CAVEAT EMPTOR! PREPARING CEMENTITIOUS MORTARS TO SUPPORT HIGH-PERFORMANCE LINING SYSTEMS: *Broom Finish or Blasted Surface?* [1]

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ABSTRACT

Cementitious repair mortars are commonly used to rehabilitate deteriorated wastewater concrete infrastructure prior to the application of high-performance lining systems. Commonly such repair mortars receive a broom finish creating a "profiled" surface prior to the application of a spray-applied protective lining system. Other recommendations require that that the cementitious mortars receive a blasted (mechanically profiled) surface to impart a mechanical profile prior to topcoating with a similar lining system. In the following paper the authors summarize the results of an investigation to quantitatively assess adhesion of a protective lining when applied to a broom finish surface verses a blasted surface.

Keywords: concrete resurfacer; broom finish; surface tensile strength; bond strength; tensile pull-off test; adhesion testing; protective coating

INTRODUCTION

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 (2-4). 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 (5,6). This problem is exacerbated by increasing concentrations of hydrogen sulfide (H_2S) gas rising beyond the levels protected by traditional protective barrier systems, ultimately negating the protection of the cementitious substrate (7-9). As a result various high-performance lining systems have emerged for specific use in severe wastewater environments (10).

Particular attention has also been given by the protective coatings industry to the repair of concrete using cementitious resurfacing mortars – both thin overlays and shallow depth overlays / replacements – prior to the application of high-performance linings (11). Resurfacing not only improves the film quality of a protective coating by providing a contiguous surface for topcoating, but ensures a monolithic barrier film at a specified nominal thickness. Due to this expanding repair market cementitious resurfacing materials and repair methods are being introduced for use under high-performance protective coatings at an increasing rate. This often results in conflicting instructions and deviations from industry standards regarding the curing, finishing and preparation. Specifically, manufacturers recommend contrasting instructions for finishing/preparing (e.g., broom finish vs. blasted surface) cementitious repair mortars prior to topcoating with high-performance lining systems for severe wastewater environments.

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[1] Adapted from the paper found in the PACE 2009 Conference Proceedings; www.sspc.org.

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OBJECTIVE OF STUDY

When applying a protective lining directly to concrete, it is widely accepted that profiling increases the surface area available for bonding between the concrete and the lining. Additionally, profiling enhances mechanical adhesion at the concrete/coating interface and helps the coating resist peeling and shear forces. (This premise excludes the affects of a chemical adhesion bond obtainable by some polymer-modified repair mortars.) It only seems logical that that profiling a cementitious resurfacing mortar offers similar benefits. But, does a broom finish profile provide similar adhesive properties as a blasted (mechanically profiled) surface?

To be effective in the rehabilitation and protection of concrete, both the cementitious repair mortar and protective lining must develop and maintain adhesive and cohesive strengths greater than the tensile strength of the parent concrete and must be able to withstand the stresses imposed on and the processes of deterioration associated with severe wastewater environments. Otherwise any cementitious resurfacer exhibiting weaker tensile properties than the parent concrete surface potentially compromises the integrity and the protective system is prone to premature failure. Because of the diverse finishing/preparation recommendations oftentimes encountered within the wastewater repair sector, 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 lining. Specifiers and users of repair materials would therefore clearly benefit from information which quantifies the bond zone strength of popular cementitious mortars.

Mechanically Profiled Surface:

A mechanically profiled surface is believed to be derived from the prevailing view that the removal of the weak surface layer – commonly formed on cementitious substrates – is paramount to achieve maximum bond strength prior to the application of a protective barrier system (12,13). Like concrete, these repair materials may form a laitance layer 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 due to the improper curing of the repair mortars. Moreover, a recent study found that most cementitious repair mortars – commonly used for wastewater rehabilitation – increased their surface tensile properties when externally cured (14). The study further concluded that the adhesion of a high-performance protective lining was maximized when the surface of these repair mortars were mechanically profiled.

