



TECHNICAL GUIDELINES

Prepared by the International Concrete Repair Institute

October 2013



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**Selecting and Specifying Concrete
Surface Preparation for Sealers,
Coatings, Polymer Overlays, and
Concrete Repair**



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About ICRI Guidelines

The International Concrete Repair Institute (ICRI) was founded to improve the durability of concrete repair and enhance its value for structure owners. The identification, development, and promotion of the most promising methods and materials are primary vehicles for accelerating advances in repair technology. Working through a variety of forums, ICRI members have the opportunity to address these issues and to directly contribute to improving the practice of concrete repair.

A principal component of this effort is to make carefully selected information on important repair subjects readily accessible to decision makers. During the past several decades, much has been reported in the literature on concrete repair methods and materials as they have been developed and refined. Nevertheless, it has been difficult to find critically reviewed information on the state of the art condensed into easy-to-use formats.

To that end, ICRI guidelines are prepared by sanctioned task groups and approved by the ICRI Technical Activities Committee. Each guideline is designed to address a specific area of practice recognized as essential to the achievement of durable repairs. All ICRI guideline documents are subject to continual review by the membership and may be revised as approved by the Technical Activities Committee.

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Synopsis

Proper surface preparation is a key element in determining the success of a concrete restoration project. Improper surface preparation may lead to the failure of the protective system or repair material, resulting in further repairs, added expense, and loss of use, and may ultimately compromise the integrity of the structure.

Surface preparation is the process by which a sound, clean, and suitably roughened surface is produced on a concrete substrate. Surface preparation includes the removal of laitance, dirt, oil, films, paint, coatings, sound and unsound concrete, and other materials that will interfere with the adhesion or penetration of a sealer, coating, polymer overlay, or repair material. Surface preparation will open the pore structure of the concrete substrate and establish profiles suitable for the application of the specified protective system or repair material.

Keywords

Abrasive blasting; acid etching; detergent scrubbing; grinding; handheld concrete breakers; high- and ultra-high-pressure water jetting; low-pressure water cleaning; microcracking; needle scaling; rotomilling; scabbling; scarifying; shotblasting; surface preparation; surface profile; surface retarders.

This document is intended as a voluntary guideline for the owner, design professional, and concrete repair contractor. It is not intended to relieve the professional engineer or designer of any responsibility for the specification of concrete repair methods, materials, or practices. While we believe the information contained herein represents the proper means to achieve quality results, the International Concrete Repair Institute must disclaim any liability or responsibility to those who may choose to rely on all or any part of this guideline.

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1.0 Introduction

1.1 Surface Preparation

This guide provides owners, designers, specifiers, contractors, and manufacturers with the tools needed to select and specify the methods for preparing concrete surfaces prior to the application of a protective system or repair material. Surface preparation is the process by which a sound, clean, and suitably roughened surface is produced on a concrete substrate. Surface preparation includes the removal of laitance, dirt, oil, films, paint, coatings, sound and unsound concrete, and other materials that will interfere with the adhesion or penetration of a sealer, coating, polymer overlay, or repair material. Proper surface preparation will open the pore structure of the concrete substrate and establish profiles suitable for the application of the specified protective system or repair material.

Proper surface preparation is a key element in determining the success of a concrete restoration project. Improper surface preparation may lead to the failure of the protective system or repair material, resulting in further repairs, added expense, and loss of use, and may ultimately compromise the integrity of the structure. The existing conditions of the concrete and the type of protective system or repair material to be applied should be considered in determining the surface preparation method(s). The designer, specifier, contractor, and manufacturer should all participate in the selection of the surface preparation method(s). Detailed attention to proper surface preparation will help ensure the long-term success of the restoration project.

1.2 Guideline Tools

The following tools are contained within the guideline to assist the user in the selection and/or specification of the proper surface preparation method(s):

- Method Selector (Section 7.0): Identifies methods capable of producing the concrete surface profile(s) (CSP[s]) typically recommended for the protective system or repair material.
- Method Summaries (Section 8.0): Discusses the capabilities, limitations, operating requirements, and environmental factors for each method.
- CSP Chips (Section 6.0): Provides replicas of surface preparation profiles produced by methods described in the guide and visual standards for specification, execution, and verification of surface profiles.

- Method Selection Checklists (Appendix A): Provides checklists to help ensure that critical information is identified, organized, and considered in the development of criteria for the selection of a surface preparation method(s).
- Testing (Appendix B): Discusses various test methods that may be used to specify and evaluate the quality of the surface preparation.
- Safety (Appendix C): Provides links to specific safety information.

2.0 Definitions

Definitions for terms used in this guideline may be found in ICRI Concrete Repair Terminology (<http://www.icri.org/GENERAL/repairterminology.aspx>).

3.0 Selecting Surface Preparation Method(s)

3.1 Project Evaluation

Concrete surface conditions, material requirements, and job-site conditions will vary considerably for each project. Most projects will have unique conditions and requirements that must be evaluated to determine which surface preparation method(s) is/are suitable for the project and which will ensure the long-term success of the protective system and/or repair material. More than one method may be capable of producing the desired results. Appendix A provides a more complete list of items to be considered and can be used as a checklist in evaluating a project. The checklist will help ensure that the various conditions affecting the surface preparation have been considered.

3.1.1 Substrate condition

The condition of the substrate, including the presence of unsound concrete, bond-inhibiting materials, substrate deterioration, cracking, and surface contaminants, need to be evaluated to determine the nature and degree of preparation required. The surface preparation method must provide a clean, sound substrate with a surface profile appropriate for the specific material installation.

3.1.2 Material requirements

Surface preparation requirements may vary with the material selected. The manufacturer of the system may have specific requirements for surface preparation, including the surface profile and moisture sensitivity, and should be consulted. Proper surface preparation could impact the

manufacturer's warranty. The properties and application requirements of the selected protective system or repair material must be determined prior to the selection of a surface preparation method.

3.1.3 Job-site requirements

Noise, vibration, dust, and water may be generated by various preparation methods. The need for uninterrupted use of the structure, concerns about the operating environment, or the potential for property damage may limit the choices. Mechanical ventilation, available power sources, the size of door openings, and minimum clearance may also affect surface preparation decisions. The surface preparation may also release hazardous contaminants (for example, asbestos from old flooring mastic). Any condition that may affect the method of surface preparation should be considered.

3.2 Evaluate Surface Preparation Method(s)

Selecting the method(s) that will provide a clean, sound substrate and optimize the success of the material installation requires knowledge of the available options. The surface profile achieved following the surface preparation is often the primary requirement in specifying the preparation method(s). The method selector chart may be used to make a preliminary identification of the methods capable of producing the required CSP.

Each of the methods capable of meeting the CSP requirement can be compared in the method summaries section, which provides data on the capabilities, limitations, operating requirements, and environmental considerations for each surface preparation method.

3.3 Select and Specify Surface Preparation Method(s)

The final selection is based on the relationship between substrate conditions, material requirements, and job-site conditions. The specification may include a CSP range as well as other criteria, such as bond strength. These requirements should be clearly defined in the specification, along with the test method(s) that will be used to evaluate the completed surface preparation. The test procedures described in Appendix B may be used in preparing the specifications to ensure that the desired results are achieved.

3.4 Quality Control

The CSP chips (CSP 1-10) provide benchmark profiles to aid in achieving the desired result. The

prepared surface should be compared to the CSP chips specified for the project. Tests, such as the tensile bond test, may be performed to verify that all deteriorated or damaged concrete has been removed. Other specified tests should be performed prior to installing the protective system or repair material. The cost of providing additional surface preparation will be significantly less than the cost of correcting a failure of the installed system or repair. Appendix B describes various tests that may be used to evaluate the prepared concrete surface. SSPC-SP 13/NACE No. 6, ASTM D5295, ASTM E1857, and ASTM F2471 provide additional considerations for surface preparation and quality control.

4.0 Mechanics of Concrete Removal

4.1 Introduction

In addition to project-specific requirements, the selection of a surface preparation method should ensure that:

- The surface is not damaged;
- The reinforcing steel is not damaged, nor its bond with the concrete compromised; and
- Vibration, impact, or construction loads do not weaken the concrete.

This section describes the mechanics used by the various surface preparation methods to remove deteriorated concrete and contaminants from the surface. This information will help users determine the potential of each preparation method to achieve the desired results and also assess the potential for damage to the substrate that may be caused by the individual methods.

4.2 Cleaning

Cleaning does not noticeably alter the profile of concrete surfaces. Cleaning and detergent scrubbing are accomplished through one or a combination of the following: the surfactant effect of detergents, the solvent effect of water, the shearing force of brushes, and the force of low-velocity water. Applicable methods: low-pressure water cleaning and detergent scrubbing.

4.3 Acid Etching and Surface Retarder

Acid etching chemically dissolves calcium hydroxide and calcium silicate, which make up the hydrated solids in cement paste. The dissolution of these materials at the surface causes a

slight loss of cement paste and produces a very light profile on the exposed surface. Surface retarders slow the hydration of cement, allowing low-pressure water cleaning to remove the retarded layer, creating an exposed aggregate surface. Applicable methods: acid etching and surface retarders.

4.4 Abrasion

Abrasive force applied through grinding with stones, abrasive discs, or blocks with embedded diamonds wears away the cement paste, fines, and coarse aggregate at a uniform rate to produce a nearly flat surface having little or no profile (Fig. 4.1). Applicable methods: grinding.

cutting the coarse aggregate to produce a surface that will become highly profiled as exposure time is increased. Applicable methods: steel shot-blasting and abrasive blasting.

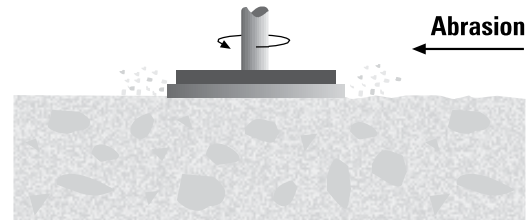


Fig. 4.1: Grinding

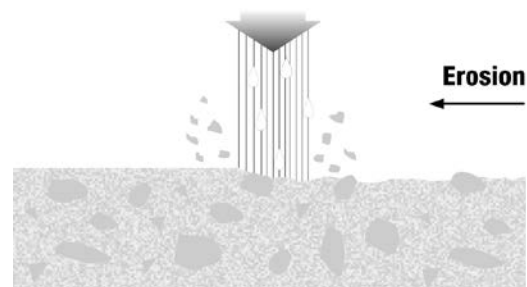


Fig. 4.2: High- and ultra-high-pressure water jetting

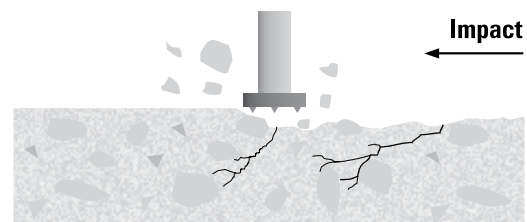


Fig. 4.3: Scarifying, scabbling, rotomilling, needle scaling

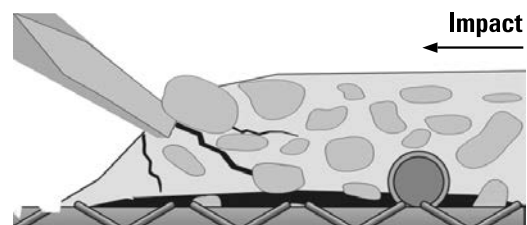


Fig. 4.4: Handheld concrete breaker

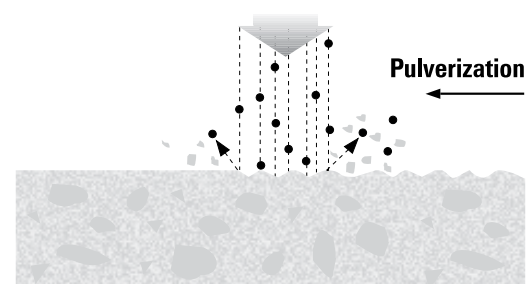


Fig. 4.5: Abrasive blasting, shotblasting

4.5 High-Pressure Water Erosion

Erosion causes the flushing away or progressive disintegration of concrete surfaces. A stream of water projected onto the surface under high pressure will result in the gradual erosion of the surface. The impact of the water and the water velocity combine to wear away the cement paste. As exposure to water jetting increases, so will the profile as the softer paste and embedded fines erode, leaving behind “islands” of the harder coarse aggregate. Under prolonged exposure to water jetting, the coarse aggregate will be undercut and washed away (Fig. 4.2). Applicable methods: high- and ultra-high-pressure water jetting.

4.6 Impact

Several preparation methods strike the surface repeatedly with hardened points to produce momentary mechanical loads that exceed the strength of the concrete, causing it to fracture. The force of the impact pulverizes and fractures the cement paste and aggregate at and adjacent to the point of contact (Fig. 4.3 and 4.4). Some of the cracks and loosened aggregate may remain, leaving a “bruised” layer at the surface. Applicable methods: scarifying, scabbling, rotomilling, needle scaling, and handheld concrete breakers.

4.7 Pulverization

The cutting effect is derived from the collision of small particles traveling at a high velocity against the concrete surface (Fig. 4.5). Because the mass of the particles is comparatively small, their impact is not known to produce bruising. Hard, sharp-edged media and high pressure can produce fast cutting rates. As with water jetting, the cement paste is usually reduced at a faster rate than the coarse aggregate. This difference in removal rate has the effect of exposing and under-

5.0 Microcracking (Bruising)

5.1 Effect on Bond Strength

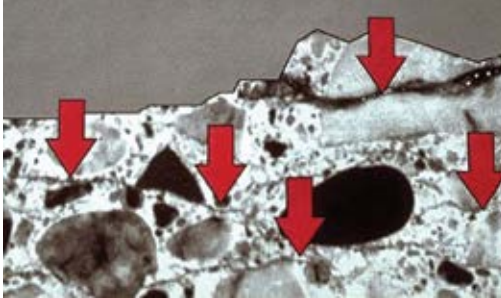


Fig. 5.1.a: Microcracking of the concrete

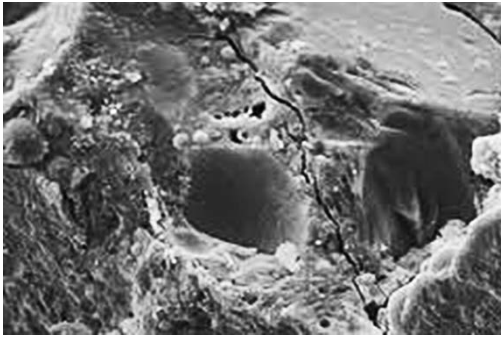


Fig. 5.1.b: Microcracking

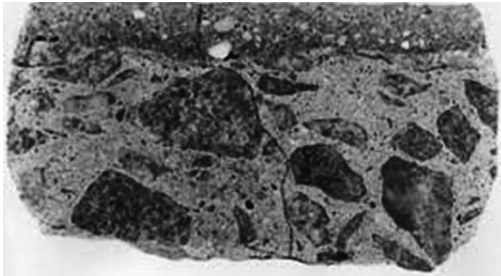


Fig. 5.1.c: Microcracking under LMC overlay

Several of the preparation methods described may locally damage the prepared substrate. Field studies have shown that bond strengths of surfaces prepared using high-impact mechanical methods are frequently lower compared to surfaces prepared using nonimpact methods. This reduction in bond strength is caused by the fracturing of the cement paste and loosening of the aggregate without fully separating from the surface. This creates a weakened or “bruised” surface layer of interconnecting microcracks typically extending to a depth of 1/8 to 3/8 in. (3 to 10 mm). Microscopic examination usually indicates that cracks initiate at the surface at approximately a 45-degree angle and propagate horizontally to produce a

weakened plane (Fig. 5.1a to 5.1c). It is generally accepted that the extent of the damage increases with the weight and power of the equipment used. However, the use of sharp, fine-toothed cutters contacting the surface at a shallow angle may reduce or prevent the development of bruising. The relative risk of introducing bruising or microcracking into the substrate is indicated for each method in Section 5.2. Surfaces prepared using impact methods should be tested using a tensile pulloff test to confirm that the prepared surface does not contain microcracks that may compromise the installation of a repair material or protective system (refer to Appendix B).

