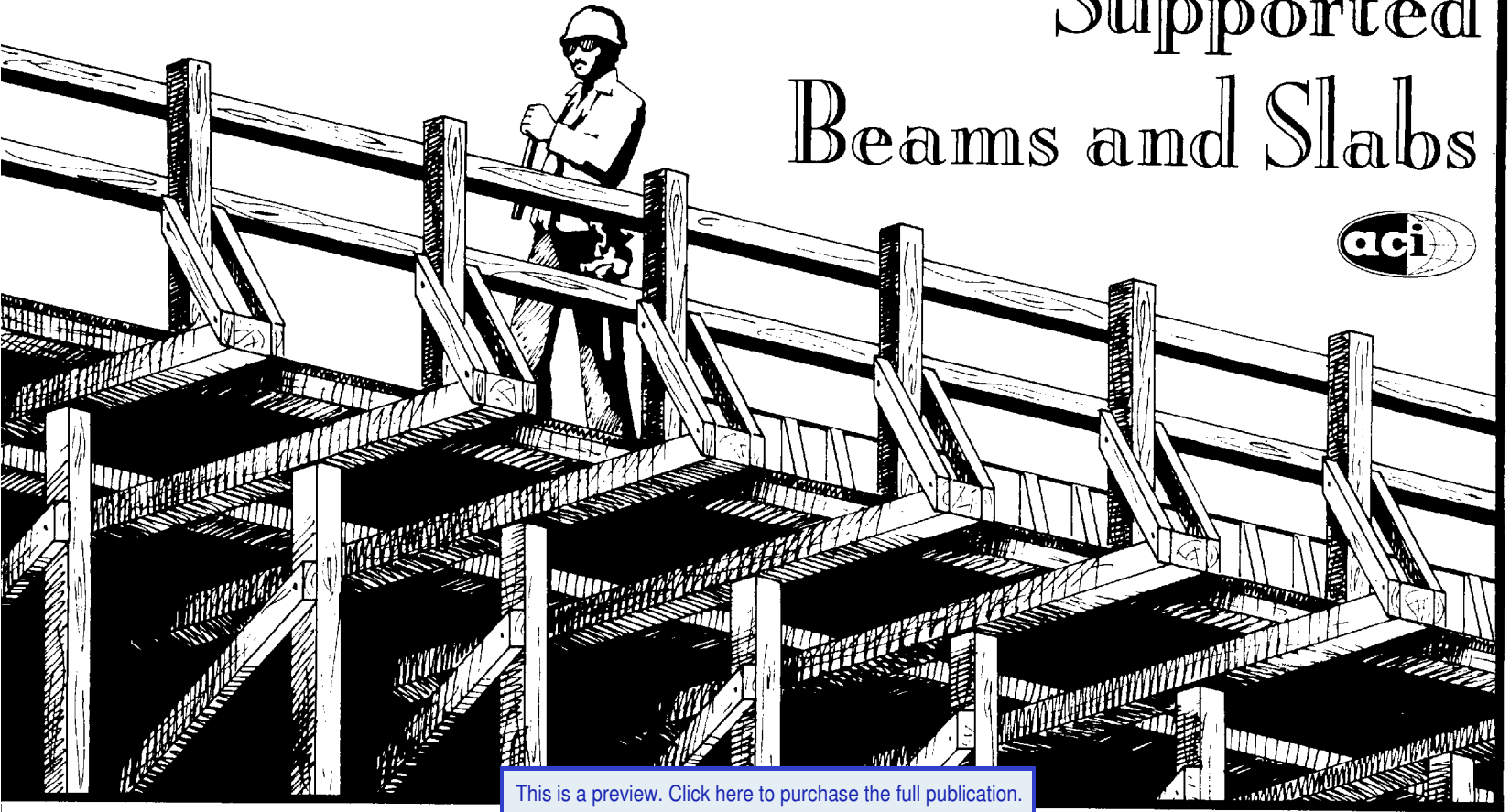
Concrete Craftsman Series·3

Supported Beams and Slabs



CONCRETE CRAFTSMAN SERIES—SUPPORTED BEAMS AND SLABS

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PREFACE

This is the third booklet in the Concrete Craftsman Series published by the American Concrete Institute. The first booklet, *Slabs on Grade* covers placing, curing and finishing. The second booklet, *Cast-in-Place Walls* covers formwork, reinforcement, placing of concrete, curing, and wall finishes.

