ARCH 2231
BUILDING TECHNOLOGY II

CONCRETE: Cement Types

Varieties of cement are used to give the concrete different characteristics:

- Normal (Type I): for most purposes
- Air-entraining: creates bubbles that add to the workability of the concrete and make it more resistant to damage caused by freezing/thawing cycles.
- Sulfate resistant (Type II or V): for concrete that will be in contact with water
- High early strength (Type III): Hardens more quickly (is used when curing must be rushed or in cold weather.)
- Low heat of hydration (Type IV): Used in massive pours such as dams where the heat generated may ruin the quality of the concrete.

CONCRETE: Aggregates + Water

- Aggregates make up ¾ of the volume of concrete
- The structural strength of concrete depends of the quality of the aggregates.
- Must be clean and free of salts.
- A range of sizes must be included in each mix to insure adhesion. (The largest aggregate must be small enough to fit between the reinforcement bars.

A set of sieves with mesh ranging from very fine to about 1/4" (6 mm) were, stacked, loaded with a sample of fine aggregate, and vibrated to sort the sample by the size of its granules. Much larger sieves are used to sort and analyze the coarse gravel. A well-graded mix of aggregate whose particles pack densely together is desirable for strong concrete.

CONCRETE: Water to Cement Ratios

- A certain amount of water is needed for the chemical reaction that combines water to cement

- More water is needed to make the cement plastic. The extra water eventually evaporates, but leaves small voids that reduce the strength of the concrete.

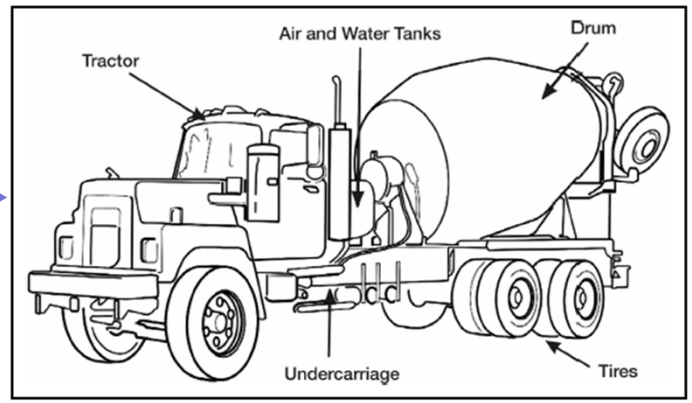
- The more water added, the weaker the concrete.

- Therefore, the weight of the water in the mix should be no more than 60% of the weight of the cement.

- Admixtures are often added to make low water concrete more plastic.

CONCRETE: Mixing

- Most concrete in mixed in *batch plants*
- Dry ingredients are mixed first and water is added last.
- The concrete is *transit mixed* en route in a rotating drum.
- Each load is delivered with a *certificate* listing its ingredients and proportions.
- A *slump test* is taken at the time of the pour to determine that the concrete is not too wet (but is workable.)



REINFORCED CONCRETE

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Methods of Construction

- **SITE-CAST** (cast-in-place or poured-in-place): concrete is poured at the building site.

- **PRE-CAST**: Structural members are cast at the plant and brought to the site. (Next class)

REINFORCING CONCRETE: Methods of Construction

SITE-CAST CONCRETE

- Some sections of a building must be site-cast because of size or position: foundations, slab-on-grade, spread footings.
- Advantage:
  - rigid connections (monolithic)
- Disadvantages:
  - Slow process
  - Heavier structure

Formwork for Site-Casting:

- Formwork is used to shape concrete.
- It must be strong enough to support the weight of the wet concrete.
- Formwork is often reusable.
- Formwork is usually oiled or waxed so concrete does not adhere to it.
- The cost of the formwork is a major part of the cost of a concrete structure. It is like building TWO structures!

REINFORCING CONCRETE : Methods of Construction : Site Cast

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE : Methods of Construction: Site Cast

- A wood stud wall with a plywood face is set on a previously poured and cured concrete footing to provide one side of the wall form. The diagonal braces hold the wall form in horizontal and vertical alignment.

REINFORCING CONCRETE : Methods of Construction: Site Cast

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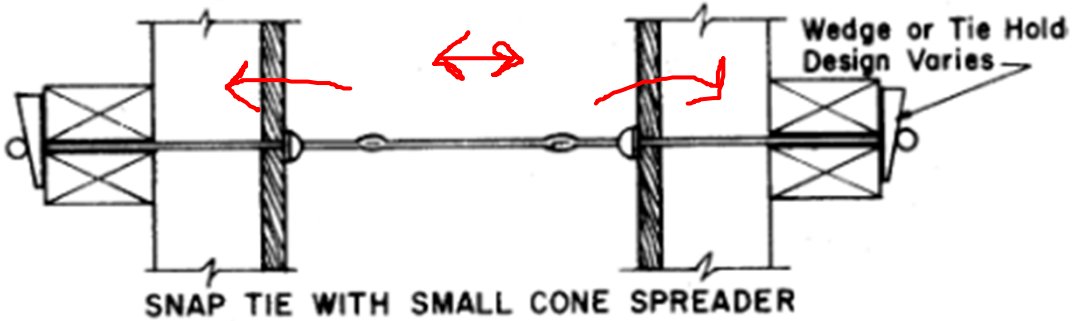
REINFORCING CONCRETE : Methods of Construction : Site Cast

Before the wall form is assembled, the inside surface of the form plywood is coated with a form release compound. The wire snap that will hold the two sides of the form together have been inserted and are projecting out of the first side. Dowels project up from the footing to bond to the wall reinforcement.

REINFORCING CONCRETE : Methods of Construction : Site Cast

courtesy of PROF. S. VAIDYA

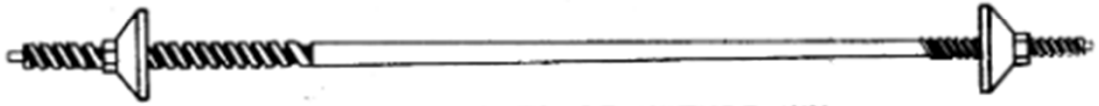


SNAP TIE WITH SMALL CONE SPREADER

WASHER SPREADER, CRIMPED FOR BREAK BACK

CONE SPREADER

NO SPREADER; MAY BE PULLED OR MAY
BE EQUIPPED WITH BREAK POINTS



TAPER TIE TO BE WITHDRAWN

STRAP TIE USED WITH PANELS

LOOP END TIE USED WITH PANELS

REINFORCING CONCRETE : Methods of Construction : Site Cast

A hotel with many identical small rooms is an ideal program for reusable formwork. After the concrete is poured and cured the forms will be pushed out and reset on the floor above.

REINFORCING CONCRETE : Methods of Construction

A system of prefabricated steel forms is used here to cast both the walls and floors at the same time. The solid floor slabs span in the short direction across each of the hotel rooms.

REINFORCING CONCRETE : Methods of Construction : Site Cast

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE : Methods of Construction : Site Cast

Most of the prefabricated wall forms have been stripped from this side of the wall and the tie ends have been snapped off. A smooth concrete surface without wood grain is produced. The inside surface of the other side form is seen through the blocked out window opening. Note the form ties in the window opening that were not embedded in the concrete.


REINFORCING CONCRETE : Methods of Construction : Site Cast

REINFORCING CONCRETE:
Methods of Construction :
Site Cast

courtesy of PROF. S. VAIDYA

Tadao Ando
Church of Light
Osaka-Fu, Japan, 1989

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Church of Light
Osaka-Fu, Japan, 1989

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Methods of Construction : Site Cast

Tadao Ando
Awaji Yumebutai, Japan
Memorial to Earthquake Victims + Conference Center, 1995

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Methods of Construction : Site Cast

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REINFORCING CONCRETE: Principles

- A marriage of steel and concrete made possible by
  - The fact that both expand and contract due to temperature change at more or less the same rate
  - The materials are chemically compatible
  - The concrete adheres to the steel
- Steel reinforcement gives the concrete tensile strength.
- Steel is used where there is tension; the concrete handles the compression.

REINFORCING CONCRETE: Principles

Comparative Physical Properties

material	working strength in tension	working strength compression	density	modulus of elasticity	coefficient of linear expansion (10-6 in/in oF)
Wood (framing lumber)	300-1000 psi	600-1700 psi	30 pcf	1,000,000-1,900,000 psi	2
brick masonry (including order, on reinforced)	0	250-13,000 psi	120 pcf	700,000-3,700,000 psi	3
structural steel	25,000-43,000 psi	25,000-43,000 psi	490 pcf	29,000,000 psi	7
concrete (unreinforced)	0	1,000-4,000 psi (22,000 psi High-Strength)	145 pcf	3,000,000-4,500,000 psi	7

REINFORCING CONCRETE: Reinforcing Bars

- Hot-rolled with *deformations* (protruding ribs) help the concrete bond to the steel.
- Bars are sized on a 1/8 inch scale (in the USA). A #6 bar is 6/8 inches in diameter.
- Rebars are rolled in a number of steel strengths.
- An engineer calculates how much “cross section” of steel is required to accommodate the stress. The engineer then chooses to use a few thick bars, or many thinner rods.

REINFORCING CONCRETE : Reinforcing Bars

Note the deformations rolled into the surface of a reinforcing bar to help it bond tightly to the concrete.

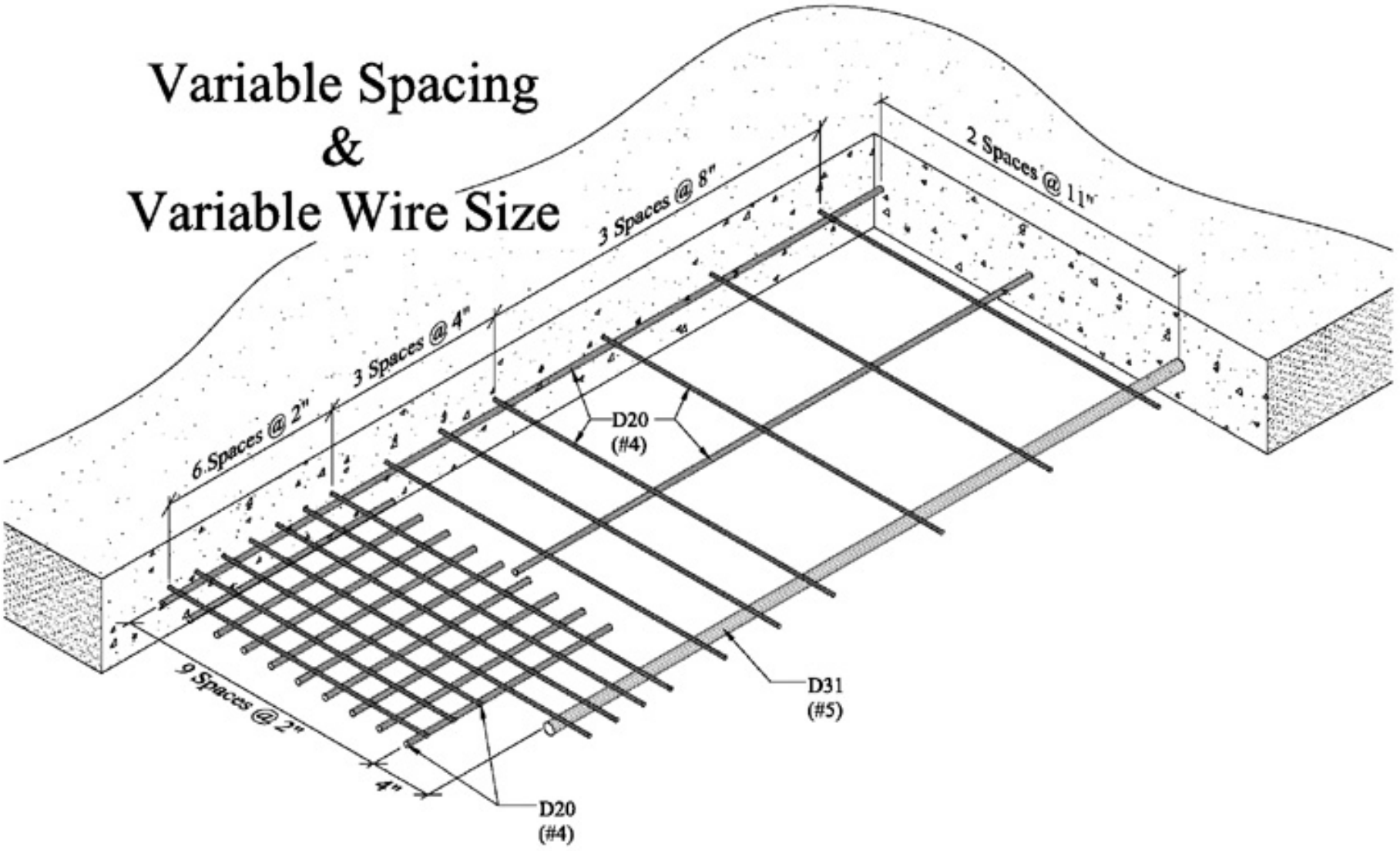
REINFORCING CONCRETE : Reinforcing Bars

Rebar sizes (U.S.)

Imperial bar designations represent the bar diameter in fractions of ⅛ inch.
(bars larger #8 have a slightly larger diameter)

Imperial Bar Size	"Soft" Metric Size	Weight (lb/ft)	Weight (kg/m)	Nominal Diameter (in)	Nominal Diameter (mm)	Nominal Area (in^2)	Nominal Area (mm^2)
#3	#10	0.376	0.561	0.375 = ⅜	9.525	0.11	71
#4	#13	0.668	0.996	0.500 = ½	12.7	0.2	129
#5	#16	1.043	1.556	0.625 = ⅝	15.875	0.31	200
#6	#19	1.502	2.24	0.750 = ¾	19.05	0.44	284
#7	#22	2.044	3.049	0.875 = ⅞	22.225	0.6	387
#8	#25	2.67	3.982	1.000 = 8/8	25.4	0.79	509
#9	#29	3.4	5.071	1.128	28.65	1	645
#10	#32	4.303	6.418	1.27	32.26	1.27	819
#11	#36	5.313	7.924	1.41	35.81	1.56	1006
#12	#40	6.424	9.619	1.5	38.1	1.76	1140
#14	#43	7.65	11.41	1.693	43	2.25	1452
#18	#57	13.6	20.284	2.257	57.33	4	2581

REINFORCING CONCRETE : Reinforcing Bars



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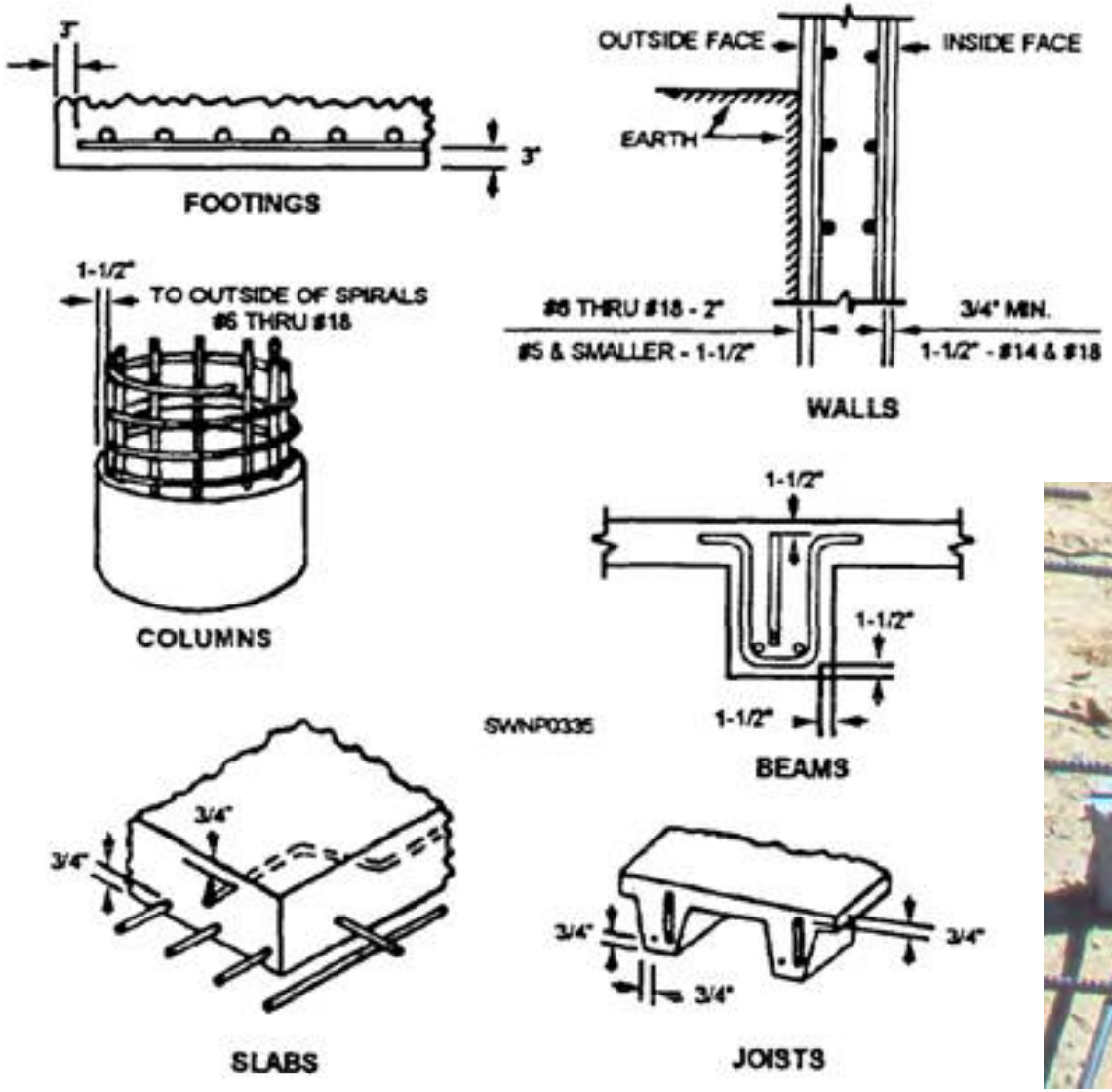
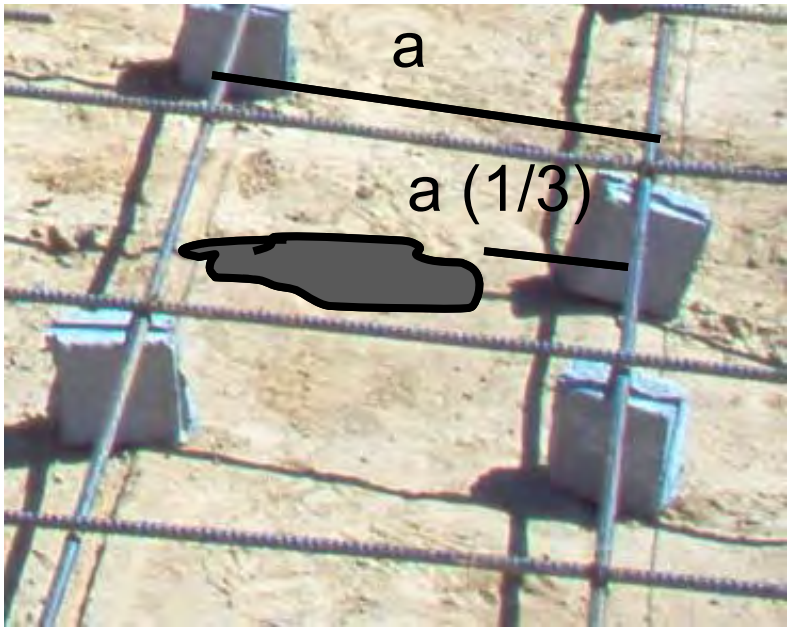
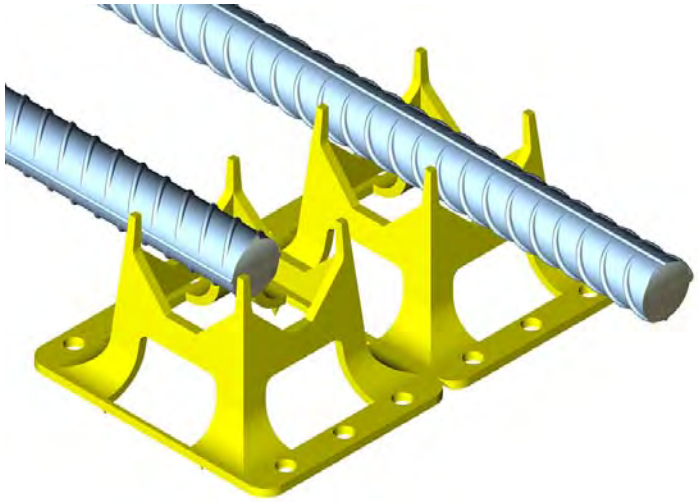
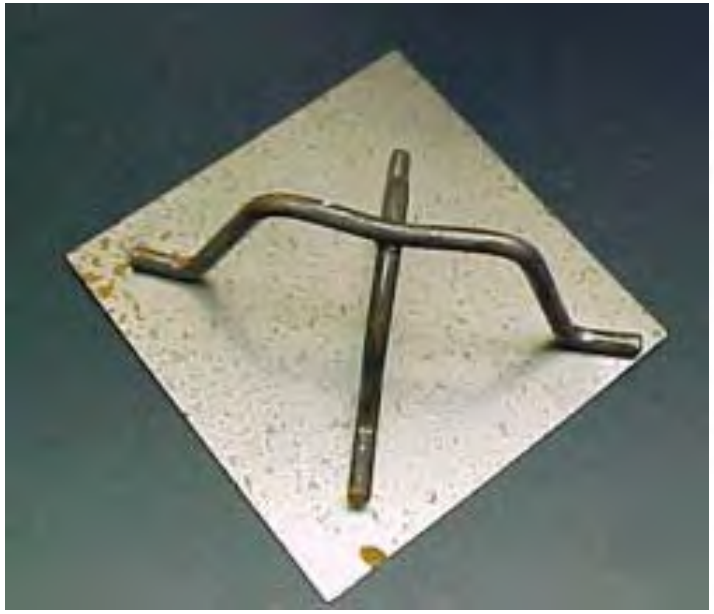
REINFORCING CONCRETE : Reinforcing Bars





