ARCH 1230
BUILDING TECHNOLOGY II

Professor Friedman

Fall 2012

SUBJECT

sitecast concrete framing systems

chapter 14

DATE	PROFESSOR
Fall 2012	Friedman

sitecast concrete

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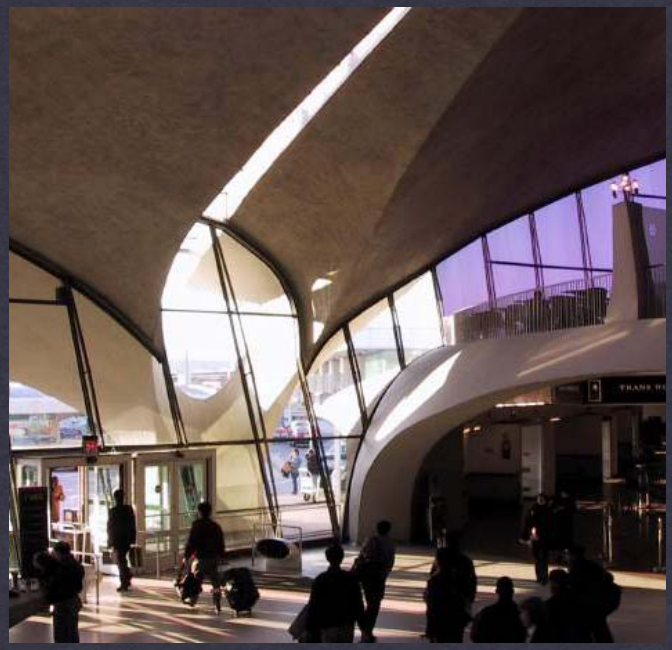

SITECAST CONCRETE

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SITECAST CONCRETE

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this week

objective:
understand the characteristics of sitecast concrete framing systems and the optional approaches available

- slab on grade
- concrete walls + columns
- one-way floor/roof framing systems
- two-way floor/roof framing systems
- concrete stairs
- Post-tensioned framing systems
- selecting a sitecast concrete framing system

SLAB ON GRADE

excavation and compaction

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SLAB ON GRADE

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formwork

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SLAB ON GRADE

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formwork

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SLAB ON GRADE

installing the reinforcement

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TYPICAL DESIGNATION:

6 X 6-W1.4 X W1.4:

6” SPACING IN EACH DIRECTION

0.135” WIRE DIAMETER

SLAB ON GRADE

welded wire reinforcement

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REINFORCEMENT OF SLABS TO PROTECT AGAINST CRACKING CAUSED BY:

- CONCRETE SHRINKAGE
- TEMPERATURE STRESSES
- CONCENTRATED LOADS
- FROST HEAVING
- SETTLEMENT

SLAB ON GRADE

role of reinforcement

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PLACEMENT OF REINFORCEMENT IN THE SLAB:

LOCATED IN BEST POSITION TO RESIST TENSILE FORCES (DEPENDS ON DESIGN)

TOWARDS BOTTOM FOR FOOTINGS

TOWARDS MIDDLE OF TYPICAL SLAB ON GRADE

MUST MAINTAIN MINIMAL COVER

SLAB ON GRADE

placement of reinforcement

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PLACEMENT OF REINFORCEMENT IN THE SLAB:

- REINFORCEMENT CAN BE PLACED ON CHAIRS OR BOLSTERS

- WELDED WIRE MESH - OFTEN PLACED ON GROUND AND LIFTED INTO POSITION DURING THE POUR

SLAB ON GRADE

placement of reinforcement

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CONCRETE

positioning / supporting the reinforcement

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SLAB ON GRADE

placement of concrete

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SITE CAST CONCRETE

cylinder test samples + slump test

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COMPRESSED AIR VIBRATES THE CONCRETE
TO ELIMINATE AIR POCKETS

SLAB ON GRADE

consolidating the concrete

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SLAB ON GRADE

screeding and floating the slab

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SLAB ON GRADE

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finishing the slab

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SLAB ON GRADE

curing under controlled conditions

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SLAB ON GRADE

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control joints

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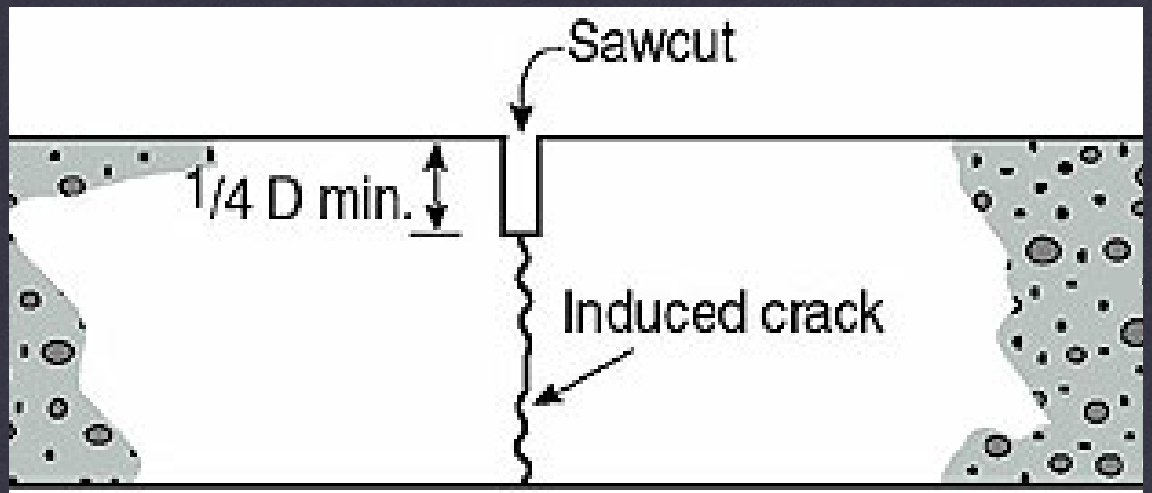
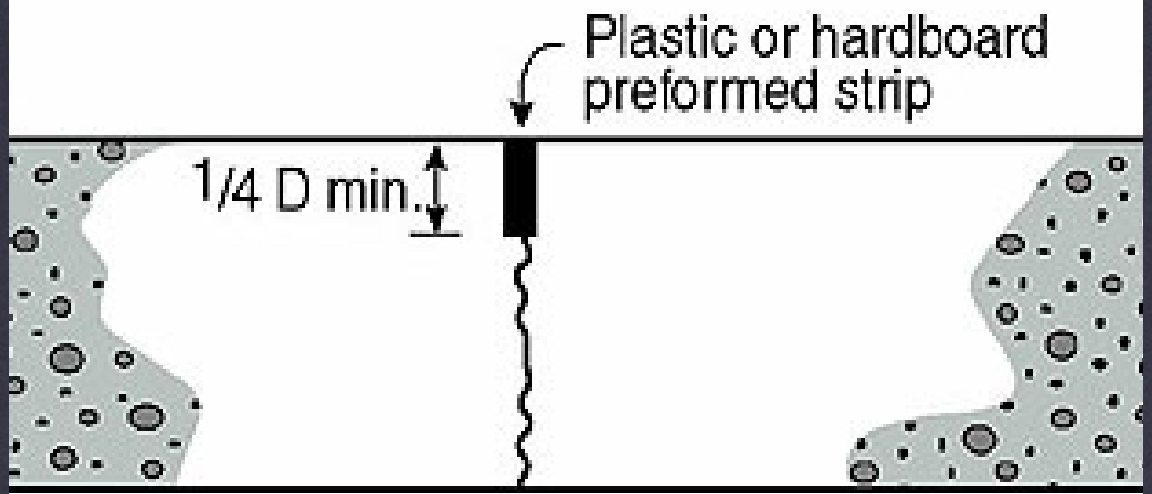
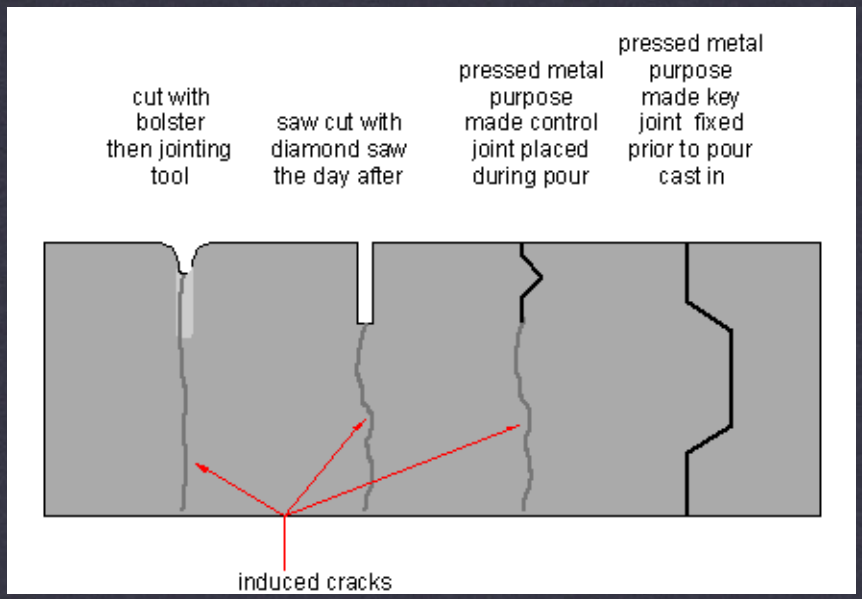


Sawed contraction joint



Premolded insert contraction joint



CONTROL JOINTS:

INTENTIONALLY WEAKENED SECTIONS THROUGH A CONCRETE SLAB

RELIEVE STRESSES WITHOUT DISFIGURING THE SLAB

TYP. SPACING: 11’-6” TO 17’-6” DIVIDE INTO SQUARE PANELS

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control joints

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SLAB ON GRADE

isolation / expansion joints

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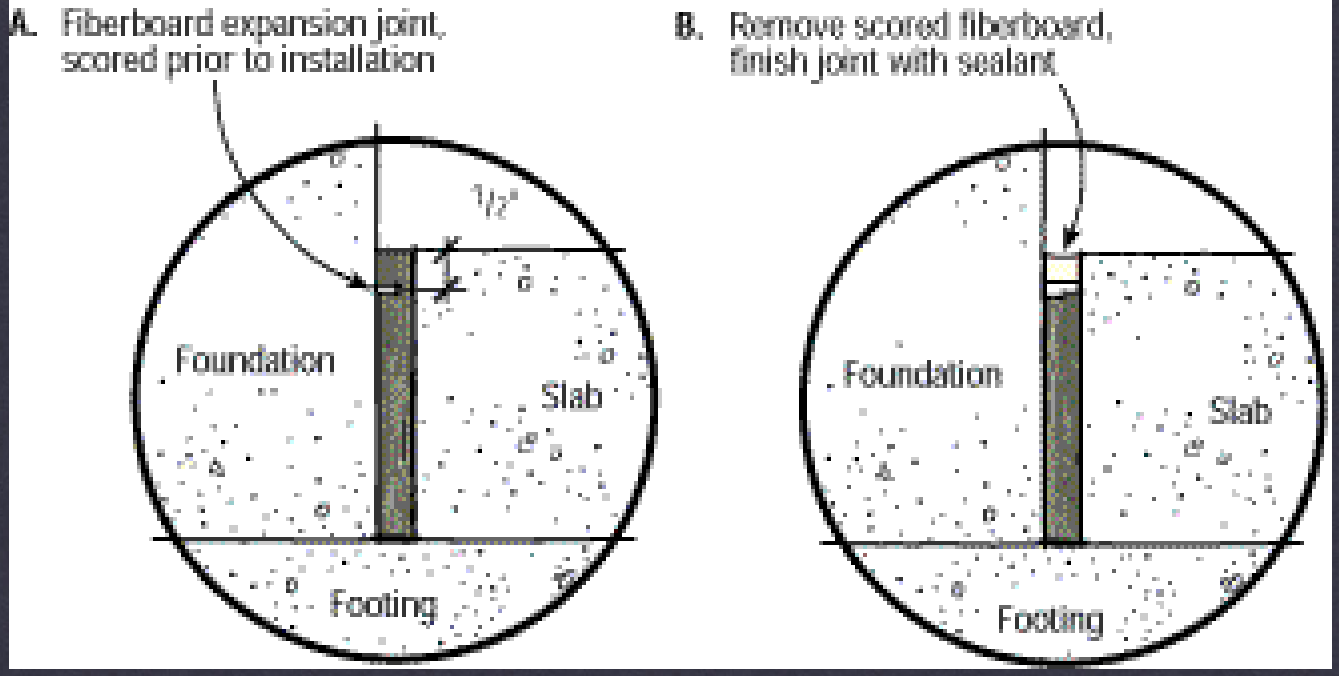
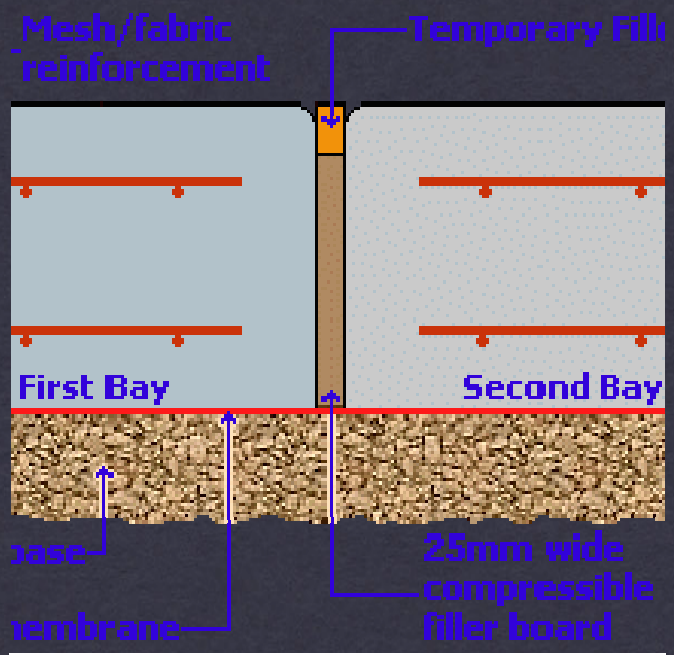
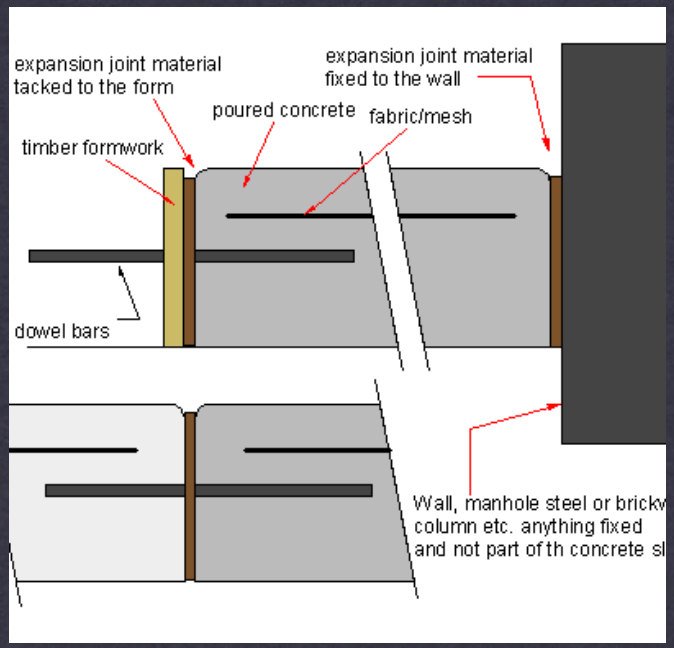
Finished Expansion Joint







EXPANSION JOINTS:

FULL DEPTH SEPARATION OF SLAB PANELS

PANELS CAN MOVE INDEPENDENTLY

TYP: 3/8” TO 3/4” WIDE

SLAB ON GRADE

isolation / expansion joints

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REDUCING CRACKING DUE TO SHRINKAGE:

- CHEMICAL ADMIXTURES
- SUPPLEMENTARY MATERIALS ADDED TO MIX (FLY ASH)
- LOWER WATER-CEMENT RATIO
- ADDITIONAL REINFORCING
- DAMP CURE PROCESS
- POST TENSIONING

