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Design, Installation, and Maintenance of Coating Systems for Concrete Used in Secondary Containment

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Foreword

This state-of-the-art report covers the design, installation, and maintenance of polymeric coating systems that are applied and directly bonded to concrete in secondary containment applications. This report is intended to inform manufacturers, specifiers, applicators, and facility owners who are required to contain chemicals and/or protect concrete in these applications.

Concrete is used in secondary containment structures because it is a cost-effective material if properly designed and installed. A chemical-resistant coating is often applied to the concrete to extend the service life of the secondary containment structure and properly contain the chemicals.

Numerous recommended practices, specifications, guides, conference proceedings, books, and technical papers have been published by NACE, SSPC, and other organizations covering the many aspects of coatings for concrete. This report focuses on those aspects of the design, materials, and procedures that are specific to coatings for concrete in secondary containment applications, making reference to other publications when appropriate. While there are numerous successful commercial products and designs for containment of chemicals, this report focuses on concrete structures that are coated with thermoset polymer coating systems. Other potentially effective containment systems, such as acid-resistant brick and thermoplastic liners, are not described in this report.

Coatings used in secondary containment applications are also called linings, lining systems, or protective barrier systems; however, for simplicity they will be referred to as coatings or coating systems in this report.

This technical committee report was drafted by NACE Task Group T-6H-52, a subcommittee of T-6H on Coating Materials for Atmospheric Service. NACE/SSPC Joint Task Group H* completed the report, which is published by NACE International under the auspices of Group Committee T-6 on Protective Coatings and Linings and by the Steel Structures Painting Council.

Contents

Section 1: Regulations

1.1 The objective of regulations on secondary containment is to prevent migration of hazardous materials into the soil, ground water, and surface water. In the United States numerous federal, state, and local regulations specifically address the containment of hazardous materials.[1-7] The Resource Conservation and Recovery Act (RCRA)[2] is a primary example of the applicable regulations that refer to containment of hazardous wastes.

1.2 Regulations on secondary containment usually require that the systems:[3]

(1) prevent migration of hazardous (regulated) materials;
(2) have a sound substrate;

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(3) be constructed of or lined with materials that are compatible with the hazardous (regulated) materials;
(4) be free of cracks or gaps; and
(5) contain the capacity of the largest tank.

Section 2: Service Conditions

2.1 The exposure of secondary containment systems to various chemicals and physical conditions is usually considered in the selection and design of the system. This section discusses the classification of exposure conditions. Appendices A and B list generic coating systems that have been successfully used in each exposure classification.

2.2 Chemicals

2.2.1 Classification by Type

Most acids and alkalis attack concrete; coatings are used to protect the concrete from attack. Most solvents and hydrocarbons do not attack concrete; however, they are classified as hazardous materials, and existing regulations require that they be contained.[3]

Chemicals can be classified by specific types and concentrations to rate the resistance of coatings to chemicals. Typically, chemicals within a specific class attack polymers in a similar manner. For acids and alkalis (with some exceptions), the higher the concentration, the more aggressive the attack. With solvents, the closer the solvent is to the solubility parameter of the coating, the more prone that coating is to swelling by permeation of that solvent. In addition, the lower the molecular weight of the solvent, the more rapidly it diffuses into the coating.

Mixing some chemicals reduces their aggressiveness to coatings (e.g., mixing acids with alkalis), assuming that the exotherm from the mixing does not cause thermal damage. (Potential thermal damage from exotherm is ignored.) Mixing other chemicals significantly increases their aggressiveness. For example, mixtures of acids and solvents or mixtures of two or more solvents are commonly used as paint strippers.

2.2.2 The chemical types used in Appendix A include:

(1) inorganic acids
(2) organic acids
(3) oxidizers and oxidizing acids
(4) alkalis
(5) chlorinated solvents
(6) oxygenated solvents
(7) hydrocarbon solvents
(8) salt solutions
(9) pesticides and herbicides

Examples of typical chemicals within each type are given in Appendix C.

