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QUALIFICATION FOR CEMENT GROUTING FOR PRESTRESSING TENDONS IN CONTAINMENT STRUCTURES

A. INTRODUCTION

This guide describes a method that U.S. Nuclear Regulatory Commission (NRC) staff (staff) considers acceptable for the use of portland cement grout as the corrosion inhibitor for prestressing tendons in prestressed concrete containment structures. This guide also provides quality standards for using portland cement grout to protect prestressing steel from corrosion.

The regulatory framework that the NRC has established for nuclear power plants consists of regulations and supporting guidelines, including, but not limited to, General Design Criterion (GDC) 1, “Quality Standards and Records” (Ref. 1), as set forth in Appendix A, “General Design Criteria for Nuclear Power Plants,” to Title 10 of the *Code of Federal Regulations,* Part 50, “Domestic Licensing of Production and Utilization Facilities” (10 CFR Part 50), and 10 CFR 50.55a, “Codes and Standards.”

GDC 1 of Appendix A to 10 CFR Part 50 states, in part, that structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. In addition, where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to ensure a quality product in keeping with the required safety function.

The prestressing tendon system of a prestressed concrete containment structure is a principal strength element of the structure. The ability of the containment structure to withstand the events postulated to occur during the life of the structure depends on the functional reliability of the structure’s principal strength elements. Thus, any significant deterioration of the prestressing elements caused by corrosion may present a potential risk to public safety. It is important that any system for inhibiting the corrosion of prestressing elements must possess a high degree of reliability in performing its intended function.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number. This Regulatory Guide is a rule as designated in the Congressional Review Act (5 U.S.C. 801–808). However, the NRC has determined this Regulatory Guide is not a major rule as designated by the Congressional Review Act and has verified this determination with the OMB.

B. DISCUSSION

Background

The recommendations of this guide are applicable when portland cement grout is used as the corrosion inhibitor for the highly stressed tendons of prestressed concrete containment structures. The recommendations of this guide are not intended for use in relation to the grout for foundation anchors.

To date, the staff has evaluated applications proposing grout as the corrosion protection system for both bar and strand tendons. The recommendations of this regulatory guide therefore apply to a grouted tendon system when the tendon is fabricated from either bars or strands. For the grouting of wire tendons, the applicant may develop a program based on similar quality standards listed in the Reference section, Bibliography, and Appendix A and submit it for staff evaluation.

Unlike greased tendons, grouted tendons are not available for direct inspection after they are grouted. Applicants are advised to thoroughly evaluate the proposed grout and grouting procedure before using the grout in the construction of the containment structure.

It is recommended that the applicants for a grouted tendon system demonstrate that the proposed system will provide a high level of reliability in every step in the design and installation of the system. It is strongly suggested that the containment post tensioning system design incorporate the following:

- preinstallation testing that would demonstrate acceptability of the system components (Ref. 4),
- a postinstallation verifications process that would ensure that the transportation and storage of the system components have not affected their reliability in service,
- a grouting procedure as recommended in this regulatory guide, and
- an inservice inspection program that would demonstrate the functionality of the containment on a periodic basis (Ref. 2).

The American Society of Mechanical Engineers (ASME) and the American Concrete Institute (ACI) have jointly published the "Code for Concrete Containments," known as either the ASME Boiler and Pressure Vessel Code, Section III, Division 2, or ACI Standard 359, which this guide refers to as "the ASME Code" (Ref. 3). This regulatory guide endorses the sections related to cement grout for grouted tendon systems of the 2001 edition of the ASME Code with the 2003 addenda, with the exceptions discussed herein.

Significant technological advances in posttensioned highway bridge construction and other building structures, as well as due to changes made in the ASME Code, have prompted a need to revise this regulatory guide for the qualification of cement grouting for prestressing tendons in containment structures. The ASME Code provides some requirements for grout constituents and for the physical and chemical properties of grout. Section C of this guide briefly describes minimum quality standards for grout materials and references the ASME Code articles where the NRC staff has found them to be applicable and acceptable. The regulatory position also outlines important considerations that affect proper grouting. To establish this position, the staff has used References 4, 5, 6, and 7, as well as data furnished by applicants that have proposed grout as the corrosion inhibitor for prestressing steel.

Table A-1 of Appendix A to this regulatory guide lists relevant American Society of Testing and Materials (ASTM) standards that the applicant may use to establish procedures and criteria for the specific grouted tendon program. However, the listing of these references does not constitute a blanket endorsement by the staff of their content. The following paragraphs discuss specific areas of concern that the NRC staff recommends applicants satisfactorily address during the development of a grouted tendon system.

