Chapter 12

Concrete Construction

Chapter 12: Concrete Construction

- **12-1 CONSTRUCTION APPLICATIONS OF CONCRETE**
- **12-2 CONCRETE CONSTRUCTION PRACTICES**
- **12-3 CONCRETE FORMWORK**
- **12-4 REINFORCING STEEL**
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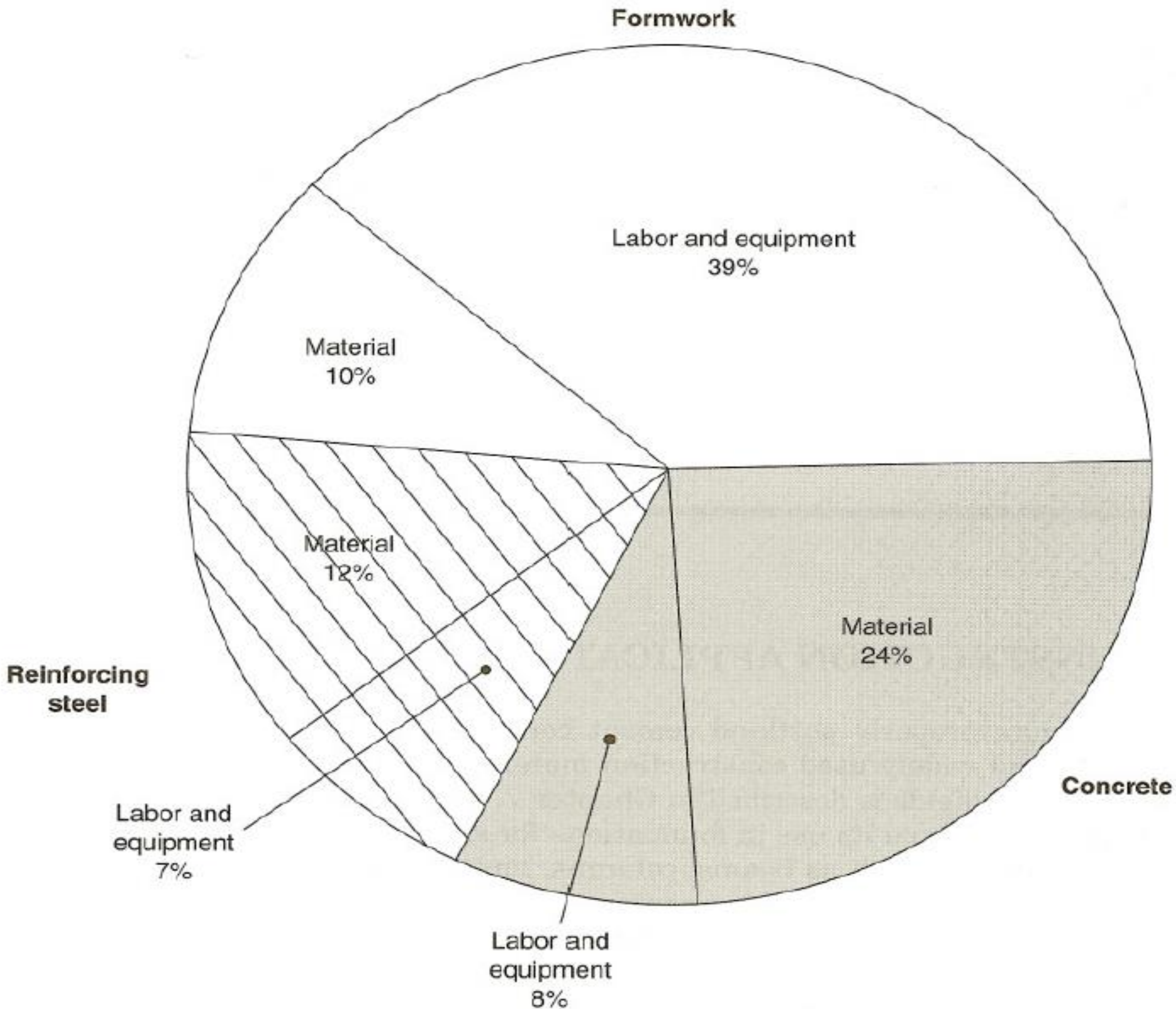
12-1 CONSTRUCTION APPLICATIONS OF CONCRETE

- Concrete, or more properly Portland cement concrete, is one of the world's most versatile and widely used construction materials.
- construction applications:
  - paving of highways and airfields.
  - its use in foundations for small structures, through structural components such as beams, columns, and wall panels, to massive concrete dams.
- all concrete used for structural purposes contains reinforcing steel embedded in the concrete to increase the concrete member's tensile strength. (*Reinforced Concrete*)

12-1 CONSTRUCTION APPLICATIONS OF CONCRETE

- The objective of the construction manager should be to develop a construction plan which minimizes construction costs while meeting all safety and quality requirements.
- Major elements of a concrete construction cost analysis include:
  - Formwork costs including labor, equipment, and materials.
  - Cost of reinforcing steel and its placement.
  - Concrete materials, equipment, and labor for placing, curing, and finishing the concrete.

FIGURE 12-1: Typical distribution of concrete construction costs.



12-1 CONSTRUCTION APPLICATIONS OF CONCRETE

1. Cast-in-Place Concrete
2. Precast Concrete
3. Prestressed Concrete
4. Architectural Concrete

1. Cast-in-Place Concrete

- Concrete structural members have traditionally been built in-place by placing the plastic concrete into forms and allowing it to harden.
- The forms are removed after the concrete has developed sufficient strength to support its own weight and the weight of any construction loads.

FIGURE 12-2: Typical cast-in-place column and wall shapes.

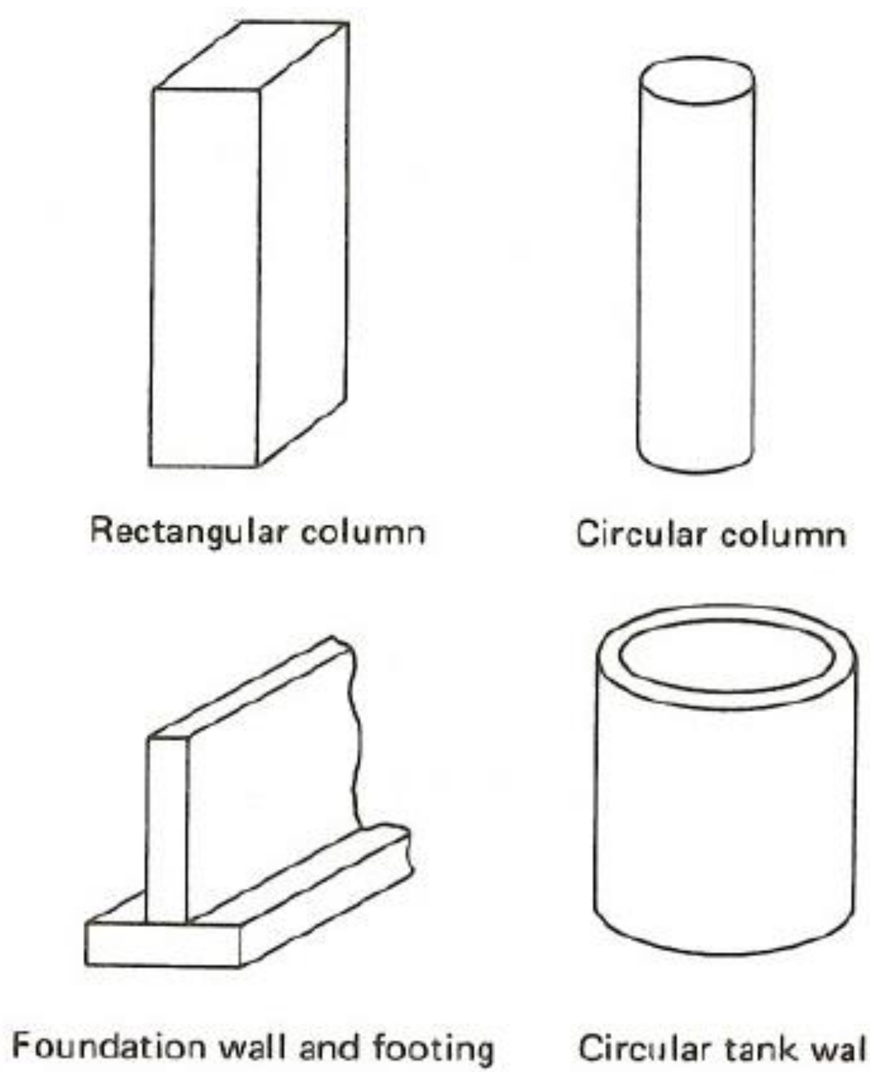
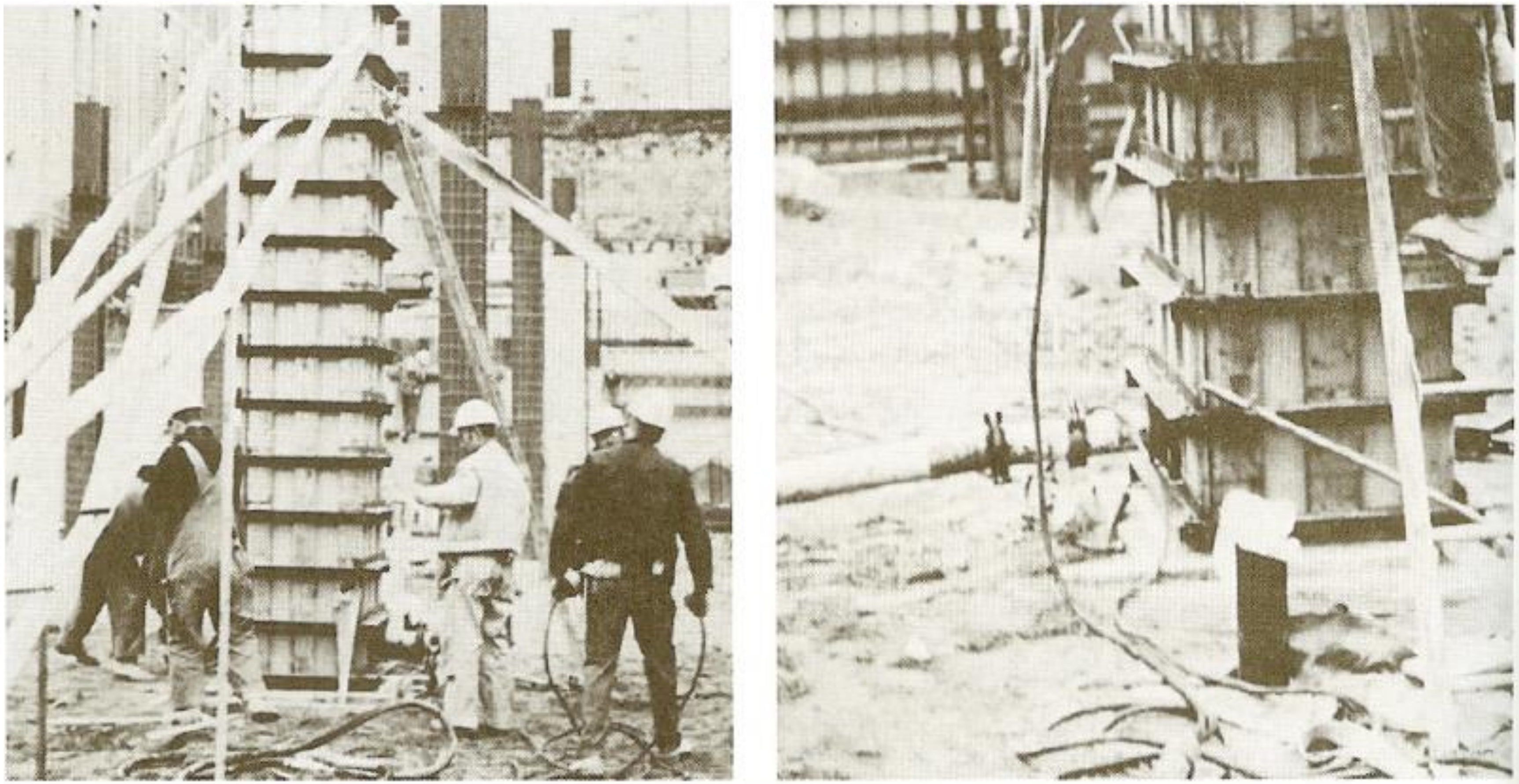


FIGURE 12-3: Pumping concrete into bottom of column form.
(Courtesy of Gates & Sons, Inc.)

