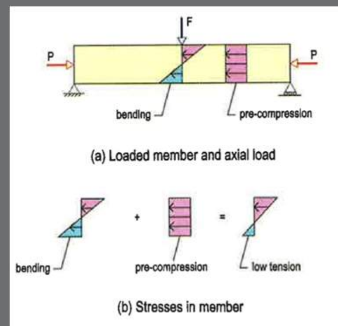

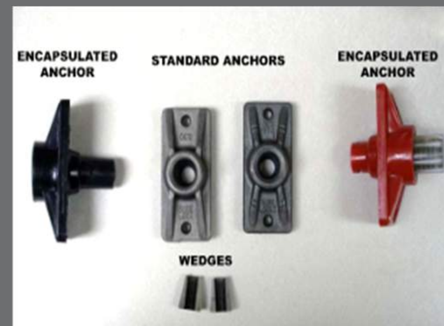

HGA

PRACTICAL POST-TENSIONING FOR BUILDINGS: STRUCTURAL PRINCIPLES & EXECUTION STRATEGIES

1

ACEC Minnesota
2026 MNSEA Annual Trade Show

SESSION 1

Practical Post-Tensioning for Buildings: Structural Principles and Execution Strategies

TUESDAY, MAY 12 | 9:45AM CT

HGA

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Structural Engineer

Kris Borchardt, PE
Structural Engineer

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PRESENTATION OUTLINE & OBJECTIVES

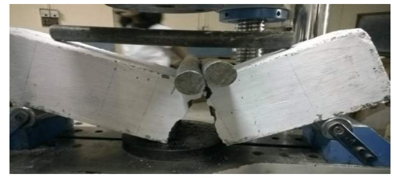
- **PART I – WHY POST-TENSION?**
  - What is post-tensioned concrete? When does it make sense to use PT as a structural system? Benefits? Drawbacks?
- **PART II – DESIGN & DOCUMENTATION**
  - After deciding that a post-tensioned system makes sense for your project, how do you go about designing and documenting?
- **PART III – CONSTRUCTION ADMINISTRATION**
  - After issuing construction documents for a post-tensioned concrete design, what can you expect during CA?
- **PRESENTATION GOAL**
  - Help you decide when, where, and how to use PT while avoiding common traps.
- **PRESENTATION FOCUS**
  - Practical decision-making, constructability, and field coordination – not just theory.

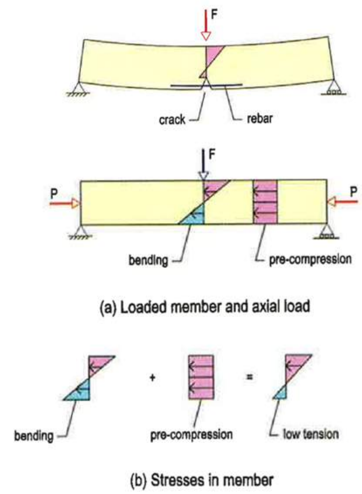
PART I - WHY POST-TENSION?

PART I – WHY POST-TENSION?

CONCRETE BEHAVIOR

- The tensile strength of concrete is approximately 10% of its compressive strength. When it cracks in flexure, there is no mechanism to regain flexural capacity, and **brittle failure** occurs.
- When mild reinforced cracks, it engages the rebar and thus has a much greater flexural capacity than unreinforced. At ultimate conditions, the rebar yields and **ductile failure** occurs.
- Prestressed and post-tensioned concrete add an additional compressive force to **reduce or even eliminate tensile stresses**.
  - In **prestressed concrete**, steel strands are tensioned before the concrete is placed and then released (cut) to induce compressive stress in the concrete.
  - In **post-tensioned concrete**, tendons are stressed after the concrete is placed and has reached a typical minimum compressive strength of 3,000 psi.

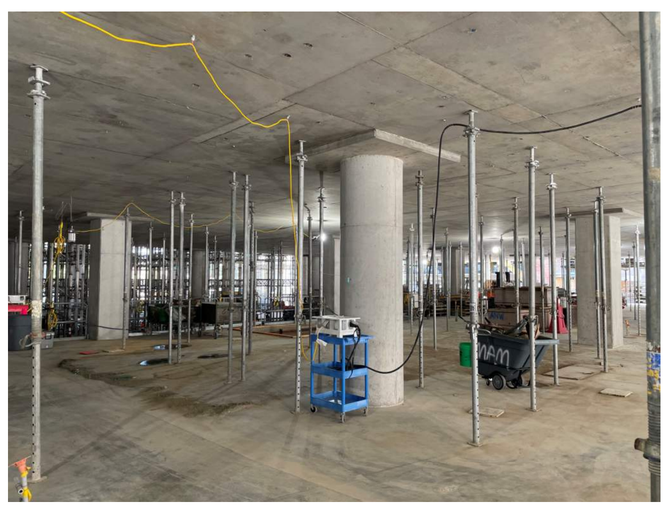




PART I – WHY POST-TENSION?

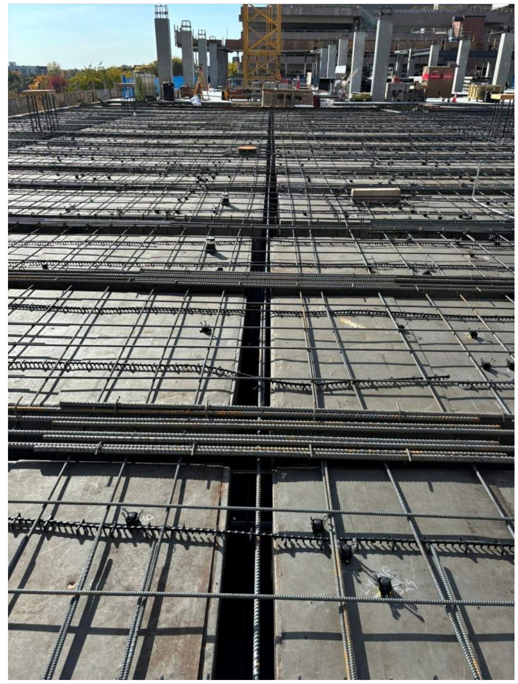
POST-TENSIONING BENEFITS

- **Structural efficiency**
  - Longer spans with thinner slabs
  - Fewer columns and lighter floor systems
- **Architectural and height efficiency**
  - Reduced floor-to-floor height or more floors for the same building height
  - Lower exterior cladding and finish costs
- **Material, cost, and sustainability**
  - Less concrete and reinforcing steel
  - Reduced construction cost and embodied carbon
- **Seismic and foundation benefits**
  - Reduced seismic mass
  - Smaller column and foundation loads
- **Serviceability and durability**
  - Improved crack control with smaller, tighter cracks
  - Reduced long-term deflections



MILD REINFORCED BENEFITS

- **Simpler design and construction**
  - No specialized PT design by the SEOR
  - No PT-qualified suppliers, labor, or stressing technicians
  - No stressing equipment or stressing operations
  - Simpler inspection and quality control during construction
- **Lower upfront cost**
  - Reduced mobilization and initial construction costs
- **Well-suited for simple or isolated conditions**
  - Often preferred for one-off slab conditions or simple structures
- **Greater flexibility for future modifications**
  - Easier coring and creation of new openings for MEP reroutes
  - No long-term tendon maintenance or protection



HOW TO DECIDE?

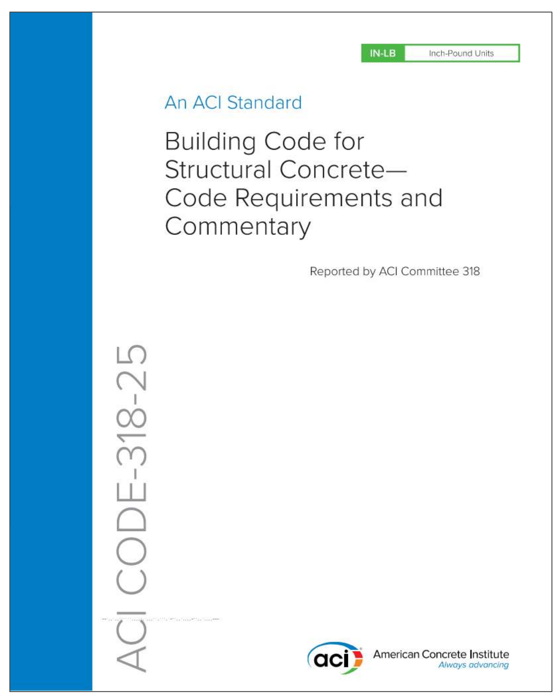
- **PT benefits scale with project size**
  - Greater square footage, more floors, or taller buildings increase PT efficiency
- **Evaluate early**
  - Perform a cost-benefit analysis during pre-design or schematic design to finalize the structural system.
  - Use internal cost estimating when available, or consult trusted suppliers for current cost data
- **Consider total project value**
  - Structural cost is only one component of the Owner's overall project cost
  - Floor-to-floor height, usable area, schedule, and long-term performance may govern
- **Construction type and use matter**
  - Structural system selection is influenced by construction type and building use
- **Common scenarios where PT is preferred or competitive**
  - Mid- and high-rise buildings
  - Parking structures
  - Podium slabs (5-over-1 construction)

PART II - DESIGN & DOCUMENTATION

PART II – DESIGN & DOCUMENTATION

CODES

- **Building Codes**
  - Jurisdiction will be governed by IBC, state, or local codes
  - Provides legal framework and adopts ACI 318. Governs seismic category, special inspection, and enforcement.
- **Structural Codes**
  - *ACI 318 – Building Code Requirements for Structural Concrete*
  - *ACI/PTI 320 – Post-Tensioned Structural Concrete – Code Requirements and Commentary*
    - ACI/PTI CODE-320-25 is a new joint code that merges PTI's technical specialization with the format of ACI's code requirements.
    - Written in mandatory language. Contains PT specific requirements.
- **Construction / Material Specification**
  - *ACI 301 Specifications for Structural Concrete*
    - Reference standard cited in project specifications.
  - *ACI 423.7 Unbonded Single Strand Tendon Materials*
    - Minimum material requirements referenced by ACI.



TYPES OF PT FLOOR SYSTEMS

PART II – DESIGN & DOCUMENTATION

TENSIONING TERMINOLOGY

- **Pre-Tensioning**
  - Tendon stressing occurs *prior* to concrete pour.
  - Common in precast plank, double tees, bridge girders.
  - Straight or harped profiles are most common.
- **Post-Tensioning**
  - Tendon stressing occurs *after* concrete pour.
  - Common in building slabs and beams.
  - Profiles can be more easily customized to be whatever you want.
- **Bonded Tendons**
  - Concrete (or grout in ducts) hardens and bonds to the tendons. Tendons transfer compression along their length
- **Unbonded Tendons**
  - Tendons are placed in sheathing with grease, so no bond. Tendons transfer compression at anchorages only

For buildings, ***unbonded post-tensioning*** is the most common.

Image(s) Source(s): Noor Prestressing

PART II – DESIGN & DOCUMENTATION

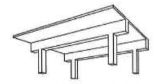
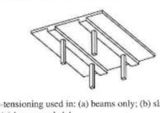
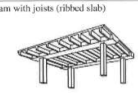
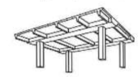
TYPES OF PT FLOOR SYSTEMS

- 1-way systems
  - 1-way beam and slab
    - Parking structures and office buildings
  - Slab, beam and girder
  - 1-way slab with wide shallow beams
    - One direction short span, other direction long span
  - If bay geometry is driving 2-way behavior, don't force a 1-way system selection.