2.2.3 Classification by Concentration

2.2.3.1 Most acids and alkalis are further classified by concentration, usually percent by weight in water. When a polymer in a coating is susceptible to attack by a specific chemical, a higher concentration of that chemical is usually more aggressive to the coating (sodium hydroxide is one notable exception). Where a known concentration of a specific chemical is to be contained, compatibility is determined by testing the resistance of the coating to that concentration of the chemical.

2.2.3.2 Evaporation, solidification, and mixing can modify the aggressiveness of a specific chemical. Many acids or alkalis will become more concentrated due to evaporation if they are spilled at a low concentration on a coating and not cleaned immediately. The higher concentrations are potentially more aggressive toward the coating. Some chemicals are spilled in the liquid state but solidify at ambient temperature, thus reducing their mobility and aggressiveness.

2.2.3.3 The concentration classifications used in Appendix A vary depending on the chemical type. For acids and alkalis, Appendix A follows the common practice of listing resistance to a dilute concentration (usually up to 10%, in water), a medium concentration (usually above 10%), and a concentrated level (the highest commonly used concentration). For solvents, Appendix A lists only the resistance to the concentrated (undiluted) level.

2.2.4 Frequency and Duration of Contact

2.2.4.1 For coatings that are suitable for continuous and long-term exposure to a chemical (i.e., suitable for immersion exposure or primary containment), frequency and duration of contact with the chemical is not a concern; however, for aggressive chemicals that will degrade a specific coating system, determining the frequency and duration of contact is important. Many factors can affect the actual exposure of the coating to the chemicals that are to be contained. These include spill frequency, spill amount, time until dilution or cleanup, effectiveness of dilution or cleanup, and temperature of the spill (see 2.2.5).

2.2.4.2 The exposure classifications used in Appendix A are 72 hours and continuous. The 72-hour classification applies to secondary containment areas subject to spills that are cleaned as soon as they are detected. The 72-hour chemical resistance requirement is often adopted for areas where spills may not be detected until after one whole weekend. The 72-hour classification is also applied to areas that are not subject to spills but are designed to contain chemicals after catastrophic failure of a primary containment tank. The continuous classification is for areas that are subject to continuous spills or areas where spills are not cleaned.

2.2.5 Surface Temperatures

2.2.5.1 Although spills from process chemicals may initially be at temperatures above ambient, these spills usually cool to ambient conditions in a relatively short period of time. Catastrophic tank failure for a chemical stored above ambient temperature is one exception. Increases in temperature caused by diluting and/or neutralizing concentrated acids and alkalis could affect the maximum temperature to which the coating is exposed.

2.2.5.2 The surface temperature classifications used in Appendix A include ambient temperatures (up to 40°C [104°F]), elevated temperatures (40°C to 70°C [104°F to 158°F]), and high temperatures (70°C to 100°C [158°F to 212°F]). These classifications are important because coatings used in secondary containment may deteriorate rapidly when exposed to chemicals at elevated or high temperatures.

2.3 Physical Conditions

2.3.1 Ambient Environment

2.3.1.1 When classifying the ambient environment to determine the exposure and suitability of a coating system, important factors include the temperature range (maximum and minimum surface temperature), the rate of temperature changes (i.e., daily due to ambient temperature swings or sudden due to thermal shock from chemical spills), and sunlight exposure.

2.3.1.2 The ambient temperature ranges used in Appendix B are as follows: low-temperature range (22°C ± 10°C [72°F ± 50°F]), which includes most indoor and controlled environments; medium-temperature range (22°C ± 20°C [72°F ± 68°F]), which includes most indoor areas without temperature control and some outdoor, covered areas; wider-temperature range (22°C ± 30°C [72°F ± 86°F]), which includes most outdoor environments; and extreme-temperature range (22°C more than ± 30°C [72°F more than ± 86°F]), which includes severe hot or cold outdoor environments.

