Design and Construction of Post-Tensioned Concrete Structures

FARHAD HUSSIAN

GIVING :

To Mom and dad…To my family and my clan…To my teachers..To my colleagues…To burn candls to illuminate for others..To each of the characters taught me find dictate this modest Rajya from Mawla…Almighty to find acceptanc and success

THE RESEARCH TARGET :

This research hope enable us to use this system in Kurdistan more than normal systems…
This system consider economic (less steel , 50% less no. of crew , time …etc
Also saving in labor and materials (mechanical , electrical , elevator , cladding)

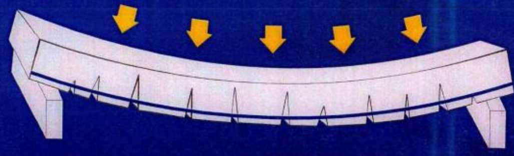
Session Outline

- **What is Prestressing?**
- **Overview of Post-Tensioning Systems**
- **Myths about Post-Tensioning**
- **Basic Design Concepts**
- **Advantages of Post-Tensioning**
- **Construction of Post-Tensioned Slabs**
- **Application of Post-Tensioning to Transfer Girders**

Prestressed Concrete

- What is prestressing?

  Prestressing is a method of reinforcing concrete. The concrete is prestressed to counteract the applied loads during the anticipated service life of the member.



Pre- and Post-Tensioned Concrete

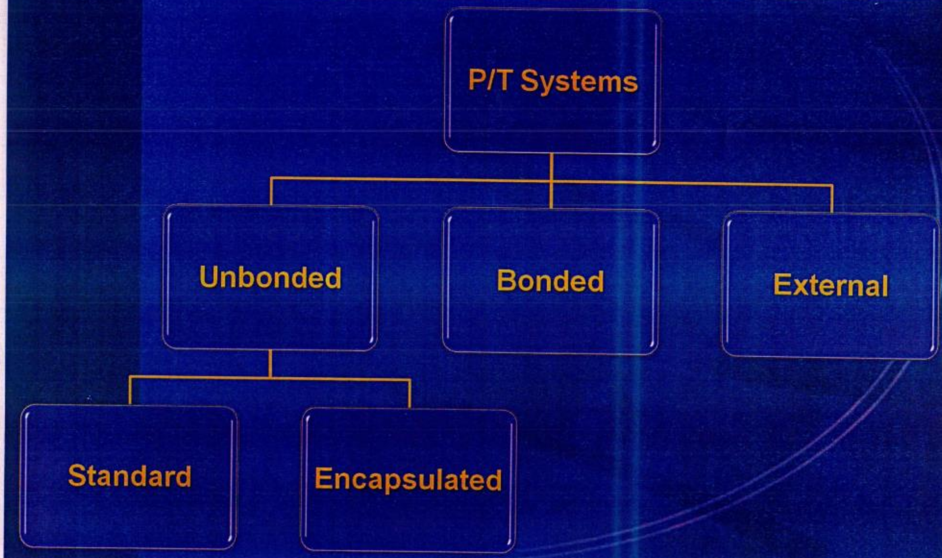
Pre-Tensioning:

Steel tendons are stressed prior to concrete placement, usually at a precast plant remote from the construction site

Post-Tensioning:

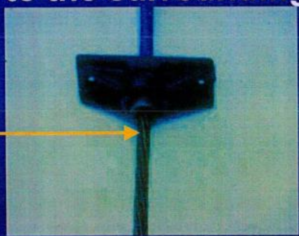
Steel tendons are stressed after the concrete has been placed and gained sufficient strength at the construction site

Post-Tensioning Systems

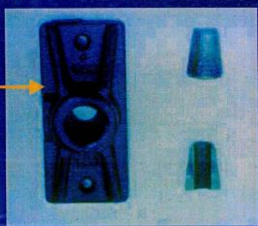


What is an Unbonded Tendon?

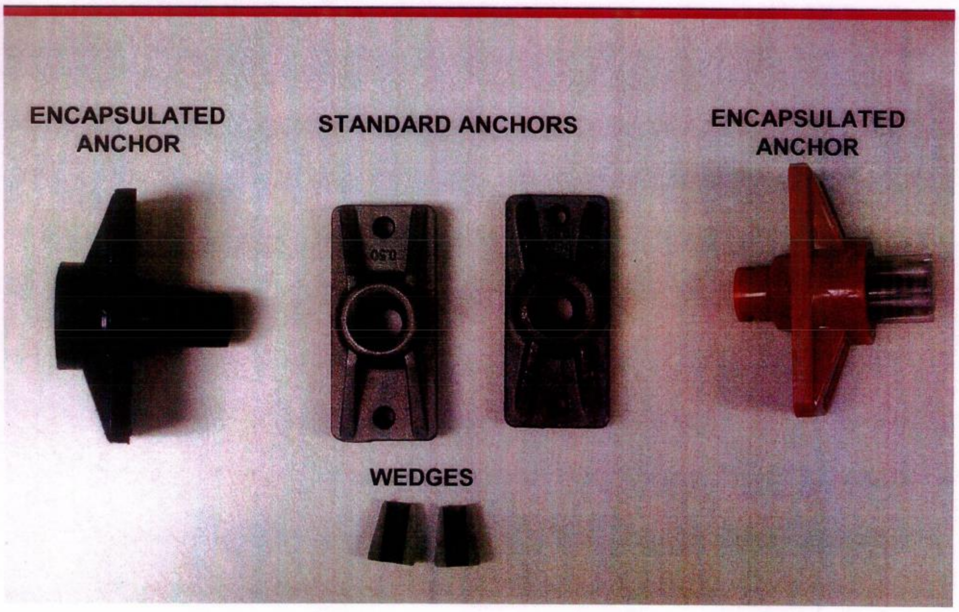
- Prestressing steel is prevented from bonding, and is free to move, relative to the surrounding concrete
- Consist of 7-wire strands
  Most commonly used sizes are 0.5" dia strands



- The prestressing force is transferred to the concrete through the anchorages only