SLAB ON GRADE methods to reduce shrinkage cracking

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CAST IN PLACE WALL

formwork for footings

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CAST IN PLACE WALL

footing w/ dowels and key

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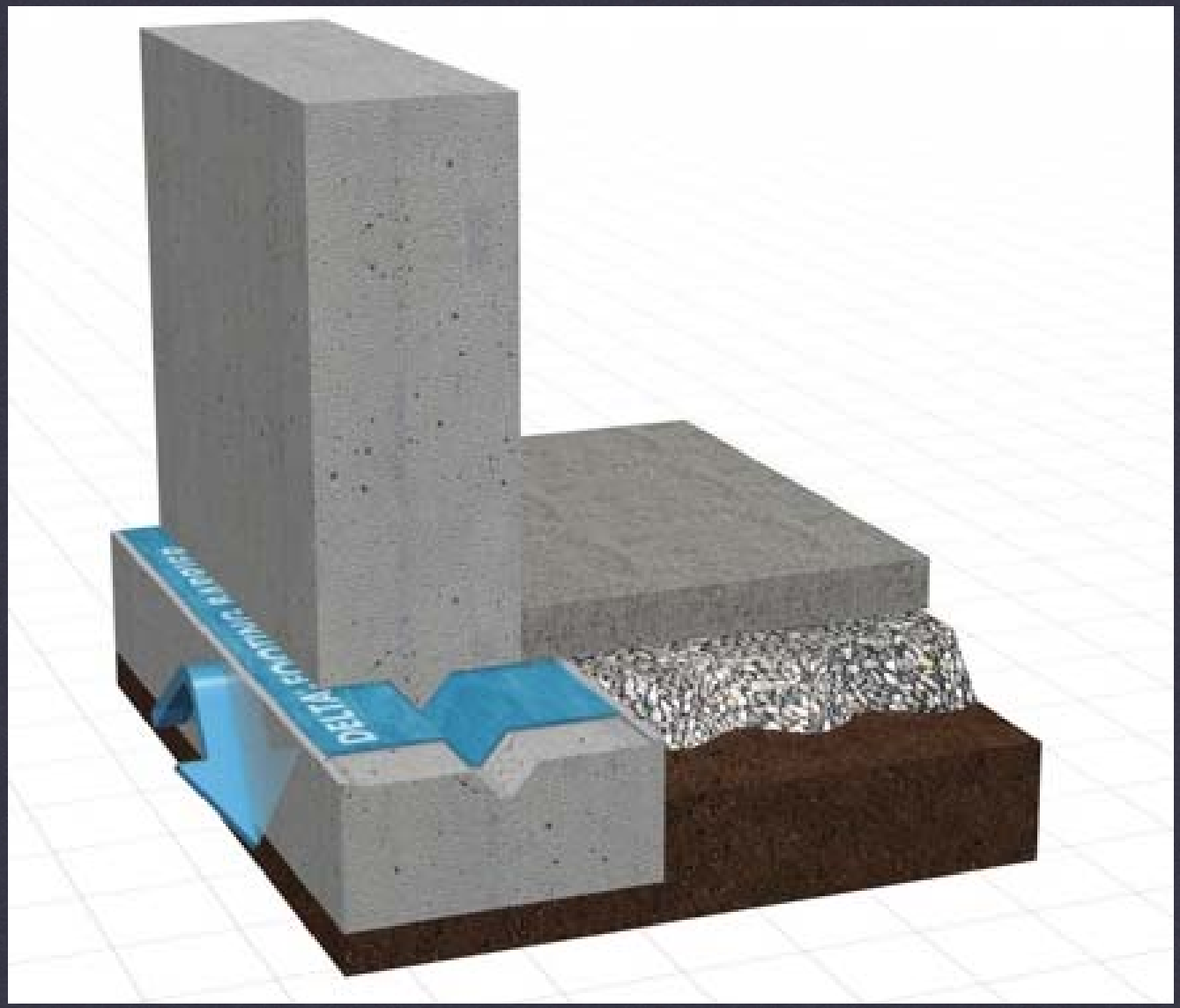

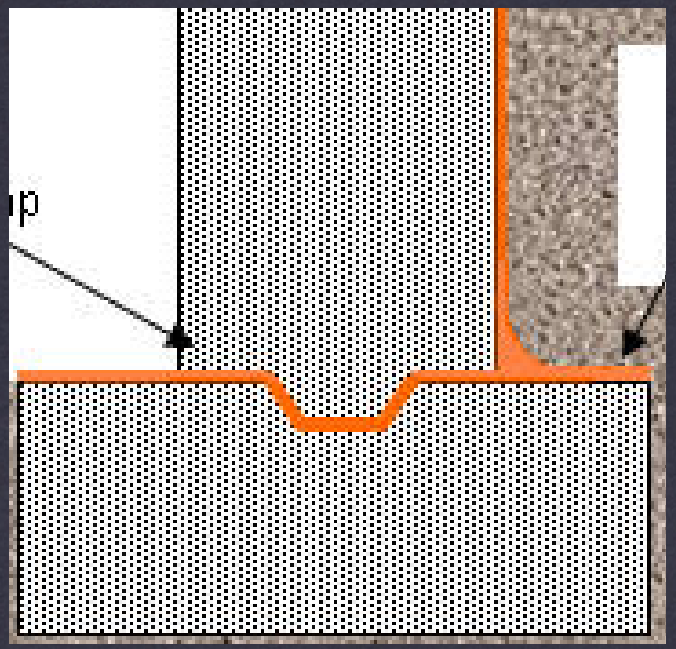

KEY PROVIDES mechanical CONNECTION

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key at footing/wall joint

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DOWEL PROVIDES CONTINUITY FOR REINFORCING

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dowel reinforcing bars

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CAST IN PLACE WALL

formwork for walls

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QuickTime™ and a
decompressor
are needed to see this picture.

CAST IN PLACE WALL

formwork for walls

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QuickTime™ and a
H.264 decompressor
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CAST IN PLACE WALL

placing the reinforcement

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formwork for walls

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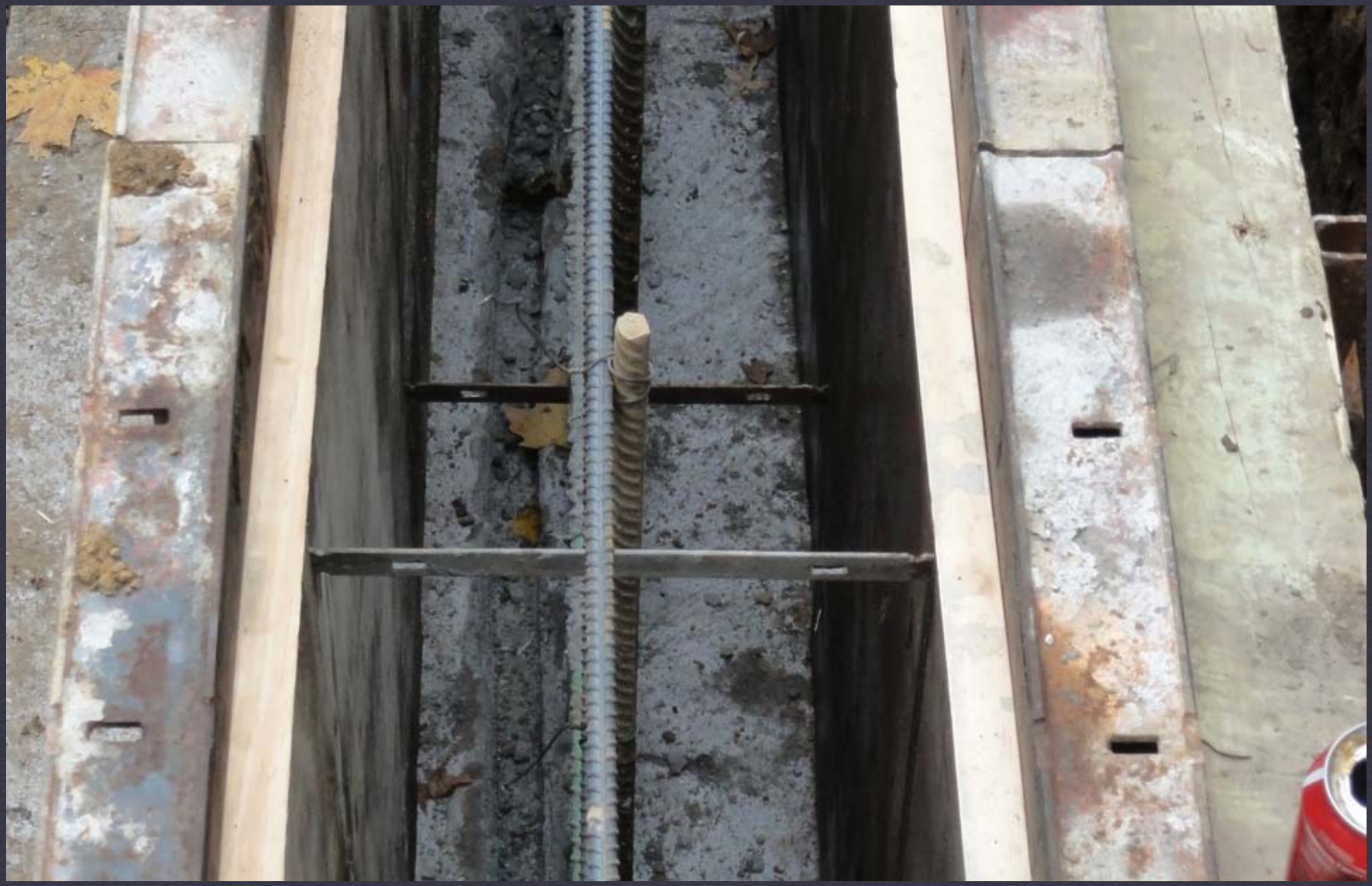

CAST IN PLACE WALL

formwork w/ rebar in place

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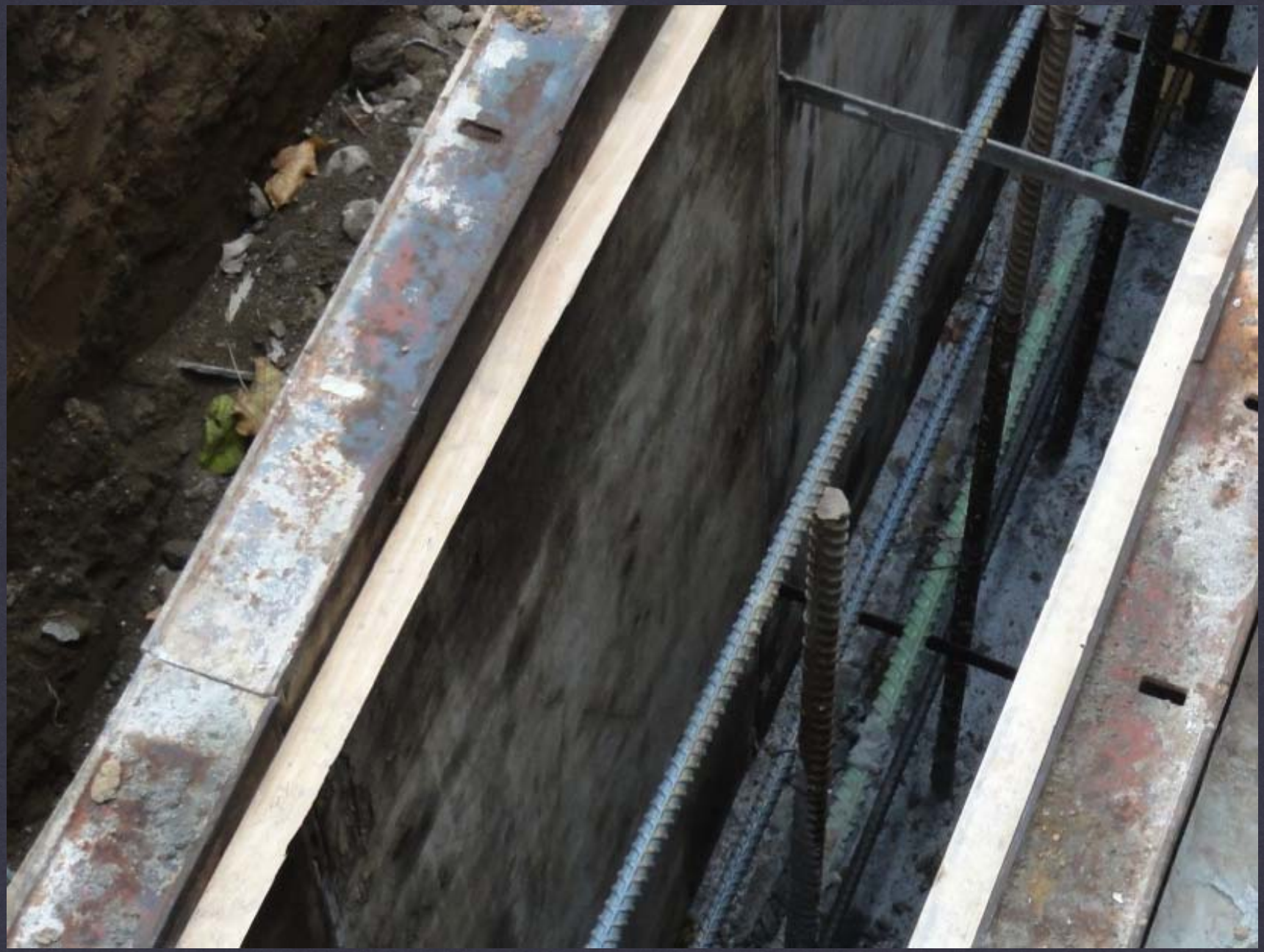

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formwork w/ rebar in place

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CONCRETE

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formwork

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CONCRETE

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formwork

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formwork

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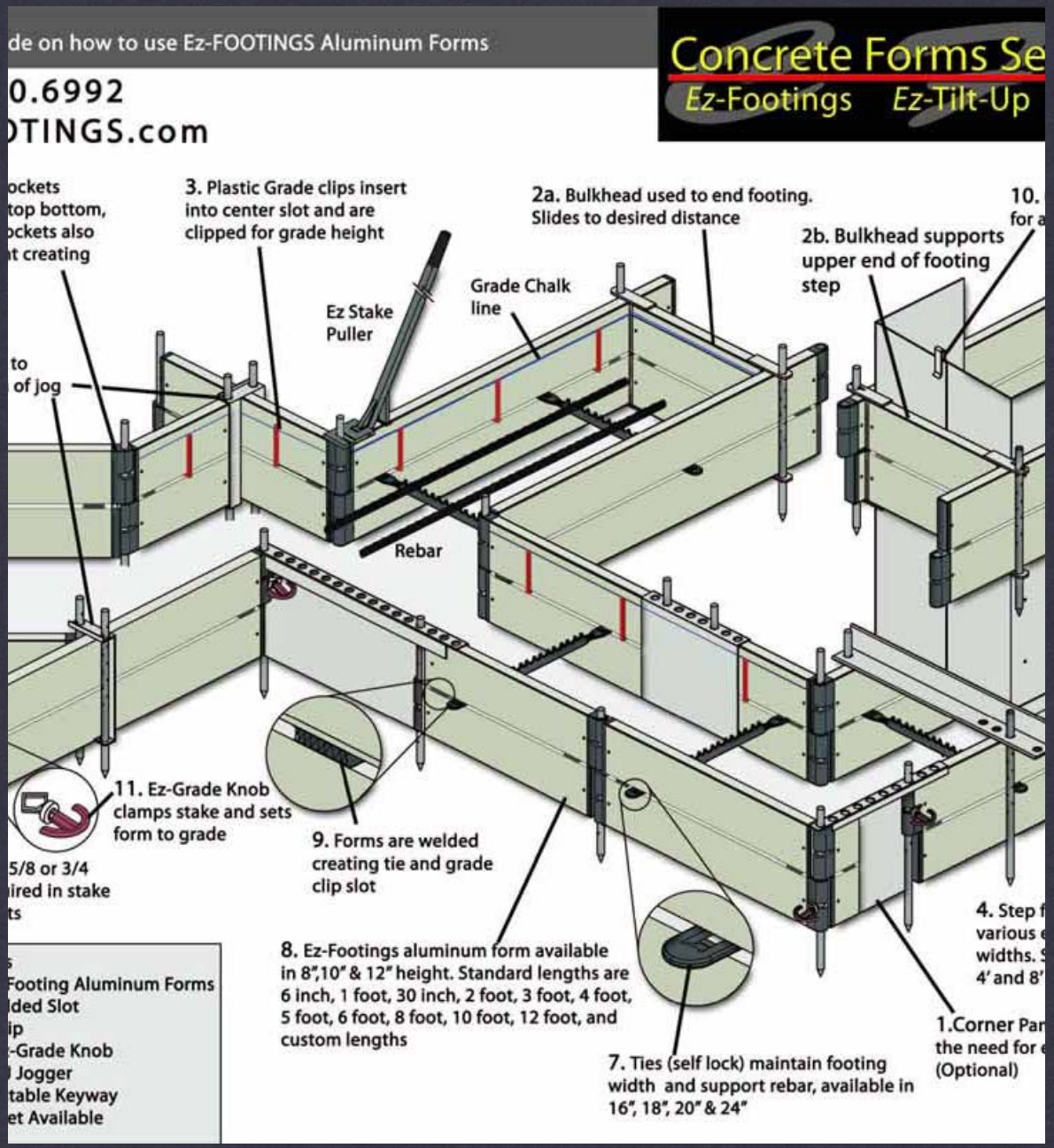

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formwork

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Formwork

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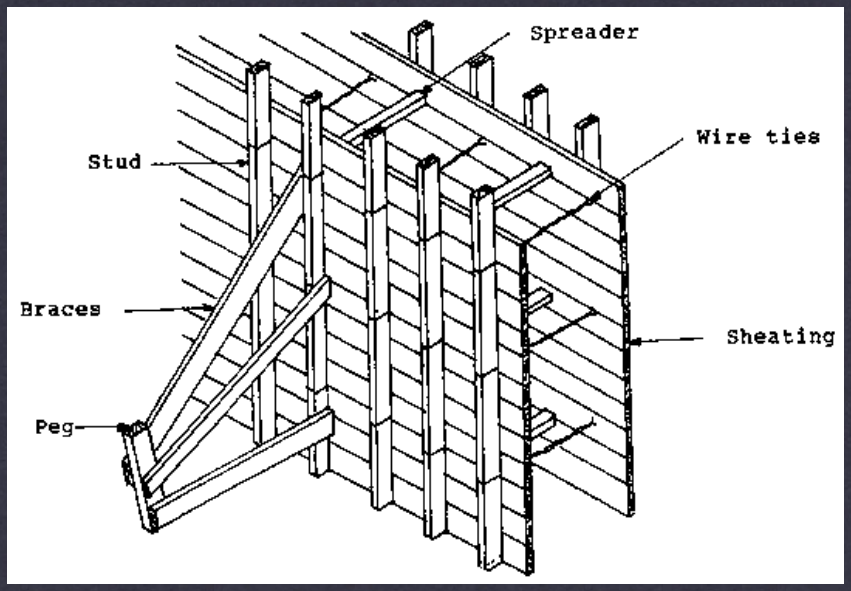