Broom Finished Surface:

Research suggests the broom finish profile for linings may have originated from the concrete repair industry. 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 (15- 18). However, the authors found no literature suggesting this finishing technique categorically alleviates the formation of a weak surface layer that may affect the bonding of a protective lining system. Is it possible that a broom finished surface eliminates the formation of a laitance layer on cementitious repair mortars and provides equal or greater tensile strength than that of the properly prepared parent concrete?

EXPERIMENTAL METHOD

Cementitious Mortars:

Cementitious mortars using similar ingredients which most closely match those of concrete are the best choices for repair materials (16). Based upon this principle, the authors surveyed 100 wastewater projects and found the four common cementitious repair composites specified for use in concrete repair under protective lining systems (19). These cementitious composites were generically classified as:

1. epoxy-modified cementitious mortars
2. acrylic-modified cementitious mortars
3. portland-based cementitious mortars
4. calcium aluminate-based cementitious mortars

Three commercially available repair materials from each generic composite type were procured for this research study. To avoid bias, the manufacturer's names were withheld from this report. The twelve cementitious 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). Testing matrices were developed to compare the surface tensile properties of the twelve mortars when applied at their respective minimum recommended thickness.

Table 1: Cementitious resurfacing materials included in the surface bond strength evaluation

Product Designation	Cementitious Mortar Type	Polymer-Modified	No. Components	Minimum Thickness	Maximum Thickness	Recommended Finishing Technique(s)
Mortar 1	Epoxy-modified	Yes	3	1/16"	1/4"	Rubber float, steel trowel, masons brush
Mortar 2	Epoxy-modified	Yes	3	1/16"	1/8"	Rubber float, steel trowel, masons brush
Mortar 3	Epoxy-modified	Yes	3	1/16"	1"	Conventional concrete finishing tools
Mortar 4A	Acrylic-modified	Yes	1	1/4"	2"	Wooden or rubber float, trowel
Mortar 5	Acrylic-modified	Yes	2	1/4"	3/4"	Trowel
Mortar 6	Acrylic-modified	Yes	2	1/8"	1.5"	Wooden or rubber float, trowel
Mortar 7	Portland-based	No	1	1/4"	1/2"	Broom
Mortar 8	Portland-based	No	1	3/8"	2"	Wooden or rubber float, trowel
Mortar 9	Portland-based	No	1	3/8"	1.5"	Wooden or rubber float, trowel
Mortar 10	Calcium Aluminate-based	No	1	1/2"	3"	Broom
Mortar 11	Calcium Aluminate-based	No	1	1/2"	1"	Broom
Mortar 12	Calcium Aluminate-based	No	1	1/2"	3"	Trowel or Broom

<u>Bond Strength Testing</u>:

The bond strength properties of the selected repair materials were assessed in accordance with ASTM[(1)] D 7234 (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, σ) 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 PosiTest Pull-Off Adhesion Tester manufactured by DeFelsko Corporation 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. All gauge readings were converted to actual pounds per square inch (psi) pressures per the calibration factors provided by the instrument manufacturer. The peak loading for this instrument using 50 mm diameter loading fixtures (dollies) after conversion is 560 psi.

[(1)] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959 USA.

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. The environmental conditions during testing were recorded as 72°F, 48% relative humidity.

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 substrate. Non-reinforced concrete panels were cast 24"x 24"x 2" 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 using a steel concrete trowel and membrane cured per ACI[(1)] 308R (23) using two coats of an acrylic membrane-curing compound conforming to the requirements of ASTM C 309 (24). 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[(2)]-SP13/NACE[(3)] No. 6 surface condition (13), and achieving an ICRI[(4)]-CSP5 surface profile (25). 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.

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 (26). The concrete panel was 24"x 24"x 2", steel trowel finished and membrane cured for a period of 28-days consistent with the panels and methods described above. The entire top face of the concrete panel was prepared by dry-abrasive blasting to an SSPC-SP13/NACE No. 6, ICRI-CSP5 profile.

