Encapsulated Post-Tensioned Concrete for Corrosive and Non-Corrosive Environments

A Guide for Structural Engineers, Architects and Owners

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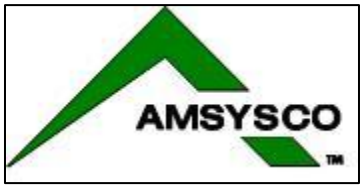

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GOAL:

Given the innovations in post-tensioning and concerns about corrosion, this non-technical white paper aims to inform Structural Engineers and Architects about the benefits of the fully-encapsulated post-tensioning system over the non-encapsulated system. This paper also serves as a resource to Owners and Developers interested in utilizing post-tensioned concrete reinforcement. The focus of this paper is primarily on unbonded, single-strand post-tensioning used in commercial and industrial construction.

OUTLINE:

Section I. Post-Tensioning & Why It Matters

Section II. Benefits of Unbonded Post-Tensioning (PT)

Section III. Comparison of Encapsulated PT to Non-Encapsulated PT

Section IV. Recommendations for Project Specifications

Appendix: Construction Details and Recommend Reading

Section I. Post-Tensioning & Why It Matters

Post-Tensioned concrete is a form of prestressing that dates back to the late-1800's[1]. Modern post-tensioning, developed in the 1950's, outgrew it adolescent phase and entered mainstream structural design in the 1970's. Since the establishment of the Post-Tensioning Institute (PTI) in 1976, post-tensioning has become an increasingly desirable method of construction for commercial and residential structures. According to PTI, the usage of post-tensioned concrete in North America increased 1200% from 1976 to 2006.[2]

Post-Tensioning has been used in marquee structures such as the Watergate Apartments[3], the Leaning Tower of Pisa (retrofitting)[4], 340 On The Park (62-story tower)[5], the Indianapolis International Airport Parking Structure[6] and Minnesota Twins Target Field[7].

[1] http://www.allbusiness.com/construction/construction-overview/8914786-1.html Bijan Aalami.
[2] http://www.post-tensioning.org Post-Tensioning Institute: 2009 Tonnage Report.
[3] http://www.kenbondy.com/images/ProfessionalArticles/Post-Tensioned%20Concrete%20in%20Buildings_ACI_SF_Bondy.pdf Ken Bondy

Owners and Developers have chosen unbonded post-tensioning (PT) in order to save construction costs without sacrificing quality. Similarly, Architects and Structural Engineers have designed structures with PT to create an open floor layout and to save material for LEED benefits. State and Local Municipalities have encouraged the used of cast-in-place concrete since it promotes local jobs. At the same time, Concrete and General Contractors have shifted towards using PT in order to speed up construction schedules with labor savings. Post-Tensioning has proved to be a viable, cost-effective alternative to structural steel, wood, precast and conventional reinforced concrete.

Section II. Benefits of Unbonded Post-Tensioning

While post-tensioning has had many research projects, case studies and real-life construction projects, PT is still considered a niche product within the A/E/C community. One reason is the lack of graduate-level engineering curriculums that rigorously teach students about the post-tensioned concrete alternative. Many courses on prestressed concrete focus more on pre-tensioning and precast rather than post-tensioning. As a result, many PT designers were self-taught or trained by their employers. That said, the diffusion of PT design knowledge has moderately increased in the recent years due to successful post-tensioned concrete projects.

Post-Tensioned concrete can positively affect the construction costs, life-cycle costs, construction schedule and structural durability. The primary benefit of PT in high-rise buildings is the ability to reduce the slab thicknesses and decrease the floor-to-floor heights. As a result, vertical elements (ex. shear walls, columns, MEP piping, elevators, curtainwall) are reduced. This material savings can help a building attain sustainability ratings (LEED) and increase its architectural appeal (refer to Figure 1). In parking structures, many universities and airports Owners have utilized Post-Tensioning to increase security-camera visibility and safety lighting due to lack of closely-spaced beams and shear walls. Table 1 illustrates examples of recently-completed construction projects and some practical benefits of unbonded PT.