Table 3.1—Post-tensioned structures: span-depth ratios for one-way slabs and beams

Suggested span-depth ratios for one-way systems (where LL/DL < 1)	
One-way slabs	48
Narrow beams with $b = h/3$	20
Wide shallow beams with $b = 3h$	30
One-way joists	40

Table 2.1—One-way framing systems

Floor system and layout of post-tensioning tendons	Typical span range (column center-to-center)	Typical additional DL + LL	Comments
One-way slab and beam  Post-tensioning used in: beams, slabs (main and temperature)	Beams = 50 to 65 ft (15 to 20 m) Slabs = 15 to 30 ft (4.5 to 9 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Commonly used in parking structures but has also been used effectively in office buildings with long spans • Specialized forming systems have been designed for this system (steel beam forms and large-panel slab forms)
Slab, beam, and girder system  Post-tensioning used in: slabs (main and temperature), beams, and girders	Slabs = 15 to 20 ft (4.5 to 6 m) Beams = 50 to 65 ft (15 to 20 m) Girders = 30 to 40 ft (10 to 12 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Generally more economical than spanning a very thick slab between beams located on column lines • Commonly used in parking structures at "turn-around" aisles and in other occupancies with short-direction spans of 30 ft (9 m) and more
One-way slab plus wide shallow beam  Post-tensioning used in: (a) beams only; (b) slab only; and (c) beams and slab	Beams = 25 to 40 ft (8 to 12 m) Slabs = 18 to 25 ft (5.5 to 7.5 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Effective for column layouts with short span in one direction and long span in orthogonal direction • Normally beams span long direction, slab spans short direction • Used primarily where structural depth is limited
Wide beam with joists (ribbed slab)  Post-tensioning used in: beams and joists *Note: Beams and joists should have the same depths*	Slabs = Typically approximately 3 ft (1 m) Beams = 20 to 35 ft (6 to 11 m) Joists = 35 to 65 ft (11 to 20 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Effective for column layouts with short span in one direction and long span in orthogonal direction • Normally beams span short direction and joists span long direction • Minimized structural depth
Wide beam with skip joists (ribbed slab)  Post-tensioning used in: beams and joists, occasionally in slab. *Note: Beams and joists should have the same depths.*	Slabs = Typically approximately 3 to 12 ft (1 to 4 m) Beams = 20 to 35 ft (6 to 11 m) Joists = 35 to 55 ft (11 to 17 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Spreads joists as far as possible without increasing cost of slab • Often allows more efficient use of post-tensioning in joists (force per 1 ft [0.3 m] of width)

PART II – DESIGN & DOCUMENTATION

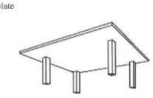
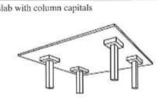
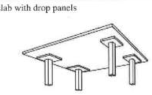
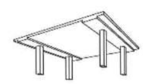
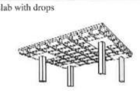
TYPES OF PT FLOOR SYSTEMS

- 2-way systems
  - Flat plate
    - Most efficient with square bays
  - Flat slab
    - Column capitals
      - Increased punching shear capacity
    - Drop panels
      - Larger panels can reduce flexural demands
    - Slab bands
      - Effective for rectangular bays
  - Waffle slab

Table 4.1—Suggested span-depth ratios for two-way systems (where LL/DL < 1)

Two-way slabs	45
Two-way slabs with drop panel	50
Two-way slabs with two-way beams	55
Two-way waffle slab (5 x 5 ft [1.5 x 1.5 m] grid)	35

Table 2.2—Two-way framing systems

Floor system and layout of post-tensioning tendons	Typical span range (column center-to-center)	Typical additional DL + LL	Comments
Flat plate  Bands in one direction, and uniformly distributed tendons in the other	20 to 30 ft (6 to 9 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Lowest formwork cost • Flexibility in column arrangement • Flat ceiling • Greatest flexibility in under-ceiling services layout • Most efficient if bay size is approximately square • Load path easy to visualize • Punching shear strength can be increased using stud rails, shearheads, or conventional shear reinforcement
Flat slab with column capitals  Bands in one direction, and uniformly distributed tendons in the other	25 to 35 ft (8 to 11 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Effective system for increasing punching shear capacity if architectural considerations permit • Small caps have minor effect on flexural behavior
Flat slab with drop panels  Bands in one direction, and uniformly distributed tendons in the other	30 to 40 ft (9 to 12 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Larger drop panels can be effective in reducing flexural reinforcement. • Normally used for longer spans
Slab with slab band  Bands in one direction, and uniformly distributed tendons in the other	25 to 40 ft (8 to 14 m)	Light: Up to 100 lb/ft^2 (5 kN/m^2) to Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2)	• Can be very effective in panels with rectangular aspect ratios • Two-way behavior must be justified to avoid more restrictive one-way code requirements
Waffle slab with drops  Ribs both ways *Note: Ideally, the "drops" and "ribs" have the same depth*	30 to 60 ft (9 to 18 m)	Medium: 100 to 200 lb/ft^2 (5 to 10 kN/m^2) to Heavy: Over 200 lb/ft^2 (10 kN/m^2)	• Very effective for heavy loading and relatively long spans • Most efficient if bay size is approximately square

PT COMPONENTS, TENDON PROFILES, AND LAYOUT

PART II – DESIGN & DOCUMENTATION

PT COMPONENTS

- ½" diameter strand
  - Low-relaxation ASTM A416
  - 270 ksi (vs 60 ksi for mild reinforcing)
    - Strand area = 0.153 in^2
    - #4 rebar = 0.20 in^2
    - (270*0.153)/(60*0.20) = ~3.4 more force
- Tendon sheathing
- Grease
- Anchorages
  - Dead ends, stressing ends, & intermediate stressing
- Unbonded tendon systems must be fully encapsulated by code

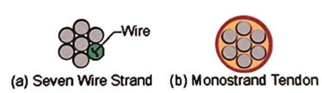
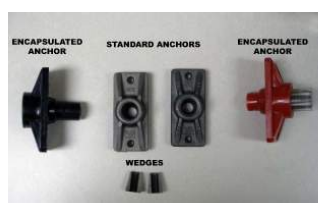


FIGURE 3.2.1-1 Unbonded Strand and Tendon (P495)



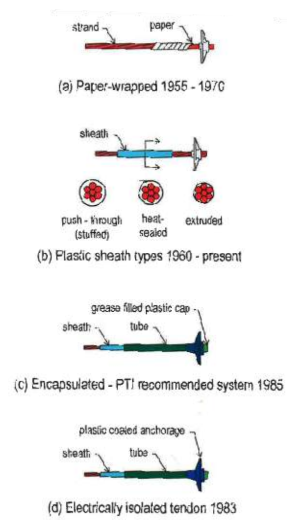


FIGURE 3.2.1-3 Chronicle of Major Developments in Unbonded Tendons (PTS204)

 Image(s) Source(s): POST-TENSIONING Concepts; Design; Construction

PART II – DESIGN & DOCUMENTATION

TENDON DRAPE

- **What is tendon drape for?**
  - If all post-tensioning in a slab were run at mid-depth and flat, the result would be uniform compression (P/A) only
  - This is still beneficial, but leaving a lot of potential capacity and deflection control on the table
- **Maximize tendon impact**
  - Provide drape
  - Cables are given specific heights at regular intervals along their length
  - Results in a specific tendon profile
  - Drape is accomplished with slab bolsters and chairs with support rebar at specific heights
  - SEOR typically gives drape (CGS) at supports and mid-span, and PT supplier builds the rest of the profile

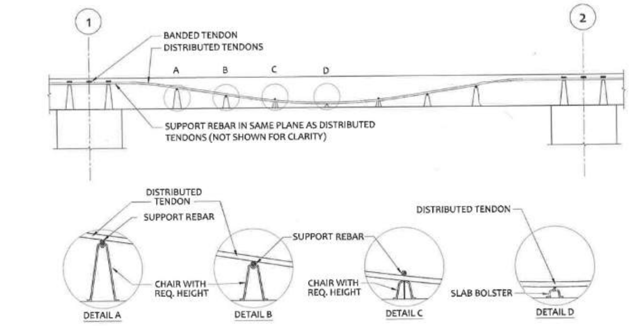
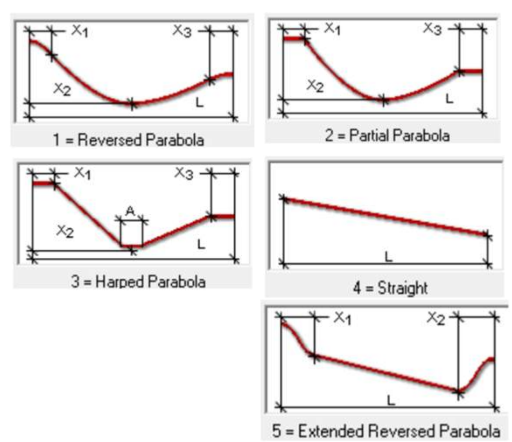


Fig. 4-2—Distributed tendon support details at columns.

PART II – DESIGN & DOCUMENTATION

PT PROFILES

- **Common Tendon Profiles**
  - Reversed Parabola
  - Partial Parabola
  - Harped Parabola
  - Straight
  - Extended Reversed Parabola
- **Applied Loads Are Important**
  - Parabolic is most common for continuous slabs and beams that are designed for uniform loads
  - Curvature of tendon profile is what provides lifting effects
  - The parabolic profile mimics the parabolic moment diagrams that result from uniform loading
  - For transfer beams or members that take large point loads, harped or another profile may be appropriate
  - For shorter spans, and spans where you don't want upward load balancing, straight tendon profile may be appropriate



WAYS TO LAYOUT PT

- Banded tendons
- Uniform tendons
- Banded-uniform
- Banded-banded

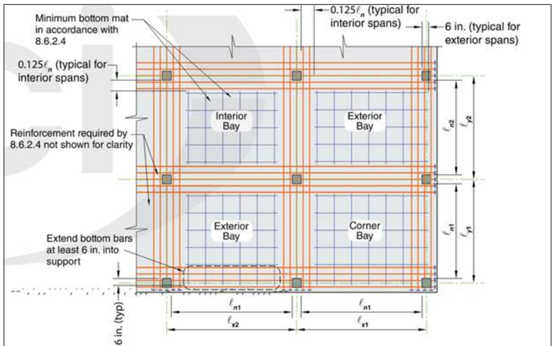


Fig. R8.7.5.5.2—Two-way slab system with banded-banded tendons and minimum bonded deformed longitudinal reinforcement between banded tendons.

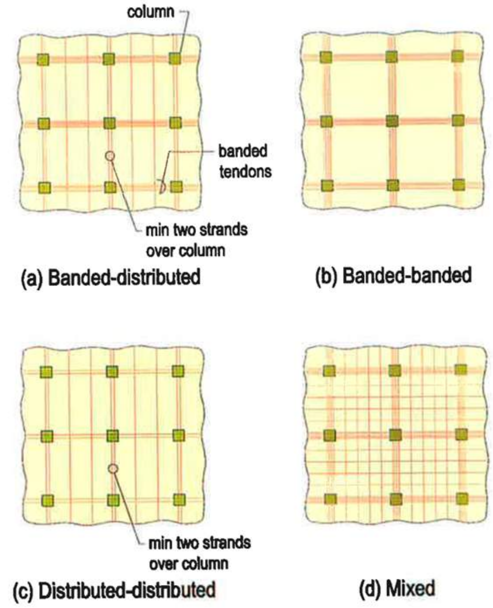


FIGURE 36.2.1-1 View of Several Tendon Arrangement Options (PT51102)

BANDED-BANDED

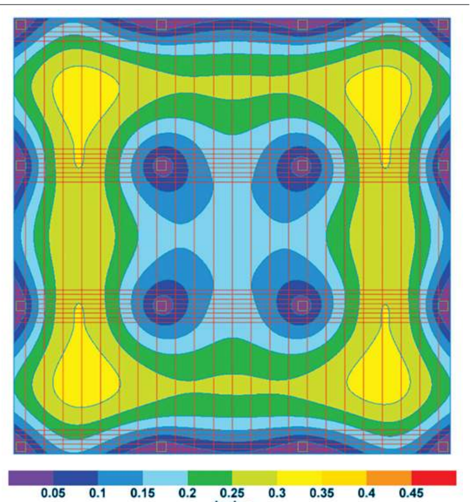


Fig. 5.6—Instantaneous elastic deflection contours of distributed-banded tendon distribution.

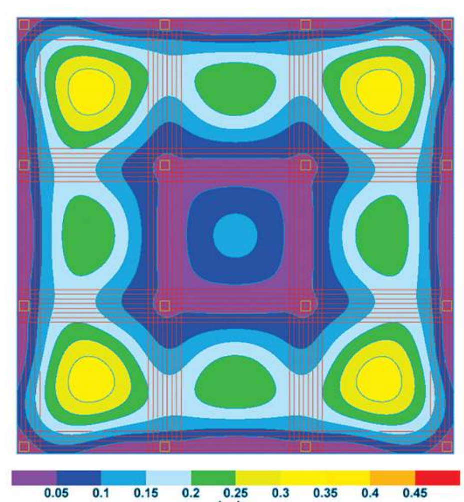
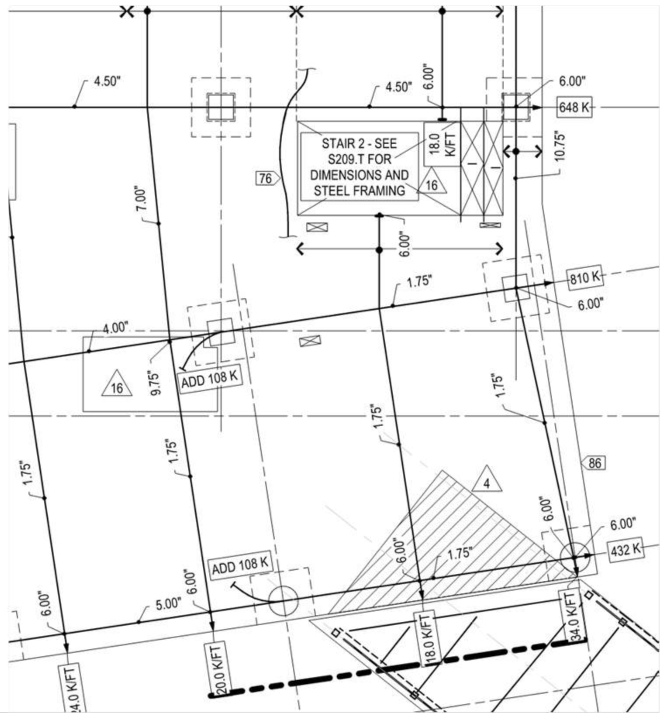


Fig. 5.7—Instantaneous elastic deflection contours of dual-banded tendon distribution.