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Formwork

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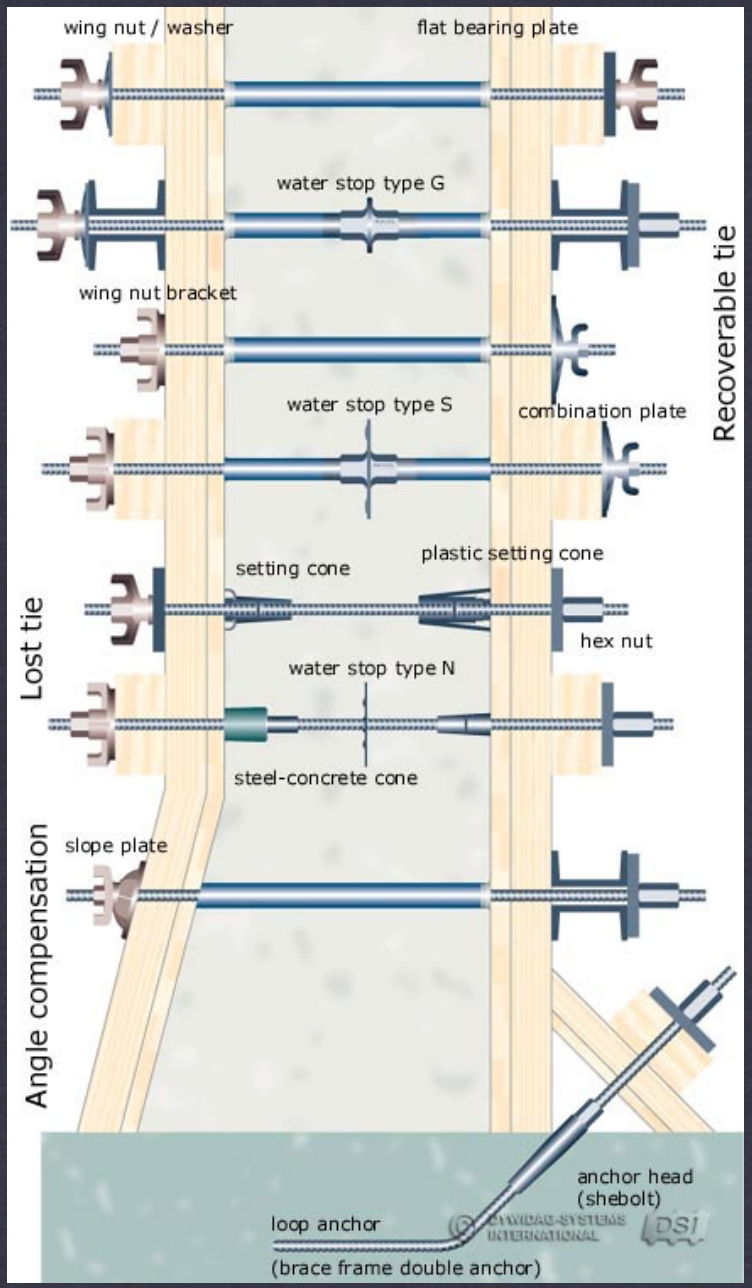

CAST IN PLACE WALL

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Form Ties

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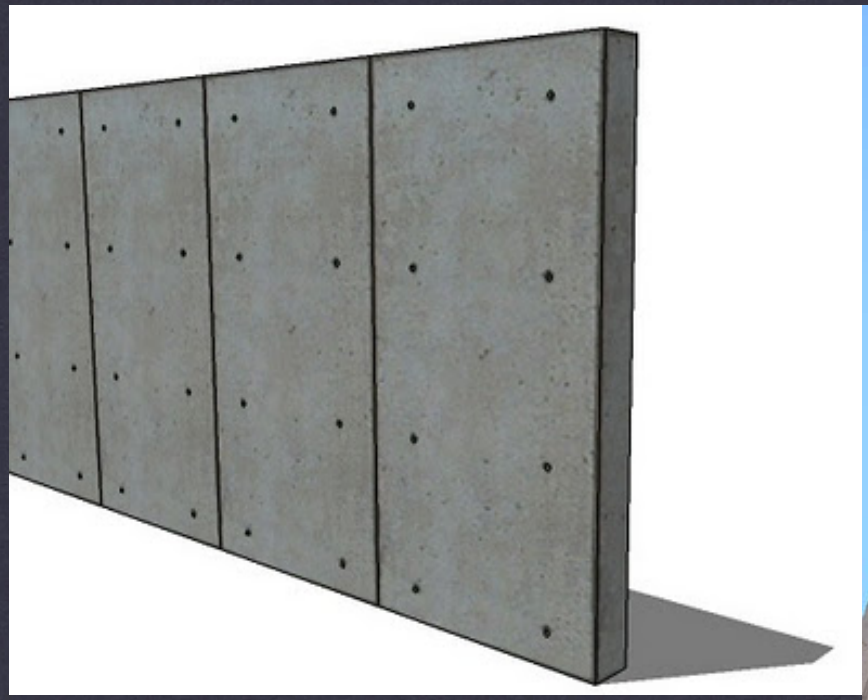

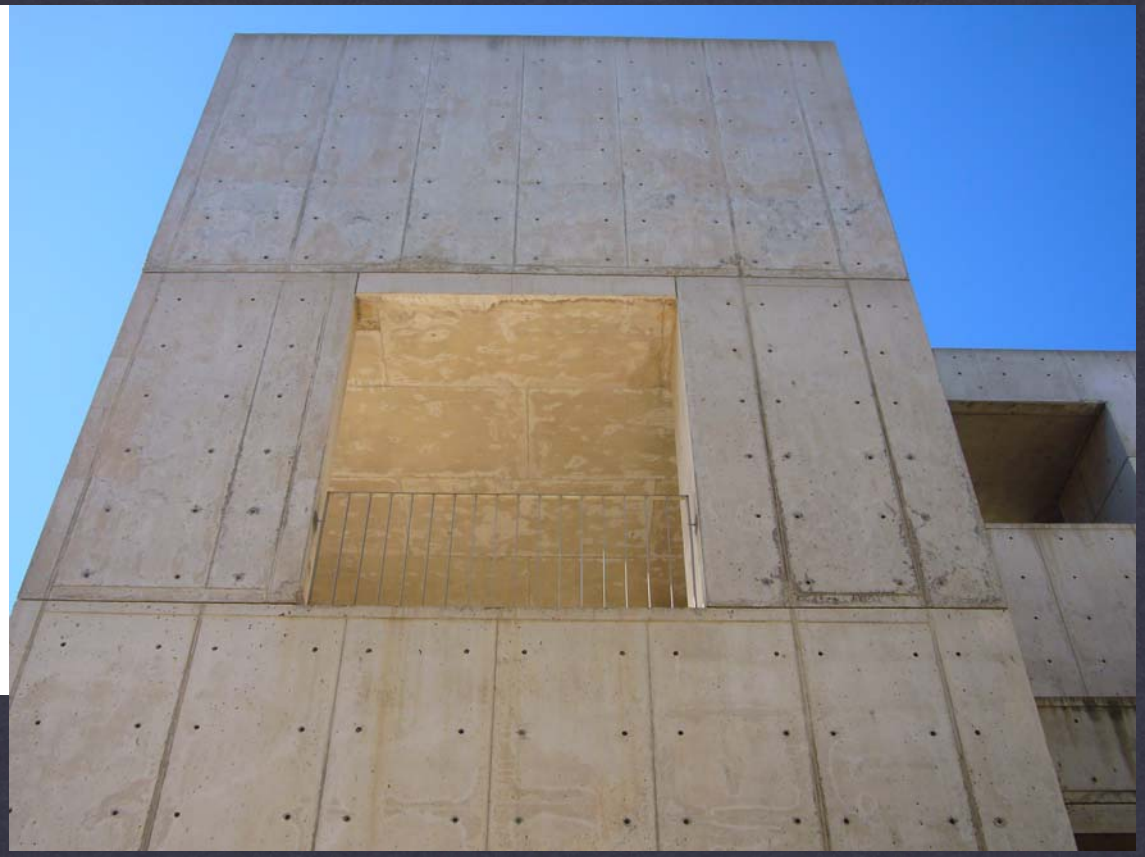

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Form Ties Exposed

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CAST IN PLACE WALL

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Form Ties Exposed

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Form Ties Exposed

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CAST IN PLACE WALL

bracing formwork for walls

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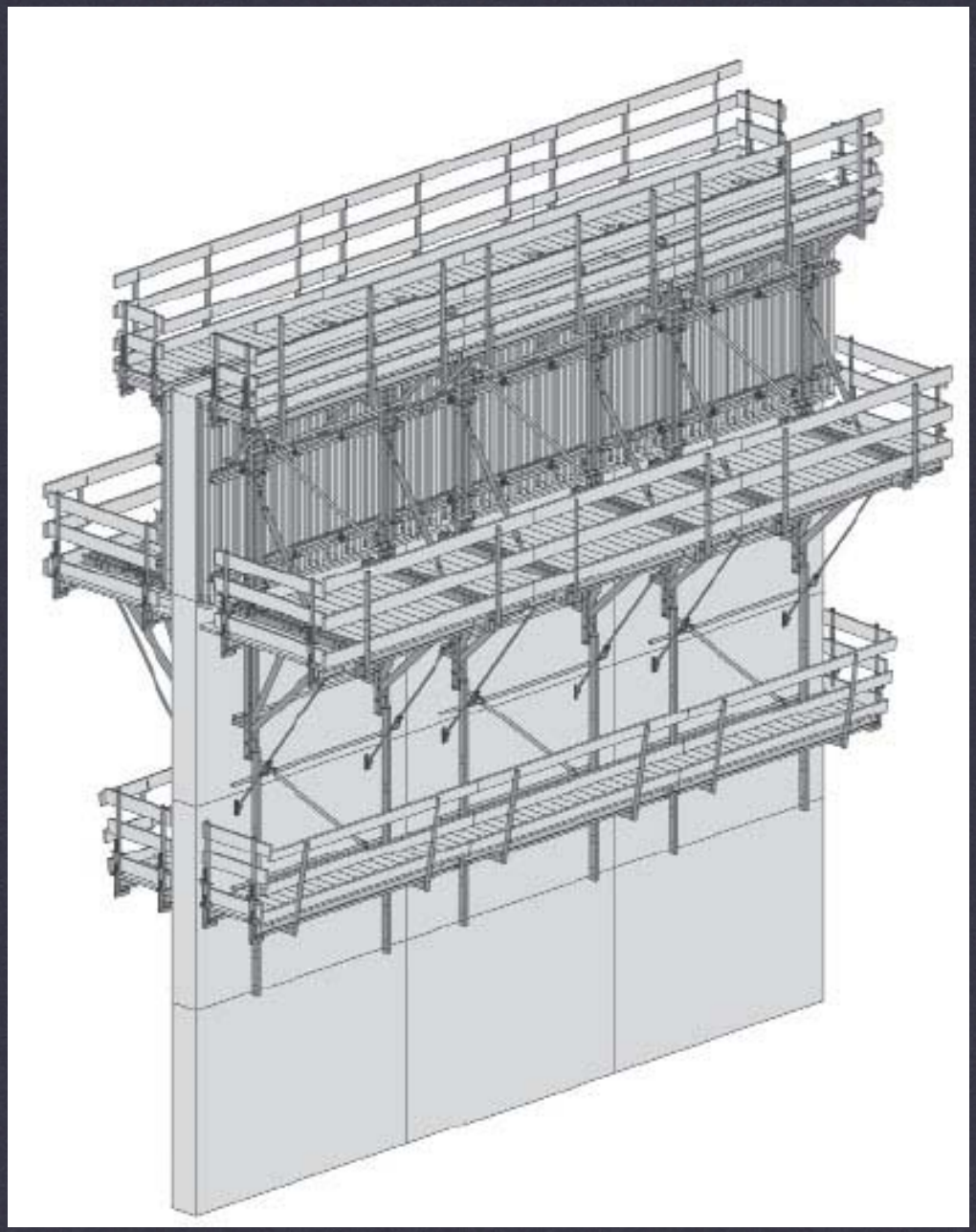

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Climbing Formwork for Skyscrapers

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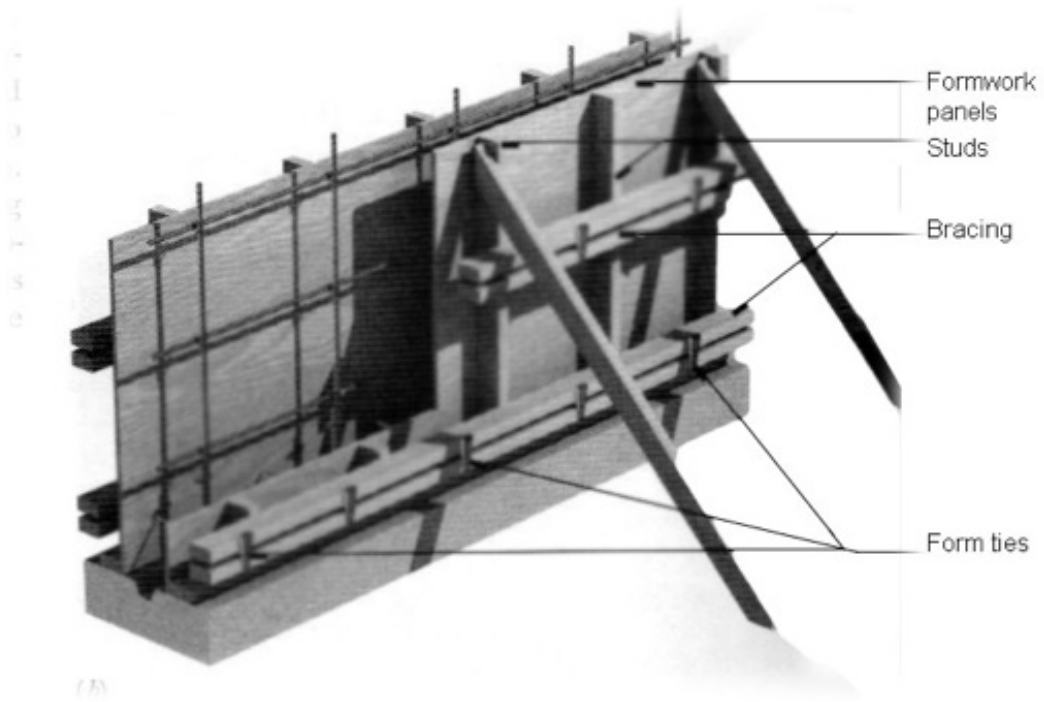
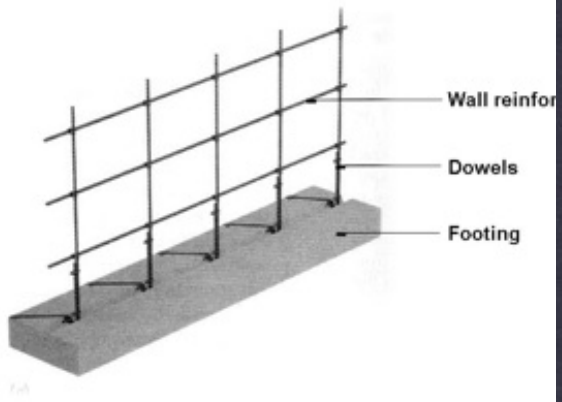
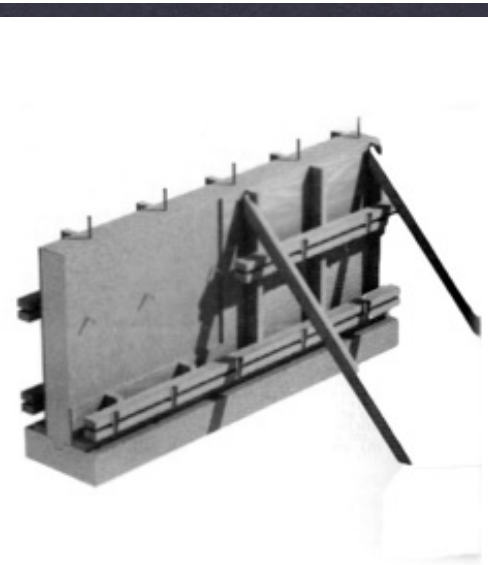
REINFORCING → FORMWORK → POUR







Concrete Formwork and Reinforcing video

CAST IN PLACE WALL

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WALL REINFORCEMENT EXTENDS TO TIE TO NEXT STAGE OF CONSTRUCTION

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sequence of construction

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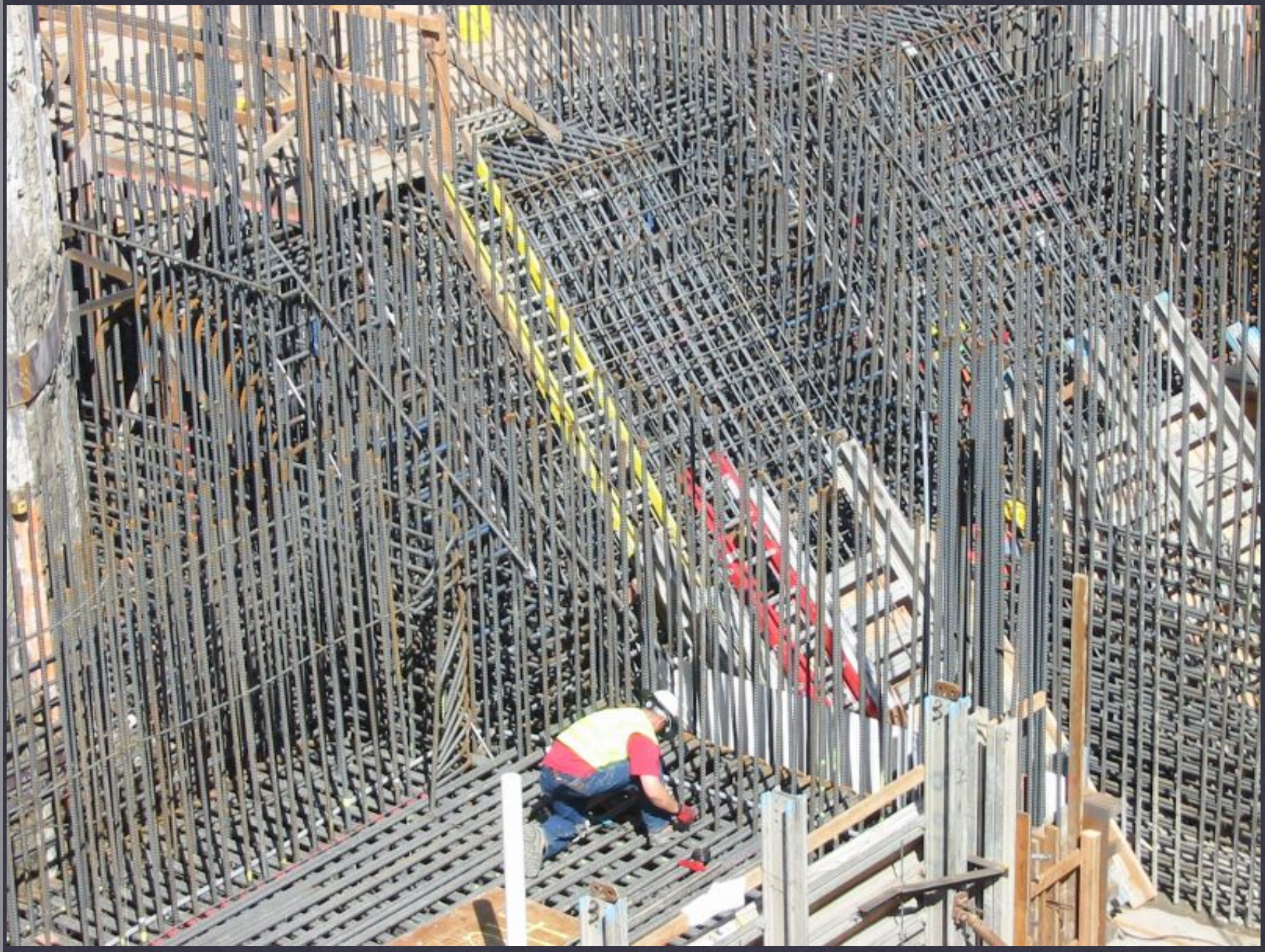

