

SSPC: The Society for Protective Coatings Technology Guide No. 20

Guide for Applying Thick Film Coatings and Surfacing Over Concrete Floors

(replaces SSPC-TU 10 of same title)

1. Scope and Description

This Guide discusses techniques and procedures to select and apply resinous coating systems over concrete floors. These thick-film systems (greater than 500 micrometers [μm] [20 mils]) include self-leveling systems, slurry systems, broadcast systems, mortar systems, fabric-reinforced systems, spray applied systems, and non-waterproofing and underlayment membranes. Application of thin-film coatings (less than 500 μm [20 mils]) and sealers, terrazzo flooring, membrane systems designed for waterproofing, and primary and secondary containment systems is beyond the scope of this Guide.

The Guide is intended for use by floor surfacing contractors, owners and specifiers, and others in the coatings and surfacings industry.

2. Referenced Standards and Publications

The latest revision of the standards below should be consulted for reference:

2.1 SSPC GUIDES, STANDARDS AND JOINT STANDARDS

SSPC-AB 1	Mineral and Slag Abrasives
SSPC-AB 2	Cleanliness of Recycled Ferrous Metallic Abrasives
SSPC-SP 13/ NACE No. 6	Surface Preparation of Concrete
SSPC-Guide 12	Guide for Illumination of Industrial Painting Projects
SSPC-TU 2/ NACE 6G197	Design, Installation, and Maintenance of Coating Systems for Concrete Used in Secondary Containment
SSPC-TR 5/ NACE 02203/ ICRI 710.1	Design, Installation, and Maintenance of Protective Polymer Flooring Systems for Concrete

2.2 INTERNATIONAL CONCRETE REPAIR INSTITUTE TECHNICAL GUIDELINES (ICRI)

No. 310.1R	Guide for Surface Preparation of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion
No. 310.2	Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays

No. 320.1R	Guide for Selecting Application Methods for the Repair of Concrete Surfaces
No. 320.2R	Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces

2.3 AMERICAN CONCRETE INSTITUTE STANDARDS (ACI)

ACI CT-13	ACI Concrete Terminology
ACI 201.1R	Guide for Conducting a Visual Inspection of Concrete in Service
ACI 201.2R	Guide to Durable Concrete
ACI 224R	Control of Cracking in Concrete Structures
ACI 302.2R	Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials
ACI 308R-01	Guide to Curing Concrete
ACI 318	Building Code Requirements for Structural Concrete and Commentary
ACI 364.1R	Guide for Evaluation of Concrete Structures Before Rehabilitation
ACI 546R	Concrete Repair Guide

2.4 ASTM INTERNATIONAL

ASTM D4060	Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
ASTM D4260	Standard Practice for Acid Etching Concrete
ASTM D4262	Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces
ASTM D4263	Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method
ASTM D7234	Standard Test Method for Pull Off Adhesion Strength of Coatings on Concrete Using Portable Adhesion Testers
ASTM D7682	Standard Test Method for Replication and Measurement of Concrete Surface Profiles Using Replica Putty
ASTM E1745	Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

- ASTM E1643** Standard Practice for Selection, Design, Installation, and Inspection of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs
- ASTM F1869** Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Sub-floor Using Anhydrous Calcium Chloride
- ASTM F2170** Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes
- ASTM F2420** Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood

2.5 US Department of Transportation, Federal Highway Administration

Alkali-Silica Reactivity Field Identification Handbook

3. Definitions

Amine Blush: Surface opalescence (blush) on coating films caused by reaction of amine co-reactant with carbon dioxide and water to form an amine carbamate. This can affect adhesion of any subsequent coat if not properly removed.

Alkali Silica Reaction (ASR): The reaction between the alkalis (sodium and potassium) in portland cement and certain siliceous rocks or minerals, such as opaline chert, strained quartz, and acidic volcanic glass, present in some aggregates. [ICRI]

Bleed Water: Water within or emerging from newly placed concrete or mortar.

Broadcast Flooring: Unfilled resins (commonly) or aggregate-filled slurries into which aggregate is scattered by a seeder or manually into the wet uncured resin or slurry which then cures with the aggregate embedded in it.

Broadcast to Saturation/Excess: The process of scattering aggregate into a wet matrix (see Broadcast) until no matrix wetness is observed (until no more aggregate can be embedded into the wet matrix).