PART II – DESIGN & DOCUMENTATION

PT TENDON LAYOUT ON PLAN

- Horizontal tendon sweeps
  - Offset columns/walls
  - Around openings
- Approximate tendon lengths for one-end, two-end, intermediate stressing
  - <=120 ft one-end stressing
  - <=240 ft two-end stressing
  - >240 ft intermediate stressing required
  - Length limits are a way to control friction losses
- Stressing locations
- 2 continuous tendons over columns for integrity requirements



PT DESIGN CONSIDERATIONS

PRELIMINARY DESIGN

- 1-way or 2-way?
- Slab thickness
  - Span to depth ratios
    - Be mindful of loss of efficiency at end spans and try to have shorter end spans or use add tendons
  - Fire endurance
  - Restrained vs unrestrained
  - Minimum precompression
    - 1-way
      - Aggressive environment >= 200 psi
      - Normal environments >= 125 psi
      - Temperature tendons = 100 psi
    - 2-way – 125 psi minimum
    - Increased cover for parking structures due to harsh environment

Floor System	Approx. Max Span/Depth Ratio
1-way slabs	48
2-way slabs	45
2-way slabs with drop panel (min drop panel L/5)	50
2-way slab with 2-way beams	55
2-way waffle slab (5'x5' grid)	35
Beams (b h/3)	20
Beams (b 3h)	30
1-way joists	40

PART II – DESIGN & DOCUMENTATION

PRELIMINARY DESIGN

- 1-way or 2-way?
- Slab thickness
  - Span to depth ratios
    - Be mindful of loss of efficiency at end spans and try to have shorter end spans or use add tendons
  - Fire endurance
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  - Minimum precompression
    - 1-way
      - Aggressive environment >= 200 psi
      - Normal environments >= 125 psi
      - Temperature tendons = 100 psi
    - 2-way – 125 psi minimum
    - Increased cover for parking structures due to harsh environment

TABLE 721.1(1)—continued
MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[m]

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hours	3 hours	2 hours	1 hour
4. Bonded or unbonded post-tensioned tendons in prestressed concrete[e, i]	4-1.1	Carbonate, lightweight, sand-lightweight and siliceous[f] aggregate concrete Unrestrained members: Solid slabs[h]	—	2	$1^1/_2$	—
		Beams and girders[j] 8" wide		$4^1/_2$	$2^1/_2$	$1^3/_4$
		greater than 12" wide	3	$2^1/_2$	2	$1^1/_2$
	4-1.2	Carbonate, lightweight, sand-lightweight and siliceous aggregate Restrained members:[k] Solid slabs[h]	$1^1/_4$	1	$^3/_4$	—
		Beams and girders[j] 8" wide	$2^1/_2$	2	$1^3/_4$	—
		greater than 12" wide	2	$1^3/_4$	$1^1/_2$	—

TABLE 721.1(3)
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a, q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hours	3 hours	2 hours	1 hour	4 hours	3 hours	2 hours	1 hour
1. Siliceous aggregate concrete	1-1.1	Slab (ceiling not required). Minimum cover over nonprestressed reinforcement shall be not less than $^3/_4$" [b].	7.0	6.2	5.0	3.5	—	—	—	—
2. Carbonate aggregate concrete	2-1.1		6.6	5.7	4.6	3.2	—	—	—	—
3. Sand-lightweight concrete	3-1.1		5.4	4.6	3.8	2.7	—	—	—	—
4. Lightweight concrete	4-1.1		5.1	4.4	3.6	2.5	—	—	—	—

PART II – DESIGN & DOCUMENTATION

LOAD BALANCING

- Counteract part or all the downward external loads and a portion of member self-weight.
- Common economical ranges
  - ~60-70% of dead load for 1-way/2-way slabs
  - ~70-80% of dead load for beams
  - ~100% of dead load for spandrel beams supporting exterior cladding
- End bays may require more PT for the same span due to loss of drape from anchorage at mid-height of slab.
- Load balancing ***does not*** reverse gravity or remove weight.
- Load balancing ***does*** create lifting effects that counteract the moments created by superimposed loading allowing for thinner (and thus lighter) floors

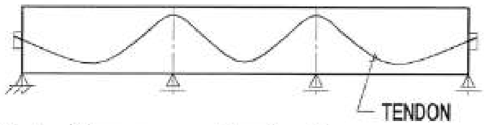
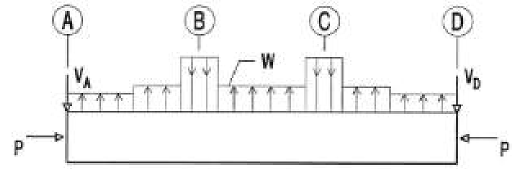
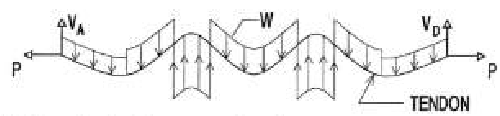


Fig. 1 - Three-span post-tensioned beam



(a) Free-body diagram of beam after removal of tendon



(b) Free-body diagram of tendon

Fig. 2 - Force system between tendon and beam

PART II – DESIGN & DOCUMENTATION

TENDON LOSSES

- **Initial Stressing (Transfer)**
  - For a single ½" cable, fpy = 243 ksi and fpu = 270 ksi
  - 0.80 fpu controls meaning the max stress is 216 ksi
  - ½" tendon has cross-sectional area of 0.153 sq in
  - Tendons are initially stressed to 33 kips per 1/2" cable
  - At transfer, the PT forces are higher, and the concrete strength is lower than it will be at service
  - Checks at transfer are a critical part of the design

Table 20.3.2.5.1—Maximum permissible tensile stresses in prestressed reinforcement

Stage	Location	Maximum tensile stress	
During stressing	At jacking end	Least of:	$0.94f_{py}$
			$0.80f_{pu}$
			Maximum jacking force recommended by the supplier of anchorage device
Immediately after force transfer	At post-tensioning anchorage devices and couplers	$0.70f_{pu}$	

PART II – DESIGN & DOCUMENTATION

TENDON LOSSES

- **Tendon Losses (Short Term)**
  - Seating at transfer, elastic shortening, and friction
- **Tendon Losses (Long Term)**
  - Creep, shrinkage, and relaxation
- **Resulting Tendon Effective Force (fse)**
  - Average force of 27 kips per ½" tendon after all losses
  - Use this for service/strength design

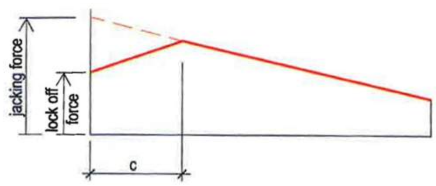


FIGURE 18.2.3-1 Tendon Force Diagram Showing Anchor Set Influence Distance c (PTS558b)

20.3.2.6 *Prestress losses*

20.3.2.6.1 Prestress losses shall be considered in the calculation of the effective tensile stress in the prestressed reinforcement, f_{se}, and shall include (a) through (f):

(a) Prestressed reinforcement seating at transfer
(b) Elastic shortening of concrete
(c) Creep of concrete
(d) Shrinkage of concrete
(e) Relaxation of prestressed reinforcement
(f) Friction loss due to intended or unintended curvature in post-tensioning tendons

PART II – DESIGN & DOCUMENTATION

ALLOWABLE STRESSES

- Often target Class U for design
- Class T can be used for beams
- Class C is not commonly used

Table 24.5.2.1—Classification of prestressed flexural members based on f_t

Assumed behavior	Class	Limits of f_t
Uncracked	U[1]	$f_t \le 7.5\sqrt{f_c'}$
Transition between uncracked and cracked	T	$7.5\sqrt{f_c'} < f_t \le 12\sqrt{f_c'}$
Cracked	C	$f_t > 12\sqrt{f_c'}$

[1]Prestressed two-way slabs shall be designed as Class U with $f_t \le 6\sqrt{f_c'}$.

Table R24.5.2.1—Serviceability design requirements

	Prestressed			
	Class U	Class T	Class C	Nonprestressed
Assumed behavior	Uncracked	Transition between uncracked and cracked	Cracked	Cracked
Section properties for stress calculation at service loads	Gross section 24.5.2.2	Gross section 24.5.2.2	Cracked section 24.5.2.3	No requirement
Allowable stress at transfer	24.5.3	24.5.3	24.5.3	No requirement
Allowable compressive stress based on uncracked section properties	24.5.4	24.5.4	No requirement	No requirement
Tensile stress at service loads 24.5.2.1	$\le 7.5\sqrt{f_c'}$	$7.5\sqrt{f_c'} < f_t \le 12\sqrt{f_c'}$	No requirement	No requirement
Deflection calculation basis	24.2.3.8, 24.2.4.2 Gross section	24.2.3.9, 24.2.4.2 Cracked section, bilinear	24.2.3.9, 24.2.4.2 Cracked section, bilinear	24.2.3, 24.2.4.1 Effective moment of inertia
Crack control	No requirement	No requirement	24.3	24.3
Computation of Δf_{ps} or f_s for crack control	—	—	Cracked section analysis	$M/(A_s \times$ lever arm), or $2/3f_y$
Side skin reinforcement	No requirement	No requirement	9.7.2.3	9.7.2.3

ALLOWABLE STRESSES

- ACI 318 has concrete stress limits for:
  - Compression immediately after transfer
  - Tension immediately after transfer
  - Compression at service loads
- Compressive stress limits do not control often
- Tensile stresses immediately after transfer can get large in transfer beams, podiums, etc. Additional mild steel can often help overcome these issues.

Table 24.5.3.1—Concrete compressive stress limits immediately after transfer of prestress

Location	Concrete compressive stress limits
End of simply-supported members	$0.70\sqrt{f_{ci}'}$
All other locations	$0.60\sqrt{f_{ci}'}$

Table 24.5.3.2—Concrete tensile stress limits immediately after transfer of prestress, without additional bonded reinforcement in tension zone

Location	Concrete tensile stress limits
Ends of simply supported members	$6\sqrt{f_c'}$
All other locations	$3\sqrt{f_c'}$

Table 24.5.4.1—Concrete compressive stress limits at service loads

Load condition	Concrete compressive stress limits
Prestress plus sustained load	$0.45\sqrt{f_c'}$
Prestress plus total load	$0.60\sqrt{f_c'}$

FLEXURE

- ACI 318 governs flexural design for PT members

$$\phi M_n = \phi(A_{ps} f_{ps} + A_s f_y)\left(d_p - \frac{a}{2}\right)$$

22.3.2 *Prestressed concrete members*

22.3.2.1 Deformed reinforcement conforming to 20.2.1, provided in conjunction with prestressed reinforcement, shall be permitted to be considered to contribute to the tensile force and be included in flexural strength calculations at a stress equal to f_y.

22.2.4 *Design assumptions for prestressed reinforcement*

22.2.4.1 For members with bonded prestressed reinforcement conforming to 20.3.1, stress at nominal flexural strength, f_{ps}, shall be calculated in accordance with 20.3.2.3.

22.2.4.2 For members with unbonded prestressed reinforcement conforming to 20.3.1, f_{ps} shall be calculated in accordance with 20.3.2.4.

22.2.4.3 If the embedded length of the prestressed strand is less than ℓ_d, the design stress of the prestressed strand shall not exceed the value given in 25.4.8.3, as modified by 25.4.8.1(b).

PART II – DESIGN & DOCUMENTATION

ONE-WAY SHEAR

- ACI 318 governs one -way shear design for PT members
- Formulas for shear capacity are different for post-tensioned members compared to regular mild reinforced concrete

22.5.6 V_c *for prestressed members*

22.5.6.1 This section shall apply to the calculation of V_c for post-tensioned and pretensioned members in regions where the effective force in the prestressed reinforcement is fully transferred to the concrete. For regions of pretensioned members where the effective force in the prestressed reinforcement is not fully transferred to the concrete, 22.5.7 shall govern the calculation of V_c.

22.5.6.2 For prestressed members, V_c shall be permitted to be the lesser of V_{ci} calculated in accordance with 22.5.6.2.1 and V_{cw} calculated in accordance with 22.5.6.2.2 or 22.5.6.2.3.