CAST IN PLACE WALL

sequence of construction

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FOOTING IS USUALLY ISOLATED FOR EACH COLUMN. REINFORCING IS OFTEN PREASSEMBLED AND TIED TO DOWELS

CAST IN PLACE COLUMN

column footing + reinforcing

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CAST IN PLACE WALL

sequence of construction

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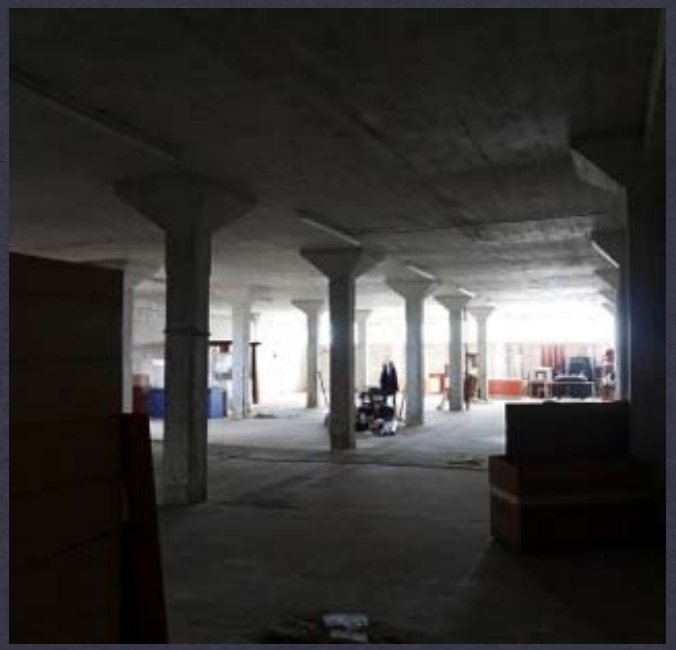

REINFORCING IN COLUMNS PROVIDES BOTH COMPRESSIVE AND TENSILE FORCE RESISTANCE TO THE CONCRETE, ALLOWING COLUMN DIMENSION TO BE REDUCED.

CAST IN PLACE COLUMN

column shape and size

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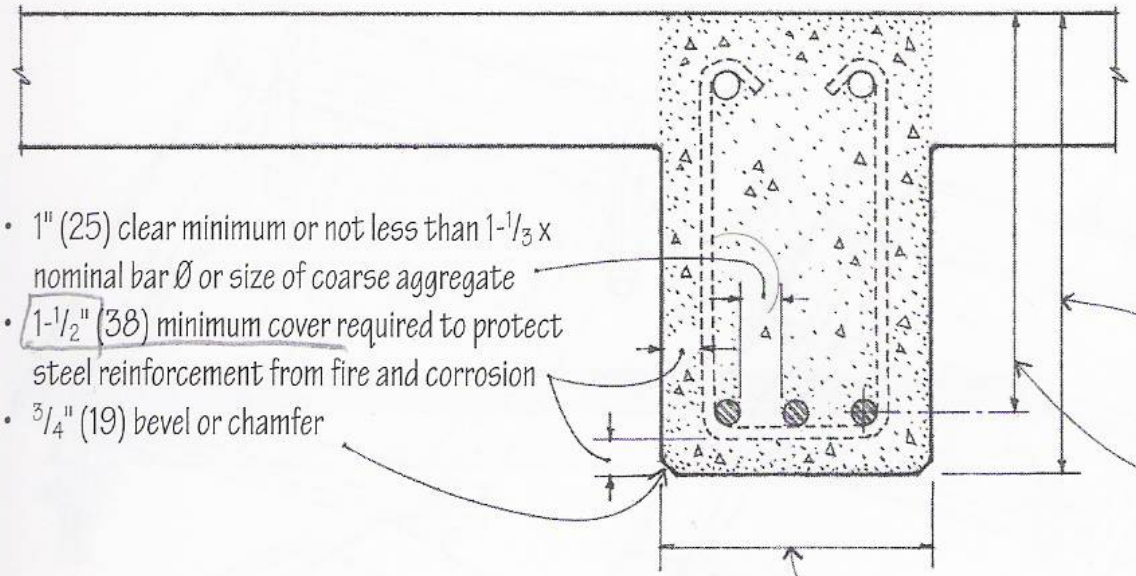
4.04 CONCRETE BEAMS



Reinforced concrete beams are designed to act together with longitudinal and web reinforcement in resisting applied forces. Cast-in-place concrete beams are almost always formed and placed along with the slab they support. Because a portion of the slab acts as an integral part of the beam, the depth of the beam is measured to the top of the slab.

- 1" (25) clear minimum or not less than 1-1/3 x nominal bar Ø or size of coarse aggregate
- 1-1/2" (38) minimum cover required to protect steel reinforcement from fire and corrosion
- 3/4" (19) bevel or chamfer

- Beam depth in 2" (51) increments
- Rule of thumb for estimating depth of a concrete beam: span/16
- Effective depth is measured from the compression face to the centroid of tension reinforcement.
- Beam width is 1/3 to 1/2 of beam depth in 2" or 3" (50 or 75) multiples.
- Beam width should be equal to or greater than width of supporting column.
- Whenever possible, vary required steel reinforcement rather than beam size.

- Reinforcing bars extend into and down column support for structural continuity and to develop the required embedment length for anchorage.

CONCRETE FRAMING SYSTEMS one-way and two-way

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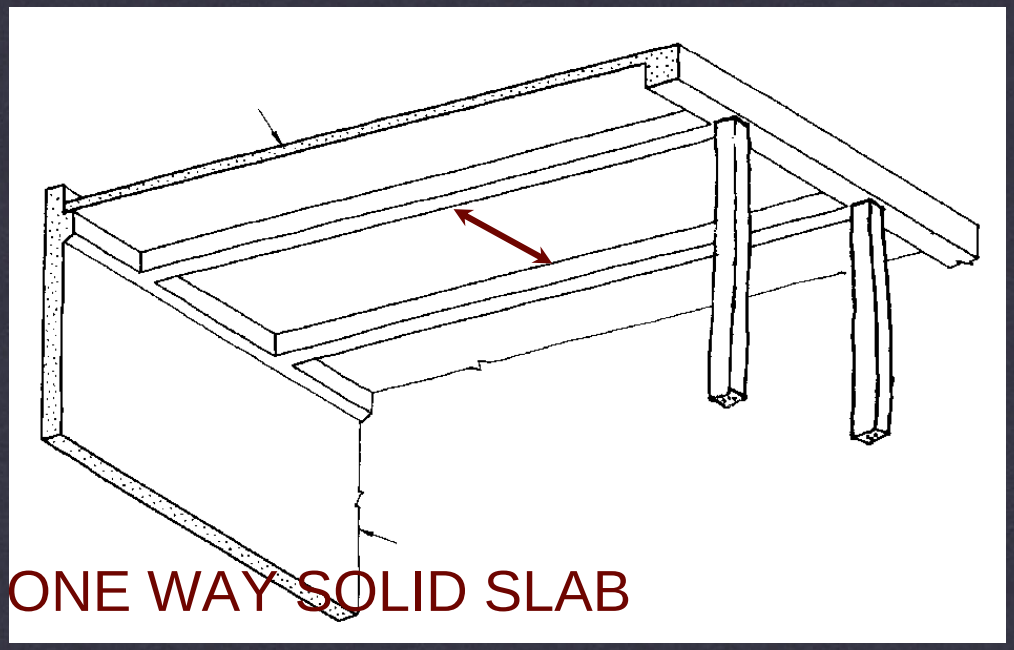
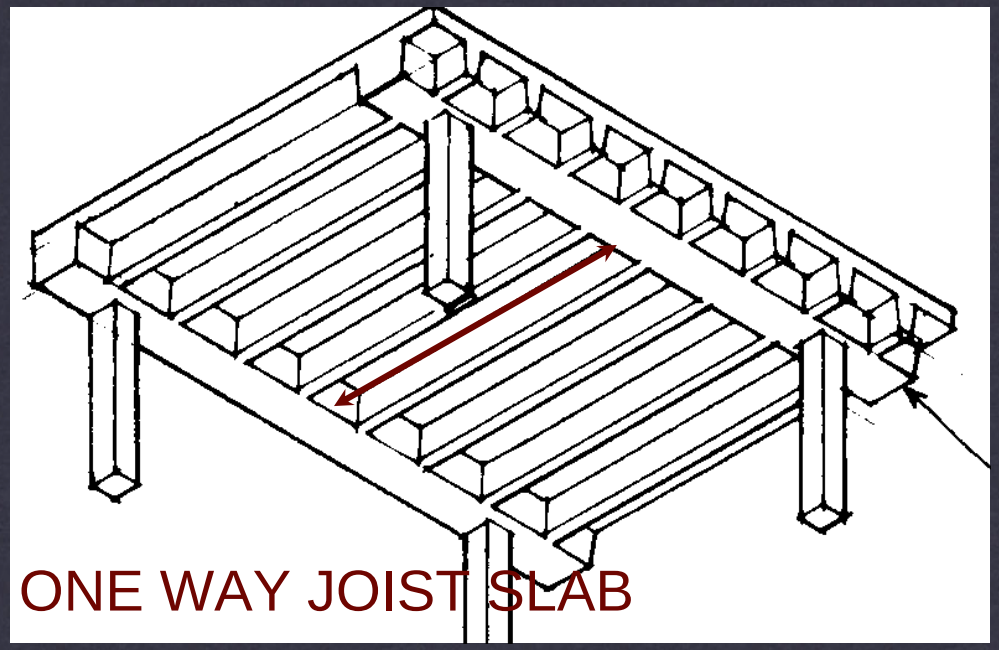
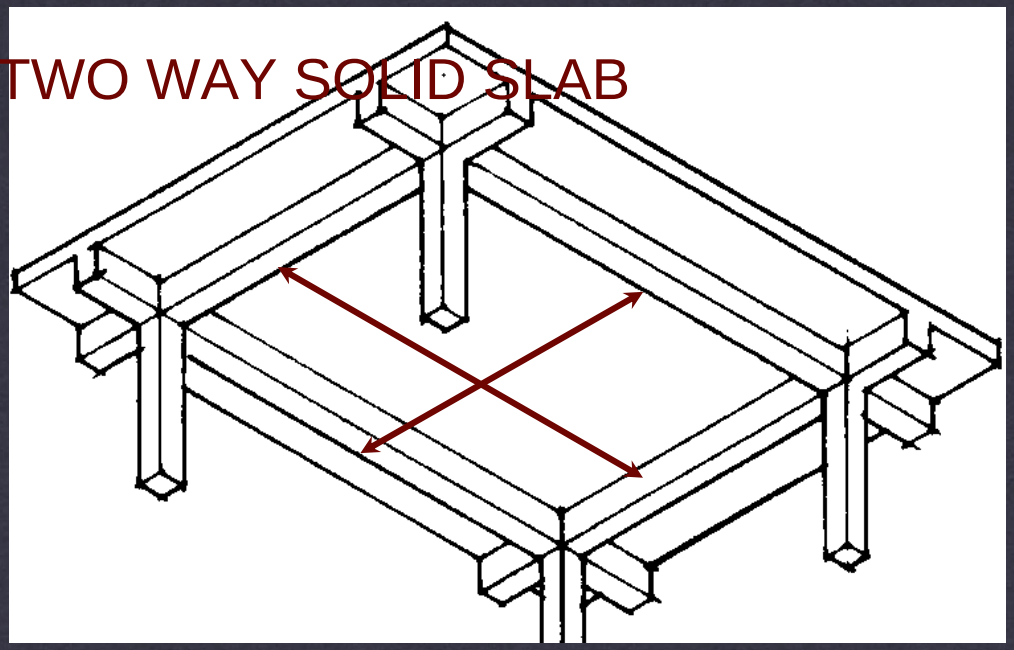


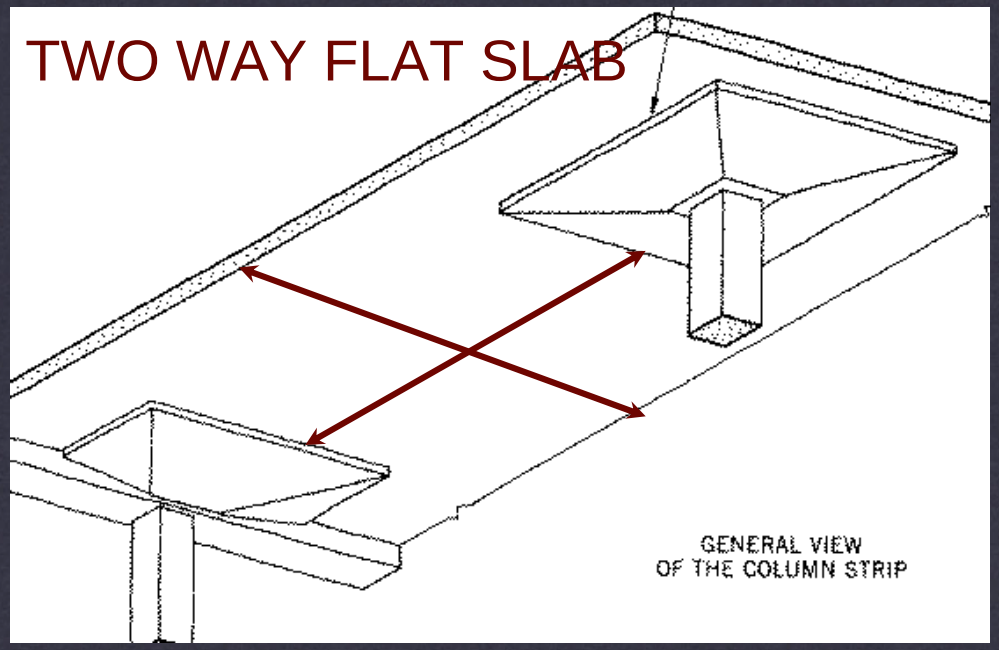
ONE WAY SOLID SLAB



ONE WAY JOIST SLAB



TWO WAY SOLID SLAB



TWO WAY FLAT SLAB

CONCRETE FRAMING SYSTEMS one-way and two-way

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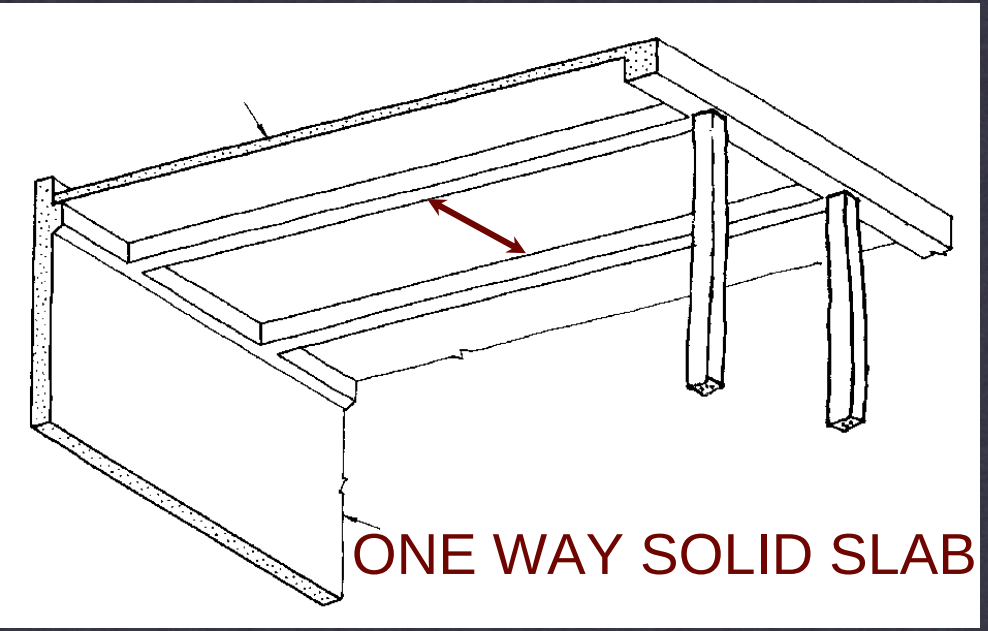
ONE-WAY SOLID SLAB:

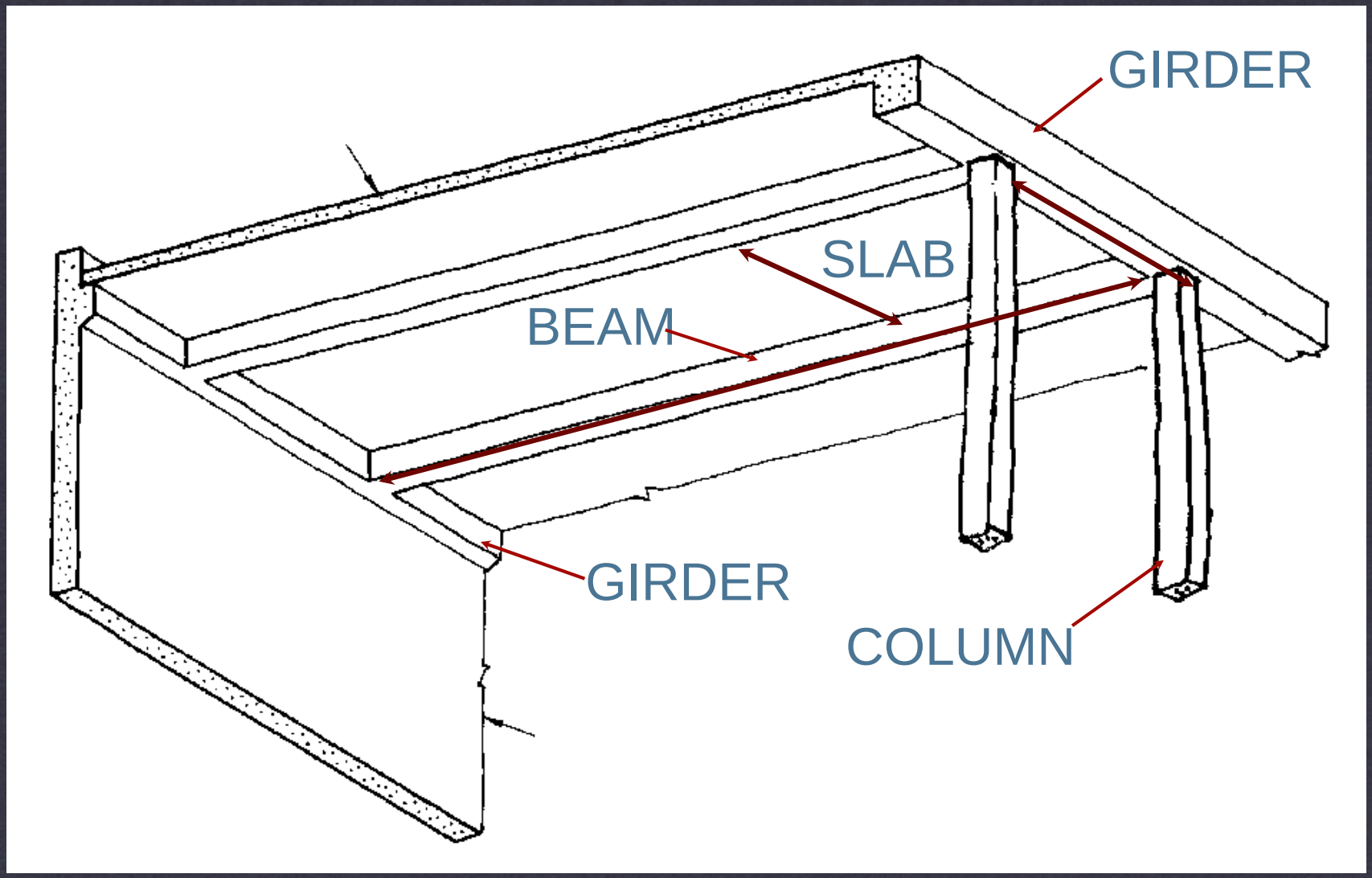
WALLS AND COLUMNS TO SUPPORT SLAB ARE ERECTED FIRST

GIRDERS AND BEAMS ARE USUALLY POURED SIMULTANEOUSLY WITH THE SLAB TO FORM ONE CONTINUOUS STRUCTURAL UNIT

THE FORMWORK MUST BE SUPPORTED UNTIL THE CONCRETE CURES AND ACQUIRES ITS STRUCTURAL STRENGTH

THE CONCRETE IS SHORED AFTER REMOVING THE FORMWORK UNTIL IT REACHES FULL STRENGTH





TYPICAL SLAB THICKNESS: 4” - 10”

CONCRETE FRAMING SYSTEMS

one-way framing

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CONCRETE FRAMING SYSTEMS

one-way framing

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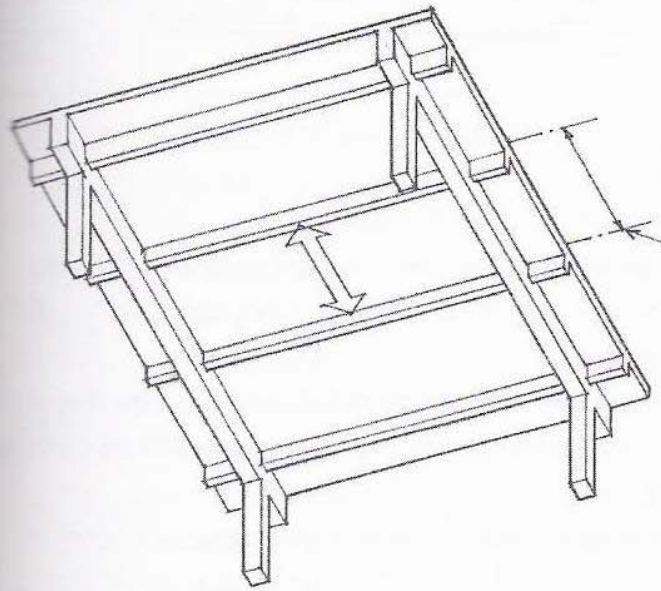
CONCRETE SLABS 4.05

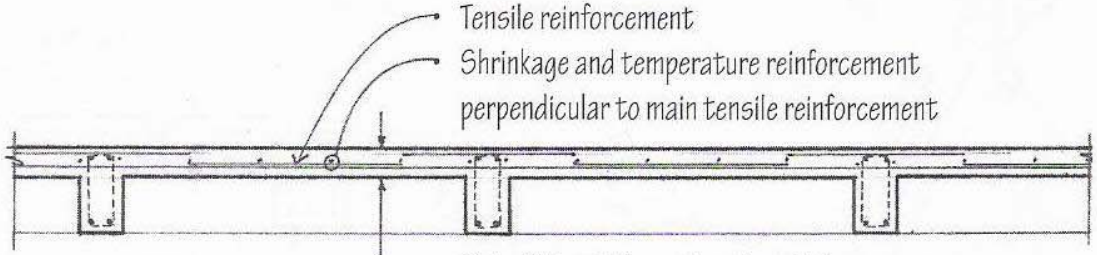
Concrete slabs are plate structures that are reinforced to span either one or both directions of a structural bay. Consult a structural engineer and the building code for the required size, spacing, and placement of all reinforcement.

CSI 03200 Concrete Reinforcement
CSI 03300 Cast-in-Place Concrete
CSI 03310 Structural Concrete

One-Way Slab

A one-way slab is uniformly thick, reinforced in one direction, and cast integrally with parallel supporting beams.





- Tensile reinforcement
- Shrinkage and temperature reinforcement perpendicular to main tensile reinforcement

- Rule of thumb for estimating thickness:
  - ☆ span/30 for floor slabs; 4" (100) minimum
  - span/36 for roof slabs
- Suitable for light to moderate loads over relatively short spans of 6' to 18' (1830 to 5490)
- Slab is supported on two sides by beams or loadbearing walls; beams, in turn, may be supported by girders or columns.

THK → L/30

6' → 18' SPANS

CONCRETE FRAMING SYSTEMS

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one-way framing

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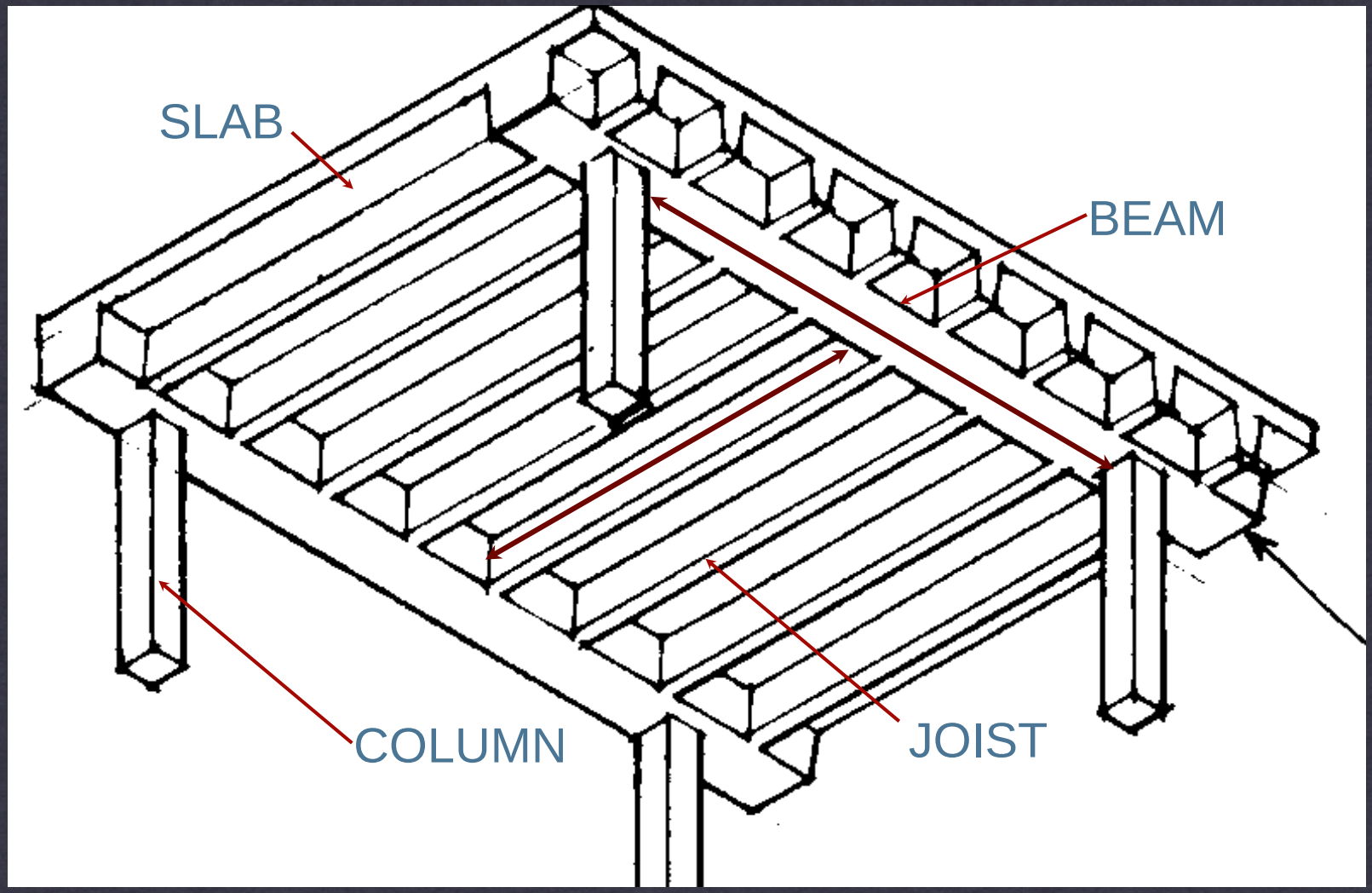

REQUIRED FOR LONGER SPANS WHERE SLAB THICKNESS IN ONE-WAY SYSTEM BECOMES PROHIBITIVE. SLAB BECOMES “RIBBED” SLAB. MORE EFFICIENT THAN ONE-WAY SOLID SLAB FRAMING

CONCRETE FRAMING SYSTEMS

one-way joist framing

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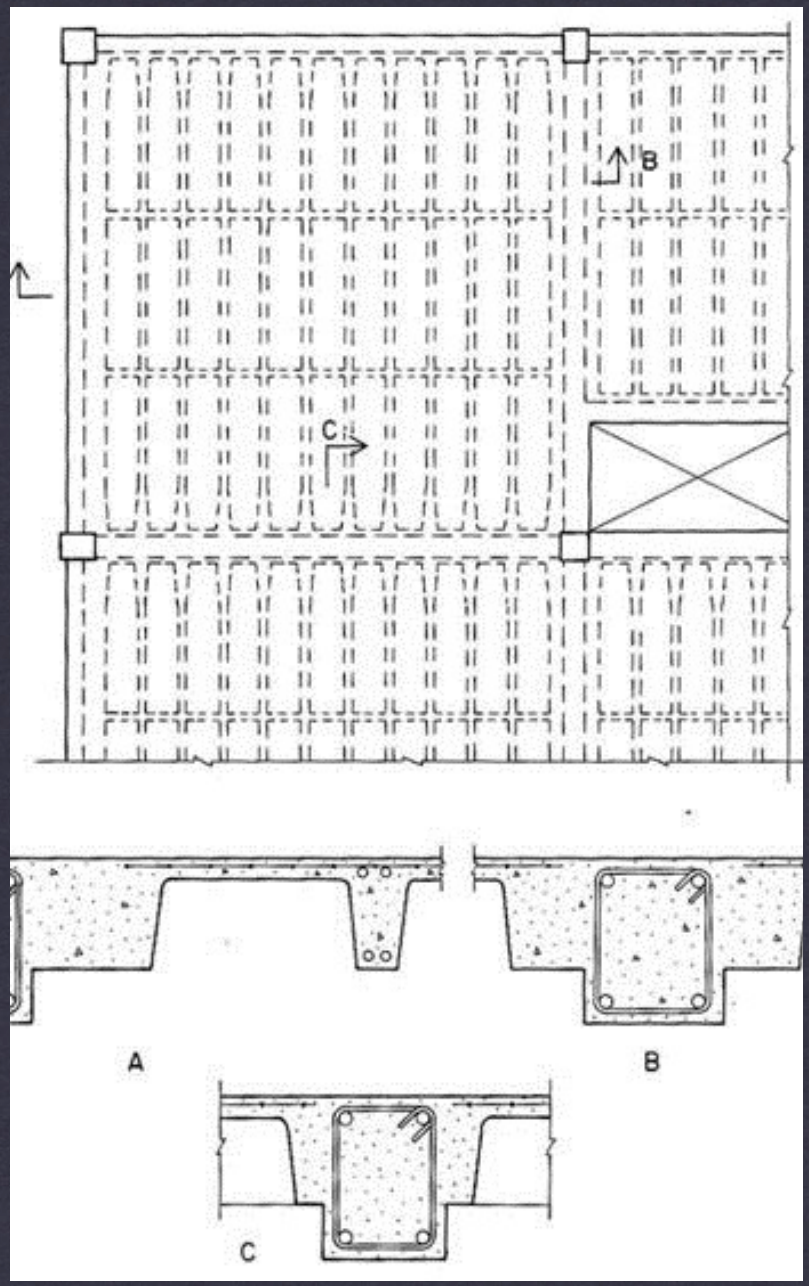
PAN FORMS DEFINE THE JOIST WIDTH AND DEPTH AS WELL AS THE BEAM DIMENSIONS. TYPICAL SPACING OF JOISTS: 20”-30” BETWEEN JOISTS



CONCRETE FRAMING SYSTEMS

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one-way joist framing

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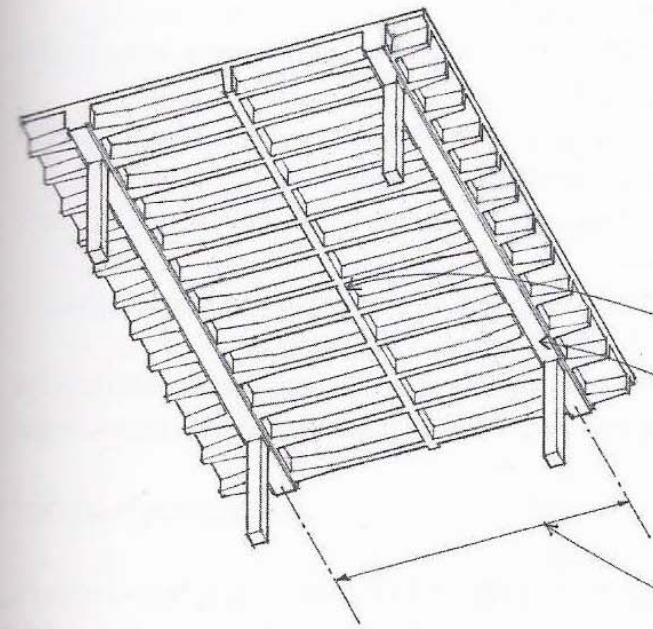
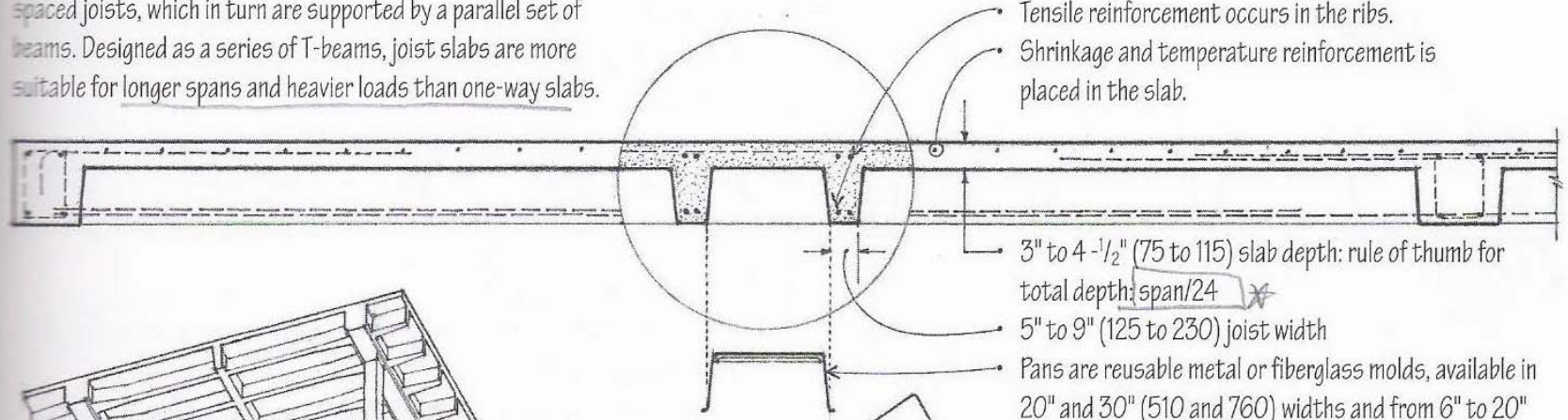
One-Way Joist Slab

A joist or ribbed slab is cast integrally with a series of closely spaced joists, which in turn are supported by a parallel set of beams. Designed as a series of T-beams, joist slabs are more suitable for longer spans and heavier loads than one-way slabs.





