



NACE TR02203/ICRI 710.1-2023/SSPC-TR 5-2023  
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# Design, Installation, and Maintenance of Protective Polymer Flooring Systems for Concrete

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# Design, Installation, and Maintenance of Protective Polymer Flooring Systems for Concrete

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## Foreword

Concrete is subject to deterioration by a variety of mechanisms. Properly selected and applied flooring systems can protect concrete from deterioration caused by impact, abrasion, and chemical attack, as well as provide the features and benefits described in Section 1 of this report.

## Scope

This technical report provides information on the design, installation, and maintenance of protective polymer flooring systems that are applied and directly bonded to concrete. This document does not detail protective polymer flooring systems installed and bonded to other substrates. Installation of polymer coating systems to exterior applications and special service conditions, such as parking decks, balconies, and swimming pool decks, requires additional consideration with respect to the concrete composition and environmental conditions. These application areas are not specifically addressed in this report. This report is intended for use by manufacturers, specifiers, applicators, and facility owners who specify protective polymer flooring systems for concrete.

## Rationale

Numerous standards, conference papers, books, and technical reports on many aspects of polymer flooring for concrete have been published by NACE, ICRI, SSPC, and other organizations. This report focuses on those aspects of design, materials, and installation procedures that can help the user attain long-term service from a variety of polymer flooring systems for a wide range of applications.

## Referenced Standards and other Consensus Documents

### **AMPP/NACE/SSPC**, [www.ampp.org](http://www.ampp.org):

|                                       |                                                                                                                                          |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| NACE Publication 6G191<br>(withdrawn) | Surface Preparation of Contaminated Concrete for Corrosion Control (Available as an historical document only).                           |
| NACE Publication 6A187<br>(withdrawn) | Reinforced Polyester and Epoxy Linings (Available as an historical document only).                                                       |
| NACE SP0188                           | Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates                                                      |
| NACE SP0892                           | Coatings and Linings over Concrete for Chemical Immersion and Containment Service                                                        |
| SSPC-CTS 1                            | Classification of Concrete Coating Finish Textures                                                                                       |
| SSPC-Guide 20                         | Guide to Applying Thick Film Coatings and Surfacing Over Concrete Floors                                                                 |
| SSPC-Guide 26                         | Concrete Floor Coating Selection Guide                                                                                                   |
| SSPC-PA 14                            | Application of Thick Film Polyurea and Polyurethane Coatings to Concrete, Steel, and Non-Ferrous Metals Using Plural-Component Equipment |
| SSPC-Paint 39                         | Two-Component Aliphatic Polyurea Topcoat Fast or Moderate Drying, Performance-Based                                                      |
| SSPC-SP 13/ NACE No. 6                | Surface Preparation of Concrete                                                                                                          |

### **American Concrete Institute (ACI)**, [www.concrete.org](http://www.concrete.org):

|            |                                                                                           |
|------------|-------------------------------------------------------------------------------------------|
| ACI 209R   | Prediction of Creep, Shrinkage and Temperature Effects in Concrete Structures             |
| ACI 212.3  | Report on Chemical Admixtures for Concrete                                                |
| ACI 212.4R | Guide for the Use of High-Range Water-Reducing Admixtures (Superplasticizers) in Concrete |
| ACI 223R   | Standard Practice for the Use of Shrinkage-Compensating Concrete                          |
| ACI 224R   | Control of Cracking in Concrete Structures                                                |

|                  |                                                                                                          |
|------------------|----------------------------------------------------------------------------------------------------------|
| ACI 224.1R       | Causes, Evaluation, and Repair of Cracks in Concrete Structures                                          |
| ACI 232.1R       | Use of Raw or Processed Natural Pozzolans in Concrete                                                    |
| ACI 302.1R       | Guide for Concrete Floor and Slab Construction                                                           |
| ACI 302.2R       | Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials                              |
| ACI 305R         | Hot Weather Concreting                                                                                   |
| ACI 306R         | Cold Weather Concreting                                                                                  |
| ACI 308R         | Guide for Curing Concrete                                                                                |
| ACI 318          | Building Code Requirements for Structural Concrete                                                       |
| ACI 360R         | Design of Slabs on Grade                                                                                 |
| ACI 503R         | Use of Epoxy Compounds with Concrete                                                                     |
| ACI 504R         | Guide to Joint Sealants for Concrete Structures                                                          |
| ACI 515.1R       | Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete |
| ACI Guide 515.2R | Guide to Selecting Protective Treatments for Concrete                                                    |
| ACI 544.1R       | State-of-the-Art Report on Fiber-Reinforced Concrete                                                     |
| ACI 546R         | Guide to Concrete Repair                                                                                 |

