Specification for Unbonded Single Strand Tendons

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Unbonded Single Strand Tendons

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This report presents performance specifications for single strand unbonded post-tensioning tendons in prestressed concrete structures. Specifications are given for tendons in both normal and corrosive environments. Where appropriate, a commentary follows most major sections of the report.

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FOREWORD

These specifications were developed to provide specific performance criteria for materials for unbonded tendons, and detailed recommendations for fabrication and installation of unbonded tendons. Specifications are presented for tendons in normal (noncorrosive) environments and for tendons in aggressive (corrosive) environments.

The numerous more restrictive material, fabrication and construction requirements for tendons used in corrosive environments are considered essential to the long-term durability of tendons used in such circumstances. In addition, the durability of prestressed structures in corrosive environments requires the use of consistently high quality concrete, and good general construction practices for such applications.

The system and text presented herein require that each user make the changes, additions or deletions necessary to adapt these specifications to the specific job conditions and specification format.

1. GENERAL CONSIDERATIONS

1.1 Scope

This specification provides detailed minimum requirements for single strand unbonded post-tensioning tendons for incorporation in prestressed concrete structures. Specifications are presented for tendons in normal (noncorrosive) environments, and for tendons in aggressive (corrosive) environments. The provisions of this specification shall also govern for nonstructural applications.

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The intent of this specification is to provide detailed specifications for all common uses of unbonded post-tensioning tendons. There are, however, certain special structures or applications which either because of their service requirements or structural behavior might impose requirements on the post-tensioning system which exceed the minimum requirements of these standard specifications. It is recommended that, in such cases, a special set of specifications be written.

Structures exposed to corrosive environments include all structures subjected to direct or indirect applications of deicer chemicals, seawater, brackish water, or spray from these sources, and possibly some structures in the immediate vicinity of seacoasts exposed to salt air. Nearly all enclosed buildings (office buildings, apartment buildings, warehouses, manufacturing facilities)

1.1 Scope (cont.)

This specification is in addition to and is intended to be used in conjunction with the "Guide Specification for Post-Tensioning Materials" published by the Post-Tensioning Institute. These specifications shall supersede or govern in any case of conflicting provisions with the "Guide Specification for Post-Tensioning Materials."

Unbonded single strand tendons fabricated by methods other than those specifically itemized in these specifications may be used when the supplier provides conclusive test data substantiating that all characteristics of the unbonded tendons, in particular, the corrosion resistive characteristics, are comparable to the characteristics of tendons fabricated in accordance with these specifications.

1.2 Definitions

(1) *Tendon* — The complete assembly consisting of anchorage and prestressing steel with sheathing when required. The tendon imparts prestressing forces to the concrete.

(2) *Unbonded Tendons* — Tendons in which the prestressing steel is permanently free to move relative to

Notes to Specifiers

are considered to be normal (noncorrosive) environments. Exposed structures (such as parking structures) in areas with very little or no snow would also be considered suitable applications for the specification for tendons in normal (noncorrosive) environments.

Nonstructural applications might include topping slabs, waterproofing slabs on fill, and post-tensioning used only for control of cracking or deflection. For nonflexural or membrane type structures primarily under tensile forces, the provisions, where appropriate, are intended to apply.

The "Guide Specification for Post-Tensioning Materials" includes strength requirements for anchorages and static and dynamic test requirements for unbonded tendons which are not reproduced in this specification. These requirements are considered applicable to unbonded tendons in accordance with the provisions of this section.

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the concrete to which they are applying their prestressing forces.

(3) *Anchorage* — The means by which the prestressing force is permanently transmitted from the prestressing steel to the concrete.

(4) *Prestressing Steel* — That element of a post-tensioning tendon which is elongated and anchored to provide the necessary permanent prestressing force.

(5) *Coating* — Material used to protect against corrosion and/or lubricate the prestressing steel.

(6) *Sheathing* — Enclosure around the prestressing steel to provide corrosion protection and to eliminate bond between the prestressing steel and the surrounding concrete.

