ANSI/AWWA C305-18
(First Edition)

American Water Works Association
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AWWA Standard

CFRP Renewal and Strengthening of Prestressed Concrete Cylinder Pipe (PCCP)

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AWWA Standard

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

Foreword

This foreword is for information only and is not a part of ANSI/AWWA C305.*

I. Introduction

I.A *Background.* Prestressed concrete cylinder pipe (PCCP) has had a long and diverse history with many changes in standards and materials. The earliest application of PCCP in the United States was in 1942. That pipe, which is now known as lined-cylinder pipe (LCP), consists of a steel cylinder with cast concrete core over-wrapped with steel wire. The continuing scarcity of steel, coupled with successful application to smaller pipe, led to the introduction of embedded-cylinder pipe (ECP) in 1953 (ref. ANSI/AWWA C301 Foreword). Site-manufactured ECP has been constructed as large as 252 in. (6.40 m) in diameter. Both types of PCCP are designed for the specific combination of internal pressure and external loads in accordance with the procedures detailed in ANSI/AWWA C304, Design of Prestressed Concrete Cylinder Pipe.

I.B. *History.* Utilities have taken steps in advance of failure to replace identified degraded pipes or repair them by encasing the degraded pipe in a reinforced concrete block or steel plate wrap, post-tensioning by wrapping tendons around the pipe, or relining. Relining is typically performed by using a steel liner, by applying carbon fiber reinforced polymeric composites (CFRP) bonded to the inner surface of the pipe, or by sliplining.

The use of CFRP for civil and structural applications began with university testing in the late 1980s, which validated its use for such applications. In the early 1990s, CFRP gained acceptance within the engineering and construction industries through increased awareness, with project applications aided by the issuance of important approvals by building code authorities.

In the late 1990s, CFRP was first used for the strengthening of large-diameter underground prestressed concrete cylinder pipe (PCCP). In the early 2000s, various municipal utilities began the widespread use of CFRP lining for degraded PCCP. The advancements of precision inspection methods increased the demand for CFRP upgrade of PCCP by equipping utility owners with critical information regarding the exact location of at-risk pipes. By about 2007, with the issuance of public contracts by various US and international utilities, installation of CFRP liner inside degraded or weak PCCP had become an acceptable renewal and strengthening system for PCCP.

* American National Standards Institute, 25 West 43rd Street, 4th floor, New York, NY 10036.

The high strength and stiffness of CFRP laminates make them suitable for pressure pipeline renewal and strengthening applications. Application of CFRP for internal strengthening of PCCP precludes the need for excavation of the pipe and is therefore especially advantageous where excavation is impossible or expensive to perform. Furthermore, the installation can be performed rapidly and therefore is especially advantageous when the available time for repair is very limited. CFRP constituents (carbon fiber and resin) are relatively inert materials and can be compatible for a variety of environments, including raw water, wastewater, and potable water, contingent upon necessary testing. Durability and compatibility should be tested for all environments that the CFRP is anticipated to be subject to during its service life, as provided in this standard.

Although CFRP for internal repair and strengthening of PCCP has been applied since 1997, the in-service history is substantially shorter than traditional construction materials. Therefore, utilities have sought consensus guidance for the design and installation of CFRP renewal and strengthening. In response, the AWWA Standards Committee on Concrete Pressure Pipe appointed a subcommittee at the Annual Conference in San Diego, Calif., in June 2009 to develop a proposal for such a standard. In March 2011, the AWWA Standards Council approved the development of a standard on "CFRP Renewal and Strengthening of Prestressed Concrete Cylinder Pipe (PCCP)" (now designated ANSI/AWWA C305) and assigned the responsibility to the AWWA Standards Committee on Concrete Pressure Pipe.

During the development of this standard, the Water Research Foundation (WRF) sponsored research and development on the CFRP renewal of PCCP that included literature review of available data, finite-element modeling of CFRP-lined PCCP subjected to external loads and internal pressures as the PCCP continues to degrade with time, full-scale testing of CFRP-lined PCCP with simulated degradation, and watertightness of CFRP during the degradation process of PCCP. The results of this research and development work form the basis of many of the provisions of this first edition of the standard. This standard was approved by the AWWA Board of Directors on June 9, 2018.

I.C. *Water Quality.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation (formerly AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM).

AWWA and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including:

1. Specific policies of the state or local agency.
2. Two standards developed under the direction of NSF†: NSF/ANSI‡ 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.
3. Other references, including AWWA standards, *Food Chemicals Codex, Water Chemicals Codex,*§ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C305 does not address additives requirements. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to:

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

* Persons outside the United States should contact the appropriate authority having jurisdiction.
† NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.
‡ American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
§ Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.

II. Special Issues.

II.A. *Intent and Suitability.* This standard describes the procedures for material selection, design, installation, and quality control and quality assurance of the CFRP renewal and strengthening of PCCP. This standard provides requirements and recommendations to assist engineers, utility managers, and constructors in the selection of CFRP systems and in design and construction of CFRP renewal of degraded PCCP or strengthening of the PCCP to accept loads in excess of the design load.

