



SSPC-TR 5
Publication No. 04-01

ICRI Technical Guideline 03741

NACE Publication 02203
Item No. 24220

Joint Technical Committee Report

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

This SSPC: The Society for Protective Coatings (SSPC)/International Concrete Repair Institute (ICRI)/NACE International (NACE) report represents a consensus of those individual members who have reviewed this document, its scope, and provisions. Its acceptance does not in any respect preclude anyone, whether he has adopted the report or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not in conformance with this report. Nothing contained in this SSPC/ICRI/NACE report is to be construed as granting any right, by implication or otherwise, to manufacture, sell, or use in connection with any method, apparatus, or product covered by Letters Patent, or as indemnifying or protecting anyone against liability for infringement of Letters Patent. This report should in no way be interpreted as a restriction on the use of better procedures or materials. Neither is this report intended to apply in all cases relating to the subject. Unpredictable circumstances may negate the usefulness of this report in specific instances. SSPC, ICRI, and NACE assume no responsibility for the interpretation or use of this report by other parties.

Users of this SSPC/ICRI/NACE report are responsible for reviewing appropriate health, safety, environmental, and regulatory documents and for determining their applicability in relation to this report prior to its use. This SSPC/ICRI/NACE report may not necessarily address all potential health and safety problems or environmental hazards associated with the use of materials, equipment, and/or operations detailed or referred to within this report. Users of this SSPC/ICRI/NACE report are also responsible for establishing appropriate health, safety, and environmental protection practices, in consultation with appropriate regulatory authorities if necessary, to achieve compliance with any existing applicable regulatory requirements prior to the use of this report.

CAUTIONARY NOTICE: The user is cautioned to obtain the latest edition of this report. SSPC/ICRI/NACE reports are subject to periodic review, and may be revised or withdrawn at any time without prior notice. SSPC, ICRI, and NACE require that action be taken to reaffirm, revise, or withdraw this report no later than ten years from the date of initial publication.

Approved November 2003

©2003, SSPC, ICRI, and NACE International

NOTICE TO THE READER: The SSPC, ICRI, and NACE releases of this publication contain identical wording in the same sequence. Publication format may differ.

SSPC: The Society for Protective
Coatings
40 24th Street, 6th Floor
Pittsburgh, PA 15222-4656
+1 (412) 281-2331

NACE International
1440 South Creek Drive
Houston, TX 77084-4906
+1 (281) 228-6200

International Concrete Repair Institute
(ICRI)
3166 S. River Road, Suite 132
Des Plaines, IL 60018
+1 (847) 827-0830

Printed by SSPC

Foreword

Concrete is subject to deterioration by a variety of mechanisms. Properly selected and applied flooring systems can protect from deterioration caused by impact, abrasion, and chemical attack, as well as provide the features and benefits described in Section 1 of this report. This technical committee report provides information on the design, installation, and maintenance of protective polymer flooring systems that are applied and directly bonded to concrete.

Numerous standards, conference papers, books, and technical reports on many aspects of polymer flooring for concrete have been published by SSPC, ICRI, and NACE, 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. This report is intended for use by manufacturers, specifiers, applicators, and facility owners

who specify protective polymer flooring systems for concrete.

This report was prepared by the SSPC/ICRI/NACE Joint Task Group N (NACE TG 005) on Coatings for Concrete Floors. This task group was comprised of members from all three organizations. At SSPC the Task Group was administered by the C.1 Unit Committee on Coatings and sponsored by Committee C.1.6 on Coatings for Concrete.

At NACE, the Task Group was administered by Specific Technology Group (STG) 02 on Protective Coatings and Linings—Atmospheric. It was also sponsored by STG 03 on Protective Coatings and Linings—Immersion/Buried, and STG 04 on Protective Coatings and Linings—Surface Preparation. At ICRI the Subcommittee on Polymer Floors was administered by the Technical Activities Committee and sponsored by the Committee on Coatings and Waterproofing.

NACE technical committee 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.

Section 1: Features and Benefits

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.

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

Accelerator¹: A substance which, when added to hydraulic-cement-based products such as concrete, mortar, or grout, increases the rate of hydration of the hydraulic cement, shortens the time of setting, or increases the rate of hardening and/or strength development.

Accelerator²: Any substance, used in small proportions, that increases the speed of a chemical reaction. In the coatings industry, this term is usually defined as a material that hastens the curing or cross-linking of a resin system. In the polyester resin field, it is defined more specifically as an additive that accelerates the action of the catalyst.

Adhesion²: A state in which two surfaces are held together by interfacial forces including valence forces, interlocking action, or both.

Adhesive Failure: The failure of one or both adherent surfaces under stress to continue to be held together.

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

Aggressive Service: Severe physical stress or chemical exposure.

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

Amine Blush: A thin film of carbamated amine at the surface of a cured epoxy system as the result of the reaction of an amine molecule with molecules of carbon dioxide and water, that results in a greasy-feeling film.

Bond-Breaker Tape: Used to prevent adhesion between the substrate and the flooring system to allow some movement at the joint or crack without causing immediate failure of the flooring system.

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

Chemical Resistance: The ability of a polymer flooring system to resist degradation and attack by a specific concentration of a chemical at a specific temperature within a given time period.

Coefficient of Friction³: The ratio of the horizontal component of force required to overcome friction to the vertical component of the object weight or normal force applied through the object causing the friction.⁴

Coefficient of Linear Thermal Expansion (CLTE): The change in length per unit length resulting from a one-degree rise in temperature.

Cohesion: Molecular attraction by which the particles of a body are united throughout the mass.

Cohesive Failure: The failure of the molecular attraction of a polymer under stress to remain united throughout the mass.

Concentration: Amount of a substance expressed in relationship to the whole.²

Concrete: A composite material that consists of a binding medium, within which is 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: A joint placed in a concrete slab at the end of an individual placement. These joints can be planned and correspond with the overall slab joint layout, or the result of an unplanned stoppage of the placement in progress.

Contaminant, Contamination: Any extraneous material on or in the concrete 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 floor slab that creates a weakened plane. This regulates the location of cracking resulting from dimensional changes of the concrete slab.

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.²

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

Concrete Curing Compound: A liquid that can be applied to the surface of newly placed concrete to slow the loss of moisture from the concrete. White pigmented curing compounds can reflect heat, providing an opportunity for the concrete to develop its physical properties at a more favorable temperature.

Disbondment: Loss of adhesion between a polymer flooring system and a substrate.

Dynamic Coefficient of Friction: The ratio of the horizontal component of force required to cause a body to slide at a relatively constant velocity to the vertical component of the weight of the object or force applied to it.³

Dynamic Crack: A crack in a concrete surface which exhibits changes in width as the concrete moves.

Efflorescence^{1,4}: A deposit of white crystals or powder on the concrete surface created by the reaction of hydrated lime with carbon dioxide and acidic pollutants.⁵ Free calcium hydroxide in concrete is soluble. As excess water is absorbed into the concrete, the calcium hydroxide goes into solution. As water is dried out of the concrete because of changes in the temperature and humidity of the environment, calcium oxide (lime) is deposited on the exterior surface as the solute dehydrates.

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.²

Expansion Joint: See *Isolation Joint*.

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

Finishing: Leveling, smoothing, compacting, and 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 physical contacting surfaces of two bodies when there is movement or tendency for movement of one body relative to another parallel to the plane of contact.⁵

Glass-Transition Temperature: The temperature at which the noncrystalline portion of a polymer is transformed from a brittle, glass-like material to a tough, rubbery material.²

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

Hazardous Substance: A substance which, by reason of being explosive, flammable, toxic, corrosive, or otherwise harmful, is likely to cause death or injury if misused.

Hazardous Waste: A waste defined in the Resource Conservation and Recovery Act (RCRA)⁶ as being subject to U.S. Federal hazardous waste regulations, or a waste that exhibits the characteristics that define a hazardous waste.

Holiday: A discontinuity in a protective coating that exposes unprotected surface to the environment.

Holiday Detector: An electrical device that locates discontinuities (holidays) in a protective polymer flooring system.

Hydrostatic Pressure: The pressure exerted by a liquid on an immersed body.

Hydraulic Pressure: A force created by the application of pressure to a saturated system.

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.²

Hydrophilic: Describes a substance that absorbs or exhibits its affinity for water (wetable).²

Hydrophobic: Describes a substance that does not absorb or exhibit affinity for water (nonwetable).²

Initiator: A material that initiates a polymerization reaction.

Isolation Joint: A joint used in concrete slab construction wherever complete freedom of vertical and horizontal movement is required between the floor and adjoining building elements. Often referred to as an *expansion joint*.

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

Laitance: A thin, weak, brittle layer of cement and aggregate on a concrete surface. The amount of laitance is increased by the degree of finishing or the amount of water used in the preparation of the concrete.⁵

Moisture Vapor Emission Rate (MVER): Amount of water vapor in pounds emitted from a 1,000 ft² area of concrete flooring during a 24-h period (multiply by 56.51 to convert to gm/m²).^{7,8}

Monolithic: Describes 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.

Osmotic Pressure: Pressure exerted on the concrete/polymer flooring interface through the capillaries in the concrete as a result of differences in solute concentration across the interface.

Permeability: 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.⁹

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 Cure (Convertible Coatings): A change in the properties of a polymeric system into a final, more stable, usable condition by the use of heat, radiation, or reaction with chemical additives.²

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 thermo-set 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 to concrete to provide for repair, protection, or enhancement.

Porosity, Surface 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: Surface contour as viewed from the edge of the surface.

Protective-Barrier Polymer Flooring System: See *Polymer Flooring*.

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 compressible material used to exclude water and solid foreign materials from joints.

Segregation: A differential in the concentrations of the components of mixed concrete that results in nonuniform proportions in the mass.

Slip Resistance: A descriptive term, encompassing all the critical material and human elements that may lead to a slip, and as such should not be used interchangeably with coefficient of friction. It is not a constant or an intrinsic property of a given surface composition, but, instead, varies with texture, wear, and contamination. It is also a function of the activities such as walking slow, fast, or running on a sloped incline or flat surface, pulling or pushing a load, and the physical condition of the individual, their behavior, and their perception.³

Stress Concentration: Localized areas of applied load as compared to uniform loading.

Static Coefficient of Friction: The ratio of the horizontal component of forces applied to a 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.³

Static Crack: A nonmoving concrete-surface crack with a constant width.

Surface Preparation: The method or combination of methods used to clean and remove loose or weak materials and contaminants, and to repair and roughen a concrete surface to promote adhesion of a protective polymer flooring system.

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

Thermal Shock: A rapid force exerted on polymer flooring as a result of a sudden change in temperature.

Thermoset, Thermoset Polymer: A material that undergoes a chemical reaction by the action of heat, catalysts, ultraviolet light, etc., causing the material to form a relatively infusible state.²

Vapor Barrier: True vapor barriers are products, such as rugged multi-reinforced membranes, that have water transmission ratings of 0.00 metric perms (0.00 U.S.perms) as determined by ASTM⁽¹⁾ E 96.^{9,10}

Vapor Retarder: A material that effectively minimizes the transmission of water vapor from the soil support system through the slab, but is not 100% effective in preventing its passage. It is generally recognized that a vapor retarder has a permeance of less than 0.2 metric perms (0.3 U.S. perms) as determined by ASTM E 96.^{9,10}

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 applied products such as polymer flooring systems.

⁽¹⁾ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

Section 3: Regulations

When specifying a polymer flooring system, applicable legislative regulations are often considerations. Unfortunately, no uniform standard covers the polymer flooring industry and the standards within each agency are fairly vague. However, knowledge of potential conflicts and research into the applicable standards can help to avoid noncompliant work practices.

The agencies and regulations that are applicable to polymer flooring projects in the United States include but are not limited to the following:

1. Environmental Protection Agency (EPA)⁽²⁾

Title 40 of the Code of Federal Regulations^{11 (3)} (40CFR) 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. Occupational Safety and Health Administration (OSHA)⁽⁴⁾

Title 29 of the Code of Federal Regulations (29CFR)¹² refers to OSHA regulations pertaining to many issues important to the polymer flooring industry. Among these issues are those concerning confined spaces, permissible exposure limits (PEL) for air contaminants, respiratory protection, exposure to crystalline silica, and other safety-related issues.

3. U.S. Food and Drug Administration (FDA)⁽⁵⁾

The FDA is currently in the process of adopting a self-administered quality control program for the food and drug industry called Hazards Analysis Critical Control Points (HACCP). If adopted, this program will require food and drug producers to develop a written manual and to maintain records following that manual, which would be open for review by the FDA. This program is similar to the ISO⁽⁶⁾ 9000 system for the food and drug industry. A significant part of this control program would be the avoidance of bacterial growth. Polymer flooring is an integral ingredient in such avoidance.

4. U.S. Department of Agriculture (USDA)⁽⁷⁾

The USDA no longer approves 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.

5. Americans With Disabilities Act (ADA)¹³

It is the responsibility of polymer flooring specifiers to consider the requirements of this Act to ensure that access to facilities is provided to persons with disabilities. In addition to the accessibility guidelines for buildings and facilities, the ADA recommends providing slip resistant surfaces.³ See Section 7, Paragraph 1(e).

6. NFPA⁽⁸⁾ 99¹⁴: National Fire Protection Association Standard for Healthcare Facilities

NFPA 99 is specific to the healthcare industry and specifies conductive flooring to “reduce the possibility of electrostatic spark discharges, with consequent ignition of flammable gases.” Polymer floor systems can be formulated with conductive filler materials to provide electrical continuity.

Section 4: Service Conditions

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

1. Traffic Conditions

The following are classifications used to rate the traffic conditions to which polymer flooring systems might be subjected.

⁽²⁾ U.S. Environmental Protection Agency (EPA), Ariel Rios Building, 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

⁽³⁾ Available from the U.S. Government Printing Office, 732 North Capitol Street NW, Washington, DC 20401.

⁽⁴⁾ U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), 200 Constitution Avenue, NW, Washington, DC 20210.

⁽⁵⁾ U. S. Food and Drug Administration (FDA), 5600 Fishers Lane, Rockville, MD 20857-0001.

⁽⁶⁾ International Organization for Standardization (ISO), 1 rue de Varembe, Case Postale 56, CH-1121 Geneve 20, Switzerland.

⁽⁷⁾ U.S. Department of Agriculture (USDA), 14th and Independence Avenue, SW, Washington, DC 20250.

⁽⁸⁾ National Fire Protection Association (NFPA), 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

- (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
 - Loading/unloading
 - Production lines

2. Chemical Conditions

The chemical resistance of a polymer floor system depends in large part 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 affects of exposure of some polymer resins to specific chemicals might be either non-existent 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 is the rapid exposure of a material to a dramatic change in temperature. In the polymer flooring industry thermal shock is commonly considered to be the rapid exposure of the composite concrete/polymer flooring system to elevated temperatures. This rapid exposure can cause the polymer system to expand 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 linear thermal expansion (CLTE) of the concrete and the polymer flooring system. Polymer flooring systems with CLTEs closer to that of the concrete substrate might perform better than systems with high CLTEs 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 resistance to thermal shock.

4. Electrostatic Conditions

A polymer flooring system can be designed to control the unwanted, sudden grounding of built-up static electricity or control of spark generation in contact with the floor. Examples of facilities that might require this type of design include microchip manufacturing facilities, electronic manufacturing facilities, and ordinance and other explosive goods manufacturing and storage facilities. Both conductive and static dissipative floor systems are permanently grounded to a true earthen ground in order to function properly. 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 with an electrical resistance of 2.5×10^4 to 1.0×10^6 ohms, as recommended by the NFPA, can drain an electrical charge of 5,000 V to zero in 0.05 seconds. Because conductive flooring drains off electrical activity so quickly, it prevents the buildup of static charge and eliminates the possibility of electrostatic discharge (ESD). Static dissipative flooring has a resistance of 1.0×10^6 to 1.0×10^9 ohms. It adds no static electricity to the environment and drains a 5,000 V charge to zero in less than 0.20 seconds. The use of static dissipative shoes, clothing, and tools assists

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

in maintaining a safe working environment. In addition to these safeguards, the structure, personnel, materials, equipment, and floor are typically maintained to provide electrical continuity with the floor. Tests for continuity in accordance with ASTM F 150¹⁵ are normally performed upon initial installation and every month thereafter.

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 preexisting 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 professional guidelines to enable a quality project.

ACI⁽⁹⁾ 302.1 R,¹⁰ ACI 360 R¹⁶ and other ACI standards 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.”¹⁷ 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 standards, including ACI 302.1 R, ACI 318,¹⁸ ACI 515.1 R,¹⁹ and ACI 224 R.²⁰ 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

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, freezing, wetting, and drying. Use of materials on exterior surfaces requires special design considerations that are beyond the scope of this report.

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 design of the soil support system provides adequate uniform support for the structure and its designed use, adequate drainage through the base and subbase, a capillary break in the compacted granular base, and a vapor barrier between the base and the subbase.

(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 may allow 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.