REINFORCING CONCRETE :
Reinforcing Bars

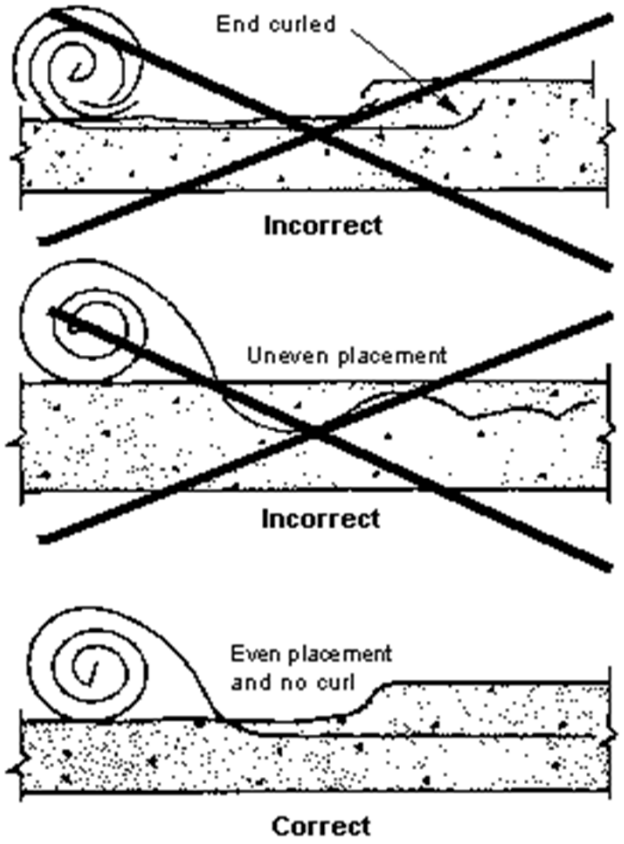




SYMBOL	BAR SUPPORT ILLUSTRATION	BAR SUPPORT ILLUSTRATION PLASTIC CAPPED OR DIPPED	TYPE OF SUPPORT	SIZES
SB		CAPPED	Slab Bolster	¾, 1, 1½, and 2 inch heights in 5 ft. and 10 ft. lengths
SBU			Slab Bolster Upper	Same as SB
BB		CAPPED	Beam Bolster	1, 1½, 2, over 2" to 5" heights in increments of ¼" in lengths of 5 ft.
BBU			Beam Bolster Upper	Same as BB
BC		DIPPED	Individual Bar Chair	¾, 1, 1½, and 1¾" heights
JC		DIPPED DIPPED	Joist Chair	4, 5, and 6 inch widths and ¾, 1 and 1½ inch heights
HC		CAPPED	Individual High Chair	2 to 15 inch heights in increments of ¼ inch
HCM			High Chair for Metal Deck	2 to 15 inch heights in increments of ¼ in.
CHC		CAPPED	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 inch heights in increments of ¼ in.
JCU		DIPPED	Joist Chair Upper	14" Span. Heights – 1" thru +3½" vary in ¼" increments

REINFORCING CONCRETE: "Reinforcing Fabric"

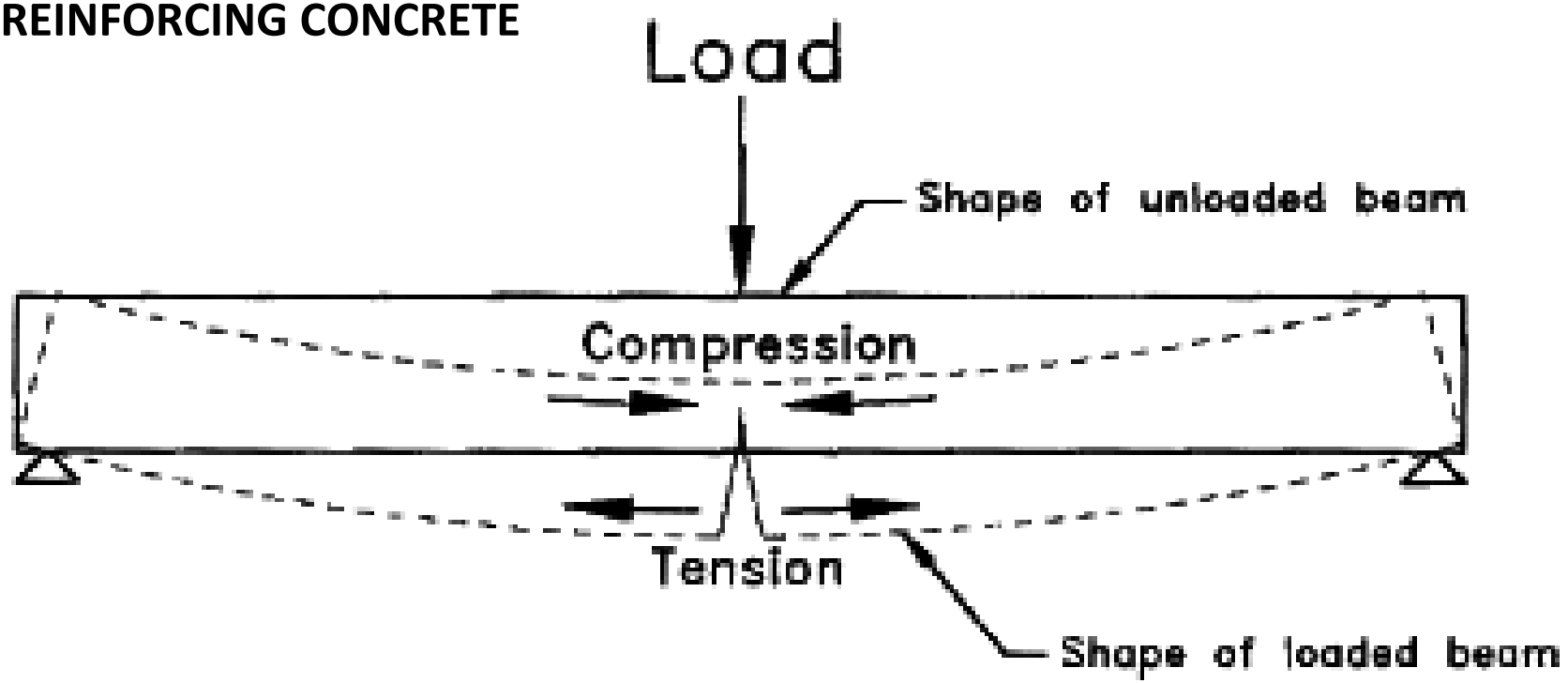
- Welded wire fabric is a mesh of rebars.
- Used mostly to reinforce slabs and walls.
- Used for economy of labor. Rolled out.

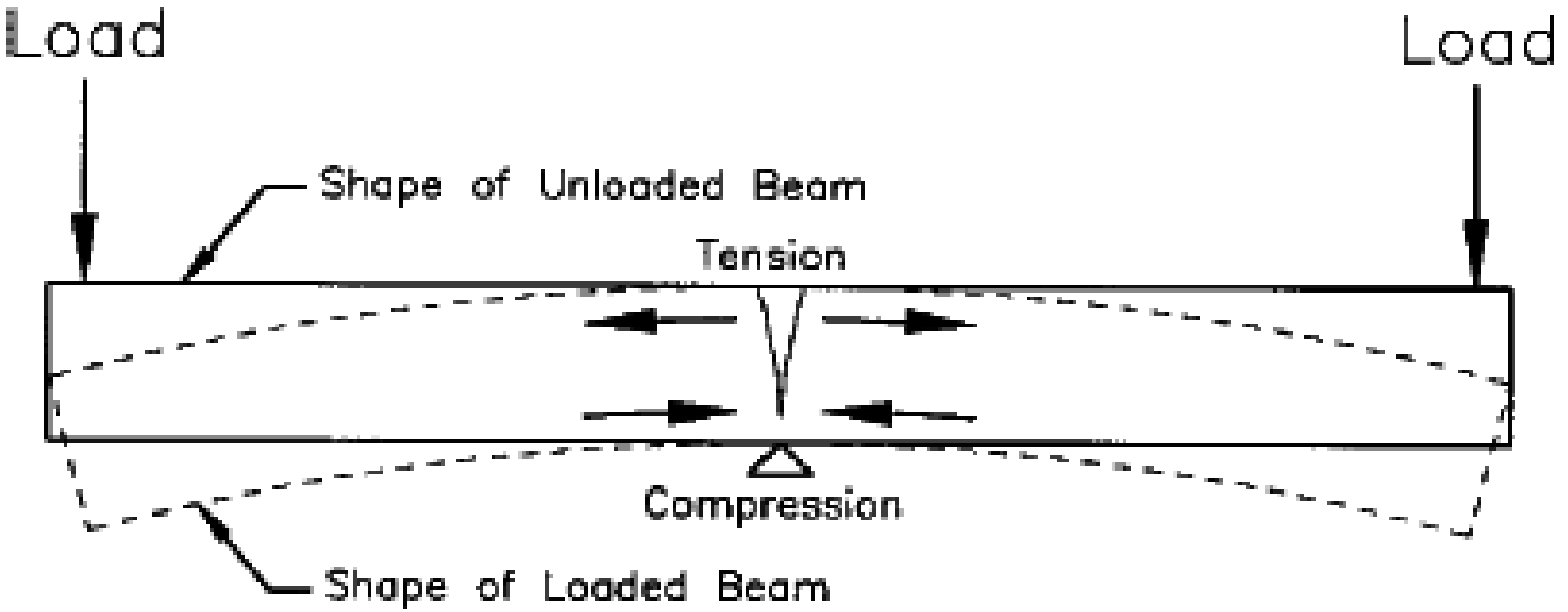


REINFORCING CONCRETE

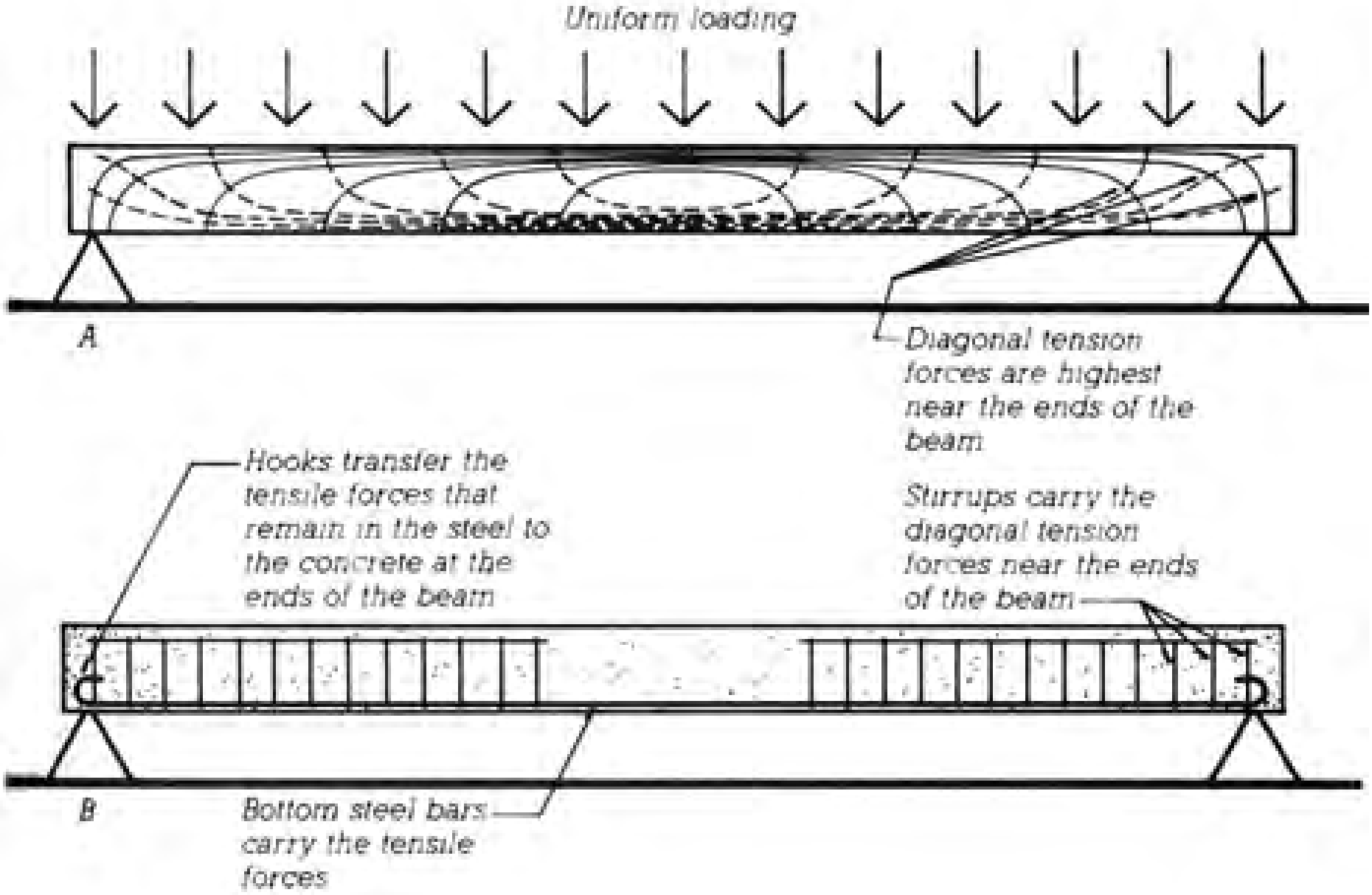
- Steel is used in beams and slabs to take the tensile stresses
- Steel is used in columns to take some compressive stresses
- Steel is often used to reduce the cracking due to stresses caused by the concrete's shrinking. Shrinking may occur due to
  - Curing
  - Thermal expansion and contraction