**ASTM International (ASTM), [www.astm.org](http://www.astm.org):**

|                       |                                                                                                                                                                   |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ASTM C150             | Standard Specification for Portland Cement                                                                                                                        |
| ASTM C267             | Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes                                                  |
| ASTM C307             | Standard Test Method for Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacing                                                          |
| ASTM C309             | Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete                                                                                  |
| ASTM C413             | Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes                                         |
| ASTM C531             | Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes |
| ASTM C579             | Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes                                  |
| ASTM C580             | Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes           |
| ASTM C722             | Standard Specification for Chemical-Resistant Monolithic Floor Surfacing                                                                                          |
| ASTM C811             | Standard Practice for Surface Preparation of Concrete for Application of Chemical-Resistant Resin Monolithic Surfacing                                            |
| ASTM C845             | Standard Specification for Expansive Hydraulic Cement                                                                                                             |
| ASTM C883 (withdrawn) | Test Method for Effective Shrinkage of Epoxy Resin Systems Used with Concrete (withdrawn without replacement, 1996)                                               |
| ASTM C884             | Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay                                                                        |
| ASTM C920             | Standard Specification for Elastomeric Joint Sealants                                                                                                             |

|                        |                                                                                                                                                                 |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ASTM C1028             | Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method |
| ASTM C1315             | Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete                                          |
| ASTM D412              | Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension                                                                                |
| ASTM D543              | Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents                                                                               |
| ASTM D638              | Standard Test Method for Tensile Properties of Plastics                                                                                                         |
| ASTM D694              | Standard Practice for Immersion Testing of Industrial Protective Coatings and Linings                                                                           |
| ASTM D1308             | Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes                                                                  |
| ASTM D2047             | Standard Test Method for Static Coefficient of Friction of Polish-Coated Floor Surfaces as Measured by the James Machine                                        |
| ASTM D2583             | Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor                                                                  |
| ASTM D2794             | Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)                                                            |
| ASTM D3359             | Standard Test Methods for Measuring Adhesion by Tape Test                                                                                                       |
| ASTM D4060             | Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser                                                                                    |
| ASTM D4258             | Standard Practice for Surface Cleaning Concrete for Coating                                                                                                     |
| ASTM D4259             | Standard Practice for Abrading Concrete                                                                                                                         |
| ASTM D4260             | Standard Practice for Acid Etching Concrete                                                                                                                     |
| ASTM D4138             | Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means                                                  |
| ASTM D4262             | Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces                                                                                   |
| ASTM D4263             | Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method                                                                            |
| ASTM D4414             | Standard Practice for Measurement of Wet Film Thickness by Notch Gages                                                                                          |
| ASTM D4518 (withdrawn) | Standard Test Methods for Measuring Static Friction of Coating Surfaces                                                                                         |
| ASTM D4580             | Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding                                                                              |
| ASTM D4587             | Standard Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings                                                                       |
| ASTM D4787             | Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates                                                         |
| ASTM D5045             | Standard Test Methods for Plane-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials                                                   |
| ASTM D5402             | Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs                                                                   |

|            |                                                                                                                                                                                            |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ASTM D6132 | Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Over Concrete Using an Ultrasonic Gage                                               |
| ASTM D6943 | Standard Practice for Immersion Testing of Industrial Protective Coatings and Linings                                                                                                      |
| ASTM D7234 | Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers                                                                       |
| ASTM E96   | Standard Test Methods for Water Vapor Transmission of Materials                                                                                                                            |
| ASTM E1745 | Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs                                                                   |
| ASTM E1824 | Standard Test Method for Assignment of a Glass Transition Temperature Using Thermo-Mechanical Analysis Under Tension                                                                       |
| ASTM F462  | Consumer Safety Specification for Slip-Resistant Bathing Facilities                                                                                                                        |
| ASTM F1679 | Standard Test Method for Using a Variable Incidence Tribometer (VIT)                                                                                                                       |
| ASTM F2659 | Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete, Gypsum Cement and Other Floor Slabs and Screeds Using a Non-Destructive Electronic Moisture Meter |
| ASTM F2170 | Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes                                                                                        |
| ASTM F3010 | “Standard Practice for Two-Component Resin Based Membrane-Forming Moisture Mitigation Systems for Use Under Resilient Floor Coverings                                                      |
| ASTM F3191 | Standard Practice for Field Determination of Substrate Water Absorption (Porosity) for Substrates to Receive Resilient Flooring                                                            |

**EOS/ESD Association, Inc. (ESDA), [www.esda.org](http://www.esda.org):**

|                  |                                                                                                                                   |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| ANSI/ESD STM 7.1 | Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items – Floor Systems – Resistive Characterization |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------|