22.5.6.2.1 The flexure-shear strength V_{ci} shall be calculated by (a) but need not be taken less than (b) or (c):

(a) $$V_{ci} = 0.6\lambda\sqrt{f_c'}\,b_w d_p + V_d + \frac{V_i M_{cre}}{M_{max}} \quad (22.5.6.2.1a)$$

(b) For members with $A_{ps}f_{se} < 0.4(A_{ps}f_{pu} + A_s f_y)$,

$$V_{ci} = 1.7\lambda\sqrt{f_c'}\,b_w d \quad (22.5.6.2.1b)$$

(c) For members with $A_{ps}f_{se} \geq 0.4(A_{ps}f_{pu} + A_s f_y)$,

$$V_{ci} = 2\lambda\sqrt{f_c'}\,b_w d \quad (22.5.6.2.1c)$$

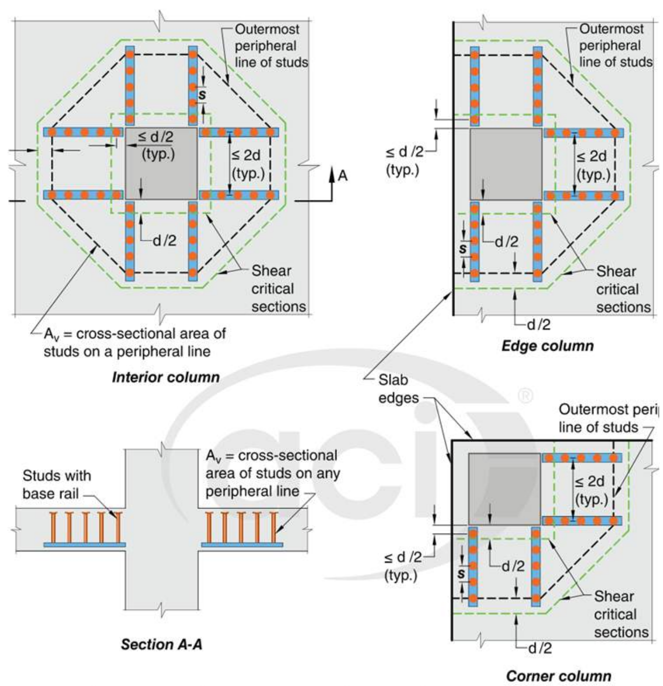
where d_p need not be taken less than $0.80h$, the values of M_{max} and V_i shall be calculated from the load combinations causing maximum factored moment to occur at section considered, and M_{cre} shall be calculated by:

$$M_{cre} = \left(\frac{I}{y_t}\right)\left(6\lambda\sqrt{f_c'} + f_{pe} - f_d\right) \quad (22.5.6.2.1d)$$

PART II – DESIGN & DOCUMENTATION

TWO-WAY SHEAR (PUNCHING)

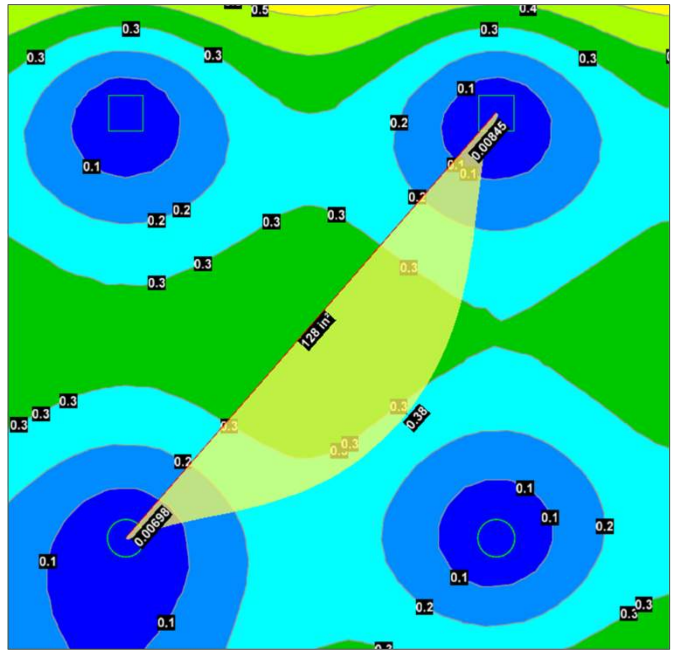
- For 2-way slabs, it is often preferred to avoid drop capitals, drop panels, etc. to keep the formwork as simple as possible or to allow for a clean exposed ceiling.
- Edge and corner columns/walls with large unbalanced moments or areas with large openings near columns/walls can significantly reduce the punching shear capacity.
- For thinner slabs or longer spans, this often means using stud rails or other in-slab shear reinforcement to provide added punching shear capacity.
- Exception is at parking slabs that will be exposed to de-icing salts. Drop caps are a good idea for additional punching shear capacity



'8.7.7—Typical arrangements of headed shear stud reinforcement and critical sections.

DEFLECTION CONTROL

- Coordinate deflection limits with building finishes
  - o TL/240 and LL/360 are common limits
  - o Tighter if supporting CMU/brick, at window supports, etc.
- Post-tensioned concrete is subject to a permanent and sustained compressive force.
  - o Deflection analysis needs to model impact of creep, shrinkage, and concrete cracking
- RAM Concept has a ***load history analysis*** tool
  - o Allows engineer to define load steps and magnitudes over set periods of time to walk through the deflections throughout the life of the slab
    - ▪ Deflection at transfer when PT forces are higher before losses and loads are typically lower.
    - ▪ Do I have too much PT balance force, which is causing upward deflections?
    - ▪ Deflection at service when PT forces are lower and superimposed loads are typically higher.
  - o Need to envelope the deflection profile and adjust PT design to meet limits at ***all stages***



MINIMUM BONDED REINFORCING

- If tensile stresses in 2-way slabs at positive moment regions are small (<2*√f'c), no additional bonded rebar is required.
- If tensile stresses exceed 2*√f'c, As.min is required. Often this is bottom steel at mid-bay.
  - If you are close to the limit, you can sometimes add additional PT force to bring the stresses below 2*√f'c to avoid As.min.
  - Maximum f.y is 60 ksi.
- At negative moment regions at columns, As.min is always required.
- Even if holding tensile stresses below the theoretical modulus of rupture, some amount of minimum bonded reinforcement is still required

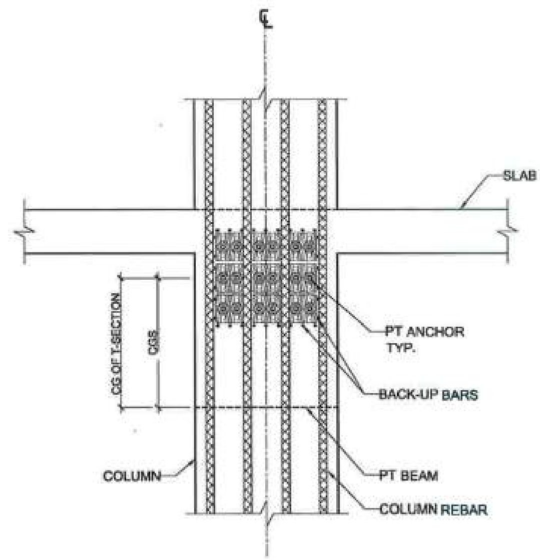
Table 8.6.2.3—Minimum bonded deformed longitudinal reinforcement $A_{s,min}$ in two-way slabs with bonded or unbonded tendons

Region	Calculated f_t afterall losses, psi	$A_{s,min}$, in.^{2}	
Positive moment	$f_t \le 2\sqrt{f_c'}$	Not required	(a)
	$2\sqrt{f_c'} < f_t \le 6\sqrt{f_c'}$	$\frac{N_c}{0.5f_y}$	(b)[1],[2]
Negative momentat columns	$f_t \le 6\sqrt{f_c'}$	$0.00075A_{cf}$	(c)[2]

[1]The value of f_y shall not exceed 60,000 psi.
[2]For slabs with bonded tendons, it shall be permitted to reduce $A_{s,min}$ by the area of the bonded post-tensioned reinforcement located within the area used to determine N_c for positive moment, or within the width of slab defined in 8.7.5.3(a) for negative moment.

DESIGN FOR CONSTRUCTABILITY

- Friendly reminder, it all must fit.
- Consider the PT beam end view at the right.
  - How does the detail need to change if they need additional tendons?
  - What if the column's longitudinal rebar is not perfectly placed?
  - How do all these anchorages possibly interact with the slab and other beam rebar not shown?

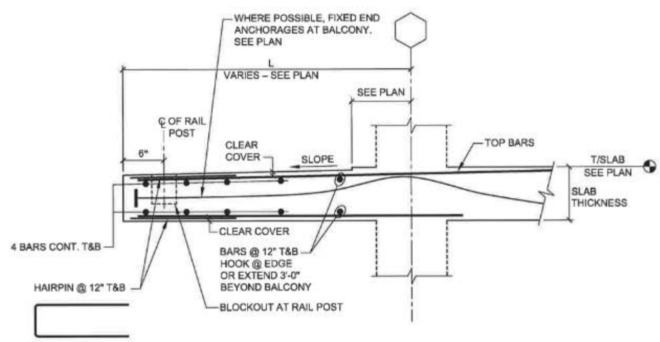


PT BEAM END VIEW

Fig. 3.5—Post-tensioned beam end view with CGS location.

BALCONIES

- Where possible used fixed end anchorages at sloped balconies to avoid water flowing around or even into the grout pockets.
- If you have tendons running in/out of the page, be conscious that tendon drape will be decreased due to slab step and sloped top surface.
- PT anchorage needs to be coordinated with railing posts. These are sometimes top mounted and other times side mounted.



AT SLOPED BALCONIES

NOTES:

1. ALL POST-TENSIONING TENDONS EXTENDING INTO BALCONIES SHALL BE AN ENCAPSULATED SYSTEM (PTI RECOMMENDS ALL POST-TENSIONING FOR STRUCTURES DESIGNED WITH ACI 318 TO BE ENCAPSULATED SYSTEM).
2. SEE PLAN FOR ADD'L REINFORCING AND POST-TENSIONING TENDONS NOT SHOWN.

Fig. 4.1—Sample section at sloped balcony. (Note: 1 in. = 25.4 mm; 1 ft = 0.3 m.)

PART II – DESIGN & DOCUMENTATION

POUR STRIPS & CONSTRUCTION JOINTS

- For longer buildings and those with stiff shear walls, pour strips are an important detail to avoid restraint cracking in the slab.
- Pour strips create a temporary release so the slab can shorten before being locked in.
- Try to consider this early in design. Being able to design the slabs as self-supporting can be a big time and money saver on projects to avoid the need for backshoring.
  - Pour strip locations affects schedule, stressing and detailing.
- Construction joints can be either stressed or not stressed depending on the condition.

Fig. 5.9—Pour strip.

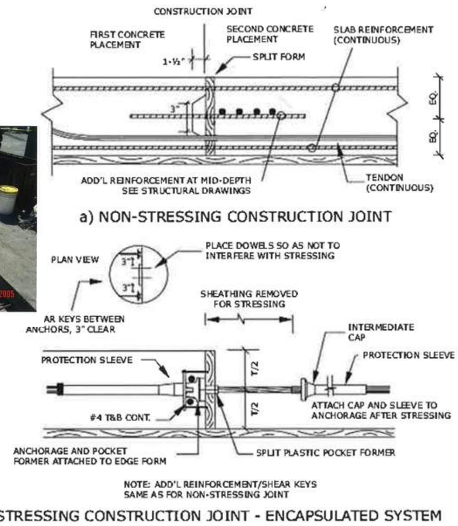


Fig. A7—Construction joints. (Note: 1 in. = 25.4 mm.)

PART II – DESIGN & DOCUMENTATION

ADD TENDONS

- Add tendons are often needed at end spans where tendon drape is less efficient due to anchoring at mid-height.
- Add tendons are also useful for areas with deflection, cracking, or vibration concerns.
- For add tendons, stagger anchorages to avoid large stress concentrations that can locally blow out the slab.
- Additional rebar is needed to engage the surrounding slab.
- Make sure to consider how they'll be stressed. Locating the live ends in the middle of the building can create the need for stressing box outs.

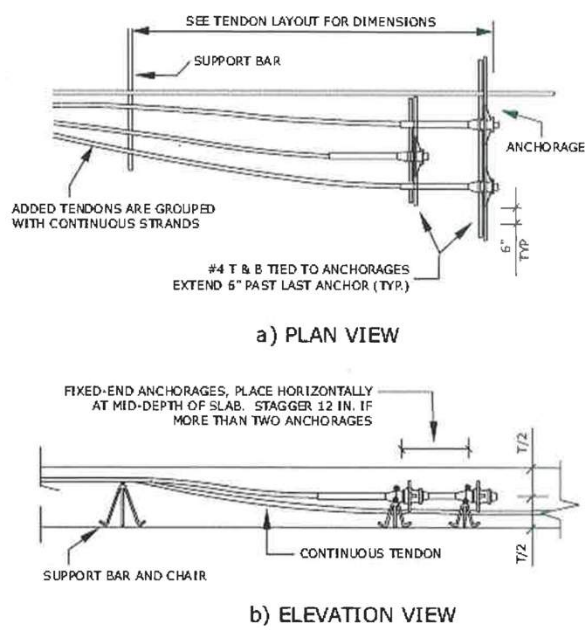


Fig. A9—Added tendons. (Note: 1 in. = 25.4 mm.)

PART II – DESIGN & DOCUMENTATION

QUICK PRELIMINARY DESIGN

Table 6.1—Post-tensioning estimate checklist

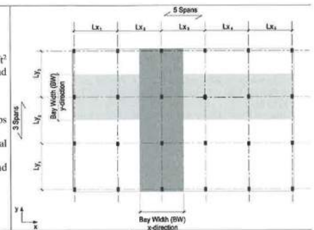
Item	Post-tensioning, lb/ft²	Nonprestressed reinforcement, lb/ft²
Gravity loads	Refer to design table	Refer to design table
Are higher *F/A* requirements applicable? (>125 psi)	Add if applicable	—
Should minimum load balancing exceed 50%?	Add if applicable	—
Exterior edge loads	Add if applicable	Add if applicable
Concentrated loads	Add if applicable	Add if applicable
Transfer girders	Add if applicable	Add if applicable
Lateral loads	—	Add if applicable
Backup and support steel	—	0.2 to 0.4
Miscellaneous trim steel and steel around openings	—	0.2 to 0.4
Pour strips	—	Add if applicable
RTS	—	Add if applicable
Punching shear	Add punching shear reinforcement or drop caps and/or drop panels as required	
Total		

Note: 1 lb/ft² = 0.05 kN/m²; 1 psi = 0.007 MPa.