REINFORCING CONCRETE



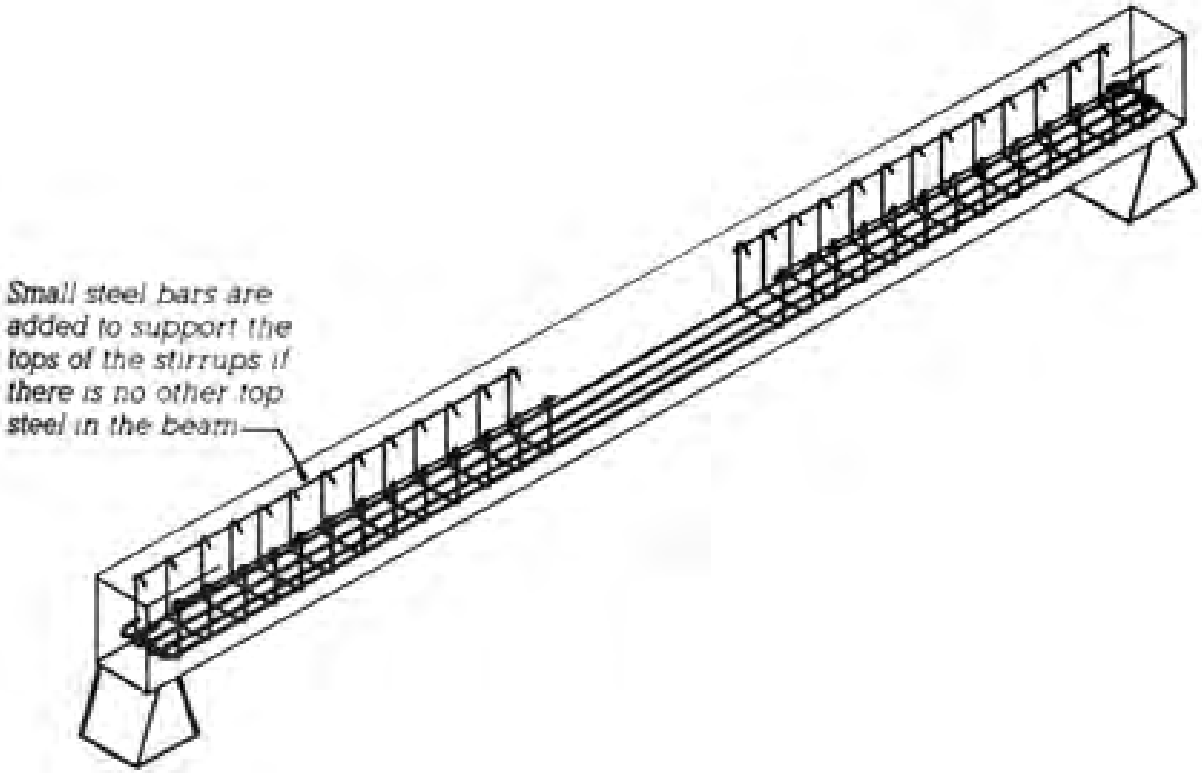


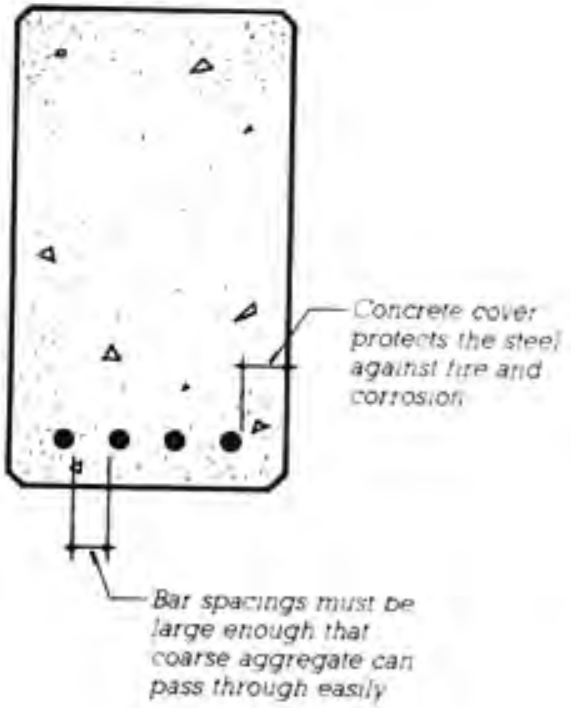
REINFORCING CONCRETE



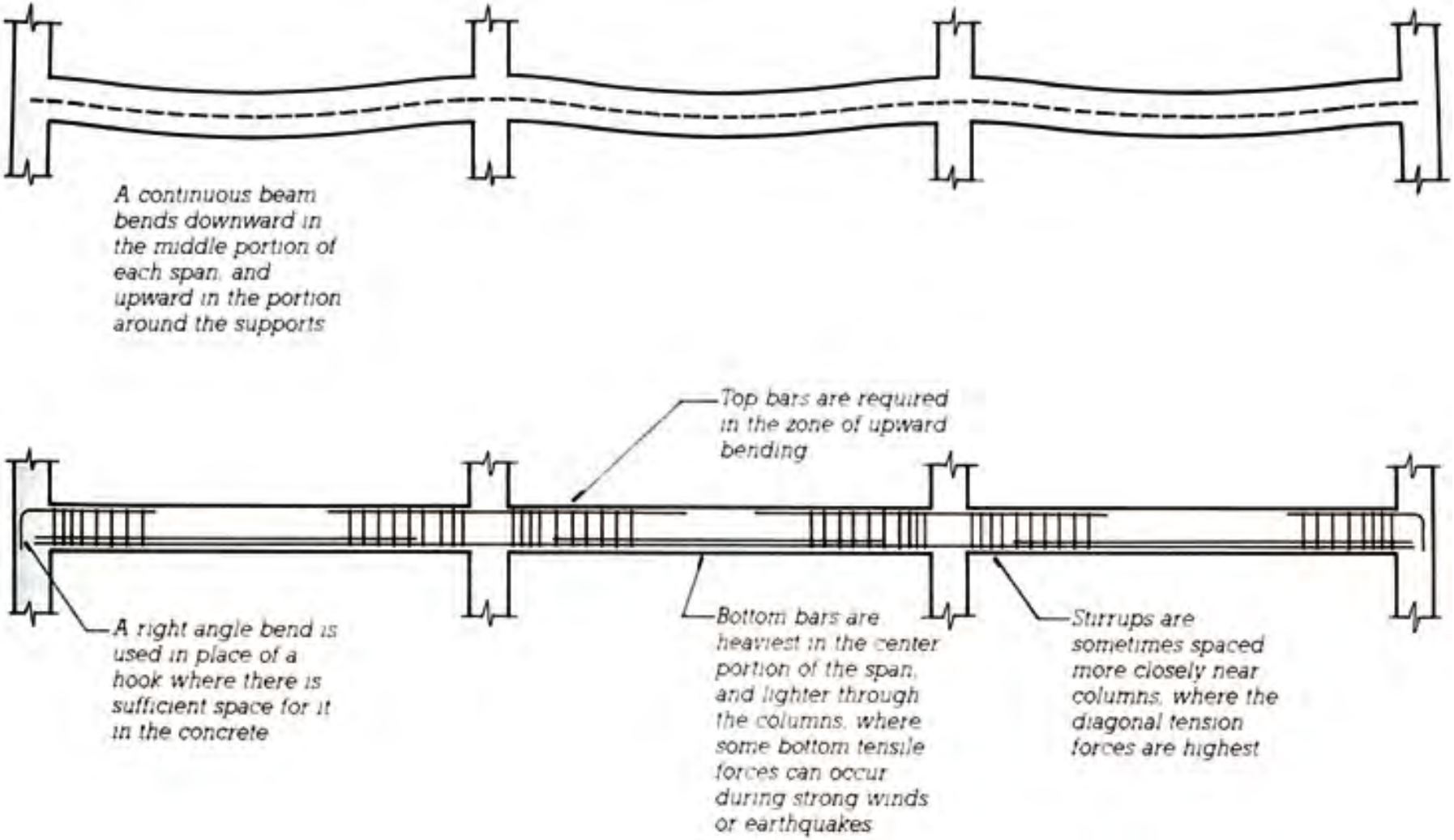
REINFORCING CONCRETE

FIGURE 13.25
(*a*) The directions of force in a simply supported beam under a uniform loading. The solid lines represent compression, and the broken lines represent tension. Near the ends of the beam, the lines of strongest tensile force move upward diagonally through the beam. (*b*) Steel reinforcing for a simply supported beam under a uniform loading. (*c*) A three-dimensional view of the same reinforcing.



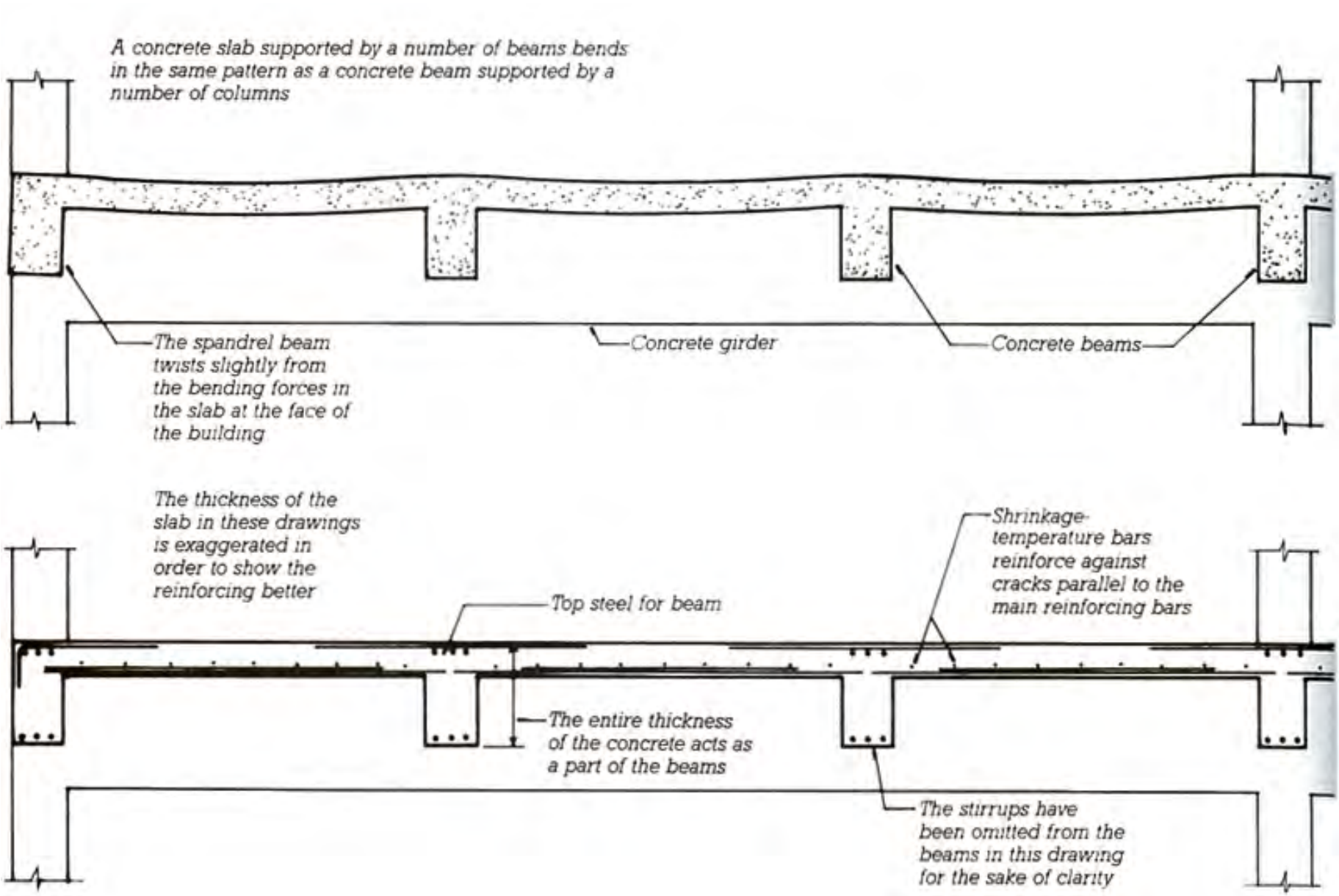


REINFORCING CONCRETE



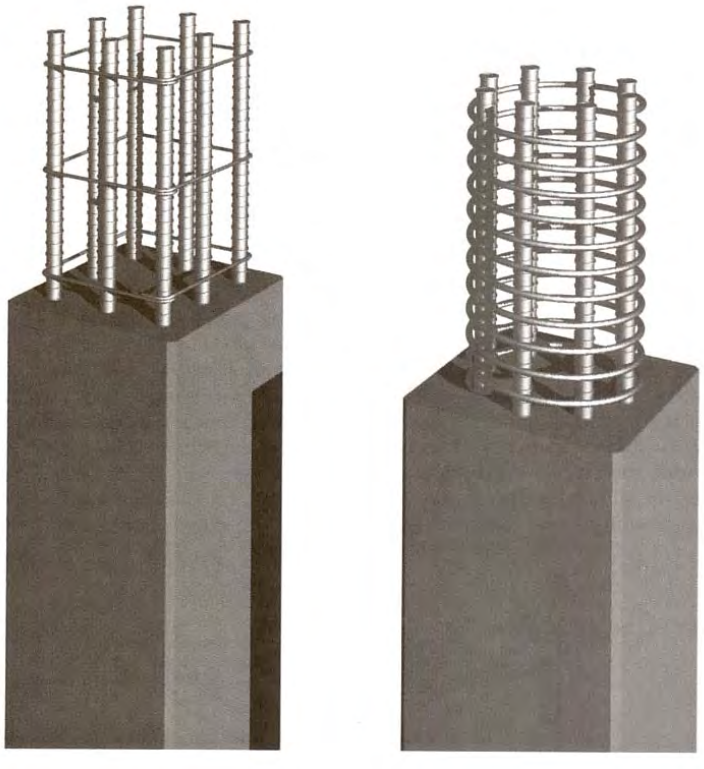
Reinforcing for a concrete beam that is continuous across several spans. The upper diagram shows in exaggerated form the shape taken by a continuous beam under a uniform loading; the broken line is the centerline of the beam. The lower diagram shows the arrangement of bottom steel, top steel, and stirrups conventionally used in this beam. The bottom bars are usually placed on the same level, but they are shown on two levels in this diagram to demonstrate the way in which some of the bottom steel is discontinued in the zones near the columns. There is a simple rule of thumb for determining where the bending steel must be placed in a beam: Draw an exaggerated diagram of the beam bending under load, as in the top drawing of this illustration, and put the bars as close as possible to the convex edges.

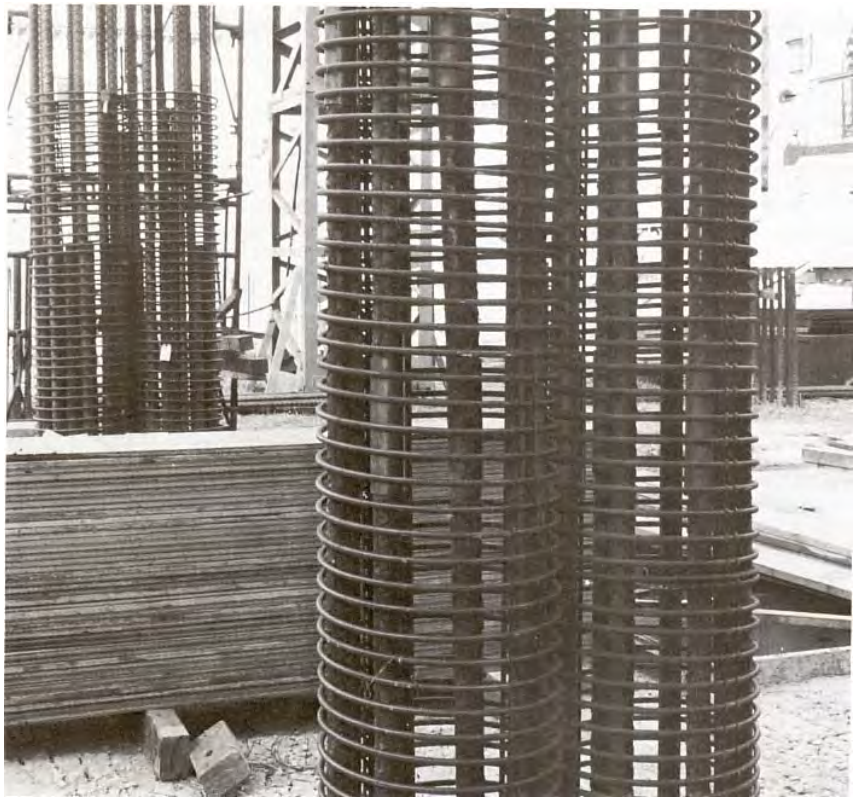
REINFORCING CONCRETE



REINFORCING CONCRETE: Columns

- Vertical bars to take some of the compressive loads (and to resist bending from wind or earthquakes.)
- Ties (smaller bars wrapped around the vertical bars) to hold them together (prevent buckling). Column ties often come in spiral form.





REINFORCING CONCRETE

REINFORCING CONCRETE

- Engineer specifies the **size** of the concrete beams, columns and slabs; the **strength of the concrete**; the **amount of steel** reinforcement and its **location** in the structure.
- The fabricator prepares the steel, bundles the rebars, labels the packages and ships to the site.
- On the site the rebars are spliced, supported on seats and wired into position,

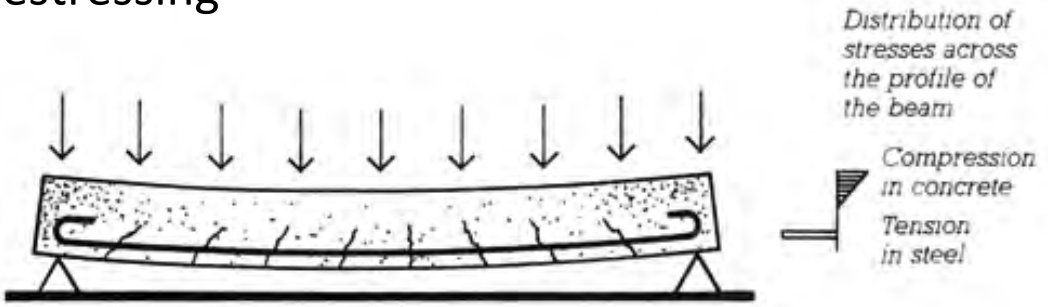
REINFORCING CONCRETE: Prestressing

- To increase the load-bearing capacity of a reinforced beam (without increasing its size or the quantity of steel reinforcing.)
- To reduce the chances of cracking on the tension side of a beam.

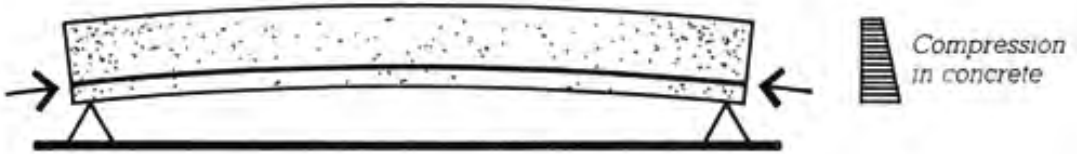
THEORY:

- The steel that takes the tensile stresses is put into tension
- The surrounding concrete is thus placed in compression.
- When the beam is loaded, the concrete's compression is lessened, but not so much that the concrete is ever exposed to tension (Therefore, no cracks!)
- Difficult to do on a construction site. Most pre-tensioning is done in a plant and brought to the site.

REINFORCING CONCRETE : Prestressing

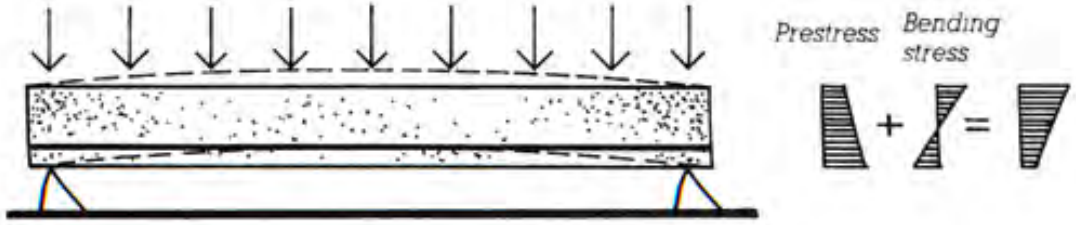


In a reinforced concrete beam, less than half the concrete is in compression, and cracks will appear in the bottom of the beam under full load



When a concrete beam is prestressed, all the concrete acts in compression. The off-center location of the prestressing steel causes a camber in the beam

The rationale for prestressing concrete. In addition to the absence of cracks in the prestressed beam, the structural action is more efficient than that of a reinforced beam. The prestressed beam therefore uses less material. The small diagrams to the right indicate the distribution of stresses across the vertical cross section of each of the beams at midspan.

