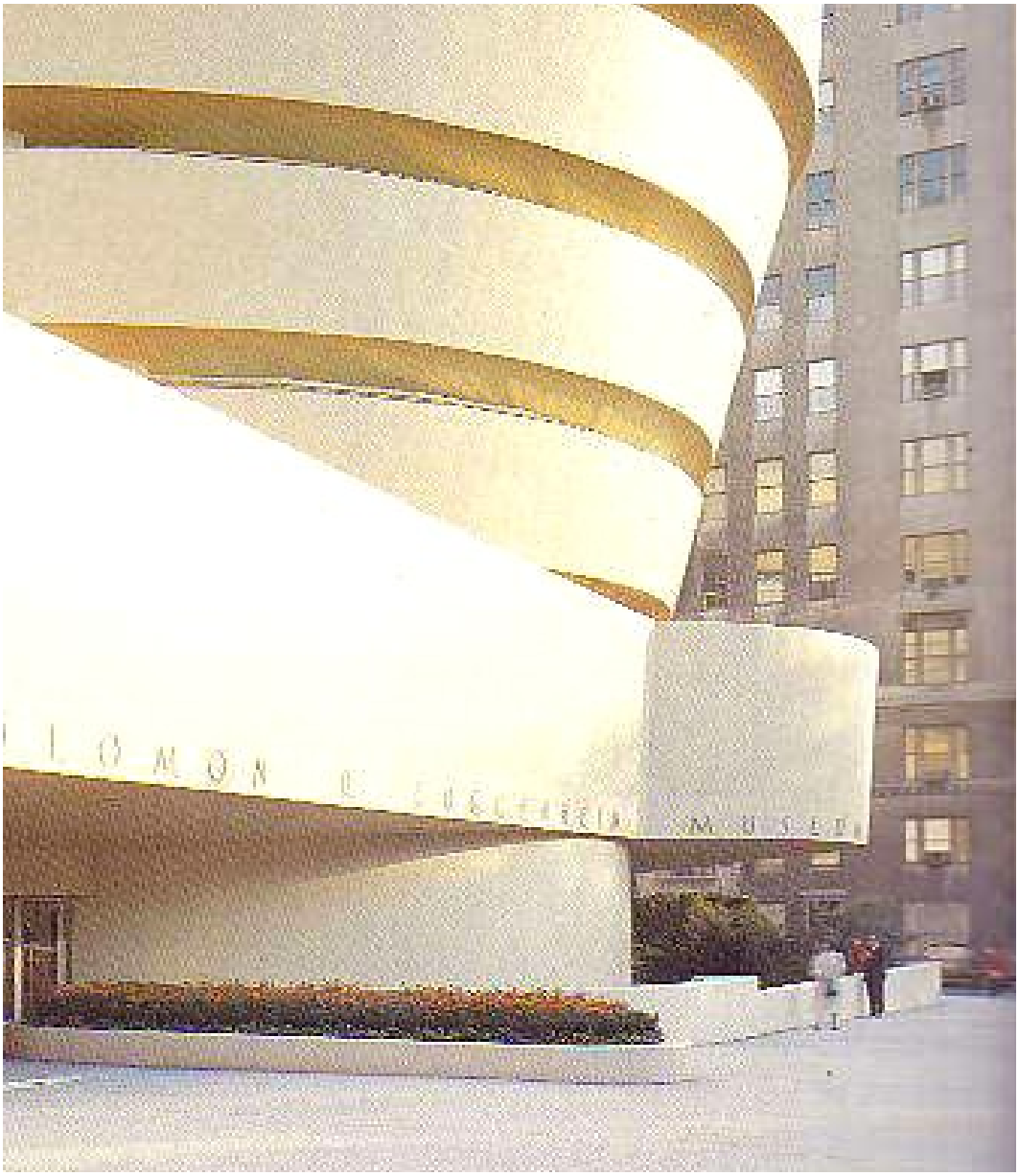
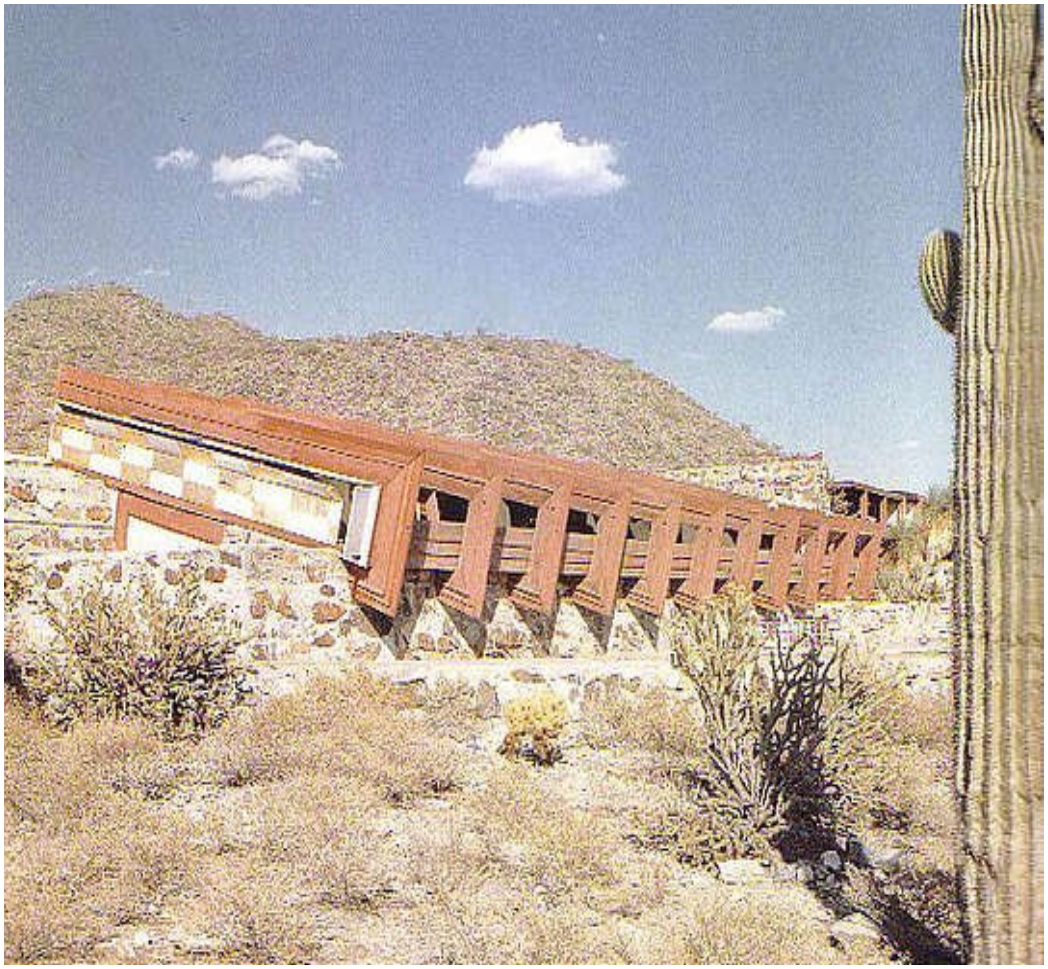
CONCRETE CONSTRUCTION

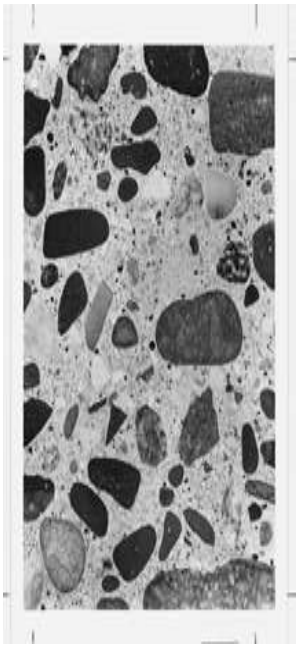


"Concrete is a plastic material susceptible to the impressions of the imagination."

Frank Lloyd Wright



- Rocklike Material
- Ingredients
  - Portland Cement
  - Course Aggregate
  - Fine Aggregate
  - Water
  - Admixtures (optional)



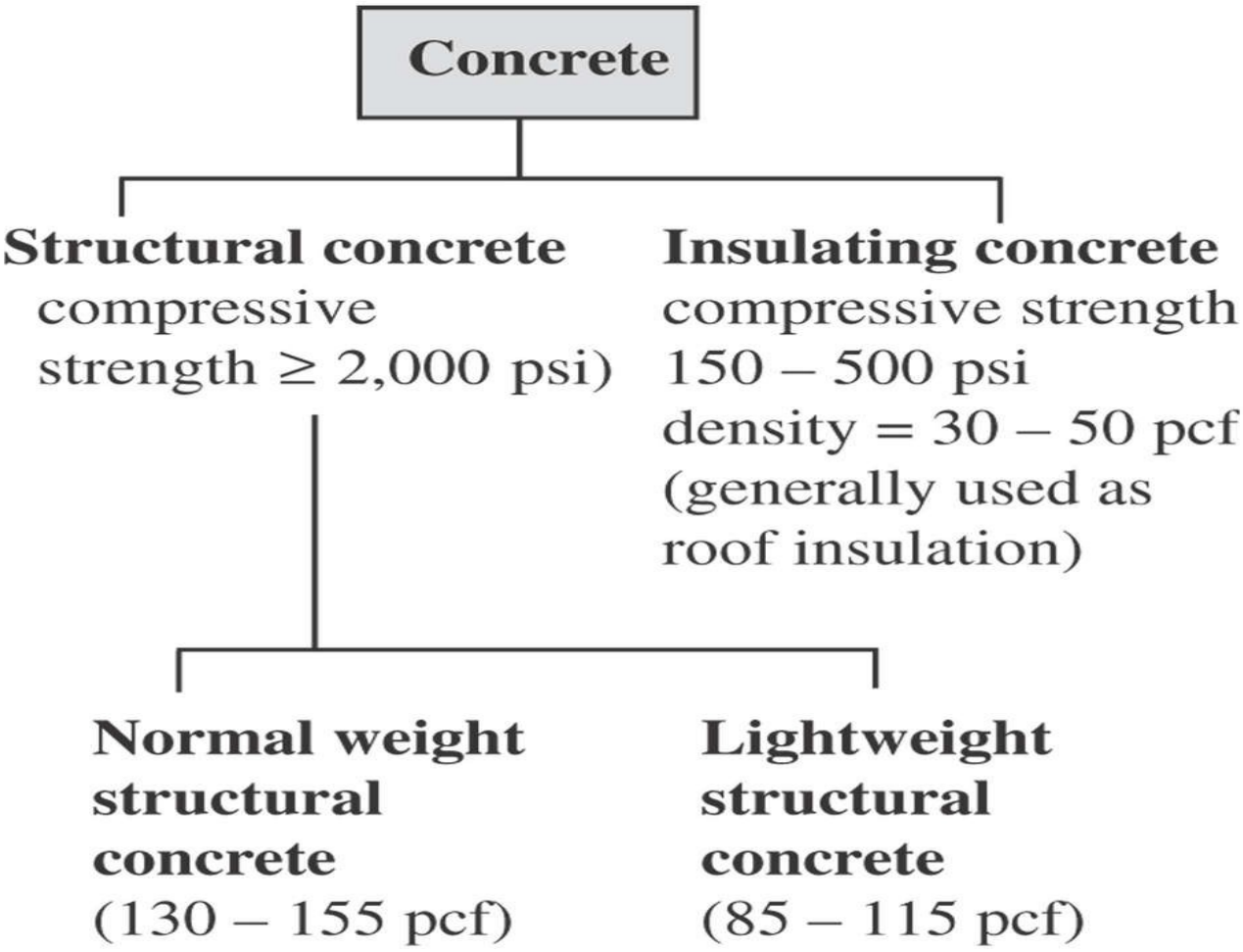
Concrete Properties

- Versatile
- Pliable when mixed
- Strong & Durable
- Does not Rust or Rot
- Does Not Need a Coating
- Resists Fire

Portland Cement

- Generic Term
- Man Made Product
- Fine gray powder
- Glue (Binder)
- Curing & Hydration

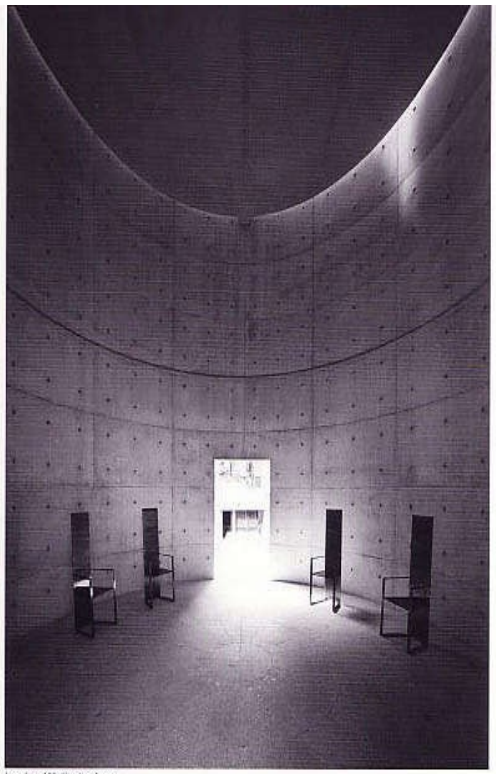
Santiago Calatrava



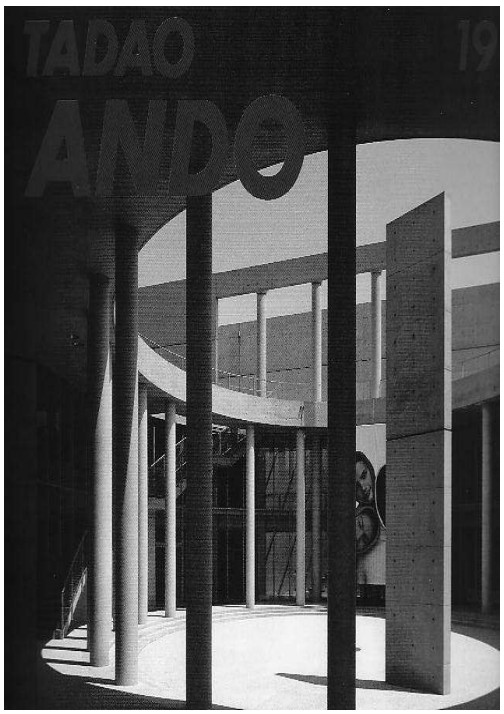
- **APPROX. COST OF CONCRETE**
- **25% - 30% concrete**
  - Placing concrete
  - Finishing concrete
- **20% - 25% steel reinforcement**
  - Placing rebar
  - Making rebar cages, etc.
- **50% - 55% formwork**
  - Percent even higher in highly complex shapes and forms

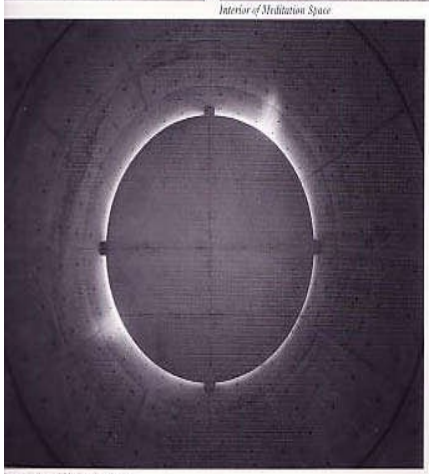
*"**A**rchitecture, to me , is an endless search of one's engagement with oneself and with society From the construction of an abstract concept to its realization."*

TADAO ANDO *AIA Gold Medal 2003*



Interior of Meditation Space





Upward view of Meditation Space

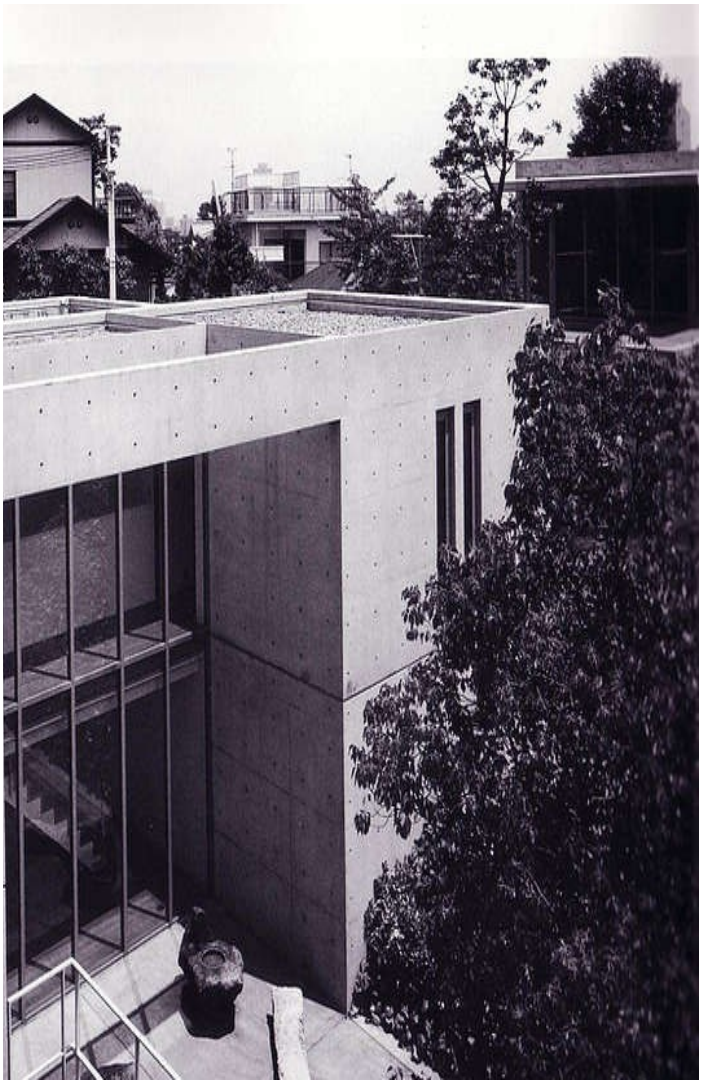
Meditation Center for UNESCO

Paris, France 1995
Tadao Ando, Architect

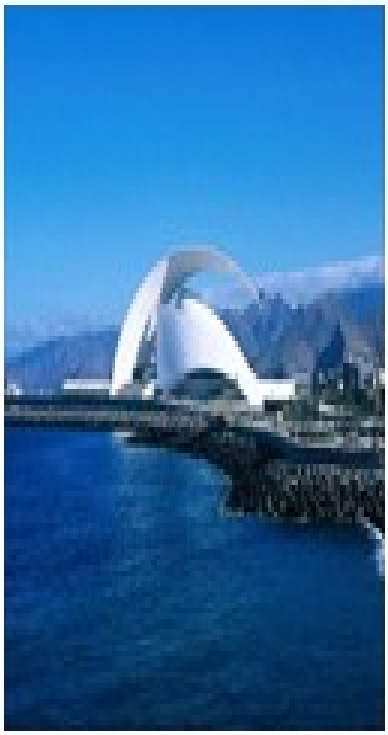
"a space of prayer for world peace"

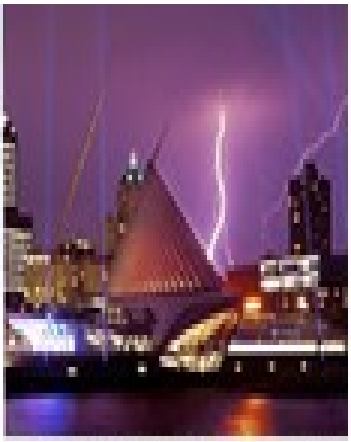
TADAO ANDO

Oyamazaki Villa Museum



Yagi house





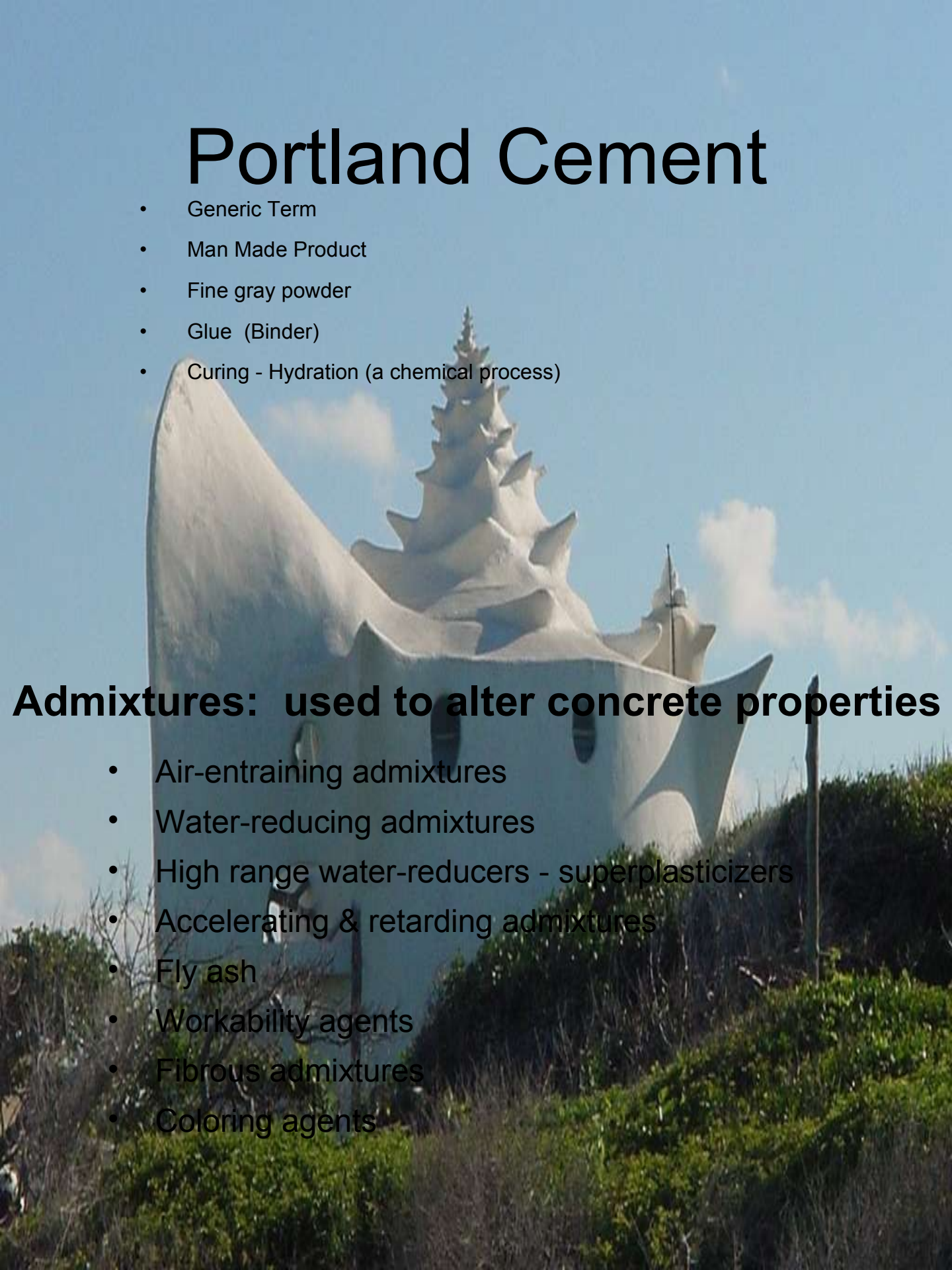
Santiago Calatrava

- A Brief History of Concrete
- 1824 - Aspidin patented Portland Cement - named after English Portland limestone
- 1850s; reinforced concrete
  1900s applied to building construction
- 1920s; prestessed concrete

Hoover Dam

Concrete Properties

- Versatile
- Pliable when mixed
- Strong & Durable
- Does not Rust or Rot
- Does Not Need a Coating
- Resists Fire



Portland Cement

- Generic Term
- Man Made Product
- Fine gray powder
- Glue (Binder)
- Curing - Hydration (a chemical process)

Admixtures: used to alter concrete properties

- Air-entraining admixtures
- Water-reducing admixtures
- High range water-reducers - superplasticizers
- Accelerating & retarding admixtures
- Fly ash
- Workability agents
- Fibrous admixtures
- Coloring agents

Type III - High Early


Type I - Normal

- Type I Normal (most applications)
- Type II & V Moderate and High Sulfate Resistance
- Type III High Early Strength
- Type IV Low Heat of Hydration

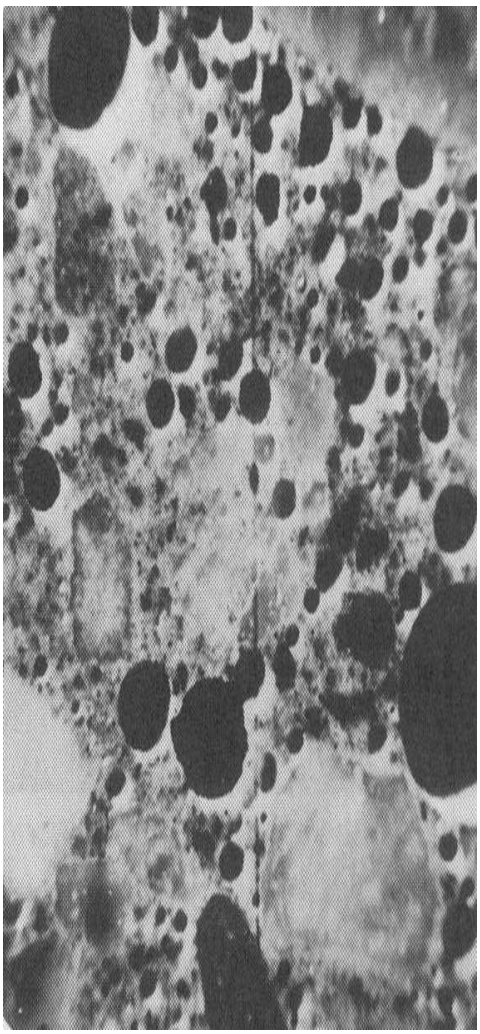
- Type 1A, IIA, IIIA - Air Entrained

Lightweight Aggregates

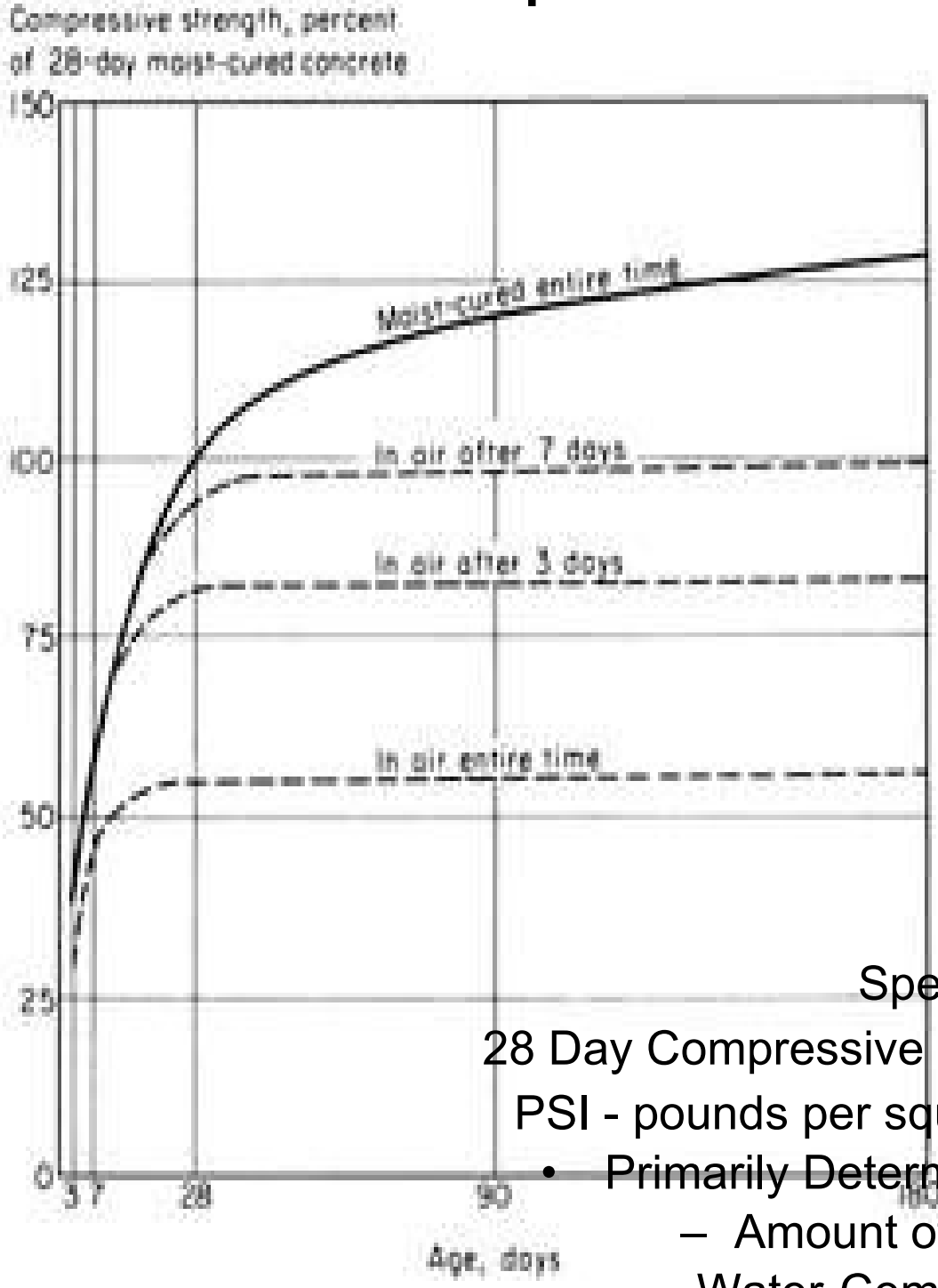
- Vermiculite is Substituted for sand / crushed stone
- Structural Lightweight
  - Density approx. 80% of reg. concrete
  - Purpose; Reduces dead weight
  - Often made from shale in Nonstructural Lightweight concrete
  - Density 20-25% of regular weight
  - Purpose: Insulating material - under roofs

AIR ENTRAINING

- Causes microscopic air bubbles in concrete
- Usually 5% - 8% of volume
- Properties:
  - Improved workability
  - Increased freeze-thaw resistance
- Paving & Exposed concrete



Concrete Compressive Strength



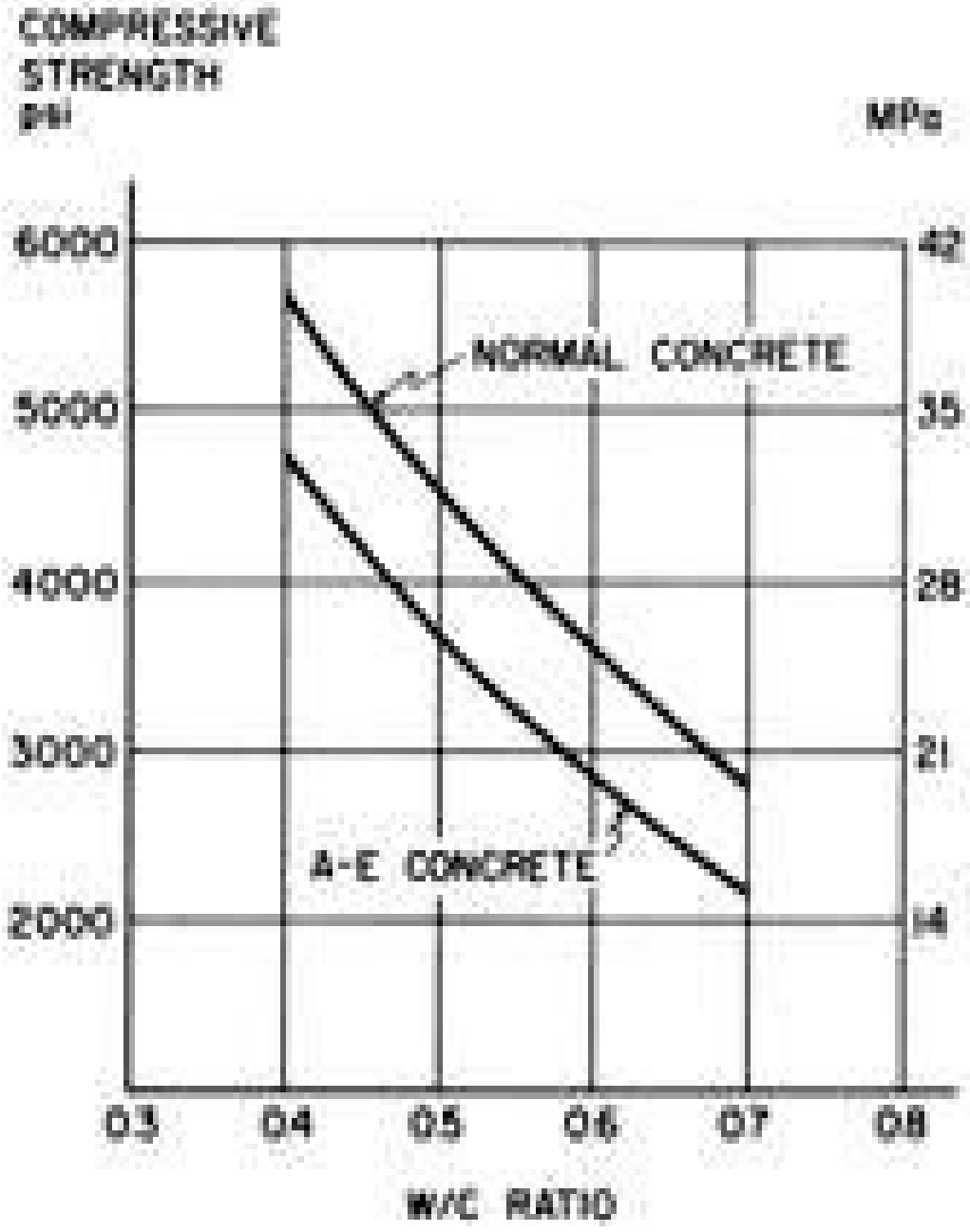
Specified by:

28 Day Compressive Strength

PSI - pounds per square inch

- Primarily Determined By:
  - Amount of Cement
  - Water-Cement Ratio
  - Admixture(s)
- Strength Ranges: 2000 - 22,000+ psi