5.2 Risk of Introducing Microcracking

Figure 5.2 identifies the potential risk of introducing microcracking when performing surface preparation using the method listed.

Surface preparation using methods resulting in a high probability of microcracking, including handheld concrete breakers, rotomilling, and scabbling, generally require further surface preparation to remove the microcracks. Surface preparation using methods resulting in a moderate probability of microcracks, including needle scaling and scarifiers, may require further surface preparation, and the surface should be evaluated to determine if the preparation created microcracks. All surfaces should be tested, regardless of preparation method, to ensure adequate concrete strength and a properly prepared surface (refer to Appendix B).

Risk of Introducing Microcracking		
● Very low	● Moderate	● High
Abrasive blasting ●		
Acid etching ●		
Handheld concrete breakers ●		
Detergent scrubbing ●		
Grinding ●		
High- and ultra-high-pressure water jetting ●		
Low-pressure water cleaning ●		
Rotomilling ●		
Needle scaling ●		
Scabbling ●		
Scarifying ●		
Shotblasting ●		
Surface retarders ●		

Fig. 5.2: Potential risk of microcracking during surface preparation

6.0 Concrete Surface Profiles (CSPs)

Several of the methods summarized are capable of producing a range of profiles on concrete surfaces. Communication of project objectives and requirements may be improved by using CSPs to define the desired surface profile (amplitude or roughness).

ICRI has identified 10 distinct profiles produced by the surface preparation methods described in this guideline. As a set, these profiles replicate degrees of roughness considered to be suitable for the application of one or more of the sealer, coating, polymer overlay systems, and/or concrete repair materials. Each profile carries a CSP number ranging from CSP 1 (nearly flat) through CSP 10 (very rough; amplitude greater than 1/4 in. [6 mm]). The profile characteristics for each preparation method are identified by CSP number in the “Profile” section of the method summaries. Molded replicas* of these

profiles provide clear visual standards for purposes of specification, execution, and verification. These benchmark profiles may be referenced in specifications, material data sheets, application guidelines, and contract documents to effectively communicate the required surface profile. It is probable that more than one profile will produce acceptable results, and a range of suitable profiles should be specified.

The concrete surfaces shown in Fig. 6.1 to 6.10 were produced using a variety of preparation methods. Although each numbered CSP replica bears the characteristic pattern and texture of the specific preparation method used, each replica is representative of the profile height (amplitude) obtained with all methods identified with the same CSP number.

**Molded replicas are available with this guideline by contacting ICRI at the number listed on the back cover of this document or on ICRI’s website at <http://www.icri.org/bookstore/bkstr.asp>.*

Caution! The texture and appearance of the profile obtained will vary depending on the concrete strength, the size and type of aggregate, and the finish of the concrete surface. On sound substrates, the range of variation can be sufficiently controlled to resemble the referenced CSP standard. As the depth of removal increases, the profile of the prepared substrate will be increasingly dominated by the type and size of the coarse aggregate.



Fig. 6.1: CSP 1
(acid-etched)

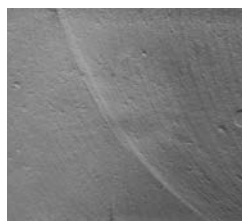


Fig. 6.2: CSP 2
(grinding)



Fig. 6.3: CSP 3
(light shotblast)



Fig. 6.4: CSP 4
(light scarification)



Fig. 6.5: CSP 5
(medium shotblast)

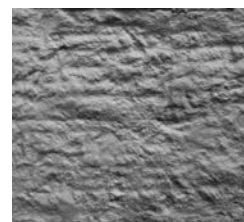


Fig. 6.6: CSP 6
(medium scarification)



Fig. 6.7: CSP 7
(heavy abrasive blast)



Fig. 6.8: CSP 8
(scabbled)



Fig. 6.9: CSP 9
(heavy scarification—
rotomilled)



Fig. 6.10: CSP 10
(handheld concrete
breaker followed by
abrasive blasting)

Figures 6.11 and 6.12 provide a guide to the general appearance of a CSP 10. After preparation is complete, the aggregate should appear clean and crisp and protrude above the paste line a minimum of 1/4 in. (6 mm).



Fig. 6.11: CSP 10—Surface prepared using handheld concrete breaker followed by abrasive blasting



Fig. 6.12: CSP 10—Surface prepared using high-pressure water jetting

7.0 Method Selector

7.1 CSP and Protective Systems

The type of protective system or repair material to be applied will impact the type of surface preparation selected. Penetrating sealers will have little or no effect on the appearance of the prepared surface. Any surface defects, contaminants, or profile resulting from the surface preparation will be visible. Thin films may be formulated to achieve high hiding power; however, even relatively minor surface imperfections and profiles produced by surface preparation equipment will be visible. High-build materials will have both high hiding power and some ability to fill irregularities and level the prepared surfaces. A smooth finish over higher profiles may be achieved by increasing the thickness of the applied coating system. Manufacturers of these materials often have minimum thickness requirements, which can be affected by the surface profile. A surface profile greater than specified by the manufacturer may result in an increase in the cost of the system. Overlays and repair materials are generally installed such that the depth of the material covers the amplitude of the surface profile.

Possible surface profiles to be used with various protective systems are given in Table 7.1. Consult the manufacturer to determine the recommended surface profile.

7.2 CSP and Preparation Methods

An approximate range of surface profiles obtained using various preparation methods is shown in Table 7.2.

Table 7.1: Protective Systems

Material to be applied	Concrete Surface Profile									
	CSP 1	CSP 2	CSP 3	CSP 4	CSP 5	CSP 6	CSP 7	CSP 8	CSP 9	CSP 10
Sealers, 0 to 3 mils (0 to 0.075 mm)										
Thin films, 4 to 10 mils (0.01 to 0.025 mm)										
High-build coatings, 10 to 40 mils (0.025 to 1.0 mm)										
Self-leveling toppings, 50 mils to 1/8 in. (1.2 to 3 mm)										
Polymer overlays, 1/8 to 1/4 in. (3 to 6 mm)										
Concrete overlays and repair materials, >1/4 in. (>6 mm)										

Table 7.2: Preparation Methods

Surface preparation method	Concrete Surface Profile									
	CSP 1	CSP 2	CSP 3	CSP 4	CSP 5	CSP 6	CSP 7	CSP 8	CSP 9	CSP 10
Detergent scrubbing										
Low-pressure water cleaning										
Grinding										
Acid etching										
Needle scaling										
Abrasive blasting										
Shotblasting										
High- and ultra-high-pressure water jetting										
Scarifying										
Surface retarder (1)										
Rotomilling										
Scabbling										
Handheld concrete breaker										

(1) Only suitable for freshly placed cementitious materials

8.0 Method Summaries

8.1 Abrasive Blasting



Fig. 8.1.a: Column



Fig. 8.1.b: Floor

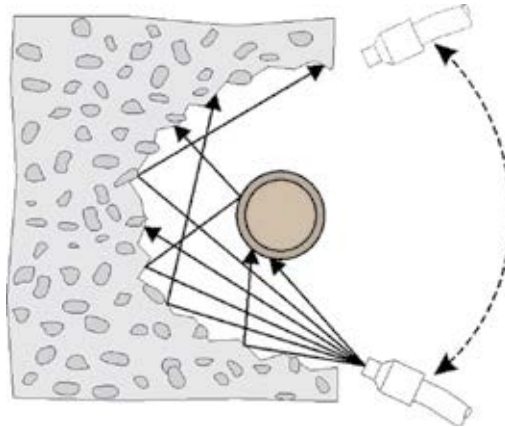


Fig. 8.1.c: Reinforcement cleaning



Fig. 8.1.d: Protective equipment

8.1.1 Summary

Abrasive blasting is used to clean and profile concrete surfaces (Fig. 8.1.a). The process can provide a light, clean profile, often referred to as a “brush blast,” or it can be used to achieve a moderate profile. It may also be used to remove surface contaminants and thin, brittle coatings or adhesive films (Fig. 8.1.b) from surfaces and corrosion products from reinforcing steel (Fig. 8.1.c). This method may be used on horizontal, vertical, and overhead surfaces and is suitable for both interior and exterior applications. Both vacuum recovery and wet abrasive blasting equipment are sometimes used to reduce environmental contamination from the abrasive blasting technique. Abrasive blasting is often used to mitigate microcracking caused by other surface preparation methods.

8.1.2 Removal

This method uses a compressed air stream with an abrasive media to clean concrete and steel surfaces. Removal is accomplished by the eroding effect of the blast media impacting the surface at high velocity.

8.1.3 Profile

CSP 2-7—Abrasive blasting should not introduce any noticeable pattern. The profile achieved is dependent on the duration of exposure to the blast stream and the size and cutting efficiency of blast media.

8.1.4 Accessibility

The small size and portability of the hose and blast nozzle provide virtually unrestricted access to all surfaces, including edges, corners, and recessed spaces.

8.1.5 Limitations

Abrasive blast is not recommended for the following:

- Removal of resilient coatings, uncured coatings or adhesives, and tar-based materials;
- When occupied space, goods, or equipment cannot be adequately protected from dust infiltration; and
- Removal of significant quantities of concrete.

8.1.6 Environmental factors

Dry abrasive blasting will produce airborne dust containing silica and particles of any material being removed.

Any special requirements for containment and disposal will depend on the specific contaminants or materials being removed. Blast media substitutes such as sodium bicarbonate are sometimes used to reduce the dust hazard or volume of debris. Water may be injected into the blast stream to reduce dust. Vacuum recovery systems may also be used with abrasive blast units to reduce dust and cleanup. Noise levels are likely to exceed 85 dB.

8.1.7 Execution

The blast media stream is directed at the surface using a controlled sweeping motion. The required duration of exposure to the blast stream will depend on the strength of the substrate, air pressure, air volume, blast media type, and degree of cleaning or profiling required. Special provisions are often needed to protect people, property, and the environment from dust and airborne debris. Blast curtains and containment areas may be used to isolate the blast process.

8.1.8 Equipment

- Blast nozzle and hose;
- Air compressor of sufficient capacity;
- Blast media hopper (meters the media into the air stream passing through the hose and nozzle);
- Moisture and oil separators to ensure clean, dry air supply; and
- Protective equipment, including an air-supplied hood (Fig. 8.1.d).

8.1.9 Materials

The most common abrasive blast materials are silica sand and slag. There are a wide variety of blast materials available to meet different needs. These materials are consumed in the blast operation and are generally not recycled.

8.1.10 Employee skill level

Medium skill level is required. Special training in safe operation and environmental hazards is required for crew members. A two-person crew per blast unit is required. One crew member will operate the blast nozzle while the other supports the operation by monitoring the blast operation and maintaining the blast media hopper, compressor, and hoses.

8.1.11 Setup and downtime

Time required for mobilization, setup, and maintenance of blast equipment and compressor will take several hours. Significant time may be needed to set up dust protection around the work area.

8.1.12 Cleanup

Dust, fine particles of concrete or other pulverized materials, and blast media are generated by the dry abrasive blast process. The area will require sweeping and/or vacuuming to collect the debris. Dust will accumulate on all unprotected surfaces and will require cleaning. Recuperative or wet abrasive blasting may substantially reduce the volume of dust generated.

8.1.13 Production rates

Productivity is highly variable and is dependent on the strength of the concrete, surface contaminants, accessibility, capacity of blast media hopper, compressor capacity, and type of blast media used. Production rate estimates range from 1000 to 6000 ft² (100 to 600 m²) per 8-hour shift per unit.

8.1.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4259 provides additional considerations for surface preparation and quality control using this method.

8.1.15 Safety hazard

Abrasive blasting will cause the release of dust containing silica. Minimum recommended personal protective equipment (PPE) is as follows:

- Eye protection—Hood incorporating eye and face protection;
- Respiratory protection—Air-supplied hood;
- Hearing protection—Earplugs and/or earmuffs;
- Protective clothing;
- Automatic shutoff for the blast nozzle; and
- Leather or specialty gloves while operating handheld equipment.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Technical Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.2 Acid Etching



Fig. 8.2.a: Etched and clean surface



Fig. 8.2.c: Spreading acid



Fig. 8.2.b: Acid applied to concrete



Fig. 8.2.d: Rinsing to remove acid

8.2.1 Summary

Acid etching is designed to remove cement paste from the surface and surface pores of concrete (Fig. 8.2.a).

8.2.2 Removal

The acid in the etching solution attacks the calcium hydroxide ($\text{Ca}(\text{OH})_2$) and calcium silicate hydrate (CSH) in the cement paste, causing rapid deterioration at the surface. The concentration and volume of solution applied are controlled to limit the depth of chemical attack. The typical depth of removal is 0.004 to 0.010 in. (0.1 to 0.25 mm). Etching will remove the cement paste and slightly profile the surface by exposing fine silica aggregate.

8.2.3 Profile

CSP 1-3—Etching should not introduce any noticeable pattern effect on sound concrete surfaces. The surface should feel like fine sandpaper with no residue or grit. The surface should have a dull, even appearance. If the surface is still smooth or glossy, repeat procedure.

8.2.4 Accessibility

The equipment used for this method is portable and maneuverable. Access may be restricted by the presence of nonportable machinery or equipment subject to damage from corrosive mist or splash.

8.2.5 Limitations

- Caution must be exercised to avoid excessive absorption of acid by the concrete. Absorption may result in the introduction of contaminants such as chlorides (in the case of muriatic/hydrochloric acid);
- The surface may require neutralization following acid etching. All traces of the acid must be removed. Incomplete removal or neutralization of the acid may leave bond-inhibiting contaminants on the surface;
- Solution is highly corrosive. Electronic equipment, machines, and other metal components should be protected or removed;
- Thorough removal of etching debris requires large quantities of rinse water, mechanical scrubbing, and vacuum removal;
- Hydrochloric acid may not be used on metallic hardened surfaces;
- A significant amount of oils, grease, and other surface deposits must be removed prior to etching;
- Not recommended for use on green concretes;
- The etching process will saturate the substrate. When used in preparation for moisture-sensitive materials, time restrictions may not allow for sufficient drying; and
- Environmental considerations may require full containment and recovery of spent acid and rinse water.

8.2.6 Environmental factors

Applied as an acid wash, the mixture may corrode metals on contact. Debris produced by acid etching will contain particles of the material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific materials or contaminant being removed. Spent acid and rinse water must be disposed of as required by local regulations or project restrictions. The acid solution may release toxic vapors.

8.2.7 Execution

1. Dilute acid mixture according to floor type, strength of concentrate, and manufacturer's recommendations. Dense or chemically hardened floors may require higher concentrations and/or multiple passes;
2. Thoroughly wet concrete surfaces to minimize absorption of the acid solution into the concrete surface. Standing water must be removed prior to application of acid;
3. Apply mixed solution uniformly (Fig. 8.2.b);
4. Agitate acid solution with stiff bristle broom or power brush for 5 to 10 minutes (Fig. 8.2.c). Do not allow surface to dry;
5. Vacuum residue;
6. Thoroughly scrub with an alkaline detergent and then vacuum the residue. Repeat as necessary to completely remove etching debris;
7. Rinse with clean water (Fig. 8.2.d), scrub, and vacuum dry; and
8. Verify that all acid etching material has been removed by checking the pH of the rinse water (refer to Appendix B.4).

8.2.8 Equipment

- Container to mix etching solution;
- Applicator: Low-pressure sprayer, plastic sprinkling can, or mop;
- Floor scrubber or disc machine equipped with an abrasive bristle brush;
- Power washer or hose to apply rinse water; and
- Vacuum system or scrubber for recovery.

The use of automatic scrubbing equipment to apply acid etching solution is not generally recommended. However, this equipment is often used to recover etching solution after it has been diluted with rinse water. Consult the equipment manufacturer to determine suitability.

8.2.9 Materials

- Acid etch solution. Typical solutions include muriatic (hydrochloric), sulfamic, phosphoric, and citric acids. **Always add acid to water—never add water to acid;**
- Alkaline detergent for cleanup scrub;
- Water source; and
- Plastic sheeting to protect materials and equipment.

