want you to apply a coating, sealer, topping, overlay, membrane, or some kind of protective or decorative material to this concrete." It's deer in the headlights time for contractors. Quickly you think, "I'm trapped amid the project cost (and my profit), the condition of the concrete substrate, the expectations of the owner, the surface preparation required, the material properties, the application conditions, and the service environment. What do I need to ask, know, do, and find out myself? Where do I go to get help?" This article intends to help with some of these questions for one of the most basic and important parts of the work: concrete surface preparation. Included in the discussion are lessons learned from industry standards and guidance documents.

The Big Picture
First, determine the project objectives. Define with the owner and other interested parties what success means on this project. Mockups can help all parties decide what can be done and can serve as a test bed for different techniques, materials, and cost vs. performance results. Decide what happens if the results are less than expected. Who pays? What are the penalties? Who can arbitrate disputes?

Agree on the project “tolerables”: how to mitigate the side effects of the construction process (e.g., noise, dust, vibration, fumes); what to do with debris; whether utilities (e.g., power, ventilation, water) are available for the needed procedures; what kind of protection for the project area is possible (e.g., from weather and traffic); and what kind of protection (from the construction activity) is needed for the environment around the project.

When it comes to thinking broadly about what surface preparation method to use, follow the steps outlined in the guideline, ICRI No. 310.2 (formerly 03732) from the International Concrete Repair Institute (ICRI). The document notes, for instance, that to determine the correct surface preparation, you must analyze the project and develop a preparation strategy by answering a number of questions, including those about the substrate conditions, coating requirements, owner requirements, application conditions, project objectives, the performance criteria and their price, and methods that will meet the performance criteria.1

It is also helpful to think in detail about what surface preparation is before determining how it is best achieved on a particular project. For concrete, SSPC-SP
Learn the Substrate’s Condition

What kind of concrete is involved? What can you learn about its properties, such as its orientation, its age, its exposure, its finish, and its quality? Surface preparation provides options for improving those properties of the host concrete that facilitate accepting the specified material.

What orientation is the substrate? Horizontal concrete can be on-grade or suspended slabs with different types of traffic. Slabs suspended above the ground can usually dry from two directions. Vertical concrete is not subject to traffic but can be exposed to wind-driven rain on elevated surfaces and hydrostatic pressure on below-surface walls. Overhead concrete may require water drainage through the slab and light-reflective coatings. Vertical and overhead concrete are subject to defects such as fins, bugholes, and formwork pattern transfer.

For slabs on grade, check for a vapor barrier. If one is present, is it over or under the subbase fill? If granular fill has been applied over the vapor barrier, the fill can act as a reservoir for water that can escape only through the slab. If no vapor barrier is present, the chances of success decrease as the moisture sensitivity of the material to be applied increases and the amount of moisture underneath the slab increases. Vapor barriers can also let water through—both from punctures (which create localized high vapor emission regions) and from the use of substandard material (out of sight, out of mind, until it becomes your problem). Some success has been reported with moisture vapor mitigation systems, but before considering them, you must first test the substrate to see if it is uniformly moist, where the moisture is coming from, and whether the changes in the substrate’s environment will affect the moisture vapor permeability. (For example, starting an HVAC system can change the dew point; covering the slab with a moisture impermeable material changes the escape path of the moisture; and changes in drainage provide external sources of water.) Testing for moisture vapor emissions and internal relative humidity only capture the situation during the time of the test; the conditions may be different after the material application. Consult ACI 302.2 R-06 if you will be using moisture-sensitive coatings.

How old is the concrete and what does its age mean? Concrete yet to be placed can be modified to reduce moisture issues, be textured for coating acceptance, or even become a decorative surface not requiring further preparation. Recently placed concrete has a relatively high rate of shrinkage (developing cracking and curling) and contains more moisture than older concrete. Applying cementitious toppings and overlays to freshly placed concrete can allow both materials to shrink at the same time.

Old concrete can be rehabilitated for change of use, restored by recoating, or repaired (thereby creating the issues of both old and new concrete on the same installation). But beware: old concrete can also be contaminated with oil, chlorides, carbonation, or other unknown materials absorbed during previous service. Coating suppliers usually recommend removing existing curing compounds, form release agents, coatings, and membranes (as well as contamination) because compatibility between different coating and concrete products is generally not known and difficult to ensure, especially when long-term service life is expected.

