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Specification for Unbonded Single-Strand Tendons

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Specification for Unbonded Single Strand Tendons

POST-TENSIONING INSTITUTE
Strength in Concrete

FRONT MATTER

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SECTION 1—GENERAL REQUIREMENTS

1.1—Scope

1.1.1—Work specified

This Specification provides minimum specific performance criteria for materials and requirements for the fabrication and installation of unbonded single-strand tendons.

Tendons used in all applications governed by ACI 318 shall be encapsulated.

This Specification governs except when specified otherwise in Contract Documents.

1.1.2—Work not specified

Scope excluded from this Specification are as follows:

(a) Ground-supported post-tensioned (PT) slabs for light commercial and residential construction

(b) Topping slabs

(c) Waterproofing slabs on fill

1.2—Definitions

The following definitions govern this Specification. For definitions not given in the following, refer to “PTI Post-Tensioning Terminology.”

Anchor—For unbonded single-strand tendons, a device that houses the wedges and transfers the prestressing force to the concrete.

Anchorage**—**A mechanical device consisting of all components required to transfer the post-tensioning force from the prestressing steel to the structure, including all accessories for encapsulation.

Coupler**—**A device used to connect the ends of tendons, making them structurally continuous.

Elongation**—**Increase in the length of prestressing steel due to the stressing force.

Encapsulated tendon**—**A tendon that is completely enclosed in a watertight covering from end to end, including anchorages, sheathing with PT coating, and an encapsulation cap over the strand tail at each end.

Encapsulation cap**—**Plastic cap filled with PT coating with a positive watertight connection to the anchorage, protecting the wedges and the strand tail.

Jack**—**A mechanical device (normally hydraulic) used to apply force to a single strand.

Licensed Design Professional (LDP)**—**An engineer or architect who is licensed to practice as defined by the statutory requirements of the professional licensing laws of a state or jurisdiction and who is responsible for the structural design and the preparation of Contract Documents for the work.

Post-tensioning (PT)**—**Method of prestressing in which prestressing steel is tensioned after concrete has hardened.

Prestressing steel**—**High-strength steel used to prestress concrete, consisting of seven-wire strands.

PT coating**—**Material used to protect the prestressing steel against corrosion and reduce friction between prestressing steel and sheathing.

PT installation drawings**—**Drawings furnished by the PT supplier showing information about the specifics of the PT system and tendon placement, including, but not limited to, the number, size, length, marking, location, elongation, and profiles.

PT installer**—**Contracting entity or entities responsible for unloading and handling the PT materials; storing and protecting them on the jobsite; and installing, stressing, and finishing tendons in accordance with the Contract Documents, including this specification.

PT supplier**—**Contracting entity responsible for furnishing and delivering to the jobsite all components of the PT system, including PT installation drawings and stressing equipment.

Sheathing**—**For unbonded single-strand tendons, an enclosure in which prestressing steel is encased to prevent bond with surrounding concrete and that contains the PT coating and provides corrosion protection.

Strand**—**High-strength steel wires wound around a center wire, typically a seven-wire strand, conforming to ASTM A416/A416M.

Strand tail**—**The protruding length of the strand from the face of the anchor casting that remains in place after the tendon tail has been cut off.

Stressing pocket**—**The recess created by the pocket former between the stressing or intermediate anchorage and the edge of the concrete to allow the nosepiece access for stressing.

Tendon**—**A complete assembly of a prestressing element consisting of anchorages and couplers, prestressing steel, PT coating, and sheathing.

Tendon profile**—**The specified path of a tendon from end to end in a member.

Tendon tail **–** The protruding length of the tendon outside of the stressing anchorage needed temporarily for stressing of the tendon.

Unbonded tendon**—**Tendon in which the prestressing steel is prevented from bonding to the concrete and is permanently free to move relative to the concrete.

Wedges**—**Pieces of tapered high-strength heat-treated steel with serrations (teeth) that penetrate the prestressing steel during transfer of prestressing force to the anchorage.

Wedge cavity**—**The tapered opening in the anchor designed to allow the strand to pass through and to accommodate the seating of the wedges.

1.3—References

1.3.1—Referenced standards and organizations

The standards and reports listed as follows were the latest editions at the time this document was prepared.

American Association for Laboratory Accreditation (A2LA)

American Concrete Institute (ACI)

117, Specification for Tolerances for Concrete Construction and Materials and Commentary

318, Building Code Requirements for Structural Concrete and Commentary

350, Code Requirements for Environmental Engineering Concrete Structures

423.7, Specification for Unbonded Single-Strand Tendon Materials

ASTM International

A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

A416/A416M, Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete

A1061/A1061M, Standard Test Methods for Testing Multi-Wire Steel Prestressing Strand

B117, Standard Practice for Operating Salt Spray (Fog) Apparatus

C1107/C1107M, Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

D92, Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester

D95, Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation

D217, Standard Test Methods of Cone Penetration of Lubricating Grease

D445, Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D512, Standard Test Methods for Chloride Ion in Water

D566, Standard Test Method for Dropping Point of Lubricating Grease (Withdrawn 2023)

D610, Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces

D638, Standard Test Method for Tensile Properties of Plastics

D792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D2265, Standard Test Method for Dropping Point of Lubricating Grease Over Wide Temperature Range

D3867, Standard Test Methods for Nitrite-Nitrate in Water

D4289, Standard Test Method for Elastomer Compatibility of Lubricating Greases and Fluids

D4658, Standard Test Method for Sulfide Ion in Water (Withdrawn 2024)

D6184, Standard Test Method for Oil Separation from Lubricating Grease (Conical Sieve Method)

International Organization for Standardization and International Electrotechnical Commission

ISO/IEC 17025, General Requirements for the Competence of Testing and Calibration Laboratories

Post-Tensioning Institute (PTI)

PTI-CRT20 G1, Manual for Certification of Plants Producing Unbonded Single Strand Tendons

PTI M10.3, Field Procedures Manual for Unbonded Single Strand Tendons

SAE International

SAE J449, Surface Texture Control

Society for Protective Coatings

SSPC-VIS2, Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces

These publications may be obtained from the following organizations:

American Concrete Institute (ACI)
38800 Country Club Drive
Farmington Hills, MI 48331
+1.248.848.3700
www.concrete.org

ASTM International
100 Barr Harbor Drive
Conshohocken, PA 19428-2959
+1.610.832.9500
www.astm.org

International Organization for Standardization (ISO)
Chemin de Blandonnet 8
CP 401
1214 Vernier, Geneva, Switzerland
+41.22.749.01.11
www.iso.org

Post-Tensioning Institute (PTI)
38800 Country Club Drive
Farmington Hills, MI 48331
+1.248.848.3180

www.post-tensioning.org

Precast/Prestressed Concrete Institute (PCI)
8770 W. Bryn Mawr Avenue Suite 1150
Chicago, IL 60631
+1.312.786.0300
www.pci.org

SAE International
400 Commonwealth Drive
Warrendale, PA 15096
+1.724.776.4841
www.sae.org

The Society for Protective Coatings
15835 Park Ten Place
Houston, TX 77084
+1.800.797.6223
www.sspc.org

1.3.2—Cited references

Sason, A. S., “Evaluation of Degree of Rusting on Prestressed Concrete Strand,” PCI Journal, V. 37, No. 3, May-June 1992, pp. 25-30

1.4—System description

Unbonded single-strand tendons consist of prestressing steel covered with PT coating and encased in continuous sheathing, with anchorages at each end and at intermediate locations as required.

1.5—Submittals

Contractor shall submit documentation that the following materials comply with Sections 1.5.1 through 1.5.7:

1.5.1—Prestressing steel

Certified mill test reports and load-elongation curves for each coil of strand, containing the following test information:

(a) Heat number and identification
(b) Specified tensile strength
(c) Yield strength at 1% extension under load
(d) Elongation at failure
(e) Modulus of elasticity
(f) Diameter of strand
(g) Net area of strand
(h) Type of material (normal-relaxation or low-relaxation)

1.5.2—Anchorages and couplers

Furnish static and fatigue test reports of representative production assemblies for each different assembly.