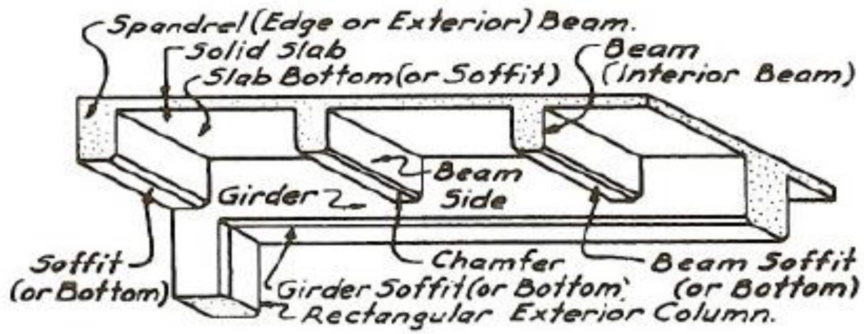


a. Preparation of form

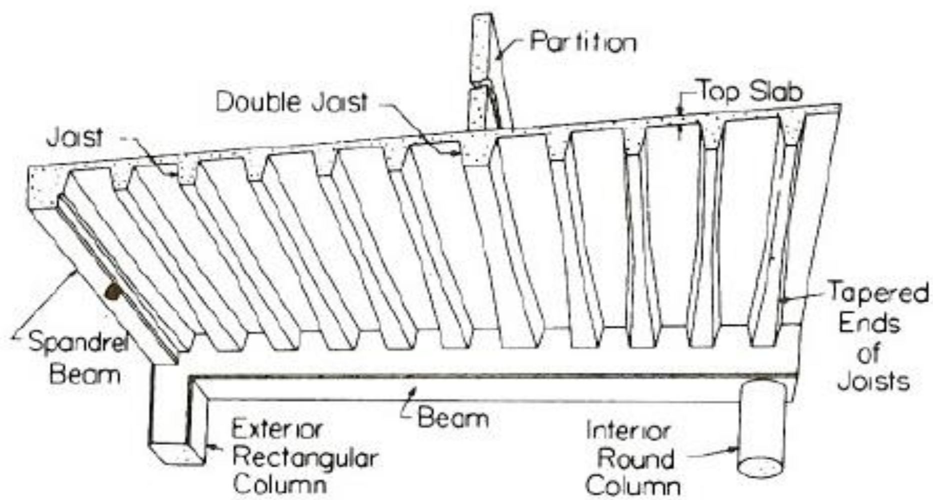
b. Pumping hose in place on fixture at bottom of form

FIGURE 12-4: Floor slab construction.

(Courtesy of Concrete Reinforcing Steel Institute)



a. Slab-beam-and-girder floor



b. Concrete joist floor

FIGURE 12-5: Waffle slab.

(Courtesy of Concrete Reinforcing Steel Institute)

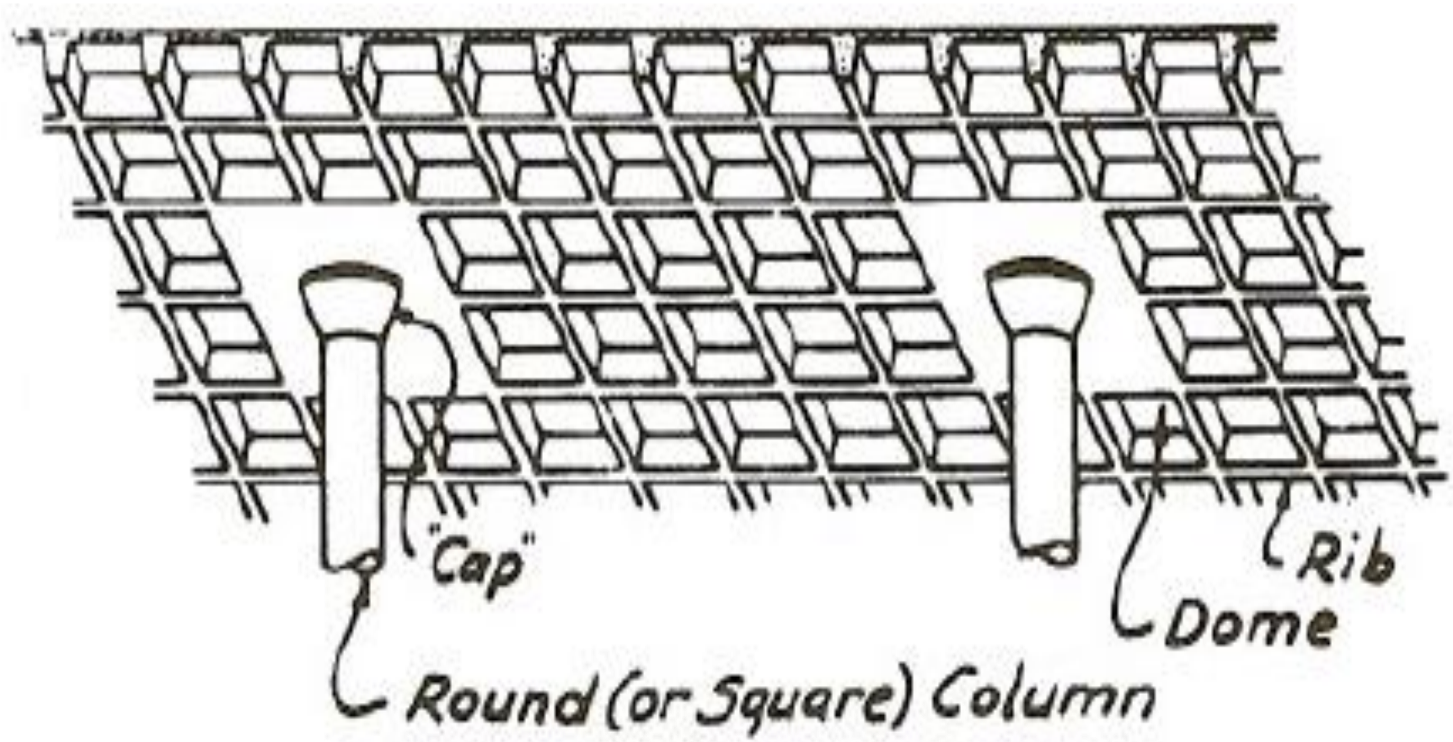
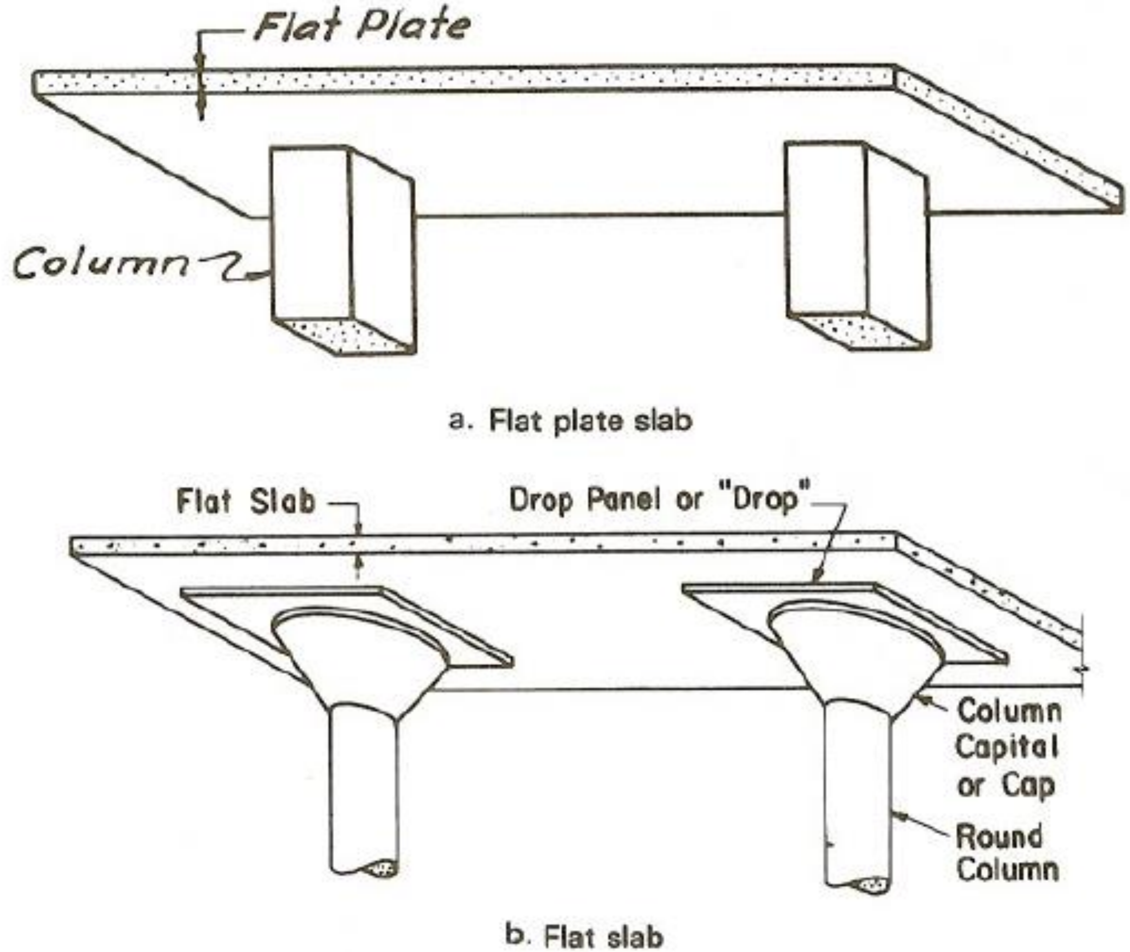


FIGURE 12-6: Flat slab and flat plate slab.

(Courtesy of Concrete Reinforcing Steel Institute)



2. Precast Concrete

- *Precast concrete* is concrete that has been cast into the desired shape prior to placement in a structure.
- There are a number of advantages obtained by removing the concrete forming, placing, finishing, and curing operations from the construction environment.
- Pre-casting operations usually take place in a central plant where industrial production techniques may be used.
- Since standard shapes are commonly used, the repetitive use of formwork permits forms to be of high quality at a low cost per unit.

Precast Concrete

- There are a number of standard shapes commonly used for precast concrete structural members.
- Figure 12-7 illustrates some common beam and girder sections.
- Figure 12-8 illustrates Precast roof and floor panels.

FIGURE 12-7: Precast beam and girder shapes.

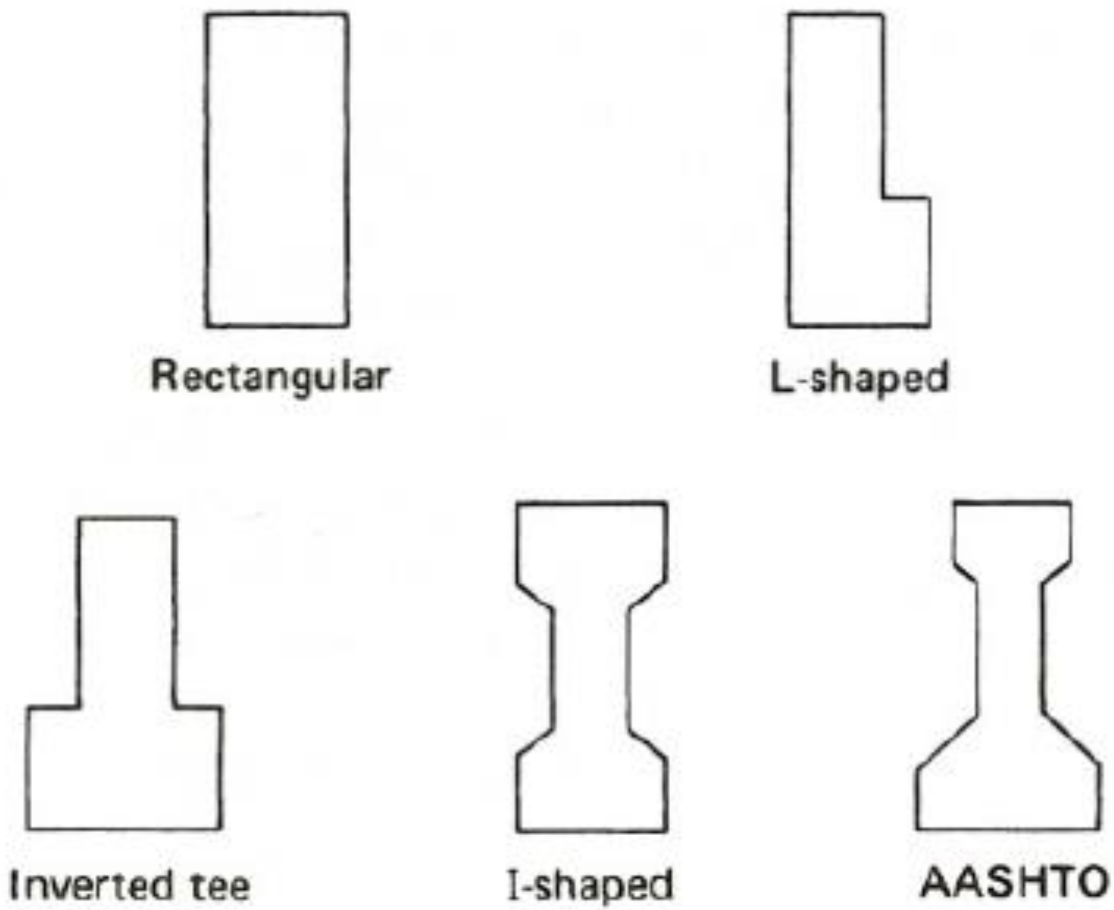


FIGURE 12-8: Precast slab shapes.