Table 6.7—Preliminary design table for two-way office buildings (flat plate or flat slab system with no drops used in calculation)

Basic design parameters and assumptions:

- Loading: DL = self-weight + 12 lb/ft² (0.6 kN/m²) (SDL); LL = 50 lb/ft² (2.4 kN/m²) (no reduction) + 15 lb/ft² (0.7 kN/m²) (partitions) (live load reduction permitted per building code)
- Slab minimum *F/A* = 125 psi (0.9 MPa) based on ACI 318-08
- Concrete: $f_c' = 5000$ psi (34 MPa); $f_{ci}' = 3000$ psi (21 MPa)
- Assumed final effective force per 0.5 in. (12.7 mm) strand tendon = 27 kips (120 kN)
- Tendon CGS: Slab – 1.5 in. (32 mm top; 1 in. (25 mm) bottom internal span; 1.75 in. (44 mm) bottom exterior span
- Cover to nonprestressed reinforcement: Slab 1 in. (25 mm) top and 0.75 in. (19 mm) bottom
- Column size: 24 x 24 in. (610 x 610 mm)



Bay width (x-direction), ft	Slab spans (Ly_1, Ly_2, Ly_3), ft	Slab size, in.	Span-depth ratio	Slab – banded direction *X*: Material required: PT, lb/ft²	Slab – banded direction *X*: Material required: Reinforcing bar, lb/ft²	Slab – uniform direction *Y*: Material required: PT, lb/ft²	Slab – uniform direction *Y*: Material required: Reinforcing bar, lb/ft²	Total*: Material required: PT, lb/ft²	Total*: Material required: Reinforcing bar, lb/ft²
20	25, 25, 25,	7.5	40.0	0.240	0.118	0.359	0.215	0.60	0.34
	27, 27, 27	8.0	40.5	0.243	0.127	0.386	0.254	0.63	0.39
	30, 30, 30	8.5	42.4	0.273	0.130	0.435	0.290	0.71	0.42
25	25, 25, 25,	7.5	40.0	0.307	0.218	0.349	0.249	0.66	0.47
	27, 27, 27	8.0	40.5	0.294	0.215	0.389	0.260	0.69	0.48
	30, 30, 30	8.5	42.4	0.300	0.228	0.449	0.318	0.75	0.55
30	25, 25, 25,	8.5	42.4	0.392	0.290	0.318	0.297	0.71	0.59
	27, 27, 27	8.5	42.4	0.383	0.310	0.363	0.310	0.75	0.62
	30, 30, 30	8.5	42.4	0.390	0.332	0.444	0.371	0.84	0.71
35	25, 25, 25,	10.0	42.0	0.498	0.372	0.311	0.305	0.81	0.68
	27, 27, 27	10.0	42.0	0.502	0.354	0.336	0.342	0.84	0.70
	30, 30, 30	10.0	42.0	0.497	0.385	0.400	0.394	0.90	0.78

*Punching shear reinforcement requirements to be determined by engineer. Allowance to be made in estimate.
Notes: 1 ft = 0.3048 m; 1 in. = 25.4 mm; 1 lb/ft² = 0.05 kN/m².

Image(s) Source(s): PTI DC20.9-11

COMPUTER-BASED ANALYSIS

2D EQUIVALENT FRAMES

- Procedure is to take strips of slabs and idealize as equivalent frames
- Slab loading, moment/shear diagrams, and tendon profiles are all evaluated one at a time
- Design for each equivalent frame takes place in its own independent model. Engineering judgment is required near irregular geometry, openings, etc.
- Final design is documented by taking the results from each equivalent frame and compiling all together
- Equivalent frame method is also useful for quick evaluations during SD or pre-design where the effort to build a full FEA model is not yet practical
- ADAPT-PC.RC is commonly used program

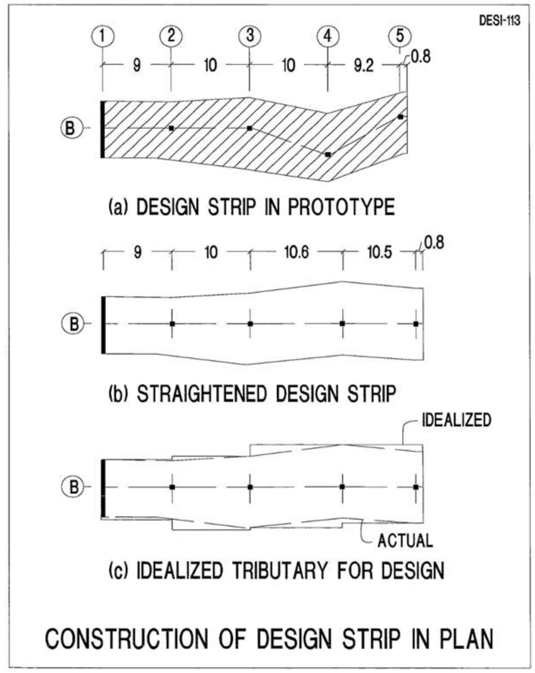
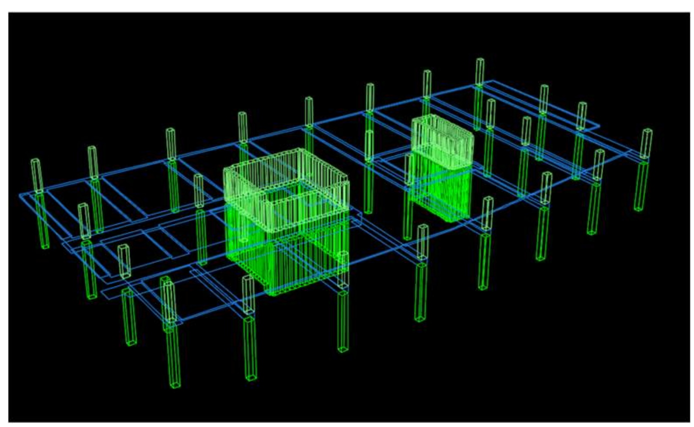


FIGURE 2.3.1-1

 Image(s) Source(s): PTI TN11

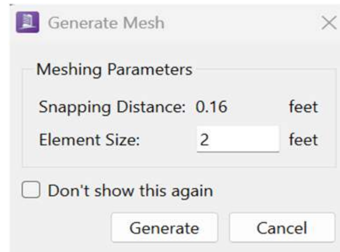
3D FINITE ELEMENT ANALYSIS

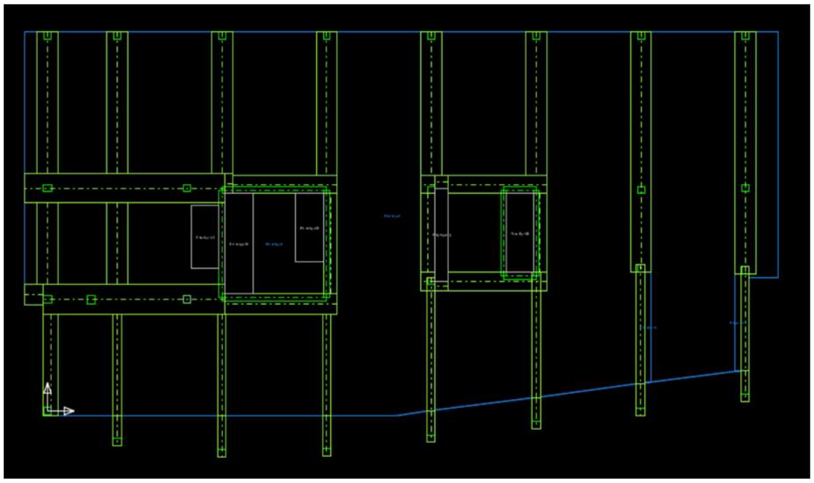
- Procedure is to build a full 3D model to perform FEA
- Design strips are used to define slab properties and lay out spans
- Slab loading, moment/shear diagrams, and tendon profiles are evaluated for all spans simultaneously
- Final design is all contained in one model
- RAM Concept is commonly used program

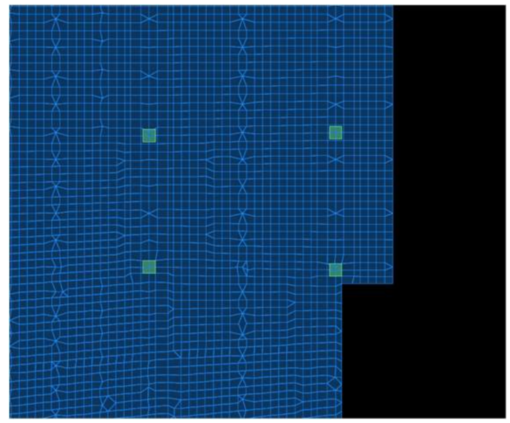


PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS







PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS

Loadings

Add Loading   Delete Loadings...

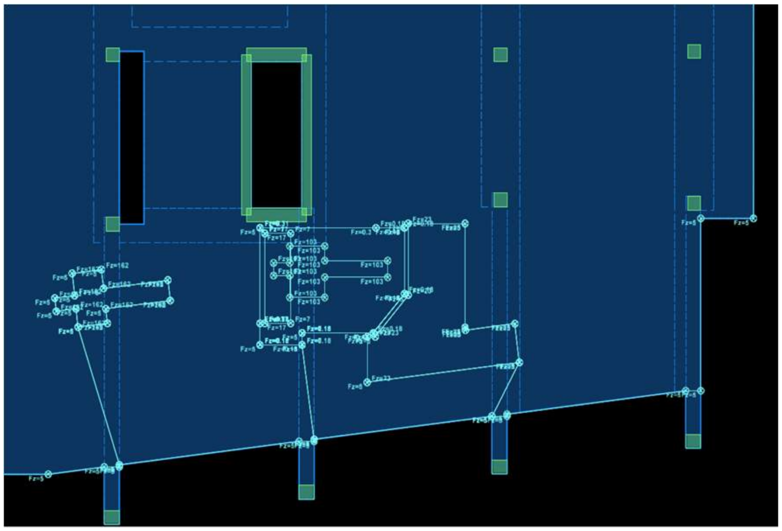
Loading Name	Loading Type	Analysis	On-Pattern Factor	Off-Pattern Factor
Self-Dead Loading	Self-Weight	Normal	1	1
Balance Loading	Balance	Normal	1	1
Hyperstatic Loading	Hyperstatic	Hyperstatic	1	1
Dead Loading	Dead	Normal	1	1
Live (Reducible) Loading	Live (Reducible)	Normal	1	1

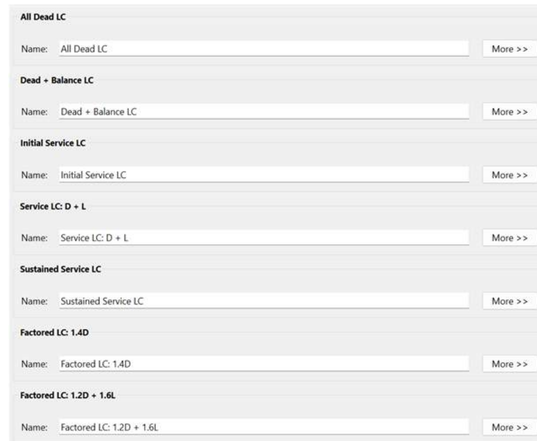
"On-Pattern Factor" is a factor that is applied to loads that fall within the loading pattern when performing pattern loading calculation; it often has a value of 1.00 or 0.75

"Off-Pattern Factor" is a factor that is applied to loads that do not fall within the loading pattern when performing pattern loading calculation; it often has a value of 0.00

PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS





PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS

Concrete Mix

Add Concrete Mix | Delete Concrete Mixes...

Mix Name	Density (pcf)	Density For Lo (pcf)	f'ci (psi)	f'c (psi)	fcui (psi)	fcu (psi)	Poisson's Ratio	Coefficient of Thermal Expan	Ec Calc	User Eci (psi)	User Ec (psi)
5000 psi	150	Density	3000	5000	3725	6399	0.2	5.556e-6	Code	2500000	3000000
6000 psi	150	Density	3000	6000	3725	7450	0.2	5.556e-6	Code	2500000	3000000
7000 psi	150	Density	3000	7000	3725	8450	0.2	5.556e-6	Code	2500000	3000000

PT Systems

Add PT System | Delete PT Systems...

System Name	Strand	Duct	Anchor	fse (ksi)	Long-Term Losses (ksi)	Minimum Radius (feet)
½" Unbonded	½" Unbonded	½" Unbonded	½" Unbonded	176.4	22	6

Add Strand | Delete Strands...

