Preparing Repair Mortars for Wastewater Service:
Broom Finish or Blasted Surface?

By Vaughn O'Dea and Rick Schwab, Tnemec Company, Inc.

Concrete is inherently durable and is used extensively in municipal wastewater construction.\(^1\) The deterioration of concrete and reduction of its service life can result, however, when exposed to conditions frequently found within these environments including abrasion, corrosion of steel reinforcement, and biogenic sulfide corrosion.\(^2,3\) The rehabilitation and protection of concrete within these aggressive exposure conditions has consistently been a challenge given the fact that no hydraulic cement, regardless of its composition, will long withstand a pH 3 or lower.\(^4,5\) This problem is exacerbated by increasing concentrations of hydrogen sulfide (H\(_2\)S) gas rising beyond the levels protected by traditional protective barrier systems, ultimately negating the protection of the cementitious substrate from biogenic sulfide corrosion.\(^6,7,8\) As a result, high-performance lining systems have emerged specifically for severe wastewater environments.\(^9\)

The protective coatings industry has also paid special attention to the repair of concrete using cementitious resurfacing mortars—both thin overlays and shallow depth replacements—before applying high-performance linings.\(^10\) Resurfacing improves the film quality of a protective coating by providing a contiguous surface for topcoating and ensures a monolithic protective barrier film at a specified nominal thickness. Because of this expanding repair market, cementitious resurfacing materials and repair methods are being introduced at an increasing rate for use under high-performance protective coatings. Unfortunately, as the repair market expands, one result has been conflicting manufacturers’ instructions and deviations from many industry standards regarding the curing, finishing and preparation (e.g., broom finish vs. blasted surface) of various cementitious materials, even those that are generally similar. In fact, commonly, manufacturers of repair mortars recommend a broom finish to create a “profiled” surface before applying the lining. Less commonly, manufacturers recommend that the cementitious mortars be blast cleaned or otherwise mechanically profiled to impart a mechanical profile before applying the lining. In the following article, the authors summarize the results of an investigation to quantitatively assess adhesion of a protective lining when applied to a broom finish surface versus a mechanically profiled concrete surface.

**Background on Adhesion**

**The Importance of Surface Profile for Lining Adhesion**

When applying a high performance protective lining directly to new concrete, it...
is widely accepted that profiling increases the surface area available for bonding the protective lining to the concrete substrate. Profiling also enhances the mechanical adhesion at the concrete/coating interface and helps the lining resist peeling and shear forces. (This premise excludes the effects of a chemical adhesion bond obtainable by some polymer-modified repair mortars.) It seems logical that mechanically profiling a cementitious resurfacing mortar would offer similar benefits to the lining performance. But because broom finishing is still common in wastewater repair, the question arises: does a broom finish profile provide similar adhesive properties to those of a blast cleaned (mechanically profiled) surface (a more expensive and time consuming process)?

**Tensile Strength and Adhesion**

To be effective in the rehabilitation and protection of concrete, a protective system, which includes both the cementitious repair mortar and protective lining, must develop and maintain adhesive and cohesive direct tensile strengths greater than the surface tensile strength of the parent concrete. This criterion ensures that the system is able to withstand the stresses imposed on, and the processes of deterioration associated with, severe wastewater environments.

A cementitious resurfacers exhibiting weaker surface tensile strength properties than the parent concrete surface potentially compromises the integrity of the protective system and is prone to cause the system to fail prematurely. The repair mortar’s surface tensile strength, or bond zone strength, which refers to the surface of the mortar that will be in contact with the coating, is not as well understood as it should be. Because of the diverse finishing/preparation recommendations oftentimes encountered within the wastewater repair industry, there is a need for a more comprehensive understanding of the general surface tensile behavior of the various hydraulic resurfacing composites for use under high performance protective linings. Specifiers and users of cementitious repair materials would clearly benefit from information that quantifies the bond zone strength of popular cementitious mortars.

