IN-LB	Inch-Pound Units
SI	International System of Units

Hazardous Material Containment in Concrete Structures—Report

Reported by ACI Committee 350

ACI PRC-350.2-21

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Reported by ACI Committee 350

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This report presents recommendations for structural design, materials, and construction of structures commonly used for hazardous materials containment, including reinforced concrete tanks, sumps, and other structures that require dense, impermeable concrete with high resistance to chemical attack. The report discusses and describes design and spacing of joints, proportioning of concrete, placement, curing, and protection against chemicals. Information on liners, secondary containment systems, and leak-detection systems is also included.

Keywords: chemical protection; liners; construction joint; containment systems; gas-tight; hazardous materials; joint sealant; liquid-tight; precast concrete; prestress; water-cementitious materials ratio; waterstop.

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ACI PRC-350.2-21 supersedes ACI 350.2R-04 and was adopted and published October 2021.

CHAPTER 1—GENERAL

1.1—Scope

This report provides guidance for the design and construction of hazardous material containment systems involving reinforced concrete construction. Hazardous material containment structures require secondary containment and, sometimes, leak-detection systems. Because of the economic and environmental impact of even small amounts of leakage of hazardous materials, both primary and secondary containment systems should be virtually leak-free. Therefore, when primary or secondary containment systems involve concrete, special design and construction techniques are required. This report supplements and enhances the requirements of ACI 350, Code Requirements for Environmental Engineering Concrete Structures, which is intended for structures commonly used in water containment, industrial and domestic water, and wastewater treatment works. ACI 350, however, does not give specific guidance on the design of the double containment systems, leak-detection systems, or the additional recommendations for enhancing liquid-tightness covered in this report. This report does not apply to primary or secondary containment of cryogenic liquids, nonliquid materials, or to systems containing radioactive materials. This document does not cover material storage requirements or environmental impacts of leaching.

The use of information in this report does not ensure compliance with applicable regulations. The recommendations in this report are based on the best technical knowledge available at the time they were written; however, they may be supplemented or superseded by applicable local, state, and national regulations. Therefore, it is important to research such regulations thoroughly. (Refer also to Section 8.1.)

Guidelines for containment and leakage-detection systems given in this report involve combinations of materials that may not be readily available in all areas. Therefore, local distributors and contractors should be contacted during the design process to determine what materials are available.

Thorough inspection of construction is essential to ensure a quality final product. The written program for inspection should be detailed and comprehensive and should be clearly understood by all parties involved. See Section 4.3 for an inspection checklist. (Refer to ACI 311.4R for guidance in inspection programs.) A preconstruction conference to discuss the program in detail is recommended. Personnel should be qualified, experienced, and certified as applicable to their specialty.

1.2—Definitions

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource.

ancillary equipment—ancillary equipment includes piping, fittings, valves, and pumps.

coating—a very low permeability barrier material that is bonded to the concrete and that is used to prevent fluid (or gas) migration through the concrete.

hazardous material—a hazardous material is defined as having one or more of the following characteristics: ignitable, corrosive, reactive, or toxic.

NOTE: The U.S. Environmental Protection Agency (EPA) listed wastes are organized into three categories under the Resource Conservation and Recovery Act (RCRA): source-specific wastes, generic wastes, and commercial chemical products. Source-specific wastes include sludges and wastewaters from treatment and production processes in specific industries such as petroleum refining and wood preserving. Generic wastes include wastes from common manufacturing and industrial processes such as solvents used in degreasing operations. Commercial chemical products consist of chemicals such as benzene, creosote, mercury, and various pesticides. Hazardous materials are considered to include liquids that are a classified as a physical hazard, health hazard, or hazard not otherwise classified, each as defined herein. The Code of Federal Regulations (CFR) Title 40—Protection of Environment, Part 261 Identification and Listing of Hazardous Waste may also be helpful in identifying categories of hazardous materials pertaining to this document.

health hazard—a chemical classified as posing one of the following hazardous effects: acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenicity; reproductive toxicity; specific target organ toxicity (single or repeated exposure); or aspiration hazard.

hazard not otherwise classified—per OSHA, an adverse physical or health effect identified through evaluation of scientific evidence during the classification process that does not meet the specified criteria for the physical and health hazard classes defined herein.

