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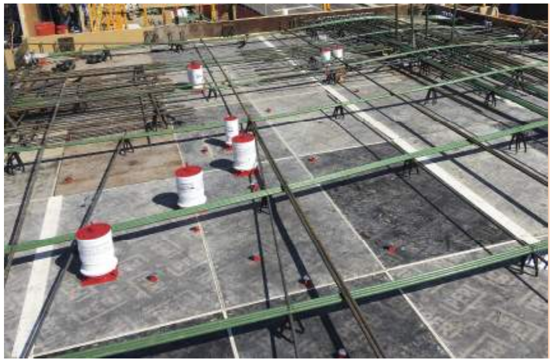
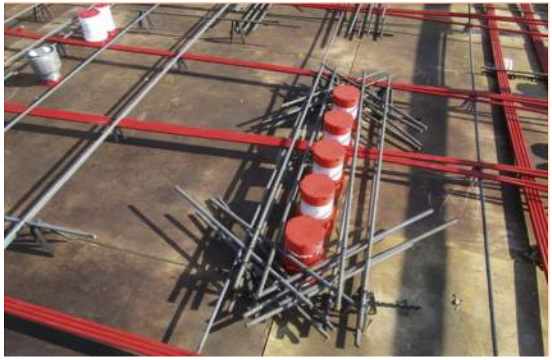
AIA Approved Continuing Education

Efficient Design Of Post-Tensioned Concrete Structures


Seth Pfeil, PE, Principal

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Provider Number: 10008945 | Course Number: PT 101 | 1 LU | HSW

Learning Objectives

#1 Describe the advantages of unbonded vs. bonded post-tensioned concrete in building construction.

#2 Identify general post-tensioned concrete terminology, including uniform and banded tendons, shear rails, slab bands, and slab steps.

#3 Define general parameters for a post-tensioned concrete building layout, including column sizing and slab thicknesses

#4 Determine the differences between concrete lateral systems including shear walls and moment frames

What is Post-Tensioned Concrete?

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Types of Post-Tensioning

UNBONDED

- Tendons are greased inside a plastic sheath, so tendons are unbonded to adjacent concrete.
- Force transmitted through anchors only.
- Commonly used for PT buildings in the United States.
- Installation is generally easier and quicker than bonded PT
- Future penetrations must be assessed carefully to avoid damaging tendons.

BONDED

- Tendons or tendon groups are encased in a flexible duct. After the tendons are stressed, cementitious grout is injected into the duct to bond the tendons to the concrete.
- Force transmitted through anchors and concrete bond.
- Commonly used for bridges in the United States
- Future penetrations are more easily coordinated
- Span lengths can be increased, and deflection can be more controlled

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What is Unbonded Post-Tensioning?

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What is Unbonded Post-Tensioning?

Two-Way Flat Plate

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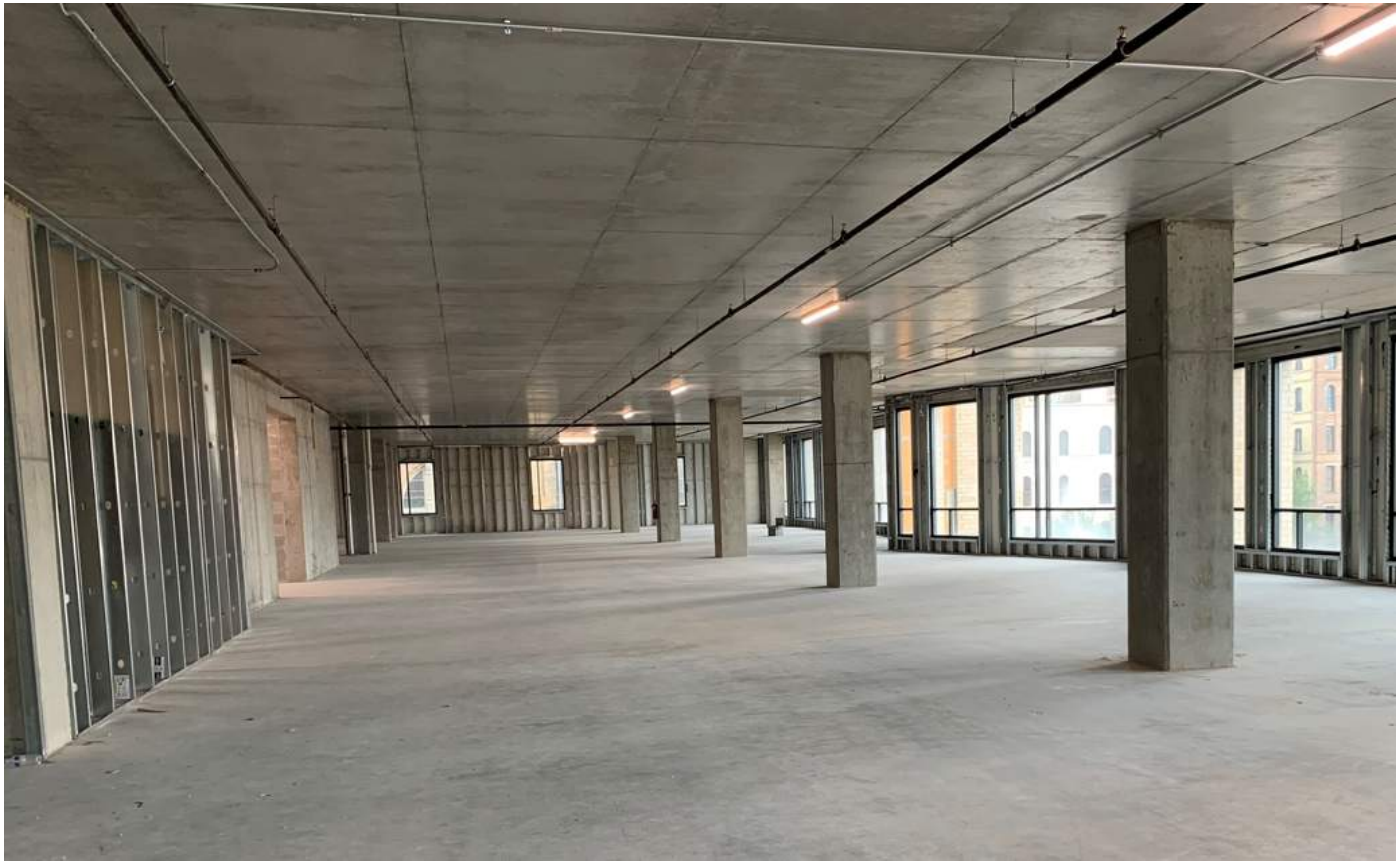
Two-Way Flat Plate



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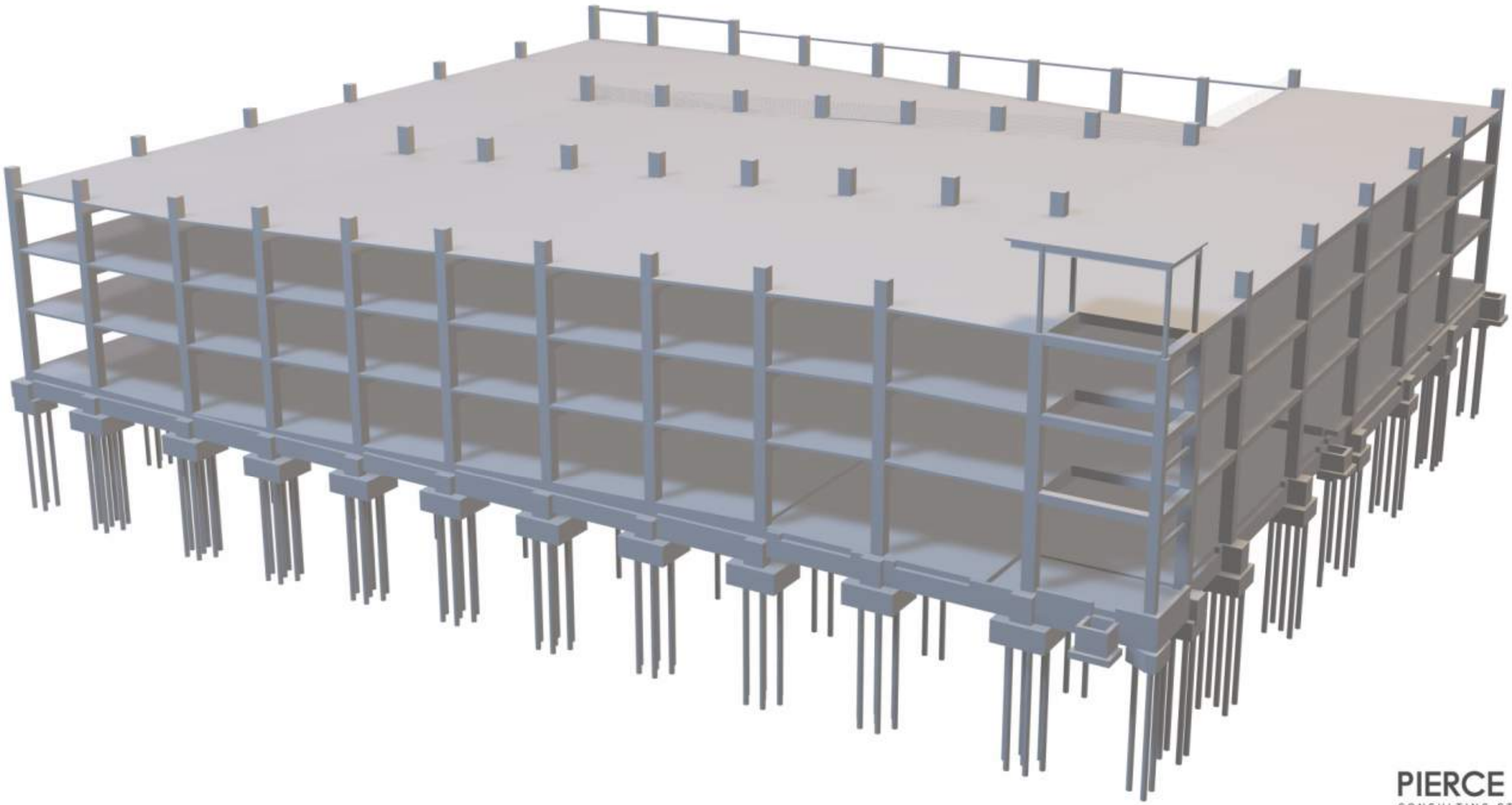
One-Way Slab and Beam



