POST TENSION CONCRETE
Design and Detailing Basics

1



POST TENSION CONCRETE IS ON THE RISE

2

POST TENSION CONCRETE IS ON THE RISE



Wood construction

Horizontal Separation (Podium)

Ground level

5-stories residential over podium

3



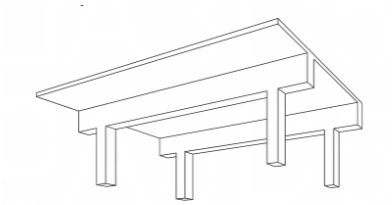
POST TENSION CONCRETE
BENEFITS

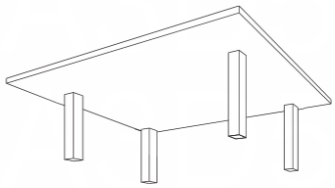
- One of the slimmest floors available
- Shallow structural depth saves skin costs
- Great at repeated floor plates over multiple levels
- Concrete shear wall is typical lateral system
- Flexible system
- Durable. Great in exposed applications
- Great acoustical performance between floors

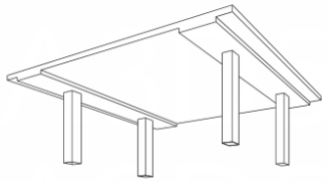
4

COMMON TYPES OF STRUCTURES

- Long Span PT
- Short Span PT
- Shallow Beam PT







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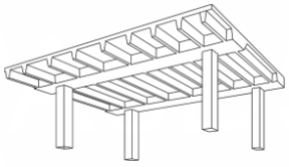
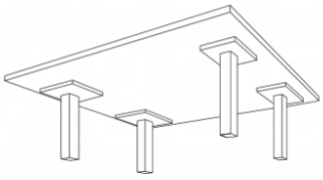
LESS COMMON TYPES OF STRUCTURES

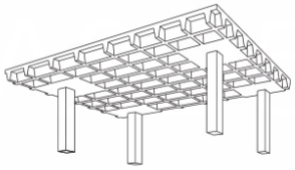
Wide Beam with Joists (Ribbed Slab)



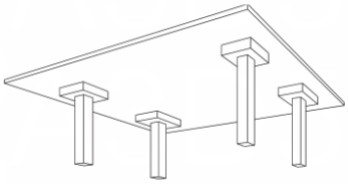
Flat Slab with Drop Panels



Waffle Slab with Drops



Flat Slab with Column Capitals



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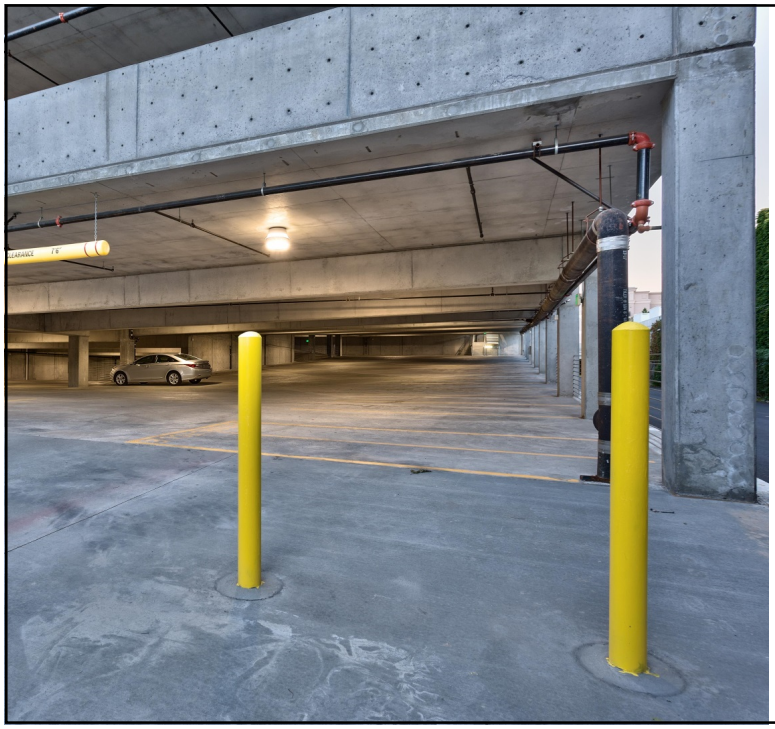
PT RULES OF THUMB

Slab thickness – Suggested span/depth ratios (round up to nearest inch)

• One-way slabs	48	*(30 ft span / 48 = 8" slab thickness)*
• Two-way slabs	45	
• Two-way slabs with two-way beams		55
• Two-way slabs with drop panels	50	
• Two-way waffle slabs (5x5 grid)	35	
• Beams, width=height/3	20	
• Beams, width=height x 3		30
• One-way joists	40	

7

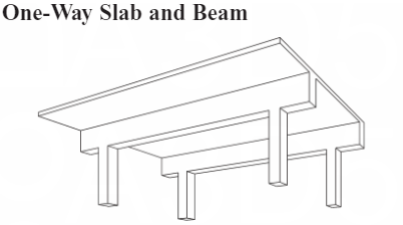


LONG SPAN PT

USAGE

- Parking Garages

One-Way Slab and Beam



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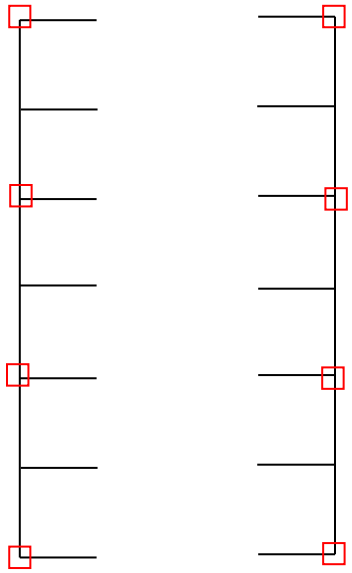
LONG SPAN PT

Typical Structural Sizes

- 60’ x 28’-6 Bay
  - 40” beam on grid
  - 7 ¼” Slab
- 60’ x 19’-6’ Bay
  - 36” Beam
  - 6” Slab



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LONG SPAN PT

PROS

- Contractors are familiar
- Easier parking/Fewer columns

CONS

- Expensive
- Does not work well below buildings

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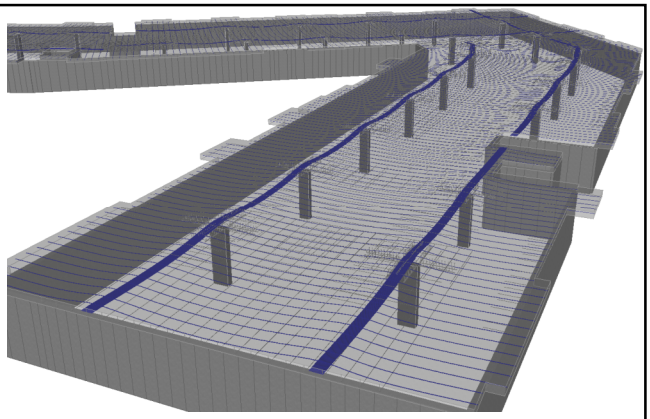
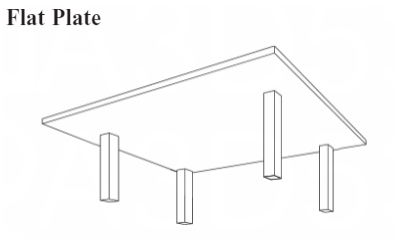
SHORT SPAN PT