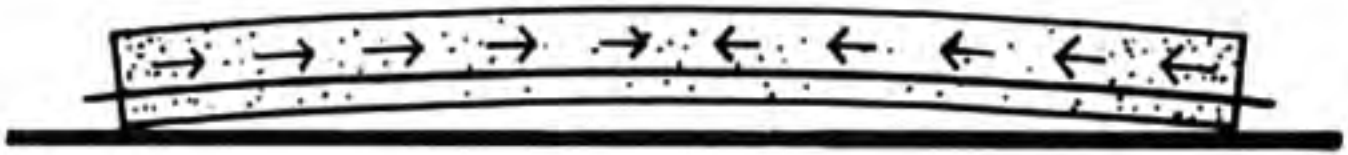


Under loading, the prestressed beam becomes flatter, but all the concrete still acts in compression, and no cracks appear

REINFORCING CONCRETE: Prestressing

1. The first step in pretensioning is to stretch the steel prestressing strands tightly across the casting bed

2. Concrete is cast around the stretched strands and cured. The concrete bonds to the strands



3. When the strands are cut the concrete goes into compression and the beam takes on a camber

REINFORCING CONCRETE: Prestressing

REINFORCING CONCRETE: Prestressing

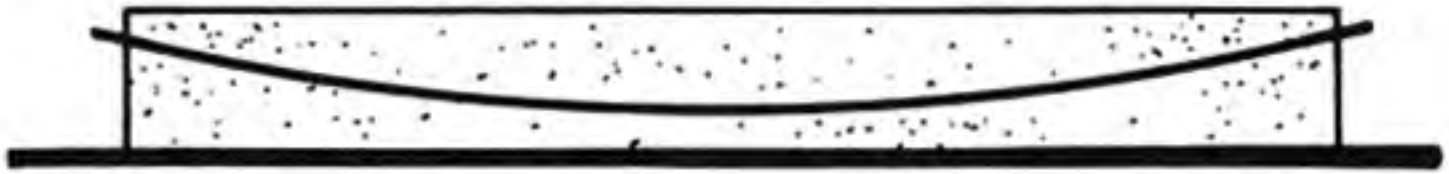
courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Post Tensioning

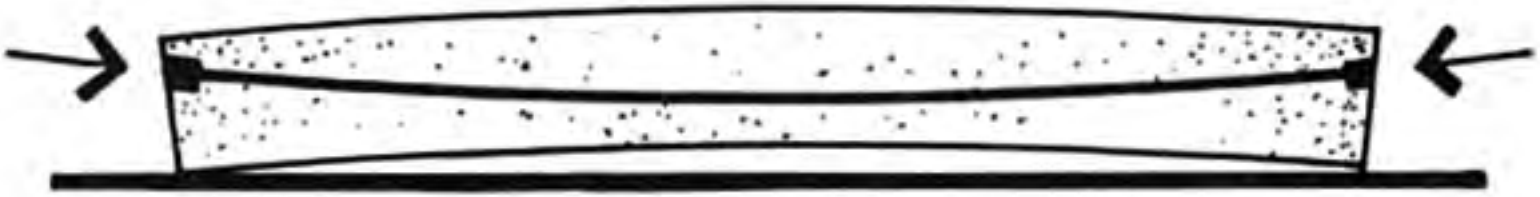
(Done mostly on the building site)

- The rebars are encased in tubes to prevent them from bonding with the concrete.
- The concrete is poured (before the bars are tensioned).
- One end of the rebar is secured and a hydraulic jack is put on the other end.
- The stretched end is anchored, thus putting the concrete in compression.

REINFORCING CONCRETE: Post Tensioning



1. In posttensioning, the concrete is not allowed to bond to the steel strands during curing

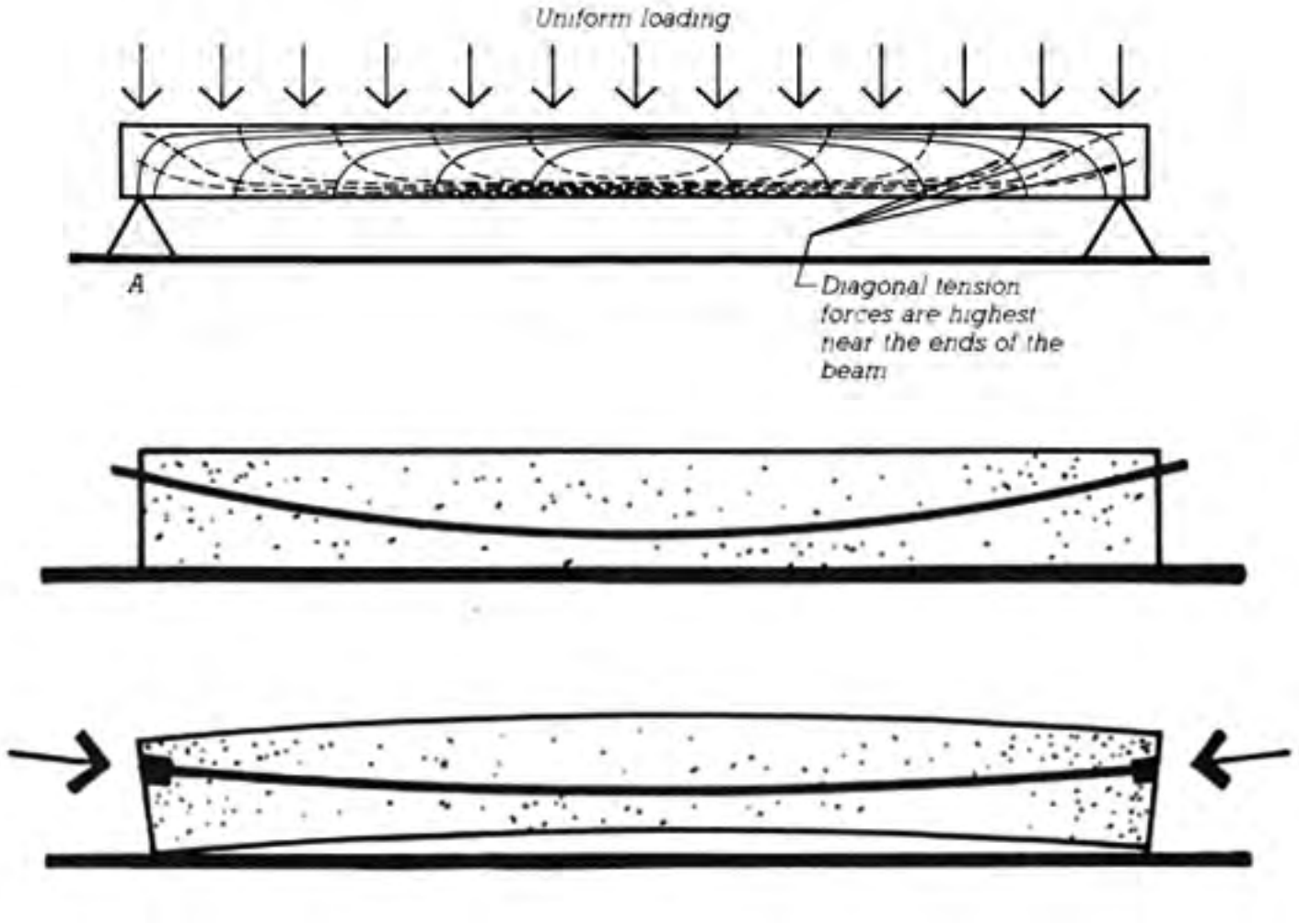


2. After the concrete has cured, the strands are tensioned with a hydraulic jack and anchored to the ends of the beam. If the strands are draped, as shown here, higher structural efficiency is possible than with straight strands

Posttensioning, using draped strands to more nearly approximate the flow of tensile forces in the beam.

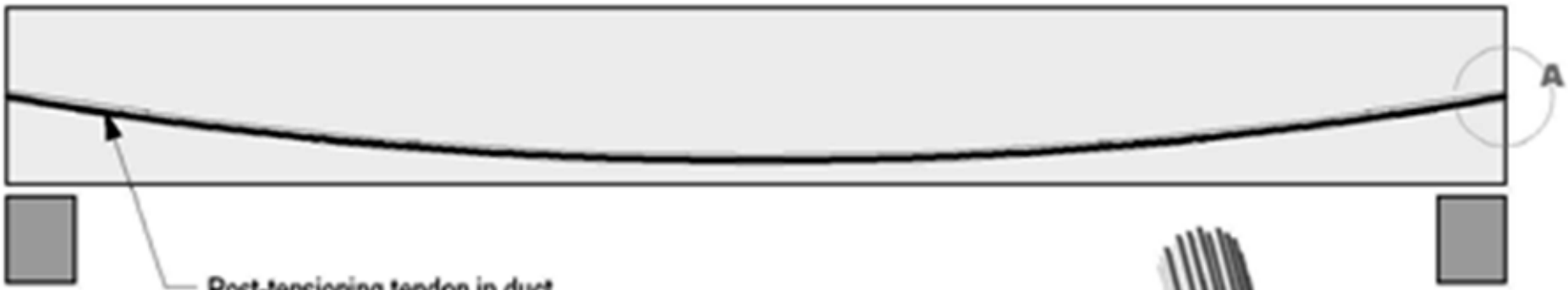
REINFORCING CONCRETE: Post Tensioning

Draping is when the rebars are positioned to take the stresses where they are greatest. (Done only in post-ensioning.)



REINFORCING CONCRETE: Post Tensioning

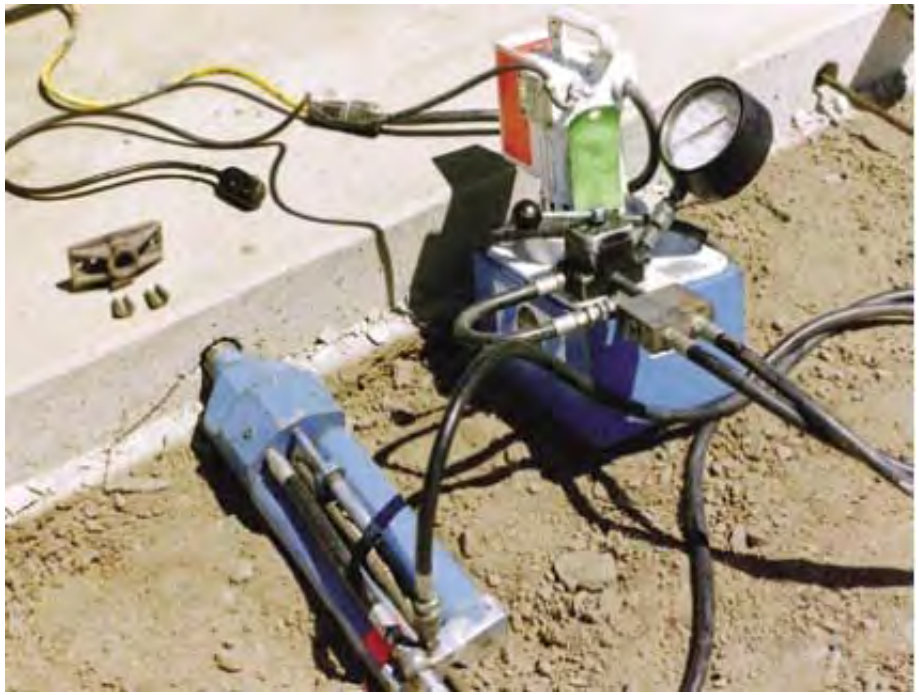
Post-tensioned Concrete is Used in Bridges and in Custom Building Structures:



Detail A

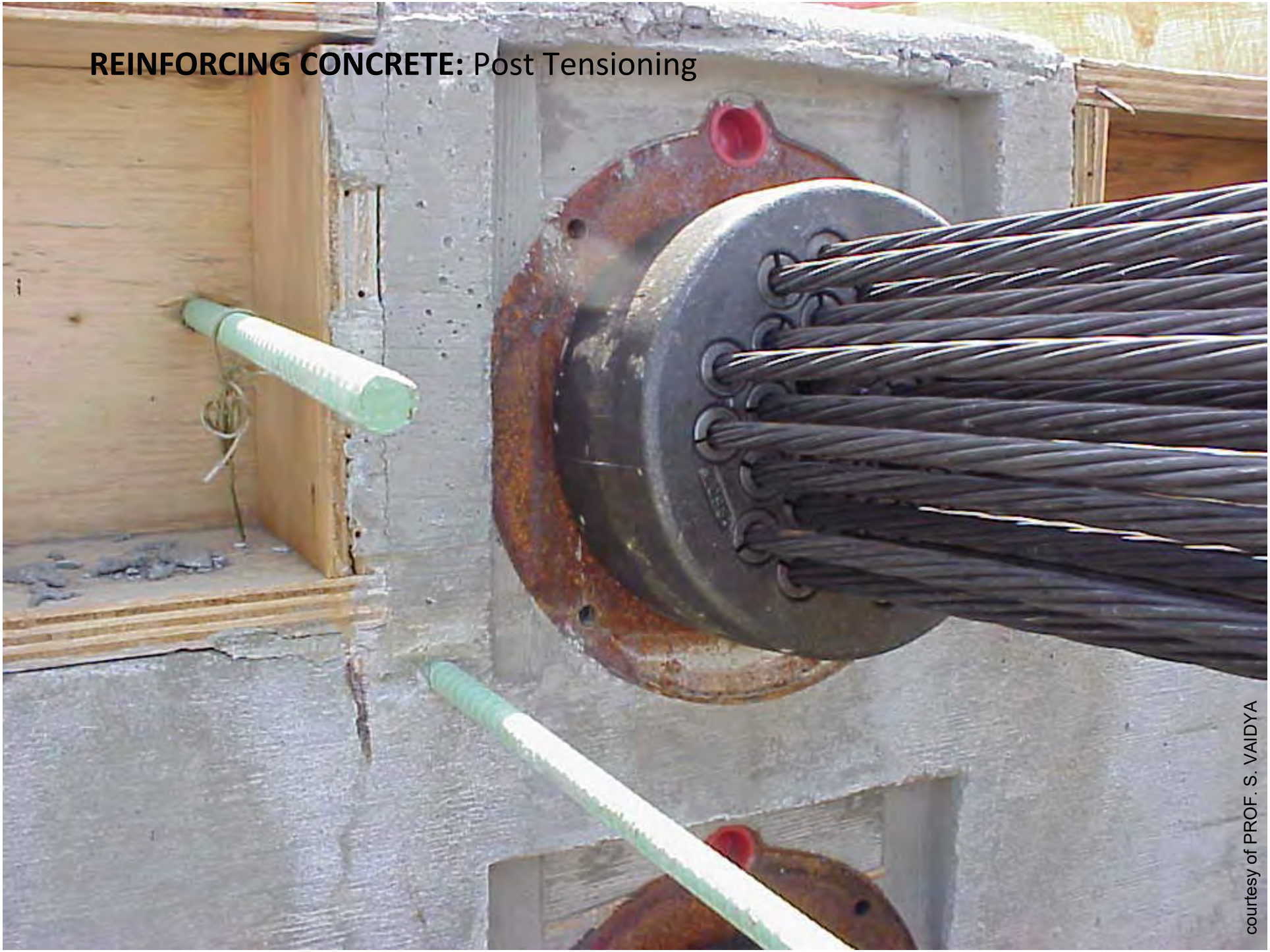
courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Post Tensioning



courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Post Tensioning



courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Post Tensioning

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Slab on Grade

Reinforced concrete slab supported by the ground it is poured on.

- 3” to 6” residential
- 6” to 12” for industrial floor or runway

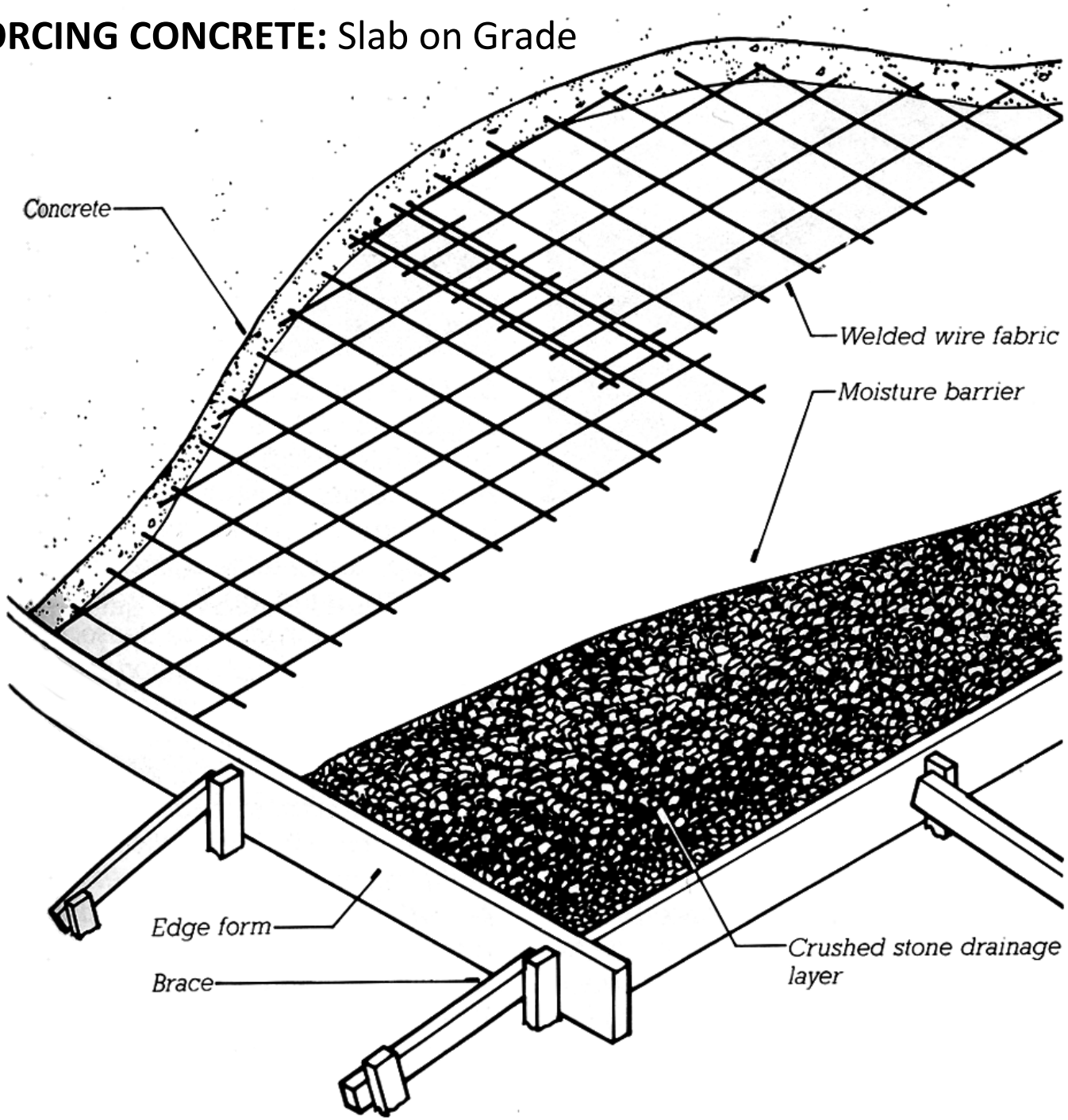
REINFORCING CONCRETE: Slab on Grade

- Process:
  - Topsoil is removed
  - 4” of crushed stone (compacted) for drainage
  - Edge form is constructed
  - Moisture barrier, usually polyethylene plastic
  - (1” to 3” of sand over the moisture barrier – absorb excess moisture and prevent ‘curling’)
  - Reinforcing mesh: welded wire fabric (a grid of rebars is used for heavier slabs)
  - Control joints (intentional crack) provided at intervals

