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THE NEW ACI STANDARD SPECIFICATION FOR UNBONDED TENDONS

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INTRODUCTION

The American Concrete Institute (ACI) recently published a new Standard, "Specification for Unbonded Single-Strand Tendon Materials (ACI 423.7-14[1])." This is an extremely important document with major ramifications for the post-tensioning (PT) industry. It is a referenced standard in Section 3.2.2 of the ACI Building Code (ACI 318-14[2]). As a referenced part of the Code, the Specification becomes law when ACI 318 is adopted by a municipality. This article focuses on Section 6.5.2(c) in the new Specification,[1] dealing with encapsulated systems, which are now required to be used in all buildings governed by ACI 318 and ACI 350. Section 6.5.2 is repeated herein in its entirety:

6.5.2—***Connection component***

Any component used to connect the sheathing to any anchorage or coupler enclosure shall conform to the following:

(a) Have a watertight, mechanical connection to the anchorage protection or coupler enclosure and a watertight connection at the tendon sheathing.

(b) Have a minimum 4 in. (100 mm) overlap between the end of the extruded sheathing covering the prestressing steel and the end of the sleeve.

(c) Within the connecting component or enclosure, either the prestressing steel shall be covered by sheathing for its full length, or the annular space between the sleeve and the strand shall be filled with PT coating in conformance with 5.2.

Subsection 6.5.2(c) is underlined because it is the subject of this discussion. This part of the Specification has a long and tortured history, which will be documented herein. Some background on the development of encapsulated anchorages is useful in understanding the issue. Before encapsulated anchorages were developed, the normal procedure was to "pull" the wedge into the fixed anchorage, which required removing approximately 12 in. (300 mm)of tendon sheathing to allow the plant equipment to grip the strand. At the stressing anchorage, the tendon sheathing was removed to allow the unsheathed strand to pass through the anchorage, resulting in a length of exposed unsheathed strand (shorter than at the fixed anchorage) behind the stressing anchorage. This removed portion of the tendon sheathing was never replaced.

Some of the early encapsulation systems still employed the use of the "pull" system, which required long and large-diameter sleeves to cover the strand that was exposed where the tendon sheathing had been removed. These long and large-diameter sleeves resulted in a potential collection point for water. However, improvements over the past several years have resulted in encapsulation systems that use a "push" system for wedge seating at fixed anchorage and sleeves that have an inside diameter only a few millimeters larger than the outside diameter of the tendon sheathing. The push-wedge seating at the fixed anchorage requires that the sheathing only be removed in the short length where the wedge is in contact with the strand. At stressing anchorages, the tendon sheathing extends through the anchorages and is cut at the jobsite close to the back of the anchorage. Therefore, in the encapsulation systems currently used, there is normally only a short length of exposed strand within the transition tube, resulting from sheathing material shrinkage and handling of the tendons during installation.

Let us return now to the main topic. In the previous edition of the Specification (ACI 423.7-07[3]), the equivalent section for encapsulated systems is repeated as follows, with the relevant subsection underlined:

2.5.2.1—***Sleeves to anchorages***

Sleeves used to connect the sheathing to the anchorage of encapsulated systems shall:

(a) Meet or exceed the same requirements as the sheathing for durability during fabrication, transportation, handling, storage, and installation;

(b) Have 0.050 in. (1.27 mm) minimum thickness;

(c) Have a positive mechanical connection to the anchorage at all stressing, intermediate, and fixed ends;
(d) Have a minimum 4 in. (100 mm) overlap between the end of the extruded sheathing covering the prestressing steel and the end of the sleeve;
(e) Be translucent or have another method of verifying that the post-tensioning coating material is free of voids;
(f) Be translucent or have other method of verifying overlap with sheathing; and
(g) Have sleeves on stressing side of intermediate anchorages long enough to cover sheathing removed during stressing and have required 4 in. overlap.

ACI 423.7-07 included a Commentary to the Specification. The Commentary to the underlined Section 2.5.2.1(e) stated:

R2.5.2.1(e)*—The requirement that prohibits voids may be satisfied by filling the sleeves with post-tensioning coating. Transition components, such as sleeves, at anchorages and couplers should be designed to be void-free. Some small bubbles and air spaces are normal and unavoidable in the fabrication and assembly process and should not normally be considered as "voids" in the context of this section.*

ACI 423.7-07 was heavily influenced by PTI's "Specification for Unbonded Single Strand Tendons," published in 2000,[4] with cross-membership (including the author) between ACI Committee 423 and the PTI Unbonded Tendon Committee (now PTI Committee M-10). Section 2.2.6.2 in PTI M10.2-00[4] is almost identical to Section 2.5.2.1 of ACI 423.7-07.

