accidents.
- Build adequate scaffolding to permit crew members to stand clear of pouring areas.
- Rebar caps are a MUST for all exposed vertical rebar.
- Inspect tools frequently, particularly hammers. GFCIs must be used with all power tools. Ensure the location of the GFCIs is close to your equipment.

Supervisor(s) should check all forms before each pour. Stripped forms should be piled in advance of any movement or change of direction. During night operations, all equipment should be equipped with sufficient flood spotlights to make the perimeter of the operations clearly visible. The pouring bucket and the boom of the paver operating controls should have a synchronized warning device to function automatically with the motion of either the boom or the traveling bucket.

- Personnel may be subject to cement poisoning (lime); therefore, ensure they have their shirt sleeves rolled down and wear gloves and goggles when working with concrete.
- If concrete buckets and cranes are used in pouring, provide each bucket with a tag line or two, depending on the location. A crew member should never ride a concrete bucket during a pour.
- Do not attempt raising of large form panels by hand or by crane in heavy gusts of wind.
- Inspect skip loader cables and brakes frequently to prevent injuries caused by falling skips.
- The mixer operator must never lower the skip without first ensuring there is no one under it.
- Keep the area around the mixer clear.
- Dust protection equipment must be issued to crew members engaged in handling cement, and they must wear the equipment when so engaged. Workers should stand with their backs to the wind, whenever possible, to prevent cement and sand from being blown into their eyes and faces.

- Whenever the mixer drum is being cleaned, the switches must be open, the throttles closed, and the control mechanism locked in the OFF position.
- Whenever possible, a flagman or watchman should be stationed near the mixer to warn all hands when a batch truck is backing up to the skip. The watchman should use a whistle to warn any personnel in the danger zone. “DANGER-KEEP AWAY” signs should be placed where they can readily be seen.

2.0.0 FORMWORK

Formwork is a temporary structure that supports its own weight and that of the freshly placed concrete as well as the live loads imposed upon it by materials, equipment, and personnel. The most commonly used form materials are earth, metal, lumber, plywood, and fiber.

As a Builder serving in the capacity of a form designer or as the supervisor of a form building crew, you should take into account the three principle objectives when using formwork – economy, quality, and safety.

Economy is the major concern since formwork may represent as much as one third of the total cost of a concrete structure. Savings depend on the ingenuity and experience of the formwork designer or supervisor. Judgment in the selection of materials and equipment, in planning fabrication and erection procedures, and in scheduling reuse of forms will expedite the job and help reduce formwork costs. In designing and building formwork, aim for maximum economy without sacrificing quality or safety. Shortcuts in design or construction that endanger quality or safety may be false economy. For example, if the forms do not produce the specified surface finish, much hand rubbing of the concrete may be required; or if forms deflect excessively, bulges in the concrete may require expensive chipping and grinding. Obviously, economy measures that lead to formwork failure also defeat their own purpose.

2.1.0 Form Design

Forms must be designed for all the weight to which they are liable to be subjected, including the dead load of the forms, the plastic concrete in the forms, the weight of crew members, the weight of equipment and materials that may be transferred to the forms, and the impact due to vibration. These factors vary with each project, but do not neglect any of them. Ease of erection and removal are also important factors in the economical design of forms. Platforms and ramp structures independent of formwork are sometimes preferred to avoid displacement of forms due to loading and impact shock from crew members and equipment. Formwork for concrete must support all vertical and lateral loads that may be applied until the concrete structure itself can carry these loads. Loads on the forms include the weight of reinforcing steel and fresh concrete, the weight of the forms themselves, and various live loads imposed during the construction process. Consideration must be given to such conditions as unsymmetrical placement of concrete, uplift, and concentrated loads produced by storing supplies on the freshly placed slab. Rarely will there be precise information about the loads to which the formwork may be subjected; therefore, the architect or Builder must make some safe assumptions that will hold good for conditions generally encountered.

2.1.1 Vertical Loads

Vertical loads on formwork include the weight of reinforced concrete together with the weight of the forms themselves, which are regarded as dead loads, and the live loads imposed by the crew members and the equipment used during construction. The majority of formwork involves concrete weighing 150 pounds per cubic foot. Minor variations in this weight are not significant, and in most cases, 150 pounds per cubic foot, including the weight of the reinforcing steel, is commonly assumed for design. Formwork weights vary from as little as 3 or 4 pounds per square foot (psf) to 10 to 15 pounds per square foot. When the frame work weight is small in relation to the weight of the concrete plus the live load, it is frequently neglected. If concrete weighs 150 pounds per cubic foot, it will place a load on the forms of 12.5 pounds per square foot for each inch of slab thickness. Thus a 6 inch slab would produce a dead load of 6 by 12.5 or 75 pounds per square foot, excluding the weight of forms. The recommended minimum construction live load to provide for the weight of crew members and equipment is 50 pounds per square foot of horizontal projection. If powered concrete buggies are used in concreting operations, it is recommended that 75 pounds per square foot be used as a minimum construction live load.

2.1.2 Lateral Pressure

When concrete is placed in the form, it is in a plastic state and behaves temporarily like a fluid, producing a hydrostatic pressure that acts laterally on the vertical forms. If concrete acted as a true liquid, the pressure developed would be equal to the density of the fluid (150 pounds per cubic foot is commonly assumed for concrete) times the depth in feet to the point at which the pressure was being considered. However, plastic concrete is a mixture of solids and water whose behavior only approximates that of a liquid, and then only for a limited time. This lateral pressure is comparable to a full-liquid head when concrete is placed full height within the period required for its initial set. With slower rates of placing, concrete at the bottom of the forms begins to harden, and the lateral pressure is reduced to less than full-fluid pressure by the time concreting is completed in the upper parts of the form.

The effective lateral pressure, a modified hydrostatic pressure, has been found to be influenced primarily by the rate of placing and the temperature of the concrete mix. Other variables that have been found to have an effect on lateral pressure include consistency of concrete, amount and location of reinforcement, vibration, maximum aggregate size, and placing procedures. However, with usual concreting practices, the range of the effects of these variables is generally small and is either neglected or compensated for in design tables.

2.1.3 Lateral Loads

Adequate lateral bracing is extremely important to stability and safety in formwork construction, but all too often, it is treated carelessly or even omitted entirely. Formwork must be braced to resist all foreseeable lateral loads, such as those imposed by wind, dumping of concrete, or any other impact, such as starting and stopping of equipment. There are many types of braces that can give forms stability. The most common type is a diagonal member and horizontal member nailed to a stud or wale. The diagonal member should make a 45-degree angle with the horizontal member. Additional bracing may be added to the form by placing vertical members (strongbacks) behind the wales or by placing vertical members in the corner formed by the intersecting wales.

2.2.0 Wall Form Design

Concrete forms must be constructed to resist the pressure exerted on them by the freshly placed concrete without deflection (side displacement) beyond a specified maximum. This maximum is very small; for a wall form, for example, the maximum deflection of sheathing, studs, and wales is not over 1/270th of the span.

Placing concrete exerts a very considerable lateral (side) pressure on the form sheathing. The pressure at the bottom of the freshly placed concrete is greater than that at the top and the pressure increases with the height of the form.

When designing formwork, you must design the sheathing, the stud, and the waler spacing to a given pressure (vertical rate of placement).

2.2.1 Vertical Rate of Placement

To determine the vertical rate of placement for concrete wall forms, divide the quantity of concrete (mixer output) placed into the form in an hour (in cubic feet) by the horizontal area of the form space being filled. Suppose you are filling a wall section for a wall 30 feet long by 12 inches thick. The horizontal area would then be 30 square feet. See the formula below.

$$\textbf{Mixer output (cubic feet/ hour)} = \frac{\textbf{Mixer yield (cubic feet)}}{\textbf{Batch time (minutes)}} \textbf{ x 60 minutes/hour}$$

Let's take the hourly rate of the 11 S mixer (11 cubic feet per load) which has an hourly output of 4 to 8 cubic yards or from 108 to 216 cubic feet (depending on personnel) in a continuous operation. However, the quantity of concrete placed in the form per hour will depend on how continuous the mixer operation is and how rapidly the mix is transferred from the mixer to the form. This quantity you will have to determine according to your knowledge and circumstances at the job site. Let's assume that you estimate 8 cubic yards or 216 cubic feet will be placed in the form per hour. In this case, the vertical rate of placement is 216 cubic feet divided by 30 square feet of horizontal area, or about 7 feet per hour. See the formula below.

$$\textbf{Rate of placing (R) (feet/hour)} = \frac{\textbf{Mixer output (cubic feet/hour)}}{\textbf{Plan area (square feet)}}$$

NOTE

For an economical design, try to keep the rate of placement to 5 feet/hour or less.

2.2.2 Pressure from Vertical Rate of Placement

To determine the maximum concrete pressure, the Builder must know the temperature of the concrete and the rate of placement per square foot. When you know these things, you can determine the maximum concrete pressure by using the chart shown in *Figure 3-1*.

For example, to find the maximum concrete pressure, first make a reasonable estimate of the temperature of the concrete, let's say 70° F, and it has a rate of placement at 7 feet per hour. Move across the table to 70°F, and then move down the table to 7 feet per hour. In this case, the maximum pressure of concrete is 1,050 pounds per square foot (psf).

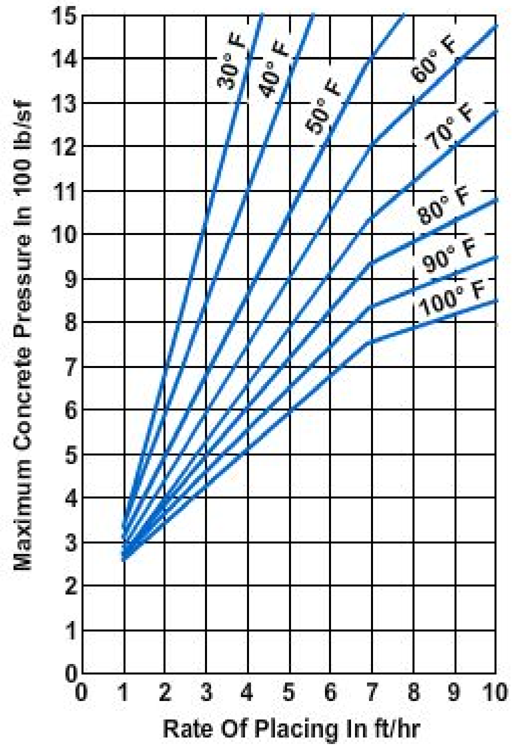


Figure 3-1 – Maximum concrete pressure graph.

2.2.2.1 Maximum Spacing of Wall Form Studs

Suppose you want to know the maximum spacing when using 3/4 inch sheathing with a concrete pressure of 600 pounds per square foot. Refer to *Table 3-1*.

Table 3-1 – Maximum Stud (Joist) Spacing for Plywood Sheathing.

Maximum Concrete Pressure	Strong way (in) 5-ply sanded, face grain, parallel to span				Weak way (in) 5-ply sanded, face grain, perpendicular to span			
(lb/sf)	1/2	5/8	3/4	1/7 ply	1/2	5/8	3/4	1/7 ply
75	20	24	26	31	13	18	23	30
100	18	22	24	29	12	17	22	28
125	17	20	23	28	11	15	20	27
150	16	19	22	27	11	15	19	25
175	15	18	21	26	10	14	18	24
200	15	17	20	25	10	13	17	24
300	13	15	17	22	8	12	15	21
400	12	14	16	20	8	11	14	19
500	11	13	15	19	7	10	13	18
600	10	12	14	17	6	9	12	17
700	10	11	13	16	6	9	11	16
800	9	10	12	15	5	8	11	15
900	9	10	11	14	4	8	9	15
1,000	8	9	10	13	4	7	9	14
1,100	7	9	10	12	4	6	8	12

Maximum Concrete Pressure	Strong way (in) 5-ply sanded, face grain, parallel to span				Weak way (in) 5-ply sanded, face grain, perpendicular to span			
1,200	7	8	10	11	-	6	7	11
1,300	6	8	9	11	-	5	7	11
1,400	6	7	9	10	-	5	6	10
1,500	5	7	9	9	-	5	6	9
1,600	5	6	8	9	-	4	5	9
1,700	5	6	8	8	-	4	5	8
1,800	4	6	8	8	-	4	5	8
1,900	4	5	8	7	-	4	4	7
2,000	4	5	7	7	-	-	4	7
2,200	4	5	6	6	-	-	4	6
2,400	-	4	5	6	-	-	4	6
2,600	-	4	5	5	-	-	-	5
2,800	-	4	4	5	-	-	-	5
3,000	-	-	4	5	-	-	-	5

Move down the chart to 600 pounds per square foot, and then go down the chart to 3/4 inch plywood sheathing. You will find that 14 inch spacing per stud is required. This chart refers to the forms with the face grain running across the supports. If the concrete pressure value falls between the two values in the column, round up to the higher value. To determine the uniform load on a stud (ULS), multiply the maximum concrete pressure by the maximum stud spacing. Then convert the answer to pounds per linear foot by dividing the result by 12. For example, the maximum concrete pressure is 1,050 pounds per square foot and the stud spacing is 14 inches. Multiply the two values together then divide by 12 which equals 1,225 (lbs/lin ft).

$$\text{Uniform Load on Stud (ULS) (pounds/linear foot)} = \frac{\text{Maximum concrete pressure (pounds/square foot)} \times \text{Maximum stud spacing (inches)}}{\text{12 inches/foot}}$$

2.2.2.2 Maximum Spacing of Wall Form Wales

When you know the spacing of the studs, the sheathing, and the maximum concrete pressure, the maximum wale spacing is not difficult to determine using the charts shown in *Table 3-2* and *Table 3-3*.

Table 3-2 – Maximum Spacing (in inches) for Wales, Ties, Stringers, and 4 inch by 4 inch or Larger Shores Where Member to be Supported is a Single Member.

Uniform load (lb/linear ft)	Supported Member Size (S4S)				
	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6
100	60	95	120	92	131
125	54	85	110	82	124
150	49	77	100	75	118
175	45	72	93	70	110
200	42	67	87	65	102
225	40	63	82	61	97
250	38	60	77	58	92
275	36	57	74	55	87
300	35	55	71	53	84
350	32	50	65	49	77
400	30	47	61	46	72
450	28	44	58	43	68
500	27	41	55	41	65
600	24	38	50	37	59
700	22	36	46	35	55
800	21	33	43	32	51
900	20	31	41	30	48
1,000	19	30	38	29	46
1,200	17	27	35	27	42
1,400	16	25	33	25	39
1,600	15	23	31	23	36
1,800	14	22	29	22	34
2,000	13	21	27	21	32
2,200	13	20	26	20	31
2,400	12	19	25	19	30
2,600	12	19	24	18	28
2,800	11	18	23	17	27
3,000	11	17	22	17	26
3,400	10	16	21	16	25
3,800	10	15	20	15	23
4,500	9	14	18	13	21

Table 3-3 – Maximum Spacing (in inches) for Ties and 4 inch or Larger Shores Where Member to be Supported is a Double Member.

Uniform load (lb/linear ft)	Supported Member Size (S4S)				
	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6
100	85	126	143	222	156
125	76	119	135	105	147
150	70	110	129	100	141
175	64	102	124	96	135
200	60	95	120	92	131
225	57	89	116	87	127
250	54	85	109	82	124
275	51	81	104	78	121
300	49	77	100	75	118
350	46	72	93	70	110
400	43	67	87	65	102
450	40	63	82	61	97
500	38	60	77	58	92
600	35	55	71	53	84
700	32	51	65	49	77
800	30	47	61	46	72
900	28	44	58	43	68
1,000	27	43	55	41	65
1,200	25	39	50	38	59
1,400	23	36	46	35	55
1,600	21	34	43	33	51
1,800	20	32	41	31	48
2,000	19	30	39	29	46
2,200	18	29	37	28	44
2,400	17	27	36	27	42
2,600	17	26	34	26	40
2,800	16	25	33	25	39
3,000	15	24	32	24	38
3,400	14	23	30	22	35
3,800	14	21	28	21	33
4,500	12	20	25	19	30

Suppose you want to find the maximum wale spacing for 2 by 4 studs and the concrete pressure is 600 pounds per square foot. Move down the chart until you reach 600 pounds per square foot, then go across to 2 by 4 lumber and you will find that the spacing for the waler and ties are 24 inches. To determine the uniform load on a wale (ULW), multiply the maximum concrete pressure (600 pounds per square foot) by the maximum wale spacing (24 inches). Convert the answer to feet by dividing the result by 12, which equals 1,200 (pounds per linear foot).

Uniform load on a wale (ULW) (pounds/linear foot) =

Maximum concrete pressure (pounds/square foot) x Maximum wale spacing (feet)

Use *Table 3-2* or *Table 3-3,* depending on the type of waler system, to determine the tie spacing based on the ULW. This number is the maximum tie spacing in inches based on wale size.

Tie wires or snap ties, depending on what system you use, must be installed at the intersection of studs and wales. Place the first tie at one half of the maximum tie spacing from the end of the wale.

2.2.3 Estimating Studs and Wales

To determine the number of studs on one side of a form, divide the form length by the maximum stud spacing, and add one for a starter. The first and last stud must be placed at each end of the form.

$$\textbf{Number of studs} = \frac{\textbf{Length of form (feet) x 12 (inches/foot)}}{\textbf{Stud spacing (inches) +1}}$$

To determine the number of wales for one side of a form, divide the form height by the maximum wale spacing and round up to the next whole number. Place the first wale one half of the maximum space up from the bottom and the remainder at the maximum wale spacing.

To determine the time required to place concrete, divide the height of the form by the rate of placement. This does NOT include the length of the form. For example, wall height of the form is 10 feet and the vertical rate of placement is 5 feet/hour. Your answer is 2 hours. *Figure 3-2* shows how you can estimate man-hours per cubic yard in most situations. These estimates are based on Seabee experiences.

Man-Hours Per Unit					
Work Element Description	**Unit (CD)**	**Direct from Chute**	**Wheeled**	**Pumped**	**Crane and Bucket**
Place Footings, Foundations:		1.0	2.0	1.50	1.50
Grade Beams		1.5	3.0	2.00	2.50
Slabs on Grade		--	--	1.68	2.24
Walls to 10' High		--	--	1.68	2.24
Columns		--	--	1.68	2.24
Suspended Slabs		--	--	1.68	2.24
Beams and Girders		--	--	1.68	2.24
Stairs		2.4	4.8	1.68	2.88

Figure 3-2 – Placing concrete labor estimates from P-405.

The following rules apply to *Figure 3-2*:

1. For each 40 feet waled, add 25%.
2. For upper stories, add per story: Placed by pump, 7%; placed by bucket or crane, 5%.
3. Construction that moves in and out of ramps, runways, or staging is not included. For moving in and out use 0.22 man-hours per linear foot.
4. Major items of consideration in planning concrete placement are: method of placement, accessibility, the rate of placement in regard to form design, and the amount and frequency of delivery being governed by the ability to screed, tamp, and finish.

