

A Short History Of Unbonded Post-Tensioning Specifications

By Gail S. Kelley



Fig. 1: A 20-story condominium building under construction. Unbonded tendons for a two-way slab are being laid out in a 'banded' configuration. Tendons in one direction are banded over the column lines. Tendons in the other direction are uniformly spaced approximately 3 feet on center

Durability has become an important issue in all types of construction as owners, engineers, and even the general public have become aware of the high cost of repairs and the potential property damage and life safety issues associated with deterioration of concrete and corrosion of the concrete reinforcing material.

In the post-tensioning industry, the importance of ensuring durability is reflected in changes to the Post-Tensioning Institute's (PTI) "Specification for Unbonded Single Strand Tendons." The current edition of the Specification (2000) includes specific requirements for the post-tensioning coating, the sheathing, and the protection of the anchorages. In aggressive environments such as parking garages and balconies that are exposed to the weather, tendon anchorages are required to have a watertight encapsulation.

There was no comprehensive, industry-wide specification for unbonded post-tensioning until 1985, however, and post-tensioning systems have changed considerably over the years. Understanding a little about the history of the post-tensioning industry, the PTI Specification, and the ACI 318 Building Code can be very helpful when doing a condition assessment or developing a repair program for a post-tensioned building.

Early Post-Tensioning Systems

When unbonded post-tensioning systems were introduced to North America in the 1950s, there were no accepted standards for design. There were also no material specifications for the components of the post-tensioning system. In 1958, ACI-ASCE Joint Committee 323 published "Tentative Recommendations

for Prestressed Concrete.” This document included recommendations for concrete cover, allowable tensile stresses, and protection of the strand or wire in unbonded systems. It did not include specific requirements for the protection system, other than that the prestressing steel be coated with a grease, wax, or asphalt-impregnated material and enclosed in a sheath.

The first post-tensioning systems consisted of ¼-in. wires bundled in groups of 3 to 12. Eight-wire bundles were the most common; the wires were coated and the bundle was spirally wrapped with reinforced kraft paper. It was referred to as a “button-headed” system since cold-formed button heads were used to secure the ends of the wires against the anchorage assembly. It was not an easy system to install. The stressing-end and intermediate anchorages required shim stacks, which made the anchorage assembly large and cumbersome. In addition, the equipment required for tensioning the wires was cumbersome to use.

By the early 1960s, contractors had started using “strand” tendons. Strand was much easier to install and stress than the button-headed wire systems, and by the mid 1970s, strand was being used for almost all applications except nuclear containment structures. Button-headed wires continued to be used in containment structures because it was easier to remove them for inspection and replacement.

Although the first strand systems were paper-wrapped, by the early 1970s, most strand systems were using plastic sheathing. Initially, there were two types of sheathing: “heat-sealed” and “push-through.” In the heat-sealed system (sometimes referred to as a “cigarette wrap”), the sheathing was fabricated from a plastic tape 20 to 40 mils (0.5 to 1 mm) thick. The tape was lapped longitudinally along the strand and the seam was heated to weld it shut. The plastic was not actually melted; it was just heated enough to become sticky. In the push-through or “stuffed” system, the coated strand was pushed into a preformed plastic tube. The heat-sealed system was more common in the United States; the push-through system was more common in the Canada.

Several types of anchorage hardware were used, including steel plates with a separate barrel anchor, or “donut,” that held wedges, cast-iron plates with wedges, and fittings that were mechanically attached (s-wedged) to the prestressing steel. There were several different sizes of cast-iron plates: oversized plates were used to allow earlier stressing, gang plates were used to anchor groups of 2 to 5 tendons, and slightly longer, narrow plates were used to allow closer spacing of the anchorages. The anchor that became the standard is what is being used today: a single strand anchor consisting of a cast-iron plate with a recess that holds a two-piece wedge.