USAGE

- Parking Garages
- Hotel, Apartments
- Podium Transfer Slabs
- Office Buildings



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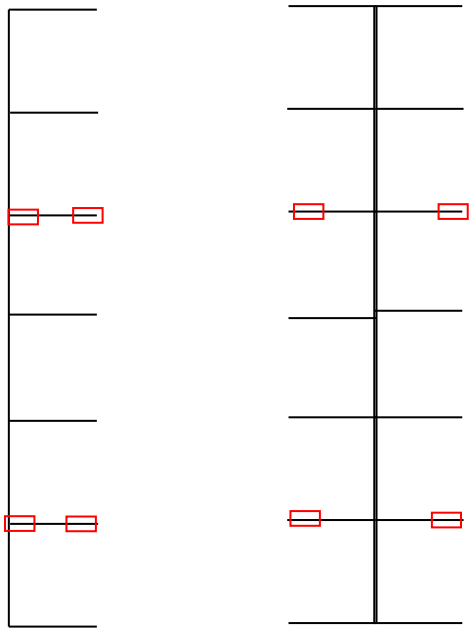
SHORT SPAN PT

Typical Structural Sizes

- Sizes for 35’ Max structural bays

- Slab Thickness
  - Parking/Residential 8”
  - Public/high live loads 10”
  - Podium Varies



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SHORT SPAN PT

PROS

- Cost Effective
- Shallow floor to floor heights
- Great for high loads/Podiums

CONS

- Difficult for exterior veneer attachment
- Columns at head of stalls

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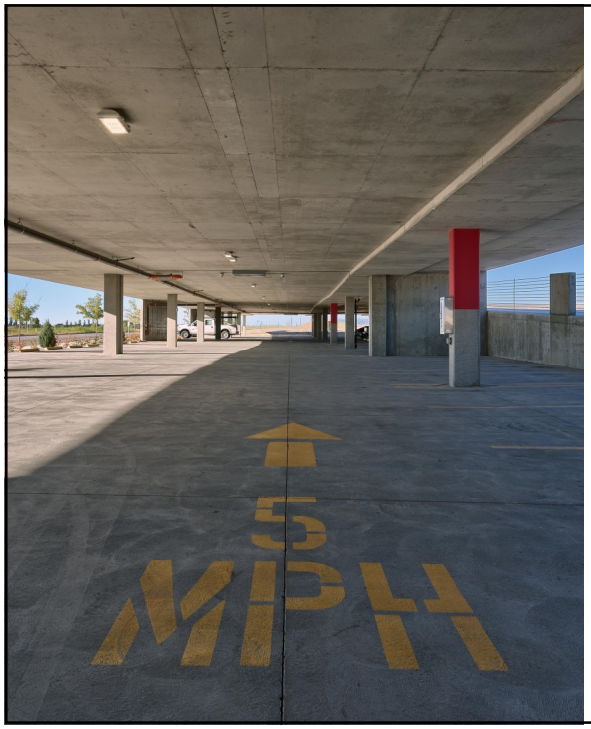
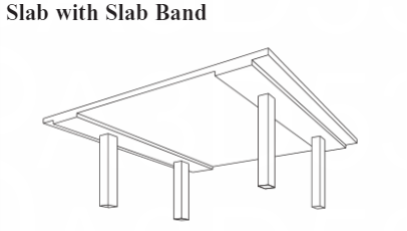


SHALLOW BEAM PT

USAGE

- Parking Garages
- Hotels, Apartments
- Podium Transfer Slabs
- Office Buildings

Slab with Slab Band



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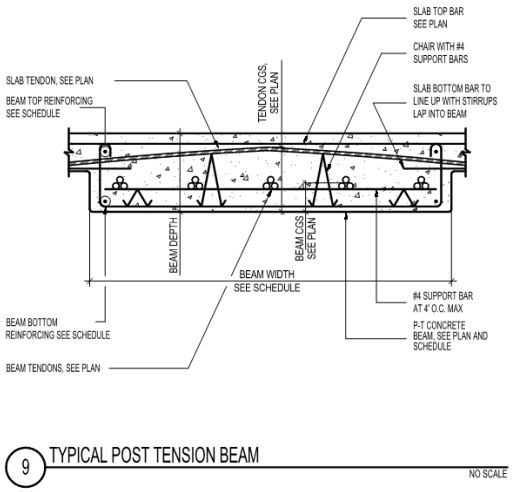

SHALLOW BEAM PT

Typical Structural Sizes

- 45’ Max structural bays
  - 7 1/4” Slab
  - 15” X 84” Wide Shallow Beams

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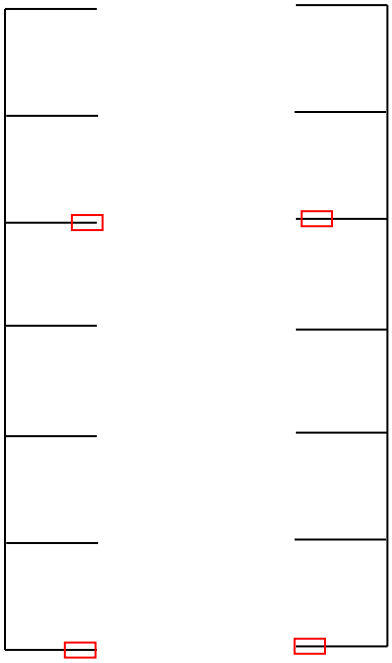
SHALLOW BEAM PT

PROS

- Cost effective
- Shallow floor to floor heights

CONS

- Difficult to attach exterior veneer
- Columns at head of stalls



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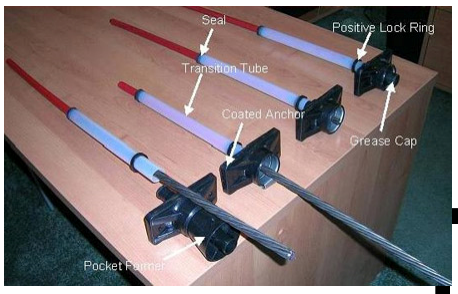
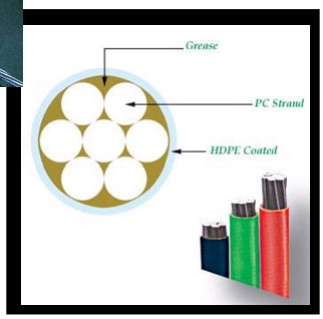
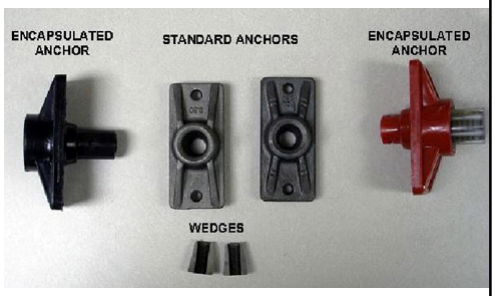
POST TENSION CONCRETE HARDWARE







