Report on Corrosion of Prestressing Steels

Reported by ACI Committee 222

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This report covers various types of prestressing steel, including some discussion on metallurgical differences, and supplements information presented in ACI 222R to include topics specifically related to prestressing steels. Deterioration mechanisms are discussed, including hydrogen embrittlement and stress-corrosion cracking. Methods to protect prestressing steel against corrosion in new construction are presented, along with a discussion of field performance of prestressed concrete structures. Finally, field evaluation and remediation techniques are presented. Appendixes present detailed information on stress-corrosion cracking and hydrogen embrittlement issues in prestressed concrete and mitigation techniques.

Keywords: anchorage; bonded; corrosion; duct; durability; grout; hydrogen embrittlement; post-tensioned; prestressed; tendon; strand; stress-corrosion cracking; unbonded.

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CHAPTER 1—INTRODUCTION

1.1—Background

Several attempts were made to prestress concrete in the 1800s, but modern development of prestressed concrete began in 1928 and is credited to E. Freyssinet of France (Lin and Burns 1981). Freyssinet understood the importance of prestressing using high-strength steel to avoid prestressing losses that significantly reduce the applied prestressing force. Use of prestressed concrete began in the United States with circular-wrapped prestressed tanks in 1941 (Schupack 1964). The first prestressed segmental concrete bridge in the United States was constructed in Madison County, TN, and opened to the public on October 28, 1950 (Bennett et al. 2002). The Walnut Lane Memorial Bridge, located in Pennsylvania, was completed in the fall of 1950 (Manning 1988). Applications of prestressing in bridge and building construction then spread rapidly and have proven to be a successful construction method. Prestressed concrete construction enhances structural efficiency, improves control of flexural cracking, and allows for structural members with reduced dimensions.

Although corrosion is not as well documented in prestressed concrete structures as in nonprestressed concrete structures, prestressed concrete members have a number of advantages regarding corrosion performance over conventional nonprestressed concrete elements. In general, prestressed concrete construction follows higher-quality control practices and material standards than conventional nonprestressed construction. These practices result in improved concrete properties that limit diffusion of chloride, which is further reduced in prestressed concrete members due to absence or reduced-level cracking. Corrosion of prestressed concrete structures appears to be restricted to specific circumstances, including improper design, construction details, and construction practices. The potential for accelerated corrosion still exists in environments contaminated with chloride ions and hydrogen sulfide and it is imperative to protect prestressing steel. Corrosion of prestressing steel in bridges and buildings may not display outward signs of corrosion. Because failure of prestressing tendons could compromise the integrity of the structure, structures subjected to corrosive conditions should be periodically inspected with specific attention focused on the condition of the prestressing system.

A number of surveys provide information concerning the potential for corrosion of prestressed structures. Burdekin and Rothwell (1981) summarized practice, specifications, and corrosion mechanisms (1981) and reported that failure to provide adequate structural details and follow proper construction practices, as well as use of low-quality materials, account for the vast majority of poor performance. Schupack reached similar conclusions in additional surveys (Schupack 1978a, 1994; Schupack and Suarez 1982). More recently, corrosion problems were discovered in grouted post-tensioned bridges (Poston et al. 2003; Hartt and Venugopalan 2002; Muszynski 2003). The problems were largely attributed to inadequate post-tensioning details and grouting practices and deficient grout materials that led to accumulation of bleedwater voids.

Because corrosion in prestressed concrete members can potentially result in fracture-critical modes of failure, more information needs to be developed, disseminated, and used. The magnitude of the corrosion problem, its projected extent, and measures that can resolve it are of vital concern to designers, contractors, and owners, and form the basis of this report.

Prestressed concrete is used in several types of construction and is described as either pretensioned or post-tensioned, depending on whether the tendons are stressed before (pre) or after (post) the concrete is placed. Pretensioned concrete refers to systems in which high-strength wires or strands are stressed in forms between bulkheads before placement of the concrete. Concrete is cast and allowed to cure to a specified strength. Because the prestressing steel is bonded with the concrete, when the steel is released from the bulkheads, the concrete is placed in compression to equilibrate the tensile forces present in the steel. Pretensioning is common practice for both standardized precast bridge girders and in precast structural building members, such as solid joists, solid and hollow-core planks, and single- and double-tee joists.

Post-tensioned concrete refers to systems in which the concrete is placed and allowed to cure to a specified strength before prestressing. Post-tensioning is applied using either bonded or unbonded tendons. Bonded post-tensioning requires that tubes or ducts with deformations be placed in