- Tensile reinforcement occurs in the ribs.
- Shrinkage and temperature reinforcement is placed in the slab.
- 3" to 4 -½" (75 to 115) slab depth: rule of thumb for total depth: span/24
- 5" to 9" (125 to 230) joist width
- Pans are reusable metal or fiberglass molds, available in 20" and 30" (510 and 760) widths and from 6" to 20" (150 to 510) depths in 2" (51) increments. Tapered sides allow for easier removal.
- Tapered endforms are used to thicken joist ends for greater shear resistance.
- Distribution rib is formed perpendicular to the joists in order to distribute possible load concentrations over a larger area: one required for spans between 20' and 30' (6 and 9 m), and not more than 15' (4.5 m) o.c. for spans over 30' (9 m).
- Joist band is a broad, shallow supporting beam that is economical to form because its depth is the same as that of the joists.
- Suitable for light to medium live loads over spans of 15' to 36' (4 to 10 m); longer spans may be possible with posttensioning.

THK → 4/24 SPANS 15' → 36'

• See 12.04–12.05 for a discussion of concrete as a construction material.

CONCRETE FRAMING SYSTEMS

one-way joist framing

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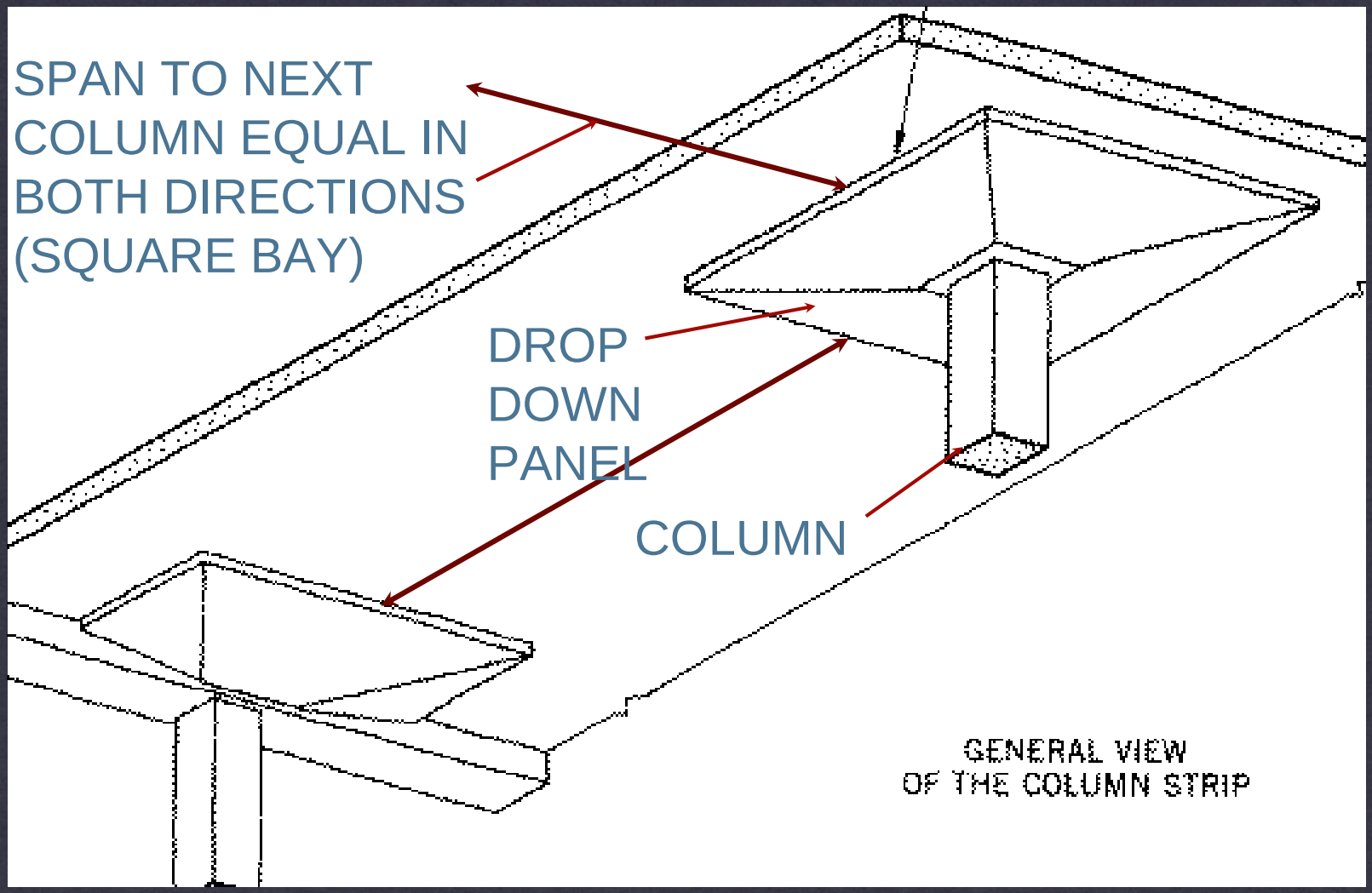
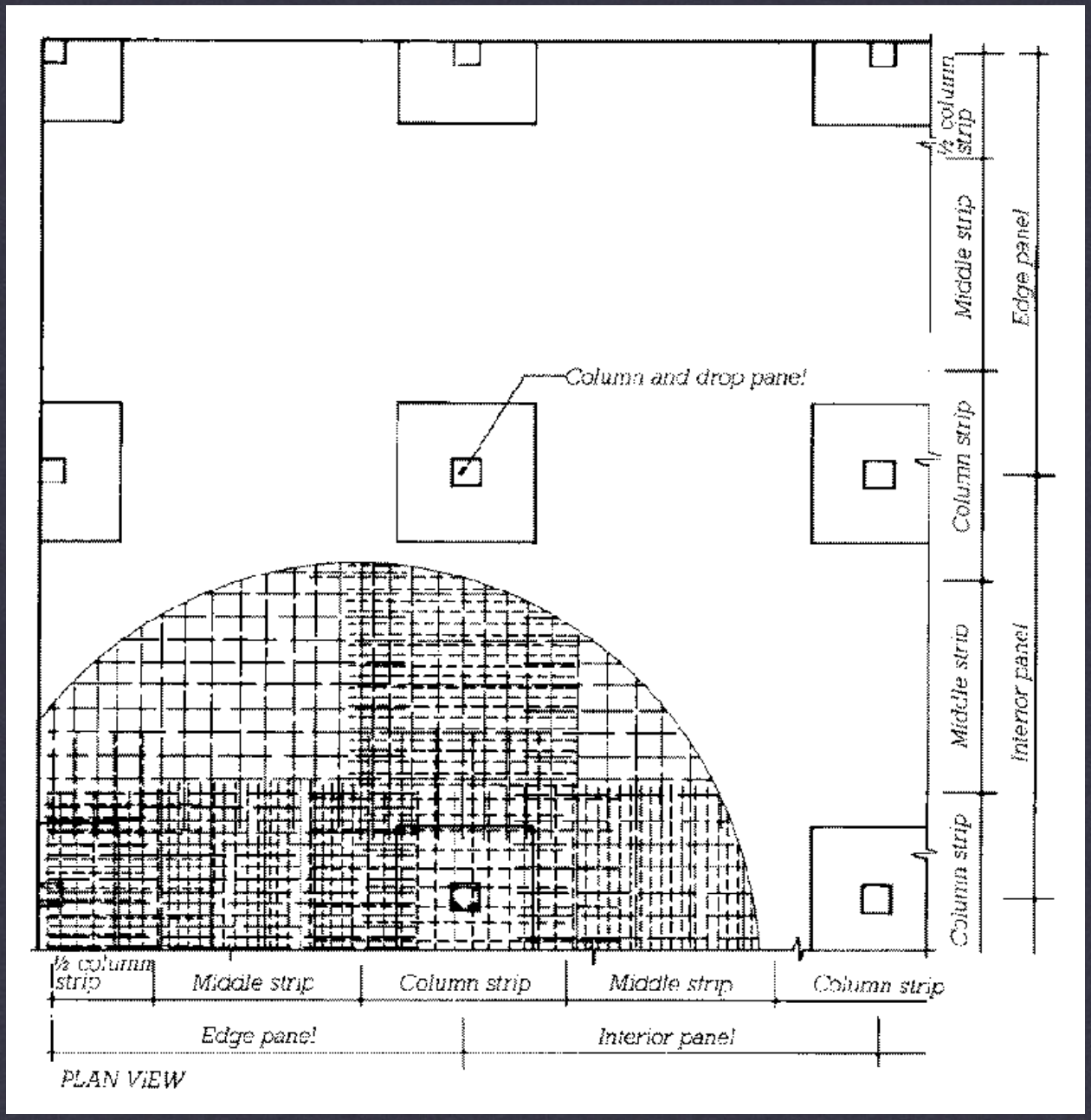


TYPICAL SLAB THICKNESS: 6” - 12”



TWO-WAY FRAMING SYSTEM:

STRUCTURAL BAY SHOULD BE CLOSE TO SQUARE

RARELY MADE WITH BEAMS

MOST TWO-WAY FRAMING SYSTEMS ARE BUILT AS FLAT SLABS WITH ONE SLAB THICKNESS

REINFORCING PATTERN REFLECTS ZONES OF CONCENTRATED STRESS

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COLUMN CAPITALS + DROPPED PANELS RESPOND TO SHEAR STRESSES TRANSFERRED FROM SLAB TO COLUMN - ADDITIONAL THICKNESS TO ADDRESS HIGHER STRESS

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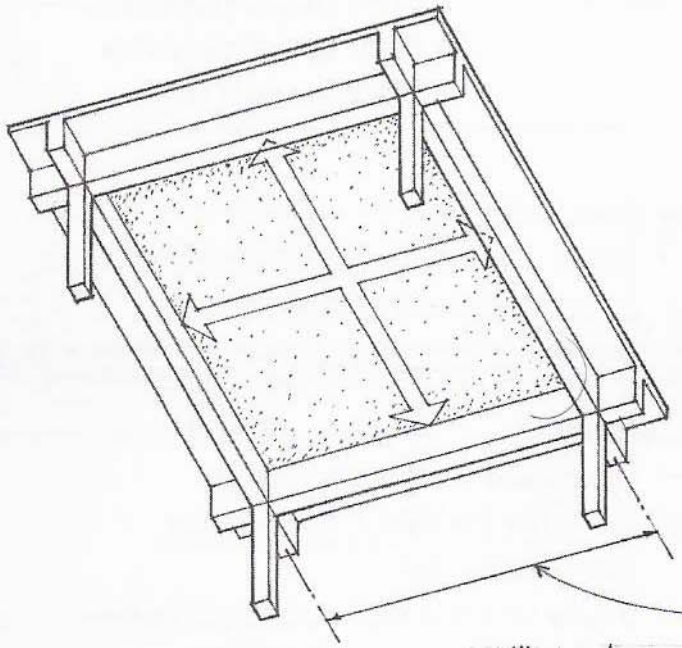
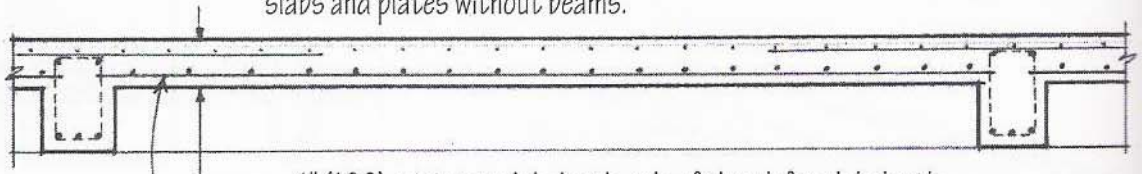
4.06 CONCRETE SLABS

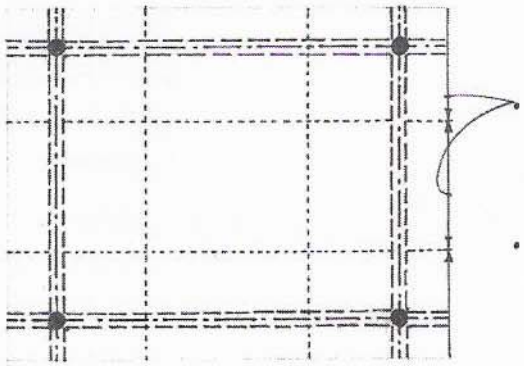


Two-Way Slab and Beam

A two-way slab of uniform thickness may be reinforced in two directions and cast integrally with supporting beams and columns on all four sides of square or nearly square bays. Two-way slab and beam construction is effective for medium spans and heavy loads, or when a high resistance to lateral forces is required. For economy, however, two-way slabs are usually constructed as flat slabs and plates without beams.



- 4" (100) minimum slab depth; rule of thumb for slab depth: slab perimeter/180
- Tensile reinforcement
- Two-way slabs are most efficient when spanning square or nearly square bays, and suitable for carrying intermediate to heavy loads over 15' to 40' (4.5 to 12 m) spans.
- To simplify the placement of reinforcing steel, two-way slabs are divided into column and middle strips, within which moments per foot are assumed to be constant.
- A continuous slab, extending as a structural unit over three or more supports in a given direction, is subject to lower bending moments than a series of discrete, simply supported slabs.



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WAFFLE SLABS ARE THE TWO-WAY EQUIVALENT OF ONE-WAY JOIST SYSTEMS.

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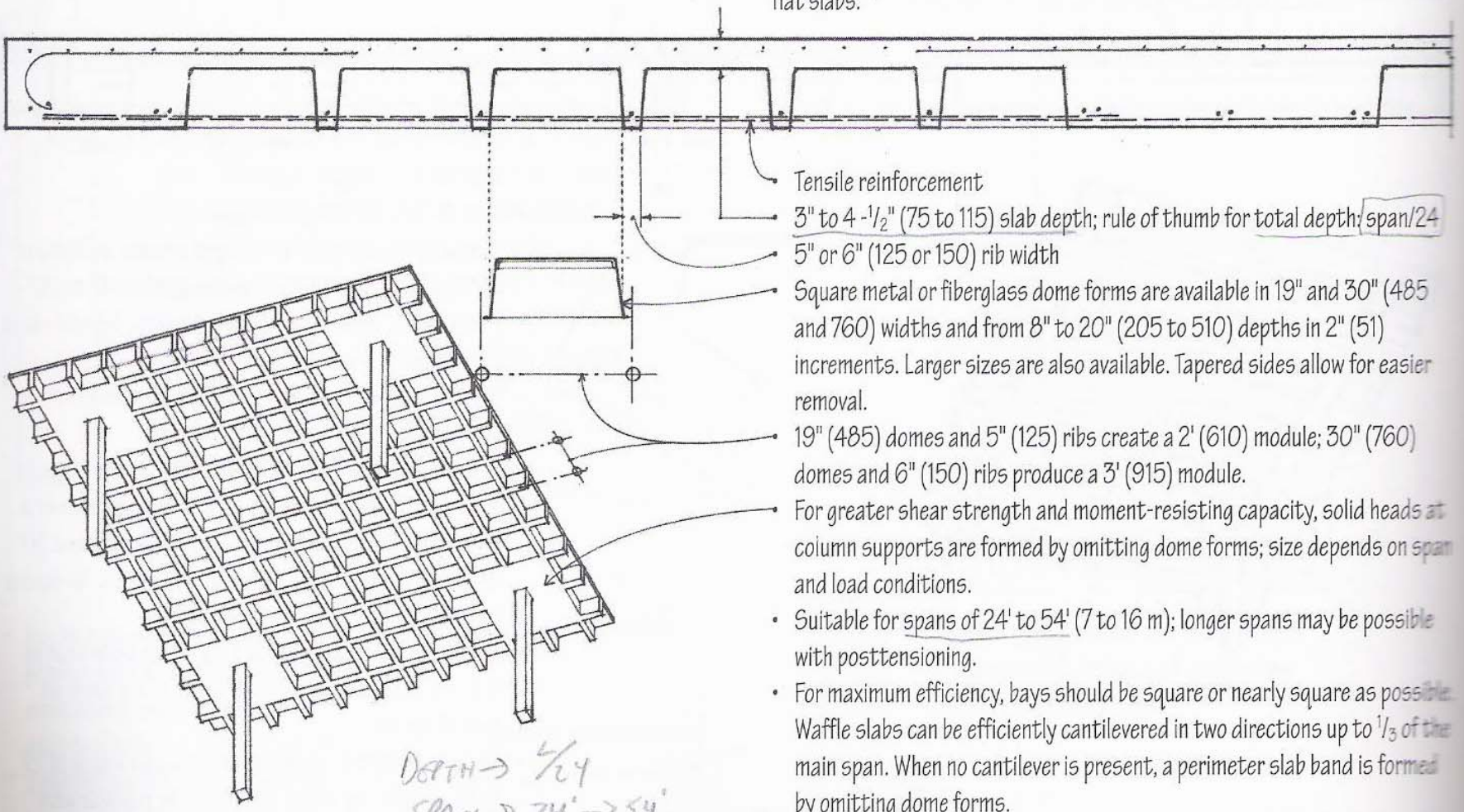
SPAN: 15' → 40'

180

Two-Way Waffle Slab

A waffle slab is a two-way concrete slab reinforced by ribs in two directions. Waffle slabs are able to carry heavier loads and span longer distances than flat slabs.



