Specification for Non-structural Maintenance Hole Rehabilitation

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TS 4.13.01 Scope

This specification is for the rehabilitation of existing sewer maintenance holes made of concrete and brick. The specification describes the requirements for maintenance hole rehabilitation for the purposes of internal corrosion protection and leak tightness against external ground water pressure. In general, the work requirements include: maintenance hole condition checks, preparation of maintenance holes with grout sealing as needed, rehabilitation materials, rehabilitation installation, sampling and testing quality assurance and all associated work. The rehabilitation shall address and correct a range of deteriorated conditions in the interior of existing maintenance holes. This specification does not include any rehabilitation or other repair that would require excavation at or around the maintenance hole and it does not apply to a fully structural maintenance hole rehabilitation.

Where needed due to active infiltration into a maintenance hole, grout sealing is a temporary measure to be used for the purpose of stopping any active infiltration for the duration of the rehabilitation installation.

Suitable rehabilitation products will achieve the required performance either by providing the specified minimum bond strength to the interior of the maintenance hole – Type A Product or by providing sufficient wall strength in the applied material – Type B product.

This specifications applies to products that are sprayed into place or trowelled into place, it does not include or apply to thermosetting cured-in-place (CIP) products by which a thermo-setting resin impregnated carrier tube–bag–is cured in place in the maintenance hole.

TS 4.13.02 References

This specification refers to the following standards, specifications or publications:

City of Toronto Standard Specifications

TS 4.01	Construction Specification for Sewer Bypass Flow Pumping

American Society of Testing and Materials

C 1583	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)
D 4787-13	Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates
D 7234-12	Standard Test Method for Pull-off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers
F 1216-16	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube

International Concrete Repair Institute

Technical Guideline No. 03732 – Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays

National Association of Corrosion Engineers

No 6. / SSPC SP 13 Surface Preparation of Concrete

TS 4.13.03 Definitions

For the purpose of this specification, the following definitions apply:

Bonded Layer means the layer of the maintenance hole rehabilitation that is bonded to the maintenance hole concrete or brick structure for bonded systems.

Build-out Layer means for some bonded systems, a layer additional to the Bonded Layer for the purpose of providing increased thickness for uniformity of rehabilitation and to meet minimum overall thickness requirements. A Build-out Layer always builds from the bonded layer surface inwards towards the interior of the maintenance hole.

Dolly means loading fixture used for pull testing to substantiate adhesion.

Substrate means the maintenance hole material surface to which the rehabilitation material is bonded (Type A Product) or applied (Type B Product). The substrate is normally the maintenance hole material surface after cleaning and preparation. Where filler material(s) are used to fill gaps, pockets or voids on the maintenance hole wall or to smooth out the maintenance hole wall surface, the substrate is the combination of the maintenance hole material and the filler material. See Figure 1 for illustration of substrate surface.

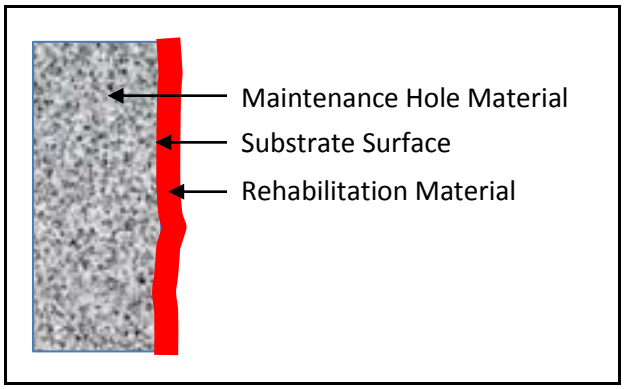

Figure 1: Illustration of substrate definition

Type A Product means utilizes bonding to the interior surface of the maintenance hole to achieve performance objectives and requirements of this specification.

Type B Product means utilizes the inherent wall strength in the in-place rehabilitation material to achieve performance objectives and requirements of this specification. While the product may also adhere to the interior of the maintenance hole adherence–bonding–is not necessary for achieving required performance.

TS 4.13.04 Description of Maintenance Hole Rehabilitation Required

The maintenance hole rehabilitation required shall result in preventing present or future groundwater infiltration into the maintenance hole and preventing present or future corrosion or deterioration of the interior surface. The material(s) used for rehabilitation shall be fully immune to corrosion or deterioration. The corrosion or deterioration to be resisted is corrosion or deterioration that is, or would be, caused by the action of municipal sewage as well as corrosion or deterioration that is, or could be, caused directly or indirectly by hydrogen sulphide (H_2S) gas that may find its way into the maintenance hole structure.

Maintenance hole rehabilitation is not required to enhance or restore the existing capacity to support or resist external or internal loads that may bear, or come to bear, on the maintenance hole structure other than as required to resist infiltration or leakage due to groundwater hydrostatic loading.

Maintenance hole rehabilitation is practical when the existing or post-preparation conditions are considered or deemed structurally sound against external and internal loads. Such external loads include earth loads and loads transmitted from other locations, for example surface vehicle loads. Such internal loads include internal hydraulic surcharging and the anchoring of rungs and platforms within the maintenance hole.

Determining whether a maintenance hole is fundamentally structurally sound and therefore is suitable for rehabilitation is not straightforward. In many cases a maintenance hole with cracks, H_2S gases deteriorated concrete or mortar or missing fabric of construction may remain fundamentally structurally sound in its situation even though it has deteriorated significantly from its originally installed condition. Careful consideration should be exercised in assessing a maintenance hole as non-structurally sound and therefore not suitable for rehabilitation.

There are some indications when a maintenance hole may be structurally unsound, which include

- noticeable collapsing
- vertical miss-alignment, for example leaning
- noticeable offsets within the interior indicating that the maintenance hole is behaving as if it is more than one structure
- significant loss of concrete or bricks.

Situations can exist where missing concrete, bricks or other material dislocations exist but do not make the maintenance hole fundamentally structurally unsound assuming these can be suitably repaired prior to the rehabilitation.

Rehabilitation may also be considered practical for use in situations where, even though none of the above listed indications exist, the maintenance hole is considered structurally deteriorated. In the case where structural deterioration is considered due to the effects of infiltration or ongoing internal corrosion, rehabilitation is aimed at halting these deterioration mechanisms thereby stabilizing the maintenance hole structure. In this case rehabilitation may represent a cost effective solution to halting further structural deterioration of the maintenance hole.

In the situation where it is determined that a fully structural rehabilitation is required that will resist all external loads bearing on the maintenance hole, which may include transmitted surface vehicle loads, this specification is not applicable. In these situations case-by-case designs should be prepared to provide for a fully structural rehabilitation of the maintenance hole in question.

TS 4.13.05 Objectives of Rehabilitation

Rehabilitation under this specification is considered not fully structural and applies to a maintenance hole that, while it maybe leaking–allowing infiltration–or internally corroding, retains its structural integrity against all external and internal loads and is expected to retain that integrity over the design and performance life of the rehabilitation. In trenchless rehabilitation of buried sewers, this condition is called partially deteriorated. This condition of maintenance hole structural integrity applies both at the time of rehabilitation and over the design and performance life of the rehabilitation.

The objectives of maintenance hole rehabilitation are:

- Prevent corrosion deterioration of interior surfaces including any deterioration due to H_2S gas entering.
- Prevent leakage of groundwater into the interior including infiltration driven by external groundwater pressure.
- Provide a smooth and uniform interior surface finish resistant to debris build-up.
- Fulfill all objectives over the design and performance life of the rehabilitation.

TS 4.13.06 Type A and Type B Rehabilitation Products

This specification assumes a maintenance hole rehabilitation system will achieve the required rehabilitation performance against in-leakage and infiltration, including infiltration driven by external hydrostatic pressure, by one of the following mechanisms.

Type A Product Has sufficient bonding strength to the maintenance hole structure surface to prevent infiltration due to external hydrostatic pressure.

Type B Product Has sufficient wall strength to resist stresses due infiltration hydrostatic pressure while providing a barrier that prevents infiltration. While it may adhere to the maintenance hole structure surface, adherence or bonding is not required to achieve performance requirements.

Type A rehabilitation product utilizes bonding to the interior of the existing maintenance hole as the mechanism by which external hydrostatic pressure, which may penetrate through the wall, is resisted. In a Type A installation neither the rehabilitation material nor the maintenance hole substrate material to which it is bonded shall separate or fail at less than the pull-off strengths as specified for Type A products. Correspondingly, the maintenance hole substrate surface preparation is critically important in achieving the required bond, both of the substrate to the maintenance holes structure and of the rehabilitation material to the substrate.

Type B rehabilitation utilizes inherent wall strength in the in place rehabilitation material as the mechanism by which external hydrostatic pressure, which may penetrate through the wall, is resisted. While the product may also adhere to the interior of the maintenance holes adherence or bonding is not necessary for performance. Correspondingly the level of maintenance holes surface preparation for a Type B product is significantly less than for a Type A product.

Type A or Type B products do not include cured-in-place (CIP) products that consist of thermo-setting resin in a carrier tube or bag that is cured-in-place in the maintenance hole.

TS 4.13.07 Information to Be Reviewed Prior to Tender Submission

When maintenance hole inspection information is available during the Tender Call period, the Contractor shall review this information. The purpose for this review is for the Contractor to be aware of the maintenance hole conditions identified in this information. When such inspection information is available, it may be provided with the Tender Call or, alternately, is available for review at a location identified in the Tender Call.

If, for Bid purposes, it is the Contractor's opinion that further inspection is required in order to submit a Bid, then the Contractor will be responsible to perform such additional inspection at no extra cost to the City. Permission to enter the City's sewer system for inspection purposes must be obtained from the Contract Administrator.

TS 4.13.08 Information to Be Submitted with Bid

The Tender Call requires the following information to be submitted with the Bid for the review and approval of the Contract Administrator. Further information could be required for submission elsewhere in the Tender Call other than in TS 4.13, herein.

Submit with Bid:

1) Completed *Maintenance Hole Rehabilitation Materials, Properties and Thickness* form (see Appendix A) including certification of the form by a professional engineer authorized to perform such work by Professional Engineers Ontario.

2) Information on the proposed maintenance hole rehabilitation system in sufficient detail such as type of materials to enable confirmation by the Contract Administrator that the rehabilitation system will meet the requirements of specification.

3) Detailed description of cleaning and preparation procedure to be used.

4) Description of the installation procedure to be used.

5) For Type A product provide documentation identifying the bond strength to be achieved in the field application. Include testing information that substantiates the bond to be achieved and the thickness at which the bond testing was performed. *Note:* Both minimum bond strengths and minimum thicknesses are specified in TS 4.13, herein.

6) For Type B product provide a sample design of the maintenance hole rehabilitation that will illustrate the design method that will used for designs required during the course of the work. *Note:* Minimum thicknesses are specified in TS 4.13, herein.

7) The quality control and quality assurance procedures to be used. Include description of how the required thickness will be assured. For Type A products provide description of how the required maintenance hole substrate surface finish will be assured and how the required bond strength will be assured.

8) The name of a professional engineer licensed in the province of Ontario who will certify the engineering designs for Type B rehabilitation product. The professional engineer shall be authorized to perform such work by Professional Engineers Ontario.

Note: The Tender Call, in other sections, may require further submittals in addition to the submittals listed above.

TS 4.13.09 Notification to Public

Prior to commencement of any Work, the Contractor shall deliver written notification to all affected parties a minimum of one week and a maximum of two weeks prior to work commencing at each location. The Contractor must schedule the works accordingly. Such written notification shall consist of letters supplied by both the Contract Administrator and the Contractor and both must be delivered at the same time.

The Contractor shall provide the Contract Administrator with a copy of such notice for approval.

TS 4.13.10 Site Investigation

The Contractor shall investigate each site before commencing any construction work in order to determine the existing conditions and identify any obstructions or any other problems that may affect the completion of the proposed works. No additional payment shall be made on account of difficulties to complete the works because the Contractor failed to investigate the site prior to commencement of the Work.

TS 4.13.11 Locating Maintenance Holes

The Contractor shall be responsible for locating the maintenance holes identified in the Tender Call for rehabilitation. Where a maintenance hole is found to be inaccessible due to being buried or paved over, or cannot be found within reasonable effort, the Contractor shall report this finding to the Contract Administrator. The Contract Administrator shall advise regarding further action.

TS 4.13.12 Weather Conditions

The Contractor shall review the Environment Canada Weather forecast or other suitable forecast bureau prior to commencement of rehabilitation operations. Where the forecast or anticipated weather conditions are such that anticipated sewer flows may exceed the Contractor's by-pass pumping capacity or may cause potential basement flooding due to out of service sewer, commencement of construction shall be delayed until favourable weather is forecast.

TS 4.13.13 Maintenance Hole Condition Check

The Tender Call assumes that maintenance holes to be rehabilitated are in suitable condition for rehabilitation according to TS 4.13 based upon available knowledge of the interior condition and structural integrity prior to Tender Call. Prior to any material procurement or installation work the Contractor shall perform a condition check of the maintenance hole sufficient to verify that the existing interior condition and structural integrity is suitable for rehabilitation.

The condition check shall verify that:

- The condition of the concrete or brick and mortar will allow for the interior surface to be reliably, completely and uniformly prepared to the specified concrete surface profile (CSP) without jeopardizing the structural integrity of the maintenance hole.

- The maintenance hole is not collapsed, collapsing–by visual check only–or leaning.

The Contractor is not required to make a structural evaluation. The condition check shall be based on observations pertaining to visible defects such as excessive cracks, deformations and misalignments that would reasonably suggest that the structural integrity against external loads is suspect.

In the condition check, the Contractor shall identify the existence of any sewers or forcemains incoming to the maintenance hole, which may impact on the level of flow control to be used in the rehabilitation installation.

Where the Contractor's condition check finds that the condition is not suitable for rehabilitation, the Contractor shall advise the Contract Administrator and include the reason for the non-suitable finding. The Contract Administrator shall provide further instruction in regard to the rehabilitation within a timeframe that will not negatively impact the Contractor's operations or schedule.

Should the Contractor, in the condition check, find other reasons why the maintenance hole is not suitable for rehabilitation, the Contractor shall advise the Contract Administrator of this finding prior to proceeding with any other Work.

TS 4.13.14 Flow Control

The Contractor shall provide flow control consistent with the requirements for the dryness needed for the rehabilitation product and its installation requirements.

When interruption of sewer line flows is necessary to properly conduct the work acceptable methods of flow control shall be provided by the Contractor. Where by-pass pumping is used, flow control shall be in according to TS 4.01.

The Contractor shall make all necessary arrangements with the owners of each building. The Contractor shall contact all property owners or tenants to co-ordinate the repair work to the sewer and minimize any impact on residents and businesses.

During the inspection and rehabilitation, sewer flows shall be shut off by the Contractor's flow control in order to enable proper inspection of the pipe invert. After the work is completed, flows shall be restored to normal. Excess sewage flows shall be transported through a closed, leak tight pipeline or by tank trucks to the nearest or most economical disposal area.

On all liner installation dates, the Contractor shall maintain on site both a primary and stand-by by-pass pump and pump power supply. Sufficient power supply and hoses shall be on site in order to allow the pump to discharge into the next downstream sewer section. The stand-by by-pass pump and power supply shall be of an equal or better capability than the primary by-pass pump and power supply.

All by-pass pumps and related equipment must be silenced equipment or contained within an acceptable sound reduction structure.

Flow Control Included Limit Provision

The Contractor shall provide for all by-pass capacity up to and including 150 mm pump configurations where a 150 mm pump shall have a minimum capacity of 4540 L/min (1200 USGPM). The Contractor shall be responsible for determining the bypass capacity. Where the Contractor has determined that the by-pass requires capacities exceeding 4540 L/min, the Contractor shall advise the Contract Administrator of the requirement and any additional cost for the higher bypass capacity. The Contract Administrator shall provide further instruction to the Contractor as needed including, as required, negotiation of additional payment for the by-pass capacities exceeding 4540 L/min.

Sufficient Capacity for Flow Control

No flow control or by-pass pumping shall be employed that has insufficient capacity to maintain flow in the sewer system. It is the Contractor's responsibility to employ flow control of sufficient capacity. No work requiring flow control shall proceed until flow control arrangements are in place that provide sufficient flow control capacity including for situations that exceed the Flow Control Included Limit Provision.

Flow Control – Incoming Forcemains

Where a forcemain or pumped sewer flows into a maintenance hole for rehabilitation, the Contractor's flow control shall have provision for dealing with the forcemain flow such that the rehabilitation can be performed without problems or limitations due to the forcemain flow.

The Tender Call identifies all known maintenance holes with incoming forcemains. During the Contractor's condition check, the existence of unidentified forcemains shall be part of the condition check. Should the Contractor discover an incoming forcemain that was not identified in the tender, the CA shall be advised and will provide further instruction. Prior to providing further instruction, the Contract Administrator may consult with the Contractor and request that the Contractor provide a proposal regarding how the previously unidentified forcemain flow control can be handled to allow the maintenance hole rehabilitation to proceed.

TS 4.13.15 Rungs and Ladders Replacement

All existing rungs and ladders shall be removed prior to the application of the linings. All bolts are to be cut flush with the maintenance hole wall. A punch or grinder is to be used to remove any sharp edges from remaining portion of the steel bolts and ensure the steel does not protrude beyond the surrounding concrete.

The Contractor shall install new fibre reinforced plastic ladder in each lined maintenance hole at same location on the same wall that the existing rungs and ladders were located on. Only approved suppliers shall be used for the ladders as specified in the Contract Documents.

Rungs and ladders shall be installed after the maintenance hole rehabilitation lining has been installed. Rungs and ladders may be installed prior to rehabilitation provided that all rungs and ladder surfaces are covered and protected from being covered or splattered by the rehabilitation materials.

At each location where the platforms and ladders are required to be attached to the newly lined wall, the hole for the stainless steel bolts shall be drilled through the liner by a carbide drill bit. The hole size to be just sufficient to permit the bolt to pass through the liner with a very tight fit. Bolts must be generously coated with SIKAFLEX 1A immediately prior to installation.

TS 4.13.16 Areas of Coverage for Maintenance Hole Rehabilitation

All interior surfaces shall receive the rehabilitation treatment except the lid, lid fitment surfaces, and the trough as shown in Figure 2. There shall be no gaps, cracking, peeling, pinholes, leaking or any other imperfections between the maintenance hole liner and the sewer CIPP liner; in the case where a CIPP liner exists or is to be installed under the Contract. The finished product must be one completely sealed system that will prevent infiltration and any corrosion of the surface subject to rehabilitation coverage.