The effectiveness of grout to perform its intended function of inhibiting corrosion depends mainly on the following two characteristics:

(1) The grout (whether freshly mixed or hardened) should not cause a chemical attack on the prestressing elements through its interaction with the material of the tendon steel, the anchor hardware, or the duct.

(2) The grout should completely fill the tendon duct on hardening to prevent water from collecting and freezing.

Various deleterious chemicals and chemical compounds, such as chlorides, nitrates, sulfates, and sulfides, have been reported as potential sources of corrosion of prestressing steel. Most of the reported failures of prestressing elements have been attributed to the presence of (1) chlorides in the atmosphere or in the constituents of grout or (2) hydrogen sulfide in the atmosphere (Refs. 8, 9, and 12). Nitrates and sulfates generally found in mixing water have been postulated to be potential sources of stress corrosion of prestressing steel. However, Reference 10 reports that oxygenated anions such as sulfates and nitrates do not exhibit intense corrosive properties in a concrete environment, and Reference 5 reports that most chlorides are neutralized during the hydration of portland cement. The threshold values below which some of these substances will not participate in initiating corrosion have not been established. Hence, ensuring that these corrosion promoters are limited to the lowest practical levels in grout constituents would be a safe and prudent approach. Water contaminated with hydrogen sulfide should not be used for grouting.

The limits recommended for chlorides, nitrates, sulfates, and sulfides in Regulatory Position C.l should not be exceeded in the overall composition of the grout. The quantities of these chemical compounds in each of the grout constituents should be determined individually by the applicable ASTM methods listed in Appendix A.

Portland cement that conforms to Type I or Type II cement in ASTM C150-07, "Standard Specification for Portland Cement" (*see* Table A-1 of Appendix A to this guide), is suitable for the grout. However, grouting under certain climatic or environmental conditions may dictate the use of other types of cement. Chlorides are normally present in cement, but the amount is usually not reported. The determination of chlorides in cement should be a requirement when specifying the cement for grout.

Admixtures should be free of any substance likely to damage the prestressing steel. Practical experience by engineers viewed the use of aluminum powder to produce expansion as having possible deleterious effects (Ref. 8). Under an alkaline environment (with a pH greater than 9), the aluminum powder generates minute bubbles of hydrogen gas, which would not endanger the tensioned steel at the prevailing range of pressures and temperatures. However, the potential for an attack of hydrogen on steel does exist if the tensioned steel elements or stressed anchorage components contain surface flaws and laminations. ACI 212.3R-04, "Chemical Admixtures for Concrete," issued 2004 (Ref. 7), prohibits the use of aluminum powder.

The protective mechanism of grout is primarily dependent on its ability to provide a continuous alkaline environment around the tensioned steel elements. The natural alkalinity of the primary product of cement hydration (i.e., calcium hydroxide) tends to be at a pH value of 12.5. The leaching of alkaline compounds with water, a possible reaction in an acidic or sulfide-containing environment, or the presence of oxygen and chloride ions may individually and collectively reduce the effectiveness of the alkaline environment. Reference 11 reports that the ability of chloride ions to develop corrosion increases with the decreasing alkalinity of the calcium hydroxide solutions. Thus, it is advisable to monitor the pH value of the in-place grout under actual field conditions and ensure that it remains above a value at which the available chloride ions in the composition of the grout do not reduce the passivating effect of the grout.

In addition, a general practice is to use a grout pump of the positive displacement type and be able to maintain an outlet pressure of at least 1 newton per square millimeter (mm) (145 pounds per square inch (psi)) (see Refs. 4 and 5). However, grout with a thixsotropic additive may need higher pumping pressures for long vertical tendons. The applicant should conduct tests to demonstrate that high pressures will not deteriorate the quality of grout; damage the duct, duct splices, or surrounding concrete; or deform the containment liner.

In addition to controlling the chemical composition of grout materials and the mixing and injection of the grout to ensure the intended protection of the prestressing steel, applicants are advised to take other precautions to mitigate the corrosion of the prestressing steel, such as:

- Keep the tendon clean, dry, free from deleterious corrosion, and undamaged up to the time it is grouted. Specific protection measures should be provided at coastal sites, at sites that have a high moisture level, or at sites near industrial areas.

- Protect a preassembled tendon-sheathing assembly that is to be installed before concreting against a corrosive environment during assembly, handling, storage, transportation, placement, and tensioning.

- Before placing the tendon in the duct, ascertain that the duct is free of obstructions, moisture, and other deleterious substances.