(7) *Coupling* — Any device designed to transfer the prestressing force from one partial length prestressing tendon to another.

2. PRESTRESSING STEEL

(a) Prestressing steel used in single strand unbonded post-tensioning tendons shall conform to ASTM A-416 Grade 250 or 270k, Regular Stress Relieved or Low Relaxation Type.

(b) Strand not specifically itemized in ASTM A-416 may be used provided it conforms to the minimum requirements of this specification and has no properties which make it less satisfactory than those listed in ASTM A-416.

Provision should be made for new steels which would include new sizes, improved characteristics of relaxation, or improved mechanical properties. However, use of prestressing steels not covered by ASTM Specifications should be permitted only when the supplier provides conclusive test data substantiating that all characteristics of the material are comparable to the properties of steels conforming to the ASTM Specifications. In particular, the stress corrosion characteristics of steels produced by quench and temper heat treatments should be carefully evaluated. Relaxation properties of new steels should be based on a minimum test period of 1000 hours.

(c) Certified Mill Test Reports shall be furnished upon request for each coil or pack of strand, containing as a

2. Prestressing Steel (cont.)

minimum the following test information:

- — Heat number and identification.
- — Standard chemical analysis for heat of steel.
- — Ultimate tensile strength.
- — Yield strength at 1 percent extension under load.
- — Elongation at failure.
- — Modulus of elasticity.
- — Diameter and net area of strand.
- — Type of material (stress-relieved or low relaxation).

(d) Relaxation losses for low relaxation type material shall be based on relaxation tests of representative samples for a period of 1000 hours, when tested at 70°F and stressed initially to not less than 70 percent of the minimum guaranteed breaking strength of the strand.

The tests shall be in accordance with ASTM A-416, and ASTM E-328.

(e) Low relaxation strand shall be provided with a mill applied continuous permanent physical marking to permit field identification.

(f) The material shall be packaged at the source in a manner which prevents

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It is not practical to run 1000 hour relaxation tests on each pack of strand. For qualitative identification of low relaxation strand, a short-term relaxation test of 30 minutes to 10 hours will suffice.

However, a 30 minute test will not provide an accurate indication of the ultimate relaxation value. Very precise testing procedures are required with mechanical (not hydraulic) equipment in a room with rigid temperature control to evaluate steel relaxation losses.

Low relaxation strand is identified by producers in packs by tags, pack markings and other means, as well as by mill certificates. Identification of low relaxation material in individual tendons at the jobsite requires the additional marking required by this specification provision. Such marking is considered necessary to avoid inadvertent reduction of structural capacity through use of stress-relieved strand in place of low relaxation strand. To provide manufacturer's time to develop a process to perform this marking, this specification should not be imposed until January 1, 1986.

For corrosion protection of strand packs, they are usually wrapped in

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physical damage to the strand during transportation and protects the material from deleterious corrosion during transit and storage.

paper impregnated with vapor phase inhibitor powder.

3. ANCHORAGES AND COUPLINGS

(a) Tendon anchorages and couplings shall be designed to develop the static and dynamic strength requirements of Section 3.1.6 (a) and Section 3.1.8 (1) and (2) of the PTI "Guide Specifications for Post-Tensioning Materials."

Castings shall be nonporous and free of sand, blow holes, voids, and other defects.

Experience with anchor castings indicates that satisfactory performance is achieved with a finish of the anchorage wedge seating area not exceeding a microfinish of 125 for stressing end anchorages, and not exceeding a microfinish of 250 for fixed anchorages.

(b) The average compressive concrete bearing stress of anchorages shall not exceed the limits set forth in Section 3.1.7 of the PTI "Guide Specifications for Post-Tensioning Materials."

Oversized anchorages may be used to allow for early stressing. However, the increase in time-dependent prestress losses due to concrete creep and shrinkage must be taken into consideration.

(c) For wedge type anchorages, the wedge grippers shall be designed to preclude premature failure of the prestressing steel due to notch or pinching effects under the static and/or dynamic test load conditions stipulated under Paragraph (a), for both stress relieved and low relaxation prestressing steel materials.