Furnish mill certificate for all anchor components, which includes anchor component manufacturer's name and location, material designation, heat number chemical analysis, material properties, and hardness test results.

Furnish mill certificate for all wedges, which includes wedge manufacturer's name and location of facilities where manufacturing and heat-treating occurs, material designation, lot number, heat number, and hardness test results.

1.5.3—Sheathing

Furnish sheathing material report covering Section 2.3.1.

1.5.4—PT coating

Furnish test results on PT coating, tested in accordance with Table 2.2.2.1.

1.5.4—PT coating

Furnish test results on PT coating, tested in accordance with Table 2.2.2.1.

1.5.5—Fabrication plant certification

Furnish proof of PT supplier's PTI Unbonded Tendon Plant Certification covering both extrusion and fabrication, or equivalent.

1.5.6—Stressing jack calibration

Furnish calibration certificates for every jack and gauge.

1.5.7—Stressing records

Complete stressing records during the stressing operation and submit to the LDP, with the following data recorded:

(a) Name of the project
(b) Floor number or concrete placement area number
(c) Tendon identification mark
(d) Calculated elongation
(e) Gauge reading to achieve required jacking force using actual jack calibration certificate
(f) Actual measured elongation at each stressing location
(g) Actual gauge reading at each stressing location
(h) Date of stressing operation
(i) Name of stressing supervisor and third-party inspector
(j) Serial or identification number of stressing equipment used at each stressing location
(k) Date of approved installation drawings used for installation and stressing
(l) Weather conditions, including temperature and rainfall

1.6—Fabrication

1.6.1—General

Fabricate unbonded single-strand tendons in a plant meeting the requirements of Sections 1.6.1.1 or 1.6.1.2. Secure tendons in bundles using a tying product that does not damage the sheathing. Use padding material between metal banding and the tendon to prevent damage to the tendon sheathing.

1.6.1.1—PTI Certified Plants

Plants shall be certified by the Post-Tensioning Institute (PTI) according to the procedures set forth in PTI-CRT20 G1.

1.6.1.2—Non-PTI Certified Plants

In non-PTI certified plants, conclusive test data certified by an independent testing laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organizations shall substantiate that all characteristics of the unbonded tendons, including traceability of all components, corrosion-resistive characteristics, sheathing, and anchorage system, including encapsulation, are equivalent to or superior to the characteristics of tendons fabricated in accordance with this Specification and the procedures set forth in PTI-CRT20 G1.

1.6.2—Handling, storage, and shipping

The PT supplier shall be responsible for the handling and storage of unbonded tendons prior to shipping, including:

1.6.2.1—Handling prior to shipping

(a) Tendons shall not be damaged during handling, loading, or moving at the supplier's plant.

(b) Smooth forklift booms, padded forks, or nylon slings shall be used to handle and lift tendons (metal chokers or chains shall not be used).

(c) Tendons shall be protected during bundling, handling, loading, and securing to the transport vehicle.

1.6.2.2—Storage prior to shipping

(a) Stored PT materials that are exposed to any precipitation (snow, rain, and so on) for longer than 7 days (staging) shall be protected from this exposure (tenting or tarping with adequate ventilation or shrink-wrapping with moisture control is appropriate). PT materials shall not be exposed to any elements known to be deleterious or corrosive.

(b) Tendons shall be stored on dunnage or paved surface with proper drainage away from tendons.

(c) Protect tendons that are exposed to sunlight (ultraviolet [UV] ray degradation). Acceptable protection includes:

- UV stabilizers added to the sheathing per the manufacturer's recommendation to achieve a minimum of 90 days of UV protection.
- Protect fabricated tendons that are exposed to sunlight (UV degradation) for longer than a maximum of 1 month from this exposure by tenting or tarping with adequate ventilation, unless UV light stabilizers are added to the sheathing per manufacturer recommendations.

1.6.2.3—Shipping

(a) Use nonmetallic tie-downs to secure tendon bundles to the bed of the transport vehicle. Metal strapping or chains shall not be used.

(b) PT supplier shall provide protection to ensure that materials will not get damaged during transport.

1.7—Delivery, handling, and storage

1.7.1—Delivery

Protect tendons, accessories, and equipment to maintain their integrity.

1.7.2—Handling and storage

1.7.2.1—Handling

Take care not to damage sheathing or anchorages during the unloading process. Chains or hooks shall not be used.

1.7.2.2—Storage

Unload as close as possible to the designated storage area to avoid excessive handling of tendons.

1.7.2.3—Exposure

(a) Upon delivery, protect all PT tendons and accessories from deicing salts and other corrosive elements. Tenting or tarping with adequate ventilation is acceptable.

(b) When long-term storage (more than 2 weeks) is required, protection per Section 1.6.2.2(c) shall apply.

1.7.2.4—Wedges and anchors

Identify wedges and anchors by individual concrete placement areas, floor sequence, or both. Only use these components in their identified concrete placement areas. In the event components intended for one concrete placement area are exchanged into another concrete placement area, note the transaction for traceability purposes.

SECTION 2—PRODUCTS

2.1—Prestressing steel

2.1.1—Mechanical properties

Prestressing steel shall conform to one of the following requirements:

(a) ASTM A416/A416M

(b) Strand not specifically identified in the latest edition of ASTM A416/A416M shall conform to or exceed the minimum requirements of this standard.

2.1.2—Thermomechanical treatment

Conduct the process at a constant and controlled range of temperature, speed, and stress to ensure proper stress relief.

2.1.3—Traceability

Control and document the strand manufacturing process in a manner that provides identification and traceability with regard to the coil(s) of strand and wire rod heat number and wire coil(s) used to produce the strand.

2.1.4—Testing

Mechanical Properties:

Perform breaking strength, yield strength, elongation, and dimensional testing on each heat of finished product(s) to confirm the requirements of Section 2.1.1.

Relaxation Properties:

Test the finished strand for relaxation at least annually, and if there is any change in the type of raw material or manufacturing process. Perform the relaxation test according to the requirements of ASTM A416/A416M and ASTM A1061/A1061M.

Perform the relaxation test as a full 1000-hour test at initial production and every third year thereafter. Interim annual relaxation tests may be performed as 200-hour tests with results extrapolated to 1000 hours, provided that the previous full 1000-hour test exhibits satisfactory results.

Reporting:

Report mechanical properties, dimensional, and relaxation testing showing appropriate heat/coil identification, steel area, and test results. Units shall be in.-lb units, and the language shall be English.

Identify testing facility used, whether in-house or otherwise, including physical address and contact information.

2.1.5—Strand producer records

The manufacturer shall produce and maintain the following records related to material production for at least 5 years:

(a) Purchasing records showing the purchase of appropriate base materials used in production

(b) Product traceability through production and shipping

(c) Test results of tests required under Section 2.1.4, conformities (or nonconformities), and resultant actions

(d) Calibration records for all testing devices indicating calibration to known standards at intervals not exceeding 1 year

(e) Records of quality performance evidencing the occasion, frequency, and percentage of accepted and rejected final products. Records shall include internal and external occurrences, such as on-site laboratory results and customer responses

(f) Suitability and testing of raw materials, including quality reports from wire or rod suppliers

(g) Procedure for the quarantine and disposal of noncompliant products and records of the same

2.1.6—Identification

Identify each coil of strand with respect to the grade, coil and heat number, quantity, and type of steel (either normal-relaxation or low-relaxation). Include identification in the manufacturing process documentation.