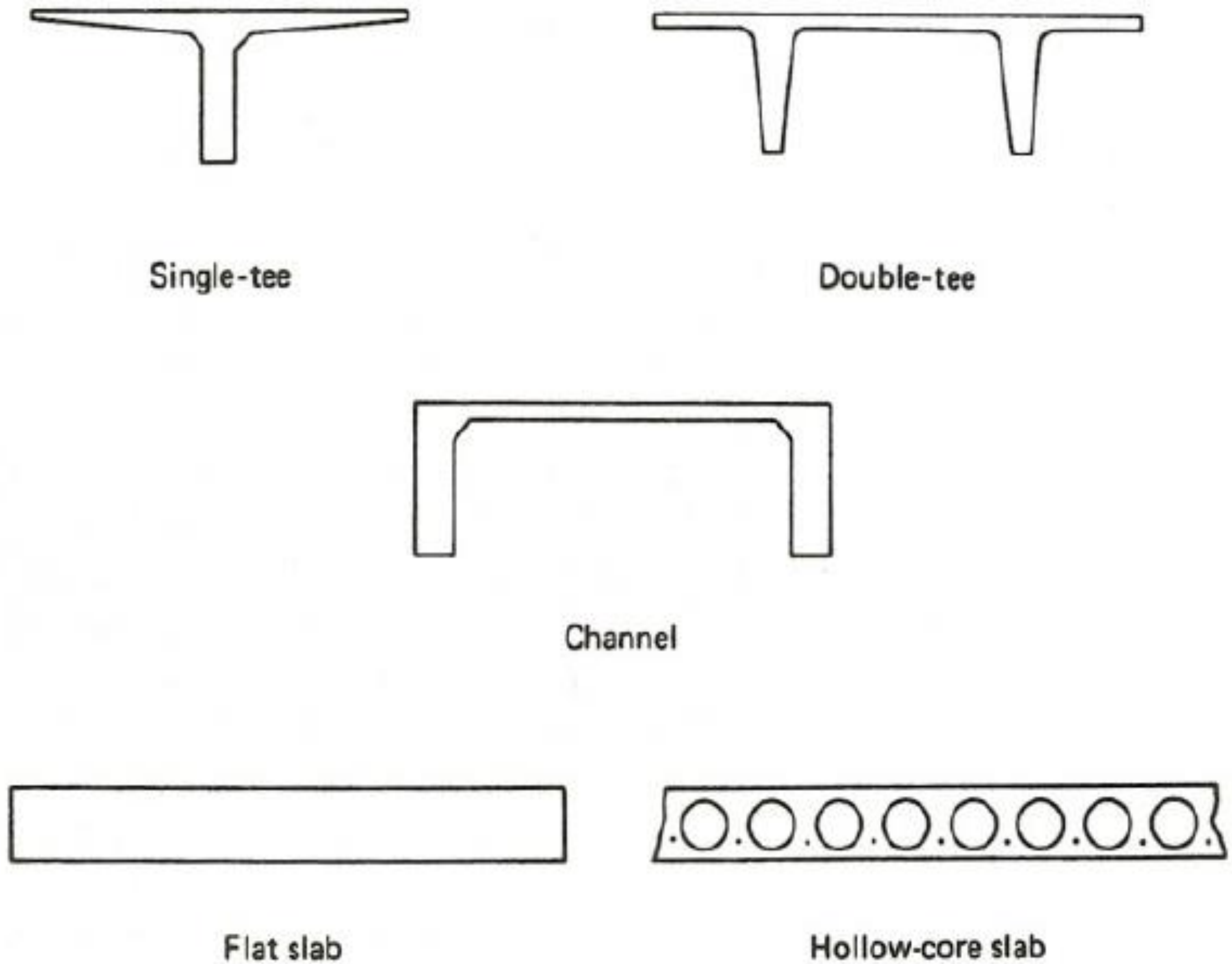


FIGURE 12-9: Steps in tilt-up construction.

(Courtesy of The Burke Company)

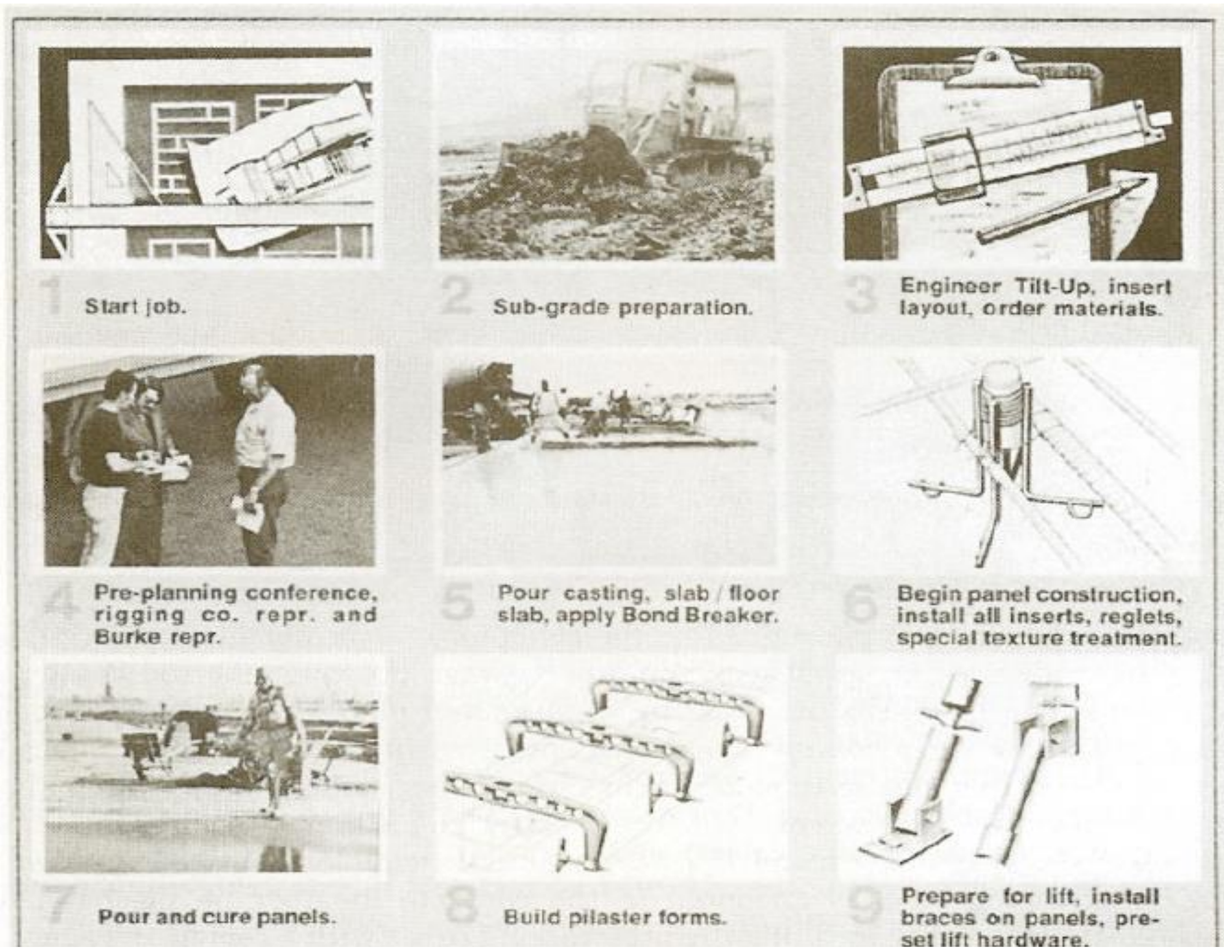
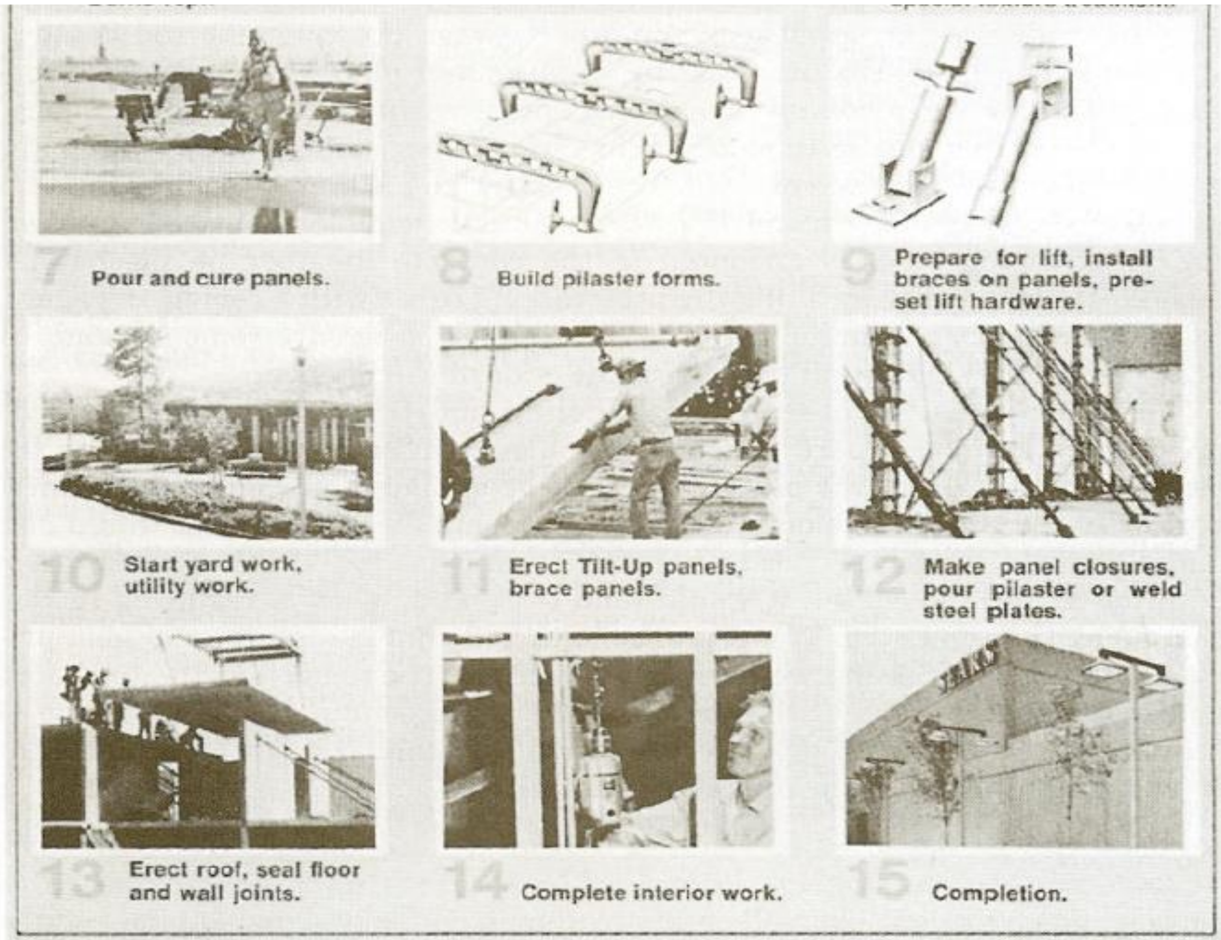


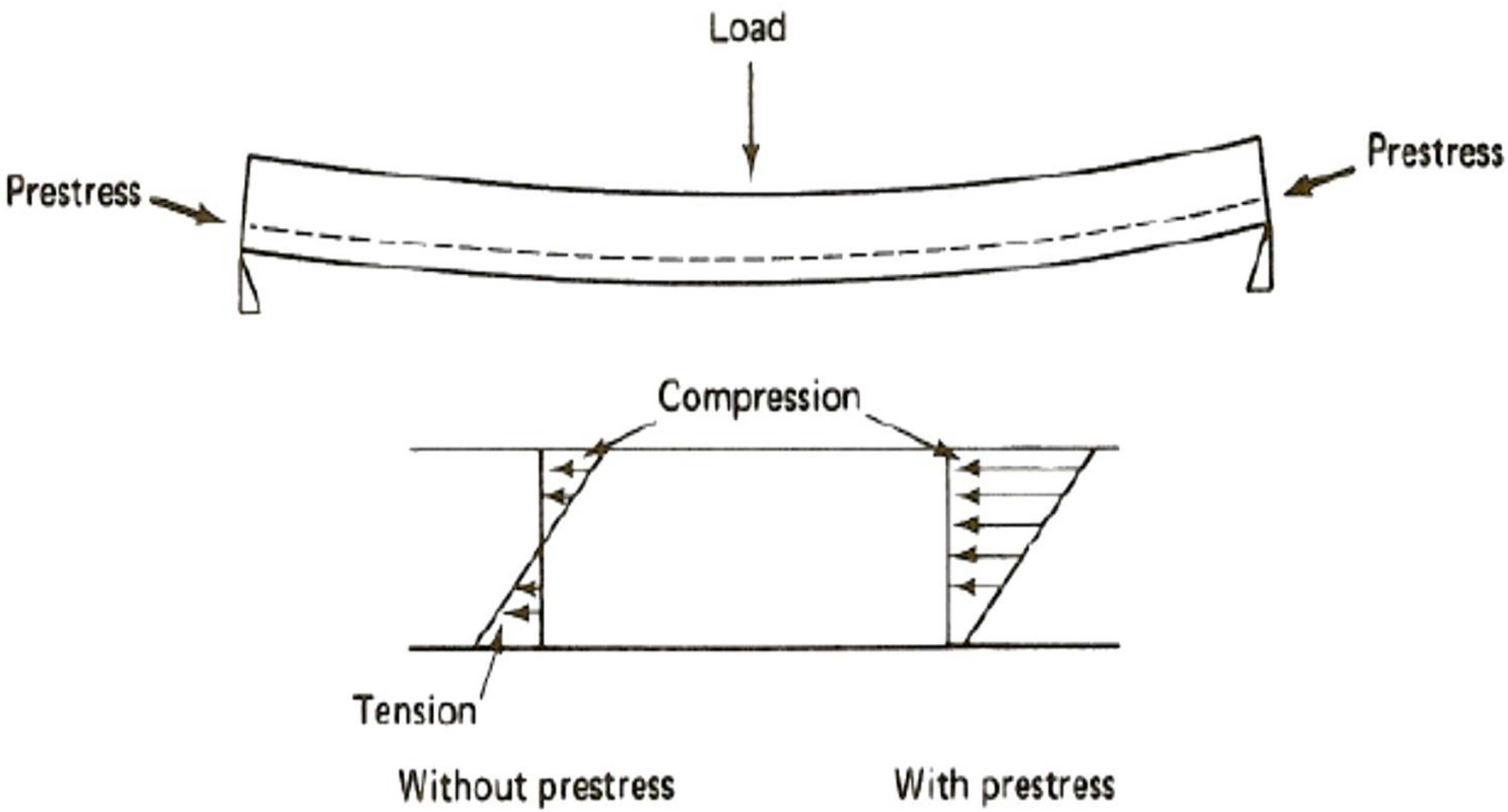
FIGURE 12-9: Steps in tilt-up construction.
(Courtesy of The Burke Company)



3. Prestressed Concrete

- *Prestressed concrete* is concrete to which an initial compression load has been applied.
- Prestressing serves to increase the load that a beam or other flexural member can carry before allowable tensile stresses are reached.
  - because the concrete is quite strong in compression but weak in tension,

FIGURE 12-10: Stresses in a Prestressed simple beam.