For fixed anchorages, the finish of the outer surface of the wedge that bears against the wedge seat may have a microfinish of up to 250. This microfinish of 250 for fixed anchorage wedges and anchor (wedge) seating areas in anchor castings is intended to safeguard against loosening of wedges during shipment of tendons. The additional roughness can be accommodated for fixed anchorages since the anchorage is attached under plant conditions in accordance with Section 6.4(b).

(d) Couplings shall be used only at locations specifically indicated on the contract documents or as approved.

Couplings shall be coated with the same corrosion preventive coating used on the strand and shall be en-

3. Anchorages and Couplings (cont.)

closed in sleeves which permit necessary movements during stressing.

(e) Anchorages intended for use in corrosive environments shall include design features permitting a watertight connection of the sheathing to the anchorage, and watertight closing of the wedge cavity, for stressing and nonstressing (fixed) anchorages. Intermediate stressing anchorages shall be designed to permit complete watertight encapsulation of the prestressing steel.

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Sufficient corrosion protection of the anchor casting is normally provided by the alkalinity of the bonded concrete encasement. Past experience and research indicate that anchor castings are much less sensitive than the strand from the standpoint of the need for corrosion protection, and that additional corrosion protection of the anchor casting is not necessary. For any application where additional corrosion protection of anchor castings is considered essential, it may be obtained by various means.

4. SHEATHING

(a) The tendon sheathing for unbonded single strand tendons shall be made of a material with the following properties:
   - Sufficient strength to withstand unrepairable damage during fabrication, transport, installation, concrete placement and tensioning.
   - Watertightness over the entire sheathing length.
   - Chemical stability, without embrittlement or softening over the anticipated exposure temperature range and the service life of the structure.
   - Nonreactive with concrete, steel and the tendon corrosion preventive coating.

The sheathing may be produced by either an extrusion process, heat sealing process, or any other process which assures a watertight enclosure over the tendon.

(b) Minimum thickness of the sheathing used in normal (noncorrosive) environments shall not be less than 0.025 in. for medium or high density polyethylene or polypropylene. Sheathing thickness for tendons used in corrosive environments

4. Sheathing (cont.)

shall not be less than 0.040 in. for medium or high density polyethylene or polypropylene.

Notes to Specifiers: *The increased sheathing thickness specified for corrosive environments is intended to provide increased resistance to damage during construction.*

(c) The sheathing shall have an inside diameter at least 0.010 in. greater than the maximum diameter of the strand.

It is preferable that the sheathing provide a smooth circular outside surface. The sheathing should not visibly reveal the lay of the strand.

(d) For applications in corrosive environments, the sheathing shall be connected to all stressing, intermediate and fixed anchorages in a watertight fashion, thus providing a complete encapsulation of the prestressing steel.

A watertight connection may be achieved by either using special connector pieces, or by spirally wrapping polyethylene adhesive tape in a double layer over the coated strand, connecting the sheathing to the anchor.

5. CORROSION PREVENTIVE COATING

(a) The corrosion preventive coating material shall have the following properties:

- Provide corrosion protection to the prestressing steel.
- Provide lubrication between the strand and the sheathing.
- Resist flow from the sheathing within the anticipated temperature range of exposure.
- Provide a continuous nonbrittle film at the lowest anticipated temperature of exposure.
- Be chemically stable and nonreactive with the prestressing steel, the sheathing material, and the concrete.

(b) The film shall be an organic coating with appropriate polar, moisture displacing, and corrosion preventive additives.

(c) Minimum weight of coating material on the prestressing strand shall be not less than 2.5 lb of coating material per 100 ft of 0.5 in. diameter strand, and 3.0 lb of coating material

The corrosion test in Table 1 is based on a coating thickness of 0.005 in. The quantities of coating material specified provide a minimum coating over the crests of the strand of approximately

5. Corrosion Preventive Coating (cont.)

per 100 ft of 0.6 in. diameter strand. The amount of coating material used shall be sufficient to ensure essentially complete filling of the annular space between the strand and the sheathing. The coating shall extend over the entire tendon length.