2.1.7—Packaging, marking, storage, and protection

Package each coil of strand in a manner that prevents physical damage to the strand during transportation and protects the strand from deleterious corrosion during transit and storage. Packaging shall meet the purchaser's requirements or, in the absence of specific requirements, shall be appropriate for the environment and conditions that are likely to be encountered during shipping. Store strand in a protected manner to prevent damage. Protect the strand from corrosion and damage until the customer takes responsibility for it. This responsibility transfer occurs at the point of delivery and acceptance. Use controlled access and strand movement to minimize the possibility of mixing strand types. Procedures shall be documented. Affix two weatherproof and durable tags to each coil of strand produced, indicating the following:

(a) Coil number
(b) Strand type (for example, ASTM A416/A416M-10 – Low-Relaxation)
(c) Grade
(d) Size
(e) Manufacturer's name or mark

2.1.8—Acceptance criteria for surface condition

Strand used for tendons shall be dry and graded as follows (guidance for evaluating the degree of rusting on strand is presented in Sason [1992]):

(a) Grade A: No visible rust

(b) Grade B: Light surface rust that can be removed by vigorous rubbing with a cloth. No pitting noticeable to the unaided eye. Discoloration on steel surface in affected area is permitted.

(c) Grade C: Surface rust, removed with a fine steel wool pad, which leaves small pits on the steel surface of not more than 0.002 in. (0.05 mm) diameter or length.

2.1.9—Compliance requirements

Submit certified mill test results and stress-strain curves. Obtain a representative stress-strain curve to certify compliance with Section 2.1.1. Provide properly marked samples from each heat or "producer's length" for verification of prestressing steel quality.

2.2—PT coating

2.2.1—PT coating

The PT coating shall have the following properties:

(a) Provide corrosion protection to the prestressing steel
(b) Provide lubrication between the strand and sheathing
(c) Resist flow within anticipated temperature range of exposure
(d) Provide continuous non-brittle coating at lowest anticipated temperature of exposure
(e) Be chemically stable and nonreactive with prestressing steel, reinforcing steel, sheathing material, and concrete

2.2.2—Tests

Provide PT coating compound that complies with the tests and associated acceptance criteria specified in Table 2.2.2.1. Conduct qualification tests 1 through 10 from Table 2.2.2.1 every 30 months or whenever any change is made to their chemical composition.

In addition, conduct and report the results of tests 1, 9, and 10 specified in Table 2.2.2.1 for every batch of PT coating supplied.

2.2.3—Minimum quantity

The minimum weight of the PT coating on the strand shall be not less than 2.5 lb (1.14 kg) per 100 ft (30.5 m) for 0.5 in. (12.7 mm) diameter strand and 3.0 lb (1.36 kg) per 100 ft (30.5 m) for 0.6 in. (15.25 mm) diameter strand. The minimum quantity of PT coating for other strand sizes can be determined by linear extrapolation. Completely fill the annular space between the stand and sheathing with coating material. The coating shall extend over the entire tendon length.

2.2.4—Shipping and handling

Transport bulk shipments of PT coating in a manner that ensures it is not mixed with any PT coating not certified according to Section 2.2.2. All shipping containers/tanks hoses and pumps being used for the transport/transfer of PT coating shall be dedicated to the transport/transfer of PT coating or be cleaned and free from any other contaminates that could have a deleterious impact on the PT coating. In the event that non-dedicated equipment is used for the transport/transfer of PT coating, verification of cleaning shall be required.

Table 2.2.2.1—Performance specification for PT coating

No.	Test description	Test method	Acceptance criteria
1	Dropping point	ASTM D2265	Minimum of 300°F (149°C)
2	Oil separation at 160°F (71°C) All weight/mass measurements shall be recorded to four significant digits in grams. Run three separate samples from the same batch. The bleed shall be calculated for each sample, and the result shall be reported as the average/mean of the three recorded samples. Final results shall be reported to the nearest two significant digits (0.xx%).	ASTM D6184 (modified)	0.5% max by mass
3	Water content	ASTM D95	0.1% maximum
4	Flash point (refers to oil component)	ASTM D92	Minimum of 300°F (149°C)
5	Corrosion test (5% salt fog at 100°F [38°C] 5 mil [0.127 mm], Q Panel Type S)	ASTM B117	Rust Grade 7 or better after 1000 hours of exposure according to ASTM D610

			The acceptance criteria of Grade 7 or better after 1000 hours of exposure requires that only 0.3% of the area exposed can have indications of corrosion. (Refer to Fig. 2.2.2.1).
6	Water-soluble ions Chlorides Nitrates Sulfides Procedure: The inside (bottom and sides) of a 1.06 qt (1 L) glass beaker (approximate outside diameter of 4.13 in. [105 mm], height of 5.71 in. [145 mm]) is thoroughly coated with 3.53 ± 0.35 oz. (100 ± 10 g) of corrosion-inhibiting coating material. The coated beaker is filled with approximately 30 oz. (900 cm^3) of distilled water and heated in an oven at a controlled temperature of 100°F (38°C ± 1°C) for 4 hours. The water extraction is tested using the noted test procedures for the appropriate water-soluble ions. Results are reported as ppm in the extracted water.	 ASTM D512 ASTM D3867 ASTM D4658	10 ppm maximum 10 ppm maximum 10 ppm maximum
7	Soak test (5% salt fog at 100°F [38°C] 5 mil [0.127 mm] coating, Q Panel Type S. Immerse panels 50% in a 5% salt solution and expose to salt fog.)	ASTM B117 (modified)	No emulsification of the coating after 720 hours of exposure.
8	Compatibility with sheathing Hardness and volume change of polymer after exposure to grease, 40 days at 150°F (66°C) Tensile strength change of polymer after exposure to grease, 40 days at 150°F (66°C)	ASTM D4289 (ASTM D792 for density) ASTM D638	Permissible change in hardness of 15%, volume 10%. Permissible change in tensile strength of 30%.
9	Cone penetration	ASTM D217	265 to 295 (NLGI 2) worked penetration.
10	Kinematic viscosity of base oil Report measurement at 104°F (40°C) in ISO Viscosity Grade numbers (Appendix A)	ASTM D445-17a	The base oil for each batch shall be within the same ISO Viscosity Grade as the PT coating that was submitted for

			tests at the 30-month intervals.