- Tensile reinforcement
- 3" to 4 -1/2" (75 to 115) slab depth; rule of thumb for total depth: span/24
- 5" or 6" (125 or 150) rib width
- Square metal or fiberglass dome forms are available in 19" and 30" (485 and 760) widths and from 8" to 20" (205 to 510) depths in 2" (51) increments. Larger sizes are also available. Tapered sides allow for easier removal.
- 19" (485) domes and 5" (125) ribs create a 2' (610) module; 30" (760) domes and 6" (150) ribs produce a 3' (915) module.
- For greater shear strength and moment-resisting capacity, solid heads at column supports are formed by omitting dome forms; size depends on span and load conditions.
- Suitable for spans of 24' to 54' (7 to 16 m); longer spans may be possible with posttensioning.
- For maximum efficiency, bays should be square or nearly square as possible. Waffle slabs can be efficiently cantilevered in two directions up to 1/3 of the main span. When no cantilever is present, a perimeter slab band is formed by omitting dome forms.
- Coffered underside is usually left exposed.

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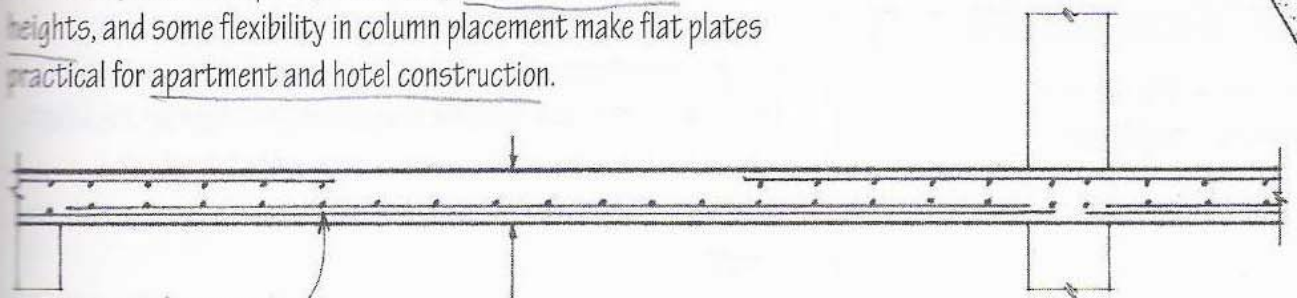
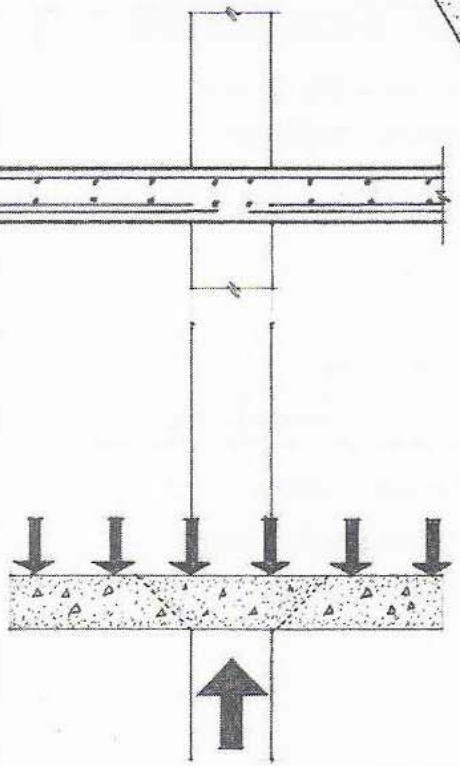
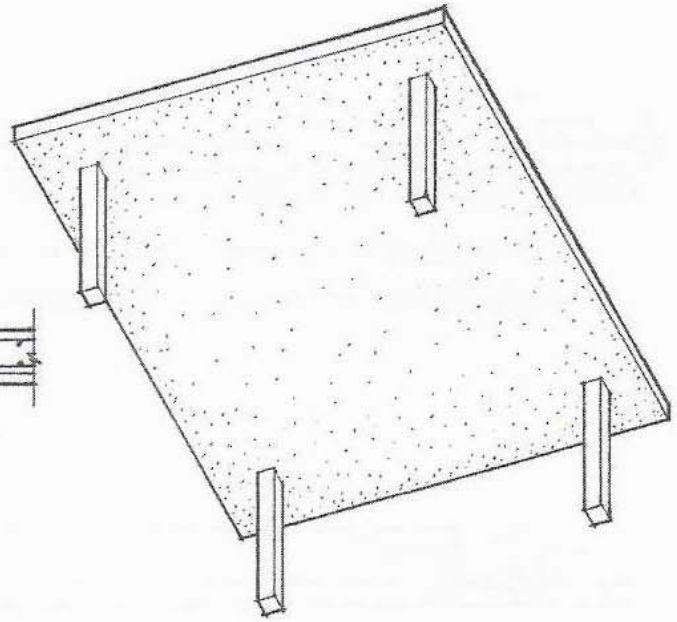
Two-Way Flat Plate

A flat plate is a concrete slab of uniform thickness reinforced in two or more directions and supported directly by columns without beams or girders. Simplicity of forming, lower floor-to-floor heights, and some flexibility in column placement make flat plates practical for apartment and hotel construction.



- Tensile reinforcement
- 5" to 12" (125 to 305) slab depth; rule of thumb for slab depth: span/33
- Suitable for light live to moderate loads over relatively short spans of 12' to 24' (3.6 to 7 m)
- While a regular column grid is most appropriate, some flexibility in column placement is possible.
- Shear at column locations governs the thickness of a flat plate.
- Punching shear is the potentially high shearing stress developed by the reactive force of a column on a reinforced concrete slab.





DEPTH → SPAN/33

SPAN: 12 → 24'

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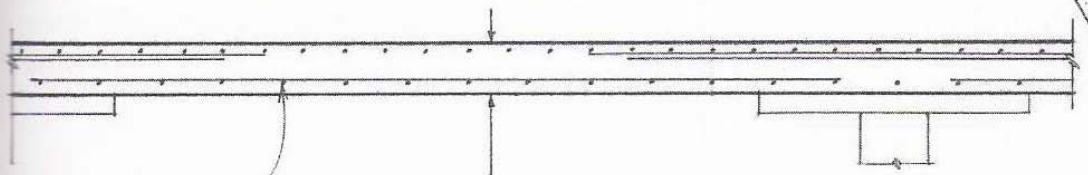
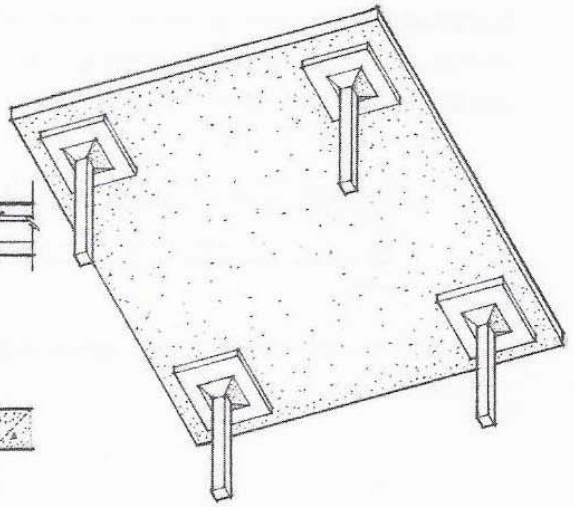
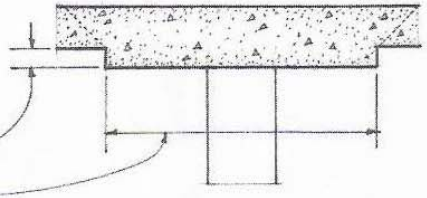
Two-Way Flat Slab

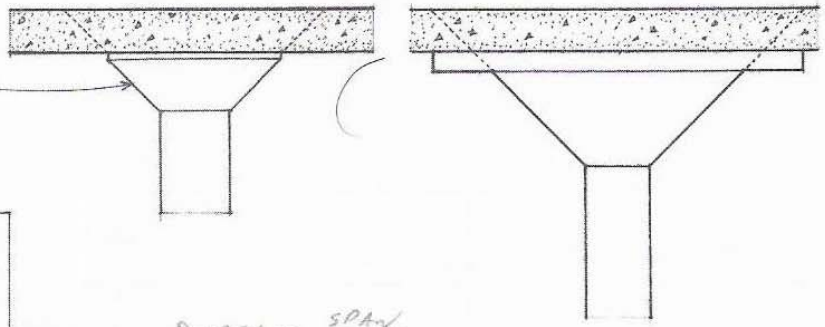
A flat slab is a flat plate thickened at its column supports to increase its shear strength and moment-resisting capacity.

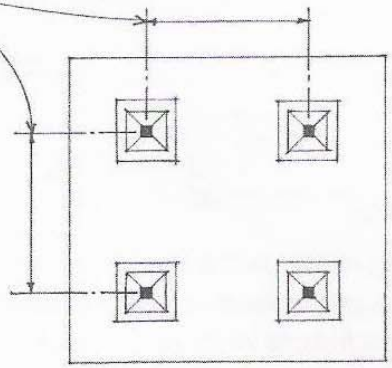




- Tensile reinforcement
- 6" to 12" (150 to 305) typical slab depth; rule of thumb for slab depth: span/36
- Drop panel is the portion of a flat slab thickened around a column head to increase its resistance to punching shear.
- Minimum projection of drop panel: 0.25 x slab thickness
- Minimum width of drop panel: 0.33 span
- Column capital may be used in place of or in conjunction with a drop panel for increased shear resistance.
- Suitable for relatively heavy loads and spans from 20' to 40' (6 to 12 m)







DEPTH → SPAN/36

SPAN: 20-40'

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CAST IN PLACE STAIR

inclined one-way solid slab

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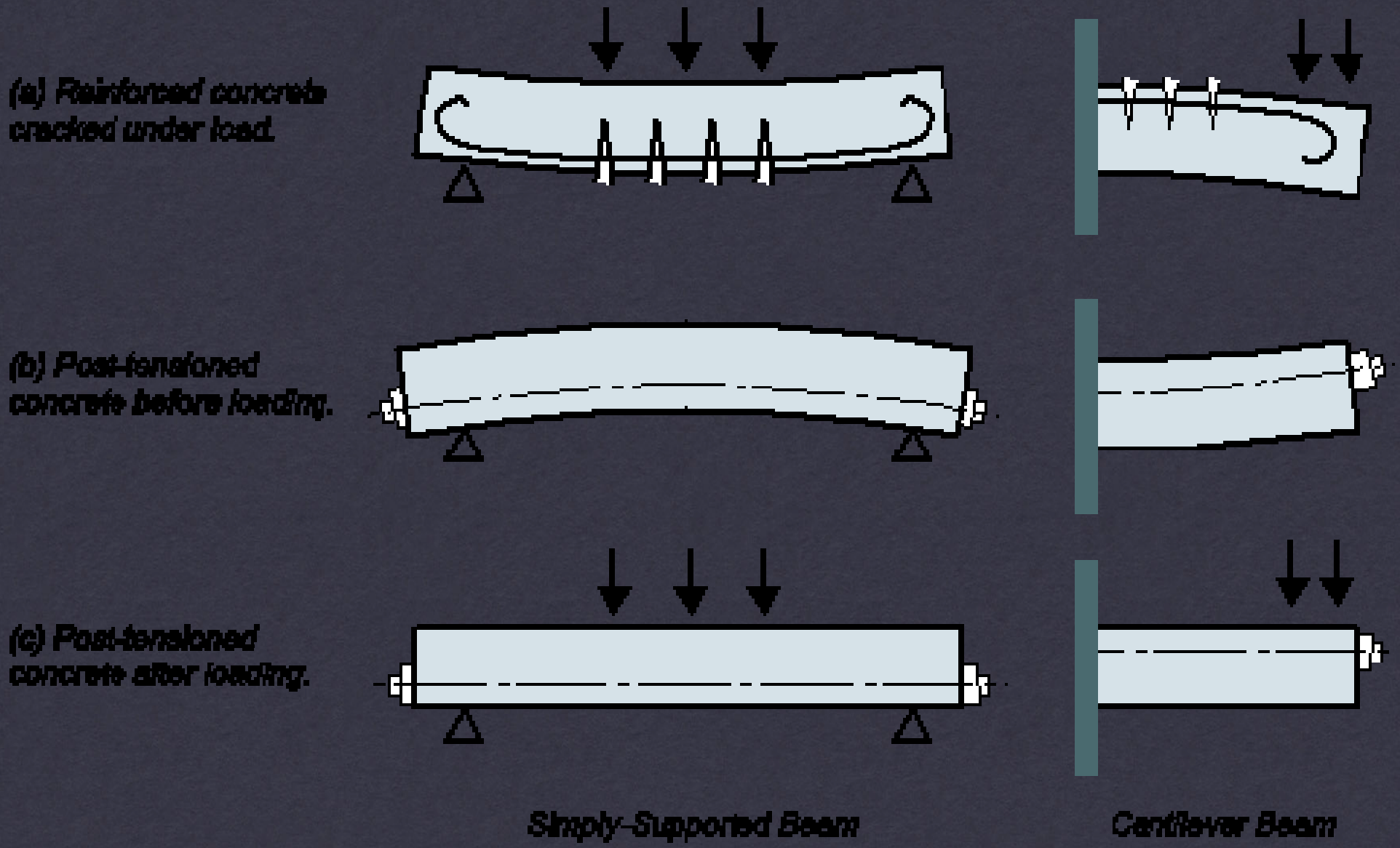
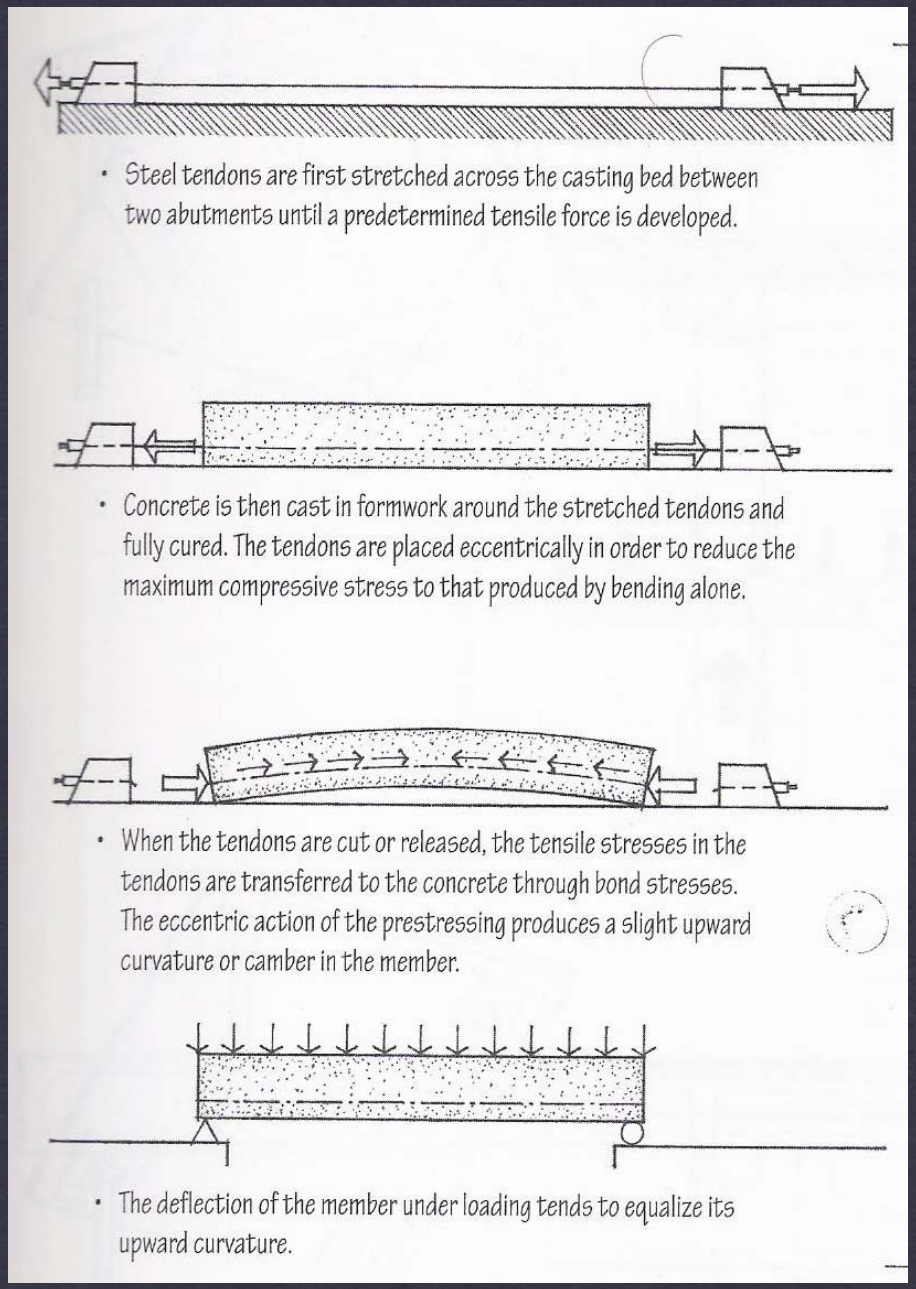

(a) Reinforced concrete cracked under load.
(b) Post-tensioned concrete before loading.
(c) Post-tensioned concrete after loading.
Simply-Supported Beam
Cantilever Beam



Pre-stressed concrete can be designed to resist creep and overloaded building loads.

-High-strength steel tendons are fed through the concrete counteracting the tensile bending stresses from the applied load into compression.