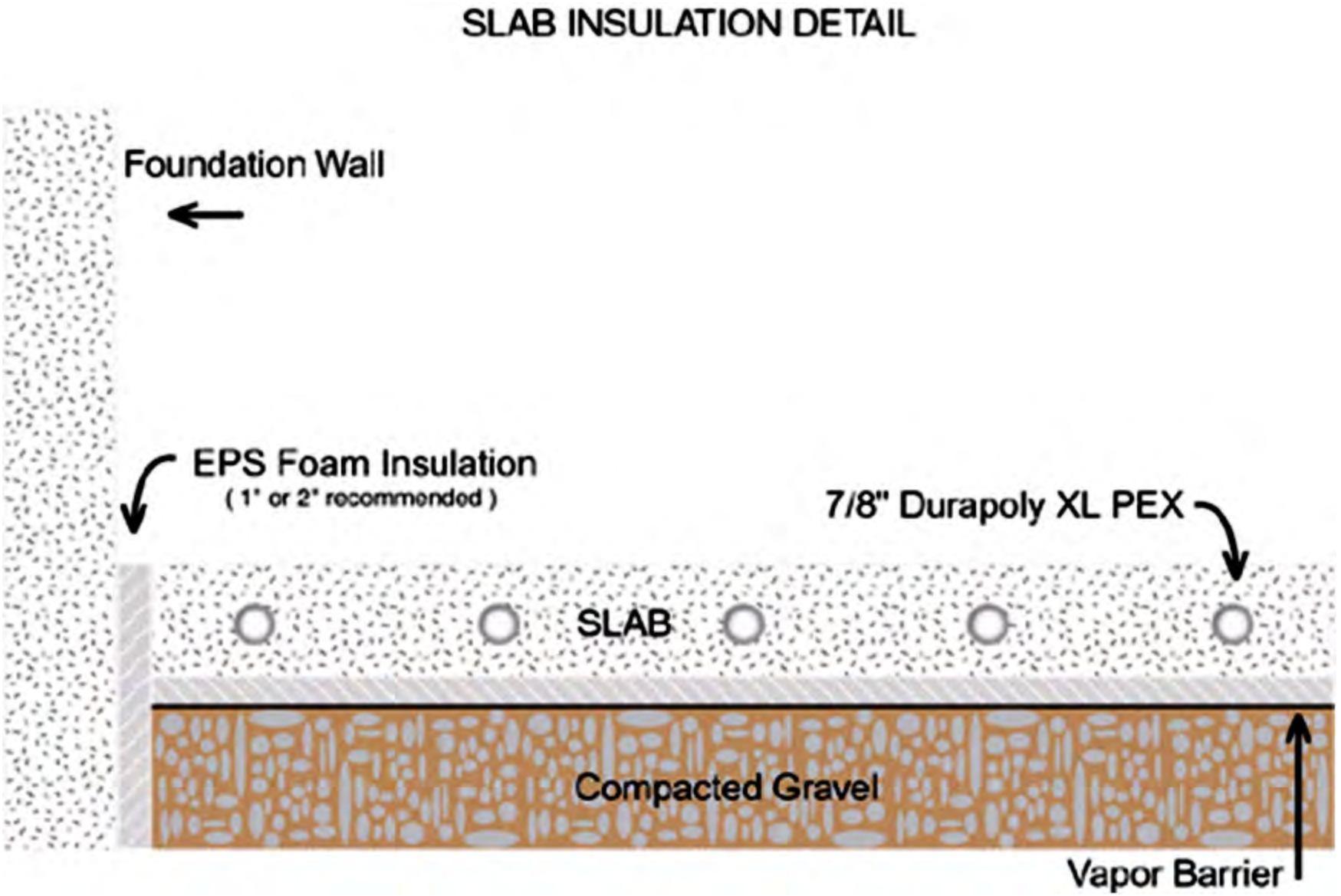
REINFORCING CONCRETE: Slab on Grade

- Process (continued)
  - Slab is poured
  - Welded wire is lifted to middle of slab
  - Top of pour is leveled by straight-edging (dragging a plank across the top)
  - After a while concrete is smoothed by floating, which brings cement paste to the surface.
  - Troweling is done for very smooth surfaces (several hours after floating)
  - Curing: Slab should be kept damp for a week.

REINFORCING CONCRETE: Slab on Grade



REINFORCING CONCRETE: Slab on Grade



A well-compacted granular fill will support this slab on grade. The polyethylene moisture barrier is in place. Rebars to prevent cracking have been regularly spaced in both directions. Plumbing pipes and electrical conduit from underground are projecting up into the building.

Laying new crack inducer grid : Joint free slabs use a plastic grid to induce a closely spaced network of fine cracks throughout the entire length and breadth of large-area slabs on grade eliminating traditional formed and sawn shrinkage control joints.

REINFORCING CONCRETE: Slab on Grade

Crack inducer grid

http://www.canzac.com/jfs/overview.html

REINFORCING CONCRETE: Slab on Grade

- Workers smooth out cement as it is poured.

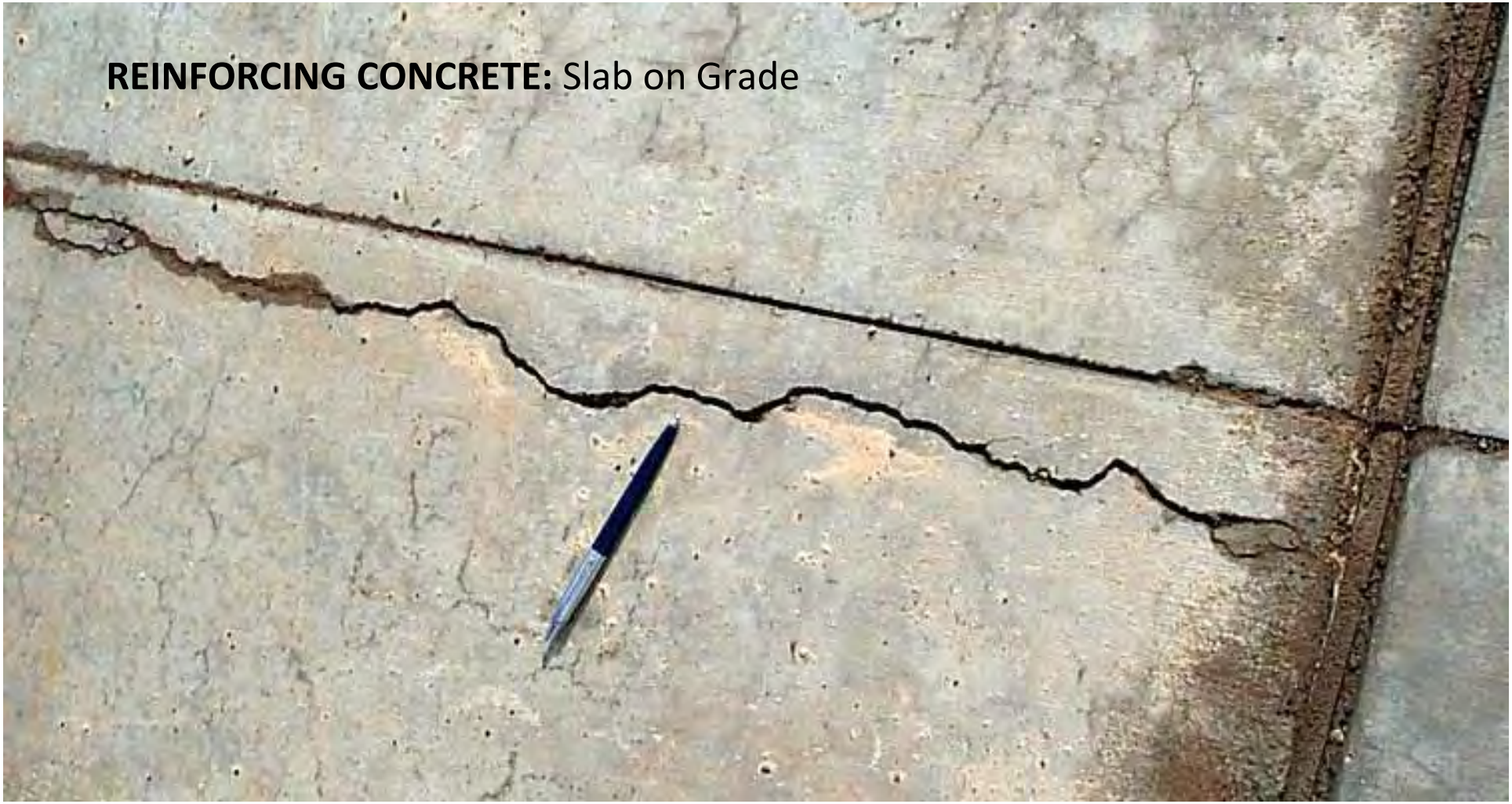
As the concrete in this slab on grade begins to harden, workers use power floats to smooth its surface.

REINFORCING CONCRETE: Slab on Grade

courtesy of PROF. S. VAIDYA

REINFORCING CONCRETE: Slab on Grade

- Hand Troweling



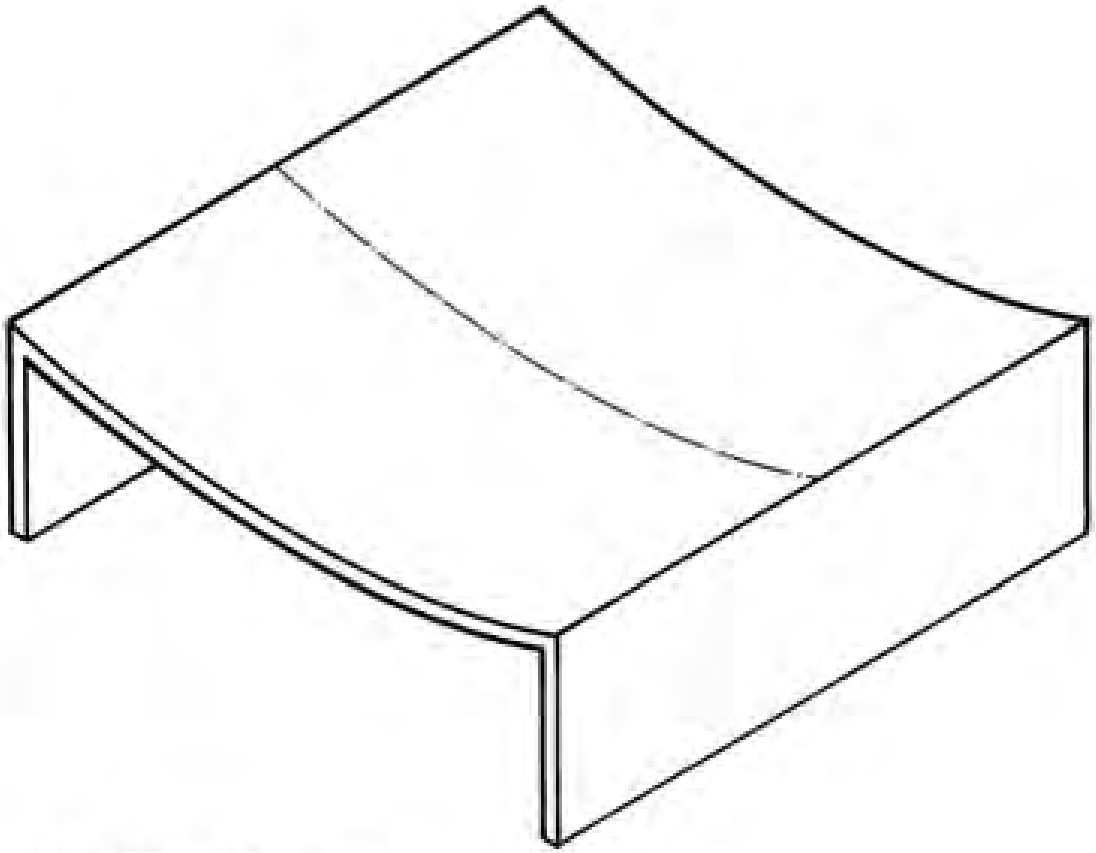
Cracks may occur if crack joints are not done properly.

Cracks are often due to unusual loading, movement, shrinkage, creep…

REINFORCING CONCRETE: Floor Slabs

- One-way: Girders and beams poured with the slab
- Structural support generally runs in one direction
  - One way solid slab
  - One-way banded slab
  - One-way ribbed slab
  - One-way wide module slab

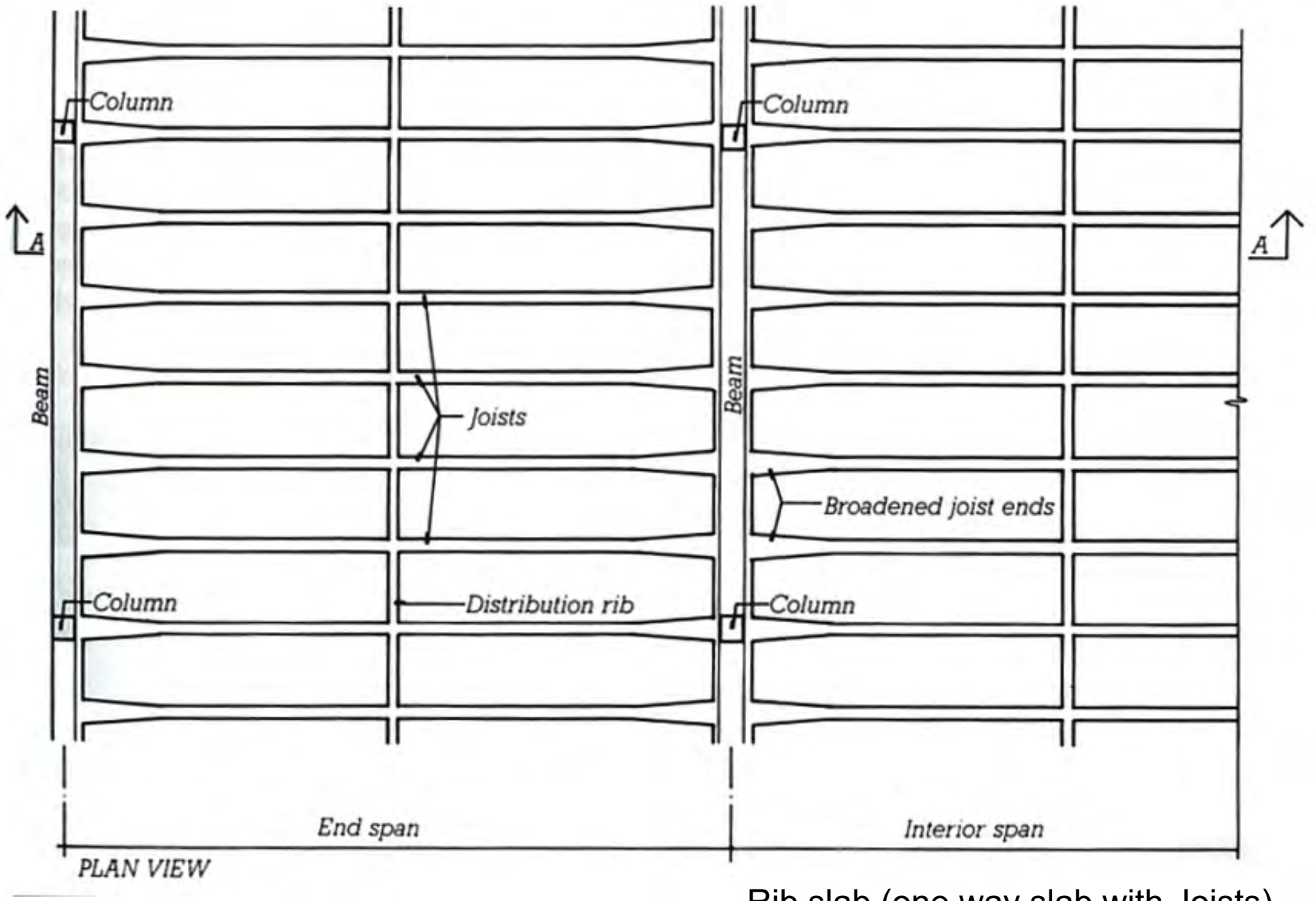
REINFORCING CONCRETE



One-Way Slab Action

Reinforcing for a one-way concrete slab. The reinforcing is similar to that for a continuous beam, except that stirrups are not usually required in the slab, and shrinkage–temperature bars must be added in the perpendicular direction. The slab does not sit on the beams; rather, the concrete around the top of a beam is part of both the beam and the slab. A concrete beam in this situation is considered to be a T-shaped member, with a portion of the slab acting together with the stem of the beam, resulting in a greater structural efficiency and reduced beam depth.

REINFORCING CONCRETE: Slabs



Rib slab (one way slab with Joists)

REINFORCING CONCRETE: Slabs

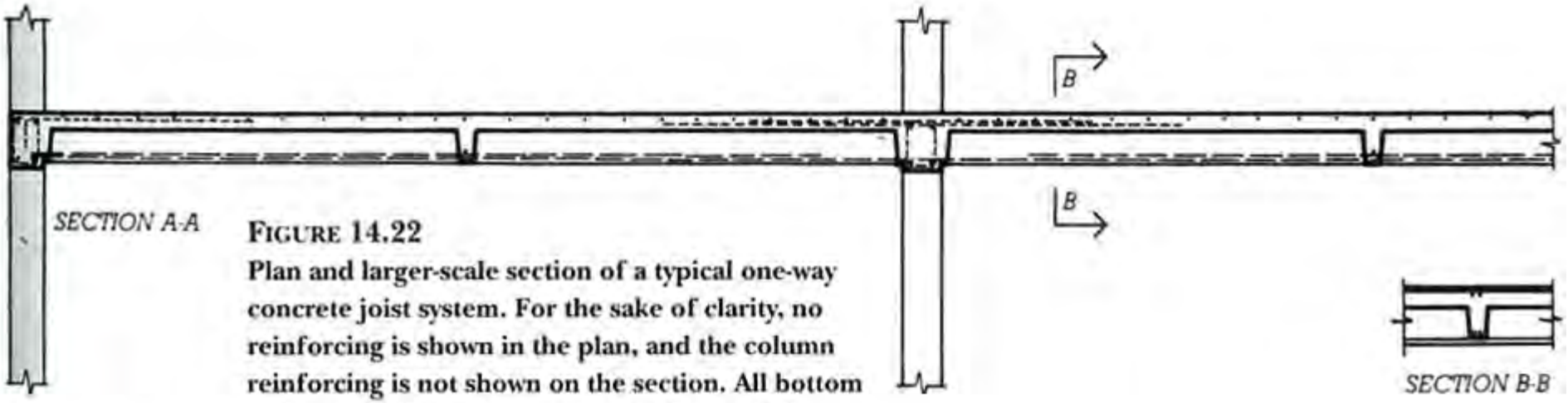
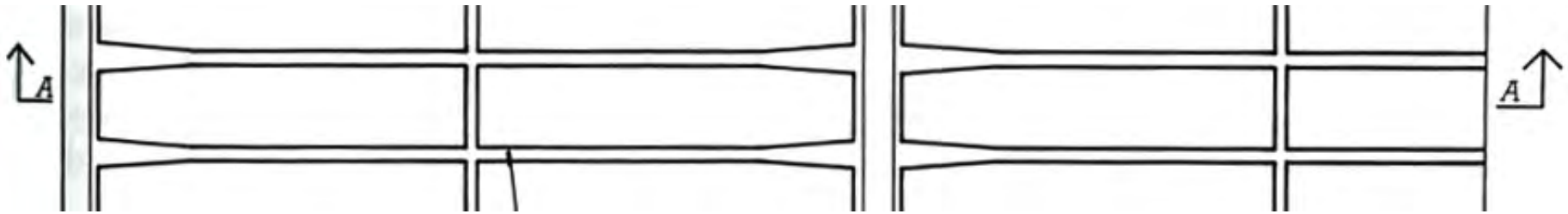


FIGURE 14.22
Plan and larger-scale section of a typical one-way concrete joist system. For the sake of clarity, no reinforcing is shown in the plan, and the column reinforcing is not shown on the section. All bottom and top reinforcing occurs in the ribs, and all shrinkage–temperature bars are placed in the slab.