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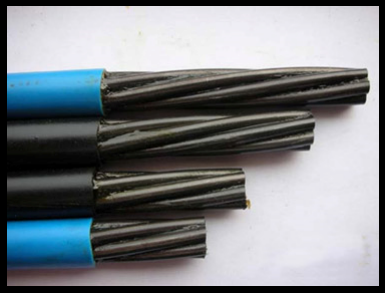
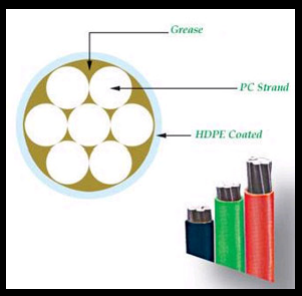
POST TENSION CONCRETE HARDWARE





Sizes	.5"	0.6
Area (in^2)	0.153	0.217
Duct Dia (in)	.5"	0.6

Low Relaxation
Grade 270

UNBONDED 7 WIRE STRAND

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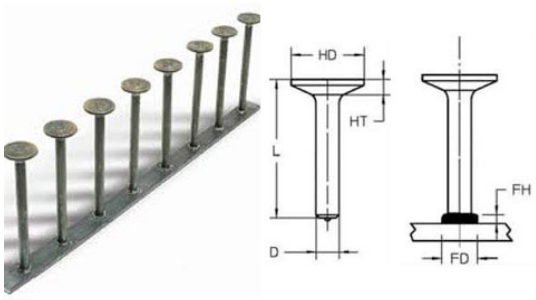
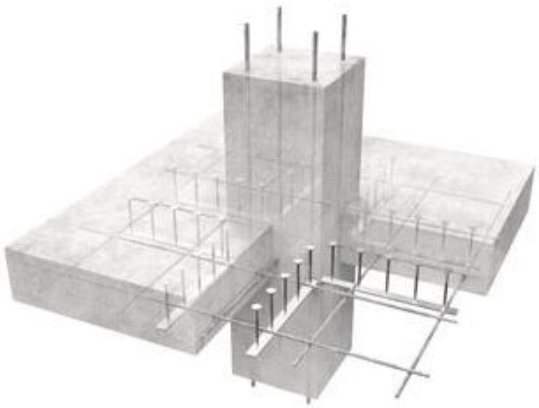
POST TENSION CONCRETE HARDWARE





Stud Rails

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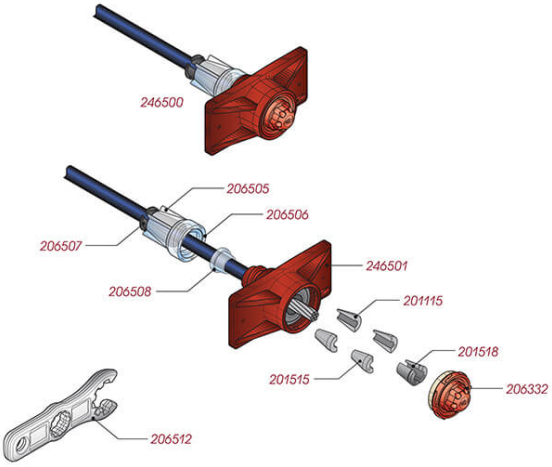
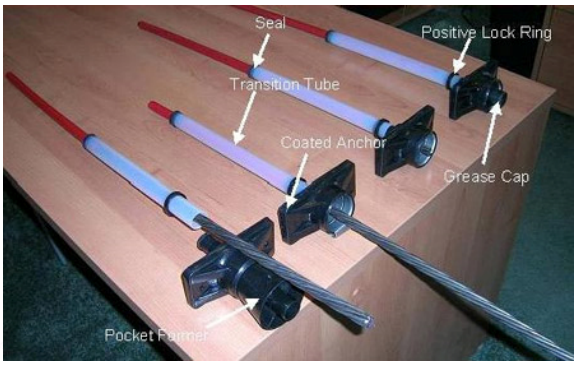
POST TENSION CONCRETE HARDWARE





Stressing End

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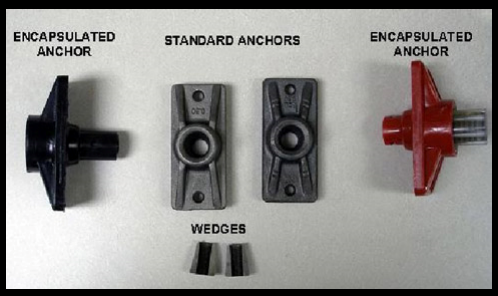
POST TENSION CONCRETE HARDWARE



Standard Anchor Dimensions

5 1/8" x 2.1/2"

Designed for 95% tendon ultimate strength

Fixed End

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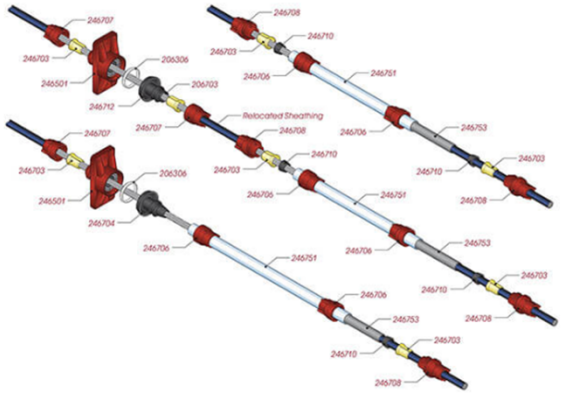
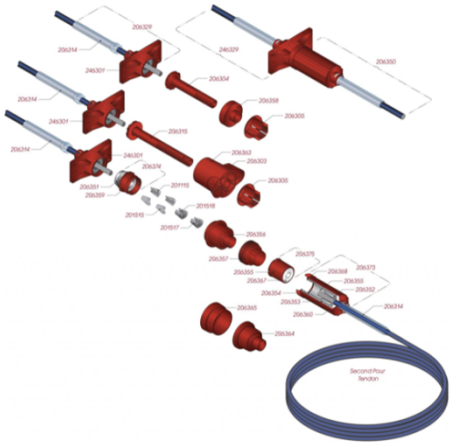
POST TENSION CONCRETE HARDWARE





