CODE REQUIREMENTS FOR ENVIRONMENTAL ENGINEERING CONCRETE STRUCTURES (ACI 350M-06) AND COMMENTARY

REPORTED BY ACI COMMITTEE 350

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The code portion of this document covers the structural design, materials selection, and construction of environmental engineering concrete structures. Such structures are used for conveying, storing, or treating liquid or other materials such as solid waste. They include ancillary structures for dams, spill-ways, and channels.

They are subject to uniquely different loadings, more severe exposure conditions, and more restrictive serviceability requirements than non-environmental building structures.

Loadings include normal dead and live loads and vibrating equipment or hydrodynamic forces. Exposures include concentrated chemicals, alternate wetting and drying, and freezing and thawing of saturated concrete. Serviceability requirements include liquid-tightness or gas-tightness.

Typical structures include conveyance, storage, and treatment structures.

Proper design, materials, and construction of environmental engineering concrete structures are required to produce serviceable concrete that is dense, durable, nearly impermeable, and resistant to chemicals, with limited deflections and cracking. Leakage must be controlled to minimize contamination of ground water or the environment, to minimize loss of product or infiltration, and to promote durability.

This code presents new material as well as modified portions of the ACI 318M-02 Building Code that are applicable to environmental engineering concrete structures.

Because ACI 350M-06 is written as a legal document, it may be adopted by reference in a general building code or in regulations governing the design and construction of environmental engineering concrete structures. Thus, it cannot present background details or suggestions for carrying out its requirements or intent. It is the function of the commentary to fill this need.

ACI 350M-06 was adopted as a standard of the American Concrete Institute on July 3, 2006 to supersede ACI 350M/350RM-01 in accordance with the Institute's standardization procedure. ACI 350M-06 is a complete metric companion to ACI 350-06.

The 2006 "Code Requirements for Environmental Engineering Concrete Structures and Commentary" are presented in a side-by-side column format, with code text placed in the left column and the corresponding commentary text aligned in the right column. To further distinguish the Code from the Commentary, the Code has been printed in Helvetica, the same type face in which this paragraph is set.

This paragraph is set in Times Roman, and all portions of the text exclusive to the Commentary are printed in this type face. Commentary section numbers are preceded by an "R" to further distinguish them from Code section numbers.

The commentary discusses some of the considerations of the committee in developing the ACI 350M Code, and its relationship with ACI 318M. Emphasis is given to the explanation of provisions that may be unfamiliar to some users of the code. References to much of the research data referred to in preparing the code are given for those who wish to study certain requirements in greater detail.

The chapter and section numbering of the code are followed throughout the commentary.

Among the subjects covered are: permits, drawings and specifications, inspections, materials, concrete quality, mixing and placing, forming, embedded pipes, construction joints, reinforcement details, analysis and design, strength and serviceability, flexural and axial loads, shear and torsion, development of reinforcement, slab systems, walls, footings, precast concrete, prestressed concrete, shell structures, folded plate members, provisions for seismic design, and an alternate design method in Appendix I.

The quality and testing of materials used in the construction are covered by reference to the appropriate standard specifications. Welding of reinforcement is covered by reference to the appropriate AWS standard. Criteria for liquid-tightness testing may be found in 350.1.

Keywords: chemical attack; coatings; concrete durability; concrete finishing (fresh concrete); concrete slabs, crack width, and spacing; cracking (fracturing); environmental engineering; inspection; joints (junctions); joint sealers; liquid; patching; permeability; pipe columns; pipes (tubes); prestressed concrete; prestressing steels; protective coatings; reservoirs; roofs; serviceability; sewerage; solid waste facilities; tanks (containers); temperature; torque; torsion; vibration; volume change; walls; wastewater treatment; water; water-cementitious material ratio; water supply; water treatment.

INTRODUCTION

The code and commentary includes excerpts from ACI 318M-02 that are pertinent to ACI 350M. The commentary discusses some of the considerations of Committee ACI 350 in developing "Code Requirements for Environmental Engineering Concrete Structures (ACI 350M-06)," hereinafter called the code. Emphasis is given to the explanation of provisions that may be unfamiliar to users of the standard. Comments on specific provisions are made under the corresponding chapter and section numbers of the code and commentary.

This commentary is not intended to provide a complete historical background concerning the development of the code, nor is it intended to provide a detailed summary of the studies and research data reviewed by the committee in formulating the provisions of the code. However, references to some of the research data are provided for those who wish to study the background material in depth.

As the name implies, "Code Requirements for Environmental Engineering Concrete Structures" may be used as part of a legally adopted code and, as such, must differ in form and substance from documents that provide detailed specifications, recommended practice, complete design procedures, or design aids.

The code is intended to cover environmental engineering concrete structures, but is not intended to supersede ASTM standards for precast structures.

Requirements more stringent than the code provisions may be desirable for unusual structures. This code and this commentary cannot replace sound engineering knowledge, experience, and judgment.

A code for design and construction states the minimum requirements necessary to provide for public health and safety. ACI 350M is based on this principle. For any structure, the owner or the structural designer may require the quality of materials and construction to be higher than the minimum requirements necessary to provide serviceability and to protect the public as stated in the code. Lower standards, however, are not permitted.