8.2.10 Labor

Medium to above-medium skill level is required to safely handle and mix hazardous materials and operate equipment.

8.2.11 Setup and downtime

Minimal time is required to mix etching solution. Filling and emptying scrubber and wet-vacuum tanks should take 10 to 20 minutes. Additional time may be required to protect material and equipment in the work area.

8.2.12 Production rates

The rates shown as follows are approximate. Actual rates will vary with the method used, density of surface, dilution ratio, and size of machines.

- Manual application with wet/dry vacuum recovery: 1600 ft²/h (150 m²/h); and
- Medium scrubber: 8000 ft²/h (740 m²/h).

8.2.13 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. Testing (such as pH testing) should verify that all acid materials have been removed by checking the pH of the rinse water before and after rinsing. ASTM D4260 provides additional considerations for surface preparation and quality control using this method.

8.2.14 Safety hazards

Acid etching involves the use of dangerous chemicals that will cause serious injury if exposed to any part of the body. Always add acid to water, as some acids may react violently if water is added to the acid. The acid may also produce dangerous vapors, which may damage the respiratory system. Operators must be trained in the proper use and handling of the acid materials. Minimum recommended PPE is as follows:

- Eye protection—Anti-fog goggles meeting ANSI requirements for high impact and face shield;
- Acid- and alkaline-resistant gloves, boots, aprons, and clothing;
- Respiratory protection using respirators equipped with acid-gases canister; and
- Hearing protection may be required if powered scrubbers are used.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.3 Handheld Concrete Breakers



Fig. 8.3.a: Jackhammer

8.3.1 Summary

Handheld concrete breakers are typically classified by their weight. Larger handheld concrete breakers (jackhammers) in the 30 lb (14 kg) class and larger (Fig. 8.3.a) are typically used on horizontal surfaces, while smaller breakers (chipping hammers) weighing 20 lb (9 kg) or less (Fig. 8.3.b) may be used on horizontal, vertical, and overhead surfaces to remove concrete to a predetermined depth (SHRP-S-336). A typical application for a chipping hammer is the removal of deteriorated and/or chloride-contaminated concrete from around reinforcing steel. Handheld concrete breakers may also be used as an initial step in preparation for overlays. This method is suitable for use in interior and exterior applications.

8.3.2 Removal

Removal is accomplished by the impact of the tool (point or chisel) on the surface. The tools may be pneumatic, electric, or hydraulic. The impact of the tool on the surface will fracture and split the concrete. This will also result in microcracks in the remaining substrate, which will affect the bond of the repair material (Fig. 8.3.c). Surfaces prepared using chipping hammers and handheld concrete breakers will require further preparation (sandblasting, waterblasting, or shotblasting) to remove microcracks in the substrate (Fig. 8.3.d and 8.3.e). The use of heavier handheld concrete breakers will result in deeper microcracking.

8.3.3 Profile

CSP 7-10—Handheld concrete breakers will produce a very irregular surface dominated by fractured coarse aggregate. They will cause microcracks in the substrate and the points and chisel will leave marks on the concrete surface.



Fig. 8.3.b: Chipping hammer with chisel and point tools

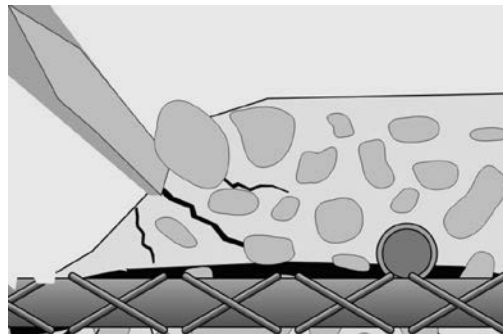


Fig. 8.3.c: Chisel tool



Fig. 8.3.d: Chipped surface using handheld concrete breaker before additional surface preparation



Fig. 8.3.e: Chipped surface followed by abrasive blasting to remove fractured substrate

8.3.4 Accessibility

Most surfaces are accessible to chipping hammers, while handheld concrete breakers are used on horizontal surfaces.

8.3.5 Limitations

- Handheld concrete breakers will induce microcracking, requiring further surface preparation;

- The use of handheld concrete breakers can damage reinforcing and other embedded items;
- The specification of smaller handheld concrete breakers (chipping hammers) in an attempt to minimize bruising will reduce production and often limits this method to low-volume removal;
- Significant loss in productivity when breaking action is other than downward;
- Localized impacts distributed over a surface inevitably result in significant variability in roughness characteristics compared to other methods. This limits the minimum thickness of repairs and overlays; and
- The use of handheld concrete breakers, followed by abrasive blasting, resulted in weaker bond strengths compared to other methods evaluated (Bissonnette et al. 2006).

8.3.6 Environmental factors

Handheld concrete breakers will produce airborne dust containing silica and particles of any other materials being removed. Special requirements for disposal of dust and debris will depend on the specific materials or contaminants being removed. Noise levels are likely to exceed 85 dB. Vibration levels are moderate to severe and will transmit through a structure. Vibration of the reinforcing steel may dislodge the reinforcing steel from the surrounding concrete, requiring additional removal to fully expose the reinforcing steel. Work area enclosures and special ventilation provisions may be required indoors to prevent dust intrusion into nearby occupied spaces.

8.3.7 Execution

Handheld concrete breakers are operated by placing the tool against the surface and activating the pneumatic, electric, or hydraulic drive system. When activated, the handheld concrete breaker rapidly impacts the tool (point or chisel) driving the working edge into the concrete surface. The operator controls the depth of removal by observation. The area being chipped will require debris removal to allow the operator to see the removal progress. Further preparation will be required to remove microcracking.

8.3.8 Equipment

- Handheld concrete breakers (Fig. 8.3.a) typically range from 30 to 90 lb (14 to 41 kg);
- Chipping hammers (Fig. 8.3.b) typically range from 12 to 20 lb (5.5 to 9.0 kg);
- Tools (chisels or points [Fig. 8.3.b]);
- Compressed air, electricity, or hydraulic power source; and
- Air hose if compressed air is used.

8.3.9 Materials

Chisels and points will require periodic sharpening and/or replacement.

8.3.10 Employee skill level

Operator skill requirements are low.

8.3.11 Setup and downtime

The setup of air hoses and changing tools is required daily. Tool changes for handheld concrete breakers will take 1 minute or less, while chipping hammers will take approximately 5 minutes.

8.3.12 Cleanup

Dust and larger pieces of concrete will be generated from the handheld concrete breaker operation. Sweeping and/or vacuuming will be required to remove the rough debris and fines to allow the operator to see the quality of the removal. Additional cleanup will be required following sandblasting or any other method used as additional surface preparation.

8.3.13 Production rates

Productivity will vary considerably depending on the size of the handheld concrete breaker used, orientation of the surface, strength of substrate, depth of removal, and type of material being removed. The typical removal rate for normal (4000 psi [27.5 MPa]) concrete using a chipping hammer is 1.5 to 4.0 ft³/h (0.04 to 0.11 m³/h) per operator. The removal rate for a handheld concrete breaker is significantly higher depending on the weight of the tool.

8.3.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate an adequate bond between the prepared surface and repair material. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface.

8.3.15 Safety hazards

Handheld concrete breakers will cause dust and produce airborne debris. Minimum recommended PPE is:

- Eye protection—Meeting ANSI requirements for high impact and face shield;
- Respiratory protection—Required in confined areas or where dust is present;
- Hearing protection—Process will likely generate noise levels in excess of 85 dB. Noise levels may require the use of earplugs and/or earmuffs; and
- Leather gloves while operating handheld equipment.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.4 Detergent Scrubbing



Fig. 8.4.a: Floor scrubbing



Fig. 8.4.c: Ride-on scrubber



Fig. 8.4.b: Floor scrubbing machine



Fig. 8.4.d: Walk-behind scrubber

This method removes oil, grease, and other deposits on concrete surfaces by scrubbing with a detergent solution.

8.4.1 Summary

This method may be used on horizontal concrete surfaces to remove dirt, oil, and grease. Corner and edge cleaning can be detailed manually. The scrubbing process should produce clean surfaces devoid of dirt, oil, grease, and loose debris without altering the surface texture. Detergent scrubbing is frequently used to prepare concrete for acid etching.

8.4.2 Removal

Removal is accomplished through the combined action of detergent/chemical cleaners, scrubbing of the surface with brushes (Fig. 8.4.a and 8.4.b), and rinsing or vacuuming of the cleaning solution and debris from the surface (Fig. 8.4.c and 8.4.d). This method is suitable for superficial removal of oil, grease, organic or inorganic residues, wax, rust, and other deposits from concrete surfaces. Absorbed fluids such as oils and grease may require several treatments to achieve acceptable results or may not be adequately removed depending on the nature of the absorbed fluid and depth of penetration.

8.4.3 Profile

CSP 1—Detergent scrubbing will not produce any noticeable pattern effect on sound concrete surfaces.

8.4.4 Accessibility

With the variety of portable and maneuverable equipment available, most surfaces are accessible. Access to corners, recesses, and between penetrations is restricted by the reach and arc of the brushes. These areas may be addressed manually.

8.4.5 Limitations

This method is limited to the removal of water-soluble or detergent-emulsifiable contaminants and debris, which can be readily loosened by light mechanical action of the scrubbers. Note that in heavily contaminated substrates, additional contaminants may diffuse to the cleaned surface within hours/days of cleaning.

8.4.6 Environmental factors

Moderate-to-heavy contamination may produce significant amounts of sludge or other debris. Some debris may be considered hazardous or otherwise unqualified for discharge into sewer systems. Debris produced by

detergent scrubbing will contain particles of the material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific materials or contaminant being removed. Suitable measures for the containment, collection, and proper disposal of debris and rinse water should be considered. Detergents and cleaning chemicals may produce odors.

8.4.7 Execution

1. Apply chemical detergent solution;
2. Scrub in chemical solution with stiff-bristled broom or scrubbing machine;
3. Collect and dispose of solution;
4. Rinse or vacuum surface to remove all residues; and
5. Repeat process as needed to achieve acceptable results.

8.4.8 Equipment

Manual methods:

- Mop;
- Floor scrubber (Fig. 8.4.a and 8.4.b);
- Pump-up sprayer;
- Stiff broom;
- Pressure washer; and
- Squeegee or wet/dry vacuum.

Mechanical methods:

- Automatic scrubbing machine (walk-behind or self-propelled—Fig. 8.4.c and 8.4.d) available in gas-, electric-, propane-, or diesel-powered models. Brush rotation speeds of up to 300 rpm;
- Brushes: Nylon bristle brushes are relatively soft. Polyethylene bristles are stiffer and more aggressive. Polyethylene/abrasive composite bristles will provide the most aggressive mechanical cleaning;
- Sizes range from an 18 to 60 in. (0.5 to 1.5 m) brush path; and
- Solution tanks range from 3 to 365 gal. (11 to 1380 L) with recovery tanks to hold scrubbing residue.

8.4.9 Materials

- Industrial detergent rated to remove heavy oil and grease; and
- Water source.

8.4.10 Labor

Low skill is required for manual scrubbing method. Medium skill is required to operate automatic scrubber and mix chemical solutions.

8.4.11 Setup and downtime

- Manual methods: Very little time is required to set up equipment and mix detergents; and
- Mechanical methods: Mixing chemicals, filling tanks, and removing debris from recovery tanks will involve some downtime. Changing brushes is quick and infrequent. Replacement frequency for pickup squeegees will depend on wear factors.

8.4.12 Cleanup

Scrubbing manually with brooms or mechanically with electric single-disc machines will generate a liquid residue that must be removed by a squeegee, vacuum, or low-pressure water cleaning method to obtain a clean surface. Automatic scrubbers have an internal squeegee/vacuum system to collect the liquid residue immediately behind the scrub brushes.

8.4.13 Production rates

The following rates are approximate. Actual rates will vary considerably with the severity of soil, size of machine, and effectiveness of chemical solution being used.

- Manual with wet/dry vacuum recovery: 500 ft²/h (50 m²/h);
- Manual with electric brush machine with wet/dry vacuum recovery: 1000 ft²/h (100 m²/h);
- Small walk-behind scrubber: 5000 ft²/h (500 m²/h); and
- Medium or large riding scrubber: 50,000 ft²/h (5000 m²/h).

8.4.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4258 provides additional considerations for surface preparation and quality control using this method.

8.4.15 Safety hazards

Operators must be trained in the proper use of this equipment and the proper handling of the cleaning solutions. Minimum recommended PPE is as follows:

- Eye protection—Anti-fog goggles meeting ANSI requirements for high impact;
- Hearing protection—Required while operating machinery; and
- Chemical-resistant gloves while handling cleaning solutions.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.5 Grinding



Fig. 8.5.a: Floor grinding



Fig. 8.5.c: Floor grinding with vacuum



Fig. 8.5.b: Grinding disc



Fig. 8.5.d: Hand grinder for detail work

8.5.1 Summary

This method may be used on horizontal, vertical, and overhead surfaces to smooth slight surface irregularities and remove thin coatings and rigid high-build coatings such as epoxy, polyurethane, and methacrylate coatings. Grinding may also be used to remove mineral deposits, efflorescence, rust, and other deposits. Grinding may be used on almost any substrate and is suitable for interior and exterior applications.

8.5.2 Removal

Removal is accomplished by the rotation of one or more abrading stones or discs applied under pressure at right angles to the concrete surface. The grinding stone or disc is moved across the surface until the desired effect is achieved.

8.5.3 Profile

CSP 1-2—Grinding produces a smooth surface. Other methods may be used in conjunction with grinding to provide the required profile. Small handheld grinders are likely to produce gouging and a circular, grooved pattern. Walk-behind units will eliminate gouging but are likely to show a circular pattern. Larger units using fine stones

should not produce any detectable pattern and are frequently used for producing polished concrete and terrazzo.

8.5.4 Accessibility

Most surfaces, including edges, are accessible. Equipment ranges from small handheld grinders to walk-behind units with multiple discs. Access to corners and tight configurations is restricted by the arc of the grinding disc.

8.5.5 Limitations

Grinding is not recommended for the following applications:

- Preparation for coating or sealing unless followed by acid etching, shotblasting, or high-pressure water-blasting;
- Removal of chlorinated rubber, acrylic, or other soft coatings or finishes;
- Removal of tile or carpet adhesives; and
- Removal of materials that may smoke or burn when heated.

8.5.6 Environmental factors

Dry grinding will produce a dust containing silica and other contaminants being removed from the surface. Dust

may be minimized with vacuum systems attached to the grinder (Fig. 8.5.a, 8.5.c, and 8.5.d). Debris generated by this method will contain fine particles of any material or contaminant being removed. Wet grinding, which may be used to minimize airborne dust, will produce a slurry residue and rinse water that will require proper disposal. Grinding soft, easily charred materials will generate smoke, which may be hazardous. Noise and vibration levels are considered to be low.

8.5.7 Execution

Grinders are moved over the surface in a linear or sweeping motion until the desired removal or effect is achieved.

8.5.8 Equipment

Grinders are available in electric-, pneumatic-, or gas-driven models. Sizes range from walk-behind machines (Fig. 8.5.a to 8.5.c) to handheld grinders (Fig. 8.5.d). Rotation speeds vary from 1000 to 9000 rpm. Grinders are typically connected to a vacuum dust recovery system.

8.5.9 Materials

The grinding medium (stone or disc) is consumed during the process. Some discs have inserts that may be changed as they wear out. Grinding discs range in diameter from 4 to 18 in. (100 to 450 mm). Their composition varies from very fine polishing media to aggressive cutting media with wet or dry diamonds. The disc shape may be flat, cone-shaped, or cup-shaped.

8.5.10 Employee skill level

Low to medium skill is required.

8.5.11 Setup and downtime

Setup requires very little time unless dust protection includes draping and taping. Changing stones or discs is quick. Frequency of replacement will depend on the composition of the stone or disc, substrate, and material being removed.

8.5.12 Cleanup

Grinding will produce a fine powder and small chips. The debris can be swept, rinsed with water, or vacuumed.