Intermediate Joint

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POST TENSION DETAILS

Anchorage

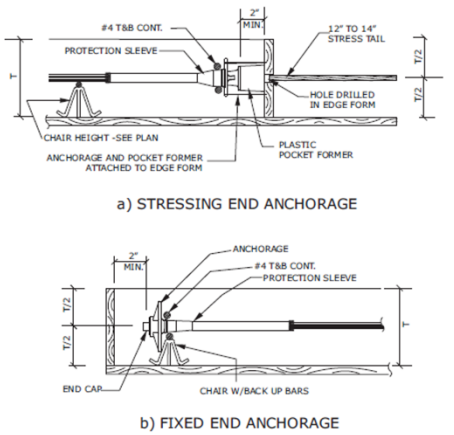

Fig. 6.5 Encapsulated System of Anchorages

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POST TENSION DETAILS

Anchorage

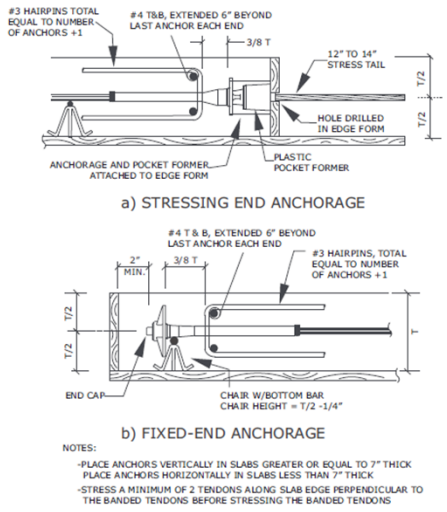

Fig. 6.6 Banded Tendon Anchorage

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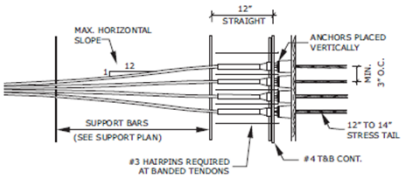
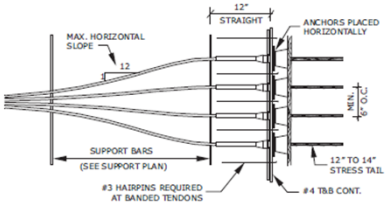
POST TENSION DETAILS

Anchorage



a) SLAB THICKNESS GREATER THAN OR EQUAL TO 7 INCHES



b) SLAB THICKNESS OF LESS THAN 7 INCHES

Fig. 6.7 Horizontal Flare of Tendons at the Anchorage Zone

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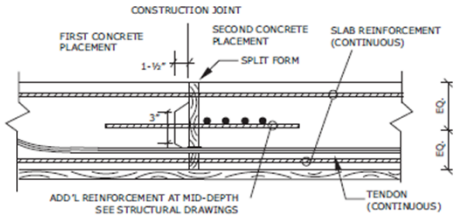
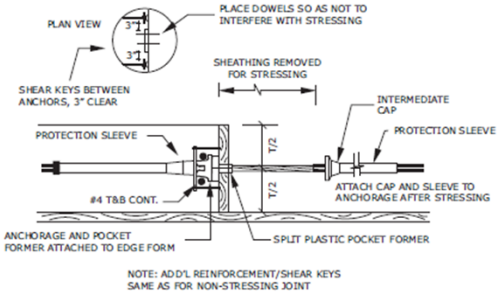
POST TENSION DETAILS

Anchorage



a) NON-STRESSING CONSTRUCTION JOINT



b) STRESSING CONSTRUCTION JOINT - ENCAPSULATED SYSTEM

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POST TENSION CONCRETE SHRINKAGE

SLABS MOVE ¾" FOR EVERY 100'

- Causes
- Considerations
  - Column Movement
  - Shear Wall Locations
  - Expansion Joints / Closure strips
  - Special Slip Details

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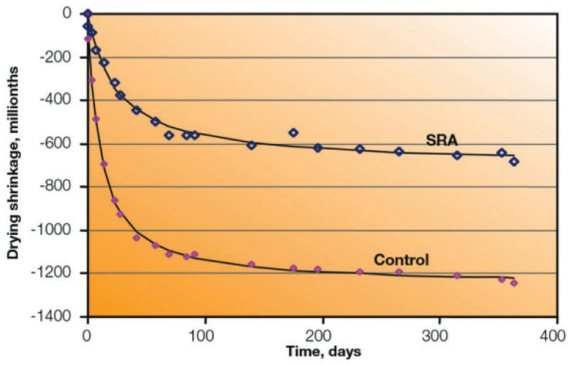
POST TENSION CONCRETE SHRINKAGE

Cause of Shrinkage

- Elastic shortening due to precompression
- Creep shortening due to precompression
- Shrinkage of Concrete
- Temperature variation



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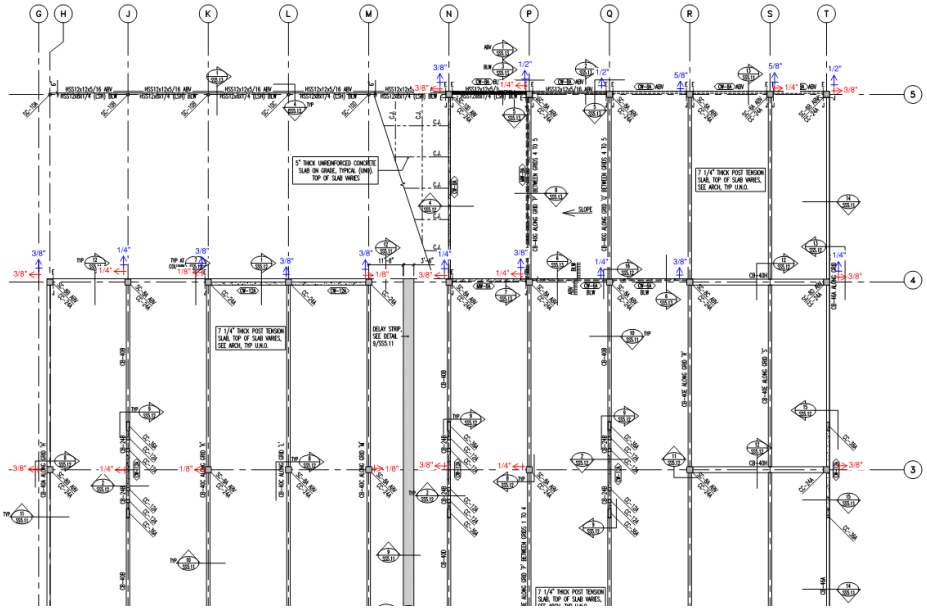
SLABS MOVE ¾" FOR EVER 100'



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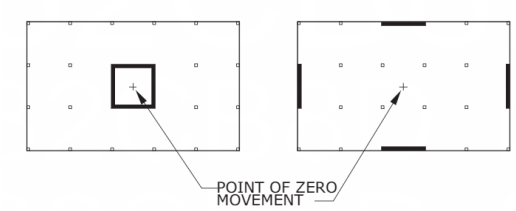
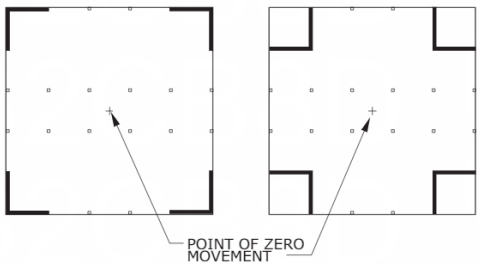
POST TENSION CONCRETE SHRINKAGE