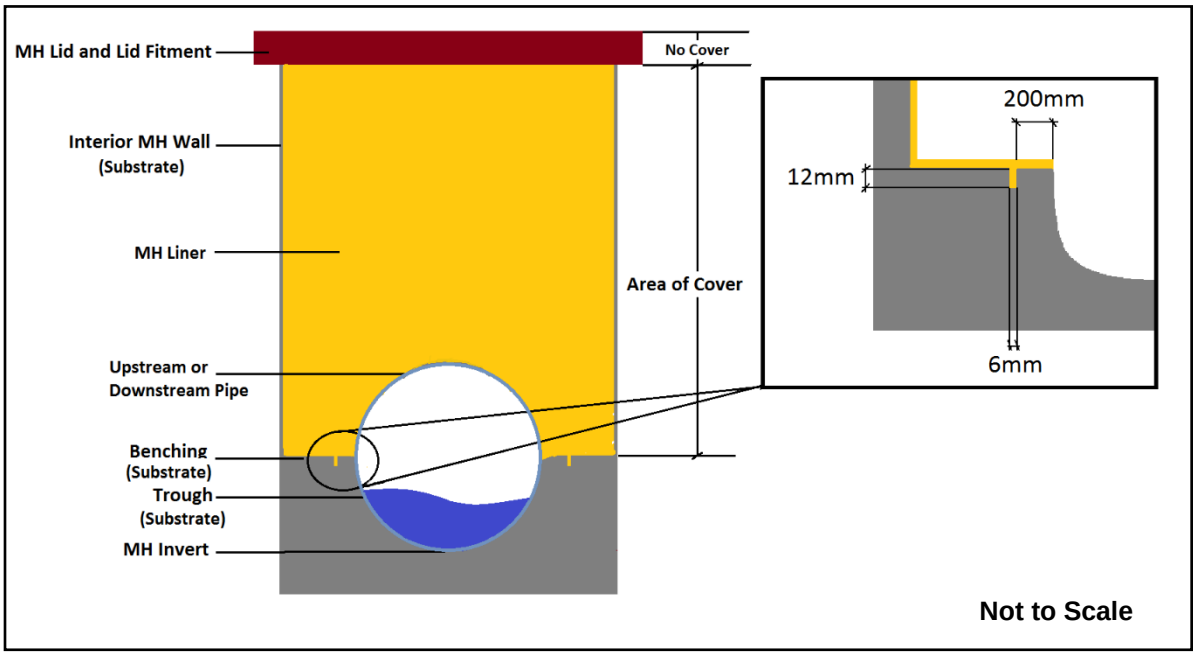

Figure 2: Requirements for maintenance hole rehabilitation liner area of coverage

Liner Edge Finish

The finished edge of a maintenance hole liner along the benching shall prevent ground water leakage. In order to improve the liner performance in preventing infiltration at the finished edge of the liner, prior to applying the liner a groove shall be cut into the maintenance hole bench. The groove shall be cut into the benching approximately 200 mm away from the trough edge, as shown in Figure 2. The grove shall be a minimum of 6 mm wide and 12 mm deep along the full length of the maintenance hole bench. During the liner application this groove shall be completely filled with the rehabilitation product ensuring the liner material does not bridge over the cut groove.

If configuration of maintenance hole makes it impossible to configure the above groove, the Contractor shall propose an alternative groove configuration which achieves the same results.

TS 4.13.17 General Performance Requirements

The performance requirements for rehabilitation are consistent with the objectives listed in TS 4.13.05, herein. These requirements apply to both Type A and Type B maintenance hole rehabilitation products.

Design Life

The design life shall be 50 years.

Performance Life

The performance life shall be 50 years.

The performance life assumes that no new factors such as degradation of maintenance hole structural integrity or a different corrosive environment not typical of municipal sewage impact on the rehabilitation.

Corrosion Resistance

The in-place rehabilitation shall be fully resistant to corrosion or any chemically related deterioration due to the effect of constant or intermittent contact with municipal sewage and hydrogen sulphide gas deterioration mechanisms. The in-place rehabilitation shall protect fully any rehabilitated surface from corrosion or deterioration caused by the same mechanisms by providing a complete and durable barrier protecting the surface from the deteriorating substance, fluid or gas.

Corrosion prevention will be achieved by a sufficiently thick deterioration resistant layer, which provides a complete barrier to the rehabilitation surface thereby preventing corrosive or deteriorating elements to come in contact with the maintenance hole surface to be protected by the rehabilitation.

When corrosion due to hydrogen sulphide gas environment is ongoing, or expected to occur in the future, cement based coatings, linings or layers that are exposed to–or could become exposed to–the sewage and hydrogen sulphide gas environment will not provide the corrosion resistance performance required and are not acceptable where resistance to hydrogen sulphide gas environment is required.

Prevention of Infiltration

The rehabilitation shall prevent infiltration of groundwater into the maintenance hole including infiltration driven by ground water pressure. The groundwater pressure requirement shall be based on the design water table.

Resistant to Debris Build-up

The in-place rehabilitation surface shall be sufficiently smooth and uniform to prevent attraction and build-up of debris found in municipal sewage. There shall be no fins, large ripples, humps, peaks, valleys, excessive protrusions or dimples that will attract or retain debris on any interior surface.

Maximum surface irregularity: ≤ 50% of average thickness

TS 4.13.18 Performance Requirements – Type A Product

Further to section TS 4.13.17 General Performance Requirements, Type A products shall also meet the following requirements.

Rehabilitation performance obtained by bonding to the maintenance hole surface including concrete, brick and mortar surfaces requires that the bonded layer will not separate from the maintenance hole due to either ground water pressure or breakdown of the bond. Ground water pressure may bear on the bonded layer due to permeability of concrete, mortar or brick or other maintenance hole wall defect paths. Breakdown of the bond may occur due to failure of the concrete, mortar or brick substrate at or below the bonded layer or deterioration of the material properties of the bonded layer itself. The variables involved in maintaining bond strength over the performance life are very difficult to quantify. A very high factor of safety on bond strength is therefore required.

Table 1: Type A – Required bond strengths (pull-off strengths) and associated parameters

Parameter	Requirement	Test Method
Substrate Pull-off Strength from MH Structure	The surface tension of the MH substrate shall meet or exceed 1,380 kPa (200 psi).	ASTM C1583
Rehabilitation Material Pull-off Strength from Substrate–the Bond Strength	The minimum of: 1,034 kPa (150 psi) or 12 times the maximum hydrostatic pressure or the product manufacturer's required bond strength, whichever of the above is greater.	ASTM D7234-12
Build-out Layers Material Pull-off Strength from Rehabilitation Product Bonded Layer	The minimum of 517 kPa (75 psi) or the product manufacturers required bond strength, whichever is greater. *Note: This requirement is applicable only to products with build-out layers on the MH interior side of the bonded layer separate to or different from the bonded layer.*	ASTM D7234-12
Hydrostatic Pressure	Corresponding to the water table at one metre below ground surface.	Hydrostatic pressure will increase with MH depth and be greatest at invert.
Thickness Total Rehabilitation	Minimum of 6 mm or the total thickness required for the specific system to achieve performance requirements, whichever is greater.	
Thickness Bonded Layer	Minimum of 3 mm or thickness required for the specific MH rehabilitation system to achieve performance requirements, whichever is greater. *Note: This requirement is applicable only to products with build-out layers separate to or different from the bonded layer.*	
Design Life	50 years	
Performance Life	50 years	

Failure of Maintenance Hole Substrate Versus Failure at Bond Interface

From a maintenance hole rehabilitation perspective, it is not relevant whether the bonded layer separates due to failure of the interface or failure of the substrate–concrete, mortar or brick. Therefore the substrate must be prepared to a level where the required bond strength to the structure is not compromised by substrate failure occurring below the required bond strength. This requires a suitable substrate strength, which is achieved by preparation of the maintenance hole surface area to which the bonded layer is attached.

Where substrate preparation may include filling or patching, the result of such filling and patching will be considered as part of the substrate. Correspondingly any separation of the filler or patching material is a failure of the substrate.

It is the Contractor's responsibility to prepare and achieve a substrate that meets with the requirements of this specification subject to the maintenance hole being in suitable condition to accept the necessary level of substrate preparation.

Bonded Layer Versus Build-out Layers in Rehabilitation

The bonded layer is the layer attached to the maintenance hole substrate. Where a rehabilitation system uses further layers of differing materials to build out thickness for reasons other than for obtaining the bond to the substrate, such layers are not considered as the bonded layer. Such other layers, which are bonded to the bonded layer, are referred to as build-out layers.

Quality Assurance

For quality assurance testing for Type A products, see section TS 4.13.27 herein.

TS 4.13.19 Performance Requirements – Type B Product

Further to section TS 4.13.17 General Performance Requirements, Type B products shall also meet the following requirements.

These are products where resistance to ground water hydrostatic pressure is achieved by having sufficient wall thickness to resist the stresses that may be caused by the external hydrostatic pressure acting on the rehabilitation material. Such a product will result in a rehabilitation wall that will not fail under the effect of ground water hydrostatic pressure. These products, while they may have some adherence to the maintenance hole structure, do not rely on adherence as the mechanism of performance.

Table 2: Type B – Required performance and design parameters

Parameter	Requirement	Note
Design Method	See next paragraph on this page	Design(s) shall be provided as submission with Tender
Design Safety Factor	2.0	
Hydrostatic Pressure	Corresponding to the water table at one metre below ground surface.	Hydrostatic pressure will increase with MH depth and be greatest at invert.
Thickness	A minimum of 6 mm or thickness required by the design for the installation, whichever is greater.	
Design Life	50 years	
Performance Life	50 years	

Design Method

The thickness shall be determined by established design methods. A safety factor of 2.0 shall be used in all designs. In cylindrical and conical maintenance hole elements, the thickness shall be sufficient to prevent buckling and thickness design according to ASTM F1216 Appendix X1 is acceptable. In non-cylindrical and non-conical maintenance hole elements, the thickness shall be sufficient to limit deflection to one per cent of the critical beam length. Design methods used shall be subject to the approval of the Contract Administrator.

TS 4.13.20 Materials

The following materials are acceptable for the maintenance hole rehabilitation

- epoxy
- polyethylene
- polyurea
- polyurethane
- PVC
- silicone.

TS 4.13.21 Backer and Filler Materials

Backer and filler material may be used in the preparation of the maintenance hole surface prior to the application of the rehabilitation material. Backer and filler materials, when needed, shall be completely underneath the bonded layer–where rehabilitation uses a bonded layer–and shall not be exposed to the maintenance hole interior environment.

Regardless of their location, backer and filler materials shall possess corrosion resistance as required for the rehabilitation.

Backer and filler materials used in preparation of the maintenance hole substrate shall be considered to be an integral part of the maintenance hole substrate and subject to the same requirements as the substrate. Where the bonded layer adhesion test fails due to failure of the backer and filler material, this shall be considered as a failure.

All backer and filler material used must be allowed the manufacture's full curing time to achieve 100 per cent cure prior to any maintenance hole installation product being applied, that is to say the material must be fully cured. This includes the use of the main maintenance hole rehabilitation material as a backer and filler material.

TS 4.13.22 Grout Sealing of Active Infiltration

Any maintenance hole with active infiltration shall be grout sealed by injection of grout from the inside prior to installation of any rehabilitation materials. The Contractor shall identify all active infiltration and stop this infiltration with a suitable grout sealing material. There shall be no active infiltration present during the application and curing of any rehabilitation material applied to the interior surfaces.

The grout installation method and the grout type used to stop all active infiltration during application and curing of the rehabilitation materials are the Contractor's responsibility.

TS 4.13.23 Cleaning and Preparation – Type A Product

Type A products use bonding to the maintenance hole surface as their mechanism of performance to achieve the requirements for the rehabilitation. Bonding is a function of both the applied product and the surface to which it is applied. The interior maintenance hole surface requires a high degree of cleaning and preparation to achieve a durable bond of sufficient strength. Preparation includes producing a suitable maintenance hole surface profile to achieve the durable bond.

Acid wash is not an accepted method of cleaning and preparation.

The Contractor shall dispose of debris from cleaning and preparation at an approved location. No debris from cleaning and preparation operations and shall remain in, or be allowed to enter, the sewer system.

Cleaning

All debris, grease, slime, scale and foreign material shall be removed from the interior surface of the maintenance hole. The means and execution of cleaning is the Contractor's responsibility.

Surface Preparation

Surface preparation of the maintenance hole shall be according to NACE No. 6/SSPC-SP 13 and to ICRI Technical Guideline No. 03732 (see Appendix C). For reference in ICRI Guideline No. 03732 bonded maintenance hole rehabilitation products shall be considered as a polymer overlay. All cracks or fractures greater than 12.5 mm shall be sealed using an acceptable backer and filler material prior to spraying the maintenance hole liner. Any backer or filler used to seal cracks in the substrate including the use of the liner material will form part of the substrate and therefore will be held to the same standard as entire substrate. After surface preparation, there shall be no cracks or fractures in the concrete substrate greater than 12.5 mm. All surface preparation requirements will be the responsibility of the Contractor.

In the case of brick maintenance holes, the preparation of the brick and mortar surfaces shall be according to the requirements for surface preparation and profile of concrete.

Surface Profile

Concrete Surface Profiles (CSPs) are defined in the ICRI Guideline No. 03732 (see Appendix C).

Required concrete surface profile: CSP 5 or higher CSP number.

It is the Contractor's responsibility to employ a preparation method that will achieve the required CSP number. While several preparation methods are capable of achieving a CSP 5, it is recommended that high or ultra high-pressure (5,000 – 10,000 psi) water jetting will be used as described in the ICRI guideline.

The Contractor shall use a method acceptable to the Contract Administrator for judging when the required concrete surface profile has been achieved. An acceptable method includes comparison to ICRI standard surface profile chips.

In the event that the condition of the existing maintenance hole concrete is not capable of being prepared to CSP 5, the Contractor shall advise the Contract Administrator of this finding and halt any further work. This may be evident by continual erosion or removal of the concrete during the preparation process so that a CSP 5 cannot be obtained or cannot be obtained without removing more than 20 mm locally or 6 mm generally of concrete material. In advising the Contract Administrator of this finding, the Contractor shall identify whether this is a localized problem in the maintenance hole or is a general problem with the maintenance hole concrete structure. The Contract Administrator shall provide instruction to the Contractor in regard to whether to proceed with the rehabilitation or to delete the maintenance hole from rehabilitation list. If deleted from rehabilitation list, the Contractor will be paid for work to this point providing the maintenance hole concrete condition was not identified or identifiable at the Contractor's maintenance hole condition check work step.

On completion of the first two maintenance holes surface preparation, the Contractor shall test that the substrate meets surface tension requirements according to section TS 4.13.28, herein.

The Contractor shall take digital photographs that show the prepared concrete surface. The photographs shall sufficient in quantity and clarity to allow the Contract Administrator to verify that the concrete surface preparation meets with the concrete surface profile requirement.

Moisture Control

Immediately prior to the application of rehabilitation materials that are intended to bond to the concrete, the concrete shall be dry to the point of no visible signs of dampness or moisture. The Contractor is responsible for the method by which this dryness is achieved. It is anticipated that a heat drying process will be necessary. Application of rehabilitation material(s) that are intended to bond to the maintenance hole shall not be accepted where the maintenance hole dryness requirement is not met.

Should the Contractor at any time during the preparation phase of work, find any reasons why the maintenance hole is not suitable for rehabilitation, such that the final liner application will not be able meet any of the required specification, the Contractor shall advise the Contract Administrator of this finding prior to proceeding with any further work on the maintenance hole.

TS 4.13.24 Cleaning and Preparation – Type B Product

Type B products use wall strength as their mechanism of performance and any adherence that may occur during the installation is not necessary of achieving performance.

Acid wash is not an accepted method of cleaning and preparation.

The Contractor shall dispose of debris from cleaning and preparation at an approved location. No debris from cleaning and preparation operations and shall remain in, or be allowed to enter, the sewer system.

Cleaning

All debris, grease, slime, scale and foreign material shall be removed from the interior surface of the maintenance hole. The means and execution of cleaning is the Contractor's responsibility.

Surface Preparation

The maintenance hole surface shall be prepared to the requirements for the system used to achieve the required performance objectives. In general this shall include removal of loose and spalling material, patching of any significant depressions or indentations and correction of any other wall defects that will negatively effect either the installation or the long-term performance of the rehabilitation system. The Contractor is responsible for any concrete surface profile that needs to be achieved for system performance.

Surface Profile

Concrete surface profiles are defined in the ICRI Guideline No. 03732 (see Appendix C).

Required concrete surface profile: CSP 2 or higher CSP number.

It is the Contractor's responsibility to employ a preparation method that will achieve the required concrete surface profile.

In the event that the condition of the existing maintenance hole concrete is not capable of being prepared to CSP 2, the Contractor shall advise the Contract Administrator of this finding and halt further work. This may be evidenced by continual erosion or removal of the concrete during the preparation process so that a CSP 2 or cannot be obtained without removing more than 20 mm locally or 6 mm generally of concrete material. The Contractor shall identify whether this is a localized problem or is a general problem with the maintenance hole concrete structure. The Contract Administrator shall provide instruction to the Contractor whether to proceed with the rehabilitation or to delete the maintenance hole from the rehabilitation list. If deleted from rehabilitation, the Contractor will be paid for work to this point providing the maintenance hole concrete condition was not identified or identifiable at the Contractor's maintenance hole condition check work step.

The Contractor shall use a method acceptable to the Contract Administrator for judging when the required concrete surface profile has been achieved. An acceptable method is comparison to ICRI standard surface profile chips.

The Contractor shall take digital photographs on completion of the concrete surface preparation that show the prepared concrete surface. The photographs shall be sufficient in quantity and clarity to allow the Contract Administrator to verify that the concrete surface preparation meets the concrete surface profile requirement.

Moisture Control

The level of moisture control for the maintenance hole be it concrete, brick or mortar shall be according to the system manufacturer's requirements in order to ensure that long-term performance of the rehabilitation is not negatively influenced by the level of moisture present during its installation.

TS 4.13.25 Installation

The details of the installation methods and procedures are the responsibility of the Contractor subject to the following provisions:

1) Installation methods and procedures shall be according to the rehabilitation system supplier recommendations.

2) Installation methods and procedures shall not produce a conflict with Contract Document requirements.

Installation Procedure for Determining Applied Thickness

The Contractor shall employ a method acceptable to the Contract Administrator, which during the installation process will determine the applied thickness of the rehabilitation materials. The Contractor shall propose the method and if in the opinion of the Contract Administrator the proposed method is not satisfactory, the Contractor shall propose a different method. The intent of the procedure is to determine upon completion of the installation process that the required thickness has been installed.

TS 4.13.26 Fit and Finish

The final rehabilitation shall provide a smooth and uniform finish fit and cover to all surfaces of the maintenance hole consistent with the objectives for rehabilitation. There shall be no ledges, shoulders or other protrusions where debris may attach or collect except as may be required for zones of permitted wall thickness changes as per the design requirements. Where a CIPP sewer liner and maintenance hole spray or trowelled applied rehabilitation material interface; there shall be no gaps, cracking, peeling, pinholes, leaking or any other imperfections between the maintenance hole rehabilitation material and the CIPP sewer liner.

For Type A products all areas of coverage shall be fully bonded to the maintenance hole surface beneath without any locations that indicate looseness or lifting.

For Type B products all areas of coverage shall be in intimate contact with the maintenance hole surface beneath without any indications of gaps or annulus.

TS 4.13.27 Quality Assurance Testing – Type A Product

The Contractor shall perform the following quality assurance tests for Type A products to the latest version of the following standards.

Table 3: Quality assurance requirements

Test	Standard	Frequency and Location
MH substrate	ASTM C1583	For each of first two MHs
Rehabilitation material bond to substrate	ASTM D7234-12 Use 50 mm Loading Fixture (Dolly)	Three tests for each rehabilitated MH at locations on the benching, near invert and near top or at locations as directed by the Contract Administrator
Rehabilitation material build out layer(s) Inter-layer bond *See Note a*	ASTM D7234-12 Use 50 mm Loading Fixture (Dolly)	One test for each rehabilitated MH at location as directed by the Contract Administrator

Note a: This test is only applicable for multi-layer rehabilitation products for which the bond strength–adhesion–between the build-out layer(s) is less than the bond strength of the innermost layer–the bonded layer–to the maintenance hole substrate. At the Contractor's option, the test(s) for the build-out layer(s) may be incorporated into the pull-off test for the bonded layer so that both bonded layer and build-out layer(s) bond strengths are tested at the same time. This option assumes that all build-out layers inter-layer bonding is equal to or greater than the required bond strength to the maintenance hole substrate.

Substrate Testing For First Two Maintenance Holes

The Contractor shall test the substrate of the first two maintenance holes for which cleaning and preparation of the maintenance hole substrate has been completed. For each of the two maintenance holes, the Contractor shall make three pull-off tests of the substrate. Unless locations are otherwise directed by the Contract Administrator, the tests shall be located near the top, near the mid point and near the bottom of the maintenance hole. The placement of the pull test dollies shall be consistent with the requirements of the liner pull tests and completed in the presence of the Contract Administrator.

In the event that any of the substrate pull tests do not meet the required strength, the Contractor shall make further substrate preparation and repeat the tests. Should any follow up tests fail, the Contractor shall change or otherwise revise the method of preparation, re-prepare the maintenance hole and repeat the testing above.

No maintenance hole liners shall be applied until substrate tests meet requirements.

