

RECOMMENDED PRACTICE FOR GROUTING OF POST-TENSIONED PRESTRESSED CONCRETE

Prepared by PCI Committee on Post-Tensioning

Peter Reinhardt
Chairman

Ted Brown
Ned H. Burns
Brian Carter
Eugene E. Dabney
Loris Gerber
Robert L. Koons
James R. Libby
Robert J. McLean

H. Kent Preston
Charles Rejcha
Morris Schupack
William Slater
Mario G. Suarez
David Swanson
Adolph Walser

These recommendations cover the grouting of post-tensioning tendons of prestressed concrete members. The purpose of grouting is to provide permanent protection to the post-tensioning steel and to develop bond between prestressing steel and the surrounding concrete. These procedures also apply to grouting of rock and soil anchors. However, more detailed consideration must be given to grout strength and injection procedures.

The contents of this report include definitions materials, ducts, equipment, mixing of the grout, grouting, and temperature considerations. The Appendix includes a reprint of U.S. Corps of Engineers Method CRD-C79-58, "Method of Test for Flow of Grout Mixtures (Flow-Cone Method)." After most sections, there is an appropriate commentary (in italics) to guide specifiers using this recommended practice.

This document was originally developed and subsequently revised by a joint committee of the Prestressed Concrete Manufacturers Association of California (PCMAC) and Western Concrete Reinforcing Steel Institute. The original recommended practice, "Guide Specification on Grouting of Post-Tensioning Tendons," was published by the PCMAC and unfortunately received limited distribution. It was the intent of the PCI Committee on Post-Tensioning to revise this document and have it published as a PCI specification in order to get broader distribution and acceptance by the industry.

1. General

1.1 Scope and purpose

These procedures also apply to grouting of rock and soil anchors. However, since the hardened grout in rock and soil anchor applications sustain the full post-tensioning force, more detailed consideration must be given to grout strength and injection procedures.

1.1.1 These recommendations cover the grouting of post-tensioning tendons of prestressed concrete members.

1.1.2 The purpose of grouting is to provide permanent protection to the post-tensioning steel and to develop bond between the prestressing steel and the surrounding concrete.

1.2 Definition of terms

All terms and symbols are as defined in "Guide Specification for Post-Tensioning Materials" published by the Prestressed Concrete Institute.

1.2.1 Admixture—Any material added to the grout other than portland cement and water.

1.2.2 Duct—The hole or void provided in the concrete for the post-tensioning tendon.

1.2.3 Grout—A mixture of cement and water with or without admixtures.

Although sand has not been used in grouting practices in the United States, it may have advantages in tendons with large void areas. Fly ash and pozzolans are occasionally used as filler materials in the United States.

1.2.4 Grout opening or vent—An inlet, outlet, or vent in the duct for grout, water, or air.

1.2.5 Post-tensioning—The method of prestressing concrete in which the tendon is stressed after the concrete has reached a specified strength.

1.2.6 Post-tensioning tendons—The complete assembly consisting of anchorage and prestressing steel with sheathing when required. The tendon

imparts prestressing forces to the concrete.

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

2. Materials

2.1 Portland cement

Portland cement should conform to one of the following:

Specifications for portland cement—ASTM C 150, Types I, II or III. Cement used for grouting should be fresh and should not contain any lumps or other indication or hydration or "pack set."

Normally, Type III Cement is only used for cold weather grouting. Trial mixes are necessary to determine an appropriate mix design using Type III Cement.

2.2 Water

The water used in the grout should be potable, clean and free of injurious quantities of substances known to be harmful to portland cement, or prestressing steel.

Known harmful substances are chlorides, florides, sulphites and nitrates.

2.3 Admixtures

Admixtures, if used, should impart the properties of low water content, good flowability, minimum bleed and expansion if desired. Its formulation should contain no chemicals in quantities that may have harmful effect on the prestressing steel or cement. Admixtures containing chlorides (as Cl⁻ in excess of 0.5 percent by weight of admixture, assuming 1 lb of admixture per sack (94 lb) of cement), florides, sulphites and nitrates should not be used.