2.2.4 Bracing of Wall Forms

Braces are used against wall forms as shown in *Figure 3-3* to keep the forms in place and in alignment despite mishaps due to external forces, such as wind, personnel, equipment, vibration, and accidents. For most military applications, this force is assumed to be 12.5 times the wall height, in feet. Braces, normally 2 by 4s, should be as strong in tension as in compression strength, or used on both sides of a wall form.

Leave designing wall forms and the bracing for wall forms to the engineers. We do not have the time or the space in this section to cover all the formulas necessary to design forms. Refer to the *American Concrete Institute* (ACI) or the *Architectural Graphic Standards* (AGS) for more information on designing of forms.

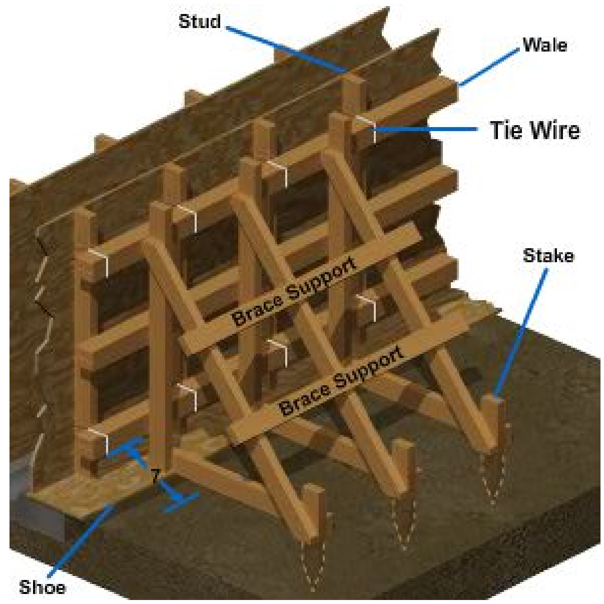


Figure 3-3 – Diagonal bracing supports.

2.3.0 Column Form Design

As with wall forms, column forms are designed according to step-by-step procedures. Wooden forms for a concrete column should be designed by the following steps:

1. Determine the materials available for sheathing, yokes, and battens. Standard materials for columns forms are 2 by 4s and 3/4 inch plywood.
2. Determine the height of the column.
3. Determine the largest cross-sectional dimension of the column.
4. Determine the yoke spacing, as shown in table 3-4, by reading down the first column until reaching the correct height of the column. Then read horizontally across the page to the column headed by the largest cross-sectional dimension. The center-to-center spacing of the second yoke above the base yoke will be equal to the value in the lower interval that is partly contained in the column

height line. Obtain all subsequent yoke spacings by reading up the height column to the top. This procedure gives maximum yoke spacings.

Figure 3-4 is based upon use of 2 by 4s and 3/4 inch sheathing. For example, if you had to construct a 9 foot column, the spacing of the yokes starting from the bottom yoke would be 8", 8", 10", 11", 12", 15", 17", 17", and 10". The space between the top two yokes has been reduced because of the limits of the column height.

Because of their height and relatively small cross-sectional area, column forms require four-way bracing to ensure alignment and resistance to wind and various other lateral forces that may occur during the placement of the concrete.

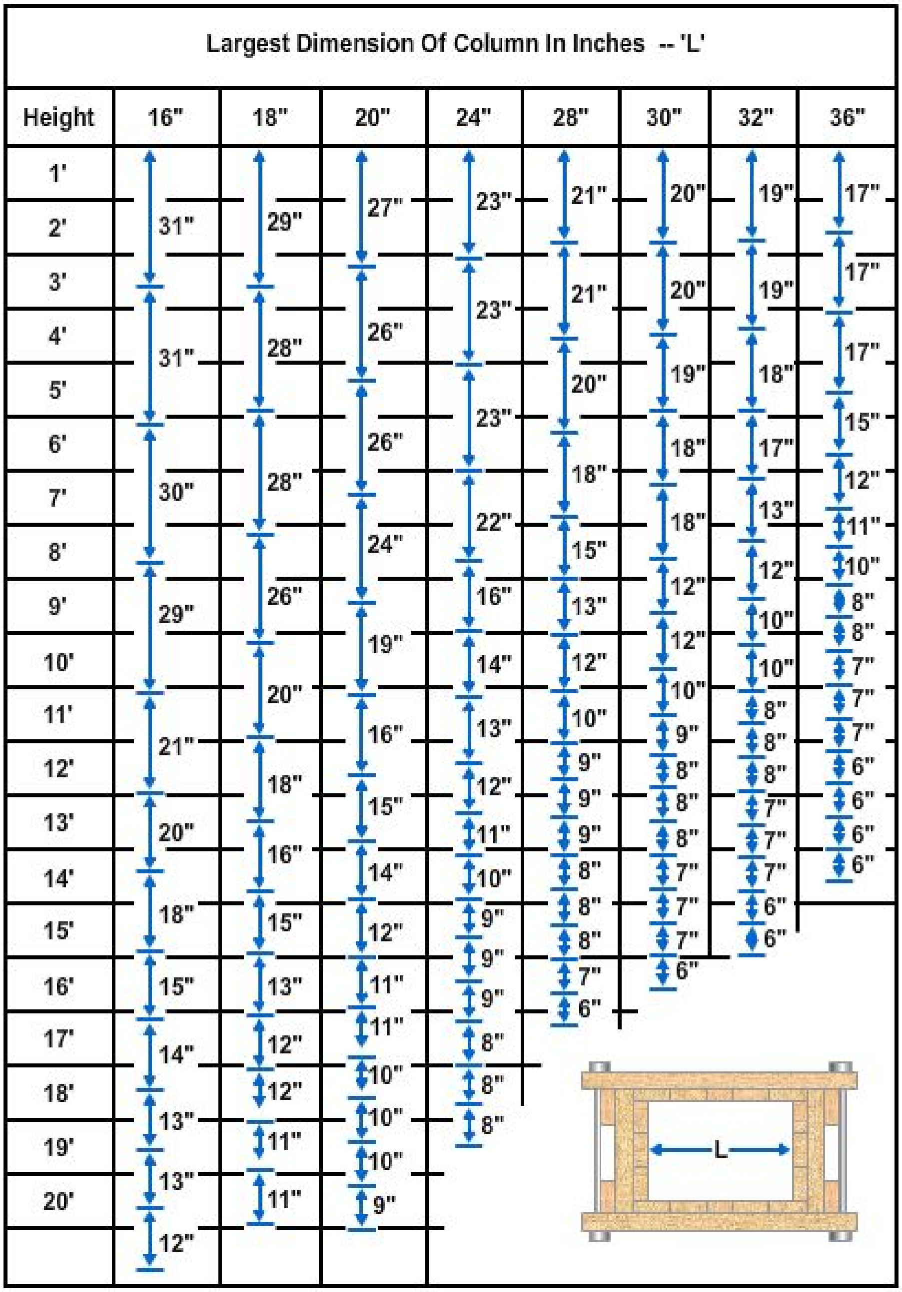


Figure 3-4 – Column Yoke Spacing.

2.4.0 Overhead Slab Form Design

The general goal of slab form design is a balanced form design. Give careful consideration to the design of the formwork due to the danger of failure from the weight of the concrete and the live load (LL) of the equipment and personnel on the forms. The following procedures uses some of the same figures used in the wall form design. See *Figure 3-5* for the nomenclature for a typical overhead form.

2.4.1 Sheathing

Sheathing shapes and holds the concrete. Plywood (usually 3/4 inch thick) or solid sheet metal (usually corrugated) is the best for use.

2.4.2 Joists

Joists support the sheathing against deflection. Joists perform the same function as studs in a wall form. Normally, you should use 4 inch lumber for joists; however, 2 inch or 3 inch stock can be used for joists if properly designed.

2.4.3 Stringers

Stringers support the joists against deflection. Stringers perform the same function as wales in a wall form, except stringers do not need to be doubled. Use 2 inch-thick lumber or larger.

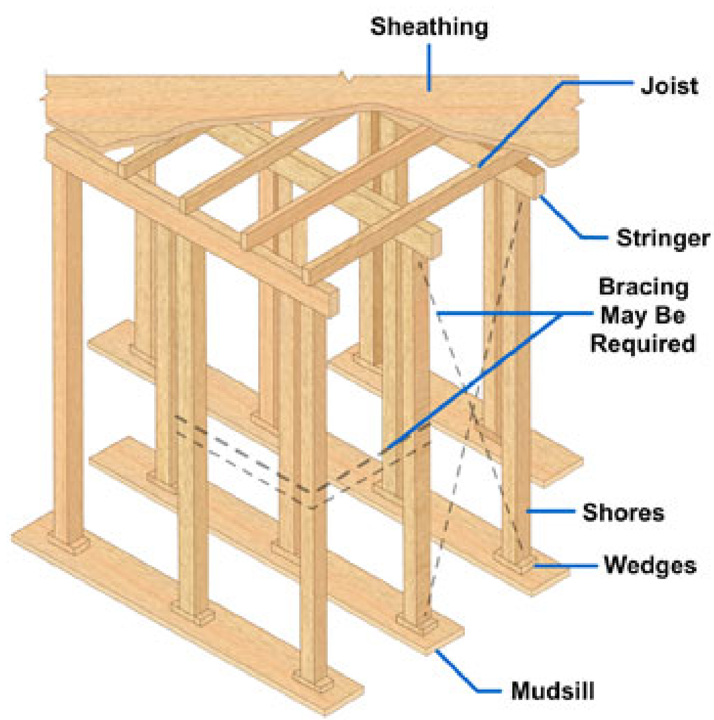


Figure 3-5 – Typical overhead slab form.

2.4.4 Shores

Shores support the stringers against deflection. Shores perform the same functions as ties in a wall form and also support the concrete at the desired elevation. The lumber used for this must be as large as the stringers but never smaller than 4 by 4 inches in dimension.

2.4.5 Lateral Bracing

Lateral bracing may be required between adjacent shores to keep the shores from bending under load. Usually 1 by 6 inch or larger stock is used for bracing. Bracing of some type will always be required to support the formwork.

2.4.6 Wedges

Wedges are normally used for two purposes: leveling of the forms and making the forms easier to strip.

2.4.7 Mudsills

Mudsills are continuous timber placed on the ground that distributes a load and provides a level surface for scaffolding and shoring.

2.4.8 Design Procedures

There is a nine step procedure for designing overhead forms.

1. The engineer will design and specify the materials you need to construct the overhead forms. Ensure that all the correct materials are on the job site and your crew is familiar with the materials and structural members.
2. Determine the maximum total load the forms will have to support. The rule of thumb for figuring the total load is live load (LL) plus dead load (DL). The live load (materials, personnel, and equipment) is estimated to be 50 pounds per square foot unless the forms will support engine-powered equipment. In this case, the LL would be 75 pounds per square foot. The dead load (concrete/rebar) is estimated at 150 pounds per cubic foot. However, you cannot add dead load to live load until you convert the dead load to square feet (SF). The formulas are as follows:

   Total Load (TL) = Live Load (LL) + Dead Load (DL)

   LL = 50 pounds/square foot
   or 75 pounds/square foot with power equipment

   $$\textbf{DL} = \frac{\textbf{150 pounds/cubic foot x slab thickness (inches)}}{\textbf{12 inches/foot}}$$

For example, if the slab is 6 inches in thickness, the formula would be as follows:

$$\textbf{DL} = \frac{\textbf{150 lbs/cf x 6 in}}{\textbf{12 in/ft}}$$

DL = 75 lbs/sf

TL = 50 lbs/sf (LL) + 75 lbs/sf

TL = 125 lbs/sf

3. Determine the maximum joist spacing. Use *Table 3-1* and read the joist spacing based on the sheathing material. Use the maximum TL in place of the maximum concrete pressure. For example, the sheathing is 3/4 inch plywood (strong way), the TL is 150 pounds per square foot, and the joist spacing would be 22 inches.
4. Calculate the uniform load on the joist. The same procedure is used as for determining uniform loads on the structural members in the wall form design.

   $$\textbf{Uniform Load on Joist (ULJ)} = \frac{\textbf{2L x Joist spacing (inches)}}{\textbf{12 inches/foot}}$$

5. Determine the maximum stringer spacing. Use *Table 3-2*; the uniform load on the joist is calculated in step 4. Round this load up to the next higher load located in the left column of the table, then read right to the column containing the lumber material used as the joist. This is the member to be supported by the stringer. The value at this intersection is the on center (OC) spacing of the stringer.
6. Calculate the uniform load on the stringer.

   Uniform Load on the Stringer (ULS str) =

   $$\frac{\textbf{TL x Maximum stringer spacing (inches)}}{\textbf{12 inches/foot}}$$

7. Determine the maximum shore spacing.

   (a) Maximum shore spacing is based on the stringer strength. Use *Table 3-2* or *Table 3-3*, depending on the type of stringer, and the uniform load on the stringer, rounded to the next higher load shown in the left column of the table. Read right to the stringer material column. This intersection is the OC spacing of the shore, which assures proper support of the stringer.

(b) Maximum shore spacing is also dependent on shore strength and end bearing of the stringer on the shore. Use the allowable load, as shown in *Tables 3-4* and *3-5*, based on the shore strength and the bearing stress strength of the stringer.

Table 3-4 – Allowable Load in Pounds on Wood Shores, Based on Shore Strength

Unsupported Length (in feet)	Nominal Lumber Size (in inches) (R indicates rough lumber; S4S indicates surfaced 4 sides					
	4 x 4 P	4 x 4 S4S	4 x 6 R	4 x 6 S4S	6 x 6 R	6 x 6 R
4	9,900	9,200	15,300	14,400	23,700	22,700
5	9,900	9,200	15,300	14,400	23,700	22,700
6	9,900	9,200	15,300	14,400	23,700	22,700
7	8,100	7,000	12,500	11,000	23,700	22,700
8	6,200	5,400	9,600	8,400	23,700	22,700
9	4,900	4,200	7,600	6,700	23,700	22,700
10	4,000	3,400	6,100	5,400	23,000	21,700
11	3,300	2,800	5,100	4,500	19,000	17,300
12	2,700	2,400	4,300	3,700	16,000	14,600
13	2,300	2,000	3,600	3,200	13,600	12,400
14	2,000	1,700	3,100	2,700	11,700	10,700
15	1,800		2,700		10,200	9,300
16					9,000	8,300
17					7,900	7,300
18					7,100	6,500
19					6,400	5,800
20					5,700	5,200
NOTE						
The values in the table above are based on wood members with the following strength characteristics: Compression parallel to grain = 750 psi; E = 1,100,000 psi.						

Table 3-5 – Allowable Loads on Specified Shores, Based on Bearing Stresses

Compression Perpendicular to Member Supported	Nominal Lumber Size (in inches)					
	4 x 4 R	4 x 4 S4S	4 x 6 R	4 x 6 S4S	6 x 6 R	6 x 6 S4S
250	3,000	3,100	5,100	4,800	7,900	7,600
350	4,600	4,300	7,100	6,700	11,100	10,600
385	5,100	4,700	7,800	7,400	12,200	11,600
400	5,300	4,900	7,700	7,700	12,700	12,100
For the table above: When the compression perpendicular to the grain of the member being supported is unknown, assume the most critical compression perpendicular to the grain.						

NOTE

Unsupported Length (UL) =

Height above the sill - Sheathing thickness - Joist thickness - Stringer thickness

This length has been rounded up to the next higher table value. For example, UL = 8 feet in height, minus 3/4 inch sheathing, minus 3 1/2 inch joist thickness, minus 3 1/2 inch stringer thickness, equals 7 feet 4 1/4 inches (round up to 8 feet), so the UL = 8 feet.

(c) Select the most critical shore spacing. Compare the spacing of the shore, based on the stringer strength (Step 7 (a)) and shore load (Step 7 (b)) and select the smaller of the two spacings.

8. Shore bracing check.

(a) Verify that the unbraced length (1) of the shore (in inches) divided by the least dimension (d) of the shore does not exceed 50. If l/d exceeds 50, the lateral and cross bracing are necessary. *Table 3-1* indicates the l/d is greater than 50 shore lengths and can be used if the shore material is sound and unspliced.

(b) In any case, it is good engineering practice to provide both lateral and diagonal bracing to all shore members if the material is available.

9. Summary.

2.4.9 Overhead Slab Design Form Procedures – Example Problem

Design the form for a roof of a concrete structure 6 inches thick by 20 feet wide by 30 feet in length. The roof will be 8 feet high above the floor (to the bottom of the slab). The concrete pump truck will be used to place the concrete.

1. Identify the material.

Sheathing: 3/4 inch plywood (strong way)

Joists: 4" x 4" lumber (S4S)

Stringers: 4" x 4" lumber (S4S)

Bracing: 1" x 6" lumber (S4S)

Mudsills: 2" x 12" lumber (S4S)

2. Determine the TL.

$$\textbf{DL} = \textbf{Concrete load} = \frac{\textbf{150 pounds/cubic feet x 6 inches}}{\textbf{12 inches/foot}}$$

= 75 pounds/square foot

LL = 75 pounds/square foot

TL = 75 pounds/square foot + 75 pounds/square foot

TL = 150 pounds/square foot

3. Determine the maximum joist spacing. Use *Table 3-1*.

3/4” plywood (strong way) and TL = 150 pounds/square foot

Joist spacing = 22 inches

4. Calculate the ULJ.

$$\textbf{ULJ} = \frac{\textbf{TL x joist spacing (inches)}}{\textbf{12 inches/foot}} = \frac{\textbf{150 lbs/sf x 22 in}}{\textbf{12 in/ft}}$$

= 275 lbs/lin ft

5. Determine the maximum stringer spacing by using *Table 3-2*.

Load = 275 pounds/linear foot

Joist material = 4” x 4” lumber (S4S)

Maximum stringer spacing = 55 inches

6. Calculate the UL stringer.

$$\textbf{TL} = \frac{\textbf{Maximum stringer spacing (inches)}}{\textbf{12 inches/foot}}$$

= 150 lbs/sf x 55 in = 12 in/ft

ULS str = 687.5 lbs/ft

7. Determine the maximum shoring spacing.

(a) Spacing based on stringer strength. Refer to *Table 3-2*.

Load = 687.6 pounds/foot (round up to 700)

Stringer material = 4” x 4” (S4S)

Maximum shore spacing = 35 inches

(b) Spacing based on the shoring strength and end bearing of the stringer, based on the allowable load in *Tables 3-4* and *3-5*.

- Allowable load based on shore strength as shown in *Table 3-4*.