Both the heat-sealed and the push-through systems had a number of durability problems. There were



Fig. 2: Stressing-end anchorages of the tendons shown in Fig 1. Since the structure will be enclosed, the tendons are not considered exposed to an aggressive environment; the anchorages are therefore not required to be encapsulated. The ends of the tendons have been taped to avoid exposing the strand

no requirements as far as the thickness or composition of the sheathing material, and these varied between different manufacturers. In the heat-sealed system, the sheathing seam often opened during handling and installation and allowed moisture to get into the sheathing. Openings in the seam also allowed the coating to leak out, which created problems during stressing, in addition to corrosion problems. If concrete got into the sheathing, the increased friction along the strand often made it impossible to stress the tendon to its full capacity.

Although there was no seam in the push-through sheathing, the tube had to be somewhat larger than the strand so that the strand could be inserted easily. This resulted in voids between the strand and the sheathing that allowed water to get into the tendon both during shipping, storage, and handling and while the tendon was in service.

The quality of the coating material used by different manufacturers also varied considerably. By the late 1970s, grease was being used as the coating material in most unbonded systems. The only standards for grease were those in ACI 359 “Code for Concrete Reactor Vessels and Containments” covering work in the nuclear industry, however. There were no requirements as far as composition or application rate of the grease in other work, and many of the greases that were used emulsified when exposed to water, or hardened over time. When the sheathing of early systems is opened, the coating is often found to be a dry, brown film that from a distance appears to be rust.

Initially, these were not considered problems since the coating and sheathing were viewed primarily as a corrosion deterrent during shipping, handling, and placing, and then a lubricant and

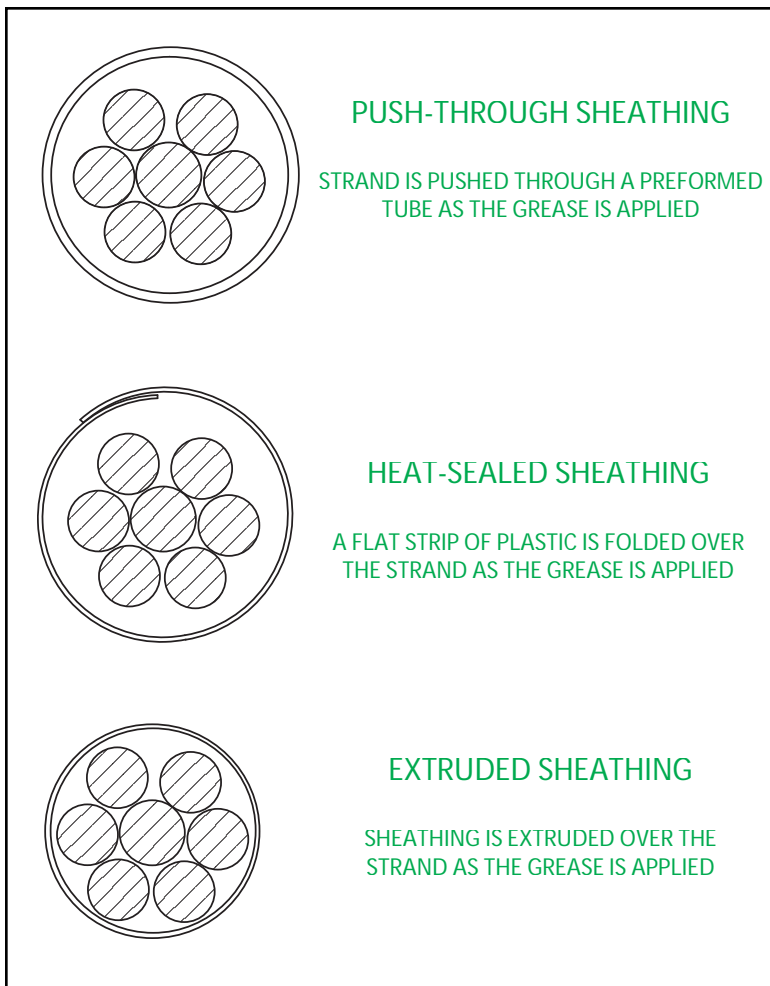


Fig. 3: Plastic sheathings used for unbonded tendons. Virtually all post-tensioning systems currently sold use extruded sheathing

bond breaker while the tendons were stressed. It was thought that the concrete would provide adequate long-term corrosion protection. Improper storage at the job site before the tendons were installed, or damage to the sheathing during handling and installation exposed the prestressing steel to water and contaminants, however. Damage to the sheathing was typically not repaired before the concrete was placed; there was thus little protection for the prestressing steel if water and contaminants penetrated through cracks in the concrete.