Concrete Compressive Strength

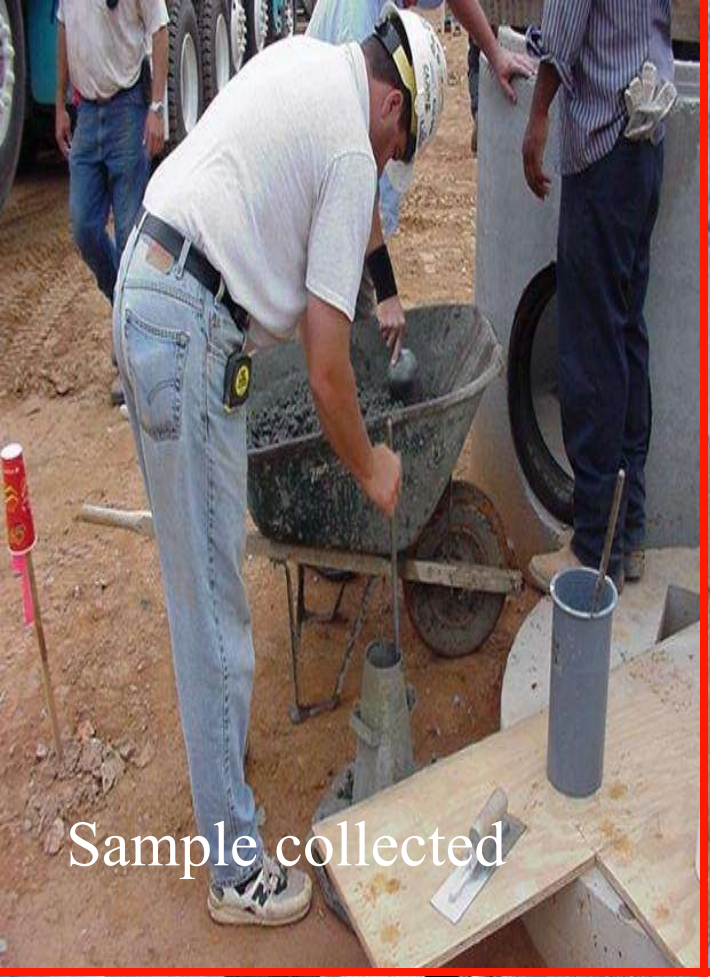


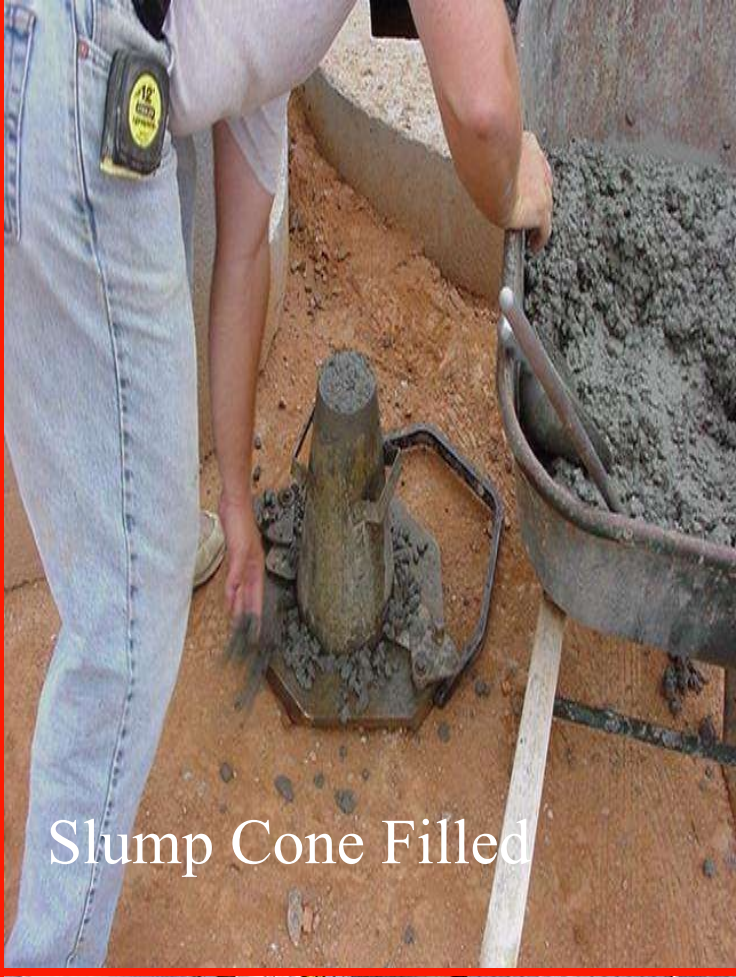
Water-Cement Ratio

- Concrete with High W/C ratio is easier to place
- Balance workability with desired qualities

CONCRETE
Vs
Other Building Materials

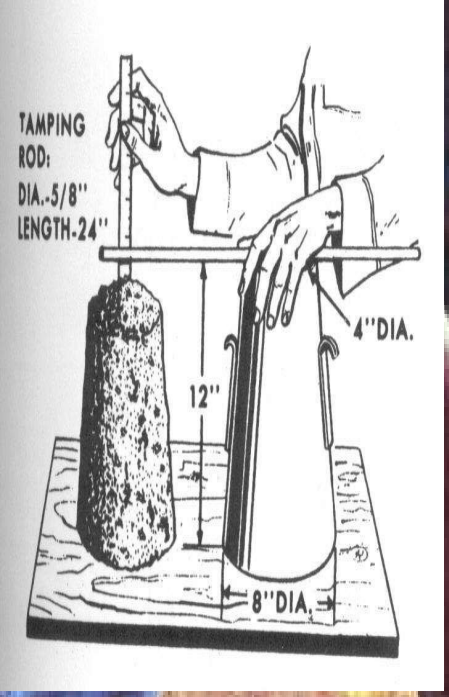
Material	Tension	Compression
Wood	700 psi	1,100 psi
Brick	0 psi	250 psi
Steel	22,000 psi	30,000 psi tp 60,000psi
Concrete	0 psi	2,000 psi to 22,000+ psi


Sample collected


Slump Cone Filled


Cone Removed and Concrete
Allowed to ‘Slump’


Slump Measured



Walls/columns	4-5 in.
Beams	4-5 in.
Slabs	3-4 in.

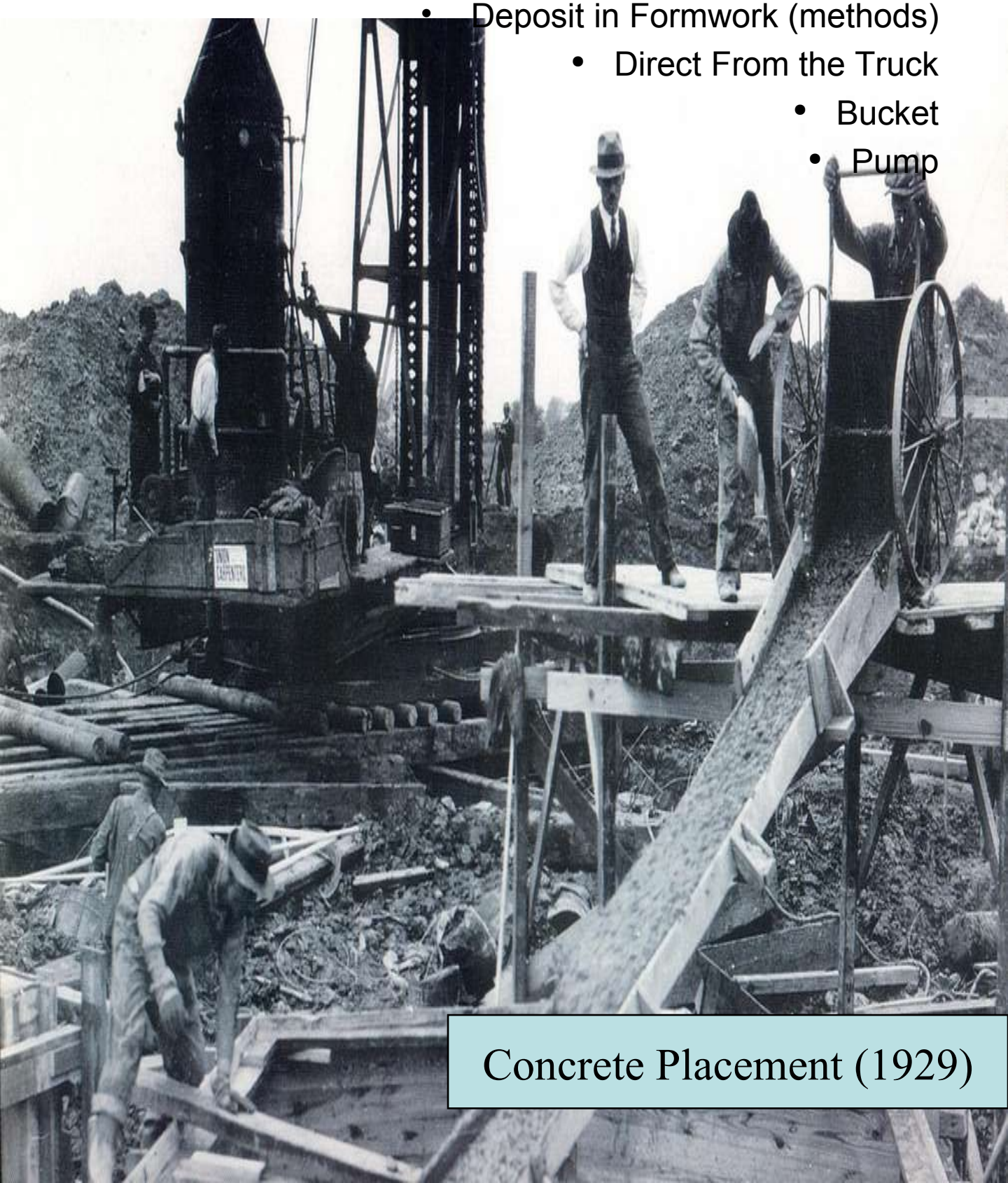
Measuring the Slump

Test Cylinders Filled with a Sampling of the Concrete Mix

Test Cylinders Curing and then strength tested (upper right)

Concrete Placement

- Not a Liquid - an *Unstable* mixture
- Will segregate if handled improperly
- Deposit in Formwork (methods)
  - Direct From the Truck
  - Bucket
  - Pump



Concrete Placement (1929)

Placement Today - not too much has changed!

Concrete Bucket being Filled

Placement of a Wall with a Crane & Concrete Bucket

Placement with a Concrete Pump

Placement with a Concrete Pump

Placement with a Conveyor

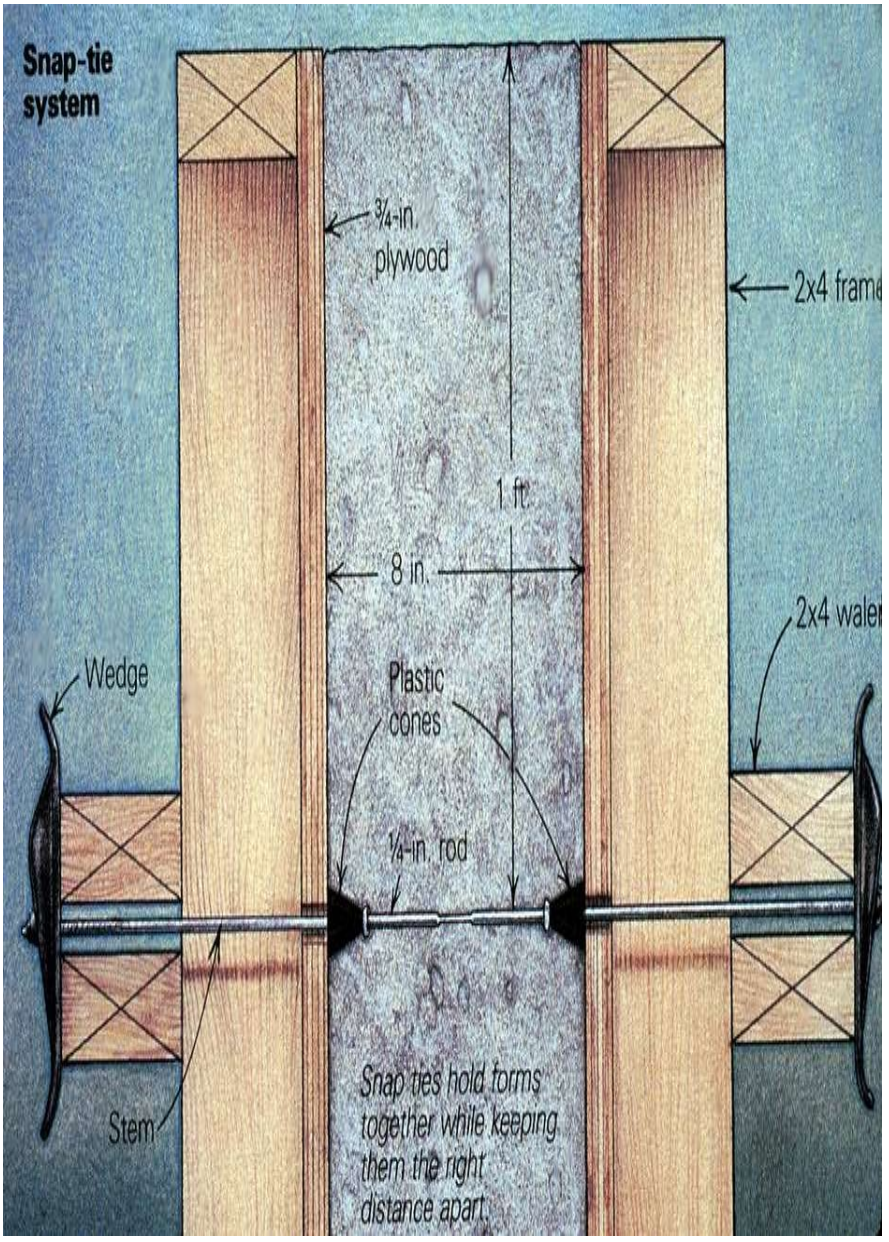
Improperly Consolidated - "Honeycomb"

Segregation - Mix *"Separates"*
Results - Non-uniformity & Unsatisfactory properties
Common Causes
- Excessive Vibration
- Dropping From Excessive Heights
- Moving Concrete Horizontally

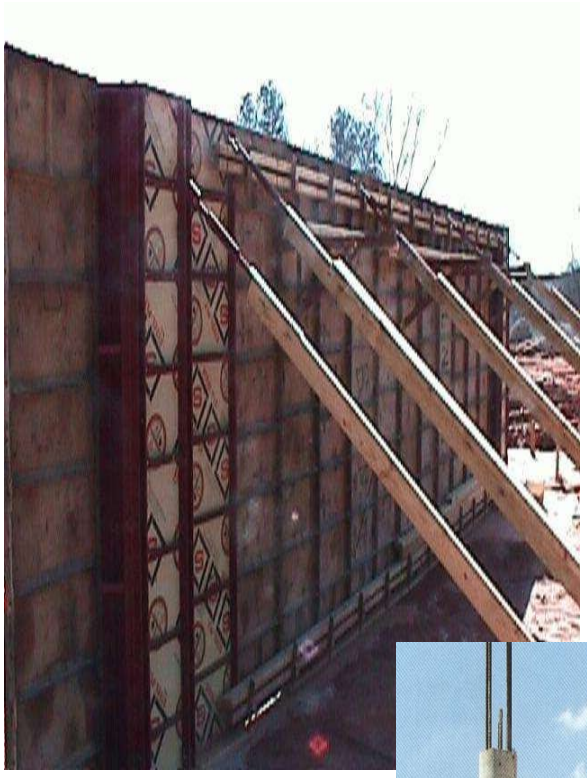
Improperly consolidated Concrete

Extensive Reinforcing *Can* Make Placement & Consolidation Difficult

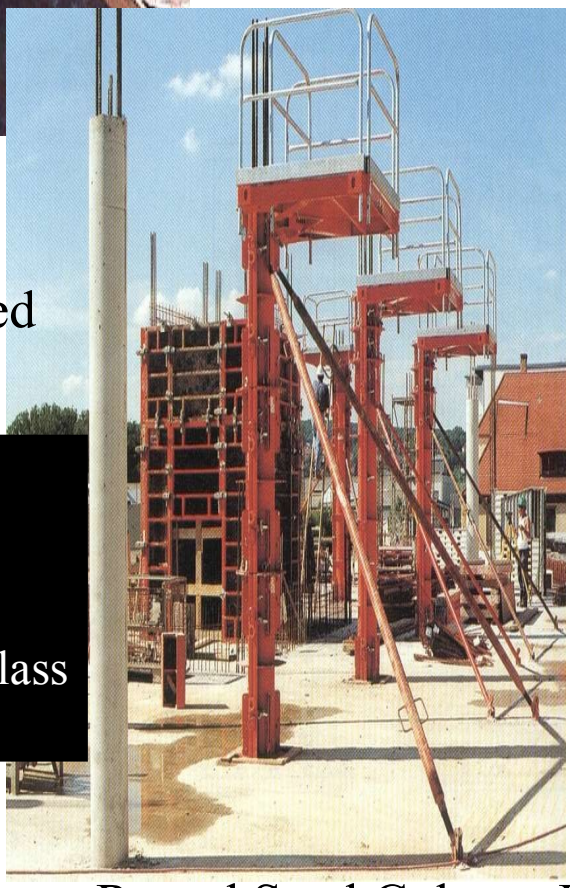
“Cold” Joint


Snap-tie system
¾-in. plywood
2x4 frame
1 ft.
8 in.
2x4 waler
Wedge
Plastic cones
¼-in. rod
Stem
Snap ties hold forms together while keeping them the right distance apart.

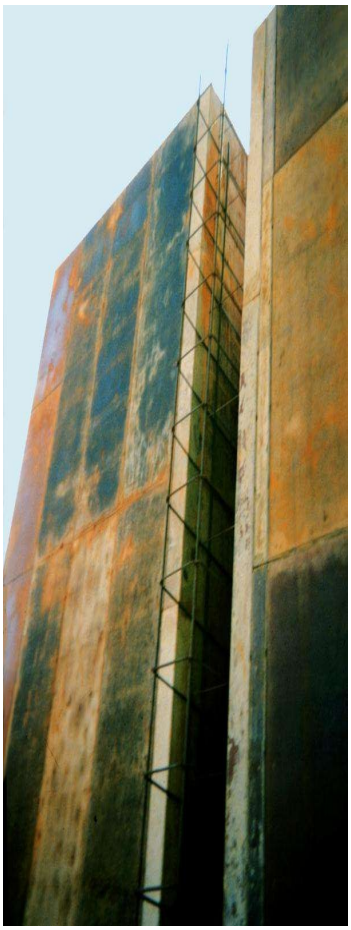
Formwork Materials



Wood - Panelized



Round Steel Column Form



Steel Wall Form

TYPES:

- Wood
- Metal
- Plastic/Fiberglass
- Cardboard

Concrete Reinforcing

- Concrete - No Useful Tensile Strength
- Reinforcing Steel - Tensile Strength
  - Similar Coefficient of thermal expansion
  - Chemical Compatibility
  - Adhesion Of Concrete To Steel

- Theory of Steel Location
  "Place reinforcing steel where the concrete is in tension"

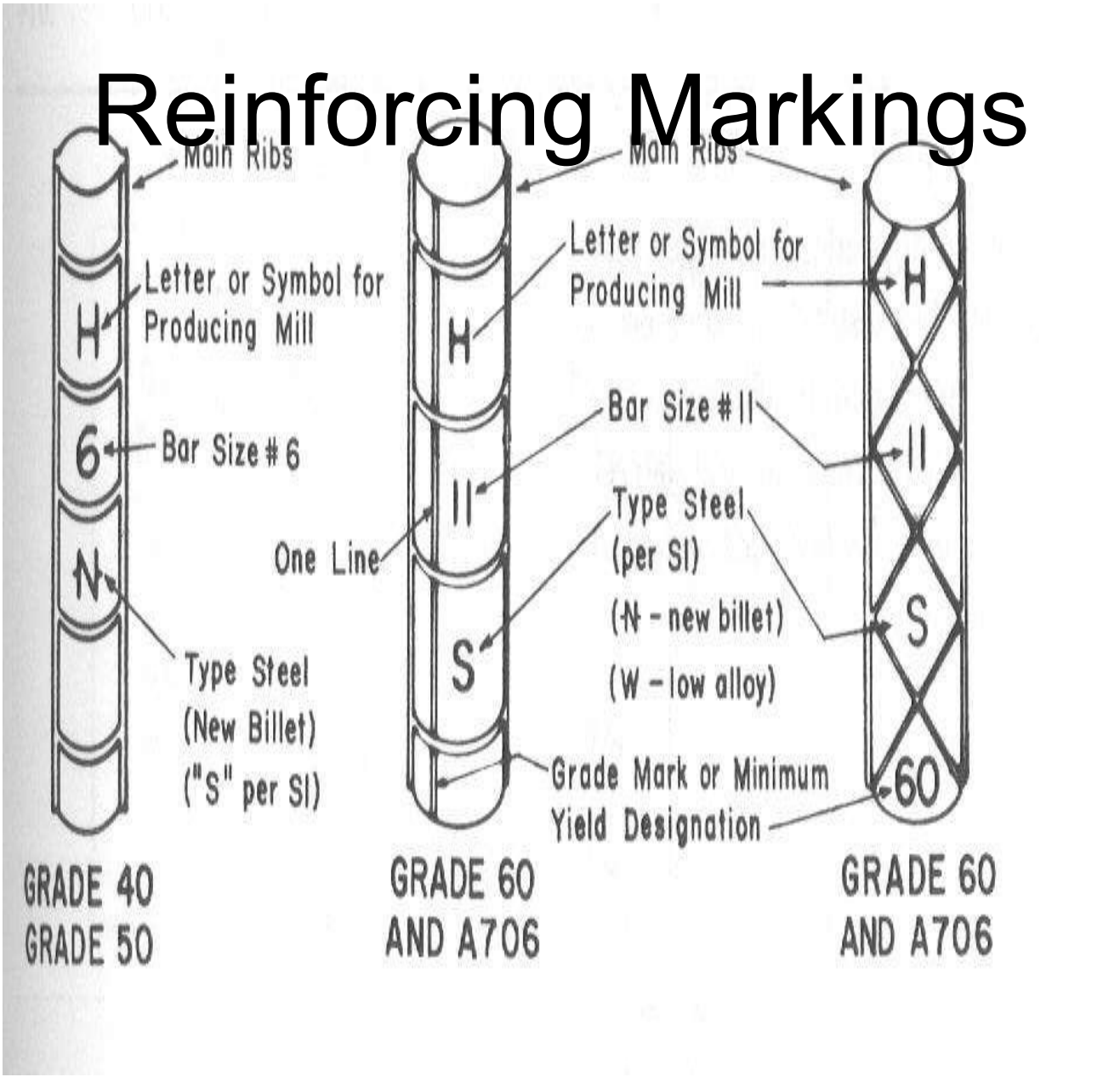
Sizes

Eleven Standard Diameters
3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 18
Number refers to 1/8ths of an inch

Grades

40, 50, 60 Steel Yield Strength (in thousands)

Reinforcing Markings



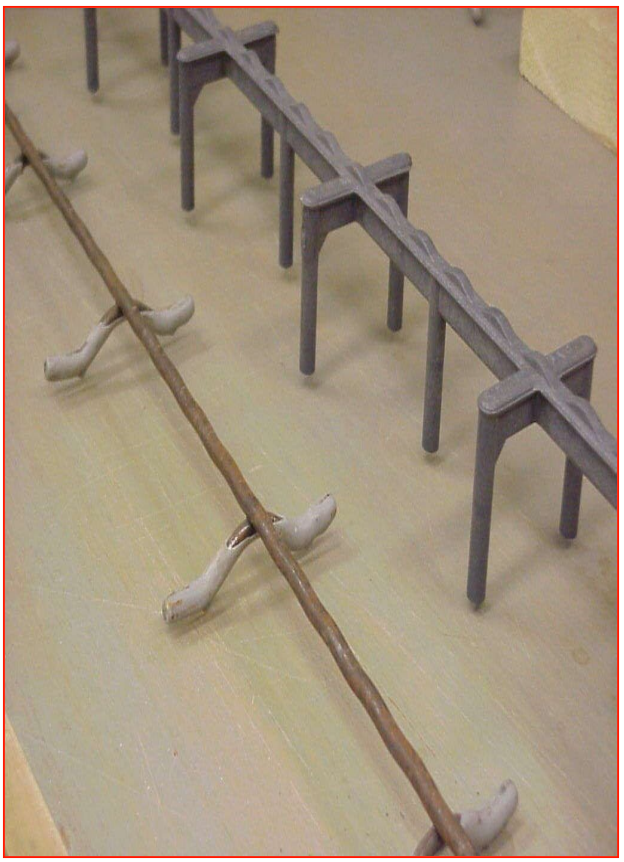
Concrete is used in conjunction with steel to provide tensile strength

- Thermal expansion the same for both materials
  - No stress created due to differential expansion and contraction
- Steel bonds well to concrete
  - Chemical bond
  - Mechanical bond, enhanced by using deformed steel rebar
- Reinforcing steel commonly available in
  - 40,000 psi (grade 40) - used when bars must be field bent
  - 60,000 psi (grade 60) - most common, difficult to bend

Reinforcing Support

- Chairs or bolsters

  Properly position the steel



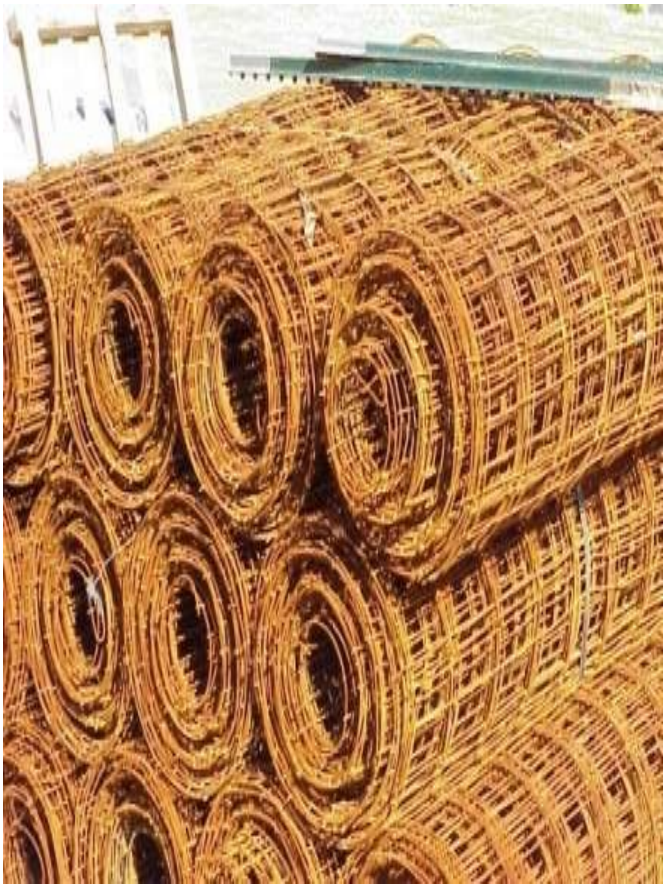
Reinforcing Special Coatings

Galvanized or Epoxy Coated
Exposure to Salts or Sea Water

WWF – Sheet (mat)

Welded Wire Fabric (WWF)

- Type of Reinforcing
- Grid of “wires” spaced 2-12 inches apart
- Specified by wire gauge and spacing
- Typical Use - Horizontal Surfaces
- Comes in Mats or Rolls
- Advantage - Labor Savings

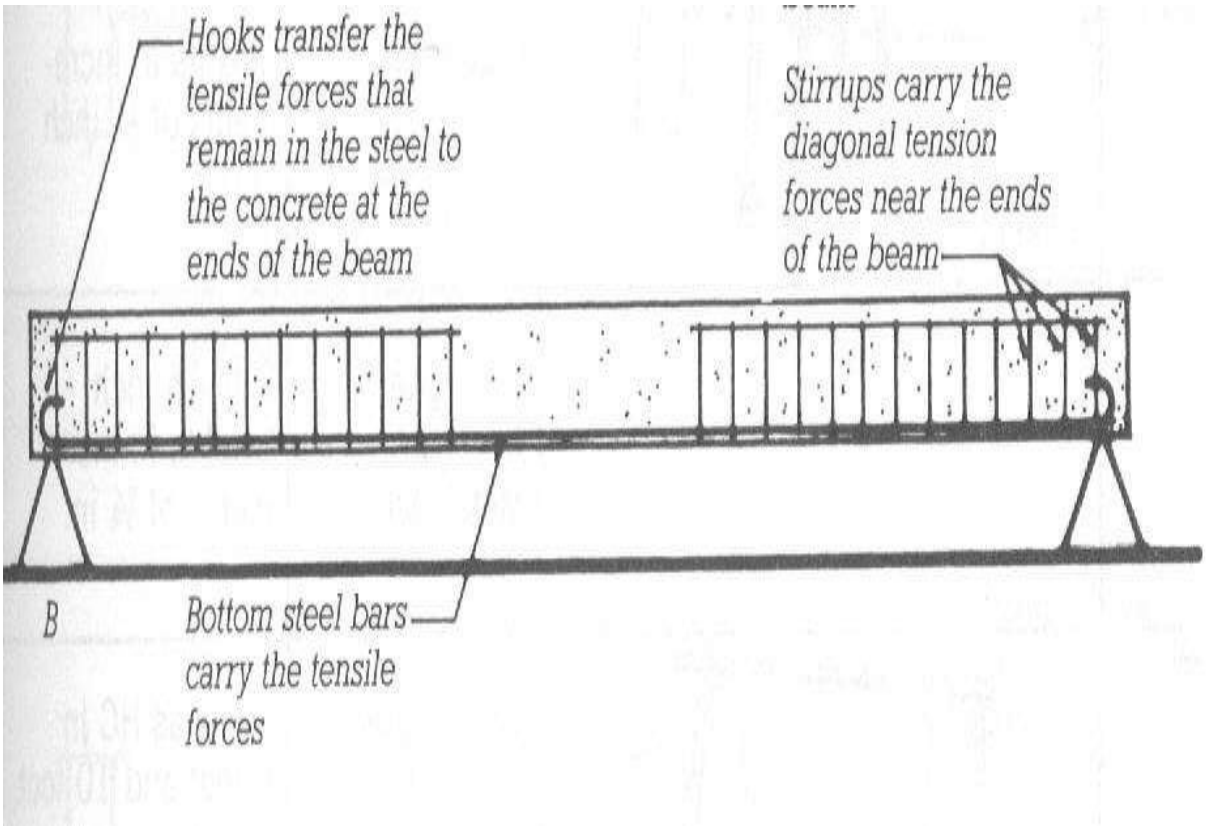


Wall Reinforcing being secured with Wire Ties

Long Bridge Pier Requiring Reinforcing Splicing

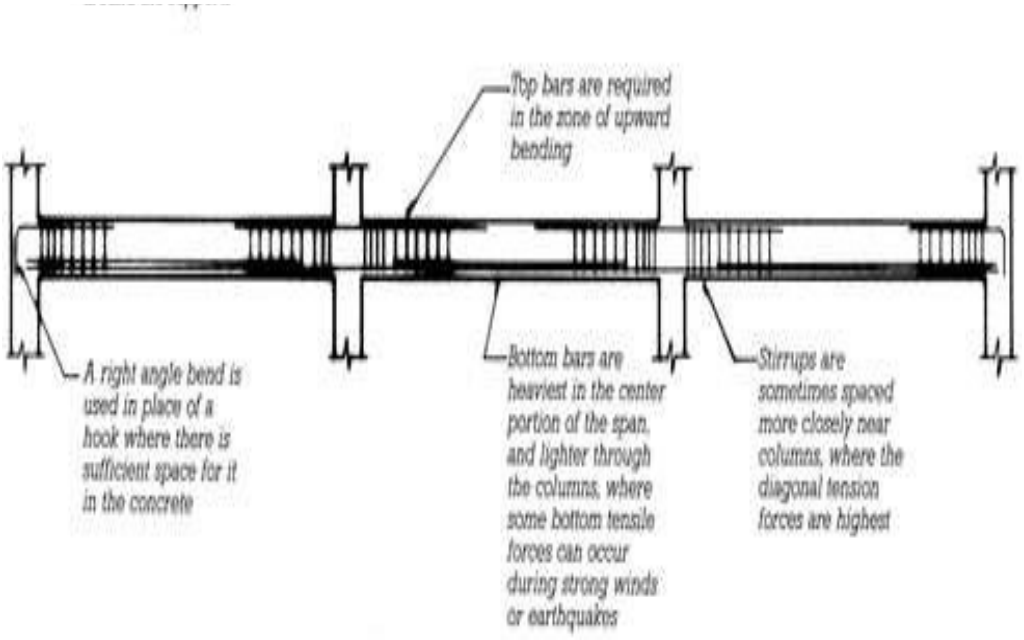
Reinforcing Stirrups

- Position Beam Reinforcing
- Resist Diagonal Forces / Resist Cracking



Reinforcing a Continuous Concrete Beam

- Most Beams are not simple span beams
- Location of Tension Forces Changes
- Midspan - Bottom in Tension
- At Beam Supports - Top in Tension



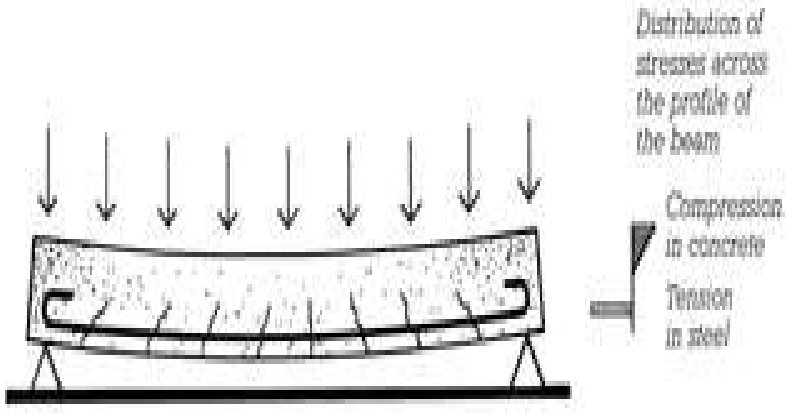
Conventionally Reinforced Concrete

- Reinforced Concrete Members

  Part of the member in compression

  Part of the member in tension
- Over half of the concrete

  Not carrying any load, it's: Holding reinforcing in position & providing protective cover



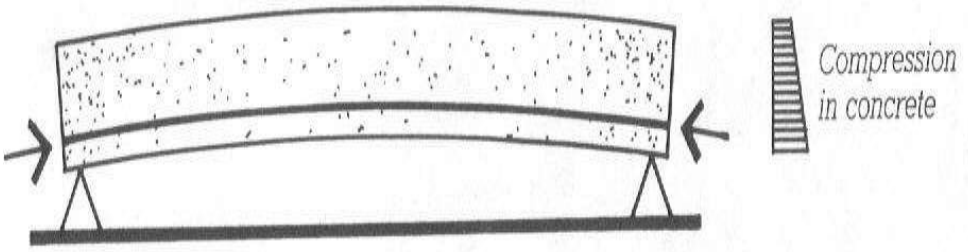
In a reinforced concrete beam, less than half the concrete is in compression, and cracks will appear in the bottom of the beam under full load