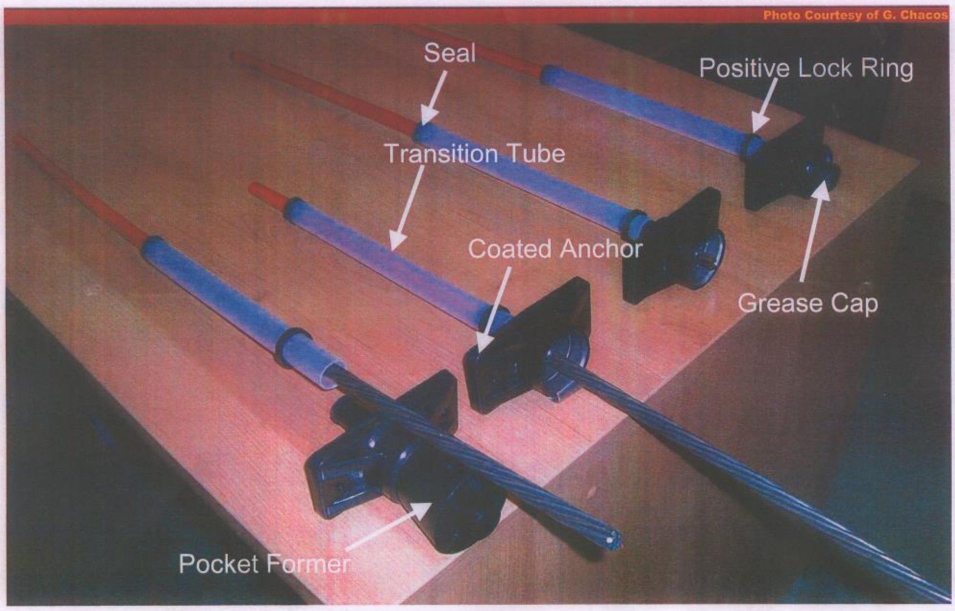
End Anchors



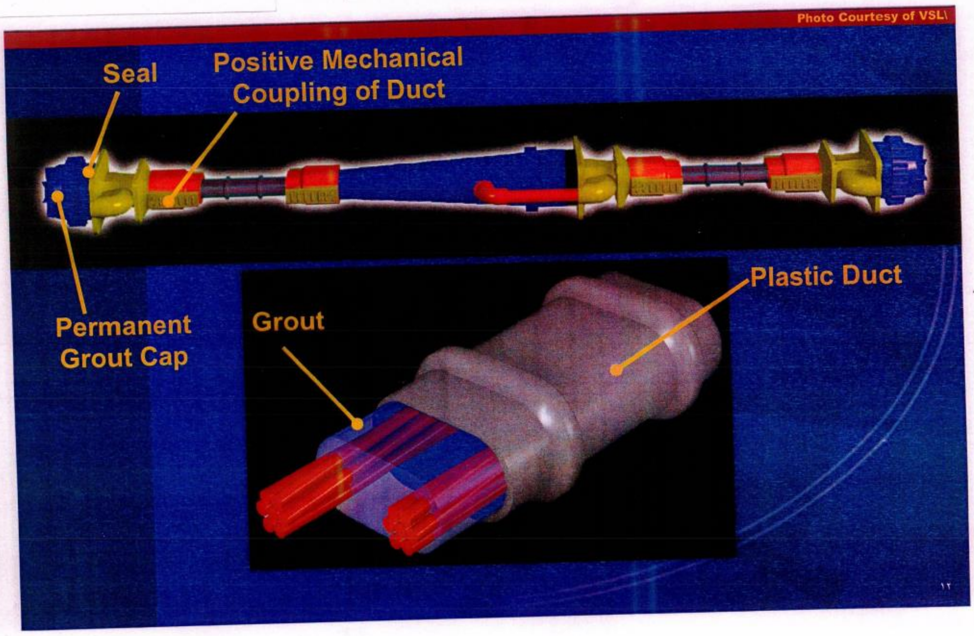
Encapsulated Tendons – When?

- Corrosive Environments
- Decks exposed and/or near the ocean
- Decks where de-icing salts (snow areas) will be used
- Slabs-on-ground where the soil has a high chloride content

Encapsulated Tendon Components



Bonded Tendons



Myths About P/T

- P/T Concrete is Crack Free
- P/T Concrete is Water Proof
- You Cannot Drill/Make Openings in P/T Slab
- If You Drill Into a Tendon, it will Fly Out of the Building
- It is Impossible to Upgrade/Repair a P/T Structure
- P/T Structures are Not Durable

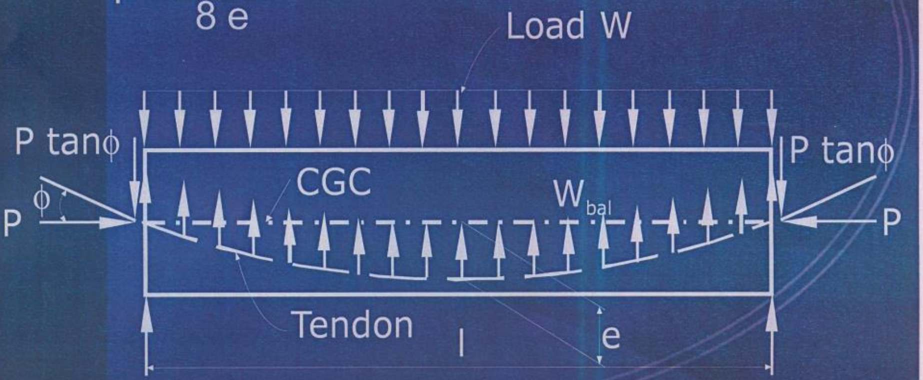
Post-Tensioning Systems
Unbonded vs. Bonded

- Unbonded
  - Economical
  - Greater layout flexibility
  - Force transmitted solely by the anchors
  - Total force limited by anchor spacing
  - Retrofit openings require more care
  - Replaceable
  - Simple stressing equipment
- Bonded
  - Can be more costly due to duct placement & grouting
  - Force transmitted by anchors and bond to concrete
  - Greater total force can be applied
  - Strain compatibility with concrete
  - Openings less difficult
  - Minimizes need for non-prestressed reinforcement
  - More complex stressing equipment required

Load Balancing

$M_1 = P \cdot e$ = Primary Moment

$$P = \frac{w_{bal}\, l^2}{8\, e}$$



Secondary Moment

M_2 = Secondary Moment

Developed in post-tensioned concrete members due to prestressing forces

Consequence of constraint by the supports to the free movement of the member

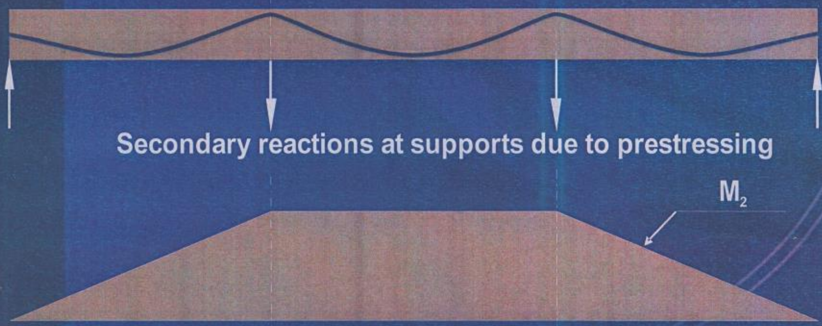
- **Only develops in indeterminate members**
- **simply supported beams have zero secondary moments**

Significant: must be accounted for in the design of prestressed concrete indeterminate structures

Secondary Moments – Cont'd

$M_{bal} = M_1 + M_2 = Pe + M_{sec}$

M_{bal} = Balanced moment by post-tensioning equivalent loads



Secondary Moments, M_2, vary linearly between supports

Preliminary Design Span/Depth Ratio

Floor System	Typical Span/Depth Ratio	
	P/T Members	RC Members
One way slabs	48	21-28
Two-way slabs	45	33
Two-way slabs with drop panels (minimum drop panel L/6 each way)	50	36

Cost Comparison
Unbonded Tendons

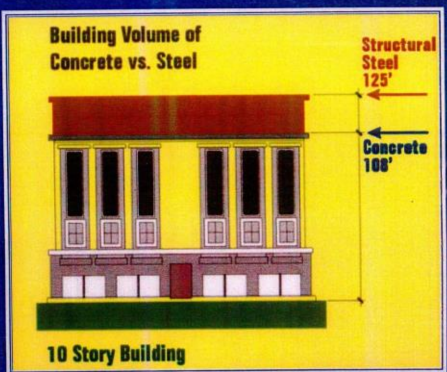
Slab Span (ft)	Slab Thick. (in.)	l/d ratio	Materials per Sq. ft[1]			Cost per Sq. ft [2]		
			Conc. (in.)	Reinf. Steel (lb)	P/T Steel (lb)	Conc. Cost	Steel Cost	Total
Non Prestressed								
30' X 30'	10+4	36	10.3	4	0	$3.97	$1.80	$5.77
Post-Tensioned								
30' X 30'	8.5	42.4	8.6	0.8	0.9	$3.32	$1.44	$4.76
30' X 30'	8	45	8.2	1.6	0.95	$3.16	$1.86	$5.02

[1] Fintel, M., Ghosh, S.K., "*Economics of Long-Span Concrete Slab Systems for Office Buildings - A Survey*", Portland Cement Association, 1982

[2] Conc. Cost=$125/Cubic Yd. Reinf. Steel Cost = $0.45/lb P/T Steel Cost= $1.20/lb

Comparison with Structural Steel Buildings

- Reduced structural depth for lower story heights, smaller column and foundation sizes
- Savings in labor and materials
  - Mechanical
  - Electrical
  - Elevator
  - Cladding



Post-Tensioned Concrete Advantages

- Long economical spans
- Effective use of high strength materials
- Permits wide flexibility in design variations
- Significantly reduces amount of non-prestressed bonded reinforcement over supports of continuous P/T structures

Post-Tensioned Concrete Advantages

- Deflection and vibration control
- Crack control and water-tightness
- Noise control
- Lateral loads (rigid frame action)
- Seismic Loads (improved behavior of moment frames)