8.5.13 Production rates

Productivity will vary depending on the grinding media selected and the type of material being removed. Estimated rates are:

- Handheld units: 20 ft²/h (2 m²/h); and
- Walk-behind units: 800 ft²/h (75 m²/h).

8.5.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4259 provides additional considerations for surface preparation and quality control using this method.

8.5.15 Safety hazards

Grinding will cause the release of dust. Minimum recommended PPE is as follows:

- Eye protection—Meeting ANSI requirements;
- Respiratory protection—May be required in confined areas where dust is present; and
- Hearing protection—Process may generate noise levels in excess of 85 dB. Noise levels may require the use of earplugs and/or earmuffs.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.6 High- and Ultra-High-Pressure Water Jetting

(5000 to 45,000 psi [35 to 275 MPa] at 2 to 50 gal./min [8 to 190 L/min])



Fig. 8.6.a: Surface preparation—handheld lance



Fig. 8.6.c: Coating removal



Fig. 8.6.b: Coating removal—robotic equipment



Fig. 8.6.d: Membrane removal—mower

8.6.1 Summary

High- and ultra-high-pressure water jetting may be used to remove laitance, efflorescence, scale, dirt, or other contaminants. With suitable pressure and a nozzle, epoxy, urethane, and methacrylate coatings and thin overlay systems may be removed (Fig. 8.6.b, 8.6.c, and 8.6.d). It may also be used to remove carbonated, freezing-and-thawing-damaged, weakened, delaminated, or otherwise undesirable concrete from the substrate. The method is suitable for horizontal, vertical, and overhead applications. Pressures in the higher ranges may be needed to remove certain coating materials. This method will clean the reinforcing steel; however, flash rust may occur. High-pressure water jetting may be used for hydro-demolition (refer to ICRI Guideline No. 310.3; SHRP-S-336).

8.6.2 Removal

Removal is accomplished when the water jet strikes the surface. The degree of removal is controlled by the force of the water jet (pressure and volume) and the length of time the water jet is in contact with the surface. Multi-jet systems rotating at a high speed (1000 to 3000 rpm) spread the force of the water over a larger area and result in minimal contact time with the surface. The multi-jet

systems are effective in removing surface contaminants, including coatings and weakened concrete. A single water jet rotating at slower speeds (300 to 900 rpm) or oscillating concentrates the force of the water and produces a longer contact time with the surface, resulting in more aggressive removal. The single-jet systems are effective in removing sound and unsound concrete.

8.6.3 Profile

CSP 3-10—When using multi-jet tools, the surface profile of sound concrete may remain largely unaffected by this process. The use of multi-jet heads and a short contact time will clean the surface while creating a minimal profile (CSP 3). Pressure and nozzle tips may be adjusted to produce the desired profile. The use of high- and ultra-high-pressure water jetting on low-strength or deteriorated surfaces will produce a much more aggressive profile as surface defects are removed. The use of a single nozzle will result in a surface profile of CSP 10. The amplitude of $\pm 1/2$ the diameter of the coarse aggregate can be expected (ICRI 310.3).

8.6.4 Accessibility

With the wide variety of portable and maneuverable equip-

ment available, most surfaces are easily accessible. Tight spaces can be accessed with a handheld lance.

8.6.5 Limitations

This method should not be used where goods or equipment may be damaged by impact from water jets or where they cannot be protected from heavy mist or flooding. Proper precautions for live electrical wiring or conduit need to be considered when using high-/ultra-high-pressure water.

8.6.6 Environmental factors

This process produces loud noise. Mist and a significant volume of water will be introduced into the work area. The volume of water introduced will range from 2 to 50 gal./min (8 to 150 L/min) and is determined by the type of removal to be performed and the requirements of the equipment selected. Environmental regulations may require containment and regulated disposal of the liquid waste generated. Frequently, the pH of the spent hydrodemolition water and suspended solids are adjusted prior to disposal.

8.6.7 Execution

The concrete surface is prepared by uniformly moving the water jet back and forth over the surface until the desired results are achieved. Automated equipment typically moves the nozzle(s) left and right as the unit advances. Standing water may need to be pumped or squeegeed off the surface. Units that clean and recycle jetting water are available. Solid debris, slurry, and water residue are disposed of as required by local regulations or project restrictions.

8.6.8 Equipment

- Water pump capable of producing the desired pressure and volume;
- Compressed air source producing a minimum of 85 ft³/min at 120 psi (2.4 m³/min at 0.8 MPa) (for power spin or rotation function);
- High-pressure hoses;
- Self-propelled equipment (Fig. 8.6.b and 8.6.d) for horizontal surfaces and handheld lance (Fig. 8.6.a) for vertical and overhead applications, corners, or other difficult-to-reach locations. Robots may be used on horizontal, vertical, and overhead surfaces;
- Suitable nozzle; and
- Runoff protection to contain water and debris.

8.6.9 Materials

Potable water is recommended and may be provided from a fire hydrant connection, tanker, or similar source capable of meeting the requirements of the equipment.

8.6.10 Employee skill level

Medium to above-medium skill level with appropriate training is required. Must be able to maintain high-pressure pumps and components and safely operate equipment. Skilled supervision may be needed if complex equipment

is used. Everyone operating high- or ultra-high-pressure waterblasting equipment must be trained in the hazards of this type of equipment.

8.6.11 Setup and downtime

Setup time is variable depending on the size of the work area and specific protective measures required. Downtime may be required to maintain equipment and replace consumable parts, such as nozzles and seals.

8.6.12 Cleanup

Collect water for proper disposal. Debris can be rinsed, swept, or vacuumed from the surface. Jetting of deteriorated surfaces may produce additional debris.

8.6.13 Production rates

The rates shown as follows are approximate and assume sound, 4000 psi (28 MPa) concrete. Actual production rates will vary considerably and will depend on the strength of the concrete, hardness and bond strength of material to be removed, preparation objectives, operator skill, and efficiency of equipment employed.

- Handheld lances—Horizontal surfaces: 125 to 300 ft²/h (12 to 28 m²/h);
- Handheld lances—Vertical and overhead surfaces: 50 to 250 ft²/h (5 to 23 m²/h); and
- Automated equipment—Horizontal, vertical, and overhead surfaces: 300 to 2000 ft²/h (30 to 200 m²/h).

8.6.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface.

8.6.15 Safety hazards

Water jetting will create a dangerous water stream, loud noise, flying debris, and water spray. A water jet cut or puncture can force bacteria into the body, resulting in a serious infection. Operators must be trained in the proper use of this equipment. Minimum recommended PPE is:

- Eye protection—Anti-fog goggles meeting ANSI requirements for high impact and face shield;
- Hearing protection—Process will generate noise levels in excess of 85 dB. Earmuff-type protectors are strongly recommended. Noise levels may require the use of earplugs and earmuffs;
- Steel-toed waterproof boots, helmet, and waterproof gloves and clothing; and

- Handheld lance operator—Metatarsal guards and protective clothing capable of deflecting the high- or ultra-high-pressure water.
Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1

(Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation. Consult ASTM E1575, ICRI 310.3, and WJTA for safety practices for pressure water cleaning.

8.7 Low-Pressure Water Cleaning

1000 to 5000 psi (7 to 35 MPa) at 2 to 10 gal./min (8 to 40 L/min)



Fig. 8.7.a: Wall and floor cleaning



Fig. 8.7.c: Floor cleaning



Fig. 8.7.b: Curb cleaning

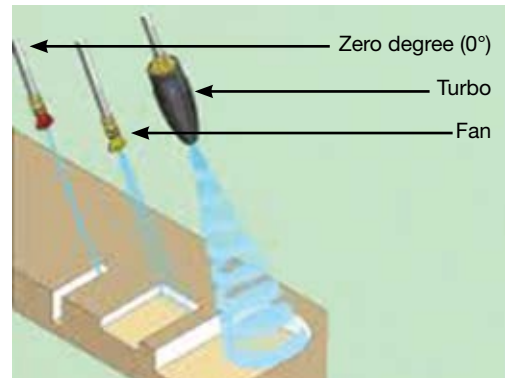


Fig. 8.7.d: Various nozzle types

8.7.1 Summary

This method may be used outdoors to remove dust, friable materials, debris, or water-soluble contaminants from concrete surfaces and surface cavities (Fig. 8.7.a to 8.7.c). It may be used in interior spaces where mist, noise, and standing water can be tolerated. The method is suitable for horizontal, vertical, and overhead applications. For surface preparation applications, low-pressure water cleaning is often used to perform a final rinse following other surface preparation techniques.

8.7.2 Removal

Water is sprayed at pressures less than 5000 psi (35 MPa) to remove dirt and loose, friable material. This method does not remove any significant amount of concrete.

8.7.3 Profile

CSP 1—This method does not produce any significant texture, profile, or pattern on sound concrete.

8.7.4 Accessibility

Most low-pressure water cleaning is performed with a handheld lance and is readily accessible to all surfaces.

8.7.5 Limitations

The presence of materials or equipment that cannot be adequately protected from mist or spray may restrict use of this method. This method is not suitable for the removal of sealers, coatings, curing membranes, or any concrete other than what is already loose.

8.7.6 Environmental factors

Mist and a large volume of water will be introduced into the work area. Debris produced by low-pressure water cleaning will contain particles of material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific materials or contaminant being removed. Environmental regulations may require containment and regulated disposal of the liquid waste generated.

8.7.7 Execution

- A water spray is methodically moved back and forth over the surface until the desired results are achieved. If automated equipment is used, the operator typically makes parallel passes. If handheld lances are used, the process will be slower but similar;
- Standing water may need to be pumped, vacuumed, or squeegeed off the surface; and
- Solid debris and water residue are disposed of as required by local regulations or project restrictions.

8.7.8 Equipment

- Booster pump (to increase pressure);
- Heater for hot water applications;
- Pressure-rated hoses;
- Wheeled equipment for horizontal surfaces; handheld lance for vertical and overhead applications, corners, or other difficult-to-reach locations;
- Suitable nozzles (Fig. 8.7.d); and
- Runoff protection to catch debris flowing off site or toward drains.

8.7.9 Materials

Water source may be provided by tanker, hydrant connection, industrial spigot, or pump.

8.7.10 Labor

Work may be performed with unskilled labor. Skilled supervision may be needed if complex equipment is used.

8.7.11 Setup and downtime

Equipment setup time is very short but additional time may be necessary to protect surfaces and install runoff protection to catch loosened materials.

8.7.12 Cleanup

Low-pressure water cleaning is often used to clean up following other surface preparation techniques or repair

procedures. Water and debris produced during the cleaning will have to be contained, collected, and disposed of.

8.7.13 Production rates

The rates that follow are approximate. Actual rates will vary with the pressure, volume of water, type of spray nozzle, number of passes, speed of travel, and efficiency of equipment employed and preparation objectives.

- 1000 to 2000 ft²/h (100 to 200 m²/h) for flat surface; and
- 250 to 1000 ft²/h (25 to 100 m²/h) for handheld equipment on vertical and overhead surfaces.

8.7.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4259 provides additional considerations for surface preparation and quality control using this method.

8.7.15 Safety hazards

Low-pressure water cleaning will create a dangerous water stream, loud noise, flying debris, and water spray. A water spray may cut or puncture the skin and can force bacteria into the body, resulting in a serious infection. Operators must be trained in the proper use of this equipment. Minimum recommended PPE is as follows:

- Eye protection—Anti-fog goggles meeting ANSI requirements for high impact and face shield;
- Handheld lance operator—Steel-toed waterproof boots, metatarsal guards, helmet, protective clothing capable of deflecting the water jet, and waterproof gloves and outer layers; and
- Hearing protection—Process will generate noise levels in excess of 85 dB. Earmuff-type protectors are strongly recommended. Noise levels may require the use of earplugs and earmuffs.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation. Consult ASTM E1575, ICRI 310.3, and WJTA for safety practices for pressure water cleaning.

8.8 Rotomilling



Fig. 8.8.a: Skid-steer-mounted rotomilling unit



Fig. 8.8.c: Rotomilled concrete surface



Fig. 8.8.b: Rotomilling drum with teeth



Fig. 8.8.d: Rotomilling used to remove membrane

8.8.1 Summary

Rotomilling is used on horizontal surfaces to remove unsound concrete, mastics or other high-build coatings, and asphaltic materials (Fig. 8.8.d). It may also be used to profile concrete substrates (Fig. 8.8.c). This method is suitable for use in interior and exterior applications, primarily on horizontal surfaces. Milling attachments mounted to excavators are used for milling vertical surfaces and corners.

8.8.2 Removal

The rotomilling equipment contains a rotating drum with teeth (Fig. 8.8.b). As the machine moves forward, the cutting teeth strike the surface with great force, fracturing material into chips and dust. The depth of concrete removal ranges from 1/4 to 4 in. (6 to 100 mm). The machine's maximum removal depth is determined by the number and size of teeth, and the size and weight of the machine. A greater number of small teeth will produce a smoother surface CSP 6 to 7, while fewer, larger teeth will produce a CSP 9 and greater. The weight of the machine provides the downward force on the cutting drum. Most machines are equipped with depth gauges,

which allow the operator to adjust and monitor the depth of removal.

8.8.3 Profile

CSP 6 to 9—Rotomilling will produce a rough surface with fractured coarse aggregate. The teeth of the rotating drum will produce a pattern with linear striations (grooving). The profile obtained is determined by the number and size of teeth. The prepared surface may be very rough and can exceed CSP 9. This method will cause microcracking in the prepared surface.

8.8.4 Accessibility

Most rotomilling equipment will reach within 6 in. (150 mm) of vertical surfaces such as walls, curbs, and columns.

8.8.5 Limitations

Supported slabs must be structurally capable of supporting large, heavy equipment. This method will produce high levels of noise, dust, and vibration. Rotomilling operations will cause microcracking. The deleterious effects of microcracking may be reduced or eliminated by following initial removal with steel shotblasting, abrasive blasting, or high- and ultra-high-pressure water jetting. The depth

of microcracking may be deeper than can be readily addressed by abrasive blasting or shotblasting.

8.8.6 Environmental factors

Rotomilling will produce airborne dust containing concrete and particles of any other materials or contaminants being removed. Requirements for containment and disposal of dust and debris will depend on the specific materials or contaminants being removed. Special ventilation provisions may be required when operating gasoline- or diesel-powered units indoors. Water that is used to control dust or clean the substrate may need to be collected and treated prior to disposal. Noise levels will exceed 85 dB. Rotomilling equipment operation results in significant vibration to the structure.

8.8.7 Execution

The surface is prepared by driving the rotomilling equipment in a straight path across the surface. The depth is controlled by adjusting the depth of the drum.

8.8.8 Equipment

Large rotomilling machines are self-propelled ride-on units that collect the debris on a conveyor and transport it to a container, usually a dump truck working with the rotomill. Smaller units consist of a special rotomilling head mounted on a skid-steer loader (Fig. 8.8.a). A rotomilling head mounted on an excavator may be used for vertical or overhead removal.

8.8.9 Materials

Teeth mounted on the rotomilling drum.

8.8.10 Employee skill level

Experienced, trained machine operators are needed to operate equipment and perform periodic maintenance or replacement of cutting heads and teeth. Additional workers with appropriate skills are needed to operate the support equipment, such as conveyors, dump trucks, microcrack mitigation equipment, and for general cleanup.

8.8.11 Setup and downtime

Machines arrive at the site ready to work. Downtime may be experienced as a result of periodic maintenance and replacement of teeth.

8.8.12 Cleanup

Debris removal equipment may include dump trucks, loaders, a conveyor system, shovels, and brooms. Large machines will convey the debris directly into a dump truck. Smaller units leave the debris on the surface, which is removed using skid-steer loaders, brooms, and shovels.

8.8.13 Production rates

The removal rate will depend on the depth and hardness of the substrate concrete. Estimated removal rates are:

- Small skid-steer-mounted machines—1000 ft²/h (90 m²/h);
- Mid-range machines—3000 to 4000 ft²/h (280 to 370 m²/h); and
- Large roadway machines—15,000 ft²/h (1400 m²/h).

8.8.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials and microcracking. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface.