Prestressing

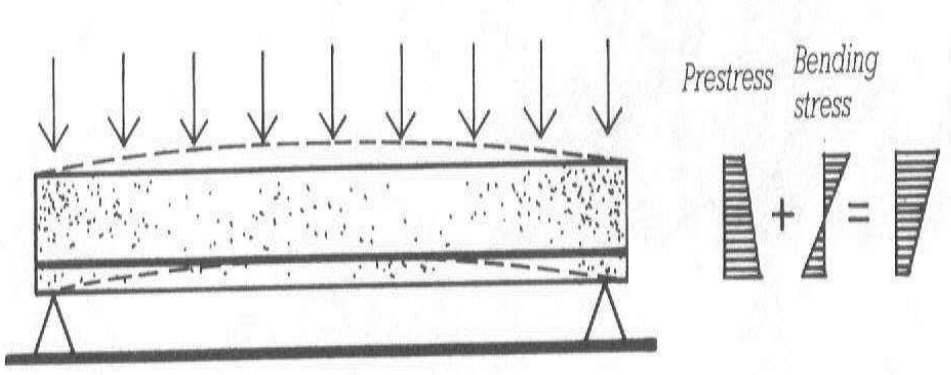
Theory; “Place all the concrete of the member in compression” (take advantage of concrete’s compressive strength of the entire member)

Advantages

- Increase the load carrying capacity
- Increase span length, or
- Reduce the member’s size



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



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

Prestressing - Pretensioning

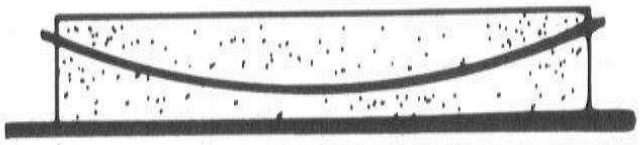
1. The first step in pretensioning is to stretch the steel prestressing strands tightly across the casting bed

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

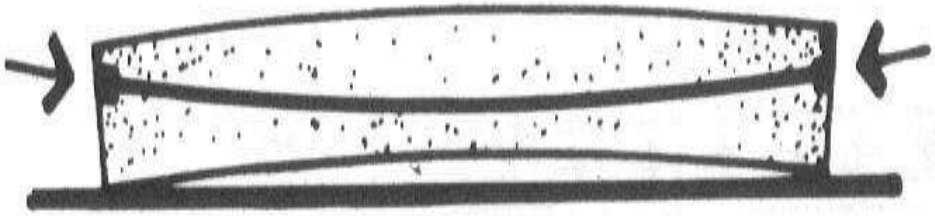
3. When the strands are cut the concrete goes into compression and the beam takes on a camber

Prestressing - Posttensioning

- Cables positioned prior to concrete placement
- Stressed after concrete placement (& curing)
- Generally performed
  at the jobsite



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

Post-Tension
Cable Strands
or Coils

Coated / Sheathed to prevent bonding and Precut to Length

Install (position) unstressed steel strands
- Often Draped
- Positioned to follow tensile forces

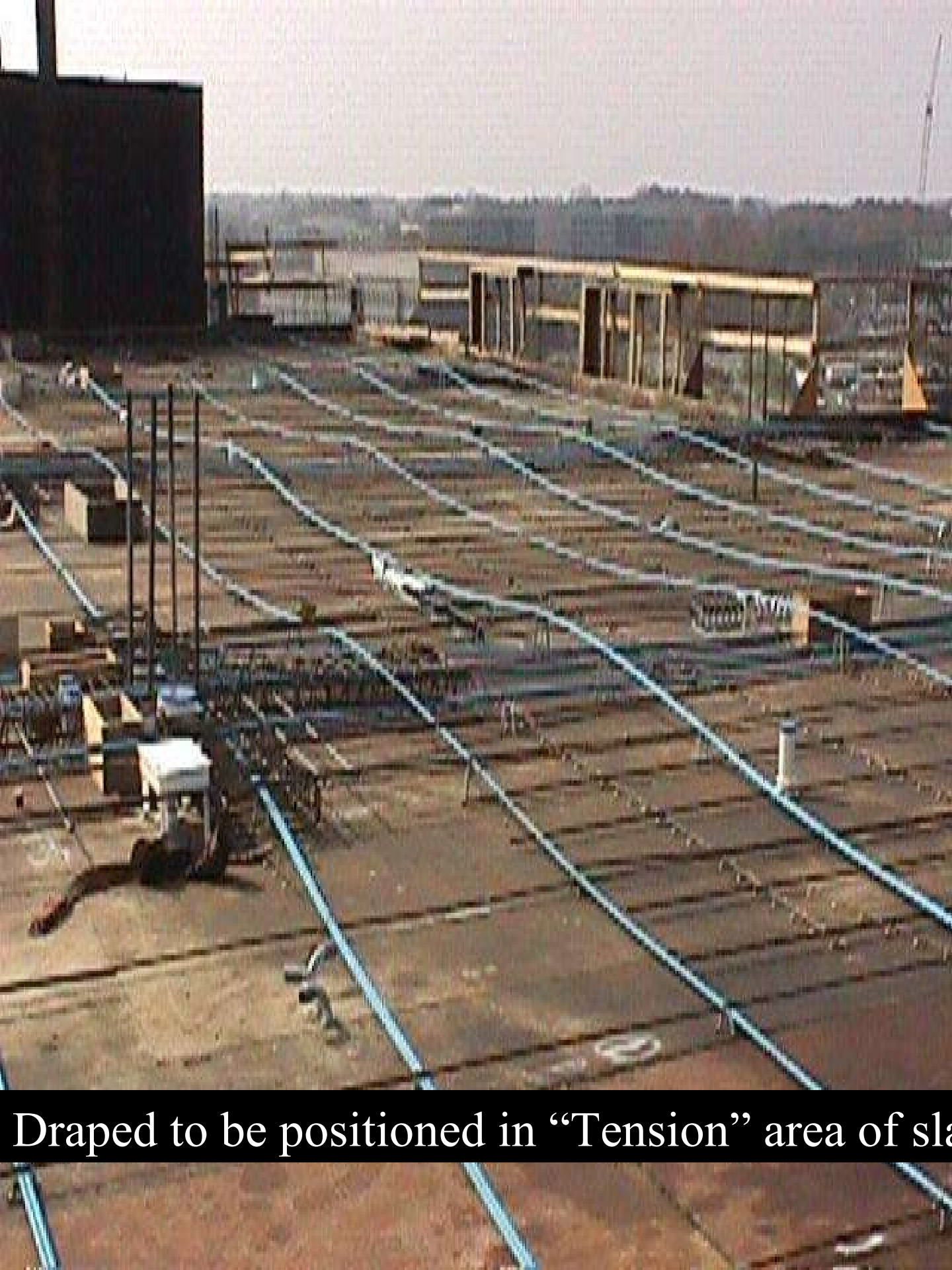
Place and Cure Concrete

Stress steel stands w/ hydraulic jack
- From one or both ends of the stand

Anchor the ends of the stands

Trim cables (& patch)

c-sheathed to prevent bonding to concrete
(note the cable is lubricated)

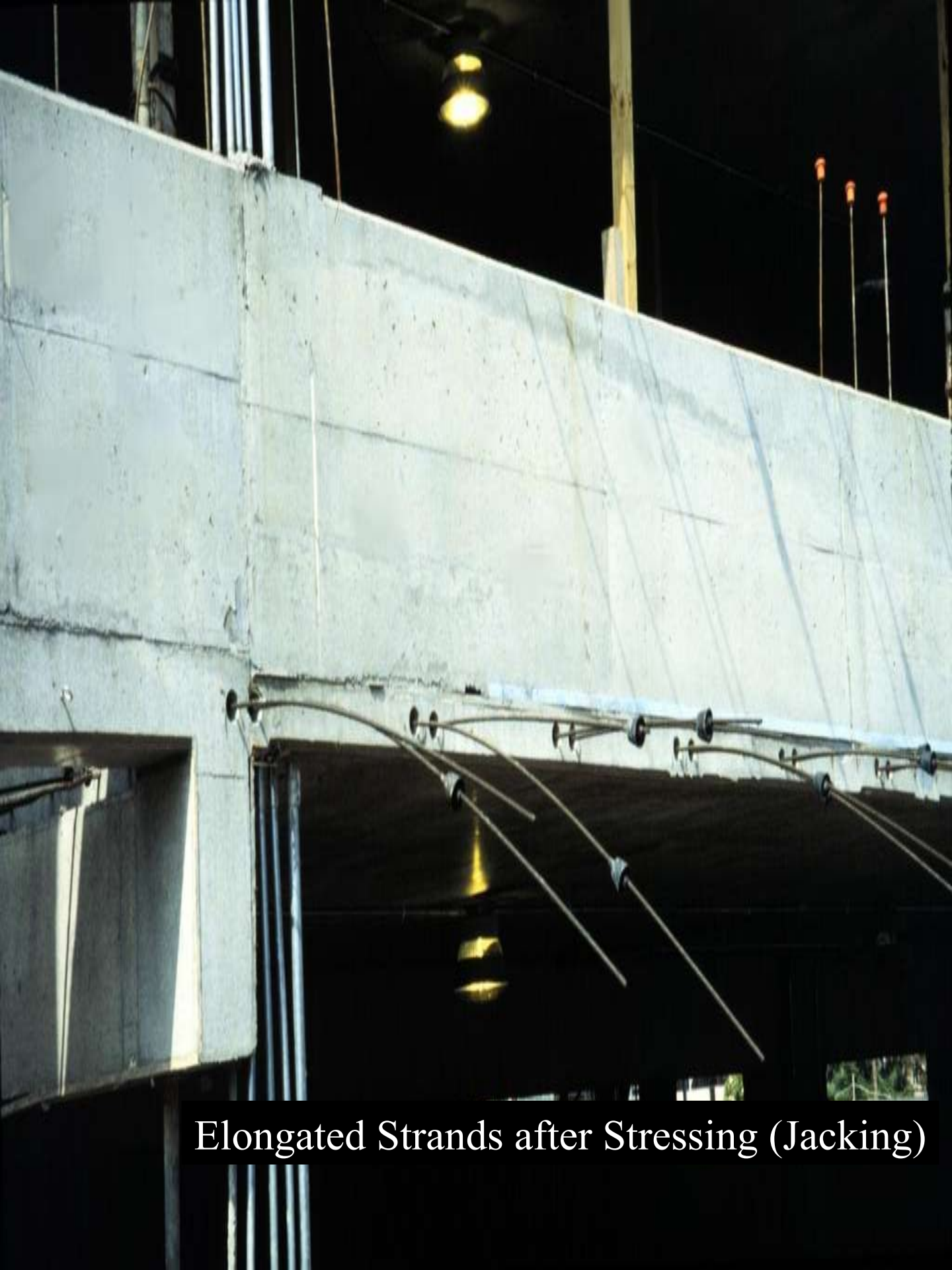


Draped to be positioned in “Tension” area of sla


Cables can be ‘Bundled’

Cable attachment to Edge Form

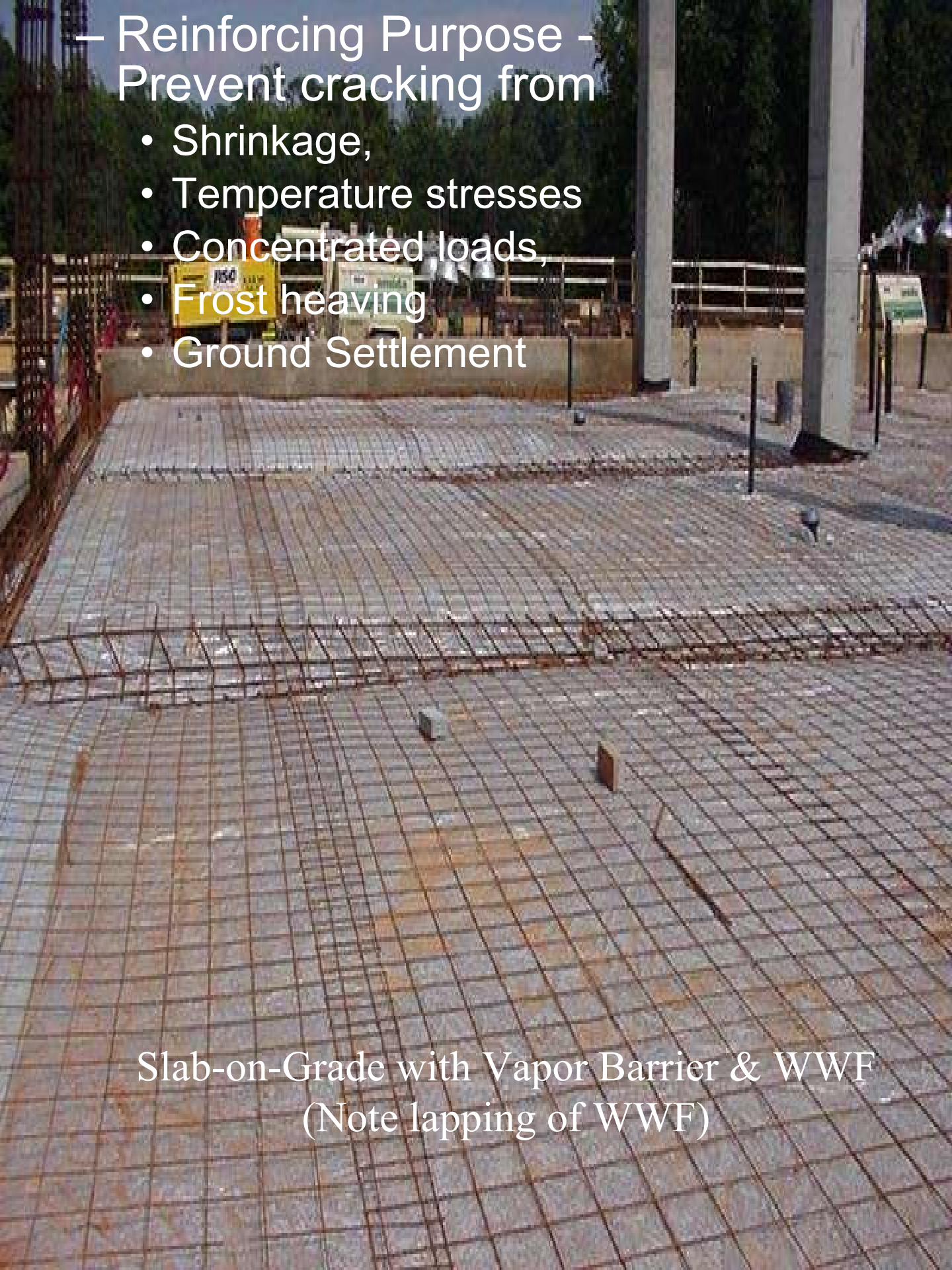
Hydraulic Jacking Machine to Stress Cable



Elongated Strands after Stressing (Jacking)

Slab-on-Grade (SOG)

Level surface of concrete supported on the ground



– Reinforcing Purpose - Prevent cracking from
  - Shrinkage,
  - Temperature stresses
  - Concentrated loads,
  - Frost heaving
  - Ground Settlement

Slab-on-Grade with Vapor Barrier & WWF
(Note lapping of WWF)

Placement with a Pump

Laser-screed

Often used for ‘superflat’ floors

Finishing
Rotary Power Trow
(Walk behind)

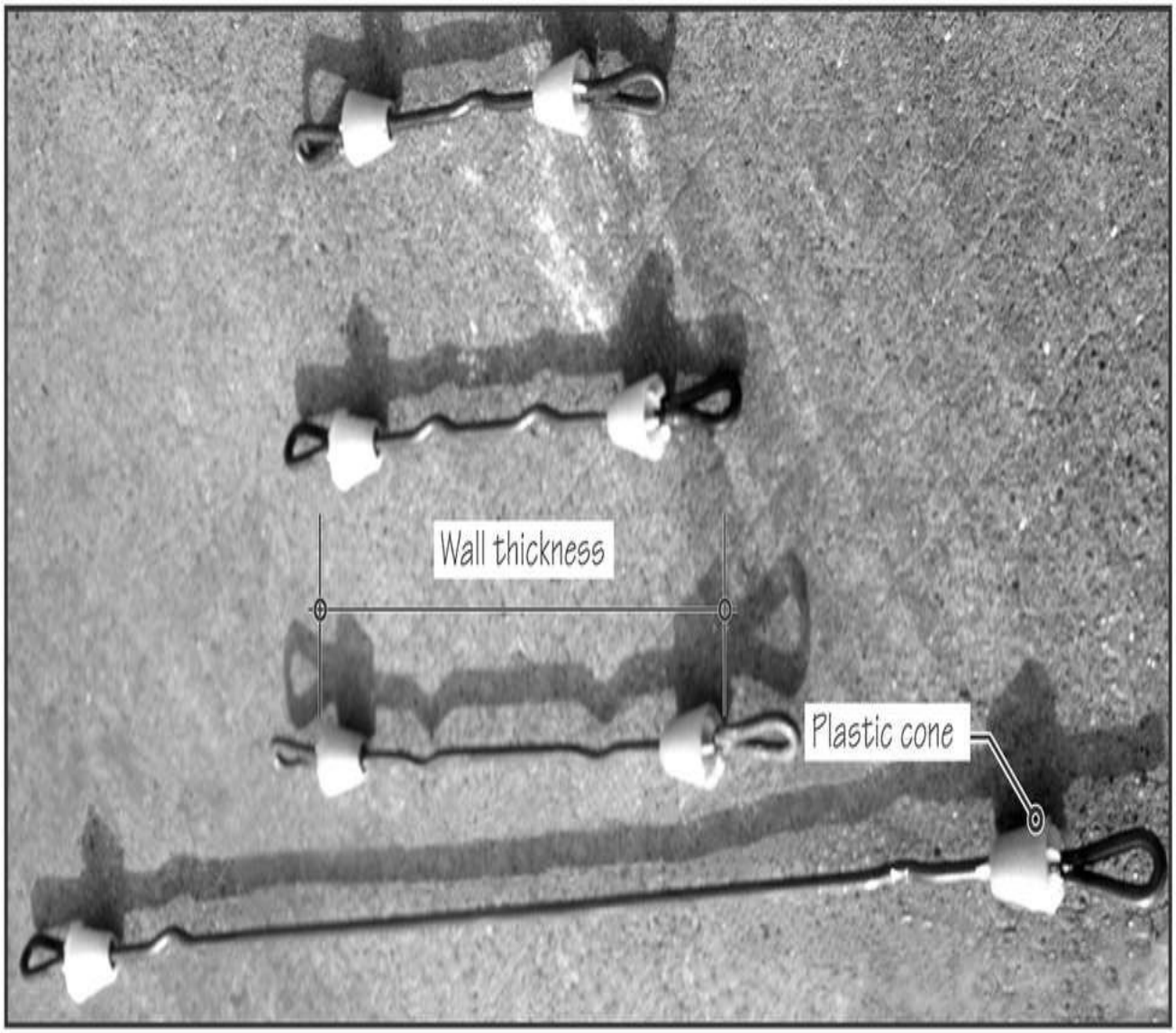
Finishing
Rotary Power Trowel
(Rider - Double Blade)

Control Joint (sawed)

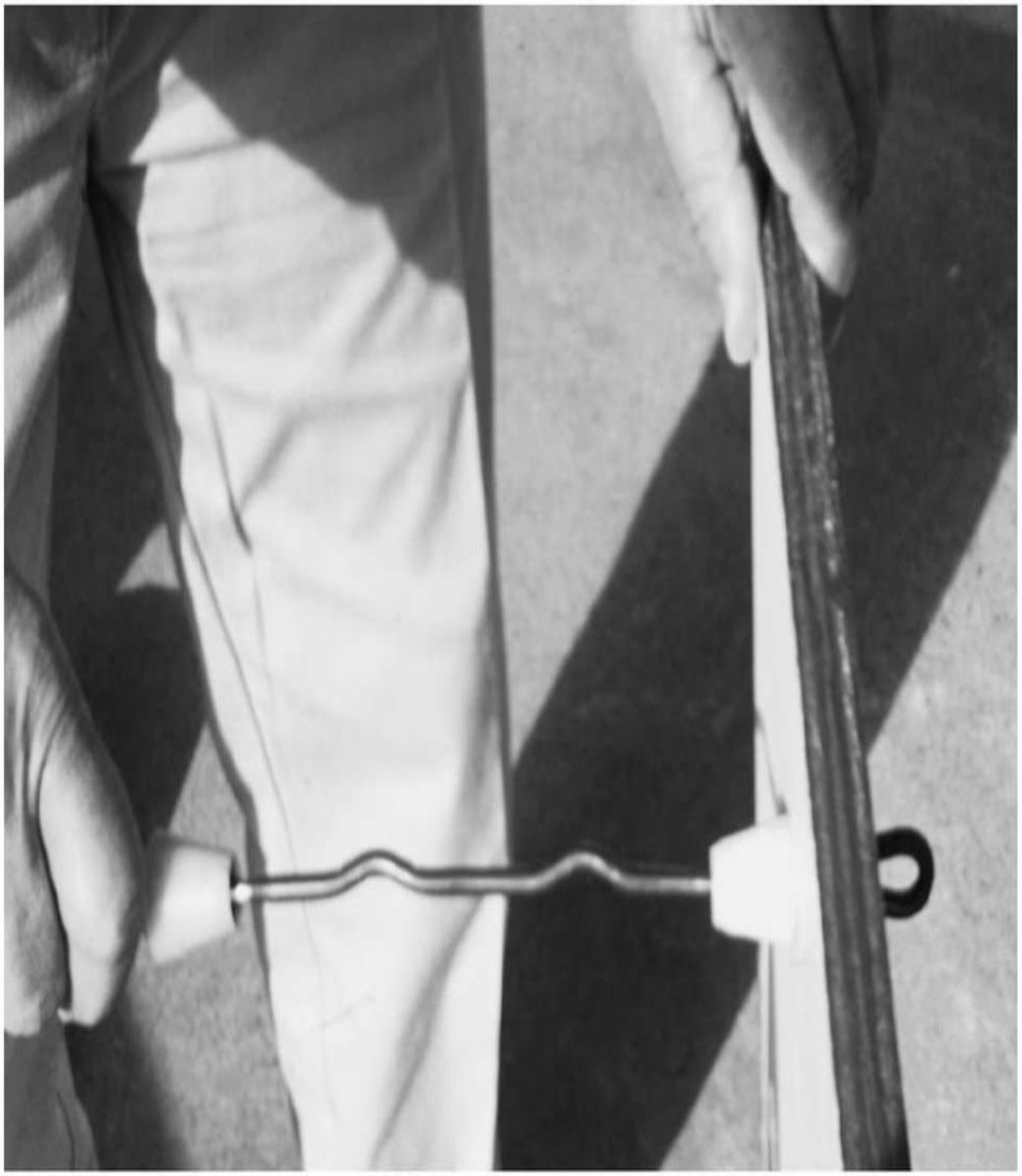
Control Joint (tooled)

Note the Broom Fini

Snap ties



Ties inserted through pre-drilled holes



Clamp placed over endloop of tie

Waler placed over clamp and locked down

Vertical stiffback attached to assembly

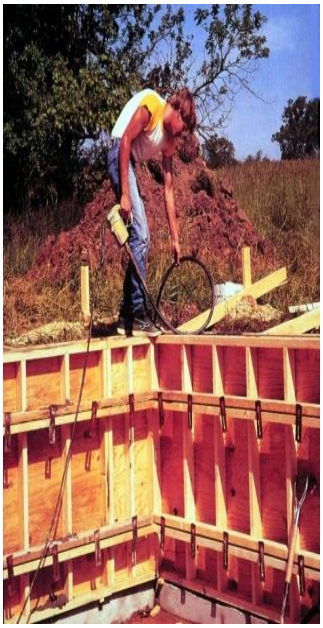
Stiffback locked in place

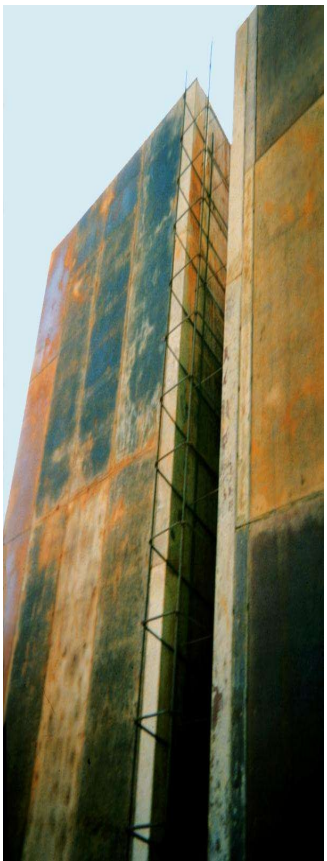
Completed connection: plywood, waler, tie & stiffback

Casting a Concrete Wall

Materials

- Stick Built of Lumber & Plywood
- Standardized prefabricated panels
- Prefabricated steel, fiberglass
- Insulated Concrete Forms
- Choice Depends on:
  - Number of uses, Irregularity of wall
  - Wall finish & tie spacing,
  - Availability & Cost





Panelized Systems

Built in-Place with:

- Panelized Sections
- Multiple Sizes
- Rent or Buy

Materials: (often)

- Higher Quality Facing Mat'l
- Metal "support system"
- Ties appropriate for the "system"

Tie Spacing

- Spaced @ or > "Stick built"

Uses

- Multiple Reuses
- Regular shapes


Panelized System

Metal & Fiberglass

Often Built:

- Specifically for a project
- Examples:
  - Multi-level Shear Walls
  - Exposed /Architectural

Materials: (often)

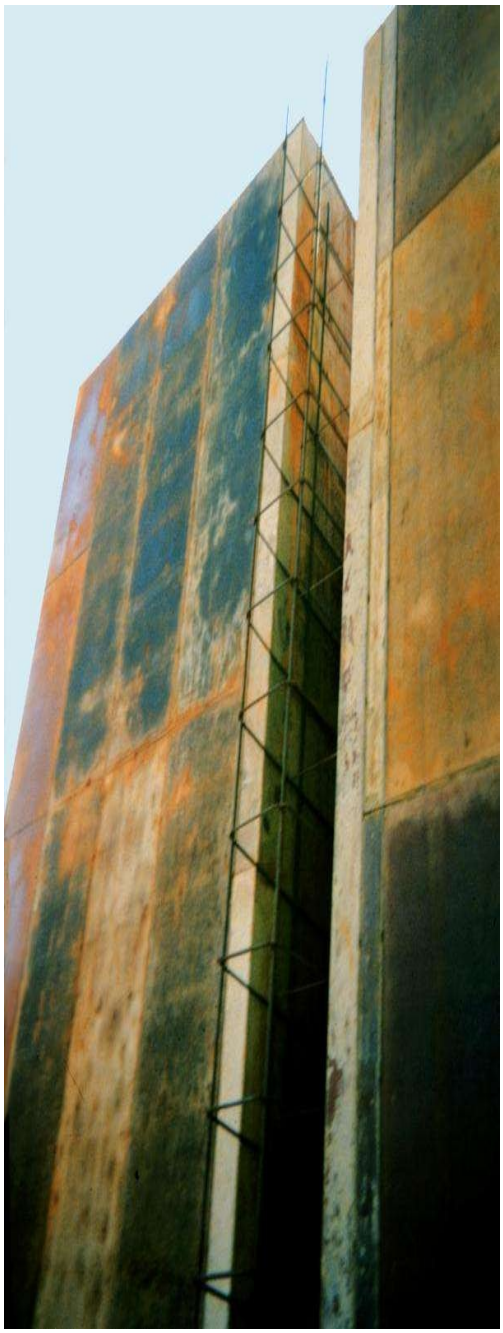
- High Quality Facing Mat'l
- Higher "quality / strength" Ties

Tie Spacing

- Larger spacing

Uses

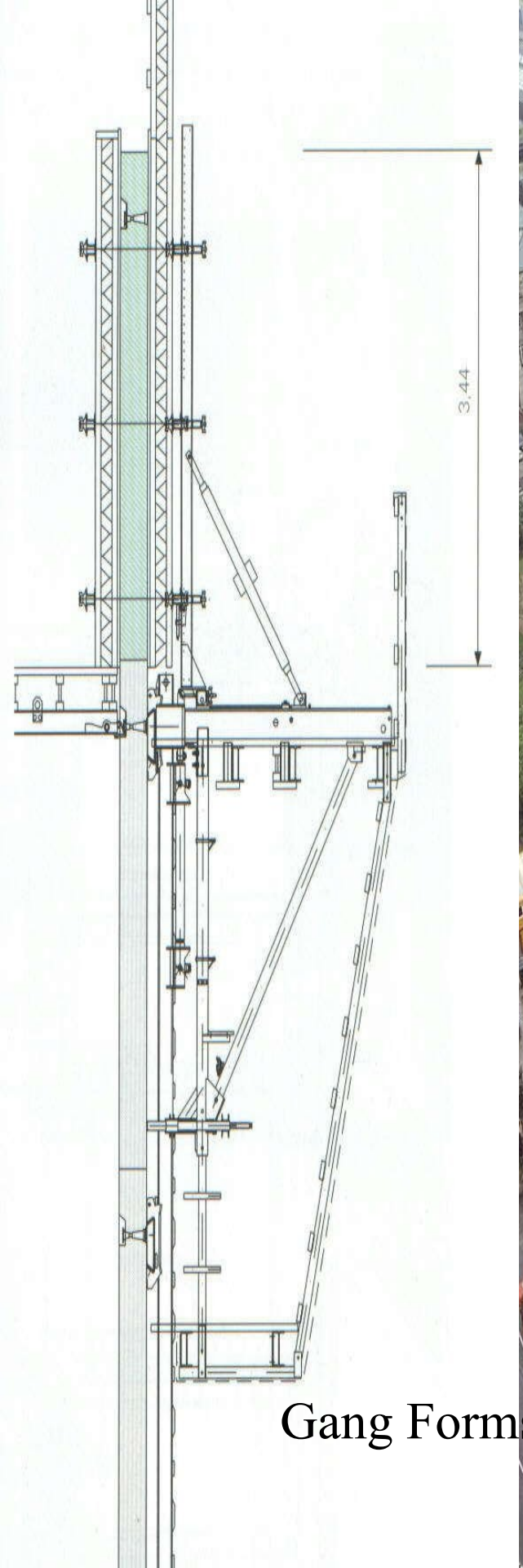
- Multiple Reuses
- Irregular or Regular shapes



Gang Forms

Assemble formwork into large sections

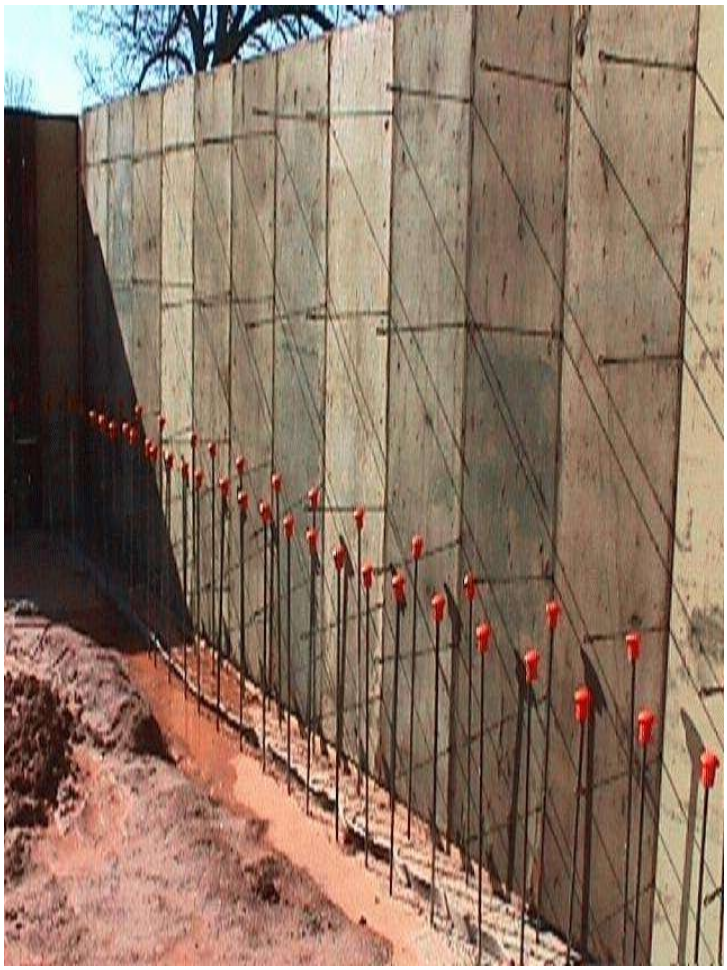
- Stick built, Panels, or any other system
- Minimizes labor, increases equipment requiren
- Increases speed of construction
- Generally used only for large, similar & repeat

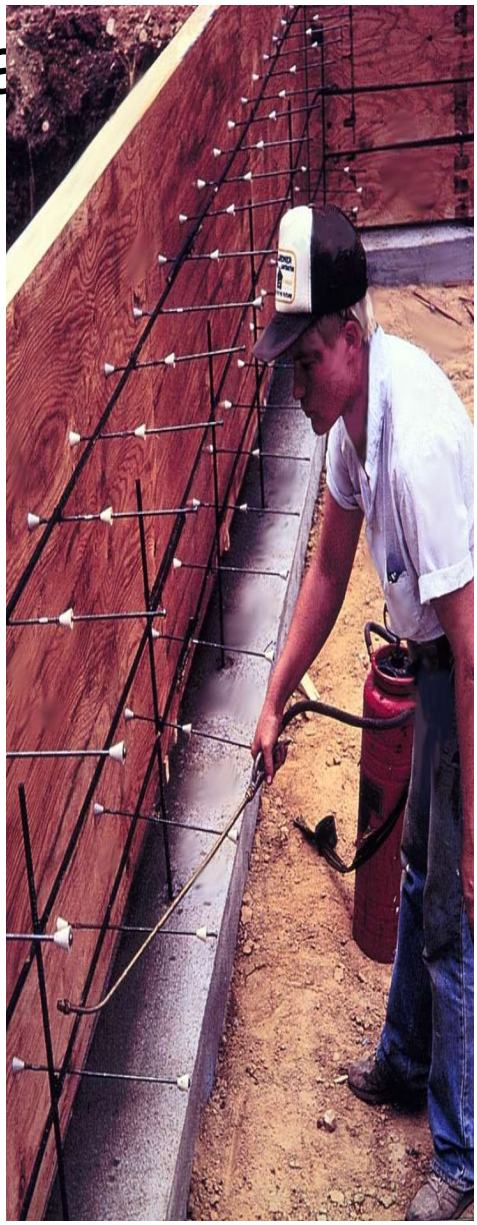


Gang Forms

Casting A Concrete Wall (cont)