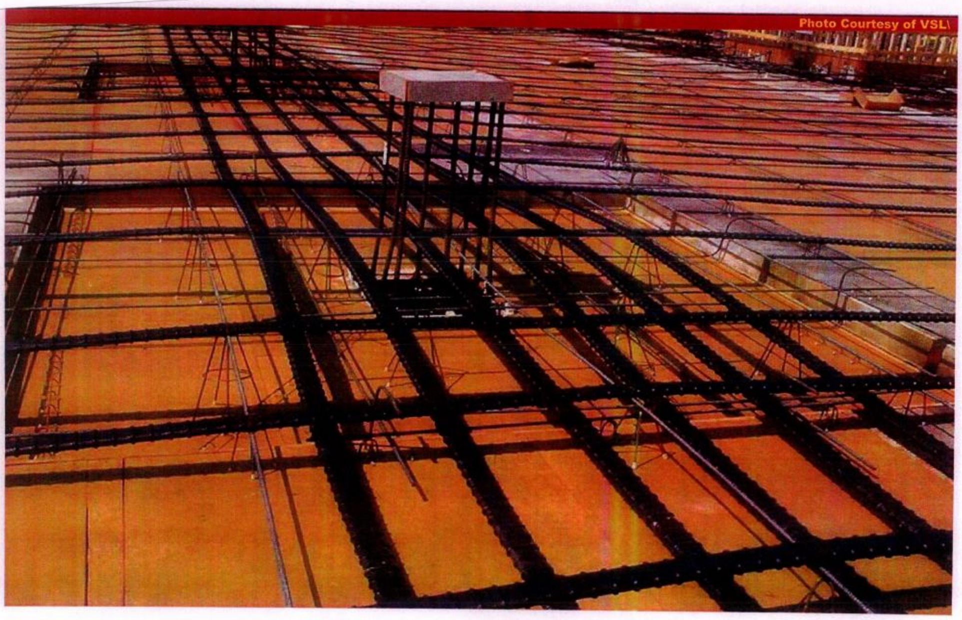
Construction Cycle

- Possible to achieve a 2-day cycle (may need overtime)
- Typical construction cycle
  - East coast 3 day (Low Seismic Areas)
  - West coast 3-4 day (Higher Seismic Areas)
- Typically need about 50% of crew for post-tensioned buildings
- Re-shoring is not required once the slab has been post-tensioned

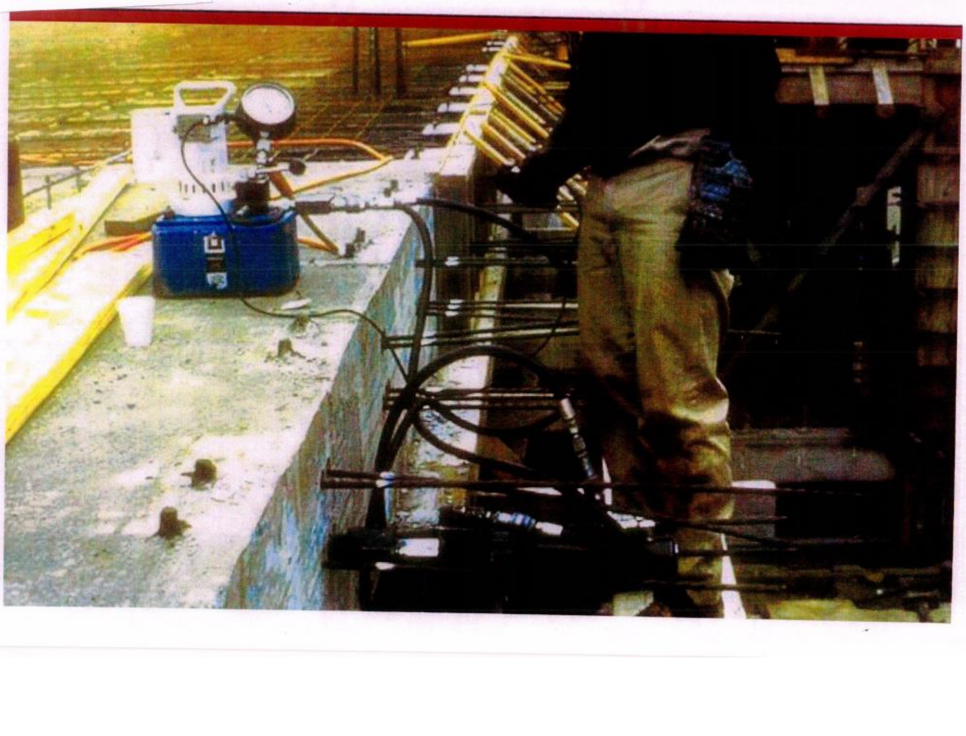
Tendon Installation

Photo Courtesy of Cary Kopczynski & Company

Two-Way Slab with Bonded P/T



Stress Tendons



Measure Elongation

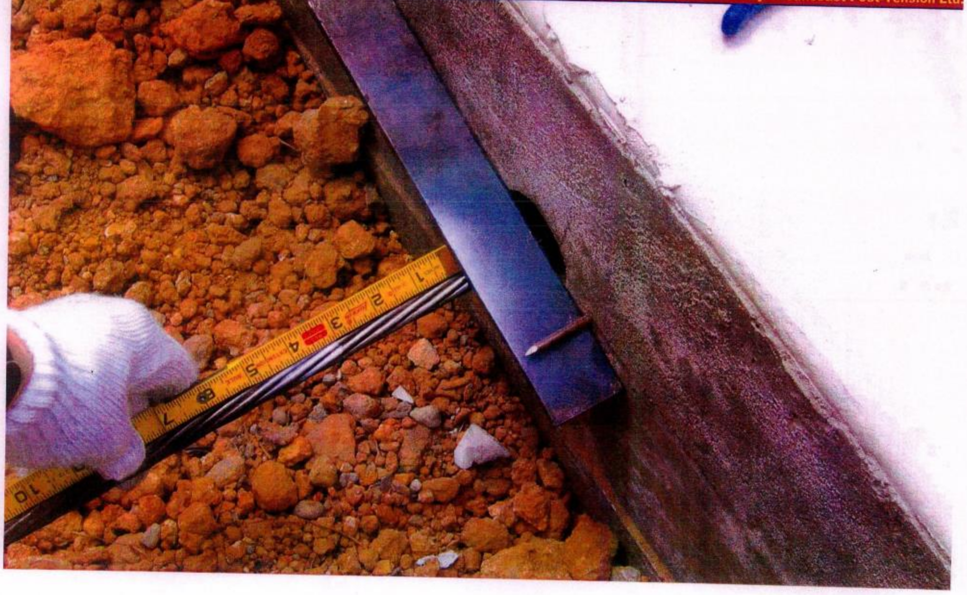
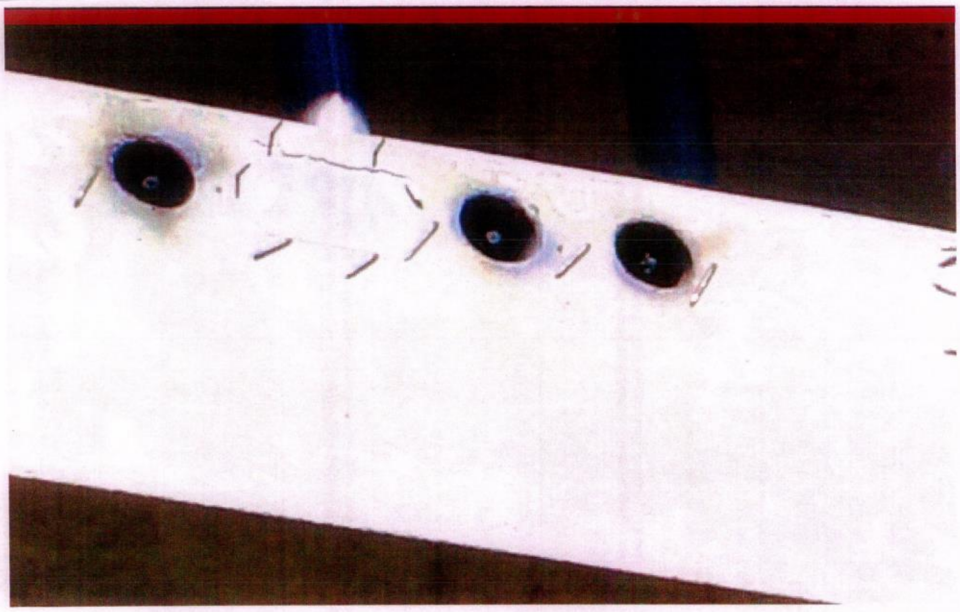


Photo Courtesy of Suncoast Post-Tension Ltd.