Committee members who contributed to the writing of both PTI M10.2-00[4] and ACI 423.7-07 were well aware of the problem with the impossible term "free of voids," which appeared in the mandatory portion of both documents (it was "absence of voids" in the PTI Specification[4]). Obviously no material is completely free of voids, and interpreted literally, this could mean that the Specifications were unenforceable because no connection component could satisfy them. Attempts were made to establish a tolerance on "voids," but each failed to reach a consensus agreement, mainly due to the impossibility of measuring and/or quantifying the amount of voids present in a sleeve. However, it was felt that the ACI 423.7-07 Commentary to Section 2.5.2.1(e) (and a similar Commentary statement in PTI M10.2-00[4]) provided sufficient wiggle room for relief from the "free of voids" requirement.

That reasoning changed in a big way when ACI 423.7-07 was revised. Sometime after 423.7-07 was developed, ACI decided to write all of its future Specifications in ASTM format with no Commentary, so the wiggle-room wording of Section R2.5.2.1(e) was no longer available. This problem was first addressed by the PTI Committee M-10, Unbonded Tendon, at its meeting in San Diego, CA, on Oct. 4, 2007, when a Task Group was formed to look into the "free of voids" problem and suggest a solution. The Task Group reported back to PTI Committee M-10 in their next meeting in St. Louis, MO, on May 6, 2008, saying that the word "void" could not be defined or quantified in this context and should not be used in the Specification. The Task Group was dissolved, with thanks, at that meeting and the issue was referred to PTI Committee DC-70, Special Topics, for their recommendations.

PTI Committee DC-70 is unique among PTI technical committees, which can be seen from its Mission Statement:

> *"Review and develop recommendations on topics that are not within the scope of other committees or require special attention."*

At the time this issue was deliberated within PTI Committee DC-70, the eight members of the committee had a combined total of over 300 years of experience in the design and construction of post-tensioned concrete. The membership included three PTI Legends, eight PTI Fellows, and two PTI Presidents. There simply was no more credible place in which to resolve this issue.

PTI Committee DC-70 studied the problem at length, and reported its recommended wording for this Specification Section at Committee M-10's meeting in Portland, OR, on May 4, 2009. The recommended change to the relevant 423.7-07 Section was as follows:

> *"Within the connecting component or enclosure, prestressing steel shall be either covered by sheathing for its full length, or be in full contact with PT coating in conformance with X.X where sheathing is not present."*

PTI Committee DC-70 commented on its recommendation with a footnote: "The word 'void' is not used. The word 'sleeve' is not used. The specification states what we want, not what we don't want."

This PTI Committee DC-70 recommendation came after much discussion among its highly experienced membership. I am a member of PTI Committee DC-70, I have considerable background in the specific issue, and I was heavily involved in the discussion. My contribution is summarized as follows:

In the middle of the 1960s, long before encapsulated anchorages were introduced, I was employed by Atlas Prestressing Corp., the company that introduced the wedge/strand post-tensioning system to the industry. On

some of the early Atlas projects in Los Angeles, CA, the city inspectors would question the fact that the end of the tendon sheathing did not extend to the back side of the stressing or fixed anchorages, leaving a short portion of strand exposed with no sheathing (as discussed previously). We tried to justify this by explaining that the PT coating (we called it grease back then) was still present on the strand in this exposed length, and the grease provided the primary corrosion protection for the strand. The inspectors would counter with, "…that's fine, but what if somebody steps on the exposed strand and wipes off the grease?" We had no satisfactory answer to that, so we conceived an in-house testing program, observed by the city inspectors, to address it and see if it was a valid concern.

We obtained a number of strand samples with PT coating, which had been applied in our fabrication process. On some of the samples, we vigorously removed the PT coating using shop rags. We dug the rags into the interstices between the wires, removing as much grease as we could until there was no visual evidence that there was ever any grease on the strand. The inspectors agreed that this was more than the equivalent of a field worker stepping on the short exposed length of strand in the field. We then ran salt fog tests (ASTM B117*) on samples with undisturbed PT coating of normal thickness, and samples with the PT coating intentionally removed as described. The results of the salt fog tests were the same on all the samples. After 1000 hours of salt fog exposure, the visible corrosion product (in accordance with ASTM D610) on the undisturbed samples was indistinguishable from the visible corrosion product on the samples where PT coating had been intentionally and vigorously removed, and both passed the tests.