  Unsupported length = 8’ - 3/4” - 3 1/2” - 3 1/2” = 7’ 4 1/4” (round up to 8 ft)

  Allowable load = 5,400 pounds

- Allowable load based on end bearing stresses as shown in *Table 3-5*. Since we do not know what species of wood we are using, you must assume the most critical and lowest compression perpendicular to the grain equals 250 and the allowable load for a 4 by 4 (S4S) equals 3,100 pounds.

- Select the most critical load.
- Determine shore spacing based on allowable load.

$$\textbf{Shore spacing} = \frac{\textbf{3,100 pounds}}{\textbf{ULS str (pounds/foot)}} \quad \textbf{x 12 inches/foot}$$

$$= \frac{\textbf{3,100 lb}}{\textbf{687.5 lb/ft}} \textbf{ x 12 in/ft}$$

$$= \textbf{54.1 in}$$

- Select the most critical shore spacing. The spacing determined in step 7(a) is less than the spacing determined in step 7(b); therefore, the shore spacing to use is 35 inches.

8. Shore deflection check.

l = 8' - 3/4" - 3 1/2" - 3 1/2" = 7' 4 1/4"

d = the actual dimension of a 4 x 4 = 3.5"

$$\textbf{l/d} = \frac{\textbf{7' 4 1/4"}}{\textbf{3.5"}} = \frac{\textbf{88.25"}}{\textbf{3.5"}} = \textbf{24.21} \leq \textbf{50}$$

Therefore, lateral and cross bracing are not required.

9. Summary.

Sheathing: 3/4 inch plywood

Joists: 4" x 4" (S4S) lumber spaced @ 22 inch OC

Stringers: 4" x 4" (S4S) lumber spaced @ 55 inch OC

Shores: 4 x 4 (S4S) lumber spaced@ 35 inch OC

Bracing: Not Required

2.5.0 Beam Form Design

Beam forms, like slab forms, carry a vertical load, and are also subjected to the lateral pressure of freshly placed concrete just as wall forms are. Beams can be formed independently to span walls and columns or monolithically (one continuous pour) as part of a floor slab system. When formed as part of a slab system, a part of the load from the slab forms may be carried by the beam form to the supporting shores and must be accounted for in the formwork design.

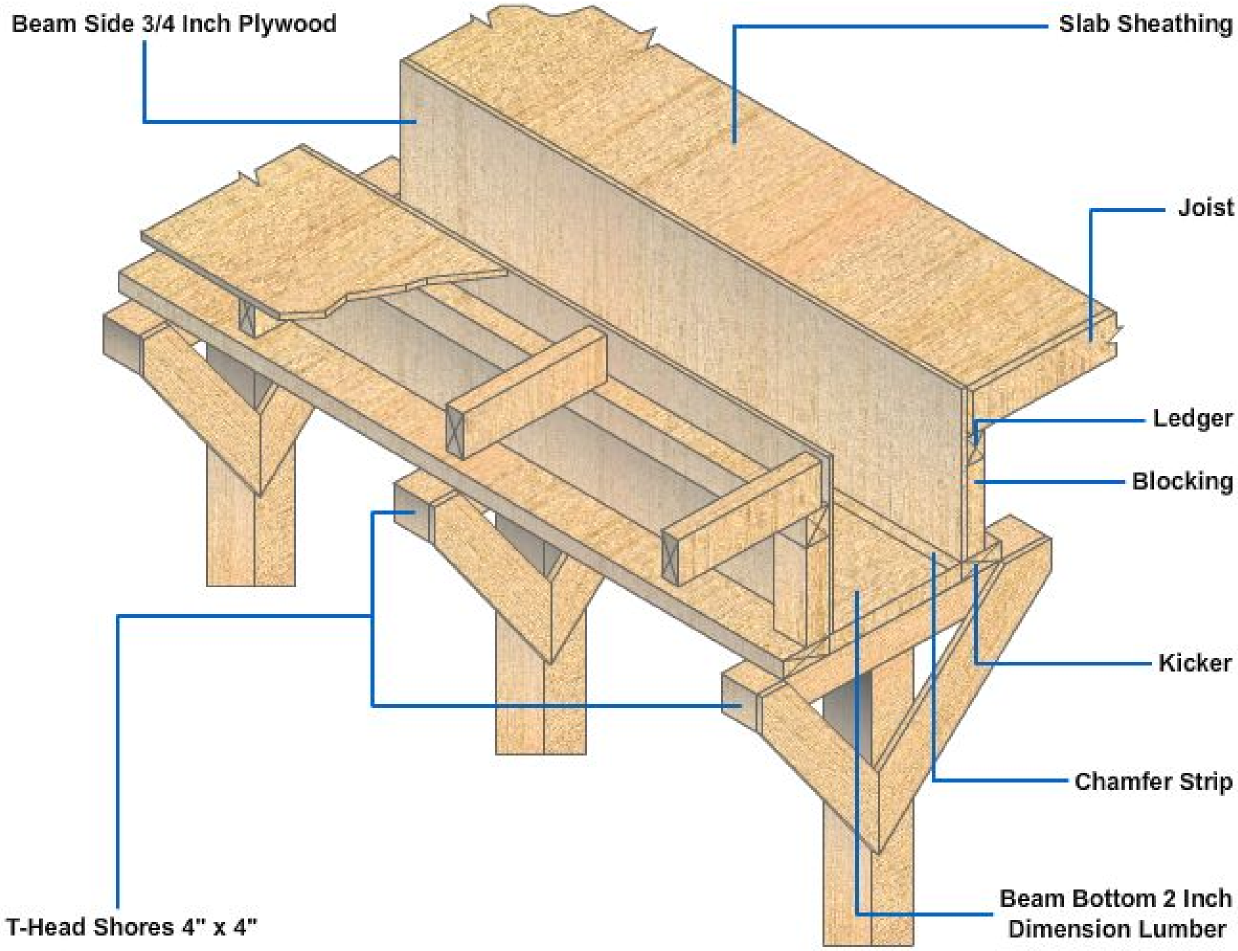


Figure 3-6 – Typical interior beam.

Figure 3-6 shows a typical interior beam form with slab forming supported on the beam sides. This drawing indicates that 3/4 inch plywood serves as the beam sides and that the beam bottom is a solid piece of 2 inch dimension lumber supported on the bottom by 4 by 4 inch T-head shores.

Close examination of *Figure 3-5* shows that when a beam is to be formed as part of a slab system, some of the design procedures have been completed. For example, the lateral pressure against the beam sides is compensated for by the slab joists which butts against the beam sides and rests on the attached ledger. All that remains to complete the design of a beam form is to determine the design load for which the form must be designed. If you know the design load, you can determine the maximum allowable bottom sheathing span (shore spacing) for the materials available. Next determine the total load per shore and complete the design with the selection of shore and bracing material that will safely support the vertical and lateral loads. You can accomplish each of these steps of beam form design by using the applicable procedures discussed in the previous section on overhead slab form design.

2.6.0 Labor Estimates

In this section we will briefly cover labor estimates for formwork according to the Seabee *Planner's and Estimator's Handbook,* NAVFAC P-405. *Figure 3-7* shows the labor chart from the P-405 which is self-explanatory on how to estimate labor. To calculate manpower estimates, you must first estimate the square footage of contact surface (SFCS). After estimating the SFCS of the work element, you then need to determine the units (100 SFCS/unit).

Work Element	Man-Hours Per Unit				
Description	Unit	Fabricate	Erect	Strip	Repair
Footing, Foundation Walls, and Grade Beams	100 SFCS	9	7	4	4
Walls to 10 feet high	100 SFCS	8	7	5	5
Columns and Piers	100 SFCS	9	10	5	5
Suspended Slabs	100 SFCS	8	12	4	5
Beams and Girders	100 SFCS	11	10	5	5
Slabs on Grade and Screed (up tp 8: thick including edge form)	100 SFCS	13 Complete			
Stairs	100 SFCS	55 Complete			
Thicken Edge and Slabs Greater then 8" Thick. Use Grade Beam Estimate	N/A	N/A			

Suggested Crew Size: Forming/Stripping: Five Builders
Forming/Stripping (Gang forms): Five Builders and two Equipment Operators

NOTES

1. Concrete forming estimates are based on using form accessories, form ties, and steel column clamps.
2. Suspended slabs, beams, and girders are figures that use 4 inch x 4 inch shores and wooden wedges. For adjustable shores, deduct 10% from erection time.
3. When forming and stripping are combined, stripping and cleaning forms will be approximately 17% of total labor.
4. On multiple use jobs, allow three man-hours for form repair per 100 sf of contact surface after four uses.
5. Gang forming usually requires a crane, an operator, and a signalman.
6. Forming walls over 10 feet high, and other high work will increase erection time 10 to 50%.

Figure 3-7 – Formwork labor chart.

For example, if you estimated 800 square feet of contact surface, then it is only a matter of dividing 800 by 100, which equals 8 units. Now enter the column for estimating man-hours per unit and you will see four separate columns: fabricate, erect, strip, and repair. It's just a matter of what scope of work you are performing and multiplying the work element by the scope of work.

You have just finished estimating 800 square feet of contact surface for your foundation wall and now you need to fabricate the formwork. To determine the man-hours required, just multiply the number of units (8) by man-hours per unit (9), which equals 72 man-hours. To find man-days, divide 72 man-hours by the number of hours you work in 1 day (determined by your unit) normally 8 hours per day, which will equal 9 duration days per person. So if you had a crew of three, it would take your crew 3 duration days to fabricate the formwork.

3.0.0 REINFORCED CONCRETE

Reinforced concrete refers to concrete containing steel (bars, rods, strands, wire, and mesh) as reinforcement and designed to absorb tensile and shearing stresses. Concrete structural members, such as footings, columns and piers, beams, floor slabs, and walls, must be reinforced to attain the necessary strength in tension. In this section, we will cover reinforcing steel and briefly discuss column, beam, and wall reinforcement.

3.1.0 Reinforcing Steel

Steel is the best material for reinforcing concrete because the coefficients of expansion of the steel and the concrete are almost the same; that is, at a normal temperature, they will expand and contract at an almost equal rate. (At very high temperatures, steel will expand more rapidly than the concrete, and the two materials will separate.)

Steel also works well as reinforcement for concrete because it makes a good bond with the concrete. This bond strength is proportional to the contact area surface of the steel to the concrete. In other words, the greater the surface of steel exposed to the adherence of the concrete, the stronger the bond. A deformed reinforcing bar is better than a plain round or square one. In fact, if you used plain bars of a given diameter instead of deformed bars, you would have to use approximately 40 percent more plain bars.

The adherence of the concrete depends on the roughness of the steel surface; the rougher the steel the better the adherence. Thus steel with a light, firm layer of rust is superior to clean steel, but steel with loose or scaly rust is inferior. Loose or scaly rust may be removed from the steel by rubbing the steel with burlap. The requirements for reinforcing steel are that it be strong in tension and, at the same time, ductile enough to be shaped or bent cold.

Reinforcing steel may be used in the form of bars or rods that are either plain or deformed or in the form of expanded metal, wire, wire fabric, or sheet metal. Each type is useful for a different purpose, and engineers design structures with these purposes in mind.

Plain bars are round in cross section. They are used in concrete for special purposes, such as dowels at expansion joints, where bars must slide in a metal or paper sleeve, for contraction joints in roads and runways, and for column spirals. They are the least used of the rod type of reinforcement because they offer only smooth, even surfaces for the adherence of concrete.

Deformed bars differ from plain bars in that they have indentations, ridges, or both on them, in a regular pattern. The twisted bar, for example, is made by twisting a plain, square bar cold. The spiral ridges along the surface of the deformed bar increase its bond strength with concrete.

Other forms used are the round and square corrugated bars. These are formed with projections around the surface that extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting. *Figure 3-8* shows a few of the various types of deformed bars available. In the United States, deformed bars are used almost exclusively, while in Europe, both deformed and plain bars are used.

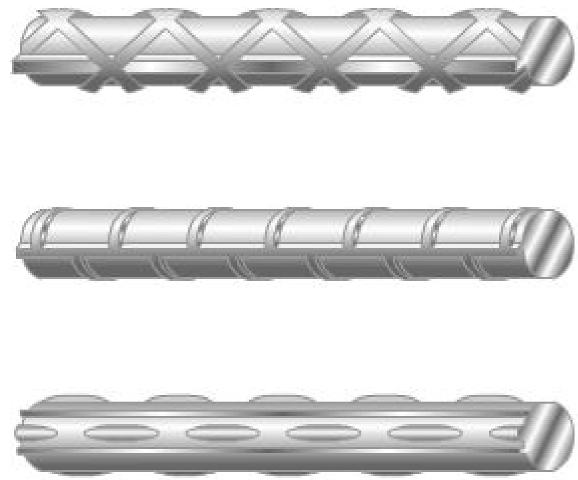


Figure 3-8 – Various types of deformed bar.

Eleven standard sizes of reinforcing bars are in use today. *Table 3-6* lists the bar number, area in square inches, weight, and nominal diameter of the 11 standard sizes. Bars No. 3 through 11 and 14 and 18 are all deformed bars.

Table 3-6 – U.S. Standard Reinforcing Steel Bars.

Bar Size Designation	Area Square Inches	Weight Pounds Per Foot	Diameter	
			Inches	Millimeters
#3	.11	.376	.375	9.53
#4	.20	.668	.500	12.7
#5	.31	1.043	.625	15.88
#6	.44	1.502	.750	19.05
#7	.60	2.044	.875	22.23
#8	.79	2.670	1.000	25.40
#9	1.00	3.400	1.128	28.58
#10	1.27	4.303	1.270	31.75
#11	1.56	5.313	1.410	34.93
#14	2.25	7.650	1.693	43.00
#18	4.00	13.600	2.257	57.33

Table 3-7 lists the bar number, area in square inches and millimeters, and nominal diameter of the 11 standard sizes. At some overseas sites, rebar procured locally could be metric. Remember that bar numbers are based on the nearest number of one-eighth inch included in the nominal diameter of the bar. To measure rebar, you must measure

across the round/square portion where there is no deformation. Do not measure the raised portion of the deformation when measuring the rebar diameter.

Table 3-7 – Comparison of U.S. Standard and Metric Rebar.

U.S. Standard Bar		Metric Bar		Metric Bar Is:
Bar Size	Area Square Inches	Bar Size	Area Square Inches	
#3	.11	10m	.16	45% larger
#4	.20	10m	.16	20% smaller
#4	.20	15m	.31	55% larger
#5	.31	15m	.31	Same
#6	.44	20m	.47	6.8% larger
#7	.60	20m	.47	22% smaller
#7	.60	25m	.78	30% larger
#8	.79	25m	.78	1.3% smaller
#9	1.00	30m	1.09	9% larger
#10	1.27	30m	1.09	14% smaller
#10	1.27	35M	1.55	22% larger
#11	1.56	35m	1.55	0.6% smaller
#14	2.25	45m	2.33	3.5% larger
#18	4.00	55m	3.88	3.0% smaller
NOTE Percent difference is based upon area of rebar in square inches.				

3.1.1 Reinforcing Bars

Reinforcing bars are hot-rolled from a variety of steels in several different strength grades. Most reinforcing bars are rolled from new steel billets, but some are rolled from used railroad-car axles or railroad rails that have been cut into rollable shapes. An assortment of strengths is available.

The *American Society for Testing Materials* (ASTM) has established a standard branding for deformed reinforcing bars. Two general systems of bar branding are used. Both serve the basic purpose of identifying the marker size, type of steel, and grade of each bar. In both systems an identity mark, denoting the type of steel used, is branded on every bar by engraving the final roll used to produce the bars so as to leave raised symbols between the deformations. The manufacturer's identity mark that signifies the mill that rolled the bar is usually a single letter or, in some cases, a symbol. The bar size follows the manufacturer's mark and is followed by a symbol indicating new billet steel (-N-), rolled rail steel (-I-), or rolled axle steel (-A-). *Figure 3-9* shows the two-grade marking system.

The lower strength reinforcing bars show only three marks: an initial representing the producing mill, the bar size, and the type of steel. The high strength reinforcing bars use either the continuous line system or the number system to show grade marks. In the line system, one continuous line is rolled into the 60,000 psi bars, and two continuous lines are rolled into the 75,000 psi bars. The lines must run at least five deformation spaces, as shown in *Figure 3-9*. In the number system, a "60" is rolled into the bar following the steel type of mark to denote 60,000 psi bars, and a "75" is rolled into the 75,000 psi bars.

AMERICAN STANDARD BAR MARKS

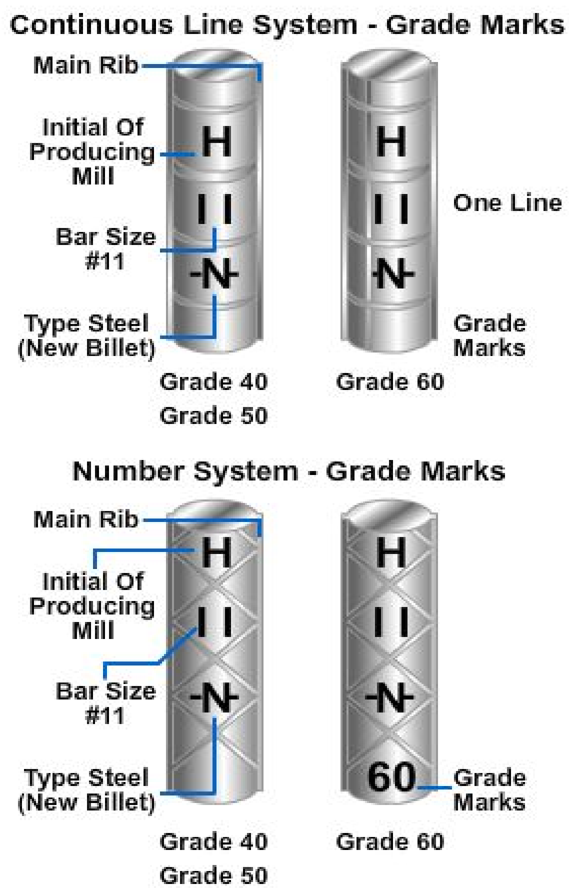
Lower strength bars show only 3 marks (no grade mark):

1st – Producing Mill (usually an initial)
2nd – Bar Size Number (#3 through #18)
3rd – Type (-N- for new Billet, A for Axle, T for Rail)
Mark "S" is a special billet steel, #14 and #18 only.

High strength bars must also show grade marks:

60 or One (1) line for 60,000 psi strength

(Grade mark lines are smaller and between the two main ribs which are on opposite sides of all American bars.)



REINFORCING BAR SPECIFICATIONS

U.S. standard specifications for enforcing bars are established by the American Society for Testing and Materials (ASTM). These standards govern strength grades, rib patterns, sizes, and markings of bars.