For Class-6 single-course industrial concrete floor slabs on grade, ACI 302.1 R-96¹⁰ suggests a minimum 31 MPa (4,500 psi) compressive strength at 28 days after concrete placement. It suggests a concrete mixture, when adjusted for local raw materials and historical performance, can be used to achieve these values:

⁽⁹⁾ American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

- Cementitious material: 279 kg/m³ (470 lb/yd³) minimum,
 - Portland cement according to ASTM C 150²¹
 - Pozzolan fly ash according to ASTM C 618²²
 - Mineral admixtures according to ASTM C 1240²³
- Water-to-cementitious ratio: 0.45 maximum

(c) Strength Development

The relatively high compressive strength of concrete provides a rigid structural base for a flooring system. Tensile strength provides adequate adhesion between the bonded flooring system and the concrete substrate. However, according to ACI 209²⁴ 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 design of the polymer system.

The rate at which concrete develops strength is important for scheduling polymer floor system installations. According to ACI 209 strength development is a function of cement type, design, compressive strength, temperature, and time. As described in ACI 305 R²⁵ and ACI 306 R,²⁶ 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 C 150 Type III cements or admixture accelerators are typically used if rapid strength development is desired. Strength development is slower for ASTM C 150 Type II and Type V cements, as well as any cements containing fly ash, such as Type IP.

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. This 28-day waiting period is a controversial topic that involves all 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 be acceptable. In addition, many construction schedules do not allow for a 28-day waiting period. For these reasons, ASTM C 150 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. In addition, low water-cementitious ratio mix designs and postcure drying methods have been used. For enclosed areas, dehumidification equipment has been used to reduce the drying time of concrete (after sufficient strength has been achieved) and to reduce humidity during installation, preventing premature failure of the polymer flooring.²⁷

Quantifiable surface properties, as discussed in Section 6, rather than a period of time, are often specified. NACE Standard RP0892²⁸ and ACI 515.1 R 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) Shrinkage

Shrinkage is a function of the loss of volume in the paste (cement and water) of concrete. Although complex in detail, this volume change is essentially the reduction in volume of the paste as a result of loss of water and from reduction in mass of the hydration products as they converge from water and cement to various chemical hydrates. Some of the ingredients and their effect on shrinkage are noted as follows:

- Cement type and amount
Cement types, listed in order from the most shrinkage to the least shrinkage, are as follows: ASTM C 150 Type III, ASTM C 150 Type I, ASTM C 150 Type II, and ASTM C 845²⁹ Type K.
- Water-to-cementitious (w/cm) ratio
Increasing the amount of water in a cement paste increases shrinkage.
- Temperature of plastic and hardened concrete
As temperatures increase, hydration and moisture loss increase, increasing the opportunity for shrinkage.
- Chemical or mineral admixtures
These substances reduce drying shrinkage by reducing the amount of water needed for a given level of workability. Although positive shrinkage reduction is achieved, it is not proportional to the reduction in water achieved.
- Curing
Following the practices of ACI 308³⁰ can help to prevent plastic shrinkage and reduce short-term drying shrinkage.

Shrinkage is divided into three phases: plastic shrinkage, short-term drying shrinkage, and long-term dry-

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

ing shrinkage. Plastic shrinkage occurs while fresh concrete is still in its plastic state prior to initial set at the surface. Stiffening of the concrete and a strength gain of 1 MPa (400 psi) define initial set. Short-term shrinkage (33% of total shrinkage) occurs in the first 28 days, and long-term shrinkage occurs at any time from 28 days up to three years from time of mixing. Ninety percent of long-term shrinkage occurs in the first year. Shrinkage can cause cracking, curling, and excessive joint movement in a concrete slab. According to ACI 209 shrinkage in concrete using Type I cement that is kept moist for seven days ranges from 415 to 1,070 $\mu\text{m}/\text{m}$ (415 to 1,070 $\times 10^{-6}$ ft/ft).²⁴

Common practices for combating problems as a result of shrinkage include:

- Minimizing mixing water in the concrete (low w/c ratio)
- Minimizing the total paste content of the concrete
- Maximizing aggregate size and total aggregate-to-paste ratio
- Using shading to prevent rapid evaporation of moisture at the surface during finishing operations to control plastic shrinkage cracking
- Erecting wind breaks
- Using moisture retaining covers
- Using monomolecular films or fog misting
- Immediate 100% moist curing for a minimum of seven days
- Placement of contraction joints, isolation joints, and construction joints in the proper location and at the proper time in accordance with ACI 302.1 R

ACI 223³¹ describes the use of ASTM C 845 Type K cements. Type K cement concrete initially expands to a volume that is greater than the initial (as cast) volume and shrinks afterward, similar to portland cement concrete. With adequate internal reinforcing, the steel provides internal restraint which is strained (stretched), and that strain is relieved upon shrinkage as the steel does not oppose the shortening of the concrete and helps pull the shrinking concrete back towards its initial volume. If properly designed the slab produces a net volume that is slightly larger than its initial volume. Because of this, highly reinforced structural designs can use continuous reinforced pavement concepts to reduce reliance on joints and produce closely spaced, tightly formed cracks. Further, total joint reduction in the range of 80 to 90% can be attained with shrinkage-compensating concrete, producing less warping in slabs on grade.

(e) Jointing of Concrete Slabs

ACI 302.1 R, ACI 360 R, ACI 504 R,³² and ACI 224 R provide recommendations on the location and design of joints for concrete structures. Joints can be clas-

sified as contraction (control) joints, isolation (expansion) joints, or construction joints.

Contraction joints are designed to accommodate shrinkage caused by drying and thermal movement. Isolation joints are designed to isolate adjacent and distinct structural sections, such as walls, column foundations, and equipment pads. Construction joints accommodate the construction schedule and can tie adjacent structural slabs together or provide for isolation jointing.

Contraction joints are usually cut as soon as possible after the finishing operation without raveling the joints by dislodging aggregates, but before random shrinkage cracking can occur. These joints are generally cut to a depth of at least one-fourth of the slab thickness. ACI 302.1 R provides recommendations on the distances between contraction joints. A commonly used criterion is that the distance in meters between joints is equal to 24 to 36 times the slab thickness in meters (the maximum distance in feet between joints would be equal to two to three times the slab thickness in inches).

(f) Concrete Finishing and Surface Characteristics

The methods used to finish a concrete surface have a significant effect on its properties. Typical surface properties including profile, porosity, and strength of concrete surfaces finished by a variety of methods as described in ACI 302.1 R. The generally preferred method of finishing concrete to receive applied polymer systems is by a light steel trowel. Two passes with the steel trowel are generally sufficient.¹⁶

(g) Concrete Cure

If the temperature is above 10°C (50°F), ACI 308 recommends seven days of moist curing for ASTM C 150 Type I portland cement-based concrete and three days for ASTM C 150 Type III portland cement-based concrete. ACI 308 also describes numerous methods of properly curing concrete, including the use of liquid membrane-curing compounds, ponding, and the use of various types of moisture-retaining covers.

Liquid membrane-curing compounds are commonly used to cure concrete and to reduce moisture loss immediately after placement and finishing of concrete surfaces. Materials and practices are described in ACI 308 and ASTM C 309.³³ Commonly used liquid membrane-curing compounds (some of which also act as sealers after the concrete has cured) include synthetic resins, waxes, and acrylic-based materials. Most of these materials are incompatible with thermo-set polymer flooring systems and are generally removed before installation.

2. Existing Concrete Floor Slabs

Existing concrete floor slabs are generally inspected to determine surface strength, overall compressive strength,

moisture movement, presence of contaminants, evidence of shrinkage, thermal movement, or structural movement. Existing slabs might have been subjected to physical abuse or chemical contamination that needs assessment and repair, or a change in the use of the facility can subject the floor system to a different set of use parameters.

(a) Surface Strength

Many polymer flooring manufacturers and design professionals specify a minimum concrete tensile bond strength of 1.4 to 2.1 MPa (200 to 300 psi), or 100% cohesive failure in the concrete substrate depending on the type of polymer flooring and the service conditions.

- ASTM D 4541³⁴ describes a procedure used to test the pull-off strength of thin-film systems.
- ACI 503 R,³⁵ Appendix A, describes a procedure used to test the pull-off strength of 0.64-cm (0.25-in.) mortar systems.

(b) Physical and Chemical Damage

Existing concrete floor slabs that have been subjected to mechanical damage (caused by impact or abrasion), chemical attack, or reinforced steel corrosion can be restored to provide a uniform, sound substrate for polymer flooring application. In cases of severe damage, the concrete is sometimes completely removed and replaced.

In order to receive and hold the patching material, all deteriorated concrete is typically removed and the surrounding sound concrete is saw-cut using procedures described in ICRI 03730.³⁶ Some contaminants can have a detrimental effect on the reinforcing steel or the applied polymer flooring if they are not completely removed.

Cementitious repairs are generally treated as new concrete. Polymeric grouts and patching materials are often used, especially when the polymer flooring is to be applied immediately after the repair.

(c) Other Defects and Imperfections

Surface voids, pinholes, and excess porosity can affect the performance of polymer flooring systems. The maximum substrate void size or porosity depends on the type of polymer flooring system being used, and the manufacturer's requirements. Voids are typically filled prior to application. If voids are not filled, trapped air may expand to create a condition known as "out-gassing," resulting in the formation of bubbles during or immediately after the polymer flooring installation. Excessive porosity in the concrete surface can result in pinhole development in the primer or in the finished polymer floor system itself.

Because they can cause holidays or thin sections in the polymer flooring, rough edges and protrusions in the surface of the concrete, such as trowel chatter, mortar splatter, ridges, penetrations, or sharp projections, are typically removed during surface preparation.

(d) Joints and Cracks

Many polymer-flooring systems are rigid and prone to reflective cracking. Therefore, existing joints and cracks are usually identified and the maximum expected movement quantified prior to polymer flooring selection. Movement at joints or cracks is a result of shrinkage, thermal cycling, dead-load settling, or live-load traffic. In existing structures over three years of age, no significant movement due to drying shrinkage is expected.^{17, 20, 37} Additional information about the identification of joints and their expected movement due to the other factors mentioned is given in ACI 302.1 R and ACI 504 R.

Monitoring joints and cracks over 24 hours can determine whether they are static or dynamic. However, all cracks have the potential for movement and can therefore be treated as dynamic cracks. Some cracks are invisible in warm conditions when the concrete is expanded, but they can become visible when temperatures are lower, when the concrete is drying (because the crack dries more slowly), or when a dye method is used to identify cracks. Joints and cracks are usually treated as described in Section 7, Paragraph 1 to prevent reflective cracking in the polymer flooring system. New and emerging technologies in the polymer flooring industry are providing polymer floor systems with elastomeric properties that also provide outstanding chemical and wear resistance. These systems are not as dependent on the jointing system in the base concrete slab on grade as are the more rigid traditional systems.

3. Moisture-Related Problems in Concrete Floor Slabs

(a) Source of Moisture

Excess moisture in concrete can produce the harmful effects of discoloration, interruption of polymerization of products, and delamination of bonded systems. Sources of excess moisture fall into three distinct categories: (1) moisture present at the surface prior to application, (2) moisture within the concrete that moves out of the concrete during and after application, and (3) moisture in contact with the concrete.

Moisture within the concrete can come from an external source or be the result of water of convenience. One often-discussed reason for waiting 28 days prior to polymer flooring installations over new concrete with a vapor barrier system in place is to allow this excess moisture to evaporate.³⁸ However, the evaporation of the excess moisture is dependent on the quantity of excess moisture, the difference in temper-

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

ature between the interior of the concrete and the exterior ambient environment, and the difference in humidity between the interior of the concrete and the external surrounding environment.

Unless an existing concrete structure is exposed to a distinct source of water and has been continuously wet, moisture migration as a result of drying is generally not a concern. However, all other issues discussed in this section apply to both new and existing concrete. It is important to determine whether a vapor barrier, a vapor retarder, or no vapor protection at all is under the existing concrete structure. If no positive side vapor protection exists, it might be impossible to install a polymer flooring system without first installing a negative side vapor-suppressing protective system. If a vapor barrier system is installed in accordance with ACI 302.1 R, the moisture vapor content of the concrete can be reduced to a desirable level by standard dehumidification and drying practices.

(b) Testing For Moisture

The following are some of the common methods used to determine the presence of or quantify the existence of and/or the movement of free moisture in concrete prior to the application of polymer flooring systems.^{39,40} However, these tests do not predict the presence and/or movement of moisture at a different point in time or under different environmental conditions of temperature and relative humidity.

- ASTM D 4263⁴¹ (Plastic Sheet Method)
This qualitative method indicates the presence of moisture movement for a particular 16-hour time period, but does not quantify the amount of moisture movement. This method has little statistical value in determining the quantity of moisture movement or the rate at which it is moving through the concrete.
- ASTM F 1869⁷ and ASTM E 1907⁸ (Determining the Rate of Moisture Emission Using Anhydrous Calcium Chloride)
This method uses anhydrous calcium chloride to make either a qualitative or quantitative evaluation of moisture emissions from the concrete expressed as $\text{g/m}^2/24 \text{ h}$ ($\text{lb}/1,000 \text{ ft}^2/24 \text{ h}$). The testing period is 72 hours.
- ASTM F 2170,⁴² Hygrometer Test (Relative Humidity Method)
- BS 5325,⁴³ Conductivity Test (Gel Bridge Method)
This method results in a “pass/fail” indication of whether or not moisture is being admitted.

- Carbide Acetylene Method⁴⁰
This is a destructive test that quantifies the specific portions of concrete removed and tested contain a measured content of moisture. It does not provide any information about the relative movement of moisture out of the concrete.
- Capacitance-Impedance Method⁴⁰
This test relies on portable electronic moisture meters that transmit strong radio waves that are absorbed by water. Calibration of the results obtained with this method depends on knowing the mix design of the concrete and the raw material used.

The polymer-flooring manufacturer can provide information on the tolerance of a specific polymer flooring system for free water or moisture migration. Polymer flooring systems have been successful when applied to concrete having moisture transmission rates of less than $15 \text{ g/m}^2/24 \text{ h}$ ($3 \text{ lb}/1,000 \text{ ft}^2/24 \text{ h}$) when measured by ASTM F 1869.⁷

Moisture-vapor movement is dependent upon the relationship between temperature and moisture content of two adjacent environments, the internal environment of concrete, and the external environment of the air surrounding the concrete.

If the vapor pressure in the air surrounding the concrete is lower than the vapor pressure within the concrete, moisture moves out of the concrete toward the area of lower humidity. Practice has shown that an effective method for reducing the moisture content of concrete floor slabs is dehumidification with air movement, which lowers the vapor pressure of air around the concrete.

For these reasons, temperature and relative humidity are usually measured during a test period. Moisture-vapor test-kit values are generally not considered useful in predicting possible problem areas unless the tests are conducted in the environment in which the floor is to be used. The air temperature and humidity around the concrete during the test are the same air temperature and humidity that are to be in place during the useful life of the floor.

When testing concrete for moisture, not all moisture tests provide sufficient information.⁴⁴ The plastic-sheet test, the mat test, conductivity meters, nuclear gauges, and surface probes do not yield sufficient information to ensure that moisture will not affect the performance of the polymer flooring system. ASTM F 1869, commonly known as the “calcium chloride test,” has been used extensively, and many flooring manufacturers are content with using this current industry standard.^{39,45} It has been pointed out that this test is only a determination of the moisture vapor emissions at a particular point in time under very specific conditions of temperature and humidity.⁴⁵ Others have

been comfortable with using this method provided a vapor barrier is present. The surface relative humidity test, as described in ASTM E 1907,⁸ has similar drawbacks. The subsurface relative humidity test, ASTM F 2170,^{42,46} uses in situ probes and has been proposed as a more accurate indicator of the moisture within the concrete. There have been cases in which moisture readings fluctuate significantly from season to season and from section to section within a floor.

(c) Moisture Problem Discovery

Occasionally, despite moisture testing, a problem is not identified until after an impermeable polymer flooring system is installed. Moisture problems with polymer floor systems in slabs on grade often manifest themselves as water-filled blisters containing trace elements of various salts and organic compounds. Blistering as a result of moisture is most common in slabs on grade. Flooring failures caused by moisture-induced blistering typically occur between one month and two years after the flooring system is installed. These blisters can vary in size (diameter and height) and frequency. Some moisture-induced blisters are dry when opened but show salt residues on the inner surfaces—evidence of the presence of moisture in the past.

Various theories have been proposed for the formation of water-filled blisters. All of these theories include excess moisture as a necessary component.