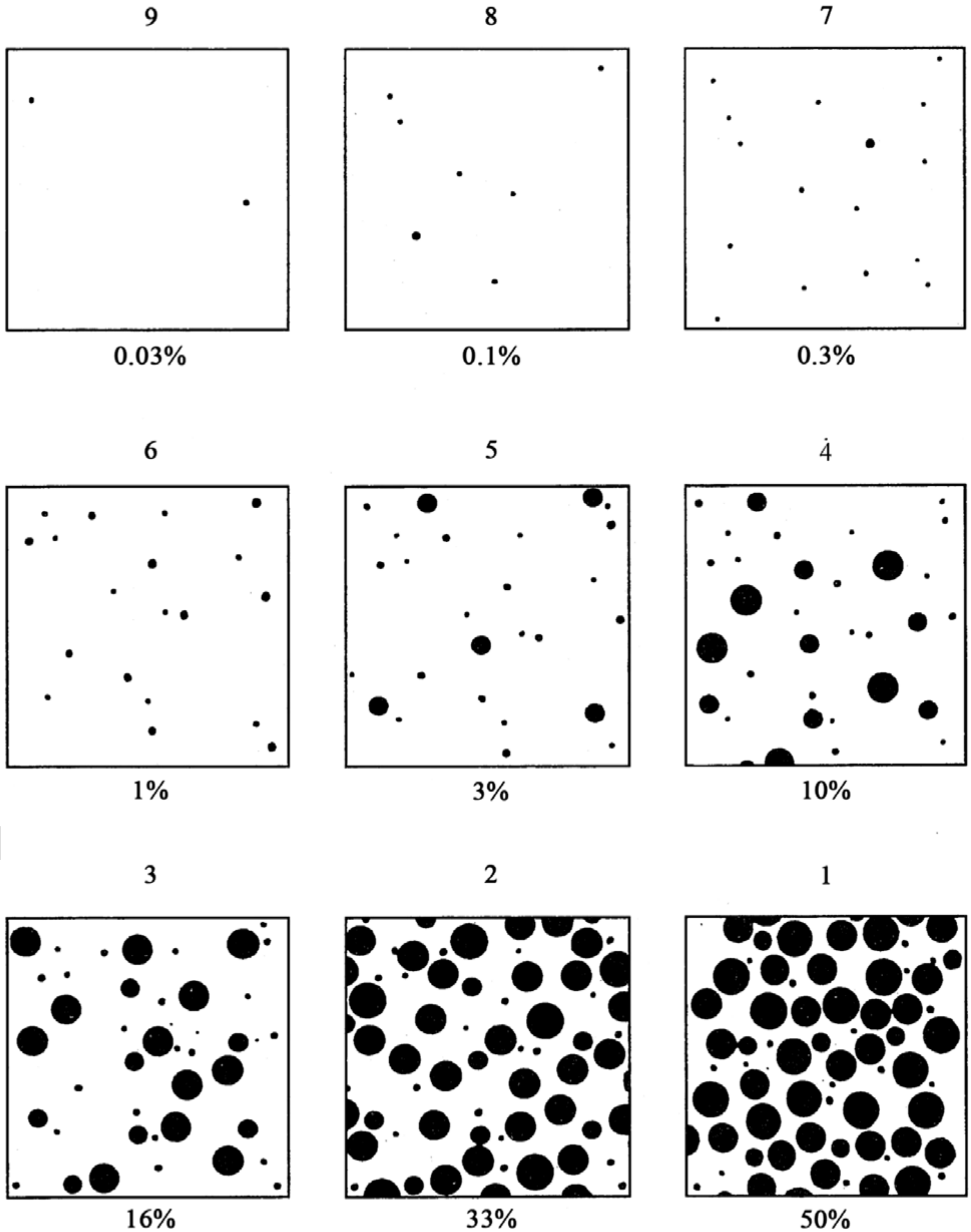

Fig. 2.2.2.1—Example of area percentages. Rating of painted surfaces of area percent rusted (SSPC-VIS 2/ASTM D610). Courtesy of ASTM International.

2.3—Sheathing

2.3.1—Sheathing

Provide tendon sheathing made of material with the following properties:

(a) Sufficient strength and durability to withstand damage during fabrication, transport, installation, concrete placement, and stressing

(b) Watertight and resistant to water vapors over the entire sheathing length

(c) Chemically stable, without embrittlement or softening over the anticipated exposure temperature range and service life of the structure. Free chloride ions shall not be extractable from the sheathing material

(d) Nonreactive with concrete, prestressing steel, reinforcing steel, and PT coating

2.3.2—Thickness

Provide sheathing with a minimum thickness of 0.050 in. (1.25 mm) for polyethylene or polypropylene with a minimum density of 0.034 lb/in.^{3} (0.941 g/cm^3).

Due to the fabrication process, slight variations in sheathing thickness may occur around the perimeter. Local reductions in sheathing thickness of up to 10% are acceptable, provided an average of four equidistant readings along the circumference equals or exceeds the required thickness.

2.3.3—Inside diameter

Sheathing shall be concentric with the strand and have an inside diameter of at least 0.030 in. (0.75 mm) greater than the maximum diameter of the strand.

2.3.4—Appearance

Sheathing shall provide a smooth, circular outside surface and shall not visibly reveal the lay of the strand.

2.3.5—Fabrication processes

Fabricate tendons by a process that provides watertight encasement of the PT coating.

2.3.6—Sheathing coverage

Provide continuous tendon sheathing over the entire length to be unbonded and prevent intrusion of cement paste or loss of the PT coating.

2.3.7—Alternate material

Alternate material and associated dimensional requirements may be used, provided that performance equivalency is determined by testing observed and certified by an independent testing laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organizations and subject to the approval of the LDP, which demonstrates that all requirements of Section 2.3 are satisfied by the alternate material.

2.4—Anchorages and couplers

2.4.1—Anchorages

Protect anchorages against corrosion by encapsulation. At all anchorages, provide a watertight connection of the sheathing to the anchorage and a watertight enclosure of the wedge cavity and prestressing steel to provide corrosion protection for the anchor, wedges, and prestressing steel. Anchorages shall meet the requirements of Section 2.4.1.1.

Encapsulated tendons that employ the use of "bare" metallic anchorages produced from a material that is subject to corrosion are unacceptable.

2.4.1.1—Anchorage-to-sheathing connection

Components used to connect the sheathing to the anchorage or coupler enclosure shall conform to the following:

2.4.1.1(a) *Connecting component requirements*—The connecting components shall:

1. Be watertight in conformance with Section 2.6.2.
2. Conform to the same requirements as the sheathing for durability during fabrication, transportation, handling, storage, and installation.
3. Have a minimum thickness of 0.050 in. (1.25 mm).
4. Have a watertight, positive mechanical or monolithic connection to the anchorage protection or coupler enclosure and a watertight connection at the tendon sheathing. The watertight connection shall meet the requirements of Section 2.4.1.1(c) for a sheathing overlap system or Section 2.4.1.1(d) for a sheathing restraint system. Hybrid encapsulation systems that use both sheathing overlap and sheathing restraint to provide and maintain a watertight connection shall meet the requirements of either Section 2.4.1.1(c) or 2.4.1.1(d). Connecting components shall not cause damage to the sheathing that would compromise the system's integrity.
5. Be translucent or have another method of verifying compliance with Sections 2.4.1.1(b) through 2.4.1.1(d).

2.4.1.1(b)—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 Section 2.2.3 where sheathing is not present.

2.4.1.1(c) *Sheathing overlap connection*—Sheathing overlap systems shall allow for a minimum sheathing movement of 4 in. (100 mm). After fabrication and up until shipment to the jobsite, the overlap shall be a minimum of 4 in. (100 mm) measured from the watertight seal to the end of the sheathing.

Test encapsulation must be in accordance with and meet the requirements of Section 2.6.2.

2.4.1.1(d) *Sheathing restraint connection*—The sheathing anchorage connection shall prevent movement of the sheathing due to handling and temperature change and maintain a watertight seal within the sheathing restraint connection.

Test encapsulation must be in accordance with and meet the requirements of Section 2.6.2.

Test the anchorage to ensure that it is in accordance with and meets the requirements of Section 2.6.1.

2.4.1.2—Bearing stresses

Average bearing stresses on concrete created by anchorages shall not exceed values computed by the following equations unless testing by an independent testing laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organizations indicates anchorage performance equivalent to or superior to anchorages satisfying the requirements of this section.

At transfer load

$$f_{cp} = 0.75 f'_{ci}\sqrt{\frac{A'_b}{A_b}}$$

but not greater than $1.25f_{ci}'$

At service load

$$f_{cp} = 0.6 f'_{c}\sqrt{\frac{A'_b}{A_b}}$$

but not greater than f_c'

where f_{cp} is the permissible concrete compressive stress; f_c' is the specified concrete compressive strength; f_{ci}' is the specified concrete compressive strength at the time of initial prestress; A_b' is the maximum area of the portion of the concrete anchorage surface that is geometrically similar to and concentric with the area of the anchorage; A_b is the net bearing area of the anchorage; and f_{cp} is the average bearing stress P/A_b in the concrete, computed by dividing the force P of the prestressing steel by the net bearing area, A_b between the concrete and bearing plate, or other structural element of the anchorage that has the function of transferring force to the concrete.

The PT supplier shall determine if any special reinforcement is required and indicate it on the installation drawings.

2.4.2—Castings

Provide castings that are nonporous and free of sand, blowholes, voids, and other defects. For casting surface conditions, refer to SAE J449.

Casting dimensions shall be compatible with anchorage system design specifications.

2.4.3—Couplers

Use couplers only at locations specified by the PT supplier and approved by the LDP. Specify the location of the couplers to maintain proper concrete cover.

Do not use couplers at points where the tendon horizontal radius of curvature is less than 20 ft (6.5 m) for 0.5 in. (12.7 mm) diameter strand (adjusted proportionally based on strand diameter for other strand diameters).