Capillary: A microscopic channel on cured concrete that permits the movement of liquid water.

Carbamate: A salt or an ester of carbamic acid. Carbamates are formed by the reaction of an amine with carbon dioxide (R_2NCO_2H) and are associated with the "amine blush."

Carbonation: The reaction between carbon dioxide and a hydroxide or oxide to form a carbonate, especially in cement paste, mortar, or concrete.

Carbonate: A breakdown product of cement exposed to carbon dioxide and hydroxide or oxide. The molecular structure is the simplest oxocarbon anion. It consists of one carbon atom surrounded by three oxygen atoms (CO_3^{2-}) in a trigonal planar arrangement.

Hydration (of Cement): The reaction of water with the calcium silicate, aluminate, or aluminoferrite components of fine Portland cement grains necessary for the setting and densifying of concrete.

Keyed (Key-in): The process by which cured concrete is removed to create a termination border for a fluid-applied flooring system.

Lap Length: The length of overlapping steel reinforcing bars.

MVE (Moisture Vapor Emissions): Description of the moisture vapor that leaves the concrete slab.

MVER (Moisture Vapor Emission Rate): Measurement of moisture vapor leaving a concrete slab.

MVT (Moisture Vapor Transmission): Description of moisture vapor that passes through a membrane.

MVTR (Moisture Vapor Transmission Rate): Rate of movement of moisture vapor through a membrane.

Planarity: General evenness of a surface in an intended direction; may be a sloped or level area.

Pozzolan: A siliceous or siliceous and aluminous material that in itself possesses little or no cementitious value but that will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties; there are both natural and artificial pozzolans. [ACI]

Recoat Window (Time): A period beginning at a point when a coating has dried or cured sufficiently to be re-coated and ending when the coating has reached a degree of cure that re-coating is not recommended without an additional surface preparation procedure such as the application of a bond coat or abrading the surface.

Resin: General term applied to a wide variety of more or less transparent and fusible products, which may be natural or synthetic. They may vary widely in color. Higher molecular weight synthetic resins are more generally referred to as polymers. In a broad sense, this term is used to designate any polymer that is a basic binder material for coatings and plastics. [Painting/Coatings Dictionary]

Self-Leveling Flooring: Resinous or polymer cementitious materials that flow out over a concrete slab to seek their own levels; they usually require termination strips rather than key-in terminations.



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Skim Coat: A thin layer of resin- or cement-based mortar used to smooth surface irregularities.

Sloping Correction: 1) An adjustment applied to a distance measured on a slope to reduce it to a horizontal distance between the vertical lines through its end points. 2) The process of installing a given pitch to a surface.

Slump: A measure of the consistency of freshly mixed concrete, mortar, or stucco equal to the subsidence measured to the nearest 1/4 inch (6 mm) of the molded specimen immediately after removal of the slump cone. [ACI]

Slurry Flooring: An aggregate, powder, filler, resin mix producing a flowable, but not necessarily self-leveling mixture. Slurry floor materials are usually troweled to the thickness of the largest aggregate in the material.

Soluble Alkali Ions: Substances that form charged hydroxide bases that dissolve in water.

Spalling: The chipping or fragmenting of a surface or surface coating caused, for example, by differential thermal expansion, contraction, or physical abrasion.

Tie-In: In an installation sequence, the joining of additional material to material already placed.

4. Design Considerations for Resinous Flooring Systems

The successful design, installation, and performance of a resinous flooring system depends on an evaluation of the existing surface conditions, the conditions of installation and the conditions of use. Each of these considerations will impact the selection of the surfacing system.

4.1 Background Information on Concrete and Concrete Placement: Proper design and placement of the underlying concrete are essential to the proper performance of any resinous surfacing system. Detailed concrete and concrete substrate requirements are discussed at length by ACI 302.2R, ACI 364.1R, ACI 201.2R, ACI 546R; ICRI Guidelines No. 310.1R, No. 320.1R and No. 310.2; and The Fundamentals of Cleaning and Coating Concrete, as well as a host of other standards and publications.