ACI 350M has no legal status unless it is adopted by government bodies having the power to regulate building design and construction. Where the code has not been adopted, it may serve as a reference to good practice.

The code provides a means of establishing minimum standards for acceptance of design and construction by a legally appointed building official or his designated representatives. The code and commentary are not intended for use in settling disputes between the owner, engineer, architect, contractor, or their agents, subcontractors, material suppliers, or testing agencies. Therefore, the code cannot define the contract responsibility of each of the parties in usual construction. General references requiring compliance with ACI 350M in the job specifications should be avoided, since the contractor is rarely in a position to accept responsibility for design

details or construction requirements that depend on a detailed knowledge of the design. Generally, the drawings, specifications, and contract documents should contain all of the necessary requirements to ensure compliance with the code. In part, this can be accomplished by reference to specific code sections in the job specifications. Other ACI publications, such as ACI 301M, "Specifications for Structural Concrete," are written specifically for use as contract documents for construction.

Committee 350 recognizes the desirability of standards of performance for individual parties involved in the contract documents. Available for this purpose are the certification programs of the American Concrete Institute, the plant certification programs of the Precast/Prestressed Concrete Institute, the National Ready Mixed Concrete Association, and the qualification standards of the American Society of Concrete Constructors. Also available are "Standard Specification for Agencies Engaged in Construction Inspection and/or Testing" (ASTM E 329) and "Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation" (ASTM C 1077).

Design aids (general concrete design aids are listed in ACI 318M-02):

"Rectangular Concrete Tanks," Portland Cement Association, Skokie, IL, 1994, 176 pp. (Presents data for design of rectangular tanks.)

"Circular Concrete Tanks Without Prestressing," Portland Cement Association, Skokie, IL, 1993, 54 pp. (Presents design data for circular concrete tanks built in or on ground. Walls may be free or restrained at the top. Wall bases may be fixed, hinged, or have intermediate degrees of restraint. Various layouts for circular roofs are presented.)

"Concrete Manual," U.S. Department of Interior, Bureau of Reclamation, 8th edition, 1981, 627 pp. (Presents technical information for the control of concrete construction, including linings for tunnels, impoundments, and canals.)

GENERAL COMMENTARY

Because of stringent service requirements, environmental engineering concrete structures should be designed and detailed with care. The quality of concrete is important, and close quality control must be performed during construction to obtain impervious concrete.

Environmental engineering concrete structures for the containment, treatment, or transmission of liquid such as water and wastewater as well as solid waste disposal facilities, should be designed and constructed to be essentially liquid-tight, with minimal leakage under normal service conditions.

The liquid-tightness of a structure will be reasonably assured if:

a) The concrete mixture is well proportioned, well consolidated without segregation, and properly cured.
b) Crack widths and depths are minimized.
c) Joints are properly spaced, sized, designed, waterstopped, and constructed.
d) Adequate reinforcing steel is provided, properly detailed, fabricated, and placed.
e) Impervious protective coatings or barriers are used where required.

Usually it is more economical and dependable to resist liquid permeation through the use of quality concrete, proper design of joint details, and adequate reinforcement, rather than by means of an impervious protective barrier or coating. Liquid-tightness can also be obtained by appropriate use of shrinkage-compensating concrete. However, to achieve success, the engineer must recognize and account for the limitations, characteristics, and properties of shrinkage-compensating concrete as described in ACI 223 and ACI 224.2R.

Minimum permeability of the concrete will be obtained by using water-cementitious materials ratios as low as possible, consistent with satisfactory workability and consolidation. Impermeability increases with the age of the concrete and is improved by extended periods of moist curing. Surface treatment is important and use of smooth forms or troweling improves impermeability. Air entrainment reduces segregation and bleeding, increases workability, and provides resistance to the effect of freeze-thaw cycles. Because of this, use of an air-entraining admixture results in better consolidated concrete. Other admixtures, such as water-reducing agents and pozzolans, are useful when they lead to increased workability and consolidation, and lower water-cementitious ratios. Pozzolans also reduce permeability.

Joint design should also account for movement resulting from thermal dimensional changes and differential settlements. Joints permitting movement along predetermined control planes, and which form a barrier to the passage of fluids, shall include waterstops in complete, closed circuits. Proper rate of concrete placement operations, adequate consolidation, and proper curing are also essential to control of cracking in environmental engineering concrete structures. Additional information on cracking is contained in ACI 224R and ACI 224.2R.

The design of the whole environmental engineering concrete structure as well as all individual members should be in accordance with ACI 350M-06, which has been adapted from ACI 318M-02. When all relevant loading conditions are considered, the design should provide adequate safety and serviceability, with a life expectancy of 50 to 60 years for the structural concrete. Some components of the structure, such as jointing materials, have a shorter life expectancy and will require maintenance or replacement.

The size of elements and amount of reinforcement should be selected on the basis of the serviceability crack-width limits and stress limits to promote long service life.

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PART 5—STRUCTURAL SYSTEMS OR ELEMENTS