

Report on Corrosion and Repair of Grouted Multistrand and Bar Tendon Systems

Reported by Joint ACI-ASCE Committee 423



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First Printing
October 2010

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ISBN 978-0-87031-395-0

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This report gives general information regarding the evaluation of corrosion damage in structures reinforced with grouted multistrand and bar tendons. A review of current practice is included along with the historical background. Specific potential problem areas for grouted tendons are discussed for each critical part of the tendon. Current methods for evaluating corrosion damage and typical repair schemes are included.

Keywords: anchorage; bonded; corrosion; duct; durability; grout; post-tensioning; prestressed; repair; strand; tendon.

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ACI 423.8R-10 was adopted and published October 2010.
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CHAPTER 1—INTRODUCTION**1.1—General**

This report is intended to provide general information on the corrosion and repair of grouted multistrand and bar tendon systems. The information is intended to represent the state of knowledge of the committee in the areas of corrosion prevention in grouted tendons, as well as evaluation and repair. It is not intended as a standard or recommended practice. A strong background in durability of grouted post-tensioning systems, including practical experience and training, is recommended before designing, constructing, evaluating, or repairing these structures.

This report focuses on the unique materials and hardware associated with grouted post-tensioning tendons. General corrosion theory for metals in structural concrete systems is not within the scope of this report. Information on corrosion theory and mechanisms can be found in ACI 222R-01 and ACI 222.2R-01.

1.2—Background

The use of grouted high-strength wire, strand, and bar post-tensioning tendons as a viable construction technique began in North America in the 1950s. Components of the standard system have changed significantly over the last half-century from shimmed button-head wire-type systems to bundles of seven-wire strand systems with wedges (Post-Tensioning Institute 2006). Post-tensioning bars may also be used in grouted systems, although they have not changed significantly since their first introduction. The latest generation of post-tensioning systems includes multiple layers of corrosion protection due to an increased awareness of the importance of a durable system.

Grout material has also undergone significant changes over the past 50 years. For the majority of this time, a standard mixture of water and portland cement was used. Sometimes chemical admixtures were included to increase pumpability or to introduce expansion in an attempt to counteract settlement and voids. As early as the 1960s (Schupack 1971), it was recognized that bleed was a problem in grouts, which could cause significant voids in the tendon. In the 1970s, an anti-bleed admixture (Schupack 1973) was developed to reduce the bleeding tendencies of grouts. This formulation was used successfully in a number of major structures, but did not see widespread use in the post-tensioning bridge and building industries. During the late 1990s and early 2000s, prepackaged grout formulations containing anti-bleed admixtures gained significant popularity in the U.S. and continue to see widespread use. A sudden change in grouting materials in the late 1990s was primarily due to the discovery of several post-tensioned bridges in Florida that had tendon corrosion (Corven Engineering, Inc. 2001). Past performance of grouted post-tensioning systems is covered in more detail in Section 4.1.

Most layers of corrosion protection for post-tensioning steel have seen significant advances in the last 5 to 10 years. The discovery of corrosion problems has also led to more

standardized methods for the evaluation of corrosion damage and repair methods.

1.3—Scope

This report includes a review and summary of the following:

- Guide specifications and training as applied to grouted post-tensioning tendons;
- Potential problem areas in grouted systems;
- Durability enhancements for each component of the tendon;
- Evaluation of corrosion problems; and
- Repair methods for grouted systems.

1.4—Limitations

This report presents a summary of the typical problems that may occur in grouted post-tensioning systems and includes guidelines for evaluation and repair. The material is general in nature and may not apply to every situation. Due to the uniqueness of each post-tensioned structure, engineering judgment must be used to determine the appropriate action based on experience and the general guidance provided in this document.

This report is not intended to be included as part of a specification document for materials, evaluations, or repairs. Evaluation of grouted post-tensioned tendons is a difficult undertaking and no single method can be used to fully describe the damage or life expectancy of a tendon. Due to the many changes in materials and equipment over the last 50-plus years, the evaluator may encounter a wide variation in the types of systems encountered. Varying climates, environments, and the structure's usage and design also play a role in possible deterioration. The evaluator must be knowledgeable about the performance of similar structures under similar conditions to get an indication, if any, of internal damage of the structure.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," <http://terminology.concrete.org>. Definitions provided herein complement that resource.

admixture—a material other than water, aggregates, cementitious materials, and fiber reinforcement, used as an ingredient in a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing.

admixture, water-reducing—an admixture that either increases slump of freshly mixed mortar or concrete without increasing water content or maintains slump with a reduced amount of water, the effect being due to factors other than air entrainment.

backflow—a condition whereby the grout front reverses direction and flows back on top of the grout layer in the bottom of the duct.

bleed—the autogenous flow of mixing water within, or its emergence from, a newly placed cementitious mixture caused by the settlement of solid materials and the mass and filtering action of strands and wires.