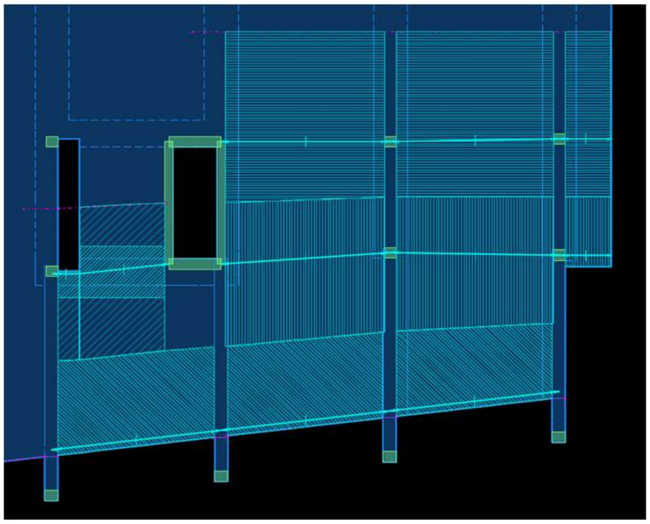
Strand Name	Aps (in^2)	Eps (ksi)	fpy (ksi)	fpu (ksi)
½" Unbonded	0.153	28000	243	270

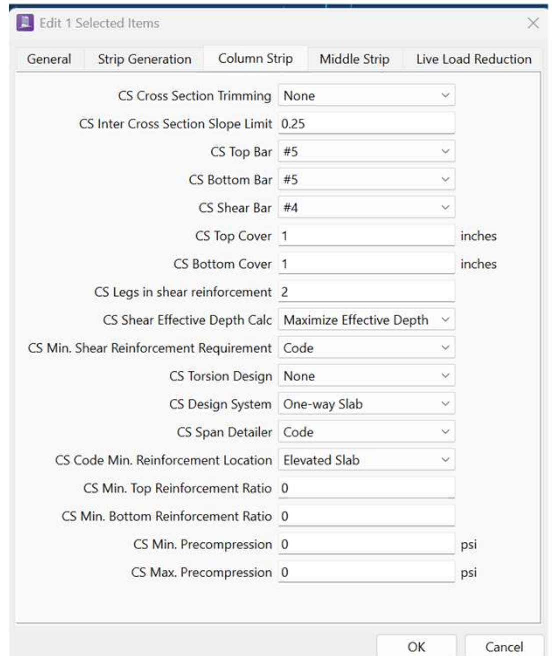
Add Duct | Delete Ducts...

Duct Name	Type	Shape	Material	Duct Height (inches)	Duct Width (inches)	Max Strands Per Duct	Wobble Friction (1/feet)	Angular Friction
½" Unbonded	Unbonded	Round	Tightly Sheathed	0.5	0.5	1	0.0014	0.07

PART II – DESIGN & DOCUMENTATION

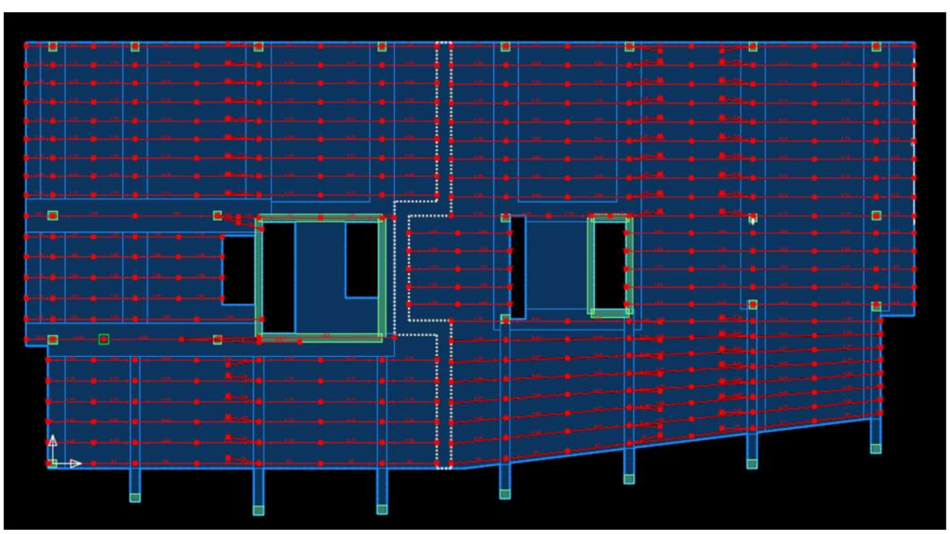
3D FINITE ELEMENT ANALYSIS





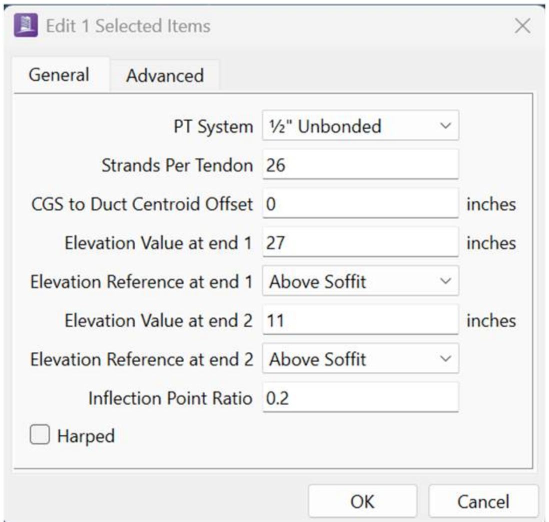
PART II – DESIGN & DOCUMENTATION

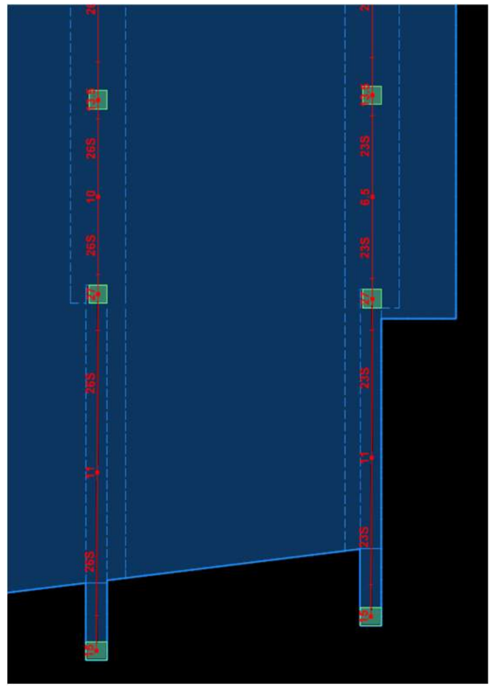
3D FINITE ELEMENT ANALYSIS



PART II – DESIGN & DOCUMENTATION

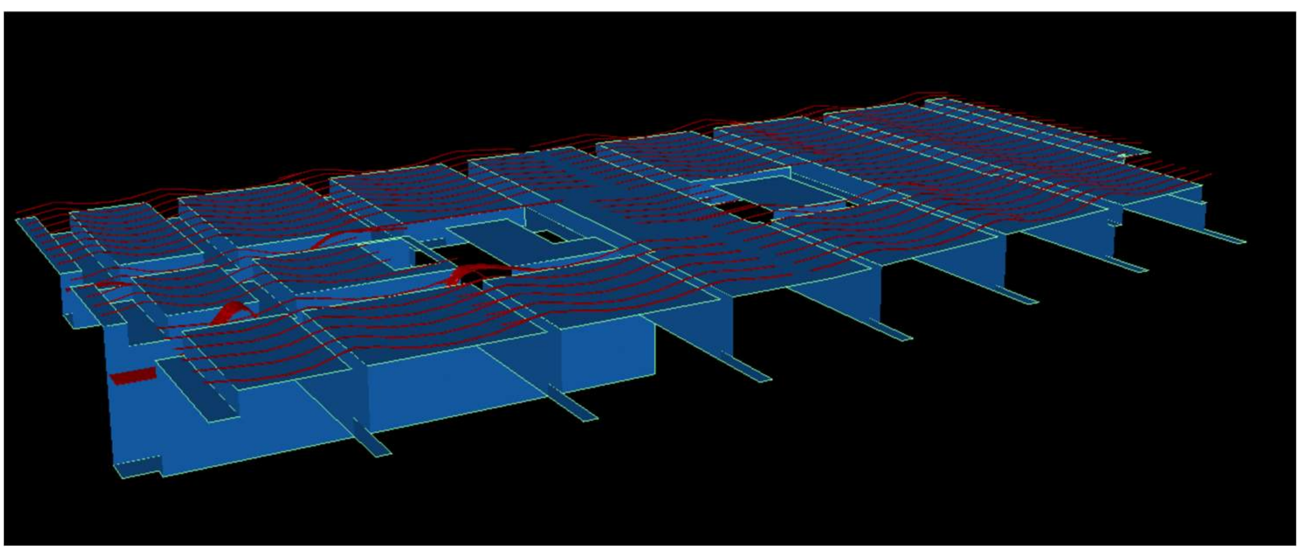
3D FINITE ELEMENT ANALYSIS





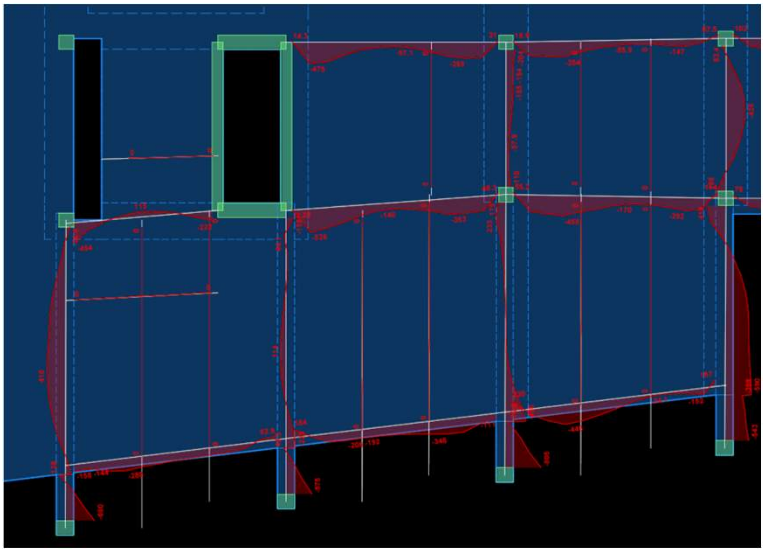
PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS



PART II – DESIGN & DOCUMENTATION

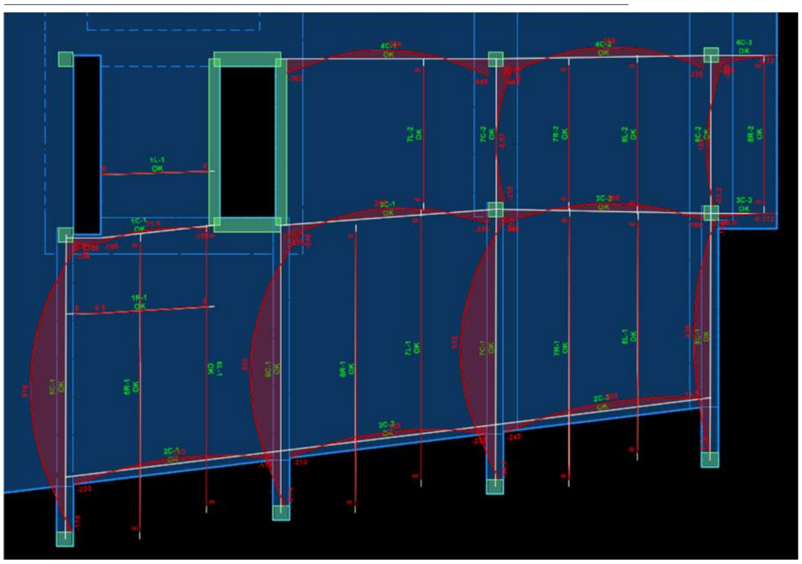
3D FINITE ELEMENT ANALYSIS



Stress diagrams by design strip

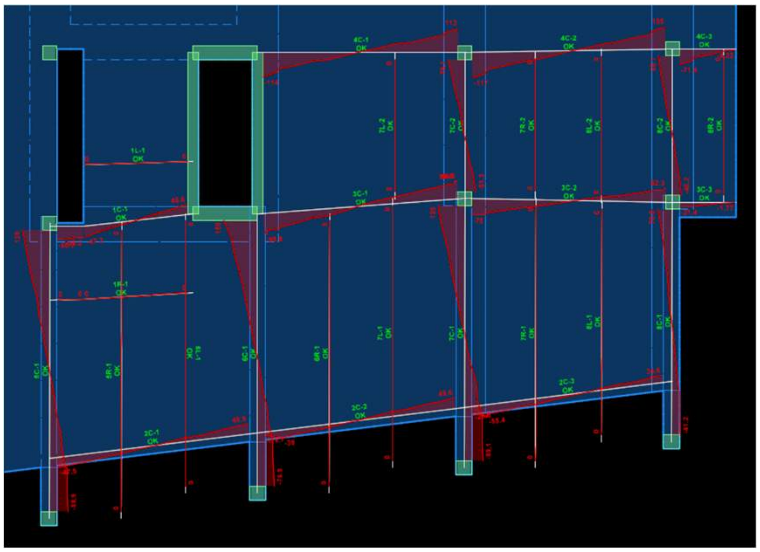
PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS



Moment diagrams by design strip

3D FINITE ELEMENT ANALYSIS



Shear diagrams by design strip

3D FINITE ELEMENT ANALYSIS

Load History

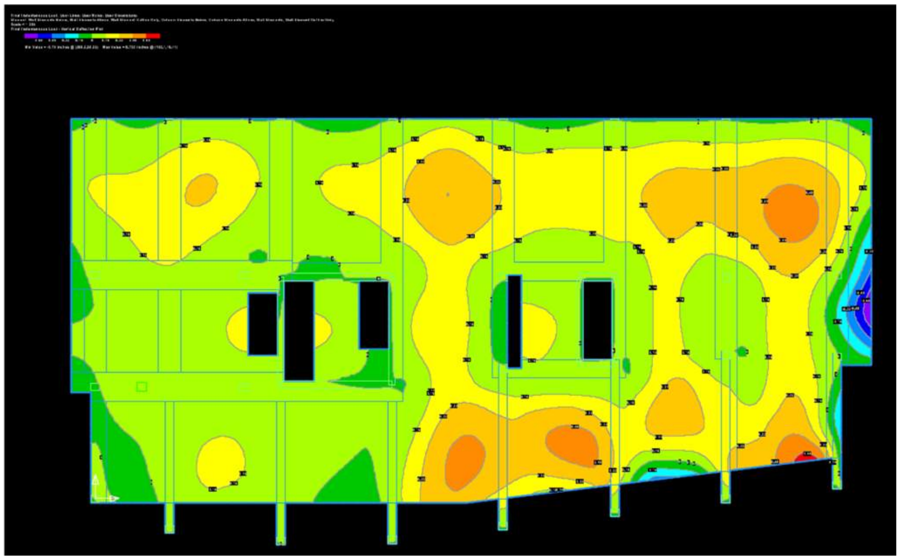
Add Load Step   Delete Load Steps...