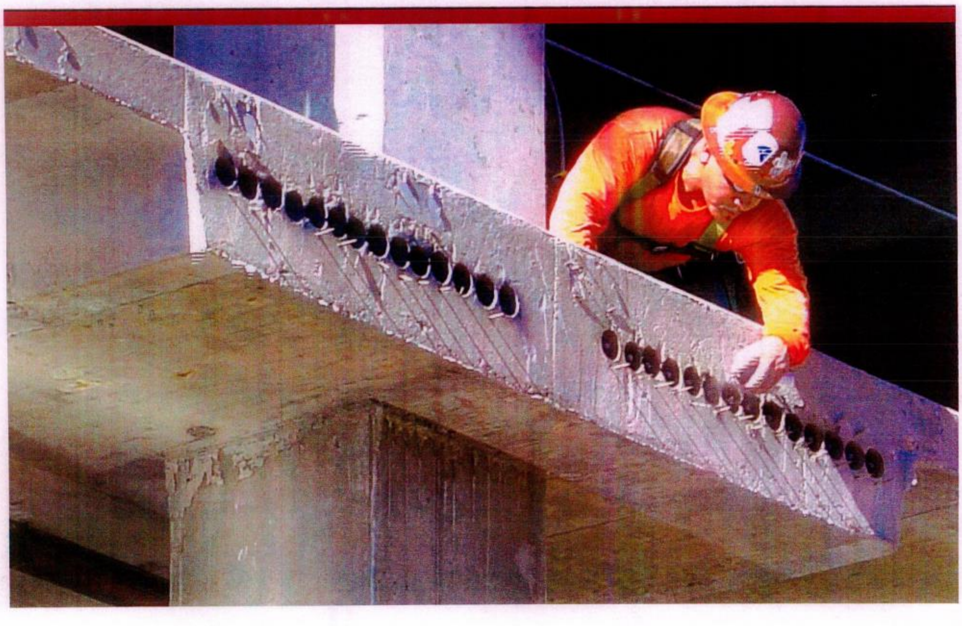
Elongations

- Measured elongation needs to be within 7% of calculated value
- Per code, for tendons outside the 7%, the EOR shall ascertain and correct the “problem”. What to do? De-Tension / Re-Tension?
- Elongation records shall be sent to the reviewing engineer by the end of the next working day after stressing
- Elongations shall be approved or rejected within three working days after stressing

Cut Tendon Tails

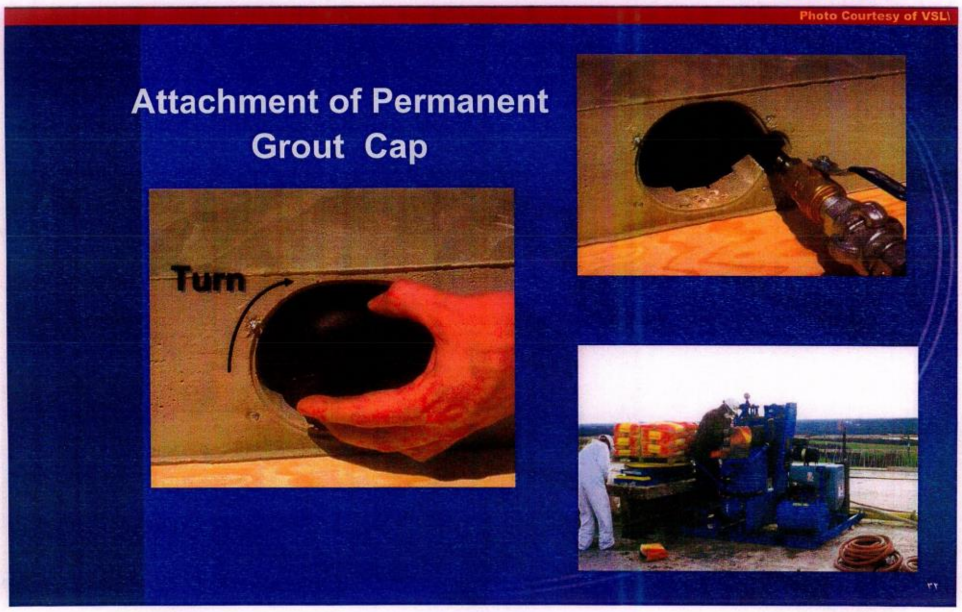


Clean Pockets



Patch End Pockets

End Installation for Bonded Tendons



One-way Slabs and Beams

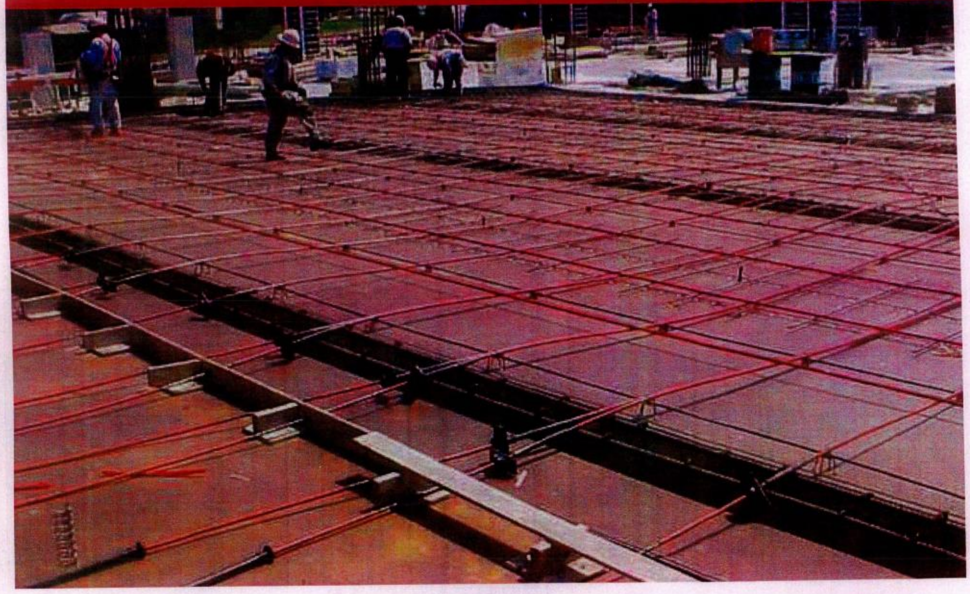
- Typically used in long span parking structures
- Slab spans typically between 18 to 30 feet
- Beams can clear span up to 65' at a 3'-0" system depth
- Maximum tensile stress is $12\sqrt{f'c}$

Post-Tensioned Parking Garage

Photo Courtesy of Suncoast Post-Tension Ltd.

One-Way Slab

Photo Courtesy of Suncoast Post-Tension Ltd.