Shear Wall Locations



(a) Favorable Arrangement of Shear Walls



(b) Unfavorable Arrangement of Shear Walls

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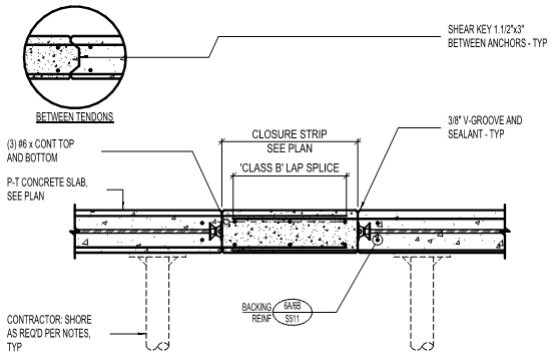
POST TENSION CONCRETE SHRINKAGE



Expansion Joints/Closure Strips

- If slab length is less that 250' no closure strip or expansion joint necessary
- For slabs lengths between 250'-325', provide one centrally located closure strip
- If the slab is between 325' and 400' use (2) closure strips open for 60 days.
- For slab greater that 400' an expansion joint is recommended.
- Cables over 100' need to be pulled from each side to minimize losses

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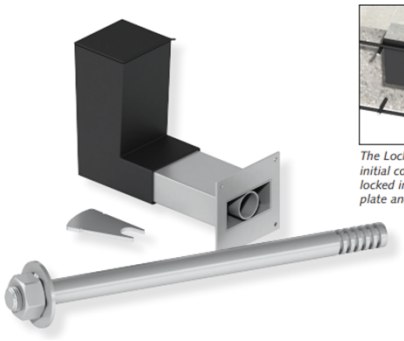
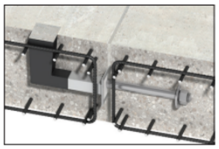
PT SHRINKAGE HARDWARE

Delay Strip Alternates

HALFEN HSD-LD Lockable Dowels.

For temporary movement joints in post tensioned slabs.





The Lockable Dowel accommodates initial concrete shrinkage and is then locked in position with a mechanical plate and epoxy resin.

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PT SHRINKAGE HARDWARE

Delay Strip Alternates



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PT SHRINKAGE HARDWARE

Delay Strip Alternates

PS=Ø®



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PT SHRINKAGE HARDWARE

Delay Strip Alternates

PS=Ø®





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PT SHRINKAGE HARDWRE

Other Applications

PS=Ø®



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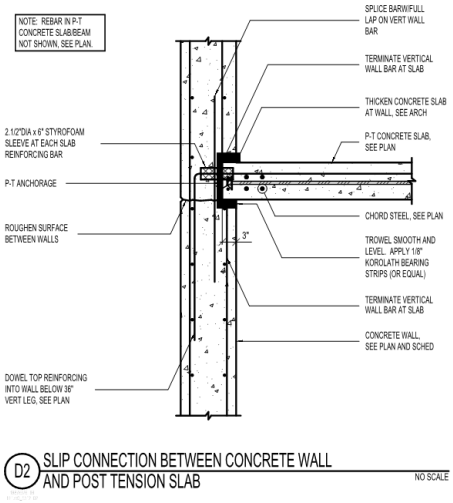
POST TENSION CONCRETE SHRINKAGE

Slip Details





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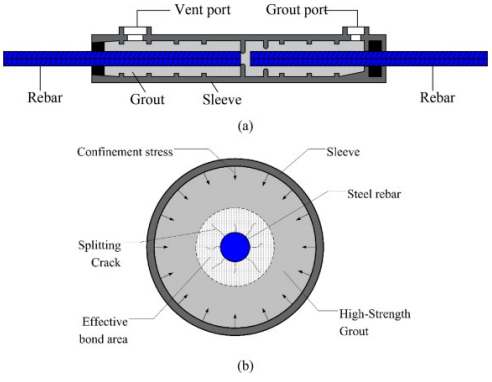
PT SHRINKAGE HARDWARE

Seismic Grout Couplers

- Type II seismic grout couplers can be used
- Typically used in Precast Connections
- Ductile and energy dissipating
- Try to use fewer bars
- Uses
  - Slab to shear wall
- Clear with contractor for availability and pricing.



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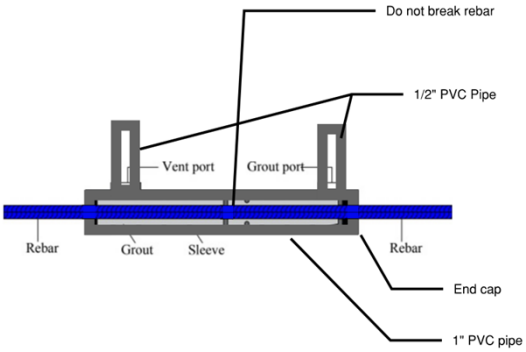
PT SHRINKAGE HARDWARE

Non-Seismic Options

- Type II grout connection
- Foam Sleaves
- PVC pipe sleaves





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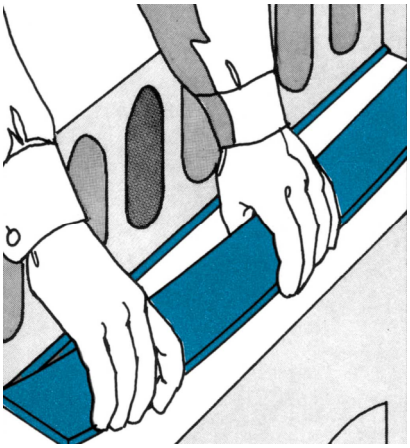
PT SHRINKAGE HARDWARE

Slip Details Bearing Material Options

- Korolath® Bearing Strips
- Neoprene Bearing Pads
- Visqeen plastic sheet.
- Felt



Korolath® Bearing Strips

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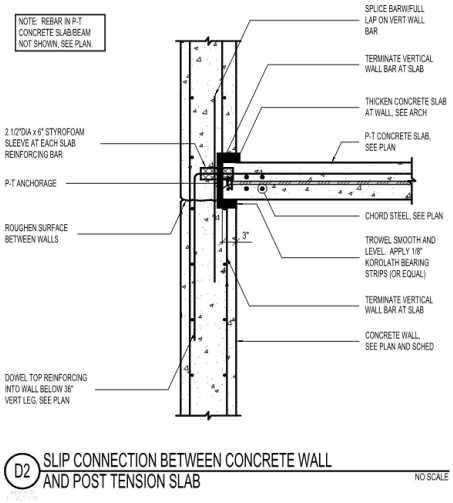
POST TENSION CONCRETE SHRINKAGE