8.8.15 Safety hazards

Rotomilling creates dust, flying debris, and loud noise. Operators must be trained in the proper use of this equipment. Minimum recommended PPE is as follows:

- Eye protection—meeting ANSI requirements;
- Respiratory protection to protect against silica containing dust. If materials being removed contain toxic substances, additional protection may be required; and
- Hearing protection—Process will generate noise levels in excess of 85 dB. Earplugs and/or earmuffs are required.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.9 Needle Scaling



Fig. 8.9.a: Needle gun



Fig. 8.9.b: Steel rods (needles)



Fig. 8.9.c: Masonry surface preparation



Fig. 8.9.d: Metal surface preparation

8.9.1 Summary

Needle scaling tools are primarily used for metal cleaning (Fig. 8.9.d); however, they are also used in concrete and masonry surface preparation (Fig. 8.9.c). This method can be used on surfaces indoor, outdoor, or underwater and on surfaces of any orientation to remove efflorescence, brittle encrustations, and coating systems. It is frequently used for work on edges and other tight spaces that cannot be accessed by larger, more automated equipment. It may be used underwater to remove barnacles and other marine shellfish attached to submerged surfaces.

8.9.2 Removal

Removal is accomplished by the superficial fracturing and pulverization of the concrete surface. The surface is impacted by the pointed tips of a bundle of steel rods that are pulsed by compressed air or hydraulics.

8.9.3 Profile

CSP 2 to 4—Needle scaling will produce random, evenly distributed impact craters around larger aggregate, imparting a textured surface.

8.9.4 Accessibility

Handheld needle scaling tools are available in several sizes, providing virtually unrestricted accessibility.

8.9.5 Limitations

Needle scaling is not recommended for removal of coatings that are thick or resilient, preparation of large surface areas, or the removal of sound concrete. Needle scaling may produce microcracking of the surface.

8.9.6 Environmental factors

Needle scaling will produce dust containing silica and particles of any material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific contaminants being removed. Noise levels are loud and vibration levels are low to medium.

8.9.7 Execution

The needle scaling tool is held against the surface with light-to-medium pressure. The pneumatically driven rods are activated by a trigger located in the unit's handle.

8.9.8 Equipment

- Needle guns ranging in weight from 2.5 to 15 lb (1 to 7 kg) (Fig. 8.9.a);
- The size of the steel rod will vary and the number of rods in a bundle range from 12 to more than 30 (Fig. 8.9.b);
- Air compressor and air hose producing 3 to 15 ft³/min at 80 to 120 psi (0.08 to 0.42 m³/min at 0.6 to 0.8 MPa); and
- Vacuum or other cleanup equipment.

8.9.9 Materials

The hardened steel rods are consumed during surface preparation.

8.9.10 Employee skill level

Low skill is required.

8.9.11 Setup and downtime

Minimal. Approximately 5 minutes per hour to change needle bundles. Rebuilding needle bundles is usually an off-site activity.

8.9.12 Cleanup

Needle scaling will generate dust and small airborne particles. The tools are not equipped to collect debris, which may be vacuumed or swept up for proper disposal.

8.9.13 Production rates

Productivity will range from 10 to 50 ft²/h (1 to 5 m²/h). Rate is dependent on size of needle gun, number of needles per bundle, available air pressure and volume, strength of substrate, and hardness of material being removed.

8.9.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4259 provides additional considerations for surface preparation and quality control using this method.

8.9.15 Safety hazards

Needle scaling tools will cause the release of dust. Minimum recommended PPE is as follows:

- Eye protection—Meeting ANSI requirements for high impact, and face shield;
- Respiratory protection—May be required in confined areas where dust is present;
- Hearing protection—Process may generate noise levels in excess of 85 dB. Noise levels may require the use of earplugs and/or earmuffs; and
- Leather gloves while operating handheld equipment.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.10 Scabbling



Fig. 8.10.a: Coating removal



Fig. 8.10.c: Multi-head scabbler



Fig. 8.10.b: Typical scabbler head



Fig. 8.10.d: Multi-head scabbler

8.10.1 Summary

Scabbling is used primarily on horizontal surfaces to remove concrete or brittle coatings such as epoxy, polyurethane, or methyl methacrylate systems up to 1/4 in. (6 mm) thick (Fig. 8.10.a) in preparation for overlays. It may also be used to deeply profile concrete surfaces. Handheld units (bush hammers) are available for vertical and overhead surfaces. This method is suitable for use in interior and exterior applications.

8.10.2 Removal

Removal is accomplished by the impact of the scabbling head (Fig. 8.10.b) on the surface. The piston-driven cutting heads are pneumatically activated. Repeated blows to the surface result in chipping and crushing of the concrete surface and material being removed.

8.10.3 Profile

CSP 7 to 9—Scabbling will produce a very irregular surface dominated by fractured coarse aggregate. Scabbling will cause microfractures in the substrate. There should be no discernible tool pattern.

8.10.4 Accessibility

Most surfaces are accessible using equipment ranging from small handheld to large walk-behind units. Corners, recesses, and tight configurations are accessible with handheld tools (bush hammers).

8.10.5 Limitations

Scabbling is not recommended for the removal of elastomeric membranes or gummy materials such as tile or carpet adhesives.

8.10.6 Environmental factors

Scabbling will produce airborne dust containing silica and particles of any other materials being removed. Any special requirements for containment and disposal of dust and debris will depend on the specific materials or contaminants being removed. Noise levels are likely to exceed 85 dB. Vibration levels are moderate to severe and will transmit through a structure. Work area enclosures and special ventilation provisions may be required indoors to prevent dust intrusion into nearby occupied work space.

8.10.7 Execution

Scabblers are operated by manually pushing the units across the surface in a back-and-forth motion at slow speed. The area being scabbled will require continuous debris removal to allow the operator to see the removal progress.

8.10.8 Equipment

- Scabbler—Manually operated walk-behind machines having up to 12 heads (Fig. 8.10.c and 8.10.d);
- Handheld tools for detail work;
- Air compressor or other air source producing a minimum of 180 ft³/min at 120 psi (5.1 m³/min at 0.8 MPa). Air volume requirements are likely to increase with larger equipment and multiple heads; and
- Air hose—1/2 to 2 in. (13 to 50 mm) in diameter.

8.10.9 Materials

Impact bits are the consumed material (Fig. 8.10.b). These are available in varying configurations with tungsten carbide inserts.

8.10.10 Employee skill level

Operator skill requirements are low.

8.10.11 Setup and downtime

Setup of air hoses and changing bits is required once per day. Bit changes will take anywhere from 10 minutes for single-head units to as much as 35 minutes for large, multi-head units.

8.10.12 Cleanup

Dust and larger particles up to 1/2 in. (13 mm) in diameter will be generated from the impact of the bits. Sweeping

and/or vacuuming will be required to continuously remove the rough debris and fines to allow the operator to see the quality of the removal.

8.10.13 Production rates

Productivity will vary considerably depending on the size of the machine, strength of substrate, depth of removal, and type of material being removed. For heavy removal, estimated rates range from 20 to 100 ft²/h (1.9 to 9.3 m²/h).

8.10.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved and microcracking has been mitigated. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4259 provides additional considerations for surface preparation and quality control using this method.

8.10.15 Safety hazards

Scabblers will cause the release of dust and will produce airborne debris. Minimum recommended PPE is:

- Eye protection—Meeting ANSI requirements for high impact and face shield;
- Respiratory protection—May be required in confined areas where dust is present;
- Hearing protection—Process may generate noise levels in excess of 85 dB. Noise levels may require the use of earplugs and/or earmuffs; and
- Leather gloves while operating handheld equipment.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.11 Scarifying



Fig. 8.11.a: Cutting drum with teeth



Fig. 8.11.b: Cutter teeth



Fig. 8.11.c: Scarified surface showing teeth marks



Fig. 8.11.d: Typical scarifying machine

8.11.1 Summary

Scarification is used primarily on horizontal surfaces for the removal of concrete and brittle coatings up to 1/8 in. (3 mm) thick. Multiple passes may be made for deeper removal. It may also be used to profile concrete surfaces (Fig. 8.11.c). Adhesives may be removed by the adjustment of spacers and the selection of appropriate cutters. Handheld units are available for vertical and overhead applications. Scarifying may be used on almost any concrete substrate and is suitable for both interior and exterior applications. This method is also known as concrete planing.

8.11.2 Removal

Removal is accomplished by the rotary action of cutters (toothed washers) on the surface to fracture or pulverize the concrete. The cutters are assembled on steel rods mounted at the perimeter of a drum that rotates at high

speeds. Removal depth may range from light surface profiling to 1/4 in. (6 mm) for smaller equipment and 1/2 to 3/4 in. (13 to 19 mm) for larger equipment. Removal depths greater than 1/8 in. (3 mm) are accomplished in multiple passes.

8.11.3 Profile

CSP 4 to 7—Scarifying will produce a parallel, striated pattern. The deepest removal pattern will be produced at surface high points.

8.11.4 Accessibility

With portable equipment ranging in size from small hand-held devices to large, self-propelled units, most surfaces are accessible to within 1/4 in. (6 mm) of the edge. Access to corners and tight configurations such as around and between pipes is restricted by the dimensions of the drum housing.

8.11.5 Limitations

Scarification is not recommended for surface preparation for sealers or coatings less than 15 mils (0.38 mm) thick or the removal of heavy elastomeric membranes. This method may cause microcracking in the substrate.

8.11.6 Environmental factors

Scarifying will produce airborne dust containing concrete and particles of the material being removed. Any special requirements for containment and disposal of dust and debris will depend on the specific contaminants being removed. Noise levels are likely to exceed 85 dB. Vibration levels are moderate. Ventilation may be required when operating gasoline- or diesel-powered units indoors.

8.11.7 Execution

With the exception of handheld units, most scarifiers are operated by pushing the machine forward over the surface, advancing at a slow walk. The depth and rate of removal are adjusted by raising or lowering the drum to increase or decrease the impact of the cutters. Several passes may be required to achieve the desired profile. Debris must be removed after each pass.

8.11.8 Equipment

- Mechanical scarifiers are available in electric-, pneumatic-, or gasoline-powered models in sizes ranging from walk-behind (Fig. 8.11.d) to self-propelled ride-on units. Path widths range from 4 to 36 in. (100 to 900 mm);
- Replacement drums (Fig. 8.11.a);
- Air compressor or other air supply (pneumatic models only); and
- Industrial vacuum cleaner to be used with vacuum adapter attachments to limit airborne dust.

8.11.9 Materials

The cutters are consumed during the removal (Fig. 8.11.b). The rate of consumption depends on the following:

- Cutter configuration;
- Cutter composition (hardened steel, tungsten carbide);
- Substrate hardness;
- Composition of materials to be removed; and
- Force of equipment on concrete surface (weight, pressure).

8.11.10 Labor

Low to medium skill is required.

8.11.11 Setup and downtime

Minimal. Setup requires very little time. Drum changes will take approximately 5 to 10 minutes. Rebuilding drums is usually done off-site.

8.11.12 Cleanup

Sweeping and removal of the dust and debris will be required.

8.11.13 Production rates

The rates shown as follows are estimates. Productivity will vary considerably depending on equipment size, depth of removal, and type of material being removed.

- Handheld units: 20 ft²/h (2 m²/h); and
- Walk-behind units: 800 ft²/h (75 m²/h).

8.11.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved and that the concrete has no bruising (microcracking). Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface. ASTM D4259 provides additional considerations for surface preparation and quality control using this method.

8.11.15 Safety hazards

Mechanical scarifiers will produce dust. If gas- or diesel-powered equipment is used, the area should be well-ventilated. Minimum recommended PPE is as follows:

- Eye protection—Meeting ANSI requirements for high impact and face shield;
- Respiratory protection—May be required in confined areas where dust is present; and
- Hearing protection—Process may generate noise levels in excess of 85 dB. Noise levels may require the use of earplugs and/or earmuffs.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.12 Shotblasting



Fig. 8.12.a: Shotblasting warehouse floor



Fig. 8.12.c: CSP 3 surface using shotblasting



Fig. 8.12.b: Shotblast equipment



Fig. 8.12.d: 8 in. (203 mm) unit for trim work

8.12.1 Summary

Shotblasting is principally used to clean and profile horizontal surfaces in preparation for the application of sealers, coatings, or polymer overlays. This method is also used to remove dirt, laitance, curing compounds, sealers, or other superficial contaminants and some existing coatings and adhesives (Fig. 8.12.c). Handheld machines are available for use on vertical surfaces. Shotblasting is suitable for use in both interior and exterior applications.

8.12.2 Removal

Removal is accomplished by the pulverizing effect of a steel shot impacting the surface at high velocity. The steel shot is propelled against the surface (Fig. 8.12.b—red arrows) by a rotating wheel. The steel shot and removed material (Fig. 8.12.b—yellow arrows) are collected with the aid of a dust collection system. The removed material is separated as waste and the steel shot is reused. The depth of removal is controlled by shot size, number of repeated passes, and rate of linear travel.

8.12.3 Profile

CSP 2 to 9—As the depth of removal increases, the profile will be increasingly dominated by the size and shape of the coarse aggregate.

8.12.4 Accessibility

Shotblasting equipment is available in a range of sizes to provide ready access to most surfaces. Removal widths range from 5 to 48 in. (130 mm to 1.2 m). Edges and corners may be detailed to within 1/4 in. (6 mm) of the vertical surfaces with specialty edging machines or handheld units.

8.12.5 Limitations

This method is generally not suitable for removing uncured resin systems and resilient or tar-based materials. Overlapping passes may lead to a stripping pattern with deeper removal in the overlap area.

8.12.6 Environmental factors

Shotblast systems produce very little airborne dust or contamination. Most models can be fitted with a filter to further lower the level of airborne dust produced. Debris

produced by shotblasting will contain particles of material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific materials or contaminant being removed. Special ventilation provisions may be required when operating gasoline-, diesel-, or propane-powered units indoors. The noise factor may exceed 85 dB. Vibration is not considered to be a factor.

8.12.7 Execution

Shotblasting provides a uniform cleaning pattern across the width of the machine. The machine is steered in a straight line across the surface. At the end of each pass, the machine is turned around and steered parallel to the previous path with minimum overlap. Some overlap is required to prevent the development of unprepared strips between passes.

8.12.8 Equipment

- Shotblasting machine including vacuum system available in gasoline-, diesel-, propane-, or electric-powered units (Fig. 8.12.a and 8.12.d);
- Power source: Requirements for electric-powered units will vary from 110/120 V at 18 A to 460 V at 80 A;
- Brooms and shovels;
- Spare parts for blaster maintenance; and
- Magnets or magnetic broom to retrieve fugitive steel shot.

8.12.9 Materials

Steel shot is the consumed material. Consumption ranges from 10 to 20 lb/h (5 to 9 kg/h). The typical size of the steel shot is shown as follows:

Type	Diameter	Profile*
S-170†	0.017 in. (0.43 mm)	CSP 3
S-230	0.023 in. (0.58 mm)	CSP 3
S-280	0.028 in. (0.71 mm)	CSP 3
S-330	0.033 in. (0.84 mm)	CSP 5
S-390	0.039 in. (1.0 mm)	CSP 5
S-460	0.046 in. (1.17 mm)	CSP 7
S-550†	0.055 in. (1.40 mm)	CSP 9

*Each type of shot will produce a CSP range. The profile obtained is also influenced by machine setup and rate of travel.

†Use of this size is not recommended by some manufacturers.

8.12.10 Labor

Individuals operating the equipment should be experienced and well-trained. An individual with intermediate mechanical skills can operate and maintain most shotblast systems. Large, electrically powered machines require connection to a three-phase, high-voltage power source that may require a licensed electrician.

8.12.11 Setup and downtime

Surfaces must be dry and broom-cleaned prior to shotblasting. Electrical equipment must be connected to an

adequate power source. A test area is required to ensure that media size and machine adjustment will achieve desired performance. Replacement of worn blasting wheels and liners is required every 20 to 40 hours and will take 20 to 45 minutes. Equipment is shut down every 30 to 60 minutes to remove debris from the collection system.

8.12.12 Cleanup

Steel shot may remain on the surface, in edges or corners, or trapped in cracks. It may be recovered by using magnets, a magnetic broom, air blasting, a vacuum, or a stiff-bristle broom.