Two-Way Slabs

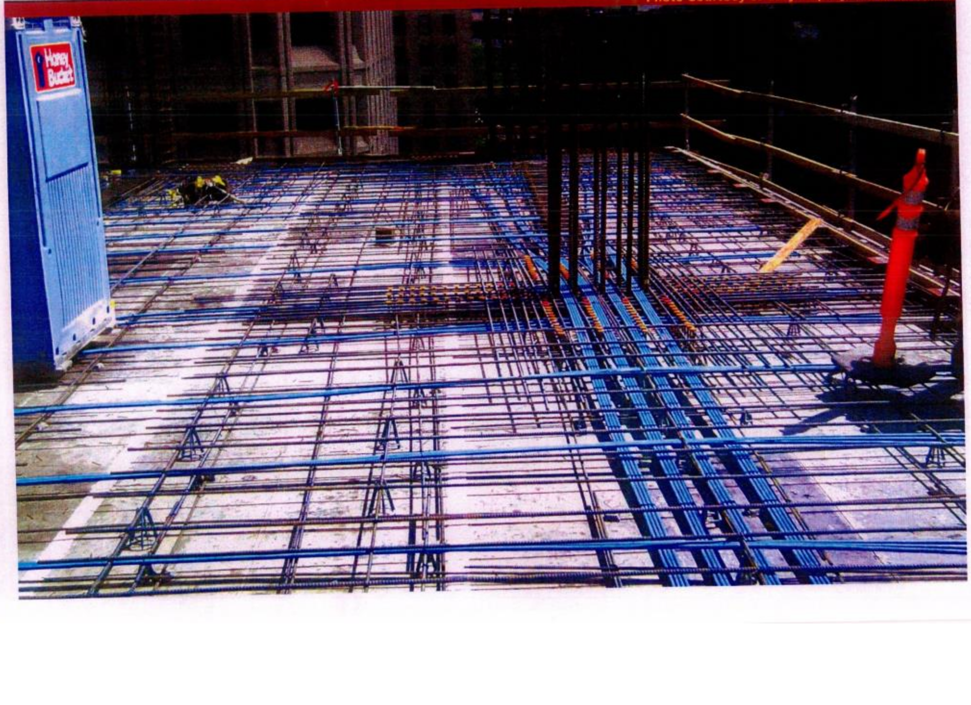
- Typically used in Residential and Office Buildings
- Slab spans between 20 to 40 feet
  - Flat Plate 20 to 30 feet
  - Slabs with Drop Caps 25 to 35 feet
  - Flat Slab 30 to 40 feet
- Maximum tensile stress is limited to $6\sqrt{f'_c}$

Two-Way Slabs

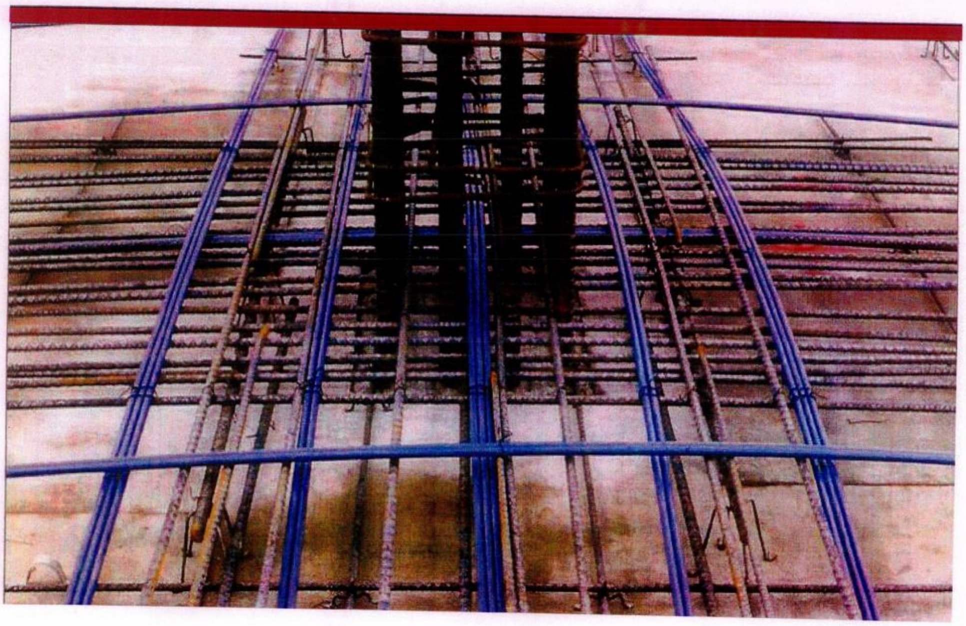
Photo Courtesy of Suncoast Post-Tension Ltd.

Two-Way Slab

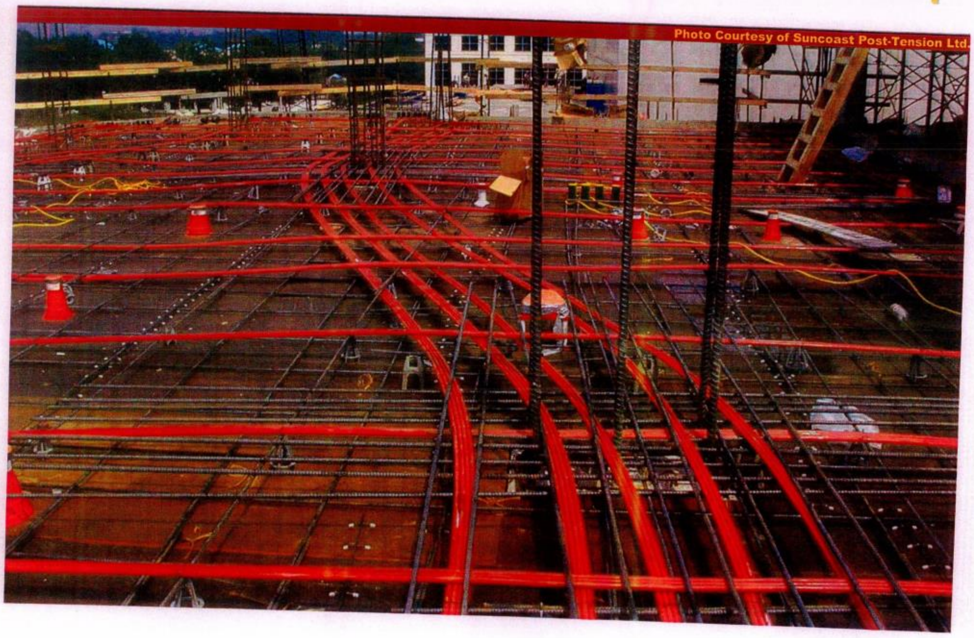
Photo Courtesy of Cary Kopczynski & Company