hazardous material tank—a hazardous material tank is a tank used to collect, store, or treat hazardous material. A hazardous material tank usually provides either primary or secondary containment of a hazardous material.

liner—a very low-permeability barrier material that is used to prevent fluid (or gas) migration through the concrete. Liners may be bonded or mechanically attached to the concrete.

membrane slab—a membrane slab is a slab-on-ground designed to be liquid-tight while having a designed thickness that results in a stiffness which allows for the capability of accepting gradual differential foundation settlements and transmit fluid loads directly to the subgrade.

pavement slabs—a pavement slab is a slab-on-ground designed to be liquid-tight and for vehicle or other concentrated loads.

physical hazard—a chemical that is classified as posing one of the following hazardous effects: explosive, flammable, oxidizer, self-reactive, pyrophoric, self-heating, organic peroxide, corrosive to metal, gas under pressure, or in contact with water emits flammable gas.

primary containment system—a primary containment system is the first containment system in contact with the hazardous material.

secondary containment system—a secondary containment system is a backup hazardous material containment system in the event the primary containment system leaks or fails.

spill—a spill is any uncontrolled release of hazardous material from the primary into the secondary containment system.

spill- or leak-detection system—a spill- or leak-detection system detects, monitors, and signals a spill or leakage from the primary containment system.

structural slab-on-ground—a slab having a designed thickness and reinforcement that allows for loads to be transferred along a path to foundation soils, structural elements, or both.

sump—a sump is any structural reservoir, usually below grade, designed for collection of runoff or accidental spillage of hazardous material. It often includes troughs, trenches, and piping connected to the sump to help collect and transport runoff liquids. Regulations may not distinguish between a sump and an underground tank.

system failure—a system failure is any uncontrolled release of hazardous material from the tank system into the environment.

tank—a tank is a stationary containment structure with self-supporting, watertight walls constructed of non-earthen material.

tank system—a tank system is comprised of its primary and secondary containment systems, and any leak-detection system or ancillary equipment.

1.3—Types of materials

This report outlines and discusses options for construction materials and provides recommendations for use, where applicable.

Tanks may be constructed of prestressed or nonprestressed reinforced concrete, or steel or other materials with concrete foundations, concrete secondary containment systems, or both. Reinforced concrete is the most widely used material for sumps, particularly below grade.

Liners for hazardous material tanks and sumps are made of stainless or coated steel, fiber-reinforced polymers (FRP), various combinations of esters, epoxy resins, or thermoplastics.

CHAPTER 2—CONCRETE DESIGN AND PROPORTIONING

2.1—General

Concrete is a general-purpose material that is easy to work with and is resistant to a wide range of chemicals, making it particularly suitable for above- and below-grade environmental primary and secondary containment systems. When properly designed and constructed, concrete containment structures are virtually impermeable and highly resistant to failure during fires. The addition of pozzolans, slag cement, and polymer modifiers can increase concrete's resistance to chemical attack. However, some joint sealants and waterstops are not rated for extreme heat and could fail in fire events. Refer to *CRSI Manual of Standard Practice* (CRSI 2009), and Zwiers and Morgan (1989) for information on exposure of concrete to elevated temperatures.

Measures that should be considered to help prevent cracking or to control the number and width of cracks include: prestressing, details that reduce or prevent restraint of movements due to shrinkage and temperature changes, higher than normal amounts of nonprestressed reinforcement, closer spacing of reinforcement, shrinkage-compensating concrete made with Type K cement or shrinkage-reducing admixtures, concrete mixtures proportioned to reduce shrinkage, extended curing, and fiber reinforcement. Fibers, where used, should be in accordance with ACI 350. Only fibers that are chemically compatible with the hazardous materials contained should be used. Additionally, some construction techniques, such as casting floors and walls monolithically (Chapter 4), help prevent or reduce cracking by eliminating the restraint of shrinkage and temperature movements of the subsequently placed concrete along the joint with the previously placed concrete. Refer to ACI 224R, 224.3R, and 224.4R for additional information on mitigation of cracking in concrete structures.

2.2—Design

2.2.1 *Design considerations*—The walls, base slabs, and other elements of containment systems should be designed for pressure due to contained material, lateral earth pressure, buoyancy, wind, seismic, and other superimposed loads. ACI 350 provides requirements for the design of both prestressed and nonprestressed tanks and other environmental struc-