2.4.3.1—Coupler enclosure

House couplers in an enclosure that is watertight between the enclosure and the sheathing. Provide an enclosure with adequate length to accommodate movement of the coupler inside the enclosure during stressing. After attaching the coupler and positioning the enclosure, fill the enclosure with PT coating and then seal it. If tape is used to connect the enclosure to the sheathing, it shall meet the requirements of Section 2.4.3.2.

2.4.3.2—Tape

Tape used as a component for sheathing repairs and when adding couplers to tendons shall:

(a) Be self-adhesive and moisture-proof

(b) Be nonreactive with sheathing, PT coating, or prestressing steel

(c) Have elastic properties

(d) Have a minimum width of 2 in. (50 mm)

(e) Have a contrasting color to the tendon sheathing

2.4.4—Assembly instructions

The supplier of the coupler enclosure system shall provide identification of all component parts of their system and provide assembly instructions that will be sent to the field.

2.5—Anchorage assembly testing

2.5.1—Validation

Confirm the adequacy of a tendon system by static, fatigue, restraint (if applicable), and hydrostatic conformance tests in accordance with the minimum requirements outlined in Sections 2.5.6, 2.5.7, 2.6.1, and 2.6.2, respectively. Use separate specimens for static and fatigue tests. Base testing on a series of three consecutive tests with strand from the same heat. Testing shall be performed by an independent laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organization selected by the system supplier manufacturer. Retesting is required whenever a component of an assembly changes or the testing criteria change. Submit data from the supplier to show compliance with provisions of Sections 2.5.6, 2.5.7, 2.6.1, and 2.6.2 upon request from the LDP.

2.5.2—Wedges

2.5.2.1—Wedge design

Design wedges used in anchors to preclude failure of prestressing steel due to notching or pinching effects under test load conditions stipulated in Sections 2.5.6 and 2.5.7 for both normal- and low-relaxation prestressing steel.

Heat-treat and case-harden wedges to meet design performance requirements with at least 58 Hardness Rockwell C (HRC) or Hardness Rockwell A (HRA) 80.1 measured at case depth (or equivalent hardness scale).

2.5.2.2—Wedge quality control

The wedge manufacturer shall perform quality control of manufacturing processes to ensure uniformity and achieve the manufacturer's specified wedge properties:

(a) Dimensions and tolerances

(b) Minimum specified surface hardness

(c) Minimum depth of surface hardness (case depth)

(d) Maximum core hardness

(e) Maximum heat-treated lot quantity shall not exceed recommended or demonstrated equipment capacity

Perform the following tests and certify compliance with the minimum requirements of this Specification for each lot of wedge sets (not wedge segments) or for each heat-treatment batch, whichever is smaller. The number of wedge sets manufactured per lot or per heat-treatment batch shall not exceed the equipment manufacturer's recommended maximum number of wedge sets for any process used:

(a) Visually inspect 5% of wedge segments for dimensions, serration profile, and surface defects.

(b) Check 2% of wedge segments for surface hardness.

(c) Check 1% of wedge segments for dimensional compliance.

(d) Test the microhardness of three cut and polished wedge segments to determine case depth, surface hardness, and core hardness.

Test samples must meet the manufacturer's specified wedge properties. If any sample fails one of the previously specified quality control tests, then all wedge segments or wedges of the production lot shall be inspected, and those not in compliance shall be rejected for use.

Wedges shall be visually free of debris, carbon residue, and other contaminants.

2.5.3—Components

Do not use component parts from different manufacturers without substantiating complete tendon test data.

2.5.4—Strength test criteria

Design anchorages and couplers to develop at least 95% of the specified tensile strength of the prestressing steel specified in Section 2.1.1. Confirm tensile strength using representative samples of strand material tested in conformance with ASTM A370.

2.5.5—Ductility test

Total elongation of the strand under ultimate load shall not be less than 2.0%, measured with a minimum gauge length of 3 ft (915 mm) between two points at least 3 in. (75 mm) from each anchorage. Tendon couplers shall not reduce elongation at rupture below that required for the anchorages.

2.5.6—Static test

Test assembly shall consist of standard production quality components with a minimum gauge length of 3.5 ft (1.1 m) between anchorages. The test shall provide a determination of yield strength, specified tensile strength, and percent elongation of the complete tendon. It is not required to use the same specimen for static and fatigue tests.

2.5.7—Fatigue test

Test assembly shall consist of standard production quality components with a minimum gauge length of 3.5 ft (1.1 m) between anchorages. In the first test, the tendon shall withstand 500,000 cycles between 60 and 66% of the specified tensile strength. In the second test, the tendon shall withstand 50 cycles between 40 and 85% of the specified tensile strength. One complete cycle involves a change from the lower stress level to the upper stress level and back to the lower stress level. It is not required to use the same specimen for both fatigue tests.

2.6—Encapsulation testing

2.6.1—Sheathing restraint tests

These tests are applicable to anchorages and couplers that solely use a sheathing restraint connection. Test representative samples of anchorages and couplers to ensure the effectiveness of the sheathing restraint connection in conformance with Sections 2.6.1.1 and 2.6.1.2. Test three fixed anchorage assemblies for both the static load and sustained load tests. Tests shall be performed, or observed and certified, by an independent testing laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organizations.

Retesting is required every 5 years or whenever a component of an assembly changes or the testing criteria change, whichever is earlier.

Encapsulated systems using components from different manufacturers are acceptable, provided they are tested in accordance with Sections 2.6.1.1 and 2.6.1.2.

2.6.1.1—Sheathing restraint static load test

2.6.1.1(a) *Samples*—Use three representative samples from production runs, selected by the independent testing laboratory and assembled by the manufacturer, for testing.

2.6.1.1(b) *Assemblies: test specimen*—The specimen is an anchorage with a sheathing restraining device and 36 in. (0.9 m) of sheathed strand. The sheathing restraining device retains sheathing at one end. Sheathing at the opposite end is held by a gripping system, with the end of the gripping device 30 ± 1/2 in. (0.8 ± 13 mm) from the bearing side of the anchorage. Use a loading device to pull the sheathing away from the anchorage and a load cell to measure the force.

2.6.1.1(c) *Static load test procedure*—During the test procedure, the following steps are required:

1. Measure the distance of the end of the gripping device from the bearing side of the anchorage and record the value.
2. Gradually apply load to the end of the sheathing by pulling only on the gripped sheathing.
3. Apply load until sheathing elongates a minimum of 1 in. (25 mm) and a minimum force of 150 lb (68.2 kg) is achieved. If the sheathing breaks along the length of the sample less than 1 in. (25 mm) from the anchorage prior to achieving both the elongation and static load criteria, reject the test and prepare and retest a new test specimen.
4. Once both criteria have been met, hold the force for 15 seconds.
5. Measure and record the distance of the end of the gripping system from the bearing side of the anchorage.
6. Record the force shown on the load cell.
7. After releasing the force, inspect the anchorage and the connection to the sheathing. Note any movement of the sheathing away from the anchorage and any damage to the sheathing or anchorage that compromises the system integrity.

2.6.1.1(d) *Acceptance criteria: static load testing*—For the static load sheathing restraint test to be acceptable, there shall be no observed movement of the sheathing away from its seal at the anchorage or any damage to the sheathing or anchorage that compromises the system integrity. All three tests shall be acceptable for the system to pass.

2.6.1.2—Sheathing restraint sustained load test

2.6.1.2(a) *Samples*—Use three representative samples from production runs, selected by the independent testing laboratory and assembled by the manufacturer, for testing.

2.6.1.2(b) *Assemblies: test specimen*—The specimen is an anchorage with a sheathing restraining device and 36 in. (0.9 m) of sheathed strand. The sheathing restraining device retains sheathing at one end. Sheathing at the opposite end is held by a gripping system, with the end of the gripping device 30 ± 1/2 in. (0.8 ± 13 mm) from the bearing side of the anchorage. Use a loading device to pull the sheathing away from the anchorage and a load cell to measure the force.