Post-application Rehabilitation Material Testing

The Contractor shall make pull-off adhesion tests of the bond strength of the rehabilitation material to the maintenance hole surface and, where applicable, the bond strength of any build-out layers. The Contractor shall use a portable pull-off adhesion tester according to the requirements of ASTM D7234-12 and shall use a 50 mm diameter loading fixture–dolly–for all pull-off adhesion tests.

The Contractor shall obtain successful test results on the first two maintenance holes rehabilitated before proceeding with the application of the rehabilitation material for any further maintenance hole.

The Contractor shall advise the Contract Administrator at least 24 hours in advance of when both dolly setting and pull testing is to take place so that the Contract Administrator may be present for the testing. Tests done without the Contract Administrator present may be rejected by the Contract Administrator.

The pull-off test shall be performed until failure–break–of substrate, adhesion, cohesion or dolly glue, that is to say the destructive pull test as defined in this specification and not halted at the minimum specified adhesion pressure.

Table 4: Type A material testing requirements

Failure Break	Description
Substrate Break (SB)	A break of the substrate — concrete, brick or mortar is visibly adhered to the liner on the dolly
Adhesion Break (AB)	A break between the substrate and the liner — break of the bond to the concrete, brick or mortar substrate
Cohesion Break (CB)	A break or separation within the liner wall
Dolly Glue Break (GB)	A dolly adhesion glue failure

No separation, pull-off, pull-apart or other breakdown of the rehabilitation material or similar breakdown of the concrete substrate shall occur below the minimum required bond strength. Any separation, pull-off, pull-apart or other breakdown–including at/in the concrete substrate–that occurs before the required bond strength–bonded layer or build out layer–is achieved shall be considered a deficiency.

The failure of the dolly adhesive will not be accepted as a completed pull test and the Contractor will be required to redo the pull test. However, the failure of the dolly adhesive at (50 psi or 35 per cent) above the minimum adhesion acceptance threshold will be accepted as a completed pull test and the Contractor will not be required to redo the pull test.

In the case where the build-out layers(s) is tested separately from the bonded layer, there shall be no separation, pull-off, pull-apart or other breakdown–including at/in bonded layer and at/in the concrete substrate–below the minimum required bond strength. Any separation, pull-off, pull-apart or other breakdown–including at/in the bonded layer and at/in the concrete substrate–that occurs before the required build-out layer(s) bond strength is achieved shall be considered a deficiency.

The Contractor shall report all pull-off testing results by completing the *Maintenance Hole Pull Test Data Sheet* (see Appendix B) for each maintenance hole and submitting to the Contract Administrator within five Working Days of liner application. Should the pull-off test results not be provided with in the required five Working Days, the Contract Administrator may at their discretion order a suspension of work for maintenance hole liner installations until pull-off test reports have be submitted.

Repair of Pull-off Test Location

The location of pull-off tests shall be repaired consistent with the rehabilitation and to the satisfaction of the Contract Administrator.

Rehabilitation Material Thickness Measurement

The Contractor shall measure and record applied liner thickness on each pull test dolly use for adhesion testing. The recorded thickness shall be the minimum liner thickness as measured on the dolly. The thickness shall be recorded on the *Maintenance Hole Pull Test Data Sheet* form.

Rehabilitation Material Cup Test Sample

At the request of the Contract Administrator, the Contractor shall supply a cup sample of the liner material immediately prior to the liner installation. The cup shall be at least 100 mm in diameter and deep enough to spray the equivalent thickness of material being applied to the maintenance hole including the full thickness if the material is being used as backer and filler. The cup material shall be made of a plastic material such that it may be peeled away from the cured material.

TS 4.13.28 Quality Assurance Testing – Type B Product

At the beginning of the installation of the rehabilitation material, the Contractor shall prepare a formed plate sample of the material by diverting material from application in the maintenance hole into the test form. The depth of the test form shall be equal to the thickness to be applied in the maintenance hole. The size of the test plate shall be sufficient for providing test specimens for testing of flexural modulus, flexural strength and tensile strength. In general this will require a 300 mm by 300 mm by the maintenance hole required thickness. A smaller plate form size shall be acceptable providing the smaller size meets with the requirements of the testing agency.

Frequency: One plate form sample for each maintenance hole lined.

Contractor shall have the plates tested by an independent testing agency, approved by the Contract Administrator and provide the agency's test reports to the Contract Administrator. The Contractor shall make arrangements with the testing agency to allow for direct communication between the Contract Administrator and the testing agency. Test reports shall be provided to the Contract Administrator within 10 Working Days of plate sample preparation.

The test results shall meet the properties used in design. Where test values do not meet these values the rehabilitation shall be considered deficient subject to design reconciliation using test values.

Liner Thickness Measurement

The Contractor shall supply two core samples of the applied liner from each lined maintenance hole and shall be a minimum of 25 mm in diameter. Sample locations shall be near the invert and near the halfway up point in the maintenance hole.

Repair of Thickness Core Sample Location

The location of pull-off tests shall be repaired consistent with the rehabilitation and to the satisfaction of the Contract Administrator.

TS 4.13.29 CCTV Inspection of Finished Maintenance Hole Rehabilitation

The Contractor shall CCTV inspect each completed and finished rehabilitated maintenance hole. The CCTV shall be according to National Association of Sewer Companies (NASSCO) Maintenance Hole Assessment and Certification Program (MACP) Level 2 for CCTV maintenance hole inspections. The Contractor shall also provide a NASSCO MACP inspection database. The Contractor shall record the spray lining product type and name under Additional Info field.

In general the CCTV camera shall enter from the top of the maintenance hole and complete 360 degree inspection of the entire surface of the maintenance hole as the camera is lowered at a uniform and steady manner to the bottom of the maintenance hole. Zoom inspection of sewer lines entering and exiting the maintenance hole is not required. The minimum recorded video resolution must be 420 lines with an NTSC size of 720 x 480 at 29.97 frames per second.

Where any potential defects or other questionable events are seen on the surface of the rehabilitation, the CCTV inspection shall zoom in to few such locations in greater detail.

The CCTV inspection electronic file shall be an MPEG 2 file. CCTV inspection video files shall play properly and completely on commonly used video file playing software applications. At a minimum the video files must play properly and completely on correctly configured, up to date versions of all the following video players: Microsoft Windows Media Player, VideoLAN VLC Player (Windows and Mac) and Apple QuickTime Player (Windows and Mac).

All submissions to be made on a removable hard-drive of reliable quality. Hard drives will become the property of the Toronto Water and will not be returned to the Contractor.

All hard drives to be properly labelled with the following information:

a) Contractor's name
b) Contract number
c) Contact person and phone number
d) Date
e) Hard drive number. e.g. 1 of 2

Each CCTV inspection shall include an inspection report in PDF format.

TS 4.13.30 Deficiencies

The CCTV inspection of the finished rehabilitation shall show no signs or evidence of leakage, lifting, bubbling or bowing inward that indicates the rehabilitation is not fully resisting external hydrostatic infiltration pressure. Such evidence will indicate a deficient installation.

Where in the Contract Administrator's opinion, there are grounds to suspect that pinholes or other similar defects exist in the rehabilitation, the Contractor, on the Contract Administrator’s request, shall undertake a Dielectric Discontinuity Test (Spark Test) according to ASTM D4787-13 over any area. Where this test indicates pinholes or similar defects, the installation will be considered deficient.

Any deficiencies shall be rectified and where, in the Contract Administrator's opinion, the deficiency is such that complete or partial removal of the maintenance hole liner is required such removal will be completed by the Contractor and no payment for the initial rehabilitation or removal work will be made. In the case of removed liners, one of the following actions may be required by the Contract Administrator

- re-application of the liner, including re-preparation of the maintenance hole
- no further work
- replacement of the maintenance hole

Where the measured liner thickness is determined to be lower than the required thickness, the Contractor may be required to apply additional material, including all necessary preparation. No additional payment shall be made for this Work.

TS 4.13.31 Warranty

All materials and workmanship shall be under warranty for two years, starting on the date the City accepts the Works performed under the Contract.

TS 4.13.32 Payment

Payment at the Contract Price shall be full compensation for all labour, Equipment and Material to do the Work.

Appendixes

Appendix A: Maintenance Hole Rehabilitation Materials, Properties and Thickness
(Form must be completed and submitted with Bid)

Appendix B: Maintenance Hole Pull Test Data Sheet

Appendix C: ICRI Technical Guideline No. 03732 – Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays

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TS 4.13 Appendix A: Maintenance Hole Rehabilitation Materials, Properties and Thickness

The Bidder must complete this form in-full and include it with the Tender Submission Package. The completed form must be certified for by manufacturer/supplier for Type A and a professional engineer authorized in the Province of Ontario for Type B.

1. Proponent's Name: _____

2. MH Rehabilitation System Name: _____

3. MH Rehabilitation System Mechanism of Performance: Check either A or B below or both if applicable.

Refer to Contract specifications for details on Type A and Type B MH rehabilitation products.

A ☐ By bonding to MH concrete structure. If checked, complete A1, A2 and A3 below.

B ☐ By wall strength. If checked, complete B1, B2, B3 and B4 below.

A1. Bonded Layer

Material: _____

Manufacturer's required bond strength to MH concrete structure: _____kPa

Manufacturer's required minimum thickness for required bond strength above: _____mm

A2. Build-out Layer (If Used).

Number of build-out layers over bonded layer: _____ Enter NA if not used.

Material: _____

Manufacturer's required bond strength to bonded layer: _____kPa

Manufacturer's required minimum thickness for required bond strength above: _____mm

For more than one build-out layer provide additional layer material, bond strength and thickness below:

_____

_____

A3. Proposed Thicknesses for Completed MH Rehabilitation

Refer to contract specifications regarding requirements for minimum thicknesses.

MH Depth Zone	Bonded Layer Thickness	Total Rehabilitation Thickness
1.5 – 2.9 m	mm (minimum 3 mm)	mm (minimum 6 mm)
3.0 – 4.4 m	mm (minimum 3 mm)	mm (minimum 6 mm)
4.5 – 6.0 m	mm (minimum 3 mm)	mm (minimum 6 mm)

B1. Material: _____

B2. Material Physical Properties to be achieved in the MH rehabilitation Installation

Flexural Modulus (ASTM D790): _____MPa Design Life Retention: _____%

Flexural Strength (ASTM D790): _____MPa Design Life Retention: _____%

Tensile Strength* (ASTM D638): _____MPa Design Life Retention: _____%

* If Applicable for design

B3. Design Method to Determine MH Rehabilitation Thickness

For cylindrical MH zones: _____

For flat surface MH zones: _____

B4. Proposed Thicknesses for Completed MH Rehabilitation

Refer to contract specifications regarding requirements for minimum thicknesses.

MH Depth Zone	Thickness for MH Cylindrical Zone	Thickness for MH Flat Surface Zone
1.5m – <3 m	mm (minimum 6 mm)	mm (minimum 6 mm)
3.0m – <4.5 m	mm (minimum 6 mm)	mm (minimum 6 mm)
4.5m – 6.0 m	mm (minimum 6 mm)	mm (minimum 6 mm)

Certification by manufacturer/supplier for Type A:

Certification by Professional Engineer for Type B:

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TS 4.13 Appendix B: Maintenance Hole Pull Test Data Sheet

Client Name												
Contract Number												
MH ID Number												
Preparation Date							<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<					
Liner Install Date	>>											
	Substrate Pull Tests						**Liner Pull Tests**					
Date												
Time												
	Upper MH		Lower MH		Benching		Upper MH		Lower MH		Benching	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Direction of Test in MH (N/S/E/W)												
Depth from MH Lid (m)												
Measured Liner Thickness												
Pull Test Reading Number												
Results												
Minimum Strength Required: kPa (psi)	1,380 (200)		1,380 (200)		1,380 (200)		As specified		As specified		As specified	
Type of Break (see below)												

Comments:

Notes:
Images of each pull test (dolly) in the MH are to be taken with the corresponding Pull Test Reading Number written on the MH wall and visible in the picture.

Types of Breaks

SB - Substrate Break*:*	Break of the substrate (concrete is visibly adhered to the liner on the dolly)
AB - Adhesion Break:	Break between the substrate and the liner (i.e. break of the bond to the substrate)
CB - Cohesion Break:	Break or separation within the liner wall
GB - Glue Break:	Dolly adhesion glue failure

Complete By: (Name and Firm)	

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TS 4.13 Appendix C –

ICRI Technical Guideline No. 03732 – Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays

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TECHNICAL GUIDELINES

Prepared by the International Concrete Repair Institute
(Reapproved 2002)

January 1997




Guideline No. 03732

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

TECHNICAL

GUIDELINES

Prepared by the International Concrete Repair Institute January 1997
(Reapproved 2002)

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

Guideline No. 03732

Note: The full version of this document includes a set of nine molded replicas of surface textures, as described on page 6. To obtain these, please contact ICRI at one of the numbers listed below.

International Concrete Repair Institute
3166 S. River Road, Suite 132, Des Plaines, IL 60018
Phone: 847-827-0830 Fax: 847-827-0832
Web: www.icri.org
E-mail: info@icri.org

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. ICRI members working through a variety of forums 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 critical 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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Acknowledgements

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Bryant Mather
Sara Ramsdell
Richard Reese
James Warner
Mark Wileczek

Contents

About this guideline

This guide provides designers, specifiers, contractors, and manufacturers with the tools needed to select and specify the methods for preparing concrete surfaces prior to the application of sealer, coating and polymer overlay systems. For the purposes of this guideline, surface preparation is the process by which sound, clean, and suitably roughened surfaces are produced on concrete substrates. This process includes the removal of unsound concrete and bond-inhibiting films, strength verification, opening the pore structure, and establishing profiles suitable for the application of the specified protective system.

Although many of the method summaries included in this document contain data on removal capabilities, a full discussion of methods for the removal of encrustations, stains, embedded contaminants, or existing coatings is beyond the scope of this guideline.

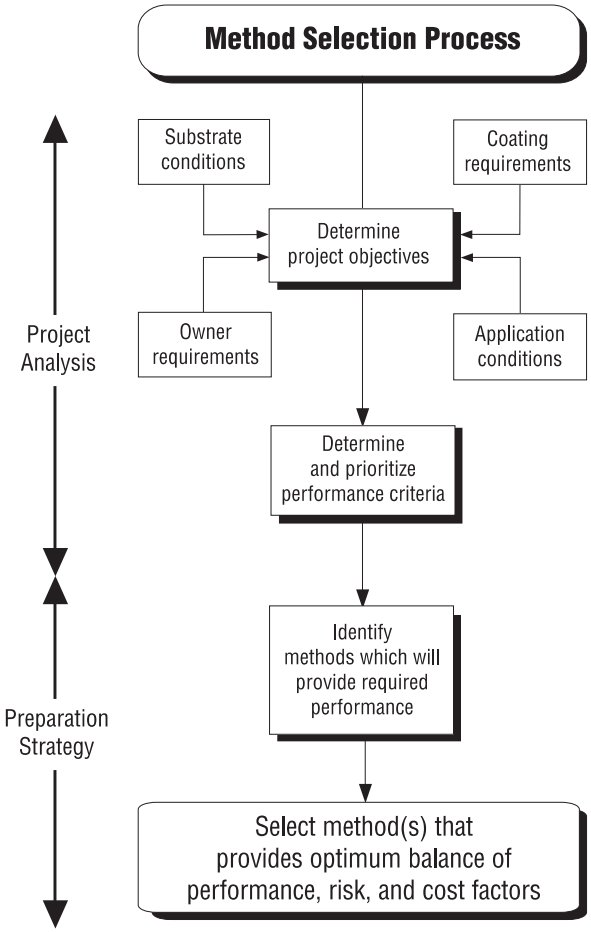
Guideline tools

1. **Method Selection Process:** A workbook designed to organize and prioritize information needed for good selection decisions is located in *Appendix A*. Sample checklists and examples are included.
2. **Method selector:** This chart identifies methods capable of producing the profile(s) typically recommended for each coating type.
3. **Method summaries:** Capabilities, limitations, operating requirements, environmental factors, and safety considerations for each method are presented.
4. **Surface profile chips:** These replicas of typical surfaces produced by one or more of the methods provide a visual standard for purposes of specification, execution, and verification.

Selecting surface preparation methods

Determine project objectives and requirements

Most coating or sealing projects will have unique conditions and special requirements that must be evaluated to determine which method(s) will best meet the engineers' and owners' objectives. The sample checklists may be used to gather data needed to identify and prioritize performance requirements (pages 34 to 36). They will help ensure that important issues will be resolved at the optimum time—before the project is underway.



1. **Substrate condition:** The strength of the substrate, and the presence of unsound or bond-inhibiting materials help define the nature and volume of preparation needed.
2. **Owner requirements:** Noise, vibration, dust, and water are effects generated by various preparation methods. The owner's need for uninterrupted use of the structure, concerns about operating environment or property damage potential will limit the choices.
3. **Material requirements:** Surface preparation requirements will vary with the protective coating system selected. The properties and application requirements of the selected system should be determined before or during this phase.
4. **Application conditions**
   Generation of dust, slurries, or water may require containment and safe disposal. Mechanical ventilation, available power sources, the size of door openings, and minimum clearance will affect surface preparation decisions.

Establish performance priorities

Performance criteria which best satisfy project objectives and requirements are developed and prioritized (*see Appendix A, p. 37*).

Example: Deck coating installation

A parking structure providing 240 spaces for hospital employees is to be protected by a traffic bearing membrane. Surface preparation will remove all deteriorated concrete, bond-inhibiting contaminants, and achieve a profile of CSP 3 to 4. Structure has a common shear wall with patient rooms for two of its four levels. The hospital requires that 85% of parking capacity remain in service throughout project.

Priorities: (ranked in order of importance)

1. Dust-free preparation to prevent finish damage to parked vehicles
2. Low noise/vibration to minimize patient discomfort
3. Achieve profile CSP 3 or 4 to provide optimum surface for bonding
4. Fast turnaround to minimize inconvenience

Evaluate surface preparation methods

Selecting the method(s) which optimize project objectives requires a good knowledge of the available options. The method selector chart may be used to make a preliminary identification of the methods capable of producing the required surface profiles. The method summaries compare data on the capabilities, limitations, operating requirements, and environmental considerations for each surface preparation method.

Select and specify surface preparation methods

Final selection is based on the relationship between cost, project objectives, and risk. The selection process workbook (*Appendix A*) provides a systematic framework for organizing project data and assessing method suitability. More than one method may be capable of producing the desired results. Further, more than one method may be required to produce those results economically. Unacceptably rough profiles on existing or prepared surfaces may be reduced through additional passes using properly selected surface preparation equipment. On occasion, the application of a resurfacing mortar may be required to achieve the profile and appearance desired. The nine concrete surface profile chips provide benchmark profiles to aid in achieving the desired result.

Mechanics of concrete removal

In addition to project-specific requirements, method selection must also be guided by the following principles of sound practice:

1. The structure to be coated should not be damaged.
2. The reinforcing steel should not be damaged nor its bond with the concrete loosened.
3. Vibration, impact, or thermal loads applied should not weaken the concrete.

This section describes the cutting mechanisms used by the methods summarized herein. This information will help users assess the relative potential of each preparation method to damage or weaken the substrate.

Two methods, low-pressure water cleaning and detergent scrubbing, do not remove sound concrete and do not noticeably alter the profile of concrete surfaces. Cleaning is accomplished through one or a combination of the following: the surfactant effect of detergents, the solvent effect of water, and the shearing force of brushes or high velocity water. A third method, acid etching, chemically dissolves calcium hydroxide, $Ca(OH)_2$ crystals and calcium silicate hydrate (C–S–H) which make up the hydrated solids in cement paste. The dissolution of these reaction products causes a slight loss of cement paste, to produce a very light profile on the exposed surface. The remaining nine methods summarized in this guideline will utilize one or a combination of the following cutting actions.

Erosion

Erosion causes the wearing away or progressive disintegration of concrete surfaces. 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 (*Figure 1*).