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One-Way Slab and Beam

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One-Way Slab and Beam

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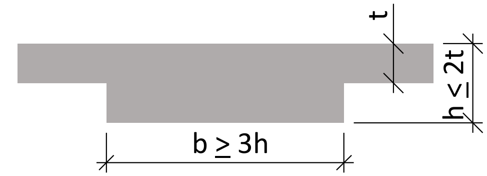
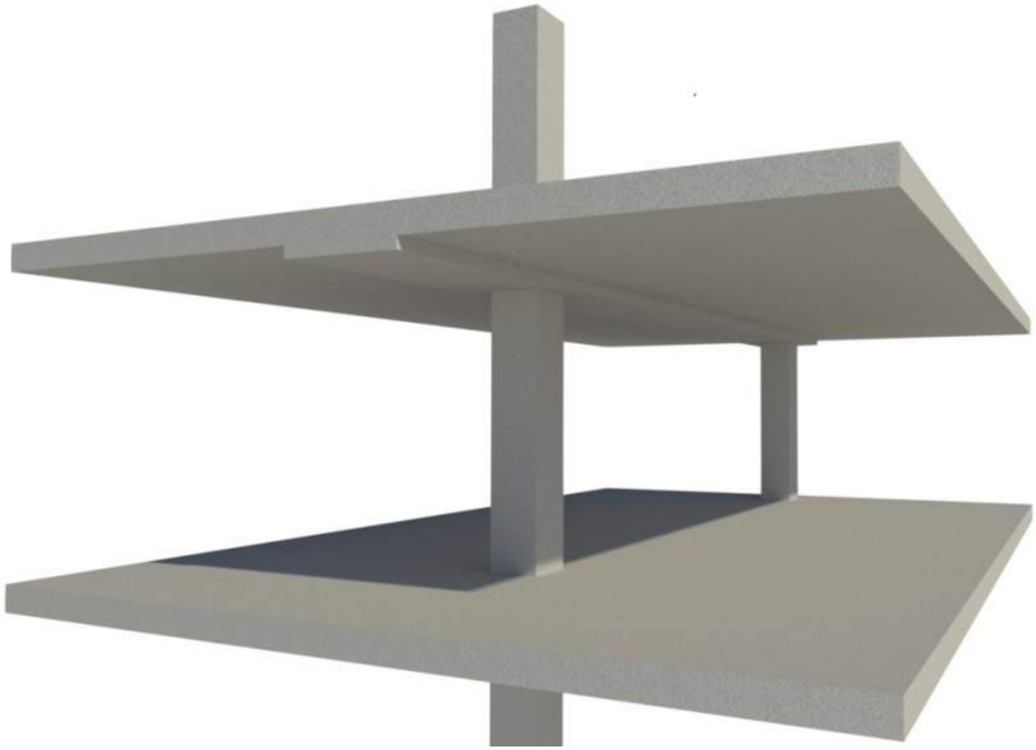
Slab Element Definitions

- Slab band
  - Achieve spans of 40’-0” or greater





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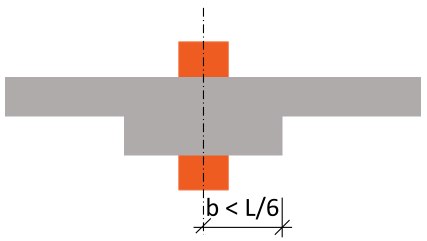
Slab Element Definitions

- Drop cap/column cap(ital)



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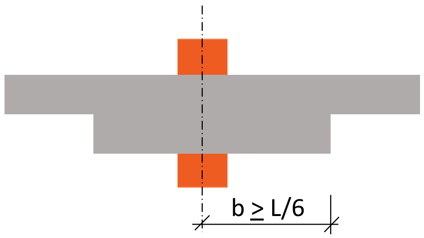
Slab Element Definitions

- Drop panel



Mildly Reinforced vs. Post-Tensioned

- Reinforcement consists entirely of rebar
- Requires significantly more rebar
- Thicker slabs required to achieve same spans
- Layout of the rebar can impact construction schedule
- May be beneficial in high restraint conditions or when future penetrations are anticipated

- Reinforcement consists of post-tensioned tendons and rebar
- Slab requires less rebar than a mildly reinforced slab
- Can achieve thinner floor slabs
- More critical for penetrations to be coordinated and laid out prior
- Lighter Structure

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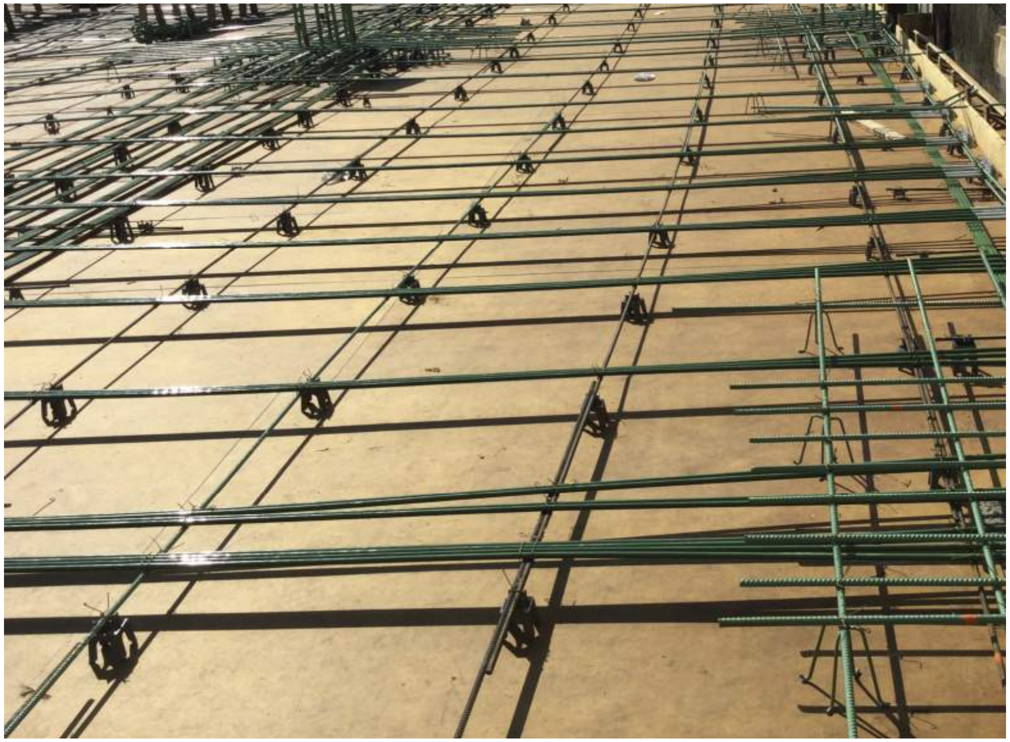
Mildly Reinforced vs. Post-Tensioned