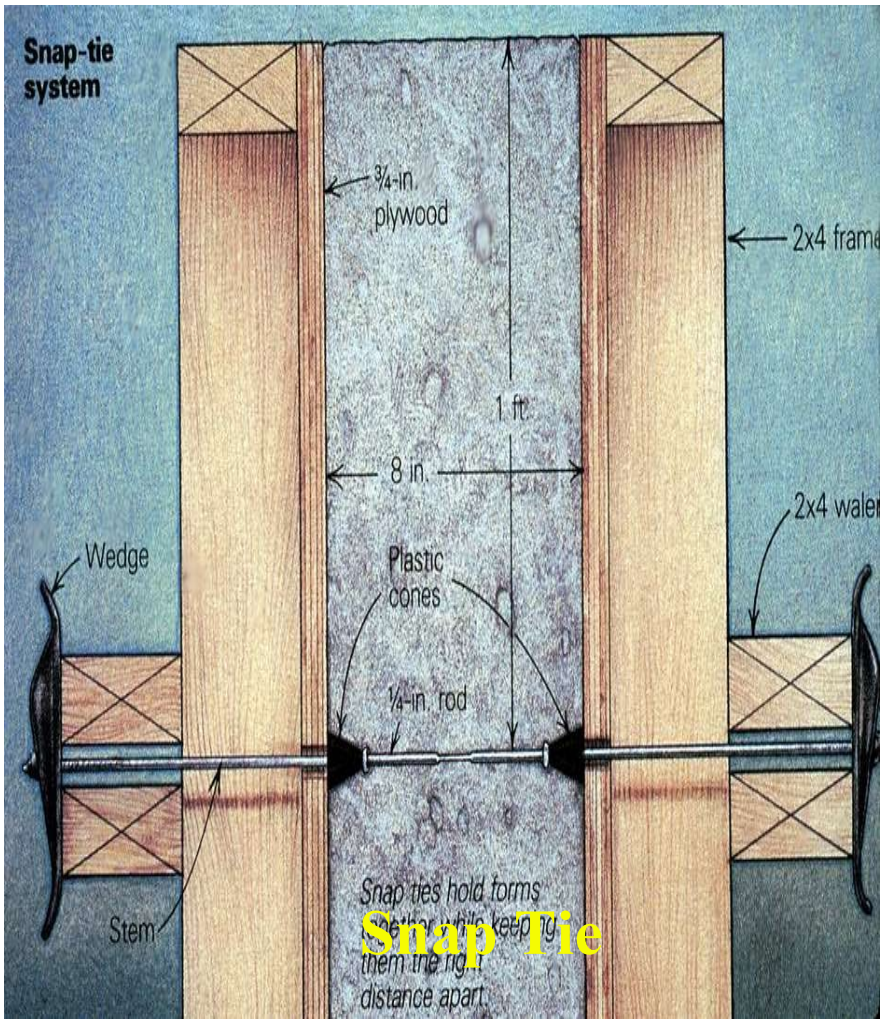
- Layout, Install one side, anchor, & brace
- Coat w/ Form Relea



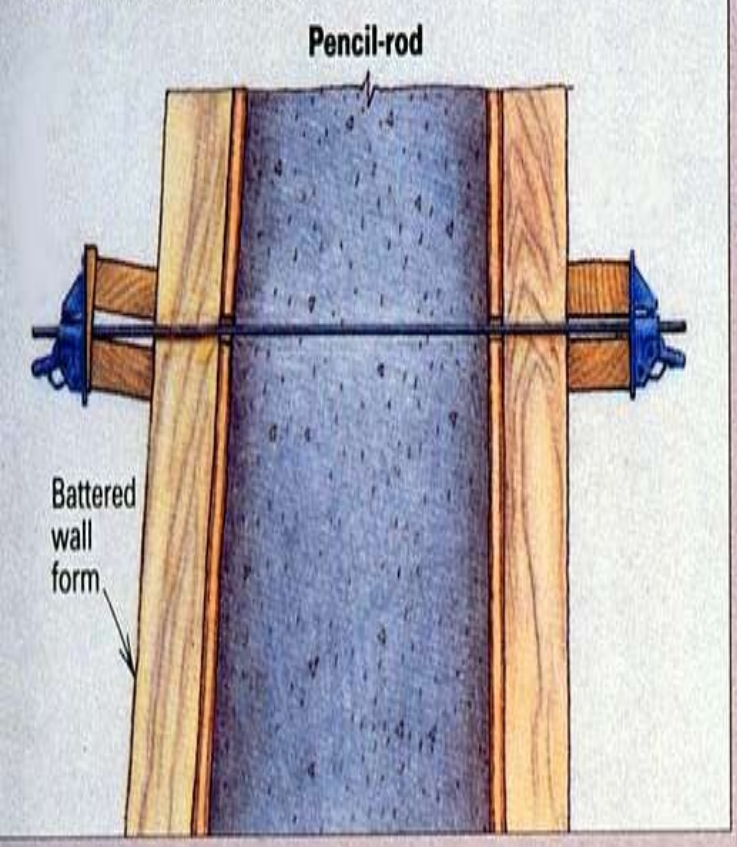


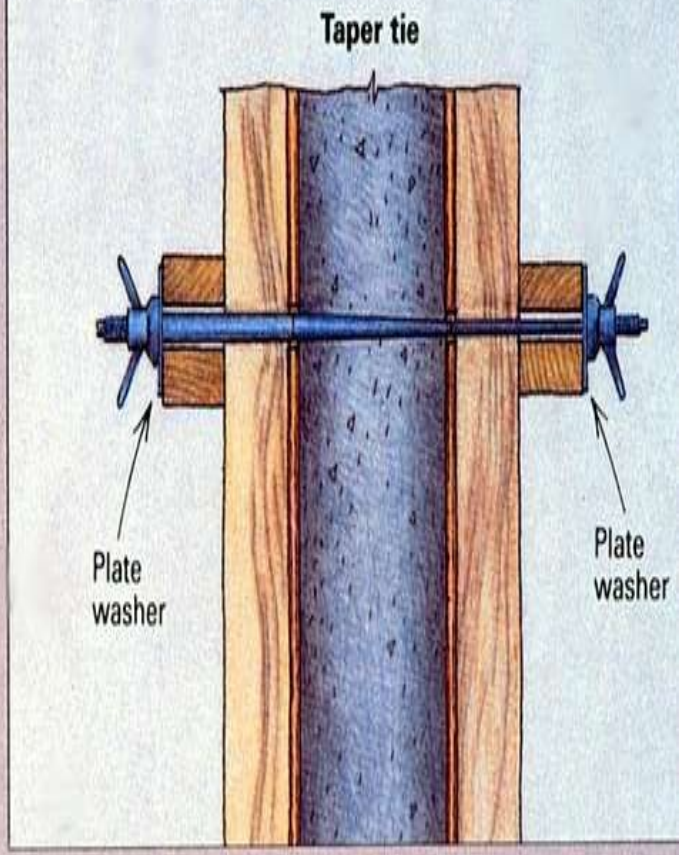
Casting A Concrete Wall (cont)

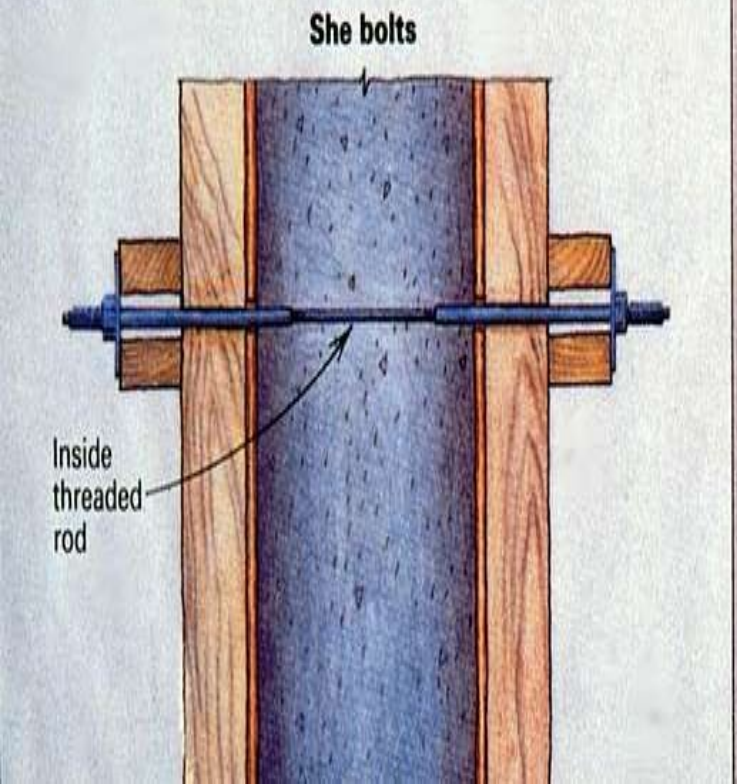
- Install Form Ties
  - "Small diameter metal rods which hold the forms together (generally remain in the wall)

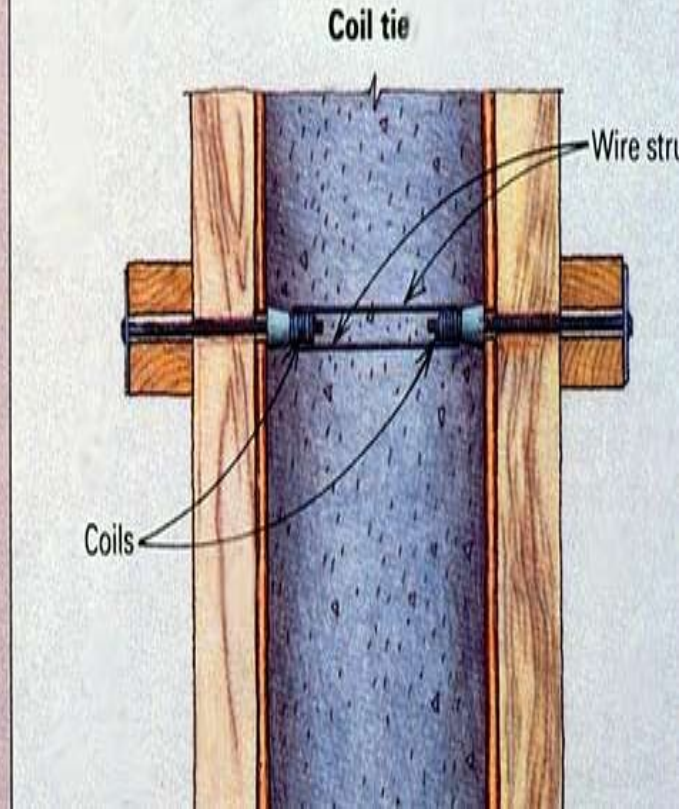


Alternative form ties

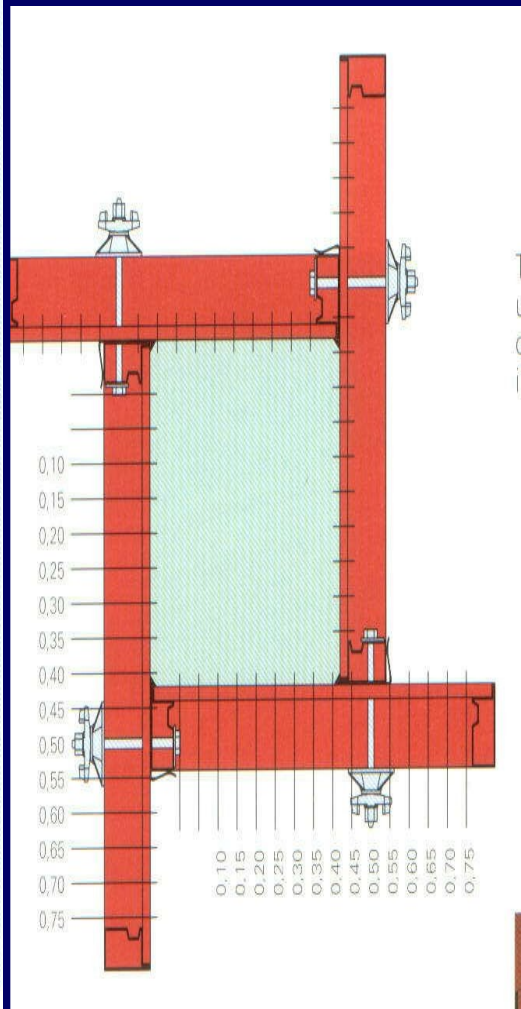








olumn Form Materials



Panelized Formwork

Formed and Braced

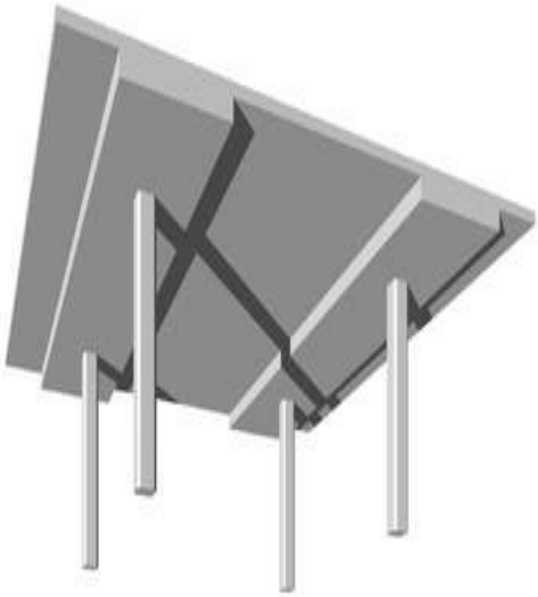
Sonotube – Waxed Cardboard
Column Form Material

Stripped Column

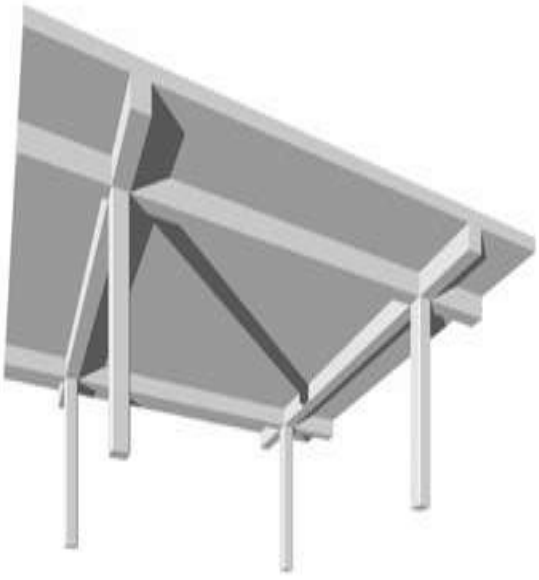
Note the spiral formwork markin

Elevated Framing Systems

- One-Way System
  - Spans across parallel lines of support furnished by walls and/or beams



- Two-Way System
  - Spans supports running in both directions



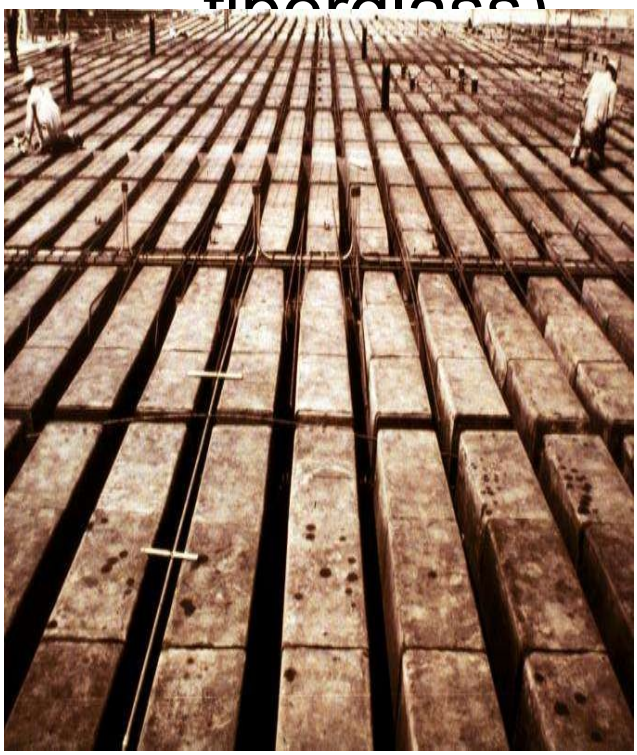
One Way Elevated Framing Systems

- One-Way

  Flat-Slab
  - Limited Depth
  - Limited Spans
  - Shorter Story Hghts
  - Underside often exposed

One Way Elevated Framing Systems

- One-Way Joist System
  - Span Greater Distances, Less Dead Load
  - Spaced ribs or joists w/ a thin top slab
  - Utilizes pans (metal, plastic, fiberglass)



One Way Elevated Framing Systems

- Wide-Module or Skip-Joist System

One-Way Slab & Beam

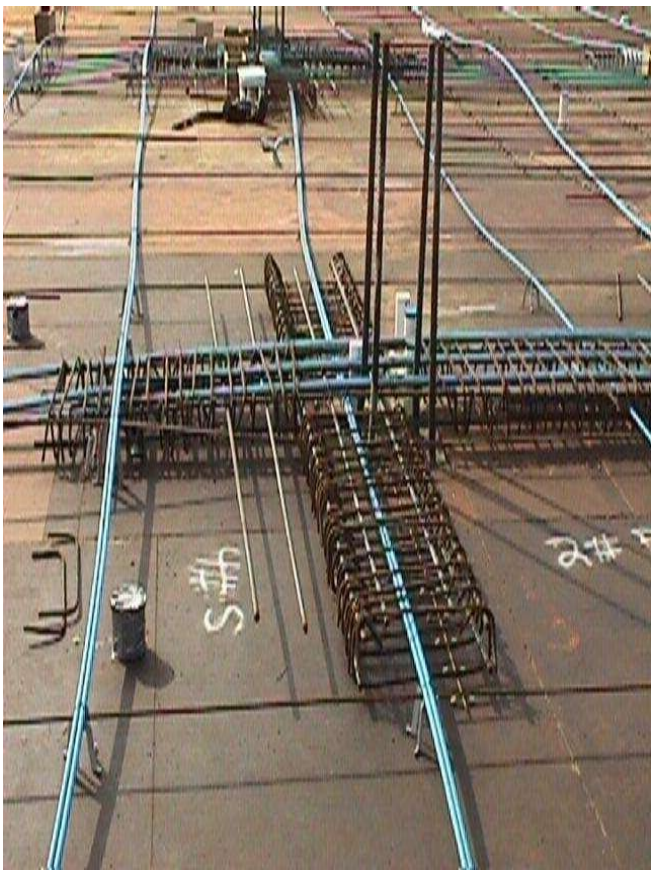
One-Way Slab & Beam

Elevated Framing Systems

- Two-Way Framing Systems
  - Often more economical than One-Way if:
    - Bay spacing (columns) square
  - Can be accomplished with a flat slab, joists, beams, etc.
  - Often associated with higher loadings

Two-Way Flat Slab

- Flat slab w/ reinforcing



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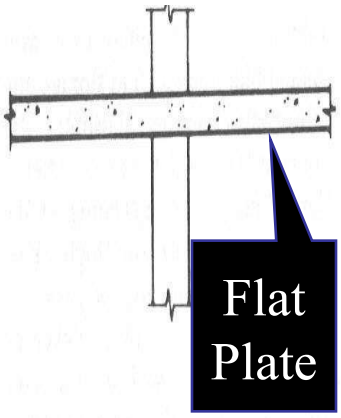
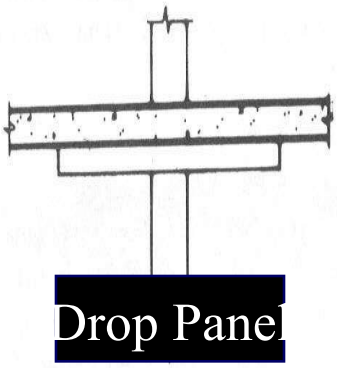
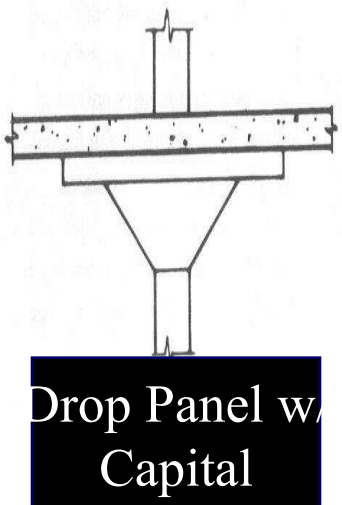
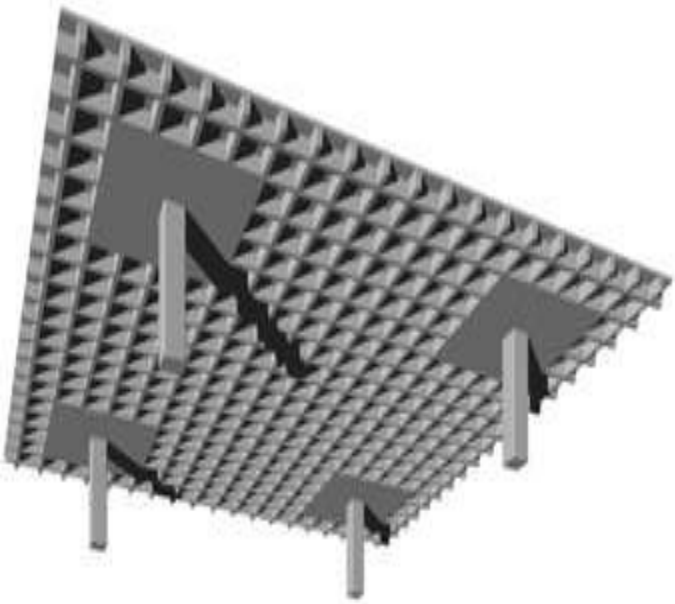
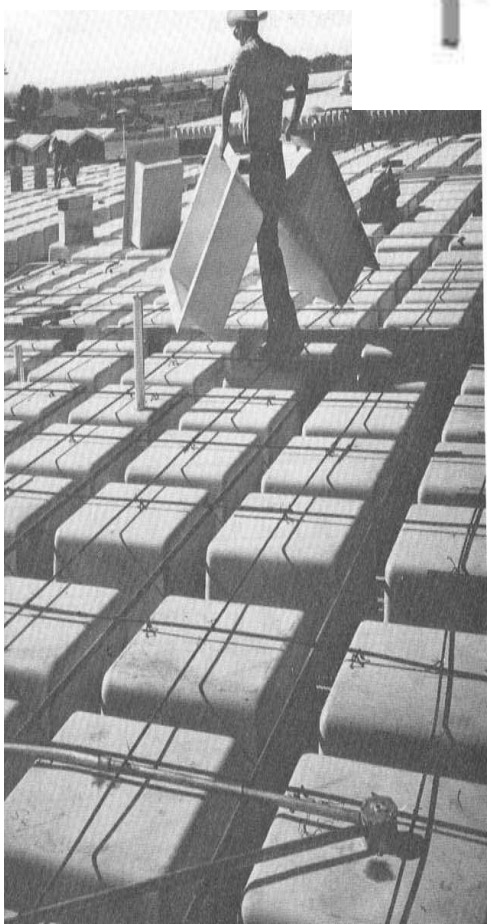






Two-Way Waffle Slab





Elevated Framing Systems

Factors to Consider

- Bay Spacing - Square or Irregular
- Span Length
- Loading
- Ceiling Treatment
- Lateral Stability

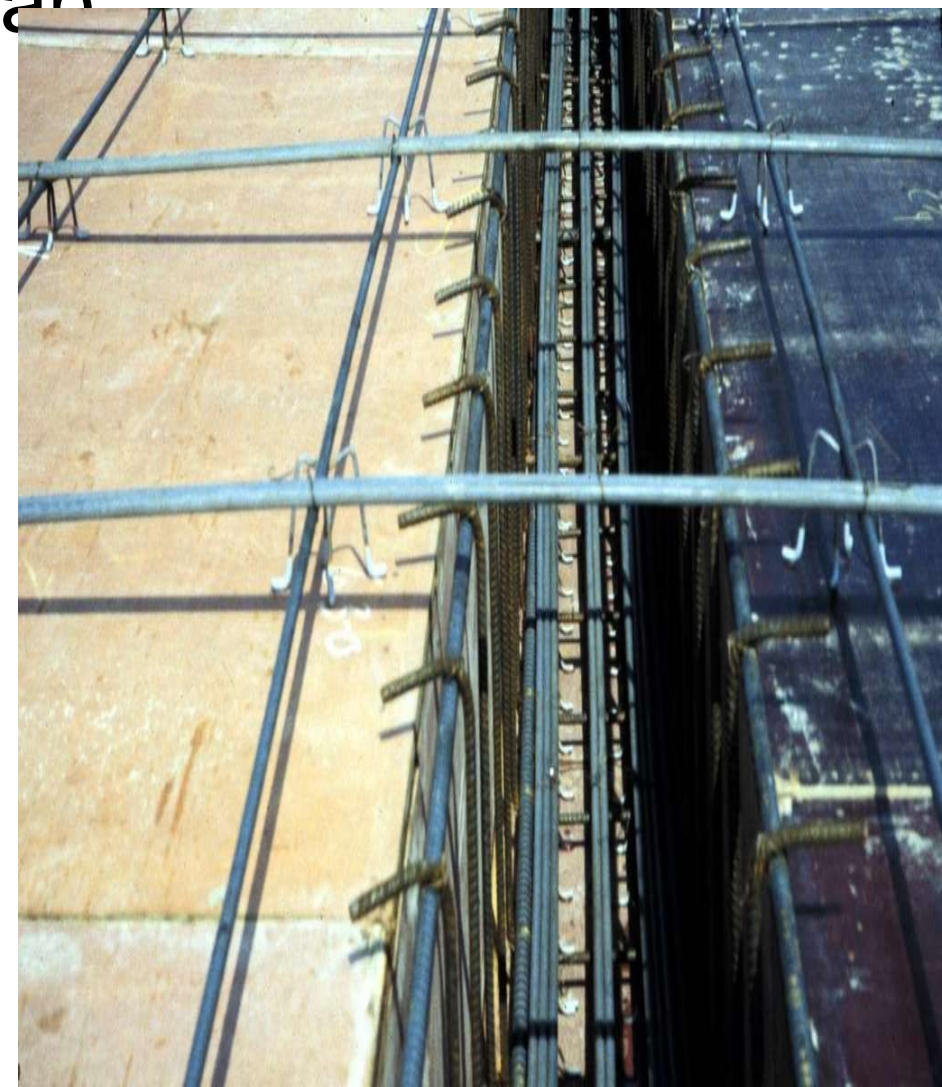
Elevated Slab Preparation

Prior to Formwork Construction

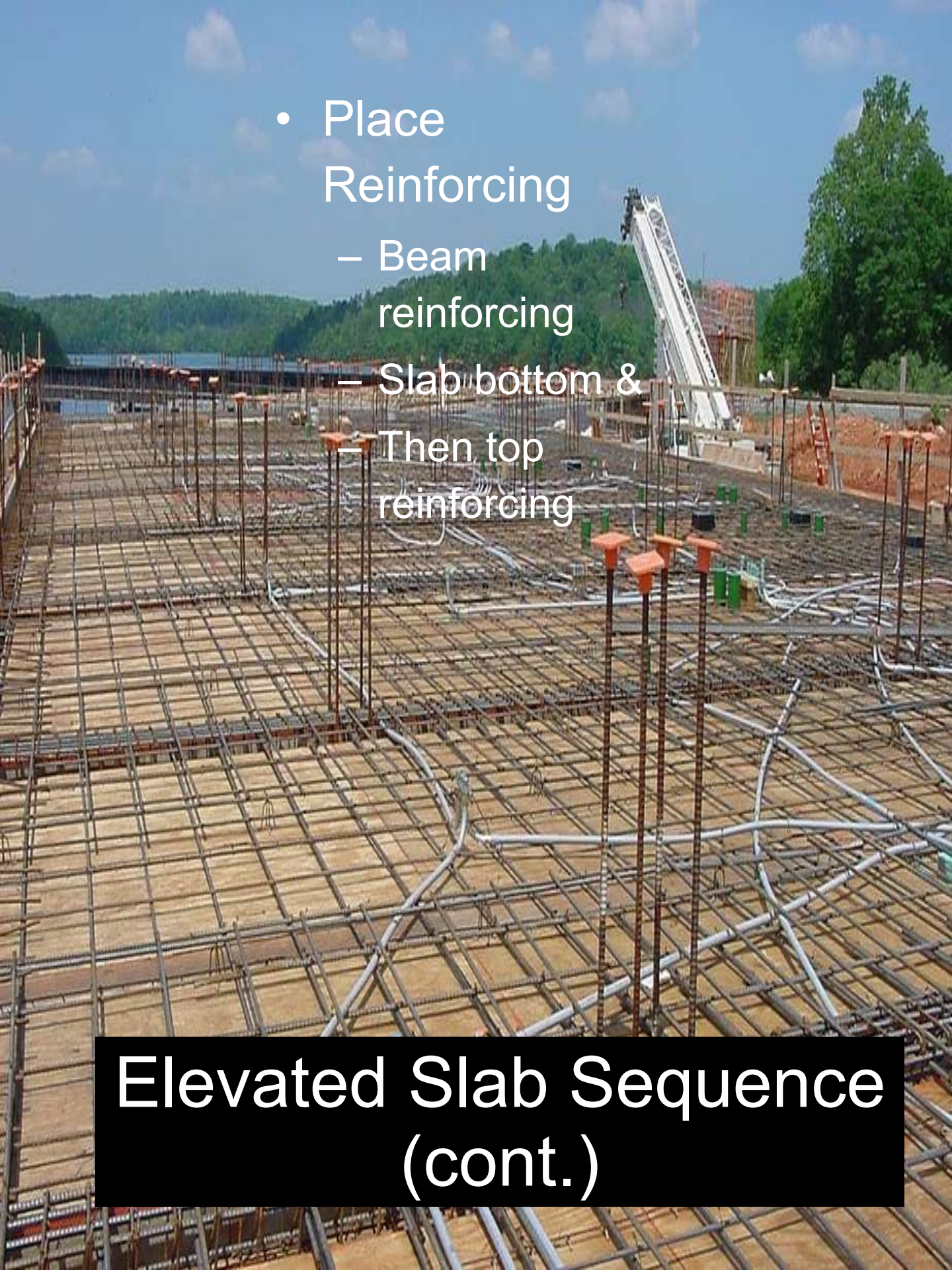
- Prepare, submit, & approve Engineered Shop Drawings
- FRPS supporting walls/columns

Elevated Slab Sequence

- Set Beam Bottoms (if required)
- Erect Beam Sides
- Form Slab




Form Beam Bottoms & Sid



- Place Reinforcing
  - Beam reinforcing
  - Slab bottom &
  - Then top reinforcing

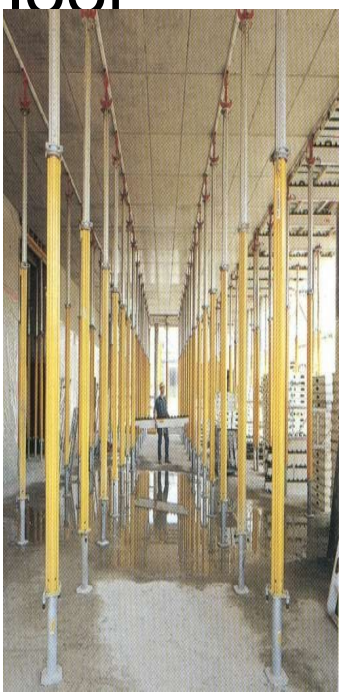
Elevated Slab Sequence (cont.)

Elevated Slab Sequence (cont.)

Place, Consolidate, & Finish
and Cure

Elevated Slab Sequence (cont.)

- Strip Formwork & Re-shore
- Re-shore (May Extend 3-4 Floors Below)
- Re-shore Purpose - Support
  - Construction Load
  - Weight of the next Floor



Elevated Slab Sequence

The following group of photos shows the sequence for installation of a one-way elevated slab.