**International Concrete Repair Institute (ICRI), [www.icri.org](http://www.icri.org):**

|                           |                                                                                                                  |
|---------------------------|------------------------------------------------------------------------------------------------------------------|
| ICRI Guideline No. 310.1R | Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion |
| ICRI Guideline No. 310.2R | Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays                |
| ICRI Guideline No. 320.2R | Selecting and Specifying Materials for Repair of Concrete Surfaces                                               |

**National Floor Safety Institute (NFSI), [www.nfsi.org](http://www.nfsi.org):**

|                  |                                                                           |
|------------------|---------------------------------------------------------------------------|
| ANSI/NFSI B101.3 | Test Method for Measuring Wet DCOF of Common Hard-Surface Floor Materials |
|------------------|---------------------------------------------------------------------------|

**Underwriters Laboratories (UL), [www.ul.org](http://www.ul.org):**

|        |                                              |
|--------|----------------------------------------------|
| UL 410 | Slip Resistance of Floor Surfacing Materials |
|--------|----------------------------------------------|

## Section 1: Introduction: Features and Benefits

Technical reports are intended to convey technical information or state-of-the-art knowledge regarding corrosion. In many cases, they discuss specific applications of corrosion mitigation technology, whether considered successful or not. Statements used to convey this information are factual and are provided to the reader as input and guidance for consideration when applying this technology in the future. However, these statements are not intended to be recommendations for general application of this technology and must not be construed as such.

The following are some of the features and benefits provided by the application of a protective polymer flooring system to a concrete slab:

- 1. Chemical protection of the substrate:** Concrete is subject to deterioration by a variety of chemicals. Properly selected polymer flooring systems can provide protection from this deterioration when properly maintained.
- 2. Permeation resistance:** The sealing of a concrete floor can often prevent permeation of water or other liquid contamination. This is especially true in areas where severe environmental or service conditions exist.
- 3. Enhancement and retention of appearance:** The installation of a polymer flooring system can reduce deterioration caused by weathering and traffic, as well as make the concrete slab more aesthetically pleasing.
- 4. Dust control:** Polymer flooring systems on concrete surfaces can help control dust from the concrete itself and enhance the removal of accumulated airborne particles.
- 5. Improvement of light reflectivity:** Reflective polymer flooring systems can be used to reduce lighting costs and to enhance worker productivity.
- 6. Creation of electrical continuity:** Conductive and static-dissipative polymer flooring systems have been used to provide electrical continuity in applications where a direct ground or indirect reference ground are required to protect personnel or sensitive materials and equipment from static electricity, or stray currents. Some conductive flooring systems are also spark-proof for safety where flammable materials are stored or handled.
- 7. Surface texture:** The application of a polymer flooring system can provide a textured finish that influences the coefficient of friction.
- 8. Identification and delineation of information:** Polymer flooring systems can be colored to identify traffic aisles, safety zones, and other areas.
- 9. Facilitation of contamination clean-up:** Polymer flooring systems can be designed and installed to provide for temporary containment of chemical splash and spills and to enhance the ease in which the contaminants are cleaned from the surface.
- 10. Adherence to regulations:** Polymer floors are sometimes required to meet various regulations (see Section 3).

## Section 2: Definitions

**Accelerating Admixture:** An admixture that causes an increase in the rate of hydration of the hydraulic cement and thus shortens the time of setting, increases the rate of strength development, or both.<sup>1</sup>

**Aggregate:** Granular material such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag used with a cementing medium to produce either concrete or mortar.

**Air Inhibition:** The prevention of complete polymerization (curing) of a reactive polymer caused by the presence of air (oxygen).

**Alkali-Aggregate Reaction (AAR):** Chemical reaction in either mortar or concrete between alkalis (sodium and potassium) from portland cement or other sources and certain constituents of some aggregates.

**Amine Blush:** Surface opalescence (blush) on epoxy films caused by reaction of amine co-reactant with carbon dioxide and water to form an amine carbonate. This can affect adhesion of any subsequent coat if not properly removed.<sup>2</sup>

**Chemical Attack:** Degradation or discoloration caused by the action of a chemical.

**Chemical Resistance:** The ability of a material to resist degradation by reaction with, dissolution by, or reduction of physical continuity from contact with a chemical agent or agents, thereby retaining its capacity to perform as a functional or aesthetic entity.

**Coefficient of Friction (COF):** The ratio between the frictional force necessary to move one surface horizontally over another and the pressure between the force, usually gravitational, acting perpendicular to the two surfaces in contact. This coefficient is a measure of the relative difficulty with which the surface of one material will slide over an adjoining surface of itself, or of another.