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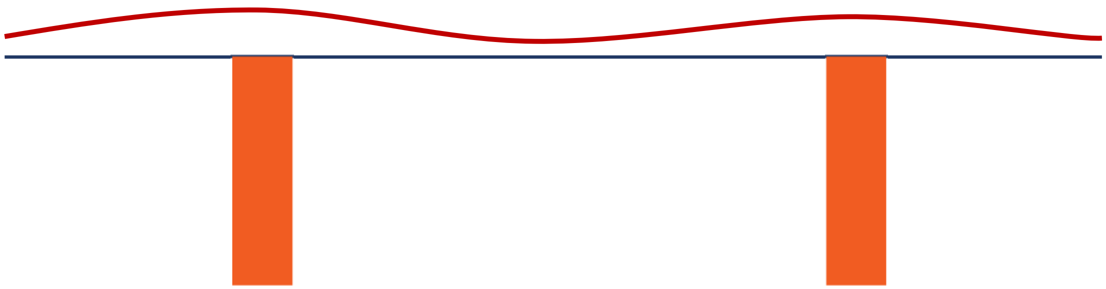
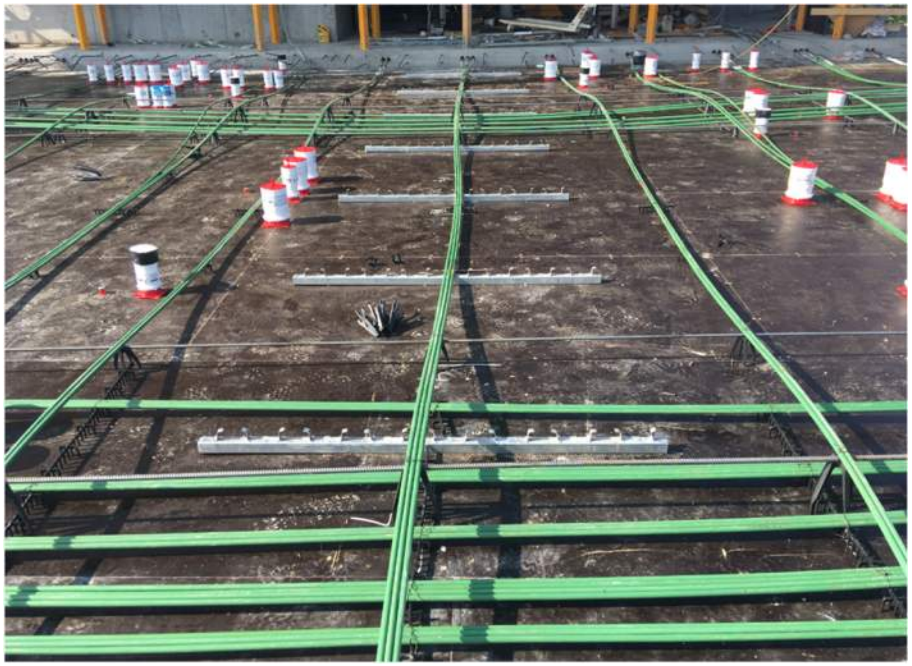
How does unbonded PT work?

- Post-tensioning tendons are laid out on site.
- Tendons typically laid out high at column locations and low at the mid-span between columns





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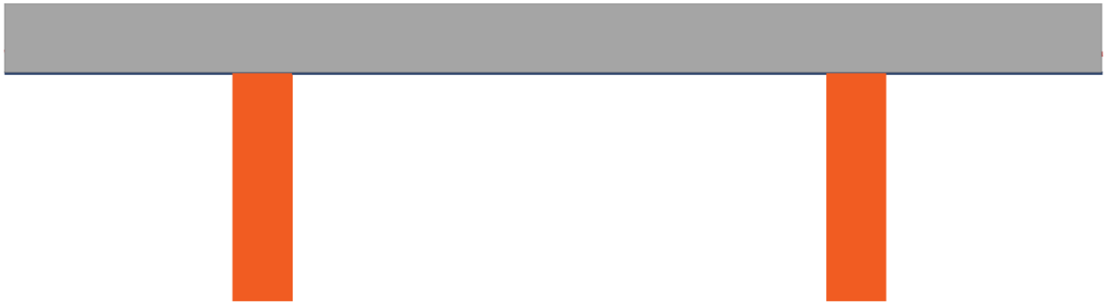
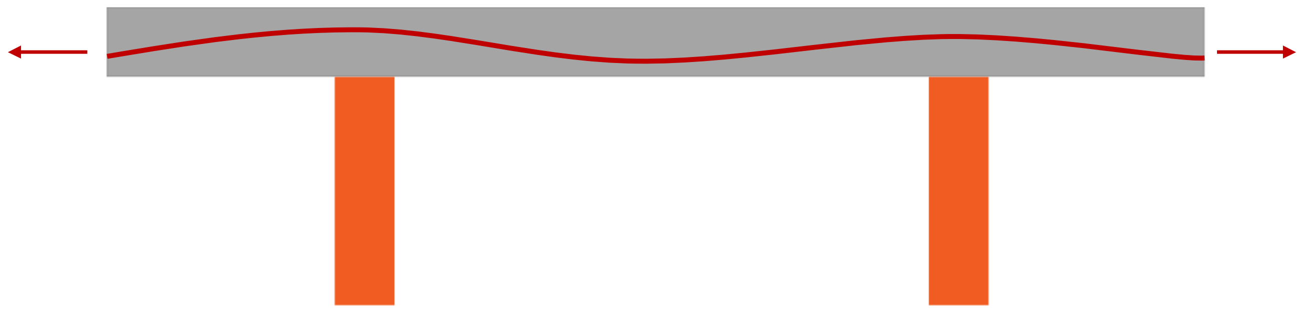
How does unbonded PT work?

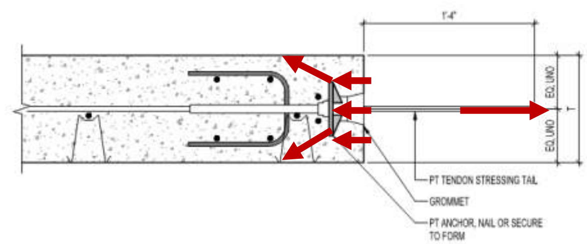


- Concrete is placed around the tendons

How does unbonded PT work?



- Tendons are stressed after concrete has cured.
- Force is transmitted through anchors bearing on the concrete.



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How does unbonded PT work?

- Once tendons are tensioned, they will want to straighten out.
- Straightening of tendons will lead to a "lift" at the slab mid-spans.
- Tension in the tendons is designed to counteract the loads the slab will support over the building lifespan.

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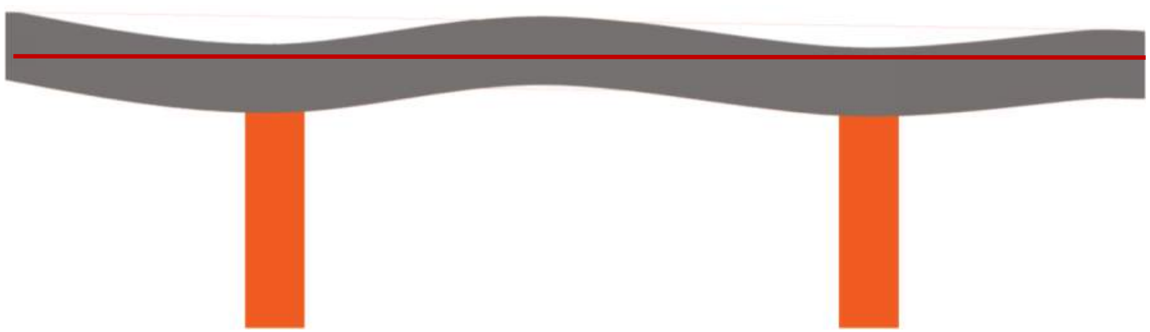


What does the SEOR do?

The SEOR will determine:

- concrete strength.
- slab thickness.
- required mild reinforcement.
- require punching shear reinforcement.
- direction of banded and uniform tendons.
- final effective forces in the tendons (this is sometimes delegated).
- tendon ordinates at columns and mid-spans (this is sometimes delegated).

What does the PT supplier do?