Prestressed-

(exaggerated)

Prestressed Concrete

- Advantages:
  - permits a smaller, lighter member to be used in supporting a given load.
  - reduces the amount of deflection in a beam.
  - Since the member is always kept under compression, any cracking that does occur will remain closed up and not be apparent.
- Disadvantages:
  - higher material, equipment, and labor cost involved in the production of prestressed components.

Prestressed Concrete

- There are two methods for producing prestress in concrete members;
  - pretensioning and
  - posttensioning.

Prestressed Concrete

- Caution must be observed in handling and transporting pretensioned prestressed members, particularly if they are asymmetrically stressed.

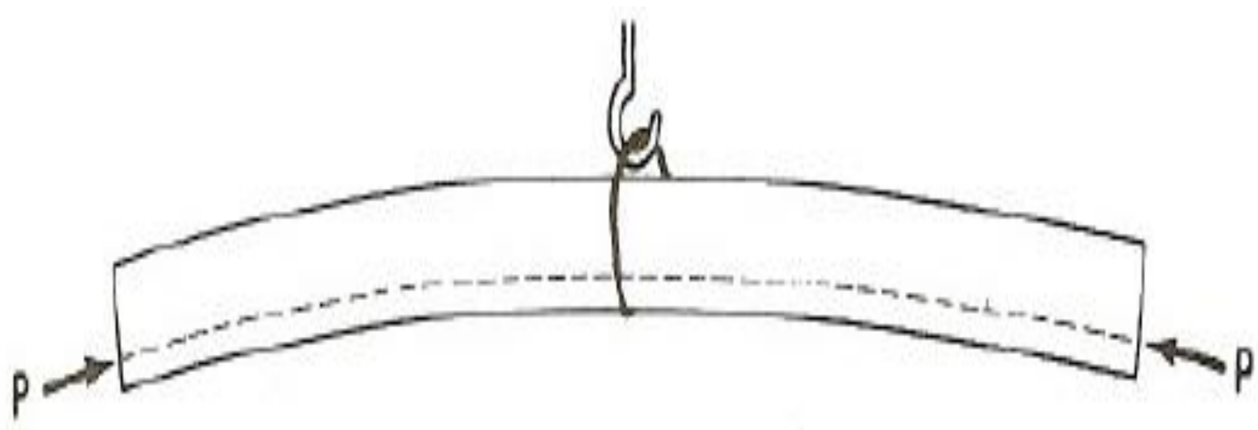


FIGURE 12-11: Lifting prestressed beam at the center.

- It should be lifted by the ends or by using multiple lift points along the beam.

4. Architectural Concrete

- The architectural use of concrete to provide appearance effects has greatly increased in recent years.
- Architectural effects are achieved by the shape, size, texture, and color used.

FIGURE 12-12: Application of architectural concrete.

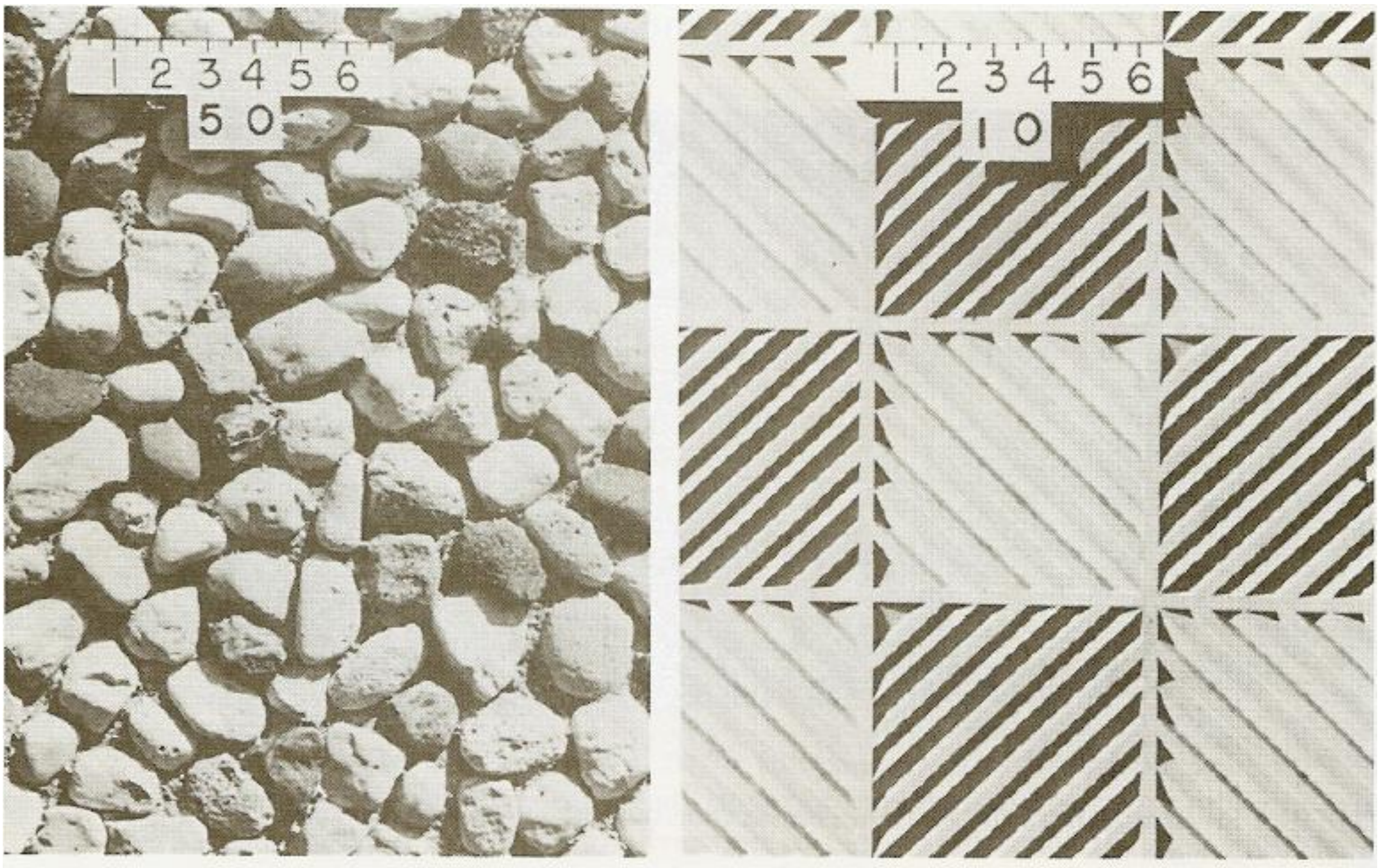
(Courtesy of Portland Cement Association)

Architectural Concrete

- Some of the major methods used for obtaining architectural concrete effects include:
  - exposed aggregate surfaces (Figure 12-13a),
  - special surface designs and textures achieved by the use of form liners (Figure 12-13b), and
  - mechanically produced surfaces (Figure 12-14).
- Exposed aggregate surfaces are produced by removing the cement paste from the exterior surface, exposing the underlying aggregate.

FIGURE 12-13: Architectural concrete surfaces.

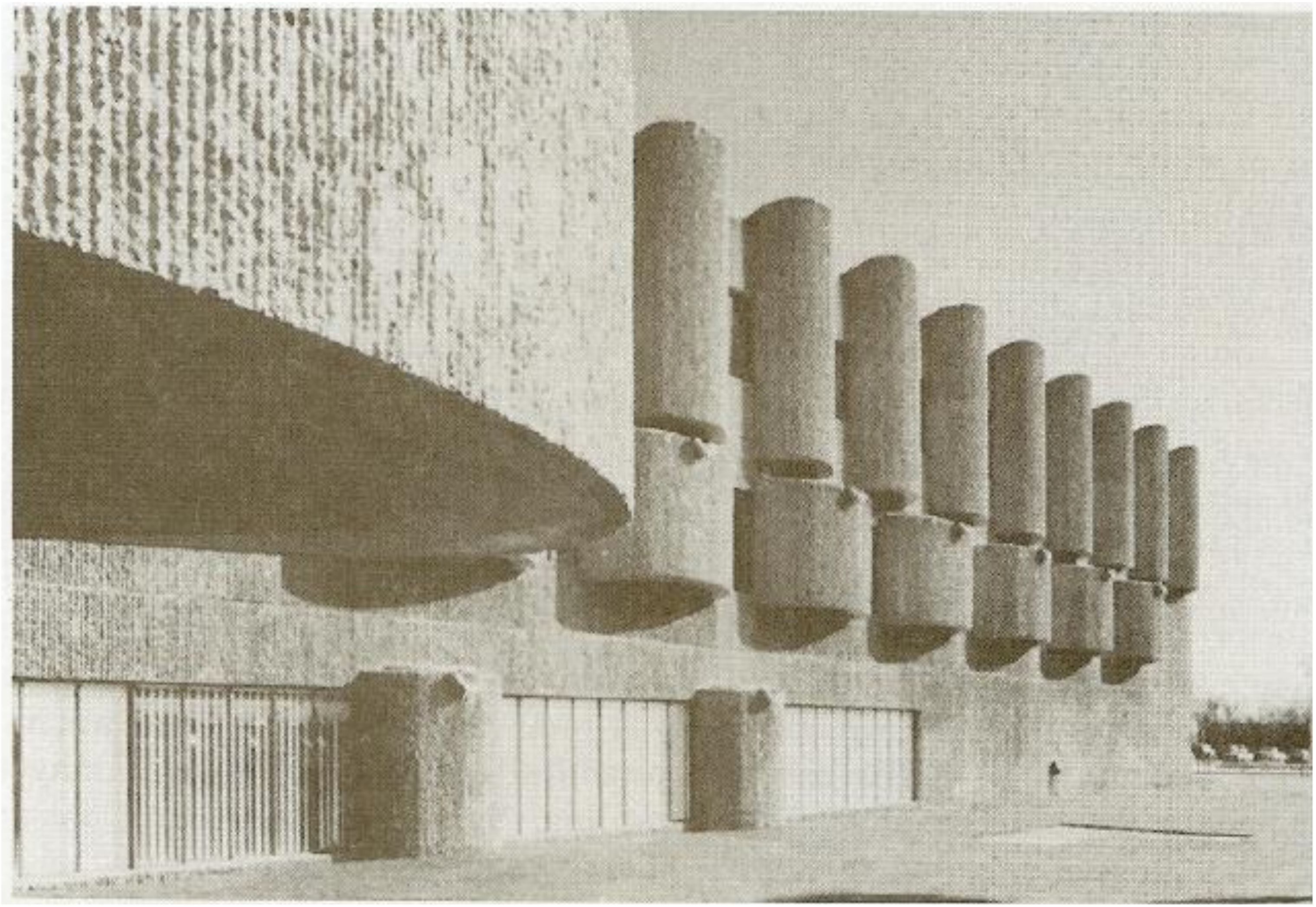
(Courtesy of Portland Cement Association)



a. Exposed aggregate

b. Pattern producer by a form liner

FIGURE 12-14: Mechanically produced concrete surface texture.
(Courtesy of Portland Cement Association)



12-2 CONCRETE CONSTRUCTION PRACTICES

- Concrete construction involves:
  – concrete batching,
  – mixing,
  – transporting,
  – placing,
  – consolidating,
  – finishing, and
  – curing.