2.6.1.2(c) *Sustained load test procedure*—During the test procedure, the following steps are required:

1. Measure the distance of the end of the gripping device from the bearing side of the anchorage and record the value.
2. Gradually apply load to the end of the sheathing by pulling only on the gripped sheathing.
3. Apply load until a force of 100 lb (45 kg) is achieved. If the sheathing breaks along the length of the sample less than 1 in. (25 mm) from the anchorage prior to achieving the sustained load criteria, reject the test and prepare and retest a new test specimen.

4. Once the required force is achieved, hold the displacement without adding additional load for 24 hours.
5. After 24 hours, release the force and inspect the anchorage and the connection to the sheathing. Note any movement of the sheathing away from the anchorage and any damage to the sheathing or anchorage that compromises the system integrity.
6. Retain sustained load test specimens for use in the hydrostatic test in accordance with Section 2.6.2.

2.6.1.2(d) *Acceptance criteria: sustained load*—For the sustained load sheathing restraint tests to be acceptable, there shall be no observed movement of the sheathing away from its seal at the anchorage or any damage to the sheathing or anchorage that compromises the system integrity. All three tests shall be acceptable for the system to pass. Refer to Section 2.6.2.3 for acceptance criteria of the hydrostatic testing performed on the sustained load tested sample.

2.6.2—Hydrostatic test

Test representative anchorages and couplers to ensure a watertight encapsulation of the prestressing steel and all connections in conformance with Sections 2.6.2.1 through 2.6.2.3. Test stressing, intermediate, and fixed anchorage assemblies. Three tests are required for each assembly. Tests shall be performed, or observed and certified, by an independent testing laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organizations.

Retesting is required every 5 years or whenever a component of an assembly changes or the testing criteria change, whichever is earlier.

Encapsulated systems using components from different manufacturers are acceptable, provided they are tested in accordance with Sections 2.6.2.1 through 2.6.2.3.

2.6.2.1—Encapsulation system using sheathing overlap connection

2.6.2.1(a) *Samples: sheathing overlap connection*—Use representative samples from production runs, selected by the independent testing laboratory and assembled by the manufacturer, for testing.

2.6.2.1(b) *Assemblies: sheathing overlap connection*—Pull and withdraw the sheathing from the anchorages so that a maximum of a 3/4 in. (+ 0 or – 1/8 in.) (19 mm + 0 or – 3 mm) overlap from the watertight seal to the end of the sheathing remains. Arrange anchorage assemblies with the 3/4 in. (19 mm) overlap in a position to ensure a uniform hydrostatic pressure for 24 hours. Use the following minimum uniform hydrostatic pressure in the test:

1. For building and other applications governed by ACI 318: 1.25 psi (0.0086 MPa)
2. For environmental structures and other applications governed by ACI 350: 10 psi (0.0688 MPa)

2.6.2.1(c) *Test procedure: sheathing overlap connection*—During the test procedure, use the following steps to detect the presence of moisture:

1. Add white pigment to the PT coating.
2. Use a colored dye in the water that will contrast with the white color of the PT coating.
3. After 24 hours, remove the encapsulated system and note the color of the PT coating.

2.6.2.2—Encapsulation system using sheathing restraint connection

2.6.2.2(a) *Samples: sheathing restraint connection*—Use anchorage assemblies that passed the sheathing restraint sustained load test in accordance with Section 2.6.1.2(c) for the hydrostatic test.

2.6.2.2(b) *Assemblies: sheathing restraint connection*—Arrange anchorage assemblies in a position to ensure a uniform hydrostatic pressure for 24 hours. Use the following minimum uniform hydrostatic pressure in the test:

1. For building and other applications governed by ACI 318: 1.25 psi (0.0688 MPa)
2. For environmental structures and other applications governed by ACI 350: 10 psi (0.0688 MPa)

2.6.2.2(c) *Test procedure: sheathing restraint connection*—During the test procedure, use the following steps to detect the presence of moisture:

1. Add white pigment to the PT coating.
2. Use a colored dye in the water that will contrast with the white color of the PT coating.
3. After 24 hours, remove the encapsulated system and note the color of the PT coating.

2.6.2.3—Acceptance criteria

Anchorages shall remain watertight for the duration of the test. For an encapsulation system to be acceptable, no colored dye shall be visible on the white PT coating inside the system. All three tests for each anchorage assembly shall be acceptable for the system to pass.

2.7—Alternative Materials

A PT system comprises a tensile element with an anchorage mechanism permanently connected at each end that transfers the force connecting the anchorage mechanisms from the tensile element into a structural element. During the application of the force, the tensile element is free to move relative to the structural element.

In an unbonded PT system, the tensile element is permanently isolated from the structural element, and both the tensile element and anchorage mechanism are permanently protected from any source that could cause corrosion or deterioration of the materials used in these elements.

In current unbonded systems, the tensile element is a steel strand, and the anchorage mechanism is a steel element with a conical void that uses steel wedges with gripping teeth that form a mechanical connection to the strand to transfer the force into the anchorage mechanism when the wedges are pulled into the conical hole.

The materials, systems, and components described herein reflect current technology. Nothing herein shall be construed to prevent other materials or components from being introduced or used, provided alternate components manufactured from different materials and associated dimensional differences shall be tested to confirm performance equivalency, including the requirements of this Specification. The use of any components after successful testing is subject to the approval of the LDP.

Proposed components comprising alternate materials shall be presented and balloted in PTI Committee M-10, Unbonded Tendon, for possible equivalency to this Specification. Conformance shall be established through testing by an independent testing laboratory accredited to ISO/IEC 17025 by A2LA or other equivalent accrediting organizations and approval by an independent task group appointed by PTI Committee M-10 and approved by the PTI Technical Advisory Board (TAB). It shall comprise a minimum five-person task group with relevant experience with the product for which the alternate material is used while not having any direct financial or monetary interest in the proposed alternative material. The independent task group shall review the new component/product, taking into account the results of the independent testing laboratories, manufacturing tolerances, and other acceptance qualifications necessary to ensure that the proposed alternate component/product of this Specification meets or exceeds the qualifications and performance of the current Specification.

SECTION 3—EXECUTION

3.1—Installation procedures

The PT installer shall conform to the requirements shown in the Contract Documents issued by the LDP, the PT supplier's installation drawings, and procedures listed in PTI M10.3.

Keep a copy of this Specification and PTI M10.3 at the jobsite.

If conflicts exist between the aforementioned documents, the requirements of the Contract Documents shall govern first, followed by the requirements of the PT supplier's installation drawings.

3.2—Installer certification

Unless otherwise specified, installation and stressing shall be performed by personnel certified by PTI's training and certification program. Personnel shall be certified in accordance with PTI's Level 1 Unbonded PT Installation program. Each crew foreman for the installation crew and the stressing crew shall be certified in accordance with PTI's Level 2 Unbonded PT Inspector or Level 2 Unbonded PT Ironworker programs. Submit the qualifications of installation personnel. The crew foreman responsible for cutting tendon tails, capping encapsulated anchorages, and patching stressing pockets shall be certified in accordance with PTI's Level 2 Unbonded PT Inspector or Level 2 Unbonded PT Ironworker programs.

3.3—Inspection

Conduct an inspection to ensure the requirements of this Specification and Contract Documents are met. This inspection shall be performed by personnel certified in accordance with PTI's Level 2 Unbonded PT Installer & Inspector program or as otherwise specified. Submit documentation of inspector certification. Inspection shall include, but not be limited to:

(a) Material cleanliness

(b) Location and quantity of materials

(c) Corresponding material and stressing equipment certifications

(d) Length of strand tails

(e) Installation of encapsulation components (sheathing overlap connections and sheathing restraint connections at all anchor locations) prior to concrete placement

(f) Installation of encapsulation caps at fixed anchors prior to concrete placement

(g) Stressing of prestressing tendons

(h) Cutting of tendon tails. Record date, personnel, and method used in accordance with Section 3.11.2.

(i) Installation of encapsulation caps at stressing anchors after cutting tendon tails. Record date and personnel in accordance with Section 3.11.1.