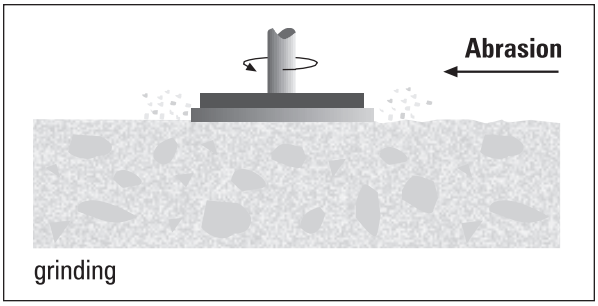


Figure 1

A stream of water projected onto the surface under high pressure is another form of erosion in which cavitation and the friction generated by water velocity combine to wear away the cement paste. Unlike grinding, water jetting will not produce a smooth, uniform surface. 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, coarse aggregate will be undercut and washed away (*Figure 2*). **Applicable Methods:** grinding, high and ultra high-pressure water jetting.

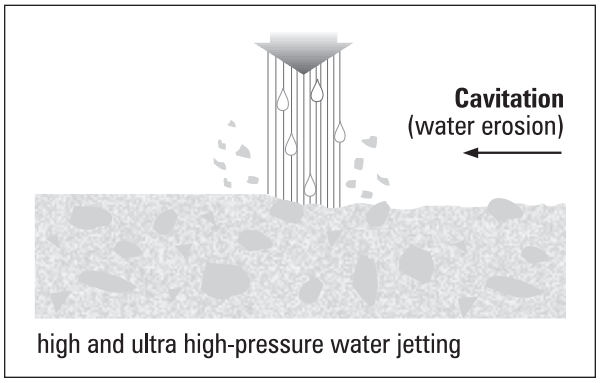


Figure 2

Impact

Several preparation methods strike the surface repeatedly with hardened points to produce momentary mechanical loads which, at the points of impact, exceed the tensile and compressive strength of the concrete, causing it to yield. The force of the impact pulverizes and fractures the structure of both cement paste and aggregate at and adjacent to the point of contact (*Figure 3*). Some of the cracks and loosened aggregate may remain leaving a "bruised" layer at the surface. **Applicable methods:** scarifying, scabbling, milling/rotomilling, needle scaling.

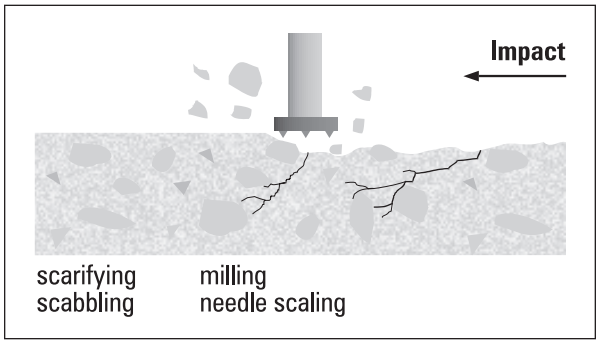


Figure 3

Pulverization

The cutting effect is derived from the collision of small particles traveling at a high velocity with the concrete surface (*Figure 4*). Because the mass of the particles is comparatively small, their impact is not known to produce bruising. Hard, sharp-edged media can produce fast cutting rates. As with water jetting, the cement paste is reduced at a faster rate than is the coarse aggregate. This difference in cutting rate has the effect of exposing and undercutting the coarse aggregate to produce a surface that will become highly profiled as exposure time is increased. **Applicable methods:** steel shotblasting, abrasive blasting.

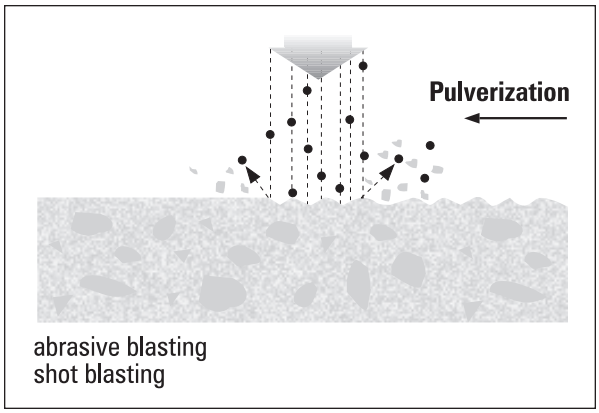


Figure 4

Expansive pressure

Two forms of expansive pressure are used to modify concrete surfaces: steam and water.

Steam: Energy from a high-temperature heat source rapidly heats the capillary and adsorbed water present in the cement paste to produce steam. This sudden increase in vapor pressure generates tensile stresses near the surface fracturing both matrix and aggregate, causing concrete material to scale or pop off in thin, flake-like chips (*Figure 5*). Because the water heats more rapidly than the surrounding concrete phases, concrete temperatures in the top 2 mm typically do not exceed 250° C at recommended travel rates. At this exposure level, substrate temperatures at a depth of 7 mm do not rise above 70° C. Best results are achieved when surfaces to be prepared are soaked with ponded water for several hours prior to flame scaling.

Although the mechanical properties of cement paste in compression are not significantly altered at temperatures below 300° C, the fracturing produced by this

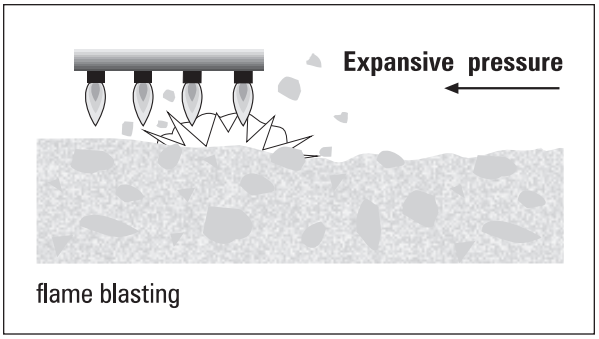


Figure 5

method of cutting may introduce additional micro-cracking near the free surface of the substrate to cause some reduction in tensile strengths. The limited test data available on the effects of this preparation method on the mechanical and durability properties of concrete are inconclusive. Further investigation into the condition of substrates prepared using this technique is needed. **Applicable methods:** flame blasting (flame scaling)

Water: Working at higher pressures, 15,000 to 45,000 psi (100 to 300 MPa), water jetting can produce a cutting effect similar to that of steam. An initial pass over horizontal concrete surfaces to be prepared using this method is sometimes taken with milling or scarifying equipment to remove ¼ to ½ inch (6 to 13 mm) of the original surface. The purpose is to introduce the cracks and micro-cracks needed to create numerous avenues of entry beneath the surface. The expansive pressure generated by water subsequently penetrating the fissures at high velocity will cause tensile failure along these planes of weakness *(Figure 6)*. **Applicable methods:** high and ultra high-pressure water jetting

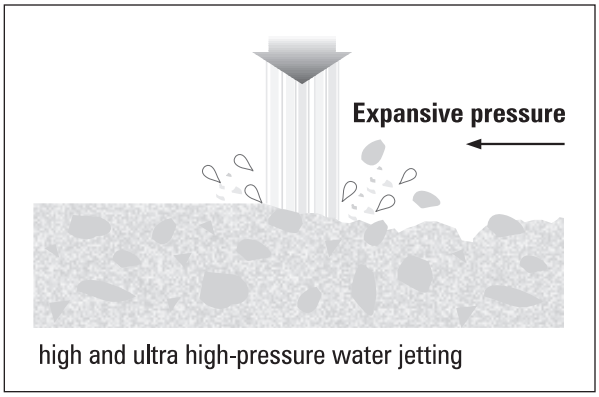


Figure 6

Bruising

Several of the preparation methods described are likely to reduce the tensile strength of the prepared substrate. Field studies have shown that bond strengths achieved on surfaces prepared using high-impact mechanical methods are frequently lower than those on surfaces prepared using non-impact methods. This reduction in bond strength is caused by fracturing of the cement paste and loosening of aggregate without fully separating from the surface. This creates a weakened or "bruised" surface layer of interconnecting micro-cracks typically extending to a depth of ⅛ to ⅜ inch (3 to 10 mm). Under microscopy, the cracks are frequently seen to initiate at the surface at approximately a 45° angle and propagate horizontally to produce a weakened plane *(Figure 3)*. 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 micro-cracking into the substrate is indicated for each method *(Figure 7*).

Risk of Introducing Micro-Cracking

○ very low ◑ moderate ● high

Abrasive (sand) blasting	○
Steel shotblasting	○
Scarifying	◑
Needle scaling	◑
High and ultra high-pressure water jetting	○
Scabbling	●
Milling/rotomilling	●
Flame blasting	◑

Figure 7

Specifying concrete surface profiles (CSP)

Several of the methods summarized are capable of producing a range of profiles on concrete surfaces. Communication of project requirements may be improved by using CSP profiles to define surface roughness.

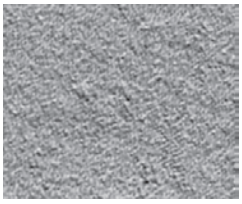
ICRI has identified nine distinct profile configurations which may be produced by the methods summarized herein. As a set, these profiles replicate degrees of roughness considered to be suitable for the application of one or more of the sealer, coating, or polymer overlay systems, up to a thickness of 1/4 in. (*see Appendix B*). Each profile carries a CSP number ranging from a base line of CSP 1 (nearly flat) through CSP 9 (very rough). The profile capabilities for each preparation method are identified by CSP number in the "Profile" section of the method summaries. Molded replicas of these profiles are included with this guideline* to 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 surface preparation requirements. When these profiles are used in conjunction with specifications for thicker coating and overlay systems, it is probable that more than one profile will produce acceptable results. When applicable, the range of suitable profiles should be specified.

The concrete surfaces shown below were produced using a variety of preparation methods. Although each numbered CSP plaque bears the characteristic pattern and texture of the specific preparation method used, each plaque is representative of the profile height obtainable with all methods identified with the same CSP number.

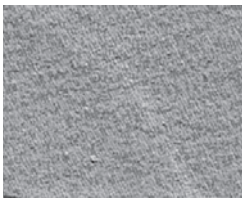
** Available by contacting ICRI at one of the number listed on the back cover*

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

Images generated using video density imaging techniques are courtesy of David Lange, Department of Civil Engineering, University of Illinois at Urbana-Champaign.



CSP 1
(acid etched)



CSP 2
(grinding)

CSP 3
(light shotblast)

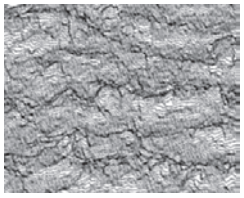
CSP 4
(light scarification)

CSP 5
(medium shotblast)

CSP 6
(medium scarification)

CSP 7
(heavy abrasive blast)

CSP 8
(scabbled)



CSP 9
(heavy scarification)

Method selector

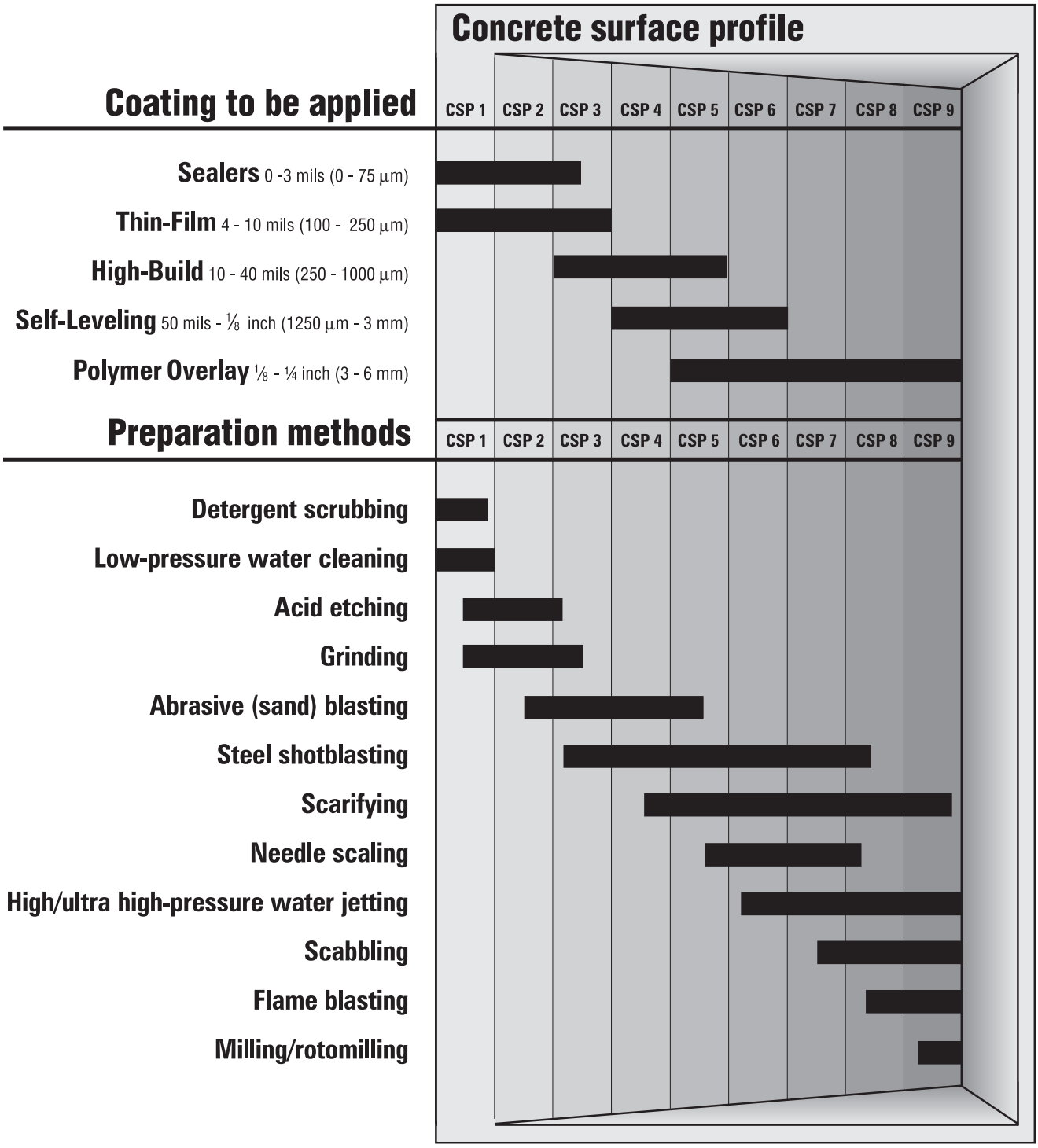


Photo: Tennant Company

Detergent Scrubbing

Chemical removal of oil, grease, and other deposits on concrete surfaces by scrubbing with a detergent solution.

Method summary

This method can be used indoors or outdoors 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 surface texture.

Purpose. Detergent scrubbing is frequently used to prepare concrete for acid etching. It may also prepare concrete surfaces for the application of sealers or surface hardeners, or for adhesive bonding.

Limitations. This method is limited to the removal of water-soluble or detergent-emulsifiable contaminants. (Debris which is readily loosened may be removed by light mechanical action by the scrubbers).

Removal. Suitable for superficial removal of oil, grease, organic or inorganic residues, some acrylic, wax, or rubber membranes, rust, and other oxidation deposits from concrete surfaces. Absorbed fluids such as oils and grease may require several treatments to achieve acceptable results. Bugholes and open pores at the surface may be scrubbed to a depth of 6 to 10 mils (150 to 250 μm).

Pattern. Detergent scrubbing will not produce any noticeable pattern effect on sound concrete surfaces.

Profile. ICRI CSP 1

A clean surface devoid of oil, grease, buildup, and loose debris. The scrubbing process should not alter surface texture.

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.

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 material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific materials or contaminant being removed. Materials likely to require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment.

Suitable measures for the containment, collection, and proper disposal of debris and rinse water should be considered. Though nontoxic, some citric acid-based cleaning solutions have a pervasive odor.

Execution

- Apply chemical detergent solution.
- Scrub in chemical solution with stiff-bristled broom or scrubbing machine.
- Collect and dispose of solution.
- Repeat process as needed to achieve acceptable results.

Equipment

Manual method:

- mop
- stiff broom
- pressure washer
- squeegee
- wet/dry vacuum

Mechanical method:

- Automatic scrubbing machine (walk-behind or self-propelled). Available in gas, electric, propane, or diesel-powered models. Brush rotation speeds up to 300 rpm.
- Brushes (disc or cylindrical pad). Nylon bristle brushes are relatively soft. Polyethylene bristles are stiffer, more aggressive. Polyethylene/abrasive composite bristles will provide the most aggressive mechanical cleaning. Sizes range from 18 to 60 inch (0.5 to 1.5 m) brush path.
- Solution tanks range from 3 to 365 gallons (11 to 1,380 L) with recovery tanks to hold scrubbing residue.

Materials

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

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

Down time. (The time considerations which follow are applicable to automatic scrubber machines). Mixing chemicals, filling tanks, and removing soilage from recovery tanks will involve some down time. For example, a 100 gallon (380 L) tank may take 20 to 30 minutes to fill. Changing brushes is quick and infrequent. Replacement frequency for pickup squeegees will depend on wear factors.

Cleanup. Scrubbing manually with brooms or mechanically with electric single disc machines will generate a liquid residue which must be removed by squeegee and vacuum to obtain a clean surface. Automatic scrubbers have an internal squeegee/vacuum system to remove the liquid residue immediately behind the scrubbing brushes.

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 ft^2 (50 m^2) per hour.
- Manual with electric disc machine with wet/dry vacuum recovery: 1,000 ft^2/hr (100 m^2/hr)
- Small walk behind scrubber: 5,000 ft^2/hr (500 m^2/hr)
- Medium or large riding scrubber: 50,000 ft^2/hr (5,000 m^2/hr)

Standards and specifications

As required by the specifications of the manufacturer or customer.

Surfaces scrubbed in preparation for etching must be clean enough to allow chemical etching solutions to bite into cement paste. Inspection may consist of one or a combination of the following methods:

- Visual inspection should show no dirt, oil, grease, or debris on the surface.
- The prepared surface should be free of bond-inhibiting barriers and demonstrate sufficient strength for the proposed application.
- Gloss meter, slip tester/traction recorder.
- A solution hand scrubbed across area to be tested. Recovered solution should be clear.

ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41).

Safety

- Eye protection: Required.
- Personal protective equipment: Latex gloves, boot protection.
- Respiratory protection: Not required.
- Hearing protection: Recommended if automatic scrubbers are used.

Photo: Buildings Consulting Group, Inc.

Low-Pressure Water Cleaning

Water is sprayed at pressures less than 5,000 psi to remove dirt and loose, friable material. This method does not remove any significant amount of concrete.

Method summary

This method may be used outdoors to remove dust, friable materials, debris, or water-soluble contaminants from concrete surfaces and surface cavities. It may be used in interior spaces where mist, noise, and severe puddling can be tolerated. The method is suitable for horizontal, vertical, and overhead applications. This method does not produce any significant texture, profile, or pattern. For surface preparation applications, low-pressure water cleaning should supplement other methods.

Purpose. Low-pressure water cleaning is used to rinse away dirt, dust, loose scale or debris generated by more aggressive surface preparation methods.

Limitations. This method is not suitable for the removal of sealers, coatings, curing membranes, or any significant volume of concrete.

Removal. Low-pressure water cleaning will not produce any measurable removal of sound concrete.

Pattern. Low-pressure water cleaning will not introduce any noticeable pattern effect on sound concrete surfaces.

Profile. ICRI CSP 1

Accessibility. With the wide variety of portable and maneuverable equipment available, most surfaces are easily accessible. Tight spaces can be accessed with a hose and hand-held lance. Presence of goods or equipment that cannot be adequately protected from mist or spray may restrict use of this method.

Environmental factors. This process produces loud noise similar to sandblasting. 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. Materials likely to require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment.

Environmental regulations may require containment and regulated disposal of the liquid waste generated.

Execution

- A water jet 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 hand-held lances are used, the process will be slower, but similar.
- Standing water may need to be pumped, vacuumed, or squeegeed off the surface.
- Solid debris and water residue are disposed of as required by local regulations or project restrictions.

Equipment

- Booster pump (to increase pressure)
- Pressure rated hoses
- Water jet: wheeled equipment for horizontal surfaces; hand-held lance for vertical and overhead applications, corners, or other difficult-to-reach locations
- Suitable nozzle tip
- Runoff protection to catch debris flowing off site or toward drains

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

Labor. Generally requires a two or three-person crew. Work may be performed with unskilled labor. Skilled supervision may be needed if complex equipment is used.