(Slab & Beam with Reinforcing & Post-Tensioning)

ns Placed & Form Support (Scaffolding) Being E

n Support (Scaffolding) Being Erected

king Support Beams Being Erected


wood Decking Being Erected

ood Decking and Beam Sides Being Erected

ood Decking and Beam Sides Being Erected

vood Decking & Beam Sides Erected

od Decking and Beam Sides Erected on a Portio

k Support System (Scaffolding)

am Reinforcing Installation

am Reinforcing Installation

am Reinforcing Installation

am Reinforcing Installed

m & Deck Reinforcing Installed

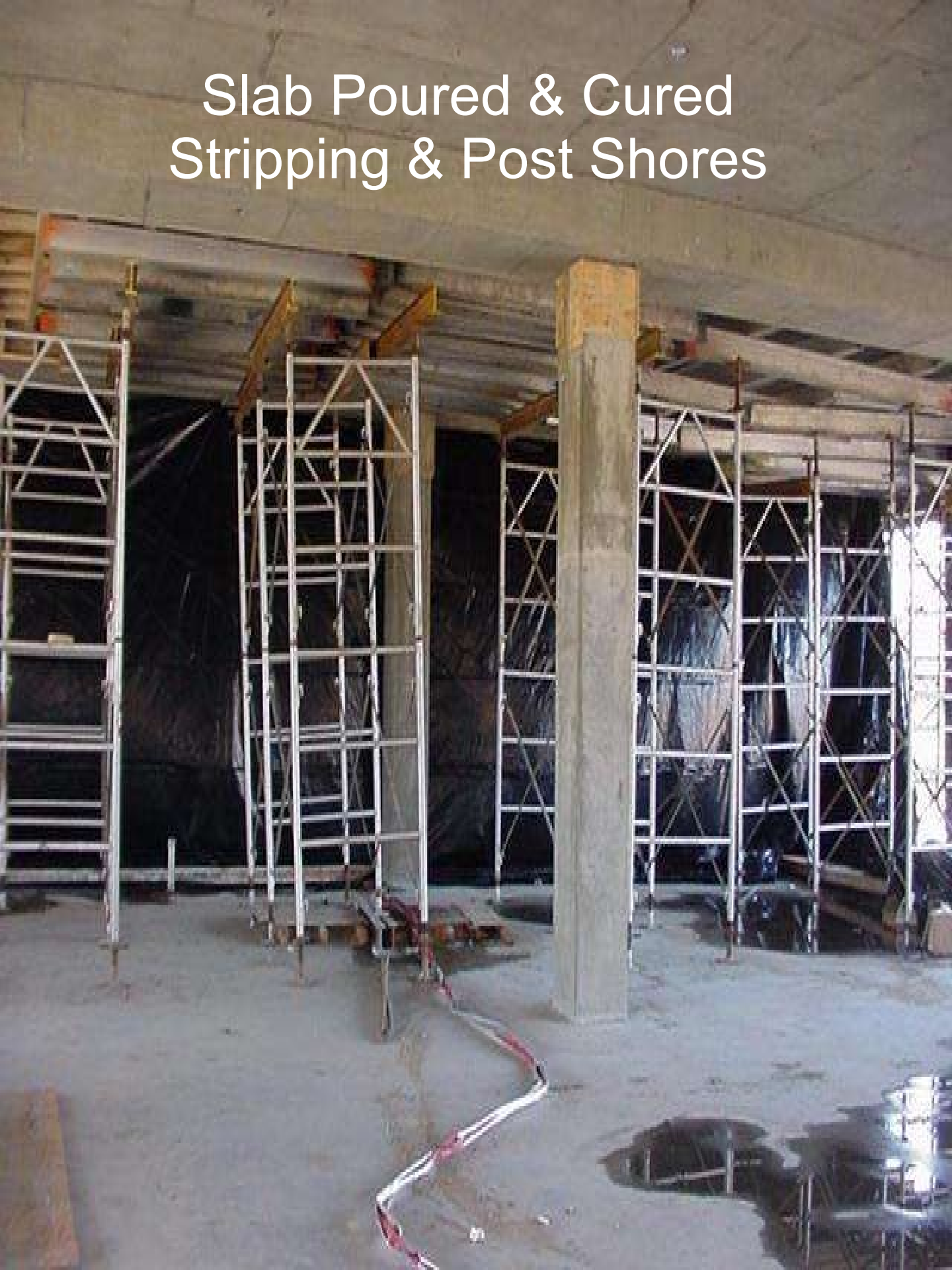
st-Tensioning Installation

st-Tensioning Installation


st-Tensioning Installed

Tensioning Complete and MPE Sleeves Installed

Slab Poured & Cured
Stripping & Post Shores



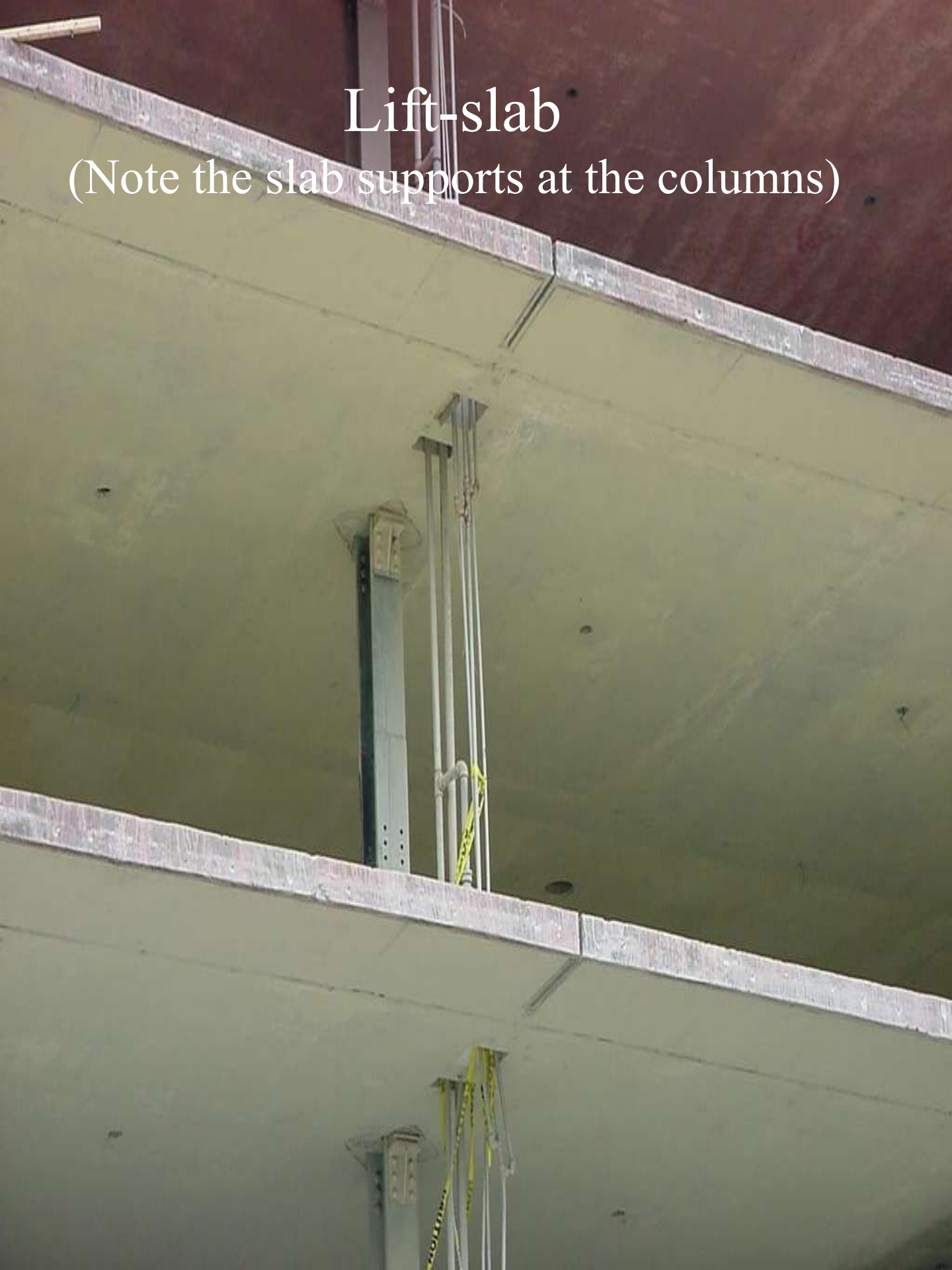
ripping formwork


ripping formwork


nwork Stripped and Reshores Installed

Site Cast Post-tensioning Systems

- Can be used with any framing system
- Reduce member size and/or
- Extend span capacity


Lift-slab
(Note the slab supports at the columns)

Tilt-Up

Walls cast Horizontally & “Tilted” into Place

Commonly used in Warehouse, Distribution, Reta

The following group of photos shows the tilt-up sequence used for construction of a Home Depot


Slab-on-Grade Placed

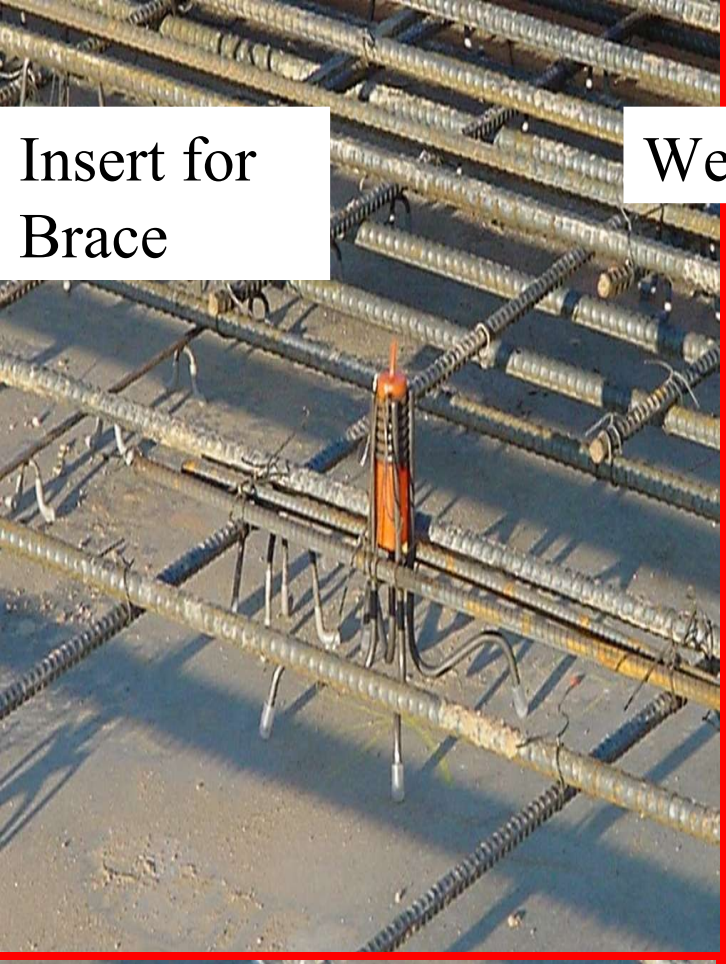

Formwork for Panels


Edge forms & Slab-on-Grade Placed


Opening Installed

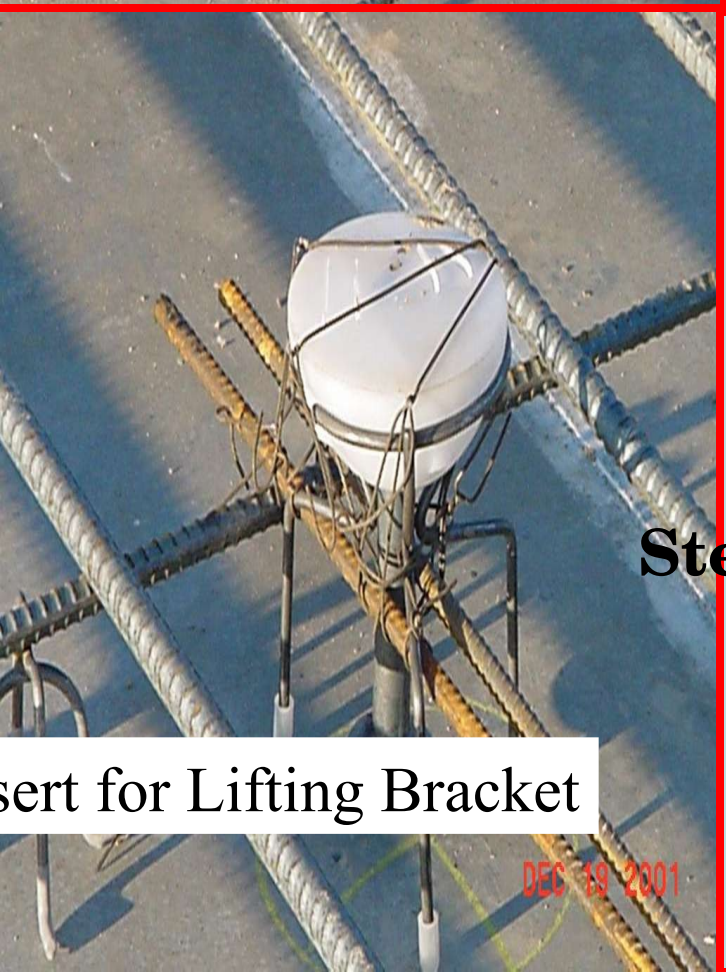

Panels formed and reinforced

Panels Formed and Reinforce
(Note the Inserts)



Insert for Brace

Weld Plate for Joist Attachmen



sert for Lifting Bracket

Inserts for

Panel Braces,
Steel Framing Anchorag
& Panel Lifting


Panels Poured

Lifting Inserts Stripped

Placement of Exterior Footing

Crane for Panel Installation

aces Installed Prior to ‘tilting-up’ the panels

Attachment of Lifting Bracket

Panel being lifted (tilted into place)

Panel being lifted (tilted into place)

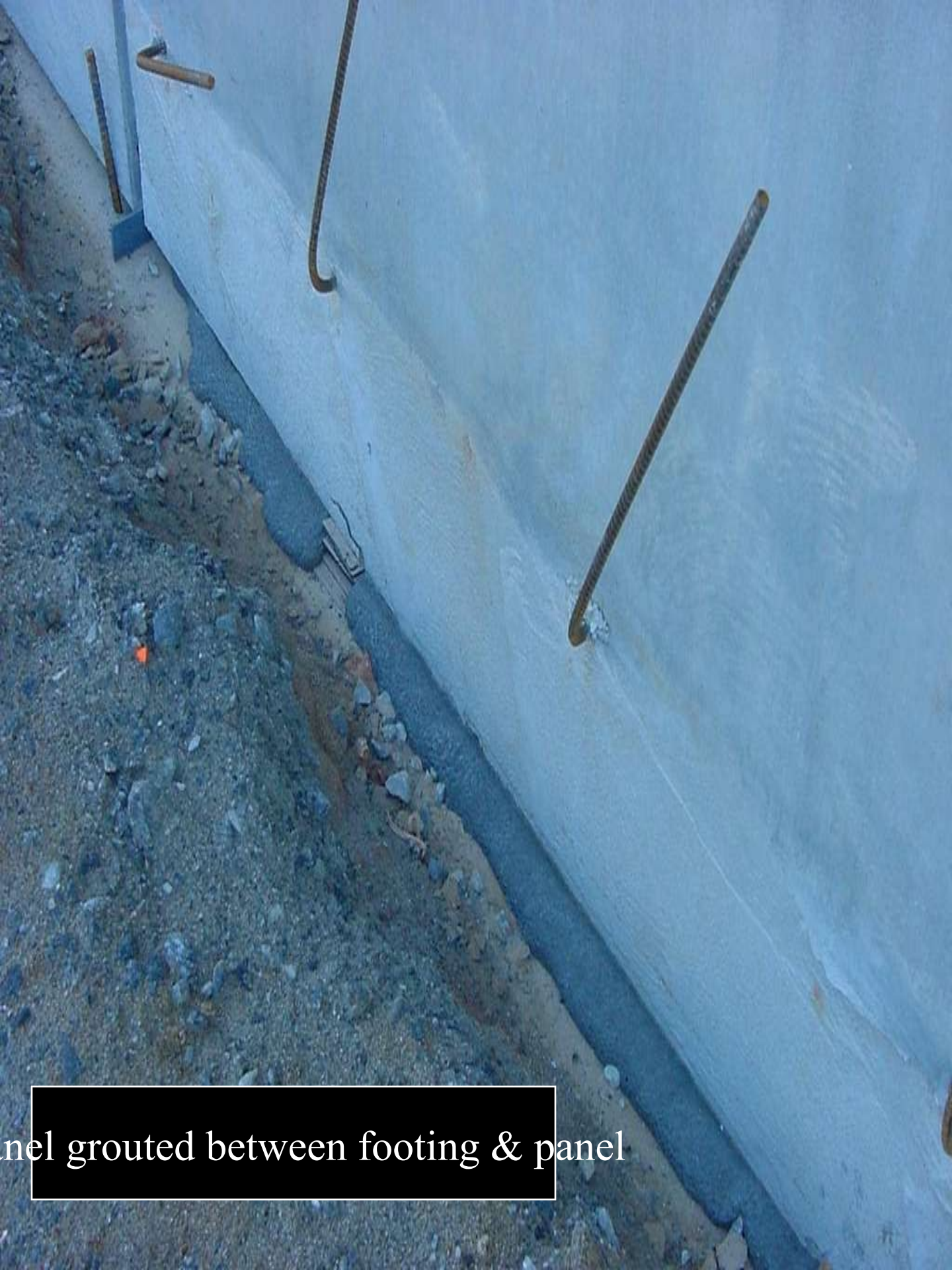
Panel being lifted (tilted into place)

Panel being lifted (tilted into pla

being placed on shims set to proper elevation

Panels being braced


Panels braced



nel grouted between footing & panel

Roof support structure anchored to panel

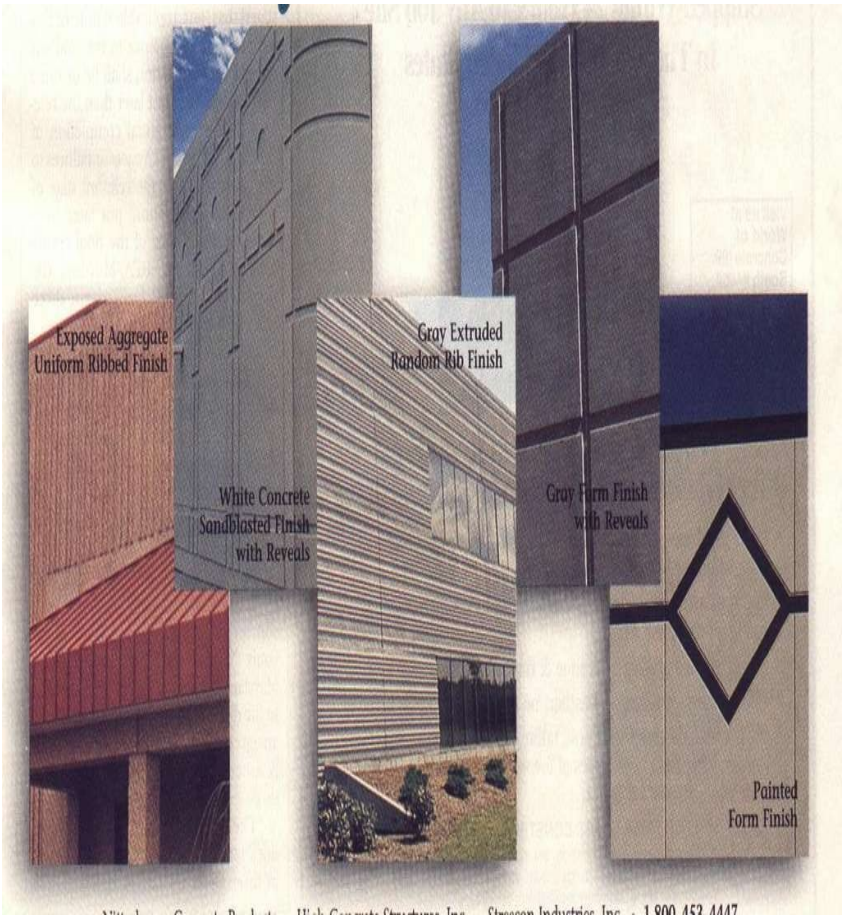
ade prepared for panel structural connection to Slab-on-

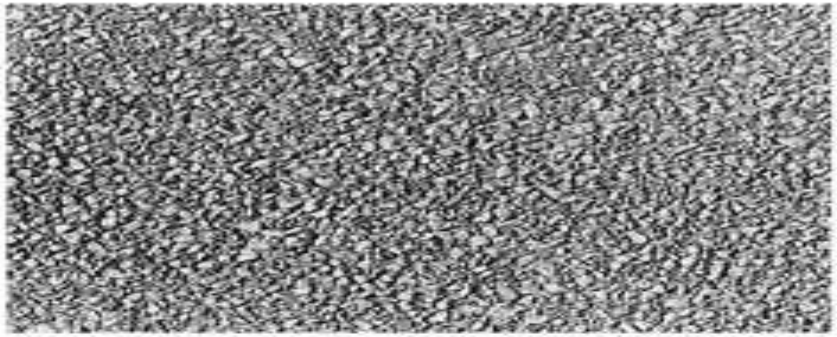
Slab-on-Grade perimeter poured to anchor the panel bottom.

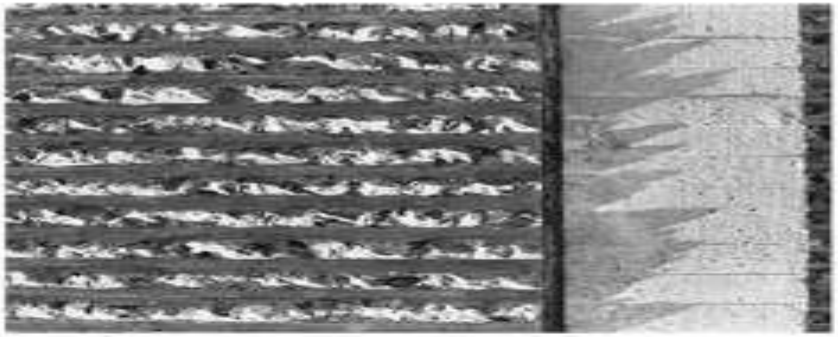

Panels erected

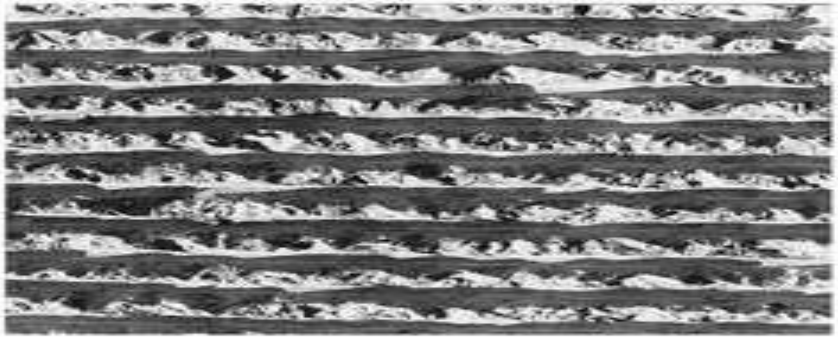
Architectural Concrete

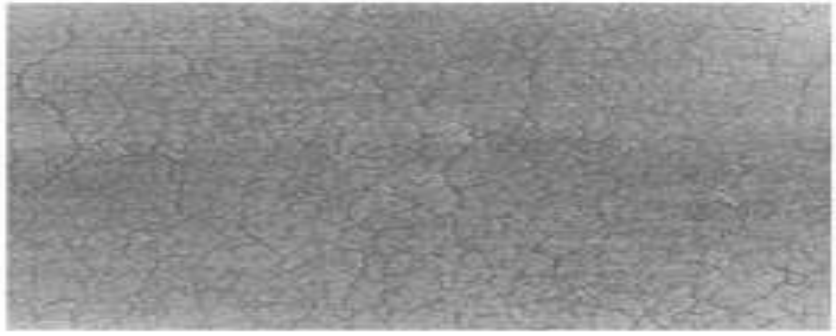
Concrete that is left exposed as finished interior or exterior surfaces.

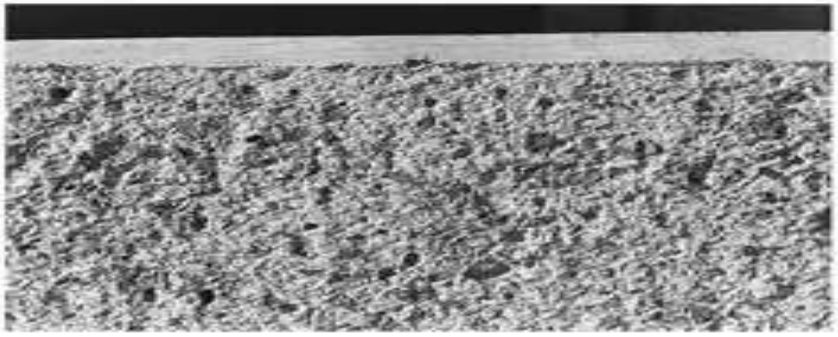












Exposed ‘Architectural’ Concrete at the University of Iowa

Exposed ‘Architectural’ Concrete at the University of Iowa

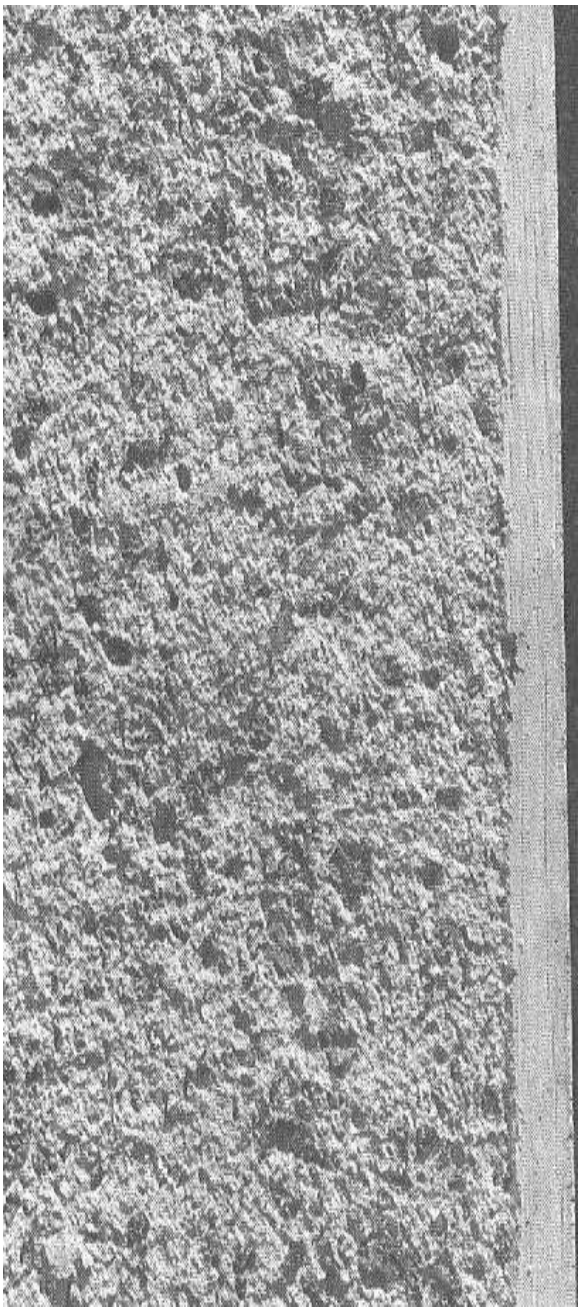
Exposed ‘Architectural’ Concrete
(Note the rough finish)

Architectural Concrete Finishes

- Exposed Aggregate
  - clean off paste
  - & expose aggregate
- Key
  - Aggregate choice
  - Mix Placement

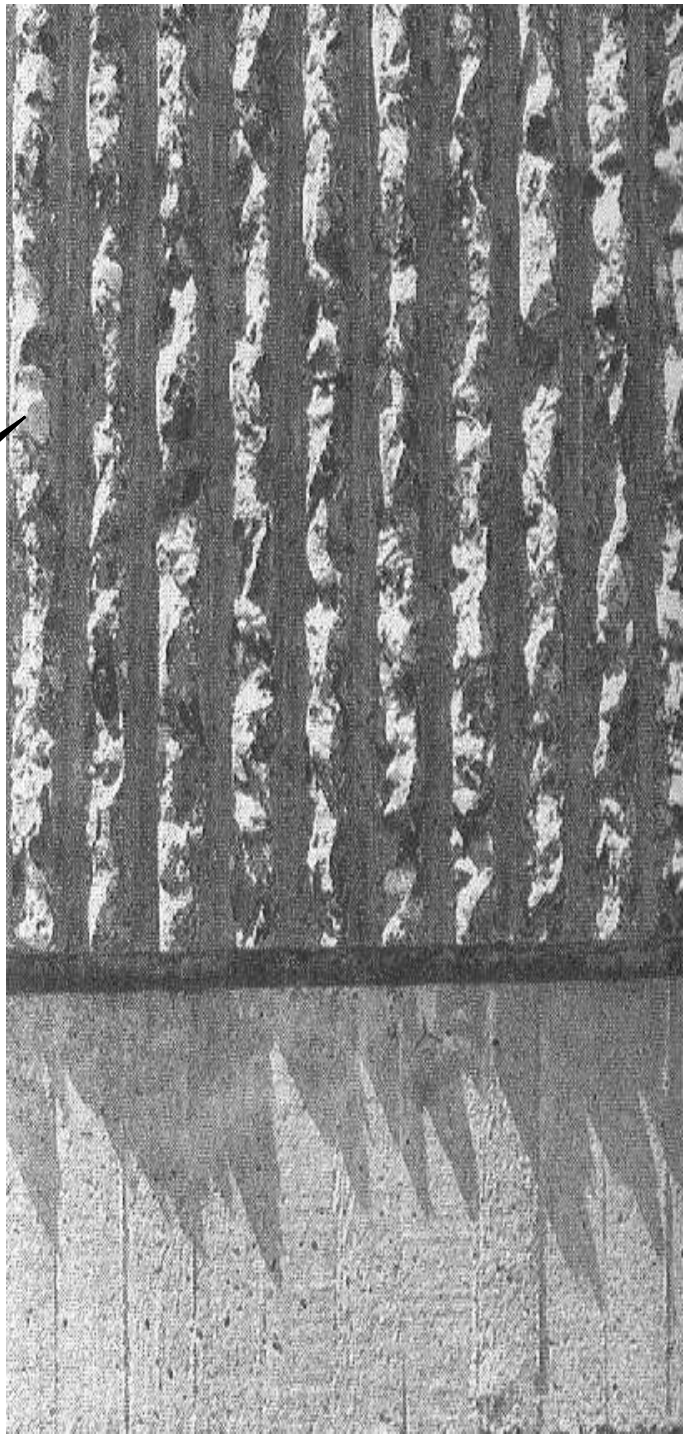
Architectural Concrete Finishes

- Mechanically remove the paste
  - Sand Blast
  - Bushhammer



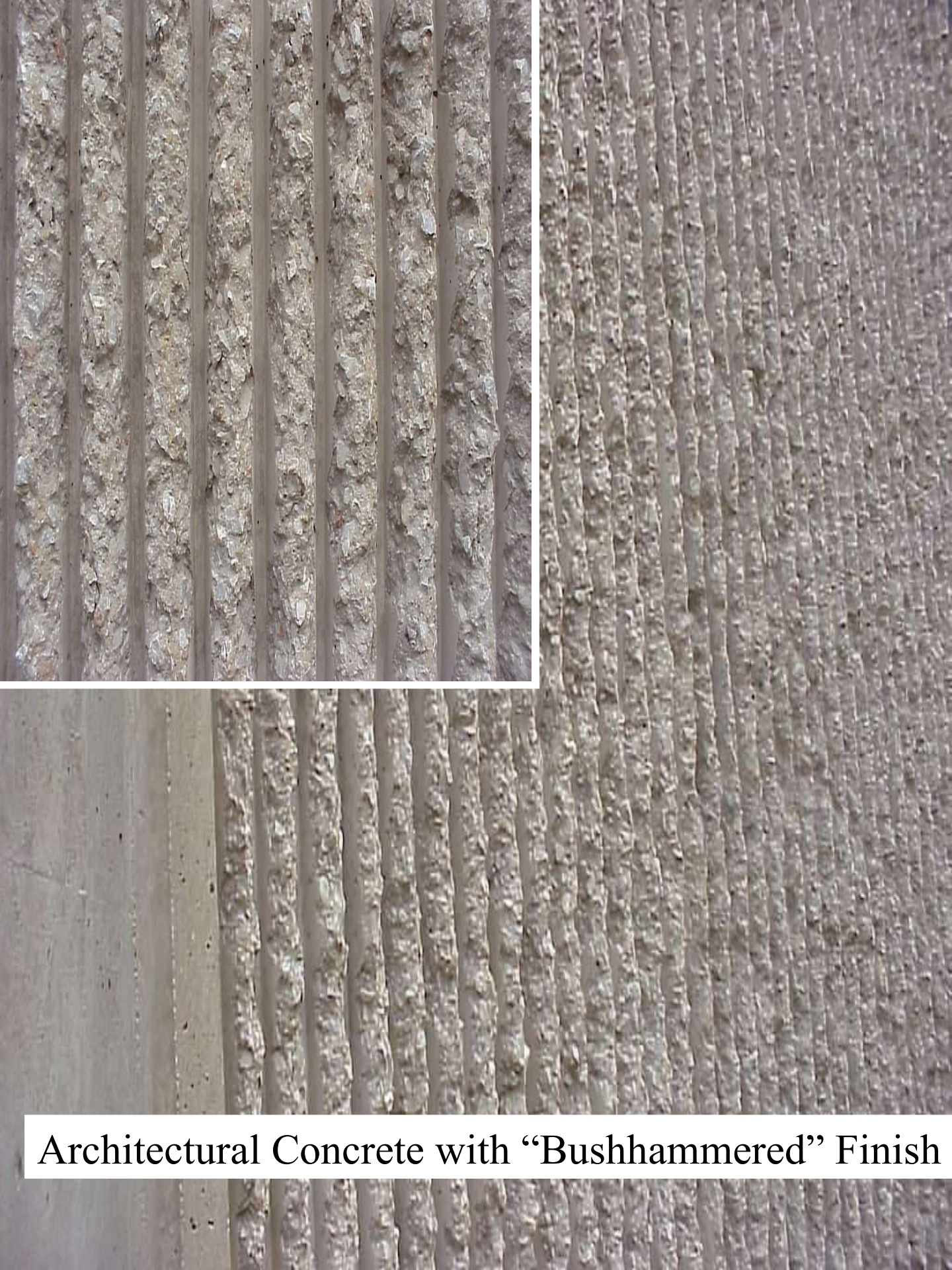
Architectural Concrete Finishes

- Liners & Form mat'ls
  - Multiple # of Finishes



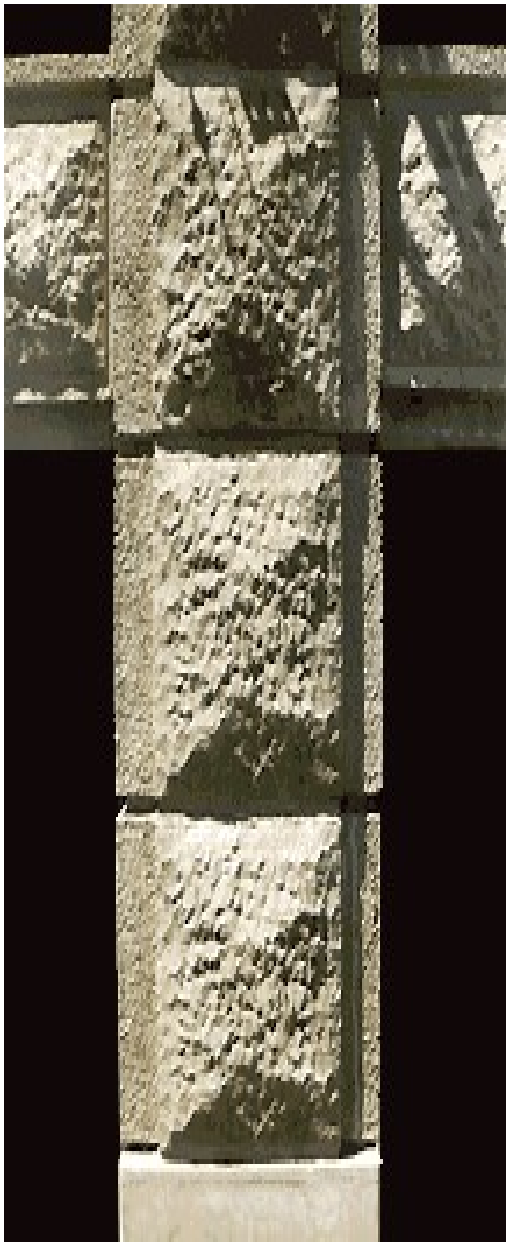
Form Liner & Bush-hammer

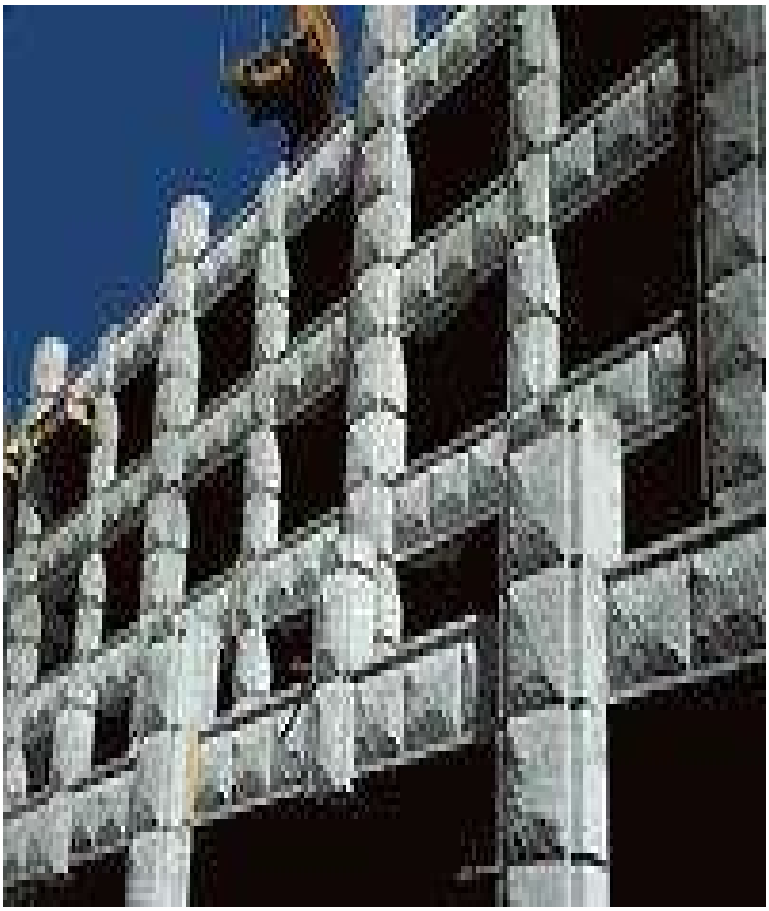
Architectural Concrete with “Bushhammered” Finish