All concrete can be subject to contamination from carbonation—a reaction between carbon dioxide in the atmosphere and hydrated components of Portland cement paste in the concrete. Carbonation occurs in two forms: early carbonation, which forms during cement hydration and produces a dusty chalky surface; and longer-term carbonation, which lowers the pH of the exposed concrete surface. Early carbonation must be removed before applying any material to the surface. Treatment of later carbonation depends on the properties of the protective systems applied. Laiance (a weak layer on the concrete surface) from bleeding and settlement during the concrete’s hardening must also be removed.

And remember: new or old concrete may have residual form release agents and curing compounds that must be removed before applying any protective material.

What exposure does the concrete have? Most deterioration mechanisms of concrete require moisture, whether from internal mechanisms (e.g., alkali aggregate reactions, sulfate attack, and freezing and thawing damage) or from the migration of deleterious influences, such as chlorides and carbonation, that lead to reinforcement corrosion, staining (except from oil), leaching, and efflorescence. Keeping water out of hardened concrete is a major reason for applying a protective system to concrete. Concrete exposed to differential temperatures (such as through an exterior wall or at the periphery of a cold storage unit) will develop a moisture profile, depending on the amount of moisture present and the temperature difference. When used for secondary containment, concrete will be subject to chemical exposures and will need chemical-resistant coatings.
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Table 1: Typical Surface Properties of Finished Concrete

<table>
<thead>
<tr>
<th>Method</th>
<th>Profile</th>
<th>Porosity(A)</th>
<th>Strength(A)</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formed concrete</td>
<td>Smooth to medium</td>
<td>Low to medium</td>
<td>Medium</td>
<td>Voids, protrusions, release agents</td>
</tr>
<tr>
<td>Wood float</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Metal trowel</td>
<td>Smooth</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Power trowel</td>
<td>Smooth</td>
<td>Very low</td>
<td>High</td>
<td>Very dense</td>
</tr>
<tr>
<td>Broom finish</td>
<td>Coarse to very coarse</td>
<td>Medium</td>
<td>Medium</td>
<td>Weak layer if not properly cured(B)</td>
</tr>
<tr>
<td>Sacking</td>
<td>Smooth</td>
<td>Low to medium</td>
<td>Low to high(B)</td>
<td>Weak layer if not properly cured(B)</td>
</tr>
<tr>
<td>Stoning</td>
<td>Smooth to medium</td>
<td>Low to medium</td>
<td>Low to high(B)</td>
<td>Weak layer if not properly cured(B)</td>
</tr>
<tr>
<td>Concrete block</td>
<td>Coarse to very coarse</td>
<td>Very high</td>
<td>Medium</td>
<td>Pinholes</td>
</tr>
<tr>
<td>Shotcrete(C)</td>
<td>Very coarse</td>
<td>Medium</td>
<td>Medium</td>
<td>Too rough for thin coatings</td>
</tr>
</tbody>
</table>

(A) These surface properties are based on similar concrete mix, placement, and vibration and are prior to surface preparation.
(B) Strength depends on application and cure.
(C) Shotcrete may be refinished after placement, which would change the surface properties shown in this table.

SSPC-TU 2/NACE 6G197.4)

What kind of finish does the concrete have? Table 1 from SSPC-SP 13 describes typical concrete surfaces with respect to different types of concrete finishes.2

Is the concrete sound? SSPC-SP 13 also describes several simple qualitative tests to determine soundness of the concrete, including lightly scratching a concrete surface with a screwdriver, file, or pocket knife; lightly striking the concrete with the edge of a hammer head; and dragging a chain across horizontal concrete.2

ICRI No. 210.3 (formerly 03739) and ASTM C 1583 quantify the soundness of the concrete substrate using near-surface tensile strength measurements and should be used to supplement the simple tests above.5,6 The same tensile tests can also be used to perform adhesion for coating compatibility during application mockup and quality control for the applied system. SSPC-SP 3 includes a table that provides guidance on acceptable concrete surfaces for many coating applications following surface preparation; while the tests are helpful, the recommendations of the coating manufacturer and good trade practice for the specific situation should always be followed.2