- Moisture vapor emission⁴⁴⁻⁴⁹
- Capillary pressure⁵⁰⁻⁵²
- Alkali silica reaction^{48, 53}
- Osmosis^{44,52,54-57}
- Polymer cure interruption^{44,50,53-55, 58}

(d) Moisture Problem Remediation

Once water blisters have occurred in a polymer floor system, there is no known solution other than to remove the affected areas and eliminate the source of moisture. Efforts to direct distinct sources away from the affected slab area have proved successful where appropriate. See Section 5, Paragraph 3(a). Barrier systems, applied as topical treatments to exposed concrete, have been used successfully to reduce moisture vapor emission rates to an acceptable level prior to application of the polymer floor system. Technologies used include but are not limited to the following:

- Alkali silicates
- Polymer-modified cementitious underlayments^{54,57}
- Controlled permeability underlayments⁴⁹
- Fibrous mat systems as underlayments⁴⁹
- Permeable flooring systems (limited use in wet or chemical environments)

Section 6: Surface Preparation

The process of preparing a concrete surface to receive a polymer floor system and the methods for creation of concrete surface profile are included in ICRI Technical Guideline No. 03732.³⁹ Other surface preparation methods include those described in ASTM D 4258,⁵⁹ ASTM D 4260,⁶⁰ ASTM D 4262,⁶¹ SSPC-SP 13/NACE No. 6,⁴⁵ NACE Publication 6G191,⁶² ASTM C 811,⁶³ and ACI 515.1 R. The ICRI document also has a companion set of molded castings to act as a physical and visual guide in the definition of acceptable surface profiles for the application of industrial coatings and polymer floor toppings.

Depending on conditions of the concrete, one or more methods of surface preparation can be specified. It is common for decontamination to precede mechanical preparation, and, if necessary, a second decontamination sometimes follows.

The objective of surface preparation is to produce a concrete surface profile that is suitable for application and adhesion of the specified flooring system. The steps typically followed to produce a suitable surface include the following:

1. Inspection of the Concrete Substrate

Inspection of the concrete substrate is conducted to determine the general condition, soundness, presence of contaminants, presence of moisture vapor emissions, and the best methods to prepare the concrete surface to meet the requirements of the polymer flooring system. Hydrophobic contaminants can be identified by a simple water drop test. A proper evaluation leads to the selection of the proper tools and equipment to accomplish the objective.

2. Removal and Replacement of Nondurable Concrete

Removal and replacement of nondurable concrete is performed prior to installation of the polymer system. Localized weak or deteriorated concrete is removed and replaced by sound concrete and structural repair materials.

3. Decontamination of the Concrete Surface

Decontamination of the concrete surface is the removal of bond-inhibiting materials such as oils, grease, wax, fatty acids, and other contaminants. This can be accomplished by the use of detergent scrubbing, low-pressure water cleaning (less than 35 MPa [5,000 psi]), steam cleaning, or

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

chemical cleaning.⁶⁴ The success of these methods is dependent on the depth of penetration of the contaminant, the contaminant's viscosity, the concrete's permeability, and the duration of exposure. Note that in areas contaminated with hydrophobic materials (oils, greases, fats), it may be necessary to decontaminate, then blast to obtain the required profile, and again decontaminate the blasted surface as most decontamination procedures (e.g., water, steam, or chemical cleaning) are only effective on the surface and do not significantly penetrate the concrete. Other contaminants can be identified by pH, infrared spectroscopy, or other chemical-analysis methods of testing. Acids and alkalis can be removed by neutralizing to form a water-soluble salt and then high-pressure water cleaning. In areas where the contaminants cannot be removed, complete removal and replacement of the contaminated concrete is typically considered.

NOTE: Decontamination methods that introduce large amounts of water can contribute to moisture-related problems as referenced in Section 5, Paragraph 2(e). Visual inspection is not always an accurate indicator of proper decontamination or cleanliness.

4. Creation of Concrete Surface Profile (CSP)

Creation of surface profile can be accomplished by a number of methods, each utilizing a selection of tools, equipment, and materials dependent on the type of substrate to be prepared and the type of system to be installed. The service temperature, and type and thickness of the selected polymer system also play an important role in the selection process. The ICRI Technical Guideline No. 03732 provides a comprehensive description of the methods of surface preparation, the tools available, and the results of utilizing those methods. The methods described include detergent scrubbing, acid etching, low-pressure water cleaning, grinding, steel shotblasting, abrasive blasting, high-pressure water blasting, scabbing, and scarifying. Among the most frequently used are:

(a) Steel Shotblasting

Steel shotblasting is the most commonly used and the preferred method for preparation of concrete floors. ICRI Technical Guideline No. 03732 describes the selection of steel shot size and the resultant CSP. The profile can also be affected by the speed at which the machine is operated. Concrete floor surface strengths vary from one floor to another and even between different areas of the same floor. The CSP is higher when blasting a concrete floor with a weak or low-strength surface. On the other hand, a hard trowel surface of high-strength concrete, properly cured, has sometimes required additional blasting to create the desired CSP.

(b) Acid Etching

Acid etching, as described in ASTM D 4260, has been used extensively (and in many cases, success-

fully) to prepare concrete floors. When performed correctly, this method is successful at removing laitance and weak paste at the surface providing a relatively uniform CSP. The most common acid used is hydrochloric acid. Some of the problems associated with its use are:

- The requirement to completely and extensively neutralize and rinse the surface (not always followed);
- Hydrochloric acid is not recommended around exposed steel or on steel-reinforced concrete because of the potential for chloride ion acceleration of steel corrosion;
- It does not work well on vertical surfaces, such as cove bases;
- It does not work if a curing membrane or various other hydrophobic contaminants are at the surface;
- Because acid etching introduces large quantities of water to the concrete, additional tests to determine the acceptable level of moisture vapor emissions are necessary after etching.

Recently, a field study was performed showing the successful use of citric acid to etch concrete.⁶⁵ This material does not create the chloride-induced corrosion of steel as mentioned above and it successfully removes the laitance and weak paste at the surface providing a relatively uniform CSP.

Regardless of the method selected or tools employed, the aim of surface preparation is to provide a surface that accepts the application of polymer-based products and allows the polymer to form a secure mechanical bond to the concrete. The type of service to which the floor system is to be subjected is a consideration when defining the thickness of the applied floor system. The ICRI Method Selector recommends the CSP for various polymer flooring systems. See Figure 1.

When using polymer floor systems that require crack isolation and/or waterproofing membranes, additional surface preparation concerns may arise. In addition to the normal surface preparation outlined above, mortar splatter, protrusions, ridges, penetrations, or sharp projections in the surface of the concrete are normally ground smooth during surface preparation.

5. Repair of Surface Irregularities

The repair of surface irregularities including spalls, cracks, deteriorated joints, slopes, and areas near transition zones, such as around drains and doorways, etc., has been considered prior to placement of the polymer system and/or the system has been designed to off-set (cover up) the thickness of the irregularities. See SSPC-SP 13/NACE No. 6⁴⁵ for identification and repair of surface defects.

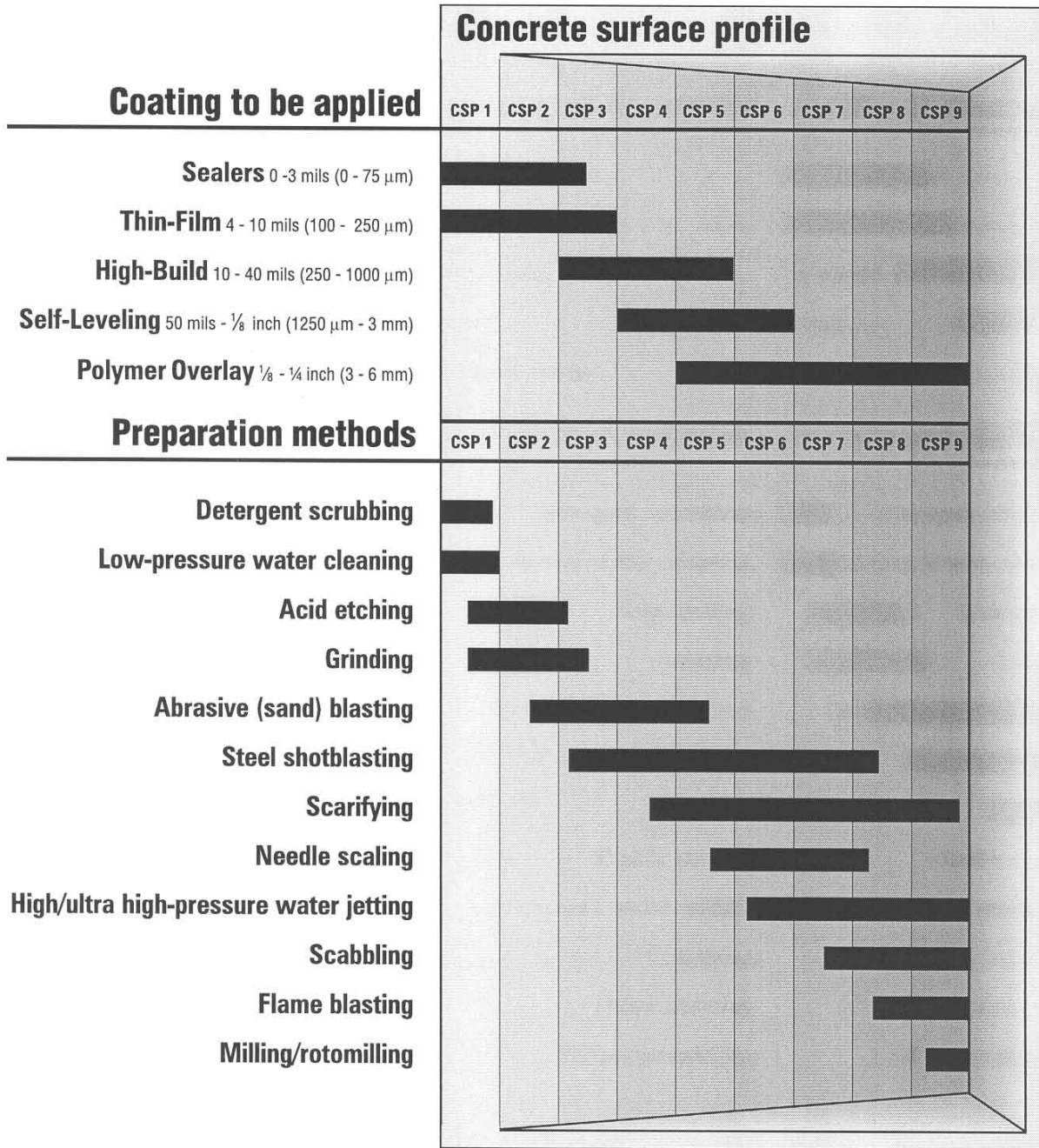


Figure 1: ICRI Method Selector

6. Testing and Inspection

Testing and inspection of the prepared surface takes into account bond strength, profile, cleanliness, pH, and moisture vapor emission. See Appendices B and C.

Section 7: Polymer Flooring System Design

Polymer flooring systems for concrete are, by definition, dependent on the structural concrete substrate to which they are bonded and as such, behave as a composite structure taking on the physical properties of the composite. Specific information on design requirements for concrete floor slabs can be found in various publications.

1. Design Considerations

(a) Flooring Thickness

The desired thickness of a polymer flooring system is typically determined by considering usage and wear patterns to include the frequency of impact, abrasion, and thermal stress to which the flooring system might be subjected. The typical physical properties of compressive, tensile, and flexural strength can be significantly higher than the concrete substrate resulting in a polymer floor system that has increased resistance to wear from abrasion and impact. Impact loads are dissipated in a conical pattern, from point of impact through the surface into the concrete. As the force penetrates the floor surface, the surface area of the cone increases resulting in a decrease of the total stress at the interface of the impact load and the area of the cone. The greater the thickness of the polymer floor system, the greater the resistance to chipping and delamination from the impact stress at the bond

line. For areas subjected to significant abrasion or gouging, increased thickness is typically used to maximize the extent of polymer flooring protection for the concrete and extend the useful life of the flooring system.

The ability of a polymer flooring system to resist chemical attack is primarily a result of the chemical resistance of the selected polymer system. For select polymer flooring systems that are not affected by the specific chemicals to which they will be exposed, the thickness of the floor system is typically determined by the physical properties listed in Paragraph 1 (a).

(b) Isolation (Expansion) Joints in Slab

Isolation (expansion) joint movement is typically allowed to continue through the polymer flooring system. The flexible joint sealant width-to-depth ratio, shown in Figure 2, is approximately 2:1. The detail might be constructed by terminating the floor system at the vertical joint interface and then installing the backer rod and sealant. Alternatively, the floor system might be installed over the joint and allowed to cure. The original joint line can then be saw-cut and the backer rod and sealant installed.

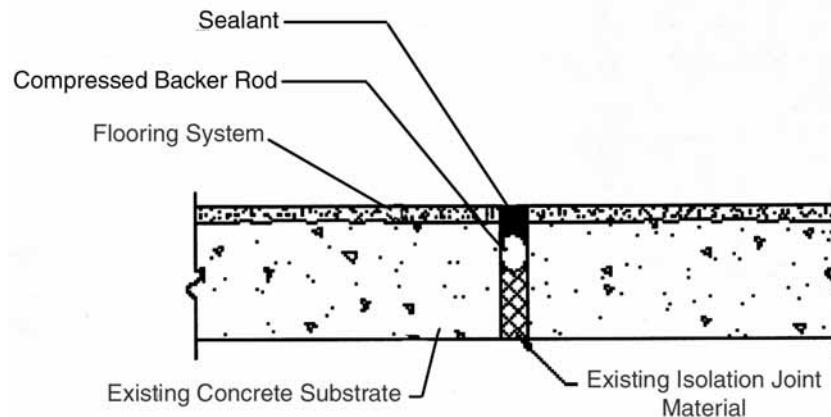


Figure 2: Isolation (Expansion) Joint in Slab

The treatment of isolation (expansion) joints at floor-to-wall junction depends on the needs of the facility. In Figure 3, the joint is terminated at the vertical termination of the concrete floor slab. The expansion board material is removed to a depth of at least half the width of the sealant. The backer rod and sealant are then installed. See Figure 13 for cove base detail at this joint.

(c) Contraction Joints, Construction Joints, and Cracks⁶⁶

Many polymer flooring systems are designed for impact and abrasion resistance. These systems are often hard and sometimes brittle. For this reason they are not designed to withstand elastic movement and are prone to crack over the top of contraction joints, construction joints, and random cracks in the concrete slab. Other polymer flooring systems are designed to be more flexible by using elastomeric

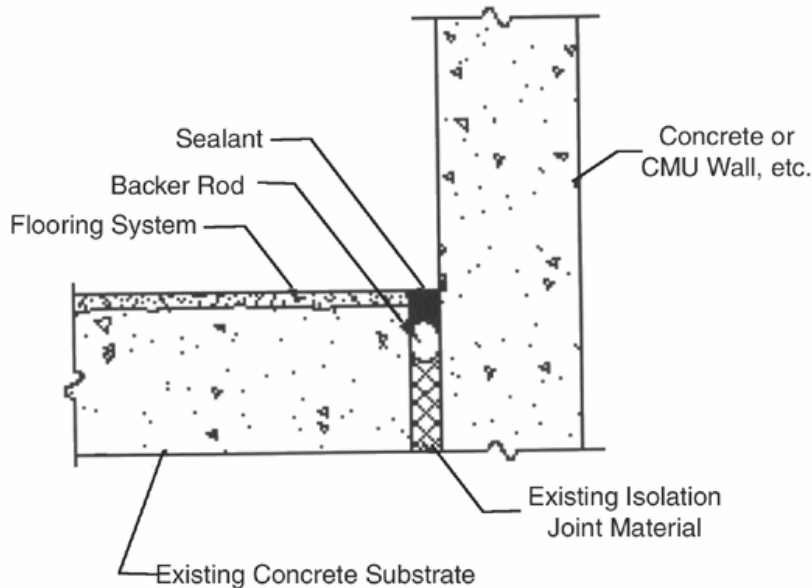


Figure 3: Isolation (Expansion) Joint at Floor/Wall Junction

resin systems.⁶⁷ Monitoring the movement of joints and cracks can determine the need for elastomeric crack-bridging membranes and floor systems.

The maximum theoretical expansion and contraction at any specific contraction (control) joint is often predicted using factors including the following:

- Shrinkage values as described in Section 5, Paragraph 1 (d)
- CLTE values as described in Section 4, Paragraph 2
- Age of the concrete
- Thickness of the concrete
- Length and width of the concrete section
- Temperature range of the concrete
- Temperature range of the surrounding environment

Actual movement can vary as a result of many factors. Therefore, any analysis using these parameters can only be used as a general guide.^{25,37}

For ACI 302.1 R-96¹⁰ Class 6 to 7 heavy-duty Industrial floors, treatment of contraction joints, construction joints, or cracks that have shown evidence of differential horizontal movement or have opened 1.6 mm (0.063 in.) or more are typically treated as illustrated in Figure 4. The concrete at the joint interface is removed to a depth of 13 mm (0.50 in.) or more and a width of 76 mm (3.0 in.) or more to allow for a thicker build up of the polymer system to armor the joint. The floor system is normally installed over the existing joint and allowed to cure. The original joint line is then saw-cut and the backer rod and sealant installed.