Rib slab (one way slab with Joists)



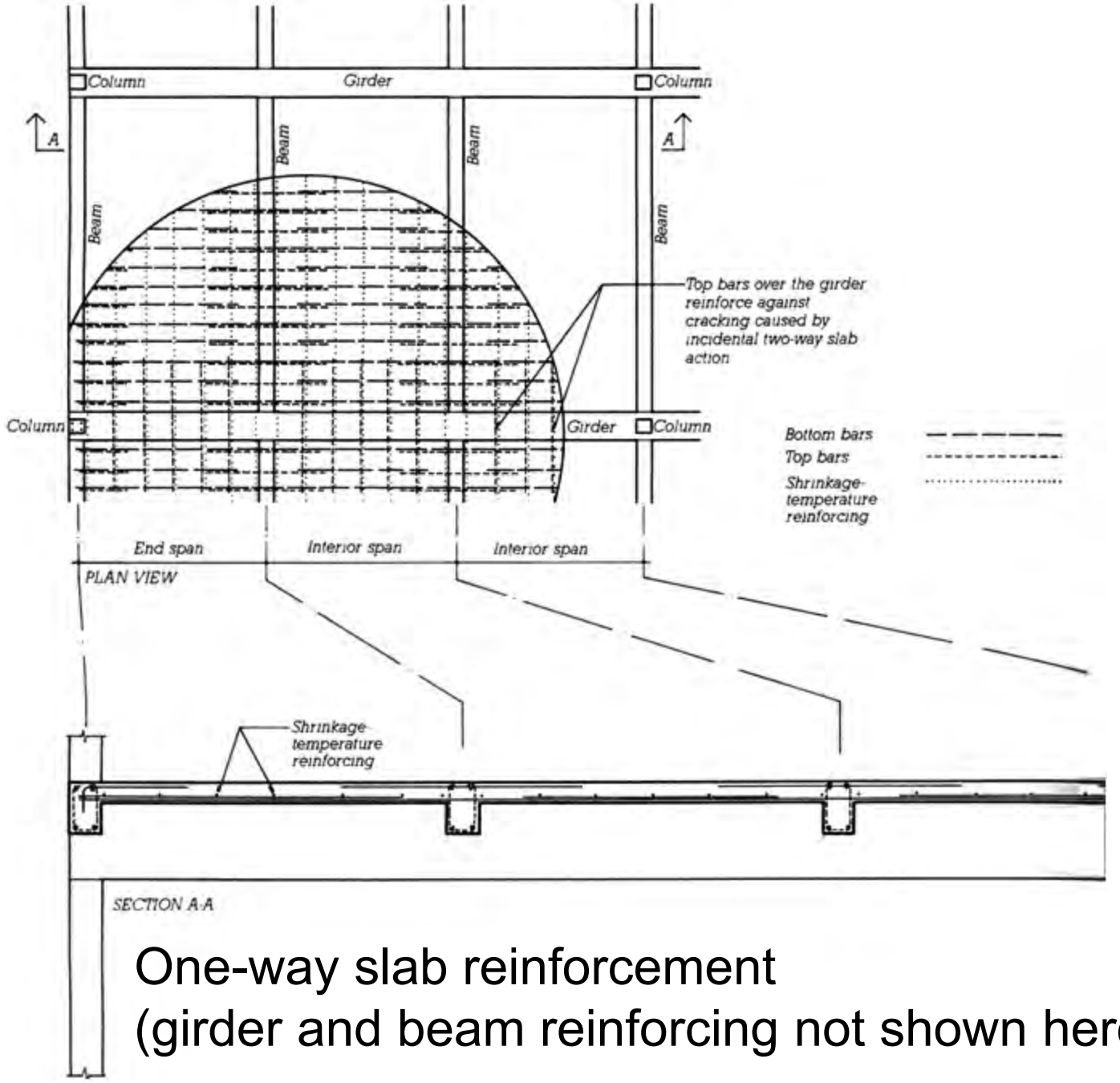
REINFORCING CONCRETE: Slabs

The one-way sitecast concrete framing systems: (*a*) One-way solid slab. (*b*) One-way solid slab with slab bands.

One way slab

One way slab with slab bands

REINFORCING CONCRETE: Slabs

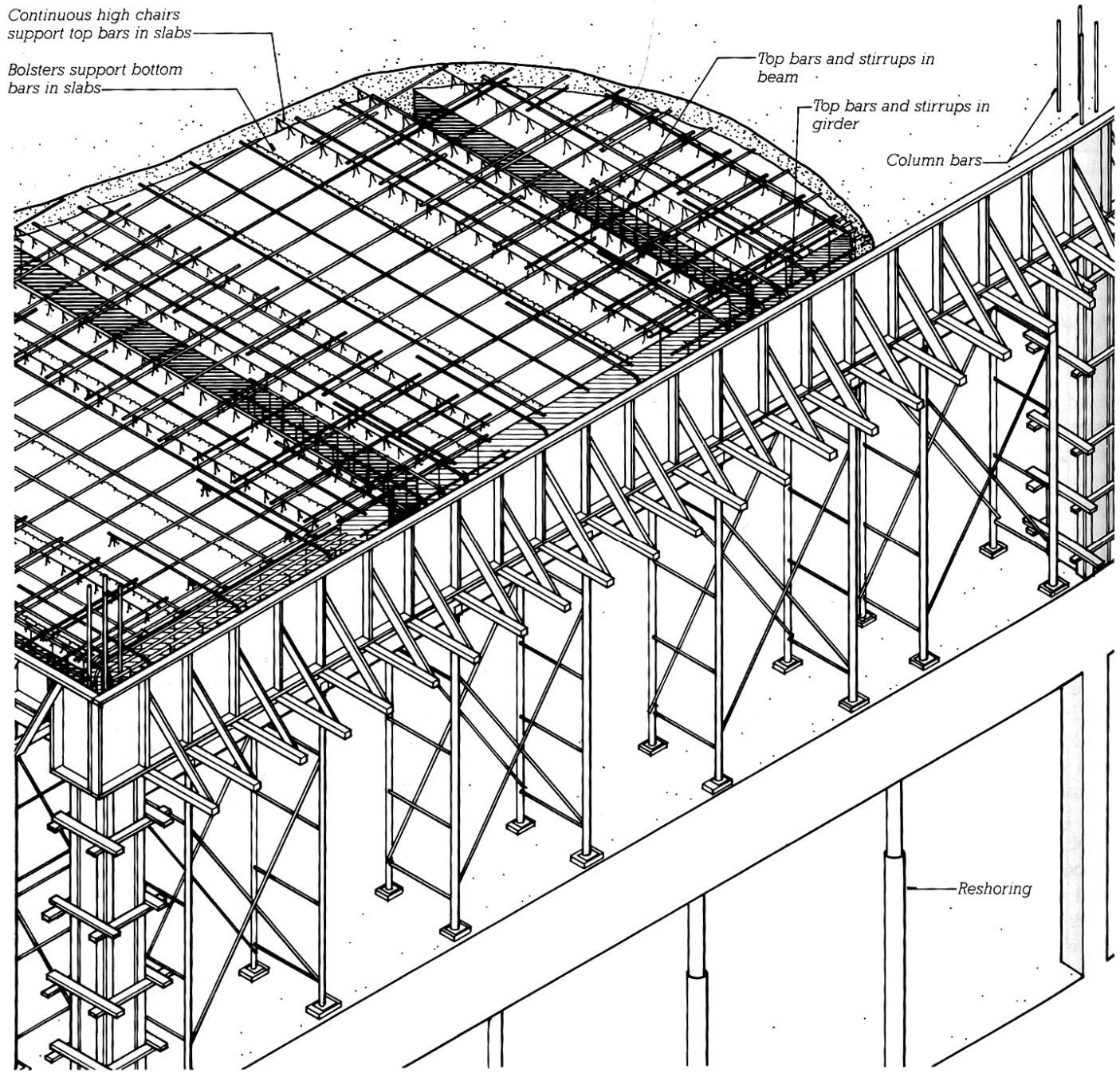


One-way slab reinforcement
(girder and beam reinforcing not shown here.)

REINFORCING CONCRETE: Slabs

One way slab reinforcement:

Slabs, beams and girders are poured together



REINFORCING CONCRETE: Slabs

Banded One-way slab construction

REINFORCING CONCRETE: Slabs

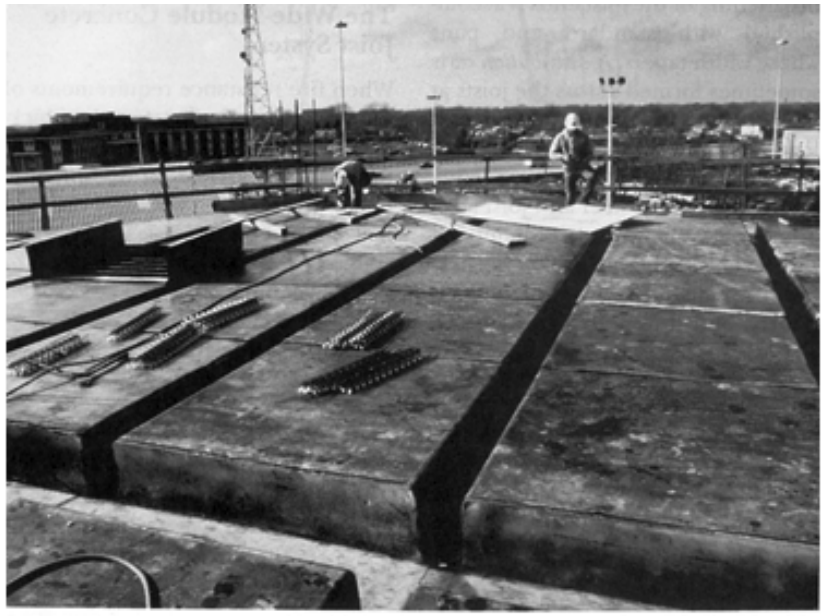
Rib slab (one way slab with Joists)

One-way wide module joist system

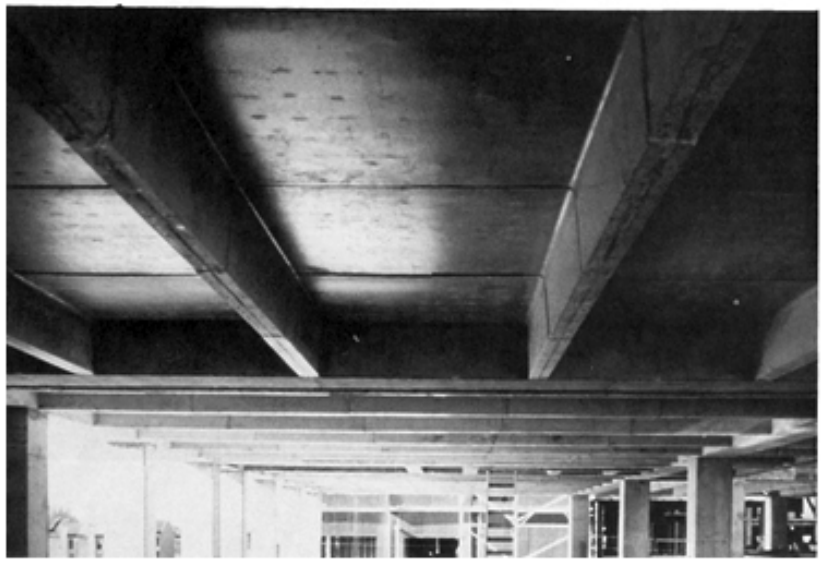
REINFORCING CONCRETE: Slabs

Rib slab (one way slab with Joists)

REINFORCING CONCRETE: Slabs



Formwork for one-way wide module joist system



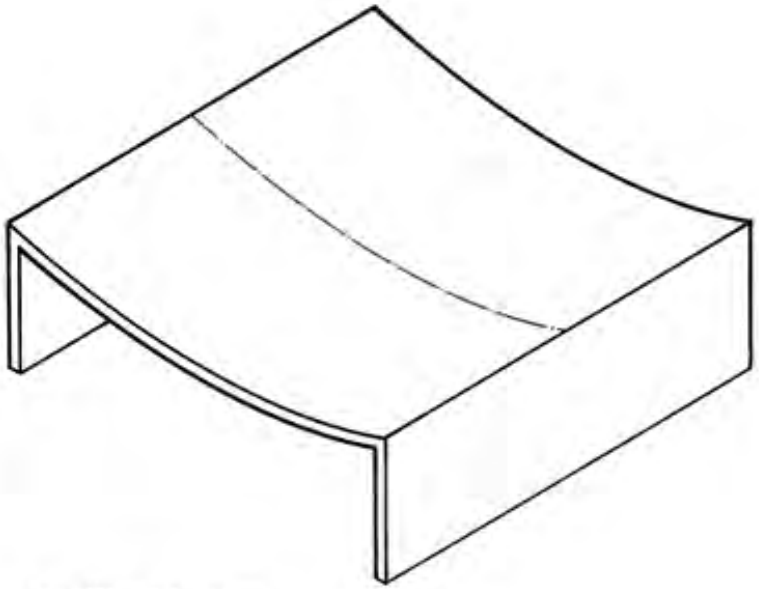
One-way wide module joist system

REINFORCING CONCRETE: Slabs

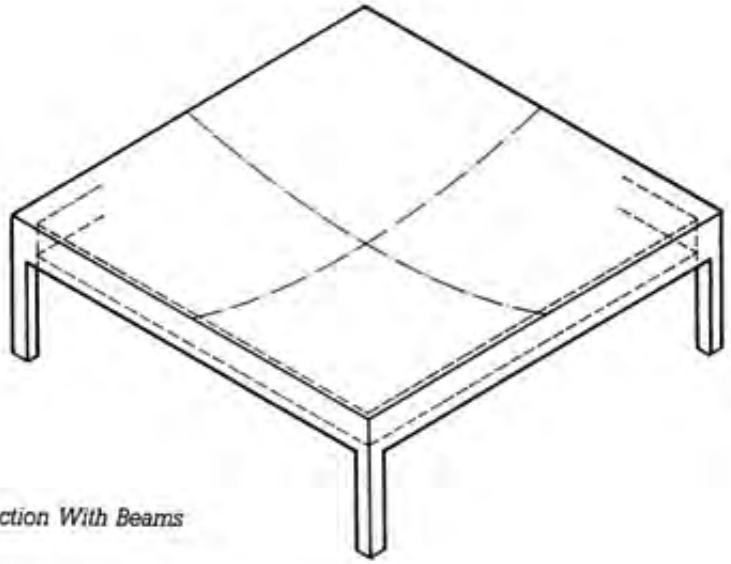
- Two way slabs: Girders and beams poured with the slab
- Structural support runs in two directions
  - Two-way solid slab
  - Flat slab
  - Flat plate
  - Waffle slab

REINFORCING CONCRETE

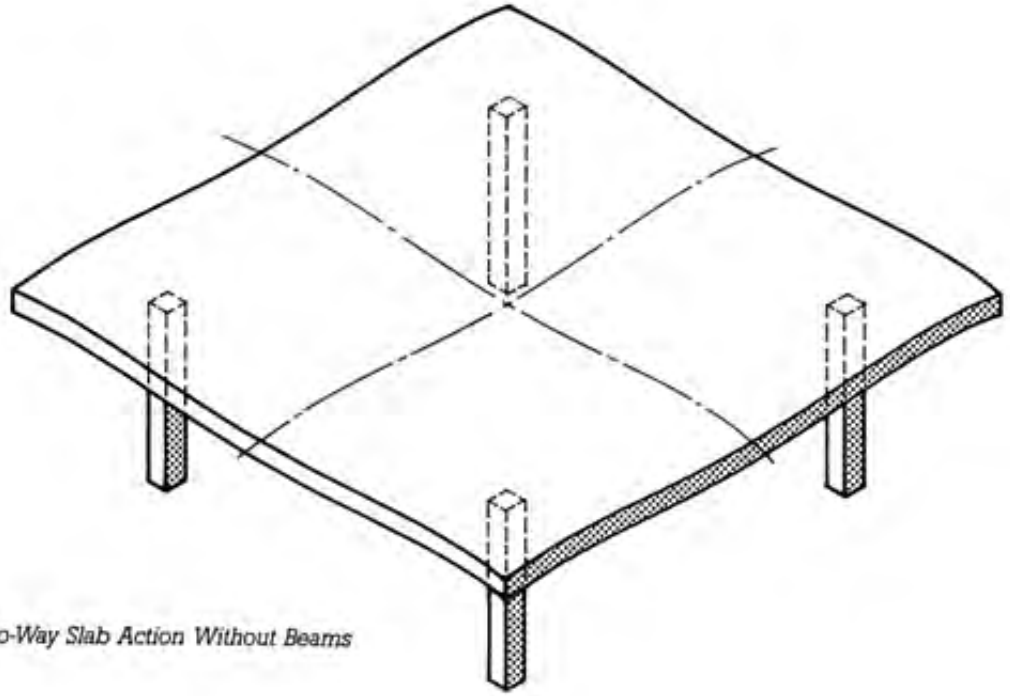
One-way and two-way slab action, with deflections greatly exaggerated.