**Laitance and Adhesion**

New concrete—along with other cementitious substrates—commonly has a weak surface layer, called laitance, resulting from use of too high a water/cement ratio, drawing of fines to the surface during surface finishing, the exudation of fines with bleed water, or improper curing. Laitance will have a weaker tensile strength than the rest of the concrete substrate, and if not removed, will weaken the concrete’s ability to provide an adequate surface for lining adhesion. It is possible that like concrete, cementitious repair materials form a laitance layer that could similarly interfere with the adhesion of the lining and the success of the complete repair system.

Unfortunately, the presence and the depth of laitance typically cannot be detected visually, but must nevertheless be removed to create a surface profile that will enhance lining adhesion.

**Mechanically Profiled Surface and Laitance**

The value of a mechanically profiled concrete surface before applying a lining reflects the prevailing view that the removal of the laitance is paramount to achieving maximum bond strength of the lining. Moreover, a recent study by...
the author found that most cementitious repair mortars commonly used for wastewater rehabilitation increased their surface tensile properties when externally cured, that is, with a curing membrane applied in accordance with ACI 308R. The study further concluded that the adhesion of a high-performance protective lining was maximized when the surface of these repair mortars was mechanically profiled, which removed the laitance layer and curing compound, where present. (Adhesion of the lining over a broom-finished surface was not addressed in the earlier study.)

**Broom Finished Surface Profile and Laitance**

Research suggests the broom finish profile for linings may have originated from the concrete repair industry practices (when no lining is involved) to improve the bond of the mortar to itself. When rehabilitating concrete using cementitious mortars in multiple lifts, it is common practice to thoroughly roughen, cross hatch, or rake the surface of the first lift of the repair mortar to promote additional mechanical bond for the subsequent lift (Fig. 1). Despite the common use of broom finishing to profile repair mortar before lining application, the authors found no literature suggesting whether or not this finishing technique categorically alleviates the formation of laitance, the weak surface layer that may affect the bonding of a protective lining system.

**Objectives of the Study**

Because of the lack of available research on repair mortars and laitance, the study described in this article was undertaken to address the following questions. Is it possible that a broom-finished surface eliminates the formation of a laitance layer on cementitious repair mortars? And is the surface tensile strength of a broom-finished surface equal to or greater than the surface tensile strength of the parent concrete so that the mortar can properly receive a high-performance lining?

**Experimental Method**

**Cementitious Mortars**

Cementitious mortars using ingredients that most closely match those of concrete are the best choices for repair materials. Based upon this principle, the authors surveyed 100 wastewater projects and found the four cementitious repair composites most commonly specified for use in concrete repair under protective lining systems. These cementitious composites are generically classified as:

- epoxy-modified cementitious mortars,
- acrylic-modified cementitious mortars,
- portland-based cementitious mortars,
- calcium aluminate-based cementitious mortars.