Concrete is mainly a mixture of Portland cement, water, and mineral aggregate, usually sand and gravel. Sometimes additives such as fly ash and pozzolans are used. The mixture cures and hardens by hydration. Water in the mix combines chemically with the cement to bind the aggregate into the rigid mass known as concrete. Although properly formulated and cured concrete is strong and rigid, it can be attacked both physically and chemically. Concrete is very strong in compression but relatively weak in tension. It can and often does crack. Concrete is also fairly porous and subject to osmotic and capillary forces that absorb and release water. Absorbed water can freeze within the concrete and cause spalling and cracking.

Strength-gain, wear-resistance, and shrinkage properties of every concrete mix design are affected by the water-to-cement (w/c) ratio, normally expressed as the weight of mixing water per weight of cement. Concrete with a lower water-cement ratio gains more strength than concrete with a higher one, but such low ratios may be difficult to place and consolidate properly because of the stiffness of the mix. Chemical admixtures (water reducers) are often used to increase workability of the concrete while keeping the water-cement ratio low. High water-cement ratios increase shrinkage cracking and reduce surface wear resistance and compressive strength.

Approximately 200 grams of water for each 1 kilogram [kg] (0.20 pounds [lb] of water for each 1 lb) of cement is required for complete cement hydration. Roughly twice that ratio, or 400 grams of water for each 1 kg (0.40 lb of water per each 1 lb) of cement, is required for mixing, because additional water is absorbed on gel pore surfaces and the cement particles should all be wetted. More water may be added to enhance workability when placing concrete, but any amount in excess of 180 grams of water for each 1 kg (0.40 lb per 1 lb) of cement is not required for the hydration process and may eventually leave the concrete via evaporation or as bleed water. The general mix design shown in Table 1 is an example of a mixture that will yield a suitable substrate.

An excess of water increases shrinkage and contributes to the formation of cracks and continuous capillaries in the hardened concrete paste. The capillaries become channels for moisture movement and for intrusive and harmful chemical solutions after the cured concrete is placed in service. Wet curing will minimize development of capillary channels.

TABLE 1
EXAMPLE OF GENERAL MIX DESIGN

Cementitious Content (minimum)	517 lbs/cubic yard (179.3 kg/m ³)
Water-Cement Ratio (by weight)	0.40-0.45
Maximum Coarse Aggregate Size	38 millimeters [mm] (1-1/2 inches)
Air content	4-6%
Slump (without high range water reducers)	less than 76 mm (3 inches)
Slump (with high range water reducers)	150 to 230 mm (6-9 inches)
Compressive Strength (28 days)	35 megapascals (MPa) (5,000 pounds per square inch [psi])
Permeability	low
Cement options	---
Water	---

4.2 Designing Concrete Surfaces for Resinous Floor

Systems: While concrete slabs should be placed in accordance with standard ACI practices, it is equally important that the concrete be designed to accommodate the intended end use. The tensile strength of a concrete substrate is important in concrete design. The tensile strength of concrete is approximately 10% of its compressive strength. The failure of a concrete substrate due to low tensile strength can result in a failure of any flooring or surfacing applied over it. Resinous flooring materials manufacturers generally recommend the minimum tensile strength of the concrete substrate to be 1.4 MPa (200 psi), but prefer tensile strength to be 2.4 MPa (350 psi) or greater as measured per ASTM D7234.

An effective concrete substrate should also be low in permeability and high in density. Water or liquid moves through concrete through small pores, or capillaries, in the form of vapor; always from an environment of high vapor pressure to low vapor pressure. Vapor pressure combines the effects of temperature and humidity. In general, moisture migrates from warm, humid conditions to cool dry conditions. It is the movement of moisture vapor within the slab—not the total quantity of moisture within the slab—that creates subsequent problems with non-permeable floor surfacings. Excess residual or free water not used in the hydration process of cement will continue to migrate out of the concrete until the moisture content of the cement reaches equilibrium with its environment. If the environment below a concrete slab is continuously wet, capillary action will pull liquid from below the slab into the slab, but moisture most frequently moves in concrete as a vapor driven by the differential in vapor pressure.

As vapor is driven through the concrete, soluble alkali ions are transmitted with it and collect at the surface. When moisture cycles back into the slab, concentrating the ionic solution, crystals can form which can create enough force to disbond a resinous surfacing. If undetected, the combined phenomena of MVER (see Section 5.5.1) and ASR (see Section 5.3) will generally result in bond failure when concrete is used as a substrate over which resinous surfacing is applied.