Down time. Setup time is typically two to four hours to protect surfaces and install runoff protection to catch loosened materials. Production may shut down periodically if water must be transported to the work area.

Cleanup. Several hundred gallons of water per hour may need to be drained away. The volume of debris trapped by collectors is usually small.

Production rates. The rates below are approximate. Actual rates will vary with the efficiency of equipment employed and preparation objectives.

- 1,000 to 2,000 ft^2/hr (100 to 200 m^2/hr) for flat surface.
- 250 to 1,000 ft^2/hr (25 to 100 m^2/hr) for hand-held equipment on vertical surfaces.

Standards and specifications

Visual inspection should find no obvious dirt, laitance, or debris on the surface. The prepared surface should be free of bond-inhibiting barriers and demonstrate sufficient strength for the proposed application. Beads of water indicate a surface contaminant that may need to be removed by other means. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41).

Safety

- Eye protection: Anti-fog goggles or face shield.
- Personal protective equipment: Rugged rubber or plastic gloves, steel-toed boots, and waterproof outer-layers.
- Respiratory protection: Not required.
- Hearing protection: Recommended.

Photo: Tennant Company

Acid Etching

Chemical removal of cement paste to clean and condition concrete surfaces prior to application of thin-film sealers or coatings.

Method summary

Acid etch is a mixture of water-soluble solvents, surface-active agents, and suitable acids designed to remove (etch) cement paste from the surface and pores of concrete. It also aids in dislodging slight traces of oils, grease, or fats remaining after detergent scrubbing. Etching produces a clean, lightly-profiled concrete surface to promote penetration and adhesion of sealers and coatings. The process will almost always be used to prepare concrete surfaces for the application of thin-film coatings. The process can be used inside or outside on most concrete, quarry tile, or stone surfaces.

Purpose. Etching is used to remove weak cement paste and to slightly profile the surface by exposing fine aggregate. This process is used to prepare concrete surfaces for the application of concrete sealers or thin-film epoxy, urethane, acrylic, and alkyd coatings.

Limitations

- Not suitable preparation for systems greater than 10 mils.
- Thorough removal of etching debris requires the use of vacuuming equipment.
- 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. (Incomplete removal will leave bond-inhibiting contaminants on the surface.)
- Hydrochloric acid may not be used on metallic hardened surfaces.
- Oils, grease, and other surface deposits must be removed prior to etching
- Not recommended for use on green concretes. Minimum age is six weeks.
- The etching process will saturate the substrate. When used in preparation for moisture-sensitive coatings, time restrictions may not allow for sufficient drying.
- Environmental considerations may require full containment and recovery of spent acid and rinse water.

Removal. The acid in the etching solution attacks the $Ca(OH)_2$ and C–S–H 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. Typical depth of removal is 4 to 10 mils (100 to 250 μm).

Pattern. Etching should not introduce any noticeable pattern effect on sound concrete surfaces.

Profile. ICRI CSP 1 – 3

Surface should feel like fine sandpaper with no residue or grit. Surface should have a dull, even appearance. If surface is still smooth or glossy, repeat procedure.

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

Environmental factors. Applied as an acid wash, the mixture may corrode metals on contact. Debris produced by acid etching 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. Materials likely to require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment. Spent acid and rinse water should

be disposed of as required by local regulations or project restrictions. Careful control of the etching process can produce a residue solution having a slightly alkaline pH of 8 or 9.

Execution

- Dilute acid mixture according to floor type and strength of concentrate. For standard concrete, use manufacturer's ratio. The usual concentration is approximately 10%. Dense or chemically-hardened floors may require higher concentrations and/or multiple passes.
- Thoroughly wet concrete surfaces. Any standing water must be removed prior to application of acid.
- Apply mixed solution uniformly at an approximate rate of 100 ft^2 (9 m^2) per gallon.
- Agitate acid solution with stiff bristle broom or power brush for five to ten minutes. Do not allow surface to dry. Vacuum residue.
- Thoroughly scrub with an alkaline detergent and vacuum residue. Repeat as necessary to completely remove etching debris.
- Rinse with clean water, scrub and vacuum dry.
- Allow floor to dry for a minimum of 12 to 16 hours.

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
- 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 equipment manufacturer to determine suitability.

Materials

- Acid etch solution. Typical solutions include muriatic (hydrochloric), sulfamic, phosphoric, and citric acids.
- Alkaline detergent for cleanup scrub
- Water source
- Plastic sheeting for machine protection

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

Down time. Minimal. Chemical mixing requires only a short period of time. Filling and emptying scrubber and wet-vac tanks should take ten to twenty minutes. Additional time required to remove portable machinery from etch area and to place plastic sheeting on non-portable machinery for protection.

Cleanup. While the surface is still wet, squeegee and vacuum acid solution and slurry debris. Immediately flood surface with alkaline detergent solution, scrub and vacuum. Some acid etching solutions produce a white residue which helps identify locations requiring additional scrubbing, rinsing, and removal. Flood etched surface with clear rinse water, scrub, and vacuum dry.

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

- Manual with wet/dry vacuum recovery: 1,600 ft^2/hr (150 m^2/hr).
- Medium scrubber: 8,000 ft^2/hr (740 m^2/hr).

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection should show a fine-grained surface profile with no white residue, dirt or debris remaining on surface. Dry surface check using a moisture meter. The prepared surface should be free of bond-inhibiting barriers and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41).

Safety

- Eye protection: Splash shield recommended.
- Personal protective equipment: Gloves, aprons, and boot protection required. Recommended materials for these items are neoprene or rubber.
- Respiratory protection: Use of respirators equipped with acid-gases canister is recommended for acid etching in poorly ventilated or confined space.
- Hearing protection: Required if automatic scrubbers are used for cleanup.
- Alkaline detergent can be used to neutralize concentrated acid spills.

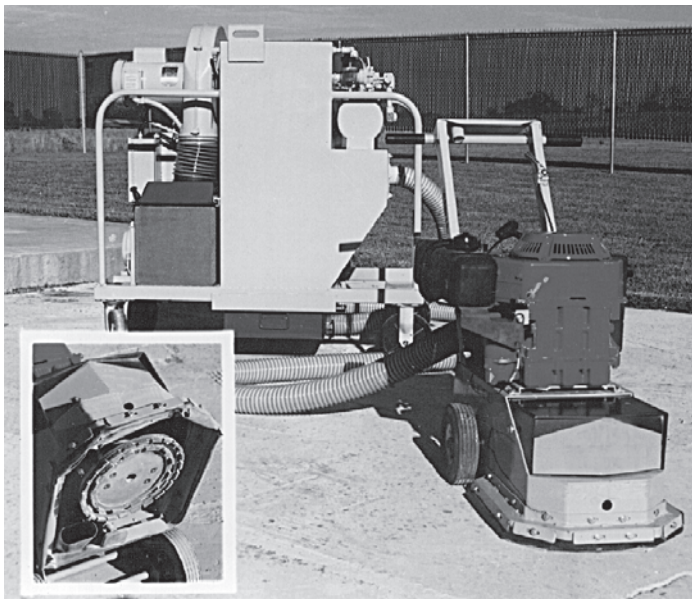


Photo: Equipment Development Co., Inc.

Grinding

The rotation of one or more abrading stones or discs applied under pressure at right angles to the concrete surface.

Method summary

This method may be used on horizontal, vertical and overhead surfaces to remove deposits or coatings, and to reduce or smooth surface profile. The grinding stone or disc is applied under pressure and moved across the surface until the desired effect is achieved. Grinding may be used on almost any substrate and is suitable for both interior or exterior applications. Efficiency considerations may limit coating removal applications to film thicknesses less than 6 mils (150 μm).

Purpose. Grinding is used on concrete surfaces to reduce or smooth slight surface irregularities and to remove mineral deposits and thin coatings.

Limitations. Grinding is not recommended for the following applications:

- Preparation of previously sealed or coated surfaces for recoating—unless followed by acid etching or shotblast.
- Surface profile is required.
- Removal of chlorinated rubber, acrylic, or other soft coatings or finishes.
- Removal of tile or carpet adhesives.
- Occupied work space (unless rigorous dust control methods are used).
- Surfaces of unknown composition.

Removal. Removal is practically restricted to surface protrusions and coatings less than 6 mils (150 μm) thick. May be used to remove noncombustible or non-heat degenerating coatings. Method will successfully remove rigid epoxy, polyurethane, and methacrylate coatings. Grinding may also be used to remove efflorescence, rust, and other oxidized deposits.

Pattern. Small hand-held grinders are likely to produce gouging and a circular, grooved pattern. Large walk-behind units fitted with aggressive media should eliminate gouging, but are likely to impart a circular pattern. Larger units using fine stones should not produce any detectable pattern.

Profile. ICRI CSP 1–3
Grinding produces a smooth surface. Other methods may be used in conjunction with grinding to produce required profile.

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

Environmental Factors. Dry grinding will produce a fine airborne dust which may be minimized with dust control attachments. Debris generated by this method will contain fine particles of any material or contaminant being removed. Materials likely to require special protective measures and handling include tile mastics, which may contain asbestos; lead-based paints; and PCB's which may have been absorbed by concrete in the vicinity of electrical equipment. Wet grinding, which may be selected to eliminate airborne dust, will produce a slurry residue. Slurry constituents from some materials may be considered toxic. Plans to collect and properly dispose of slurry and rinse water must be considered. Grinding soft, easily charred materials will generate smoke which may be considered hazardous.

Preparation should include plans to adequately protect occupants and workers. Noise and vibration levels are considered to be low.

Execution

Equipment. Appropriate selection of a grinder depends on the location and size of the area, specific removal requirements, and accessibility. They are available in electric, pneumatic, or gas-driven models. Sizes range from hand-held grinders to walk-behind machines. Rotation speeds vary from 1,000 to 9,000 rpm.

Materials. The grinding medium (stone or disc) is the consumed material, and will vary with job specific application requirements:

- Size: diameter ranges from 4 to 18 inches (100 to 450 mm).
- Composition: varies from very fine polishing media to aggressive cutting media with wet or dry diamonds.
- Shape: flat, cone-shaped, or cup disc.

Labor. Low to medium skill required.

Down time. Minimal. 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.

Cleanup. Grinding will leave a fine powdered residue of the removed material. The residue generated can be swept, rinsed with water, or vacuumed.

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

- Hand-held units: 20 ft^2/hr (2 m^2/hr)
- Walk-behind units: 800 ft^2/hr (75 m^2/hr)

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile objectives. The prepared surface should be free of bond-inhibiting barriers and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41).

Safety

- Eye protection: Required.
- Personal protective equipment: Heavy gloves, steel-toed boots. Skin should be protected by clothing and barrier creams. Dust may produce alkali burns or allergic skin reaction.
- Respiratory protection: Required. Process will generate airborne dust. Mask should be approved for silica and other airborne dusts, and fit tightly to contours of face. If material being ground contains toxic substances, additional protection may be required.
- Hearing protection: Recommended.

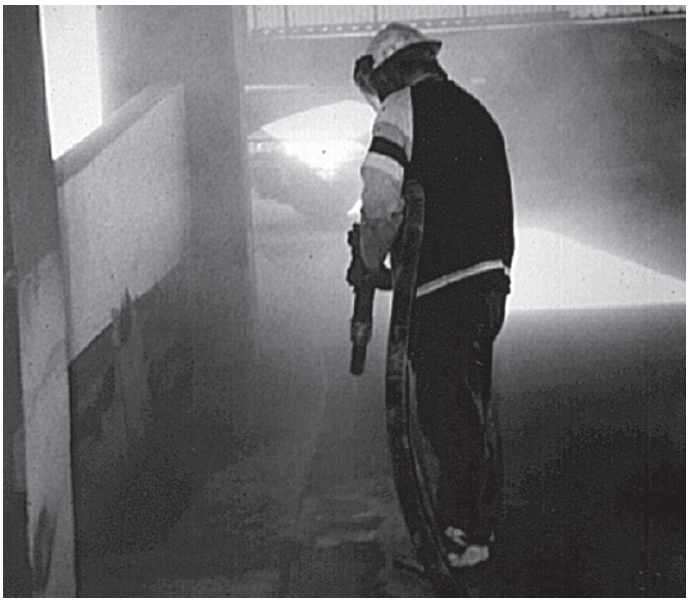


Photo: Buildings Consulting Group, Inc.

Abrasive (Sand) Blasting

This method uses compressed air intermixed with an abrasive medium to clean concrete or steel surfaces. The air stream is channeled through a nozzle directly at the surface.

Method summary

Abrasive blasting is used to clean and profile concrete surfaces in preparation for the application of sealers, coatings, and polymer overlays. The process can provide a light cleaning profile, often referred to as a "brush blast," or it can be used to achieve a much heavier surface lineation for deep cleaning and profiling. It may also be used to remove surface contaminants and thin, brittle coatings, or adhesive films. Water may be introduced into the blast process to reduce airborne dust. Vacuum recovery systems may also be used with abrasive blast units to reduce dust and cleanup. This method may be used on horizontal, vertical, and overhead surfaces, and is suitable for both interior and exterior applications.

Purpose. Abrasive blasting is a highly flexible process capable of producing a range of profiles suitable for the application of the following systems:

- sealers: 0 to 4 mils (0 to 100 μm)
- thin-film coatings: 4 to 10 mils (100 to 250 μm)
- high-build coatings: 10 to 30 mils (250 to 750 μm)
- broadcast systems: 30 mils to ¼ inch (750 μm to 6 mm)
- monolithic toppings: ⅛ to ¼ inch (3 to 6 mm)

Limitations. Abrasive blasting typically generates a large volume of airborne dust. Increased profiles may become visible through concrete sealers and thin or clear coatings, producing an unsightly finish.

Abrasive blast is not recommended for the following applications:

- Removal of resilient coatings, uncured coatings or adhesives, and tar-based materials.
- It should not be used when occupied space, goods, or equipment cannot be adequately protected from dust infiltration.
- High volume concrete removal.

Removal. Removal is accomplished by the eroding effect of the blast media impacting the surface at high velocity. Depth of removal may range from a minimum of 1 to 2 mils (25 to 50 μm) to a practical maximum of 30 mils (750 μm).

Pattern. Abrasive blasting should not introduce any noticeable pattern effect.

Profile. ICRI CSP 2 – 4
Profile achieved is dependent upon duration of exposure to blast stream and size and cutting efficiency of blast media used.

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

Environmental Factors. Abrasive blasting will produce airborne dust containing silica, concrete constituents and particles of any material being removed. Special provisions are often needed to protect people, property, and the environment. Blast curtains and containment areas may be used to isolate the blast process. Blast media substitutes such as sodium bicarbonate are sometimes used to reduce the dust hazard or volume of debris.

Any special requirements for containment and disposal will depend on the specific contaminants or materials being removed. Materials likely to require special handling

include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment. Noise levels are likely to exceed 85 dB.

Execution

The blast media stream is directed at the surface using a controlled sweeping motion. The duration of exposure to the blast stream depends on the strength of substrate and the degree of cleaning and profiling required.

Equipment

- Air compressor of sufficient capacity to drive the equipment and blast media selected
- Blast media hopper (meters the media into the air stream passing through the hose and nozzle)
- Moisture and oil separators to insure clean, dry air supply
- Blast nozzle and hose

Materials. The blast medium, e.g. silica sand, slag (black beauty), etc. is the consumed material.

Labor. Medium to above-medium skill level required. Special training in safe operation and related environmental issues is recommended for crew members. Two workers per blast unit is standard—one to operate the blast nozzle, the other to support the blast media hopper and compressor and to manage the hoses.

Down time. Hours needed for set up and removal of work area protection may be significant. Time required for mobilization, setup, and maintenance of blast equipment and compressor is minimal.

Cleanup. Dust, fine particles of concrete or other pulverized materials, and a relatively large volume of expended blast media are generated by the abrasive blast process. Water soluble blast media, which can be flushed into conventional drainage systems, may substantially reduce the volume of debris to be collected and removed.

Production rates. Productivity is highly variable and is dependent upon the strength of the concrete, any surfacing materials or contaminants, accessibility, capacity of blast media hopper and compressor, and type of blast media used.

Production rate estimates range from 1,000 to 6,000 ft^2 (100 to 600 m^2) per eight hour shift per unit.

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile. The prepared surface should be free of dust, debris, bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

- Eye protection: Required.
- Personal protective equipment: Helmet, hood, and heavy gloves, boots and clothing are recommended for blast nozzle operator. Skin should be protected by clothing and barrier creams. Dust may produce alkali burns or allergic skin response.
- Respiratory protection: Required. Supplied air system is routinely used for blast nozzle operator.
- Hearing protection: Required.
- Safety devices: Blast nozzle must be equipped with an automatic shut-off device.

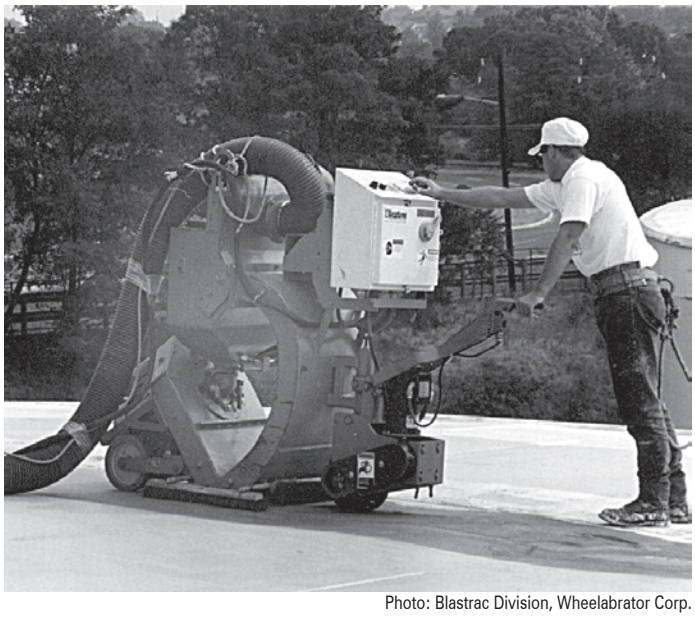


Photo: Blastrac Division, Wheelabrator Corp.

Steel Shotblasting

Steel shot is centrifugally propelled at high velocity onto the surface. This process is confined in an enclosed blast chamber which recovers and separates dust and reusable shot.

Method summary

Shotblasting is principally used to roughen horizontal surfaces in preparation for the application of sealers, coatings, or polymer overlays. This method is also used to remove some existing coatings, adhesives, and surface contaminants. Hand-held machines are available for use on vertical surfaces. Shotblasting is suitable for use in both interior and exterior applications.

Purpose. Cleaning and profiling concrete surfaces by removing dirt, laitance, curing compounds, sealers, or other superficial contaminants in preparation for the application of protective materials.

Shotblasting is suitable for the removal of polyurethane coatings up to 10 mils (250 μm) thick, tile mastics, and brittle coatings such as epoxy or methyl methacrylate systems up to ⅛ inch (3 mm) thick. Removal of thicker materials may require multiple passes.

Limitations. This method is generally not suitable for removing uncured resin systems, resilient coatings, adhesives, and tar-based materials. The pattern and profile of shotblasted surfaces may be visible through concrete sealers and thin or clear coatings.

Removal. Removal is accomplished by the pulverizing effect of steel shot impacting the surface at high velocity. Depth of removal is controlled by shot size, machine setup, and rate of travel. Generally, the maximum recommended depth of removal for a single pass is ¼ inch (6 mm).

Pattern. The "double exposure" that occurs at the point of overlap between successive passes produces a parallel striping effect at intervals determined by the width of cut. Skilled operation of equipment can minimize striping effect.

Profile. ICRI CSP 2 – 8
As the depth of cut increases, the profile will be increasingly dominated by the size and shape of the coarse aggregate.

