TENTATIVE SPECIFICATION FOR POST-TENSIONING MATERIALS

Prepared by PCI Committee on Post-Tensioning
PETER REINHARDT,
Chairman

ARTHUR R. ANDERSON
KENNETH B. BONDY
TED BROWN
NED H. BURNS
BRIAN CARTER
EUGENE E. DABNEY*
JOHANN F. ENDERLEIN
RENE FRIEDRICH
LORIS GERBER
ROBERT L. KOONS
JAMES R. LIBBY
ROBERT J. McLEAN
DWIGHT E. PATTON
H. KENT PRESTON
CHARLES REJCHA
WILLIAM SLATER
ALLAN H. STUBBS
MARIO G. SUAREZ
ADOLF WALSER
* *Past chairman*

The PCI Committee on Post-Tensioning carefully developed this specification as a guide to engineers designing and specifying post-tensioned concrete structures and also as a basis for establishing the testing phase of a certification program for post-tensioning materials. Much of the information in this specification was coordinated with ACI Committee 301, responsible for a revision to Specifications for Structural Concrete for Buildings (ACI 301-66), Chapter 15, Prestressed Concrete, and with ACI Committee 423 which prepared the report, "Tentative Recommendations for Concrete Members Prestressed with Unbonded Tendons."

Earlier committee work resulted in PCI Specifications SPC-111-60, "Tentative Recommended Practices for Grouting Post-Tensioned Prestressed Concrete," and SPC-117-64, "A Report of Field Experiences in Grouting Post-Tensioned Prestressed Cables." The committee plans to up-date these reports in the near future.

Comments and discussion of this tentative specification are invited; discussion will close April 1, 1971.

Peter Reinhardt, Chairman

1. Scope

1.1. This specification provides the minimum requirements for post-tensioning materials which are a part of the prestressed concrete structural elements of any building, bridge or other structure.

1.2. For non-structural applications, such as topping slabs, waterproofing, slabs on fill, crack control and deflection control, the provisions shall govern where applicable.

1.3. For non-flexural or membrane type structures primarily under tensile forces, the provisions shall govern where applicable.

2. Definitions

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

2.2. Bonded Tendons—Tendons which are bonded to the concrete through grouting or other approved means, and therefore are not free to move relative to the concrete.

2.3. Unbonded Tendons—Tendons in which the prestressing steel is permanently free to move relative to the concrete to which they are applying their prestressing forces.

2.4. Anchorage—The means by which the prestressing force is permanently transmitted from the prestressing steel to the concrete.

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

2.6. Coating—Material used to protect against corrosion and/or lubricate the prestressing steel.

2.7. Sheathing—Enclosure around the prestressing steel to avoid temporary or permanent bond between the prestressing steel and the surrounding concrete.

3. Prestressing Steel

3.1. Wire—Wire used in post-tensioning tendons shall conform to ASTM A-421, "Specifications for Uncoated Stress-Relieved Wire for Prestressed Concrete." Oil tempered wires shall not be used.

3.2. Strand—Strand used in post-tensioning tendons shall conform to ASTM A-416, "Specifications for Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete."

3.3. Strand or wire not specifically itemized in ASTM A-416 or A-421, including low relaxation strand or wire, may be used provided they conform to the minimum requirements of these specifications and have no properties which make them less satisfactory than those listed in ASTM A-416 or A-421.

3.4. High Strength Alloy Steel Bars—

3.4.1. Bars, during manufacture, shall be cold stretched (proof stressed) to the minimum yield strength as indicated in 3.4.2. After stretching, all bars shall be subjected to a stress-relieving heat treatment to produce the prescribed physical properties.

3.4.2. After processing, the physical properties of the bars shall conform to the amounts prescribed in Tables 1 and 2.

Table 1. Physical properties of smooth bars

Nominal diameter in.	Nominal area sq. in.	Minimum breaking strength kips		Minimum yield strength @ 0.7% extension kips	
		Grade 145	Grade 160	Grade 145	Grade 160
¾	0.442	64	71	58	62
⅞	0.601	87	96	78	84
1	0.785	114	126	102	110
1⅛	0.994	144	159	129	139
1¼	1.227	178	196	160	172
1⅜	1.485	215	238	193	208

Table 2. Physical properties of deformed bars

Nominal diameter in.	Effective area sq. in	Minimum breaking strength kips		Minimum yield strength @ 0.7% extension kips		Weight lb./ft.
		Grade 150	Grade 160	Grade 150	Grade 160	
⅝	0.290	43	46	37	39	0.97
¾	0.433	65	69	55	59	1.53
1	0.854	128	136	109	116	3.00
1¼	1.295	194	207	165	176	4.55

3.4.3. Approximate modulus of elasticity (based on nominal area) of 30,000,000 psi.

3.4.4. Minimum elongation in 20 diameters after rupture of 4.0 percent.

3.4.5. Minimum reduction of area from measured area of 20 percent.

3.4.6. Bars shall be fabricated and processed to meet the above physical specifications from steel conforming to ASTM Designations A-322 and A-29.