(d) Test results in accordance with Table 1 shall be provided for the corrosion preventive coating material.

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0.005 in.

6. INSTALLATION REQUIREMENTS

6.1 General

(a) Prestressing tendons shall be firmly supported at intervals not exceeding 4 ft to prevent displacement during concrete placement. Placing tolerances shall be in accordance with the applicable Construction Specifications.

Tendons should be attached to supporting chairs or reinforcement in such a way that the sheathing is not damaged.

Vertical deviations in tendon location should be kept to ¼ in. for slab thickness dimensions less than 8 in.; ⅜ in. in concrete with dimensions over 8 in., but not over 2 ft; and ½ in. in concrete with dimensions over 2 ft. These tolerances should be considered in establishing tendon cover dimensions, particularly in applications exposed to deicer chemicals or salt water environments where use of additional cover is recommended.

Horizontal plane deviations which may be necessary to avoid openings, ducts, chases, inserts, etc., should have a radius of curvature of not less than 21 ft. Slab behavior is relatively insensitive to horizontal location of tendons.

(b) The tendons shall not be exposed to excessive temperatures, welding sparks or electric ground currents.

Excessive temperatures are defined as temperatures which deleteriously affect the prestressing steel, anchorages, protective coating, or sheathing material.

Table 1. Performance Specification for Corrosion Preventive Coating.

Test	Test Method	Acceptance Criteria
1. Dropping point °F (°C)	ASTM D-566 or ASTM D-2265	Minimum 300 (148.9)
2. Oil separation at 160°F (71.1°C) percent by weight	FIMS 791B Method 321.2	Maximum 0.5
3. Water, percent maximum	ASTM D-95	0.1
4. Flash point, °F (°C) (Refers to oil component)	ASTM D-92	Minimum 300 (148.9)
5. Corrosion test 5 percent salt fog at 100°F (37.8°C) 5 mils, minimum hours (Q Panel Type S)	ASTM B-117	For normal environments: Rust Grade 7 or better after 720 hours of exposure according to ASTM D-610. For corrosive environments: Rust Grade 7 or better after 1000 hours of exposure according to ASTM D-610*
6. Water soluble ions†		
a. Chlorides, ppm maximum	ASTM D-512	10
b. Nitrates, ppm maximum	ASTM D-992	10
c. Sulfides, ppm maximum	APHA 427D (15th Edition)	10
7. Soak test 5 percent salt fog at 100°F (37.8°C) 5 mils coating, Q panels, Type S. Immerse panels 50 percent in a 5 percent salt solution and expose to salt fog.	ASTM B-117 (Modified)	No emulsification of the coating after 720 hours of exposure
8. Compatibility with sheathing		
a. Hardness and volume change of polymer after exposure to grease, 40 days at 150°F	ASTM-D4289	Permissible change in hardness 15 percent Permissible change in volume 10 percent
b. Tensile strength change of polymer after exposure to grease, 40 days at 150°F	ASTM D-638	Permissible change in tensile strength 30 percent

*Extension of exposure time to 1000 hours for greases used in corrosive environments requires use of more or better corrosion inhibiting additives.

†**Procedure:** The inside (bottom and sides) of a 1L Pyrex beaker (approximate outside diameter 105 mm, height 145 mm) is thoroughly coated with 100 ± 10 g of corrosion preventive coating material. The coated beaker is filled with approximately 900 cc of distilled water and heated in an oven at a controlled temperature of 100°F ± 2°F for 4 hours. The water extraction is tested by the noted test procedures for the appropriate water soluble ions. Results are reported as ppm in the extracted water.

Commentary to Table 1

The tests for corrosion preventive coatings presented in Table 1 are considered to be base line tests, to ensure that minimum corrosion protection properties are provided. New developments of coating materials may not meet some of these test requirements, and in such case other and more comprehensive tests may be necessary to ascertain their adequacy.