2.3.2 Traffic Conditions

The traffic condition classifications used in Appendix B include:

(1) occasional foot traffic
(2) constant foot traffic
(3) fork lift
(4) drum storage
(5) process area
(6) tank storage
(7) heavy traffic (tanker trucks, steel-wheeled vehicles)

Section 3: Concrete

3.1 Concrete Design for New Structures[8-11]

Proper concrete design and installation practices are required to ensure the performance and success of the concrete as the substrate of the secondary containment system.

3.1.1 Concrete Properties

Describing specific raw materials and mix designs for concrete is beyond the scope of this report. These topics are adequately covered in numerous American Concrete Institute documents.[(1)] It is important to know the desired properties of the finished concrete structure and concrete surface and how they affect the coating to be applied. The properties of concern, the factors that affect these properties, and common specifications are given in the following paragraphs.

3.1.1.1 Strength

3.1.1.1.1 Compressive strength provides a rigid structural base for the coating. Tensile strength provides adequate adhesion between the coating system and the concrete. Tensile and shear strength ensure the concrete survives the stresses applied by the curing coating on the concrete. Tensile and flexural strength resist cracking in the concrete during curing and drying of the concrete and during thermal cycling.

3.1.1.1.2 In addition to installation, finishing, and curing practices, the strength of concrete is affected by the type of cement, the amount of cement in the mix, the water-to-cement ratio, and the air content. According to ACI 209,[12] the tensile strength of concrete ranges from 6 to 8% of the compressive strength. For secondary containment, ACI 350.2R[10] recommends a minimum of 28 MPa (4,000 psi) compressive strength and 1.7 MPa (250 psi) tensile strength at 28 days after concrete placement. The following mix design is typical for achieving these values:

(1) cement content: 200 kg/m^3 (600 lb./yd) minimum,
(2) water-to-cement ratio: 0.45 maximum,
(3) air content (depends on geographical location): 4 to 8%.

3.1.1.2 Strength Development

The rate at which concrete develops strength is important for scheduling coating application. According to ACI 209, strength development is a function of cement type, 28-day design compressive strength, temperature, and time. As described in ACI 305R[13] and ACI 306R,[14] the early rate of strength development increases with increased temperature; however, the ultimate strength achieved is lower for concrete that is placed at elevated temperatures. ASTM[(2)] C 150[15] Type III cement or accelerators are used where rapid strength development is required, but often at the unwanted expense of increased shrinkage. Strength development is slower for ASTM C 150 Type II and Type V cements.

3.1.1.3 Surface Strength

Surface strength enables the concrete to remain intact during surface preparation. It also helps to maintain adequate adhesion between the coating system and the concrete when subjected to stress from curing of the coating, thermal movement, and physical abuse. Surface strength is a function of the concrete design strength, segregation, and the cure at the surface. Segregation reduces surface strength and can be caused by too much vibration during placement or excessive finishing and can result in a high water-to-cement ratio or an excess of fine aggregate at the surface. Surface strength depends on the normal concrete cure parameters described in Paragraph 3.1.1.1, plus the added variable of how long the surface is kept moist. Concrete based on ASTM C 150 Type I cement reaches 50% of 28-day strength if the surface is not kept moist, 80% if the surface is kept moist for three days, and full 28-day strength if the surface is kept moist for seven days. Concrete based on ASTM C 150 Type III cement reaches full 28-day strength if kept moist for three days.[16]

3.1.1.4 Surface Imperfections and Porosity

Defects such as surface voids, tieholes, bugholes, pinholes, and excess porosity may affect the application or performance of the coating. Protrusions such as

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[(1)] American Concrete Institute (ACI), 38800 International Way, Country Club Drive, Farmington Hills, MI 48331.
[(2)] American Society for Testing and Materials (ASTM), 100 Barr Harbor, West Conshohocken, PA 19428-2959.