**Coefficient of Linear Thermal Expansion (CLTE):** The change in linear dimension per unit length per degree of temperature change.

**Cohesive Failure:** A fracture or break within a given coat or material (the coating breaks within itself).

**Concentration:** Amount of a substance expressed in relationship to the whole.<sup>3</sup>

**Concrete:** A composite material that consists of a binding medium, within which are embedded particles or fragments of aggregate. The binding medium used to make portland cement concrete is a mixture of portland cement and water.

**Construction Joint:** The interface between concrete placements intentionally created to facilitate construction.

**Contaminant, Contamination:** Any extraneous material on or in any surface that can negatively affect the performance of a polymer flooring system on concrete.

**Contraction Joint:** A formed, sawed, or tooled joint in a concrete structure to create a weakened plane to regulate the location of cracking resulting from the dimensional change of different parts of the structure.

**Control Joint:** See *Contraction Joint*.

**Crack:** See *Dynamic Crack*, *Static Crack*.

**Cross-Linking:** When applied to polymer molecules, refers to the creation of chemical links between molecular chains to form a three-dimensional or network polymer, generally by covalent bonding. Extensive cross-linking, found in most thermosetting resins, makes all of the linked chains into one larger molecule. Cross-linking generally toughens and stiffens polymer floorings. Thermosetting materials cross-link under the influence of heat and catalysis. Cross-linking might also be induced by the use of catalysts, ultraviolet light, and/or electron curing.

**Disbondment:** The separation resulting from insufficient adhesion of a coating to an undercoating or other substrate.

**Dynamic Crack:** (Active Crack): Any crack for which the mechanism causing the cracking is still active; any crack that is still propagating.

**Elastomer:** A natural or synthetic polymer that has the capability of recovering its original size and shape after deformation. After removal of a tensile load, an elastomer returns to approximately its original length.

**Expansion Joint:** See *Isolation Joint*.

**Finish:** The texture or appearance of a surface after finishing operations have been performed.

**Finishing:** Leveling, smoothing, compacting, or otherwise treating surfaces of a fresh or recently placed concrete, mortar, or polymer flooring system to produce the desired appearance and texture.

**Friction:** The resistance developed between the physically contacting surfaces of two bodies when there is a movement or attempted movement of one body relative to the other parallel to the plane of contact (SSPC-Guide 20).

**Gap-Graded Aggregates:** Aggregate containing particles of both large and small sizes, in which particles of certain intermediate sizes are wholly or substantially absent.

**Glass Transition Temperature:** The temperature at which the non-crystalline portion of a polymer is transformed from a brittle, glass-like material to a tough, rubbery material.

**Grout, Grouting:** A mixture of cementitious or polymer materials used as filler for cracks or other voids in a concrete or polymer surface that is to be coated.

**Hazardous Material:** A substance which, by reason of being explosive, flammable, toxic, corrosive, or otherwise harmful, is likely to cause death or injury (acute or chronic) if misused.

**Holiday:** A discontinuity or void in a coating film that exposes the substrate.

**Hydrolysis:** A disruptive reaction of a compound with water, which causes the compound to split into two parts, one of which combines with the hydrogen ion ( $H^+$ ) of water and the other with the hydroxyl ion ( $OH^-$ ) of water.

**Hydrophilic:** Describes a substance that absorbs or exhibits affinity for water (wetable).

**Hydrophobic:** Describes a substance that does not absorb or exhibit affinity for water (non-wetable).

**Initiator:** A chemical compound that initiates a polymerization reaction.

**Isolation Joint:** A separation between adjacent sections of a concrete structure to allow relative movement in three directions and through which all of the bonded reinforcement is interrupted.

**Joint:** See *Contraction Joint*, *Construction Joint*, or *Isolation Joint*.

**Laitance:** A layer of weak material derived from cementitious material and aggregate fines either (1) carried by bleeding to the surface or to internal cavities of freshly placed mixture; or (2) separated from the mixture and deposited on the surface or internal cavities during placement of the mixture.

**Liquid Membrane-Curing Compound:** A liquid applied to the surface of newly placed concrete that retards the loss of water, and, if pigmented, reflects sunlight.

**Moisture Vapor Emissions:** The flow of water from concrete in the form of moisture vapor as the result of 1) mix water during the drying process, 2) water transmission through the slab from another source, 3) water introduced through other means such as weather, water washing, etc.

**Monolithic:** A term used by the polymer flooring industry to describe a seamless polymer flooring system.

**Osmosis:** Movement of a solvent through a semipermeable membrane into a solution of higher-solute concentration that tends to equalize the concentrations of solute on the two sides of the membrane.