Providing drainage under the concrete slab helps to reduce the source of water below it. Use of vapor barriers is required to eliminate moisture sources from below the slab. The vapor barrier should meet the requirements of ASTM E1745, with a permeance of less than 0.3 perms [grains/(ft² • hr • inHg)] as tested in accordance with ASTM E1745 Section 7. Placement of this moisture barrier should be continuous as described in ASTM E1643. ACI 302 recommends a 50 mm (2-inch) layer of granular self-draining compactible fill above the vapor barrier. If ACI 302 is followed, extraordinary measures should be taken to keep this fill dry. Water captured within the fill layer will act as a reservoir under the slab. In most cases, it is more advantageous to pour the concrete directly onto the moisture vapor barrier, and use moisture curing techniques to prevent drying shrinkage cracking. The practice of wet-curing concrete (ACI 308-92, Chapter 2), using burlap and a waterproof cover, is preferred over the practice of using curing compounds. Although excellent curing compounds are available, proper wet curing facilitates hydration without potential for chemical

interference of the curing compound with subsequent resinous system application. A water-cured, light steel troweled finish is most suitable for subsequent application of resinous systems. Any placement method, however, that maximizes surface strength is acceptable. Minimal finishing normally produces the strongest surface.

4.3 Condition Surveys of Existing Concrete Substrate:

Accurate and thorough condition surveys should be performed by experienced and qualified personnel prior to specification preparation. Condition surveys will also ensure the existing specification addresses site conditions. Surveys should be carried out according to referenced standards, including but not limited to ACI 201.1R and ICRI No. 310.1R and the SSPC Concrete Coating Condition Assessment Guide.

4.3.1 Condition Assessment of Existing Substrate

A non-laboratory field inspection of the substrate should include:

- Verification of the dimensions of the substrate.
- Verification of the planarity and slope.
- Verification of the concrete surface strength. A strategy should be developed for rehabilitation or removal of areas of inadequate surface strength.
- Determination of the presence of chloride, sulfate and other soluble salts. Contaminating salts are frequently present in plants and other facilities where chemicals and solvents are used.
- Determination of the presence of existing sealers, coatings or surfacings.
- Determination of moisture conditions through appropriate concrete moisture testing
- Determination of the presence of Alkali Aggregate Reaction
- Identification of static and moving cracks
- Using the MOHS hardness test to determine integrity of the surface
- Noting presence of spalls, pop-outs, aggregated surfaces and other imperfections
- Evaluating for process-based contamination

For at least two weeks prior to application, environmental conditions should be representative of normal operating conditions at the facility in order to allow the concrete substrate to reach equilibrium.

4.4 Considerations for Coating System Selection:

There are many factors that influence the ideal type of resinous flooring system for a given project. The following factors should be considered to properly choose and specify the correct system.

4.4.1 Condition of Concrete Substrate: When a seamless resinous floor covering is considered, the type of substrate and present condition should be understood and factored into the decision making process. Spalled concrete, major cracks, the type and condition of joints, or the lack of joints, uneven surfaces, corroded surfaces, improper support and stiffness,

etc., are types of conditions that should be addressed and considered to ensure the final flooring system will perform as the customer intends.

4.4.2 Prevailing Site Conditions at Time of installation:

In addition to the considerations for surface conditions, other jobsite conditions at the time of installation ultimately affect the resin-based flooring system. Some of the key site conditions to be aware of include:

- Temperature and air flow of the area where the resin-based system will be installed at the time of installation,
- Other trades that will be working in the building during installation or occupancy by the customer,
- Requirements for masking, dust control, odor control, finish protection and site access.

4.4.3 Chemical Resistance: Correctly selected and applied resin-based floorings are effective in protecting substrates from attack from many types of chemical spills. When choosing a resin-based floor to protect from chemical attack, the type and concentration of chemical exposure with the floor should be considered. In addition, the manufacturer and contractor should know the temperature of the spillage, the frequency and duration of the exposure, and the type and frequency of cleaning and emergency wash-downs.

Resistance to particular chemicals does not exclude the possibility of surface staining. Some chemicals will cause a discoloration of the resin-based flooring without affecting the integrity and durability of the system. This discoloration is purely aesthetic and its likelihood should be communicated to the owner. If appearance is a major requirement, it should be included in the project specifications and materials selected accordingly.