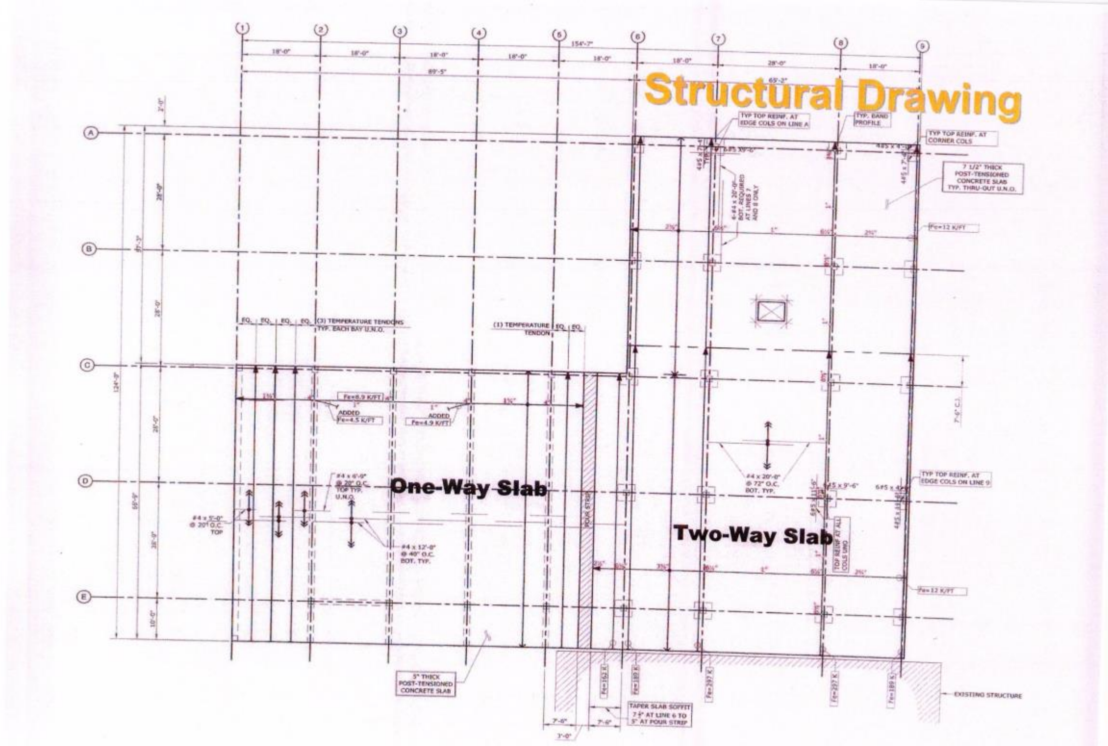


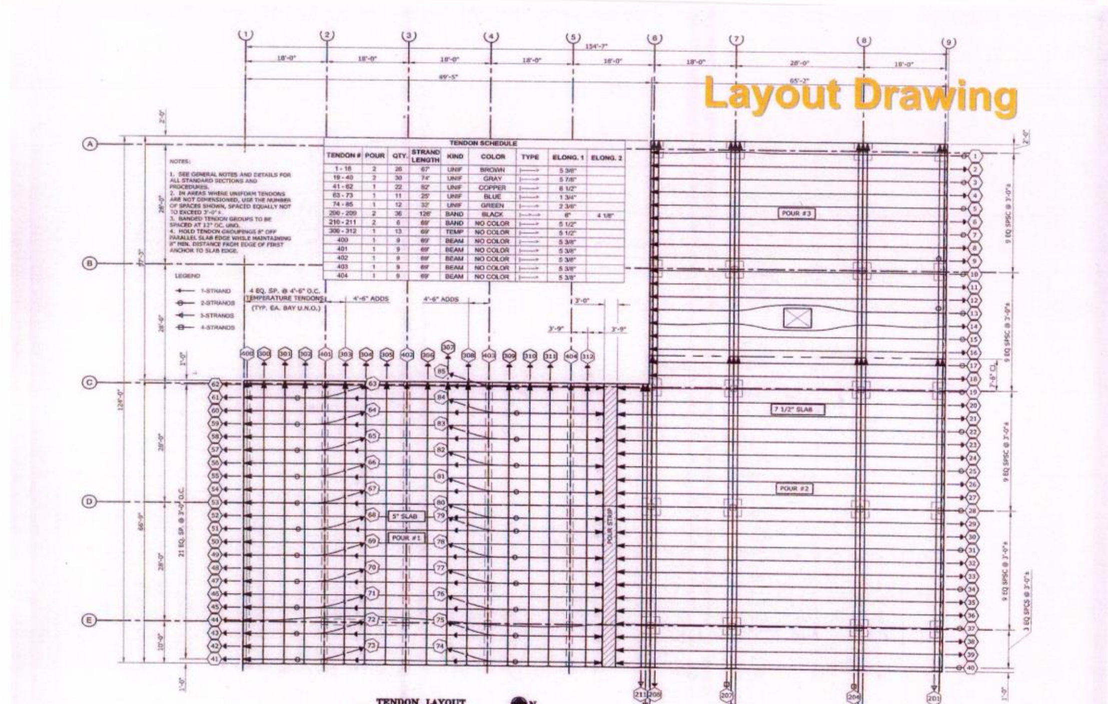
Tendon Layout in 2-Way Slabs



Tendon Sweep



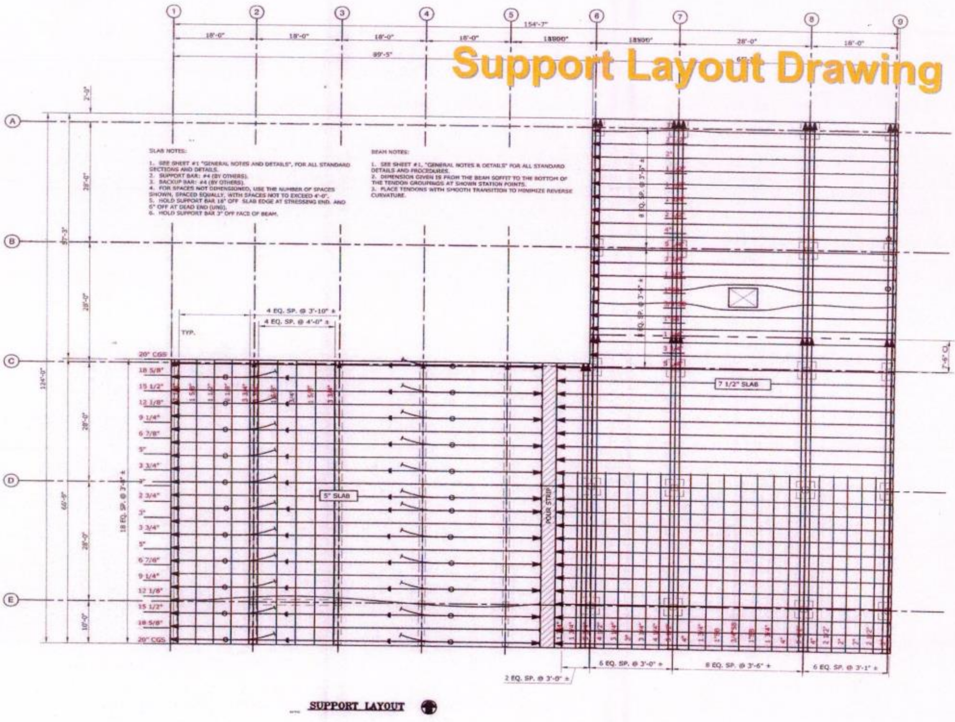




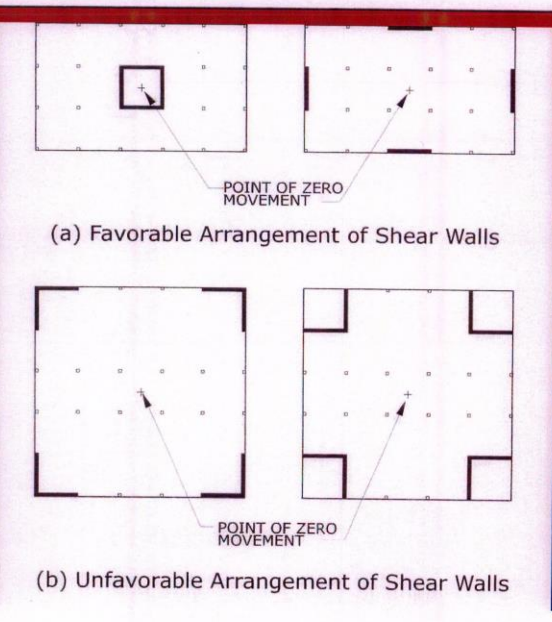
TENDON SCHEDULE

TENDON #	POUR	QTY.	STRAND LENGTH	KIND	COLOR	TYPE	ELONG. 1	ELONG. 2
1 - 18	2	28	67'	UNIF	BROWN	⟼	5 3/8"	
19 - 40	2	30	74'	UNIF	GRAY	⟼	5 7/8"	
41 - 62	1	22	82'	UNIF	COPPER	⟼	6 1/2"	
63 - 73	1	11	25'	UNIF	BLUE	⟼	1 3/4"	
74 - 85	1	12	33'	UNIF	GREEN	⟼	2 3/8"	
200 - 209	2	36	126'	BAND	BLACK	⟼	8"	4 1/8"
210 - 211	2	6	69'	BAND	NO COLOR	⟼	5 1/2"	
300 - 312	1	13	69'	TEMP	NO COLOR	⟼	5 1/2"	
400	1	9	69'	BEAM	NO COLOR	⟼	5 3/8"	
401	1	9	69'	BEAM	NO COLOR	⟼	5 3/8"	
402	1	9	69'	BEAM	NO COLOR	⟼	5 3/8"	
403	1	9	69'	BEAM	NO COLOR	⟼	5 3/8"	
404	1	9	69'	BEAM	NO COLOR	⟼	5 3/8"	

