Concrete Structures for Containment of Hazardous Materials

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: construction joint; joint; joint sealant; precast concrete; prestress; water-cementitious material ratio; waterstop.

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CHAPTER 1—GENERAL

1.1—Scope

This report is intended for use in the structural design and construction of hazardous material containment systems. 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, 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.

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based on the best technical knowledge available at the time they were written; however, they may be supplemented or superseded by applicable local, state, and national regulations.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

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 ensure that materials are available.

Proper and 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. (See 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

The definitions in Sections 1.2.1 through 1.2.11 have been correlated with the U.S. Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) regulations.

1.2.1 *Hazardous material*—A hazardous material is defined as having one or more of the following characteristics: ignitable (NFPA 49), corrosive, reactive, or toxic.

NOTE: EPA-listed wastes are organized into three categories under 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. The list of generic wastes includes wastes from common manufacturing and industrial processes such as solvents used in degreasing operations. The third list contains specific chemical products such as benzene, creosote, mercury, and various pesticides.

1.2.2 *Tank*—A tank is a stationary containment structure with self-supporting, watertight walls constructed of nonearthen material.

1.2.3 *Environmental tank*—An environmental tank is a tank used to collect, store, or treat hazardous material. An environmental tank usually provides either primary or secondary containment of a hazardous material.

1.2.4 *Tank system*—A tank system includes its primary and secondary containment systems, leak-detection system, and the ancillary equipment.

1.2.5 *Ancillary equipment*—Ancillary equipment includes piping, fittings, valves, and pumps.

1.2.6 *Sump*—A sump can be 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.

1.2.7 *Primary containment system*—A primary containment system is the first containment system in contact with the hazardous material.

1.2.8 *Secondary containment system*—A secondary containment system is a backup system for containment of hazardous materials in case the primary system leaks or fails for any reason.

1.2.9 *Spill or system failure*—A spill or system failure is any uncontrolled release of hazardous material from the primary containment system into the environment or into the secondary containment system. It may also be from the secondary containment system into the environment.

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

1.2.11 *Membrane slab*—A membrane slab is a slab-on-ground designed to be liquid-tight and transmit loads directly to the subgrade.

1.3—Types of materials

This report provides guidance for the design and construction of environmental tanks and sumps of reinforced concrete construction. 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 environmental tanks and sumps are made of stainless or coated steel, fiber-reinforced plastics (FRP), various combinations of esters, epoxy resins, or thermoplastics.

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

CHAPTER 2—CONCRETE DESIGN AND PROPORTIONING

2.1—General

Concrete is particularly suitable for above- and below-grade environmental primary and secondary containment systems. When properly designed and constructed, concrete containment systems are impermeable and highly resistant to failure during fires. See ACI 216R, CRSI (1980), and Zwiers and Morgan (1989) for information on exposure of concrete to elevated temperatures.

Concrete is a general-purpose material that is easy to work with and is resistant to a wide range of chemicals. It is used in construction of both primary and secondary containment systems. The addition of pozzolans, latex, and polymer modifiers can increase concrete's resistance to chemical attack.

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, concrete mixtures proportioned to reduce shrinkage, and fiber reinforcement. 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. See ACI 224R and ACI 224.3R for additional information on mitigation of cracking in concrete structures.

Table 2.1—Wall thickness and reinforcement locations based on concrete placement consideration

Description	Wall height	Minimum thickness	Reinforcement location
Cast-in-place concrete	Over 10 ft (3000 mm)	12 in. (300 mm)	Both faces
	4 to 10 ft (1200 to 3000 mm)	10 in. (250 mm)	Both faces
	Less than 4 ft (1200 mm)	6 in. (150 mm)	Center of wall
Precast concrete	4 ft (1200 mm) or more	8 in. (200 mm)	Center of wall
	Less than 4 ft (1200 mm)	4 in. (100 mm)	Center of wall
Description		Minimum wall thickness	
Tendon prestressed concrete tanks		See ACI 350	
Wrapped prestressed concrete tanks		See ACI 350	

Note: Placement windows (temporary openings in the forms) or tremies are recommended to facilitate concrete placement in cast-in-place walls greater than 6 ft (1800 mm) in height.

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 structures. See ASTM C 913 for additional design provisions relating to factory-precast sumps.

ACI 372R, AWWA D110, ACI 373R, and AWWA D115 provide additional guidance for the design of prestressed concrete liquid-containment structures. See ACI 223 for information and guidance on shrinkage-compensating concrete.

Roofs should be designed for dead loads, including any superimposed dead loads (insulation, membranes, mechanical equipment, and earth load, if buried) and live loads (snow, pedestrians, and wheel loads, if applicable).

A minimum slope of 2% should be included in the design of floors and trench bottoms to prevent ponding and help drainage. Secondary containment systems for flammable and combustible liquids should have a slope that is in accordance with NFPA 30, "Flammable and Combustible Liquids Code," or an applicable fire code.

2.2.2 *Wall thickness and reinforcement*—The minimum wall thickness and reinforcing steel location in walls should comply with Table 2.1.

2.2.3 *Footings*—Footings should be cast on top of, or monolithically with, the floor slab to enhance liquid tightness.