TAking the ComplexiTy Out of Post Tension Design
Post Tension Concrete

Why Post Tension Concrete?

Images from Ingenia Magazine
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

COMMON TYPES OF STRUCTURES

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

USAGE
- Parking Garages

LONG SPAN PT

One-Way Slab and Beam
LONG SPAN PT

**PROS**
- Contractors are familiar
- Easier parking/Fewer columns

**CONS**
- Expensive
- Does not work well below buildings
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

SHORT SPAN PT

**USAGE**
- Parking Garages
- Hotel, Apartments
- Podium Transfer Slabs
- Office Buildings
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
SHALLOW BEAM PT

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

**PROS**
- Cost effective
- Shallow floor to floor heights

**CONS**
- Difficult to attach exterior veneer
- Columns at head of stalls
SHORT SPAN PRECAST

Typical Structural Sizes

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

POST TENSION CONCRETE SHRINKAGE

SLABS MOVE ¾” FOR EVERY 100’

- Considerations
  - Column Movement
  - Expansion Joints / Closure strips
  - Shear Wall Locations
  - Special Slip Details
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
POST TENSION CONCRETE SHRINKAGE

Shear Wall Locations

(a) Favorable Arrangement of Shear Walls

(b) Unfavorable Arrangement of Shear Walls

POST TENSION CONCRETE SHRINKAGE

Slip Details
PT RULES OF THUMB

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

- One-way slabs 48
- 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

(30 ft span / 48 = 8" slab thickness)

POST TENSION LAYOUT
POST TENSION LAYOUT

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
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

Post Tension Values for 0.6 Dia cables
- Stressed to 46 kip
- Losses about 6.3 kips
- Design strength 38 kips
**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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**COMPRESSIVE STRESS IMMEDIATELY AFTER TRANSFER**
*(24.5.3.1)*

Gross compressive stress is limited to:
- Ends of simply supported member
  \[ \leq 0.70 f_{ct}' \]
- All other locations
  \[ \leq 0.60 f_{ct}' \]
- \( f_{ct}' \) is the concrete strength at stressing
  (usually 3500psi for a 5000psi mix)
TENSILE STRESS IMMEDIATELY AFTER TRANSFER
(24.5.3.2)

“Extreme fiber tensile stress” $f_t$

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

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)
  \[ f_t \leq 6\sqrt{f_c} \]
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

BALLANCE CASE

![Ballance Case Diagram](image.png)
STRENGTH CASE

Fig. 5.14 Nominal Strength with Non-Prestressed Reinforcement

MINIMUM POST TENSION (24.4.4.1)

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

\[
\frac{26 \text{ kips}}{\text{Area}} \text{ for } \frac{3}{8} \text{ cables}
\]
REBAR LAYOUT IN PT MEMBERS

Minimum Lengths
- Remember L/3 and L/6

MINIMUM REBAR (8.6.2.3)

Positive moment two-way slabs

\[ f_t \leq 2 \sqrt{f_y} \]

\[ A_{s_{\text{min}}} \text{ Not Required} \]

\[ 2 \sqrt{f_y} < f_t \leq 6 \sqrt{f_y} \]

\[ A_{s_{\text{min}}} = \frac{N_t}{0.5 f_y} \]

\[ f_t = N_t \]

N_t = 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.
MINIMUM REBAR TWO-WAY (8.6.2.3)

Negative moment two-way slabs

\[ A_s = 0.0075 \times A_{cf} \]

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

\[ A_{cf} = \frac{30}{2} \times 12 \times 8 = 1440 \]

or

\[ A_{cf} = \frac{30+15}{2} \times 12 \times 8 = 2160 \]

So \( A_s = 0.0075 \times 2160 = 1.62 \)

(5) #5 min

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
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

MINIMUM REBAR ONE WAY (9.6.2.3)

One-way Slabs

\[ A_{s,\text{min}} = 0.004 \times A_t \]

\( A_t \) is area of concrete between center of gross section to and extreme tension face

Simplifies to

\[ A_{s,\text{min}} = 0.002 \times A_t \]

For 7 ¾” slab

\[ A_{s,\text{min}} = 0.002 \times 7.25” \times 13” = 0.172 \]

Use #4 at 12” O.C.

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

TYPICAL REBAR EXAMPLE

Fig. 18.3.7—Typical arrangements of headed shear stud reinforcement and critical sections.

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QUESTIONS?

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