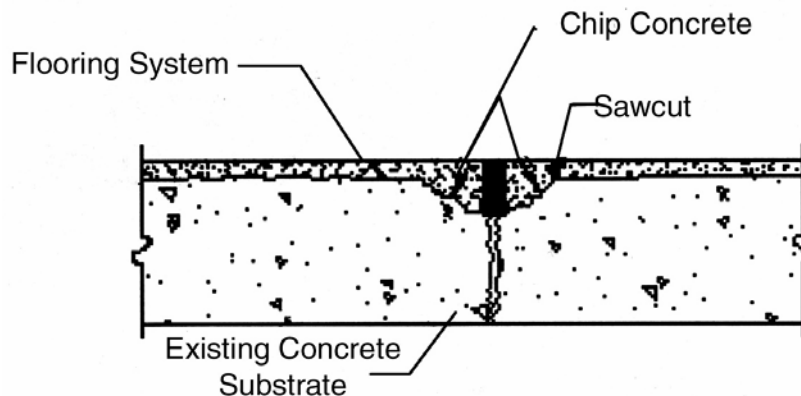


Figure 4: Contraction Joint, Construction Joint, or Crack at Heavy-Duty Floor Slab

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

For ACI 302.1 R-96¹⁰ Class 3 to 5 light-vehicular industrial and commercial floors, treatment of contraction joints, construction joints, or cracks that have shown no evidence of movement are typically treated as illustrated in Figure 5. The concrete joint depth is typically one-fourth the thickness of the concrete slab, in accordance with ACI 302.1. The detail might be

constructed by terminating the floor system at the vertical joint interface and then installing the backer rod and sealant. Alternatively, the floor system might be installed over the joint and allowed to cure. The original joint line is then saw-cut and the backer rod and sealant installed.

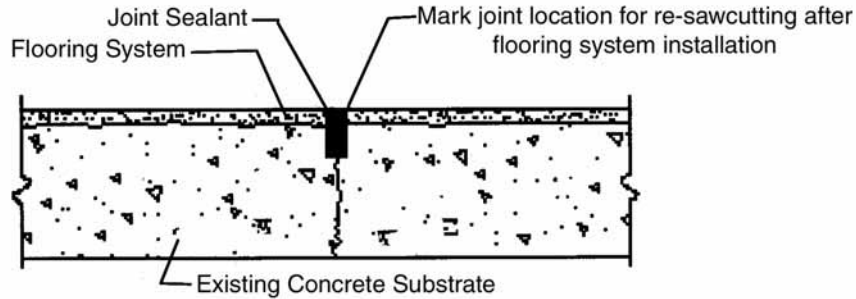


Figure 5: Contraction Joint, Construction Joint, or Crack at Light-Duty Floor Slab

Figure 6^{67,68-70} illustrates the use of an elastomeric layer over construction joints, contraction joints, and shrinkage cracks. This layer is bonded directly to the concrete and subsequently to the monolithic polymer flooring system. This design might allow the monolithic continuity of a bonded polymer flooring system. It is dependent on the elastomer remaining flexible throughout the expected service temperature range,

and provides for protection from reflective cracking from the base concrete up through the polymer flooring system. To further reduce the probability of experiencing problems with stress concentration in the form of reflective cracking over construction joints, contraction joints, or cracks, reinforcement is sometimes added to the elastomer to enhance tensile strength. See Figures 6 and 7.

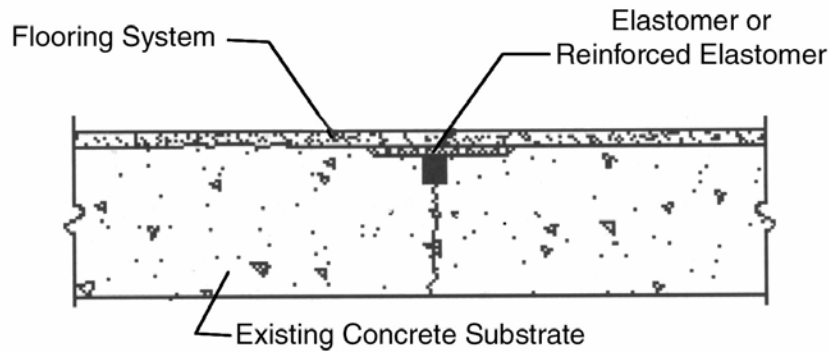


Figure 6: Contraction Joint, Construction Joint, or Crack with Elastomer Underlayment at Light-Duty Floor Slab

From ACI 302.1 R-96¹⁰ Class 1 to 4 concrete floors are designed for foot traffic and light vehicular traffic in institutional and commercial facilities. Treatment of contraction joints, construction joints, or cracks that have shown no evidence of deflection are typically treated as illustrated in Figure 6. The concrete joint depth is typically one-fourth the thickness of the concrete slab. The detail might be constructed by filling the exposed concrete joint to full depth with the

elastomeric membrane and allowing the elastomer to overfill to form an underlayment on either side of the joint as in Figure 6. When concrete cracks are numerous, the detail might be constructed by installing a continuous underlayment over the floor slab as illustrated in Figure 7. As an option, reinforcing fabric might be laid into the elastomer in accordance with manufacturers' recommendations. See Figures 6 and 7.

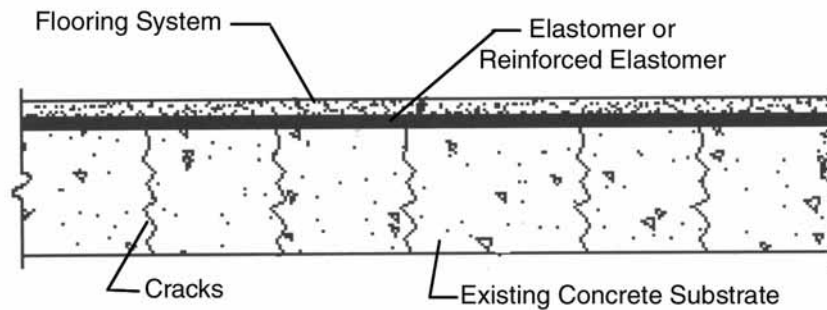


Figure 7: Contraction Joint, Construction Joint, and/or Crack with Reinforced Elastomer Underlayment at Light Duty Floor Slab

(d) UV Light and Weathering Resistance

All thermoset polymeric materials degrade when exposed to UV light. This degradation can result in loss of gloss, color changes, chalking, or cracking. Rainwater, condensation, humidity, and thermal cycling can compound UV degradation. This degradation can be reduced by the use of inorganic pigments and fillers, UV absorbers, and free-radical scavengers, as well as by the use of UV-resistant topcoats.

(e) Textured Surface

In areas where foot traffic is expected and a floor could be wet from spills, cleaning, or rainwater, providing a textured surface is an important safety factor. Many polymer flooring systems include some type of texture incorporated into the design of the surface.⁷¹ This texture can range from relatively smooth to extremely rough. In almost all cases there is a trade-off between texture (lack of surface smoothness) and cleanability.⁷² An example is the food industry where cleanability is imperative and often the floors are wet and/or saturated with oils and fats, which dramatically affects the coefficient of friction and makes the surface difficult to clean. Textured surfaces are usually created by one of the following methods:

- Brushing or rolling a texture (stipple) into a thixotropic topcoat
- Adding aggregate into the resin when applying a liquid-rich sealing topcoat⁷³
- Adding aggregate as a broadcast into the wet resin after application to the floor
- Using a dry trowel-applied mortar system with the surface unsealed

The type or roughness of a texture finish can be qualified by the profile or peak height, the frequency or amount of texture, i.e., the distance between peaks, the angularity of the texture, or the sharpness of the

peaks.⁷¹⁻⁷³ Although ASTM and Underwriters Laboratories, Inc. (UL)⁽¹⁰⁾ are both standards-generating organizations, and both specify 0.5 as the minimum static coefficient of friction for a floor surface,^{3,76} they are not regulators. Sacher⁷⁷ calls the 0.5 value only a benchmark, but acknowledges it is essential that the product yields a static coefficient of friction of at least 0.5. English⁷⁸ has summarized numerous arguments in a case to establish a minimum coefficient of friction of 0.5 as the threshold of safety. The current federal regulations in the U.S. include an obscure reference to 0.5 by OSHA¹² and a recommendation in the Americans with Disabilities Act.⁷⁹

(f) Aesthetics

Polymer flooring systems are often installed in locations to enhance the attractiveness of the facility. Where aesthetics are of prime concern, the owners' representative typically consults directly with the polymer flooring system manufacturer and installing contractor to review the capabilities of the selected system and the conditions of the facility, maintenance, and protection from other trades if applicable.

2. Terminations

(a) Floor

For applications in which the polymer flooring system is not designed to cover the entire floor, the concrete at the perimeter of the polymer flooring is often terminated at a sawcut, with the concrete removed vertically down to the depth of the floor system and horizontally back into the floor area to be installed approximately 100 to 150 mm (4 to 6 in.) (see Figure 8). This technique, called "keying in," has been used to help the polymer flooring system resist undercutting, peeling, or delamination stress to which a system is subjected as a result of traffic, thermal movement, or water penetration.

⁽¹⁰⁾ Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096.

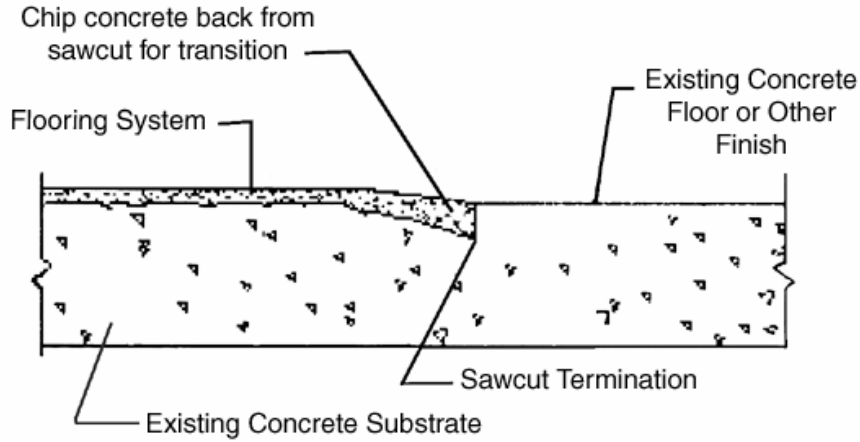


Figure 8: Leading Edge Floor Termination Design

Terminations also occur at various embeds that include but may not be limited to angle irons (Figure 9); floor drains (Figure 10); pipe-floor penetrations,

unsleeved (Figure 11); or pipe-floor penetrations, sleeved (Figure 12).

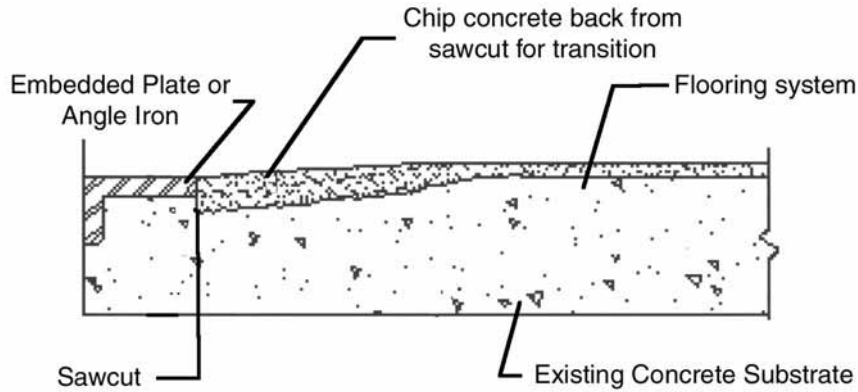


Figure 9: Floor Termination Design at Embedded Angle Iron or Plate

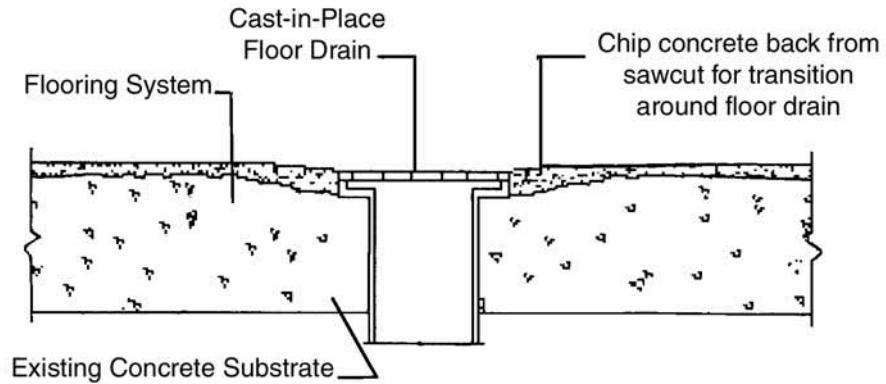


Figure 10: Floor Termination Design at Floor Drain

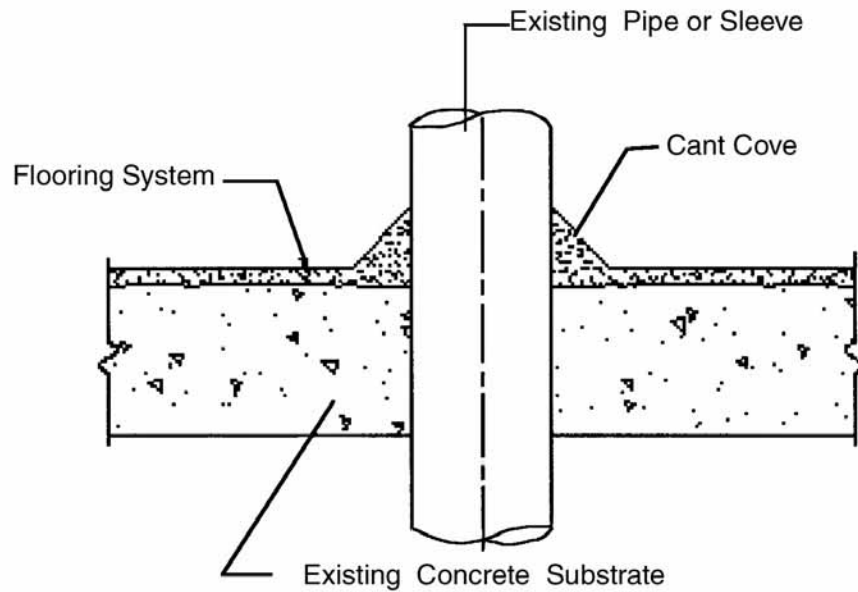


Figure 11: Floor Termination Design at Unsleeved Pipe Penetration

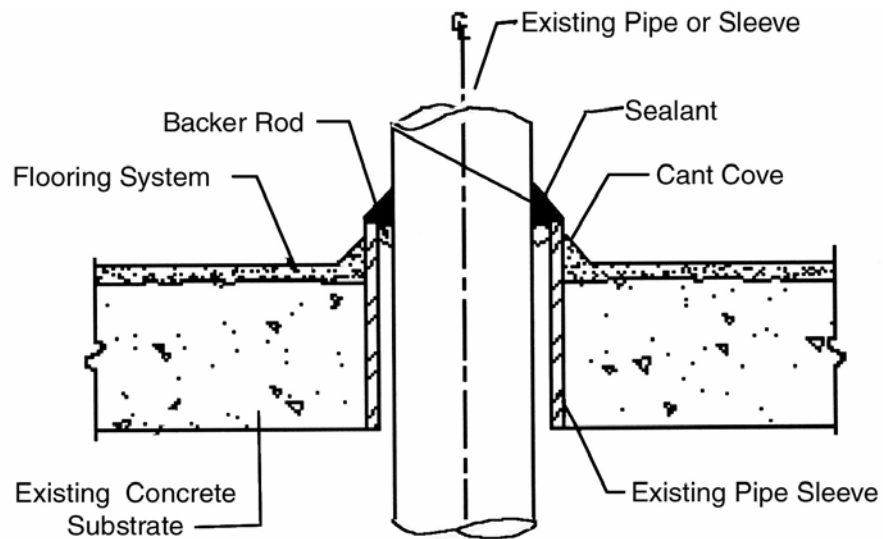


Figure 12: Floor Termination Design at Unsleeved Pipe Penetration

(b) Wall

For applications in which the polymer flooring system is required to turn up a wall surface as a cove or a

wainscot, a number of termination methods are possible depending on the desired function, materials of construction, and desired final appearance. Figures 13 to 18 provide illustrations of several methods.