12-2 CONCRETE CONSTRUCTION PRACTICES

- Transporting and Handling
- Placing and Consolidating
- Finishing and Curing
- Hot-Weather Concreting
- Cold-Weather Concreting

Transporting and Handling

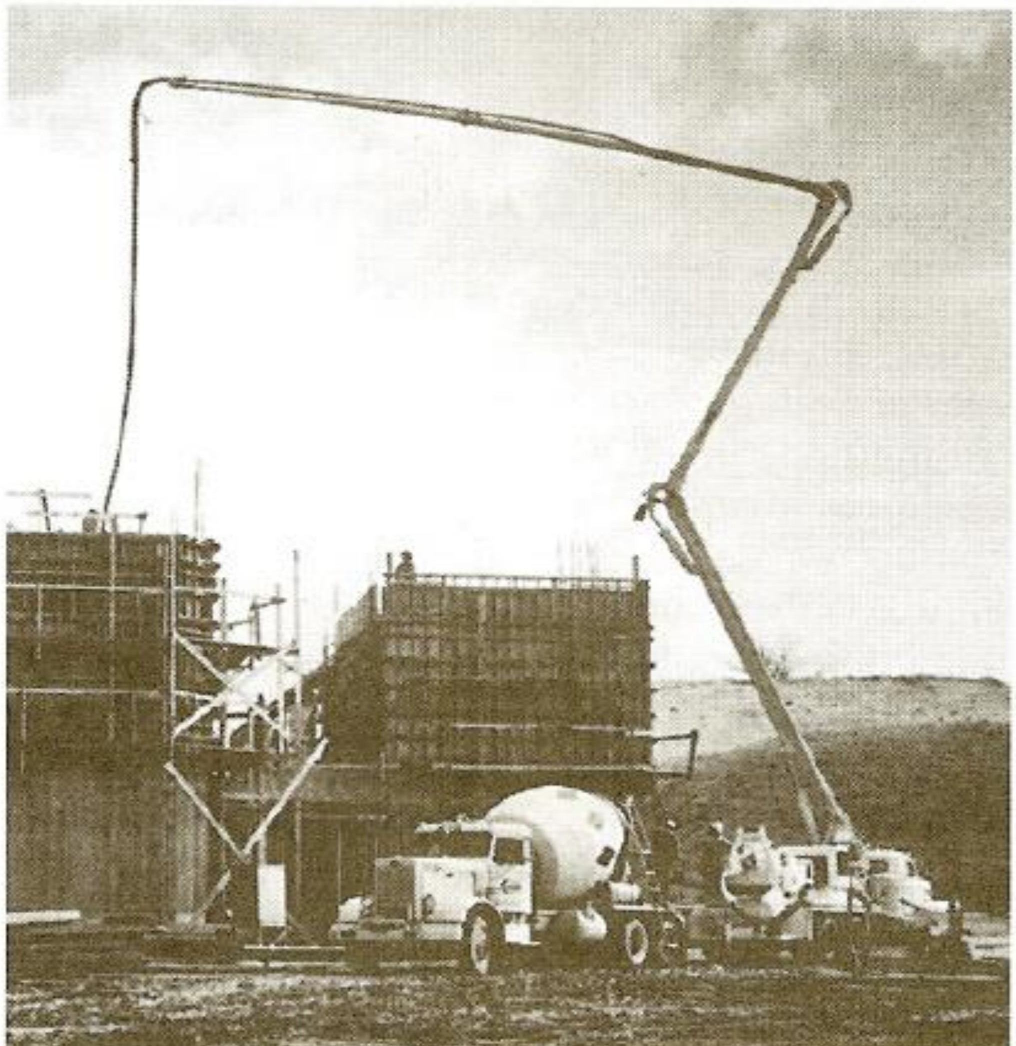
- A number of different items of equipment are available for moving concrete from the mixer to its final position.
  - wheelbarrows,
  - buggies,
  - chutes,
  - conveyors,
  - pumps,
  - buckets, and
  - trucks.
- care must be taken to avoid segregation when handling plastic concrete.

Wheelbarrow

• Buggies

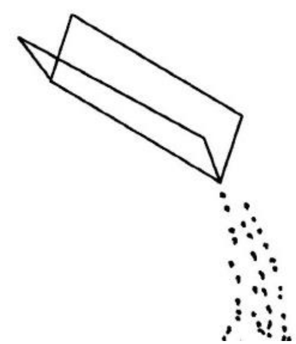
FIGURE 12-15: Concrete pump and truck mixer.

(Courtesy of Challenge-Cook Bros., Inc.)



Transporting and Handling

- Concrete conveyors: move concrete either horizontally or vertically.
- Chutes are widely used for:
  - moving concrete from the mixer to haul units, and
  - placing concrete into forms.



- Truck mixers are equipped with integral retracting *chutes*
- It used for discharging concrete directly into forms within the radius of the chute.
- When chuting concrete,
  - the slope of the chute must be high enough to keep the chute clean
  - but not high enough to produce segregation of the concrete.

Placing and Consolidating

- *Placing:* the movement of plastic concrete into its final position (usually within forms).
  - Before placing concrete, the underlying surface and the interior of all concrete forms must be properly prepared.

Placing and Consolidating

- *Consolidation:* is the process of removing air voids in concrete as it is placed by using.
  - *Concrete vibrators*
    - hand rodding or spading may be employed.
  - Immersion-type electric,
  - pneumatic, or
  - hydraulic concrete vibrators are widely used.

Finishing and Curing

- *Finishing:* is the process of bringing the surface of concrete to its final position and imparting the desired surface texture.
- https://youtu.be/BwyzeekfnCY
- Finishing operations include:
  - Screeding: is the process of striking off the concrete in order to bring the concrete surface to the required grade

  https://www.youtube.com/watch?v=LSyTBM5nfMU
  - Floating: When the concrete has hardened enough, the concrete is floated with a wood or metal float,

  https://www.youtube.com/watch?v=aRFdoVcJAPc
  - Troweling: with a steel trowel follows floating when a smooth dense surface is desired, and

  https://www.youtube.com/watch?v=N1C-Zi-5qzE
  - brooming: the concrete may be *broomed* by drawing a stiff broom across the surface.

FIGURE 12-16: Roller finisher being used on large slab pour.
(Courtesy of CMI Corp.)

Hot-Weather Concreting

- The rate of hardening of concrete is greatly accelerated when concrete temperature is appreciably higher than the optimum temperature of 50 to 60°F (10 to 15.5°C).
- 90 degrees Fahrenheit (32°C) is considered a reasonable upper limit for concreting operations.

Cold-Weather Concreting

- The problems of cold-weather concreting are essentially opposite to those of hot-weather concreting.
- Concrete must not be allowed to freeze during the first 24 h after placing (to avoid permanent damage and loss of strength).
  - Keep Minimum 50°F (l0°C) for at least 3 days after placing.
  - Use Type III (high early strength) cement or
  - Use an accelerator to reduce concrete setting time during low temperatures

12-3 CONCRETE FORMWORK

- **General Requirements for Formwork**
- **Typical Formwork**
- **Minimizing Cost of Formwork**
- **Construction Practices**
- **Formwork Safety**

General Requirements for Formwork

- The principal requirements for concrete formwork are that it should be:
  - safe
  - produce the desired shape and surface texture
  - and economical.
- Procedures for designing formwork that will be safe under the loads imposed by:
  - plastic concrete,
  - workers and other live loads, and
  - external forces (such as wind loads)

FIGURE 12-18: Typical wall form.

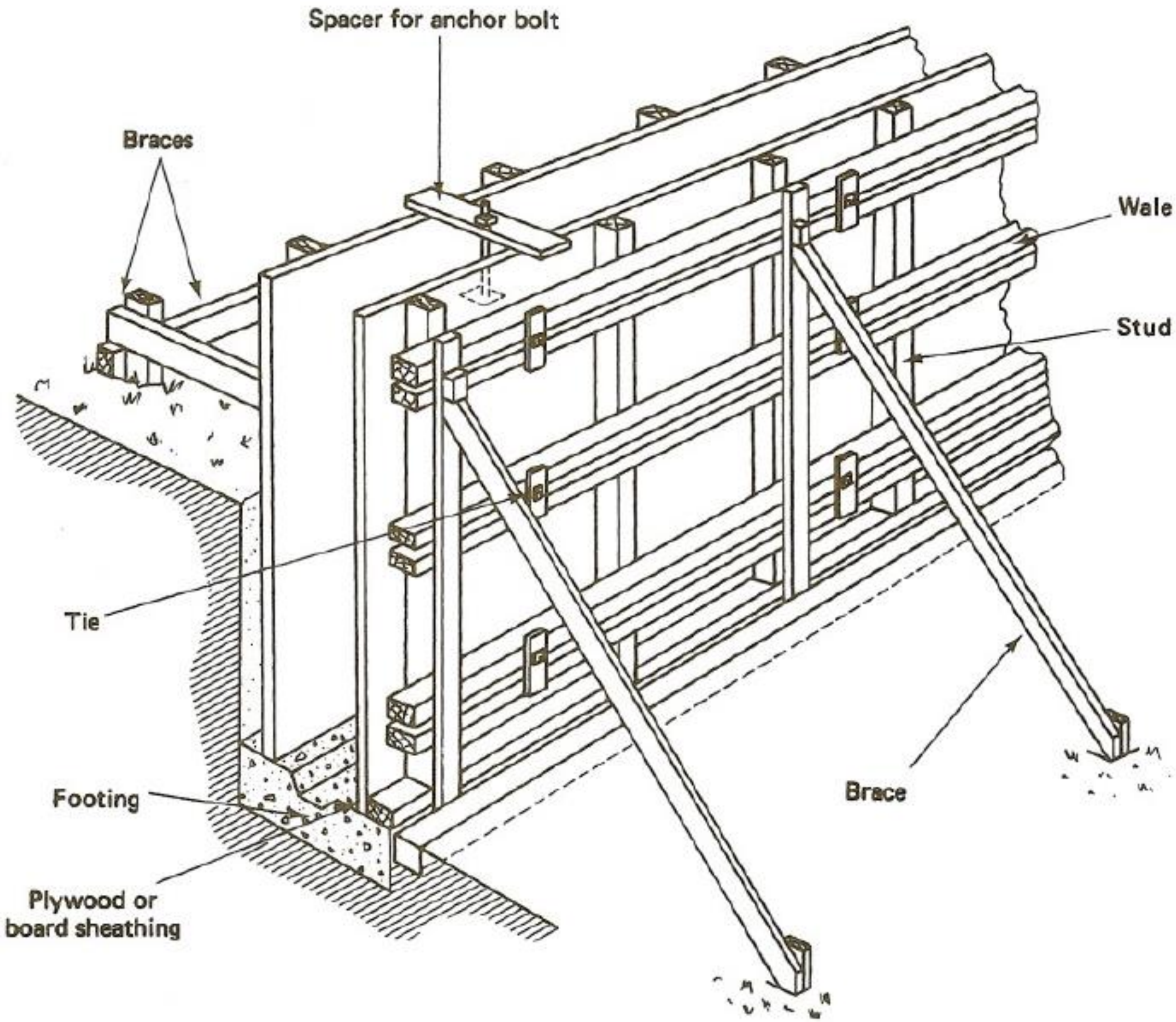


FIGURE 12-20: Typical column form.

(U.S. Department of the Army)

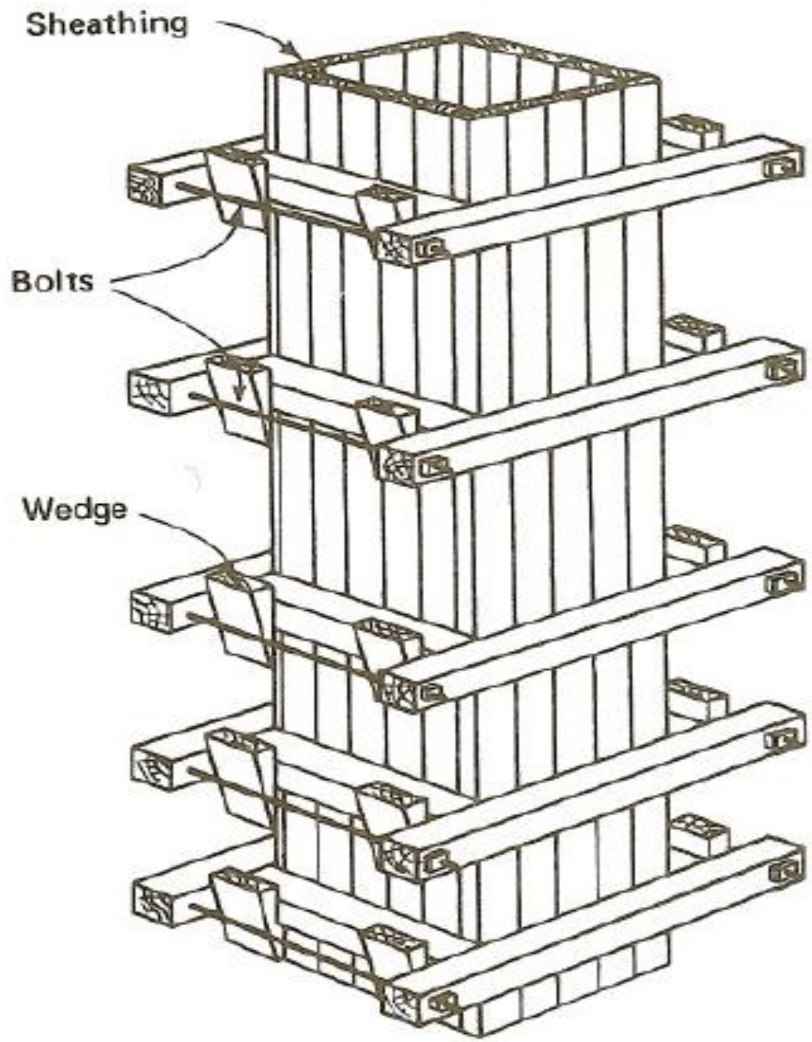


FIGURE 12-21: Form for elevated slab.