A process for producing an extruded sheathing was patented in the early 1970s. This resulted in a much more durable system, since the sheathing fit closely around the greased strand and there was no seam. Since it was a patented system, the other types of sheathing continued to be used. By the late 1970s, however, most unbonded post-tensioning systems used extruded sheathing.

PTI Specification For Unbonded Single Strand Tendons

The 1985 Specification included minimum thickness requirements for the sheathing, performance

requirements for the strand coating, and minimum coating coverage rates. This marked the first industry standards for the sheathing and coating used in unbonded post-tensioning systems. The Specification also included definitions of normal (non-corrosive or non-aggressive) and aggressive (corrosive) environments and a requirement for watertight connection of the sheathing to the anchorage in aggressive environments.

The 1985 Specification was published as an article in the *Journal of Prestressed Concrete* and was included in the PTI Design Manual. It was subsequently revised and republished as the "Specification for Unbonded Single Strand Tendons, 1st Edition" in 1993. The second edition was published in December 2000. Changes in these subsequent editions reflect increasing awareness of the requirements for durability. These changes include an increase in the minimum thickness of the sheathing and more stringent requirements for the coating material.

In addition, the importance of corrosion protection of the anchorage was emphasized. The minimum concrete cover to the wedge cavity of the anchorages was increased, and the permissible length of strand projecting from the face of the wedges was reduced. A stipulation requiring anchorages intended for use in aggressive environments be fully protected against corrosion was added, and the definition of an aggressive environment was expanded. The 2000 edition of the Specification defines an aggressive environment as one in which structures are exposed to direct or indirect applications of deicing chemicals, seawater, brackish water, spray from these sources, or salt-laden air. Structures or parts of structures where the anchorage pockets are wetted or in direct contact with soils are also considered as exposed to an aggressive environment.

In 1995, PTI submitted the specification to ACI Committee 423 for processing as an ACI/ANSI standard. This document is expected to be completed by the end of 2001.

Changes In ACI 318

Changes to the ACI 318 Building Code also reflect the increasing importance of durability. Prestressed concrete was first included in ACI 318 in 1963. The 1963 Code included provisions for concrete cover and allowable tensile stresses. The requirements for sheathing material and corrosion protection were not specific, however. The Code only indicated that "unbonded strand shall be permanently protected against corrosion." A section entitled "Corrosion Protection for Unbonded Tendons" was added to the 1971 Code. It stipulated that unbonded tendons be completely coated with a suitable material to ensure corrosion protection, and required that the tendon be continuously wrapped in order to prevent bonding with the surrounding concrete and loss of the coating material.