**Permeability:** Herein refers to the rate of water vapor transmission through unit area of flat material induced by a vapor-pressure-per-unit difference between two specific surfaces at a designated temperature and humidity.

**Pinhole:** A very small discontinuity of the polymer flooring system caused by the formation of a void in the system film thickness as the liquid resin is absorbed into the substrate, extending from the exterior of the film in a conical concave shape to the substrate.

**Plastic Cracking, Plastic Shrinkage Cracking:** Cracking that occurs in the surface of fresh concrete soon after it is placed and while it is still plastic.

**Polymer Flooring:** A liquid or a liquid with fillers and/or reinforcement that is applied to a substrate and cures by heat or by catalyzing to form a thermoset polymer that bonds to and protects the substrate and provides a barrier for the containment of chemicals.

**Polymer Flooring System:** Any combination of liquid-polymer products used as sealers, coatings, or mortars for installation on concrete to provide for repair, protection, ease of maintenance, or enhancement.

**Porosity:** The ratio, usually expressed as a percentage, of the volume of voids in a material to the total volume of the material, including the voids.

**Profile, Surface Profile:** The topographical contour of the concrete surface.

**Reflective Cracking:** Cracking that develops in a polymer flooring system directly over a dynamic crack in the concrete.

**Reinforcement:** Fabrics and functional fillers that improve the physical properties of the polymer flooring system. Aramid, polyester, fiberglass, and carbon fabrics are commonly used reinforcements. Micaceous silicate, micaceous iron oxide, glass flake, and graphite flake offer increased physical properties and reduced permeability.

**Sealant, Joint Sealant:** A flexible material used to exclude water and solid foreign materials from joints.

**Slip Resistance:** The relative force that resists the tendency of the shoe or foot to slide along the walkway surface. Slip resistance is related to a combination of factors including the walkway surface, the footwear bottom, and the presence of foreign materials between them (ASTM D2047).

**Soundness:** A qualitative measure of the suitability of the concrete to perform as a solid substrate or base for a coating or patching material. Sound concrete substrates usually exhibit strength and cohesiveness without excessive voids or cracks.

**Static Coefficient of Friction:** The ratio of the horizontal component of forces applied to a stationary body that just overcomes the friction or resistance to slipping to the vertical component of the weight of the object of force applied to it (ASTM D2047).

**Static Crack:** A nonmoving concrete-surface crack that does not change in width over time.

**Stress Concentration (Point Loading):** Localized areas of applied load as compared to uniform loading.

**Surface Preparation:** The method or combination of methods used to clean a concrete surface, remove loose and weak materials and contaminants from the surface, repair the surface, and roughen the surface to promote adhesion of a protective coating or lining system (SSPC-SP 13/NACE No. 6).

**Texture:** The height of the major peaks relative to the major valleys of the polymer floor finish. The visual, and especially the tactile, characteristics of the surface.

**Thermal Expansion:** See *Coefficient of Linear Thermal Expansion*.

**Thermal Shock:** The rapid exposure of a material to a dramatic change in temperature.

**Thermoset, Thermoset Polymer:** A material that undergoes a chemical reaction by the action of heat, catalysts, ultra-violet light, etc., causing the material to form a relatively infusible state.

**Vapor Barrier:** See *Vapor Retarder*.

**Vapor Retarder:** (formerly vapor barrier) A material or construction that impedes the transmission of water vapor under specified conditions (ASTM E1745).

**Water of Convenience:** The amount of water over that which is required for complete hydration of the hydraulic cement that is added to a concrete mixture for the sole purpose of increasing the workability of the mix.

**Workability:** A subjective measure of the ease of installation of concrete and applied products such as polymer flooring systems.

### Section 3: Regulations and Codes

Installation of seamless flooring systems throughout the world should comply with national and regional regulations and building codes. The agencies and regulations that are applicable to polymer flooring projects in the United States include but are not limited to the following:

#### 1. U.S. Environmental Protection Agency (EPA)

Title 40 of the U.S. Code of Federal Regulations<sup>4</sup> (40 CFR) contains the EPA regulations dealing with paint and coating issues. These issues range from lead-based paint activities (possibly important when removing old flooring systems), volatile organic compound (VOC) emissions, and protection of drinking water and the environment through secondary containment requirements. These requirements can be applicable to some flooring projects. The regulations describe the results to be achieved, but do not specify how to achieve those results, e.g., thickness of flooring material, permeation rates, etc.