Slip Details





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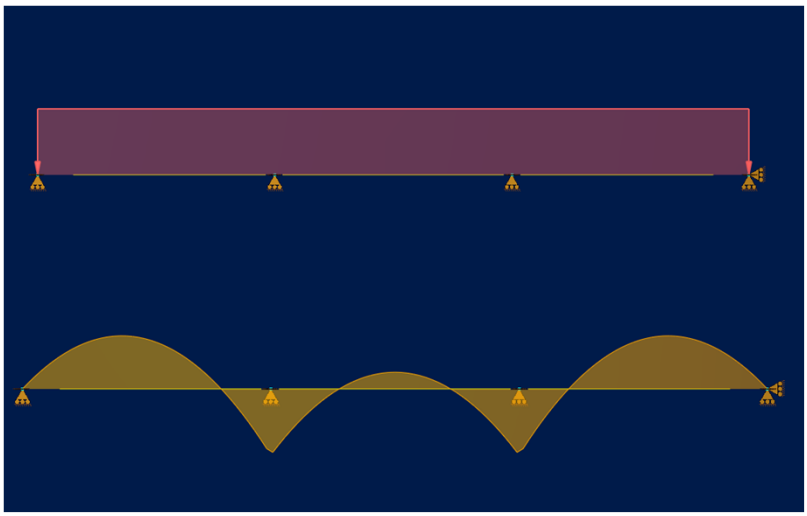
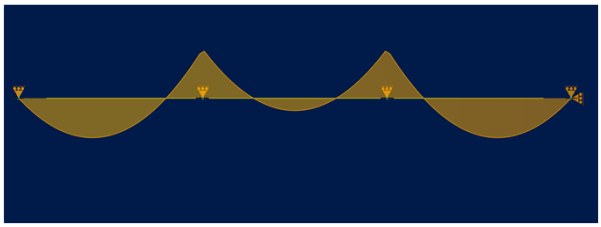
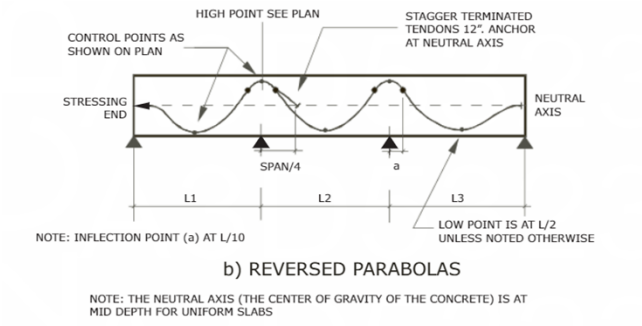
POST TENSION LAYOUT



42

POST TENSION LAYOUT





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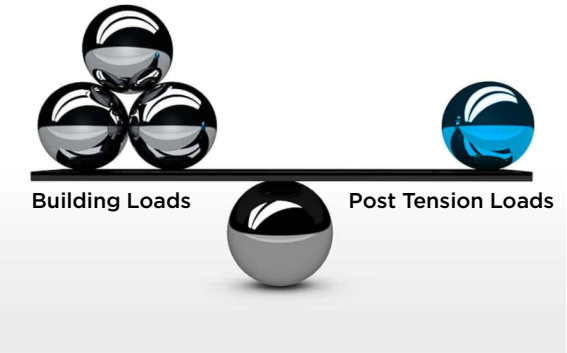
POST TENSION BALANCING

Post Tension Balancing Rules

- Post tension should take care of stresses from service loads*
- Rebar should be used for ultimate loads
- Add PT until checks over the columns are working
- Use added PT at end bays/high moments
- Use consistent drape where possible



*Heavy /Transient Loads are uneconomical so use more rebar

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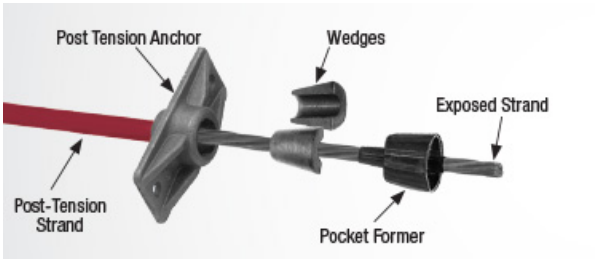
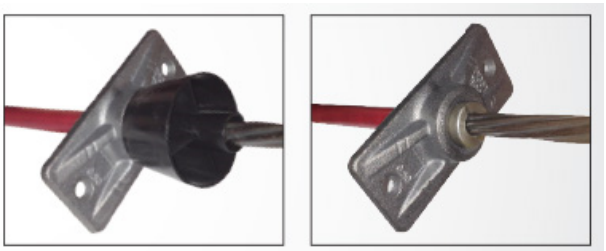
POST TENSION LOSSES





Losses due to:

- Friction losses
  - Due to friction between cable and sheathing
- Seating losses
  - Wedges move 0.25in after the jack releases
- Elastic shortening of concrete
  - Concrete elastically compresses
- Concrete volume change
  - Concrete shrinkage and creep
- Relaxation of prestressed steel

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POST TENSION LOSSES

Post Tension Values for ½ Día cables

- Stressed to 33 kip
- Losses about 6.3 kips
- Design strength **26.8 kip**

Post Tension Values for 0.6 Día cables

- Stressed to 46 kip
- Losses about 6.3 kips
- Design strength **38 kips**



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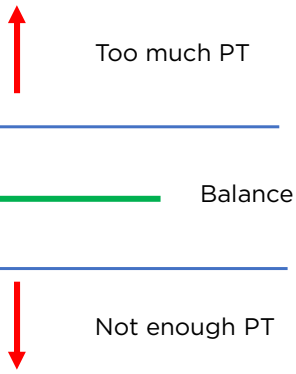
POST TENSION LAYOUT

Post Tension Balancing Checks

- Compressive stress immediately after transfer
- Tensile stress immediately after transfer
- Strength load case
- Service load case
- Minimum PT



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COMPRESSIVE STRESS IMMEDIATELY AFTER TRANSFER (24.5.3.1)



Gross compressive stress is limited to:

- Ends of simply supported member

$$\leq .70 f_{ci}'$$

- All other locations

$$\leq .60 f_{ci}'$$

- f_{ci}' is the concrete strength at stressing (usually 3500psi for a 5000psi mix)

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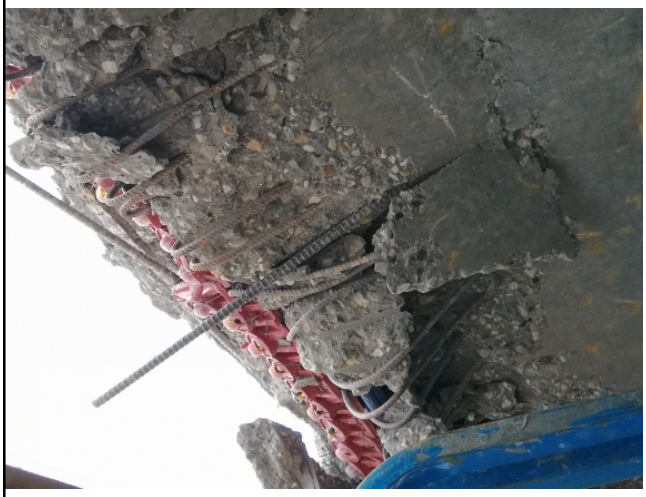
TENSILE STRESS IMMEDIATELY AFTER TRANSFER (24.5.3.2)



"Extreme fiber tensile stress" f_t

- Ends of simply supported member
  $\leq 6\sqrt{f'_c}$
- All other locations
  $\leq 3\sqrt{f'_c}$
- This check is ensuring you do not break the concrete before loading
  - Staged stressing is an option

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SERVICE CASE (25.5.2.1)