Reinforcing bars are produced from three kinds of steel; new billet, axle, or rail; in three grades of useful (yield) strengths. The yield strength of a bar is its useful strength.

The three ASTM Bar Specifications are:

A615 – Billet steel deformed bars
- Grade 40 – Sizes #3-#11
- Grade 60 – Sizes #3-#11, #14 and #18

A616 – Rail steel deformed bars
- Grade 40 – Sizes #3-#11
- Grade 60 – Sizes #3-#11

A617 – Axle steel deformed bars
- Grade 40 – Sizes #3-#11
- Grade 60 – Sizes #3-#11

Figure 3-9 – American standard reinforcing steel bar marks.

3.1.2 Expanded Metal and Wire Mesh Reinforcement

Expanded metal or wire mesh is also used for reinforcing concrete. Expanded metal is made by partly shearing a sheet of steel, as shown in *Figure 3-10, View A*. The sheet steel has been sheared in parallel lines and then pulled out or expanded to form a diamond shape between each parallel cut. Another type is square rather than diamond shaped, as shown in *Figure 3-10, View B*. Expanded metal is customarily used during plastering operations and light reinforcing concrete construction, such as sidewalks and for small concrete pads that do not have to bear substantial weight, such as transformer and air-conditioner pads.

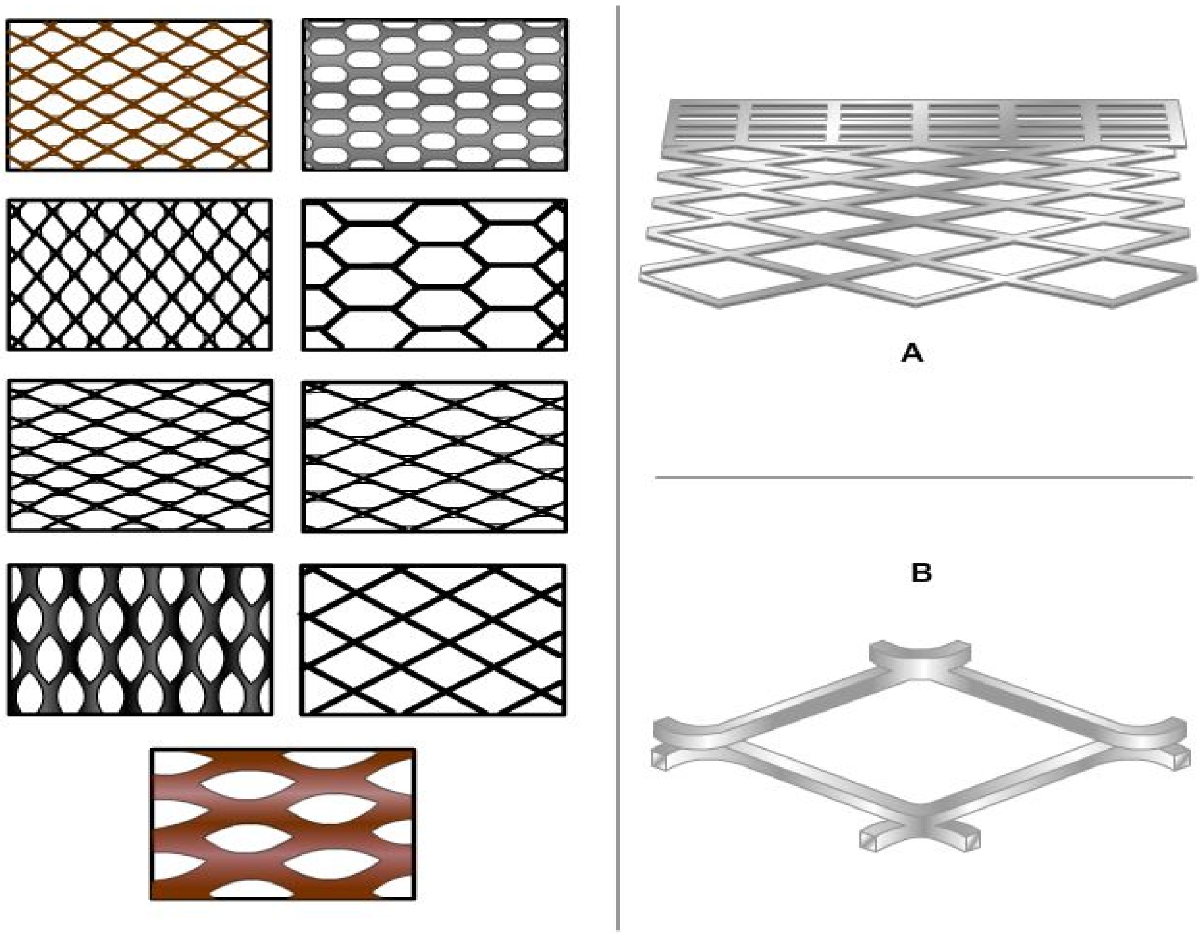


Figure 3-10 – Expanded or diamond mesh steel reinforcement.

3.1.3 Welded Wire Fabric

Welded wire fabric, shown in *Figure 3-11*, is fabricated from a series of wires arranged at right angles to each other and electrically welded at all intersections. Welded wire fabric, referred to as WWF within the NCF, has various uses in reinforced concrete construction. In building construction, it is most often used for floor slabs on well-compacted ground. Heavier fabric, supplied mainly in flat sheets, is often used in walls and for the primary reinforcement in structural floor slabs. Additional examples of its use include road and runway pavements, box culverts, and small canal linings.

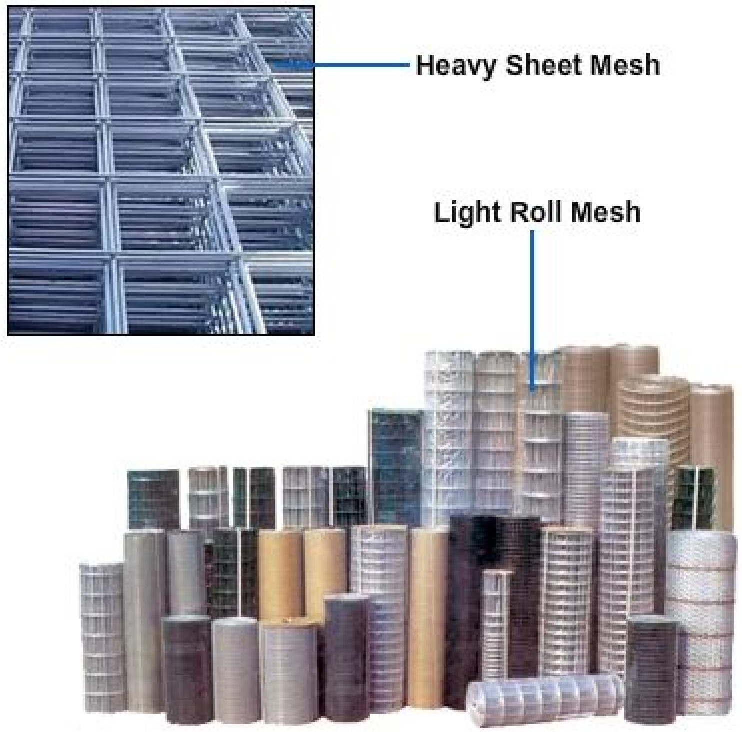


Figure 3-11 – Welded wire fabric reinforcement.

Four numbers are used to designate the style of wire mesh; for example, 6 by 6 - 8 by 8 (sometimes written 6 x 6 x 8 x 8 or 6 x 6 - W 2.1 x W 2.1). The first number (in this case, 6) indicates the lengthwise spacing of the wire in inches; the second number (in this case, 6) indicates the crosswise spacing of the wire in inches; the last two numbers (8 by 8) indicate the size of the wire on the Washburn and Moen gauge. More recently the last two numbers are a W number that indicates the size of the cross-sectional area in the wire in hundredths of an inch. See *Table 3-8*. WWF is currently available within the Navy stock system using the four-digit system, 6 by 6 - 8 by 8, as of this writing, but if procured through civilian sources, the W system is used.

Light fabric can be supplied in either rolls or flat sheets. Fabric made of wire heavier than W4 should always be furnished in flat sheets. Where WWF must be uniformly flat when placed, fabric furnished in rolls should not be fabricated of wire heavier than W 2.9. Fabricators furnish rolled fabric in complete rolls only. Stock rolls will contain from 700 to 1,500 square feet of fabric determined by the fabric and the producing location. The unit weight of WWF is designated in pounds per one hundred square feet of fabric, as shown in *Table 3-8*. Five feet, six feet, seven feet, and seven feet six inches are the standard widths available for rolls, while the standard panel widths and lengths are seven feet by twenty feet and seven feet six inches by twenty feet.

Table 3-8 – Common Stock Sizes of Welded Wire Fabric.

Style Designation		Weight Approximate Pounds per 100 Square Feet
Current Designation (by W-Number)	Previous Designation (by Steel Wire Gauge)	
Panels/Sheets		
6 x 6 – W 1.4 x W 1.4	6 x 6 – 10 x 10	21
6 X 6 –W 2.1 X W 2.1	6 X 6 – 8 X 8	29
6 X 6 – W 2.9 X W 2.9	6 x 6 – 6 x 6	42
6 x 6 – W 4.0 x W 4.0	6 x 6 – 4 x 4	58
4 x 4 – W 1.4 x W 1.4	4 x 4 – 10 x 10	31
4 x 4 – W 2.1 x W 2.1	4 x 4 – 8 x 8	43
4 x 4 – W 2.9 x W 2.9	4 x 4 – 6 x 6	62
4 x 4 – W 4.0 x W 4.0	4 x 4 – 4 x 4	86
Rolls		
6 x 6 – W 1.4 x W 1.4	6 x 6 – 10 x 10	21
6 x 6 – W 2.9 x W 2.9	6 x 6 – 6 x 6	42
6 x 6 – W 4.0 x W 4.0	6 x 6 – 4 x 4	58
6 x 6 – W 5.5 x W 5.5	6 x 6 – 2 x 2	80
4 x 4 – W 4.0 x W 4.0	4 x 4 – 4 x 4	86

3.2.0 Column Reinforcement

A column is a slender, vertical member that carries a superimposed load. Concrete columns, especially those subjected to bending stresses, are always reinforced with steel. A pier or pedestal is a compressive member that is short (with height usually less than three times the least lateral dimension) in relation to its cross-sectional area and carries no bending stress. A bearing wall could be classified as a continuous pier. In concrete columns, vertical reinforcement is the principal reinforcement. A loaded column shortens vertically and expands laterally; so lateral reinforcements in the form of lateral ties are used to restrain the expansion. Columns reinforced in this manner are called tied columns, shown in *Figure 3-12, View A*. If the restraining reinforcement is a continuous winding spiral that encircles the core and longitudinal steel, the column is called a spiral column as shown in *Figure 3-12, View B*.

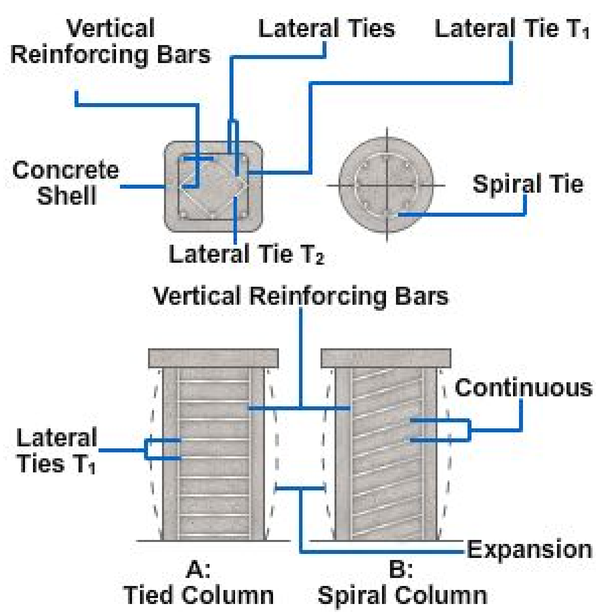


Figure 3-12 – Reinforced concrete columns.

3.3.0 Beam Reinforcement

Beams are the principal load-carrying horizontal members. They take the load directly from the floor and carry it to the columns. Concrete beams can either be cast in place or precast and transported to the job site. *Figure 3-13* shows several common types of beam reinforcing steel shapes. Both straight and bent-up principal reinforcing bars are needed to resist the bending tension in the bottom over the central portion of the span. Fewer bars are necessary on the bottom near the ends of the span where the bending movement is small. For this reason, some bars may be bent so that the inclined portion can be used to resist diagonal tension. The reinforcing bars of continuous beams are continued across the supports to resist tension in the top in that area.

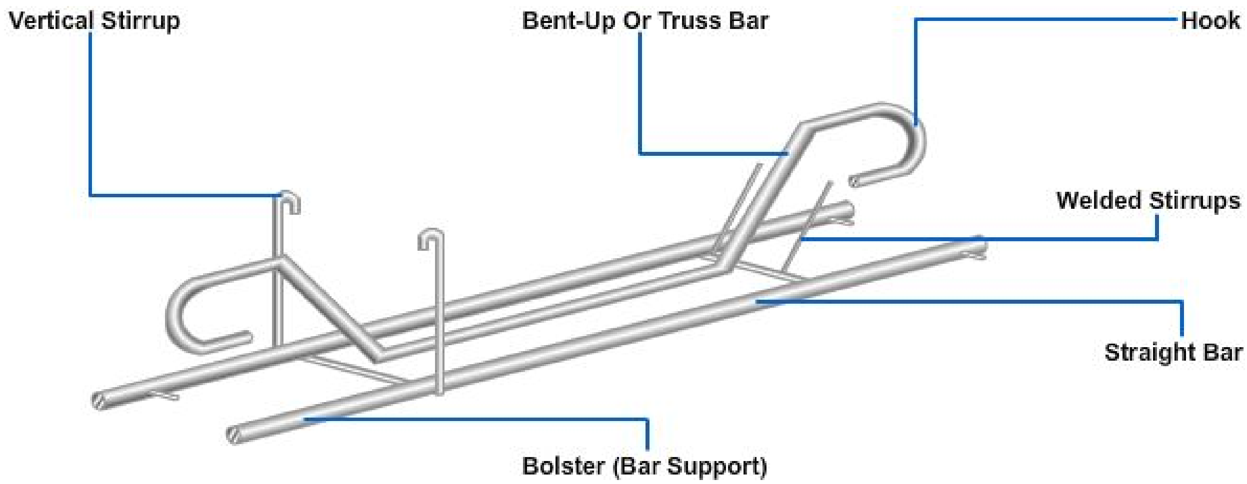


Figure 3-13 – Typical shapes of reinforcing steel.

3.4.0 Wall Reinforcement

The placement of steel reinforcement in load-bearing walls is the same as for columns, except that the steel is erected in place and not preassembled. Horizontal steel is tied to vertical steel at least three times in any bar length. The wood block is removed when the form has been filled up to the level of the block, as shown in *Figure 3-14*.

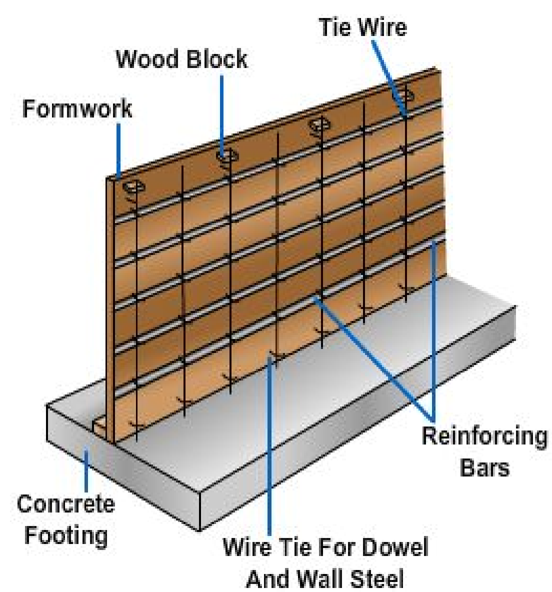


Figure 3-14 – Steel in place in a wall.

4.0.0 DESIGN of CONCRETE MIXTURES

From your previous studies, you know that the basic ingredients used in the production of concrete are cement (usually Portland cement), water, and both fine and coarse aggregates. You also know that certain admixtures are used occasionally to meet special requirements. The design of a concrete mixture consists of determining the correct amount of each ingredient needed to produce a concrete that has the necessary consistency or workability in the freshly mixed condition and that has desired strength and durability characteristics in the hardened condition.

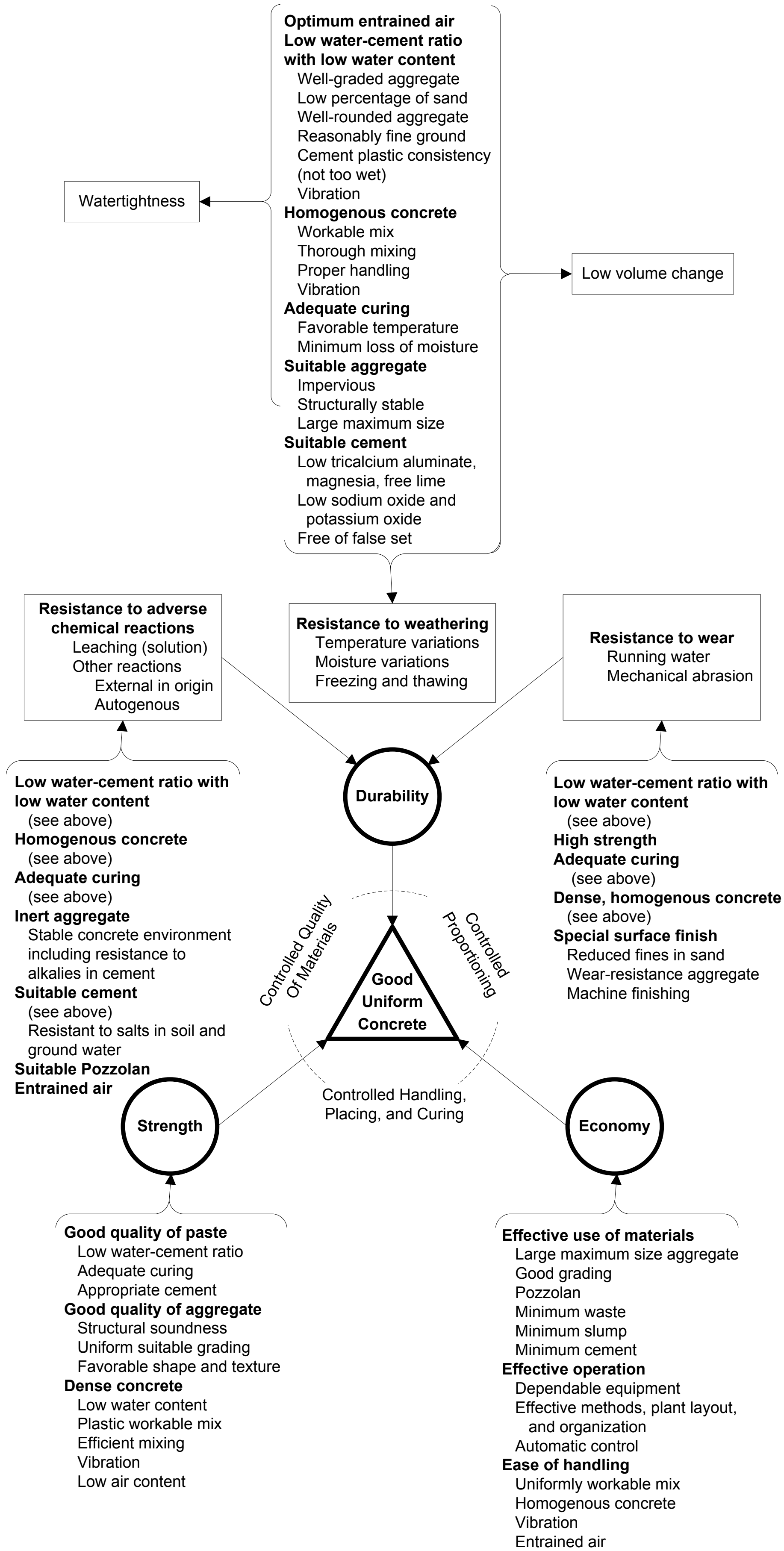


Figure 3-15 – Concrete proportions.