Surface Profile Requirements

What are the requirements of the surface profile for the applied coating? The required profile will depend on the thickness of the material to be applied. ICRI No. 310.2 (formerly 03732) describes three thicknesses of material:

- sealers (0–3 mils) [0–75 µ];
- thin film coatings (4–10 mils) [100–250 µ]; and
- high build coatings, self leveling coatings, and polymer overlays (10 mils–1/4 inch) [250 µ–6mm].1

ACI defines a sealer as a liquid applied to the surface of hardened concrete to either prevent or decrease the penetration of liquid or gaseous media. A sealer is absorbed by the concrete, is colorless, and leaves little or nothing visible on the surface.7 Sealers require surface preparation mainly to promote penetration into the concrete; any visible defects or profile will be unaffected. Depending on the chemical makeup of the sealer, different amounts of breathability (moisture vapor emission), darkening, and protection are provided.

Generally, breathable sealers such as silanes and siloxanes will prevent the absorption of liquid water while allowing moisture vapor to escape without noticeably changing the appearance of the concrete. Some sealers, such as silicates and fluorosilicates, change the pH of the concrete and are reported to also densify and improve abrasion resistance of the concrete surface. Stains and dyes for concrete may also fall into the sealer category, depending on their drying film formation, unless the only purpose of the stain is to change the color of the concrete. Surface polishing has also recently gained popularity as an enhancement for concrete surfaces. Frequently, the polished concrete is stained and then sealed.

Thin-film coatings may be formulated to mask very minor defects and surface disolorations. Suitable surface preparation techniques for thin-film coatings depend on several factors. Patterns from surface preparation and any but the smallest defects will likely become visible through the coating. If the amplitude of the surface profile is greater than the dry film thickness, a smooth coating surface is not possible. Some thin-film coatings on smooth horizontal surfaces can become very slippery when wet and generally require periodic recoating if subjected to wear from traffic. Thin-film coatings that are impermeable or otherwise sensitive to moisture tend to be problematic unless the concrete substrate is very dry.

Thicker coatings, such as self leveling...
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Characterizing Surface Preparation

One way of describing surface preparation is by comparing the substrate’s surface roughness with various other surfaces, such as the ICRI CSP specimens or sandpaper, or by using semi-quantifiable methods such as ASTM E 965 (commonly called the “sand patch test”). More sophisticated methods are being developed, including ASTM E 2157 and laser profilometry, which are compared with ASTM E965 in the VTRC reference. Other techniques occasionally referenced are ASTM standard WK16987 (in development), which takes measurements from a cast replica of the roughened concrete surface (ASTM D 4417 Method C/NACE RP0287-95).

The most common guidance for the materials, polymer overlays, toppings, and high-build coatings, have much in common with thin-film coatings regarding the relationship between surface profile and dry film thickness, moisture sensitivity, and wear; however, thicker coating layers can fill larger defects, create surface texture to yield slip-resistant surfaces; and provide longer service life than thin-film coatings.