(j) Filling of stressing pockets. Record date, personnel, weather conditions, and product used in accordance with Section 3.12.2.

3.4—Delivery

The PT installer shall inspect tendons and all accessory items at the time of delivery to the jobsite, prior to offloading. Notify the PT supplier of any observed damages prior to offloading. After acceptance, the PT installer shall have responsibility for all material at the jobsite.

3.5—Handling

Use nonmetallic slings to lift tendons. Do not use metal chokers or chains. Do not drag tendons on truck beds, concrete surfaces, formwork, or any other surface where tendon sheathing damage can occur.

3.6—Protection

Do not store tendon bundles and accessory items where they will be subjected to rain, snow, or standing water. Handle and store accessory items so that they are not damaged during or after unloading.

3.7—Tendon installation

3.7.1—Support intervals

Support PT tendons at intervals not exceeding 4 ft (1.25 m). Placing tolerances shall be in accordance with this section, ACI 117, or the Contract Documents— whichever is the most restrictive.

3.7.2—Support system

Attach tendons to support chairs or reinforcement in a manner that does not cause damage to the sheathing and that will prevent displacement during concrete placing operations.

3.7.3—Protection

Do not expose tendons to welding sparks, electric ground currents, or excessive temperatures that deleteriously affect the prestressing steel, anchorages, PT coating, or sheathing material. Keep tendons and components clean and undamaged.

Protect all exposed metal tendon components within 24 hours after their exposure during installation.

3.7.4—Protection from water

Prevent water from entering the tendons during installation.

3.7.5—Stressing anchorages

3.7.5.1—Placement

Install and securely position stressing anchorages in formwork at locations indicated on the installation drawings.

3.7.5.2—Attachment requirements

Securely attach stressing anchorages to edge forms. Connections shall be sufficiently rigid to avoid accidental loosening. Attach the anchor to the edge form using fasteners that will not corrode or are protected from corrosion by other means.

3.7.5.3—Installation

Install stressing anchorages perpendicular to the tendon axis. Do not start any transition curvature in the tendon closer than 1 ft (0.3 m) from the stressing anchorage.

3.7.5.4—Cover requirements

Minimum concrete cover from the top, bottom, and edge of concrete for anchorages shall not be less than the specified cover to reinforcement at other locations in the structure. At angled slab edges, maintain minimum concrete cover at all edges of the anchorage. Unless otherwise specified, concrete cover from the exterior edge of the concrete to the wedge cavity shall not be less than 2 in. (50 mm).

3.7.5.5—Pocket formers

Pocket formers used to provide a void at the stressing anchorages shall prevent intrusion of cement paste into the wedge cavity.

3.7.5.6—Encapsulation

Prior to concrete placement, install all components of the encapsulation system following the PT supplier's instructions to completely seal the anchorage from moisture. For encapsulation systems that use a sheathing overlap connection per Section 2.4.1.1(c), the overlap shall be a minimum of 1 in. (25 mm), measured from the sealed surface to the end of the sheathing at all times prior to concrete placement. The connection between the encapsulation components and the sheathing shall be watertight and meet the requirements of Section 2.4.1.1. Install encapsulation caps as soon as possible and within 8 hours after cutting the tendon tails. The inspection agency shall verify the proper installation of the encapsulation system in accordance with Section 3.2.

3.7.5.7—Encapsulation cap cover

Unless otherwise specified, concrete cover from the exterior edge of the concrete shall not be less than 1 in. (25 mm) to the encapsulation component.

3.7.6—Intermediate anchorages

3.7.6.1—Placement

Install and securely position intermediate anchorages in formwork at locations indicated on the installation drawings. Embed intermediate anchorages in the first concrete placed at a construction joint.

3.7.6.2—Installation

Install intermediate anchorages perpendicular to the tendon axis. Do not start any transition curvature in the tendon profile or alignment closer than 1 ft (0.3 m) from the intermediate anchorage.

3.7.6.3—Cover requirements

Top and bottom cover requirements of Section 3.7.5.4 shall apply to intermediate anchorages.

3.7.6.4—Pocket formers

Pocket formers used to provide a void at intermediate anchorages shall prevent intrusion of cement paste into the wedge cavity.

3.7.6.5—Encapsulation

Prior to concrete placement, install all components of the encapsulation system following the PT supplier’s instructions to completely seal the anchorage from moisture. For encapsulation systems that use a sheathing overlap connection per Section 2.4.1.1(c), the sealed surface of the sleeve shall overlap the sheathing by a minimum of 1 in. (25 mm) at all times prior to concrete placement. After stressing, complete the intermediate encapsulation by installing the intermediate components following the PT supplier’s instructions to completely seal the wedge cavity from moisture. The connection between the encapsulation components and the sheathing shall be watertight and meet the requirements of Section 2.4.1.1. Install encapsulation components within 8 hours after stressing.

3.7.7—Fixed anchorages

3.7.7.1—Attachment

Install fixed anchorages on the tendon:

(a) At the fabrication plant prior to shipment to the jobsite

(b) At the jobsite, provided the PT supplier furnishes appropriate equipment and installation instructions satisfactory to the LDP

3.7.7.2—Wedge seating methods for fixed anchorages

Attach fixed anchorages to the prestressing steel by any method that permanently fastens the anchor to the strand. Systems that use wedges to grip the strand may employ any method, including pulling the wedges into the wedge cavity (pull method); pushing the prestressing steel, which in turn pulls the wedges into the wedge cavity (strand push method); pushing the wedges into the wedge cavity without applying force on the strand (wedges push method); or any other method that will prevent release of the prestressing steel and satisfies the requirements of Section 2.5.4. When permitted, substantiate other methods by testing acceptable to the LDP, validated through testing and then approved by the LDP.

Limit temporary force applied to seat wedges to a percentage of the specified tensile strength of the prestressing steel as follows:

Pull method = 80 to 85%

Strand push method = 85 to 90%

Wedges push method = 85 to 120%

The method used to connect a fixed anchorage to a tendon shall limit the amount of wedge travel to no more than 0.050 in. (1.25 mm) between the fully seated position resulting from any of the three aforementioned methods and the position when a force of 95% of the specified tensile strength is applied to the tendon.

The fixed-end wedge seating method that is chosen shall result in the wedge halves being seated with a maximum offset between wedge halves of 1/4 in. (6.44 mm). The strand tail extending past the wedge after completion of the seating method shall be no greater than the maximum length specified by the encapsulation system manufacturer to ensure proper seating of the encapsulation cap.

3.7.7.3—Placement

Place and securely position fixed anchorages in formwork at locations shown on the installation drawings. Concrete cover requirements of Section 3.7.5.4 apply to fixed anchorages.

3.7.7.4—Encapsulation

Connect the encapsulation cap and the sheathing to the anchorage to completely seal the area against moisture. For encapsulation systems that use a sheathing overlap connection per Section 2.4.1.1(c), the sealed surface of the sleeve shall overlap the sheathing by a minimum of 1 in. (25 mm) at all times prior to concrete placement. For encapsulation systems that solely rely on a sheathing restraint connection per Section 2.4.1.1(d) without complying with all the requirements of Section 2.4.1.1(c), firmly engage the sheathing of the tendon into the restraint device to prevent slippage. The connection between the encapsulation components and the sheathing shall be watertight, meeting the requirements of Section 2.4.1.1. Install the encapsulation cap after coating the strand tail and wedge cavity with PT coating, meeting the requirements of Sections 2.2.1 and 2.2.2.

3.7.8—Sheathing inspection and repair

3.7.8.1—Sheathing damage

After installing the tendons in the forms and prior to the concrete placement, inspect the sheathing for damage. Repair damaged areas, including any breach or split, by restoring the PT coating in the damaged area and repairing the sheathing. Sheathing repairs shall be watertight and acceptable to the LDP.

3.7.8.2—Repair procedure

Tape repair procedures shall conform to PTI M10.3 and be acceptable to the LDP.