8.12.13 Production rates

The following rates are approximate and assume a sound horizontal concrete surface. Actual production rates may vary considerably and depend on the strength of the concrete, the type of material being removed, preparation objectives, operator skill, and efficiency of equipment employed.

- Small units (5 to 8 in. [130 to 200 mm]): 150 to 250 ft²/h [15 to 25 m²/h];
- Medium units (8 to 13 in. [200 to 330 mm]): 350 to 1800 ft²/h [30 to 170 m²/h]; and
- Large units (15 to 30 in. [380 to 760 mm]): 2000 to 7500 ft²/h [200 to 700 m²/h].

8.12.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength. Beads of water may indicate a surface contaminant that could require further surface preparation to achieve a clean surface.

8.12.15 Safety hazards

Shotblasting may cause the release of high-velocity steel shot. If gas- or diesel-powered equipment is used, the area should be well-ventilated. Minimum recommended PPE is:

- Eye protection—Meeting ANSI requirements for high impact and face shield;
- Respiratory protection—May be required in confined areas where dust is present; and
- Hearing protection—Process may generate noise levels in excess of 85 dB. Noise levels may require the use of earplugs and/or earmuffs.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

8.13 Surface Retarder



Fig. 8.13.a: Application of surface retarder



Fig. 8.13.c: Rinsing of exposed surface



Fig. 8.13.b: Removal of retarder using broom and rinse water



Fig. 8.13.d: Exposed surface

8.13.1 Summary

Concrete surface hydration retarders may be used to remove the surface of unhydrated cement following concrete placement. The process exposes the aggregate and provides a deep profiled textured finish for bonding materials such as epoxies and cementitious grouts, toppings, and overlays (Fig. 8.13.c and 8.13.d). Surface retarders may be used to provide a light profile for rapid-hardening concrete, spray-applied mortars, or shotcrete. They are suitable for freshly placed, sloped, and horizontal surfaces. Some specialty types of surface retarders are designed to apply to formwork prior to concrete placement to achieve an architectural finish or a profiled surface for construction joints.

8.13.2 Removal

This method involves the application of a material that temporarily inhibits the surface hydration of freshly placed concrete or mortar. The retarder is washed off within several days following application to provide a high-profile, textured surface. This method does not cause microcracking.

8.13.3 Profile

CSP 5 to 10—Surface hydration retarders produce a range of profiles depending on the following factors:

- The chemical composition of the surface hydration retarder;

- The speed of hydration of the freshly placed concrete or mortar, the temperature of the material, the ambient conditions, and other factors;
- The time between application of the retarder and removal; and
- The pressure of the wash water and aggressiveness of the removal of the retarder.

Retarders may be used to produce a CSP 10 for the application of monolithic toppings, additional layers of shotcrete or spray-applied mortar, and epoxy or cementitious grouts. The surface hydration retarder should not produce any noticeable pattern.

8.13.4 Accessibility

The surface retarder may be used on any surface that can be accessed prior to hardening of the freshly placed concrete or mortar. The surface retarder may have to be covered, which could affect accessibility. Formwork retarders should typically be allowed to dry prior to concrete or mortar placement.

8.13.5 Limitations

Surface hydration retarders are suitable for application to freshly placed cementitious concrete or mortar. They should not be used on:

- Hardened substrates;

- When control of the hydration is not possible or when timing of the removal of the retarded material cannot be accurately assessed; and
- When close tolerance of the surface profile (less than CSP 5) is required.

8.13.6 Environmental factors

Surface hydration retarders will produce wash water that will have a pH similar to that of the freshly placed concrete or mortar (pH 12 to 13.5). The chemical composition of the retarder may require additional precautions (consult the manufacturer's material safety data sheet [MSDS]).

8.13.7 Execution

Follow the manufacturer's recommendation for mixing and application of the retarder. Apply the surface hydration retarder immediately following placement of fresh concrete or mortar by evenly spraying the liquid material onto the surface in accordance with the manufacturer's instructions (Fig. 8.13.a).

For spray-on surface types, prevent the surface from drying by covering the surface with polyethylene, burlap/polyethylene laminate, or other impervious sheet covering. For formwork retarders, allow to dry or harden in accordance with the manufacturer's instructions.

Allow the concrete to cure sufficiently to resist the effects of the washing of the unhydrated surface material (typically overnight). Retarders slow the hydration process but do not stop it and need to be removed before the surface can harden and prevent removal (typically remove within 4 days following application). Periodic inspections are needed to determine the amount of hardening that has occurred to determine the timing of the removal of the unhydrated material.

The retarder and unhydrated cement may be removed using potable water with a garden-hose nozzle or a pressure washer with sufficient power to expose the aggregate (Fig. 8.13.b and 8.13.c). Rinse until the washing water runs clear. Dispose of the debris and wash water in accordance with state and local requirements. Overspray of the surface hydration retarder can usually be removed by rinsing with water.

8.13.8 Equipment

A sprayer is recommended to evenly apply the retarder material. A garden hose or pressure washer should be used to remove the retarder and unhydrated material following curing.

8.13.9 Materials

Surface hydration retarder and polyethylene, burlap, or other impervious sheet film for curing of the system.

8.13.10 Employee skill level

Low skill is required for application and removal. Moderate skill is required to assess proper timing of removal.

8.13.11 Setup and downtime

Minimum setup is required for preparing the retarder for application. Time must be allowed for the concrete or mortar to cure sufficiently to allow the removal of the unhydrated material to the desired depth.

8.13.12 Cleanup

Cleanup and disposal of rinse water and unhydrated material will be required. Incidental overspray during the washing operation may require precautions for flying debris caused by pressure washing.

8.13.13 Production rates

Productivity is very high. Limiting factors are typically determined by the accessibility of the application area to the surface hydration retarder spray, the amount of area that can be covered with the film after surface hydration retarder application, and the labor involved in washing off and disposal of the unhydrated material and wash water. The production rate is estimated at 300 to 1000 ft²/h (28 to 93 m²/h) depending on placement configuration.

8.13.14 Quality control

Various test techniques are described in Appendix B. The practitioner is encouraged to specify the appropriate test to verify that the desired surface preparation results have been achieved. At a minimum, verify that the CSP required by the specifications has been achieved. Visual inspection should show no dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting materials. A bond test may be required to demonstrate adequate bond strength.

8.13.15 Safety hazards

Surface retarders are chemicals that may cause injury if exposed to any part of the body. In addition, water will be used to rinse the unhydrated material from the surface. This rinse water will be highly alkaline (pH 12 to 13.5). Employees must be trained in the proper use and handling of the retarder materials. Minimum recommended PPE is:

- Eye protection—Anti-fog goggles meeting ANSI requirements for chemical resistance, high impact, and face shield;
- Alkaline-resistant gloves, aprons, and clothing;
- Respiratory protection using respirators equipped with acid-gases canister;
- Hearing protection may be required if powered scrubbers are used; and
- Boots, gloves, and water-resistant clothing are required during the washing operation.

Consult the material and equipment manufacturer's current recommended safety procedure. Consult ICRI Guideline No. 120.1 (Sections 2.0 through 7.0) for guidelines and recommendations for safety in the concrete repair industry. Refer to Appendix C for additional information on safety issues related to concrete surface preparation.

9.0 References

9.1 Referenced Standards and Reports

The standards and reports listed as follows were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

ASTM International

ASTM D4258, "Standard Practice for Surface Cleaning Concrete for Coating"

ASTM D4259, "Standard Practice for Abrading Concrete"

ASTM D4260, "Standard Practice for Liquid and Gelled Acid Etching of Concrete"

ASTM D5295, "Standard Guide for Preparation of Concrete Surfaces for Adhered (Bonded) Membrane Waterproofing Systems"

ASTM E1575, "Standard Practice for Pressure Water Cleaning and Cutting"

ASTM E1857, "Standard Guide for Selection of Cleaning Techniques for Masonry, Concrete, and Stucco Surfaces"

ASTM F2471, "Standard Practice for Installation of Thick Poured Lightweight Cellular Concrete Underlayments and Preparation of the Surface to Receive Resilient Flooring"

International Concrete Repair Institute

ICRI Technical Guideline No. 120.1, "Guideline and Recommendations for Safety in the Concrete Repair Industry"

ICRI Technical Guideline No. 310.3, "Guide for the Preparation of Concrete Surfaces for Repair Using Hydrodemolition Methods"

The Society for Protective Coatings

SSPC-SP 13/NACE No. 6, "Surface Preparation of Concrete"

Transportation Research Board

SHRP-S-336, "Techniques for Concrete Removal and Bar Cleaning on Bridge Rehabilitation Projects," Chapter 4; Hand-held Pneumatic Breakers; Chapter 6, Hydrodemolition

WaterJet Technology Association

WJTA, "Recommended Practices for the Use of High Pressure Water jetting Equipment"

These publications may be obtained from these organizations:

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428
www.astm.org

International Concrete Repair Institute (ICRI)
10600 West Higgins Road, Suite 607
Rosemont, IL 60018
www.icri.org

The Society for Protective Coatings (SSPC)
40 24th Street, 6th Floor
Pittsburgh, PA 15222
www.sspc.org

Transportation Research Board Office (SHRP)
500 Fifth Street, NW
Washington, DC 20001
www.trb.org

WaterJet Technology Association (WJTA)
906 Olive Street; Suite 1200
St. Louis, MO 63101
www.wjta.org

9.2 Cited References

Bissonnette, B.; Courard, L.; Vaysburd, A. M.; and Belair, N., 2006, "Concrete Removal Techniques," *Concrete International*, V. 28, No. 12, Dec., pp. 49-55.

Appendix A

Surface Preparation Selection

The Method Selection Process

Surface preparation decisions require a thorough understanding of the substrate conditions, protective system or repair material requirements, and the job-site conditions. The type of material selected for installation will generally determine the type of surface preparation required and the resulting concrete surface profile (CSP) to be achieved. However, substrate conditions can vary, ranging from concrete in good condition to deteriorated concrete. Careful examination and testing of the substrate will ensure that the proper surface preparation method(s) is/are selected.

The checklists that follow will help ensure that critical information is identified and considered. The information collected during the initial evaluation phase is used to develop criteria for the selection of a surface preparation method(s). Once the criteria have been determined, the Method Selector (Section 7.0) and Method Summaries (Section 8.0) may be used to identify the method, or combination of methods, most likely to produce the desired results for the project.

A.1 Substrate Condition

The condition of the substrate, including strength, cause and extent of deterioration, existing coatings and sealers, and many other factors, will define the nature and degree of preparation required. Although a discussion of the various techniques to perform a complete survey of existing conditions is beyond the scope of this guideline, the following checklist provides examples of the types of information that should be considered. Methods to test and verify the surface preparation are provided in Appendix B.

The following is a checklist of the items found in the Substrate Condition Evaluation Tree (Fig. A.1):

A.1.1 Surface Conditions

- Efflorescence, Encrustations, Soil
 - a) Type
 - b) Thickness
 - c) Bond strength
- Surface Imperfections
 - a) Laitance
 - b) Bugholes

- c) Dusting
 - d) Ridges
 - e) Exposed aggregate
 - f) Abrasion
- Previous Patches
- Bond Breaking Contaminants
 - a) Form Release
 - b) Curing Compound
 - c) Existing Membrane/Coatings
 - d) Oil
 - e) Latex modifiers

A.1.2 Soundness

- Delaminated Concrete Depth
 - a) Spalled
 - b) Strength
 - c) Porosity
 - d) Freeze/Thaw
 - e) Alkali Reactivity
 - f) Sulfate Attack
- Pull-off tests
- Chloride Content and Penetration Depth
- Carbonation Depth and pH

A.1.3 Hazardous Materials

- PCB
- Frangible Asbestos
- Chemicals
- Lead
- Heavy Metals

A.1.4 Finish

- Formed
- Wood Float
- Metal Trowel
- Power Trowel
- Broom Finish
- Sacking
- Stoning
- Block
- Shotcrete

A.1.5 Moisture

- Concrete Maturity (Fresh/Green Concrete)
- Hydrostatic Pressure
 - a) Positive Hydrostatic
 - b) Negative Hydrostatic
- Substrate Moisture
 - a) Internal Relative Humidity (Probes)
 - b) Moisture Vapor Emission
- Vapor Barrier Present
 - a) Over Granular Fill
 - b) Under Granular Fill
- No Vapor Barrier
- Drainage

A.1.6 Joints and Cracking

- Cold Joints
- Construction Joints
- Expansion

- Dynamic
- Static
- Cracking
- Leaking

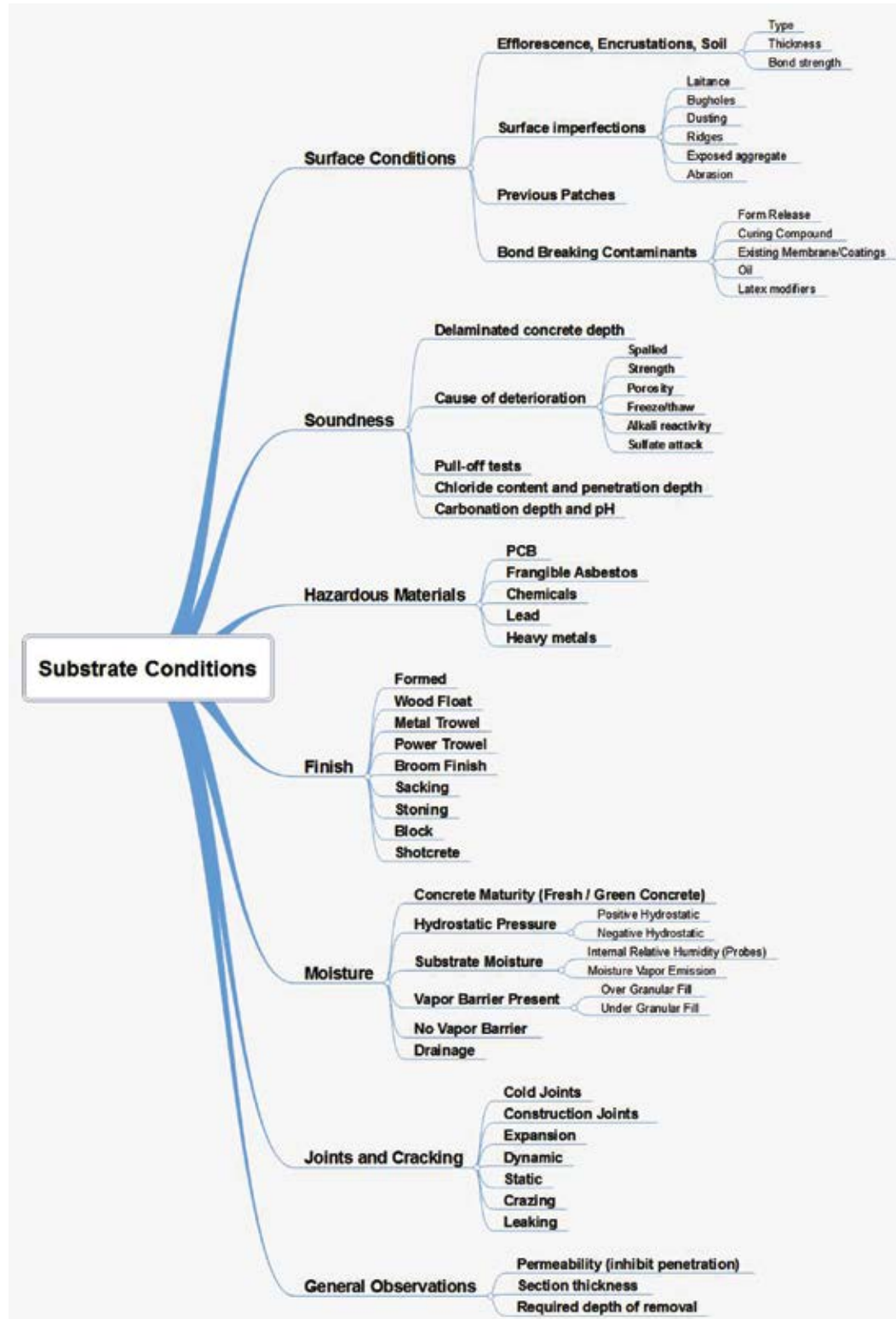


Fig. A.1: Substrate Condition Evaluation Tree

A.1.7 General Observations

- Permeability (inhibit penetration)
- Section Thickness
- Required Depth of Removal

- c) Moisture vapor emission
- d) Cleaning method
- Alkali tolerance
- Cleanliness (dust)

A.2 Protective system and repair material requirements

Decisions concerning surface preparation cannot be made without knowing the properties and application requirements of the material to be applied. Surface preparation and profile requirements in particular will vary with the repair material and/or protective system.