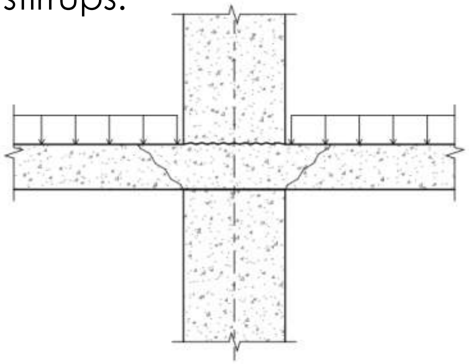
The PT supplier will determine:

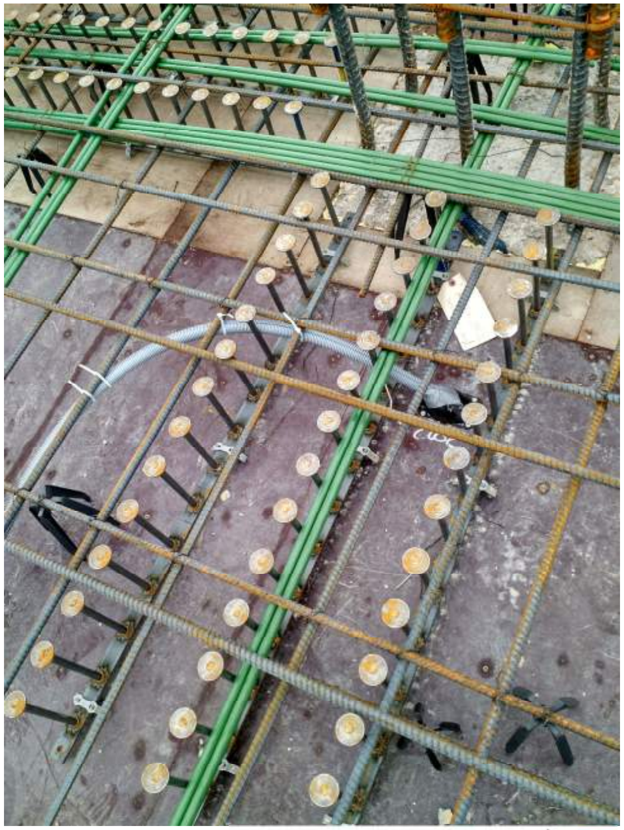
- the number of tendons required to achieve the specified final effective forces.
- layout of tendon support bars and tendons.
- height of chairs and support bars along tendon length.
- locations of required hairpins.

Additional PT Slab Considerations

Punching Shear

- Punching shear can occur as a result of all the loading on a slab having to travel to a column.
- Slab thickness, column sizes, slab loading and penetrations can all impact punching shear capacities.
- Punching shear capacities at columns can be increased with stud rails, column caps or stirrups.





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Additional PT Slab Considerations

Penetrations

- Should be located during design phase if possible.
- Any penetrations added after slab is placed will require the slab to be scanned.
- Penetration locations need to be coordinated with SEOR and accounted for in slab design.
- It is possible to plan for future openings/penetrations as long as coordination occurs during design and construction process.

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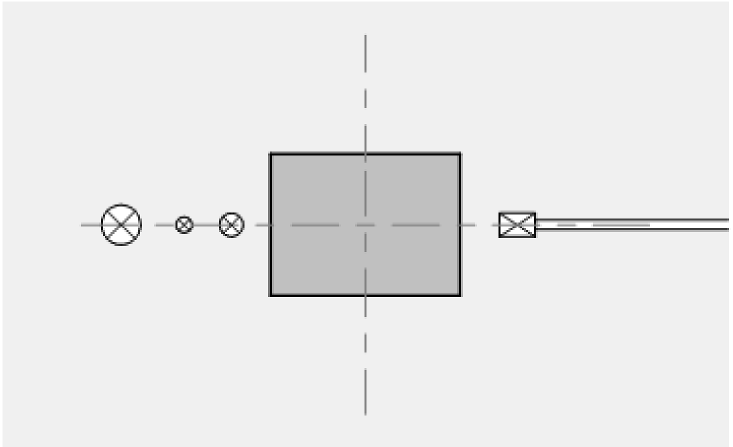
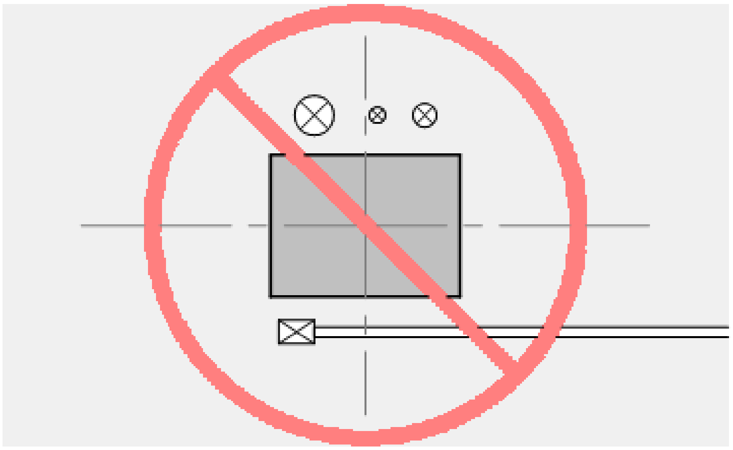
Slab Penetrations



ACCEPTABLE



UNACCEPTABLE

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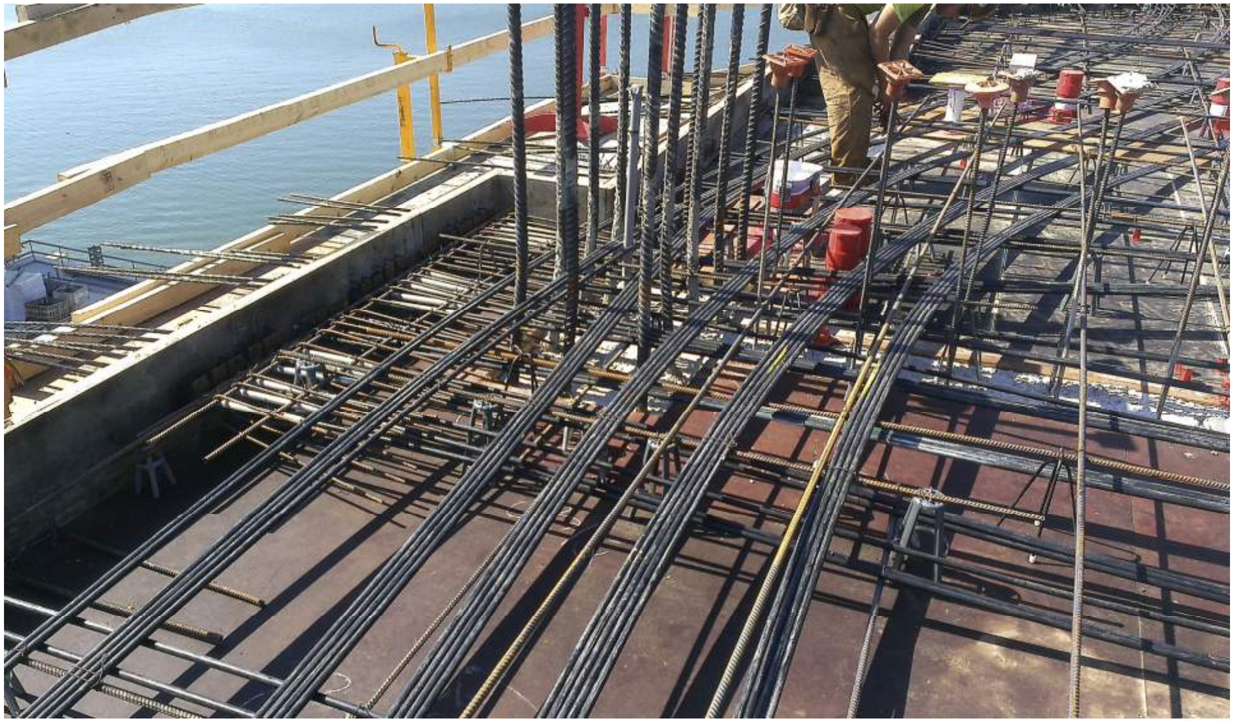
Additional PT Slab Considerations

Sweeps

- Tendons can be swept around openings (with care), or to follow meandering column layout.
- Hairpins are required at some sweeps.
- Limit sweeps to a radius of 10'-0".



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Additional PT Slab Considerations

Sloping and Drainage

- Locate drains in center of column bays.
- Parking slabs-typically maintain uniform thickness and slope both top and bottom of slab.
- Plaza slabs-either keep bottom of slab flat and slope top or keep top and bottom flat and slope insulation.
- Location of slope transition at speed ramps or larger slope transitions to be coordinated with structural layout.

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Additional Considerations

Shrinkage and cracking

- Concrete cracks
- Overall shrinkage of a slab can be approximated as 1”/100’ of length
- Typically, ~65% of shrinkage occurs within first 90 days after placement. Remaining shrinkage occurs over remaining life of building.

