

Report on Corrosion and Repair of Unbonded Single-Strand Tendons

Reported by Joint ACI-ASCE Committee 423

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Reported by Joint ACI-ASCE Committee 423

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This report gives general information regarding evaluating corrosion damage in structures reinforced with unbonded single-strand post-tensioning tendons. Historical development of those parts of the building code dealing with durability and corrosion protection is explained. Evolution of the types and components of unbonded tendons is described. Specific aspects of corrosion in unbonded single-strand tendons are described, and common problems in structures reinforced with these tendons are discussed. Methods are presented for repairing, replacing, and supplementing tendons.

Keywords: allowable stresses; anchorage; corrosion; concrete construction; corrosion; corrosion protection; cover; durability; embrittlement; external post-tensioning; post-tensioning; concrete; prestressed concrete; sheathing; single-strand tendons; unbonded post-tensioning.

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CHAPTER 1—INTRODUCTION

1.1—General

This report provides general information on the evaluation of known or suspected corrosion problems in unbonded single-strand tendons, historical information of the types and components of unbonded tendons and on the durability and corrosion protection provisions in the building code, and describes typical repair methods in use today. Expertise in design, construction, evaluation, and repair of structures using single-strand unbonded tendons is strongly recommended for a team undertaking evaluation and repair of corrosion problems.

Historically, there have been corrosion problems with other types of pre- and post-tensioning systems (Nehil 1991); however, certain aspects of corrosion of unbonded single-strand tendons are unique. The causes and effects of corrosion of unbonded single-strand tendons are, in several respects, different from those of bonded conventional reinforcing or other post-tensioning (PT) systems, so the methods for evaluating and repairing corrosion of single-strand tendons are also different. For example, because the tendons are largely isolated from the surrounding concrete, they may not be affected by deleterious materials such as chlorides and moisture in the concrete. The surrounding concrete does not stop corrosion alone because, if water gains access to the inside of the sheathing, PT coating is rendered ineffective. Measures taken to repair and protect

the surrounding concrete may not repair or reduce deterioration of the prestressing steel where corrosion has been initiated. The tendons usually require separate evaluation and repair.

1.2—Background

Unbonded PT systems were introduced to North America in the 1950s. At that time, there were no accepted standards for design or material specifications for prestressing steels. Guidance came in the form of tentative recommendations from Joint ACI-ASCE Committee 323 (1958), Bureau of Public Roads (1954), or Structural Engineers Association of Northern California (SEA/NC) (1959). Unbonded tendons in the early systems used bundles of wires or strands, sometimes inaccurately called cables, of various diameters, and were assumed to be protected by PT coating and paper sheathing that were sometimes applied by hand (Nehil 1991; Schupack 1991a).

The use of unbonded tendons became more common during the late 1950s and early 1960s, as progress was made in establishing design and materials standards. Acceptance of the concept was regional at first and was largely the result of sales efforts and design tutoring by tendon suppliers. The use of post-tensioning increased rapidly during the late 1960s and 1970s as advantages of the system were demonstrated. For many types of structures, these advantages included shorter construction time, reduced structural depth, increased stiffness, and savings in overall cost. In addition to the use in enclosed buildings, unbonded PT systems were used in parking structures and slabs-on-ground, and bonded post-tensioning was used on water tanks, bridges, dams, and soil tie-back systems. Unbonded multi-wire and multi-strand tendons have been used extensively in nuclear power structures.

Incidents of corrosion of unbonded single-strand tendons began to surface during the 1970s. It was believed that corrosion protection would be provided by the PT coating during shipping, handling, and installation, and by the concrete thereafter. The early PT coatings, however, often did not provide the corrosion-inhibiting characteristics that are presently required in ACI 423.7 or PTI M10.2. In the early 1980s, the Post-Tensioning Institute (PTI) recognized the structural implications of corrosion and began implementing measures to increase the durability of unbonded PT systems (Post-Tensioning Institute 1985). Relying on the experience and practice of the nuclear industry's use of corrosion-inhibiting hydrophobic grease, similar performance standards for grease were adopted. In 2000, PTI published the second edition of its "Specification for Unbonded Single Strand Tendons (PTI M10.2-00)." In ACI 318-89, measures were incorporated that related the required protection of the tendons and the quality of the concrete to the environmental conditions that could promote corrosion of the post-tensioning.