Under service case we limit the "Extreme fiber tensile stress" f_t

- Class U(1): (Uncracked)
  $f_t \leq 7.5\sqrt{f'_c}$
- Class T: (Transition)
  $7.5\sqrt{f'_c} \geq f_t \leq 12\sqrt{f'_c}$
- Class C: (Cracked)
  $f_t \geq 12\sqrt{f'_c}$

(1) Two-way slabs are limited to Class U(1): (Uncracked)
$f_t \leq 6\sqrt{f'_c}$

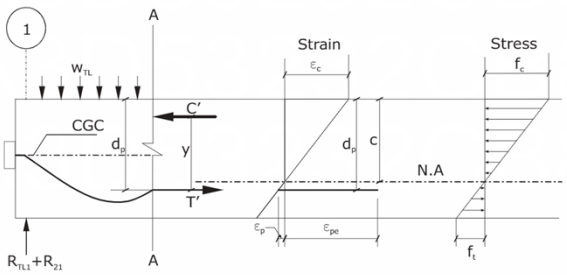

Fig. 5.10 *FBD* Showing Service Load Stresses and Strains

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SERVICE CLASS

What Class Should I Use?

- Class U: (Uncracked)
  - Two-way slabs
  - Most one-way slabs and beams
  - Corrosive environments
    - Parking garages
- Class T: (Transition)
  - Protected one-way slabs and beams where cracking under service loads is acceptable
- Class C: (Cracked)
  - When cracking under service loads is acceptable
  - Heavy Transient Loads
  - Analysis is be performed based on cracked section



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BALLANCE CASE

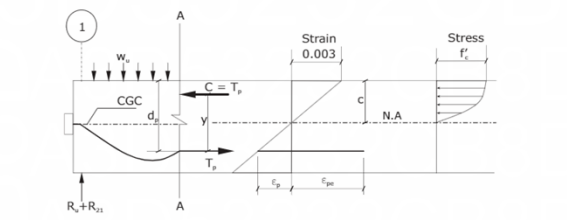

Fig. 5.12 *FBD* at Nominal Strength

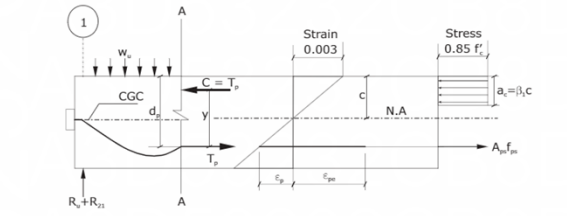

Fig. 5.13 *FBD* at Nominal Strength with Rectangular Stress Block

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STRENGTH CASE

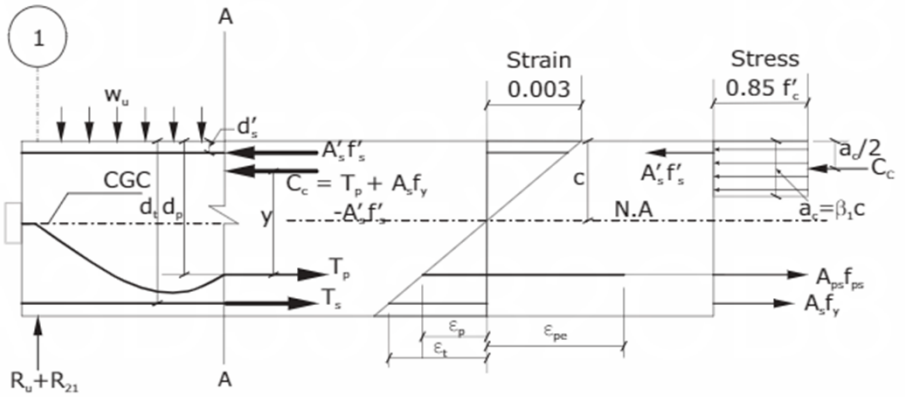

Fig. 5.14 Nominal Strength with Non-Prestressed Reinforcement

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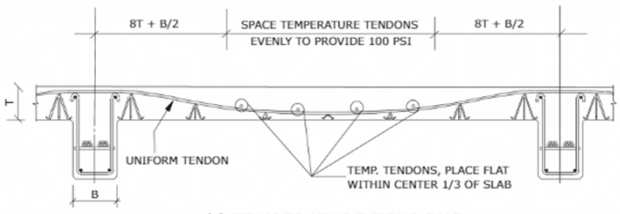
MINIMUM POST TENSION (24.4.4.1)

Minimum PT

- Shrinkage and Temperature
  - 100 psi
- Corrosive environments
  - 150 - 200 psi
- Based on gross area

$\frac{26.8\ kips}{Area}$ for ½ cables



b) TEMPERATURE TENDONS

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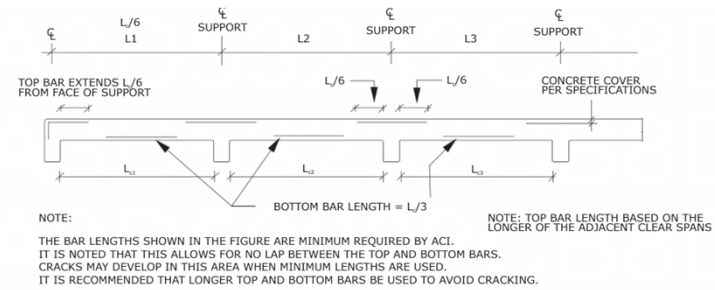
Minimum Lengths

- Remember L/3 and L/6



c) LAYOUT FOR MINIMUM STEEL

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MINIMUM REBAR (8.6.2.3)

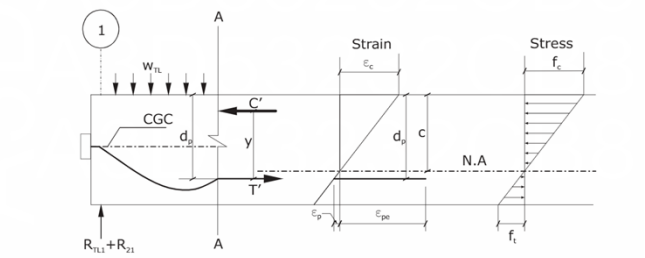

Fig. 5.10 *FBD* Showing Service Load Stresses and Strains

Positive moment two-way slabs

$$f_t \le 2\sqrt{f'_c}$$

$A_{s\,min}$ Not Required*

$$2\sqrt{f'_c} < f_t \le 6\sqrt{f'_c}$$

$A_{s\,min} = \frac{N_c}{0.5 f_y} = N_c$

N_c = Total resultant tensile force under service loads.

Min rebar needs to take about double the needed force for service load case.