Tests 1 and 2

Limiting the dropping point to 300°F minimum is intended to ensure product stability under elevated temperatures, possible during tendon fabrication and installation. Together with Test 2, the bleeding of the lighter components from the coating is minimized.

Test 3

Water content is limited to exclude the presence of free water in the coating material.

Test 4

This test refers to the oil component in the coating material. Too low a flash point indicates higher content of volatile derivatives, which affect the long term stability and change of consistency of the coating material.

Test 5

This test provides a method to determine the effectiveness of the corrosion preventive properties of the coating. The method is a standard test used for corrosion preventive coatings such as paints, etc. The acceptance criteria of Grade 7 or better (according to ASTM D-610) after 720 hours of exposure requires that only 0.3 percent of the area exposed can have indications of corrosion. (See Fig. 1 – Examples of Area Percentages from ASTM D-610.) The test is conducted on 3 x 6 in. steel panels with a coating thickness of 0.005 in. When determining the percent of area corroded, only the area inside ¼ in. from the edges of the panel is evaluated.

Test 6

Water soluble ions known to cause corrosion are limited by this requirement.

Test 7

The soak test is designed to determine the ability of the coating to provide corrosion protection after having been exposed to standing water for a period of time. Certain coatings will absorb water to the extent that they will emulsify and break down the barrier against moisture reaching the steel. This test will guard against inadvertent use of such coatings.

Test 8

Certain petroleum derivatives react with polyethylene or polypropylene, changing its physical properties to the point where they are no longer usable as sheathing materials. This test is required to preclude the use of coatings with such derivatives.