Consider the characteristics of concrete on a relative basis and in terms of degree of quality required for a given construction project. *Figure 3-15* shows some of the properties of good concrete, their interrelationships, and various elements that control the properties. A study of this figure points up the relative basis of the characteristics. A single batch of concrete cannot possess the maximum of strength, durability, and economy. For example, entrained air makes handling easier and is, therefore, conducive to economy; entrained air promotes watertightness, but entrained air makes concrete less dense and thereby reduces the strength. The goal is to achieve an optimum balance of all the elements. A thorough discussion of all the factors involved in the production of good concrete is beyond the scope of this manual. A wealth of information is available to you in government and commercial publications, especially the *American Concrete Institute* (ACI) manuals.

The design of or the selection of a mix, the necessity for a trial mix, the methods of controlling the mix proportions, and the units of measure to be used in the batching all depend on the nature and size of the job and the extent to which requirements are set forth in the specifications or on the plans. An example of the simplest form of concrete batching is the mixing of a very small amount of concrete using the 1:2:4 carpenter's mix. The relative volumes of cement, sand, and gravel could be measured in bucketfuls, or even in shovelfuls, and with sufficient water added to give reasonable consistency. A more refined procedure is to fabricate a 1 cubic foot wooden measuring box to give you greater control over the proportions of the ingredients. To mix approximately 1 cubic yard of 1:2:4 concrete, you use the "Rule of 42." Add the numbers of the mix design together 1 + 2 + 4 = 7, then divide the rule (42) by the mix design (7), which equals 6. This means it will take 6 parts per cubic foot of material. For example:

Cement (1 x 6) 6 cubic feet

Sand (2 x 6) 12 cubic feet

Gravel (4 x 6) 24 cubic feet

Total of dry mix 42 cubic feet = 1 cubic yard produced

NOTE

One bag of cement equals one cubic foot of cement.

In addition to the carpenter's mix, there are other popular rule-of-thumb mixes:

1:1:2 – very rich mix. Use when great strength is required.

1:2:5 – a medium mix. Use in large slabs and walls.

1:3:5 – a lean mix. Use in large foundations or as a backing for masonry.

1:4:8 – a very lean mix. Use only in mass placing.

To achieve more control over the proportional quantities of cement, water, and aggregate for a concrete mix, you can use one of three methods: book, trial batch, or absolute volume. These three methods of proportioning concrete mixtures will be briefly covered in this section.

- The BOOK METHOD is a theoretical procedure establishing data to determine mix proportions.
- The TRIAL BATCH METHOD is based on an estimated weight of concrete per unit volume.

- The Absolute Volume method is based on calculations of the ABSOLUTE VOLUME occupied by the ingredients used in the concrete mixture.

For a more thorough discussion, you should refer to the most recent edition of *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete* (ACI 211.1), published by the American Concrete Institute (ACI), and the *Engineering Aid Intermediate/Advanced.*

4.1.0 Book Method

The Book Method is a theoretical procedure in which established data is used to determine mix proportions. Because of the variation of the materials (aggregates) used, mixes arrived at by the book method require adjustment in the field following the mixing of trial batches and testing. Design concrete mixtures to give the most economical and practical combination of the materials that will produce the necessary workability in the fresh concrete and the qualities in the hardened concrete.

4.1.1 Selecting Mix Characteristics

Certain information must be known before a concrete mixture can be proportioned. The size and shape of structural members, the concrete strength required, and the exposure conditions must be determined. The water-cement ratio, the aggregate characteristics, the amount of entrained air, and the slump are significant factors in the selection of the appropriate concrete mixture.

4.1.2 Water-Cement Ratio

The water-cement ratio is determined by the strength, durability, and watertightness requirements of the hardened concrete. The ratio is usually specified by the structural design engineer, but you can arrive at tentative mix proportions from knowledge of a prior job. Always remember that a change in the water-cement ratio changes the characteristics of the hardened concrete. Use *Table 3-9* to select a suitable water-cement ratio for normal weight concrete that will meet anticipated exposure conditions. Note that the water-cement ratios in *Table 3-9* are based on concrete strength under certain exposure conditions.

Table 3-9 – Maximum Permissible Water-Cement Ratios for Various Exposure Conditions.

Exposure Condition	Normal-weight Concrete, Absolute Water-Cement Ratio by Weight
Concrete protected from exposure to freezing and thawing and exposure to de-icer chemicals. Select water-cement ratio on basis of strength, workability, and finishing needs.	
Watertight concrete:	
In fresh water	0.50
In sea water	0.45
Frost resistant concrete:	
Thin sections: any section with less than 2inch cover over reinforcement and any concrete exposed to deicing salts	0.45
All other structures	0.50
Exposure to sulfates:	
Moderate	0.50
Severe	0.45
Placing concrete under water	Not less than 650 pounds of cement per cubic yard (386 kilograms per cubic meter)
Floors on grade	Select water-cement ratio for strength, plus minimum cement requirements.

If possible, perform the tests using job materials to determine the relationship between the water-cement ratio you select and the strength of the finished concrete. If you cannot obtain laboratory test data or experience records for the relationship, use *Table 3-10* as a guide. Enter *Table 3-10* at the desired f'_c (specified compressive strength of the concrete in pounds per square inch, psi) and read across to determine the maximum water-cement ratio.

Table 3-10 – Relationship Between Water-Cement Ratios and Compressive Strength of Concrete.

Specified Compressive Strength	Maximum Absolute Permissible Water-Cement Ratio, by Weight	
f'_c psi*	**Non-Air-Entrained Concrete**	**Air-Entrained Concrete**
2,500	0.67	0.54
3,000	0.58	0.46
3,500	0.51	0.40
4,000	0.44	0.35
4,500	0.38	**
5,000	**	**

* 28-day strength. With most materials, the water-cement ratios shown will provide average strengths greater than required.

** For strengths above 4,500 psi (non-air-entrained concrete) and 4,000 psi (air-entrained concrete) proportions should be established by the trial batch method.

You can interpolate between the values. When both exposure conditions and strength must be considered, use the lower of the two indicated water-cement ratios. If flexural strength, rather than compressive strength, is the basis of design, such as in a pavement, perform the tests to determine the relationship between the water-cement ratio and the flexural strength. An approximate relationship between flexural strength and compressive strength is as follows:

f'_c = compressive strength, psi

R = flexural strength, psi

k = a constant, usually between 8 and 10

4.1.3 Aggregate

Use fine aggregate to fill the spaces between the coarse aggregate particles and to increase the workability of a mix. In general, aggregate that does not have a large grading gap or an excess of any size, but gives a smooth grading curve, produces the best mix.

Use the largest practical size of coarse aggregate in the mix. The maximum size of coarse aggregate that produces concrete of maximum strength for a given cement content depends upon the aggregate source as well as the aggregate shape and grading. The larger the maximum size of the coarse aggregate, the less paste (water and cement) required for a given concrete quality. The maximum size of aggregate should never exceed one fifth of the narrowest dimension between side forms, one third of the depth of slabs, or three fourths of the distance between reinforcing bars.

4.1.4 Entrained Air

Use entrained air in all concrete exposed to freezing and thawing, and, sometimes under mild exposure conditions, to improve workability. Always use entrained air in paving concrete regardless of climatic conditions. *Table 3-11* gives recommended total air contents of air-entrained concretes. When mixing water remains constant, air entrainment increases slump. When cement content and slump remain constant, less mixing water is required. The resulting decrease in the water-cement ratio helps to offset possible strength decreases and improves other paste properties such as permeability. The strength of air-entrained concrete may equal, or nearly equal, that of non-air-entrained concrete when cement contents and slump are the same. The upper half of *Table 3-11* gives the approximate percent of entrapped air in non-air-entrained concrete, and the lower half gives the recommended average total air content percentages for air-entrained concrete based on level of exposure.

Table 3-11 – Approximate Mixing Water and Air Content Requirements for Different Slumps and Maximum Sizes of Aggregates.

Water, Pounds per Cubic Yard of Concrete, for Indicated Maximum Sizes of Aggregate*								
Slump, inches	3/8 inch	1/2 inch	3/4 inch	1 inch	1 1/2 inch	2 inch**	3 inch**	6 inch**
Non-Air-Entrained Concrete								
1 to 2	350	335	315	300	275	260	240	210
3 to 4	385	365	340	325	300	285	265	230
6 to 7	410	385	360	340	315	300	285	
Approximate Amount of Entrapped Air In Non-Air-Entrapped Concrete, %	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-Entrained Concrete								
1 to 2	305	295	280	270	250	240	225	200
3 to 4	340	325	305	295	275	265	250	220
6 to 7	365	345	325	310	290	280	270	--
Recommended Average Total Air Content, % for Level of Exposure								
Mild Exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate Exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Extreme Exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

* These quantities of mixing water are for use in computing cement factors for trial batches. They are maximums for reasonably wellshaped angular coarse aggregates graded within limits of accepted specifications.

** The slump values for concrete containing aggregate larger than 1 1/2 inches are based on slump tests made after removal of particles larger than 1 1/2 inches by wet screening.

4.1.4.1 Mild Exposure

Mild exposure includes indoor or outdoor service in a climate that does not expose the concrete to freezing or de-icing agents. When you want air entrainment for a reason other than durability, such as to improve workability or cohesion or to improve strength in low cement factor concrete, use air contents lower than those required for durability.

4.1.4.2 Moderate Exposure

Moderate exposure means service in a climate where freezing is expected but where the concrete is not continually exposed to moisture or free water for long periods before freezing, or to deicing agents or other aggressive chemicals. Examples are exterior beams, columns, walls, girders, or slabs that do not contact wet soil or receive direct application of deicing salts.

4.1.4.3 Severe Exposure

Severe exposure means service where the concrete is exposed to deicing chemicals or other aggressive agents, or where it continually contacts moisture or free water before freezing. Examples are pavements, bridge decks, curbs, gutters, sidewalks, or exterior water tanks or sumps.

4.2.0 Trial Batch Method

In the trial batch method of mix design, use actual job materials to obtain mix proportions. The size of the trial batch depends upon the equipment you have and the number of test specimens you make. Batches using 10 to 20 pounds of cement may be big enough, although larger batches produce more accurate data. Use machine mixing if possible, since it more nearly represents job conditions. Always use a machine to mix concrete containing entrained air. Be sure to use representative samples of aggregate, cement, water, and air-entraining admixture in the trial batch. Prewet the aggregate and allow it to dry to a saturated, surface-dry condition. Then place it in covered containers to maintain this condition until you use it. This action simplifies calculations and eliminates errors caused by variations in aggregate moisture content. When the concrete quality is specified in terms of the water-cement ratio, the trial batch procedure consists basically of combining paste (water, cement, and usually entrained air) of the correct proportions with the proper amounts of fine and coarse aggregates to produce the required slump and workability. Then calculate the large quantities per sack or per cubic yard. Refer to the *Engineering Aid Advanced NRTC* for further information and calculations of the trial batch method and the absolute volume method.

4.3.0 Absolute Volume Method

The absolute volume method is based on calculations of the volume occupied by the ingredients used in the concrete mixture. For this procedure, select the water-cement ratio, slump, air content, and maximum aggregate size, and estimate the water requirement as you did in the trial batch method. Before making calculations, you must have certain other information such as the specific gravities of the fine and coarse aggregate, the dry-rodded unit weight of the coarse aggregate, and the fineness modulus of the fine aggregate (refer to ACI 214). Now you can determine the dry-rodded unit weight of coarse aggregate and calculate the quantities per cubic yard of water, cement, coarse aggregate, and air. Finally, subtract the sum of the absolute volumes of these materials in cubic feet from 27 cubic feet per 1 cubic yard to give the specific volume of the aggregate. If needed, more trial batches should be mixed to obtain the desired slump and air content while you keep the water-cement ratio constant.

4.4.0 Mix Variations

The proportions arrived at in determining mixes will vary somewhat depending upon which method is used because of the nature of the methods. One method is not necessarily better than another. Each method begins by assuming certain needs or requirements and then proceeds to determine the other variables. Since the methods begin differently and use different procedures, the final proportions vary slightly. This is to be expected, and it further points out the necessity of trial mixes in determining the final mix proportions.

4.5.0 Mix Adjustments

Construction crews in the field convert the designed trial mix proportions into field mix proportions suitable for the mixing equipment available. Remember, however, that the trial mix method was designed under controlled conditions based on certain assumptions that may not exist in the field. For this reason, field crews must often adjust the mix for moisture and entrained air.

4.6.0 Admixtures

Admixtures include all materials other than Portland cement, water, and aggregates that are added to concrete, mortar, or grout immediately before or during mixing. Admixtures are sometimes used in concrete mixtures to improve certain qualities such as workability, strength, durability, watertightness, and wear resistance. They may also be added to reduce segregation, reduce heat of hydration, entrain air, and accelerate or retard setting and hardening. The same results can often be obtained by changing the mix proportions or by selecting other suitable materials without resorting to the use of admixtures (except air-entraining admixtures when necessary). Whenever possible, compare these alternatives to determine which is more economical and/or convenient. Any admixture to be in concrete should be added according to current specifications and under the direction of the engineer in charge.

The most commonly used admixture in concrete mixtures is an air-entraining agent of the type discussed in the previous section on Mix Adjustments for entrained air. In general, air-entraining agents are derivatives of natural wood resins, animal or vegetable fats or oils, alkali salts of sulfated or sulfonated organic compounds, and water-soluble soaps. Most air-entraining agents are in liquid form for use in the mix water. The instructions for the use of the various agents to produce a specified air content are provided by the manufacturer.

Automatic dispensers, made available by some manufacturers, permit more accurate control of the quantities of air-entraining agents used in the mix. The main reason for using intentionally entrained air is to improve the resistance of the concrete to freezing and thawing exposure. However, there are other important beneficial effects in both freshly mixed and hardened concrete, which include workability, resistance to deicers, sulfate resistance, strength, abrasion resistance, and watertightness.

4.7.0 Slump Test

The slump test measures the consistency of concrete. Do not use it to compare mixes having wholly different proportions or containing different sizes of aggregates. When different batches are tested, changes in slump indicate changes in materials, mix proportions, or water content. *Table 3-12* gives recommended slump ranges for various types of construction.

Table 3-12 – Recommended Slumps for Various Types of Construction.

Concrete Construction	Maximum Slump (in inches*)	Minimum Slump (in inches*)
Reinforced Foundation Walls and Footings	3	1
Plain Footings, Caissons, and Substructure Walls	3	1
Beams and Reinforced Walls	4	1
Building Columns	4	1
Pavements and Slabs	3	1
Mass Concrete	2	1
* May be increased 1 inch for consolidation by methods such as rods and spades. 1 inch – 25 mm		

4.8.0 Compressive Test

The compressive strength of concrete (the ability to resist a crushing force) is, as previously explained, controlled by the water-cement ratio. However, the theoretical compressive strength related to a particular water-cement ratio will be attained only if the actual amount of water added is carefully regulated according to the considerations previously mentioned. Samples cast from the mix being used must be cured and tested to determine what compressive strength was actually attained.

The first step is to obtain a sample of the concrete. The sample should consist of not less than 1 cubic foot when it is to be used for strength tests. Smaller samples may be permitted for routine air content and slump tests.

During the sampling procedures, use every precaution that will assist in obtaining samples representative of the true nature and condition of the concrete sample, as follows:

1. Sampling from stationary mixers except paving mixers. The sample must be obtained by passing a receptacle completely through the discharge stream of the mixer at about the middle of the batch or by diverting the stream completely so that it discharges into a container. Care must be taken not to restrict the flow from the mixer in such a manner as to cause the concrete to segregate. These requirements apply to both tilting and non-tilting mixers.
2. Sampling from paving mixers. The contents of the paving mixer must be discharged, and the sample must be collected from at least five different portions of the pile.
3. Sampling from revolving drum truck mixers or agitators. The sample must be taken at three or more regular intervals throughout the discharge of the entire batch, except that samples must not be taken at the beginning or end of the discharge. Sampling must be done by repeatedly passing a receptacle through the entire discharge stream or by diverting the stream completely so that it

discharges into a container. The rate of discharge of the batch must be regulated by the rate of revolution of the drum, and not by the size of the gate opening.

Transport the sample to the place where test specimens are to be molded or where the test is to be made and remix it with a shovel at the minimum amount to ensure uniformity. Protect the sample from sunlight and wind during the period between taking and using, which must not exceed 15 minutes.

Tests are made on 6 by 12-inch cylinders, cast in cylindrical molds. For the final test, a cylinder is cured for 28 days; however, the probable 28-day strength that a mix will attain can be estimated by determining the 7-day strength (which actually runs about 2/3 of the 28-day strength). Therefore, one or more cylinders are tested after 7 days of curing.

Test cylinders are cast in either metal or heavy cardboard molds. For filling, place a mold on a metal base plate. To avoid loss of the mix water, you can seal the bottom of the mold to the base plate with paraffin. A cardboard mold is expendable, that is, for stripping it from the test cylinder, it is simply torn off. A metal mold is hinged so that it can be stripped by opening. Before the mold is filled, lightly oil the inside surface and base to prevent the concrete from bonding (adhering) to the mold and plate.