Aluminum powder of the proper fineness and quantity or other approved gas evolving material which is well dispersed through the other admixture

may be used to obtain 5 to 10 percent unrestrained expansion of the grout.

All admixtures should be used in accordance with the instructions of the manufacturer.

Admixtures commonly used to provide expansion of the grout may also reduce the water requirement, or improve flowability at a given water content, and retard set. Such admixtures are normally used. However, research in progress for basically horizontal tendons in rigid ducts suggest that satisfactory grout quality may be achieved without admixtures.

Current international standards suggest that bleeding may be measured in a metal or glass cylinder with an internal diameter of approximately 4 in., with a height of grout of approximately 4 in. However, recent research in the United States indicates that more representative test results may be achieved using a grout specimen of approximately 20 in. height and 1½ in. diameter. During the test, the container should be covered to prevent evaporation. It is suggested that the following approximate limits on bleeding be used to evaluate the acceptability of the grout: 2 percent of the volume 3 hours after mixing; a maximum of 4 percent. In addition, the separated water should be absorbed after 24 hours.

3. Ducts

3.1 Forming

(a) *Formed ducts*—Ducts formed by sheath left in place should be of a type that would not permit the entrance of cement paste. They should transfer bond stresses as required and should retain shape under the weight of the concrete. Metallic sheaths should be of a ferrous metal, and they may be galvanized.

(b) *Cored ducts*—Cored ducts should be formed with no constrictions which would tend to block the passage

of grout. All coring materials should be removed.

Materials commonly used for formed ducts are 22 to 28 gage galvanized or bright spirally wound or longitudinally seamed steel strip with flexible or semirigid seams.

3.2 Grout openings or vents

All ducts should have grout openings at both ends. For draped cables all high points should have a grout vent except where cable curvature is small, such as in continuous slabs. Grout vents or drain holes should be provided at low points if the tendon is to be placed, stressed and grouted in a freezing climate. All grout openings or vents should include provisions for preventing grout leakage.

Research in progress suggests that high point grout vents may be eliminated for bridge tendons up to 400 ft long in rigid conduit. However, current practice does utilize high point grout vents.

Material used for grout vents or drain holes may be either plastic or ferrous metal.

Grout vent details for rock and soil anchors require special considerations particular to the applications.

3.3 Duct size

For tendons made up of a plurality of wires, bars, or strands, duct area should be at least twice the net area of the prestressing steel.

For tendons made up of a single wire, bar or strand, the duct diameter should be at least ¼ in. larger than the nominal diameter of the wire, bar or strand.

3.4 Placement of ducts

After placing of ducts, reinforcement and forming is complete, an inspection should be made to locate possible duct damage. Ducts should be securely fastened at close enough intervals to avoid displacement during concreting.

All unintentional holes or openings in the duct must be repaired prior to concrete placing.

Grout openings and vents must be securely anchored to the duct and to either the forms or to reinforcing steel to prevent displacement during concrete placing operations.

There are two methods of placing tendons. First, preassembled tendons may be placed as a unit prior to placing concrete. Second, bearing plates and duct sheathing may be installed prior to placing the concrete, and then after concreting, the prestressing steel and anchorages are installed. Supports for preplaced tendons must be adequate to resist the tendon weight. When only the duct is placed prior to concreting, supports must resist buoyancy forces.

4. Equipment

4.1 The grouting equipment should include a mixer capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement. The equipment should be able to pump the mixed grout in a manner which will comply with all provisions of this recommended practice.

Commercially available plaster and concrete mixers are not suitable for mixing grout.

4.2 Accessory equipment which will provide for accurate solid and liquid measures should be provided to batch all materials.

4.3 The pump should be a positive displacement type and be able to produce an outlet pressure of at least 150 psig. The pump should have seals adequate to prevent introduction of oil, air or other foreign substance into the grout, and to prevent loss of grout or water.

4.4 A pressure gauge having a full scale reading of no greater than 300 psi should be placed at some point in the

grout line between the pump outlet and the duct inlet.

It is suggested that standby water flushing equipment should be available where difficult grouting conditions exist. This equipment should be in addition to the grouting equipment. The standby water flushing equipment should utilize a different power source than the grouting equipment, have sufficient capacity to flush out any partially grouted enclosures if necessary due to blockage or breakdown of grouting equipment, and should be capable of developing a pressure of at least 300 psig.