3.4.7. Permissible variation is bar size is + 0.030 in., − 0.010 in. from nominal specified diameter for smooth bars and + 3 percent, −2 percent from nominal weight for deformed bars.

3.4.8. Tests to determine the physical properties shall be performed on full sections of bars.

4. Bonded Tendons

4.1. Anchorages—The anchorages shall develop at least 90 percent of the minimum specified ultimate strength of the prestressing steel, tested in an unbonded state without exceeding anticipated set. The anchorage shall be so arranged that the prestressing force of the tendon may be verified prior to removal of the stressing equipment, if so desired.

4.2. Sheathing—Sheathing material for bonded tendons shall be strong enough to retain its shape and resist unrepairable damage during construction. It shall prevent the entrance of cement paste from the concrete. Material left in place shall not cause harmful electrolytic action nor deteriorate. The inside diameter shall be at least ¼ in. larger than the nominal diameter of single wire, bar or strand tendons, or in the case of multiple wire, bar or strand tendons, the inside cross-sectional area of the sheathing shall be at least two times the net area of the prestressing steel. Sheathing shall be capable of transmitting forces from grout to the surrounding concrete.

Sheathing shall have grout openings at each end and at all high points except where tendon curvature is small and the tendon is relatively level, such as in continuous slabs.

Drain holes shall be provided at low points if the tendon is to be placed, stressed and grouted in freezing climate.

4.3. Grout—

4.3.1. Grout shall consist of a mixture of portland cement, water and an expansive admixture approved by the Engineer.

4.3.2. Cement used for grout shall be fresh portland cement, sieved and free of lumps, Types I, II or III, in accordance with ASTM C-150. Air-entraining cement shall not be used. When Type III cement is used, care shall be taken against too early hardening, particularly in hot weather.

4.3.3. Water used in mixing grout shall be potable.

4.3.4. Approved admixtures shall not contain chlorides, fluorides or nitrates. The admixture may be dispensed in solid or liquid form. The expansive admixture shall produce a minimum unconfined expansion of the grout of 2 percent and a maximum of 10 percent.

4.3.5. Proportions of materials shall be based on tests made on the grout before grouting is begun. The water content shall be the minimum necessary for proper placement, and shall not exceed a water-cement ratio of 0.45 (approximately 5 gallons of water per sack of cement). The pumpability of the grout may be determined by the Engineer in accordance with the U.S. Corps of Engineers Method CRD-C79. When this method is used, the efflux time of a grout sample immediately after mixing shall not be less than 11 seconds.

4.3.6. All grout shall pass through a screen with 0.07 in. maximum clear openings prior to being introduced into the grout pump.

4.4. Couplings—Couplings of bonded tendons shall be used only at locations specifically indicated and/or approved by the Engineer. Couplings shall not be used at points of sharp tendon curvature. All couplings shall develop at least 95 percent of the minimum specified

ultimate strength of the prestressing steel without exceeding anticipated set. The coupling of tendons shall not reduce the elongation at rupture below the requirements of the tendon itself. Couplings and/or coupling components shall be enclosed in housings long enough to permit the necessary movements, and fittings shall be provided to allow complete grouting of all the coupling components.

4.5. Multiple Tendons—Tendons composed of multiple strands, wires or bars in a common sheath should be tensioned simultaneously unless the effects of interferences between the elements are considered.

4.6. Ultimate Strength—Ultimate strength for bonded tendons shall not be taken greater than the ultimate capacity of the anchorages or couplings when they are located at critical sections under ultimate load. Bond transfer lengths between anchorages and the zone where full prestressing force is required under service and ultimate loads shall be sufficient to develop the specified ultimate strength of the prestressing steel.

5. Unbonded Tendons

5.1. Anchorages—The anchorages of unbonded tendons shall develop at least 95 percent of the minimum specified ultimate strength of the prestressing steel without exceeding anticipated set. The total elongation under ultimate load of the tendon shall not be less than 2 percent measured in a minimum gauge length of 10 ft.