- Ensure that ducts used to protect grouted tendons are mortar-tight and nonreactive with concrete, prestressing steel, and grout. The contact surfaces of the tendons and the sheathing are potential areas for the formation of corrosion cells and hydrogen evolution. From the perspective of tendon corrosion, this practice is critical if the elapsed time between the tensioning and grouting is long and if the duct contains moisture with or without deleterious substances.

- Take steps to minimize the time duration between tensioning and grouting processes. This is critical from the standpoint of stress corrosion or hydrogen stress cracking.

Portland cement grout can provide effective corrosion protection of prestressing tendons if applicants take the appropriate precautions to eliminate potential sources of corrosion. To this end, the highest achievable quality control is necessary for each constituent of the grout, the tendon material, the tendon duct material, and the method of mixing and pumping the grout and for ensuring that the tendon is surrounded from end to end with qualified grout.

C. REGULATORY POSITION

Codes, standards, specifications, and guides (listed in the Reference section, Bibliography, and Appendix A), either in their entirety or in part, cover the qualification for cement grouting for prestressing tendons in containment structures. The NRC staff considers the sections of the ASME Code, Section III, Division 2, "Code for Concrete Reactor Vessels and Containments," related to cement grout for grouted tendon systems to be acceptable, subject to the regulatory positions on specific code sections as described below.

1. CC-2241, Constituents for Cement Grout

Acceptable admixtures may be used if tests have demonstrated that their use improves the properties of grout (e.g., increases workability, reduces or controls bleeding, prevents water separation when pumped at high pressure, entrains air, expands the grout, or reduces shrinkage). The quantities of harmful chemical compounds in the admixture should be kept to a minimum. Hydrogen peroxide and powdered aluminum metal are not acceptable air-entraining admixtures (Ref. 7). Calcium chloride should not be used as a constituent of the admixture. The following are the limits on deleterious substances and pH:

a. The quantity of the following chemical compounds (added individually for each constituent and expressed as parts per million (ppm) parts of water) in the overall grout composition should not exceed the following limits (Ref. 13):

   (1) chlorides 100 ppm (200 ppm if the pH is maintained above 12),
   (2) nitrates 100 ppm,
   (3) sulfates* 250 ppm, and
   (4) sulfides 2 ppm (see Ref. 14 for the test method).

b. The pH value of the grout at the inlet and the outlet of the duct should be maintained above 11.6 (or 12, if the allowable chloride content is 200 ppm).

c. For the duration of the grouting period, the amount of deleterious chemical compounds in the grout constituents should be checked both weekly and whenever the composition of the grout constituents is changed or is suspected of having changed because of contamination, exposure, or source variation.

2. CC-2243.2, Physical Properties of the Grout

The water-cement ratio should be as low as possible for the proper pumping of the grout; however, the water-cement ratio should not exceed 0.45 by weight. Water shall not be added to increase grout flowability that has been decreased by delayed use of the grout.

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* Sulfates in the form of sulfur trioxide as a cement component need not be considered.

3. CC-2441, Tendon Ducts, Channels, Trumpets, and Transition Cones

The size of the duct should allow for the insertion and tensioning of tendons without undue difficulty. Vents and drains should be checked for possible obstructions before grouting. Ducts should be maintained free of water.

4. CC-4281, Equipment for Grouting

The grouting equipment should include a mixer that is capable of continuous mechanical mixing and that can produce a grout free of lumps and undispersed cement. To this end, the applicant should conduct tests to demonstrate the optimum range of mixing time and to determine the sequence of placing the constituent materials in the mixer under extreme anticipated environmental conditions.

A screen having clear openings not more than 3 mm (1/8 inch) for standard grout, and 5 mm (3/16 inch) for grout with a thixsotropic additive, should be provided between the mixed grout and the pump to ensure that the grout does not contain lumps. If lumps of cement remain on the screen, the batch should be rejected.

5. CC-4282, Grouting

The temperature at any point in the tendon duct during grouting shall be above 5 degrees Celsius (C) (40 degrees Fahrenheit (F)). The end anchorages and the tendon duct shall maintain above 5 degrees C (40 degrees F) for a period of 48 hours after grouting or until the grout reaches a minimum of 5.5 megapascals (MPa) (800 psi) compressive strength. The grout temperature should not exceed 32.2 degrees C (90 degrees F) during the mixing and pumping operations, unless the applicant can establish, through testing, that a higher temperature will not adversely affect the quality and performance of the grout.

An applicant that chooses to use qualified grout or concrete as a means to permanently protect the anchor hardware is strongly advised to provide the protection on the following bases:

a. All exposed anchor hardware should be thoroughly examined before being provided with the permanent protection.

b. The permanent protection should be designed and constructed in a manner that would prevent the intrusion of water and deleterious chemical compounds to the anchorage components.