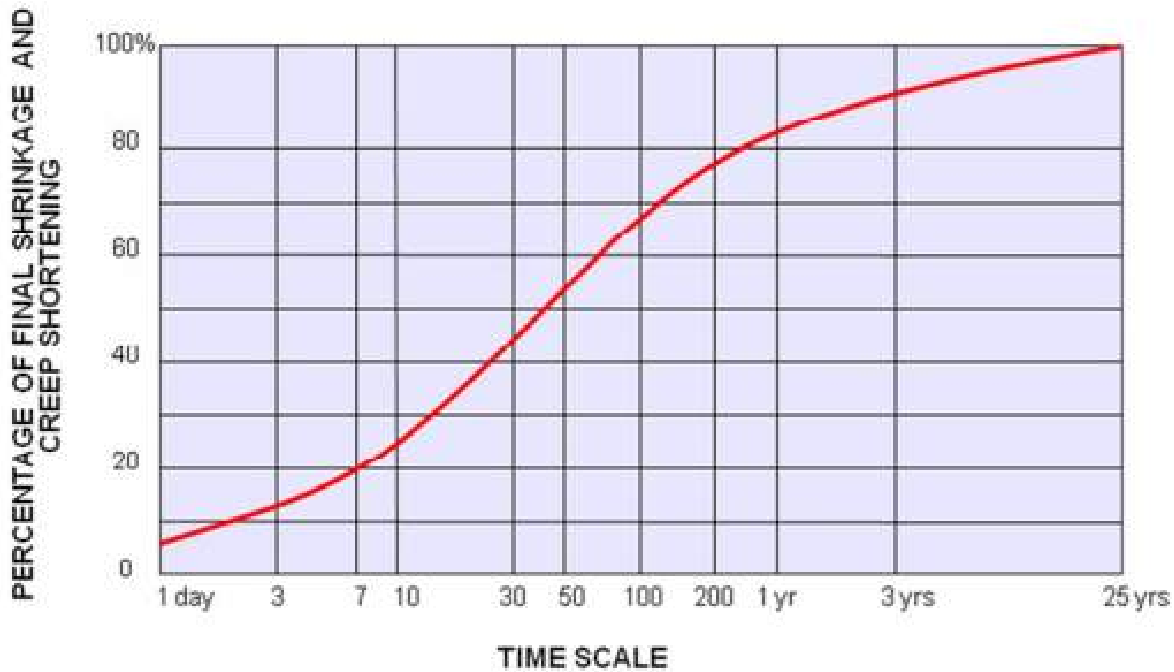

FIGURE P.2.7-1 Variation of the Combined Creep and Shrinkage Shortening with Time for Typical Post-Tensioned Members (P569)

Figure from Technical Note 458 “Shortening Estimate of Post-Tensioned Members”

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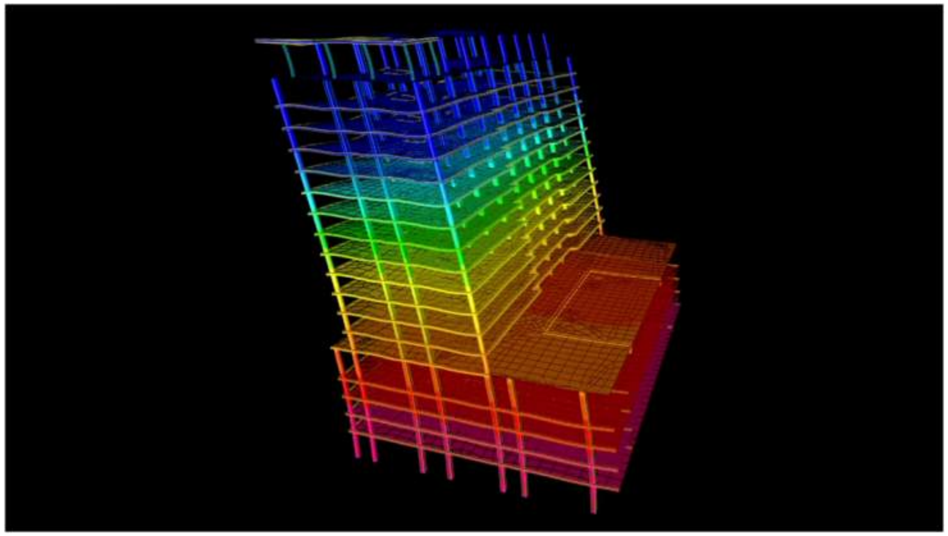
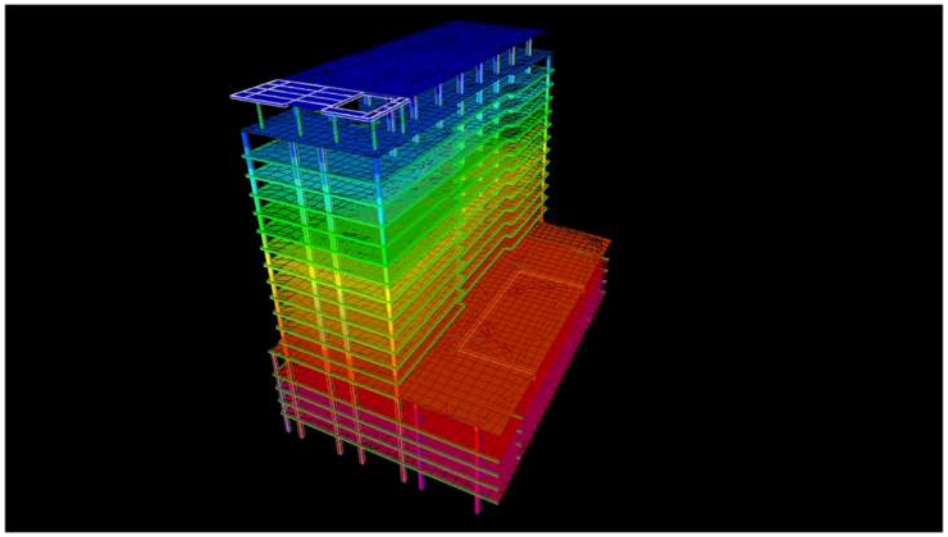
Layout of Structural Elements: Lateral Systems



Moment Frames



Shear Walls

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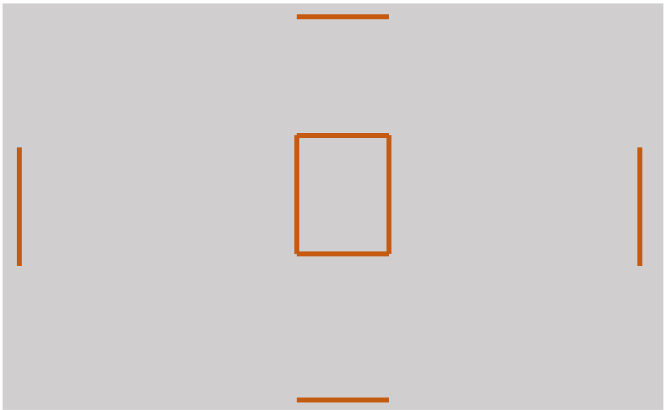
Shear Wall Locations



Acceptable Shear Wall Locations

Unacceptable Shear Wall Locations

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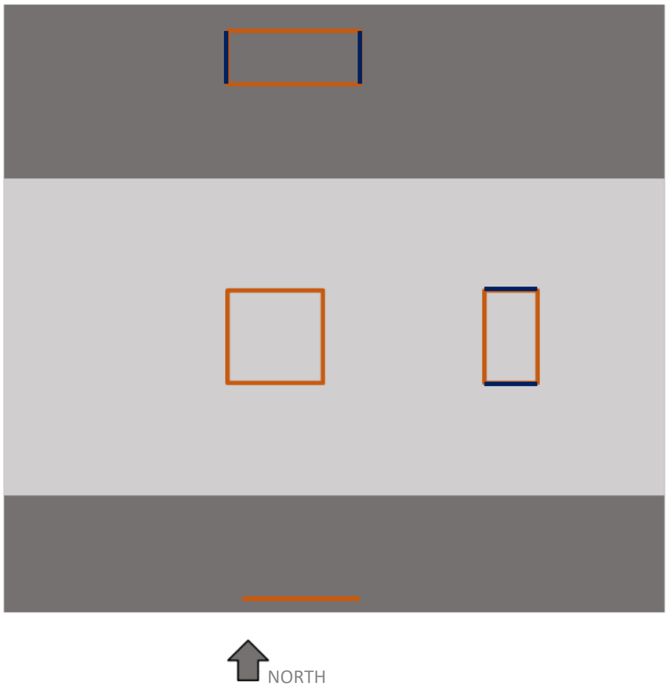
Shear Wall Orientations