(Courtesy of American Concrete Institute)

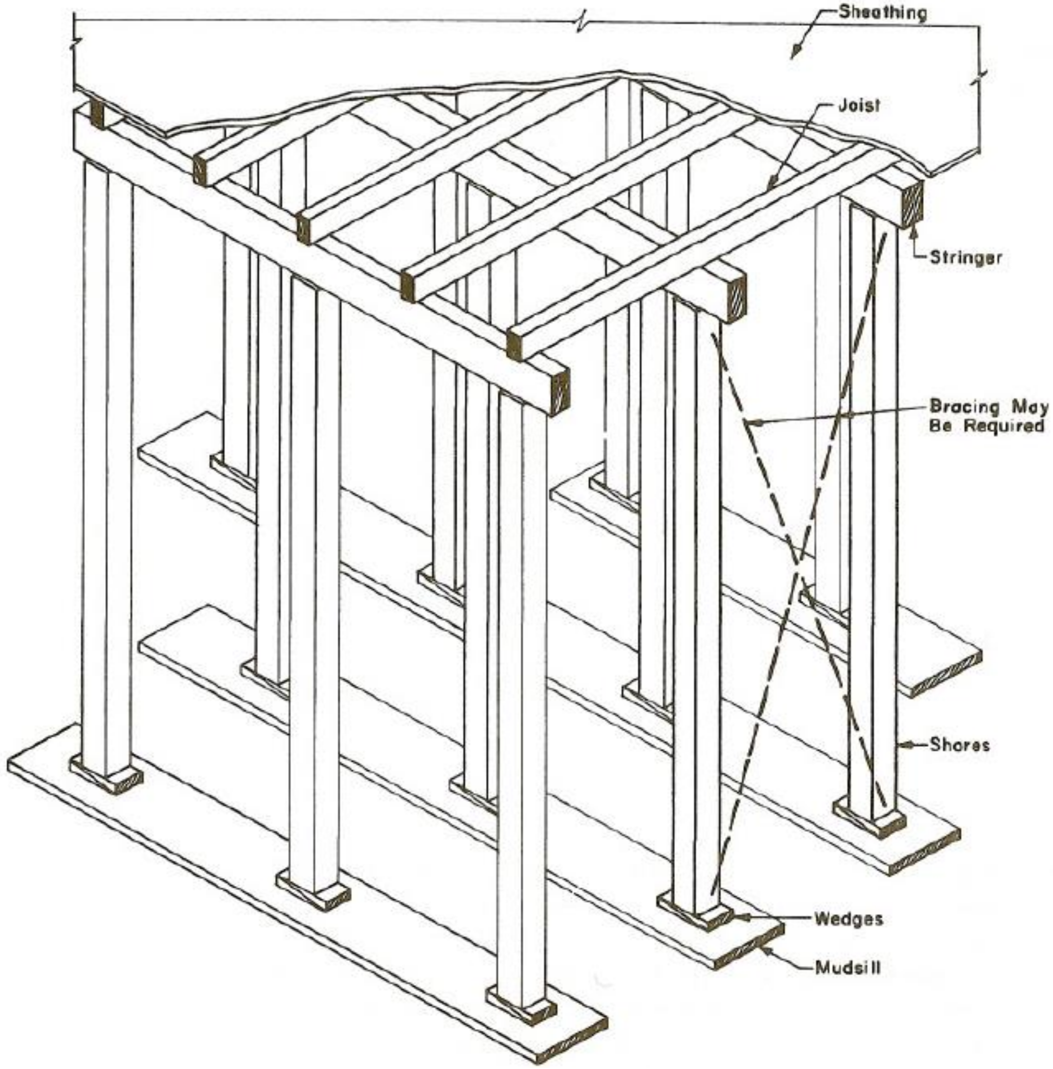


FIGURE 12-22: Beam and slab form.

(Courtesy of American Concrete Institute)

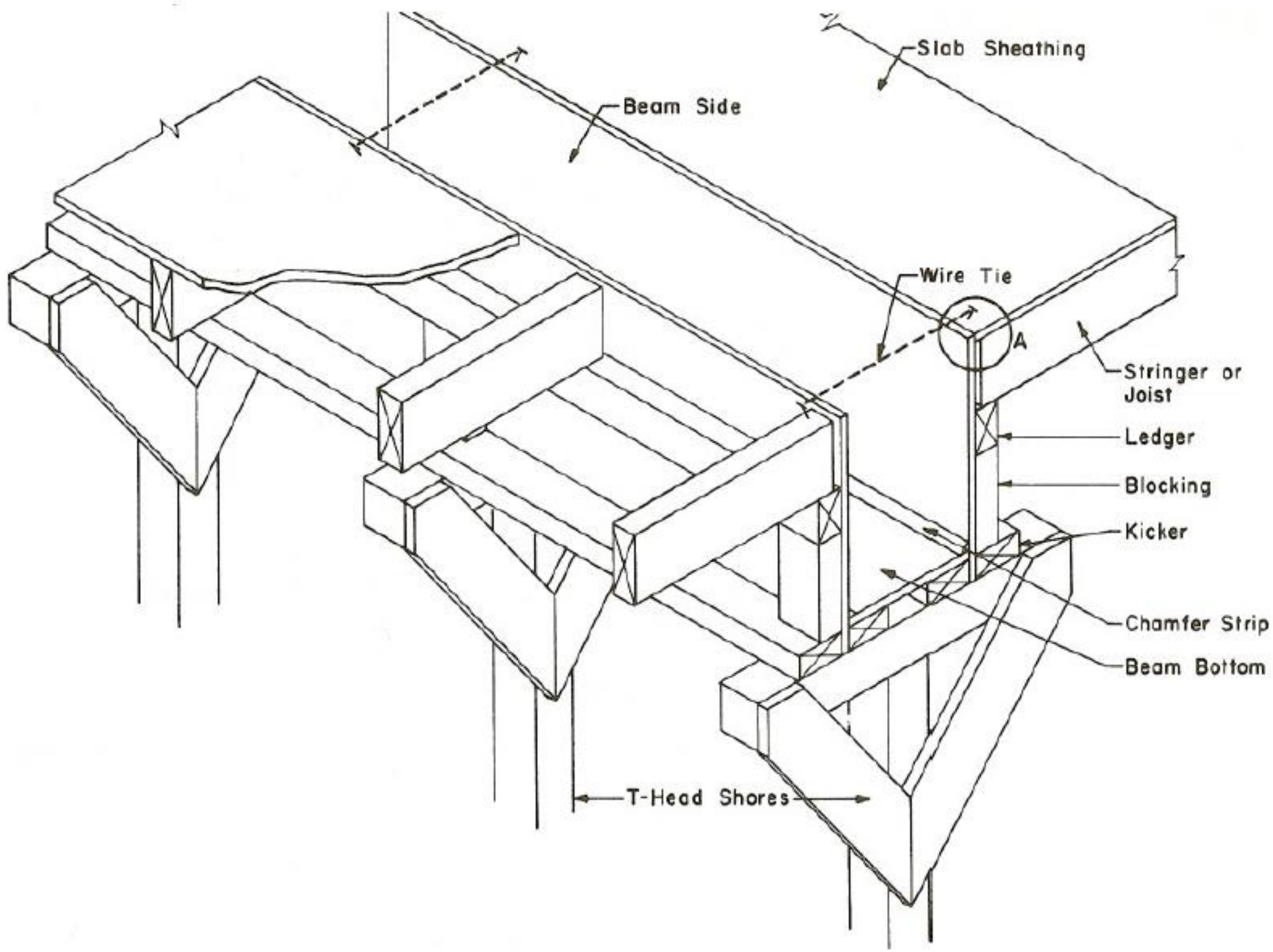


FIGURE 12-23: One-way slab form.

(Courtesy of American Concrete Institute)

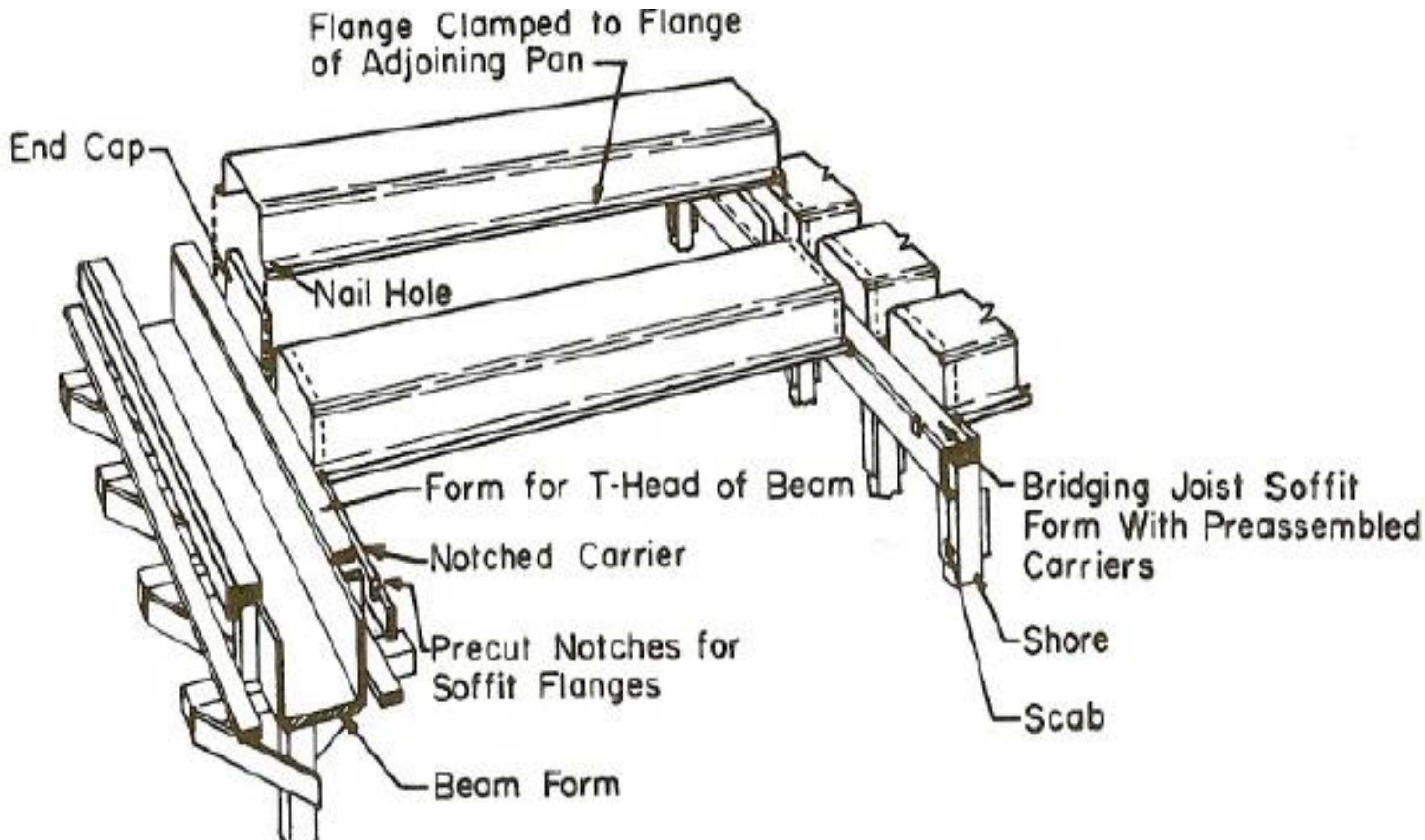


FIGURE 12-24: Two-way slab form.

(Courtesy of American Concrete Institute)