This third booklet is intended to provide construction knowledge for the apprentice, journeyman, and foreman involved with cast-in-place elevated slabs and beams. For the apprentice craftsman, it provides a source of information to help supplement his practical experience. For the foreman, it provides technical background on such topics as shoring, reshoring, form removal, reinforcement placement, and concrete placing, finishing, and curing. This booklet is not intended as a design aid, but rather a guide to good practice.

The design of supported slabs and beams is the responsibility of a professional engineer. Designs are usually reviewed and approved by local building authorities and governed by codes such as the Uniform Building Code, Standard Building Code, BOCA (Building Officials and Code Administrators) Code and others which reference "Building Code Requirements for Reinforced Concrete" (ACI 318).

The selection and design of formwork is the responsibility of the contractor. The system selected must consider economics, schedule, quality, and safety. If the craftsman is involved with the selection, he must not assume responsibility beyond his level of experience. Poor selection may cost more money, and more important, may cause injury or death to fellow workers.

While the craftsman is not responsible for the structural design of the slabs and beams, he is responsible for good quality workmanship and a final product that meets the requirements of the job plans and specifications.

Information in this booklet should be used as a guide to good practice. Plans and specifications for a project and local building requirements must be followed, even if they differ from the information in this booklet.

CHAPTER 1
GENERAL

The American Concrete Institute defines slabs and beams as follows:

Slab: A flat, horizontal or nearly so, molded layer of plain or reinforced concrete, usually of uniform but sometimes of variable thickness, either on the ground or supported by beams, columns, walls, or other framework.

Beam: A structural member subjected primarily to flexure (bending).

Elevated slabs and beams require shoring to properly support the formwork during the casting and curing sequences.

Appendixes A, B, C, D, and E contain valuable information regarding concrete in general, materials and mix proportioning, and a detailed listing of definitions of words used throughout this booklet. In addition to the slab and beam definitions above, it is important that the following terms also be defined at this point:

Form: The mold or sheathing and its reinforcing members which contact the concrete and give the concrete final shape.

Formwork: The total system of support for freshly placed concrete, including the mold or sheathing which contacts the concrete as well as supporting members, hardware, and necessary bracing.

Falsework: Any temporary structure erected to support work in the process of construction.

Shoring: A System of vertical or inclined supports for forms; may be wood or metal posts, scaffold type frames, or various patented members.

Reshoring: The placing of shores snugly under a stripped concrete slab or structural member after the original formwork and shores have been removed from a large area, thus requiring the new slab or member to deflect and support its own weight and existing construction loads prior to the installation of reshores.

Backshoring: The placing of shores snugly under a stripped concrete slab or structural member after the original formwork and shores have been removed from a small area without allowing the slab to deflect or support its own weight or existing construction loads from above.

Stay-in-place forms: Forms left in place that may or may not become an integral part of the structural frame. These forms may be the rigid type such as metal deck, precast concrete, wood, plastics, and fiberboard, or the flexible type such as reinforced, water-repellent corrugated paper or wire mesh with waterproof paper backing.

Craftsmen who seek further in-depth information should read American Concrete Institute's publication SP-4, *Formwork for Concrete*, by M. K. Hurd. This extensive volume contains detailed discussions on formwork planning, materials, loads and pressures, design, design tables, construction, architectural concrete, shells, domes, folded plates, tunnels, and shafts.

Other ACI documents may be of interest to the craftsman. A publication list may be requested from the American Concrete Institute. Appendix F contains a bibliography of appropriate ACI and CRSI documents. CRSI has several valuable documents on reinforcement placement and a publication list may also be requested from them.

CHAPTER 2
FORMWORK—GENERAL

Formwork materials

Material requirements for elevated slabs fall into two categories:

a. forms for the slab, including horizontal members
b. vertical support for slab forms

Formwork for flat slabs or slab and beam construction generally consists of plywood and dimensional lumber such as 2 × 4's, 4 × 4's, or 4 × 6's. Fig. 2.1, 2.2 and 2.3 show various slab designs and notations that will be used throughout this booklet.

If the slab design is for a two-way joist (waffle), Fig. 2.3(e), or for one-way joist (pan-joist), Fig. 2.3(c) or 2.3(d), the formwork will generally be steel. These materials are readily available from suppliers and may be rented for each project. Table 2.1 shows available sizes.

Many building designs have a structural steel frame with a corrugated metal decking attached to the steel beams. Reinforcing is set and concrete placed directly onto the corrugated stay-in-place decking. Depending on span and slab thickness, it may be necessary to provide vertical supports under the metal decking while the concrete is placed and cured.