### Table 2: Surface Preparation Methods for Concrete (Ref. 1)

<table>
<thead>
<tr>
<th>Method</th>
<th>Equipment</th>
<th>Mechanism</th>
<th>Surface Texture Achieved</th>
<th>CSP Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detergent Scrubbing</td>
<td>Mop and Pail, Floor Scrubber</td>
<td>Emulsification</td>
<td>No change</td>
<td>0-1</td>
</tr>
<tr>
<td>Low Pressure Water Rinse</td>
<td>Pressure Washer</td>
<td>Emulsification (if soap in water), Erosion (of loose particles)</td>
<td>Removal of loose debris</td>
<td>0-1</td>
</tr>
<tr>
<td>Acid Etching</td>
<td>Acid, Mixing Container, Neutralizing Agent</td>
<td>Reaction</td>
<td>Light profile, removal of concrete paste, discoloration</td>
<td>1-3</td>
</tr>
<tr>
<td>Dry Grinding</td>
<td>Dry Grinder</td>
<td>Erosion</td>
<td>Smooth surface, dust, debris to remove, pattern</td>
<td>1-3</td>
</tr>
<tr>
<td>Wet Grinding</td>
<td>Wet Grinder</td>
<td>Erosion</td>
<td>Wet, smooth surface, slurry, debris to remove, pattern</td>
<td>1-3</td>
</tr>
<tr>
<td>Dry Abrasive Blasting</td>
<td>Dry Sand Blast</td>
<td>Pulverization, Erosion, Expansive Pressure</td>
<td>Dusty substrate, light profile (depending on media, size, pressure, time) debris to remove</td>
<td>2-4</td>
</tr>
<tr>
<td>Recuperative Abrasive Blasting</td>
<td>Vacuum Recovery Sand Blasting</td>
<td>Pulverization, Erosion, Expansive Pressure</td>
<td>Light profile (depending on media, size, pressure, time)</td>
<td>2-4</td>
</tr>
<tr>
<td>Wet Abrasive Blasting</td>
<td>Wet Sand Blast</td>
<td>Pulverization, Erosion, Expansive Pressure</td>
<td>Wet substrate, light profile (depending on media, size, pressure, time) debris and slurry to remove</td>
<td>2-4</td>
</tr>
<tr>
<td>Shot Blasting</td>
<td>Shot Blast Unit</td>
<td>Pulverization, Impact Erosion</td>
<td>Dust free substrate, some pattern, depth dependent on shot size, sustrate hardness, equipment</td>
<td>2-8</td>
</tr>
<tr>
<td>Scarifying</td>
<td>Scarifier</td>
<td>Impact</td>
<td>Dusty substrate with striated pattern, bruising likely, debris to remove</td>
<td>4-9</td>
</tr>
<tr>
<td>Needle Scaling</td>
<td>Needle Scaler</td>
<td>Impact</td>
<td>Similar to shot blasting, striated pattern, debris to remove</td>
<td>5-8</td>
</tr>
<tr>
<td>Scabbling</td>
<td>Scabbler</td>
<td>Impact</td>
<td>Dusty substrate, irregular pattern, fractured aggregate, bruising likely, debris to remove</td>
<td>7-9</td>
</tr>
<tr>
<td>Hydrodemolition, Hydroblasting, Water Jetting</td>
<td>High- and Ultra-High-Pressure Water Blast</td>
<td>Erosion, Expansive Pressure</td>
<td>Saturated substrate, debris to remove, profile dependent on substrate hardness, equipment, pressure, time</td>
<td>6-9</td>
</tr>
<tr>
<td>Flame Blasting</td>
<td>Special Oxy-acetylene Torch, Saturated Substrate Helpful</td>
<td>Expansive Pressure, Reaction</td>
<td>Irregular chipped surface, hot, charred debris to remove, bruising possible</td>
<td>8-9</td>
</tr>
<tr>
<td>Rotomilling</td>
<td>Rotomiller</td>
<td>Impact</td>
<td>Dusty substrate (unless water used to suppress dust), grooving, tool marks, fractured aggregate, bruising likely</td>
<td>9</td>
</tr>
<tr>
<td>Liquid Surface Etchant</td>
<td>Specialty Chemical, Fresh Concrete</td>
<td>Reaction</td>
<td>Exposed aggregate, green wet concrete with debris to remove using pressure wash, curing still required, no bruising, depth dependent on retarder chemistry, curing rate, length of exposure</td>
<td>3-9</td>
</tr>
</tbody>
</table>
required profile for each coating thickness is also found in ICRI No. 310.2 (formerly 03732), which assigns a concrete surface profile (CSP) number based on the coating to be applied; the document further defines profile with physical replica specimens prepared with different surface preparation techniques.\(^1\) The higher the CSP number, the more aggressive the profile.