The upper-half of the concrete panel – Section A (ref Exhibit 1 below) – was designated as the Concrete Control Panel-A (CCP-A) and remained unchanged from the surface preparation condition (SSPC-SP13/NACE No. 6, ICRI-CSP5). CCP-A was used to determine the in-situ tensile strength of the concrete control panel with the specific uniaxial adhesion testing instrument. 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. Upon 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. The CCP-B was used to determine the in situ tensile strength using the uniaxial testing instrument when a 100% solids epoxy barrier system was

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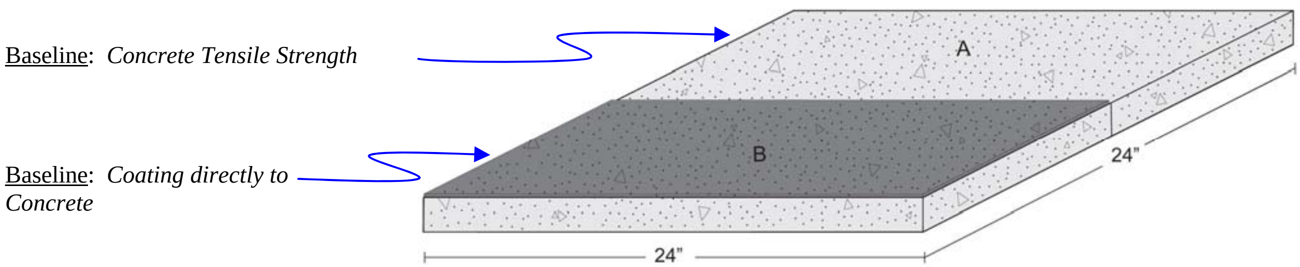
[(2)] American Concrete Institute (ACI), PO Box 9094, Farmington Hills, MI 48333-9094 USA.
[(3)] SSPC: The Society for Protective Coatings (SSPC), 40 24th Street, 6th Floor, Pittsburgh, PA 15222-4643 USA.
[(4)] NACE International (NACE), 1440 South Creek Dr., Houston, TX 77084-4906 USA.
[(4)] International Concrete Repair Institute (ICRI), 3166 S. River Road, Suite132, Des Plaines, IL 60018 USA.

applied directly to the prepared concrete substrate. Both CCP-A and CCP-B serve as the control for this study. The baseline tensile adhesion values are outlined in Exhibit 1.

***Exhibit 1:* Concrete Control Panel—Tensile Strength**

CCP Section	System	Surface Preparation	Avg. Tensile Strength *(psi)*	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*
A	Concrete	SSPC-SP13/ NACE No. 6, ICRI-CSP5	**521**	100% A	100% A	100% A
B	Concrete/ 100% solids EP	SSPC-SP13/ NACE No. 6, ICRI-CSP5	**538**	100% A	100% A	100% A



To isolate the material properties that directly affect surface tensile strength, two testing matrixes were developed to evaluate the twelve repair mortars using the experimental method to determine which surface finishing technique (i.e., blasted surface or broom finish) maximizes adhesion of a protective lining system. And, perhaps more importantly, the comparison of these results to the bond strength of a coating applied directly to properly prepared concrete – CCP-B.