[4] http://casehistories.geoengineer.org/volume/volume1/issue3/IJGCH_1_3_2.pdf
[5] http://midwest.construction.com/features/archive/0607_feature5.asp
[6] http://constructoragc.construction.com/mag/2008_3-4/features/0803-72_AGC.asp
[7] http://www.bizjournals.com/twincities/stories/2010/03/01/focus5.html

Figure 1 – Potential Benefits of Unbonded PT

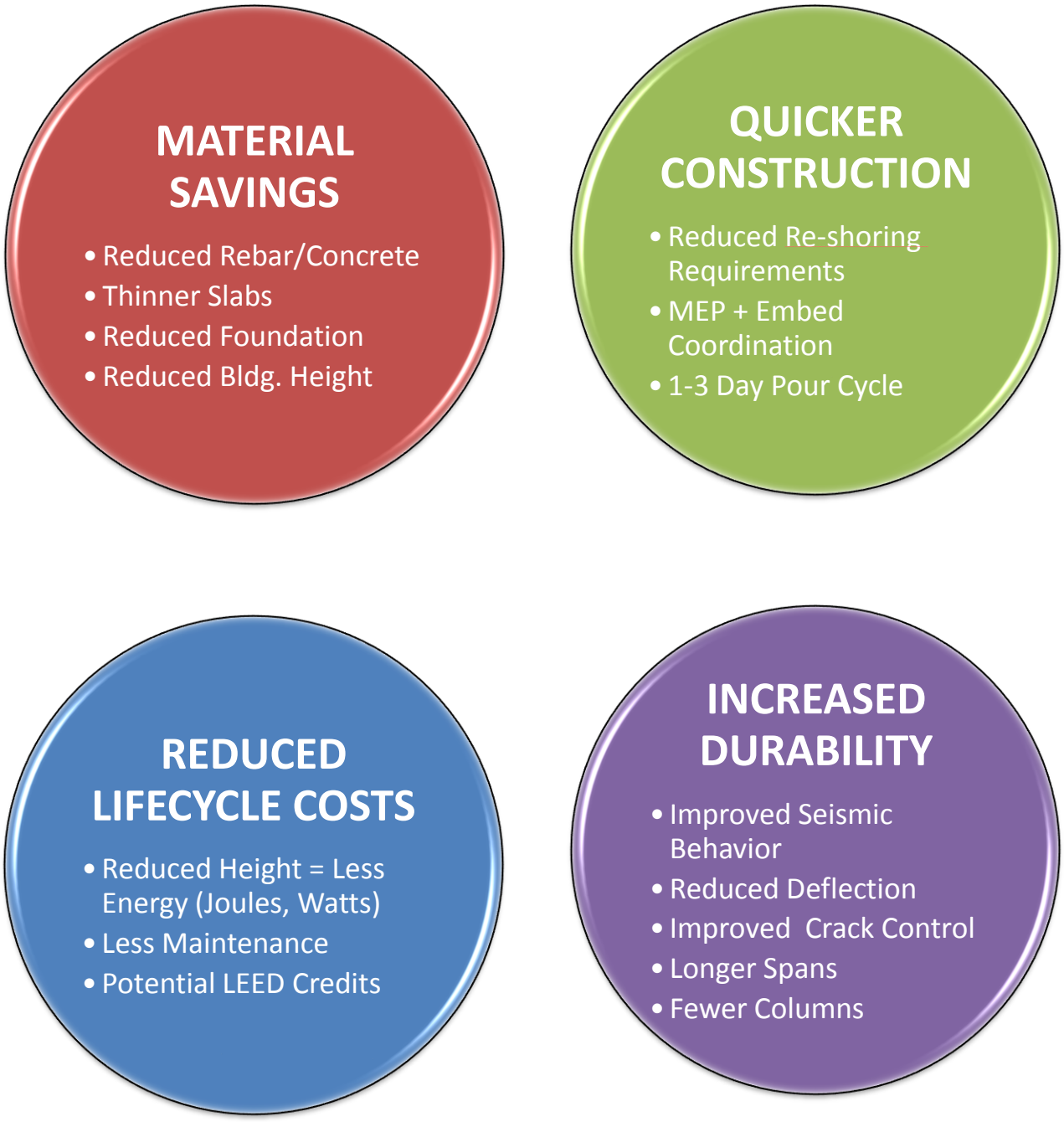
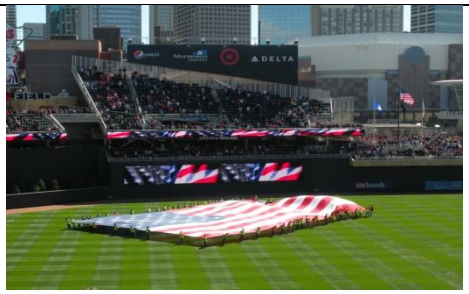