Load History Step Name	**Load Combination**	Duration (days)	Total Age (days)
Maximum Short Term Load	Initial Service LC	30	33
Sustained Load	Sustained Service LC	5000	5033
Final Instantaneous Load	Service LC: D + L	0	5033

Define load history analysis steps and load combinations

PART II – DESIGN & DOCUMENTATION

3D FINITE ELEMENT ANALYSIS

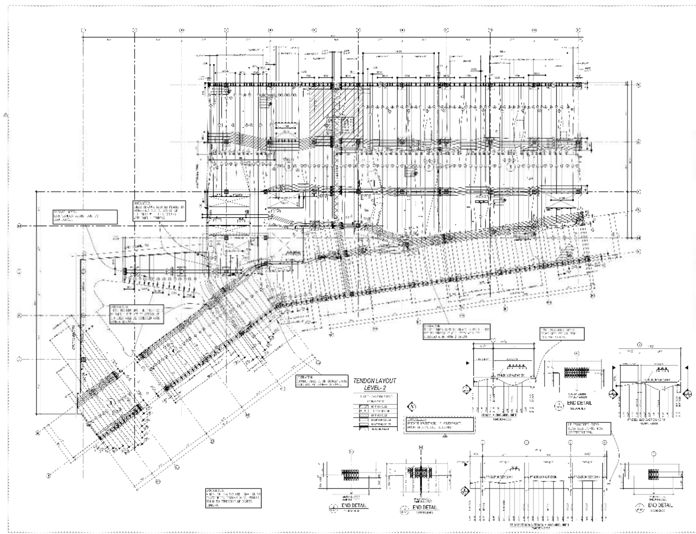


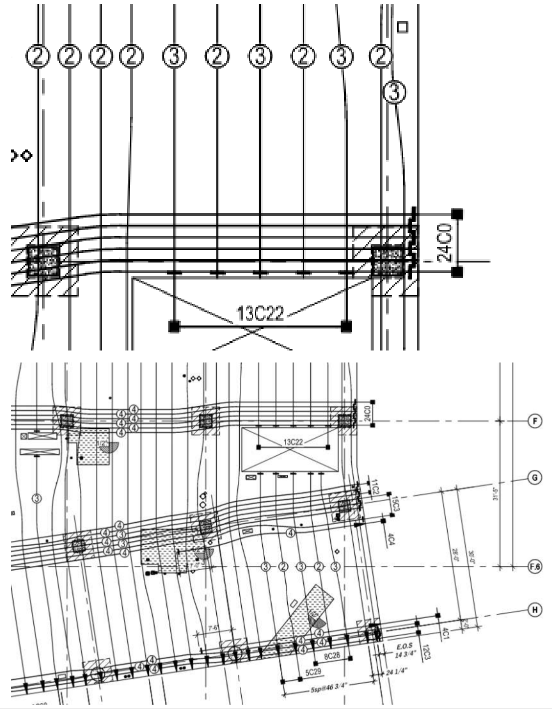
Color contour deflection plots

PART III - CONSTRUCTION ADMINISTRATION

PART III – CONSTRUCTION ADMINISTRATION

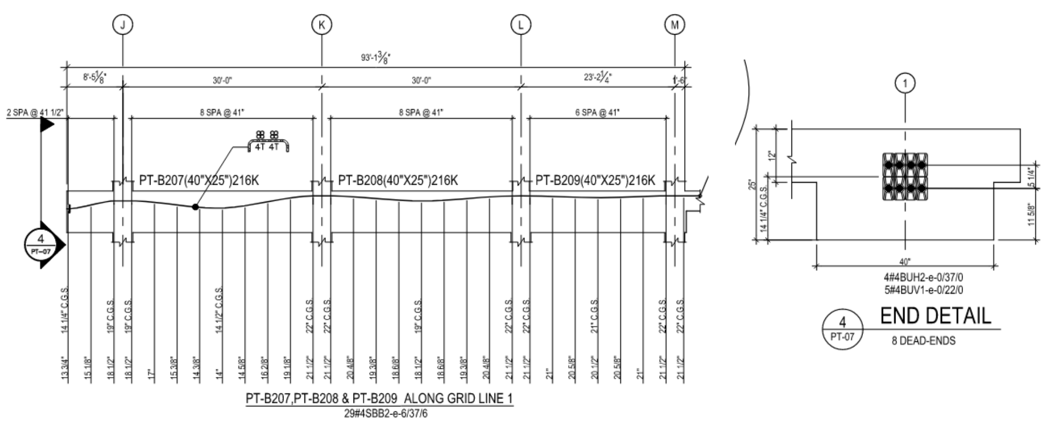
PT SHOP DRAWINGS





PART III – CONSTRUCTION ADMINISTRATION

PT SHOP DRAWINGS



PT SHOP DRAWINGS

Pour 5	Pour 4	Pour 3	Pour 2	Pour 1	Mark	Color (AMSYSCO)	BM/U/T B/U	Length (FT)	Type	30deg PF	45deg PF	Anchor (0.0812)	A1	A2	A3	A4	A5	Extra
				66	C 0	NO COLOR	B	169	2			|-->-->	99.0	68.0				
				8	C 1	BLU	B	42	1			|-->	40.0					
				11	C 2	RED	B	171	2			|-->-->	98.0	71.0				
				27	C 3	WHT	B	168	2			|-->-->	98.0	68.0				
				4	C 4	BLK	B	44	1			|-->	42.0					
		8	7		C 5	YEL	B	23	1			|-->	21.0					
			7		C 6	ORG	B	58	1			|-->	56.0					
			3		C 7	BWN	B	53	1			|-->	51.0					

Mark	PL/EA MIN A1	MAX A1	MIN MIN A2	MAX A2	MIN A3	MAX A3	MIN A4	MAX A4	MIN A5	MAX A5
C 0	7.56	8.70	5.24	6.02						
C 1	3.10	3.56								
C 2	7.49	8.61	5.45	6.27						
C 3	7.49	8.61	5.24	6.02						
C 4	3.25	3.73								
C 5	1.52	1.74								
C 6	4.33	4.99								
C 7	3.96	4.56								

Mark	FORCES FROM ADAPT A1	A2	A3	A4	A5
C 0	28.32	28.65			
C 1	28.32				
C 2	28.32	28.32			
C 3	28.32	28.65			
C 4	28.32				
C 5	26.73				
C 6	28.72				
C 7	28.56				

PT SHOP DRAWINGS

- Anchorage zone reinforcement with hairpins

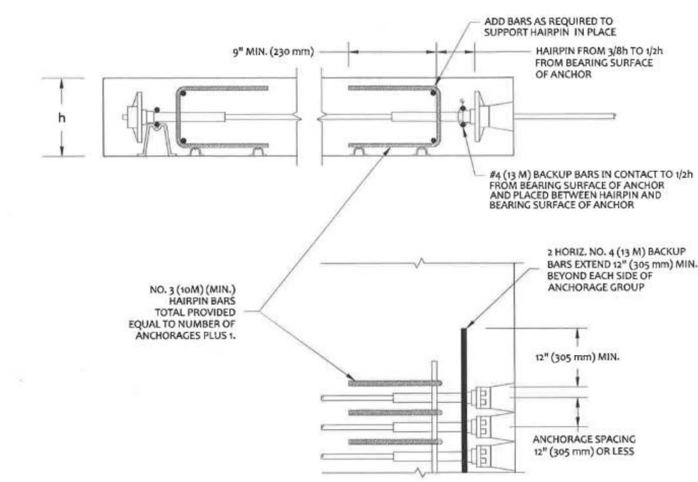
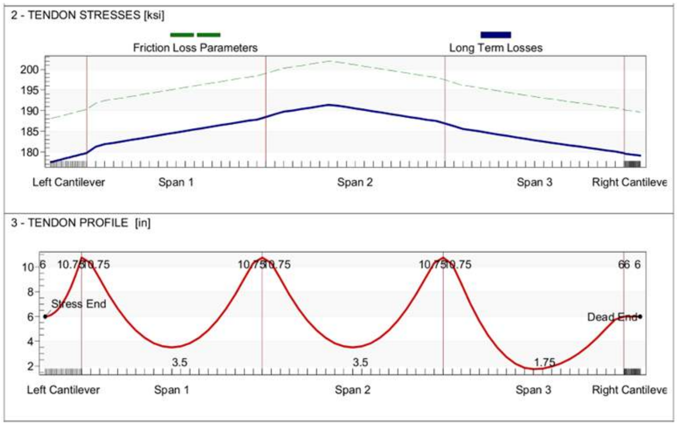


Fig. 4-3a—Anchorage zone reinforcement with hairpins for groups of single strand tendon anchorages in slabs.

Image(s) Source(s): PTI M10.3-16

PT TENDON LOSSES



4 - SUMMARY

Average initial stress (after release)..................	195.69	ksi
Long term stress losses	10.57	ksi
Final average stress	185.12	ksi
Final average force in tendon	28.32	k
Anchor set influence from left pull (202.05ksi;0.748) ..	46.85	ft
Elongation at left pull before anchor set	8.389	inch
Elongation at left pull after anchor set	8.139	inch
Total elongation after anchor set	8.139	inch
Ratio of total elongation to tendon length after anchor set	0.082	inch/ft
Jacking force	33.05	k

CRITICAL STRESS RATIOS :
At stressing 0.800; At anchorage 0.705; Max along tendon 0.748

- Sources of losses
  - Friction
  - Seating (anchorage) loss
  - Concrete elastic shortening
  - Concrete creep
  - Concrete shrinkage
  - Tendon relaxation

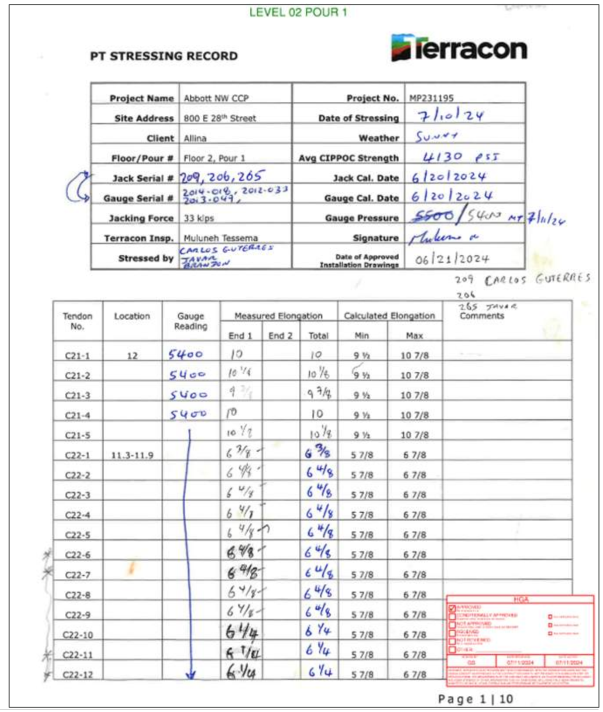
 Image(s) Source(s): ADAPT-FELT

ISSUES IN THE FIELD

PART III – CONSTRUCTION ADMINISTRATION

TENDON ELONGATIONS

- Common to stress when concrete reaches a minimum compressive strength of 3,000 psi.
- Elongation acceptance ±7%
  - Often PT shop drawings show min and max allowable elongations.
- Stressing Reports are often handwritten and numbers can be hard to read
- Inspector should indicate any issues or out of the norm occurrences in the comments to help Engineer review
- Real world elongations may be too short or too long.
  - See PTI TN #16, PTI FAQ #6, and Structures Magazine March 2025 for more information on out of tolerance elongations.