Mechanically Profiled Surface Matrix:

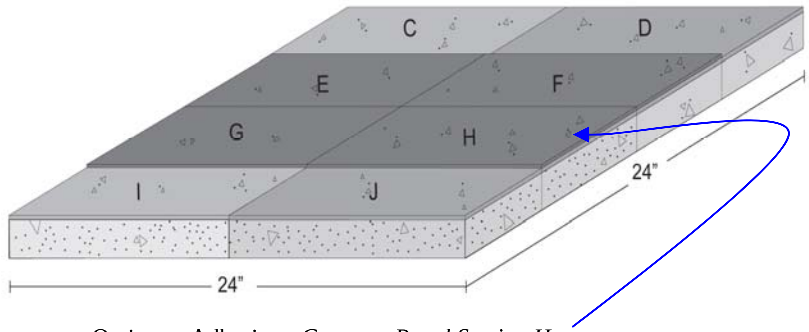
This testing matrix comprises eight quadrants (concrete panel sections) that compare the bond strengths of the twelve repair mortars by evaluating the influences of curing/not-curing, when mechanically prepared/not-prepared, and when topcoated/not-topcoated with a high-performance lining system (Exhibit 2). Excerpts from the research study concluding the effects of curing and mechanically profiling these cementitious repair mortars are presented below (14).

Each of the twelve selected cementitious mortars were 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 (Exhibit 2). 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.

Upon the proper curing (hydration) period for each respective cementitious mortar, the lower sections G, H, I, J were blasted to an SSPC-SP13/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 and 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 reported for the respective mortars (Appendix B).

Exhibit 2: **Bond Strength Matrix—Trowel Finished /Mechanically Profiled**

Concrete Panel Section	Mortar System[1]	Acrylic Membrane Cured *(ACI 308)*	Subsequent Surface Preparation[2]
C	Concrete/ Mortar X	No	None
D	Concrete/ Mortar X	Yes	None
E	Concrete/ Mortar X/ 100% solids EP	No	None
F	Concrete/ Mortar X/ 100% solids EP	Yes	None
G	Concrete/ Mortar X/ 100% solids EP	No	ICRI-CSP3
H	Concrete/ Mortar X/ 100% solids EP	Yes	ICRI-CSP3
I	Concrete/ Mortar X	No	ICRI-CSP3
J	Concrete/ Mortar X	Yes	ICRI-CSP3



Optimum Adhesion: *Concrete Panel Section H determined to yield optimum bond strength.*

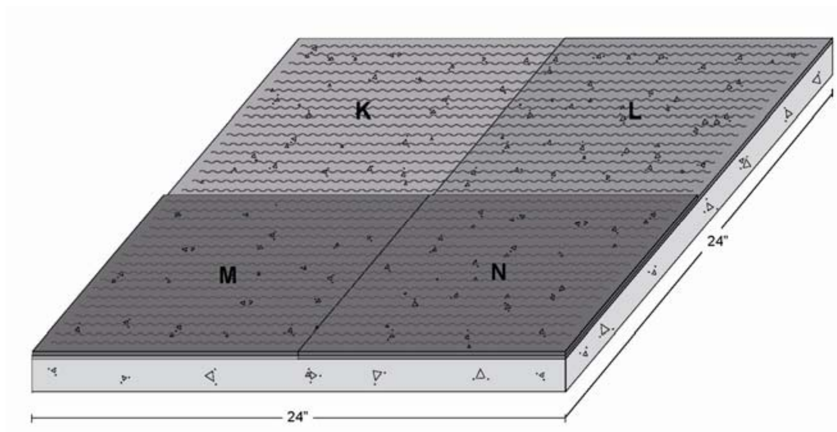
Broom Finished Surface Matrix:

To assess the effect of curing and topcoating, a testing matrix composed of four quadrants was designed (concrete panel sections). Each section compared the surface bond strengths upon receiving a broom finish by evaluating both the influences of curing and topcoating with a high-performance lining system (Exhibit 3).

Each of the twelve selected cementitious mortars were 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 masons 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 (Exhibit 3). 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 and 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 reported for the respective mortars (Appendix B).