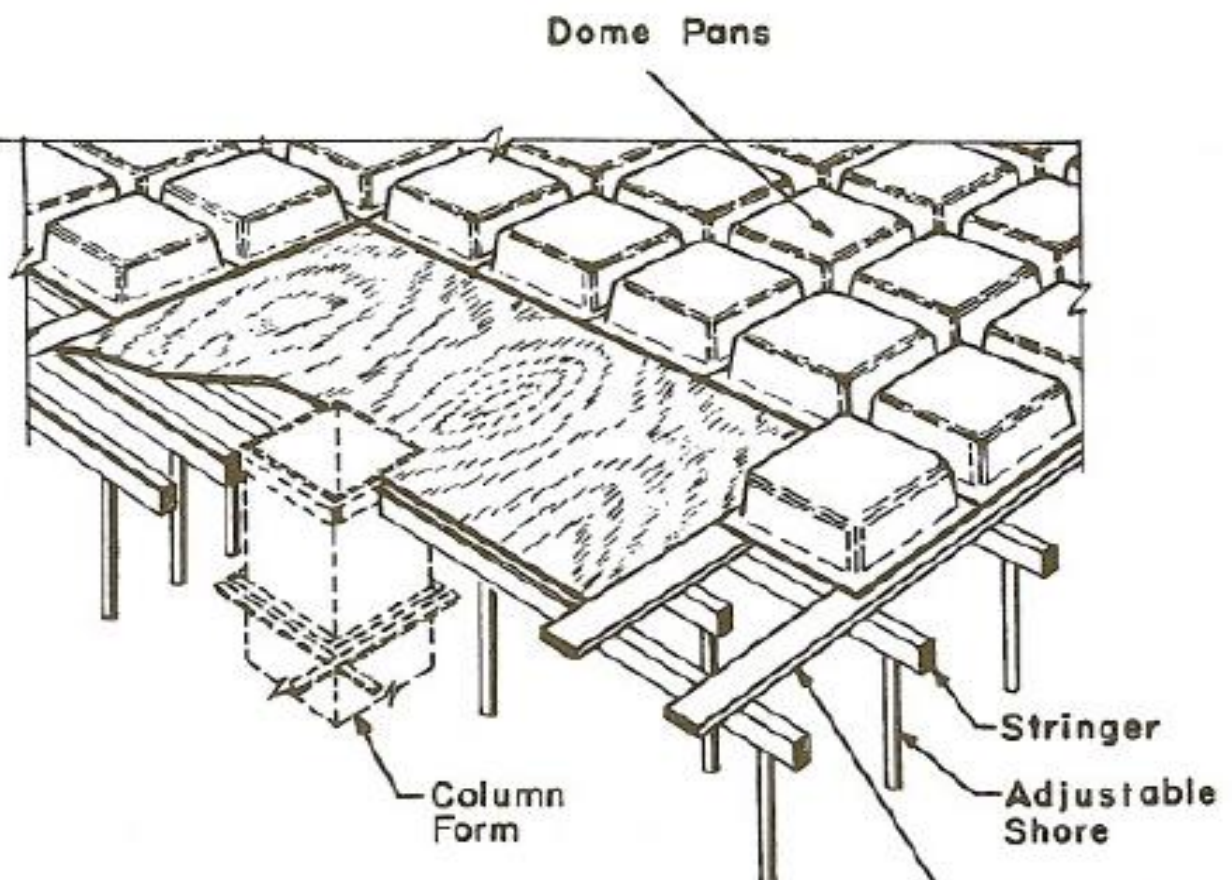
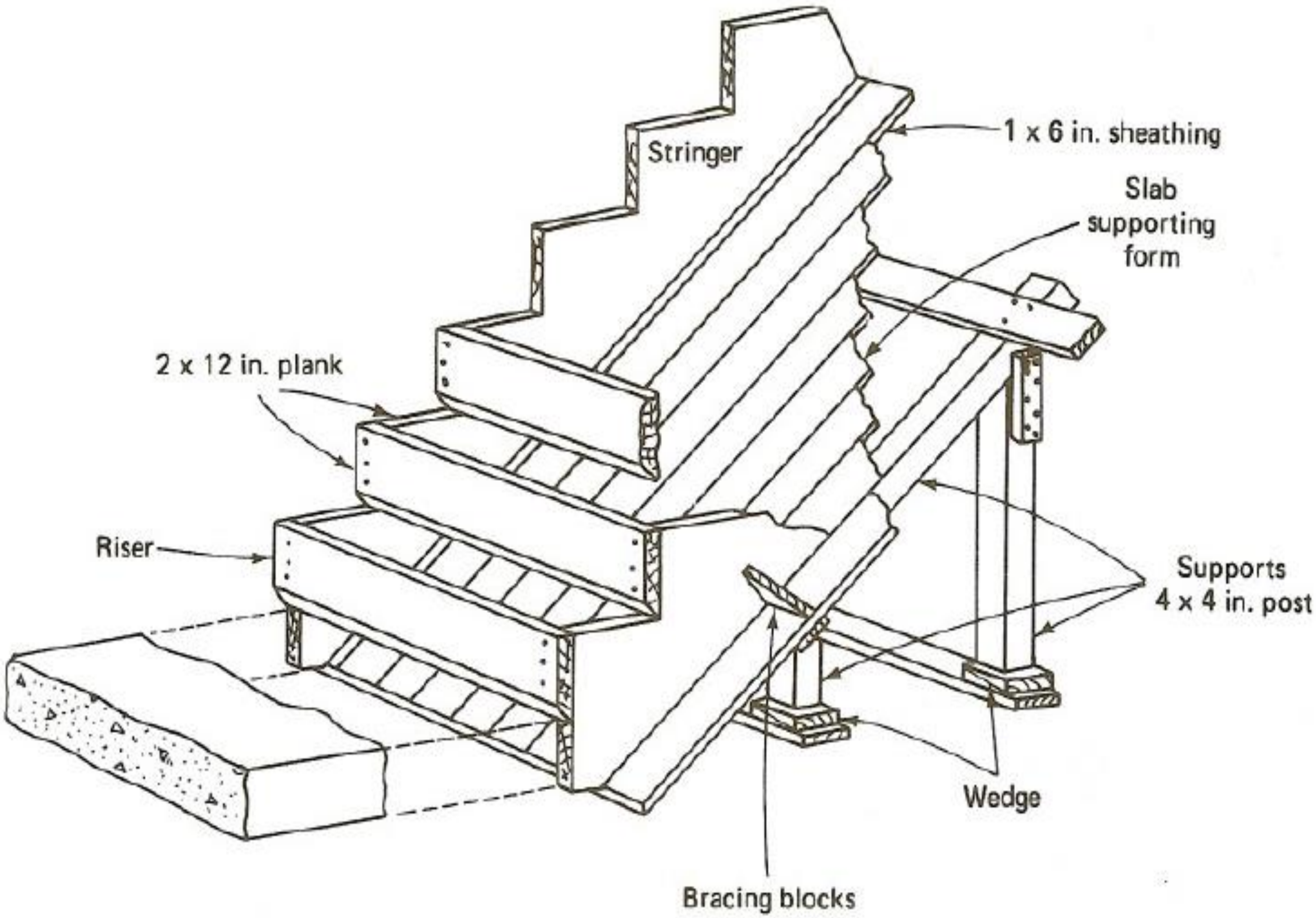


FIGURE 12-25: Wood form for stairway.

(U.s. Department of the Army)



Minimizing Cost of Formwork

- repetitive use of forms can lower formwork cost.
- Multiple-use forms may be either:
  - standard commercial types or
  - custom-made by the contractor.
    - use assembly-line techniques whenever possible.
- *Flying forms* (Figure 12-26)*:* are often economical in repetitive types of concrete construction.
- use of *slip forms* and *tilt-up construction* techniques (*Where appropriate*)

FIGURE 12-26: Repositioning flying form.

(Courtesy of Lorain Division, Koehring Co.)

Formwork Safety

1) Provide adequate foundations for all formwork.
2) Provide adequate bracing of forms.
3) Control the rate and location of concrete placement so that design loads are not exceeded.
4) Ensure that forms and supports are not removed before the concrete has developed the required strength.
5) When placing prefabricated form sections in windy weather, care must be taken to avoid injury due to swinging of the form caused by wind forces.
6) Clean the site from the nails.

12-4 REINFORCING STEEL

- **Concrete Reinforcing Steel**
- **Placement of Reinforcing**

Concrete Reinforcing Steel

- Concrete reinforcing steel is available as:
  - standard reinforcing bars,
  - spirals (for column reinforcing), and
  - welded wire fabric (WWF).
- Deformed bars -American Society for Testing and Materials (ASTM) standard sizes listed in Table 12-1.

TABLE 12-1: ASTM standard reinforcing bar sizes

Size Number	Weight		Diameter		Section Area	
	lb/ft	kg/m	in.	mm	sq in.	mm^2
3	0.376	0.560	0.375	9.52	0.11	71
4	0.668	0.994	0.500	12.70	0.20	129
5	1.043	1.552	0.625	15.88	0.31	200
6	1.502	2.235	0.750	19.05	0.44	284
7	2.044	3.042	0.875	22.22	0.60	387
8	2.670	3.973	1.000	25.40	0.79	510
9	3.400	5.059	1.128	28.65	1.00	645
10	4.303	6.403	1.270	32.26	1.27	819
11	5.313	7.906	1.410	35.81	1.56	1006
14	7.650	11.384	1.693	43.00	2.25	1452
18	13.600	20.238	2.257	57.33	4.00	2581

Concrete Reinforcing Steel

- Two marking systems are used to identify ASTM standard reinforcing bars, (Figure 12-28),
  - the continuous line system and
  - the number system.

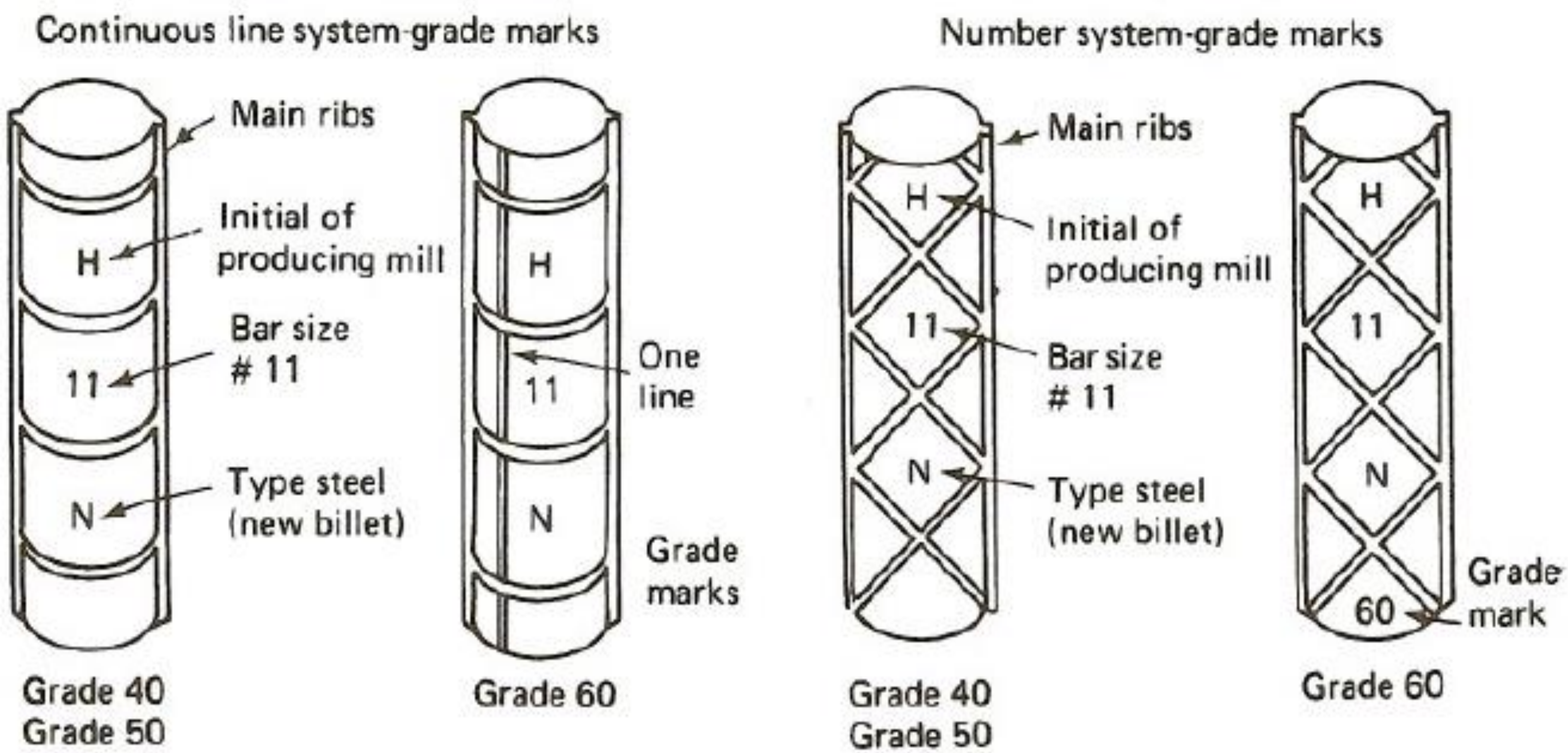


TABLE12-2: Steel wire data for welded wire fabric

Wire Size Number		Diameter		Area		Weight	
Smooth	Deformed	in.	mm	sq in.	mm^2	lb/ft	kg/m
W31	D31	0.628	16.0	0.31	200	1.054	1.568
W28	D28	0.597	15.2	0.28	181	0.952	1.417
W26	D26	0.575	14.6	0.26	168	0.934	1.390
W24	D24	0.553	14.1	0.24	155	0.816	1.214
W22	D22	0.529	13.4	0.22	142	0.748	1.113
W20	D20	0.505	12.8	0.20	129	0.680	1.012
W18	D18	0.479	12.2	0.18	116	0.612	0.911
W16	D16	0.451	11.5	0.16	103	0.544	0.810
W14	D14	0.422	10.7	0.14	90	0.476	0.708
W12	D12	0.391	9.9	0.12	77	0.408	0.607
W11	D11	0.374	9.5	0.11	71	0.374	0.557
W10	D10	0.357	9.1	0.10	65	0.340	0.506
W9.5		0.348	8.8	0.095	61	0.323	0.481
W9	D9	0.338	8.6	0.09	58	0.306	0.455
W8.5		0.329	8.4	0.085	55	0.289	0.430
W8	D8	0.319	8.1	0.08	52	0.272	0.405
W7.5		0.309	7.8	0.075	48	0.255	0.379
W7	D7	0.299	7.6	0.07	45	0.238	0.354
W6.5		0.288	7.3	0.065	42	0.221	0.329
W6	D6	0.276	7.0	0.06	39	0.204	0.304
W5.5		0.265	6.7	0.055	35	0.187	0.278
W5	D5	0.252	6.4	0.05	32	0.170	0.253
W4.5		0.239	6.1	0.045	29	0.153	0.228
W4	D4	0.226	5.7	0.04	26	0.136	0.202
W3.5		0.211	5.4	0.035	23	0.119	0.177
W2.9		0.192	4.9	0.029	19	0.099	0.147
W2.5		0.178	4.5	0.025	16	0.085	0.126
W2		0.160	4.1	0.02	13	0.068	0.101
W1.4		0.134	3.4	0.014	9	0.048	0.071

Placement of Reinforcing

- reinforcing steel is used primarily to resist tension and thus prevent cracking or failure of the concrete member under tension.
  - Since concrete is weak in resistance to tensile forces,
- Tension may be induced by:
  - shrinkage of concrete as it hardens,
  - temperature changes
  - bending and shear forces.
- Typical placement of reinforcing steel in concrete structural members is illustrated in Figure 12-29.

FIGURE 12-29: Placement of reinforcing steel.