Accessibility. Shotblasting equipment is available in a range of sizes to provide ready access to most surfaces. Edges and corners may be detailed to within ¼ inch (6 mm) of the vertical surfaces with specialty edging machines or hand-held units. Access to tight configurations, such as around and in between pipes, is restricted by the width of the machine used.

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. Materials likely to require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment.

Special ventilation provisions may be required when operating gasoline, diesel, or propane-powered units indoors.

With the exception of some large machines, noise levels will usually be below 85 dB. Vibration is not considered to be a factor.

Execution

The machine is steered in a straight line across the surface. At 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.

Equipment

- Shotblasting machine: available in gasoline, diesel, propane, or electrically-powered units
- Power source: requirements for electric powered units will vary from 110/120 V @ 26 A to 460 V @ 60 A
- Brooms and shovels
- Spare parts for blaster maintenance
- Magnets or magnetic broom to retrieve fugitive steel shot

Materials. Steel shot is the consumed material. Consumption ranges from 10 to 20 lbs/hr. Commonly used sizes of steel shot are shown below:

Type	Diameter	Profile
S-170[1]	0.017 in. (0.43 mm)	CSP 3[2]
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[1]	0.055 in. (1.40 mm)	CSP 7

1 Use of this size is not recommended by all manufacturers.

2 Association of profile with shot size is not precise as profile obtained is also influenced by machine set up and rate of travel.

Labor. Experienced or well-trained personnel to operate equipment is recommended. One worker 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 which may require a licensed electrician.

Down time. Surfaces must be dry and broom cleaned prior to shotblasting. A test area is required to insure 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 collection system.

Cleanup. Steel media may remain on the surface, in edges or corners, or trapped in cracks. It may be recovered by using magnets, magnetic broom, air blast, vacuum, or stiff bristle broom.

Production rates. The following rates are approximate and assume sound, 5,000 psi (35 MPa) concrete. Actual production rates will vary considerably and will depend on the strength of the concrete, the type of material being removed, preparation objectives, operator skill, and efficiency of equipment employed.

Small units: 150 to 250 ft^2/hr (14 to 23 m^2/hr)

Medium units: 350 to 1,500 ft^2/hr (33 o 140 m^2/hr)

Large units: 2,000 to 4,500+ ft^2/hr (190 to 420+ m^2/hr)

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile. The prepared surface should be free of dust, debris, bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

Eye protection: Required.

Personal protective equipment: Skin protection may be required during removal of hazardous materials and handling of debris.

Respiratory protection: May be required during removal of hazardous materials and handling of debris.

Hearing protection: Recommended.

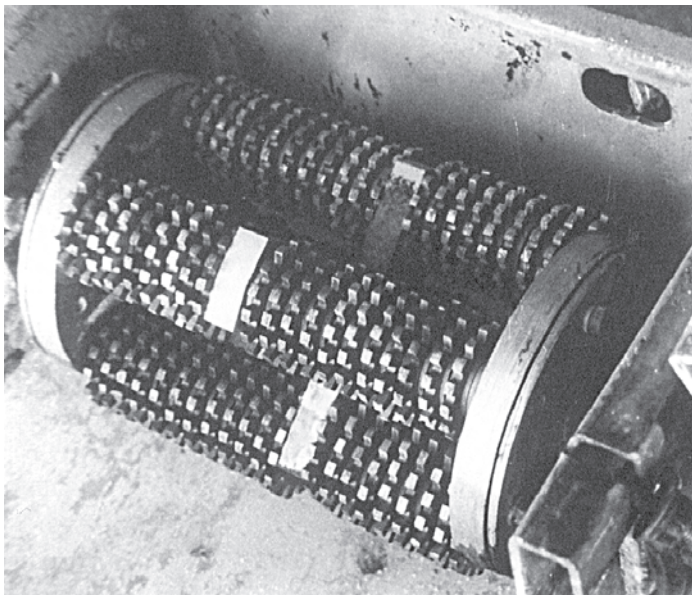


Photo: Restruction Corporation

Scarifying

The rotary action of the cutters (toothed washers) impacts the surface at a right angle to fracture or pulverize the concrete. The cutters are assembled on tempered steel rods mounted at the perimeter of a drum which rotates at high speeds.

Method summary

Scarification is used primarily on horizontal surfaces for the removal of concrete or brittle coatings up to ⅛ inch (3 mm) thick. It may also be used to profile concrete surfaces. Hand-held units are available for vertical, and overhead applications. Scarifying may be used on almost any substrate and is suitable for both interior or exterior applications. This method is also known as concrete planing.

Purpose

- The removal of brittle coatings such as epoxy, polyurethane, or methyl methacrylate systems up to ⅛ inch (3 mm) in preparation for the application of replacement coatings.
- Removal of deteriorated or contaminated concrete to depths ranging from ⅛ to ¾ inch (3 to 19 mm) depending on the strength of the substrate, cutter configuration, and size and power of the machine.
- Removal of high spots in order to level slabs.
- Profiling of concrete surfaces in preparation for the application of high-build coatings greater than 15 mils (375 μm), self-leveling systems, broadcast, thin overlays or placement of other repair materials.
- Removal of adhesives may be accomplished by the adjustment of spacers and the selection of appropriate cutters.

Limitations. Scarification is not recommended for surface preparation for sealers or coatings less than 15 mils (375 μm) or the removal of heavy elastomeric membranes.

This method may cause micro-cracking in substrate. (It has been demonstrated that micro-cracking will reduce the strength of the bond between the substrate and materials placed over it.) The deleterious effects of micro-cracking may be reduced or eliminated by following initial removal with steel shotblasting, abrasive blasting, or high and ultra high-pressure water jetting. The use of sharp, fine-toothed cutters may prevent the development of micro-cracking.

Removal. Removal depth may economically range from light surface profiling to ¼ inch (6 mm) for smaller equipment, and ½ to ¾ inch (13 to 19 mm) for larger equipment. Removal depth greater than ⅛ inch (3 mm) is accomplished in multiple passes.

Pattern. Scarifying will produce a parallel, striated pattern. The deepest striations will be produced at surface high points.

Profile. ICRI CSP 4 – 9

Accessibility. With portable equipment ranging in size from small hand-held scarifiers to large self-propelled units most surfaces are accessible to within ¼ inch (6 mm) of the edge. Access to corners and tight configurations such as around and in between pipes is restricted by the dimensions of the drum housing. The smaller walk-behind machines are able to pass through standard door openings.

Environmental factors. Scarifying will produce airborne dust containing concrete constituents 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. Materials likely to require special handling include tile mastics,

which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment.

Noise levels are likely to exceed 85 dB. Vibration levels are moderate. Special ventilation arrangements will be required when operating gasoline or diesel-powered units indoors.

Execution

With the exception of hand-held units, most scarifiers are operated by pushing the machine forward over the surface, advancing at a slow walk. The depth and rate of cutting 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.

Equipment

- Scarifier: available in electric, pneumatic, or gasoline powered models in sizes ranging from hand-held to self-propelled ride-on units. Path widths range from 4 to 36 inches (100 to 900 mm)
- Replacement drums: plan on four drums per machine for each eight hours of continuous operation
- Air compressor or other air supply (pneumatic models only)
- Industrial vacuum cleaner to be used with vacuum adapter attachments to limit airborne dust

Materials. The cutters are the consumed material. Rate of consumption depends on the following:

- Cutter configuration
- Cutter composition (hardened steel, tungsten carbide)
- Substrate hardness
- Composition of materials to be removed

Labor. Low to medium skill required.

Down time. Minimal. Setup requires very little time unless dust protection includes draping and taping. Drum changes will take approximately five minutes. (See "materials" and "equipment" above to assist in estimating frequency of drum change). Rebuilding drums is usually an off-site activity.

Cleanup. Scarifying will generate dust and larger debris. While most scarifiers are not equipped to pick up debris, many units have adapters which may be used with industrial vacuum cleaners to contain dust. Sweeping and removal of the rough debris will be required.

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

- Hand held units: 20 ft^2/hr (2 m^2/hr)
- Walk-behind units: 800 ft^2/hr (75 m^2/hr)

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile. The prepared surface should be free of dust, debris, bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

- Eye protection: Required.
- Personal protective equipment: Skin should be protected by clothing and barrier creams. Dust may produce alkali burns or allergic skin reaction.
- Respiratory protection: Mask should be approved for silica and other airborne dusts, and fit tightly to contours of face. If materials being removed contain toxic substances, additional protection may be required.
- Hearing protection: Recommended.

Photo: Equipment Development Co., Inc.

Needle Scaling

Impacting the surface with pointed tips of a bundle of steel rods contained by a steel tube and pulsed by compressed air.

Method summary

This method can be used on concrete surfaces indoors, outdoors, or underwater, to remove efflorescence, brittle encrustations, and rigid coating systems. It is frequently used for work on edges and other tight spaces which cannot be accessed by larger, more automated equipment. It may be used underwater to remove barnacles and other marine shell fish attached to submerged surfaces. It is suitable for use on horizontal, vertical, and overhead surfaces.

Purpose. Needle scaling is used to remove coatings or brittle encrustations in preparation for the application of protective coatings or other repair work. It is an excellent method for detailing corners, edges, and most recessed areas. It is suitable for preparing concrete surfaces for high-build coatings, self-leveling and broadcast applications, and thin overlays.

Limitations. Needle scaling is not recommended for the following applications:

- Preparation for coatings less than 15 mils (375 μm)
- Removal of thick, resilient coatings
- Preparation of large surface areas
- Removal of sound concrete

Removal. Removal is accomplished by the superficial fracture and pulverization of concrete surfaces to which the unwanted material is adhered. Depth of concrete removal will typically be in the range of $^{1}/_{16}$ to $^{1}/_{8}$ inch (1.5 to 3 mm) and is dependent on aggregate size and composition.

Needle scaling is generally suitable for the following removal applications:

- Rigid coatings to 15 mils (375 μm)
- Soft or flexible coatings to 30 mils (750 μm)
- Brittle deposits to ¼ inch (6 mm)

Pattern. Needle scaling will produce random, evenly distributed impact craters around larger aggregate, imparting a heavy "orange peel" texture to the surface.

Profile. ICRI CSP 5 – 8

Accessibility. Hand-held needle scalers are available in several sizes providing virtually unrestricted accessibility.

Environmental factors. Debris produced by needle scaling will contain particles of any material or contaminants being removed. Any special requirements for containment and disposal will depend on the specific contaminants being removed. Materials likely to require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment. Noise and vibration levels are low to medium.

Execution

Rod (needle) points are held against the surface with light to medium pressure. The pneumatically driven rods are activated by a trigger located in the unit's handle.

Equipment

- Needle gun: several sizes of pneumatic, hand-held units are available which vary in weight from 2½ to 15 lb. (1 to 7 kg). Size of rod bundle will vary from 12 to more than 30 rods.
- Replacement rod bundles: plan for six bundles per gun for each eight hours of continuous operation.
- Air hose

• Air compressor or other air supply producing 3 to 15 cfm @ 80 to 120 psi.

Materials. The hardened steel rods are the consumed material.

Labor. Low skill required.

Down time. Approximately five minutes per hour to change needle bundles. Rebuilding needle bundles is usually an off-site activity.

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

Production rates. Productivity will range from 10 to 50 ft^2/hr (1 to 5 m^2/hr). Rate is dependent on size of needle gun, number of needles per bundle, strength of substrate, and hardness of material being removed.

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile. The prepared surface should be free of dust, debris, or bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

• Eye protection: Required.

• Personal protective equipment: Skin should be protected by clothing and barrier creams. Dust may produce alkali burns or allergic skin response.

• Respiratory protection: Process will generate airborne dust. Mask should be approved for silica and other airborne dusts, and fit tightly to contours of face. If materials being removed contain toxic substances, additional protection may be required.

• Hearing protection: Recommended.

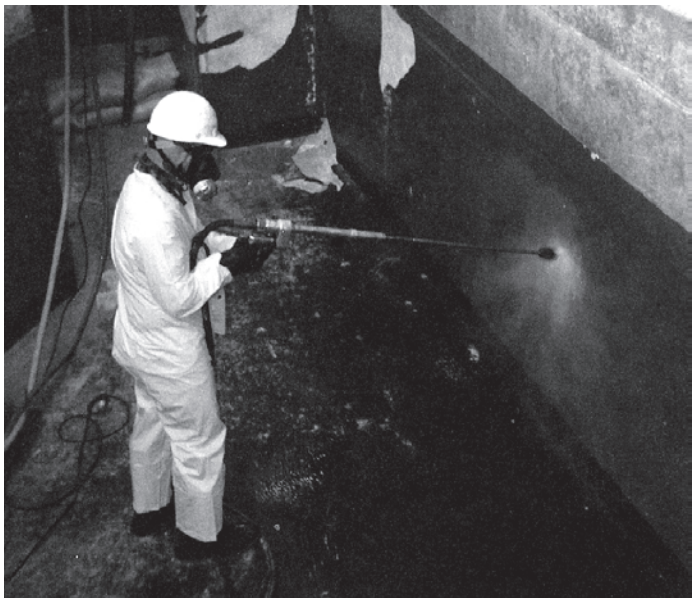


Photo: Allstate GeoTek, Inc.

High and Ultra High-Pressure Water Jetting

Water is sprayed at pressures between 5,000 and 45,000 psi (35 to 300 MPa) to remove heavy encrustations of dirt and loose, friable material. This method can also remove some coatings.

Method summary

This method may be used outdoors to remove heavy encrustations of efflorescence, scale, dirt, or water soluble contaminants from concrete surfaces and surface cavities. It may also be used in some interior spaces where heavy mist, spray, high noise levels, and severe puddling can be tolerated. Water jetting, at the higher pressures, effectively removes some coating systems. Suitable for horizontal, vertical, and overhead applications. This method is not economically suitable for the removal of sound concrete.

Purpose. High and ultra high pressure jetting may be used to remove laitance, efflorescence, scale, dirt, or other water-soluble contaminants. With suitable pressures and nozzle tips, high-strength epoxy, urethane, or methacrylate coating and thin overlay systems may be removed. It may also be used to remove carbonated, freezing-and-thawing damaged, or otherwise weakened material from concrete surfaces.

Limitations. High and ultra high-pressure water jetting is not recommended for the following applications:

- Removal of sound concrete.
- It 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.

Removal. Unsound concrete may be removed to depths of ¼ to ¾ inch (6 to 19 mm) and is dependent on the depth of deterioration.

Pattern. Properly done, high and ultra high-pressure water jetting should not produce any noticeable pattern in durable concrete. However, poor operator technique or inappropriate selection of pressure and nozzle tips may severely etch sound concrete.

Profile. ICRI CSP 6 – 9

The surface profile of durable concrete may remain unaffected by this process. 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.

Accessibility. With the wide variety of portable and maneuverable equipment available, most surfaces are easily accessible. Tight spaces can be accessed with a hand-held lance.

The presence of goods or equipment that cannot be adequately protected from mist or spray may restrict use of this method.

Environmental factors. This process produces loud noise, similar to sandblasting. Heavy mist and a significant volume of water will be introduced into the work area. The volume of water introduced will range from 2 to 10 gallons per minute (3 to 38 liters per minute) and is determined by the requirements of the equipment selected. The possibility that environmental regulations may require containment and regulated disposal of the liquid waste generated should be considered.

Execution

The concrete surface is prepared by methodically moving the water jet back and forth over the surface until the

desired results are achieved. If automated equipment is used, the operator typically makes parallel passes. If hand-held lances are used, the process will be slower, but similar. Standing water may need to be pumped or squeegeed off the surface. Units that clean and recycle jetting water are available. Dispose of solid debris, slurry, and water residue as required by local regulations or project restrictions.

Equipment

- Water pump with desired pressure capability
- Compressed air source producing a minimum of 85 cfm @ 120 psi
- High-pressure hoses
- Water jet: wheeled equipment for horizontal surfaces; hand-held lance for vertical and overhead applications, corners, or other difficult to reach locations. Robots may be used on horizontal and vertical surfaces.
- Suitable nozzle tip
- Runoff protection to catch debris flowing off site or toward drains

Materials

- Water source: Potable water is recommended and may be provided by tanker, hydrant connection, industrial spigot, or pump

Labor. Two or three person crew per machine. Medium to above medium skill level with appropriate training required. Must be able to assemble high-pressure components and safely operate equipment capable of causing sudden, severe injury. Skilled supervision may be needed if complex equipment is used.

Down time. Setup time is variable depending on the size of the work area and specific protective measures required. Time to cover and protect surfaces and install runoff protection to catch debris may be estimated at 6 to 10 man-hours for typical applications.

Cleanup. Large volumes of water may need to be drained away. The volume of debris trapped by collectors is usually small. High and ultra high-pressure jetting of deteriorated surfaces may produce much more debris.

Production rates. The rates shown below are approximate and assume sound, 5,000 psi (35 MPa) concrete. Actual production rates will vary considerably and will depend on the strength of the concrete, hardness and bond strength of any coating being removed, preparation objectives, operator skill, and efficiency of equipment employed.

- Horizontal surfaces: 125 to 300 ft^2/hr (12 to 28 m^2/hr)
- Vertical surfaces: 50 to 250 ft^2/hr (5 to 23 m^2/hr)

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection should show no dirt, laitance or debris on the surface. The prepared surface should be free of bond-inhibiting barriers and demonstrate sufficient strength for the proposed application. Beads of water indicate a surface contaminant that may require increased depth of removal to achieve suitably clean surfaces. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

The operator must be protected from high velocity rebound. Hands and feet require additional protection as they might inadvertently contact the water jet.

- Eye protection: Anti-fog goggles meeting ANSI requirements for high impact, and face shield.
- Personal protective equipment: Metal-mesh gloves are strongly recommended, steel-toed boots, metatarsal guards, helmet, and waterproof outer-layers.
- Respiratory protection: May be required in areas where high impact could cause an accidental release of toxic substances.
- Hearing protection: Process will generate noise levels in excess of 85 dB. Earmuff type protectors strongly recommended.

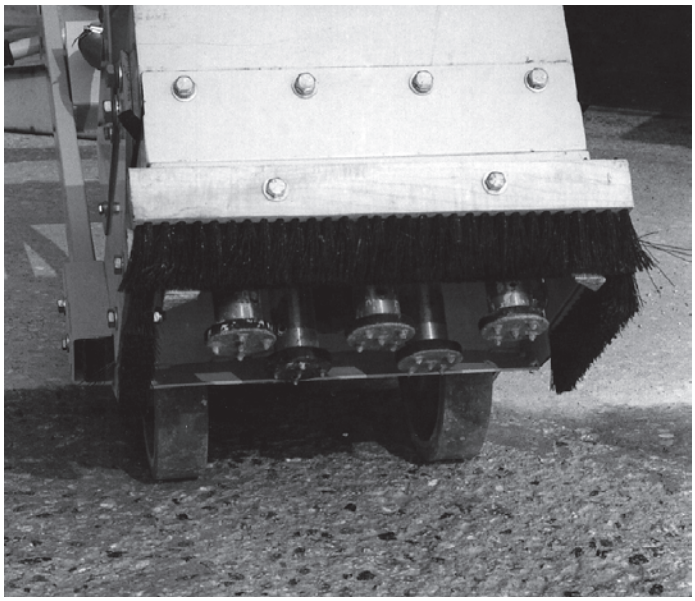


Photo: Equipment Development Co., Inc.

Scabbling

Impacting the substrate at right angle with piston-driven cutting heads to create a chipping and powdering action. The driving mechanism is compressed air.

Method summary

Scabbling is used primarily on horizontal surfaces to remove concrete or brittle coatings up to 1/4 inch (6 mm) thick. It may also be used to deeply profile concrete surfaces. Hand-held units, some of which are commonly known as "bush hammers," are available for light service on vertical and overhead surfaces. This method is suitable for use in interior and exterior applications.

Purpose

- The removal of brittle coatings such as epoxy, polyurethane, or methyl methacrylate systems up to ¼ inch (6 mm) in preparation for overlays over ⅛ inch (3 mm) thick.
- Removal of deteriorated or contaminated concrete to depths ranging from ⅛ to ¾ inch (3 to 19 mm) depending upon the strength of the substrate, size and power of the machine, and bit configuration.
- Deep profiling of concrete surfaces in preparation for placement of overlays or other repair materials.