#### 2. U.S. Occupational Safety and Health Administration (OSHA)

Title 29 of the U.S. Code of Federal Regulations (29 CFR) Part 1926<sup>5</sup> refers to OSHA regulations pertaining to many issues important to the polymer flooring industry. Among these issues are those concerning illumination, ventilation, noise exposure, confined spaces, permissible exposure limits (PEL) for air contaminants, personal protection equipment, exposure to crystalline silica, toxic substances, and other safety-related issues.

#### 3. U.S. Food and Drug Administration (FDA)

The U.S. Code of Federal Regulations Title 21 (21 CFR) – Food and Drugs Chapter 1 – Food and Drug Administration Department of Health and Human Services Subchapter B – Food for Human Consumption Part 110, “Current Good Manufacturing Practice in Manufacturing, Packaging, or Holding Human Food,” provides general recommendations with respect to facility design and maintenance. Within this same document, Subchapter C – Drugs: General, Part 211, “Current Good Manufacturing Practice in Manufacturing for finished pharmaceuticals, Subpart C – Buildings and Facilities,” requires that aseptic processing areas have floors, walls, and ceilings of smooth, hard surfaces that are easily cleanable.<sup>6</sup>

The U.S. Food and Drug Administration (FDA) publishes the Food Code,<sup>7</sup> a model that assists food control jurisdictions at all levels of government by providing them with a scientifically sound technical and legal basis for regulating the retail and food service segment of the industry (restaurants, grocery stores, and institutions such as nursing homes). This document states: “Except as specified under § 6-201.14 and except for antislip floor coverings or applications that may

be used for safety reasons, floors, floor coverings, walls, wall coverings, and ceilings shall be designed, constructed, and installed so they are SMOOTH and EASILY CLEANABLE.”

Hazard Analysis and Critical Control Point (HACCP)<sup>(1)</sup> is an internationally recognized management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement, and handling, to manufacturing, distribution, and consumption of the finished product. An HACCP system requires that potential hazards are identified and controlled at specific points in the process. This includes biological, chemical, or physical hazards. Within these facilities, the walls, floors, and ceilings are typically made of durable materials impervious to moisture, provide adequate floor drainage (slope of floors to drains be at least 0.64 cm per 30.5 cm (0.25 in per foot) in all areas where floors are subject to flooding-type cleaning, or where normal operations release or discharge water or other liquid waste on to the floor.

#### **4. U.S. Department of Agriculture (USDA)<sup>(2)</sup>**

The USDA no longer qualifies or maintains a list of approved polymer flooring products for use in food processing facilities. Instead, the USDA is working with the FDA on the HACCP policy. It is at the discretion of the processor to manage bacterial growth and meet the required quality and sanitary standards.

## **Section 4: Service Conditions**

This section discusses the classification of service conditions to which polymer flooring systems are exposed. A flooring system is designed to withstand the anticipated impact, abrasion, and splash and spill of chemical exposure, provided that the floor system is maintained in accordance with the manufacturers’ recommendations.

### **1. Traffic Conditions**

Traffic conditions dictate the flooring system that meets the needs of the applications. These conditions can range from occasional foot traffic to steel wheel traffic in combination with heavy impact. The degree of dirt and abrasives in combination with maintenance procedures also impacts the abrasion resistance required by the flooring system. Evaluation of the service conditions for physical abrasion and impact includes the following exposures:

- (a) Abrasion areas
  - Occasional foot traffic
  - Constant foot traffic
  - Vehicular traffic
    - Pneumatic tires
    - Solid polymer tires
    - Hard rubber tires
    - Steel wheels
    - Air pallets
- (b) Impact areas
  - Drum storage
  - Mechanics’ tools and equipment
  - Loading/unloading
  - Pallet movement and storage
  - Product and scrap material impact

<sup>(1)</sup> International HACCP Alliance, 120 Rosenthal Center, 2471 Texas A&M University, College Station, TX 77843-2471, [www.haccpalliance.org](http://www.haccpalliance.org).

<sup>(2)</sup> U.S. Department of Agriculture (USDA), 14th and Independence Ave. SW, Washington, DC 20250, [www.usda.gov](http://www.usda.gov).

## 2. Chemical Conditions

The chemical resistance of a polymer floor system depends largely on the resistance of the system's polymer resin to the specific chemical reagent to which it is exposed. Other characteristics of the polymer flooring system that can contribute to chemical resistance include the cross-link density of that polymer, the type and amount of pigments and other fillers, the thickness of the polymer flooring system, and the type and amount of reinforcement used.