Form the test specimens by placing the concrete in the mold in three layers of approximately equal volume. In placing each scoopful of concrete, move the scoop around the top edge of the mold as the concrete slides from it to ensure a symmetrical distribution of the concrete within the mold. Further distribute the concrete with a circular motion of the tamping rod. Rod each layer with 25 strokes of a 5/8-inch round rod, approximately 24 inches in length and tapered for a distance of 1 inch to a spherically shaped end having a radius of approximately 1/4 inch. Distribute the strokes uniformly over the cross section of the mold, making sure they penetrate into the underlying layer. Rod the bottom layer throughout its depth. Where voids are left by the tamping rod, tap the sides of the mold to close the voids. After the top layer has been rodded, strike the surface of the concrete off with a trowel and cover with a glass or metal plate to prevent evaporation.

After about 24 hours of hardening, strip the mold off and immerse the cylinder in either water, moist sand, moist sawdust, or moist earth for curing. At the expiration of the curing period (7 or 28 days), cap the cylinder on both ends with a thin layer of gypsum casting plaster or sulfur capping compound. For testing, place the cylinder under the piston of a machine capable of applying a very high pressure (for a 6 inch-diameter cylinder with a compressive strength of about 6,000 pounds per square inch, the rupturing pressure must reach about 170,000 pounds). Apply pressure, increasing it until the cylinder collapses.

4.9.0 Flexural Test

The flexural strength is its ability to resist a breaking force. The flexural strength of concrete is considerably less than its compressive strength. For a flexural strength test, a test beam cast in a test beam mold, like the one shown in *Figure 3-16*, is cured and then broken by a beam breaker.

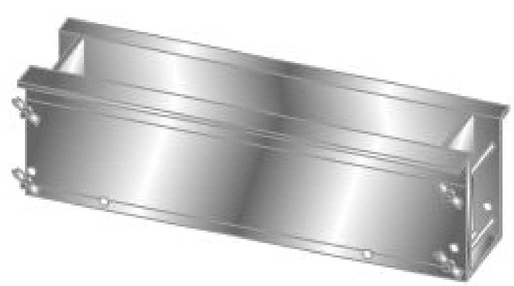


Figure 3-16 – Test beam mold.

The test specimen must be formed with its long axis horizontal. Place the concrete in layers approximately 3 inches in depth, and rod each layer 50 times for each square foot of area. The top layer must slightly overfill the mold. After rodding each layer, spade the concrete along the sides and ends with a mason's trowel or other suitable tool. When the rodding and spading operations are completed, strike off the top with a straightedge and finish with a wood float. The test specimen must be made promptly and without interruption. Cure the test beams for a period of 28 days. Like cylinders, the flexural strength may be determined after 7 days, utilizing the probable 28-day strength of concrete.

4.10.0 Computing Concrete

To compute the volume of concrete required for a concrete pad, multiply the length of the pad by its width times its thickness to get cubic feet (length x width x thickness). For example, a concrete pad is 20 feet long by 30 feet wide with a slab thickness of 4 inches. First convert the 4 inches into feet by dividing 3 by 12 to get 0.333 feet. Next, multiply the 20 feet by 30 feet to get 600 square feet. Then multiply 600 square feet by 0.333 to determine the volume in cubic yards of concrete required for the pad which, in this case, is 200 cubic feet.

Concrete is ordered and produced in quantities of cubic yards. To calculate the number of cubic yards required for the pad, divide the cubic feet of the pad by 27. This is required because there are 27 cubic feet in 1 cubic yard. Therefore, the concrete pad described in the previous paragraph, which has a volume of 200 cubic feet, requires 7.41 cubic yards of concrete.

$$\textbf{CD} = \frac{\textbf{Length x Width x Thickness (feet)}}{\textbf{27 cubic feet/cubic yard}}$$

30' x 20' x 4" = 30' x 20' x .333' = 200 cubic feet

$$\frac{\textbf{200 cubic feet}}{\textbf{27 cubic feet/cubic yard}} = \textbf{7.41 cubic yards}$$

Concrete projects often present varying degrees of difficulty; therefore, extra concrete is required to compensate for these difficulties. Once the total number of cubic yards of concrete is computed, add a little extra, normally 10 percent, to compensate for waste. To calculate the excess needed, multiply the cubic yards by 10 percent. In the above case, multiply 7.41 cubic yards by .10 to get 0.741 cubic yards. Add the 0.741 percentage to the 7.41 cubic yards for a total of 8.15 cubic yards required for the concrete pad.

Another method for estimating concrete is shown in Table 3-52 of the NAVFAC P-405, which covers the 037 rule. This is a decimal equivalent to 1 cubic yard divided by 27 cubic feet which equals .037037. This method is accurate; however, the Seabees prefer the *L* x *W x T ÷ 27* method.

4.11.0 Batching Concrete

Batching is the process of weighing or volumetrically measuring, and introducing into a mixer the ingredients for a batch of concrete. To produce a uniform quality concrete mix, measure the ingredients accurately for each batch. Most concrete specifications require that the batching be performed by weight rather than by volume because of inaccuracies in measuring aggregate, especially damp aggregate. Water and liquid air-entraining admixtures can be measured accurately by either weight or volume. Batching by using weight provides greater accuracy and avoids problems created by bulking of damp sand. Volumetric batching is used for concrete mixed in a continuous mixer and in the mobile concrete mixer (crete mobile) where weighing facilities are not at hand.

Specifications generally require that materials be measured in individual batches within the following percentages of accuracy: cement 1%, aggregate 2%, water 1%, and air-entraining admixtures 3%.

The equipment used should be capable of measuring quantities within these tolerances for the smallest to the largest batch of concrete produced. The accuracy of the batching equipment should be checked periodically and adjusted when necessary.

4.11.1 Mixing Concrete

Concrete should be mixed until it is uniform in appearance and all the ingredients are evenly distributed. Do not load mixers above their rated capacities, and operate them at approximately the speeds for which they were designed. If the blades of the mixer become worn or coated with hardened concrete, the mixing action will be less efficient. Replace worn blades and periodically remove the hardened concrete, preferably after each production of concrete.

When a transit mixer (TM), shown in *Figure 3-17*, is used for mixing concrete, 70 to 100 revolutions of the drum at the rate of rotation designated by the manufacturer as *mixing speed* are usually required to produce the specified uniformity. No more than 100 revolutions at mixing speed should be used. All revolutions after 100 should be at a rate of rotation designated by the manufacturer as *agitating speed.* Agitating speed is usually about 2 to 6 revolutions per minute, and mixing speed is generally about 6 to 18 revolutions per minute. Mixing for long periods of time (about 1 or more hours) at high speeds can result in concrete strength loss, temperature rise, excessive loss of entrained air, and accelerated slump loss.

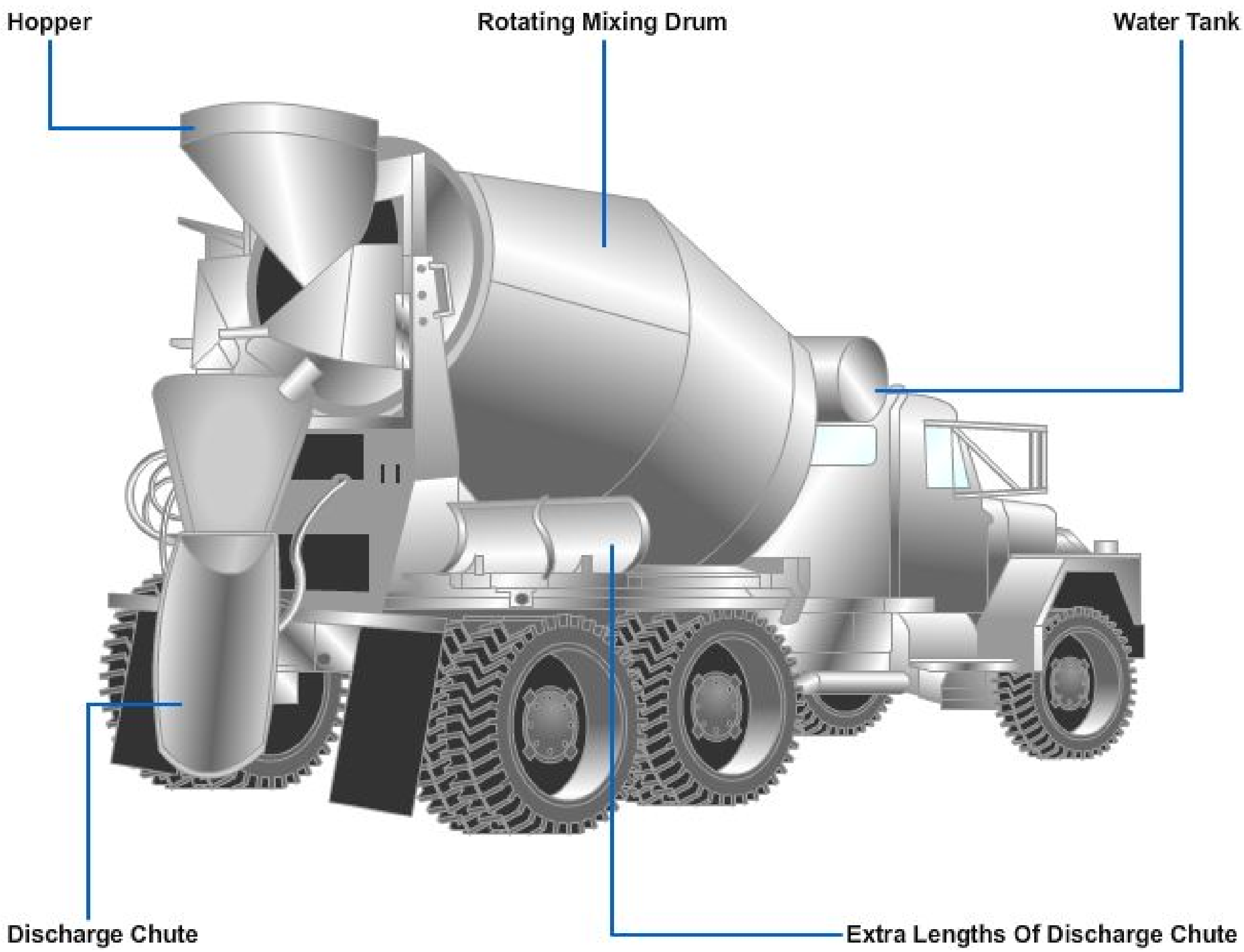


Figure 3-17 – Transit mixer.

Deliver and discharge concrete mixed in a transit mixer within 1 1/2 hours or before the drum has revolved 300 times after the introduction of water to cement and aggregates or the cement to the aggregates. Always operate mixers and agitators within the limits of the volume and speed of rotation designated by the equipment manufacturer.

4.11.1.1 Overmixing Concrete

Overmixing concrete damages the quality of the concrete, tends to grind the aggregate into smaller pieces, increases the temperature of the mix, lowers the slump, decreases air entrainment, and decreases the strength of the concrete. Also, overmixing puts needless wear on the drum and blades of the transit mixer.

To select the best mixing speed for a load of concrete, estimate the travel time to the project (in minutes) and divide this into the minimum desired number of revolutions at mixing speed, 70. The results will be the best drum speed; for instance, if the haul is 10 minutes, 70 divided by 10 equals 7. With this drum speed, the load will arrive on the job site with exactly 70 turns at mixing speed with no overmixing of the concrete mix and no unnecessary wear on the equipment. If the concrete cannot be discharged immediately, the operator should turn the drum at the minimum agitating speed of 2 revolutions per minute. When the transit mixer arrives at the project having used the minimum amount of mixing turns, the operator is able, if necessary, to delay discharging the concrete. The maximum delay is 300 rotations.

4.11.1.2 Remixing Concrete

Concrete begins to stiffen as soon as the cement and water are mixed. However, the degree of stiffening that occurs in the first 30 minutes is not usually a problem; concrete that is kept agitated generally can be placed within 1 1/2 hours after mixing.

Fresh concrete left to agitate in the mixer drum may be used if upon remixing it becomes sufficiently plastic to be compacted in the forms. Under careful supervision a small amount of water may be added to remix the concrete provided the following conditions are met:

1. Maximum allowable water-cement ratio is not exceeded.
2. Maximum allowable slump is not exceeded.
3. Maximum allowable mixing and agitating time (or drum revolutions) is not exceeded.
4. Concrete is remixed for at least half the minimum required mixing time or number of revolutions.

Adding too much water to make concrete more fluid should not be allowed because this lowers the quality of the concrete. Remixed concrete can be expected to harden quickly. Subsequently, a cold joint may develop when concrete is placed next to or above the remixed concrete.

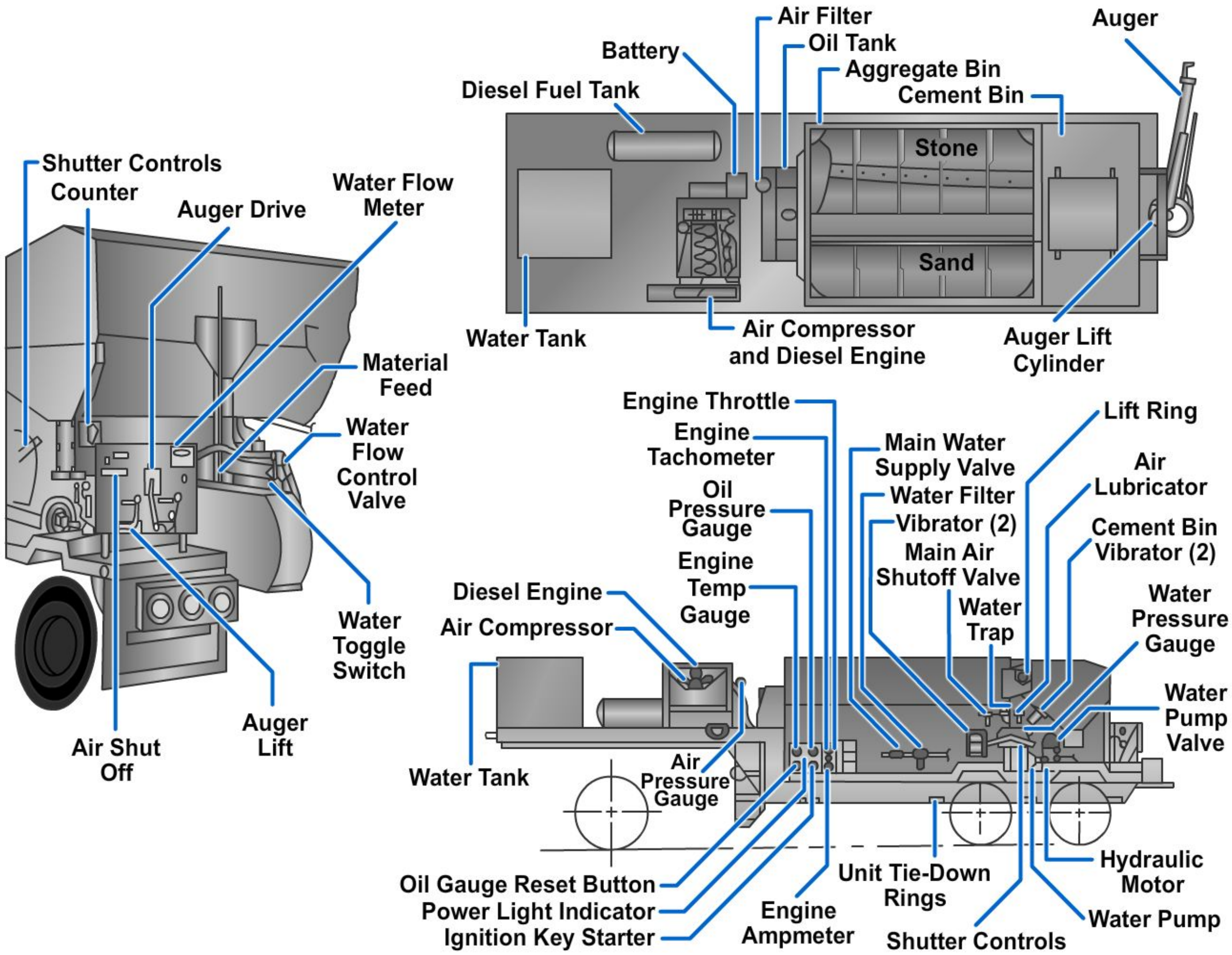


Figure 3-18 – Mobile concrete mixer plant.

4.11.2 Mobile Concrete Mixer Plant

The trailer-mounted mobile concrete mixer plant shown in *Figure 3-18* carries cement, sand, and coarse aggregates in divided bins mounted on the unit. The cement is carried in a separate bin located across the rear of the unit, and the sand and aggregate are carried on each side of the unit. Water is carried in a single tank mounted in front of the aggregate bins and is pumped to the mix auger. Sand and aggregates are accurately proportioned by weight and simultaneously dropped with a mixture of cement from the material feed system into the charging end of the mix auger/conveyor at the rear of the unit. At this point, a predetermined amount of water enters the mix auger.

The action of this combined auger and paddle homogenizer mixes the ingredients and water rapidly, thoroughly, and continuously to produce a continuous flow of uniformed quality concrete. The material mixing action is a continuous process that can proceed until the aggregate bins are empty. On the other hand, mixing and delivery may be stopped at any time and then started again at the will of the operator. This permits production to be balanced to the demands of the placing and finishing crews and other job requirements.

Operators assigned to the crete mobile must thoroughly read and understand the technical manual before operating the plant.

The following are the mobile concrete mixer plant cautions and warnings:

- Follow all preventive maintenance procedures.
- Do not allow any foreign matter in the cement bin.
- Do not allow particles larger than 1 1/2 inch in the aggregate bin.
- Do not allow the waterlines and flow meters to freeze with water in them.
- Do not run the water pump dry.
- Do not continue to operate the machine if the hydraulic oil temperature exceeds 190°F.
- Wash out the auger within 20 minutes of the last use.
- Never attempt to operate the unit while in motion.
- Never attempt to repair the machine while in operation; always turn the power source off.
- Keep your entire body clear from all moving parts.
- Never attempt to walk on top of the aggregate bin to cross from the cement bin to the water tank. Use the ladder.
- Never walk or stand under the auger.
- Never climb inside the aggregate bin; use a small pole to dislodge any aggregate that has bridged.
- Never enter the cement bin while in operation; there are moving parts inside the bin.

4.12.0 Transit Mixer Safety

The use of transit mixers on construction projects impose traffic problems that must be considered. Caution must be used during backing of the transit mixer. Backing should be controlled by a signalman, positioned so the operator can clearly observe the directions given. Extreme caution must be used when traveling over uneven terrain on a construction site. The stability of the mixer is greatly reduced with the extra weight of the concrete in the mixer unit. In such cases, a slow speed is recommended. Some additional safety precautions that must be enforced are as follows:

1. Secure the discharge chute properly using the lock provided.
2. Check to make certain other personnel are in the clear before starting the mixer charging or discharging.
3. Make sure you stop the mixer before making any adjustments.