We concluded from these tests, and the city inspectors agreed, that the short length of exposed and greased strand behind the anchorages would not affect the functionality or performance of the tendons, and that issue was forever put to bed.

In the PTI Committee DC-70 discussions, I used the results of these old tests to support the argument that a short length of strand, which is visually verifiable to be in contact with PT coating, will have corrosion resistance equivalent to the same length of strand with the thickness of PT coating normally applied in fabrication of the tendon. In other words, it is not necessary to completely fill the connecting components with PT coating. Adequate corrosion resistance is provided in the connectors if it can be visually verified that the strand is simply in contact with PT coating for its full unsheathed length.

The revisions to ACI 423.7-07 proceeded within ACI Committee 423 in ASTM format, including the following wording of Section 6.5.2(c), which incorporated the DC-70 recommendation:

6.5.2(c)*—Within the connecting component or enclosure, prestressing steel shall be either covered by sheathing for its full length, or be in full contact with PT coating in conformance with X.X where sheathing is not present.*

ACI 423.7-07, with that wording, was approved by the full ACI Committee 423 and the ACI Technical Activities Committee (TAC). After ACI Committee 423 and TAC approval, the document was put out to public comment (part of the ACI Standardization process). A comment was received (from an individual outside of the PT industry) who disagreed with the "full contact" requirement, and felt that the connecting components should be fully filled with PT coating. In a virtual meeting to resolve responses to public comments, held on Sept. 11, 2014, Joint ACI-ASCE Committee 423, after much discussion and some dissent among the members, voted to revise the wording of Section 6.5.2(c) to the following, which is the way it currently appears in the published version of ACI 423.7-14[1]:

6.5.2(c)*—Within the connecting component or enclosure, either the prestressing steel shall be covered by sheathing for its full length, or the annular space between the sleeve and the strand shall be filled with PT coating in conformance with 5.2.*

So after 8 years and many hundreds of hours of discussion within several PTI and ACI committees, we have come full circle. One public comment from one individual, from outside the PT industry, has reversed years of discussion, deliberation, voting, and approvals from the most experienced minds in the industry, and we are now back to filling the sleeves with PT coating, with an implication that the PT coating must be free of voids.

I have been deeply involved in the entire process described previously (Chair of PTI Committee M-10 at the relevant times, and a member of PTI Committee DC-70 and Joint ACI-ASCE Committee 423 at all times) and I have the following personal opinions, comments, and recommendations:

Filling the connecting components with PT coating is not necessary for corrosion protection of the strand. Acceptable corrosion protection of any exposed strand within the sleeve of an encapsulated anchorage is achieved if the exposed strand can be seen to be in contact with PT coating for its full length.

* One of the tests required by ACI 423.7-14 for approval of PT coating, along with ASTM D610 (See Table 7.2.1, Test #5)

Filling sleeves at the jobsite is a time-consuming, unnecessary step that is problematic during construction and can lead to long-term problems if the sleeves are overfilled.

While the wording of Section 6.5.2(c) does not contain the offensive term "free of voids," the requirement that the components be "filled with PT coating" implies that and puts the tendon supplier at some risk, either of system approval or subsequent litigation.

The PTI Committee DC-70 recommendation eliminates the possibility that the Specification could be used for proprietary reasons. Filling the connecting components with PT coating, albeit unnecessary, may present difficulties for some otherwise fully functional encapsulation systems. The "full contact" recommendation from PTI Committee DC-70 solves the problem.

In conclusion, I would strongly urge the members of the PTI Committee M-10 and Joint ACI-ASCE Committee 423 to reconsider the wording of this subsection and return it to the fully adequate, workable, non-proprietary, and risk-free wording recommended by the PTI Special Topics Committee.

REFERENCES

1. Joint ACI-ASCE Committee 423, "Specification for Unbonded Single-Strand Tendon Materials (ACI 423.7-07)," American Concrete Institute, Farmington Hills, MI, 2007, 21 pp.

2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary," American Concrete Institute, Farmington Hills, MI, 2014, 519 pp.

3. Joint ACI-ASCE Committee 423, "Specification for Unbonded Single-Strand Tendon Materials (ACI 423.7-14)," American Concrete Institute, Farmington Hills, MI, 2014, 8 pp.

4. PTI Committee M-10, "Specification for Unbonded Single Strand Tendons (PTI M10.2-00)," Post-Tensioning Institute, Farmington Hills, MI, 2000, 36 pp.

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