Architectural Concrete with “Bushhammered” Finish

Simulated Stone Form Liner

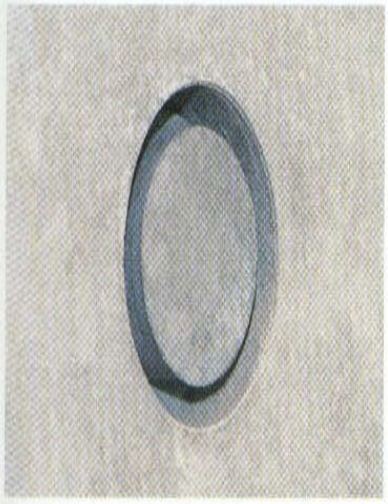


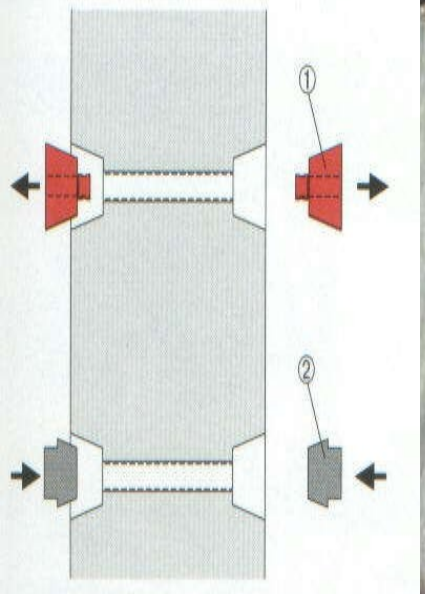



Form Tie Location
Rustication Location


Formwork Joint
Formwork Blemishes

Form Tie Holes





Rusted Bar Supports


Patching

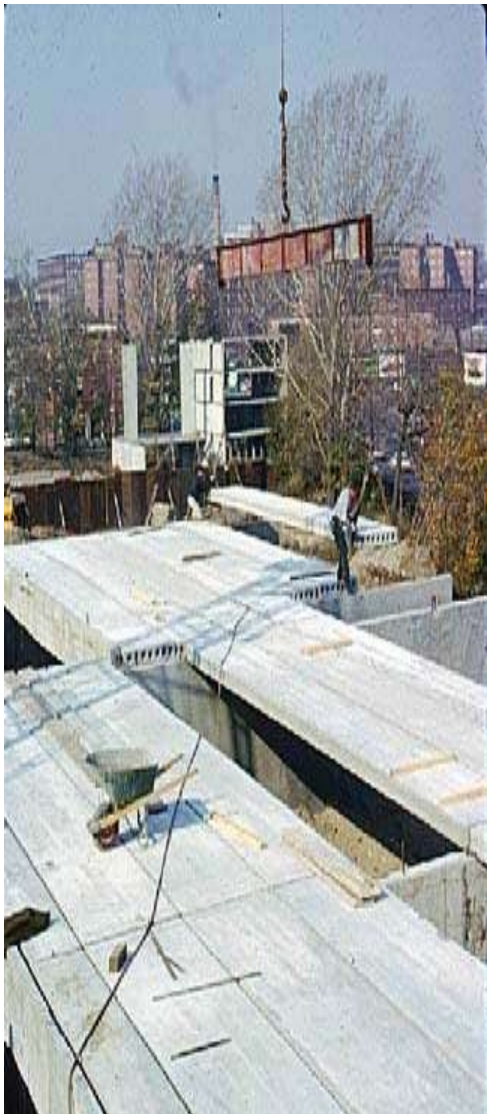
Designing Economically

- Of three elements - conc., reinf., formwork -
  - Formwork is generally the most expensive element
  - Formwork - high % of labor
- Economies - simplification & standardization
  - Identical bay spacing
  - Flat plate - when possible
  - Standardize column & beam sizes

Site Cast Concrete & Building Codes

- Fire resistant
  - Assuming adequate re-steel coverage
  - Most uses - Unlimited Height & Area
- Resistance to lateral loading
  - Rigid joints

PRECAST STRUCTURAL & ARCHITECTURAL CONCRETE




Turner

Precast Hollowcore Planks/Decking

Double Tee’s

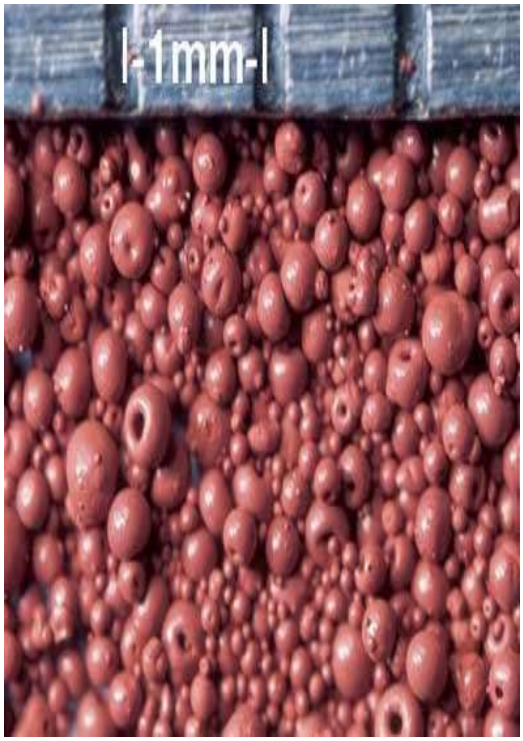
Single Tee’s

Prestressing process
and finished product

Parking Garage
both **sitecast** and **precast** concrete

Tarping process for vapor curing of hollow cure planks

Correctional Facility in Texas


I-1mm-I


MIX READY
MIX READY
MIX READY
MIX READY

PRECAST CONCRETE
+
POURED IN PLACECONCRETE

- PRETENSIONED
- PRESTRESSED

Hollowcore Precast Concrete Plank

- precast, prestressed concrete continous
- voids reduce weight, cost
- electrical or mechanical conduits
- top surfaces can be prepared for the installation of floor covering
- underside can be used as a finished ceilling
- excellent fire resistance

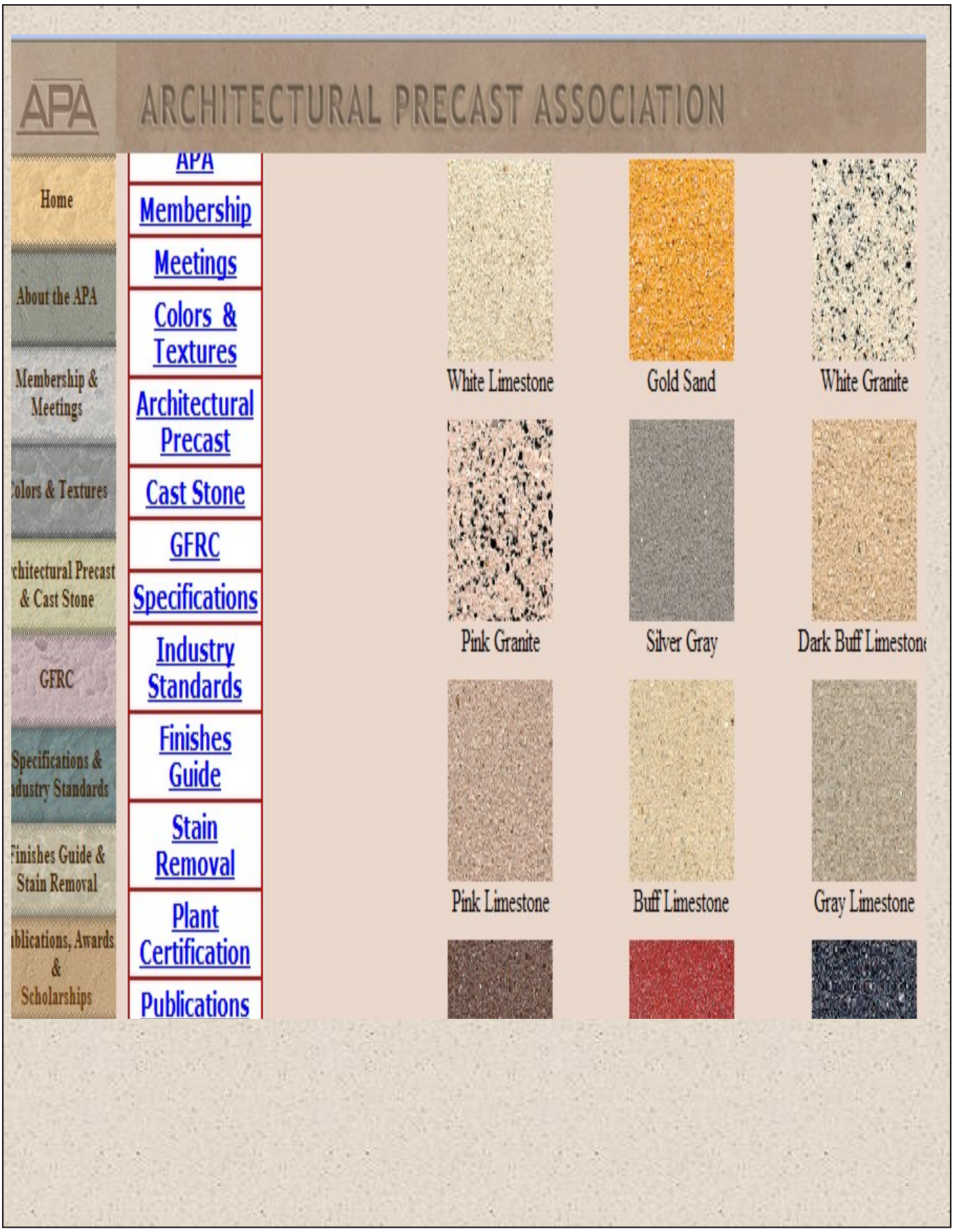
SPANCRETE

http://www.pff.org.uk/PDFs/PFF_Hollowcore_and_prestressed.pdf

://webs.demasiado.com/forjados/tipologia/prefa/hormigon/alveolar2.

CAST-IN-PLACE CONCRETE

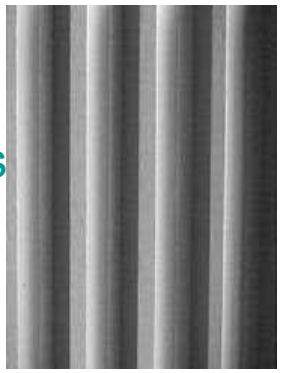
http://www.archprecast.org/



lily available colors. But any color can be custom ordered.

Wood Patterns

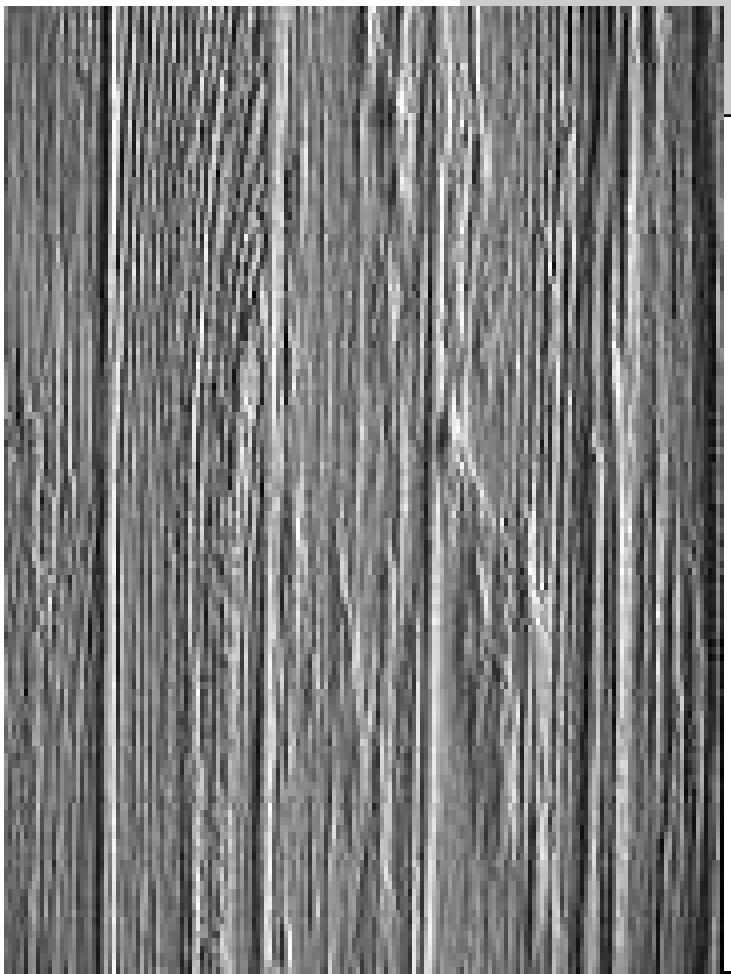
- Ribbed Patterns
- Fractured Patterns
- Other Patterns
- Form Liner Materials



Form Liners

r architectural concrete surfaces

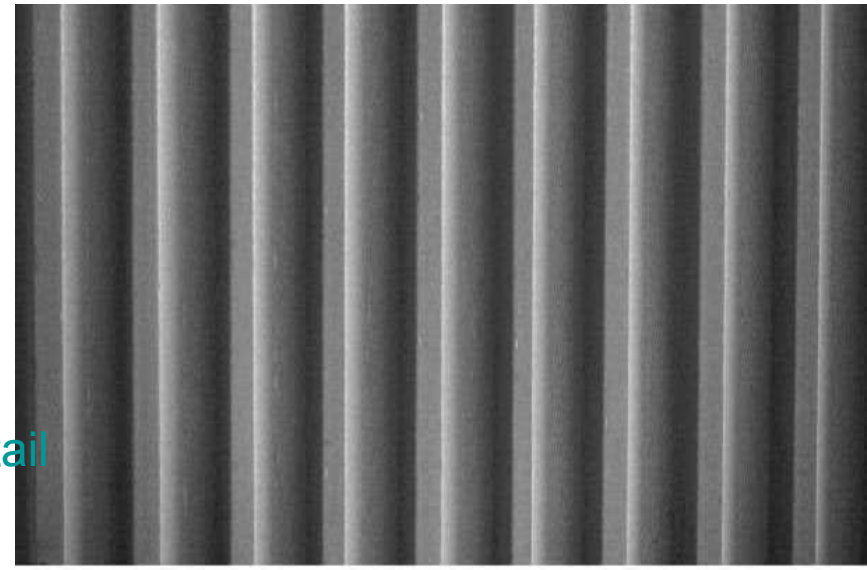
Wood Patterns

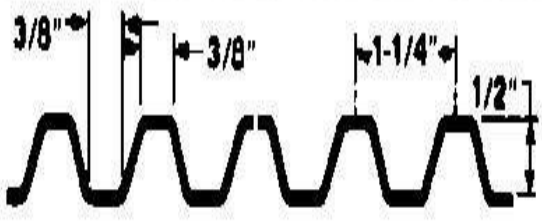


Patterns include:

- 4" Wide Aged Cedar
- 2" Wide Aged Wood
- 4" Wide Aged Wood
- Barnwood
- 6" Wide Cedar
- Cedar Stake
- Grooved Barnwood
- Rough-Sawn Plank
- Extra Rough-Sawn
- 1½" Variable Sawn
- Tongue and Groove

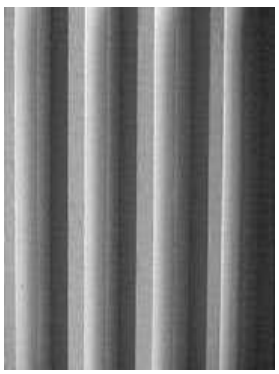
A Guide Specification
Form Liner "Cut Sheet" Detail





Form Liners

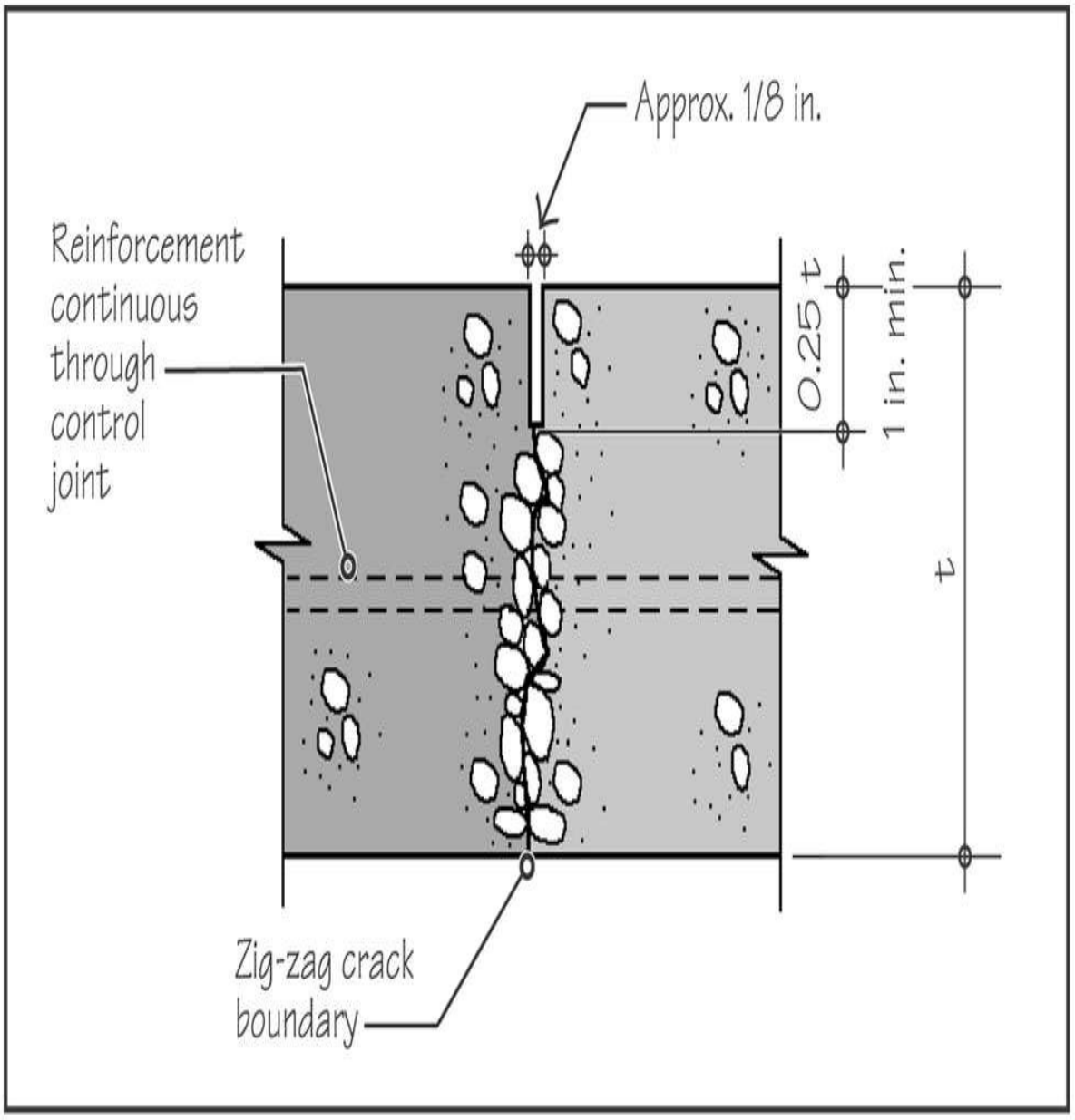
For architectural concrete surfaces



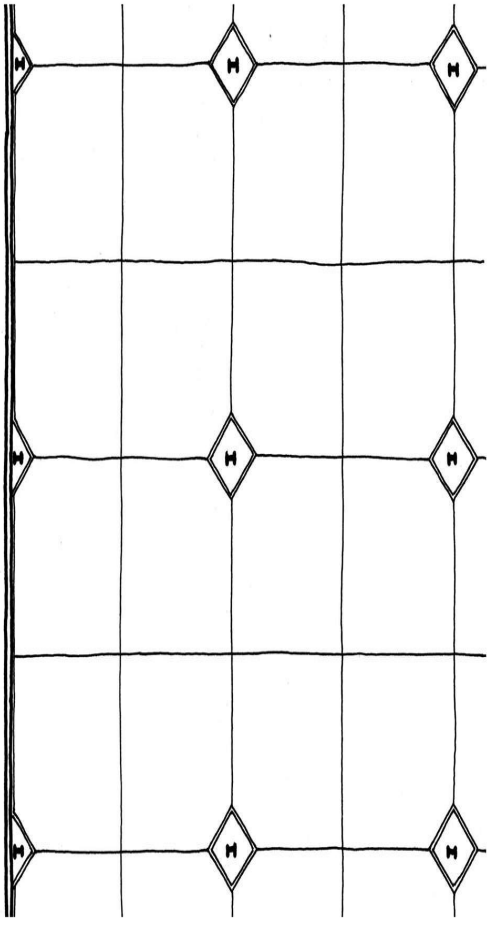
Ground-supported isolated concrete slab, cont'd

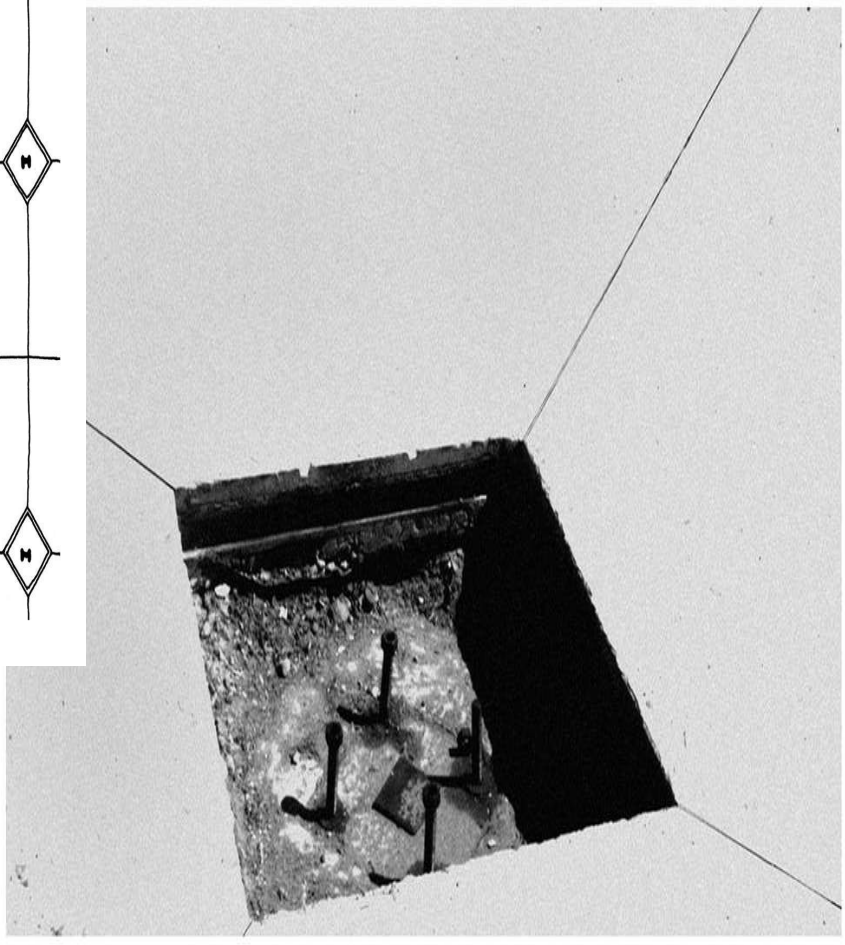
- Joints
  - Control joints
    - accommodate shrinkage, reduce random cracking
    - Extend about 1/4 of depth of slab
    - Typically 1/8 inch wide, sawcut or tooled
  - Isolation joints
    - Isolates slab from structural components
    - full depth of slab
  - Construction joint (cold joint)
    - Non-movement joint
    - Used where concrete cannot be placed in one operation
    - Shear key
      - prevents differential movement
      - Assures aggregate interlock

Section through control joint

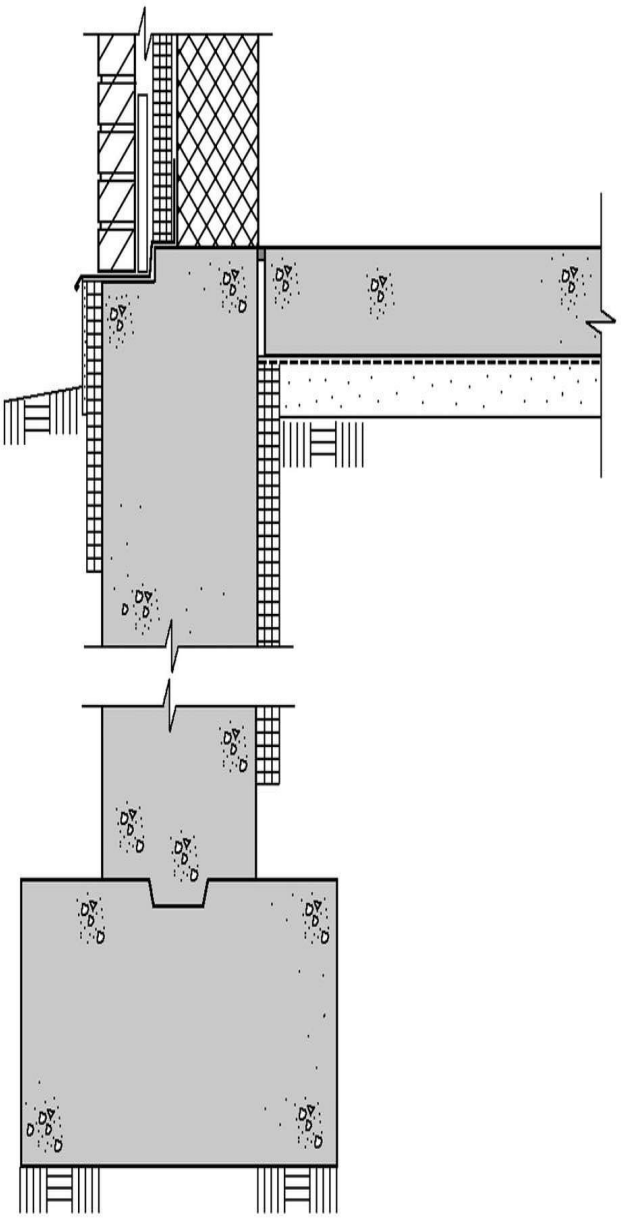


Isolation joints & control joints in interior isolated slab

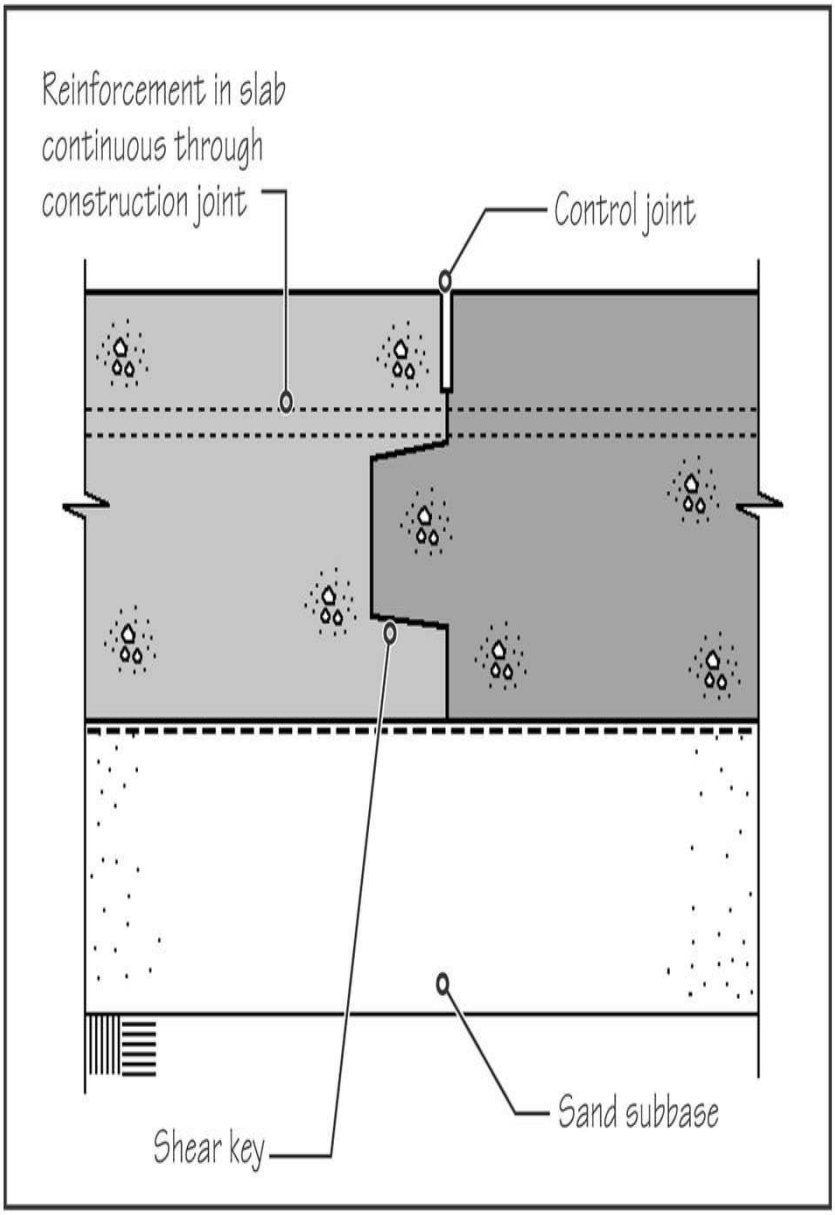




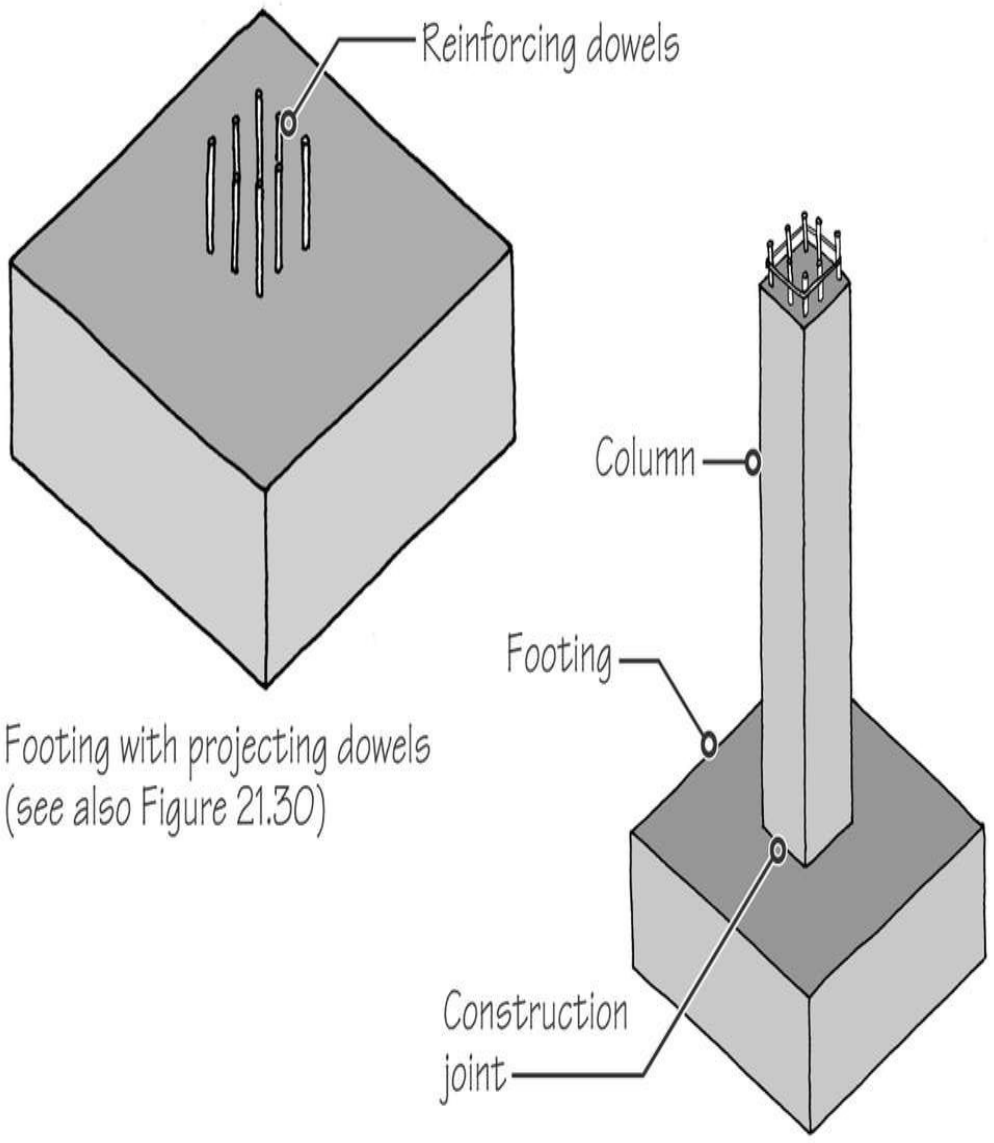
Section: isolated slab at load-bearing wall