5.2. Coating—Unbonded tendons shall have the prestressing steel permanently protected against corrosion by a properly applied coating of galvanizing, epoxy, grease, wax, plastic, bituminous or other approved material. The coating shall remain ductile and free from cracks and shall not become fluid over the entire operating or anticipated range of temperatures. The coating shall be chemically stable, and be nonreactive to cement, chlorides, and the material used for sheathing. The coating material shall adhere to and be continuous over the entire tendon length to be unbonded.

5.3. Sheathing—The sheathing for unbonded tendons shall have sufficient tensile strength and water-resistance to resist unrepairable damage and deterioration during transport, storage at jobsite, and installation. The sheathing shall be continuous over the tendon length to be unbonded. The sheathing shall prevent the intrusion of cement paste and the escape of coating material. The sheathing may be a continuous tube or spirally wrapped.

5.4. Couplings—Couplings of unbonded tendons shall be used only at locations specifically indicated and/or approved by the Engineer. Couplings shall not be used at points of sharp tendon curvature. All couplings shall develop at least 95 percent of the minimum specified ultimate strength of the prestressing steel without exceeding anticipated set. The coupling of tendons shall not reduce the elongation at rupture below the requirements of the tendon itself. Couplings and/

or coupling components shall be enclosed in housings long enough to permit the necessary movements. All the coupling components shall be completely protected with a coating material prior to final encasement in concrete.

5.5. Multiple Tendons—Tendons composed of multiple strands, wires or bars in a common sheath should be tensioned simultaneously unless the interferences between the elements are considered.

5.6. Ultimate Strength—Ultimate strength for unbonded tendons shall not be taken greater than the ultimate capacity of the anchorages or couplings.

6. Bearing Stresses

The average bearing stresses of the concrete created by the anchorage shall not exceed the values allowed by the following equations:

At service load—

$$f_{cp} = 0.6\, f'_c \sqrt{A'_b / A_b}$$

but not greater than f'_c

At transfer load—

$$f_{cp} = 0.8\, f'_{ci} \sqrt{(A'_b / A_b) - 0.2}$$

but not greater than $1.25\, f'_{ci}$

where f_{cp} = permissible compressive concrete stress

f'_c = compressive strength of concrete

f'_{ci} = compressive strength of concrete at time of initial prestress

A'_b = 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 = bearing area of the anchorage

As used in the above equations, f_{cp} is the average bearing stress, P/A, in the concrete computed by dividing the force P of the prestressing steel by the net projected area, A_b, between the concrete and the bearing plate or other structural element of the anchorage which has the function of transferring the force to the concrete.

Special reinforcement, required for the performance of the anchorage, shall be indicated by the tendon supplier.

7. Static and Dynamic Test Requirements

7.1. Static Tests—The test assembly shall consist of standard production quality components and the tendons shall be at least 10 ft. long. The test assembly shall be tested in such a manner to allow accurate deter-

mination of the yield strength, ultimate strength and percent elongation of the complete tendon to insure compliance with this specification. The specimen used for the static test need not be one that has been subjected to dynamic loading.

7.2. Dynamic Tests—A dynamic test shall be performed on a representative specimen and the tendon shall withstand, without failure, 500,000 cycles from 60 percent to 66 percent of its minimum specified ultimate strength, and also 50 cycles from 40 percent to 80 percent of its minimum specified ultimate strength. The period of each cycle involves the change from the lower stress level to the upper stress level and return to the lower. The specimen used for the second dynamic test need not to be the same used for the first dynamic test. Systems utilizing multiple strands, wires or bars may be tested utilizing a test tendon of smaller capacity than the full size tendon. The test tendon shall duplicate the behavior of the full size tendon and generally shall not have less than 10 percent of the capacity of the full size tendon. Dynamic tests are not required on bonded tendons, unless the anchorage is located or used in such manner that repeated load applications can be expected on the anchorage.

8. Specification Compliance Requirements

8.1. Conformance Testing—The adequacy of a tendon system shall be confirmed by satisfactory static and dynamic conformance tests in accordance with the minimum requirements outlined in Section 7.

8.2. Compliance—The Engineer shall require that data be submitted to show compliance with the provisions of Section 7.

8.3. Prestressing Steel—Certified mill test results and typical stress-strain curves shall be submitted when requested. The typical stress-strain curve shall be obtained by approved standard practices. For materials not covered by Section 3, the guaranteed breaking strength, yield strength, elongation, composition and other pertinent data shall be submitted. In this case, samples from each heat (or lot in case of strands), properly marked, shall be provided for verification of prestressing steel quality.