***Exhibit 3:* Bond Strength Matrix—Broom Finished**

Concrete Panel Section	System[1]	Acrylic Membrane Cured *(ACI 308)*	Subsequent Surface Preparation
K	Concrete/ Mortar X	No	None
L	Concrete/ Mortar X	Yes	None
M	Concrete/ Mortar X/ 100% solids EP	No	None
N	Concrete/ Mortar X/ 100% solids EP	Yes	None



ANALYSIS

Blasted (Mechanically Profiled) Surface Matrix:

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 tensile strength properties. Membrane curing is the most practical method of curing vertically- and overhead-placed repair mortars 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 industry guidelines of the protective coatings industry.

Broom Finished Surface Matrix:

The results for the twelve cementitious repair mortars suggest that Concrete Panel Section M (broom finished profile and no membrane curing) achieved the maximum 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 with protective lining systems.

The results of these testing matrices can now be evaluated to determine which surface finish optimizes the adhesion of a high-performance lining system 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 Exhibits 4-7, along with the Concrete Control Panel B *(CCP-B)*. Recall, the optimum tensile adhesion value is greater than or equal to the adhesion of a high-performance protective system applied directly to properly prepared concrete (CCP-B). This baseline, for use in our study, is 538 psi (ref Exhibit 1).

Tensile Strength Comparisons of Mortar Panel Sections H vs. M:

Exhibit 4:

EPOXY-MODIFIED CEMENTITIOUS MORTARS

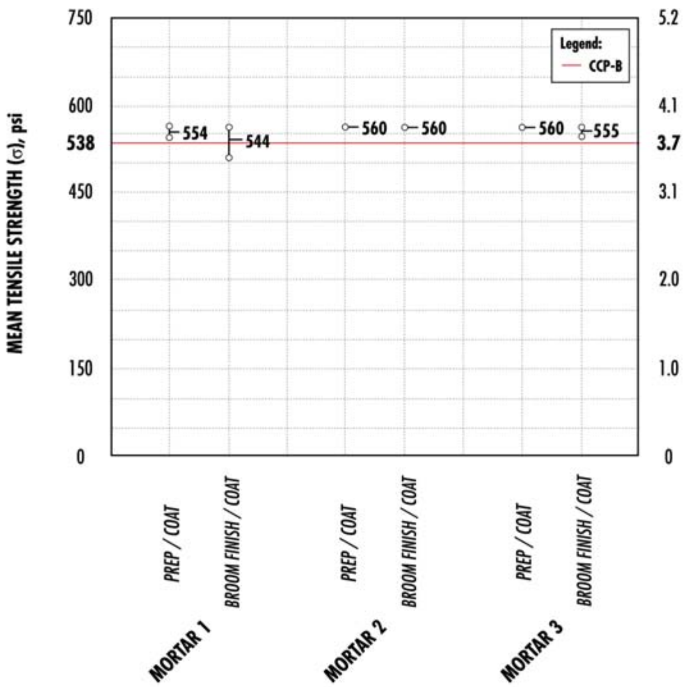


Exhibit 5:

ACRYLIC-MODIFIED CEMENTITIOUS MORTARS

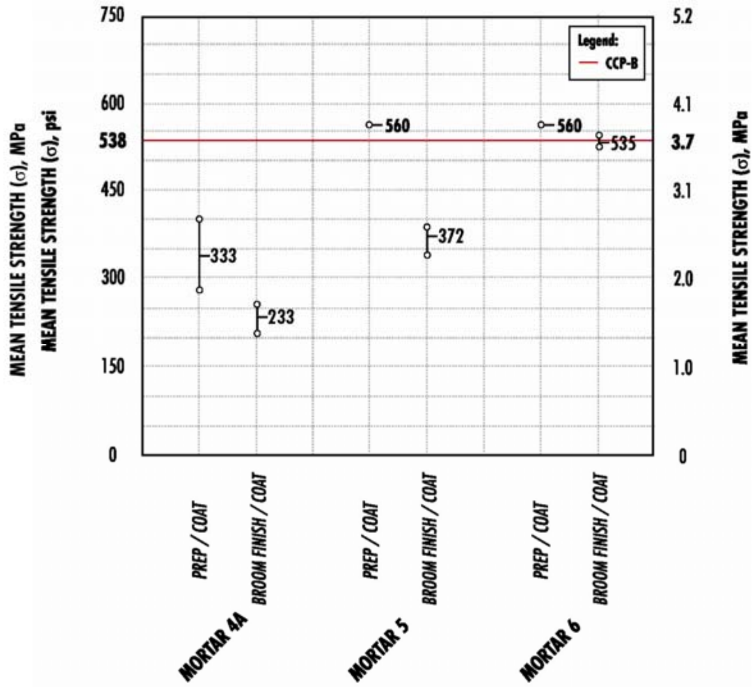


Exhibit 6:

PORTLAND-BASED CEMENTITIOUS MORTARS

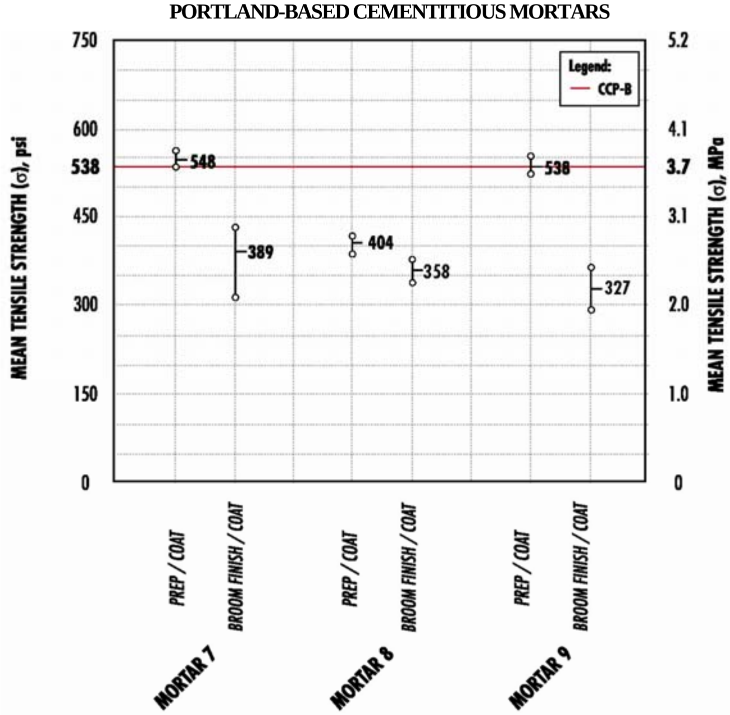
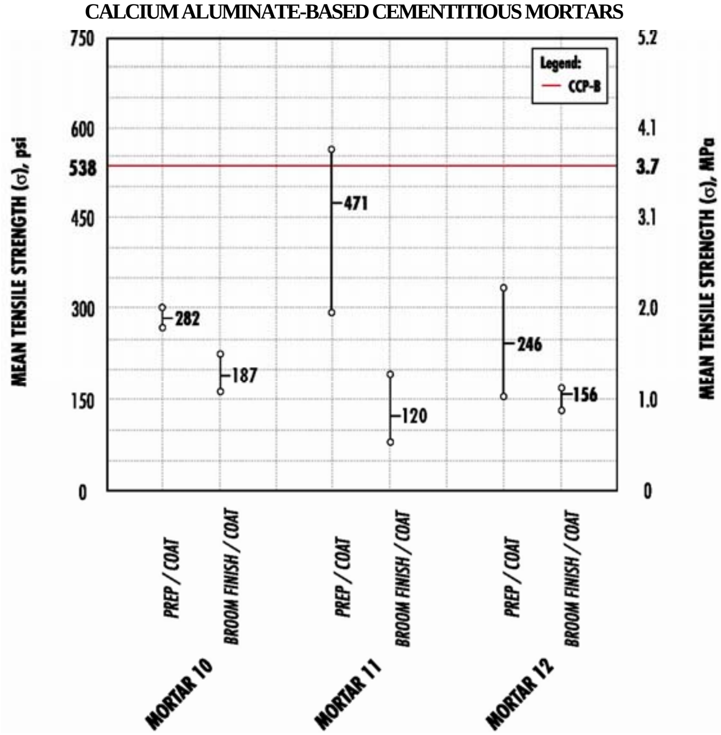