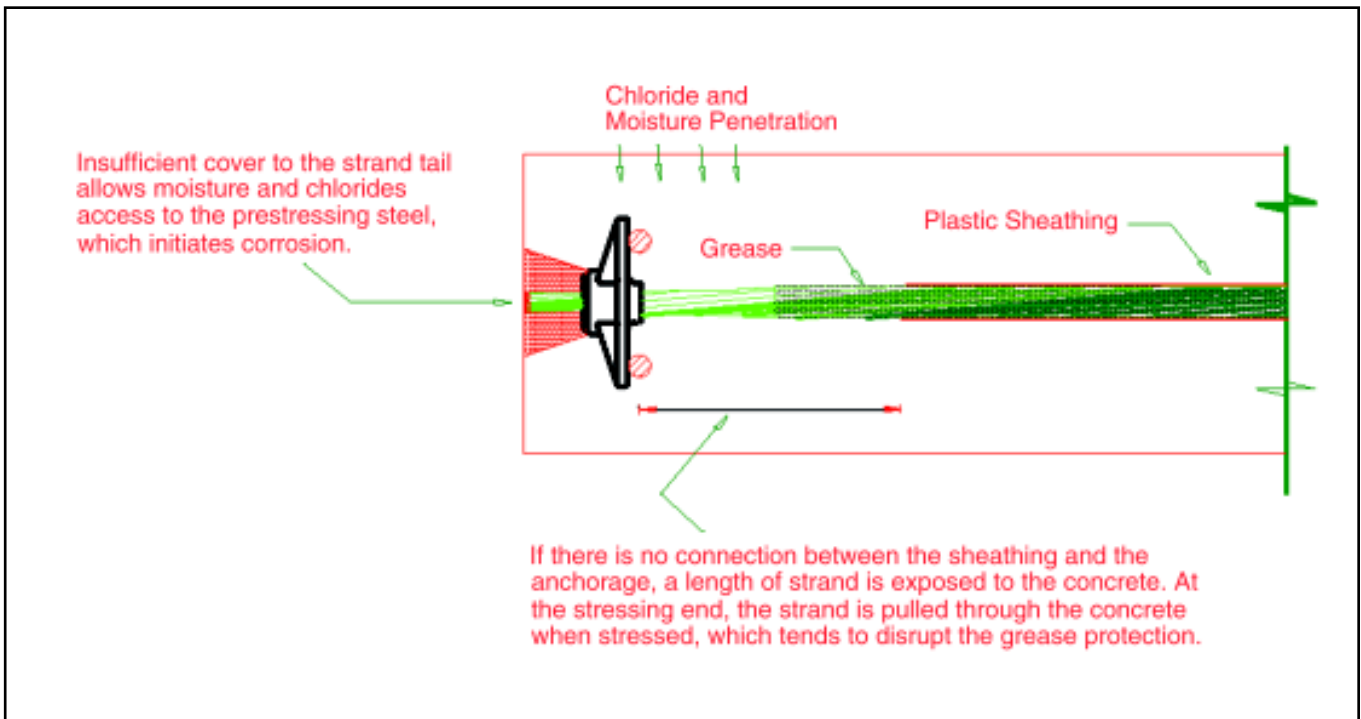


Fig. 4: Potential corrosion problems at the stressing end of an unbonded tendon in an aggressive environment

In the 1977 Code, the allowable water/cement ratio (w/c) for structures in corrosive environments was reduced from 0.50 to 0.45. This requirement pertains to all concrete structures and can be significant when determining repair recommendations, since the w/c has a direct effect on the permeability of the concrete. A discussion was added in Section 7.7.5 of the Commentary to the 1983 Code to call attention to the importance of air content, water-cement ratio, chloride ion content, and cement type when designing for corrosion protection.

There were significant changes with respect to durability requirements for both prestressed and nonprestressed reinforcement in ACI 318-89. The criteria given in Chapter 18 for corrosion protection of unbonded prestressing tendons was replaced by a reference to the 1985 "Specification for Unbonded Single Strand Tendons." ACI 318-95 was revised to reference the 1993 version of the Specification.

Summary

As with other types of construction, the deterioration in post-tensioned buildings is typically due to a number of factors, including lack of adequate maintenance, poor quality control during construction, and inadequate durability of the components. Although the PTI Specification and ACI 318 deal with the design and construction of new structures, the changes in these two documents reflect what is the most important thing to keep in mind when doing an evaluation or repair of a post-tensioned building: almost all deterioration, to the concrete as well as the post-tensioning system, will in some

manner be the result of water leakage. There is little value in doing a repair project unless the source of the water is identified and eliminated.

Knowing about code changes is also helpful for making appropriate repair recommendations. For example, it is typically not necessary to use an elastomeric waterproofing membrane on a post-tensioned slab because there tends to be little or no cracking. In older structures with highly permeable concrete, however, an elastomeric membrane may significantly reduce deterioration due to corrosion of the reinforcing steel.

The Post-Tensioning Institute publishes technical documents and reference manuals covering various aspects of post-tensioning design and construction. To find out more about post-tensioning, visit their Web site at: www.post-tensioning.org.

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