The following is a checklist of the items found in the Material Requirement Evaluation Tree (Fig. A.2):

A.2.1 Substrate Strength

- Tensile bond strength

A.2.2 Profile

- Sealers—0 to 3 mils (0 to 0.075 mm): CSP 1-2
- Thin film coatings—4 to 10 mils (0.01 to 0.025 mm): CSP 1-3
- High build coatings—10 to 40 mils (0.025 to 1.0 mm): CSP 3-5
- Self-leveling—50 mils to 1/8 in. (1.2 to 3.0 mm): CSP 4-6
- Polymer overlays (1/8 to 1/4 in. ([3 to 6 mm]): CSP 5-9
- Concrete overlays, toppings, and repairs—>1/4 in. (>6 mm): CSP 5-10

A.2.3 Other

- Application thickness
- Moisture tolerance
 - a) Wet substrate OK
 - b) Dry substrate needed

A.3 Job-site Conditions

Noise, vibration, dust, and water may be generated by various preparation methods. These can disrupt use of the structure or damage its contents. The owner's need for uninterrupted use of the structure, concerns about the operating environment, or property damage potential may limit the choice of surface preparation method. The generation of dust, slurries, or large volumes of water may introduce requirements for their containment and safe disposal. The type and capacity of mechanical ventilation and available power sources, the size of door openings, and minimum vertical clearance are all examples of application conditions that will affect decisions regarding surface preparation method selection.

The following is a checklist of the items found in the Jobsite Conditions Evaluation Tree (Fig. A.3):

A.3.1 Accessibility

- Physical Constraints
 - a) Height
 - b) Load Bearing Capacity
 - c) Doors
 - d) Access
 - e) Width/Turning Radius
 - f) Area
- Surface Orientation
 - a) Horizontal
 - b) Vertical
 - c) Overhead
 - d) Slab on Grade
 - e) Supported

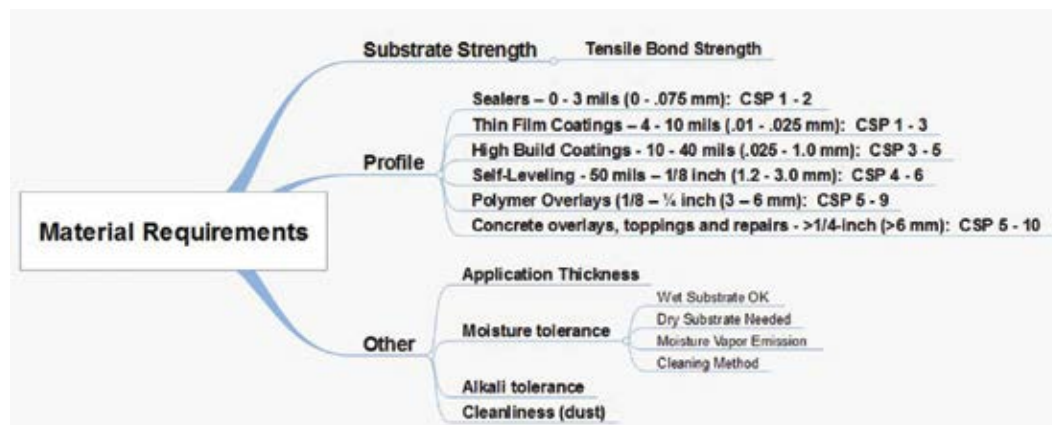


Fig. A.2: Material Requirement Evaluation Tree

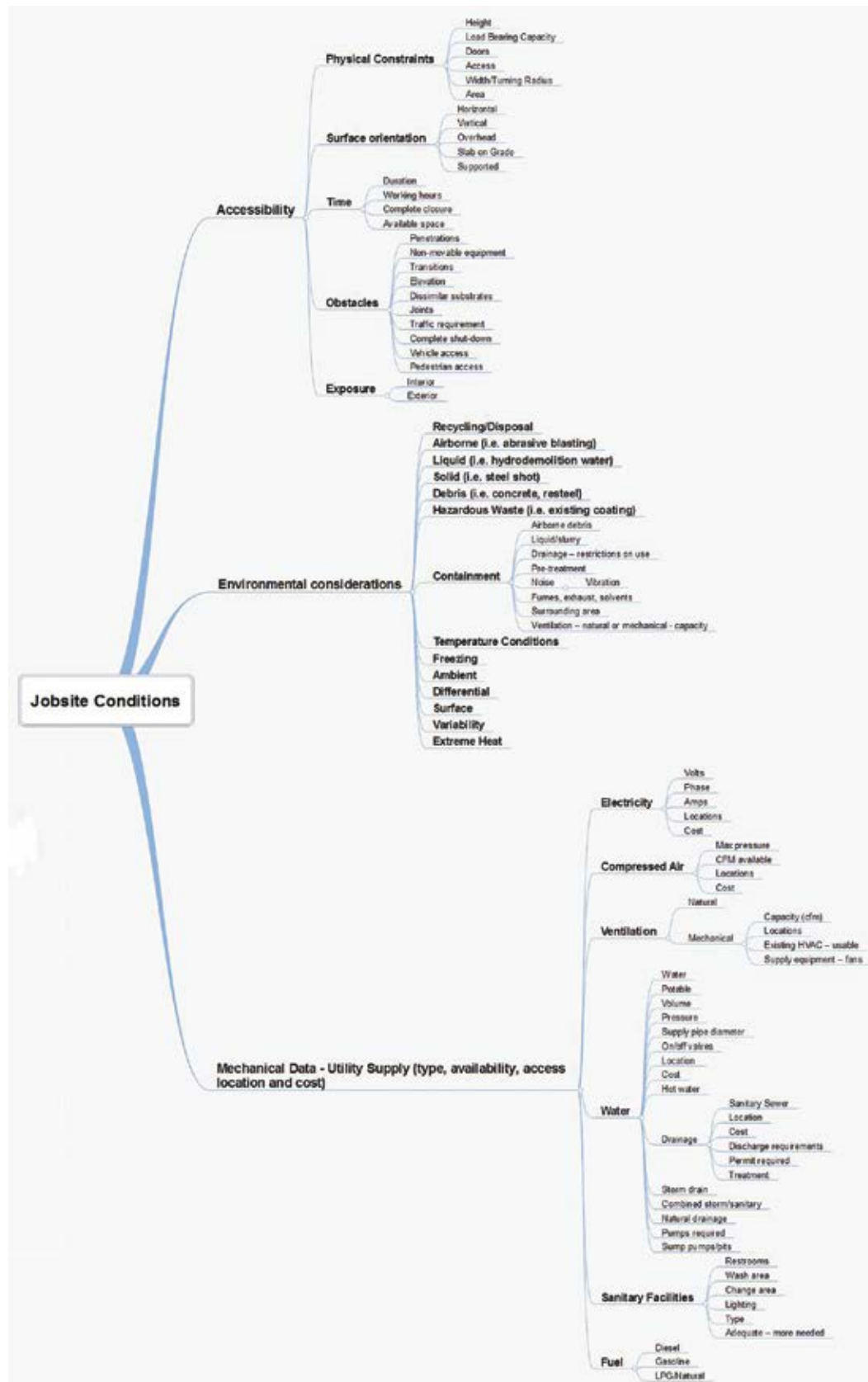


Fig. A.3: Jobsite Conditions Evaluation Tree

- Time
 - a) Duration
 - b) Working Hours
 - c) Complete Closure
 - d) Available Space
- Obstacles
 - a) Penetrations
 - b) Non-Movable Equipment
 - c) Transitions
 - d) Elevation
 - e) Dissimilar Substrates
 - f) Joints
 - g) Traffic Requirement
 - h) Complete Shut-Down
 - i) Vehicle Access
 - j) Pedestrian Access
- Exposure
 - a) Interior
 - b) Exterior

A.3.2 Environmental Considerations

- Recycling/Disposal
- Airborne (i.e. abrasive blasting)
- Liquid (i.e. hydrodemolition water)
- Solid (i.e. steel shot)
- Debris (i.e. concrete, resteel)
- Hazardous Waste (i.e. existing coating)
- Containment
 - a) Airborne Debris
 - b) Liquid/Slurry
 - c) Drainage—restrictions on use
 - d) Pre-treatment
 - e) Noise
 - f) Vibration
 - g) Fumes, Exhaust, Solvents
 - h) Surrounding Area
 - i) Ventilation—natural or mechanical—capacity
- Temperature Conditions
- Freezing
- Ambient
- Differential
- Surface
- Variability
- Extreme Heat

A.3.3 Mechanical Data— Utility Supply (type, availability, access location and cost)

- Electricity
 - a) Volts
 - b) Phase
 - c) Amps
 - d) Locations
 - e) Cost
- Compressed Air
 - a) Maximum Pressure
 - b) CFM Available
 - c) Locations
 - d) Cost
- Ventilation
 - a) Natural
 - b) Mechanical
 - 1. Capacity (cfm/cmm)
 - 2. Locations
 - 3. Existing HVAC—usable
 - 4. Supply equipment—fans
- Water
 - a) Portable
 - b) Volume
 - c) Pressure
 - d) Supply pipe diameter
 - e) On/off valves
 - f) Location
 - g) Cost
 - h) Hot Water
 - i) Drainage
 - 1. Sanitary Sewer
 - 2. Location
 - 3. Cost
 - 4. Discharge Requirements
 - 5. Permit required
 - 6. Treatment
 - j) Storm Drain
 - k) Combined Storm/Sanitary
 - l) Natural Drainage
 - m) Pumps Required
 - n) Sump Pumps/Pits
- Sanitary facilities
 - a) Restrooms
 - b) Wash Area
 - c) Change Area
 - d) Lighting
 - e) Type
 - f) Adequate—more needed
- Fuel
 - a) Diesel
 - b) Gasoline
 - c) LPG Natural

Appendix B Testing

Test methods to determine the quality and suitability of the concrete surface following surface preparation.

Index

- B.1 Tensile Bond Strength Test—
ICRI 210.3 and ASTM C1583/C1583M
- B.2 Adhesion Test—ASTM D7234
- B.3 Knife Adhesion Test—ASTM D6677
- B.4 Measuring the Surface pH following
Chemical Cleaning—ASTM D4262
- B.5 Surface Profile—ICRI 310.2R
- B.6 Replica Putty—ASTM D7682
- B.7 Replica Tape—ASTM D4417
- B.8 Laser Profilometry
- B.9 Sand Method—ASTM E965
- B.10 Visual Inspection—ASTM D4258
- B.11 Petrographic Analysis—ASTM C856
- B.12 Surface Cleanliness Using Tape—
ASTM E1216
- B.13 Sounding the Surface—
ASTM D4580/D4580M
- B.14 Water Absorption—ASTM F21
- B.15 Moisture in Concrete—ASTM D4263,
ASTM F1869, ASTM F2170, and
ASTM F2420
- B.16 ICRI Concrete Slab Moisture Testing
Certification Program

B.1 Tensile Bond Strength Test

ICRI Technical Guideline No. 210.3, “Guide for Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials,” and ASTM C1583/C1583M, “Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method).”

The tensile bond test is used to assess the adequacy of the prepared substrate prior to the installation of material (test the substrate only) or following the application (test the repair composite system). The advantage of evaluating the prepared substrate is that additional surface preparation may be performed if necessary without the cost of removing the applied material afterward. The test is used to determine the potential for bond failure between the applied material and the prepared substrate.

This test is conducted by coring the substrate or repair composite, attaching a metal disc within

the cored area, and applying a load perpendicular to the surface and measuring the force required to cause failure at the substrate or within the repair composite. Load at failure is recorded in pounds per square inch (psi). The location of the failure will identify the weakest link in the repair application and may be an indicator of inadequate surface preparation. Tensile bond test devices are shown in Fig. B.1.a and B.1.b.



Fig. B.1.a: Tensile bond test device

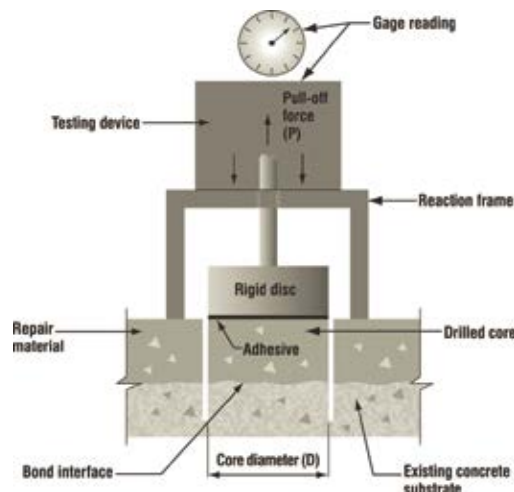


Fig. B.1.b: Tensile bond test device
(repair composite system)

B.2 Adhesion Test

ASTM D7234, “Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers” (Fig. B.2).

This test method covers procedures for evaluating the pull-off adhesion strength of a coating on concrete. The test determines the greatest perpendicular force (in tension) that a surface area can bear before a plug of material is detached.

Failure will occur along the weakest plane within the system, which includes:

- Adhesive to test fixture;
- Adhesive to the coating surface;
- Adhesion of each coating layer within a system;
- Adhesion of the coating to the substrate; and
- Tensile strength within the substrate.

The general pulloff adhesion test is performed by scoring through the coating down to the surface of the concrete substrate at a diameter equal to the diameter of the loading fixture (dolly, stud), and securing the loading fixture normal (perpendicular) to the surface of the coating with an adhesive. After the adhesive is cured, a testing apparatus is attached to the loading fixture and aligned to apply tension normal to the test surface. The force applied to the loading fixture is then increased and monitored until a plug of material is detached. When a plug of material is detached, the exposed surface represents the plane of limiting strength within the system. The nature of the failure is qualified in accordance with the percent of adhesive and cohesive failures, and the actual interfaces and layers involved. The pulloff adhesion strength is computed based on the maximum indicated load and the fracture surface area.



Fig. B.2: Portable adhesion tester

B.3 Knife Adhesion Test

ASTM D6677, “Standard Test Method for Evaluating Adhesion by Knife”

This test method covers the procedure for assessing the adhesion of coating films to substrate by using a knife. This test method is used to establish whether the adhesion of a coating to a substrate or to another coating (in multi-coat systems) is at a generally adequate level. This test requires uses a utility knife to remove the coating. It helps determine if the adhesion of a coating to a substrate or to another coating (in multi-coat systems) is acceptable.

Using a knife and straightedge, two cuts are

made into the coating with a 30- to 45-degree angle between them and down to the substrate, which intersects to form an “X.” At the intersection of the two cuts, the point of the knife is used to attempt to peel the coating from the substrate or from the coating below. This is a highly subjective test and its value depends on the inspector’s experience.

B.4 Measuring the Surface pH following Chemical Cleaning

ASTM D4262, “Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces”

Chemical cleaning and etching is sometimes used to prepare concrete for coating. Residual chemicals not removed by water rinsing may adversely affect the performance and adhesion of coatings applied over prepared concrete surfaces. This test method is used to determine if residual chemicals have been removed by measuring the acidity or alkalinity of the final rinsed surface.

B.5 Surface Profile

ICRI 310.2R Concrete Surface Profile (CSP) profiles.

The surface preparation specification may include a CSP required profile, which can be compared with the CSP molded replicas available from ICRI. These replicas provide a visual comparison with the actual profile created during the surface preparation.

Place CSP replicas (Fig. B.3) on the prepared surface and visually compare the profile with the replicas. The profile of the surface should be in the range specified.