In 2007, ACI published ACI 423.7, which provides detailed specifications for PT coating. With the adoption of this specification, the term "grease" was replaced with the more generic term "PT coating" to address other mate-

rials used as protection systems inside the sheathing. These improved coatings were introduced by PTI M10.2 long before the publication of ACI 423.7. Structures built before the adoption of these standards, especially those in aggressive environments, are more likely to experience corrosion of the PT system than those designed and built since then.

Tendons that are broken or damaged by corrosion can be repaired or supplemented by several methods. The more difficult task is determining the extent of corrosion damage and degree to which tendon repairs are needed. This report provides guidance on the evaluation of suspected or known corrosion problems and describes repair methods currently in use.

1.3—Scope

This report reviews the following:

- a) Codes and code changes affecting unbonded PT tendons
- b) Past and present corrosion protection systems and how they have changed to enhance corrosion protection
- c) Types of corrosion damage found in prestressing steel
- d) Methods for evaluating structures that are suspected of, or known to have, corrosion damage in the PT system
- e) Basic repair options

1.4—Limitations

This report presents a summary of typical problems experienced with unbonded PT systems and includes general guidelines for evaluating and repairing single-strand tendons. While the methods presented are general in nature, they are not universally applicable. Standard specifications and details are not included because each structure is unique and should be analyzed accordingly.

This report is not intended to be included as a part of specifications for investigations and repairs. Presently, there is no practical method to determine the total extent of damage to a PT system. The unpredictable nature of tendon failures exhibited by inadequately protected, corroding strand makes estimating tendon life uncertain.

A wide variation exists in the durability and rate of deterioration of older PT systems. This is due, in part, to the composition of the parts of the tendon: strand, anchors, PT coating, and sheathing, and in part to the quality of the surrounding concrete, environmental exposure, and type of maintenance performed on the structure. The investigator should rely on available information on the historical performance of similar structures and should be experienced in interpreting external evidence that may give an indication of latent internal problems.

CHAPTER 2—DEFINITIONS

2.1—Definitions

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” <http://www.concrete.org/Tools/ConcreteTerminology.aspx>. Definitions provided herein complement that resource.

post-tensioning (PT) coating—material used to protect the prestressing steel against corrosion and reduce friction

between prestressing steel and sheathing; this term has been adopted to refer to grease or other materials, or a combination of both, that may be used inside the sheathing to protect the strand.

CHAPTER 3—REVIEW OF CODE REQUIREMENTS AND CHANGES

3.1—General

When evaluating corrosion damage in post-tensioned structures with unbonded tendons, the investigator should consider the age of the structure and the standards or practices available to the licensed design professional and contractor at the time of construction.

Although ACI published building regulations for reinforced concrete as early as 1920, ACI 318-47 was the first to acknowledge the significance of environmental exposure. ACI 318-47, ACI 318-51, and ACI 318-56 also recognized the importance of clear cover and concrete quality in providing adequate corrosion protection to the nonprestressed bonded reinforcement.

Joint ACI-ASCE Committee 323 (1958) addressed the protection of prestressing steel in three areas of recommended practice: concrete cover; allowable tensile stresses; and, for embedded systems, protection of the strand or wire with PT coating and a sheathing material. Since 1958, provisions for prestressed concrete have included requirements for corrosion protection. The PT coating and sheathing were viewed, by most, primarily as a lubricant and bond breaker, and secondarily as a corrosion deterrent during shipping, handling, and placing. Long-term corrosion protection was viewed by some as being provided by the uncracked concrete cover.

Prestressed concrete was first included in ACI 318-63 with provisions for concrete cover, allowable tensile stresses, and strand protection. These items were modified occasionally, but the substantive change came in ACI 318-89 when durability was emphasized.

3.2—Cover requirements for unbonded tendons

ACI 318-63 required the following:

- a) The following minimum thickness of concrete cover shall be provided for prestressing steel, ducts, and nonprestressed steel:

Cover, in. (mm)

Concrete surface in contact with ground.....2 (50)

Beams and girders:

Prestressing steel and main reinforcing bars 1.5 (40)

Stirrups and ties 1 (25)

Slabs and joists exposed to weather 1 (25)

Slabs and joists not exposed to weather 75 (20)

- b) In extremely corrosive atmosphere or other severe exposures, the amount of protection shall be suitably increased.

Eight years later, in ACI 318-71, the cover requirements for prestressed members cast against and permanently exposed to earth increased from 2 in. (50 mm) to 3 in. (75 mm). In