6. CC-4432, Tendon Assembly

The tendon should be clean, dry, free from deleterious corrosion, and undamaged up to the time of grouting. The preassembled tendon sheathing assembly should be protected against corrosive influences when the assembly commences and during and at the end of the grouting operation.

D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[1] may use this guide and information regarding the NRC's plans for using this regulatory guide. In addition, it describes how the NRC staff complies with the Backfit Rule (10 CFR 50.109) and any applicable finality provisions in 10 CFR Part 52.

Use by Applicants and Licensees

Applicants and licensees may voluntarily[2] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged. The acceptable guidance may be a previous version of this regulatory guide.

Licensees may use the information in this regulatory guide for actions which do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59. Licensees may use the information in this regulatory guide or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this regulatory guide. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this regulatory guide, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this regulatory guide Examples of such unplanned NRC regulatory actions include; issuance of an order requiring the use of the regulatory guide, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this regulatory guide, generic communication, or promulgation of a rule requiring the use of this regulatory guide without further backfit consideration.

During inspections of specific facilities, the staff may recommend that licensees consider various actions consistent with staff positions in this regulatory guide, as one acceptable means of meeting the underlying NRC regulatory requirement. Such recommendations would not ordinarily be considered backfitting even if prior versions of this regulatory guide are part of the

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1 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52; and the term "applicants," refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

2 In this section, "voluntary" and "voluntarily" means that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

licensing basis of the facility with respect to the subject matter of the inspection. However, unless this regulatory guide is part of the licensing basis for a plant, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this regulatory guide constitutes a violation.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised regulatory guide and (2) the specific subject matter of this regulatory guide is an essential consideration in the staff's determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this regulatory guide or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to adhere to new rules, orders, or guidance if 10 CFR 50.109(a)(3) applies.

Conclusion

This regulatory guide is not being imposed upon current licensees and may be voluntarily used by existing licensees. In addition, this regulatory guide is issued in conformance with all applicable internal NRC policies and procedures governing backfitting. Accordingly, the NRC's staff issuance of this regulatory guide is not considered backfitting, as defined in 10 CFR 50.109(a)(1), nor is it deemed to be in conflict with any of the issue finality provisions in 10 CFR Part 52.

If a licensee believes that the NRC is either using this regulatory guide or requesting or requiring the licensee to implement the methods or processes in this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409 and NRC Management Directive 8.4.

GLOSSARY

admixture—Material added to the grout for the purpose of achieving certain properties.

anchorage—An assembly of various hardware components that secures a tendon at its ends after it has been stressed and imparts the tendon force into the concrete.

bar tendons—High-strength steel bars that are normally available from 16 to 44 millimeters (5/8 to 1-3/4 inches) in diameter and are usually threaded with very coarse thread.

bleed—The autogenous flow of mixing water within, or its emergence from, newly placed grout caused by the settlement of the solid materials within the mass.

corrosion—The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.

duct/sheath—A hole or void provided in the concrete for the posttensioning tendons. A duct may be provided by embedding metal sheathing in cast-in-place concrete.

grout—A mixture of cementitious materials and water, with or without mineral additives or admixtures, that is proportioned to produce a consistency that may be pumped without segregation of the constituents when injected into the duct to fill the space around the prestressing steel.

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

pH—A measure of the acidity or alkalinity of a solution, which is numerically equal to 7 for neutral solutions; pH increases with increasing alkalinity and decreases with increasing acidity. The pH scale commonly in use ranges from 0 to 14.

prestressing steel—Those elements of a posttensioning tendon that are tensioned and anchored to provide the necessary permanent prestressing force.

strand—An assembly of several high-strength steel wires wound together. A seven-wire strand usually consists of six outer wires wound in a long-pitch helix around a single straight wire of a similar diameter.

stress-corrosion cracking—Cracking of a metal produced by the combined action of corrosion and tensile stress (applied or residual).

tendon—A single or group of prestressing elements and their anchorage assemblies, which impart a compressive force to a structural member. Also included are ducts, grouting attachments, and grout. The main prestressing element is usually a high-strength steel member made up of a number of strands, wires, or bars.

thixotropic—A material property that enables the cement grout to stiffen in a short time while at rest but allows it to acquire a lower viscosity when mechanically agitated.

wire tendons—Tendons consisting of small-diameter, high-strength steel wires.

REFERENCES[3]

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.

2. Regulatory Guide 1.90, "Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons," U.S. Nuclear Regulatory Commission, Washington, DC.