(Courtesy of Concrete Reinforcing Steel Institute)

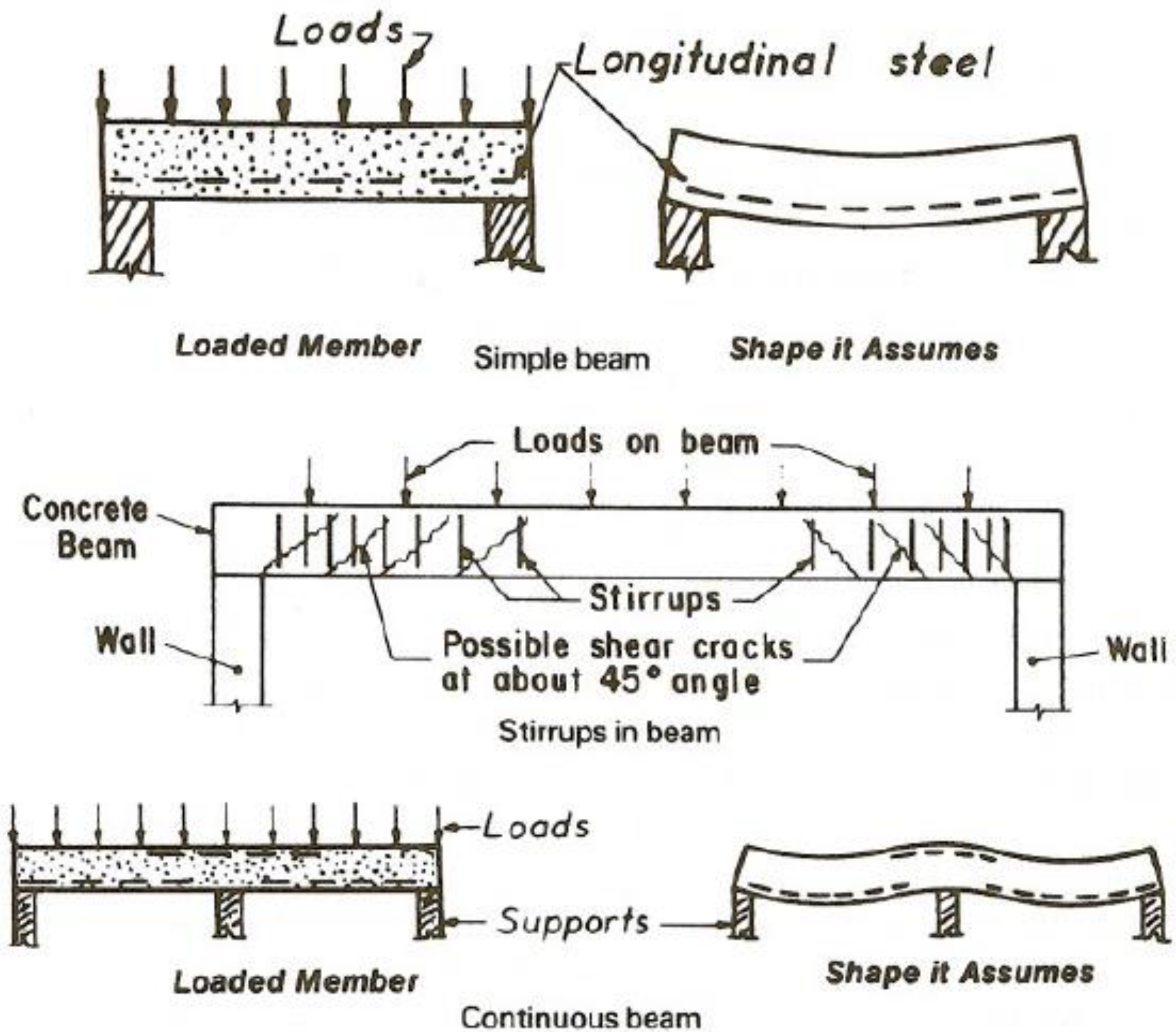
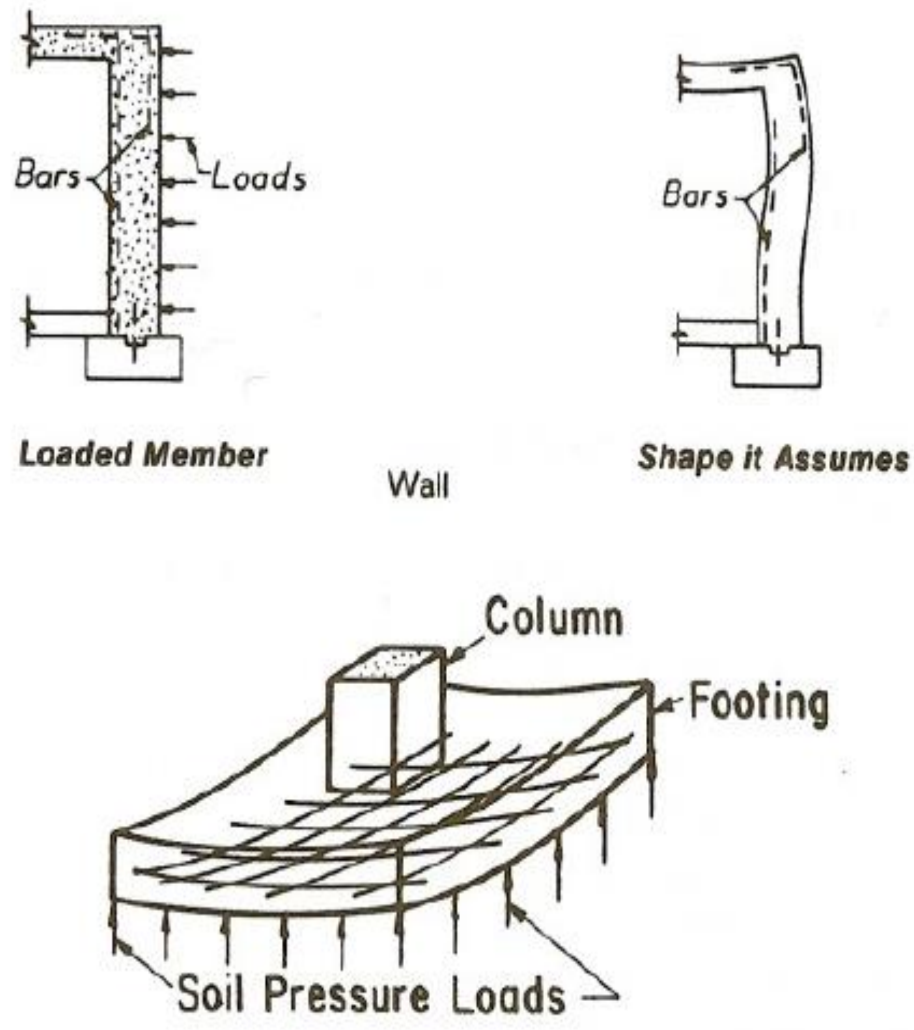


FIGURE 12-29: Placement of reinforcing steel.

(Courtesy of Concrete Reinforcing Steel Institute)



Placement of Reinforcing

- Standard types and sizes of wire bar supports are illustrated in Figure 12-30.

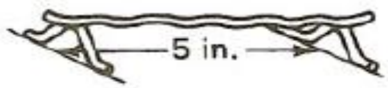
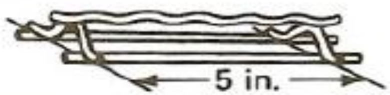
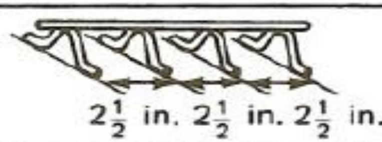
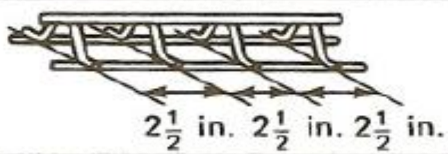
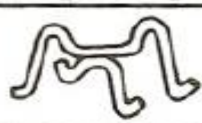
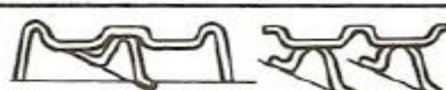
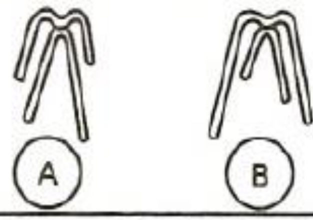
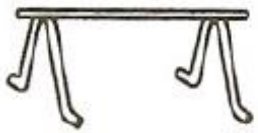
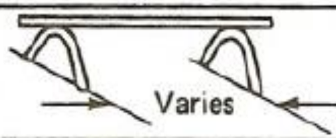
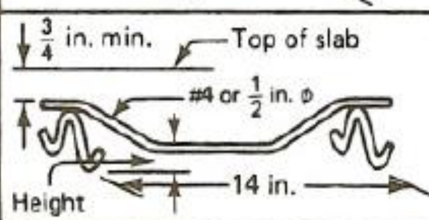
Symbol	Bar support illustration	Type of support	Standard sizes
SB		Slab bolster	$\frac{3}{4}$, 1, $1\frac{1}{2}$, and 2 in. heights in 5 ft and 10 ft lengths
SBU*		Slab bolster upper	Same as SB
BB		Beam bolster	1, $1\frac{1}{2}$, 2; over 2 in. to 5 in. height in increments of $\frac{1}{4}$ in. in lengths of 5 ft
BBU*		Beam bolster upper	Same as BB
BC		Individual bar chair	$\frac{3}{4}$, 1, $1\frac{1}{2}$, and $1\frac{3}{4}$ in. heights
JC		Joist chair	4, 5, and 6 in. widths and $\frac{3}{4}$, 1, and $1\frac{1}{2}$ in. heights

FIGURE 12-30: Wire bar supports.

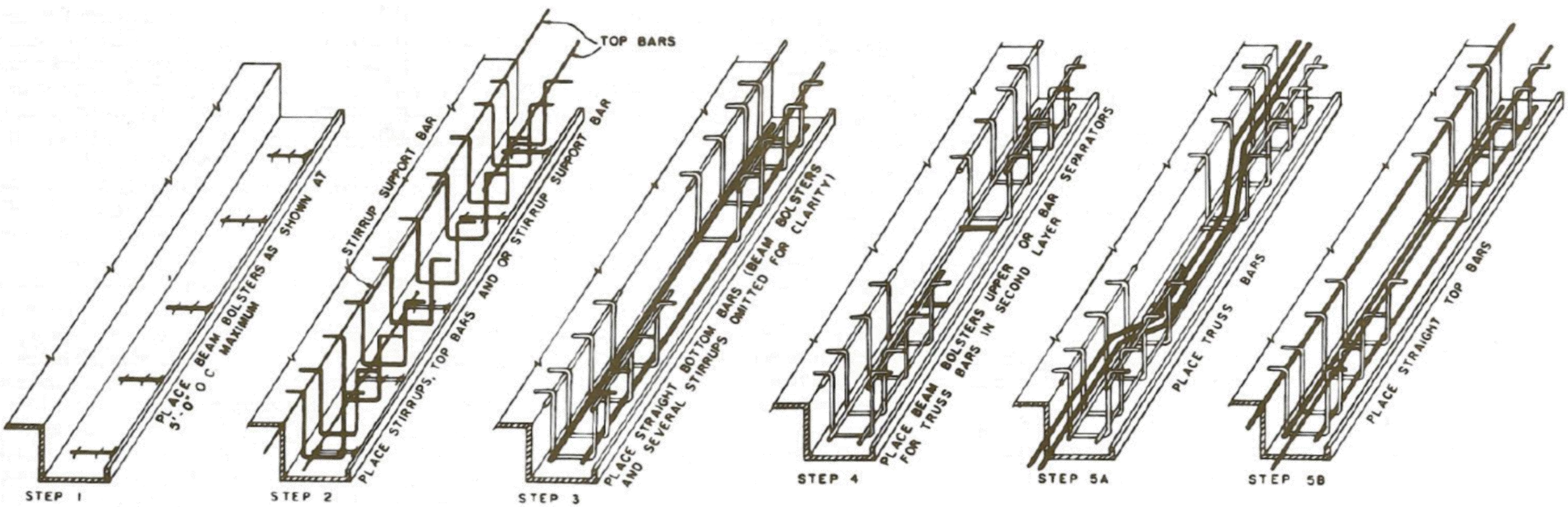
(Courtesy of Concrete Reinforcing Steel Institute)

HC		Individual high chair	2 to 15 in. heights in increments of $\frac{1}{4}$ in.
HCM*		High chair for metal deck	2 to 15 in. heights in increments of $\frac{1}{4}$ in.
CHC		Continuous high chair	Same as HC in 5 foot and 10 foot lengths
CHCU*		Continuous high chair upper	Same as CHC
CHCM*		Continuous high chair for metal deck	Up to 5 in. heights in increments of $\frac{1}{4}$ in.
JCU**		Joist chair upper	14 in. Span. Heights −1 in. through +3$\frac{1}{2}$ in. vary in $\frac{1}{4}$ in. increments

* Available in Class A only, except on special order.
** Available in Class A only, with upturned or end bearing legs.

Placement of Reinforcing

- Figure 12-31 illustrates the CRSI-suggested sequence for placing reinforcing steel in a deep, heavily reinforced concrete beam



12-5 QUALITY CONTROL

- **Common Deficiencies in Concrete Construction**
- **Inspection and Testing**

Common Deficiencies in Concrete Construction

- Adequate Quality Control must be exercised over concrete operations.
  - to be obtained the required strength, durability, and appearance.
- Quality control measures specifically applicable to formwork are described in Section 12-3.
- Deficiencies in concrete construction practice may usually be traced to inadequate supervision of construction operations.
- A review by the U.S. Army Corps of Engineers has produced a list of repetitive deficiencies observed in concrete construction.

Inspection and Testing

- The inspection and testing associated with concrete Quality Control may be grouped into five phases.
  1. mix design;
  2. concrete materials quality;
  3. batching, mixing, and transporting concrete;
  4. concrete placing, vibrating, finishing, and curing; and
  5. testing of fresh and hardened concrete at the job site.

Inspection and Testing

- Mix design includes:
  - the quantity of each component in the mix,
  - the type and gradation of aggregates,
  - the type of cement,.
- Aggregate testing includes:
  - tests for organic impurities and excessive fines,
  - gradation,
  - resistance to scratch, and
  - aggregate moisture.

Inspection and Testing

- Recent developments in concrete testing technology have greatly reduced the time required to obtain results from on-site testing of plastic concrete.
  - For example, a nuclear water/cement gauge is now available which measures within 15 minutes:
    - the cement content,
    - water content, and
    - water/cement ratio of plastic concrete.