With sufficient drainage and housekeeping standards, excellent service life can be achieved under conditions of highly aggressive chemical spillage. Due to the wide variety of chemical products used in industry and the diversity of synthetic resin floorings, it is not practical to provide a simple guide to chemical resistance. Manufacturers should be consulted for their experiences in similar environments and with laboratory testing results.

For more aggressive chemical environments, such as secondary containment, please refer to SSPC-TU 2/NACE 6G197.

4.4.4 Wear resistance and durability: In general, the service life of a resinous flooring system is proportional to the total thickness of the applied system. A thin coating will wear quicker than a thicker slurry filled system under the same conditions. This service life can be affected by numerous operational factors including the level and type of traffic, frequency and type of cleaning, use of non-skid aggregates, and exposure to chemical conditions. Physical wear and abrasion resistance of coatings or flooring systems can be compared using standardized laboratory abrasion tests such as ASTM D4060.

4.4.5 Temperature Resistance: Resinous flooring systems are utilized in a variety of ambient and extreme temperature conditions. The performance of the system in extreme conditions will be dependent upon the rate of temperature change, the coefficient of thermal expansion relative to the substrate (system design), and the thermal buffering (thickness) of the bond interface.

4.4.6 Slip Resistance - wet or dry service conditions:

Smooth surfaced resin-based flooring can be designed to produce excellent slip resistance when dry; however, these same surfaces require a texture to maintain adequate slip resistance under contaminated conditions. The heavier the degree of contaminants, the coarser the surface texture should be to retain the required level of slip resistance.

As a general rule, smoother and less porous flooring surfaces are easier to clean and coarse textured surfaces are more difficult to clean. Designing a resinous floor requires a compromise between slip resistance and ease of cleaning.

Flooring should be selected with sufficient texture to meet the specific working conditions requirements while allowing for an effective cleaning program.

4.4.7 Environmental Considerations: As the building community responds to environmental concerns through scoring systems such as Leadership in Energy and Environmental Design (LEED), resin based flooring systems evolve. Environmental concerns include minimizing Volatile Organic Compounds (VOCs), eliminating of hazardous chemicals, improving Indoor Air Quality (IAQ), increasing useful service life, minimizing embodied energy, using renewable resources, and recycling materials.

Seamless flooring and coatings provide a means of helping to maintain a clean environment at the site of installations through the use of non-porous, cleanable, and long lasting materials.

4.4.8 UV Resistance and Color Retention: When selecting resin-based flooring materials in areas exposed to prolonged sunlight, high intensity lighting, or ultra-violet radiation, it is important to note that some materials will discolor over time. Some pigments and synthetic resin binders are more susceptible to this discoloration, which is purely aesthetic. If aesthetic appearance is a major requirement, care should be taken in choosing materials that do not discolor from this exposure. Refer to manufacturer's recommendations for UV resistant or UV stable materials.

Historically, the standard colors offered were relatively limited because of the availability of pigments with the required level of chemical resistance. However, as technologies develop and color options increase, more emphasis is being placed on the aesthetic requirements of color. When installing a resin-based floor, care should be taken to control batch rotation to avoid inevitable variations in shade resulting from the manufacturing of the materials. In addition, application techniques and environmental conditions may cause slight variations in color.

4.4.9 Moisture Content: Moisture within the concrete substrate is an important consideration in any material selection specification. More detail concerning moisture testing is included in Section 5.5.2. Specific synthetic resin systems are being designed by manufacturers to properly address moisture issues within the substrate and should be utilized when moisture is a concern.

4.4.10 Installation Schedule Requirements: It is important to understand the customer's downtime requirements when selecting materials for resinous floor installation. The time required for mobilizing, surface preparation, application of the materials and subsequent cure may interfere with the customer's normal operations. The pot-life and cure times of resin-based systems vary, and are considerations during the selection process. Resin-based flooring system technology is evolving and systems are available that allow for rapid application and cure.

4.4.11 Budget: Most flooring decisions depend on the customer's allowable budget. A manufacturer's creativity in designing new systems and a contractor's abilities to streamline the installation process help to provide the best value for the customer, and the customer should ensure the resources are available to pay for a properly installed, well designed floor. Additionally, unforeseen jobsite situations do arise and adequate contingencies should be in place to properly compensate the installer.