Support Layout Drawing



Arrangement of Shear Walls



Floor Shortening and Restraint Cracking

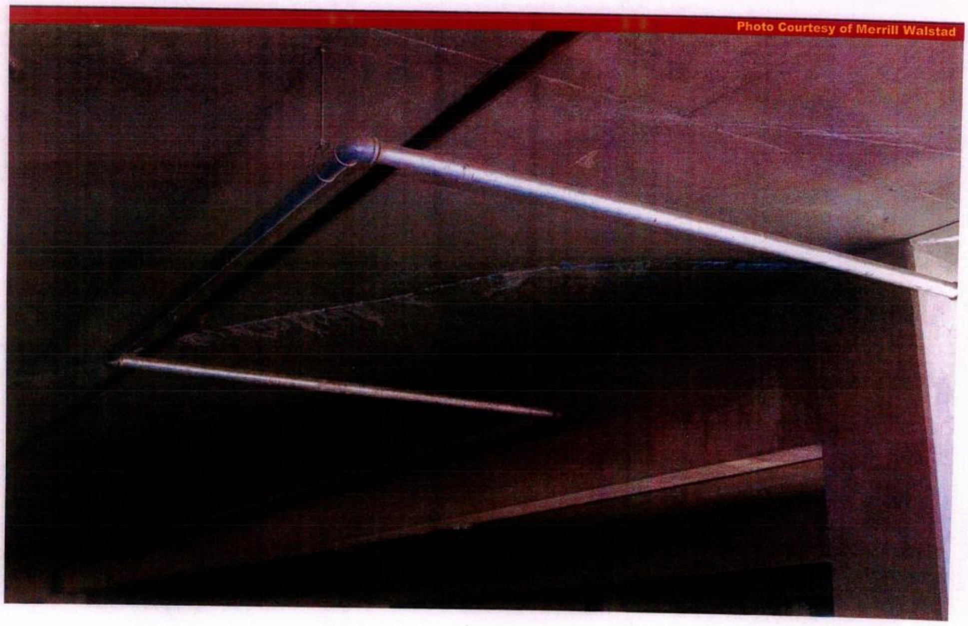
- Sources of Cracking
  - Short floor-to-floor height
  - Short stiff columns
  - Stiff lateral load resisting elements
- Factors Contributing to Floor Shortening
  - Elastic shortening due to precompression
  - Creep shortening due to precompression
  - Shrinkage
  - Temperature drop
- Show Joint and Separation Details on Structural Drawings
- Inspect Separation Details During Construction

Restraint Cracking

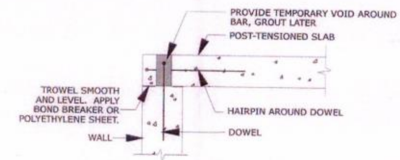
Photo Courtesy of Merrill Walstad

Restraint Cracks

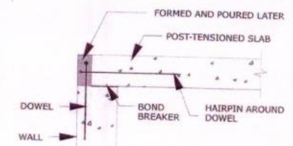
Photo Courtesy of Merrill Walstad



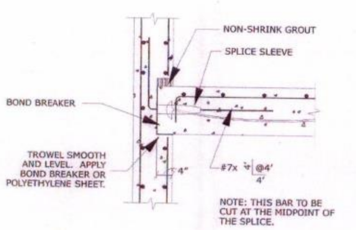
Movement Joints



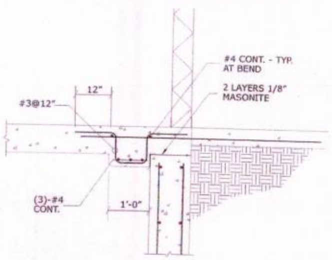
(a) Wall-Slab Release Connection Detail (Option #1)



(b) Wall-Slab Release Connection Detail (Option #2)

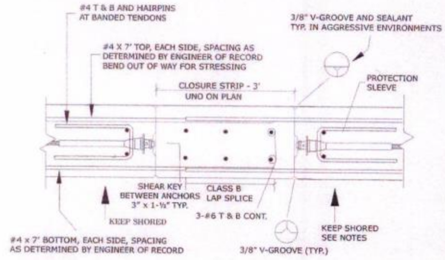


(c) Connection of Post-Tensioned Slab To Wall With Splice Sleeves



(d) Connection of Post-Tensioned Slab to Basement Wall

Closure Strip



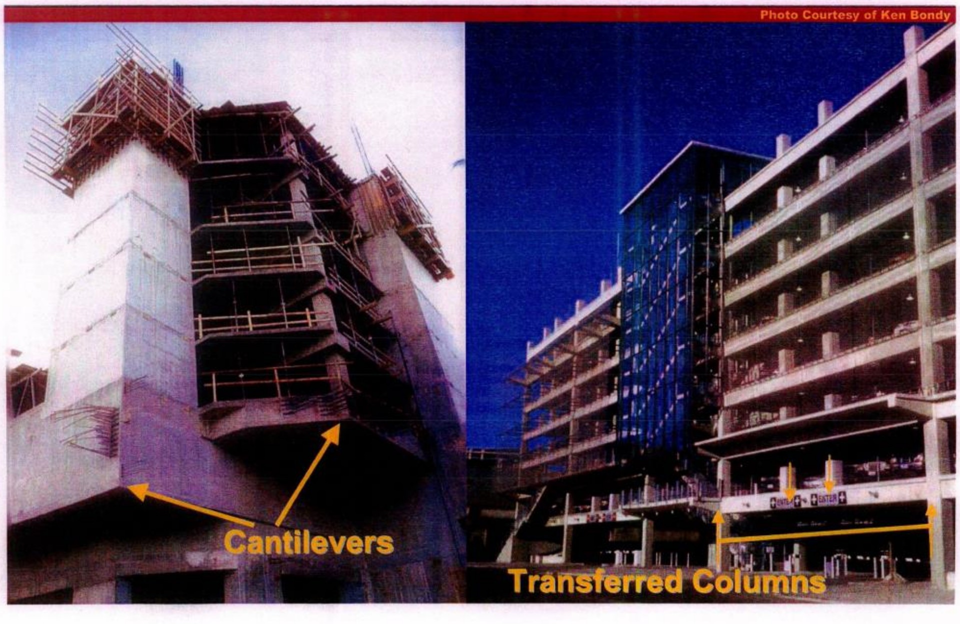
NOTES:

1. RETAIN SHORING UNTIL CONCRETE IN CLOSURE STRIP REACHES 75 PERCENT OF SPECIFIED SLAB CONCRETE STRENGTH.
2. CLOSURE STRIP TO BE FILLED WITH NON-SHRINK CONCRETE.
3. ROUGHEN AND CLEAN JOINTS. WET PRIOR TO PLACING CONCRETE.
4. ELIMINATE ACCIDENTAL MISALIGNMENT BETWEEN EDGE OF SLABS THAT ARE TO BE JOINED WITH A CLOSURE STRIP. USE MECHANICAL METHODS SUCH AS JACKING IF NECESSARY.
5. PROVIDE WATERPROOFING MEMBRANE IF REQUIRED FOR WATER-TIGHTNESS.
6. IF CLOSURE STRIP WILL BE IN AN AGGRESSIVE ENVIRONMENT, SEAL ANCHORAGE POCKETS PER THE PROJECT SPECIFICATIONS AND CAULK JOINT ALL THE WAY AROUND WITH FLEXIBLE SEALANT.
7. CONTRACTOR SHALL NOTE THAT THERE ARE SPECIAL SHORING CONDITIONS ON EITHER SIDE OF THE CLOSURE STRIP, ESPECIALLY FOR MULTI-STORY STRUCTURES.