cementitious materials—materials having cementing properties.

corrosion inhibitor—a chemical compound, either liquid or powder, usually intermixed in concrete and sometimes applied to concrete, and that effectively decreases corrosion of steel reinforcement.

duct—a conduit (plain or corrugated) to accommodate prestressing steel for post-tensioned concrete.

fluidity—a measure of time, expressed in seconds, necessary for a stated quantity of grout to pass through the orifice of the flow cone.

grout—a mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of the constituents; injected into the duct to fill the space around the tendon.

high-range water-reducing admixture—see **admix-ture, water-reducing**.

inlet—tubing or duct used for injection of grout into duct.

outlet—tubing or duct to allow the escape of air, water, grout, and bleed water from the duct.

post-tensioning—method of prestressing in which prestressing steel is tensioned after concrete has hardened.

set—the condition reached by a cement paste, mortar, or concrete when it has lost plasticity to an arbitrary degree, usually measured in terms of resistance to penetration or deformation; initial set refers to first stiffening; final set refers to attainment of significant rigidity; also, strain remaining after removal of stress.

set time—the lapsed time from the addition of mixing water to a cementitious mixture until the mixture reaches a specified degree of rigidity as measured by a specific procedure.

steel, prestressing—high-strength steel used to prestress concrete, commonly seven-wire strands, single wires, bars, rods, or groups of wires or strands.

tendon—an assembly consisting of a tensioned element (such as a wire, bar, rod, strand, or a bundle of these elements) used to impart compressive stress in concrete, along with any associated components used to enclose and anchor the tensioned element.

thixotropic—a reversible, time-dependent decrease in viscosity when a fluid is subjected to increased shear stress or shear rate.

vacuum grouting—a process by which a partial vacuum is generated within a void to create a pressure differential that allows grout to flow into and substantially fill the void through a single grout inlet.

volume change—an increase or decrease in volume due to any cause.

CHAPTER 3—REVIEW OF CURRENT PRACTICE

3.1—General

Code requirements in the area of post-tensioning durability were very minimal prior to publication of the Post-Tensioning Institute's (PTI), "Specification for Grouting of Post-Tensioned Structures," in 2001 (current edition published in 2003 [PTI Committee on Grouting Specifications 2003]). This comprehensive document focuses on

grouting, including materials, construction, and testing, with emphasis on new construction.

The American Segmental Bridge Institute (ASBI) established a Grouting Certification Program in 2001. The program format, which includes both lecture and live demonstrations of grout testing and pumping, culminates in a certification exam. General detailing for durability in post-tensioning systems is covered in addition to grouting. Grouting best practices taught at this course follow the PTI Specification (PTI Committee on Grouting Specifications 2003).

Certain state departments of transportation (DOT) have developed their own detailed specifications for durability of post-tensioned bridges. The Florida Department of Transportation (FDOT), for example, maintains a comprehensive state specification (FDOT 2007).

3.2—Grouting requirements

The PTI Specification (PTI Committee on Grouting Specifications 2003) is divided into four main sections: materials, design, testing, and construction. This specification should be consulted for a full description of requirements in each area. Basic concepts are summarized in Sections 3.2.1 through 3.2.4.

3.2.1 Materials—Grout consists of cement and water and may also include chemical or mineral admixtures as well as fine sand. Pozzolans used in concrete may also be used in grout. Silica fume and fly ash, both Class C and Class F, are the most commonly used. Because fly ash may vary considerably from different sources, a consistent source should be used to achieve similar field properties to the ones found during mixture development in the lab. Fly ash can potentially reduce bleed, increase workability, and reduce permeability. Silica fume has been shown to improve corrosion protection in concrete by reducing the permeability of the concrete. In grouts, however, the particles may agglomerate because the coarse aggregate that aids in mixing is absent. Recent testing has shown better performance with interground silica fume cements (Brooks 2003).

Chemical admixtures used in grout have included high-range water-reducing admixtures, anti-bleed admixtures, expansive admixtures, and corrosion inhibitors. High-range water-reducing admixtures help achieve workability at low water-cementitious material ratios. For constant water content, adding only water reducers or high-range water-reducing admixtures usually increases bleed, so the admixture should not be added beyond the mixture design amount.

Anti-bleed admixtures, also called gelling agents or stabilizers, are necessary for applications requiring strong bleed resistance or water retention in grout. Silica fume and fly ash mildly improve bleed resistance, but are not adequate alone for the high water-retentive properties needed for many applications. Bleed in grouts is discussed in Section 4.3.

Expansive agents were used in grouts for many years with the premise of counteracting bleed and voids with expansion of the grout. A small amount of expansion to offset settlement may be desirable, but the use of foaming-type expansion admixtures should be avoided. These admixtures may have widely varying levels of expansion when combined with different cements. They also may use an interconnected air