All of the above considerations will affect the expected cost of the installation. In general, the following factors increase the cost of the material and the system installation:

- specialized material performance requirements, including enhanced resistance to chemicals, wear/abrasion, etc.
- special aesthetic requirements
- number of application steps required
- amount of surface conditioning/preparation necessary
- amount of site remediation necessary
- limitations on time available to complete installation
- restrictions on available work space

5. General Surface Preparation

5.1 Physical condition of the substrate: Successful installation of problem-free seamless flooring requires a substrate that is properly prepared. Proper subfloor preparation includes removal of any substances that will interfere with the initial bond or cause loss of bond after installation. Obvious surface contaminants, degraded concrete, and excess moisture within the concrete are all potential problems during or after the resinous floor installation. This section reviews some of the conditions that may lead to premature coating failure. Where possible, suggestions for measuring and remediation are included. Remember that the product manufacturer will always provide specific subfloor preparation requirements; those requirements are primary and should be closely reviewed and followed.

5.1.1 Surface Contaminants

5.1.1.1 Oil and Grease: Oil and grease should be removed from concrete substrates prior to subsequent surface profiling and application of any other coating or surfacing materials. If concrete removal is specified or required, remove concrete according to contract specifications.

Water-soluble or detergent-emulsifiable contaminants should be removed by scrubbing with a detergent solution as described in ICRI No. 310.2. Following the application of suitable chemical detergent solution, the surface should be scrubbed with a stiff-bristled broom, brush, or scrubbing machine. Used solution should be collected and properly disposed. The process should be repeated as necessary to achieve acceptable results.

Oils and greases that are not water-soluble or detergent-emulsifiable may be removed by use of steam. Steam should be applied over the affected area to allow oil or grease to rise to the surface. Residue should be removed and the surface should be rinsed clean. The process should be repeated until acceptable results are achieved when performing ASTM F22, Standard Test Method for Hydrophobic Surface Films by the Water-Break Test.

There are also microbial methods of removing animal fats and oils from concrete substrates. These methods may take several days to effectively remove contaminating oils and grease. It is recommended that the owner or owner's representative provide prior approval to use these types of products as they may contaminate the facility operations.

Some surfacing manufacturers offer oil-tolerant primers, commonly referred to as direct-to-oil (DTO) primers, which can be applied after mitigating techniques described above. Job specifications or surfacing manufacturer's instructions should be followed carefully when using these primers.

5.1.1.2. Soluble Salt Mitigation: Contaminating salts are frequently present under existing conditions in plants and other facilities where chemicals and solvents are used. Current industry standards do not specifically address extraction and analysis of soluble salts in concrete, however data is evolving. Soluble salts and other similar contaminants should be removed according to project specification or as required by the surfacing manufacturer with the approval of the facility owner or owner's representative

5.2 Chemical Attack: Chemical attack can occur because concrete is alkaline and chemically reactive. It can be attacked by mineral acids; some alkalis; numerous salt solutions; and organic acids such as fermenting liquids, sugars, and animal oils. Corrosive solutions penetrating to the steel reinforcement may be particularly destructive because the large displacement of corrosion products of steel can cause cracking and spalling of concrete.

5.3 Alkali-Silica Reaction (ASR): Alkali-silica reaction occurs in concrete when soluble alkali ions such as sodium and potassium react with chemically active forms of silica (usually present in the sand or gravel aggregate).

produces an expansive gel, which absorbs a significant quantity of water. Expansion of the amorphous silica gel creates internal pressures within the concrete leading to paste fractures and deterioration of the concrete.

ASR is manifested by cracking followed by spalling, strength loss, and disintegration of the concrete matrix, which sometimes causes pop outs, fragments of concrete that break away leaving a shallow, conical depression. When the amount of alkali is greater than the amount of reactive siliceous aggregates the alkali silica gel may absorb water and swell, causing expansion soon after curing. This is frequently manifested after one or more years. The Federal Highway Administration has published Alkali-Silica Reactivity Field Identification Handbook, a visual ASR guide to help identify ASR. This handbook is available for download at http://www.fhwa.dot.gov/pavement/pub_details.cfm?id=800.