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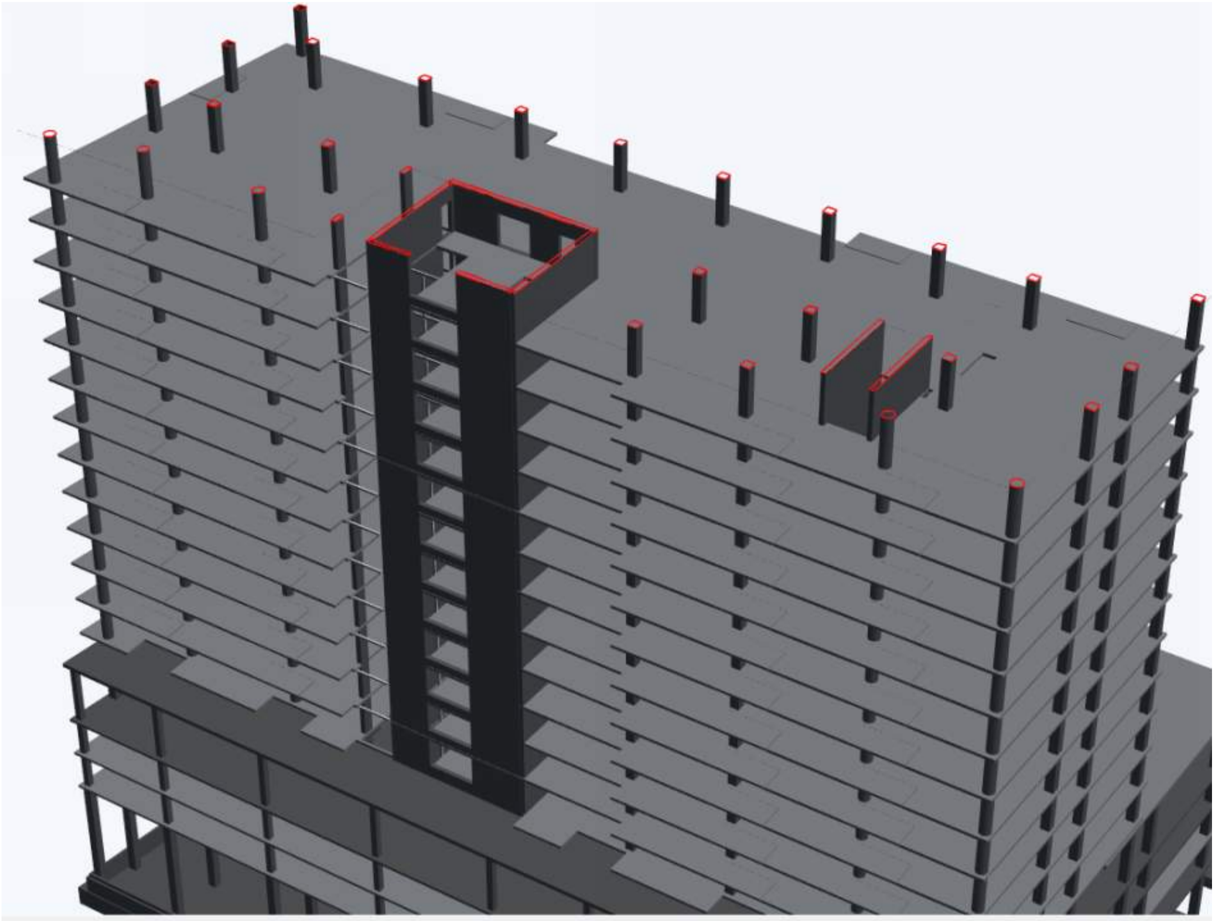
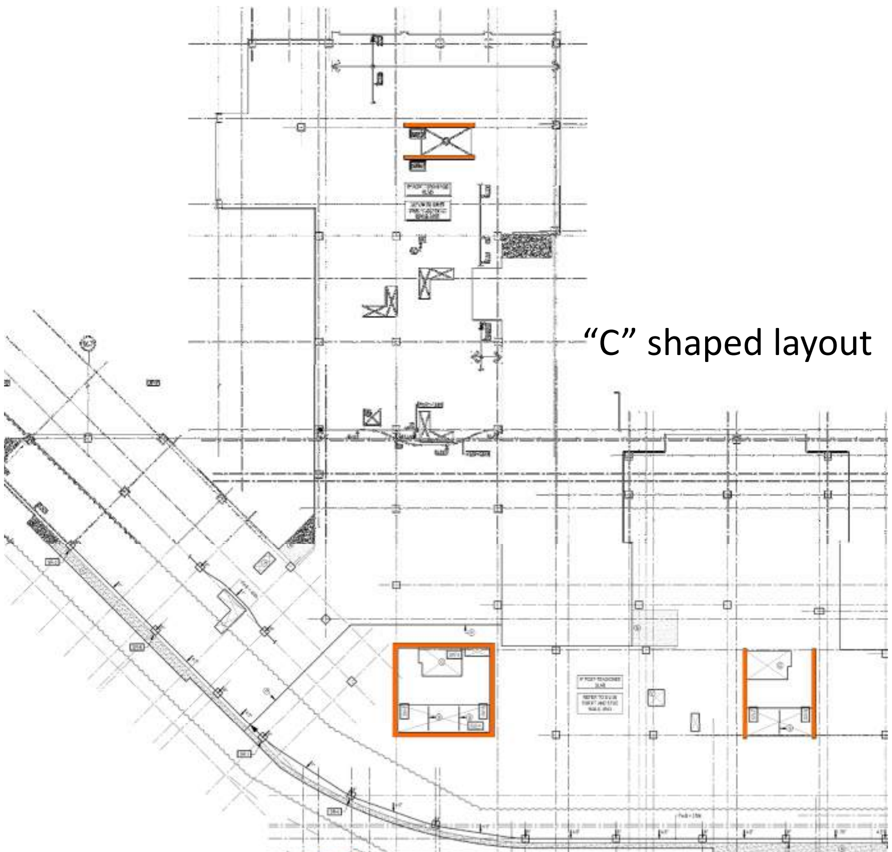
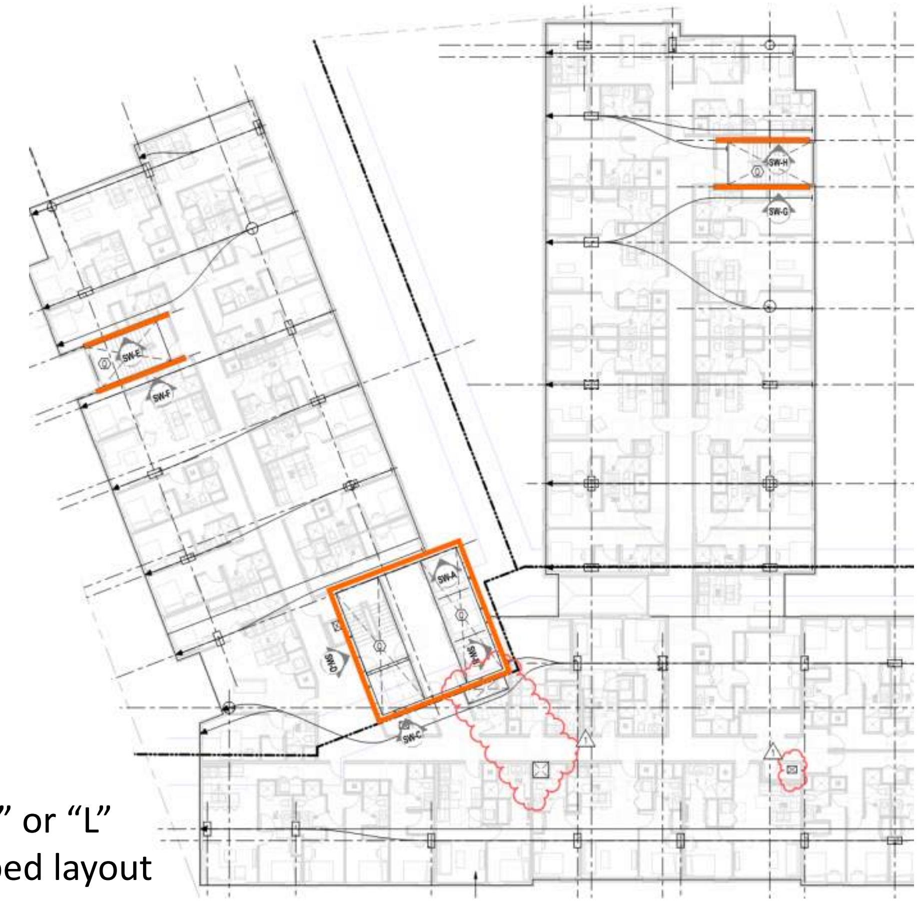


Shear Wall Layouts



"C" shaped layout

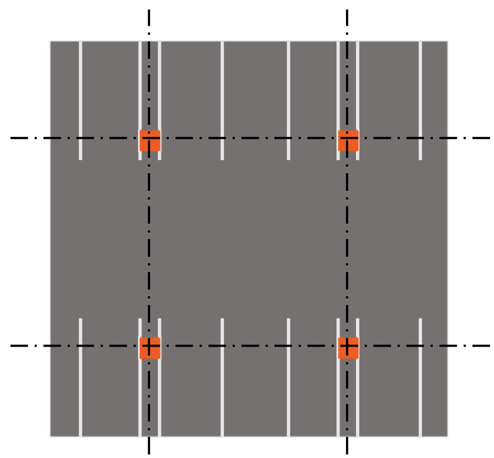


"T" or "L" shaped layout

Layout of Structural Elements: Columns

2-way flat plate

- Stack columns full-height – transfer beams are large, reduce clear heights, and are expensive
- 30’ x 30’ bays or smaller.
- Leave room for columns in parking levels: provide a column line on each side of drive aisle and column lines between every 3 parking spaces.