### (a) Classification of Chemicals

Chemicals can be classified by generic type and concentration. Examples of typical chemicals in various chemical classifications are listed in Appendix A. Generally, chemicals within a specific class react with specific polymers in a similar manner. The higher the concentration of an acid, alkali, or solvent, the more aggressive the attack. If a known concentration of a specific chemical is to be exposed to the polymer flooring system at a given temperature, the effect of that exposure can be predetermined by testing the resistance of the flooring system in accordance with test procedures identified in Appendix B.

### (b) Frequency and Duration of Contact

Frequency and duration of chemical contact are typical considerations in the design of flooring systems that are to be exposed. Increased concentration of the chemical as a result of evaporation or increases in reactivity caused by combination with other chemicals can create a more aggressive chemical reagent. Some of the negative effects of exposure of some polymer resins to specific chemicals might be either nonexistent or reversible if the exposure is short-lived and infrequent. Good housekeeping programs can be very effective in reducing the effect of chemical attack on polymer floor systems.

### (c) Surface Temperature

The temperature of the chemical that comes in contact with the polymer flooring system has an effect on the degree to which the resin system resists degradation from the exposure. In addition to the increased reactivity of the chemical at higher temperatures, the polymer floor system itself can sometimes undergo a change in physical properties. Those changes include detrimental effects on elasticity, hardness, permeability, adhesion, and volume stability above its glass transition temperature.

## 3. Temperature Conditions

When classifying the ambient environment to determine the temperature exposure and suitability of a flooring system, factors including the source of heat, surface temperature range (both wet and dry), duration of exposure, and the rate of temperature change are all considerations.

Thermal shock can cause the polymer system to expand or contract at a much faster rate than the concrete, causing stress at the bond line in excess of the tensile strength of the concrete, resulting in delamination. The stresses applied to the concrete/polymer flooring interface from thermal shock are affected by the difference in coefficient of thermal expansion (CTE) of the concrete and the polymer flooring system. Polymer flooring systems with CTEs closer to that of the concrete substrate might perform better than systems with high CTEs in applications designed for service in thermal shock conditions. Use of composite fabric reinforcement, inert flake fillers, mineral or metallic fillers, elastomeric systems, or combinations of these technologies increases the resistance to thermal shock.

## 4. Electrostatic Conditions

Electrostatic discharge or the generation of triboelectric energy are of major concern in industries such as microchip manufacturing, electronic manufacturing, ordnance, and other industries requiring safeguards, to protect facilities, personnel, materials, equipment, and products from damage caused by an electrostatic discharge or spark caused by the buildup and release of static electricity. A polymer flooring system can be designed to be electrically conductive or static dissipative and, with or without conductive footwear, provide a system to alleviate this problem. Conductive and static dissipative floorings and coatings are designed to provide protection from electrical charges causing harm to workers or products.

The differences between conductive and static dissipative flooring systems are largely found in the measurement of the resistance of the flooring system to the flow of electricity. Conductive flooring has an electrical resistance of  $2.5 \times 10^4$  to  $1.0 \times 10^6$  ohms, and it can drain an electrical charge of 5,000 V to zero in 0.05 seconds. Static dissipative flooring has a resistance of  $1.0 \times 10^6$  to  $1.0 \times 10^9$  ohms. It will prevent the generation of static electricity and drain a 5,000 V charge to zero in less than 0.20 seconds. Conductive floor systems are permanently grounded to a true earth ground to function properly. Performance testing is conducted in accordance with ANSI/ESD STM 7.1 to verify the flooring systems conductive properties.

## 5. Exterior Conditions

In addition to the considerations for temperature conditions listed in Item 3, other typical considerations for exterior conditions include the effects of ultraviolet (UV) light, abrasion, freezing, wetting, and drying. Use of materials on exterior surfaces requires special design considerations that are beyond the scope of this report.

## Section 5: Properties of Concrete

When the installation of a flooring system on a concrete slab is being considered, one of two conditions is always present. Either the concrete is pre-existing and the protective flooring system designer has no influence on its quality or manner of construction, or the concrete is currently being designed and those involved in the choice of a protective flooring system have an opportunity to provide recommendations.

ACI 302.1R, ACI 302.2R, ACI 360R and other ACI guides provide information addressing concerns over concrete mix design, mixing, transportation, installation, and curing of concrete. In addition, there are a number of documents that discuss the proper design of concrete floor slabs on grade. These discussions include "the aspects of subgrade, vapor barrier, concrete mix design, volume changes, placing, finishing, curing, and drying of concrete that directly or indirectly affect the subsequent installation of polymer floor toppings and coatings."<sup>8</sup> The following information addresses those areas of particular interest to personnel concerned with concrete floor slabs that receive polymer flooring systems.