Some bridge designs use a metal stay-in-place deck for structural steel bridges or a precast stay-in-place concrete plank for bridges with precast-prestressed concrete beams. This eliminates the need for formwork for the interior spans. Formwork will be required to be built for the exterior overhang of the bridge.

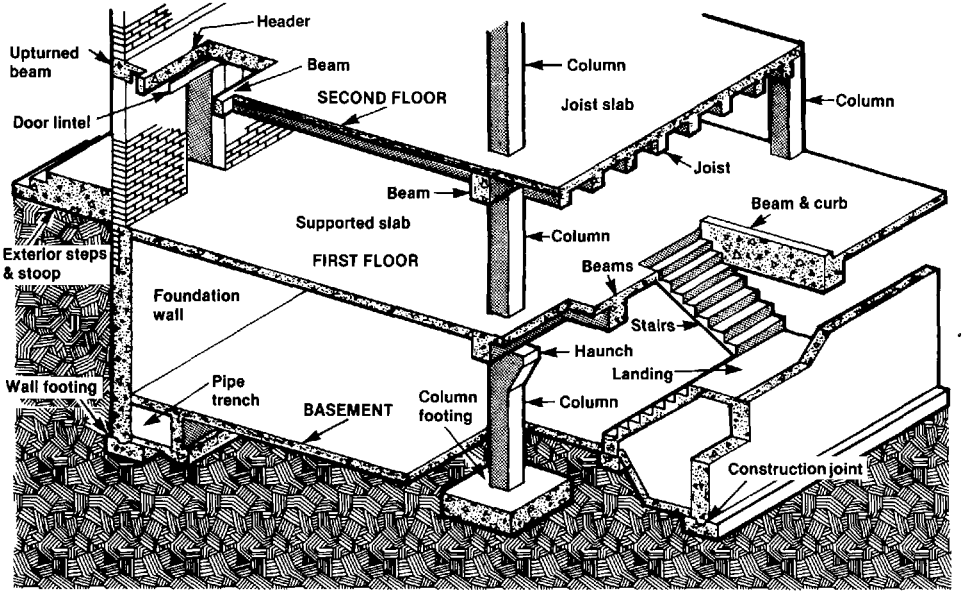


Fig. 2.1—Reinforced Concrete building elements

For multistory buildings with a structural steel or precast concrete frame and a flat slab, formwork can be supported by using prefabricated hangers that rest on the structural beams. This eliminates the need for shoring. Such hangers are available from accessory suppliers.

Supports for the elevated formwork are usually:

a. Wood shores (4 × 4's, 4 × 6's, etc.)
b. Prefabricated tubular welded frame shoring (ladder frames) either of steel or aluminum.
c. Prefabricated individual post shores either steel or aluminum.
d. Flying forms. These are complete prefabricated formwork systems usually supported on trusses with rollers that can be moved by a crane (''flown'') to its next position.