Fig. B.3: CSP replicas

B.5.1 Measuring the Surface Profile

Visual observation of the surface profile may not provide a satisfactory determination of the surface profile. More qualitative/quantitative

methods, including the Replica Putty and Sand Method, are available to further define the surface profile. The measurement of roughness can lead to optimization of bonding strength.

B.6 Replica Putty

ASTM D7682, “Standard Test Method for Replication and Measurement of Concrete Surface Profiles Using Replica Putty”



Fig. B.4.a: Method A Visual

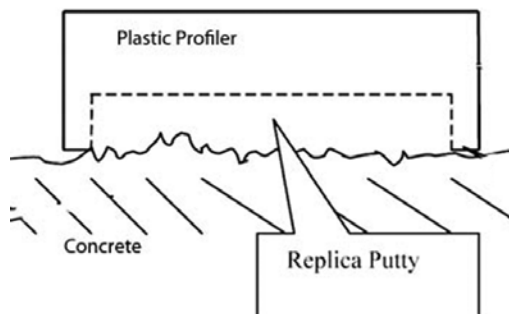


Fig. B.4.b: Replica putty applied to the surface



Fig. B.4.c: Method B Quantitative

Ensuring that the correct surface profile has been achieved can best be done with the use of replica putty. A permanent replication of the surface may be viewed (Method A—Fig. B.4.a) and/or measured (Method B—Fig. B.4.c) to form a permanent record of the surface preparation.

Replica putty is applied to the surface (Fig. B.4.b) and allowed to cure. Once removed from the surface, the putty represents a reverse image of the surface. The peaks and valleys of the surface can be measured using a specially modified thickness gauge (Fig. B.4.c). The data can be analyzed to determine the surface profile range (highest measured peak to lowest measured valley).

B.7 Replica Tape

ASTM D4417, “Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel”



Fig. B.5.a: Surface replica tape kit



Fig. B.5.b: Measuring the surface profile

Method C uses a special tape containing compressible foam attached to a noncompressible uniform plastic film (Fig. B.5.a and B.5.b). A burnishing tool is used to impress the foam face of the tape into the surface to create a reverse replica of the profile that is measured using a spring-loaded micrometer. This method is designed for relatively smooth surfaces (CSP 1 to 3) prepared using sand, grit abrasive blasting,

or steel shotblasting and may not be applicable to rougher profiles.

B.8 Laser Profilometry

The digital surface roughness meter (DSRM) measures the surface roughness of a prepared surface using a line laser.

The DSRM (Fig. B.6) is placed flush with the surface to be measured. An image of the profile is transmitted to a computer, where the image is digitized; the profiles are automatically isolated and measured for roughness. This method will provide a permanent record of the surface roughness. (Maerz, N. H.; Chepur, P.; Myers, J.; and Linz, J., 2001, "Concrete Roughness Measurement Using Laser Profilometry for Fiber Reinforced Polymer Sheet Application," Presented at the Transportation Research Board 80th Annual Meeting, 12 pp.)



Fig. B.6: Digital surface roughness meter

B.9 Sand Method

ASTM E965, "Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique"

The average surface texture (macro-texture) may be measured using a known volume of sand or other fine grain material and spreading it uniformly over the surface and measuring the area covered. Using the standard formula for volume ($L \times W \times D$), the approximate amplitude of the surface may be determined. This method will assist in determining the amount of material that may be necessary to fill the macro-texture before applying a uniform layer of material over the surface.

Apply a known volume of sand to the surface. Carefully spread the sand in a circular motion using a large flat spreading tool, slowly increasing the diameter of the circular motion until all the sand has been spread. Measure the diameter of

the circle and calculate the average depth. $AD = (V \text{ sand} / A \text{ area of the circle})$. Figures B.7.a and B.7.b depict this method.

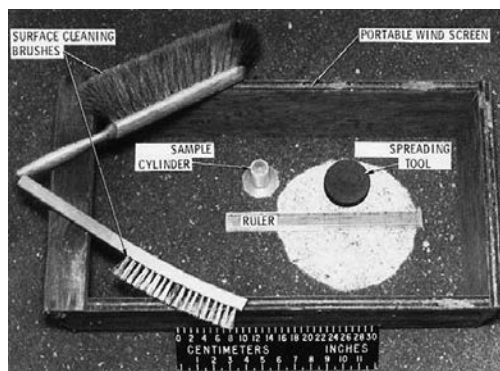


Fig. B.7.a: Sand test (ASTM E965)



Fig. B.7.b: Measuring sand spread

B.10 Visual Inspection

ASTM D4258, "Standard Practice for Surface Cleaning Concrete for Coating"

This describes a method of surface cleaning that is intended to provide a clean, contamination-free surface without removing concrete from an intact, sound surface. Following the cleaning, visually examine the prepared surface to verify that it is free of debris, dust, dirt, oil, grease, loosely adherent concrete, and other contaminants. Test surfaces cleaned with detergent or non-solvent emulsifying agents for pH following ASTM Test Method D4262. Moisture content may be determined following ASTM Test Method D4263.

B.11 Petrographic Analysis

ASTM C856, "Standard Practice for Petrographic Examination of Hardened Concrete"

While petrography can be used to detect a variety of flaws within concrete, it can also be used following surface preparation to determine if the method used to prepare the surface caused microcracking in the substrate.

The test is made by extracting a sample of the concrete and observing it under a microscope (Fig. B.8.a). Microcracks (Fig. B.8.b) weaken the substrate and should be removed by further surface preparation prior to installation of any materials.



Fig. B.8.a: Microscopic examination

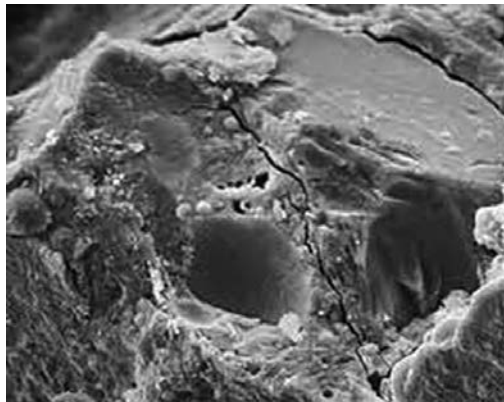


Fig. B.8.b: Microcracks

B.12 Surface Cleanliness Using Tape

ASTM E1216, “Standard Practice for Sampling for Particulate Contamination by Tape Lift”



Fig. B.9: Transparent tape, magnifying light, and background for measuring surface contamination

This practice covers procedures for sampling surfaces to determine the presence of particulate contamination 5 mm and larger. The practice consists of the application of a pressure-sensitive tape to the surface followed by the removal of particulate contamination with the removal of the tape (Fig. B.9).

B.13 Sounding the Surface

ASTM D4580/D4580M, “Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding”

The surface may be sounded either before or after surface preparation to determine if there is any delaminated concrete. Delaminated concrete will produce a hollow sound when a chain is dragged over the area or the surface is struck with a hammer. Areas that are delaminated should be marked for further preparation.

- Electromechanical sounding device (Fig. B.10.a)—Uses an electric-powered tapping device, sonic receiver, and recorder mounted on a cart. The cart is pushed across the concrete surface and delaminations are recorded.



Fig. B.10.a: Electromechanical sounding device

- Chain drag—Consists of dragging a chain over the concrete surface (Fig. B.10.b). The detection of delaminations is accomplished by the operator hearing a dull or hollow sound. Tapping the surface with a steel rod or hammer may be substituted for the chain drag (Fig. B.10.c).
- Rotary percussion—Uses a dual-wheel, multi-toothed apparatus attached to an extension pole, which is pushed over the concrete surface (Fig. B.10.d). The percussive force caused by the tapping wheels will create either a dull or hollow sound, indicating a delamination.



Fig. B.10.b: Chain dragging the surface



Fig. B.10.c: Sounding using a hammer



Fig. B.10.d: Rotary percussion tool

B.14 Water Absorption

ASTM F21, “Standard Test Method for Hydrophobic Surface Films by the Atomizer Test”

The presence of water-repelling materials may interfere with the bond or penetration of applied material. Surface preparation should remove any water-repellent material that may interfere with the performance of the applied material. The atomizer test is performed by

applying a fine water spray to the dry concrete surface and observing the wetting pattern. In the absence of hydrophobic films, the water droplets will wet the surface and spread immediately and darken the surface as the water is absorbed. In areas where hydrophobic materials are present on the surface, the water will not wet the surface but will tend to remain as fine droplets or beads of water on the surface (Fig. B.11). This test is less effective on extremely low-permeability concrete or surfaces with dense finishes upon which water may bead, even in the absence of hydrophobic materials.

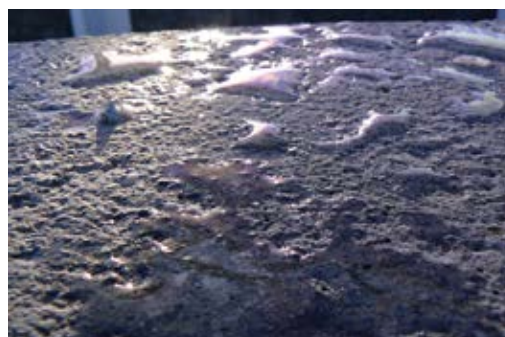


Fig. B.11: Water beading on a water-repellent surface

B.15 Moisture in Concrete

High levels of moisture in a concrete substrate can have a detrimental effect on many types of applied materials. Most manufacturers of coatings and overlay materials have specific levels of moisture that must be reached before their products can safely be installed. ASTM offers several methods to measure moisture in concrete slabs, as follows:

- Plastic Sheet Method—ASTM D4263, “Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method.”



Fig. B.12.a: Moisture in concrete test using the plastic sheet method

For this method, an 18 in. (460 mm) square transparent polyethylene sheet, at least 4 mils

(0.10 mm) thick, is taped to the concrete surface (Fig. B.12.a). The plastic sheet remains in place for a minimum of 16 hours, after which the plastic is removed; the underside of the sheet and the concrete surface are then visually inspected for the presence of moisture.

- Calcium Chloride (CaCl) Method—ASTM F1869, “Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride.”

This test method (Fig. B.12.b) quantifies the amount of water vapor emitting from the surface region of a concrete subfloor and is performed as follows:

1. Prepare a 20 x 20 in. (500 x 500 mm) area of the concrete surface by dry vacuum grinding to a CSP 1 to 2 to remove any existing coatings, adhesive, or surface contamination.

Note: If an existing coating, sealer, or adhesive is removed, the prepared surface must be left open for 24 hours before installing the test kit. If the surface was bare concrete, then after the surface is ground, the kit can be installed immediately.

2. The dish of calcium chloride crystals with lid and tape is weighed to the nearest 0.004 oz (0.1 g) on a calibrated gram scale.
3. The starting weight, date, time, location, and ambient conditions are recorded along with the name of the person performing the test.
4. The tape is removed and taped to the underside of the plastic dome, the dish is opened, and the lid is inverted and placed beneath the dish and placed in the center of the prepared area.
5. Immediately after setting the dish, the plastic dome is placed over the dish with the dish as close to center beneath the dome as possible, and the dome sealed to the concrete surface.
6. After a minimum of 60 hours, but no more than 72 hours, the dish is removed and resealed with the original lid and tape.
7. The sealed dish is reweighed on a calibrated scale.
8. The moisture vapor emission rate (MVER) is calculated by multiplying the increase in weight by the exposure area and dividing by the time period. The MVER value is expressed in pounds of water / 1000 ft² (100 m²) / 24 hours.



Fig. B.12.b: Moisture vapor emission test using the calcium chloride method

- Moisture Probe Method—ASTM F2170, “Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes”



Fig. B.12.c: Moisture probe method equipment

This test method measures the moisture within the concrete and is a predictor of what the moisture level will be in the slab, top-to-bottom, once the slab is covered. The method uses a humidity probe (Fig. B.12.c) to measure the relative humidity in a concrete subfloor at a specific target depth. For slabs on ground or on a metal deck, the measurement is taken at a depth equaling 40% of the slab thickness. If the slab is elevated such that it can dry from the top and bottom, the measurement is taken at 20% of the slab thickness. A rotary hammer drill with a carbide bit is used to drill into the concrete to the target depth. After the proper depth has been confirmed, the hole is brushed and vacuumed thoroughly clean. A full-depth ribbed hole liner is then inserted to the bottom of the drilled hole such that a relative humidity (RH) measurement can be taken at the specific target depth after the liner has been in place for a minimum period of 72 hours. The RH probe (Fig. B.12.d) can be installed immediately and left in place for the entire test period or inserted after the 72-hour equilibration

period. A measurement is recorded on the reader unit when the RH % does not drift more than 1% in 5 minutes which, in most cases, will take at least 1 hour after a probe is inserted into the liner.



Fig. B.12.d: Installing a moisture probe

- Hood Test—ASTM F2420, “Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood”



Fig. B.12.e: ASTM F2420 Test being conducted

The hood method (Fig. B.12.e) is similar to the ASTM F1869 calcium chloride method. However, the units are different and therefore not directly comparable as the hood method is measuring the RH above the slab, while the calcium chloride test is measuring pounds of moisture vapor emission per 1000 ft² (100 m²) per 24-hour period. Both of these tests measure moisture in approximately the top 1/4 to 1/2 in. (6 to 13 mm) of the slab while ASTM F2170 measures moisture within the slab thickness. The hood test is performed by:

1. Cleaning the surface;

2. Sealing an insulated hood firmly to the concrete substrate;
3. Placing a stopper in the probe hole;
4. Allowing a minimum period of 72 hours to elapse before taking readings with a probe;
5. Removing the stopper;
6. Inserting a humidity probe and allowing the probe to equilibrate (probe has reached equilibrium when RH readings do not drift more than 1% over a period of 20 minutes); and
7. Taking readings using the humidity probe (Fig. B.12.e).

B.16 ICRI Concrete Slab Moisture Testing Certification Program

ICRI has a Concrete Slab Moisture Testing Certification program. The purpose of this program is to help improve the performance of concrete slab moisture testing in the United States to result in more consistent, accurate results that will help flooring manufacturers, architects, and contractors to make better decisions as to when a concrete floor is ready for a floor-covering installation. This certification program has two tiers and the certification is valid for 5 years. Tier 1 applicants are those who are not regularly engaged in moisture testing, yet have an active interest in learning more about the tests, what the tests mean, and how the tests should be performed. Tier 2 applicants are those who have applied for full certification as an ICRI Concrete Slab Moisture Testing Technician—Grade 1. The ICRI certification program is based on the following four (4) ASTM Standards, including all Annexes and Appendixes:

- F710, “Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring; Section 5.3 pH Testing”
- F1869, “Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride”
- F2170, “Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes”
- F2420, “Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood”

For further information on the ICRI certification program, visit: <http://www.icri.org/Certification/certificationinfo.asp>.

Appendix C

Safety

Safety recommendations for each method are included in the Safety section of the method summaries. This information is intended only to alert users to the nature of the safety issues associated with the method described. Consult the equipment manufacturer's safety requirements for each type of equipment described.

ICRI publications related to safety:

- ICRI Technical Guideline No. 120.1, "Guideline and Recommendations for Safety in the Concrete Repair Industry," Sections 2.0 through 7.0, <http://www.icri.org/publications/bookstore.asp>.
- ICRI White Papers covering hearing and respiratory protection, http://www.icri.org/PUBLICATIONS/2009/PDFs/septoct09/CRBSeptOct09_Silica.pdf; http://www.icri.org/PUBLICATIONS/2012/PDFs/janfeb12/CRBJanFeb12_SafetySolutions.pdf.

OSHA Regulations:

Refer to the OSHA regulations that pertain to each of the surface preparation methods described. These regulations include but are not limited to:

- Eye Protection: 29 CFR - 1926.102, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10665.
- Personal Protective Equipment - Construction: 29 CFR - 1926.28, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10614.
- Respiratory Protection: 29 CFR - 1926.103, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10666&p_table=STANDARDS.
- Hearing Protection: 29 CFR - 1926.101, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10664&p_table=STANDARDS.
- Hazard Communication: 29 CFR - 1926.59, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10633&p_table=STANDARDS.



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