- Slab is temporarily allowed to cure in smaller segments
- Can locate the lateral system in the middle of the individual pour
- Allows for internal stressing – may be critical on subterranean projects
- Typically remain open for 30 to 60 days. Deck will still move for many months/years

Transfer Girders

Photo Courtesy of Ken Bondy



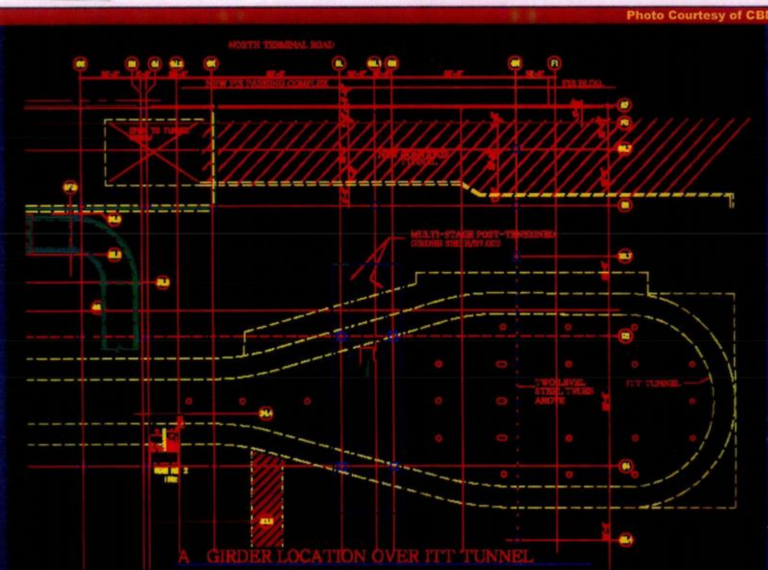
Transfer Girders

Photo Courtesy of DYWIDAG Systems International

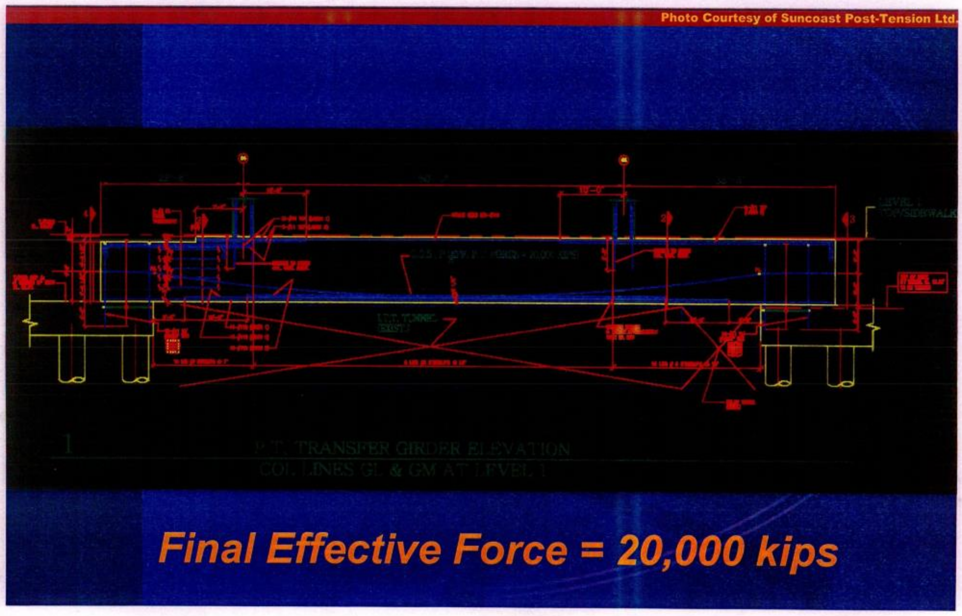
- Harped profile may be more efficient to resist concentrated loads
- P/T forces can balance the dead loads
- Stage stressing to avoid overstressing the beams
- Multi-strand tendons when large forces are required

Case Study
Transfer Girder over Tunnel

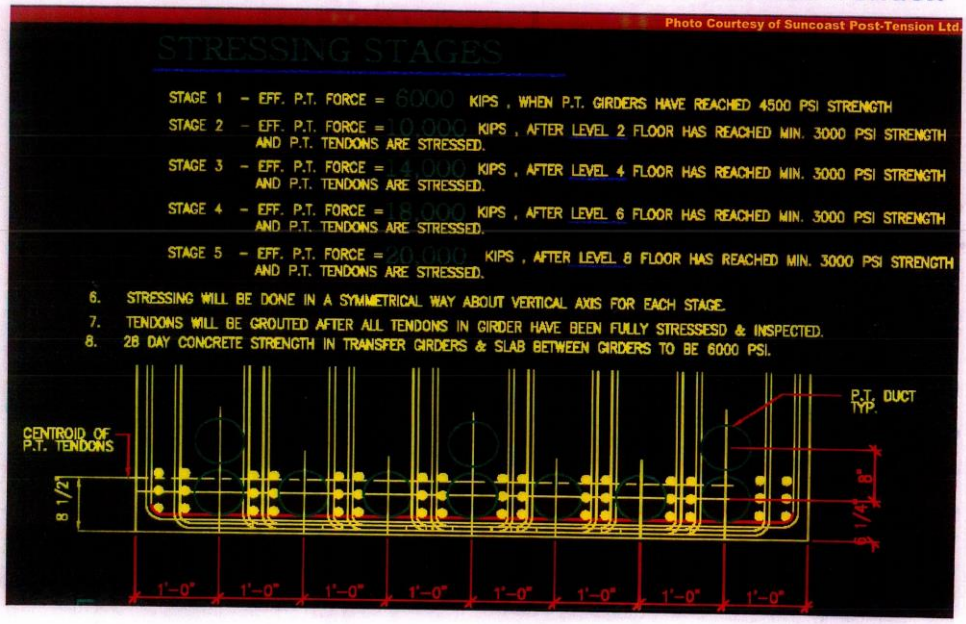
Photo Courtesy of CBM Engineers



P/T Transfer Girder
Elevation at Level 1



Original Design
Bonded Tendon



Revised Design

Unbonded Post-Tensioned

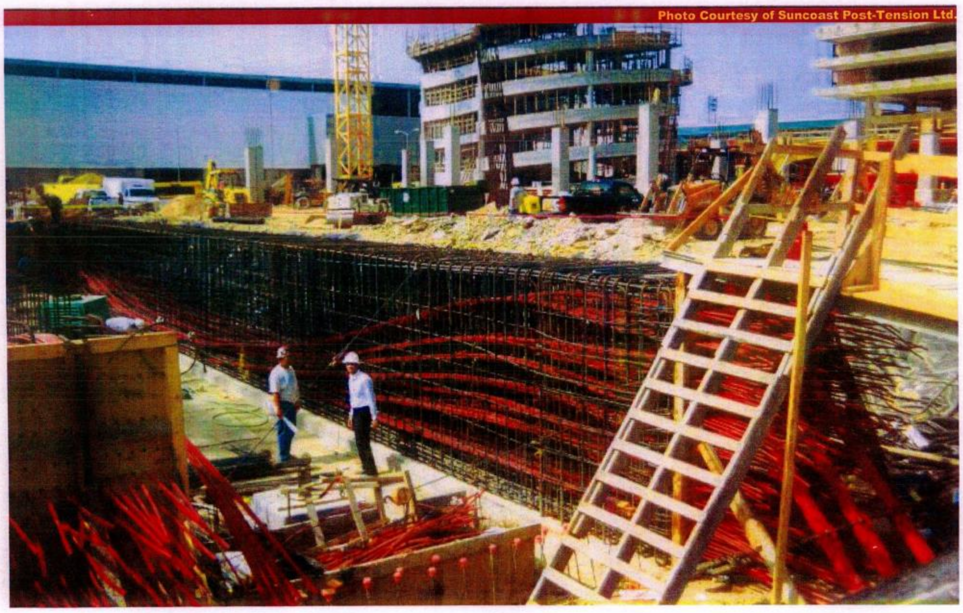
Photo Courtesy of Suncoast Post-Tension Ltd.

Construction

Photo Courtesy of Suncoast Post-Tension Ltd.

End Anchorage Layout

Tendon Layout



Reasons to Consider P/T

- P/T slab is typically 30% thinner
- Long-term creep problems are virtually eliminated by load balancing
- Moment of inertia approaches I_{gross}
- The slab can be stressed and the forms removed in 2-3 days
- The 21 to 28 day shoring time for rebar concrete does not apply to P/T
- Flexibility in Column Layout
- Large Cantilevers

Thank You!