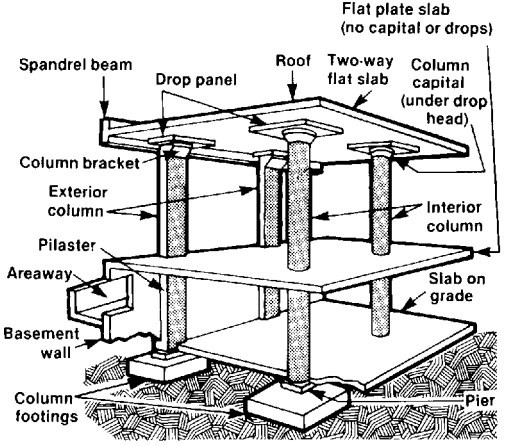


Fig. 2.2—Reinforced concrete building elements

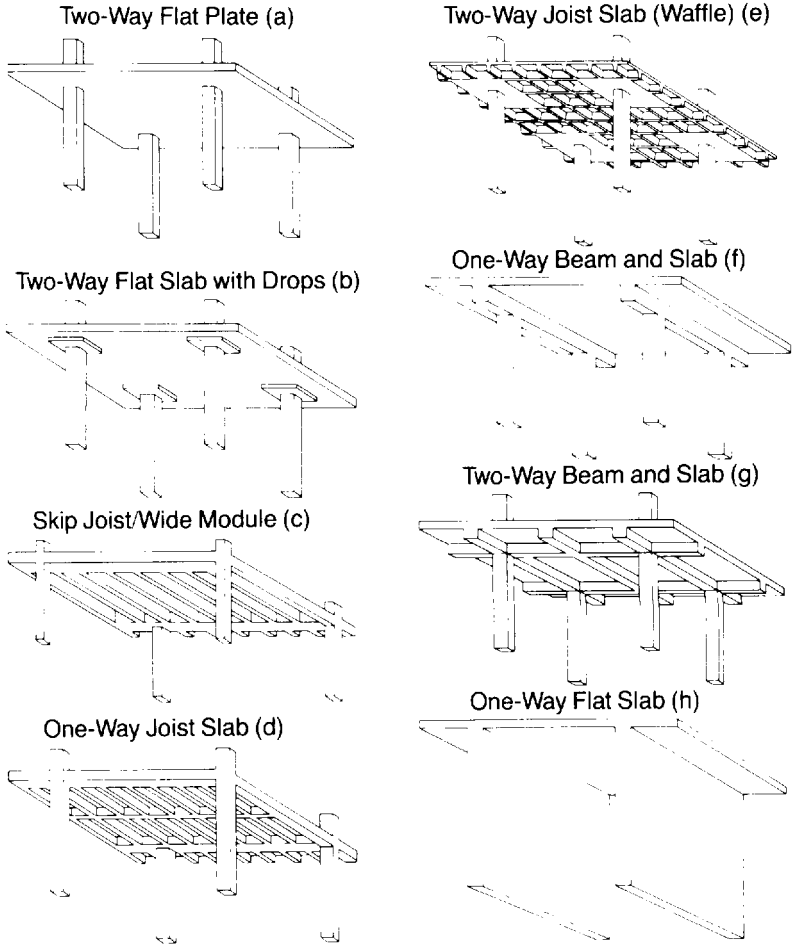
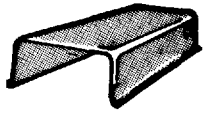


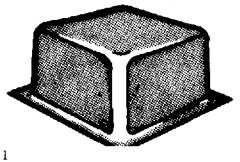
Fig. 2.3—Typical elevated slab systems (Courtesy of Ceco Corp.)

Table 2.1—Standard dimensions for one- and two-way joist forms

TYPICAL ONE-WAY JOIST FORM



TYPICAL TWO-WAY JOIST FORM
(waffle flat slab)



ONE-WAY JOIST CONSTRUCTION[1]

Module	Standard Forms		Special Filler Forms[4]	
	Width[2]	Depth[3]	Width[2]	Depth[3]
2'-0"	20	8, 10, 12	10, 15	8, 10, 12
3'-0"[5]	30	8, 10, 12, 14, 16, 20	10, 15, 20	8, 10, 12, 14, 16, 20
4'-0"[6]	40	12, 14, 16, 18, 20, 22, 24	20, 30	12, 14, 16, 18, 20, 22, 24
5'-0"	53	16, 20	—	—
6'-0"	66	14, 16, 20	—	—

TWO-WAY JOIST CONSTRUCTION[1]

System	Standard Forms		Special Filler Forms[4]	
	Width[2]	Depth[3]	Width[2]	Depth[3]
2'-0" Module 19" x 19" Square with 2½" Flanges	19 x 19	8, 10, 12, 14, 16	—	—
2'-6" Module 24" x 24" Square with 3" Flanges	24 x 24	8, 10, 12, 14, 16, 20	—	—
3'-0" Module 30" x 30" Square with 3" Flanges	30 x 30	8, 10, 12, 14, 16, 20	20 x 20 20 x 30	8, 10, 12, 14, 16, 20 8, 10, 12, 14, 16, 20
4'-0" Module 41" x 41" Square with 3½" Flanges	41 x 41	12, 14, 16, 20, 24	—	—
5'-0" Module 52" x 52" Square with 4" Flanges	52 x 52	14, 16, 20, 24	40 x 40	14, 16, 20, 24

NOTES
1. All dimensions are in inches, except the module designations.
2. Width is the horizontal clear distance, between two consecutive joists, measured at the bottom of the joists.
3. Depth is the vertical distance, measured between two consecutive joists from the underside of the concrete slab to the bottom of the joists.
4. Special filler forms may be available only in limited quantities. Availability should be investigated before specifying these forms.
5. Tapered endforms are available for the one-way 3'-0" module. These forms are 30 inches wide at one end and 25 inches wide at the other end, and they are 36 inches long. Standard depths of these forms are 8, 10, 12, 14, 16, and 20 inches.
6. Tapered endforms are available for the one-way 4'-0" module. These forms are 40 inches wide at one end and 34 inches wide at the other end, and they are 36 inches long. Standard depths of these forms are 12, 14, 16, 18, 20, 22, and 24 inches. These forms are generally available only on the West Coast.

e. Horizontal shores. These are adjustable span members used to support forms over relatively long spans, thereby reducing the number of vertical supports.