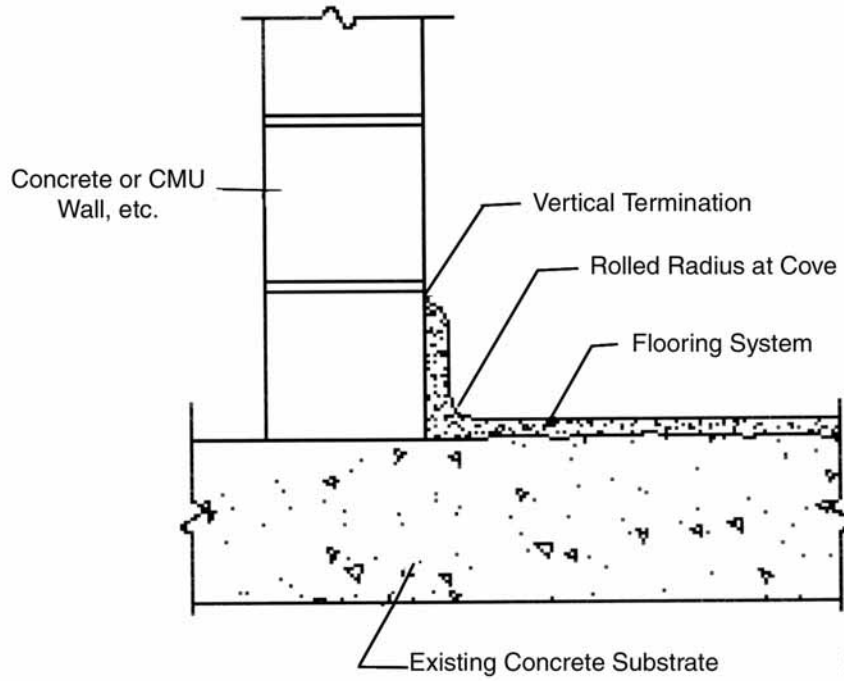


Figure 13: Rolled Radius Cove Base Detail

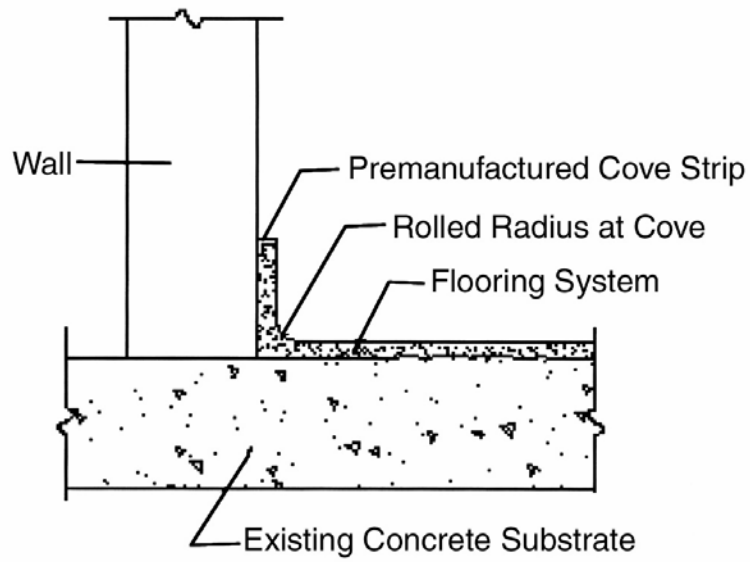


Figure 14: Cove Strip Cove Base Detail

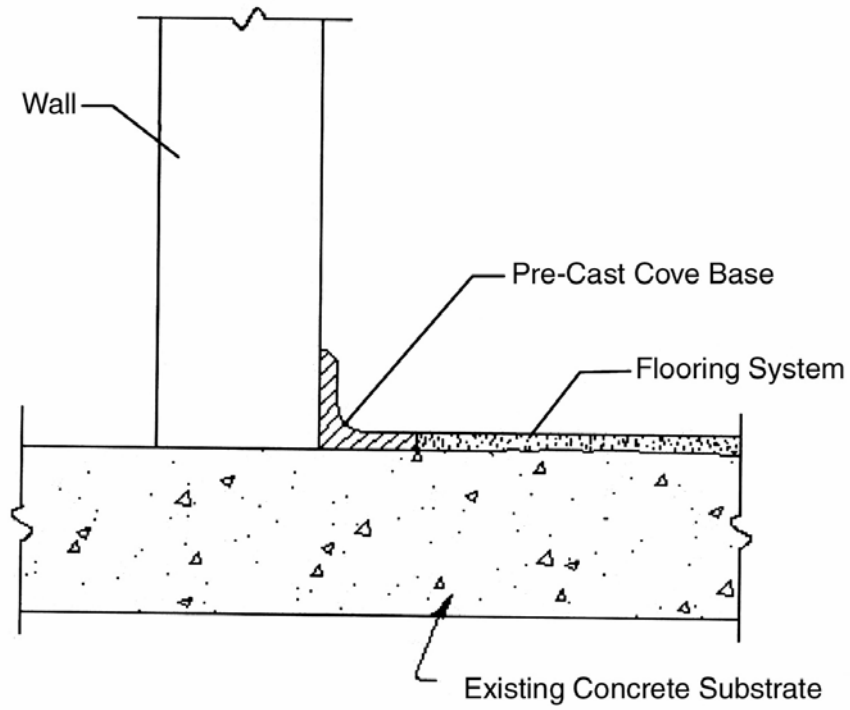


Figure 15: Pre-Cast Cove Base Detail

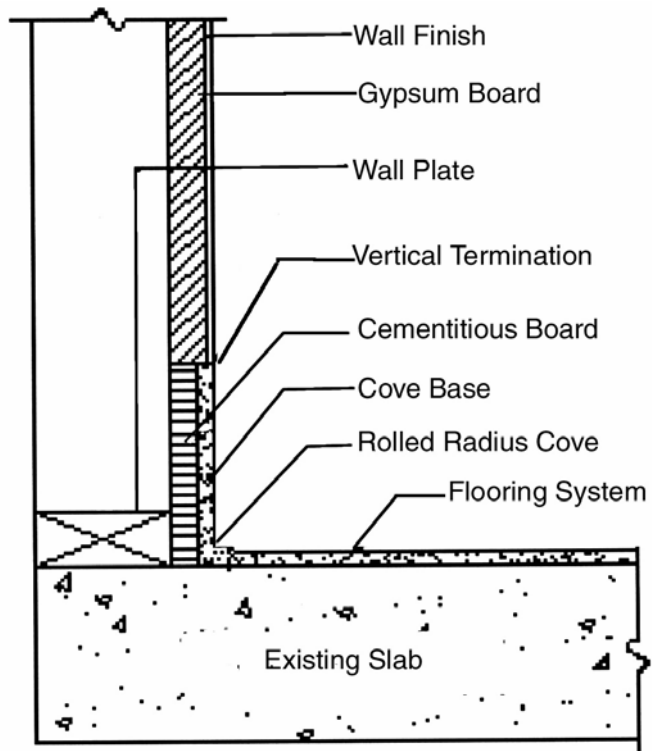


Figure 16: Gypsum Wall Board Cove Base Detail

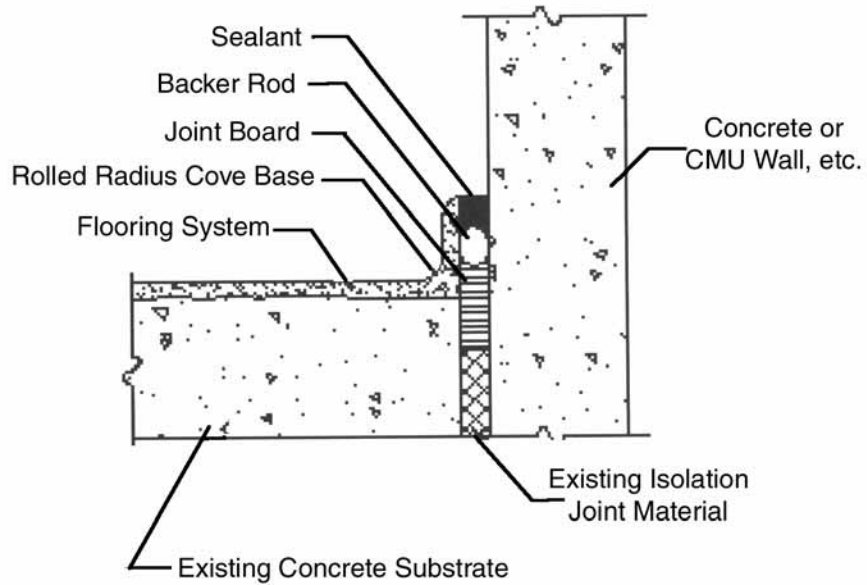


Figure 17: Isolation (Expansion) Joint and Cove Base Detail at Floor/Wall Junction

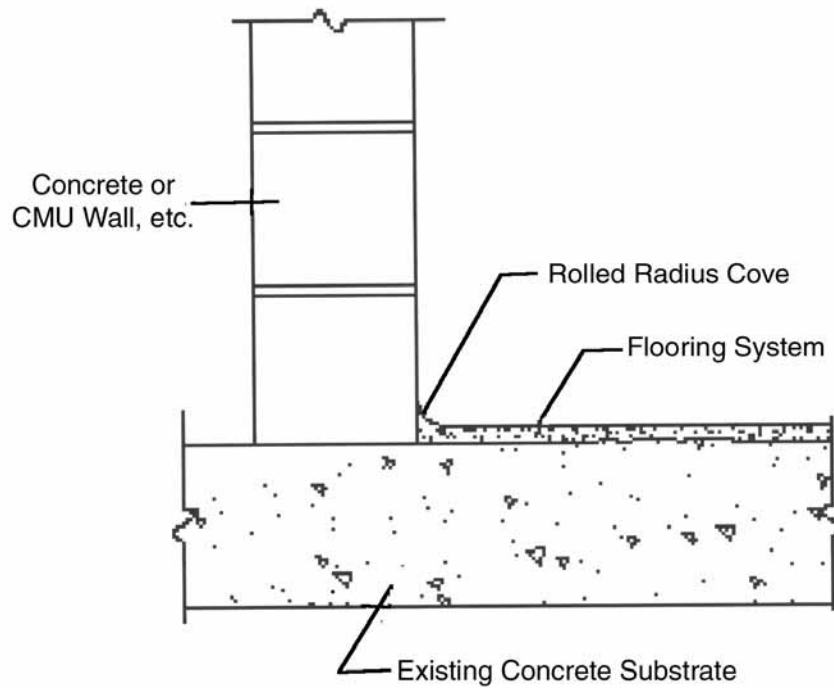


Figure 18: Radius Cove Base Detail

3. Adhesion³⁴

Most flooring systems depend on the concrete substrate for structural integrity. Maintaining adhesion to that substrate, even after weathering and chemical exposure, is an important property of a flooring system. Maintaining intercoat adhesion in multi-layer coating systems and patching materials is also a consideration in the selection of a complete system.

Properties of the concrete substrate that affect adhesion include surface strength, profile, cleanliness, porosity, and moisture content. Relevant properties of the primers

include viscosity, surface tension, physical strength, chemical affinity for the concrete, and resistance to alkalis and hydrolysis. For multi-layer systems, the relevant properties also include the amount of amine blush in epoxies, the amount of wax in unsaturated polyesters and vinyl esters, and numerous application-related phenomena. Any failure mode, other than cohesive failure in the concrete, indicates potential adhesion problems. Minimum adhesion to concrete reflects the anticipated tensile strength of the concrete which can be estimated to be between 6 and 8% of its compressive strength. Typically this ranges from 1 to 2 MPa (200 to 300 psi).³⁰

Section 8: Materials Used for Polymer Flooring

Polymer flooring system formulations and designs are proprietary. The manufacturer is the best source of information on the application, installation, performance, designs, and verifiable field histories of its specific materials and systems. This section provides an overview of typical generic polymer flooring systems. The properties and performance of a flooring system within a generic classification vary.

1. Polymer Types

The physical and chemical resistance properties for the most common generic materials used as protective polymer flooring systems can vary widely as a result of polymer modifications, mixtures (hybrids), plasticizers, fillers, reinforcement, and curing conditions. Section 4 explains the importance of specific polymer flooring properties and discusses some methods used to overcome the deficiencies of a given polymer.

(a) Epoxies^{35,81,73,80, 82-84}

Thermoset epoxies are polymers that are reaction products of epoxy resins and various hardeners. Common epoxy resins include bisphenol A, bisphenol F, and phenol novolac-based epoxy resins. Commonly used hardeners include aliphatic amines, cycloaliphatic amines, amidoamines, and polyamides. Numerous modifiers, diluents, and solvents are often included in various formulations. The properties of epoxy polymer systems for flooring applications range from hard and brittle with good to excellent chemical resistance, to flexible elastomers with reduced chemical resistance. Novolac-based epoxy resins reacted with aliphatic or cycloaliphatic amines produce polymer flooring systems with high cross-link densities and excellent chemical resistance. Historically, aromatic amines were commonly used in high-chemical-resistant formulations, but toxicity concerns and regulations have significantly reduced their current use.

(b) Unsaturated Polyesters (UP)⁸⁵

Unsaturated polyesters are polymers that are reaction products of UP resins and peroxide initiators. The reaction products of saturated and unsaturated acids

and polyols are common UP resins. The resins are diluted with a vinyl coreactant, usually styrene. Methyl ethyl ketone peroxide, cumene hydrogen peroxide, and benzyl peroxide are common initiators for UP resins, while cobalt or tertiary amines are used to promote the reaction. The common unsaturated polyester polymer floorings exhibit high strength and good chemical resistance, but they are prone to shrinkage and air inhibition during curing.

(c) Vinyl Esters (VE)^{81,86,87}

Vinyl esters are polymers that are reaction products of VE resins and peroxide initiators. The reaction products of methacrylic acid and epoxy resin (bisphenol A, F, or novolac) are common VE resins. These resins are typically diluted with a vinyl coreactant, usually styrene. They can also be modified with elastomers. Methyl ethyl ketone peroxide, cumene hydrogen peroxide, and benzyl peroxide are common initiators for VE resins, while cobalt or tertiary amines are used to promote the reaction. The common vinyl ester polymer floorings exhibit high strength and good chemical resistance, but are prone to shrinkage, air inhibition during curing, and limited shelf life.

(d) Polyurea⁸⁸

Thermoset polyureas are elastomeric polymers that are reaction products of amines and isocyanates. The elastomeric qualities can exceed 500% elongation. These products are typically used in flooring, coating, lining, and jointing applications. They can be subclassified as either aromatic or aliphatic. Aliphatic polyureas have better color stability and UV resistance than aromatic polyureas. Polyurea materials set within seconds and fully cure within hours. Mixtures of polyols and amines are often reacted with isocyanates to produce polyurethane/polyurea hybrids.

(e) Polyurethane⁸⁹⁻⁹¹

Thermoset polyurethanes are polymers that are the reaction products of polyol resins and isocyanates.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

Many classes and types of polyols, amines, and isocyanates are commonly used to produce polymer floors. Polyurethanes can be subclassified as elastomeric (>100% elongation) or nonelastomeric (<100% elongation). They are also classified as either aromatic or aliphatic, depending on the type of isocyanates used. Polyurethane floorings can range from high strength with good chemical resistance to very flexible with reduced strength and chemical resistance. Polyurethanes are sometimes used with cement and aggregate blends to form hybrid cementitious/urethane floor systems.

(f) Acrylic⁹²

Acrylics used in polymer flooring installations usually consist of a mixture of high-molecular-weight acrylic resins that are coreacted with methyl methacrylate in a free-radical polymerization initiated by benzyl peroxide. Acrylics can vary in strength and flexibility depending on the choice of raw materials. However, like unsaturated polyester and vinyl ester polymer floorings, these materials are prone to shrinkage and air inhibition during curing.

(g) Epoxy Elastomer^{67,69}

Thermoset epoxy elastomers are polymers that are reaction products of proprietary elastomeric materials with epoxy backbone and/or amine hardeners. The uses of epoxy elastomer systems for flooring applications range from crack-bridging membranes to wear-resistant and chemical-resistant resilient overlays. These systems maintain their elastomeric properties at temperatures below freezing.

(h) Other Thermoset Polymers

Other thermoset polymers occasionally used in polymer flooring systems include chemically cross-linked elastomers, and chemical hybrids such as epoxy phenolic, polyurethane-modified epoxy, acrylic urethane, polysulfide, and epoxy siloxane

2. Reinforcement and Fillers

(a) Silica Fillers

Silica fillers (including silica sand, glass, quartz, and various silica-containing minerals) are the most commonly used fillers for polymer floors. They are used at levels of up to 80% by weight, and can range in size from less than 1.0 μm (0.04 mils) to one-fourth the polymer flooring thickness. Silica fillers are available in round or angular particles, glass flakes, and mica. They are sometimes treated with functional organo-silanes for enhanced workability, improved physical properties, reduced porosity, and increased chemical resistance. The advantages of using silica fillers include reduced cost, reduced permeability, decreased curing shrinkage, and CLTE, as well as increased chemical and creep resistance. The disadvantages usually include reduced flexibility and reduced tensile strength.

(b) Carbon Fillers

Carbon and graphite fillers cost more than silica and other fillers and are generally used only when their specific properties are desired. Like silica fillers, they can be used at high levels, can range in size from 1.0 μm (0.04 mils) to one-fourth the polymer flooring thickness and can be round or angular particles or flakes. Carbon and graphite fillers are conductive and can be used in conductive primers and conductive floor systems. They are resistant to chemicals such as hydrofluoric acid, hydrofluosilicic acid, sodium hypochlorite, and concentrated alkalis, that can rapidly attack silica-based fillers. In addition, they are nonsparking, allowing for use in polymer flooring applications requiring spark-resistant surfaces. In addition to these special properties, carbon fillers reduce permeability, curing shrinkage and CLTE, while increasing chemical and creep resistance. The disadvantages include reduced strength, flexibility, and hardness, as well as a limited color selection.