5.0.0 PRECAST and TILT-UP CONCRETE

Precast and tilt-up construction is the fabrication of structural members or panels at a place other than its final position of use. This fabrication can be done anywhere, although these procedures are best adapted to a factory or prefab yard. Job site precasting is not uncommon for large projects. Precast concrete can be produced in several different shapes and sizes, including piles, girders, and roof members. Prestressed concrete is especially well adapted to precasting techniques.

Tilt-up concrete is a special type of precast concrete in which the units are tilted up and placed using cranes or other types of lifting devices.

Wall construction, for example, is frequently done with precast wall panels originally cast horizontally (sometimes one above the other) as slabs. This method has many advantages over the conventional method of casting in place in vertical wall forms. Since a slab form requires only edge forms and a single surface form, the amount of formwork and form materials required is greatly reduced. The labor involved in slab form concrete casting is much less than that involved in filling a high wall form. One side of a precast unit cast as a slab may be finished by hand to any desired quality of finishing. The placement of reinforcing steel is much easier in slab forms, and it is easier to attain thorough filling and vibrating. Precasting of wall panels as slabs may be expedited by mass production methods not available when casting in place.

5.1.0 Precast Concrete

Generally, structural members, including standard highway girders, poles, electric poles, masts, and building members, are precast by factory methods unless the difficulty or impracticability of transportation makes job site casting more desirable. On the other hand, concrete that is cast in the position that it is to occupy in the finished structure is called cast-in-place concrete.

5.1.1 Precast Concrete Floors, Roof Slabs, Walls, and Partitions

The most commonly used precast slabs or panels for floor and roof decks are the channel and double-T types shown in *Figure 3-19, Views A* and *B*.

The channel slabs vary in size with a depth ranging from 9 to 12 inches, width from 2 to 5 feet, and thickness from 1 to 2 inches. They have been used in spans of up to 50 feet. If desired or needed, the legs of the channels may be extended across the ends and, if used in combination with the top slabs, may be stiffened with occasional cross ribs. Wire mesh may be used in the top slabs for reinforcement. The longitudinal grooves, located along the top of the channel legs, may be grouted to form keys between adjacent slabs.

The double-T slabs vary in size from 4 to 6 feet in width and 9 to 16 feet in depth. They have been used in spans as long as 50 feet. When the top slab size ranges from 1 1/2 to 2 inches in thickness, it should be reinforced with wire mesh.

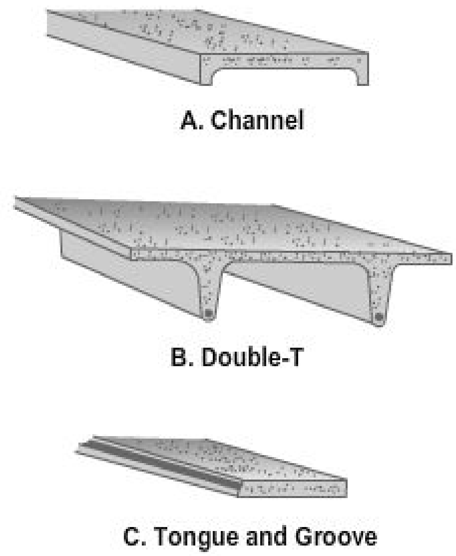


Figure 3-19 – Typical precast panels.

The tongue and groove panel shown in *Figure 3-19, View C* could vary extensively in size according to the design requirement. These panels are placed in position much like tongue and groove lumber, that is, the tongue of one panel is placed inside the groove of an adjacent panel. They are often used as decking panels in large pier construction.

Matching plates are ordinarily welded and used to connect the supporting members to the floor and roof slabs.

Panels precast in a horizontal position, in a casting yard or on the floor of the building, are ordinarily used in the makeup of bearing and nonbearing walls and partitions. These panels are placed in their vertical positions by cranes or by the tilt-up procedure, as shown in *Figures 3-20* and *3-21*.

Figure 3-20 – Precast panels being erected by use of crane and spreader bars.

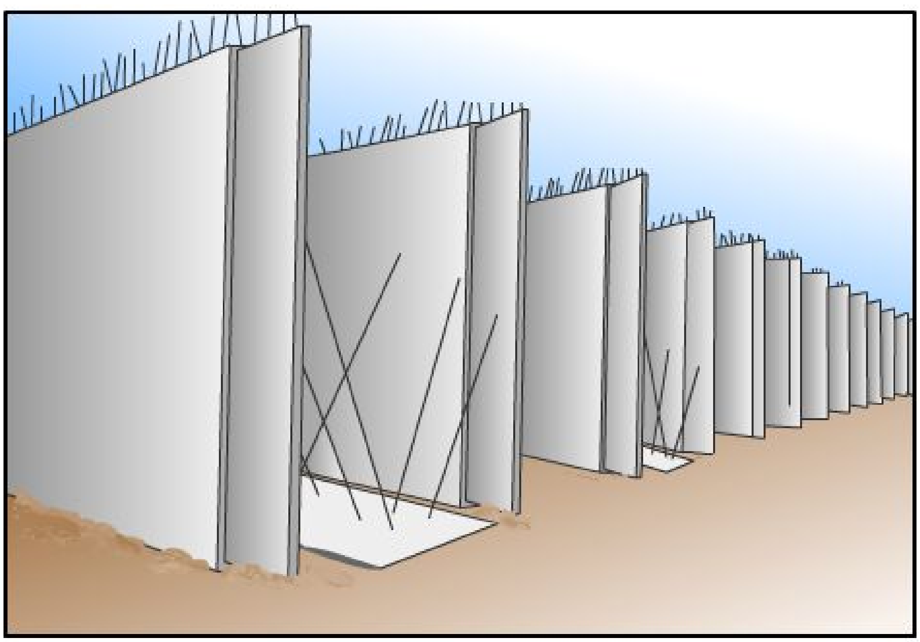


Figure 3-21 – Precast panels in position.

Usually, these panels are solid, reinforced slabs, 5 to 8 inches thick, with the length varying according to the distances between columns or other supporting members.

When windows and door openings are cast in the slabs, extra reinforcements should be installed around the openings.

A concrete floor slab with a smooth, regular surface can be used as a casting surface. When this smooth surface is used for casting, it should be covered with some form of liquid or sheet material to prevent bonding between the surface and the wall panel. The upper surface of the panel may be finished as regular concrete is finished by troweling, floating, or brooming.

Sandwich panels are panels that consist of two thin, dense, reinforced concrete-face slabs separated by a core of insulating material such as lightweight concrete, cellular glass, plastic foam, or some rigid insulating material.

These panels are sometimes used for exterior walls to provide additional heat insulation. The thickness of the sandwich panels varies from 5 to 8 inches, and the face slabs are tied together with wire or small rods, or in some other manner. Welded or bolted matching plates are also used to connect the wall panels to the building frame, top and bottom. Caulking on the outside and grouting on the inside should be used to make the joints between the wall panels watertight.

5.1.2 Precast Concrete Joists, Beams, Girders, and Columns

Small closely spaced beams used in floor construction are usually called joists; however, these same beams when used in roof construction are called purlins. The cross sections of these beams are shaped like a T or an I. The ones with the inverted T-sections are usually used in composite construction where they support cast-in-place floor or roof slabs.

Beams and girders are terms usually applied to the same members, but the one with the longer span should be referred to as the girder. Beams and girders may be conventional precast design or prestressed. Most of the beams will be I-shaped unless the ends are rectangular. The T-shaped ones can also be used.

Precast concrete columns may be solid or hollow. If the hollow type is desired, heavy cardboard tubing should be used to form the core. A looped rod is cast in the column footing and projects upward into the hollow core to help hold the column upright. An opening should be left in the side of the column so that the column core can be filled with grout. This causes the looped rod to become embedded to form an anchor. The opening is dry packed.

5.1.3 Advantages of Precast Concrete

Precast concrete has the greatest advantage when identical members are to be cast because the same forms can be used several times. Some other advantages are listed below.

- Quality of concrete can be controlled.
- Smoother surfaces and plastering are not necessary.
- Less storage space is needed.
- Concrete member can be cast under all weather conditions.
- There is better protection for curing.
- Weather conditions do not affect erection.
- Erection time is faster.

5.2.0 Pre-Stressed Concrete

A pre-stressed concrete unit is one in which engineered stresses have been placed before it has been subjected to a load. When pre-tensioning is used, the reinforcement (high tensile strength steel strands) is stretched through the form between the two end abutments or anchors. A predetermined amount of stress is applied to the steel strands. The concrete is then poured, encasing the reinforcement. As the concrete sets, it bonds to the pre-tensioned steel. When it has reached a specified strength, the tension on the reinforcement is released. This pre-stresses the concrete, putting it under compression, thus creating a built-in tensile strength.

Post-tensioning involves a precast member that contains normal reinforcing in addition to a number of channels through which the pre-stressing cables or rods may be passed. The channels are usually formed by suspending inflated tubes through the form and casting the concrete around them. When the concrete has set, the tubes are deflated and removed. Once the concrete has reached a specified strength, pre-stressing steel strands or tendons are pulled into the channels and secured at one end. They are then stressed from the opposite end with a portable hydraulic jack and anchored by one of several automatic gripping devices.

Post-tensioning may be done where the member is poured or at the job site. Each member may be tensioned, or two or more members may be tensioned together after erection. In general, post-tensioning is used if the unit is over 45 feet long or over 7 tons in weight. However, some types of pre-tensioned roof slabs will be considerably longer and heavier than this.

When a beam is pre-stressed, either by pre-tensioning or post-tensioning, the tensioned steel produces a high compression in the lower part of the beam. This compression creates an upward bow or camber in the beam, as shown in *Figure 3-22*. When a load is placed on the beam, the camber is forced out, creating a level beam with no deflection.

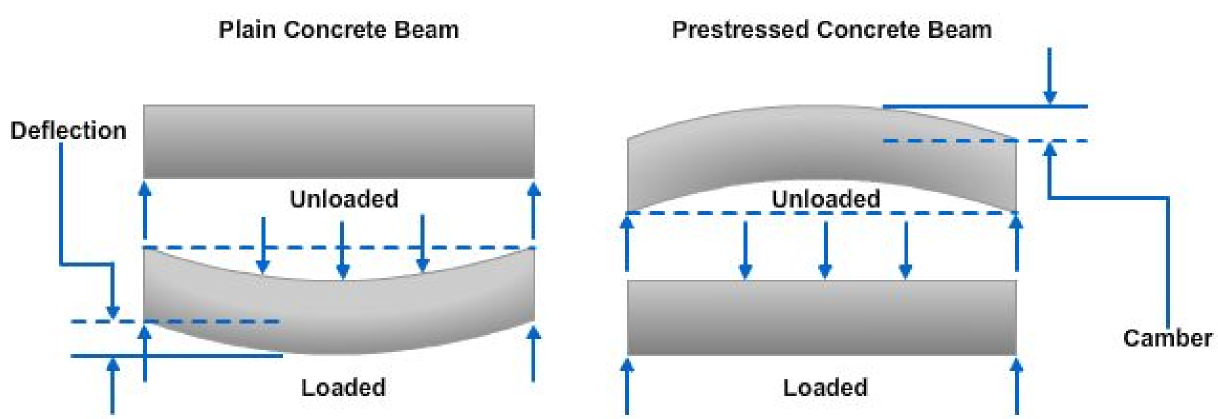


Figure 3-22 – Comparison of plain and pre-stressed concrete beams.

Those members that are relatively small or that can be readily precast are normally pre-tensioned. These include precast roof slabs, T-slabs, floor slabs, and roof joists.

5.3.0 Special Types of Concrete

Special types of concrete are essentially those with unique physical properties or those produced with unusual techniques and/or reproduction processes. Many special types of concrete are made with Portland cement as a binding medium; some use binders other than Portland cement.

5.3.1 Lightweight Concrete

Conventional concrete weighs approximately 150 pounds per cubic foot. Lightweight concrete weighs 90 to 120 pounds per cubic foot, depending on its intended use. Lightweight concrete can be made by using either gas-generating chemicals or lightweight aggregates such as expanded shale, clay, or slag. Concrete containing aggregates like perlite or vermiculite is very light in weight and is primarily used as insulating material. Lightweight concrete is usually classified according to its weight per cubic foot.

Semi-lightweight concrete has a unit weight of 115 to 130 pounds per cubic foot and an ultimate compressive strength comparable to normal concrete. Sand of normal weight is substituted partially or completely for the lightweight fine aggregate.

Insulating lightweight concrete has a unit weight ranging from 15 to 90 pounds per cubic foot, and its compressive strength seldom exceeds 1,000 psi. This type of concrete is generally used for insulating applications, such as fireproofing.

Structural lightweight concrete has a unit weight of 85 to 115 pounds per cubic foot and a 28-day compressive strength in excess of 2,500 psi. This type is used primarily to reduce the dead-load weight in concrete structural members such as floors, walls, and roof sections in high-rise structures.

5.3.2 Heavyweight Concrete

Heavyweight concrete is produced with special heavy aggregates and has a density of up to 400 pounds per cubic foot. This type is used principally for radiation shielding, for counterweights, and for other applications where higher density is desired. Except for density, the physical properties of heavyweight concrete are similar to those of normal or conventional weight concrete.

5.4.0 Tilt-Up Construction

Tilt-up concrete construction is a special form of precast concrete building. This method consists basically of job site prefabrication in which the walls are cast in a horizontal position, tilted to a vertical position, and then secured in place. Tilt-up construction is best suited for large one-story buildings, but it can be used in multi-story structures. Usually, multi-story structures are built by setting the walls for the first story, placing the floor above, and then repeating the procedure for each succeeding floor. An alternate method is to cast two to four story panels.

The wall panels are usually cast on the floor slab of the structure. Care must be exercised to ensure that the floor slab is smooth and level and that all openings for pipes and other utilities are temporarily plugged. The casting surface is treated with a good bond-breaking agent to ensure the panel does not adhere when it is lifted.

5.4.1 Reinforcement of Tilt-Up Panels

The steel in a tilt-up panel is set in the same manner as it is in a floor slab. Mats of reinforcement are placed on chairs and tied as needed. Reinforcement should be as near the center of the panel as possible. Reinforcing bars are run through the side forms of the panel. When welded wire fabric or expanded wire mesh is used, dowel bars are used to tie the panels and their vertical supports together. Additional reinforcement is generally needed around openings.

The panel is picked up or tilted by the use of pickup inserts. These inserts are tied into the reinforcement. As the panel is raised into its vertical position, maximum stress will occur; therefore, the location and number of pickup inserts are extremely important. Some engineering manuals provide information on inserts, their locations, and capacities.

5.4.1.1 Tilt-Up Panel Foundations

An economical and widely used method to support tilt-up panels is a simple pad footing. The floor slab, which is constructed first, is NOT poured to the perimeter of the building to permit excavating and pouring the footings. After the panel is placed on the footing, the floor slab is completed. It may be connected directly to the outside wall panel, or a trench may be left to run mechanical, electrical, or plumbing lines.

A commonly used alternative method is to set the panels on a grade beam or a foundation wall at floor level. Regardless of the type of footing, the panel should be set into a mortar bed to ensure a good bond between the foundation wall and the panel.

5.4.1.2 Panel Connections

The panels may be tied together in a variety of ways. The location and the use of the structure will dictate what method can or CANNOT be used. The strongest method is a cast-in-place column with the panel reinforcing steel tied into the column. This does NOT allow for expansion and contraction. It may be preferable to tie only the corner panels to the columns and allow the remaining panels to move.

Various other methods of connecting the panels are also used. A butted connection, using grout or a gasket, can be used if the wall does NOT contribute any structural strength to the structure. Steel columns are welded to steel angles or plates secured in the wall panel. Precast columns can also be used. Steel angles or plates are secured in both the columns and plate, and welded together to secure the panel.

When panel connections that do not actually hold the panels in place are used, the panels are generally welded to the foundation and to the roof by using steel angles or plates. All connections must provide waterproof joints. This is accomplished by the use of expansion joint material.

5.4.2 Prefabrication Yard

Precasting is done either in central prefabrication plants or on-site prefabrication plants, depending upon the product and its application. On-site or temporary prefabrication plants are generally more suitable for military operations. These plants are without roofing and are subject to weather and climate considerations. The prefabrication yard is laid out to suit the type and quantity of members to be processed. It must be on firm, level ground, providing ample working space and access routes. Bridge T-beams, reinforced concrete arches, end walls, and concrete logs are typical members produced at these plants. A schematic layout of a prefabrication yard suitable for producing such members is shown in *Figure 3-23*. A prefabrication unit of this size can be expected to produce approximately 6,000 square feet of precast walls per day. The output will vary according to the experience of the personnel, equipment capabilities, and product requirements.

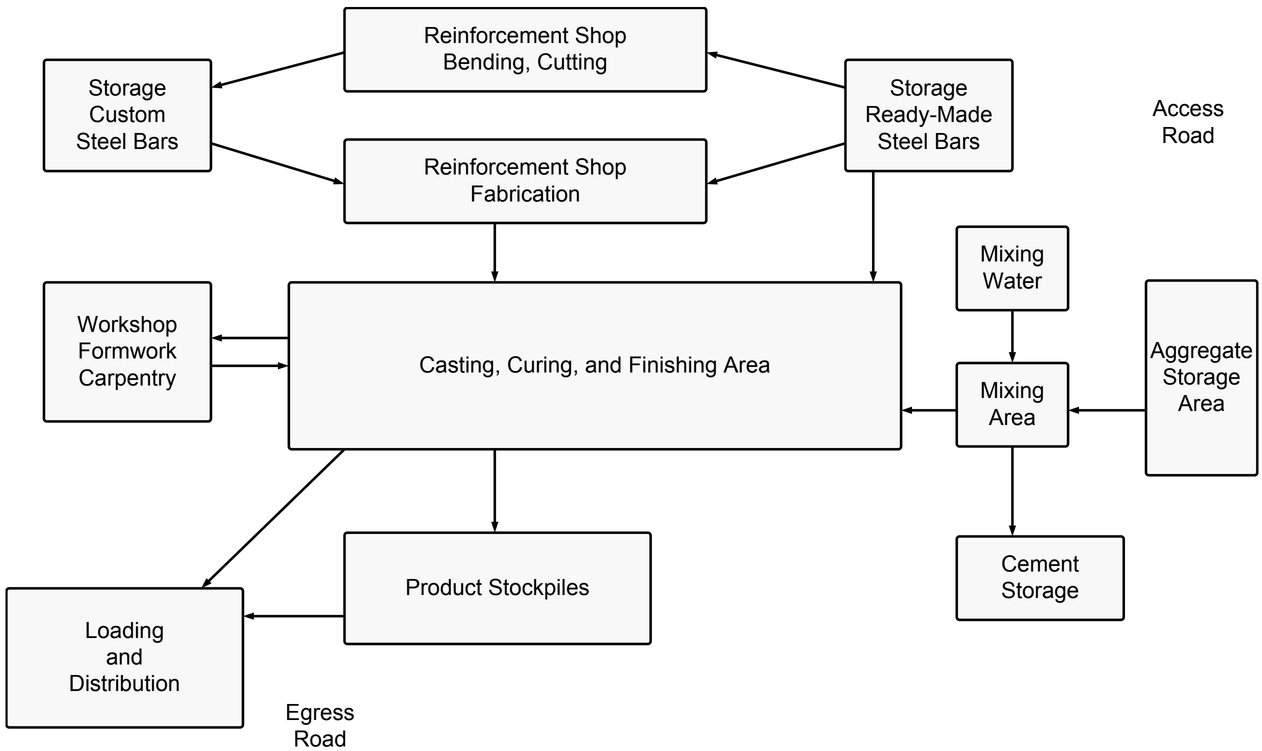


Figure 3-23 – Layout of prefab yard.