One-Way Slab Action

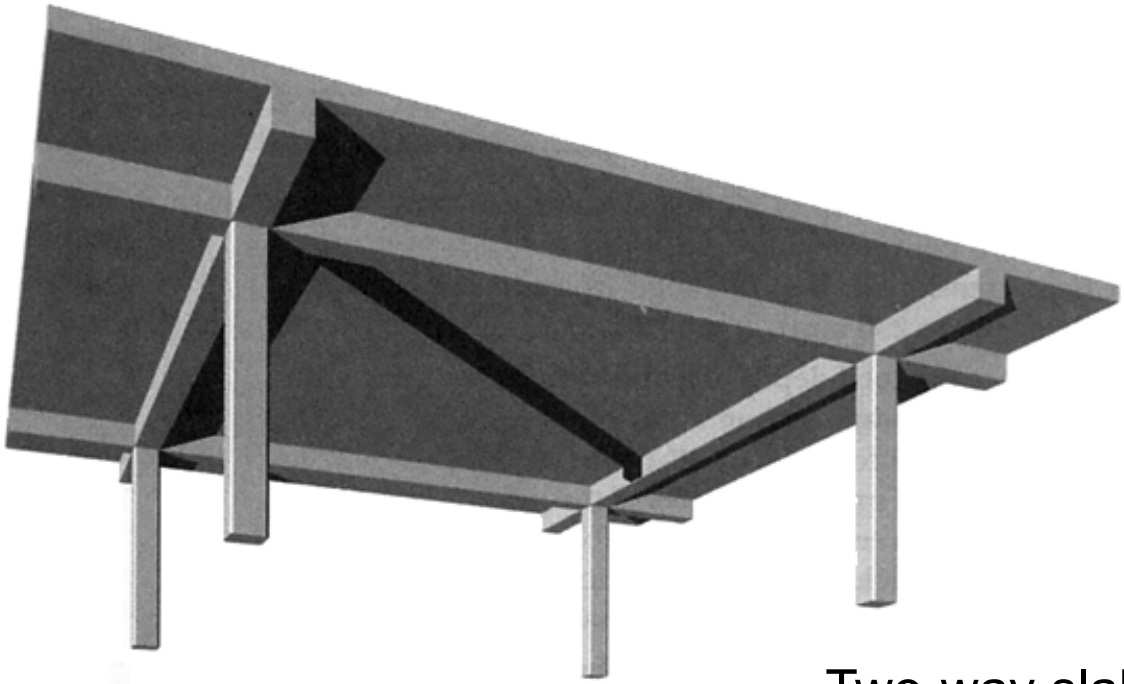


Two-Way Slab Action With Beams

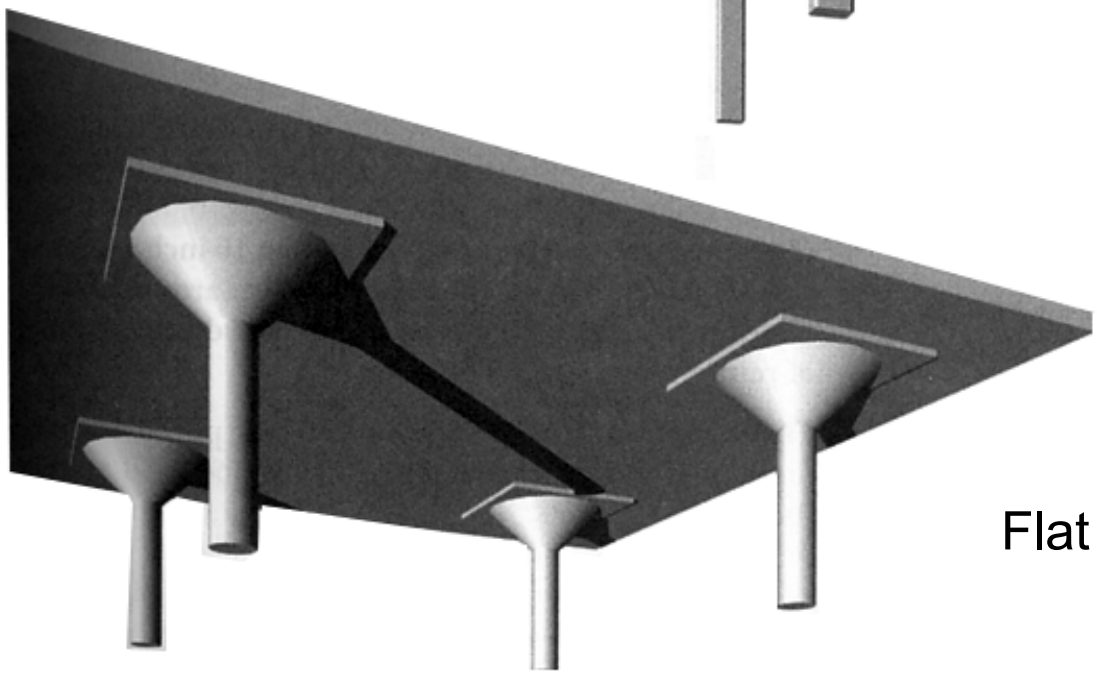


Two-Way Slab Action Without Beams

REINFORCING CONCRETE: Slabs



Two-way slab



Flat slab (two-way)

REINFORCING CONCRETE: Slabs

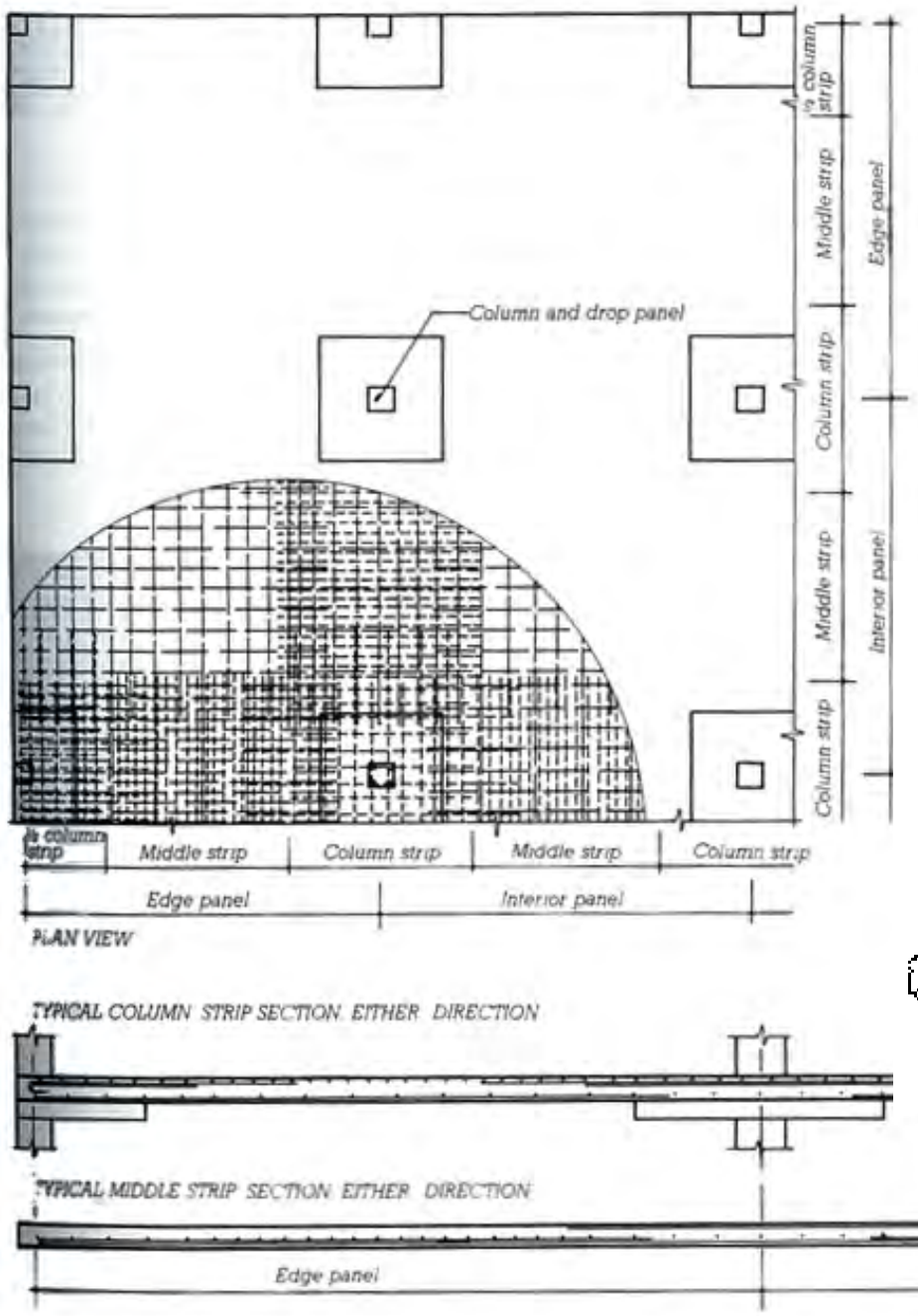
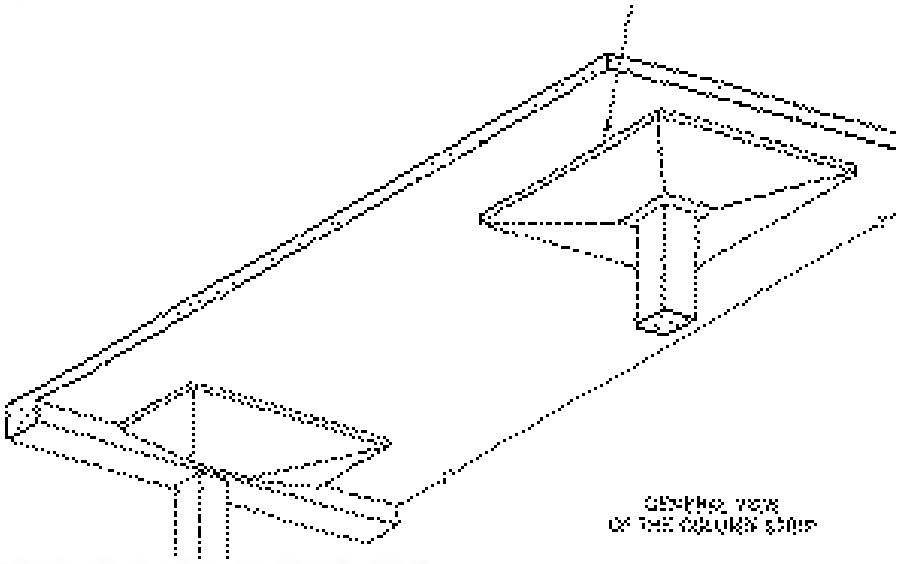
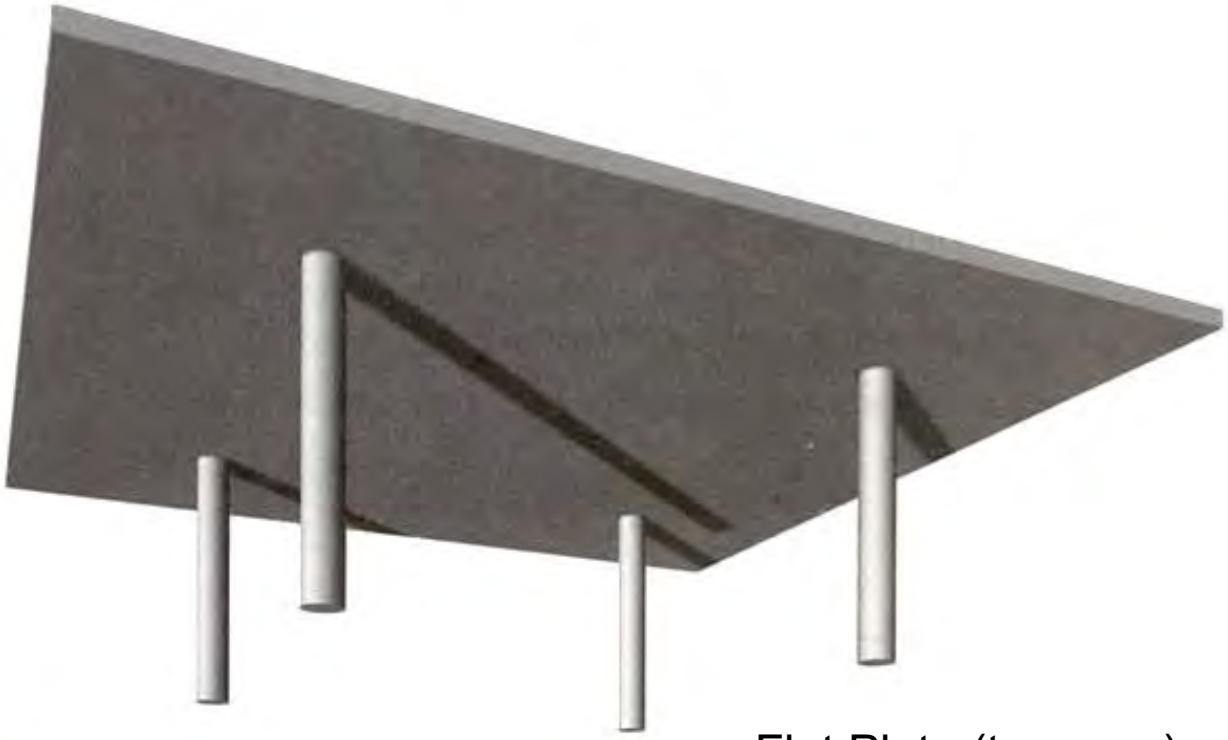


FIGURE 14.28
Plan and larger-scale section of a typical two-way flat slab system. The reinforcing pattern consists of column strips and middle strips, with each strip changing pattern slightly to accommodate the different bending forces that occur in the edge panels around the perimeter of the building. The system shown uses only drop panels, without mushroom capitals. The reinforcing in a two-way flat-plate system is essentially identical to this example; the only difference is that the flat plate has no drop panels.



Two-way flat slab

REINFORCING CONCRETE: Slabs

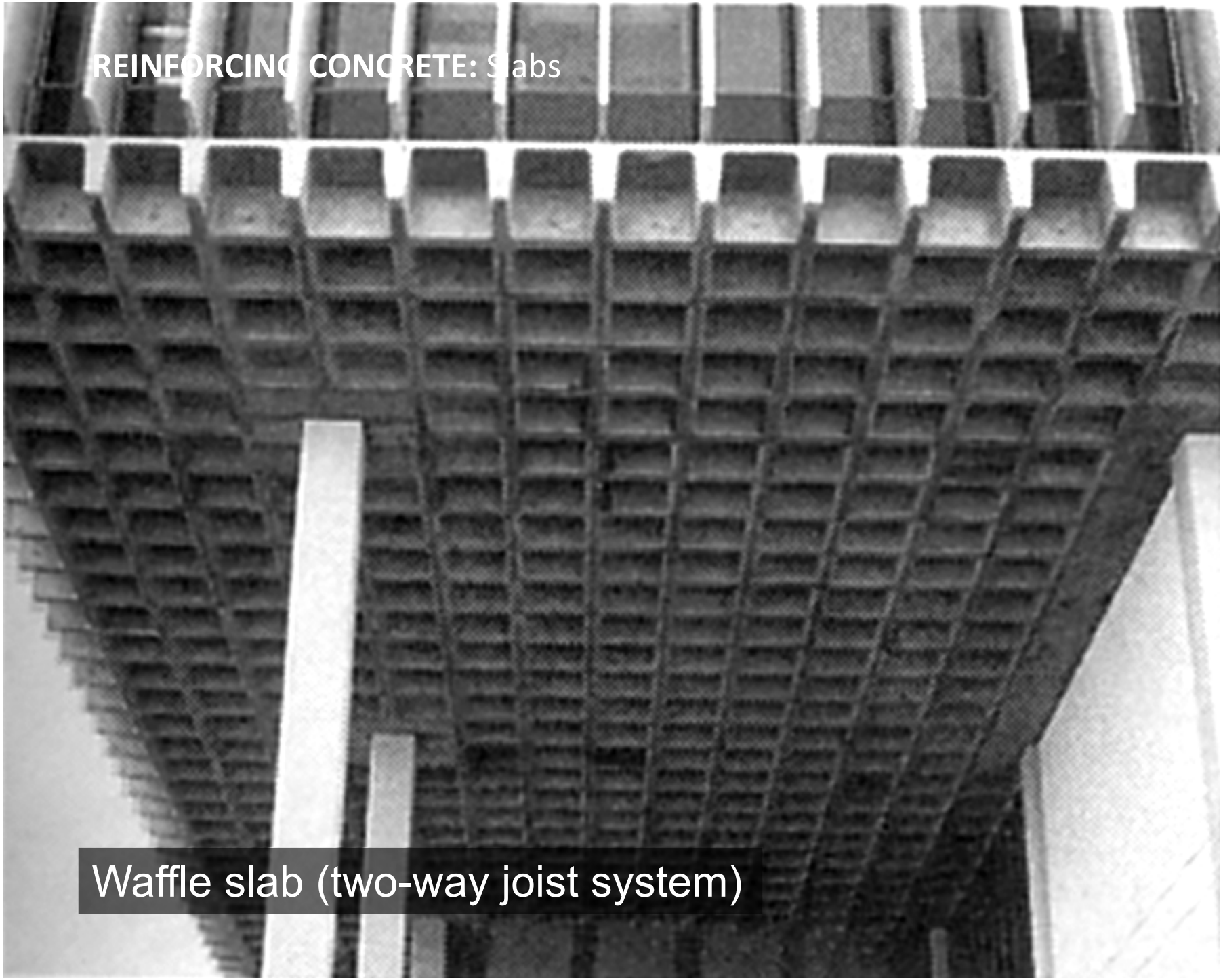


Flat Plate (two-way)

Waffle slab (two-way joist system)

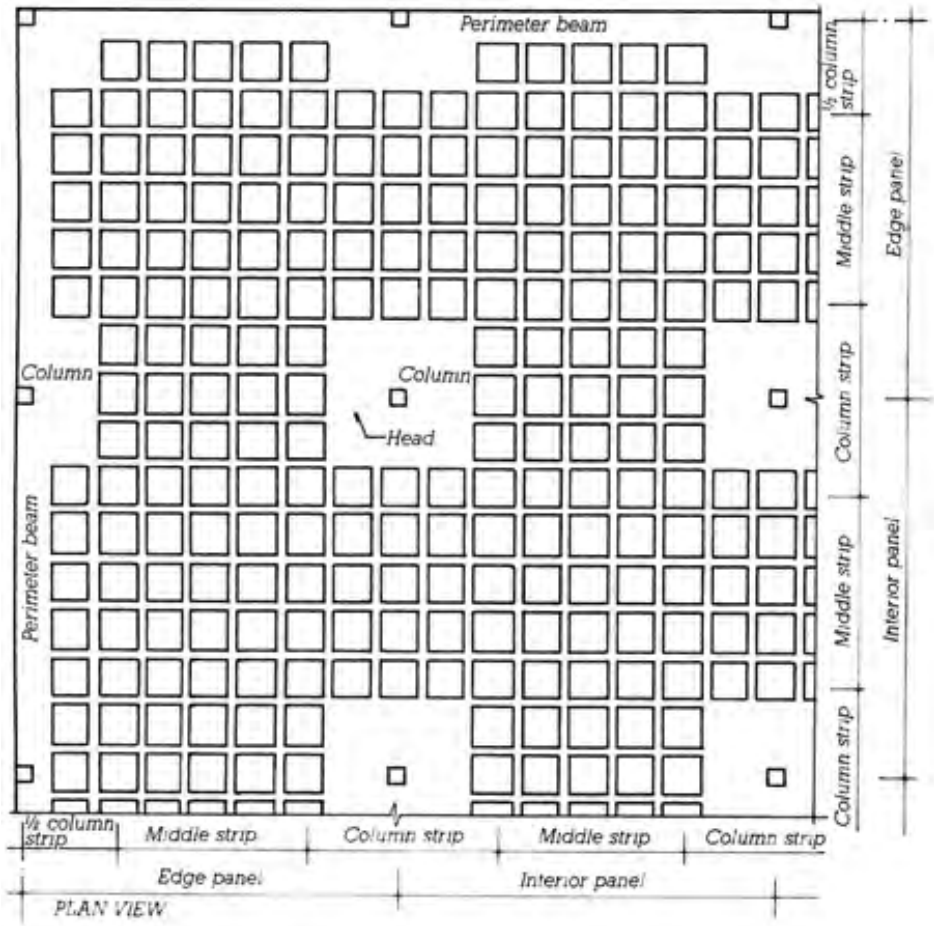
REINFORCING CONCRETE: Slabs

Two-way flat plate

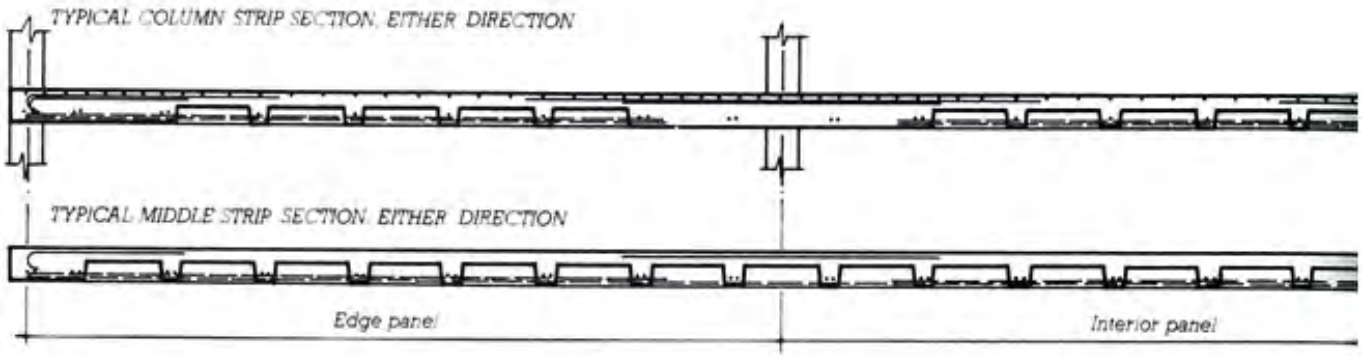


Waffle slab (two-way joist system)