Table 1 – Projects benefitting from Unbonded PT

PROJECT	BUILDING TYPE	STRUCTURAL ENGINEER	BENEFIT from PT
Guthrie Theatre, Minneapolis	Arts	Erickson Roed & Associates	Accommodated heavy live loads in large, column-free area
Pinnacle's Lumière Barge, St. Louis	Casino	M.A. Engineering	Reduced weight 20% to enable casino to float on water
340 on the Park, Chicago	High-Rise Condos	Magnusson Klemenic Associates	Enabled more floors, increased floor-to-floor heights with thinner slabs
600 N. Fairbanks, Chicago	High-Rise Condos	Werner Sobek	Saved 15' to 20' of building height and over $2M of vertical elements
One Museum Park West, Chicago	High-Rise Condos	Samartano & Co.	Deleted 50% of transfer girders and 35% of interior columns to open floor layout
Epic Systems Campus, Madison	Low-Rise Offices	Magnusson Klemenic Associates	Reduced deflections in irregular column-layout at a lower cost
Eddy St. Notre Dame Garage, South Bend	Parking Garage	Fink Roberts & Petrie	Allowed for better lighting and viewing for security cameras with fewer beams
Indianapolis Int'l Airport, Indianapolis	Parking Garage	Ter Horst Lamson Fisk Consultants	Allowed for longer spans, fewer beams, thinner slab to reduce dead load
Parkview Condo Garage, Chicago	Parking Garage, Underground	Chris Stefanos & Associates	Enabled heavy-loading from recreational park on top of garage
Louisville Arena, Louisville	Stadium	Walter P. Moore	Enabled column-free area for practice court areas
Target Field, Minneapolis	Stadium	Walter P. Moore	Supported heavy loads from upper level stadium seating



Upper-left: Indianapolis International Airport Garage, **Upper-right:** Target Field
Bottom-left: 600 N. Fairbanks, **Bottom-middle:** 340 on the Park, **Bottom-right:** Guthrie Theatre & Garage

Section III. Comparison of Encapsulated PT to Non-Encapsulated PT

Until 1985, there was not an industry-wide specification for unbonded post-tensioning.[8] Early forms of the encapsulated PT system came on the market in late-1980's. Whereas decades of structures were successfully built with non-encapsulated PT ("regular" PT), industry innovation produced a PT system to address corrosion-protection (see Table 2 for comparison). With the advent of the encapsulated system, the anchor was coated in plastic and other accessories were installed to prevent exposed steel strand (refer to Appendix). The construction community embraced the encapsulated system and installed it on structures exposed to "aggressive environments" (rain, ice, salt-spray, chemicals).

Table 2 – Comparison of Encapsulated to Non-Encapsulated Systems

Component	ENCAPSULATED	"REGULAR "
Plastic Sheathing	50 ML	40 or 50 ML
Anchors	Plastic-Coated Metal	Uncoated Metal
Pocket Formers	**YES (2")**	**YES (1.5")**
Snap Caps	**YES**	NO
Wedges	**YES**	**YES**
Translucent Sleeves	**YES**	NO
--- filled with grease	**YES**	N/A
Positive Mechanical Connection	**YES**	NO
Seal Plugs	**YES**	NO
Protection during shipping	**YES**	*Depends on spec.*

In 2000, the publication of the Post-Tensioning Institute's *Specification for Unbonded Single Strand Tendons* (2nd edition) standardized the requirements for the encapsulated system. In 2003 and 2007, the PT specification was tightened, through addendums, by increasing the plastic-sheathing thickness and concrete cover.

The main hesitation in using the encapsulated system is the increase of material cost and labor expertise. However, the price difference between the two systems has been reduced though economies of scale and the manufacturing learning curve. The price to upgrade from a non-encapsulated to an encapsulated system is now outweighed by the benefit of long-term corrosion-protection for Owners.

[8] http://www.icri.org/publications/2001/PDFs/julyaug01/CRBJulyAug01_Kelley.pdf Concrete Repair Bulletin

Furthermore, industry certifications provided by Post-Tensioning Institute and ironworker unions have contributed towards awareness within the installation community.

Section IV. Recommendations for Project Specifications

Whereas Post-Tensioning Institute (PTI) and American Concrete Institute (ACI 423.7-07) have developed thorough specifications for unbonded post-tensioning, this paper proposes several recommendations for project specifications. The proposed recommendations are meant to increase the quality and durability of unbonded post-tensioning during the fabrication and installation processes.