*Recommend continuous bottom mat for crack control

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MINIMUM REBAR TWO-WAY (8.6.2.3)

Negative moment two-way slabs

A_s=.00075 A_{cf}

A_{cf} is the larger of the two cross-sectional areas intersecting the column

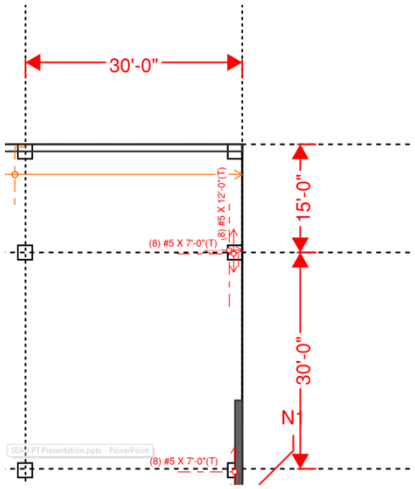
A_{cf} =30/2*12*8=1440

or

A_{cf} =(30+15)/2*12*8=2160

So A_s =.00075*2160=1.62

(5) #5 min



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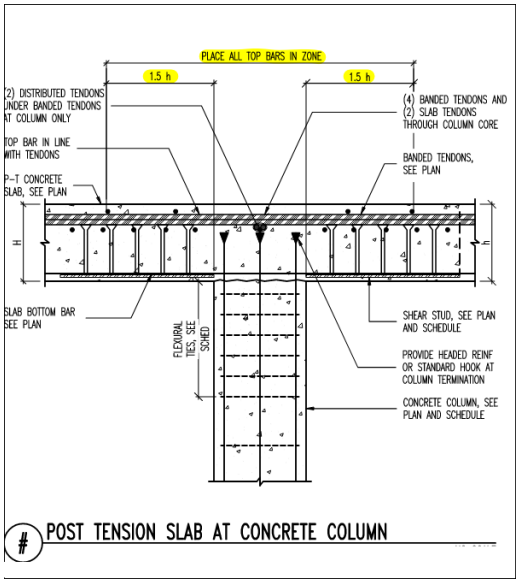
REBAR PLACEMENT

Negative moment two-way slabs

- Placement Critical
- Code requires placement as close as practical to extreme tension fiber
- Place in top of slab at all supports
- Arrangement at top of column most difficult part of two-way slabs
- Provide at walls



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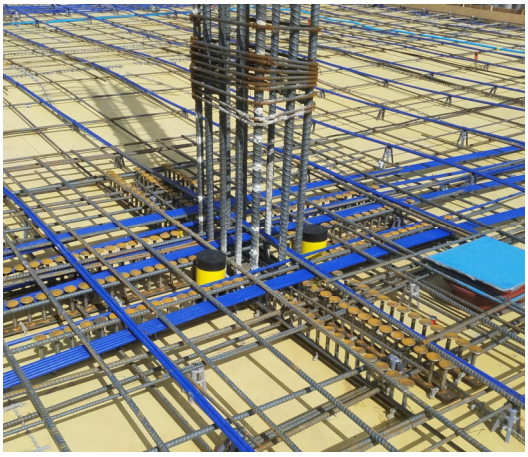
MINIMUM PT OVER COLUMNS

Structural integrity

Code requires (2) ½" diameter cable run through column core in both directions.

Provides catenary action to prevent collapse if there is a punching shear failure.

Can be done with rebar when needed per 8.7.5.6.3



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MINIMUM REBAR ONE WAY (9.6.2.3)

One-way Slabs

$A_{s\ min}$=.004 A_{ct}

A_{ct} is area of concrete between center of gross section to and extreme tension face

Simplifies to

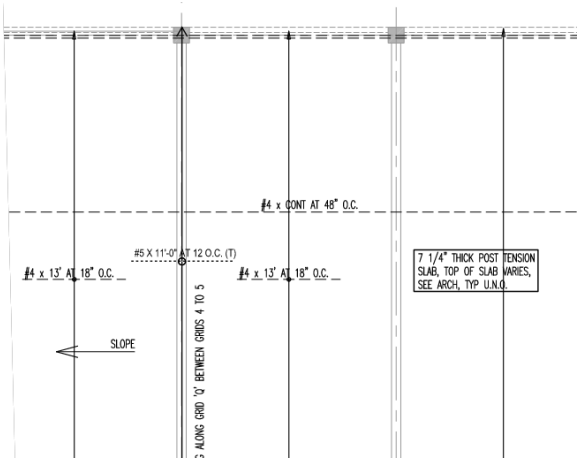
$A_{s\ min}$ = .002 A_T

For 7 ¼" slab

$A_{s\ min}$ = .002 *7.25" * 13" = .172

Use #4 at 12" O.C.

One-way slabs require more steel. Two-way PT slabs may be more economical for this reason alone



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STUD RAIL DESIGN

Two Main Checks

(1) Check stress at d/2 from column face.

$$\phi 8\sqrt{f'_c}$$

Design stud rail size and spacing required shear

(2) Extend stud rail until stress drops to

$$\phi 2\sqrt{f'_c}$$

Do not forget to include stress from moments and eccentricity.

Stud rails required for all columns in seismic design category D,E and F per 18.14.5.1

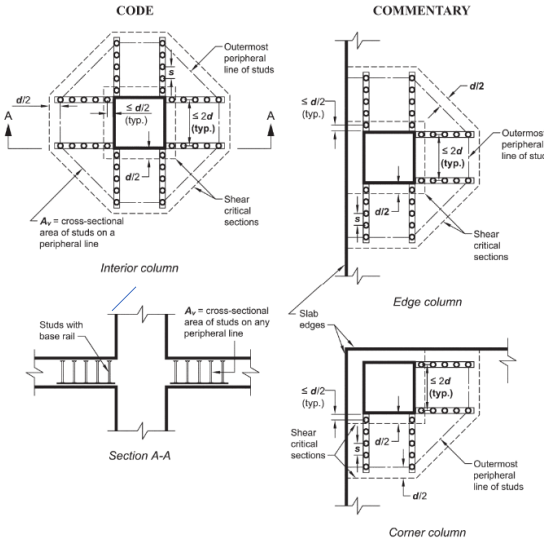

Fig. R8.7.7—Typical arrangements of headed shear stud reinforcement and critical sections.

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POST TENSION LAYOUT

Post Tension Balancing Checks

- Compressive stress immediately after transfer
- Tensile stress immediately after transfer
- Strength load case
- Service load case
- Minimum PT

Too much PT

Balance

Not enough PT

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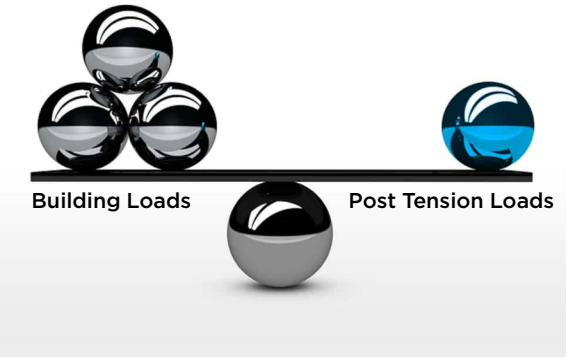
POST TENSION BALANCING

Post Tension Balancing Rules

- Post tension should take care of stresses from service loads*
- Rebar should be used for ultimate loads
- Add PT until checks over the columns are working
- Use added PT at end bays/high moments
- Use consistent drape where possible



*Heavy /Transient Loads are uneconomical so use more rebar

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QUESTIONS?

BHB STRUCTURAL

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