3.8—Tendon tolerances

3.8.1—General

The bearing surface between the anchorage and concrete shall be concentric with the tendon. The anchorage shall be perpendicular to the direction of the tendon at the anchorage.

Place tendons and anchorages within the tolerances of ACI 117 for reinforcement placement, distance between reinforcement, and concrete cover. These tolerances apply separately to both vertical and horizontal dimensions and may be different for each direction, except in slabs, where the horizontal tolerance shall not exceed 1 in. (25 mm) in 15 ft (4.6 m) of tendon length.

3.7.8.2—Repair procedure

Tape repair procedures shall conform to PTI M10.3 and be acceptable to the LDP.

3.8—Tendon tolerances

3.8.1—General

The bearing surface between the anchorage and concrete shall be concentric with the tendon. The anchorage shall be perpendicular to the direction of the tendon at the anchorage.

Place tendons and anchorages within the tolerances of ACI 117 for reinforcement placement, distance between reinforcement, and concrete cover. These tolerances apply separately to both vertical and horizontal dimensions and may be different for each direction, except in slabs, where the horizontal tolerance shall not exceed 1 in. (25 mm) in 15 ft (4.6 m) of tendon length.

3.8.2—Profile tolerances

Unless otherwise specified, deviations from the tendon design profile for beams and slabs shall not exceed:

(a) 0.25 in. (6 mm) for member depth less than or equal to 8 in. (200 mm)

(b) 0.375 in. (9.5 mm) for member depth greater than 8 in. (200 mm) and less than or equal to 2 ft (610 mm)

(c) 0.5 in. (12.7 mm) for member depth greater than 2 ft (610 mm)

3.8.3—Lateral deviations

Permit lateral deviations in tendon locations if necessary to avoid openings, ducts, chases, and inserts. Such deviations shall have a radius of curvature of no less than 480 strand diameters. When a radius of curvature of less than 480 diameters is necessary, additional hairpin reinforcement acceptable to the LDP may be required.

3.9—Concrete placement

3.9.1—General

Prevent water and cement paste from entering the tendons during concrete placement and curing.

3.9.2—Placement

The position of PT tendons, the tendon support system, and nonprestressed reinforcement shall remain within tolerance during concrete placement.

3.9.3—Protection of tendons

Support pump lines, chutes, and other concrete placing equipment above tendons.

3.9.4—Sheathing repairs

Repair damage to sheathing that occurs during concrete placement in accordance with the requirements of Section 3.7.8.2.

3.10—Tendon stressing

3.10.1—General

Stress tendons in conformance with PTI M10.3 unless otherwise specified by the PT supplier. Stress the tendons in sequence and at locations as specified on the installation drawings.

3.10.2—Protection from water

Prevent water from entering the tendons prior to completion of the tendon finishing operation.

3.10.3—Stressing jacks

Equip stressing jacks with jack grippers that will not notch the strand more severely than normal anchoring wedges.

3.10.4—Jack calibrations

Individually identify and calibrate stressing jacks and gauges to known standards at intervals not exceeding 6 months or at the beginning of each new project. Provide calibration certificates for each jack and gauge used. The calibrated jack-gauge system shall be capable of measuring the jacking force within an accuracy of 2%.

An independent testing agency or the PT supplier furnishing the stressing equipment shall perform the jack calibration. If the PT supplier performs the jack calibration, the jack calibration shall reference the certificate from an independent testing agency specifying the latest calibration date of the test instrument. Provide the test instrument certificate if requested.

3.10.5—Elongation measurements

Take and record elongation measurements and gauge readings at each stressing location immediately after stressing. Measured elongations shall agree with calculated elongations within ±7%. Discrepancies exceeding ±7% shall be resolved by all parties involved in the PT process to the satisfaction of the LDP.

3.11—Tendon finishing

3.11.1—Cutting of tendon tails

Tendon tails shall not be cut until the LDP approves the stressing records. Once approval has been given, cut the tendon tails within 1 day. After cutting the tendon tail, the strand tail shall not be less than 0.5 in. (12.7 mm) from the face of the anchor casting. Minimum concrete cover shall comply with Section 3.7.5.7. Install encapsulation caps within 8 hours after the removal of the tendon tails. If cutting or capping is delayed, provide protection to prevent moisture from entering the wedge cavity.

3.11.2—Cutting methods

Remove the tendon tail by oxyacetylene cutting, abrasive wheel, hydraulic- or electric-powered cold shear, gas plasma cutting, or another method acceptable to the LDP that will not damage the strand, anchorages, or encapsulation. If an oxyacetylene cutter is used, flames shall not be directed toward the wedges.

3.11.3—Encapsulation

Before filling stressing pockets, inspect stressing anchorages to ensure the encapsulation system complies with Section 3.2.

3.12—Stressing pockets

3.12.1—Preparation

Prior to installing concrete patch material, clean the inside concrete surfaces of the stressing pocket to remove any laitance or PT coating. Place the concrete patch material to ensure complete bonding and filling of the stressing pocket.

3.12.2—Timing

Unless otherwise specified, use grout conforming to ASTM C1107/C1107M to fill the stressing pocket within 1 day after tendon tail cutting. Concrete patch material used for stressing pocket filling shall not contain chlorides or other chemicals known to be deleterious to prestressing steel and shall be nonreactive with prestressing steel, anchorage materials, and concrete.

APPENDIX A—ISO VISCOSITY GRADES FOR INDUSTRIAL OILS

Table A1

ISO Viscosity Grades for industrial oils

ISO Viscosity Grade	Kinematic viscosity at 104°F (40°C), min cSt	Kinematic viscosity at 104°F (40°C), mid cSt	Kinematic viscosity at 104°F (40°C), max cSt
2	1.98	2.2	2.42
3	2.88	3.2	3.52
5	4.14	4.6	5.06
7	6.12	6.8	7.48
10	9	10	11
15	13.5	15	16.5
22	19.8	22	24.2
32	28.8	32	35.2
46	41.4	46	50.6
68	61.2	68	74.8
100	90	100	110
150	135	150	165
220	198	220	242
320	288	320	352
460	414	460	506
680	612	680	748
1000	900	1000	1100
1500	1350	1500	1650
2200	1980	2200	2420
3200	2880	3200	3520

The Post-Tensioning Institute provides the following activities in support of its members and the industry:

- Technical and certification committees that provide consensus guides, reports, manuals, specifications, standards, and certification manuals
- Spring PTI Convention and Fall PTI Committee Days to facilitate the work of its committees
- Technical sessions at the Spring PTI Convention to provide a forum for technical information exchange
- Educational seminars and webinars to disseminate information on post-tensioned concrete
- Programs for certification of personnel working with post-tensioned concrete, for certification of plants producing unbonded single-strand tendons, and for certification of multistrand and bar post-tensioning systems
- Research projects and student scholarships
- Coordination and cooperation with other related societies
- The PTI *JOURNAL*

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The Post-Tensioning Institute

Established in 1976, the Post-Tensioning Institute is recognized as the worldwide authority on post-tensioning. PTI is dedicated to expanding post-tensioning applications through marketing, education, research, teamwork, and code development while advancing the quality, safety, efficiency, profitability, and use of post-tensioning systems.

One of PTI's principal functions is to provide technical guidance on the design, construction, maintenance, and repair & rehabilitation of post-tensioned structures. PTI has published many informative manuals and technical guides covering most aspects of post-tensioning. In addition, PTI publishes the PTI JOURNAL, Newsletters, Technical Notes, Frequently Asked Questions, and Technical Updates that give in-depth discussion and/or analysis of issues pertinent to designers in the post-tensioning field. Members are also kept up-to-date on industry-related events and information on the PTI Web site at www.post-tensioning.org.

PTI technical committees, as well as PTI as a whole, operate under a consensus process that ensures that all participants have their views considered. Members of the Institute include major post-tensioning materials fabricators; manufacturers of prestressing materials; companies supplying materials, services, and equipment used in post-tensioned construction; and professional engineers, architects, and contractors. Individuals interested in the activities of PTI are encouraged to become a member.