ASR is best determined by recognized testing agencies equipped to perform petrographic analysis. If levels of ASR have been discovered and the condition of the substrate has been determined to be treatable by removal and replacement of specified sections of concrete substrate, those sections should be removed and replaced according to contract specifications or using the methods described below. If ASR has been determined to be treatable by mitigating surface treatment techniques approved by the surfacing manufacturer, those procedures should be carried out according to the contract specification or the surfacing manufacturer's instructions.

5.4 Carbonation: Although naturally occurring in all atmospherically exposed concrete, the fine surface crazing and softening of concrete upper surfaces particularly manifests itself when the surface is exposed to increased levels of airborne carbon dioxide during the hardening stage. Exhaust from direct-fired heaters commonly used during cold weather increases the carbon dioxide levels, and is a leading, though not the only, cause of excess carbonation.

Generally, carbonated concrete surfaces are soft or powdery, with insufficient tensile strength to maintain substrate-bonding properties required for surfacing adhesion. Standard adhesion testing methods, described in ASTM D7234, can be used to determine concrete surface strength required by surfacing manufacturers or project specifications. A concise discussion of carbonation can be found in the chapter entitled "Condition Assessment" in The Fundamentals of Cleaning and Coating Concrete.

5.5 Moisture Considerations

5.5.1 Moisture Vapor Emission (MVE): While the building community has used the terms moisture vapor transmission (MVT) and moisture vapor emission (MVE) interchangeably, the floor covering industry has settled on the term moisture vapor emission (MVE) or moisture vapor emission rate (MVER) to characterize the process of moisture egressing from the top surface of a concrete slab. Moisture vapor emissions can cause failures in non-permeable coatings and flooring systems.

When considering any concrete moisture test method, certain caveats should be understood. The first involves the

slab itself: none of the test methods have any value at all if a moisture vapor barrier is not present beneath the slab. The second caveat involves the test data itself: test results are a reflection of conditions at the time of the test - no test has proven adept at determining future performance.

5.5.2 Testing for Moisture: There are four commonly accepted methods of identifying the presence of an adverse moisture condition within a concrete subfloor: the concrete moisture meter, the calcium chloride test, the relative humidity test, and the plastic sheet method. All four methods perform well but each has limitations that, if ignored, can result in a failed project.

It is important to note that the tests do not correlate and never will because they measure different variables. The calcium chloride test measures the amount of moisture being emitted from the slab while the relative humidity test and the concrete moisture meter measure the amount of moisture within the slab. The plastic sheet method is simply a qualitative test indicating a positive or negative moisture emissions result. As such, a calcium chloride test can yield results acceptable enough to conclude a concrete subfloor is dry and yet a relative humidity test or handheld concrete moisture meter test, performed on the very same slab and run concurrently with the calcium chloride test, can indicate the presence of an adverse moisture condition.

The **concrete moisture meter** is an easy-to-use, non-invasive instrument for the non-destructive evaluation of moisture content in concrete. The electrodes transmit parallel low frequency signals, calibrated to give average moisture content by comparing the change in impedance between damp and acceptably dry concrete. The meter is simply placed on the clean surface of a concrete subfloor and a reading is presented on a small display. As easy as it is to use, the meter is as easily fooled. Differences in concrete density, aggregate size, location of reinforcing steel within the body of the slab, and surface contamination can all affect the ability of the meter to accurately assess concrete subfloor moisture. Moisture meters are best used as a quick comparative indicator and should not be used as the sole evaluation method to determine the acceptability of coating the concrete with a non-breathable coating.

The **calcium chloride test** is designed to measure the amount of moisture vapor emissions from the surface of a concrete slab in accordance with the procedure in ASTM F1869.

The calcium chloride test dynamically measures the amount of moisture vapor that is being emitted from the surface of the slab by placing a desiccant, a material with a high affinity for water, under a sealed dome. Results are reported as pounds of moisture per 1,000 ft² of floor space (or kg per 100 m²) in any given 24 hours of time. Therefore, a test result of four pounds would mean that for every 24 hours of time, four pounds (or roughly about ½ gallon) of water is being emitted from every 1,000 square feet of slab surface area.

Both the handheld moisture meter and the calcium chloride test share a serious limitation: neither is able to identify moisture more than about 13 to 19 mm (1/2 to 3/4 inch) below