Recommendations:

1. GENERAL
    a. Require the encapsulated PT system on all enclosed buildings (with exterior cladding) – even on buildings considered to be in a non-aggressive environment.
    b. Require the encapsulated PT system on all commercial/industrial slab-on-ground concrete due to potential exposure to flooding, rising water table, etc.
    c. Require PT Manufacturer/Supplier to supply PT extruded and fabricated materials from a PTI Certified Plant with a record of business in supplying PT for five (5) years.
    d. Require PT Installer to have at least two (2) onsite individuals with a current PTI Level 2 Unbonded Ironworker Certification, or approved equal. All other onsite personnel should have a PTI Level 1 Unbonded Certification, or approved equal.
    e. Require PT Inspector to have at least one (1) onsite individual with a current PTI Level 2 Unbonded Field Inspector Certification, or approved equal.
2. HANDLING, STORAGE & SHIPPING
    a. Require shrink-wrapped PT bundles during transit for all buildings.
    b. Require PT bundles be shipped on tarpped trucks, or by other methods for all elevated and commercial slab-on-ground structures.
3. TESTING
    a. Require field-friction test by PT Manufacturer/Supplier within past (5) years to determine friction-loss coefficients (assuming no change in PT coating or plastic sheathing manufacturing process). *The recommended values in ACI-318 Table R18.6.2*

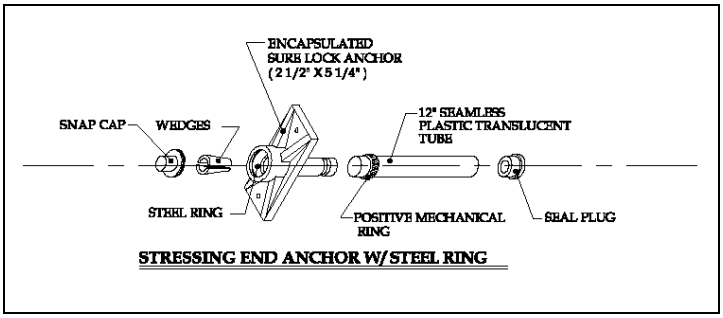
have not been updated to account for improved manufacturing methods and PT raw materials.

b. Require PT Manufacturer/Supplier provide documentation of successful testing of PT coating within past (5) years.

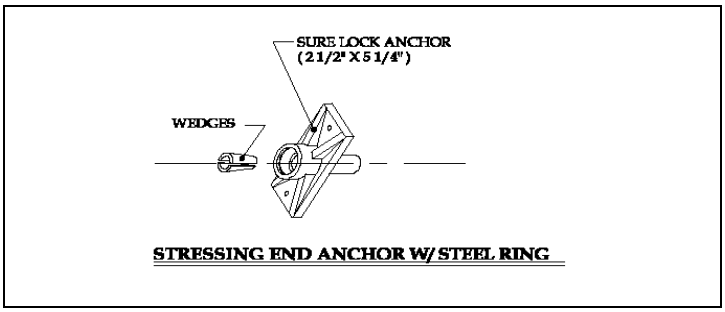
4. INSTALLATION
    a. Install a plastic tarp (visqueen) over construction joints to prevent water intrusion at intermediate anchorages. *The intermediate anchors and strand are temporarily exposed to the elements until the adjacent pour has been cast*.
5. STRESSING & MEASURING ELONGATIONS
    a. Prior to stressing, spray WD-40, or approved equal, into anchor cavity to remove dirt, concrete, etc. Wipe strand before stressing tendons.
    b. Before and after stressing operations, use a piece of flat/straight metal, instead of wood, as the benchmark for measuring tendon elongations (spray-paint or ink).
6. FINISHING
    a. Cut tendon tails, cap anchorages and grout pockets at all slab edges and pour strips within 1 day of elongation approval by Engineer of Record. If approval process takes more than one week, protect un-grouted pockets.
    b. Prior to grouting, coat/spray the pocket-formed surface with a resin-bonding agent to produce a better grout cap.
7. SAFETY
    a. Require PT Installer to conduct basic maintenance/cleaning, as directed by equipment supplier, on stressing jack after every 500 stressing operations. *This will help the equipment retain its calibration and avoid breakdowns*.