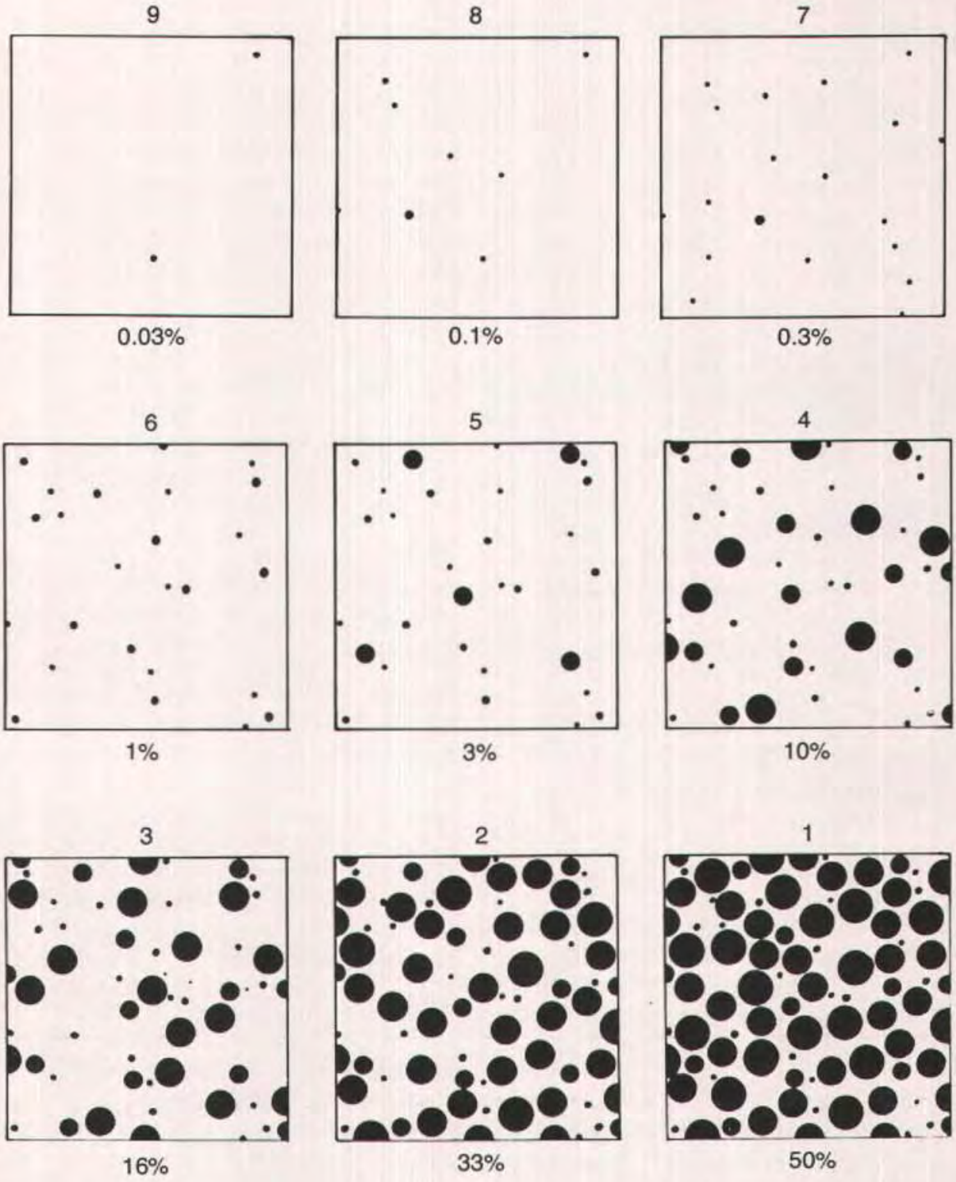

Fig. 1. Examples of area percentages. Rating of painted steel surfaces as a function of area percent rusted (SSPC-Vis 2/ASTM D-610). Courtesy American Society for Testing and Materials (ASTM).

6.2 Stressing Anchorages

(a) Stressing anchorages shall be installed perpendicular to the tendon axis. Curvature in the tendon profile shall preferably not be closer than 3 ft from the stressing anchorage.

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When tendon curvature starts closer than 3 ft from a stressing location, special attention must be given to ram and wedge centering during the stressing operation. With sharp curvatures at the anchorages, local friction will develop adversely affecting the tendon efficiency and elongation.

(b) Stressing anchorages shall be attached to the bulkhead forms by either bolts, nails, or threaded pocket former fittings. The connections shall be sufficiently rigid to avoid accidental loosening due to construction traffic or during concrete placement. Minimum concrete cover for the anchorage shall not be less than the minimum cover to the reinforcement at other locations in the structure.

(c) Pocket formers used to provide a void form at stressing and intermediate stressing anchorages shall positively preclude intrusion of concrete or cement paste into the wedge cavity during concrete placement. The depth of the pocket former from the edge of the concrete to the face of the anchorage shall not be less than 1½ in. for normal environments nor 2 in. for corrosive environments.

6.3 Intermediate Anchorages

(a) Intermediate anchorages may be installed either embedded in concrete or bearing against the hardened concrete at the construction joint. In the latter case, the anchorage shall have a flat bearing side and the concrete bearing area shall be smooth and without ridges.

(b) When placing intermediate anchorages against already hardened concrete, special attention must be paid to the perpendicularity between the bulkhead form and tendon during

6.3 Intermediate Anchorages (cont.)

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tendon placement. This type of anchorage is not recommended for use in corrosive environments.

(c) Minimum cover requirements of Section 6.2(b) apply to intermediate anchorages.

6.4 Fixed Anchorages

(a) Fixed end anchorages shall be installed on the tendon at the suppliers plant prior to shipment to the jobsite.

(b) For wedge type anchorages, the fixed end wedges shall be seated, with a load of not more than 80 percent of the minimum ultimate tensile strength of the tendon. The seating load shall be sufficient to ensure adequate capacity of nonstressing anchorages.

Due to variations in equipment and materials, a tolerance of ±3 percent is recommended on the load for seating fixed end wedges.

(c) Fixed end anchorages shall be placed in the formwork at the locations shown on the placing drawings, and securely fastened to the reinforcing steel. Minimum cover requirements of Section 6.2(b) apply to fixed end anchorages.

(d) Fixed end anchorages intended for use in corrosive environments shall be closed or capped at the wedge cavity side with a watertight cover. This cover shall preferably be shop installed, after filling the void around the wedge grips with corrosion preventive coating material, comparable to that used as a corrosion preventive coating over the length of the tendon (see Table 1).