3. ASME Boiler and Pressure Vessel Code, Section III, Division 2, "Code for Concrete Reactor Vessels and Containments," 2001 Edition through 2003 Addenda, American Society of Mechanical Engineers, New York, NY.[4]

4. "Guide Specification for Grouting of Post-Tensioned Structures," 1st Edition, Post-Tensioning Institute, Phoenix, AZ, February 2001.[4]

5. Maxwell-Cook, P.V., "Report on Grout and Grouting of Prestressed Concrete," *Proceedings of the Seventh Congress of the Fédération Internationale de la Précontrainte*, 1974.[4] International Federation for Structural Concrete (FIB—Fédération Internationale du Béton, the parent organization of Euro-International Concrete Committee (CEB) and International Federation for Prestressing (FIP), Case Postale 88, CH-1015 Lausanne, Switzerland.

6. ACI 301-05, "Specifications for Structural Concrete," American Concrete Institute, Farmington Hills, MI, 2006.[4]

7. ACI 212.3R-04, "Chemical Admixtures for Concrete," American Concrete Institute, Farmington Hills, MI, 2004.[4]

8. Szilard, R., "Corrosion and Corrosion Protection of Tendons in Prestressed Concrete Bridges," *American Concrete Institute Journal*, 66(1), January 1969: pp. 42–59.[4]

9. ACI 222R-01, "Protection of Metals in Concrete against Corrosion," American Concrete Institute, Farmington Hills, MI, 2001.[4]

10. Scott, G.N., "Corrosion Protection Properties of Portland Cement Concrete," *American Water Works Association Journal*, 57(8), August 1965.[4]

11. Hausman, D.A., "Steel Corrosion in Concrete," *Materials Protection*, National Association of Corrosion Engineers, Houston, TX, November 1967.[4]

12. Leonhardt, F., *Prestressed Concrete Design and Construction*, 2nd Edition, William Hurst, Berlin, 1964.[4]

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3 Publicly available NRC published documents are available electronically through the Electronic Reading Room on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR.Resource@nrc.gov.

2 Copies of the non-NRC documents included in these references may be obtained directly from the publishing organization.

13. NUREG/CR-0092, "Corrosion of Steel Tendons in Concrete Pressure Vessels—Review of Recent Literature and Experimental Investigations," U.S. Nuclear Regulatory Commission, Washington, DC, 1988.

14. *Standard Methods for the Examination of Water and Wastewater*, 21st Edition, American Public Health Association, Washington, DC, 2005.[4]

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<u>NUREG-Series Reports</u>

NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Chapter 3, "Design of Structures, Components, Equipment, and Systems," Section 3.8.1, "Concrete Containment," Revision 0, November 1975; Revision 1, July 1981; and Revision 2, March 2007.

<u>Regulatory Guide</u>

Regulatory Guide 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments," July 1990.

Non-NRC Documents

Gerwick, B.C., *Construction of Prestressed Concrete Structures*, 2nd Edition, John Wiley & Sons, Inc., New York, 1993.

Nawy, E.G., *Prestressed Concrete: A Fundamental Approach*, 2nd Edition, Prentice Hall, New Jersey, 1996.

Post Tension Tendon Installation and Grouting Manual, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, May 26, 2004.

APPENDIX A

LIST OF RELEVANT AMERICAN SOCIETY OF TESTING AND MATERIALS STANDARDS

Table A-1 lists relevant American Society of Testing and Materials (ASTM) standards by ASTM designation and title.

Table A-1 List of Relevant ASTM Standards

ASTM DESIGNATION	TITLE
C109-99	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. Cube Specimens)
C150-07	Standard Specification for Portland Cement
C185-08	Standard Test Method for Air Content of Hydraulic Cement Mortar
C191-08	Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C260-06	Standard Specification for Air-Entraining Admixtures for Concrete
C494-05	Standard Specification for Chemical Admixtures for Concrete
C937-02	Standard Specification for Grout Fluidifier for Preplaced Aggregate Concrete
C939-02	Standard Test Method for Flow of Grout for Preplaced Aggregate Concrete
C940-98	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
C942-04	Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory
C953-06	Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory
C1090-05	Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout
C1152-04	Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete
C1218-99	Standard Test Method for Water-Soluble Chloride in Mortar and Concrete
D512-04	Standard Test Methods for Chloride Ion in Water
D516-07	Standard Test Method for Sulfate Ion in Water
D596-06	Reporting Results of Analysis of Water
D1129-03	Terms Relating to Water
D1293-05	pH of Water and Waste Water
D3867-04	Standard Test Methods for Nitrite-Nitrate in Water