APPENDIX

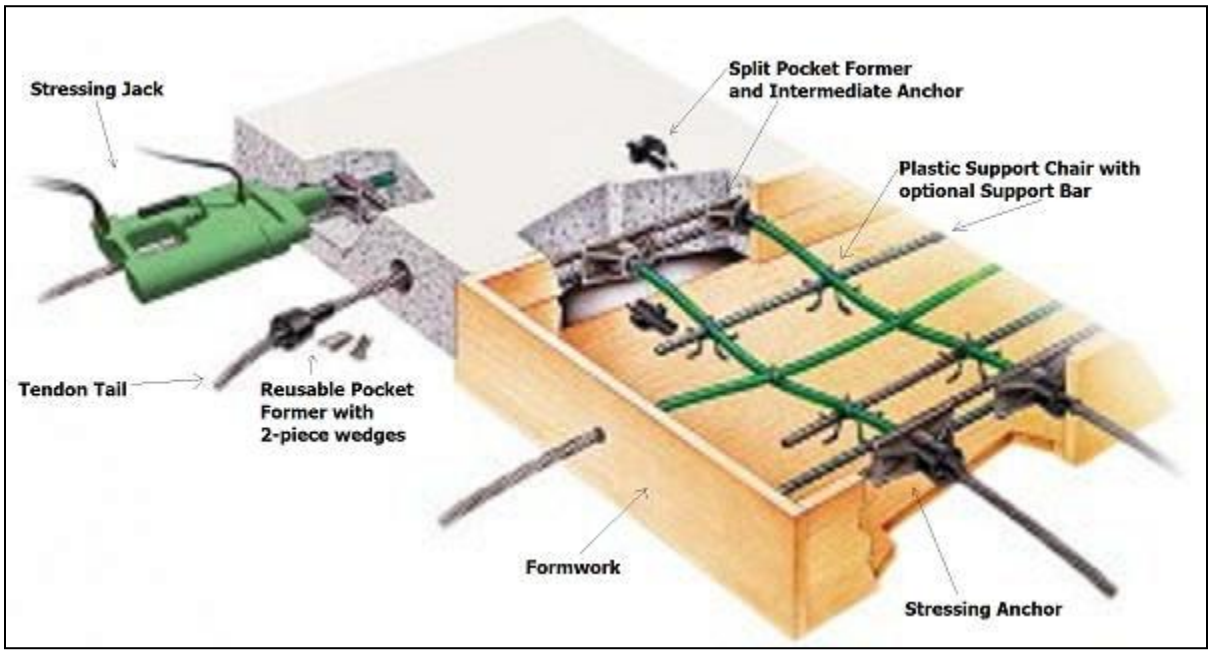
Construction Details



Detail 1 Example of Encapsulated PT System at Stressing End



Detail 2 Example of Non-Encapsulated PT System at Stressing End



Detail 3 Concrete Floor Slab with Post-Tensioned Tendon

Recommended Reading

1. Specification for Unbonded Single-Strand Tendons (2nd Edition, 2000, Post-Tensioning Institute). Addenda #1 issued Nov. 2003. Addenda #2 issued Nov. March 2007.
2. Field Procedures Manual for Unbonded Single-Strand Tendons(3rd Edition, 2000, Post-Tensioning Institute)
3. Ten-Year Marine Atmosphere Exposure Test of Unbonded Prestressed Concrete Prisms (2000, Post-Tensioning Institute)
4. Proper Filling of Single-Strand Tendon Stressing Pockets (Post-Tensioning Institute, FAQ #11)
5. ACI-318-08 Building Code Requirements for Structural Concrete and Commentary, Chapters 7 and 18 (American Concrete Institute)
6. *ACI 423.4R-98 'Corrosion and Repair of Unbonded Single Strand Tendons'* (1998, American Concrete Institute, ACI/ASCE Committee 423)
7. *ACI 423.6R-01 'Specification for Unbonded Single-Strand Tendons and Commentary'* (2001, American Concrete Institute, ACI Committee 423)
8. *ACI 423.3R-05 'Recommendations for Concrete Members Prestressed with Unbonded Tendons'* (2005, American Concrete Institute, ACI Committee 423)
9. *ACI 423.7-07 'Specification for Unbonded Single-Strand Tendon Materials and Commentary'* (2005, American Concrete Institute, ACI Committee 423)

About AMSYSCO, Inc.

AMSYSCO, Inc. has been a post-tensioning and barrier cable manufacturer/supplier in the United States since 1981. The company is a participating member of Post-Tensioning Institute since 1984 and is a PTI-Certified Supplier. AMSYSCO's construction experience includes apartments/condominiums, hospitals, industrial warehouses, office buildings, parking structures, repair/renovation, residential housing, schools, stadiums, storage tanks, and tennis courts.

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