**Table 1: Cementitious Resurfacing Materials Included in Surface Bond Strength Evaluation**

<table>
<thead>
<tr>
<th>Product Designation</th>
<th>Cementitious Mortar Type</th>
<th>Minimum Thickness</th>
<th>Maximum Thickness</th>
<th>Mfr’s Recommended Finishing Technique(s)</th>
<th>Mfr’s ACI External Curing Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortar 1</td>
<td>Epoxy-modified</td>
<td>1/16&quot;</td>
<td>1/4&quot;</td>
<td>Rubber float, steel trowel, masons brush</td>
<td>None</td>
</tr>
<tr>
<td>Mortar 2</td>
<td>Epoxy-modified</td>
<td>1/16&quot;</td>
<td>1/8&quot;</td>
<td>Rubber float, steel trowel, masons brush</td>
<td>None</td>
</tr>
<tr>
<td>Mortar 3</td>
<td>Epoxy-modified</td>
<td>1/16&quot;</td>
<td>1&quot;</td>
<td>Conventional concrete finishing tools</td>
<td>None</td>
</tr>
<tr>
<td>Mortar 4A</td>
<td>Acrylic-modified</td>
<td>1/4&quot;</td>
<td>2&quot;</td>
<td>Wooden or rubber float, trowel</td>
<td>ACI 308</td>
</tr>
<tr>
<td>Mortar 5</td>
<td>Acrylic-modified</td>
<td>1/4&quot;</td>
<td>3/4&quot;</td>
<td>Trowel</td>
<td>ACI 308</td>
</tr>
<tr>
<td>Mortar 6</td>
<td>Acrylic-modified</td>
<td>1/8&quot;</td>
<td>1.5&quot;</td>
<td>Wooden or rubber float, trowel</td>
<td>ACI 308</td>
</tr>
<tr>
<td>Mortar 7</td>
<td>Portland-based</td>
<td>1/4&quot;</td>
<td>1/2&quot;</td>
<td>Broom</td>
<td>&lt;5-8 hrs apply coating; &gt;8 hrs ACI</td>
</tr>
<tr>
<td>Mortar 8</td>
<td>Portland-based</td>
<td>3/8&quot;</td>
<td>2&quot;</td>
<td>Wooden or rubber float, trowel</td>
<td>ACI 308</td>
</tr>
<tr>
<td>Mortar 9</td>
<td>Portland-based</td>
<td>3/8&quot;</td>
<td>1.5&quot;</td>
<td>Wooden or rubber float, trowel</td>
<td>ACI 308</td>
</tr>
<tr>
<td>Mortar 10</td>
<td>Calcium Aluminate-based</td>
<td>1/2&quot;</td>
<td>3&quot;</td>
<td>Broom</td>
<td>ACI 308</td>
</tr>
<tr>
<td>Mortar 11</td>
<td>Calcium Aluminate-based</td>
<td>1/2&quot;</td>
<td>1&quot;</td>
<td>Broom</td>
<td>&lt;70% R.H. Curing Required; &gt;70% None</td>
</tr>
<tr>
<td>Mortar 12</td>
<td>Calcium Aluminate-based</td>
<td>1/2&quot;</td>
<td>3&quot;</td>
<td>Trowel or broom</td>
<td>Not listed</td>
</tr>
</tbody>
</table>
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tars, and
• calcium aluminate-based cementitious mortars

Three commercially available repair materials from each generic composite type were procured for this research study. The mortars vary in their respective surface preparation requirements, minimum application thicknesses, curing requirements (and durations), surface finishing technique(s), and subsequent surface preparation required to receive a high-performance coating (Table 1 on p. 34). Testing matrices were developed to compare the surface tensile properties of the twelve mortars when applied at their respective minimum recommended thickness.

**Bond Strength Testing**

The surface tensile strength properties of the selected repair materials—with and without a high-performance topcoat—were assessed in accordance with ASTM D 7234 (Fig. 2).20 This test method delineates a procedure for evaluating the direct tensile strength (commonly referred to as adhesion) of a coating on concrete (or other cementitious substrate). The test determines either the greatest perpendicular force (normal stress, \( \sigma \)) that a surface area can bear before a plug of material is detached.21 The uniaxial testing instrument used for this tensile strength assessment was the self-aligning tensile pull-off adhesion tester using 50-mm (2-in.) diameter dollies. Tension was applied until failure was achieved, and the maximum normal stress and the location of the failure were recorded. The peak loading for this instrument using 50-mm diameter loading fixtures (dolls) after conversion is 560 psi. (See sidebar on p. 33)

Failure occurs along the weakest plane within the system. The test results were reported as determined by observing the bottom of the dollies with the following designations:
• Concrete substrate: A
• Mortar: B
• Epoxy topcoat: C (where applied)
• Adhesive (glue): Y
• Loading Fixture (Dolly): Z