Another method of describing surface preparation techniques is by the mechanism of concrete removal or treatment. Mechanisms include cleaning, erosion, impact, pulverization, chemical reaction, and expansive pressure. Table 2, which is based on information in ICRI No. 310.2 (formerly 03732), compares different surface preparation techniques, which are also briefly described below.\(^1\)

Cleaning with low-pressure water (pressure washing <5000 psi) and scrubbing with detergent do not remove sound concrete or change the concrete surface profile. Removal of surface contaminants from scrubbing, use of surfactants, and water velocity followed by vacuum removal of the cleaning solution produces a wet substrate and removes minor amounts of dirt, oil, grease, dust, friable, materials, debris, or other water-soluble contaminants. ASTM D 4258, ASTM D 4259, and a guidance document from the Water Jet Technology Association are useful resources.\(^14,15,16\)

Erosion methods (i.e., grinding) uniformly wear away the concrete surface with abrasive force from grinding media such as abrasive discs. This method leaves a dry dusty surface with very little profile. See ASTM D4259 for guidance on good practice of this technique.\(^15\)

Chemical reaction methods include acid etching and the use of surface retarders for fresh concrete. Acid etching dissolves the cement paste (and limestone aggregate, if present), producing a very light profile on the concrete surface that has a relatively low pH unless neutralized. Acid etching does not work well on vertical surfaces or on concrete that has had a curing compound or sealer applied. ASTM D 4260 provides guidance for acid etching and D4262 for surface neutralization following acid etching.\(^17,18\)

Surface retarders are used only for freshly placed concrete. The cement hydration adjacent to the layer of surface retarder is delayed, while the remaining concrete continues to harden normally. After sufficient strength has developed in the underlying concrete, the layer affected by the retarder is removed by pressure washing and scrubbing, leaving an exposed aggregate wet surface suitable for placement of cementitious overlays and toppings. Guidance on surface retarders is usually supplied by the material producer.
Some methods of surface preparation can cause “bruising” (Fig. 1, p. 42). Bruising occurs when a surface layer is weakened by interconnected microcracks in concrete substrates; the microcracks are caused by use of impact, pulverization, and other mechanical methods for surface preparation. Be careful of bruising when using bush hammers, scarifiers, and rotomilling machines for surface preparation. Scarifiers and rotomilling (also known as surface planers or milling machines) use the chipping action of multi-tipped cutting wheels that rotate at high speeds to chip away at the concrete surface. Bush hammers and scarblers use serrated hammers with rows of pyramidal points and remove concrete by pounding the surface with piston-driven cutting heads placed at a right angle to the surface. The bruised layer typically extends to a depth of 1⁄8 to 3⁄8 in. (3 to 10 mm) and frequently results in lower bond strengths as compared to surfaces prepared with nonimpact methods.

Abrasive blasting, shotblasting, and hydrodemolition are methods not only for surface preparation, but can also be used to remediate bruised concrete. Shot blasting, used to strip, clean and profile surfaces, produces a roughened texture that is dry and relatively dust free. Depending on the size of the steel shot, its speed, and machine design, the method can selectively remove softer and more brittle portions of the substrate. Hydrodemolition uses very-high-pressure water jets to prepare the surface, producing a saturated deeply profiled substrate. ICRI No. 310.3 (formerly 03737) discusses hydrodemolition in great detail.19 The hardness of the concrete, speed of hydrodemolition jet travel, impingement angle, and pressure of the water jet control the amount of removal.

Primers are sometimes used as a form of surface conditioning following surface preparation. Primers are used to improve the bond between the prepared surface and the subsequent coating material or to improve the surface for coating.
Conclusions

Unless the concrete surface is properly prepared, even the best sealer, coating, topping, overlay, or membrane will not perform satisfactorily. Trial applications that follow the manufacturer’s instructions and good trade practices referenced in this article are the best means of achieving good system performance; they also provide acceptance criteria for proceeding with an installation. On any trial areas, bond testing, substrate cleanliness, substrate surface hardness, porosity, and moisture condition evaluation should be performed to assure integrity of the substrate preparation effectiveness, coating adhesion, and finished appearance.

Notes

1. ICRI No. 03732, Guideline for Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays (1997), International Concrete Repair Institute, Des Plaines, IL.
2. SSPC SP 13/NACE No. 6, Surface Preparation of Concrete (2003), SSPC: The Society for Protective Coatings, Pittsburgh, PA.
5. ICRI No. 03739, Guideline to Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials (2004), International Concrete Repair Institute, Des Plaines, IL.
6. ASTM C1583/C1583M-04e1, Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and
An Overview of Preparing Concrete for Coatings:


19. ICRI G03737, Guideline for the Preparation of Concrete Surfaces for Repair Using Hydrodemolition Methods (2004), International Concrete Repair Institute, Des Plaines, IL.

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