(c) Other Functional Fillers

Pigments such as titanium dioxide and other inorganic oxides are used primarily for aesthetic purposes and to protect the polymer from UV degradation. Pigments can also reduce permeability.

(d) Fiberglass Fabric Reinforcement^{85,93}

Fiberglass is sometimes used as structural fabric reinforcement in polymer flooring systems. It is particularly useful in applications requiring a monolithic structure. Chopped-strand mat, woven fiberglass fabrics, engineered fabrics, and surface veils are commonly used. Polyester, vinyl ester, and epoxy polymer flooring systems often use fiberglass reinforcement. Fiberglass-reinforced polymer flooring application techniques are similar to those used in other industries and include hand lay-up, chopper-gun, and spray application with or without a chopper-gun attachment. Reinforcement levels of up to 50% by weight are possible. Fiberglass reinforcement increases tensile strength, flexural strength, compressive strength, impact resistance, and crack-bridging performance of polymer flooring systems. In addition, fiberglass reinforcements distribute shrinkage stresses during polymerization of polyester and vinyl ester resin systems. However, the use of fiberglass-reinforced polymer flooring systems can increase the structural integrity beyond the capability of the flooring/concrete interface, which can increase the possibility of delamination.

(e) Other Fabric Reinforcements⁹⁴

Polyester, aramid, and carbon fibers can also be used as fabric reinforcement for polymer flooring systems.

tems. These fabrics are typically more expensive than fiberglass and are used only for special applications in which their specific engineering properties are desired. Examples include the use of polyester fabric reinforcement to replace fiberglass in applications in which exposure to hydrofluoric acid, hydrofluosilicic acid, or sodium hypochlorite are expected.

Section 9: Installation

1. Concrete Cure and Surface Preparation

See Sections 5 and 6.

2. Patching of Concrete Surface Imperfections

(a) Types of Imperfections

Some systems, such as trowelled systems and high-build leveling systems, can tolerate minor imperfections without repairs. However, concrete defects such as voids, bugholes, excess porosity, and physical and chemical damage are usually filled or repaired prior to installation of the polymer flooring system. Most polymer flooring systems cannot be successfully applied until defects and damage are repaired and adequately cured, although some systems can be applied immediately after patching.

(b) Patching Materials

Materials such as slurries, mortars, and polymer concrete are used to level, smooth, and patch concrete surfaces to provide a substrate that is suitable for the application of a polymer flooring system. These materials are normally applied after initial surface preparation and, when properly selected and applied, have the following characteristics:

- Good adhesion
- Adequate strength
- Low volumetric shrinkage
- Compatibility with the polymer flooring to be applied
- Proper consistency for the installation
- Adequate cure time

Shrinkage of a patching material can reduce the adhesion of that material to the concrete substrate. For this reason ACI 503 R provides information and suggestions on the use of epoxy compounds with concrete to promote adhesion.³⁵ Differences in thermal expansion between the concrete, patching material, and polymer flooring system can cause stresses during thermally induced movement that can reduce adhesion between these layers.

The most common types of patching materials are polymer-modified cementitious, and materials made from the same type of polymer resin materials as the selected polymer flooring system. Cementitious mat-

3. Alternative Systems

Protective systems other than thermoset polymer flooring systems include acid-resistant brick, quarry tile, polymer concrete, and polymer-modified concrete.

erials generally cost less than polymeric materials, but polymeric materials generally cure faster and have higher strength, better adhesion, and increased chemical resistance.

Patching materials are available for installation to horizontal surfaces by a variety of methods. Some are designed as slurries for self-leveling applications while others are designed as mortars for slope-and-fill applications or for deep patching applications. Still others are designed for vertical applications in those conditions for which a vertical cove might be desired.

The repaired section is typically evaluated to determine whether to perform additional surface preparation prior to polymer flooring installation.

3. Priming

(a) Materials

A primer is considered part of the polymer flooring system and is typically formulated with a resin system compatible to that of the body of the polymer flooring system. Desirable attributes of a primer include excellent adhesion; low surface tension; and low viscosity to wet-out, penetrate, and seal the porous concrete surface. Because concrete is an alkaline material and moisture is often present, the properly chosen primer is resistant to alkali and has the ability to cure in the presence of moisture. (See Section 5, Paragraph 2 [e]).

The use of solvent-based materials as primers on concrete substrates is common. Water is a natural solvent and formulations of water-based primers have become more common as well. However, the stresses introduced from the shrinkage of these primers and the time required for sufficient evaporation of the solvent prior to applying the next coat are important factors to consider.

Conductivity in concrete can range significantly depending on concrete materials used, density, mass, and moisture content, as well as size, location, and quantity of reinforcing steel used. If the conductivity of the concrete floor is low and discontinuity testing is specified for the polymer flooring to verify a holiday-free installation, a conductive primer can be used to ensure effective discontinuity testing. (See Appendix C).

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

(b) Installation

Primers are typically applied to concrete surfaces using a squeegee, roller, brush, or spray equipment.

(c) Out-Gassing

Concrete contains air. When the temperature of the concrete rises the air in the pores expands. If liquid-polymer flooring materials are being installed onto concrete that is in this condition, out-gassing is likely to occur. This out-gassing can produce pinholes or blisters in primers and polymer flooring systems. To reduce the risk of pinholes, the primer and polymer flooring are usually applied when the concrete temperature is constant or decreasing.

4. Polymer Flooring System

(a) Materials

Polymer flooring systems typically include a single-component or multiple-component resin system, one or more aggregate blends, and optional fabric reinforcement.

Material storage under adverse conditions or beyond the shelf life of a resin system can affect the condition of the materials and the properties of the polymer flooring system. Manufacturers recommend that most polymer flooring materials be stored at 10 to 30°C (50 to 86°F). However, it is not uncommon for materials to be subjected to temperatures as low as -10°C (14°F) or as high as 60°C (140°F) during shipping. These adverse conditions can cause resin materials to crystallize or polymerize.

Multi-component polymer resin and hardener materials are designed and formulated by the manufacturer to be blended at specific ratios to produce the typical physical properties. Deviation from the prescribed mix ratio affects these properties and the chemical resistance of the flooring system. Accelerators and initiators in unsaturated polyester and vinyl ester systems are sometimes added in the field to adjust for environmental conditions or accelerate the cure of the polymer flooring. These are typically added at rates that vary from 1 to 2% by volume as they only control the rate at which the polymerization of the system occurs.⁸⁶ Most epoxy and urethane systems are designed to be mixed at a specific ratio that may range from 1:1 up to 6:1 by volume. Deviating from the prescribed mix ratio almost always significantly affects the performance of the product.

(b) Installation Methods

Mixing

The most common method for mixing two- or three-component liquid materials utilizes a mixing blade attached to a power drill or motor. For aggregate-

filled systems, either bucket mixers with 20-L (5-gal) buckets rotated around a mixing blade by an attached motor assembly, or traditional gas-or electric-powered mortar drum mixers are most often used. While manual mixing can sometimes be adequate to thoroughly mix the materials, it is time consuming and difficult to accomplish on a consistent basis. Resins containing pigment and fine fillers can separate or settle during storage and shipping. The component containing the pigment and filler is often individually mixed before mixing with the other component. The mixed liquids are then mixed with the aggregate if required by the system design.

Application

- Roller Application: The most common method of installing thin-film flooring systems is by use of the squeegee-and-backroll or dip-and-roll method.
- Spray Application: One- and two-component materials that do not contain large fillers are occasionally applied using spray equipment. Air-assisted or high-volume, low-pressure (HVLP) spray equipment can be used for one-component or premixed two-component materials. Plural-component, high-pressure, airless-spray equipment with heated lines and air-assisted spray guns are commonly used to apply high-viscosity or short-pot-life two-component, high-solids materials.
- Troweling is commonly used for applying aggregate-filled systems after placement by screed box, gauge rake, or screed form.
- Liquid-rich systems are generally applied to floor surfaces by self-leveling methods such as pouring, using a notched squeegee, and back-rolling with a spiked roller. Aggregate can be broadcast into a liquid system to imbed the aggregate for the purpose of providing a texture and/or to build the thickness of the system.

(c) Reinforcement⁹⁵

Methods for laminating fabric reinforcement into polymer flooring systems include the use of conventional hand lay-up techniques and chopper-gun attachments for one- or two-component spray equipment. Whichever method is used, the saturating resin is usually mechanically worked into the reinforcement with ribbed or serrated rollers to completely saturate the reinforcement and to eliminate any entrapped air. This is especially important at corners, edges, and overlaps.

(d) Multilayer Recoat Windows

Proper intercoat adhesion between layers of a multilayer polymer flooring system is essential for adequate performance. Each layer is mechanically and/or chemically bonded to the previous layer. The time

between installation of different layers is referred to as the recoat window. This is typically defined as the time of earliest opportunity to apply subsequent layers and the latest possible time to apply subsequent layers to ensure chemical bond between the two layers. The recoat window is usually defined by the polymer flooring manufacturer.

(e) Environmental Conditions

Thermoset resins are affected by temperature. The temperature of the polymer flooring material, the concrete substrate, and the surrounding air affect the workability, cure rate, and the resulting physical properties of the flooring system. Although special formulations are available, typical systems are designed to be installed within a relatively narrow range of temperatures, from 10° to 32°C (50° to 90°F). Lower temperatures can increase viscosity, reduce the evaporation rates of solvents or volatile co-reactants, and reduce the cure rate. Higher temperatures tend to reduce viscosity, increase the evaporation rate, and accelerate the cure rate. Installations at temperatures exceeding the designated range can result in increased residual stress from shrinkage and reduced physical properties.

Excessive moisture can profoundly affect the cure of many thermoset materials commonly used in polymer flooring installations. Moisture might be present as a result of residual water in the concrete, water condensed on the concrete, high humidity, rain, or a high water table. The effects of excess moisture include

blushing of amine-cured epoxies, cure inhibition of unsaturated polyesters and vinyl esters, poor film formation in water-based polymer floorings, and carbon dioxide formation in polyurethanes.

Excessive air movement can affect polymerization of the system and the resultant physical properties. However, stagnant air in confined areas can inhibit the cure on the surface of systems containing styrene or methyl methacrylate that use a coating containing a wax in solution.

(f) Cure

Polymerization (cure) of thermoset resin materials is a complex function of time, temperature, and chemical formulation. In most cases, the selected polymer flooring system has been formulated to cure as rapidly as possible while providing sufficient working time for mixing and application. Both the physical strength and the chemical resistance of a polymer flooring system increase as the system cures. Each layer of a multilayer system is typically formulated to cure as soon as possible so as to support the traffic of the installing mechanics, tools, and equipment.

Thermoset resin materials can be formulated to cure slowly at elevated temperatures or quickly at lower temperatures. Polymer flooring system manufacturers can provide additional information on the performance of particular resins.

Section 10: Testing and Inspection

1. Testing

Testing methods used to quantify the properties of installed polymer flooring systems include evaluations of the concrete substrate and polymer flooring thickness, discontinuity testing, and evaluation of the cure. Information about the latter three items can be found in Appendix C.

2. Inspection

Routine inspections of polymer flooring installations can prolong the service life of the system. Early detection of defects often allows for the repair of polymer flooring systems prior to undercutting and substrate damage. Problems often noted during routine inspections include:

- Chemical degradation (color change, etching,

flaking, softening, or swelling)

- Physical damage (impact cracking, indentation, gouging, or tearing)
- Disbondment (blistering, undercutting, or shearing)
- Cracking at joints, edges, or corners
- Weathering (chalking or crazing)

Because delamination is often not visually evident, polymer flooring surfaces are often tapped with a metal object to check for delamination. The chain-drag method of ASTM D 4580⁹⁶ is also useful in detecting delamination or hollow areas. Cracking might not be visually evident when the polymer flooring is expanded as a result of elevated temperatures but can be checked by applying water or a dye, or by waiting until the polymer flooring temperature is lower.

Section 11: Maintenance

Once a polymer flooring system is installed and fully cured in accordance with the manufacturer's recommendations (see Section 9), the expected length of protective service provided by the polymer flooring system depends on the care and maintenance provided. This care normally con-

sists of regular maintenance (cleaning and caring for the polymer floor) and repair (fixing areas that have been impacted, abraded, or otherwise damaged during service). Regular maintenance and repair ensure that the full

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

economic and protective value of the flooring system is realized.

The maintenance of a polymer flooring system can be accomplished in several ways. Sweeping, vacuuming, or rinsing can keep grit, metal filings, or processing powders from being ground into the coating if done regularly.

A polymer floor achieves its full life expectancy only if physical abuse to the flooring system is minimized. Examples of physical abuse include dragging pallets across the floor or dropping the front forks of lift vehicles, tools, piping, or equipment that is being worked on overhead. Floors can also be exposed to fuels, hydraulic fluid, lubricating oils, and other chemicals. Allowing chemicals to remain on a polymer floor surface can lead to premature coating failure. Immediate removal of liquid contaminants as part of normal housekeeping activities can prevent staining, discoloration, and degradation of the polymer flooring system and minimize slipping hazards.

Section 12: Repair

Polymer flooring systems can crack, chip, or break as a result of shrinkage, thermal movement, structural movement, the impact of dropped tools and equipment, or the abrasive effect of wheeled vehicles. In order to maintain a polymer flooring system in top condition and to prevent further deterioration, repairs to damaged areas are typically made soon after discovery.

Occasionally, concrete surfaces exposed after chipping, cracking, or breaking of the polymer flooring system can become soiled with oil, dirt, process chemicals, or other foreign contaminants. These can prevent the adhesion of polymer flooring repair materials. In such cases, the contamination is normally removed or neutralized before repairs begin. This activity is identical to the surface preparation that would be performed on the original, undamaged concrete floor. Although repaired areas are of a smaller size, it is just as important to have a properly prepared repair area as it is to have a properly prepared concrete surface prior to application of a complete polymer flooring system.

Section 13: Health and Safety

Numerous health, safety, and environmental regulations address worker safety, a topic beyond the scope of this report. Potentially hazardous materials encountered during the handling and installation of polymer flooring systems include:

- The chemicals to be contained
- Cleaning solutions
- Abrasive media
- By-products of surface cleaning and preparation
- Liquid resins
- Catalysts and solvents in polymer flooring materials

Liquid detergents, water, and/or other compatible cleaning agents are often used with cleaning machines or scrubbers to clean floors that are required to be at a high level of cleanliness or "like-new" condition. This can be done weekly or as often as needed. Because bristles or pads can scratch the coating, mechanical scrubbers, buffers, or sweepers that have soft bristles are used. After cleaning, all of the dirty cleaning solution is removed and the floor is rinsed thoroughly. Dirty cleaning solution remaining on the floor can attract contaminants that make them more difficult to remove in the future.

Steam cleaning is sometimes used to clean floors. However, the thermal shock of near-boiling water on an ambient temperature polymer floor system can cause the system to shear off the substrate. Even though the surface of the system may not have cracked from thermal shock, the coating may eventually begin delaminating. See Section 4, Item 3.

The procedures used for a successful repair are similar to those used in a typical initial installation:

- (a) Delaminated or damaged polymer floorings and concrete are removed until only sound concrete (or sound, bonded polymer flooring) remains.
- (b) Contamination is removed.
- (c) The existing concrete and/or polymer flooring is properly prepared.
- (d) Cracks are repaired.
- (e) The repaired polymer flooring system is tested for adhesion.

Often with the impact of heavy loads and the transfer of heavy objects by vehicular traffic, the polymer joint systems of concrete and polymer flooring typically require repair and maintenance.

With repairs and regular maintenance, a polymer flooring system can provide many years of service.

Material safety data sheets are a source of information on the hazards and handling of hazardous materials, and "Good Painting Practice: SSPC Painting Manual"⁶⁴ and NACE Publication TPC 2⁹⁷ provide information on safety during polymer flooring installation.