5.4.2.1 Casting

The casting surface is very important in making precast concrete panels. In this section, we will cover two common types: earth and concrete. Regardless of which method you use, a slab must be cast in a location that will permit easy removal and handling.

Castings can be made directly on the ground with cement poured into forms. These earth surfaces are economical but only last for a couple of concrete pours. Concrete surfaces, since they can be reused repeatedly, are more practical.

When building casting surfaces, you should keep the following points in mind:

- The sub-base should be level and properly compacted.
- The slab should be at least 6 inches thick and made of 3,000 psi or higher reinforced concrete. Large aggregate, 2 1/2 inches to 3 inches maximum, may be used in the casting slabs.
- If pipes or other utilities are to be extended up through the casting slab at a later date, they should be stopped below the surface and the openings temporarily closed. For wood, cork, or plastic plugs, fill almost to the surface of the opening with sand, insert the plug, and top with a thin coat of mortar that is finished flush with the casting surface.
- It is important to remember that any imperfections in the surface of the casting slab will show up on the cast panels. When finishing the casting slab, ensure there is a flat, level, and smooth surface without humps, dips, cracks, or gouges. If possible, cure the casting surface, keeping it covered with water (pending). However, if a curing compound or surface hardener is used, make sure it will not conflict with the later use of bond-breaking agents.

5.4.2.2 Forms

The material most commonly used for edge forms is 2-by lumber. The lumber must be occasionally replaced, but the steel or aluminum angles and channels may be reused many times. The tops of the forms must be in the same plane so that they may be used for screeds. They must also be well braced to remain in good alignment.

Edge forms should have holes in them for rebar or for expansion/contraction dowels to protrude. These holes should be one fourth of an inch larger in diameter than the bars. At times, the forms are spliced at the line of these bars to make removal easier.

The forms, or rough bucks, for doors, windows, air conditioning ducts, and so forth, are set before the steel is placed and should be on the same plane as the edge forms.

5.4.2.3 Bond-Breaking Agents

Bond-breaking agents are one of the most important items of precast concrete construction. The most important requirement is that they must break the bond between the casting surface and the cast panel. Bond-breaking agents must also be economical, fast drying, easily applied, easily removed, or leave a paintable surface on the cast panel, if desired. They are broken into two general types: sheet materials and liquids.

Many commercially available bond-breaking agents are available. You should obtain the type best suited for the project and follow the manufacturer’s application instructions. If commercial bond-breaking agents are not available, several alternatives can be used.

- Paper and felt effectively prevent a bond with a casting surface, but usually stick to the cast panels and may cause asphalt stains on the concrete.
- Plywood, fiberboard, or metal joints, when oiled, can effectively break a bond and can be used many times. However, the initial cost is high, and joint marks are left on the cast panels.
- Canvas gives a very pleasing texture and is used where cast panels are lifted at an early stage. It should be either dusted with cement or sprinkled with water just before placing the concrete.
- Oil gives good results when properly used, but it is expensive. The casting slab must be dry when the oil is applied, and the oil must be allowed to absorb before the concrete is placed. Oil should not be used if the surface is to be painted, and crankcase oil should never be used.
- Waxes, such as spirit wax (paraffin) and ordinary floor wax, give good to excellent results. One mixture that may be used is 5 pounds of paraffin mixed with 1 1/2 gallons of light oil or kerosene. The oil must be heated to dissolve the paraffin.
- Using liquid soap requires special care to ensure that an excess amount is not used, or the surface of the cast panel will be sandy.

Materials should be applied after the side forms are in place and the casting slab is clean but before any reinforcing steel is placed. To ensure proper adhesion of the concrete, keep all bond-breaking materials off the reinforcing steel.

5.4.2.4 Reinforcements and Inserts

Reinforcing bars (rebar) should be assembled into mats and placed into the forms as a unit. This allows for rapid assembly on a jig and reduces walking on the casting surface which has been treated with the bond-breaking agent.

Extra rebars must be used at openings. They should be placed parallel to and about 2 inches from the sides of openings or placed diagonally across the corners of openings.

The bars may be suspended by conventional methods, such as with high chairs or from members laid across the edge forms. However, high chairs should not be used if the bottom of the cast panel is to be a finished surface. Another method is to first place half the thickness of concrete, place the rebar mat, and then complete the pour. However, this method must be done quickly to avoid a cold joint between the top and bottom layers.

When welded wire fabric (WWF) is used, dowels or bars must still be used between the panels and columns. WWF is usually placed in sheets covering the entire area and then clipped along the edges of the openings after erection.

If utilities are going to be hidden or flush-mounted, pipe, conduit, boxes, sleeves, and so forth should be put into the forms at the same time as the reinforcing steel. If the utilities pass from one cast panel to another, the connections must be made after the panels are erected but before the columns are poured. If small openings are to go through the panel, a greased pipe sleeve is the easiest method of placing an opening in the form. For larger openings, such as air-conditioning ducts, forms should be made in the same manner as for doors or windows.

After rebar and utilities have been placed, all other inserts should be placed. These will include lifting and bracing inserts, anchor bolts, welding plates, and so forth. Make sure these items are firmly secured so they will not move during concrete placement or finishing.

5.4.2.5 Pouring, Finishing, and Curing

With few exceptions, pouring cast panels can be done in the same manner as other pours. Since the panels are poured in a horizontal position, a stiffer mix can be used. A minimum of six sacks of cement per cubic yard with a maximum of 6 gallons of water per sack of cement should be used along with well graded aggregate. As pointed out earlier though, you will have to reduce the amount of water used per sack of cement to allow for the free water in the sand. Large aggregate, up to 1 1/2 inches in diameter, may be used effectively. Work the concrete into place by spading or vibration, and take extra care to prevent honeycombing around outer edges of the panel.

Normal finishing methods should be used, but many finishing styles are available for horizontally cast panels, including patterned, colored, exposed aggregate, broomed, floated, or steel troweled. Regardless of the finish used, finishers must do the finishing of all panels in a uniform manner. Spots, defects, uneven brooming or troweling, and so forth will be highly visible when the panels are erected.

Without marring the surface, start curing as soon as possible after finishing. Proper curing is important, so cast panels should be cured just like any other concrete to achieve proper strength. Curing compound, if used, prevents bonding with other concrete or paint.

5.4.3 Lifting Equipment and Attachments

Tilt-up panels can be set up in many different ways and with various kinds of power equipment. The choice depends upon the size of the job. Besides the equipment, a number of attachments are used.

5.4.3.1 Equipment

The most popular power equipment is a crane, but other equipment includes a winch and an A frame, used either on the ground or mounted on a truck. When a considerable number of panels are ready for tilting at one time, power equipment speeds up the job.

5.4.3.2 Attachments

Many types of lifting attachments are used to lift tilt-up panels. Some of these attachments are locally made and are called hairpins; other types are available commercially. You can make hairpin types on the job site by making 180 degree bends in the ends of two vertical reinforcing bars. Then place the hairpins in the end of the panel before pouring the concrete. These lifting attachments must protrude from the top of the form for attaching the lifting chains or cables, but go deep enough in the panel form so they will not pull out.

Among the commercial types of lifting attachments, you will find many styles with greater lifting capacities that are more dependable than hairpins if properly installed. These are used with lifting plates. For proper placement of lifting inserts, refer to the plans or specs.

5.4.3.3 Spreader Bars

Spreader bars may be permanent or adjustable but must be designed and made according to the heaviest load they will carry plus a safety factor. They are used to distribute the lifting stresses evenly, reduce the lateral force applied by slings, and reduce the tendency of panels to bow.

5.4.4 Point Pickup Methods

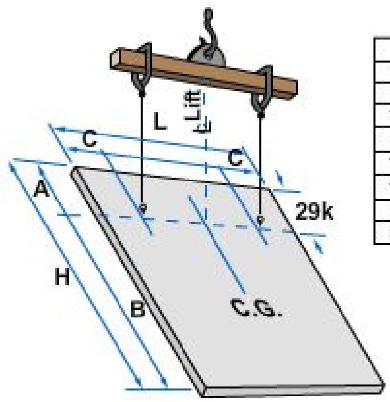
Once the concrete has reached the desired strength, the panels are ready to be lifted. The strength of the inserts is governed by the strength of the concrete.

CAUTION

An early lift may result in cracking the panel, pulling out the insert, or total concrete failure. The time taken to wait until the concrete has reached its full strength prevents problems and minimizes the risk of injury.

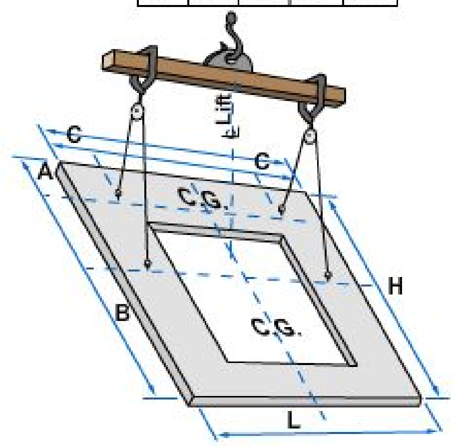
Several different pickup methods are used. The following are just some of the basics. Before using these methods on a job, make sure that you check the plans and the specs to see if these are stated there. *Figure 3-24* shows four different pickup methods: 2, 2-2, 4-4, and 2-2-2.

Two Point Pickup Is Best Suited To Wall Panels 10' To 18' In Height, And Up To 18' In Width For Panels 5" To 8" In Panel Thickness.

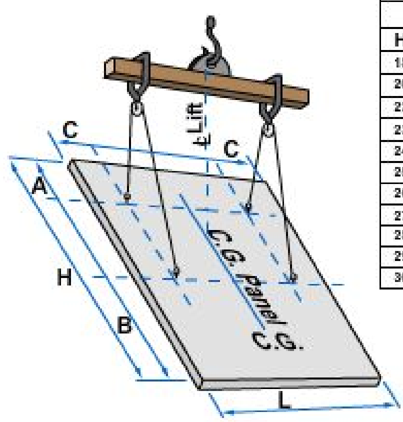


Trial Points			
H	A	L	C
8'	2' 3"	14'	2' 10"
10'	2' 10"	15'	3' 1"
12'	3' 6"	16'	3' 4"
14'	4' 1"	17'	3' 6"
16'	4' 7"	18'	3' 8"
18'	5' 0"	19'	3' 10"
20'	5' 2"	20'	4' 1"

Truck Door 2 - 2 Pickup				
Trial Locations				
H	A	B	L	C
18'	3' 0"	7' 10"	14'	2' 10"
20'	3' 3"	8' 6"	16'	3' 4"
22'	3' 7"	9' 6"	18'	3' 8"
24'	3' 10"	10' 6"	19'	3' 10"
26'	4' 0"	11' 6"	20'	4' 1"
27'	4' 3"	12' 0"	21'	4' 4"
28'	4' 6"	12' 6"	22'	4' 6"
29'	4' 9"	12' 10"	23'	4' 8"
30'	5' 0"	13' 1"	24'	4' 11"

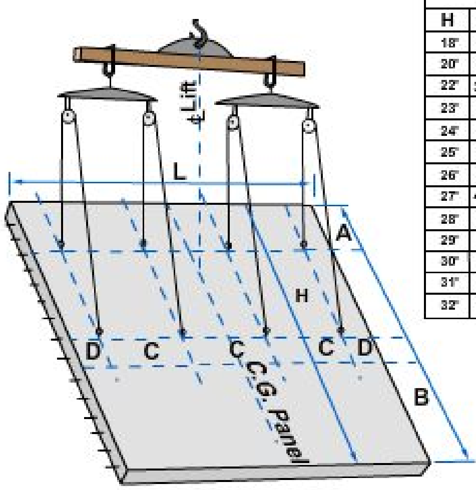


2 - 2 Point Pickup				
Trial Locations				
H	A	B	L	C
18'	3' 3"	7' 7"	12'	2' 6"
20'	3' 7"	8' 4"	14'	2' 10"
22'	3' 11"	9' 3"	15'	3' 1"
23'	4' 2"	9' 7"	16'	3' 4"
24'	4' 4"	10' 1"	17'	3' 6"
25'	4' 6"	10' 6"	18'	3' 8"
26'	4' 8"	11' 0"	19'	3' 10"
27'	4' 10"	11' 4"	20'	4' 1"
28'	5' 0"	11' 9"	21'	4' 4"
29'	5' 2"	12' 2"	22'	4' 6"
30'	5' 4"	12' 7"	23'	4' 8"



2 - 2 - 2 Point Pickup				
Trial Locations				
H	A	B	L	C
30'	4' 2.5"	9' 7"	16'	3' 4"
32'	4' 6"	10' 3"	18'	3' 8"
34'	4' 10"	10' 10"	19'	3' 10"
36'	5' 0"	11' 6"	20'	4' 1"
38'	5' 4"	12' 2"	22'	4' 6"
40'	5' 7"	12' 3"	24'	4' 11"
42'	5' 9"	12' 4"	26'	5' 1"

4-4 Point Pickup					
Trial Locations					
H	A	B	L	C	D
18'	3' 3"	7' 7"	18'	4' 8"	2' 0"
20'	3' 7"	8' 4"	20'	5' 3"	2' 1.5"
22'	3' 11"	5' 3"	22'	5' 10"	2' 3"
23'	4' 2"	9' 7"	24'	6' 4"	2' 6"
24'	4' 4"	10' 1"	26'	6' 10"	2' 9"
25'	4' 6"	10' 6"	28'	7' 4"	3' 0"
26'	4' 8"	11' 0"	30'	8' 0"	3' 0"
27'	4' 10"	11' 4"	32'	8' 6"	3' 4"
28'	5' 0"	11' 9"	34'	9' 0"	3' 6"
29'	5' 2"	12' 2"	36'	9' 6"	3' 8"
30'	5' 4"	12' 7"	38'	10' 2"	3' 10"
31'	5' 7"	13' 0"	39'	10' 4"	4' 0"
32'	5' 9"	13' 4"	40'	10' 6"	4' 3"



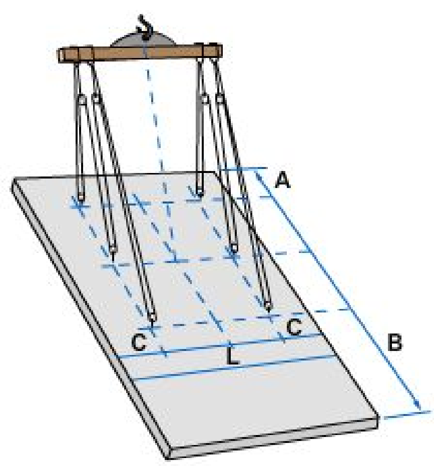


Figure 3-24 - Different types of pickup points.

The 2-point pickup is the simplest method, particularly for smaller panels. The pickup cables or chains are fastened directly from the crane hook or spreader bar to two pickup points on or near the top of the precast panel.

The 2-2 point pickup is a better method and is more commonly used. Variations of the 2-2 are 4-4 and 2-2-2 or combinations of pickup points as designated in the job site specifications. These methods use a combination of spreader bars, sheaves, and equal length cables. The main purpose is to distribute the lifting stresses throughout the panel during erection. Remember, the cables must be long enough to allow ample clearance between the top of the panel and the sheaves or spreader bar.

5.4.5 Erecting, Bracing, and Jointing Panels

Erecting is an important step in the construction phase of the project. Before you start the erecting phase, for increased safety you should make sure that all your tools, equipment, and braces are in proper working order. All personnel must be well informed and the signalman and crane operator understand and agree on the signals to be used. During the erection of the panels, make sure that the signalman and line handler are not under the panel and that all unnecessary personnel and equipment are away from the lifting area. After the erection is complete, make sure that all panels are properly braced and secured before unhooking the lifting cables.

Bracing is an especially important step. After all the work of casting and placing the panels, you want them to stay in place. The following are some steps to take before lifting the panels:

- Install the brace inserts into the panels during casting if possible.
- Install the brace inserts into the floor slab either during pouring or the day before erection.
- Install solid brace anchors before the day of erection.
- If brace anchors must be set during erection, use a method that is fast and accurate.

Although there are several types of bracing, pipe or tubular braces are most common. They usually have a turnbuckle welded between sections for adjustment. Some braces are made with telescoping sleeves for greater adaptability. Cable braces are normally used for most projects. Wood bracing is seldom used except for low, small panels or for temporary bracing.

Joining the panels is simple. Just toe all the panels together, covering the gap between them. You can weld, bolt, or pour concrete columns or beams. Steps used to tie the panels should be stated in the plans and specs.

Summary

This chapter provided information on the hazards inherent in working with concrete, and the steps you should take to provide for the safety of your crew. You also learned about different characteristics associated with concrete form design and concrete mix design, as well as the procedures in batching concrete. You should now be able to estimate concrete construction and labor, and identify the procedures and methods associated with precast and tilt-up construction.

Additional Resources and References

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

American Concrete Institute (ACI Standards 200 & 300 series), Box 19150, Redford Station, Detroit, MI, 1987.

Concrete and Masonry, FM 5-742, Headquarters, Department of the Army, Washington, DC, 1985.

Design and Control of Concrete Mixtures, 13th ed., Portland Cement Association (PCA), Skokie, IL, 1989.

Engineering Aid Advanced, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Equipment Operator Advanced, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, NAVFAC P-405, Naval Facilities Engineering Command, Alexandria, VA, 1994.

OSHA Standards for the Construction Industry, 29 CFR, Part 1926, Commerce Clearing House, Inc., 4025 West Peterson Avenue, Chicago, IL, 1991.

Safety and Health Requirements Manual, EM 385-1-1, Department of the Army, Washington, DC, 1991.