Exhibit 7:

CALCIUM ALUMINATE-BASED CEMENTITIOUS MORTARS



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 fact, 8 of the 12 mortars when broom finished yielded significantly lower tensile strengths than that of properly prepared concrete; this surface profiling method didn't even meet the benchmark tensile strength for the optimum bonding of the lining system. The epoxy cementitious composites were the only mortars that exhibited comparable surface tensile strengths when broom finished and mechanically profiled.

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. There was 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.) A laitance layer manifests as a weakened or decreased surface tensile strength compared to properly prepared concrete, and requires removal in accordance with industry standards set forth by the protective coatings industry (13). 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 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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APPENDIX A

Epoxy Modified Cementitious Mortars:

Mortar 1 is a commercially available three-component epoxy modified cementitious thin overlay/ resurfacer. According to the product data sheet, this material is used for surfacing, patching, and filling voids and bugholes in concrete and other cementitious substrates prior to topcoating with high-performance coatings for use in mild to aggressive environments. The mortar can be applied by trowel or rubber float to a thickness range of 1/32-1/4". The manufacturer requires only 15 hours hydration at 75°F to achieve proper cure; no external wet- or membrane-curing required. The mortar can be topcoated with high-performance coatings without subsequent preparation of the mortar.

Mortar 2 is a commercially available three-component epoxy modified cementitious thin overlay/ resurfacer. According to the product data sheet, this material is used for structural resurfacing and pore filling of bugholes, blowholes, and honeycombing and for the repair of damp or saturated substrates such as sewage treatment plants, water treatment plants, tanks, tunnels, and drains. The mortar can be applied by trowel, rubber float, or masons brush to a thickness range of 1/32-1/8". The manufacturer requires only 24 hours hydration at 75°F to achieve proper cure; no external wet- or membrane-curing required. The mortar can be topcoated with high-performance coatings without subsequent preparation of the mortar.

Mortar 3 is a commercially available three-component epoxy modified cementitious thin overlay/ resurfacer. According to the product data sheet, this material is an economical epoxy patching and surfacing compound that exhibits excellent bond strength to concrete and other masonry surfaces. It is ideally suited for patching spalled concrete and masonry wall surfacing to accept subsequent topcoats. The mortar can be applied by trowel, rubber float, or masons brush to a thickness range of 1/16-2" (when adding pea recommended loading of pea gravel). The manufacturer requires only 12 hours hydration at 75°F to achieve proper cure (at less than 1" thickness); no external wet- or membrane-curing required. The mortar can be topcoated with high-performance coatings without subsequent preparation of the mortar.

Acrylic Modified Cementitious Mortars:

Mortar 4A is a commercially available one-component latex modified cementitious shallow concrete overlay /resurfacer for vertical and overhead repairs. According to the product data sheet, this material is recommended for rehabilitation of above or below grade, vertical or horizontal deteriorated concrete structures. The manufacturer requires the use of a primer or a scrub coat (a thin layer of the mortar) prior to the placement of the recommended 1/4-2.0" thickness. The manufacturer requires proper curing of the acrylic-modified mortar immediately after placement in accordance with ACI 308 for 72 hours using a water-based membrane curing compound. (Mortar 4A replaces Mortar 4 which has been discontinued from the marketplace.)