II.B. *Advisory Information on Product Application.* The successful application of CFRP renewal or strengthening of PCCP will be the product of design, materials, and installation. CFRP system manufacturers and installers should be contacted for detailed product information and material properties regarding the capabilities of the CFRP system and proper methods of field installation. The design of the renewal system will require knowledge of the existing pipe and surrounding soil.

II.C. *Qualifications.* CFRP renewal and strengthening of PCCP requires understanding of all the physical, chemical, and environmental factors that influence a successful and quality installation. Recognizing the importance of the experience and qualifications of the designer, manufacturer, and constructor involved in these applications and that the consequences of failure are severe, the purchaser should take the necessary steps to assure itself that all personnel in all facets of the work are qualified.

II.D. *Contractual Relations.* AWWA standards do not include provisions involving business relations. Such relations are a proper topic for purchaser specifications, but not for AWWA standards. Warranties or guarantees are examples of such relations, as well as many experience requirements. Section III.A of this foreword provides guidance on purchaser options and alternatives that a purchaser should provide in a typical bid package for CFRP renewal and strengthening of PCCP, including warranties (Sec. III.A [8] and Sec. III.A [9]) and experience criteria (Sec. III.A [6]). The constructor is responsible for the result of the installation work executed.

II.E. *Limitations.* The CFRP system is best suited for the renewal of degraded PCCP with broken wires with a relatively smooth interior surface. When the inner core concrete is degraded partially through the wall thickness (e.g., due to the chemistry of water), the degraded concrete should be removed, and the surface should be restored with structurally sound concrete or other approved materials. The surface of the restored areas shall be finished to adequate roughness before application of CFRP (see Sec. 4.4.1). The application of CFRP to severely deformed PCCP as described in Sec. 2.1.2.3 is beyond the scope of this standard.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following information should be provided by the purchaser in a typical bid package related to CFRP renewal and strengthening of PCCP:

1. Standard used—that is, ANSI/AWWA C305, of latest revision.
2. Details of federal, state, and local requirements (Sec. 3.1).
3. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.
4. Constructability-related details.
    a. Access and staging considerations
    b. Location of access holes relative to pipe segments requiring work
    c. Minimum manhole diameter that allows for access to job site
    d. Location of pipes to be strengthened
    e. Water intrusion, leakage, and flood potential
    f. Plan and profile of the pipeline
    g. Time permitted for construction
    h. Working hours allotted
    i. Noise mitigation requirements
    j. Special safety issues
5. Design-related details.
    a. Diameter of the pipe, design drawings containing PCCP parameters, specifications, and year of construction of PCCP
    b. Laying schedule, pipe and joint design details, and as-built drawings
    c. Working and transient pressures and all other loads required in design of CFRP renewal (see Sec. 2.4 for details)
    d. Installation condition, cover height, in situ and backfill soils, and compaction level
    e. Condition of interior surface of the PCCP and surface-preparation requirements before CFRP installation
    f. Joint condition and design details of CFRP termination and continuity through the joint
    g. The thrust force to be transmitted through the joints
    h. Fittings and special features on the pipe segments selected for CFRP renewal

6. The experience and submittal requirements for the CFRP designer, material manufacturer, CFRP installer and inspector, and a requirement that the submittals be provided concurrently with the bid.

7. Allocation of responsibility for construction-related activities.

   a. Traffic control
   b. Dewatering of the pipeline
   c. Chlorination and disinfection procedure
   d. Permitting
   e. Public relations
   f. Disposal of waste materials created during construction
   g. Bulkhead installation and removal
   h. Confined space entry and lockout/tagout
   i. Monitoring of groundwater to control leakage into the pipe

8. Whether a warranty on the materials and workmanship of the constructor for the CFRP system used for renewal or strengthening of the pipe is required, and the terms of the warranty.

9. Whether the warranty, if required, is a bonded warranty and the length of the bonded warranty period.

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard shall be provided by the purchaser.

IV. Major Revisions. This is the first edition of the standard.

V. Comments. If you have any comments or questions about this standard, please call AWWA Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603, write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.

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CFRP Renewal and Strengthening of Prestressed Concrete Cylinder Pipe (PCCP)

SECTION 1: GENERAL

Sec. 1.1 Scope, Purpose, and Application

The purpose of this standard is to provide the minimum requirements for material selection, design, installation, and quality control and quality assurance of the CFRP renewal and strengthening of PCCP. The scope of this standard covers all PCCP, including embedded-cylinder pipe (ECP) and lined-cylinder pipe (LCP). The scope of this standard is limited to the wet lay-up application of CFRP; this standard does not apply to pre-cured laminates adhered to the pipe wall, dry lay-up application, or automated/robotic CFRP installation methods (see Sec. 2.1.1). This standard is not applicable to the design of CFRP liner for severely deformed PCCP as described in Sec. 2.1.2.3.

Sec. 1.2 Definitions

Terms in this standard pertaining to CFRP shall be defined as in ASTM D883, Standard Terminology Relating to Plastics; ASTM D3878, Standard Terminology for Composite Materials; and ASTM D907, Standard Terminology of Adhesives. When definitions of terms are in conflict, definitions in ASTM D3878 shall have precedence.