Limitations

- Scabbling frequently causes micro-cracking in concrete substrates. (It has been demonstrated that micro-cracking will reduce the strength of the bond between the substrate and most materials placed over it.) The deleterious effects of micro-cracking may be reduced or eliminated by following initial removal with steel shotblasting, abrasive blasting, or high and ultra high-pressure water jetting.
- Scabbling is not recommended for the removal of elastomeric membranes or gummy materials such as tile or carpet adhesives.

Removal. Depth of economical concrete removal is dependent on aggregate size and strength of the substrate and may range from ⅛ to ¾ inch (3 to 19 mm).

Pattern. Scabbling will produce a very irregular surface dominated by fractured coarse aggregate. There should be no discernible tool pattern.

Profile. ICRI CSP 7 – 9

Accessibility. With portable equipment ranging in size from small hand-held to large walk-behind units, most surfaces are accessible to the edges. Corners, recesses, and tight configurations are generally accessible with properly-sized bits fitted to hand held, single piston units. Care should be taken to avoid damage to adjacent walls or equipment.

Walk-behind units will pass through standard door openings and will require a minimum vertical clearance of 4 feet (1.2 m).

Environmental factors. Scabbling will produce airborne dust containing concrete constituents 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. Materials likely to require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment. Noise levels are likely to exceed 85 dB. Vibration levels are moderate to severe. Work area enclosures and special ventilation provisions may be required indoors to prevent dust intrusion into nearby occupied work space.

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 sweeping to allow the operator to see the removal progress.

Equipment

- Scabbler: manually-operated machines range from single-head, hand-held units to walk-behind units having up to twelve heads
- Air compressor or other air source producing a minimum of 180 cfm @ 120 psi. Cfm requirements are likely to increase with larger equipment and multiple heads. (Disregard air requirements if hydraulic scabblers are used.)
- Air hose: ½ to 2 inches (13 to 50 mm) I.D.

Materials. Impact bits are the consumed material. These are available in varying configurations of tungsten carbide inserts.

Labor. Operator skill requirements are considered low.

Down time. Minimal. Setup requires very little time, unless dust protection includes draping and taping. 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. Scabbler machines require little maintenance.

Cleanup. Dust and larger particles up to ½ inches (13 mm) in diameter will be generated from the impact of the bits. Scabblers are rarely equipped to pick up this debris. Sweeping and vacuuming will be continuously required to remove the rough debris and fines.

Production rates. Productivity will vary considerably depending on size of machine, strength of substrate, depth of removal, and the type of material being removed. For heavy removal, estimated rates range from 20 ft^2/hr (2 m^2/hr) to 100 ft^2/hr (9 m^2/hr).

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile. The prepared surface should be free of dust, debris, or bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41).

Safety

- Eye protection: Required.
- Personal protective equipment: Skin should be protected by clothing and barrier creams. Dust may produce alkali burns or allergic skin response.
- Respiratory protection: Required. Mask should be approved for silica and other airborne dusts, and fit tightly to contours of face. If materials being removed contain toxic substances, additional protection may be required.
- Hearing protection: Recommended.

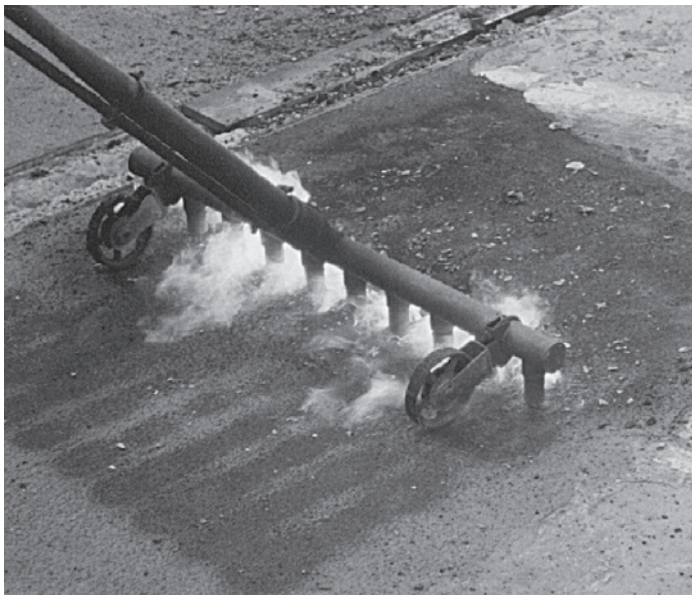


Photo: Concrete Cleaning Inc.

Flame Blasting

The combination of oxygen and acetylene to produce a flame which is passed at a given height and rate over the substrate.

Method summary

Flame blasting is used on horizontal, vertical, and overhead surfaces to remove contaminated concrete, mastics, or other high-build coatings. The applicability of this method is restricted by the presence of a 3,200° C (5,800° F) open flame, and the generation of toxic fumes which may accompany the removal of some materials. This process does not generate dust and is suitable for interior and exterior applications.

Purpose. To remove elastomeric membranes, paints, coatings up to ¼ inch (6 mm) in preparation for the application of overlays over ⅛ inch (3 mm) thick. Flame blasting may also be used to remove grease and oil contaminants.

Limitations. This method may not be used in the vicinity of flammable or combustible materials. It will generate a heavy volume of smoke and fumes when used to remove membranes, coatings, and other hydrocarbons from the substrate. Flame blasting may produce micro-cracking. Although some bond strength testing suggests that the process does not cause micro-cracking, the data are insufficient to be conclusive. (It has been demonstrated that micro-cracking will reduce the strength of the bond between the substrate and most materials placed over it.) The deleterious effects of micro-cracking may be reduced or eliminated by following initial removal with steel shotblasting, abrasive blasting, or high and ultra high-pressure water jetting.

Removal. Removal is accomplished by the superficial fracturing of the substrate induced by the expansive force of superheated pore water. Depth of removal ranges from ⅛ to ¼ inch (3 to 6 mm) per pass.

Pattern. Flame blasting will produce an irregular, chipped surface with no discernible pattern.

Profile. ICRI CSP 8 and higher

Sharp angular surface with a profile amplitude ranging from ⅛ to ¼ inch (3 to 6 mm).

Accessibility. The equipment is relatively small and highly maneuverable. A hand-held torch connected to the fuel source with flexible hoses provides unrestricted access to include edges, corners, and recessed spaces. However, access may be restricted by the presence of combustible adjacent surfaces, or non-portable machinery or equipment.

Environmental factors. Flame blasting will generate hot, flying debris capable of igniting combustible materials in the vicinity of the process. The acetylene-oxygen combustion products are not hazardous. However, the heat of the flame may generate smoke and fumes which may be respiratory irritants or toxic, depending upon contaminants present in the substrate or materials being removed. Materials likely to pose a respiratory hazard and require special handling include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment. It is probable that the risk factors posed by the vaporization of contaminants or materials being removed cannot be reliably accessed in every instance. In these circumstances, the prudence and utility of using this method would need to be very carefully considered.

Execution

Concrete surfaces to be cleaned and profiled by this method must be presoaked for one to two hours to

produce saturated, surface dry conditions. This step is required to insure that the substrate contains enough moisture to generate the expansive force required to fracture the surface.

Equipment

- Specialized equipment designed to shape the flame, positively control fuel sources, and project the flame onto the substrate is required
- Sufficient hose to transport fuel from the storage location to the work area

Materials. Acetylene and oxygen are the consumed materials. These industrial gases must be available in appropriate containers.

Labor. Operators must be trained by the manufacturer of the equipment and skilled and knowledgeable in the handling of oxygen-acetylene mixtures. Operators must know when and how to use high temperature open flames and which materials are hazardous when they burn or decompose under heat.

Down time. Minimal. Some time is required for setup and changing tanks.

Cleanup. Flame blasting produces debris consisting of concrete chips. If the substrate was protected by a coating or other barrier system, the chips may be covered with a charred polymer residue. Debris may be removed with oil-free air blast or by mechanical or manual sweeping with stiff-bristled brushes.

Production rates. Rates depend on the thickness and composition of the materials being removed, the number of flames, and the rate of travel. Estimated rates range from 50 to 600 ft^2/hr (5 to 55 m^2/hr).

Standards and specifications

As required by the specifications of the manufacturer or customer.

Visual inspection to verify profile. The prepared surface should be free of dust, debris, bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

Flame blasting will induce the explosive fracture of aggregate which may propel hot, airborne fragments as far as 20 feet (6 m).

- Eye protection: Goggles and face shield meeting ANSI requirements for high impact resistance are required. Radiant energy shading as recommended by flame equipment manufacturers.
- Personal protective equipment: Helmet and heavy, heat resistant insulating gloves are required. Skin should be protected by heavy, noncombustible clothing and steel-toed boots.
- Respiratory protection: May be required depending upon the composition of materials being removed. It is probable that, at a minimum, the use of masks fitted with organic vapor canisters will be required during the removal of materials containing polyurethane, methacrylate or epoxy compounds.
- Hearing protection: Recommended.

Photo: Lanford Brothers Company, Inc.

Milling/Rotomilling

An aggressive method for removing the upper level of a concrete substrate by "clawing" or grooving using a large machine with cutting teeth attached to a rotating drum.

Method summary

Milling is used on horizontal surfaces to remove unsound concrete, mastics or other high-build coatings, and asphaltic overlays. It may also be used to deeply profile concrete substrates. This method is suitable for use in interior and exterior applications.

Purpose. Heavy-duty removal of deteriorated concrete and virtually any overlay, coating, or mastic materials in preparation for the placement of protective overlays.

Limitations. Slabs must be structurally able to support large, heavy equipment. This method will produce high levels of noise, dust, and severe vibration.

Milling operations will probably cause micro-cracking. (It has been demonstrated that micro-cracking will reduce the strength of the bond between the substrate and most materials placed over it.) The deleterious effects of micro-cracking may be reduced or eliminated by following initial removal with steel shotblasting, abrasive blasting, or high and ultra high-pressure water jetting.

Removal. The cutting teeth strike the surface with great force, fracturing material into chips and dust. Depth of concrete removal ranges from ¼ to 4 inches (6 to 100 mm). Removal depth is determined by the number and size of teeth. Smaller teeth in greater numbers are used when shallow removal depths are desired. Most machines are equipped with depth gauges which allow the operator to limit the depth of cut.

Pattern. Milling will produce a very irregular surface dominated by fractured coarse aggregate. A tool pattern will range from linear striations to deep grooving.

Profile. ICRI CSP 9

Extremely rough, chipped surface with a profile amplitude ranging from ¼ to ½ inches (6 to 13 mm). Profile obtained is determined by the number and size of teeth.

Accessibility. Most milling equipment will reach to within 6 inches (150 mm) of walls, and 12 inches (300 mm) of corners. A vertical clearance of approximately 6 feet 8 inches (2 m) is required. Turning radii will need to be plotted to determine if there is sufficient space for maneuver around columns, wall, and corners. Shoring of supported levels may be required.

Environmental factors. Milling will produce airborne dust containing concrete constituents and particles of any other materials or contaminants being removed. Any special requirements for containment and disposal of dust and debris will depend on the specific materials or contaminants being removed. Materials likely to require special handling and disposal include tile mastics, which may contain asbestos; lead-based paint; and PCBs which may have been absorbed by concrete in the vicinity of electrical equipment. Work area enclosures to prevent dust intrusion into occupied work space may be needed. Special ventilation provisions may be required when operating gasoline or diesel powered units indoors.

If water is used to control dust or clean the substrate, the run off will have a high pH and may contain regulated substances. Filtration systems or settlement tanks may be needed in conjunction with drainage systems to meet environmental requirements.

Noise levels will exceed 85 dB. Vibration levels are severe.

Execution

- Milling equipment is driven in a straight path.
- Depth is controlled by observing depth gauge. Multiple passes may be required.
- Each pass must overlap the adjacent pass.
- Debris is removed from the site.

Equipment

- Milling machine (transported by tractor and low-bed trailer with ramp)
- Debris removal equipment may include dump trucks, loader, conveyor system, shovels and brooms
- Shoring devices may be required to support machine weight on elevated slabs

Materials. Milling heads or "teeth."

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

Down time

- Job site must be prepared to receive equipment. Electrical hazards, structural capacity analysis, environmental requirements, and safety issues must be addressed prior to machine operation.
- Mobilization of the equipment onto the surface, installation and adjustment of cutting heads, and dust/debris control equipment.
- Smaller work areas may require equipment to be shut down at 30 minute intervals for debris removal.
- Periodic inspection, adjustment, or replacement of cutting heads or drive train components is required to maintain specified cutting depth and profile. Replacement of cutting heads is generally needed every 20 hours of operating time.

Cleanup. Chips and dust may be removed with water, air, brooms, or shovels. Self-propelled sweepers are commonly used.

Production rates. Estimated rates are listed below:

- 1000 ft^2/hr (90 m^2/hr) for small machines
- 3000 to 4000 ft^2/hr (280 to 370 m^2/hr) for mid-range machines
- 15,000 ft^2/hr (1400 m^2/hr) for large highway machines

Standards and specifications

Milled substrates are visually inspected to confirm compliance with specifications for profile and depth of removal. The prepared surface should be free of dust, debris, bond-inhibiting barriers, and demonstrate sufficient strength for the proposed application. ACI 515.1R describes methods and criteria for judging surface cleanliness and strength (see ref. page 41). Laboratory testing may be required to verify complete removal of specified contaminants.

Safety

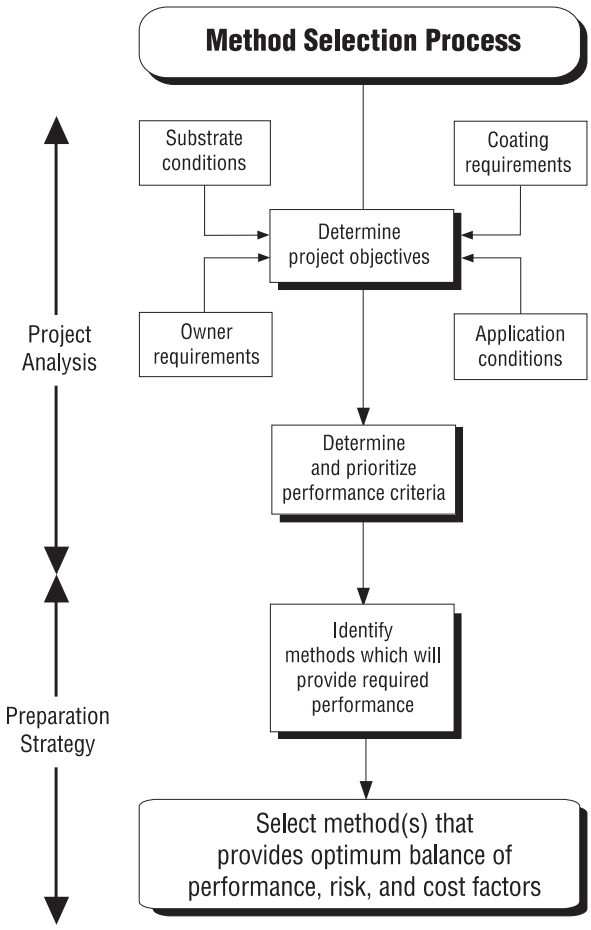
- Eye protection: Required.
- Personal protective equipment: Skin should be protected by clothing and barrier creams. Dust may produce alkali burns or allergic skin response.
- Respiratory protection: Required. Process will generate airborne dust. Mask should be approved for silica and other airborne dusts, and fit tightly to contours of face. If materials being removed contain toxic substances, additional protection may be required.
- Hearing protection: Required.

Appendix A

The Method Selection Process

The initial step in the selection process is to determine project objectives and requirements. Consistently good preparation decisions cannot be achieved without a thorough understanding of the material requirements, substrate conditions, and the owner's objectives and operating needs. Because the surface preparation method(s) used will determine the substrate profile, consideration of methods should be deferred until after the coating system has been selected and film thickness requirements are known. It is only after performance requirements have been identified and prioritized, and selection criteria have been defined, that the selection of specific methods of surface preparation can be made.

The checklists which follow in *Section 1* help ensure that critical information is identified and considered on every project. The data generated in the evaluation phase are analyzed to identify project priorities and to develop criteria for the selection of surface preparation methods. This phase is discussed in *Section 2*. Examples of need prioritization are included to underscore the fact that selection decisions will be driven by a series of trade-offs. Once project requirements, priorities and selection criteria have been determined, the Method Summaries and Method Selector (pages 7 to 31) may be used to identify the method, or combination of methods, most likely to produce the desired results for that project. The Method Selector may be used to quickly match typical coating system requirements and methods capable of producing the required profile. The factors which should shape the selection decision are reviewed in *Section 3*.



Appendix A

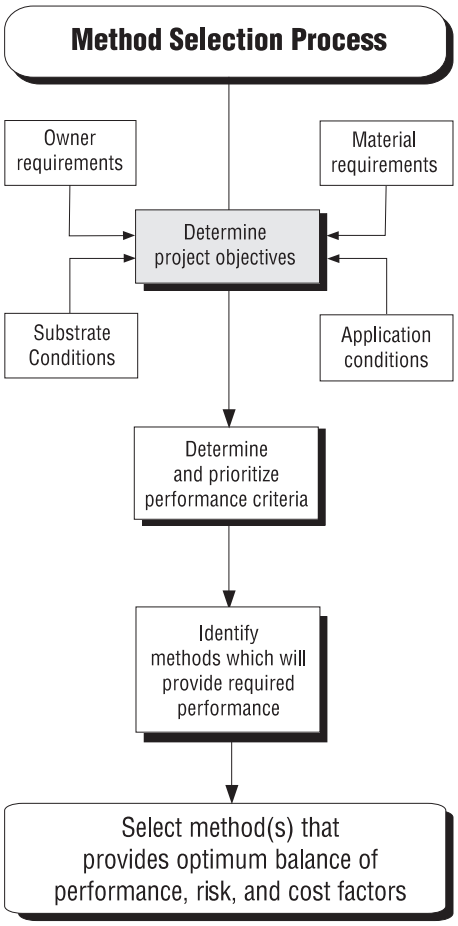
Section 1

Determine project objectives and requirements

The information gathered in this phase is needed to develop specific criteria for determining which method or combination of methods will best meet the engineer's and owner's objectives. Checklists on the following pages provide examples of the data needed to identify and prioritize performance requirements.

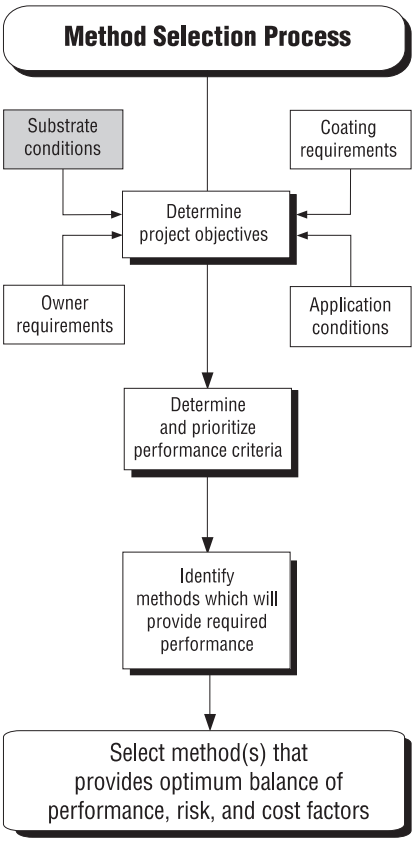
1. **Substrate condition:** The strength of the substrate and the presence of unsound or bond-inhibiting materials help define the nature and volume of preparation needed. Although a discussion of the various techniques and test methods used to evaluate the condition of concrete is beyond the scope of this guideline, the checklists provide examples of the types of information which should be considered.
2. **Owner requirements:** Noise, vibration, dust, and water are among the possible effects generated by various preparation methods. These can disrupt routine 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 will often limit the choices.
3. **Material requirements:** Good decisions about surface preparation cannot be made without knowing the properties and application requirements of the selected material. Surface preparation, and profile requirements in particular, will vary with the protective system selected. Ideally, the protective coating system to be applied should be selected before or during this phase. The short description of these broad coating categories provided in *Appendix B* help illustrate the effect substrate profile may have on the performance and appearance of these systems.
4. **Application conditions**
   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 which will affect surface preparation decisions.