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Columns – Transfer Conditions

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Columns

REFER TO HANDOUT

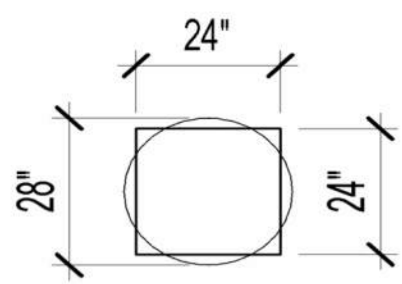
Column Sizing Guidelines

Floors	Square	Circle	Rect 12	Rect 18	Rect 24
5	18"x18"	18"Ø	12"x18"	18"x18"	24"x18"
10	20"x20"	24"Ø	12"x32"	18"x22"	24"x18"
15	24"x24"	28"Ø	12"x48"	18"x32"	24"x24"
20	28"x28"	32"Ø	12"x64"	18"x44"	24"x32"
25	32"x32"	36"Ø	12"x80"	18"x54"	24"x40"
30	34"x34"	40"Ø	12"x96"	18"x64"	24"x48"

- Assumptions: All levels are residential loading, 8 inch slabs, 30' x 30' bays, f'c = 8,400 psi max, 10' floor-to-floor height, shear wall lateral system
- Shaded columns should only be considered in unique situations

General Column Sizing Rules of Thumb

1. Minimum column diameter in inches equals column height in feet. Ex. 20 ft tall column → 20 in minimum column dimension
2. Required circular column diameter is larger than the side of a square column for the equivalent area. Example 24"X24" column ≃ 28" Ø column



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Layout of Structural Elements: Slabs

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Slab Thickness Guidelines

Typical residential level: 8” slab

Typical parking level: 8”-9” slab

Typical retail level: 10”-12” slab

Typical podium levels:

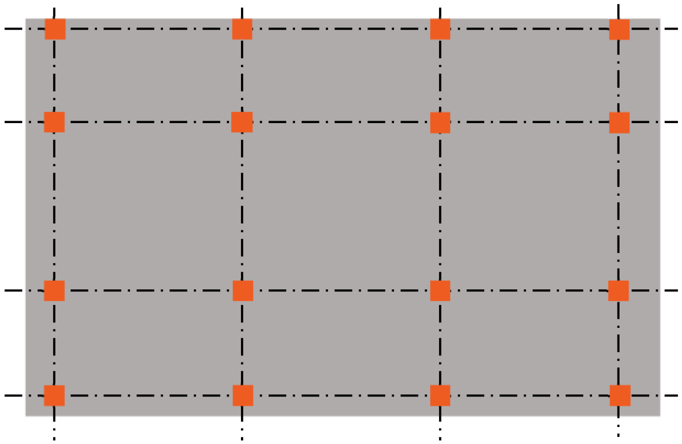
- Supporting 4 levels: 12”-14”
- Supporting 5 levels: 14”-16”
- Supporting 6 levels: 16”-18”
- Supporting 7 levels: 18”-20”
- Supporting 8 levels: 20”-22”
- Supporting 9 levels: 22”-26”

Assumptions: 30’ x 30’ bays, f’c = 6,000 psi, 2-hour fire rating, podiums supporting CFMF residential levels

Column Layout

Rectangular footprints ≤ 58’ wide:

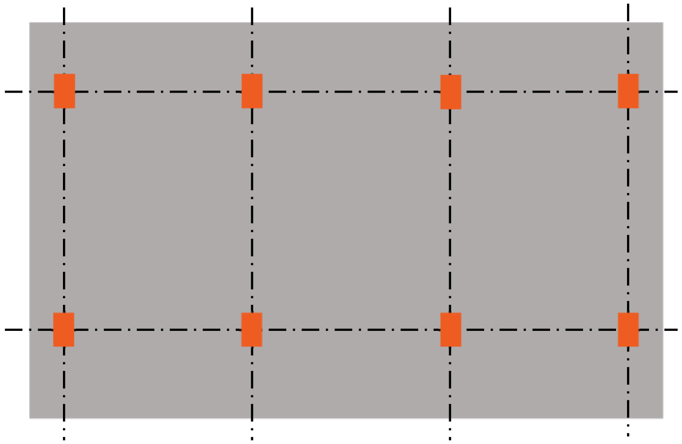
Three bay layout



14’-30’-14’ x 30’ bays

- 8” slab for residential floors.
- More columns across building width.
- Smaller columns.

One bay layout with cantilevers



38’ bay with 10’ cantilever each side

- 9” slab for residential floors.
- Fewer columns across building width.
- Larger columns.

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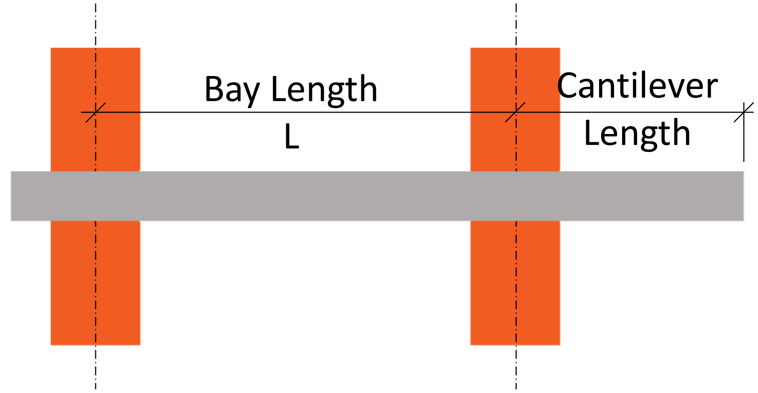
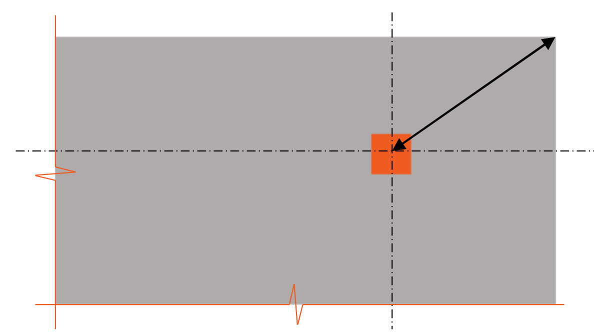
Slab Cantilevers

- Rule of thumb: cantilever length $\leq$ 1/3*L (L = length of adjacent bay).
- Factors affecting cantilever length: slab thickness, concentrated or unique loading conditions, deflection limitations.
- At slab corner, cantilever length is measured from column CL to slab corner.