4.5 The grouting equipment should contain a screen having clear openings of 0.125 in. maximum size to screen the grout prior to its introduction into the grout pump. If a grout with a thixotropic additive is used, a screen opening of $\frac{3}{16}$ in. is satisfactory. This screen should be easily accessible for inspection and cleaning.

A thixotropic grout undergoes marked changes in fluidity depending on whether the grout is in motion or quiescent. This property is produced by additives.

4.6 The grouting equipment should utilize gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.

4.7 Under normal conditions, the grouting equipment should be capable of continuously grouting the largest tendon on the project in no more than 20 minutes.

5. Mixing of grout

5.1 Water should be added to the mixer first, followed by portland cement and admixture, or as required by the admixture manufacturer.

5.2 Mixing should be of such duration as to obtain a uniform thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. The grout should be continuously agitated until it is pumped.

Equipment currently in use normally requires 1½ to 3 minutes to satisfactorily mix the grout.

5.3 Water should not be added to increase grout flowability which has been decreased by delayed use of the grout.

5.4 Proportions of materials should be based on tests made on the grout before grouting is begun, or may be selected based on prior documented experience with similar materials and equipment and under comparable field conditions (weather, temperature, etc.). The water content shall be the minimum necessary for proper placement, and when Type I or II cement is used should not exceed a water-cement ratio of 0.45 or approximately 5 gallons of water per sack (94 lb) of cement.

The water content required for Type III cement should be established for a particular brand based on tests.

The pumpability of the grout may be determined by the Engineer in accordance with the U.S. Corps of Engineers Method CRD-C79 (see Appendix). When this method is used, the efflux time of the grout sample immediately after mixing should not be less than 11 seconds. The flow cone test does not apply to grout which incorporates a thixotropic additive.

Hardened grout made in accordance with this specification at a temperature of 65 F and a relative humidity of approximately 70 percent will produce 28-day compressive strengths of about 4000 psi when cured under confined conditions.

6. Grouting

6.1 Preparation of duct

6.1.1 Flushing of metal ducts should be optional with the post-tensioning contractor.

Historically, flushing has been used to clear the duct of foreign materials, and to wet the duct and tendon surfaces to improve the groutability. When tendons are flushed, the water may be removed by oil-free air, or it may be displaced by the grout. In recent years, grouting experiences with rigid conduit and prestressing steel placed after concreting indicate that flushing is not necessary and may be undesirable for large tendons since it is difficult to remove the water from the duct.

6.1.2 Ducts with concrete walls (cored ducts) should be flushed to ensure that the concrete is thoroughly wetted.

6.1.3 Water used for flushing ducts may contain slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.1 lb per gallon.

6.2 Injection of grout

6.2.1 All grout and high point vent openings should be open when grouting starts. Grout should be allowed to flow from the first vent after the inlet pipe until any residual flushing water or entrapped air has been removed, at which time the vent should be capped or otherwise closed. Remaining vents should be closed in sequence in the same manner.

6.2.2 The pumping pressure at the tendon inlet should not exceed 250 psig.

When pumping grout, pressures in excess of 250 psi result in a separation of water and cement, which may cause a blockage. Excessive pressures could also result in cracking or damage to the structural element. It is therefore advisable to keep grout

pumping pressures under this level. This can be done by visually monitoring the pressure gage, or by equipment which includes automatic or manual bypasses.

6.2.3 If the actual grouting pressure exceeds the maximum recommended pumping pressure, grout may be injected at any vent which has been, or is ready to be, capped as long as a one-way flow of grout is maintained. If this procedure is used, then the vent which is to be used for injection should be fitted with a positive shutoff.

6.2.4 When one-way flow of grout cannot be maintained as outlined in Section 6.2.3, the grout should be immediately flushed out of the duct with water.

6.2.5 Grout should be pumped through the duct and continuously wasted at the outlet pipe until no visible slugs of water or air are ejected and the efflux time of the ejected grout should not be less than the injected grout. To insure that the tendon remains filled with grout, the outlet and/or inlet should be closed. Plugs, caps or valves thus required should not be removed or opened until the grout has set.