References

1. ACI 116 R (latest revision), "Cement and Concrete Terminology" (Farmington Hills, MI: ACI).
2. S. LeSota, ed., Coatings Encyclopedic Dictionary (Blue Bell, PA: Federation of Societies for Coatings Technology [FSCT],⁽¹¹⁾ 1995).
3. ASTM D 2047 (latest revision), "Standard Test Method for Static Coefficient of Friction of Polish-Coated Floor Surfaces as Measured by the James Machine" (West Conshohocken, PA: ASTM).
4. ASTM C 125 (latest revision), "Standard Terminology Relating to Concrete and Concrete Aggregates" (West Conshohocken, PA: ASTM).
5. SSPC-Guide 11 (withdrawn), "Guide for Coating Concrete" (Pittsburgh, PA: SSPC). Replaced by SSPC-PA 7, Applying Thin Film Coatings to Concrete (2002).
6. U.S. Code of Federal Regulations (CFR) Title 42 (latest revision), "Public Health and Welfare," Chapter 82, "Solid Waste Disposal" (Washington, DC: Office of the Federal Register).
7. ASTM F 1869 (latest revision), "Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride" (West Conshohocken, PA: ASTM).
8. ASTM E 1907 (latest revision), "Standard Practices for Determining Moisture-Related Acceptability of Concrete Floors to Receive Moisture-Sensitive Finishes" (West Conshohocken, PA: ASTM).
9. ASTM E 96 (latest revision), "Standard Test Methods for Water Vapor Transmission of Materials" (West Conshohocken, PA: ASTM).
10. ACI 302.1 R (latest revision), "Guide for Concrete Floor and Slab Construction" (Farmington Hills, MI: ACI).
11. U.S. Code of Federal Regulations (CFR) Title 40, "Protection of Environment," Part 260, "Hazardous Waste Management System: General" (Washington, DC: Office of the Federal Register, 1997).
12. U.S. Code of Federal Regulations (CFR) Title 29, Part 1910 (latest revision), "Toxic and Hazardous Substances," OSHA Regulations (Washington, DC: Office of the Federal Register).
13. Public Law 101-336, "Americans with Disabilities Act of 1990" (Washington, DC: Office of the Federal Register, 1992).
14. NFPA 99 (latest revision), "Standard for Health Care Facilities" (Quincy, MA: NFPA).
15. ASTM F 150 (latest revision), "Standard Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring" (West Conshohocken, PA: ASTM).
16. ACI 360 R (latest revision), "Design of Slabs on Grade" (Farmington Hills, MI: ACI).
17. R. Johnson, "Design of Concrete Slabs on Grade to Receive Polymer Floor Toppings and Coatings," in Increasing the Value of Coatings, Proc. SSPC 1998 Seminars, held November 1998 (Pittsburgh, PA: SSPC, 1998).
18. ACI 318 (latest revision), "Building Code Requirements for Structural Concrete" (Farmington Hills, MI: ACI).
19. ACI 515.1 R (latest revision), "Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete" (Farmington Hills, MI: ACI).
20. ACI 224 R (latest revision), "Control of Cracking in Concrete Structures" (Farmington Hills, MI: ACI).
21. ASTM C 150 (latest revision), "Standard Specification for Portland Cement" (West Conshohocken, PA: ASTM).
22. ASTM C 618 (latest revision), "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete" (West Conshohocken, PA: ASTM).
23. ASTM C 1240 (latest revision), "Standard Specification for Use of Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout" (West Conshohocken, PA: ASTM).
24. ACI 209 R (latest revision), "Prediction of Creep, Shrinkage and Temperature Effects in Concrete Structures" (Farmington Hills, MI: ACI).
25. ACI 305 R (latest revision), "Hot Weather Concreting" (Farmington Hills, MI: ACI).
26. ACI 306 R (latest revision), "Cold Weather Concreting" (Farmington Hills, MI: ACI).
27. T.K. Greenfield, "Dehumidification Equipment Reduces Moisture in Concrete During Coating Application," MP 33, 3 (1994): pp. 39-40.
28. NACE Standard RP0892 (latest revision), "Coatings and Linings over Concrete for Chemical Immersion and Containment Service" (Houston, TX: NACE).

⁽¹¹⁾ The Federation of Societies for Coatings Technology (FSCT), 492 Norristown Road, Blue Bell, PA 19422.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

29. ASTM C 845 (latest revision), "Standard Specification for Expansive Hydraulic Cement" (West Conshohocken, PA: ASTM).
30. ACI 308 (latest revision), "Standard Practice for Curing Concrete" (Farmington Hills, MI: ACI).
31. ACI 223 (latest revision), "Standard Practice for the Use of Shrinkage-Compensating Concrete" (Farmington Hills, MI: ACI).
32. ACI 504 R (latest revision), "Guide to Joint Sealants for Concrete Structures" (Farmington Hills, MI: ACI).
33. ASTM C 309 (latest revision), "Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete" (West Conshohocken, PA: ASTM).
34. ASTM D 4541 (latest revision), "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers" (West Conshohocken, PA: ASTM).
35. ACI 503 R (latest revision), "Use of Epoxy Compounds with Concrete" (Farmington Hills, MI: ACI).
36. ICRI Guideline No. 03730 (latest revision), "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" (Des Plaines, IL: ICRI).
37. R. Johnson, "Understanding Volume Changes of Concrete Before Resurfacing," Concrete Repair Bulletin, (September/October 1998): pp. 8-11.
38. T.I. Aldinger, "Coating New Concrete: Why Wait 28 Days?" Proceedings of Protective Polymer Floorings for Flooring and Other Concrete Surfaces, held November 10-15, 1991 (Pittsburgh, PA: SSPC, 1991), pp. 1-4.
39. ICRI Guideline No. 03732 (latest revision), "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays" (Des Plaines, IL: ICRI).
40. L. Harriman, "Drying and Measuring Moisture in Concrete—Part II," MP 34, 2 (1995): pp. 34-36.
41. ASTM D 4263 (latest revision), "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method" (West Conshohocken, PA: ASTM).
42. ASTM F 2170 (latest revision), "Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes" (West Conshohocken, PA: ASTM).
43. BS 5325 (latest revision), "Code of Practice for Installation of Textile Floor Coverings" (London, UK: BSI⁽¹²⁾).
44. "Understanding Concrete Floors and Moisture Issues," CD-ROM (Skokie, IL: Portland Cement Association [PCA],⁽¹³⁾ 2000).
45. SSPC-SP 13/NACE No. 6 (latest revision), "Surface Preparation of Concrete" (Pittsburgh, PA: SSPC, and Houston, TX: NACE.).
46. NT Build Method 474 (latest revision), "Concrete, Vapor Concentration in Drilled Holes" Espoo, Finland: Nordtest⁽¹⁴⁾).
47. C. Hall, S. O'Connor, "How Water Transmission Affects Slab-on-Grade Flooring Systems," JPCL 14, 2, (1997): pp. 86-102.
48. R. Cain, "Reducing Bond Failures Caused by Moisture Vapor Transmission," Concrete Repair Bulletin, (January/February 1999).
49. B. Clyne, "Concrete Vapor Emission Control for Flooring Materials and Coated Surfaces," Floor Seal Technology⁽¹⁵⁾ Report.
50. R.W. Day, "Moisture Penetration of Concrete Floor Slabs, Basement Walls, and Flat Slab Ceilings," Practical Periodical on Structural Design and Construction, (November 1996): pp. 104-107.
51. T. Dudick, "Hydrostatic and Capillary Pressure on Concrete Coatings," presented at SSPC 96, held November 17-21, 1996 (Pittsburgh, PA: SSPC).
52. M. Gunter, H.K. Hilsdorf, "Stresses Due to Physical and Chemical Actions of Polymer Coatings on a Concrete Substrate," in Adhesion Between Polymers and Concrete (Aix-en-Provence, France: Chapman and Hall,⁽¹⁶⁾ 1986), pp. 8-21.
53. B. Higgins, "Moisture-Related Flooring Failures: Dispelling the Myths," SINAK Corporation⁽¹⁷⁾ literature, <http://www.sinak.com/faq/faq.htm> (September 25, 2002).
54. F.A. Pfaff, F.S. Gelfant, "Osmotic Blistering of Epoxy Coatings on Concrete," JPCL 14, 12, (1997): pp. 52-64.
55. S. Wisser, S., "Behavior of Solvent-Free Epoxy Resin Systems on Water-Absorbent Concrete Surfaces," Kunstharz Nachrichten 18 (1983): pp. 20-25.

⁽¹²⁾ British Standards Institution (BSI), British Standards House, 389 Chiswick High Road, London W4 4AL, UK.

⁽¹³⁾ Portland Cement Association (PCA), 5420 Old Orchard Road, Skokie, IL 60077.

⁽¹⁴⁾ Nordtest Tekniikantie 12 FIN-02150 Espoo, Finland.

⁽¹⁵⁾ Floor Seal Technology, 1005 Ames Avenue, Milpitas, CA 95035.

⁽¹⁶⁾ Chapman and Hall/CRC Press, 2000 NW Corporate Blvd., Boca Raton, FL 33431.

⁽¹⁷⁾ SINAK Corporation, 861 Sixth Avenue, Suite 411, San Diego, CA 92101.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

57. D. White, "Preventing Osmotic Blistering in the Repair and Protection of Damp Concrete," in *Technologies for a Diverse Industry*, held November 17-21, 1996 (Pittsburgh, PA: SSPC), pp. 207-209.
58. S.L. Sarkar, "Understanding Floor Covering Failure Mechanisms," *Concrete Repair Bulletin*, (March/April 1999): pp. 6-11.
59. ASTM D 4258 (latest revision), "Standard Practice for Surface Cleaning Concrete for Coating" (West Conshohocken, PA: ASTM).
60. ASTM D 4260 (latest revision), "Standard Practice for Acid Etching Concrete" (West Conshohocken, PA: ASTM).
61. ASTM D 4262 (latest revision), "Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces" (West Conshohocken, PA: ASTM).
62. NACE Publication 6G191 (withdrawn), "Surface Preparation of Contaminated Concrete for Corrosion Control" (Houston, TX: NACE). (Available from NACE as an historical document only.)
63. ASTM C 811 (latest revision), "Standard Practice for Surface Preparation of Concrete for Application of Chemical-Resistant Resin Monolithic Surfacing" (West Conshohocken, PA: ASTM).
64. PCA Publication IS214 (latest revision), "Removing Stains and Cleaning Concrete Surfaces" (Skokie, IL: PCA).
65. B.S. Fultz, *Cleaning of Concrete Using Citric Acid*, Proc. SSPC 2000, held November 12-16, 2000 (Pittsburgh, PA: SSPC, 2000), pp. 4-8.
66. J.W. Prane, *Sealants and Caulks* (Blue Bell, PA: FSCT, 1989).
67. G. French, "Comparison of Flexible and Rigid Epoxy Systems for Concrete Protection," *Concrete Repair Bulletin*, (January/February 1999).
68. T.D. Barkey, W.R. Slama, N.B. Fancher, "Physical and Mathematical Representations for the Determination of Crack-Bridging Ability of Lining Systems," in *Managing Costs and Risks for Effective and Durable Protection*, Proc. SSPC 94, held November 11-17, 1994 (Pittsburgh, PA: SSPC, 1994), pp. 152-162.
69. J. Durig, "Internally Flexible Epoxy," *Concrete Repair Bulletin*, (November/December 1996): pp 9-12.
70. F.A. Pfaff, F.S. Gelfant, "Testing New Crack-Bridging Designs Used in Lining Systems Over Concrete," in *Innovations for Preserving and Protecting Industrial Structures*, Proc. SSPC 93, held November 13-18, 1993 (Pittsburgh, PA: SSPC, 1993), pp. 126-139.
71. J. Hermele, "An Introduction to Anti-Slip Coatings," *JPCL* 16, 1 (1999).
72. T. Murphy, "In Search of Slip-Resistant Flooring," *Plant Services*, (March 2001).
73. ACI 503.3 (latest revision), "Standard Specification for Producing a Skid-Resistant Surface on Concrete by the Use of a Multi-Component" (Farmington Hills, MI: ACI).
74. D.J. De Renzo, ed., *Corrosion Resistant Materials Handbook*. 4th ed. (Park Ridge, NJ: Noyes Publications,⁽¹⁸⁾ 1985).
75. D.J. De Renzo, ed., *Handbook of Corrosion Resistant Polymer Floorings* (Park Ridge, NJ: Noyes Publications, 1986).
76. UL 410 (latest revision), "Slip Resistance of Floor Surfacing Materials" (Northbrook, IL: Underwriters Laboratory).
77. Sacher, A. "Slip Resistance and the James Machine 0.5 Static Coefficient of Friction—Sine Qua Non," *ASTM Standardization News*, August (1993).
78. W. English, "Should the Threshold of Safety be .50?" August 29, 2002, <http://www.englishxl.com/point5.html> (August 29, 2002).
79. U.S. Code of Federal Regulations (CFR), Title 28, Part 36, Appendix A4.5, "Ground and Floor Surfaces," *Standards for Accessible Design, Americans with Disabilities Act, Accessibility Guidelines for Buildings and Facilities*. (Washington, DC: Office of the Federal Register, 1992).
80. J. Durig, "Comparison of Epoxy Technology for Protective Coatings and Linings in Wastewater Facilities," Proc. SSPC 99, held November 1999 (Pittsburgh, PA: SSPC, 1999).
81. T. Millard, "Epoxy and Vinyl Ester Flooring for Concrete," *JPCL* 5, 8 (1988): pp. 36-47.
82. NACE Standard RP0591 (latest revision), "Coatings for Concrete Surfaces in Non-Immersion and Atmospheric Service" (Houston, TX: NACE).
83. C.G. Munger, *Corrosion Prevention by Protective Coatings* (Houston, TX: NACE, 1985).
84. *Good Painting Practice: SSPC Painting Manual*, vol. 1, 4th ed. (Pittsburgh, PA: SSPC, 2002).

⁽¹⁸⁾ William Andrew Publishing, Noyes Publications, 13 Eaton Avenue, Norwich, NY 13815.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

85. NACE Publication 6A187 (withdrawn), "Reinforced Polyester and Epoxy Linings" (Houston, TX: NACE). (Available from NACE as an historical document only).
86. D.J. Herzog, T.B. Brown, "Proper Cure of Vinyl Ester Resins," MP 33, 4 (1994): pp. 30-33.
87. C.H. Hare, Protective Coatings: Fundamentals of Chemistry and Composition (Pittsburgh, PA: SSPC, 1994).
88. "Polyurea 101, AIA/CES⁽¹⁹⁾ Training Program" (latest revision) (Kansas City, MO: PDA⁽²⁰⁾).
89. A.H. Roebuck, R.W. Foster, "100 Percent Solids Plural Component Urethane Coatings," JPCL 5, 2 (1988): pp. 22-27.
90. R.R. Roesler, W. Cibulas, M.B. Bassi, "Polyurethanes: Low VOC Coatings for Concrete," in Protective Coatings for Flooring and Other Concrete Surfaces, Proc. SSPC 91, held November 10-15, 1991 (Pittsburgh, PA: SSPC, 1991).
91. T.D. Wayt, M.B. Bassi, "Polyurethane Coatings for Concrete," Proc. Concrete: Surface Preparation, Coatings and Linings, and Inspection Techniques (Houston, TX: NACE, 1991).
92. B.F. Schafran, C.W. Armstrong, "Repair and Maintenance of Refrigerated Warehouse Floors," JPCL 8, 3 (1991): pp. 60-64.
93. R.W. Washburn, M.J. Galloway, W.R. Slama, "Reinforced, Chemical-Resistant, Thermoset Linings," JPCL 2, 10 (1985): pp. 30-42.
94. W.H. Julius, S.S. McDowell, "Continuous Needle Punched Non-Woven Polyester Fabric for Improvement of Corrosion Resistance and Thermal Shock of Reinforced Monolithic Coatings for Concrete," in Innovations for Preserving and Protecting Industrial Structures, Proc. SSPC 93, held November 13-18, 1993 (Pittsburgh, PA: SSPC, 1993), pp. 119-122.
95. R.M. Mayer, N. Hancox, Design Data for Reinforced Plastics—A Guide for Engineers and Designers (Boca Raton, FL: Chapman and Hall, 1994).
96. ASTM D 4580 (latest revision), "Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding" (West Conshohocken, PA: ASTM).
97. NACE Publication TPC 2 (latest revision), "Coatings and Linings for Immersion Service" (Houston, TX: NACE).
98. ASTM C 267 (latest revision), "Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes" (West Conshohocken, PA: ASTM).
99. ASTM C 413 (latest revision), "Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes" (West Conshohocken, PA: ASTM).
100. ASTM D 543 (latest revision), "Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents" (West Conshohocken, PA: ASTM).
101. ASTM D 1308 (latest revision), "Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes" (West Conshohocken, PA: ASTM).
102. ASTM C 307 (latest revision), "Standard Test Method for Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacing" (West Conshohocken, PA: ASTM).
103. ASTM D 412 (latest revision), "Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension" (West Conshohocken, PA: ASTM).
104. ASTM D 638 (latest revision), "Standard Test Method for Tensile Properties of Plastics" (West Conshohocken, PA: ASTM).
105. ASTM C 580 (latest revision), "Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes" (West Conshohocken, PA: ASTM).
106. ASTM C 579 (latest revision), "Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes" (West Conshohocken, PA: ASTM).
107. ASTM D 5045 (latest revision), "Standard Test Methods for Plane-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials" (West Conshohocken, PA: ASTM).
108. ASTM D 2794 (latest revision), "Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)" (West Conshohocken, PA: ASTM).
109. ASTM D 3359, "Standard Test Methods for Measuring Adhesion by Tape Test" (West Conshohocken, PA: ASTM).

⁽¹⁹⁾ The American Institute of Architects (AIA), Continuing Education System (CES), 1735 New York Avenue, NW, Washington, DC 20006-5292.

⁽²⁰⁾ Polyurea Development Association (PDA), 14 West Third Street, Suite 200, Kansas City, MO 64105.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

110. ASTM C 531 (latest revision), "Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes" (West Conshohocken, PA: ASTM).