Keyed construction joint in slab

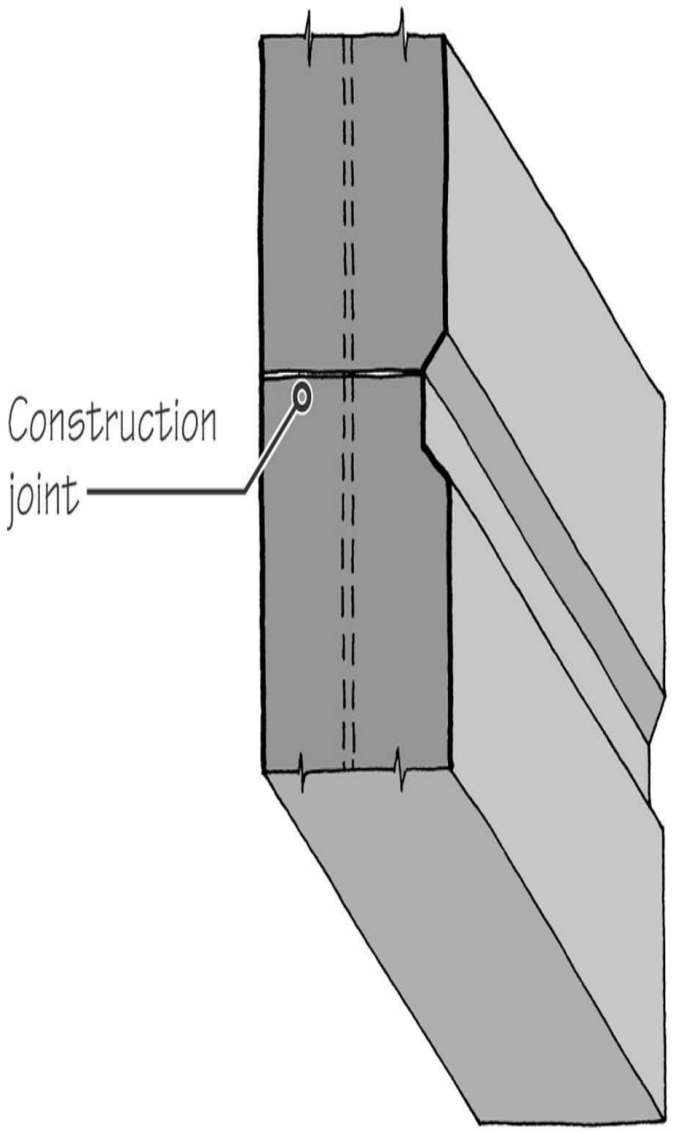


Construction joint between column & footing



Footing with projecting dowels (see also Figure 21.30)

Horizontal construction joint in wall



Ground-supported isolated concrete slab, cont'd

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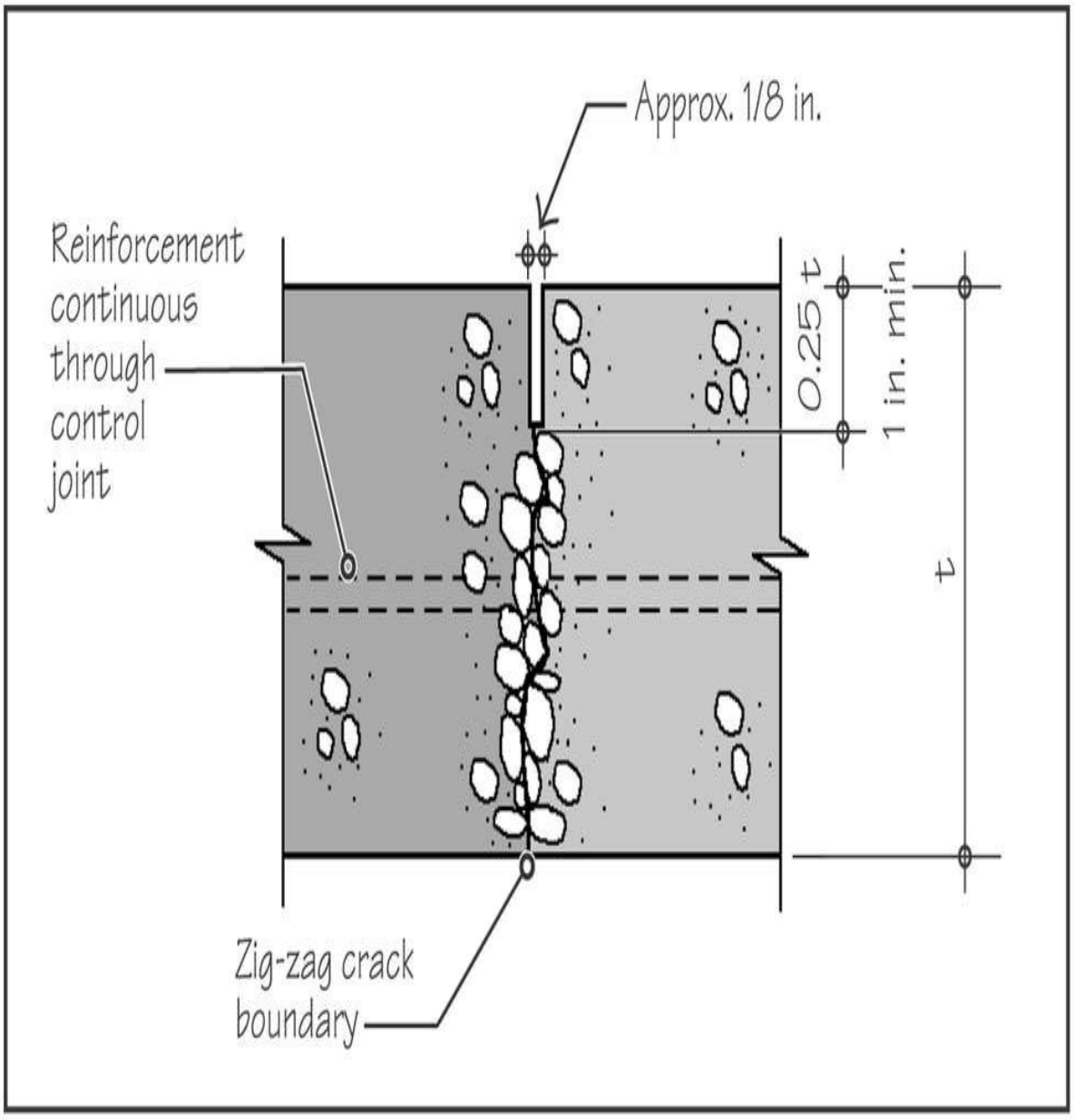
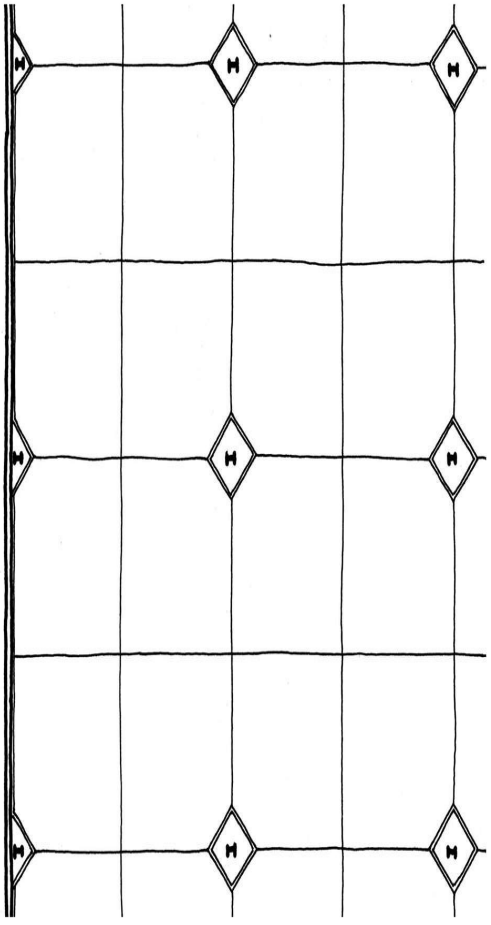
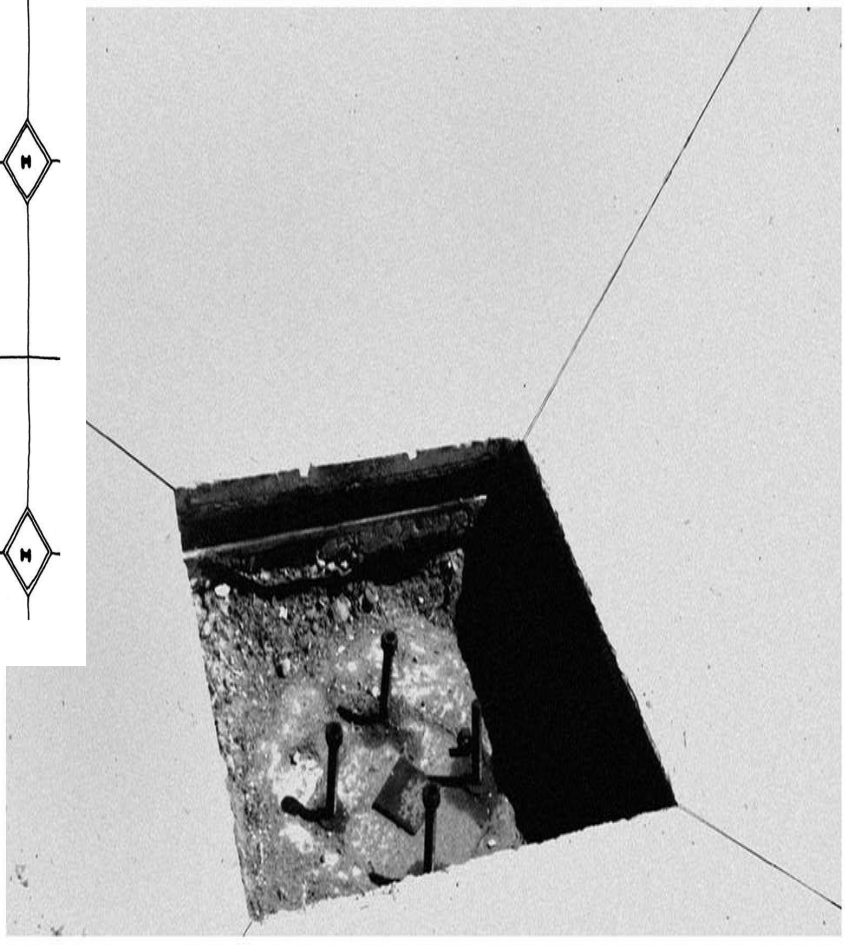
Section through control joint

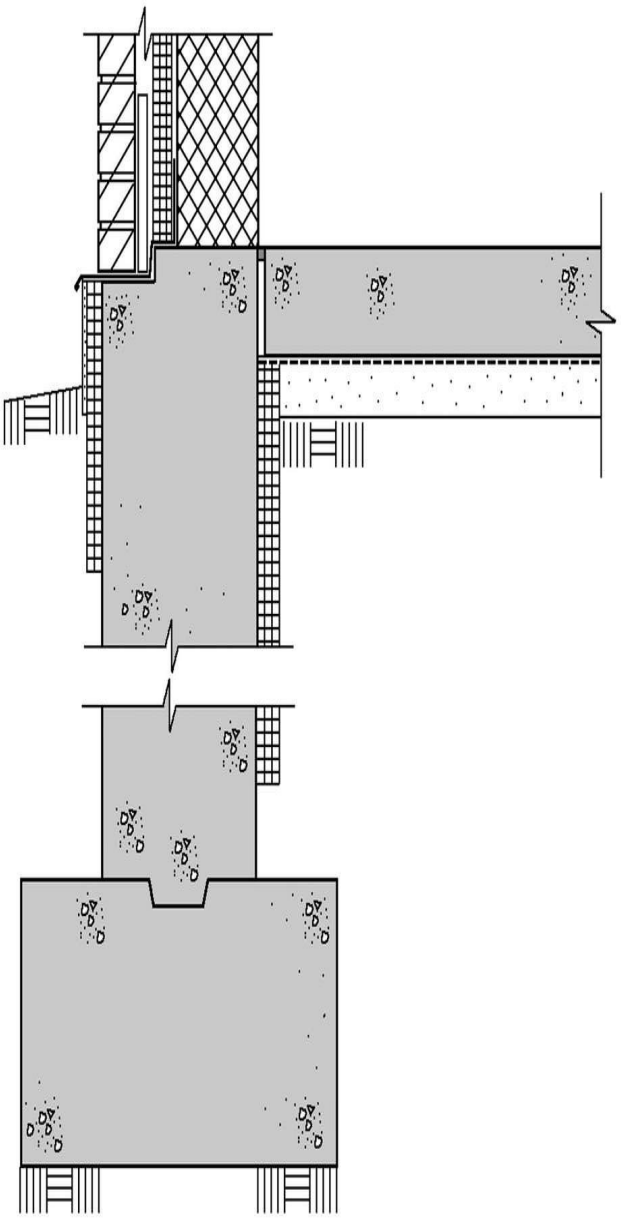


Isolation joints & control joints in interior isolated slab

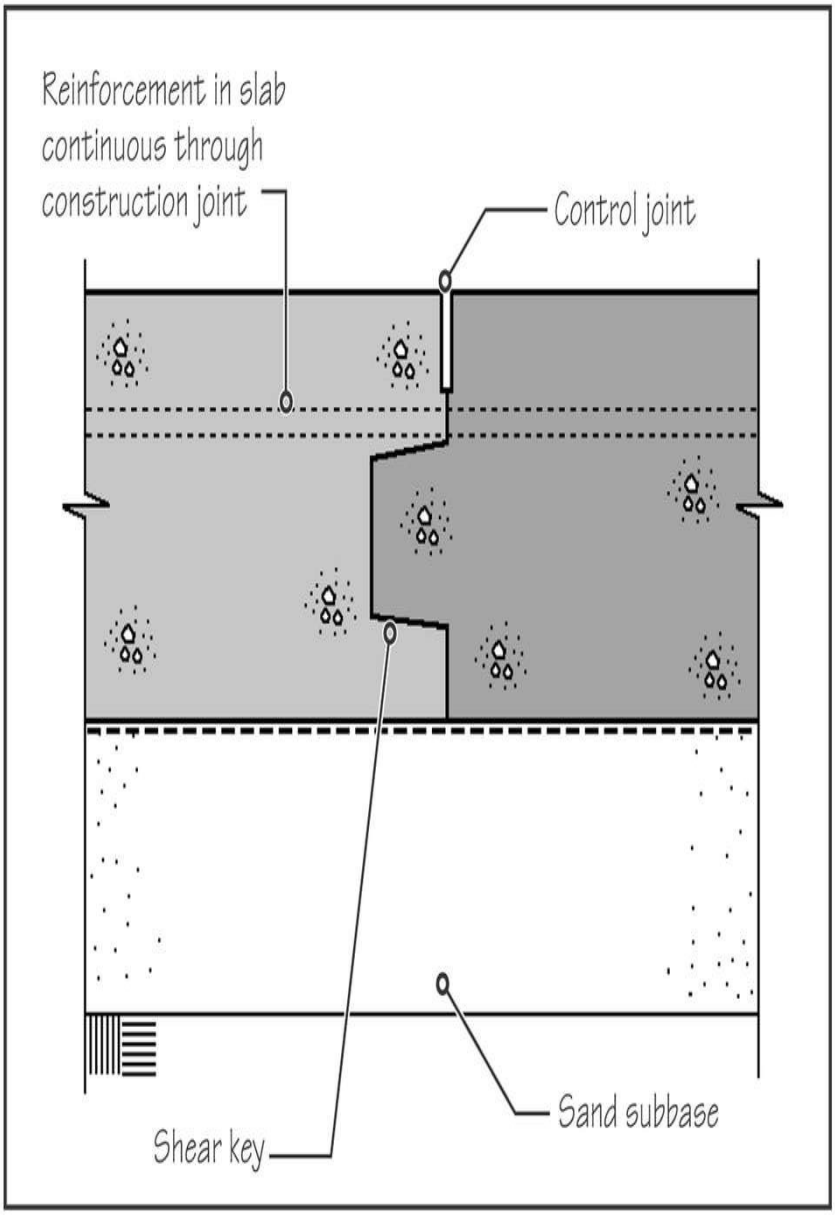




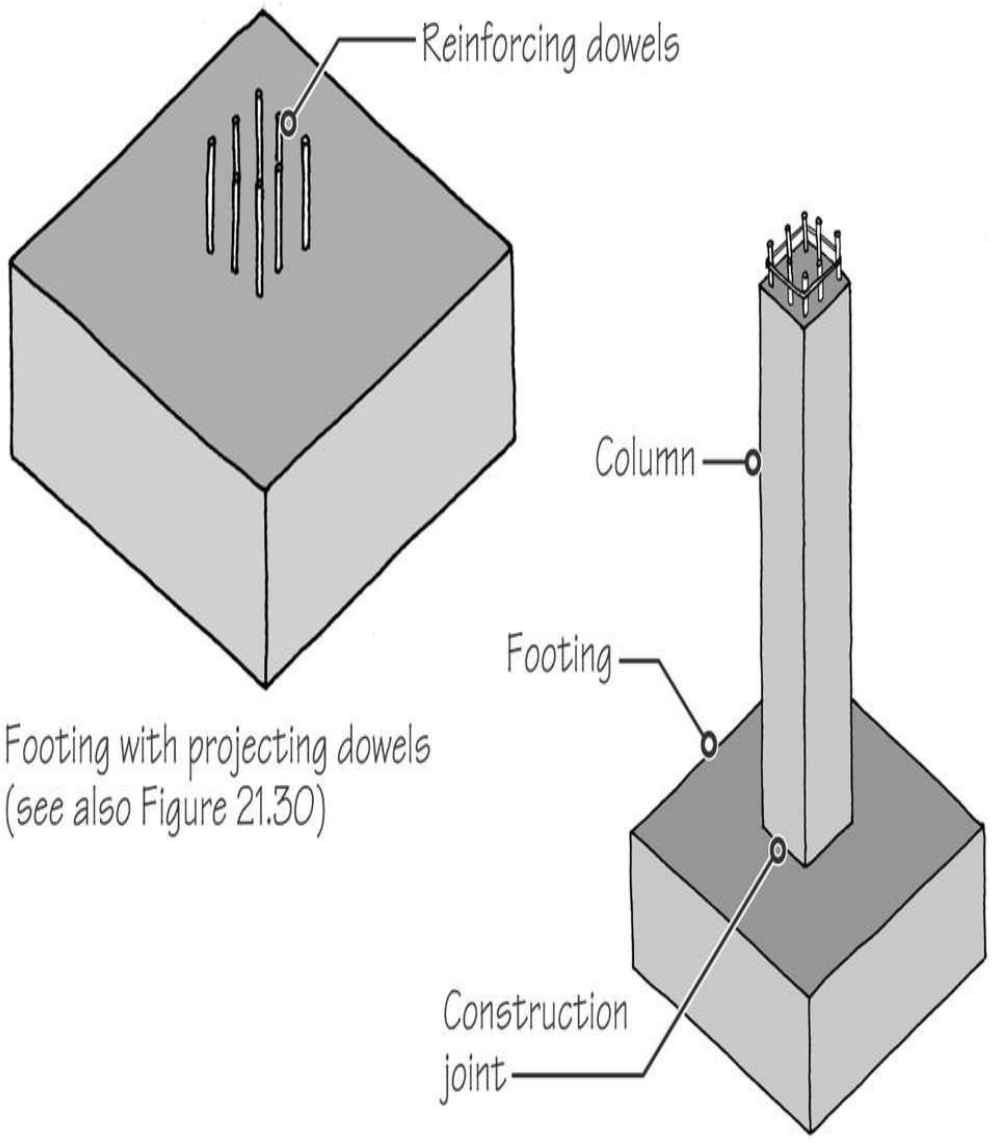
Section: isolated slab at load-bearing wall



Keyed construction joint in slab

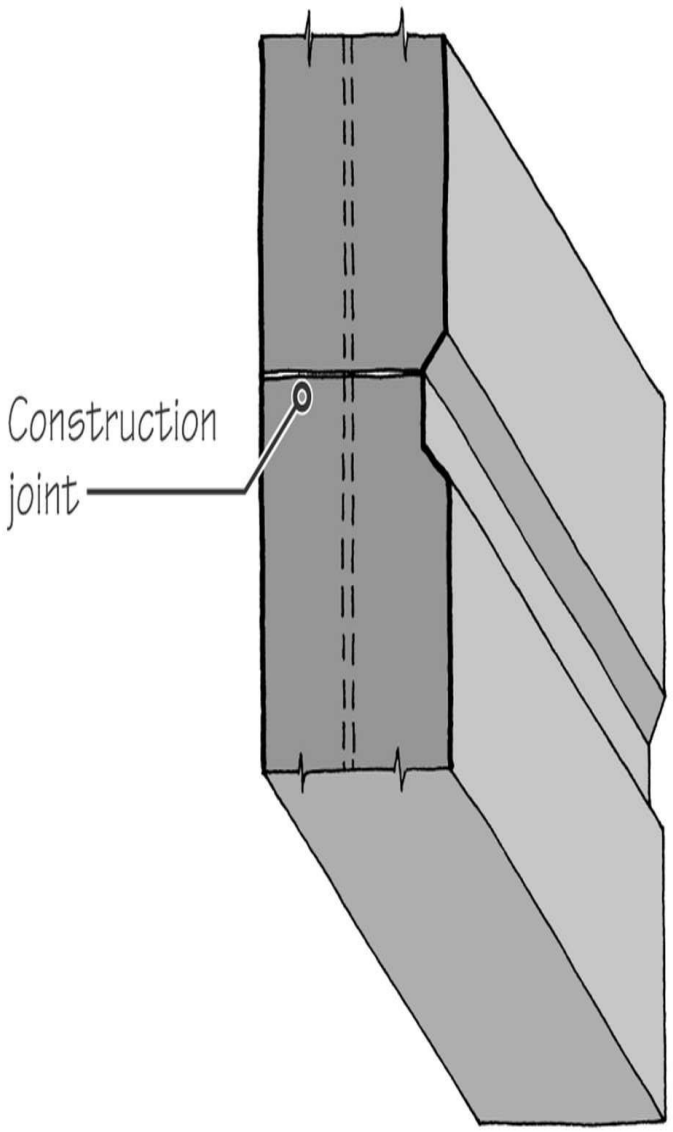


Construction joint between column & footing

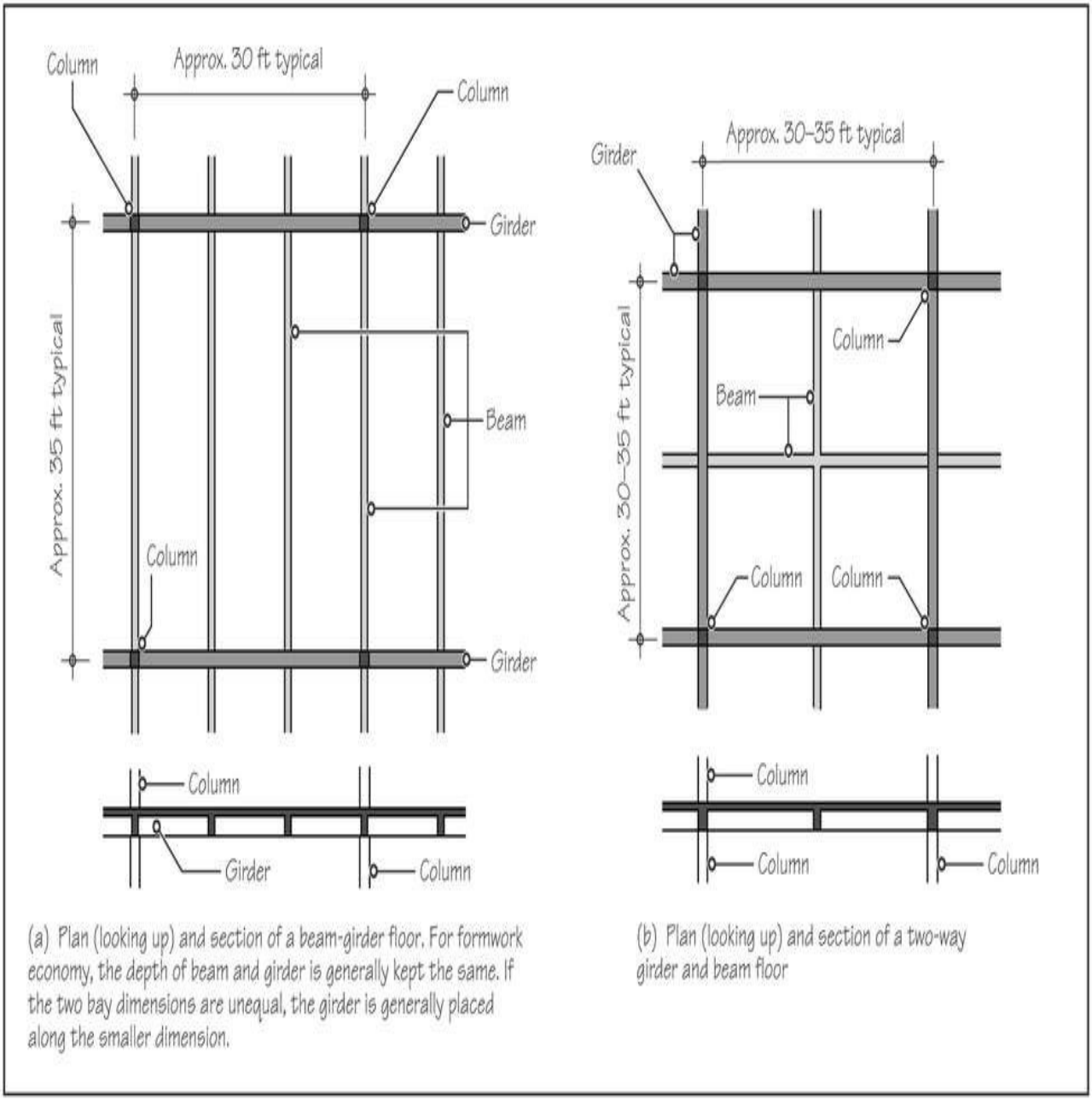


Footing with projecting dowels (see also Figure 21.30)

Horizontal construction joint in wall



Beam and girders with slab floors increase spans, decrease economy



(a) Plan (looking up) and section of a beam-girder floor. For formwork economy, the depth of beam and girder is generally kept the same. If the two bay dimensions are unequal, the girder is generally placed along the smaller dimension.

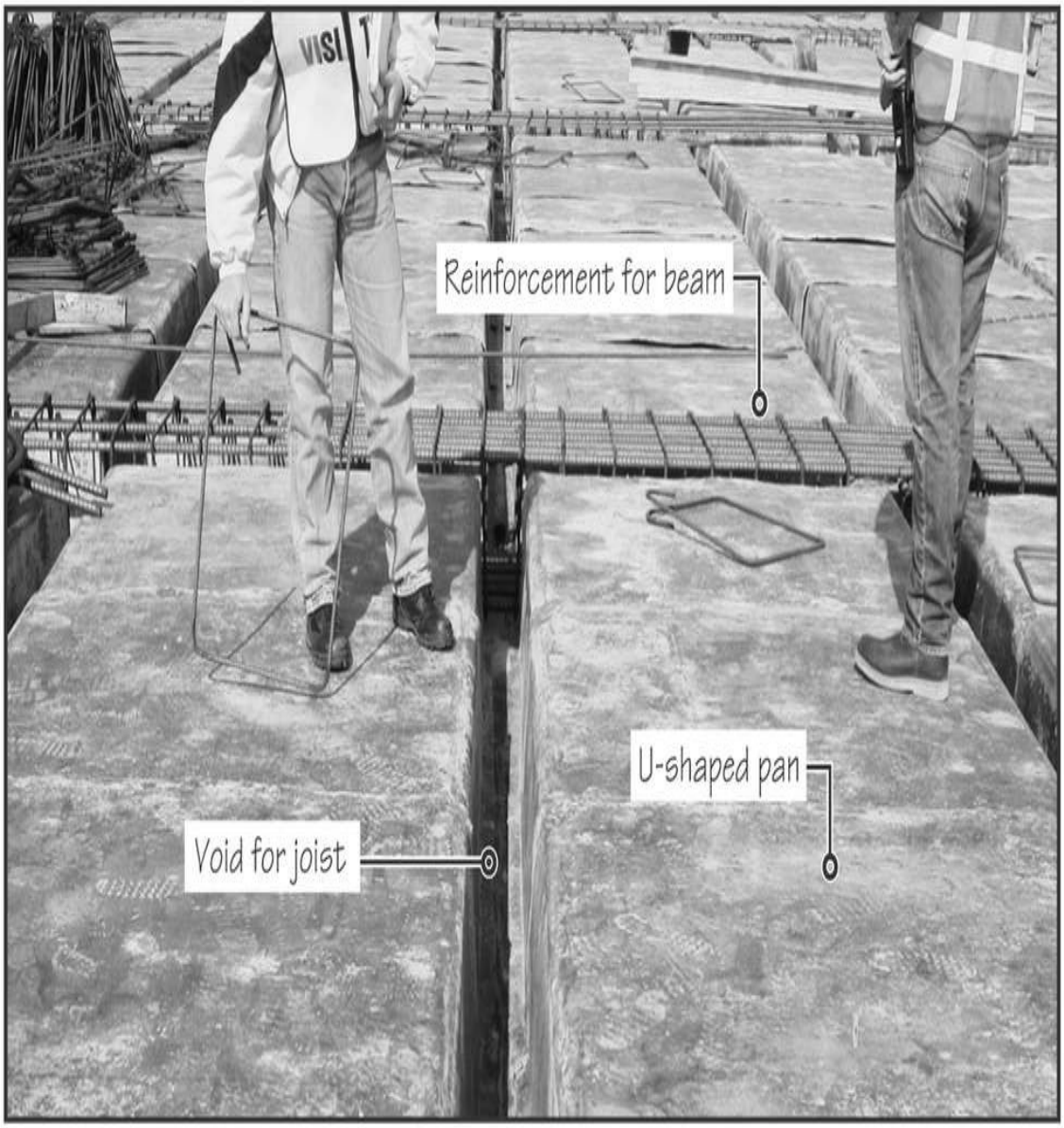
(b) Plan (looking up) and section of a two-way girder and beam floor

One-way and two-way slabs

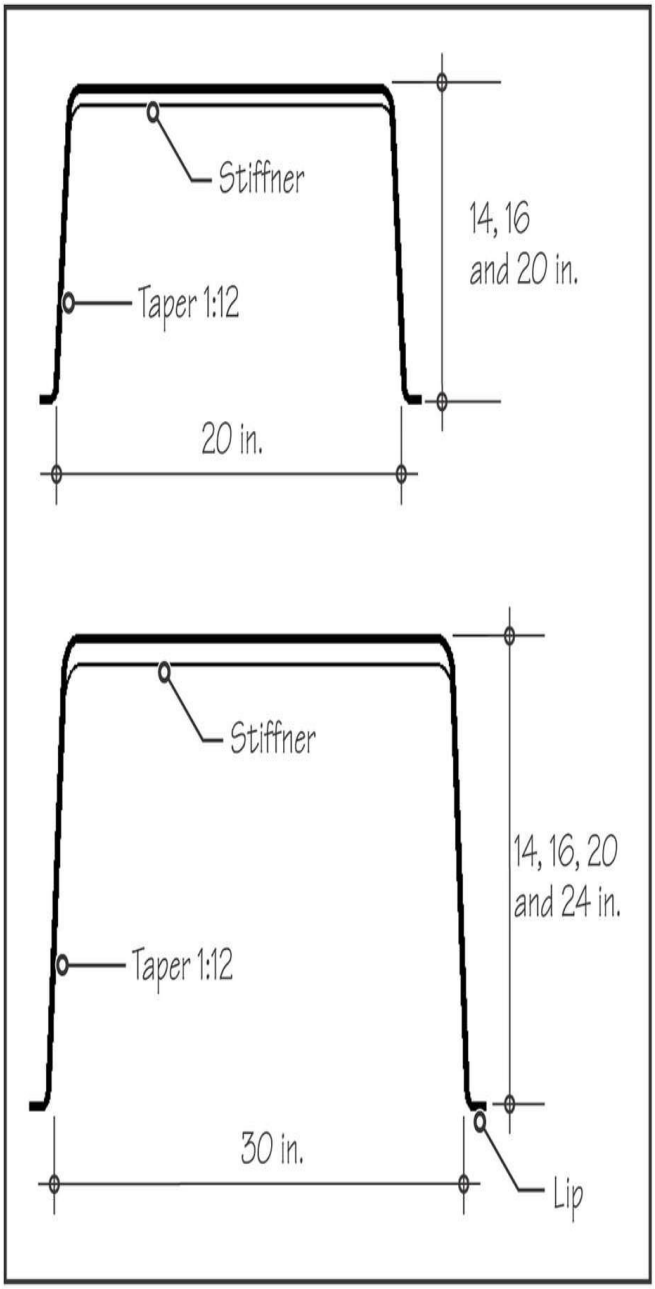
- Slabs become thicker as spans increase
  - Uneconomical when slab exceeds 8 inches
  - Dimensions maximized
    - One-way slab, 16 fts wide
    - Two-way, square slab 24 ft. wide
- Beams and girders can be added to slabs to increase spans & reduce slab thickness
  - Beam and girder sizes vary
    - Increase cost and complexity of formwork
  - Not commonly used due to lack of economy