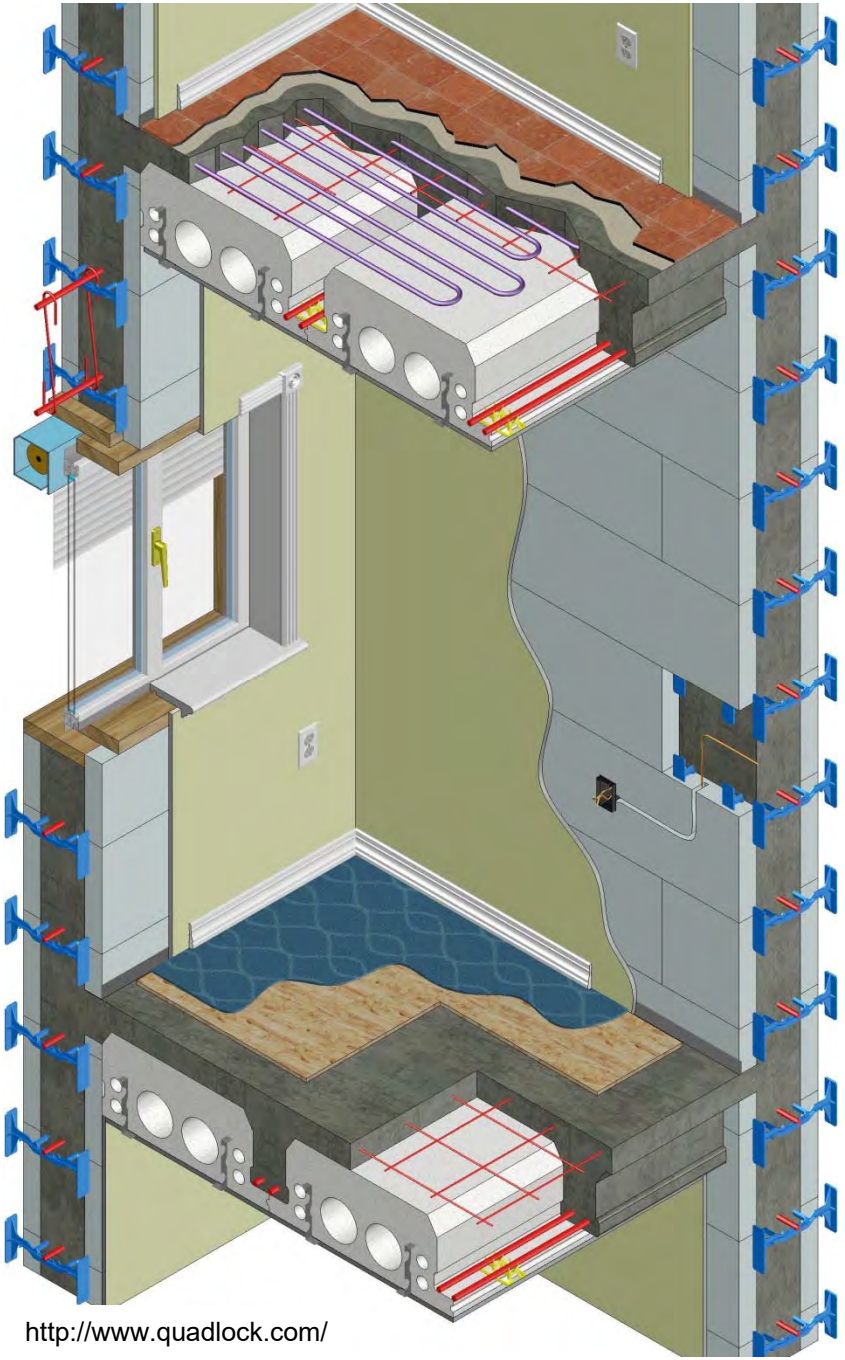
REINFORCING CONCRETE: Slabs



Waffle slab
(two-way joist system)

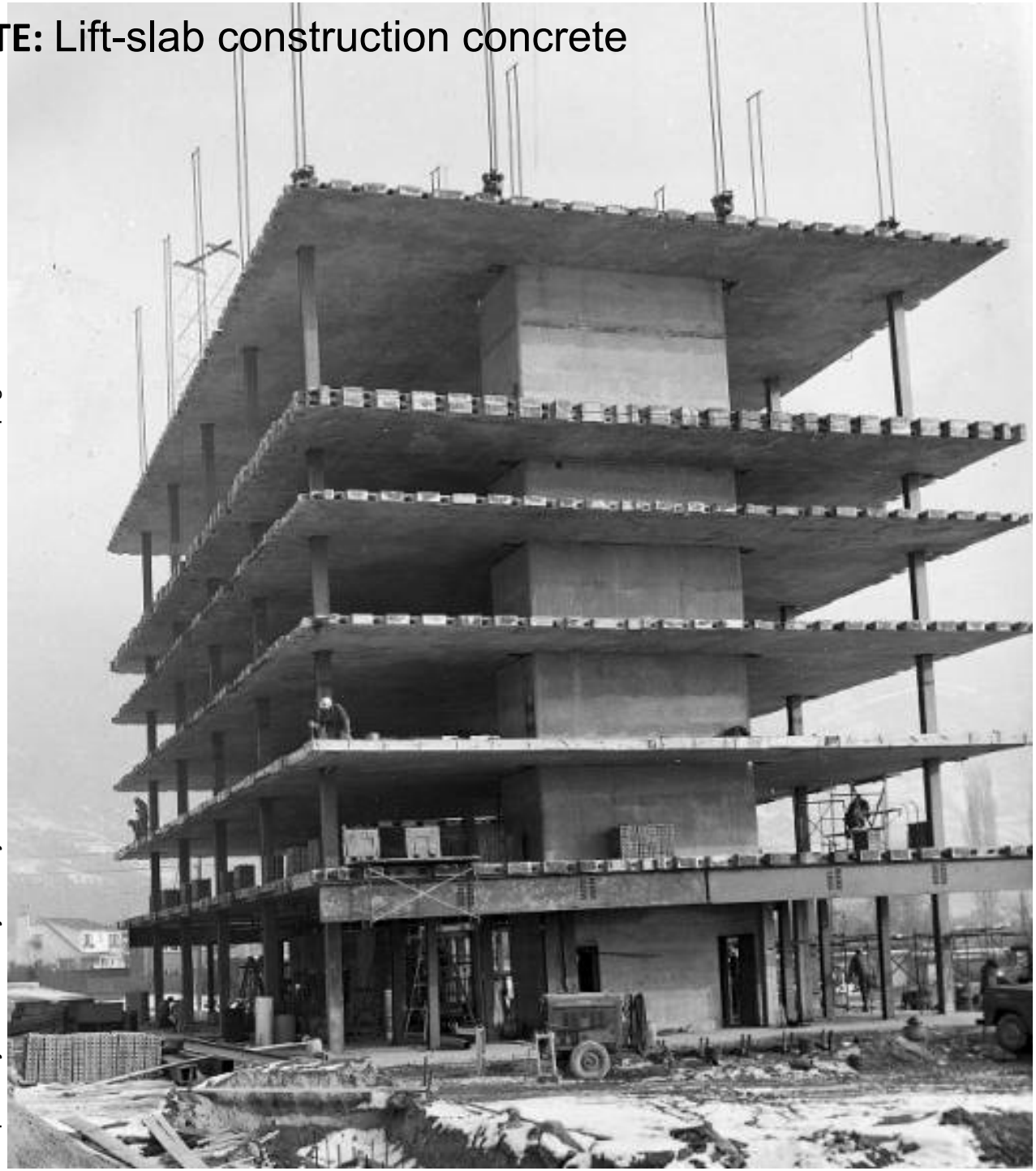


REINFORCING CONCRETE: Insulating Concrete Forms



http://www.quadlock.com/

REINFORCING CONCRETE: Lift-slab construction concrete



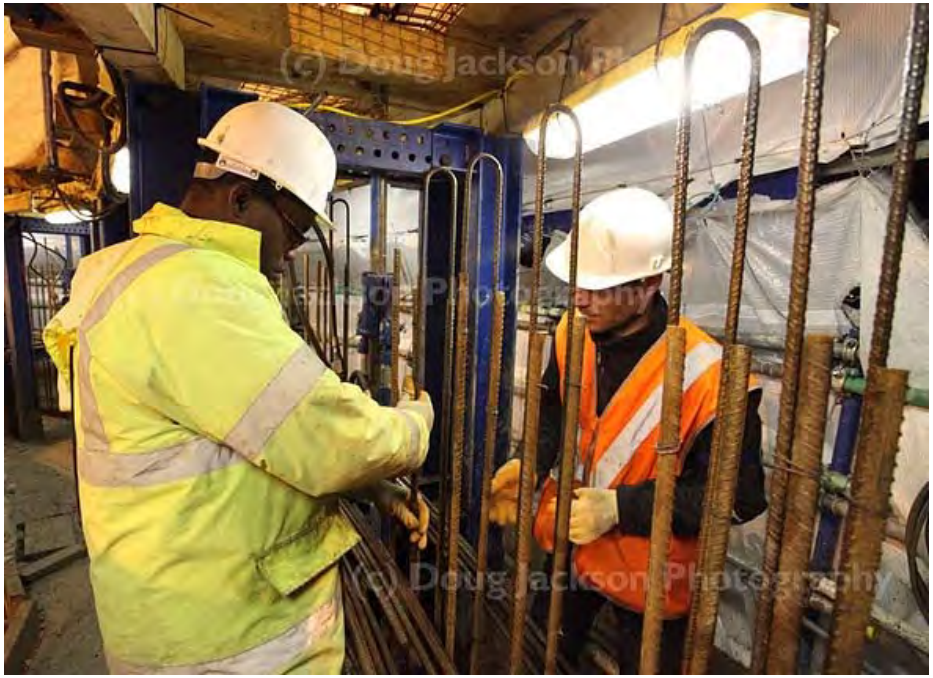
http://lib.byu.edu/sites/byuhistory/files/2010/04/Deseret-Towers-construction.png

REINFORCING CONCRETE:

flying formwork, concrete

http://www.efcoforms.com/pages_products/products/adjust_a_truss.html#

REINFORCING CONCRETE: slip forming concrete

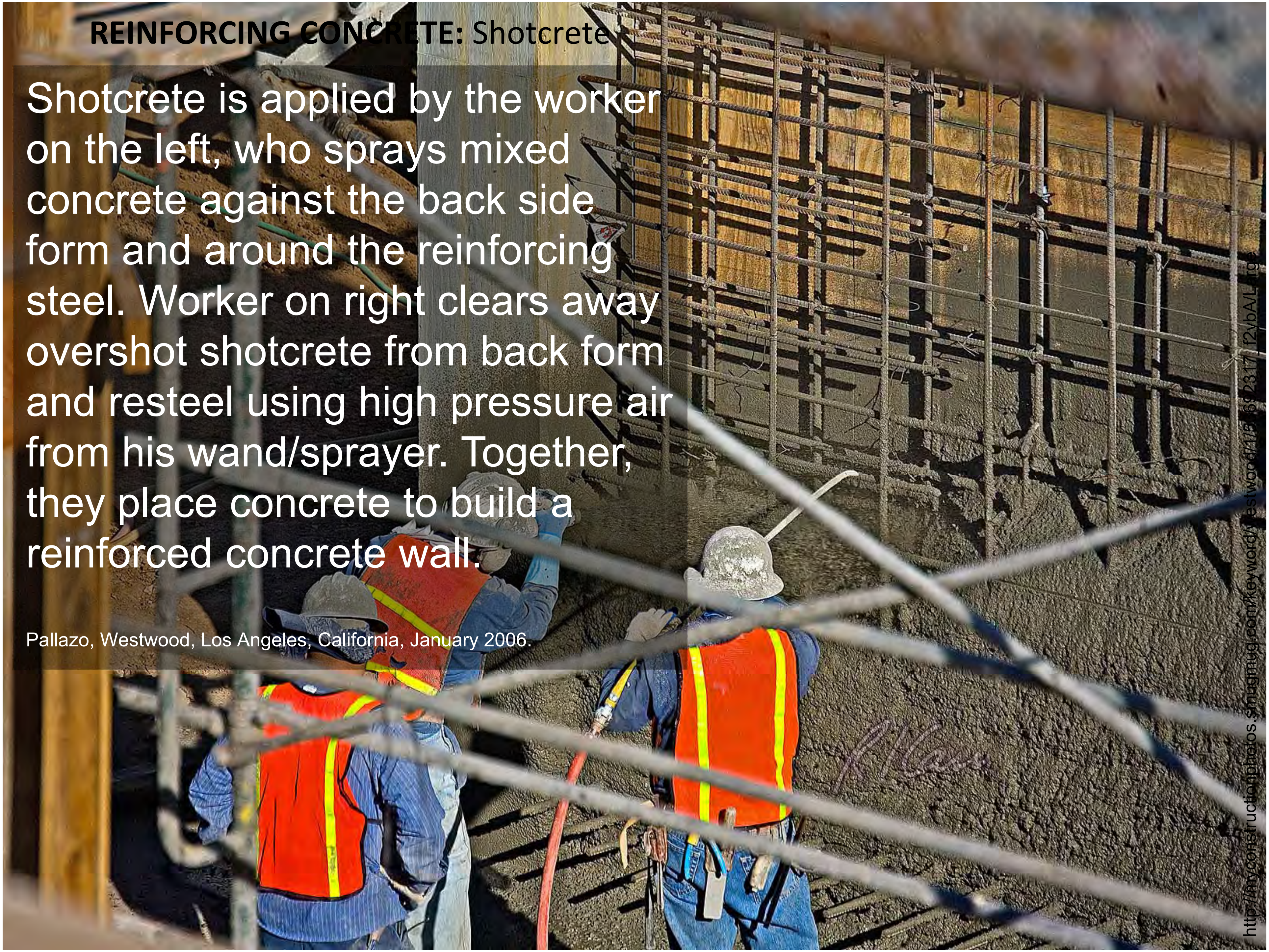


REINFORCING CONCRETE: tilt-up construction concrete

http://rigidwall.com/wp-content/uploads/2009/09/Tilt-Up-Wall-Going-Up-2.jpg

REINFORCING CONCRETE: Shotcrete

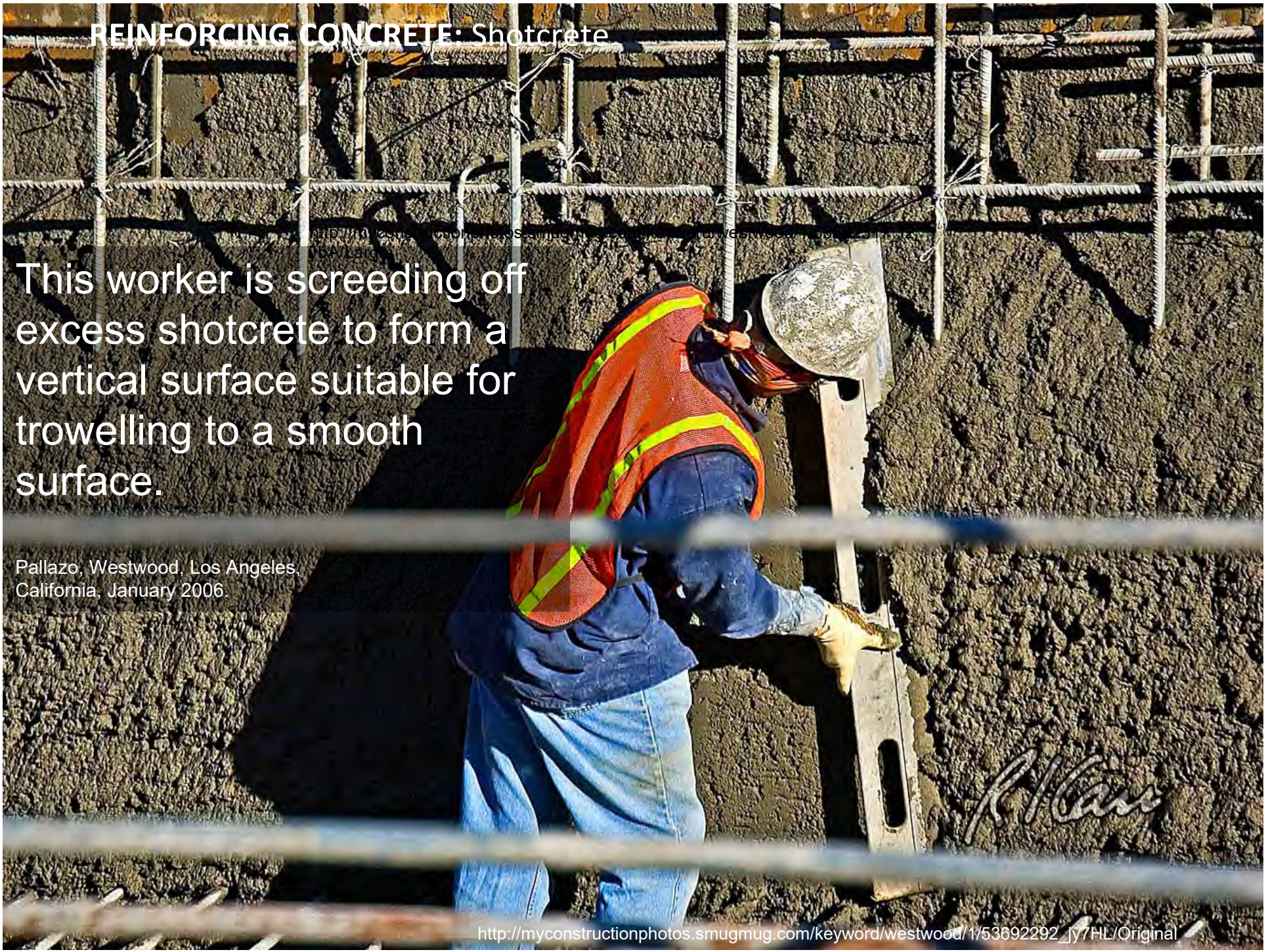
Shotcrete is applied by the worker on the left, who sprays mixed concrete against the back side form and around the reinforcing steel. Worker on right clears away overshot shotcrete from back form and resteel using high pressure air from his wand/sprayer. Together, they place concrete to build a reinforced concrete wall.



Pallazo, Westwood, Los Angeles, California, January 2006.

http://myconstructionphotos.smugmug.com/keyword/westwood/1/5 692317_f2ybA/Large

REINFORCING CONCRETE: Shotcrete



This worker is screeding off excess shotcrete to form a vertical surface suitable for trowelling to a smooth surface.

Pallazo, Westwood, Los Angeles, California, January 2006.

http://myconstructionphotos.smugmug.com/keyword/westwood/1/53692292_jy7HL/Original

Reading:

Allen and Iano,
Sitecast Concrete Framing Systems
Chapter 14, pp. 565-599

Ching, Building Construction Illustrated,
Chapter 1, pp. 1.32
Chapter 3, pp. 3.16
Chapter 6, pp. 6.04

Quiz Next Class

REINFORCING CONCRETE: wed sites

Bull Floats:
http://www.youtube.com/watch?v=6RS6425XuXA&feature=player_embedded

Jay-Ton - Slab Power Trowe:
https://www.youtube.com/watch?v=yEeq8ZyOQaY

Aluminum forms manufacturer:
http://www.wallties.com/multimedia.htm

Reinforced Concrete
https://www.youtube.com/watch?v=cZINeaDjisY

Reinforced Concrete Resisting Shear
https://www.youtube.com/watch?v=WIKSsr95xeM