Cohesive failures and the percent of each were denoted as A, B, C, or Y. Adhesive failures by the interfaces at which they occur where denoted A/B, B/C, C/Y, etc.
• Concrete Substrate Panels: In laboratory work it is common to produce a high strength substrate to maximize the chance of obtaining adhesive bond failure as opposed to a tensile (cohesive) failure of the concrete substrate. Non-reinforced concrete panels were cast 24 in. x 24 in. x 2 in. to provide a common substrate for testing. The concrete was a high-strength 5,500 psi Portland Type I design mix conforming to ASTM C 387.22 The top faces of the panels (exposed side) were finished and membrane cured per ACI 308R14 using two coats of an acrylic membrane-curing compound conforming to the requirements of ASTM C 309.23 The concrete panels were both cast and cured in a controlled laboratory environment (72 F and 48% RH) and remained in the forms for 7 days; the panels were demolded and maintained in laboratory conditions. After a period of 28 days, the concrete panels were prepared by dry-abrasive blasting the top face of the panels to an SSPC SP 13/NACE No. 6 surface condition,12 and achieving an ICRI-CSP5 surface profile.24 The concrete substrate panels serve as the parent concrete for our study.
• Epoxy Coating (EP): A high-build, 100% solids, two-component, high functionality amine epoxy was used as a representative high-performance protective lining used over cementitious mortars in aggressive environments. The epoxy was applied in a single coat to a dry film thickness (DFT) of 30 mils.

This commercially available high-performance lining is recommended for use over concrete and steel in highly corrosive wastewater and other chemically aggressive environments. The suggested thickness range for this product is 30–80 mils DFT. When applied directly to properly prepared concrete, the technical data sheet indicates that the adhesion exceeds the tensile strength of concrete (cohesive concrete failure).
• Concrete Control Panel (CCP): A single, randomly selected concrete substrate panel was withheld for use as a control in accordance with the sampling procedures outlined in ASTM D 3665.25 The concrete panel was 24 in. x 24 in. x 2 in., finished, membrane cured, and prepared consistent with the panels and methods described above.

The upper half of the concrete panel—Section A (Fig. 3 on p. 37)—was designated as the Concrete Control Panel-A (CCP-A) and remained unchanged from the surface preparation condition (SSPC-SP 13/NACE No. 6, ICRI-CSP5). CCP-A was used to determine the tensile
The lower half of the concrete panel section—denoted CCP-B—was topcoated with 30 mils’ DFT of the epoxy coating and allowed to cure for 7 days. After the 7-day cure, sections A and B were evaluated for bond strength using methods outlined in ASTM D 7234 using the adhesion tester with 50 mm diameter dollies (Figs. 4a, 4b, and 4c on p. 38). The CCP-B was used to determine the tensile strength of the representative parent concrete substrate using the uniaxial testing instrument when a 100% solids epoxy barrier system was applied directly to the prepared substrate. Both CCP-A and CCP-B serve as the control for this study. The baseline tensile adhesion values are outlined in Fig. 3. As Fig. 3 shows, in the tensile strength tests, all failures of the lined concrete were cohesive, occurring within the concrete, not within the lining or at the lining-concrete interface. Hence, as indicated in the lining manufacturer’s data sheet, the lining adhesion exceeded the tensile strength of the concrete substrate. These results confirm that proper preparation and application procedures were followed.

After the tests, the bond strength of broom-finished and mechanically profiled coated mortar test panels would be compared to CCP-B to determine whether or not the coated cementitious repair mortar exhibits properties equal to the coated concrete control, and if finishing technique affects the soundness of the surface of the repair mortar and its ability to properly accept the coating.

**Testing Matrices**

Two testing matrices were developed to determine which surface finishing technique (e.g., blasted surface or broom finish) maximizes adhesion of the protective lining applied to the twelve repair mortars. The results were then compared to the tensile strength of CCP-B, which represents a coating applied directly to properly prepared concrete.