### 1. Concrete Design for New Slabs

Any flooring system that is bonded to a concrete substrate depends on the concrete for its composite structural integrity. Details concerning the design of concrete floor slabs are addressed in numerous ACI documents, including ACI 302.1R, ACI 318, ACI 360R, ACI 515.1R, and ACI 224R. The range of service conditions and exposures of polymer flooring systems varies widely, affecting the specific design considerations.

The effects of shrinkage, thermal movement, live loads, and dead loads are typically considered and accommodated in the design of the concrete mix, reinforcement, slab thickness, and joint layout. Achieving the proper slope to facilitate drainage is also an important design consideration in areas subjected to wet processing or requiring wash down. Proper concrete design and installation practices can provide concrete of sufficient quality to allow for the successful installation of polymer flooring systems with very low permeability. Proper design and installation can reduce the incidence of polymer flooring system failures resulting from improper mix design, poor placement and finishing practices, poor curing practices, and common moisture-related problems attributed to improper selection and installation of vapor-barrier systems.

#### (a) Soil Support System

The soil support system consists of subgrade, sub-base, and base materials. The proper design of the soil support system provides adequate uniform support for the structure and its designed use, adequate drainage through the base and sub-base, a capillary break in the compacted granular base, and a vapor barrier between the base and the sub-base.

#### (b) Concrete Composition

Concrete, in its most basic form, is comprised of portland cement, fine aggregate, coarse aggregate,

water, and air. Concrete often contains chemical admixtures and mineral admixtures to aid in workability and affect setting times, physical strengths, and density. Water and cement create a paste that binds the other ingredients together. The addition of fine aggregate to the paste produces a mortar. The addition of coarse aggregate to the mortar produces concrete. The use of chemical and mineral admixtures allows for the production of high-performance concrete. The type and amount of cementitious ingredients in the mix, the water-to-cementitious ratio, the total aggregate-to-paste ratio of the mortar, the ratio of coarse aggregate to fine aggregate, the use of chemical or mineral admixtures, and the air content (both entrapped and entrained) all play pivotal roles in the production and installation of quality concrete floor slabs.

(c) Strength Development

The relatively high compressive strength of concrete provides a rigid structural base for a flooring system. Tensile strength of the concrete provides adequate adhesion for the bonded flooring system. However, according to ACI 209R, the tensile strength of concrete ranges from only 6 to 8% of its compressive strength. The tensile adhesion of polymer-based products applied to concrete is limited to the weaker tensile strength of the two surfaces. Because of concrete's low flexural and tensile strength, cracking often occurs and usually transfers through the floor system unless preventative measures are taken in the design of the concrete and/or in the formulation of the polymer system.

The rate at which concrete develops strength is a function of the environmental conditions and is important for scheduling polymer floor system installations. According to ACI 209R, strength development is a function of cement type, design, compressive strength, temperature, and time. As described in ACI 305R and ACI 306R, the early rate of strength development increases with increased temperature; however, the ultimate strength achieved is generally lower for concrete that is placed at elevated temperatures. ASTM C150 Type III cements or accelerating admixtures are typically used if rapid strength development is desired. Strength development is slower for ASTM C150 Type II and Type V cements, as well as any cements containing fly ash.

Polymer flooring systems have traditionally been installed no sooner than 28 days after concrete placement. The 28-day waiting period originated as a civil engineering structural requirement and was adopted by the polymer flooring industry because it usually allowed sufficient time for the required concrete compressive strength and complementary tensile strength to develop. This time period was then transposed onto the concept of concrete drying.<sup>9</sup> This 28-day waiting period is a controversial topic that involves facility owners, polymer flooring manufacturers, applicators, and design professionals. Many factors affect strength development and moisture movement in concrete. These factors can reduce or increase the time required for strength and moisture levels to become acceptable. In addition, many construction schedules do not allow for a 28-day waiting period. For these reasons, ASTM C150 Type III high early-strength cements, mineral admixtures, chemical admixtures, heat-cure blankets, and combinations of these materials and methods have been used to accelerate the strength development of concrete.

Quantifiable surface properties, as discussed in Section 5, rather than a period of time, are often specified. NACE SP0892 and ACI 515.1R do not recommend specific periods of time for cure, but these standards do address surface dryness, surface strength requirements, and other surface quality issues.

(d) Concrete Shrinkage and Shrinkage Control

Concrete shrinkage is a reduction in volume caused primarily by loss of water.

Plastic shrinkage occurs when moisture is lost from the surface of fresh concrete before it sets (either by evaporation or by absorption into the substrate).

Autogenous shrinkage occurs when moisture is consumed into hydration reactions, causing self-desiccation of the concrete.

Drying shrinkage occurs when moisture is lost from hardened concrete (ACI 224.1).