One-way joist floor viewed from below

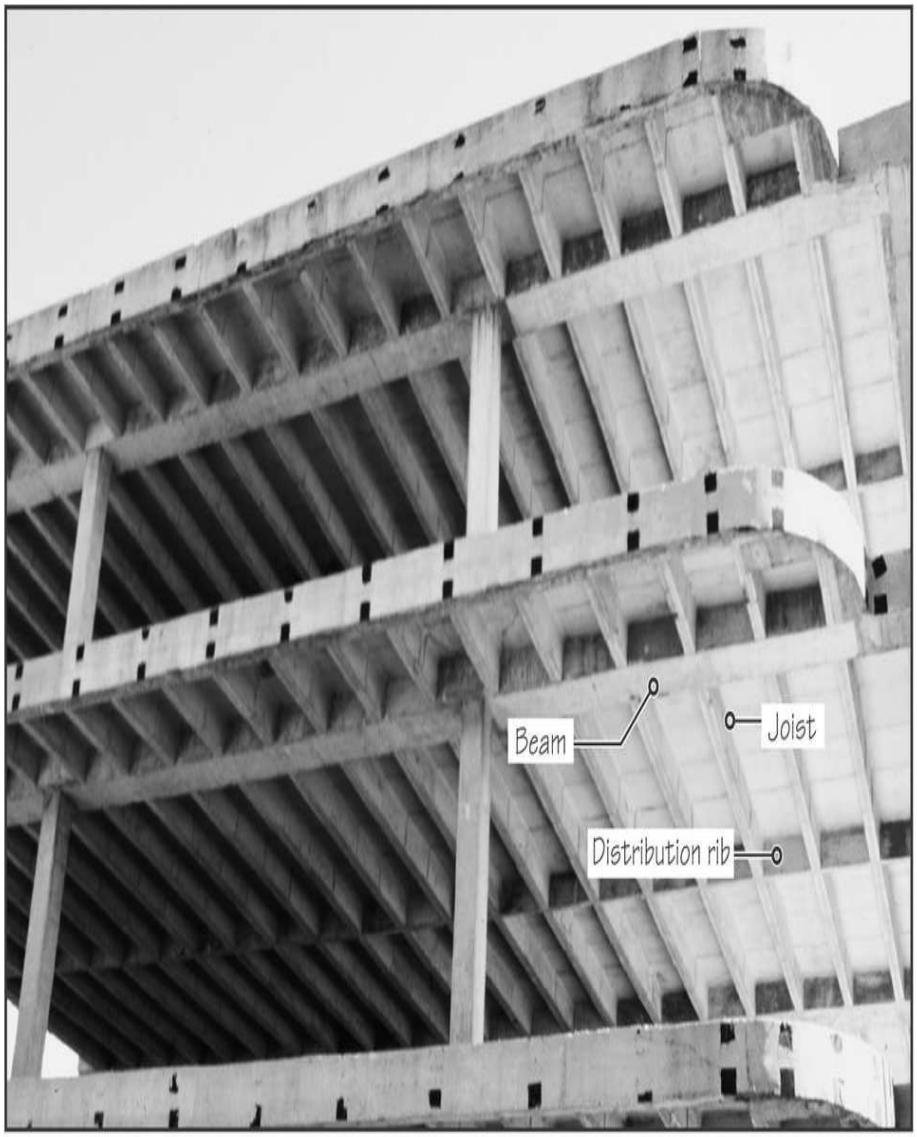
Standard module formwork with beam reinforcement laid



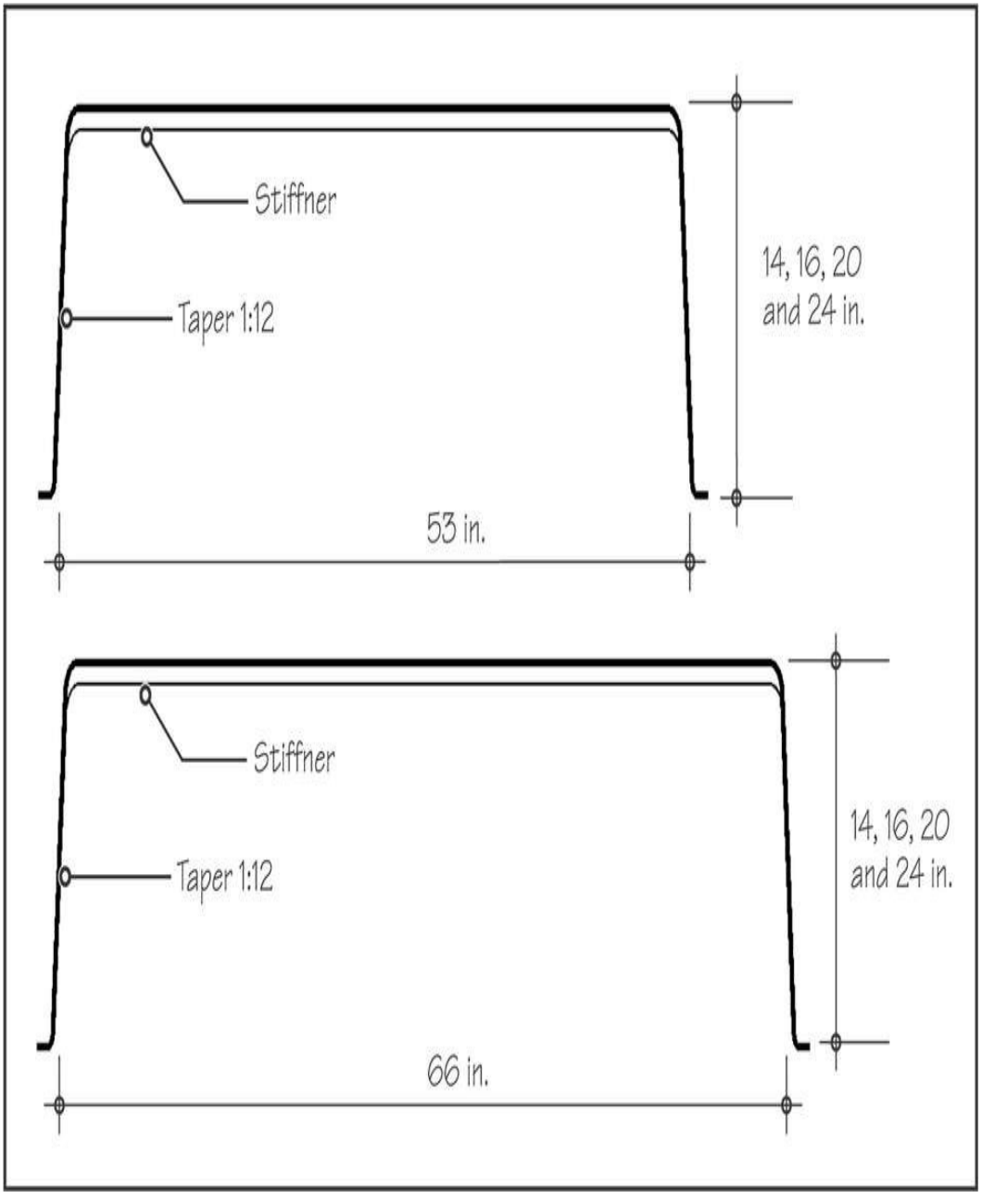
Standard module pan sizes



Tapered pans, widened joist ends

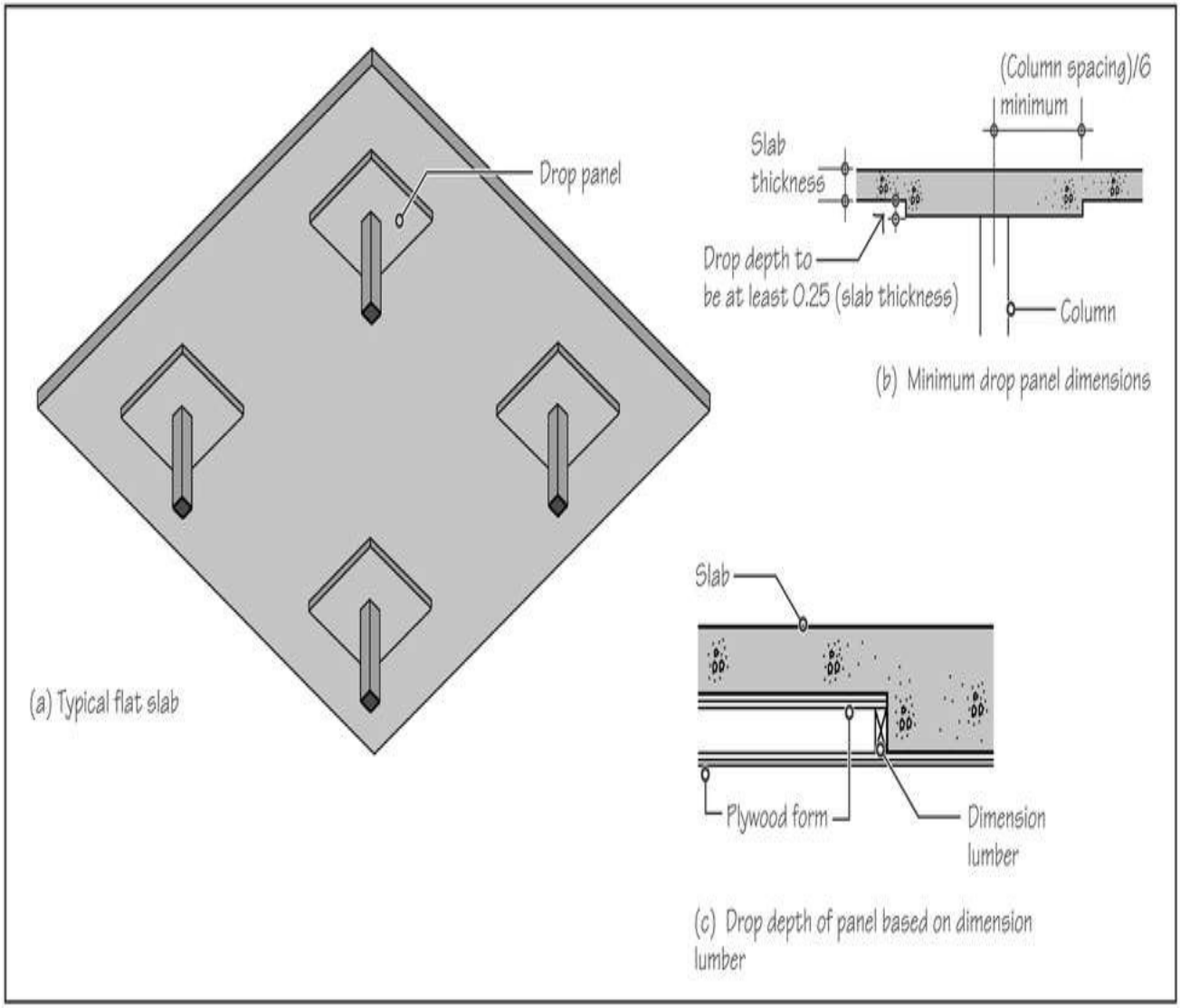


Wide-module pans

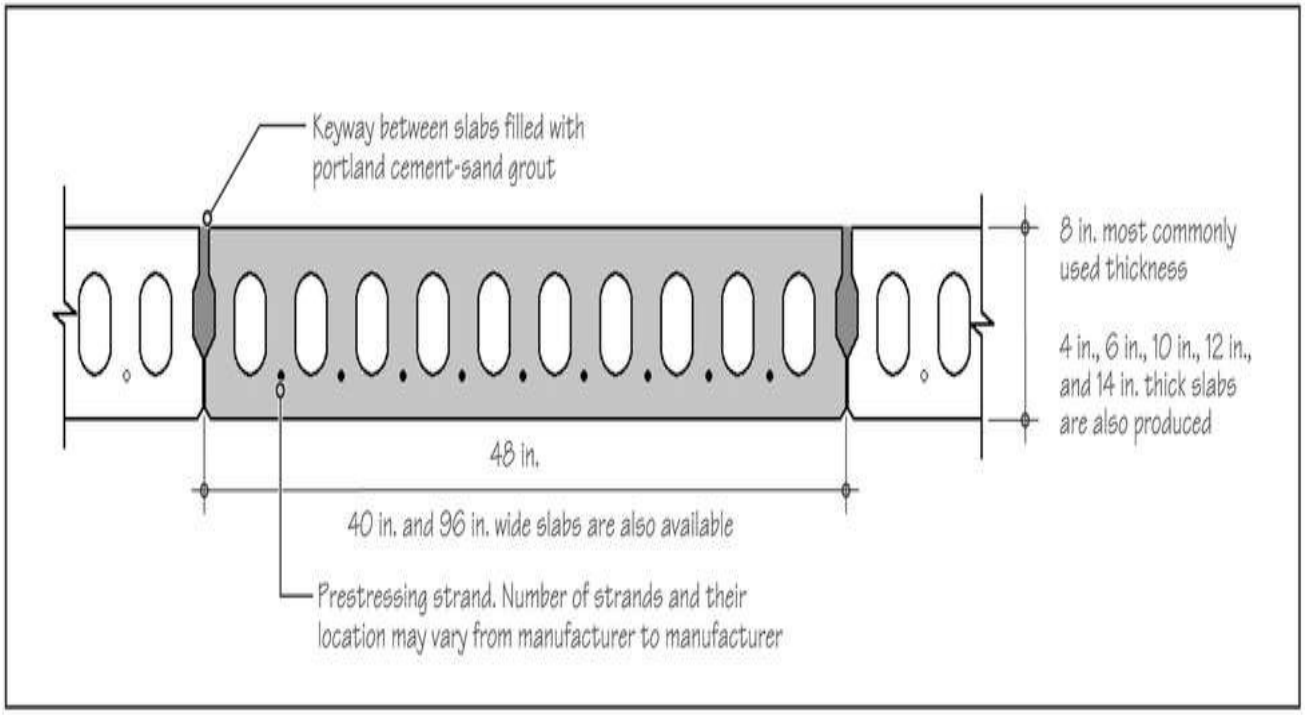


Flat plate slab: light occupancies, lower ceiling height, small, square bays

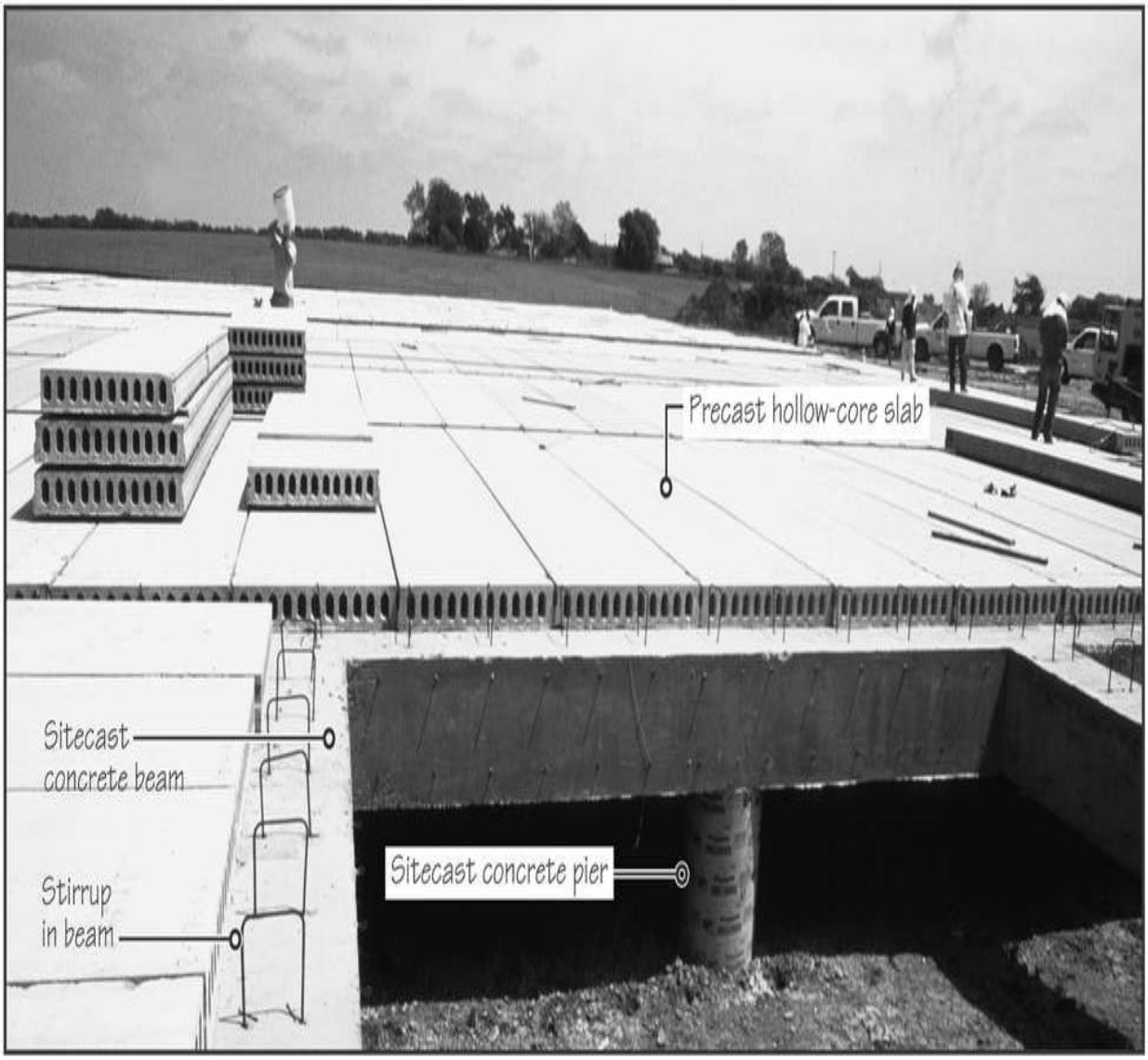
Flat slab has round column and drop panels



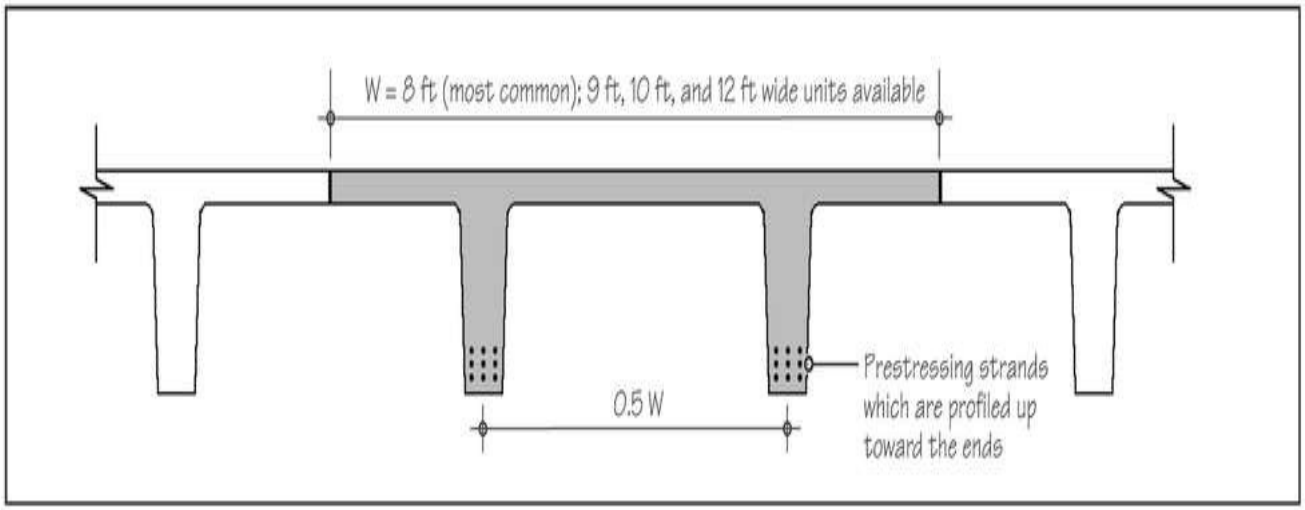
Section through hollow core slab



Precast concrete hollow core slabs rest on site-cast concrete columns and beams

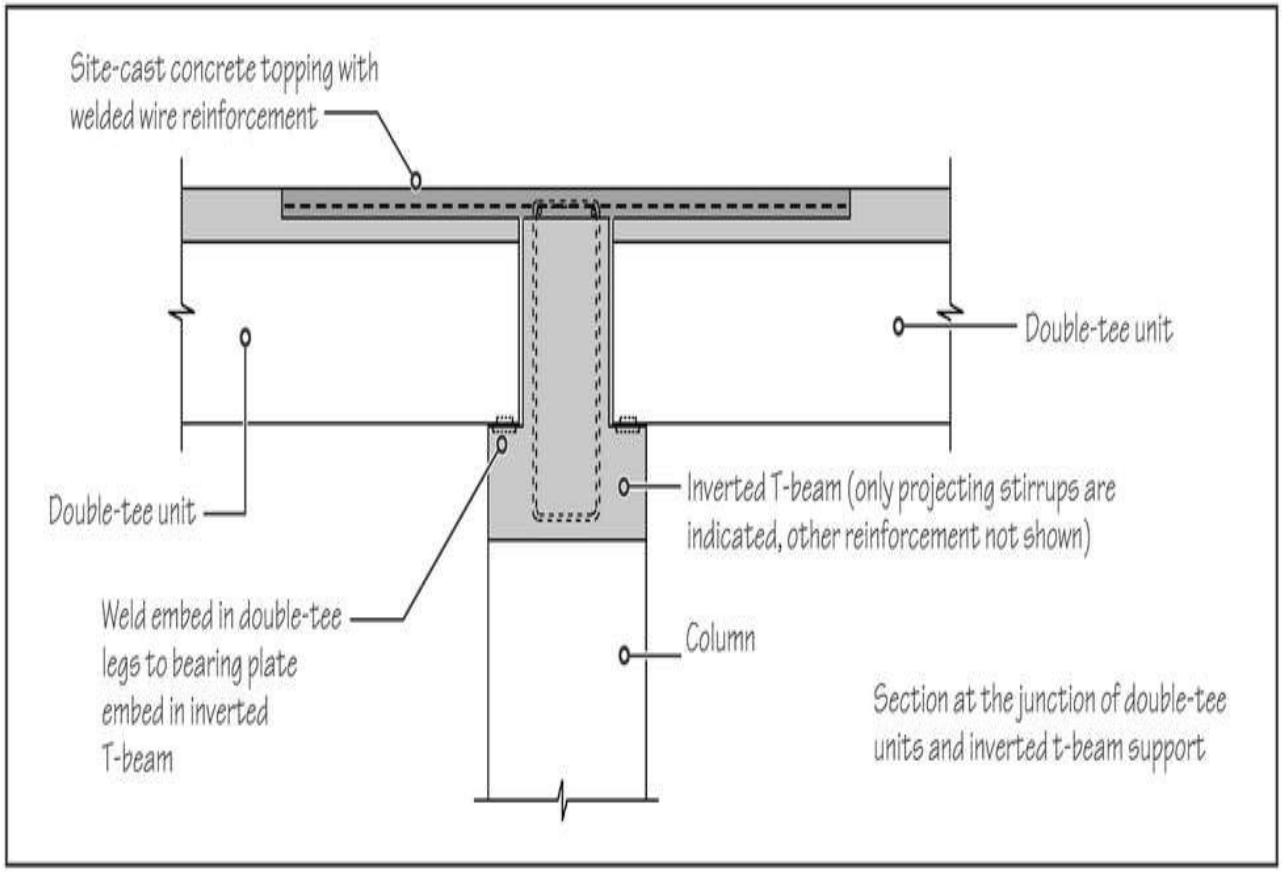


Section through double-tee floor

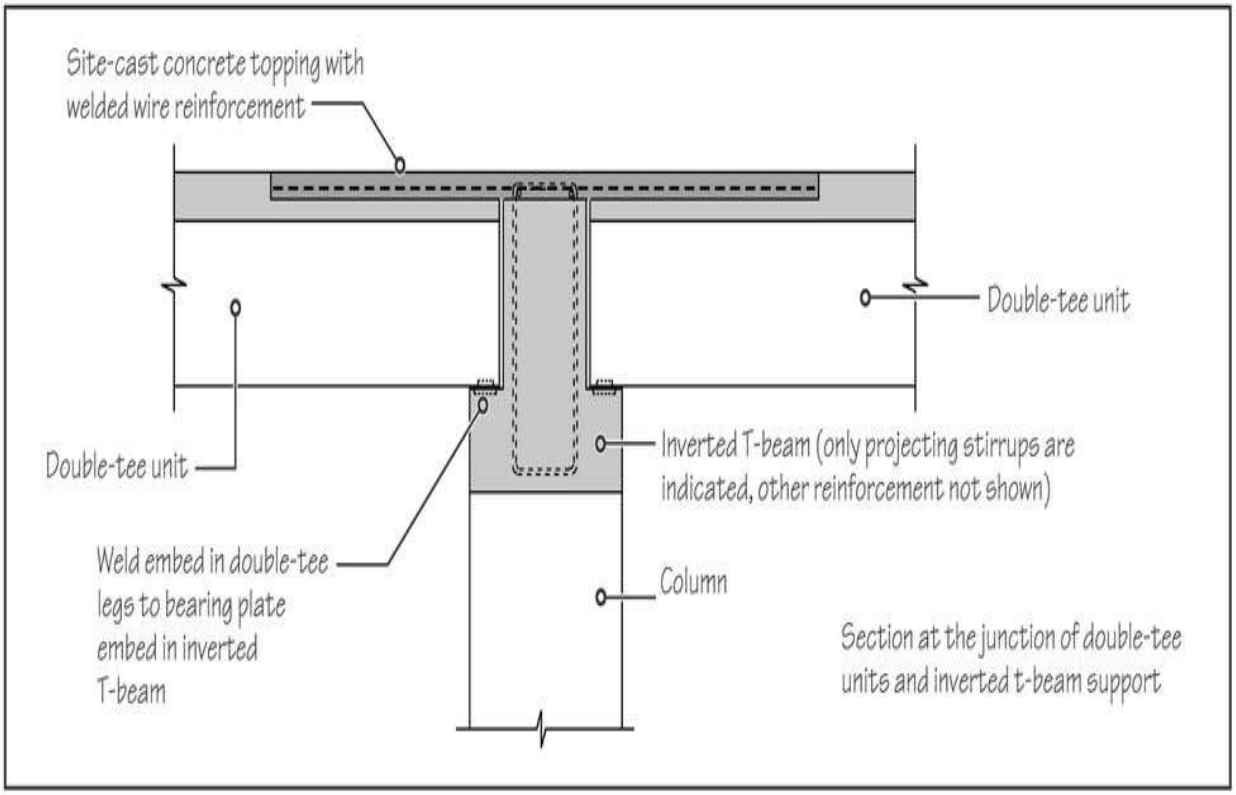


Double-tee units on precast inverted T-beams

Double-tee meet at column and beam



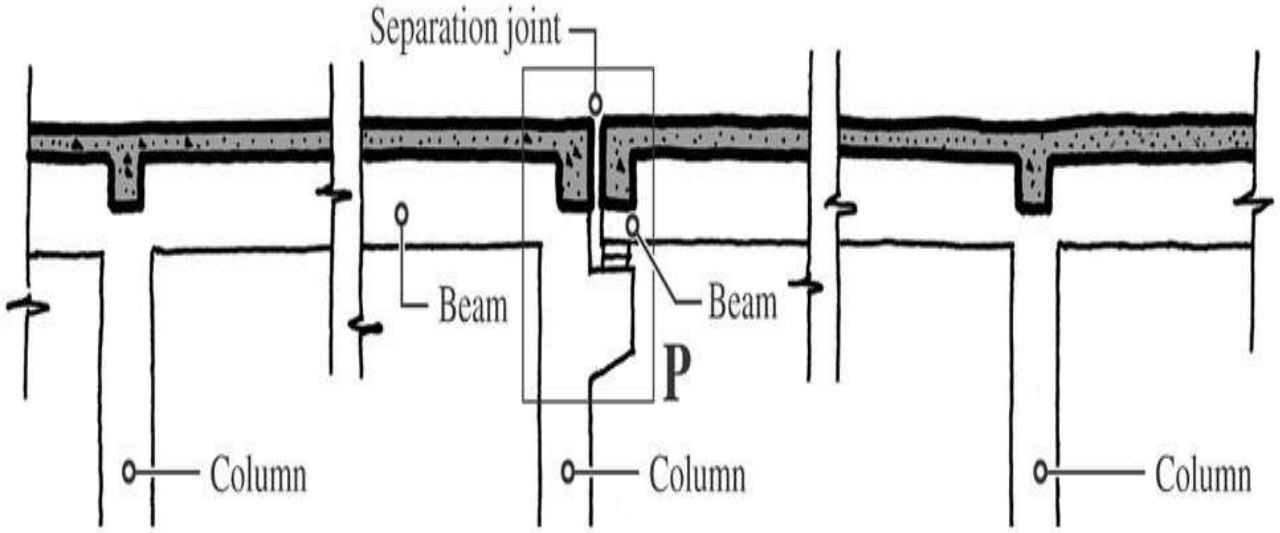
Inverted T-beam



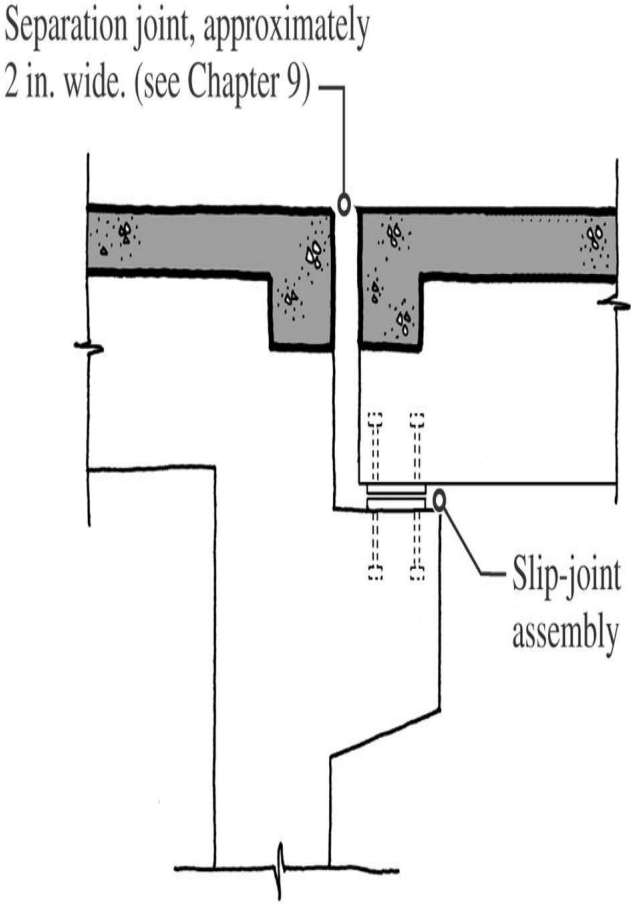
Fire resistance of concrete members

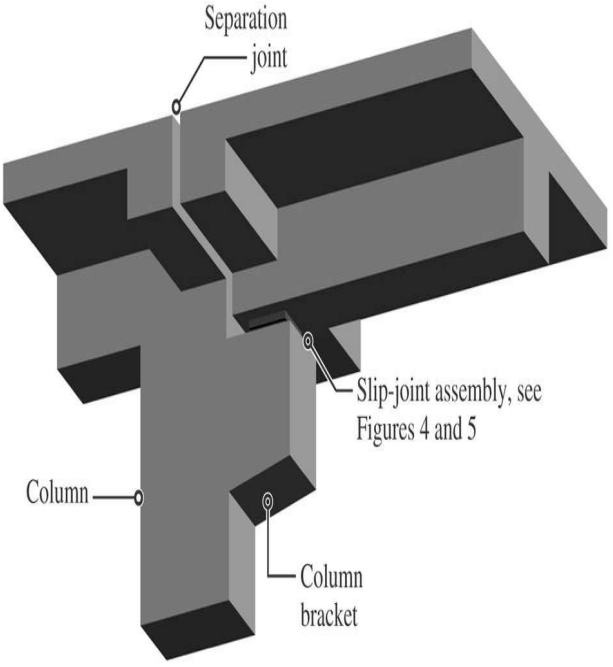
- Thickness of member
- Type of course aggregate
- Covering of reinforcement and prestressing tendons

Building separation joint: Single column, site cast

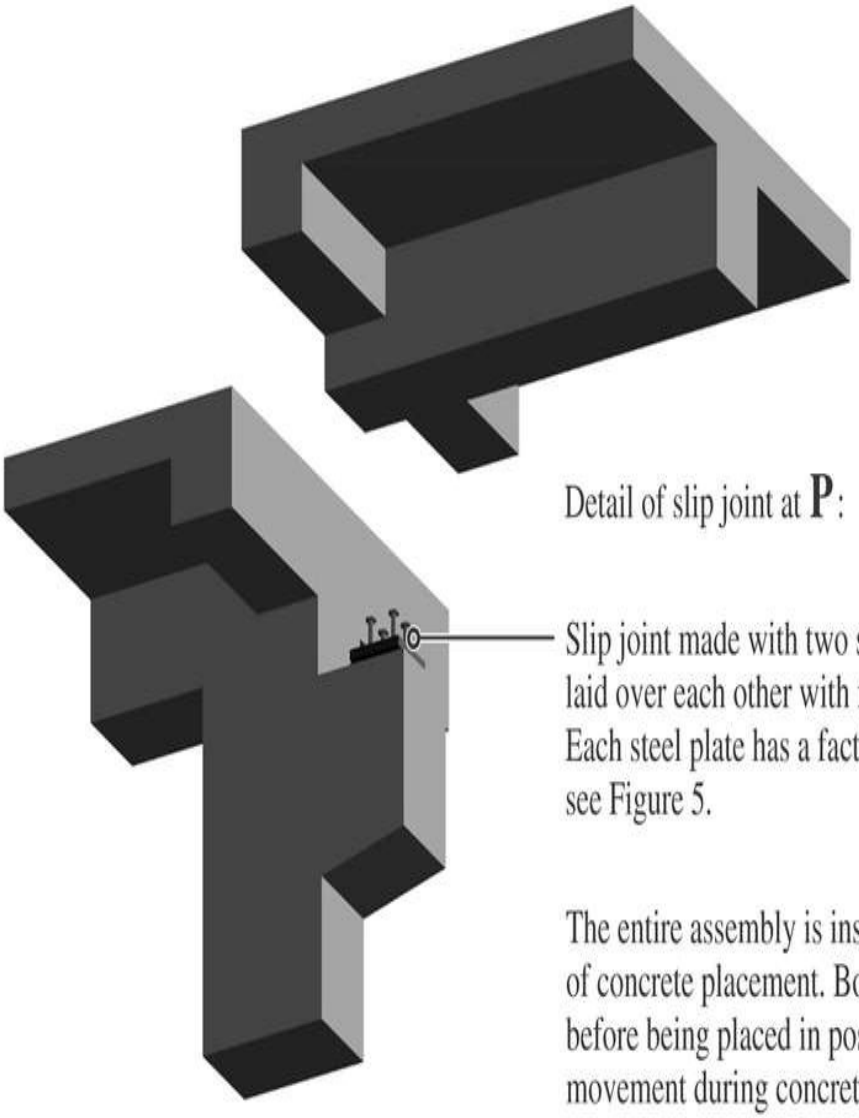


Slip joint assembly





Slip joint assembly



Detail of slip joint at **P**:

Slip joint made with two steel bearing plates laid over each other with no anchorage between them. Each steel plate has a factory-expoxied teflon sheet, see Figure 5.

The entire assembly is installed in position at the time of concrete placement. Both plates are taped together before being placed in position to prevent their movement during concreting.

The End