- **Mechanically Profiled Surface Matrix:** This testing matrix comprises eight quadrants (concrete panel sections) that compare the bond strengths of the twelve repair mortars by evaluating the influences of curing/no curing, mechanical preparation/no preparation, and topcoating/no topcoating with a high-performance lining system (Fig. 5 on p. 38). Excerpts from the research study on the effects of curing and mechanically profiling these cementitious repair mortars are presented below.13
Each of the twelve selected cementitious mortars was applied to the concrete substrate panels at their respective minimum recommended thickness. The concrete panels were first dampened with potable water to achieve a saturated surface dry (SSD) condition. A scrub coat of each mortar was then applied to the prepared concrete substrate panel followed by the immediate application using a rubber float. The mortars were finished using a steel trowel to obtain a smooth, uniform finish. In order to test the effect of mortar hydration with and without external curing, an acrylic membrane-curing compound was applied to half of the mortar (Fig. 5). The left half of the concrete panel—Sections C, E, G, I—received no external curing; the right half of the panel—Sections D, F, H, J—were cured using two coats of an acrylic curing compound in accordance with ACI 308R.

After the proper curing (hydration) period for each respective cementitious mortar, the lower sections G, H, I, J were blasted to an SSPC-SP 13/NACE 6, ICRI-CSP3 profile to remove the curing compound (where used) and weak laitance layer of the mortar (where present). The 100% solids epoxy coating was immediately applied to the middle sections E, F, G, H of the panel and allowed to cure for an additional 7 days.

Following the 7 days’ cure of the epoxy coating, each panel section was tested for bond strength using ASTM D 7234 adhesion tester using 50-mm diameter dollies. Each section was tested in triplicate, and an average value was reported for the respective mortars.

- Broom-Finished Surface Matrix: A testing matrix composed of four quadrants (concrete panel sections) was established to assess the effects of broom finishing of the 12 repair mortars with and without topcoating. Each panel section compared the surface bond strength of the mortar upon receiving a broom finish by evaluating both the influences of curing/not curing and topcoating/not topcoating with a high-performance lining on the repaired surface (Fig. 6 on p. 40).

Each of the twelve selected cementitious mortars was applied to the concrete substrate panels at their respective minimum recommended thickness. The concrete panels were first dampened with potable water to achieve a saturated surface dry (SSD) condition. A scrub coat of each mortar was then applied to the concrete panel followed by the immediate application using a rubber float. The mortars were finished using a mason’s brush to produce a broom finish profile. In order to test the effect of mortar hydration with and without external curing, an acrylic membrane-curing compound was applied to half of the mortar (Fig. 6 on p. 40).

The left half of the concrete panel—Sections K, M—received no external curing; the right half of the panel—Sections L, N—were cured using two coats of an acrylic curing compound in accordance with ACI 308R. Upon the proper curing (hydration) period for each respective cementitious mortar, the 100% solids epoxy coating was applied directly to the lower sections M, N of the panel and allowed to cure for an additional 7 days. Following the 7 days’ cure of the epoxy coating, each panel section was tested for bond strength using ASTM D 7234.
adhesion tester using 50 mm diameter dolly (Figs. 7a, 7b, and 7c on p. 40).

**Analysis**

**Blasted (Mechanically Profiled) Surface Matrix**

Of the mechanically prepared sections, Concrete Panel Section H (membrane cured and blasted profile) achieved the maximum bond strength when topcoated with a protective lining system. This is not entirely unexpected given that liquid membrane-curing compounds prevent the loss of moisture from the mortar, thereby allowing the development of surface tensile strength properties. Membrane curing is the most practical method of curing vertically- and overhead-placed repair mortars common to wastewater rehabilitation where job conditions are not favorable for wet-curing in accordance with ACI 308R. What’s more, membrane curing compounds must be removed prior to the application of the lining system in accordance with guidelines of the protective coatings industry.\(^1\)