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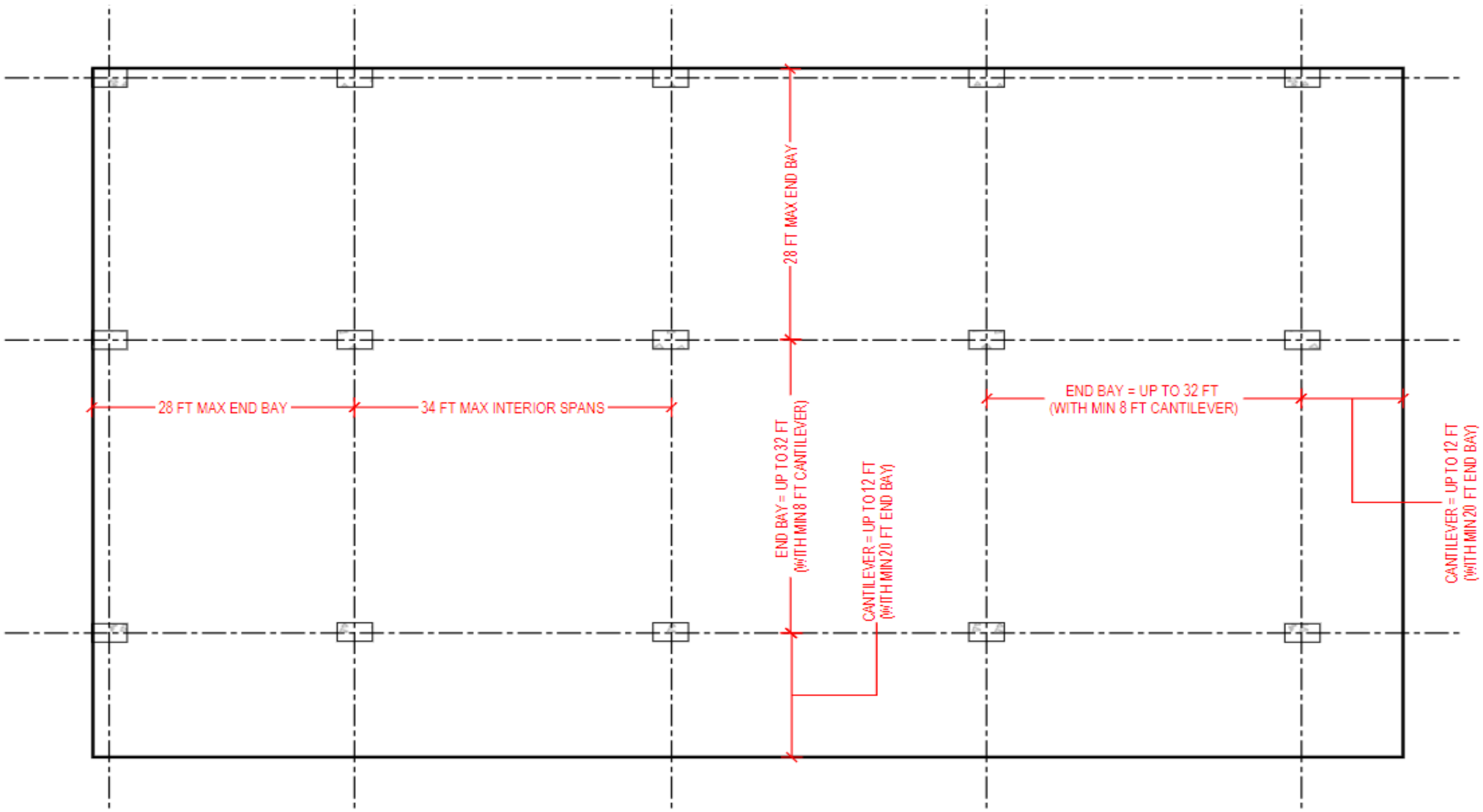
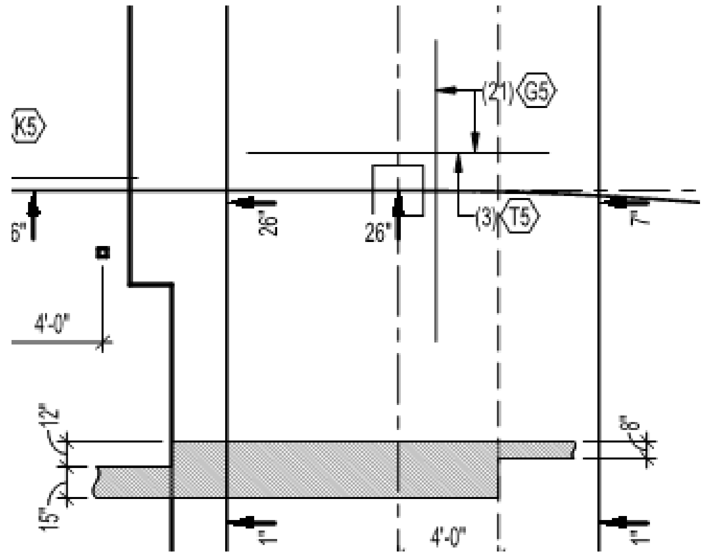
8" PT Slab Spans

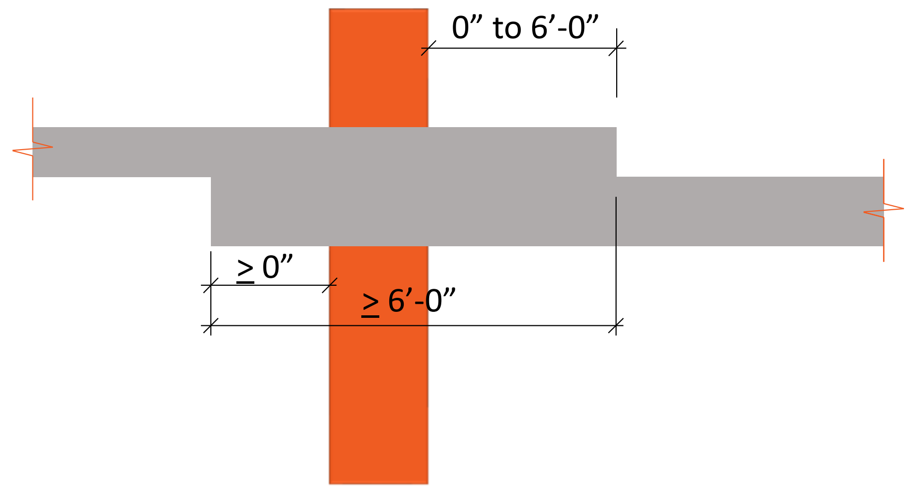


REFER TO HANDOUT

Assumptions:
-Lightweight Exterior Cladding
-Typical Residential Loading

Slab Steps





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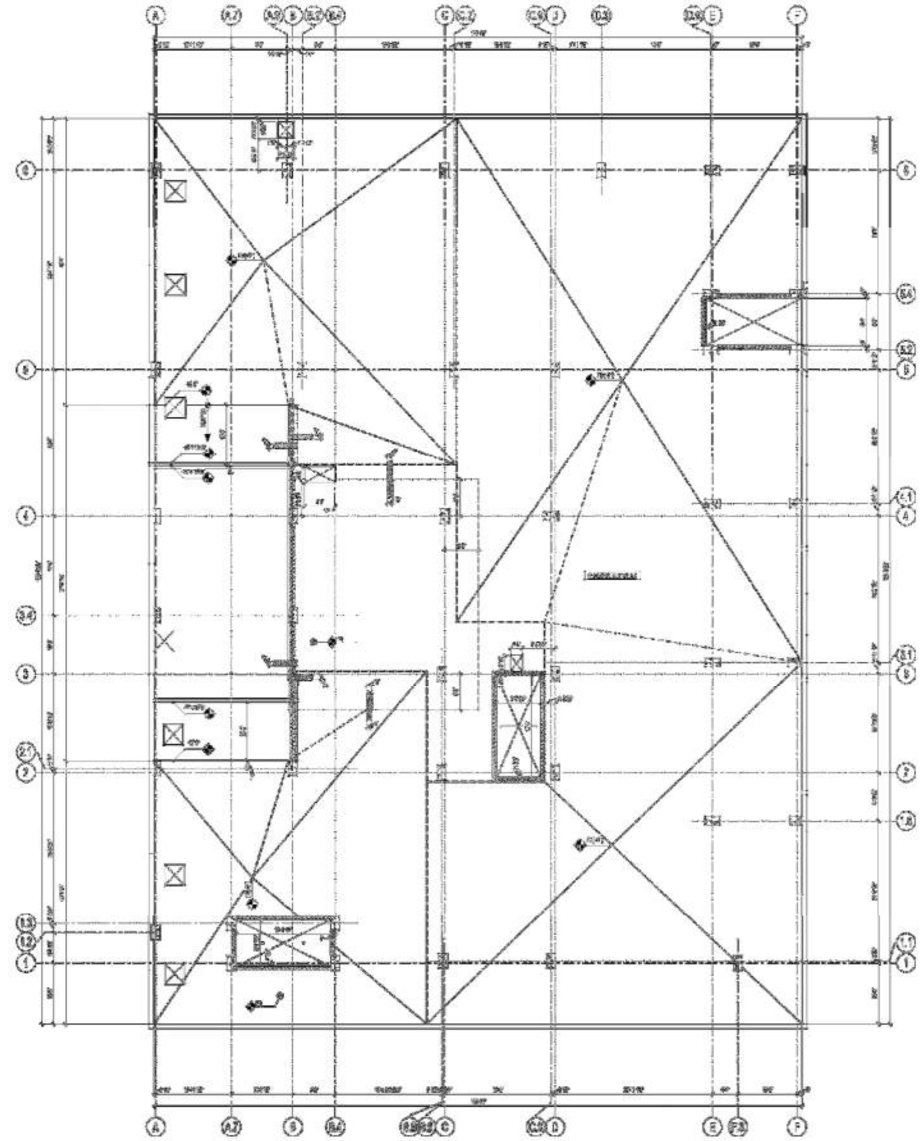
Slab Edge Plans



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Questions?

Reach out to us for questions or clarifications

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