LEVEL 02 POUR 1

PT STRESSING RECORD

Terracon

Project Name	Abbott NW CCP	Project No.	MP231195
Site Address	800 E 28th Street	Date of Stressing	7/10/24
Client	Allina	Weather	Sunny
Floor/Pour #	Floor 2, Pour 1	Avg CIPPOC Strength	4130 psi
Jack Serial #	209, 206, 265	Jack Cal. Date	6/20/2024
Gauge Serial #	2014-018, 2012-033, 2013-047,	Gauge Cal. Date	6/20/2024
Jacking Force	33 kips	Gauge Pressure	~~5500~~ / 5400 MT 7/11/24
Terracon Insp.	Muluneh Tessema	Signature	[illegible]
Stressed by	Carlos Guterres, Javar, Branson	Date of Approved Installation Drawings	06/21/2024

209 Carlos Guterres
206
265 Javar

Tendon No.	Location	Gauge Reading	Measured Elongation			Calculated Elongation		Comments
			End 1	End 2	Total	Min	Max	
C21-1	12	5400	10		10	9 ½	10 7/8	
C21-2		5400	10 1/8		10 1/8	9 ½	10 7/8	
C21-3		5400	9 7/8		9 7/8	9 ½	10 7/8	
C21-4		5400	10		10	9 ½	10 7/8	
C21-5			10 1/8		10 1/8	9 ½	10 7/8	
C22-1	11.3-11.9		6 3/8		6 3/8	5 7/8	6 7/8	
C22-2			6 4/8		6 4/8	5 7/8	6 7/8	
C22-3			6 4/8		6 4/8	5 7/8	6 7/8	
C22-4			6 4/8		6 4/8	5 7/8	6 7/8	
C22-5			6 4/8		6 4/8	5 7/8	6 7/8	
C22-6			6 4/8		6 4/8	5 7/8	6 7/8	
C22-7			6 4/8		6 4/8	5 7/8	6 7/8	
C22-8			6 4/8		6 4/8	5 7/8	6 7/8	
C22-9			6 4/8		6 4/8	5 7/8	6 7/8	
C22-10			6 1/4		6 1/4	5 7/8	6 7/8	
C22-11			6 1/4		6 1/4	5 7/8	6 7/8	
C22-12			6 1/4		6 1/4	5 7/8	6 7/8	

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APPROVED [illegible]

Page 1 | 10

PART III – CONSTRUCTION ADMINISTRATION

ISSUES IN THE FIELD

- Incorrectly installed anchors and pocket formers.
  - Rainwater or concrete can get inside anchor or pocket former.
    - Encapsulated system can be compromised.
    - Concrete in the anchor can negatively affect stressing operations
  - Tendon eccentricity during stressing.
  - Broken/damaged anchors or pocket formers.
  - Reverse curvature

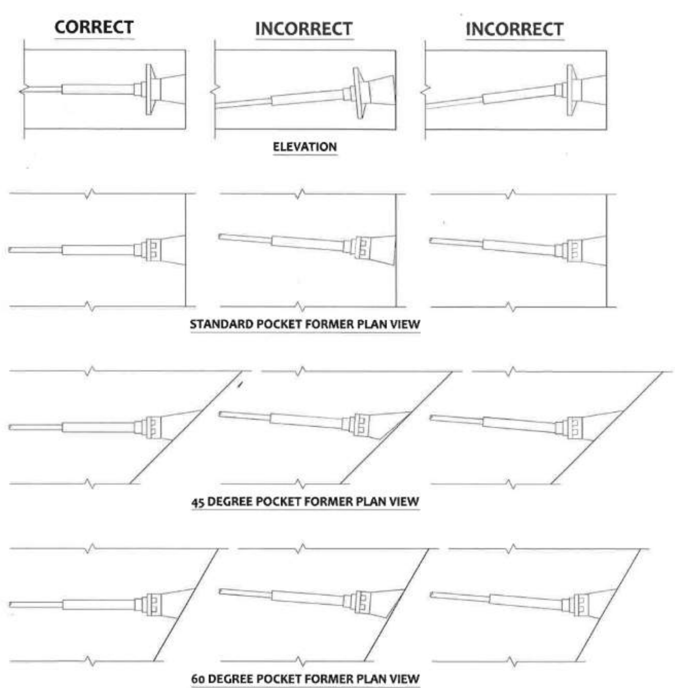


Fig. 4-1—Anchor and pocket former to be installed perpendicular to edge form.

PART III – CONSTRUCTION ADMINISTRATION

ISSUES IN THE FIELD

- Tendons grouped together into bundles too soon.
  - Plastic flutes get bent/cracked.
    - Encapsulated system can be compromised.
  - Hairpin bars can get twisted to fit between tendons

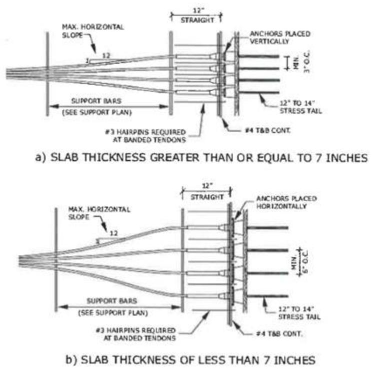


Fig. 7.6—Horizontal flare of tendons at anchorage zone.

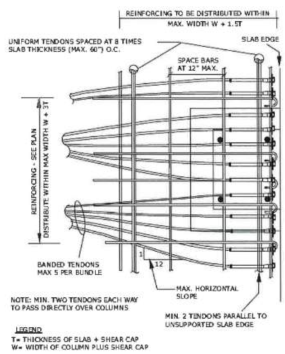
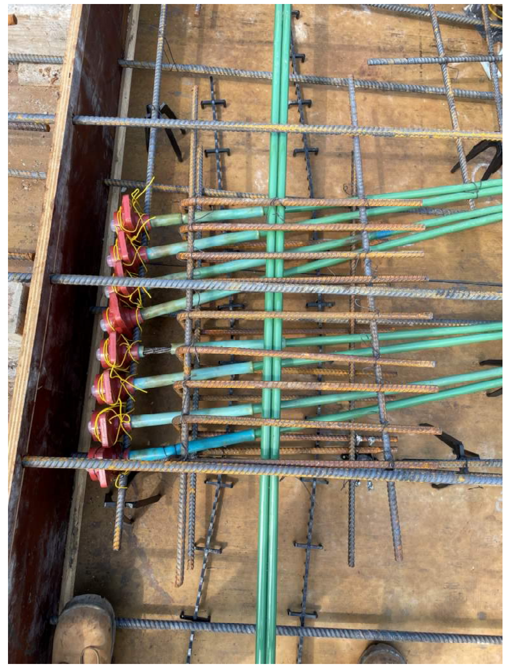


Fig. A6—Two-way slab system exterior columns. (Note: 1 in. = 25.4 mm.)



PART III – CONSTRUCTION ADMINISTRATION

ISSUES IN THE FIELD

- Penetrations near anchorage zones
  - Tendon compressive force can crush sleeves within shaded region.
  - Provide Schedule 40 steel pipes (or approved equal) to protect the sleeve from crushing.

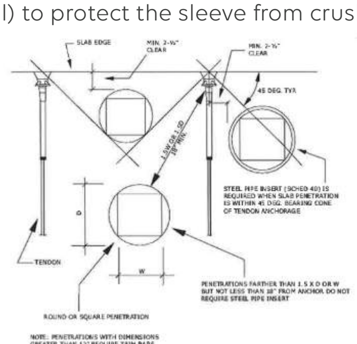


Fig. A4—Reinforcement at anchorage zone penetrations. (Note: 1 in. = 25.4 mm.)

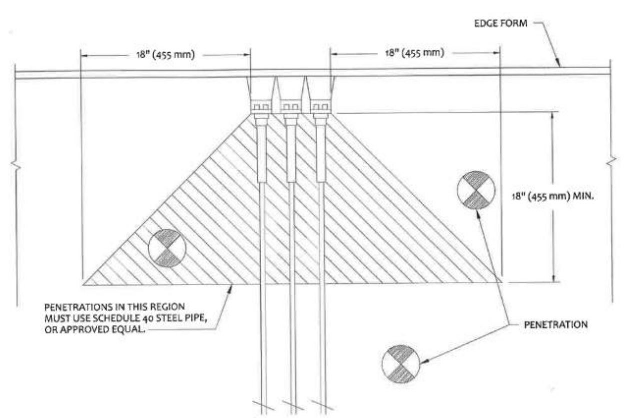


Fig. 4-5—Penetrations near tendon anchorage zone.

Caution: Electrical, mechanical, and railing sleeves are not to be installed after the PT inspection.

- Hatched region can be quite wide at banded tendon regions. Plan with other team members to have them avoid this region, if possible, to reduce sleeve cost.

PART III – CONSTRUCTION ADMINISTRATION

ISSUES IN THE FIELD

- Tendons too close to openings.
  - There will be other mild trim bar around most openings.
  - Tendons too close to edge of concrete can cause blowouts.
- Missing hairpins at horizontal sweeps and not separating tendons through sweeps
  - Tendons straighten out and can cause blowouts without hairpins to restrain them.
  - If tendons are not separated, they can roll over one another and damage sheathing or even cause tendons to break.
- Sweeping tendons too close to corner of opening.
  - Tendons too close to edge of concrete can cause blowouts.

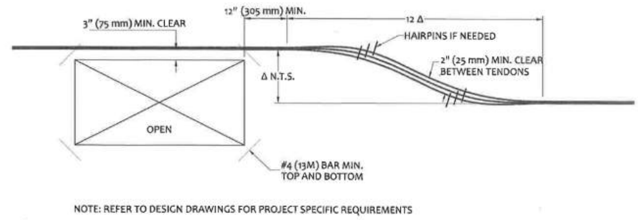
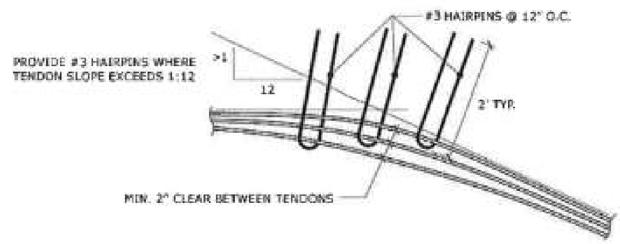


Fig. 4-6 —Typical detail of tendons deviating around an opening and tendon sweeps.



PART III – CONSTRUCTION ADMINISTRATION

ISSUES IN THE FIELD

- Reverse curvature puts unintended forces on members.
  - Can cause concrete to split in tension
  - Can cause blowouts
  - More likely in deeper/longer members because it can be hard to see the reverse curvature sometimes.
  - Be careful about tendon support heights to make sure this doesn't occur.

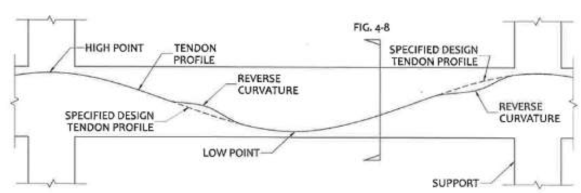


Fig. 4-9—Tendon profile in beam.

Fig. 4-10—Result of reverse curvature.

ISSUES IN THE FIELD

- Conduit and other in slab non-structural elements can be a big challenge.
- The conduit installer needs to be knowledgeable about PT to ensure appropriate installation occurs that does not affect the design.

Fig. 8.4—Large group of conduits in slab.

ISSUES IN THE FIELD

- Poor concrete consolidation at anchorage area.
- Good concrete vibration is key in these areas.

Fig. 8.5—Poor concrete consolidation in anchorage area.

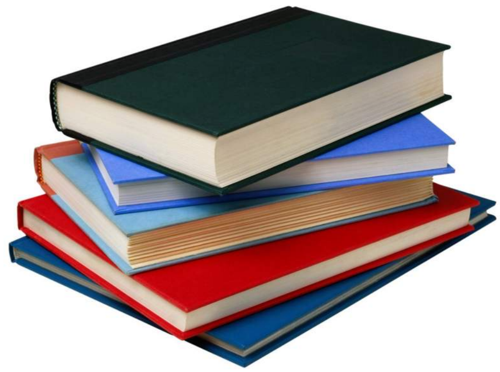
LEARNING FOR ANOTHER DAY

TOPICS NOT COVERED

- PT specifications
- PT general structural notes
- Transfer beams
- Podium slabs
- Transfer caps
- Slab steps
- Vertical PT
- PT foundations and ground anchors
- External PT
- Bonded PT
- Design for lateral loads in moment frame buildings
- Torsion
- Mat (raft) Foundations
- PT slabs-on-ground
- Seismic design of PT Floors
- Sport courts
- Vibration

ADDITIONAL LEARNING

- PTI
  - April 2026 Webinar – PT Documentation from Design to Construction: Best Practices
  - Post-Tensioning Manual 7th Edition
  - PTI DC20.2-22 Restraint Cracks and Their Mitigation in Unbonded Post-Tensioned Building Structures
  - PTI M10.3-16 Field Procedures Manual for Unbonded Single Strand Tendons
  - PTI DC20.9-11 Guide for Design of PT Buildings
  - (17) FAQs and (24) Technical Notes (TN)
- Post-Tensioning Concepts; Design; Construction by Bijan O. Aalami
- ACI 320-25 Post-Tensioned Structural Concrete Code
- ACI 423.10R-16 Guide to Estimating Prestress Loss



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