**Broom-Finished Surface Matrix**

Of the broom-finished sections, the results for the twelve cementitious repair mortars suggest that Concrete Panel Section M (broom-finished profile and no membrane curing) achieved the maximum mortar surface bond strength when topcoated with a protective lining system. A few of the mortars actually yielded higher adhesion values in Concrete Panel Section N (broom-finished and membrane curing compound). Upon closer examination, it is plausible that the anomalous improvement in tensile strength derived from proper curing exceeded any diminished bonding of the lining system to the mortar by the presence of the membrane “bond breaker.” Nevertheless, when canvassing the candidate repair mortars used in this study, it appears that a broom-finished surface is not recommended to receive a membrane curing compound if topcoated...
The results of these testing matrices can now be evaluated to determine which surface finish optimizes the adhesion of a high-performance lining to a cementitious repair mortar. The surface tensile strengths of Concrete Panel Section H (Prep/Coat) and Concrete Panel Section M (Broom Finish/Coat) have been juxtaposed in Figs. 8–11 (p. 42), along with the Concrete Control Panel B (CCP-B). Recall, the optimum surface tensile strength (pull-off adhesion) value for coatings over mortar test panels in our study is greater than or equal to the adhesion of a high-performance protective lining applied directly to properly prepared concrete (CCP-B). The baseline coating pull-off adhesion for CCP-B for use in our study, is 538 psi (Fig. 3).

Tensile Strength Comparisons of Mortar Panel Sections H vs. M
For each of the four repair composite types tested, Figs. 8–11 compare the coating pull-off adhesion values of Panel H (mechanical preparation) against those of Panel M (broom finish). Figures 8–11 also show the coating adhesion values of panels H and M relative to 538 psi for CCP-B, our baseline coating adhesion value.

Conclusions
Our findings indicate that a blasted (mechanically profiled) surface offers superior adhesion to that of a broom finished (profiled) surface when preparing cementitious repair mortars to receive high-performance lining systems. In sum, 7 of the 12 mechanically profiled panels had surface tensile strengths equal to or greater than that of properly prepared concrete, as indicated by the coating pull-off adhesion values in Figs. 8–11. In contrast, 8 of the 12 broom finished mortars yielded near-surface tensile strengths significantly lower than that of properly prepared concrete.

Adhesion of coatings over most broom-finished mortars didn’t even meet the benchmark surface tensile strength 538 psi of CCP-B Control for the optimum bonding of the lining system. Based on the coating adhesion values, the epoxy cementitious composites were the only mortars that, when broom finished and mechanically profiled, exhibited tensile strengths comparable to each other and to CCP-B.

Further, it was concluded a broom-finished surface generally forms a weak upper surface (laitance) layer on the majority of the cementitious composites tested in this study. This conclusion was drawn from observing a clear pattern of preferential failure in this surface zone, which indicates that the repair material, when broom finished, was generally the weakest link in the repair system. (An exception to this finding was the epoxy cementitious composite, possibly because the epoxy polymerization prevents the formation of the laitance layer.) A laitance layer manifests as a weakened or decreased surface tensile strength compared to properly prepared cementitious mortar, and requires removal in accordance with standards set forth by the protective coatings industry.11,12

It should be noted that this study contrasted mortar surfaces prepared to an ICRI-CSP3 profile only to detect a weak upper surface (laitance) layer. Greater surface rugosity (amplitude) may be required by the coatings manufacturer for long-term adhesion performance within wastewater environments.

Buyers beware! Beware of exaggerated claims of experience with surface

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1Cementitious Resurfacing Mortars, Refer to Table 1.
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finishing of cementitious repair materials. Beware of anecdotal evidence as means of a repair mortar’s capability. Beware of crotchets or other forms of unorthodox experience as evidence of success. Instead, request that manufacturers submit testing of compatibility of the entire system in accordance with industry consensus standards. Request that manufacturers provide laboratory testing to substantiate surface finishing and preparation requirements when topcoated with high-performance lining systems. Require manufacturers to provide clear instructions for curing, finishing, and preparation in application instructions and on component labels of cementitious repair materials. And lastly, be diligent and perform testing of onsite mock-ups of candidate cementitious repair mortars when topcoated with high performance protective lining systems.

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