Current research indicates that use of standpipes at high points of grouted tendons is a satisfactory substitute for a positive means of shutoff. Standpipes permit free expansion which tends to push out any bleed water that may occur at high points.

Vertical or nearly vertical tendons made up of strands, which tend to act as filters for the grout, require special consideration. Because of exaggerated bleed, special grouting techniques should be used to ensure complete filling of the top portion of the tendon. This may be achieved by two stages of grouting, free expansion of grout pushing the bleed water out at the high points, or admixtures which increase the water retentivity so that bleed is controlled.

7. Temperature considerations

7.1 In temperatures below 32 F, ducts should be kept free of water to avoid damage due to freezing.

This is normally accomplished with low point drains.

7.2 Concrete temperature—The temperature of the concrete should be 35 F or higher from the time of grouting until job cured 2 in. cubes of grout reach a minimum compressive strength of 800 psi.

At 35 F grout may be expected to reach 800 psi cube strength in about 5 days.

7.3 Grout temperature—Grout should not be above 90 F during mixing or pumping. If necessary, the mixing water should be cooled.

Difficulties in pumping grout may occur when the grout temperature in the mixer exceeds 90 F.

(See p. 25 for Appendix)

Discussion of this committee report is invited. Please forward your discussion to PCI Headquarters by March 1, 1973, to permit publication in the March-April 1973 issue of the PCI JOURNAL.

APPENDIX

(Issued 1 Sept. 1958)

CRD-C 79-58

METHOD OF TEST FOR FLOW OF GROUT MIXTURES (Flow-Cone Method)

Scope

1. This method of test covers the procedure to be used both in the laboratory and in the field for determining the flow of grout mixtures by measuring the time of efflux of a specified volume of grout from a standardized flow cone.

Apparatus

2. (a) Flow Cone. — The flow cone shall conform to the dimensions and other requirements indicated in Fig. 1.

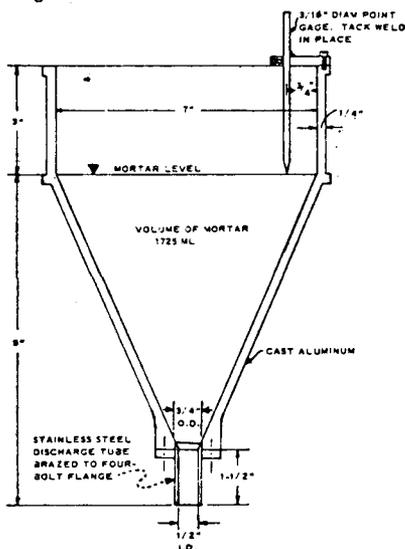


Fig. 1. Cross section of flow cone

(b) Stop Watch. — A stop watch having a least reading of not more than 0.2 sec.

Calibration of Apparatus

3. The flow cone shall be firmly mounted in such a manner that the

top will be level and the cone free from vibration. The discharge tube shall be closed by placing the finger over the lower end. A quantity of water equal to 1725 ± 1 ml shall be introduced into the cone. The point gage shall be adjusted to indicate the level of the water surface.

Sample

4. The test sample shall consist of 1725 ± 1 ml of gout.

Procedure

5. Moisten the inside surface of the flow cone (Note). Place the finger over the outlet of the discharge tube. Introduce grout into the cone until the grout surface rises into contact with the point gage. Start the stop watch and remove the finger simultaneously. Stop the stop watch at the first break in the continuous flow of grout from the discharge tube. The time indicated by the stop watch is the time of efflux of the grout. At least two tests shall be made for any grout mixtures.

Note. — A recommended procedure for insuring that the interior of the cone is properly wetted is to fill the cone with water and, one minute before beginning to add the grout sample, allow the water to drain from the cone.

Report

6. The report shall include:

- (a) Average time of efflux to the nearest 0.2 sec,
- (b) Temperature of the sample at the time of test,
- (c) Ambient temperature at the time of test,
- (d) Composition of the sample, and
- (e) Information on the physical characteristics of the sample.