111. ASTM C 883 (latest revision), "Test Method for Effective Shrinkage of Epoxy Resin Systems Used with Concrete" (West Conshohocken, PA: ASTM).

112. ASTM C 884 (latest revision), "Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay" (West Conshohocken, PA: ASTM).

113. ASTM E 1356 (latest revision), "Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry or Differential Thermal Analysis" (West Conshohocken, PA: ASTM).

114. ASTM E 1824 (latest revision), "Standard Test Method for Assignment of a Glass Transition Temperature Using Thermomechanical Analysis Under Tension" (West Conshohocken, PA: ASTM).

115. ASTM D 4587 (latest revision), "Standard Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings" (West Conshohocken, PA: ASTM).

116. ASTM D 4414 (latest revision), "Standard Practice for Measurement of Wet Film Thickness by Notch Gages" (West Conshohocken, PA: ASTM).

117. ASTM D 4138 (latest revision), "Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means" (West Conshohocken, PA: ASTM).

118. ASTM D 6132 (latest revision), "Standard Test Method for Nondestructive Measurement of Dry Film Thickness

of Applied Organic Coatings Over Concrete Using an Ultrasonic Gage" (West Conshohocken, PA: ASTM).

119. ASTM D 4787 (latest revision), "Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates" (West Conshohocken, PA: ASTM).

120. NACE Standard RP0188 (latest revision), "Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates" (Houston, TX: NACE).

121. ASTM D 2583 (latest revision), "Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor" (West Conshohocken, PA: ASTM).

122. ASTM D 5402 (latest revision), "Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs" (West Conshohocken, PA: ASTM).

123. ASTM D 4518 (withdrawn), "Standard Test Methods for Measuring Static Friction of Coating Surfaces" (West Conshohocken, PA: ASTM).

124. ASTM C 1028 (latest revision), "Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method," (West Conshohocken, PA: ASTM).

125. ASTM F 462 (latest revision), "Consumer Safety Specification for Slip-Resistant Bathing Facilities," (West Conshohocken, PA: ASTM).

126. ASTM F 1679 (latest revision), "Standard Test Method for Using a Variable Incidence Tribometer (VIT)" (West Conshohocken, PA: ASTM)

Bibliography

AASHTO T 277 (latest revision). "Rapid Determination of the Chloride Permeability of Concrete." Washington, DC: AASHTO.

Aldinger, T. "Concrete Coating Work Procedures." In *Achieving Quality in Polymer Flooring Work, Proc. of SSPC 92*, held November 1992. Pittsburgh, PA: SSPC, 1992, pp. 80-86.

Arnold, J. "Management Procedures for Maintenance Painting of Industrial Floors." *JPCL* 6, 5 (1989): pp. 41-45.

ASTM C 722 (latest revision). "Standard Specification for Chemical-Resistant Resin Monolithic Surfacing." West Conshohocken, PA: ASTM.

ASTM D 4060 (latest revision). "Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser." West Conshohocken, PA: ASTM.

ASTM D 4259 (latest revision). "Standard Practice for Abrading Concrete." West Conshohocken, PA: ASTM.

ASTM D 4518 (latest revision). "Test Methods for Measuring the Static Friction of Coating Surfaces." West Conshohocken, PA: ASTM.

ASTM E 1356 (latest revision). "Test Method for Glass Transition Temperatures by Differential Scanning Calorimetry or Differential Thermal Analysis." West Conshohocken, PA: ASTM.

ASTM E 1824 (latest revision). "Test Method for Assignment of a Glass Transition Temperature of Thermomechanical Analysis Under Tension." West Conshohocken, PA: ASTM.

Boova, A.A. "A Guide to Selecting Industrial Flooring Systems." *JPCL* 7, 2 (1990): pp. 36-44.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

- Boova, A.A. "Decorative Protective Flooring Systems." CORROSION/90, paper no. 346. Houston, TX: NACE, 1990.
- Boyd, R. "Quality Control in Cleaning and Coating Concrete." In *Protective Polymer Floorings for Flooring and Other Concrete Surfaces, Proc. SSPC 91*, held November 10-15, 1991. Pittsburgh, PA: SSPC, 1991, pp. 5-7.
- BS 8204-2 (latest version). "Screeds, Bases, and in-situ Flooring. Concrete Wearing Surfaces. Code of Practice," Annex B "Determination of the Abrasion Resistance Value (ARV)." London, UK: BSI.
- Coating and Lining Inspection Manual*. Pittsburgh, PA: SSPC, 1991.
- Dively, R.W. "Osmotic Blistering of Coatings and Linings Applied to Concrete Surfaces." *MP* 33, 5 (1994): pp. 42-44.
- Durig, J. "Internally Flexible Epoxy." *Concrete Repair Bulletin* (November/December 1996).
- French, G. "Comparison of Flexible and Rigid Epoxy Systems for Concrete Protection." *Concrete Repair Bulletin* (January/February 1999).
- Gelfant, F.S. "A Historical Perspective on the Advancement of Coating Technology for the Protection of Concrete." CORROSION/93, paper no. 445. Houston, TX: NACE, 1993.
- Gelfant, F.S. "Contaminated Concrete: Effect of Surface Preparation Methods on Coating Performance." *JPCL* 12, 12 (1995): pp. 60-72.
- Glass, J.J. "Choosing a Flooring System to Protect Concrete from Aggressive Chemicals." *JPCL* 9, 2 (1992): pp. 65-68.
- Greenfield, T.K. "Inspection of Coatings Applied to Concrete." *MP* 31, 10 (1992): pp. 32-35.
- Greenfield, T.K. "Specifying Coatings for Concrete Surfaces." *MP* 33, 7 (1994): pp. 37-41.
- Gunter, M., and H.K. Hilsdorf. "Stresses Due to Physical and Chemical Actions in Coatings on a Concrete Substrate." In *Adhesion Between Polymers and Concrete: Bonding, Protection, Repair, Proc. RILEM⁽²¹⁾ Conference*, held September 16-19, 1986. H.R. Sasse, ed. Cachan Cedex, France: RILEM, 1986. pp. 8-21.
- Hazen, F. "Corrosion Proofing of Concrete Structures in Pulp and Paper Mills." In *Innovations for Preserving and Protecting Industrial Structures, Proc. SSPC 93*, held November 13-18, 1993. Pittsburgh, PA: SSPC, 1993, pp. 16-34.
- Hazen, F. "Repair and Resurfacing of Paper Mill Bleach Plant Floors." In *Protective Polymer Floorings for Flooring and Other Concrete Surfaces, Proc. SSPC 91*, held November 10-15, 1991. Pittsburgh, PA: SSPC, 1991, pp. 151-167.
- Hewlett, P.C. "Methods of Protecting Concrete." In *Protection of Concrete*. Eds. R.K Dhir and J.W. Green. London, UK: Chapman and Hall, 1990.
- Julius, W.H. "Tips on Avoiding Coating Failures on Concrete." *JPCL* 10, 12 (1993): pp. 35-43.
- Kapsanis, K. "Coating Concrete: A Review of Regulations, Technical Activities, and Resources." *JPCL* 8, 8 (1991): pp. 58-65.
- McGown, R.L. "Protection of Concrete Substrates Using Protective Coatings: An Overview." In *Protective Polymer Floorings for Flooring and Other Concrete Surfaces, Proc. SSPC 91*, held November 10-15, 1991. Pittsburgh, PA: SSPC, 1991, pp. 46-52.
- "Modern Plastics Encyclopedia '96." *Modern Plastics* 72, 12 (1995): p. B153
- Murphy, T. and J. Durrig. "Selecting a Flooring System: Considerations for a Seamless Flooring System." *Plant Services* (June 1998).
- Neville, F. and E.J. Wolf. "Monolithic Linings and Floorings for the Pulp and Paper Industry." *JPCL* 8, 8 (1991): pp. 44-48.
- Nixon, R., R.W. Drisko, eds. *The Fundamentals of Cleaning and Coating Concrete*. Pittsburgh, PA: SSPC, 2001.
- Nixon, R.A. and R.H. DeWolf. "Protecting Concrete with Resinous Floor Toppings: An Owner's Guide." *JPCL* 9, 2 (1992): pp. 36-44.
- Nixon, R.A. and R.H. DeWolf. "Repairing and Protecting Concrete Floors in Industrial Facilities: An Owner's Guide for Avoiding Resinous Floor Topping Failures." In *Protective Polymer Floorings for Flooring and Other Concrete Surfaces, Proc. SSPC 91*, held November 10-15, 1991. Pittsburgh, PA: SSPC, 1991, pp. 125-150.

⁽²¹⁾RILEM, ENS, Bâtiment Cournot, 61 avenue du Président Wilson, F-94235 Cachan Cedex, France.

SSPC-TR 5/ICRI Technical Guideline 03741/NACE Publication 02203

- Pfaff, F.A. and F.S. Gelfant. "Osmotic Blistering of Epoxy Coatings on Concrete." *JPCL* 14, 12 (1997): pp. 52-64.
- Pierce, J.M. "Coating Enhancement Procedures for Concrete Structures." In *Achieving Quality in Polymer Flooring Work, Proc. SSPC 92*, held November 19, 1992. Pittsburgh, PA: SSPC, 1992, pp. 173-174.
- Riesterer, W.H. "Hydrostatic, Capillary, Osmotic and Other Pressures." In *Innovations for Preserving and Protecting Industrial Structures, Proc. SSPC 93*, held November 13-18, 1993. Pittsburgh, PA: SSPC, 1993.
- Schupack, M. "Divorces and Ruptured Relations Between Epoxies and Concrete." *Concrete Construction* (October 1980): pp. 735-738.
- SSPC-PA 7 (latest revision), "Applying Thin Film Coatings to Concrete." Pittsburgh, PA .
- Steele, J. "Measuring Adhesion of Coatings to Concrete and Steel" *MP* 40, 1 (2001): pp. 36-40.
- Steele, J. "Successful Polymer Flooring and Lining of Concrete." Presented at NACE Seminar, Successful Coating and Lining of Concrete. Houston TX: NACE, 1994.
- Suprenant, B.A. "Moisture Movement Through Concrete Slabs." *Concrete Construction* (November 1997): pp. 879-885.
- Suprenant, B.A. and W.R. Malisch. "Where to Place the Vapor Retarder." *Concrete Construction* (May 1998): pp. 427-433.
- Wilson, F.D. "The Right Material for the Right Job." *MP* 29, 2 (1990): pp. 32-35.

Appendix A: Classification of Chemicals

The following list provides examples of typical chemicals in each chemical classification mentioned in Section 4.

1. Mineral Acids
 - Sulfuric
 - Nitric
 - Hydrochloric
 - Hydrofluoric
 - Phosphoric
 - Chromic
2. Organic Acids
 - Formic
 - Acetic
 - Acrylic
 - Adipic
 - Terephthalic
 - Fatty Acids
3. Oxidizers and Oxidizing Acids
 - Nitric Acid
 - Chromic Acid
 - Peroxides
 - Hypochlorites
4. Alkalis
 - Sodium Hydroxide
 - Calcium Hydroxide
 - Ammonia
5. Chlorinated Solvents
 - Methylene Chloride
 - Ethylene Dichloride
6. Oxygenated Solvents (often subdivided as follows):
 - a) Alcohols
 - Methanol
 - Ethanol
 - b) Ethers
 - Ethylene Glycol
 - Phenol
 - c) Ketones
 - Acetone
 - Methyl Ethyl Ketone
 - d) Esters
 - Vinyl Acetate
 - Butyl Acetate
7. Hydrocarbon Solvents (often subdivided as follows):
 - a) Aliphatic
 - Butane
 - Hexane
 - Cyclohexane
 - Butadiene
 - b) Aromatic
 - Benzene
 - Ethylbenzene
 - Styrene
 - Xylene
 - Toluene
 - Cumene
8. Salt Solutions
 - Nitrates
 - Chlorides
 - Sulfates
 - Phosphates
 - Chromates

Appendix B: Flooring System Materials Test Procedure

The following is a list of test methods that can be used to quantify the physical properties of a specific polymer flooring system and verify its compatibility with a specific environment. Materials qualified for a specific application are usually based on testing of new lab-applied materials; performance can vary for materials that were applied in field conditions and have weathered. This Appendix is provided for optional reference only and is not to be considered a list of guidelines for compatibility testing.

Chemical Immersion Testing

Although floor systems are not designed to be subjected to immersion, some applications may have such a frequency of spillage that the owner's representative would prefer to install a polymer flooring system that is capable of withstanding complete immersion in the defined environment

Immersion Testing

Immersion testing is performed with a molded or free-film sample of the polymer flooring (no substrate) that is immersed in the chemical (or water) and monitored for changes in properties and appearance.

- ASTM C 267⁹⁸ Chemical resistance test
- ASTM C 413⁹⁹ Water absorption test
- ASTM D 543¹⁰⁰ Chemical resistance test
- ASTM D 1308¹⁰¹ Household chemical test

Physical Testing

Tensile Strength

- ASTM C 307¹⁰²
- ASTM D 412¹⁰³
- ASTM D 638¹⁰⁴

Modulus of Elasticity and Elongation

- ASTM D 412
- ASTM D 638
- ASTM C 580¹⁰⁵

Flexural Strength

- ASTM C 580

Compressive Strength

- ASTM C 579¹⁰⁶

Fracture Toughness

- ASTM D 5045¹⁰⁷

Impact Resistance

- ASTM D 2794¹⁰⁸

Permeability

- ASTM E 96

Adhesion Testing

Testing for adhesion after various exposure tests might be a better indicator of expected performance. For example, adhesion testing can be performed after immersion testing, after UV exposure, after impact testing, and after thermal cycling.

- ASTM D 4541
- ACI 503 R, Appendix A
- ASTM D 3359¹⁰⁹

Thermal Testing

The effect of temperature and heat on polymer floorings can be quantified by using the standardized tests listed below.

Shrinkage

- ASTM C 531¹¹⁰
- ASTM C 883¹¹¹

Thermal Expansion

- ASTM C 531
- ASTM C 884¹¹²

Maximum Temperature

- ASTM E 1356¹¹³
- ASTM E 1824¹¹⁴

UV Testing

- ASTM D 4587¹¹⁵

Appendix C: Flooring Systems Test Procedures

The following test methods can be used to quantify the properties of an installed polymer flooring system. This section is provided for optional reference only and is not to be considered a list of guidelines for testing methods.

Polymer Flooring Thickness

- ASTM D 4414¹¹⁶ is a wet-film thickness test that is performed during polymer flooring installation.
- ASTM D 4138¹¹⁷ is a destructive method that is not accurate on concrete unless numerous specimens are tested.
- ASTM D 6132¹¹⁸ is a nondestructive method of measuring the thickness of cured polymer floorings on concrete using an ultrasonic gauge.

Discontinuity Testing⁷⁹

High- or low-voltage electrical charges to detect discontinuity, holidays, or pinholes in the coating

- ASTM D 4787¹¹⁹
- NACE Standard RP0188¹²⁰

Cure Evaluation

- ASTM D 2583¹²¹ Hardness Test
- ASTM D 5402¹²² Solvent Rub Test
- ASTM D 4541³⁴ Portable Adhesion Test
- ASTM D 3359 Adhesion by Tape Test
- ACI 503 R³⁵ Appendix A, Adhesion Test

Coefficient of Friction (Slip Resistance)

- ASTM D 2047 James Machine friction measurement

- UL Standard 410⁷⁷ James Machine with leather, dry, wet, or oily
- ASTM D 4518¹²³ Static friction on inclined plane
- ASTM C 1028¹²⁴ Dynamometer pull on dry or wet surfaces
- ASTM F 462¹²⁵ Brungraber test for bathing facilities
- ASTM F 1679¹²⁶ Portable test for wet or dry surfaces

ASTM D 2047 is a laboratory test method using the James Machine, and although specifically designed for testing flooring materials that are polish coated, it is commonly used to test floor coatings and flooring systems, and contains a compliance criterion of 0.5 minimum on a dry surface. UL Standard 410 has an expanded scope covering numerous types of floor covering materials and also uses the James Machine apparatus and a leather shoe dry, coated with water or coated with cutting oil. UL 410 also specifies a minimum pass criterion of 0.5 average (0.45 minimum) static coefficient of friction. UL tests and certifies flooring systems to meet this standard. ASTM D 4518 measures the static friction of coated surfaces using an inclined plane or, along with ASTM C 1028 by a horizontal pull method on dry or wet surfaces using a dynamometer. ASTM F 462, the Brungraber test, specifically designed for bathing facilities, and F 1679 are also portable tests that may be used to measure the static coefficient of friction of wet or dry floor surfaces. The ATBCB⁽²²⁾ reported on a comparison of the various portable slip machines and found the Brungraber Tester (ASTM F 462) was recommended as the best portable device for measuring slip resistance under dry conditions.

⁽²²⁾ U.S. Architectural and Transportation Barriers Compliance Board (ATBCB) (also known as "The Access Board"), 1331 F Street, NW, Suite 1000, Washington, DC 20004-1111.