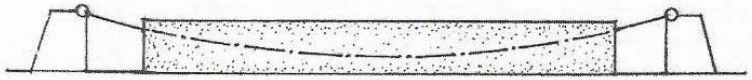
-Enables the pre-stressed member to deflect less, carry a greater load, and/or span a greater distance than a conventionally reinforced member of the same size, proportion, and weight.

-Two pre-stressing techniques:
Pre-tensioning and Post-tensioning.

-**Pre-tensioning** is done at a pre-casting plant. It pre-stresses a concrete member by stretching the reinforcing tendons before the concrete is cast.

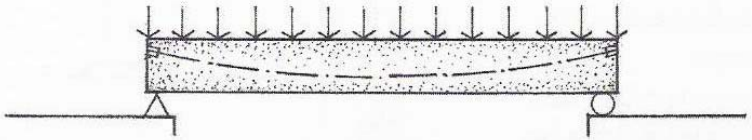
Pre-tensioned, Pre-cast concrete video

- Unstressed steel tendons, draped inside the beam or slab form, are coated or sheathed to prevent bonding while the concrete is cast.



- After the concrete has cured, the tendons are clamped on one end and jacked against the concrete on the other end until the required force is developed.

- The tendons are then securely anchored on the jacking end and the jack removed. After the posttensioning process, the steel tendons may be left unbonded, or they may be bonded to the surrounding concrete by injecting grout into the annular spaces around the sheathed strands.



- The deflection of the member under loading tends to equalize its upward curvature.

-**Post-tensioning**: pre-stresses a concrete member by stretching the reinforcing tendons after the concrete is cast. (on the site).

CONCRETE

prestressing concrete structural elements

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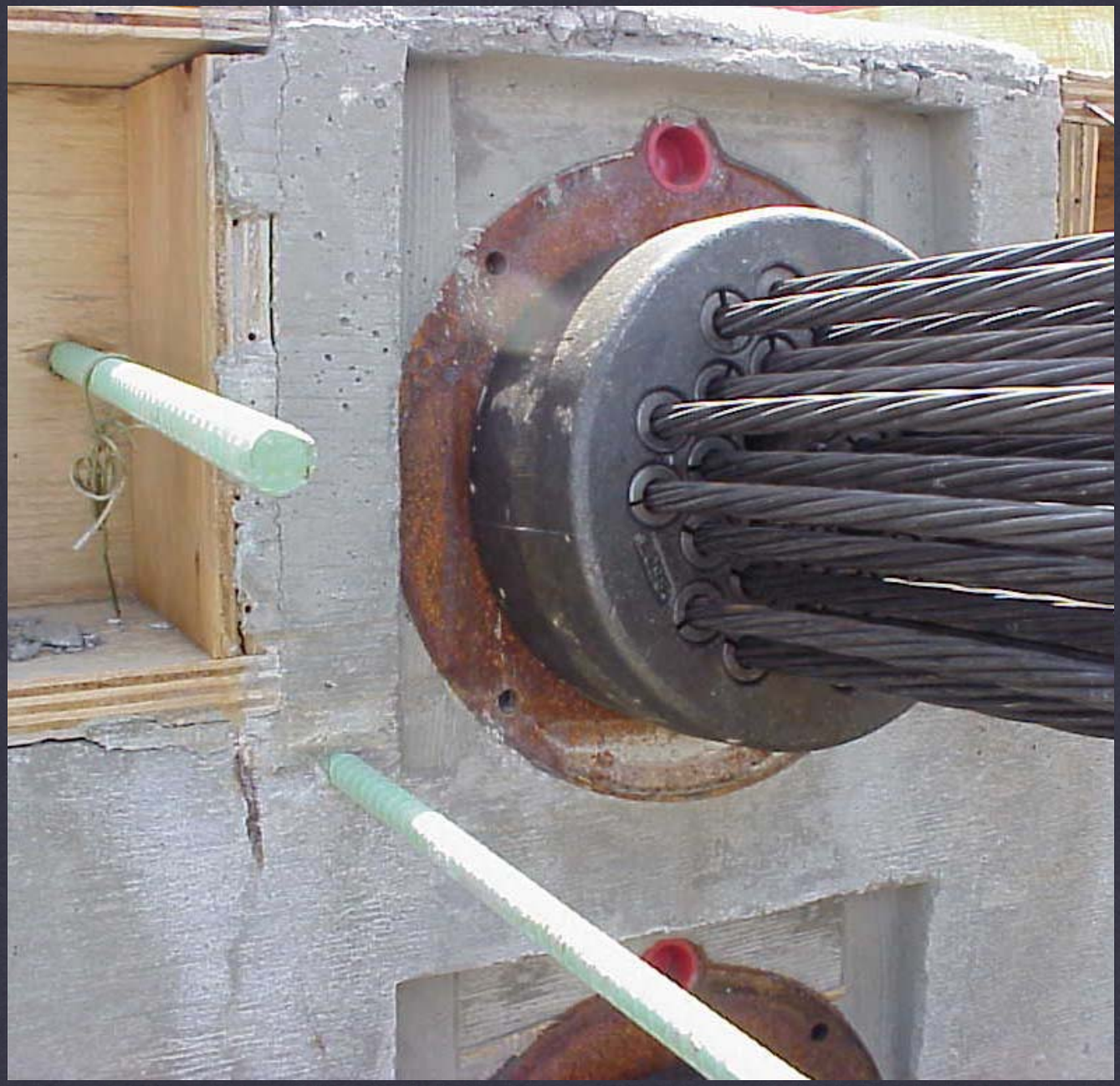

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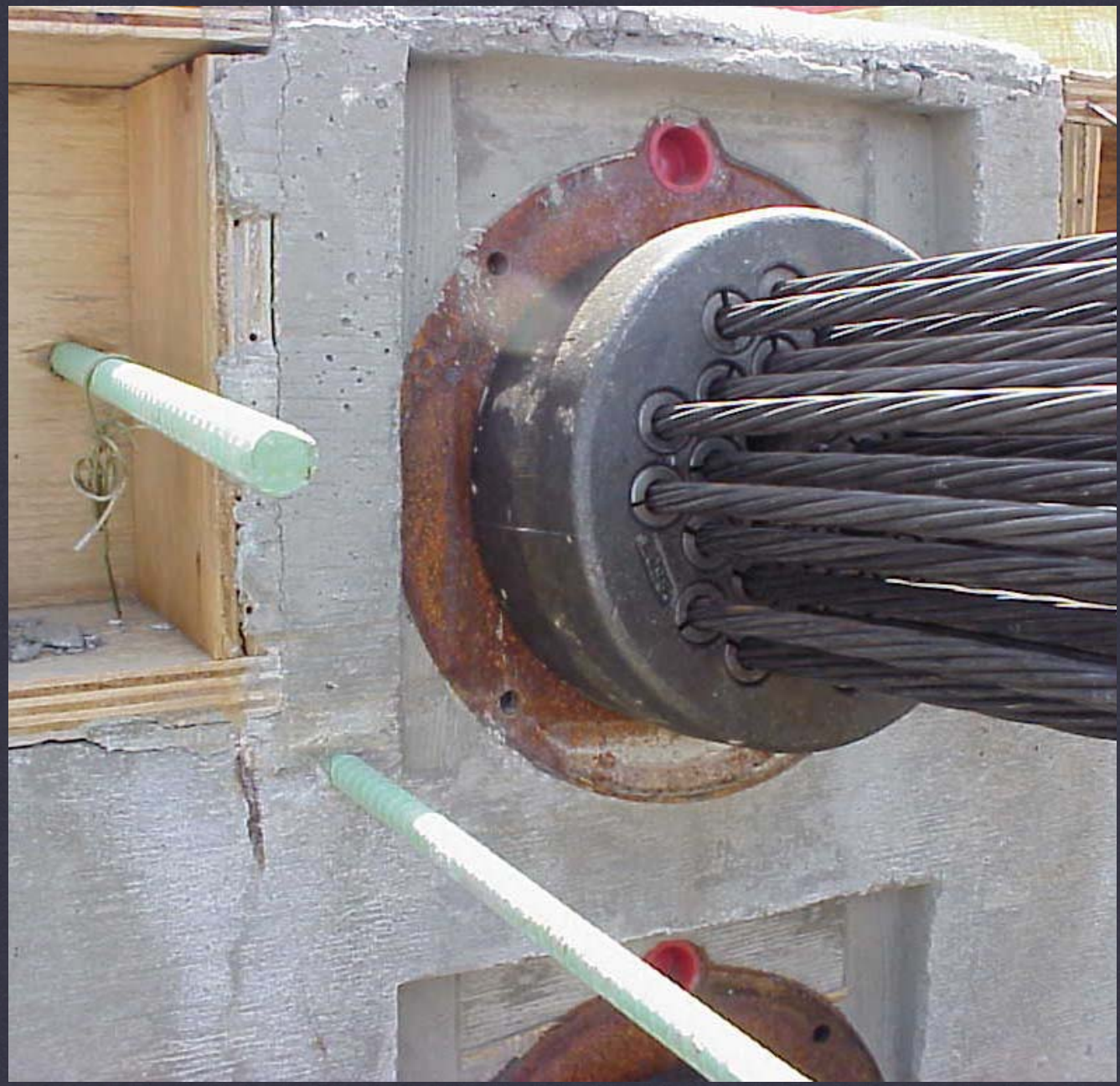
PRE TENSIONING:

PRECAST CONCRETE ELEMENTS CAST AROUND STRETCHED REINFORCED (IN THE SHOP)

POST TENSIONING:

REINFORCEMENT INITIALLY PREVENTED FROM BONDING. TENSIONED WITH JACK THEN GROUTED (ON SITE)



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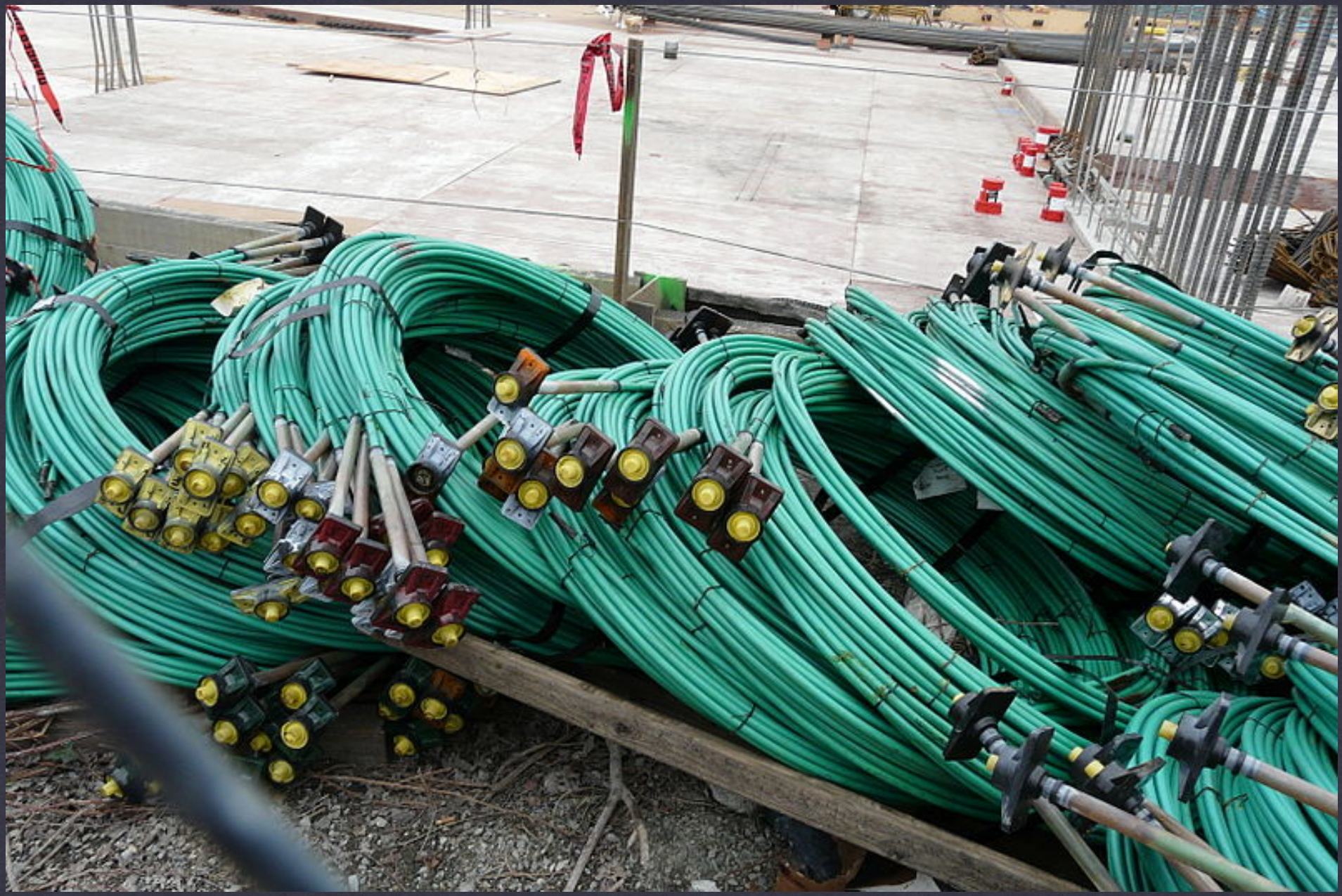

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POSTTENSIONING CAN BE APPLIED TO ANY SITECAST CONCRETE FRAMING SYSTEM

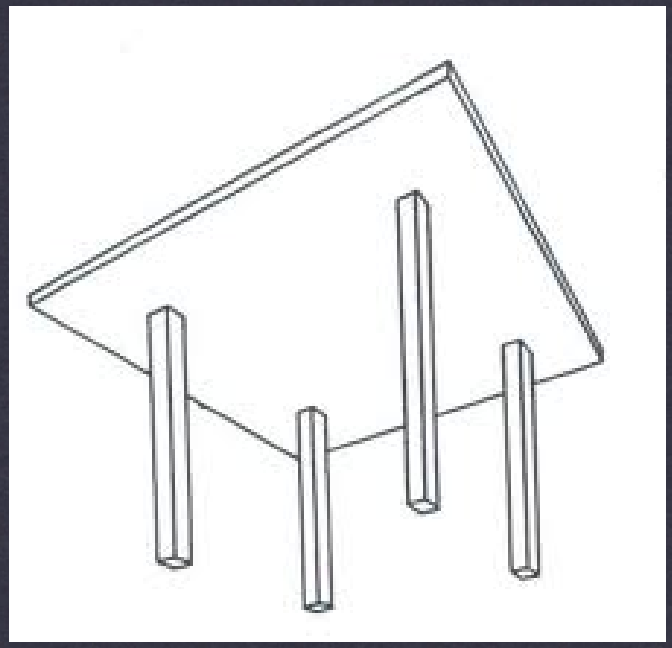
POSTTENSIONING:

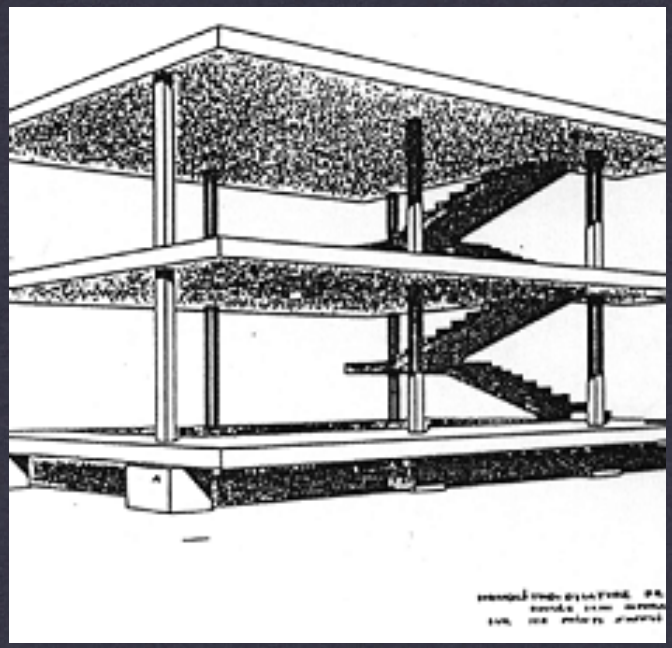
- REDUCES MEMBER SIZES
- REDUCES DEFLECTION
- EXTENDS SPANNING CAPABILITY

TWO-WAY FLAT PLATE STRUCTURES ARE MOST COMMONLY POSTTENSIONED

Post-tensioned Concrete slab placement- video

Pre-stressed/ Pre-cast Concrete Factory tour





SITECAST POSTTENSIONED FRAMING SYSTEM

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CASE STUDIES- MILSTEIN HALL, CORNELL

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CASE STUDIES- MILSTEIN HALL, CORNELL

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CASE STUDIES- MILSTEIN HALL, CORNELL

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CASE STUDIES- BURJ DUBAI

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SELECTION CRITERIA:	
ARE THE BAYS SQUARE?	YES - TWO-WAY SYSTEM
HOW LONG ARE THE SPANS?	25’ TO 30’ - TWO-WAY FLAT PLATE > 30’ - ONE-WAY JOIST SYSTEM
HOW HEAVY ARE THE LOADS?	HEAVY LOADS - THICKER SLABS + LARGER BEAMS(ONE-WAY SOLID SLAB)
WILL THERE BE A FINISHED CEILING BELOW THE SLAB?	NO - MUST CONSIDER THE AESTHETIC OF THE SYSTEM
MUST THE FRAME SUPPLY LATERAL FORCE RESISTANCE?	YES - ONE-WAY SYSTEM

SELECTING A SITECAST FRAMING SYSTEM

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wrap up:

SITECAST CONCRETE ACHIEVES A UNIQUE CONTINUITY OF STRUCTURE AND FORM.

- unlimited possibilities for the designer
- any shape than can be formed can be cast
- some types of elements can only be sitecast:
  - slab on grade
  - footings
  - two-way slab systems
- sitecast concrete is massive and monolithic - imparting a powerful architectural character