The size of the project and number of reuses of the formwork will determine which support system will be used. For smaller projects the contractor may own wood shores, post shores, or ladder frames and elect to build the necessary formwork in place. On large multistory projects, such as hotels and condominiums, flying forms may be used, since the number of reuses warrants the investment in a form system that can be recycled quickly and does not require dismantling and reassembling for each use.

Tunnel forms are a variation of the flying form. In such cases, the walls and slab are cast at the same time. After the specified concrete strength is reached, the tunnel form sides can be moved inward, and the entire form lowered and removed from the "tunnel" and "flown" to the next position.

The following chapters contain more specific information and illustrations for each of the slab designs discussed above.

Tolerances

Unless the contract documents specify a more rigid tolerance, formwork should be constructed to produce slabs to the following tolerances:

Variation of slab soffit from level or slope indicated on drawings should not exceed ± 1/4 in. in 10 ft, ± 3/8 in. in any bay or 20 ft of length, or ± 3/4 in. for the entire length. Variations in soffit level are to be measured

before removal of supporting shores. The contractor is not responsible for variations due to deflection, except when the deflections are caused by poor concrete quality or curing or misplacement of reinforcement.

Variations in the sizes and locations of openings should be no more than −1/4 in. or +1/2 in. Variations in slab thickness may be − 1/4 in. or +1/2 in. maximum.

Camber/tolerances

It may be necessary to set formwork elevations before concreting to compensate for the following:

a. Deflection or settlement of the formwork and supports.

b. Deflection of the completed structure under load from the time it begins to carry its own weight.

c. Optical sag (the illusion of sagging in long members even though they are perfectly horizontal).

d. Camber is an intentional upward deflection which compensates for normal downward deflection. It must be measured from the bottom of the slab after concreting and before stripping.

Formwork deflection or settlement will be caused by loads on the formwork, closure of form joints, crushing of lumber, settlement of mudsills, shrinkage of lumber, and the like. A frequently used rule of thumb has been to camber 1/4 in. per 10 ft of span to take care of these deflections and movements.

When wood members are used, the number of horizontal joints where end grain bears on horizontal grain should be kept to a minimum to minimize crushing. Soil under mudsills should be stable so that little or no settlement occurs. Mudsills should not be placed on frozen ground, new backfill with inadequate compaction, or where water will be flowing. See Fig. 2.4 for typical mudsill applications.

Available Information

Manufacturers or local suppliers of shoring or formwork materials will provide catalogs describing their materials and the appropriate safe working loads. Many of these bulletins will have tables showing the permissible span of the product for various slab thicknesses and distances between supports. Reviewing this material and maintaining a personal library of these catalogs should be a continuing part of career growth.

Loads

Formwork for concrete must support all vertical and lateral (horizontal) loads that may be applied until these loads can be carried by the concrete structure itself. Loads on the forms include the weight of the reinforcing bars and fresh concrete, the weight of the forms themselves, and various live loads that will occur during construction. Dumping of concrete, movement of construction equipment, and action of the wind may produce lateral forces which must be resisted by the formwork.

Dead load is the weight of the reinforced concrete and the weight of the forms. Live load is the weight of material storage, workmen, and equipment, including dumping and movement of construction equipment.

Though structural concrete can vary in weight from 60 to 300 pounds per cubic foot (lb/ft^3), most structural slabs will use concrete weighing about

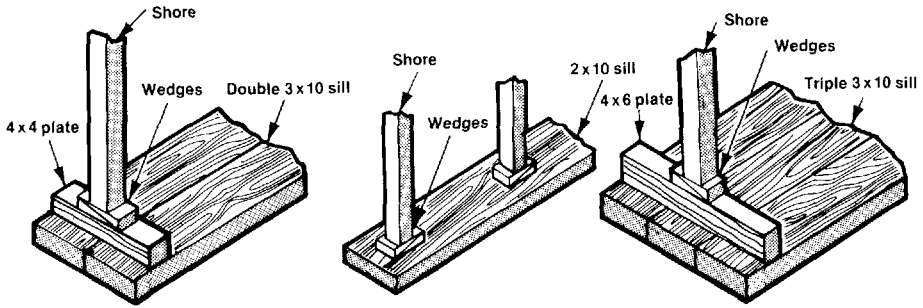


Fig. 2.4—Examples of wood mudsills