6.5 Sheathing Inspection

After installing the tendons in the forms and prior to concrete casting, the

6.5 Sheathing Inspection (cont.)

sheathing shall be inspected for possible damage.

In corrosive environments, damaged areas shall be repaired by restoring the corrosion preventive coating in the damaged area, and repairing the sheathing. Repairs of sheathing shall be watertight, and must be approved by the engineer of record.

Tape used to repair sheathing shall be adhesive moisture proof tape, spirally wrapped around the tendon to provide at least two layers of tape.

Notes to Specifiers

For tendons used in noncorrosive environments small damaged areas in the tendon sheathing may be permitted without repair.

7. TENDON STRESSING

(a) Hydraulic stressing rams used to stress unbonded single strand tendons shall be equipped with stressing grippers which will not notch the strand more severely than normal anchoring wedges.

(b) Stressing rams and gauges shall individually be identified and calibrated against known standards at intervals not exceeding 6 months. Calibration certificates for each jack used shall be available upon request.

It is preferable to calibrate rams and gauges together as a unit. However, gauges may be calibrated against a master gauge of known accuracy, provided the rams are calibrated against the same master gauge.

(c) Elongation measurements shall be made at each stressing location to verify that the tendon force has been properly achieved. Measured elongations shall agree with calculated elongations within ±5 percent. Discrepancies exceeding ±5 percent shall be resolved with the designer/engineer of record.

Correlation of calculated and measured elongations within a ±5 percent tolerance requires that the elongation calculations be based on the correct modulus of elasticity and area of steel of the tendon or tendons under consideration. Further, the friction and wobble coefficients used are average values and may vary slightly from project to project. Variations in calculated and measured elongation values in excess of 5 percent should be evaluated from the standpoint of the number of tendons involved and the structural significance of the

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variation. Excess elongation resulting from a friction coefficient smaller than that assumed in calculations is usually not a structural problem.

(d) Stressing records shall be filled out during the tensioning operation, with the following data recorded as a minimum:
- Tendon mark or identification.
- Required elongation.
- Gauge pressure to achieve required elongation.
- Actual elongation achieved.
- Actual gauge pressure.
- Date of stressing operation.
- Signature of the stressing operator or inspector.
- Serial or identification number of jacking equipment.

Stressing records shall then be turned over to the owner or their representative for verification and safekeeping.

8. TENDON FINISHING

(a) Trimming of excess tendon length. As soon as possible after tendon tensioning and satisfactory check of elongation, the excess tendon length shall be cut. The tendon length protruding beyond the wedges after cutting shall be between 0.75 and 1.25 in.

The tendon may be cut by means of either oxyacetylene cutting, abrasive wheel or hydraulic shears. In case of oxyacetylene cutting of the tendon, care shall be taken to avoid directing the flame toward the wedges.

(b) Stressing pockets shall be filled with nonshrink mortar as soon as practical after tendon stressing and cutting. Under no circumstrances shall the grout or mortar used for

It is recommended that stressing pockets be filled within 15 days after removal of the stressing tails. Earlier filling of stressing pockets is desirable when practical.

pocket filling contain chlorides or other chemicals known to be deleterious to the prestressing steel.

For tendons used in corrosive environments, the exposed strand and wedge areas shall be coated with tendon coating material comparable to that used over the length of the tendon and a water-tight cap shall be applied over the coated area. Prior to installing the pocket mortar, the inside concrete surfaces of the pocket shall be coated or sprayed with a resin bonding agent.

Metric (SI) Conversion Factors

1 ft = 0.305 m
1 in. = 25.4 mm
1 oz. = 28.4 g
1 g = 0.035 oz
1 in.^{3} = 16.4 cm^3
1 lb = 4.448 N
1 ksi = 6.895 MPa
1 cc = 0.061 in.^{3}
C = (5/9) (F − 32)

* * *

NOTE: Discussion of this report is invited. Please submit your comments to PCI Headquarters by November 1, 1985.