The checklists will help ensure that the most important issues will be considered and resolved at the optimum time—before the project is underway.



Appendix A

Substrate Condition



Surface

Soil/Efflorescence/Encrustation

Type _____

Thickness _____

Bond strength _____

Surface imperfections

❒ laitance ❒ bugholes ❒ ridges ❒ exposed aggregate ❒ abrasion

❒ other _____

Bond-breaking contaminants

❒ oil ❒ membranes ❒ coatings ❒ curing films ❒ latex modifiers

❒ other _____

Soundness

Deteriorated concrete depth _____

Cause _____

Pull-off test results _____

Chloride content _____

Hazardous materials present

❒ PCB ❒ asbestos mastic ❒ pesticides ❒ chemicals

❒ heavy metals ❒ other _____

Special containment or disposal required _____

_____

General observations

Permeability (inhibit penetration) _____

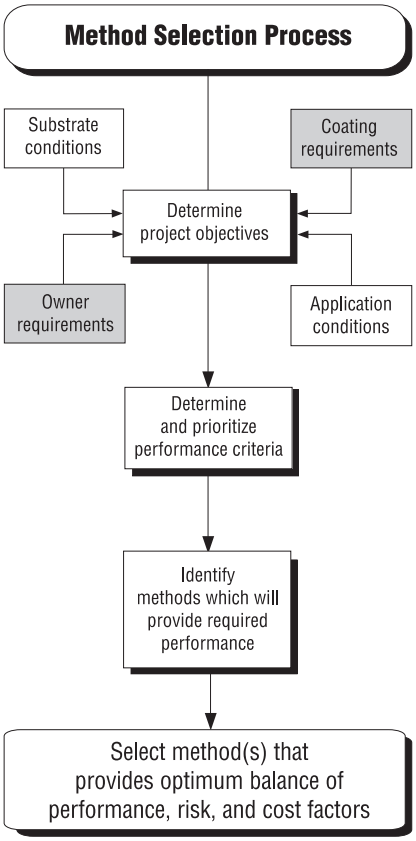
Section thickness _____

Required depth of removal _____

Moisture content _____

Appendix A

Owner Requirements



Project objectives

_____

_____

_____

_____

_____

_____

Appearance of applied system

Texture: ❒ smooth ❒ slip-resistant ❒ reflect substrate contours

Opacity: ❒ clear ❒ translucent ❒ solid color

Structure utilization needs

Work period

hours _____ duration _____

Negative effects

noise _____ water/slurry _____

dust _____ smoke & fumes _____

vibration _____ flying debris _____

Material Requirements

Substrate

Tensile strength (ICRI No. 3735 ACI 503 Appendix A)

_____

Surface profile
acceptable range (CSP numbers) _____

Material

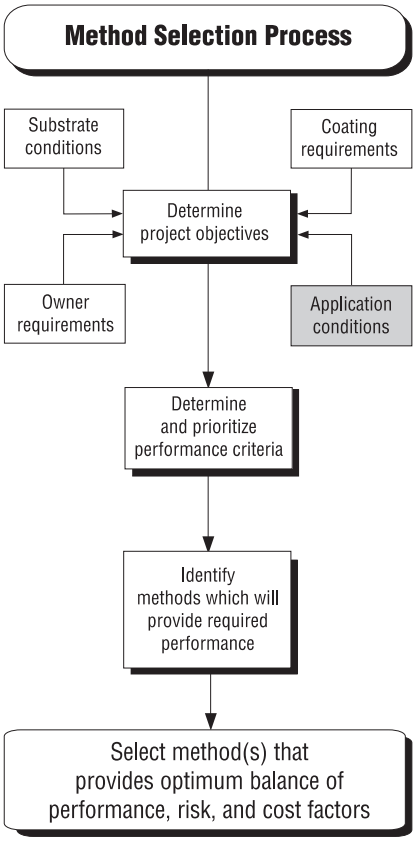
Film thickness wet: _____ dry: _____

Moisture tolerance _____

Alkali tolerance _____

Appendix A

Application Conditions



Accessibility

Surface orientation

❒ horizontal ❒ vertical ❒ overhead

turning radius _____ door openings_____ min. vertical clearance _____

load-bearing capacity _____

non-portable equipment/machinery _____

notes _____

Environmental considerations

containment of airborne debris _____

containment and disposal of liquid/slurry debris _____

drainage system _____

restrictions on use _____

containment and disposal of solid debris _____

hazardous waste containment and disposal_____

Mechanical data

Electricity types available_____

locations _____

Air maximum pressure _____

available cfm_____

locations _____

Ventilation natural _____

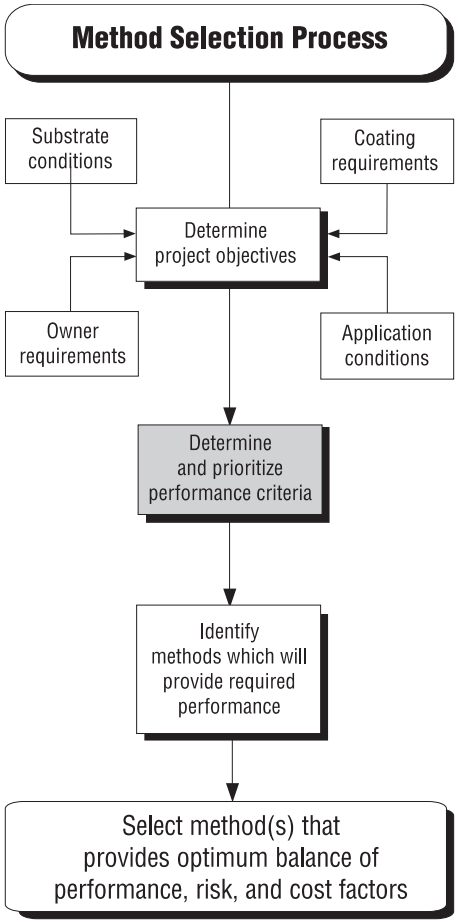
mechanical _____

Appendix A

Section 2

Establish performance priorities

Surface preparation methods should not be specified until the performance criteria which best satisfy project objectives are identified. Information on existing conditions, requirements, and project objectives collected in the evaluation phase is used to develop performance criteria, which are then prioritized. These should be ranked in descending order of importance. Objectives and requirements that are not essential should not be listed. This process allows competing demands to be carefully weighed to ensure that the performance criteria most critical to the success of the project become the selection criteria. Two sample lists are shown below:



Example 1: Interior floor replacement

A 30 x 70 foot (9 x 22 m) room in a large production facility is to be converted from shipping into an electronic components assembly area. The existing $^1/_8$ inch (3 mm) aggregate-filled MMA floor is to be replaced with an epoxy, antistatic conductive floor coating. The conductive floor will be installed during a 96 hour facility shut down. Dust must not circulate in the climate-controlled building. A surface profile of CSP 2 – 3 is required to ensure fiber continuity in the base coat.

Priorities: (ranked in order of importance)

1. Achieve CSP 3 or lower to meet floor system requirement to ensure conductive function
2. Dust-free preparation in order to preclude product quality problems
3. Fast turn-around to complete project within shut down window
4. Low vibrationto maintain calibration of sensitive instrumentation

Example 2 Deck coating installation

A 240 stall structure providing employee parking for general hospital is to be protected by a traffic bearing membrane. Surface preparation must remove all deteriorated concrete, bond-inhibiting contaminants, and leave deck surfaces with a profile within a range defined by CSP 3 – 4. The parking structure has a common shear wall with patient rooms for two of its four levels. The hospital requires that 85% of parking capacity remain in service throughout project.

Priorities: (ranked in order of importance)

1. Dust-free preparation to prevent finish damage to parked vehicles
2. Low noise/vibration to minimize patient discomfort
3. Achieve profile CSP 3 or 4 to provide optimum surface for bonding
4. Fast turn around to minimize employee inconvenience

Appendix A

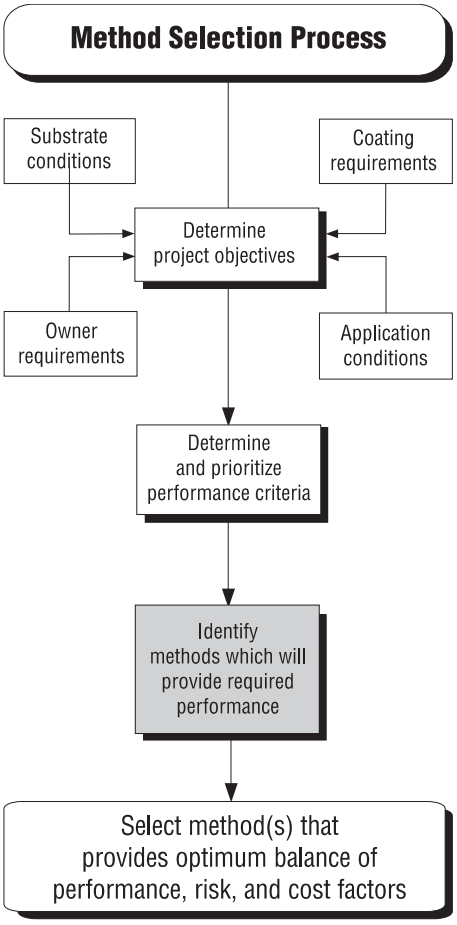
Section 3

Selecting and specifying methods of surface preparation

Most coating or sealing projects will have unique conditions and special requirements that must be carefully evaluated before the selection criteria can be established. Selecting the method(s) which optimize project objectives requires a good knowledge of the available options. The Method Summaries and Method Selector contained in this guideline (pages 7 to 31) allow users to readily compare data on the capabilities, limitations, operating requirements, and environmental considerations for each surface preparation method. Using the performance criteria developed earlier (*Sections 1 and 2*), the number of suitable methods is likely to be quickly narrowed to 1 to 3 potential selections. The Method Selector (page 7) may be used make a preliminary identification of the methods capable of producing the required surface profiles. In some cases, however, specific project conditions may preclude the use of the methods suggested.

Careful evaluation of competing priorities will be required to determine the best selection. Selection criteria provide a systematic framework for assessing method suitability and guide decisions when compromise is needed to ensure achievement of the most important project objectives.

In some instances, more than one method may be needed to produce the desired results. For example, high impact mechanical methods which produce surface "bruising" may sometimes provide the most efficient means of achieving the required degree of cleaning. In these circumstances, subsequent treatment with shot or abrasive blasting, fine scarification or high and ultra high-pressure water jetting may be used to restore substrate soundness. In another example, the most cost effective approach to surface preparation may include the use of a method which produces a high profile in the substrate. Material consumption on prepared concrete surfaces is influenced by several factors including substrate surface area, porosity, waste, uniformity of film thickness, and the volume of material needed to fill in surface depressions caused by profiling. If necessary, unacceptably high or rough profiles on existing or prepared surfaces may be reduced by means of additional passes using properly selected surface preparation equipment. On occasion, the application of a resurfacing mortar or leveling film of a coating material compatible with the system to be applied may be required to achieve the profile and appearance desired.



Final selection is based on the relationship between cost, project objectives, and risk.

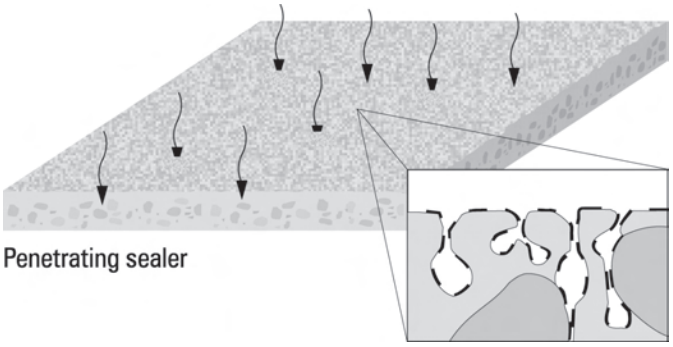
Appendix B

Sealers and coatings

Concrete sealers

0 to 3 mils (0 to 75 μm) dry

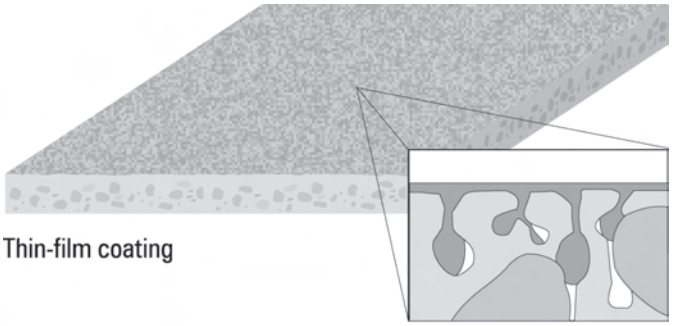
Penetrating sealers such as silanes or siloxanes will have little or no effect on the appearance of the treated surfaces. Any surface defects, contaminants, or profile will be visible. Film-forming sealers such as epoxies, urethanes, and acrylics, in unpigmented formulations may substantially darken concrete and impart a sheen. Lack of hiding power is comparable to that of the penetrating sealers. Pigmented formulations may hide stains and impart a degree of light reflectivity; however, surface irregularities and profile will not be altered.


Penetrating sealer

Thin-film coatings

4 to 10 mils (100 to 250 μm) dry

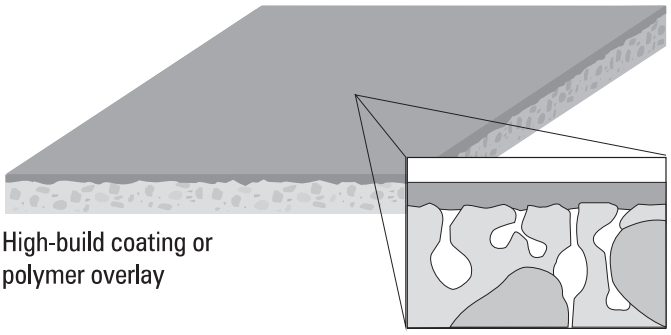
These products may be formulated to achieve high hiding power. However, even relatively minor surface imperfections and all but the lowest of profiles produced by surface preparation equipment will show through.


Thin-film coating

High-build coatings, self-leveling coatings, and polymer overlays

10 mils to ¼ inch (250 μm to 6 mm) dry

The selection of these materials for application provides the specifier with many more preparation options. These materials will have both high hiding power and some ability to fill in irregularities and level prepared surfaces. The contractor's ability to produce a smooth finish over higher profiles improves with increasing thickness of the applied coating system.


High-build coating or polymer overlay

Appendix C

Safety

Safety implications anticipated for each method are included in the Safety section of the method summaries. The information is intended only to alert users to the nature and magnitude of the safety issues associated with the method described.

Referenced OSHA regulations apply to typical hazards that may reasonably accompany a selected method of surface preparation. Additional regulations may apply depending on the work area conditions and jurisdiction. Consult a safety professional or OSHA about applicable regulations.

For further information, refer to the OSHA regulations that pertain to each of the protection categories referenced in the method summaries. Included therein are detailed references to safety protocols, equipment standards, personnel training, and documentation needed to meet OSHA requirements.

OSHA Regulations

Eye Protection
29 CFR 1919.133 (General Industry)
1926.102 (Construction)

Personal Protective Equipment
29 CFR 1910.132 (General Industry)
1926.28 (Construction)

Respiratory Protection
29 CFR 1910.134 (General Industry)
1926.103 (Construction)

Hearing Protection
29 CFR 1910.95 (General Industry)
1926.101 (Construction)

Hazard Communication
29 CFR 1910.1200 (General Industry)
1926.59 (Construction)

Appendix D

References and Related Material

American Concrete Institute. Annual. *Manual of Concrete Practice*, Five Parts, Detroit, MI, "Guide to the use of Waterproofing, Damp-proofing, Protective, and Decorative Barrier Systems for Concrete," ACI 515.IR, Chapter 3, Concrete Conditioning and Surface Preparation. (note in particular: Section 3.5 "Tests for surface quality prior to application")

ASTM American Society for Testing and Materials. Annual. *Annual Book of ASTM Standards*, Philadelphia, PA. Note: Use the latest available issue of each ASTM standard.

ASTM D 4258 Standard Practice for Surface Cleaning Concrete for Coating This practice defines methods of cleaning concrete to remove grease, dirt, and loose material prior to the application of coatings. The procedures outlined in the standard include: broom cleaning, vacuum cleaning, air blast cleaning, water cleaning, detergent water cleaning, and steam cleaning of concrete surface for applying coatings for light duty service. ***Broom cleaning:*** is to remove most surface dust and other loosely adherent solid contaminants. ***Vacuum cleaning:*** removes dust and other debris by the use of a heavy duty industrial vacuum. ***Air blast cleaning:*** uses compressed air and abrasive at 80 to 100 psi through a blast nozzle held approximately 2 feet from the substrate. ***Water cleaning:*** uses a stream of clean potable water of sufficient pressure to remove debris. Hand scrubbing with stiff-bristled brush may also be required. ***Detergent water cleaning:*** the removal of water-soluble surface contaminants, oils, grease, and other emulsifiable materials using a detergent or non-solvent emulsifier and stiff-bristled brush. ***Steam cleaning:*** uses a jet of high-pressure steam to remove contaminants. Detergents or non-solvent emulsifying agents may be added to aid in removal. Areas where detergents or non-solvent emulsifying agents are used must be flushed with potable water to meet an acceptable criteria for pH. An acceptable surface after cleaning of concrete by one or more of these methods shall be a substrate free of oil, grease, loosely adhering concrete, and other contamination.

ASTM D 4259 Standard Practice for Abrading Concrete This is a standard practice to provide a clean and roughened surface that is free of laitance, form release agents, curing agent, oil, grease, and other penetrating contaminants. The surface shall be free of fins, projections and loosely adhering concrete, dirt, and dust particles. Suitable methods include: using rotary impact, vertical impact, and circular grinding equipment; ***Water blast cleaning:*** using a high pressure water blasting unit and fresh potable water; ***Abrasive blast cleaning:*** including wet or dry open-blast cleaning with nozzles and self-contained recirculating blast-cleaning apparatus.

ASTM D 4260 Standard Practice for Acid Etching Concrete The intent of this practice is to prepare concrete surfaces prior to the application of coatings by altering the surface profile and removing foreign materials, such as weak surface laitance. All grease, oil and other penetrating contaminants should be removed prior to acid etching. Fins and protruding surface irregularities are to be removed by mechanical means. Typical acid solutions covered by this method include: muriatic (hydrochloric), sulfamic, phosphoric and citric acids. ***Note:*** Hydrochloric acid shall not be used where chlorides are prohibited. The acid solutions are applied to a surface that has been pre-wetted with potable water. After scrubbing with a stiff-bristle brush, the surface is flushed with fresh potable water to remove reaction products.

ASTM D 4262 Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces This test method is used when chemical cleaning or acid etching has been employed to prepare concrete surfaces for coating. The acidity or alkalinity of the final rinse water is measured using pH test paper with a minimum range of from 1 to 11 pH. Measurement of at least two areas in each 500 square feet at random locations is required. The final pH reading shall not be more than 1.0 lower or 2.0 points higher than the original pH of the rinse water unless otherwise specified.

ASTM D 4263 Standard Test Method For Indicating Moisture in Concrete by the Plastic Sheet Method This test method indicates the presence of capillary moisture in concrete by taping a plastic sheet 18 inches square to the surface to be coated. The test should be conducted when the ambient conditions and surface temperature are within the established parameters for application of the specified coating system. The plastic is to remain on the substrate for a minimum of 16 hours. Upon removal, the area is inspected for the presence (or absence) of moisture.

ASTM D 4285 Standard Test Method for Indicating Oil or Water in Compressed Air This test method uses either an absorbent or nonabsorbent collector that is positioned 24 inches in front of the discharge air after any in-line oil and water separators. After a period of not less than 1 minute, the collector is inspected for indications of oil discoloration or water.

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