Mortar 5 is a commercially available two-component acrylic polymer modified cementitious shallow concrete overlay/resurfacer. According to the product data sheet, this material is recommended for interior or exterior, above or below grade concrete surfaces. The manufacturer use of a primer or a scrub coat (a thin layer of the mortar) prior to the placement of the recommended 1/4-3/4" thickness. The manufacturer requires proper curing of the acrylic-modified mortar immediately after placement in accordance with ACI 308 for a minimum 72 hours. The manufacturer explicitly states no feather edging of this material and that 1/4" saw cuts should be employed.

Mortar 6 is a commercially available two-component acrylic polymer modified cementitious shallow concrete overlay /resurfacer. According to the product data sheet, this material is recommended for above or below grade, vertical or horizontal concrete or masonry structures, including parking structures, water/wastewater treatment plants, bridges, roadways, tunnels, and dams. The manufacturer requires the use of a primer or a scrub coat (a thin layer of the mortar) prior to the placement of the recommended 1/8-1.5" thickness. The manufacturer requires proper curing of the acrylic-modified mortar immediately after placement in accordance with ACI 308 for 48 hours. Additionally, the manufacturer cautions the topcoating of the mortar with itself or with epoxy topcoats when a membrane curing compound is used.

Portland-Based Cementitious Mortars:

Mortar 7 is a commercially available portland-based cementitious shallow concrete overlay /resurfacer. According to the product data sheet, this material is prescribed for use on below grade wastewater brick or concrete substrates applied by hand or by delivery methods (e.g., shotcrete) to a minimum recommended thickness of 1/8". The manufacturer recommends no finishing if applied by shotcrete delivery; otherwise, if applied by trowel, a broom or brush finish is needed to provide a desirable bonding surface. The product data sheet recommends the mortar to be topcoated within 5-8 hours after placement with a chemical resistant lining. If 8 hours has elapsed, the mortar must be cured by means of fog spray, wet burlap or an appropriate curing compound.

Mortar 8 is a commercially available portland-based, shrinkage compensated, fiber-reinforced cementitious shallow concrete overlay/resurfacer. According to the product data sheet, this material is recommended in manholes, lift stations, wet wells, bridges, tunnels, and marine structures. The mortar can be applied by trowel or by use of low pressure spray equipment to a minimum thickness of 3/8". If applied by hand, a scrub coat (a thin layer of the mortar) is recommended to be worked into the substrate for maximum bond. The manufacturer recommends constant wet curing for 7 days in accordance with ACI 308 or the application of a membrane curing compound compliant with ASTM C 309.

Mortar 9 is a commercially available single component, fiber-reinforced, portland-based cementitious shallow concrete overlay/resurfacer. According to the product data sheet, this thick repair material is recommended for patching and resurfacing of deteriorated concrete, including water tanks and reservoirs, sewerage treatment plants, concrete water and sewer pipes, manholes and vaults, marine structures, bridge structures, and tunnels and parking garages. This mortar can be applied by trowel or with low pressure spray equipment to a minimum thickness of 3/8". The manufacturer recommends a trowel finish, followed by curing per ACI 308 with two coats of a curing compound, conforming to ASTM C 309, for minimum 3 days.

Calcium Aluminate-Based Cementitious Mortars:

Mortar 10 is a commercially available 100% calcium aluminate-based cementitious shallow concrete overlay/resurfacer. According to the product data sheet, this material is recommended for concrete or masonry manholes, wet wells, pipe and other wastewater treatment structures. This mortar can be applied by trowel or with low pressure spray equipment to a minimum thickness of 1/2". The manufacturer recommends a trowel finish, followed by curing per ACI with two coats of an approved curing compound. No specific curing duration listed on product data sheet.

Mortar 11 is a commercially available 100% calcium aluminate-based cementitious resurfacer. According to the product data sheet, this material is recommended for concrete or masonry wastewater structures to rebuild the substrate prior to topcoating with high-performance epoxy topcoat. The mortar can be applied by trowel or with low-pressure spray equipment to a minimum thickness of 1/2". The manufacturer recommends a broom finish following the trowel application to optimize epoxy adhesion. Relative humidity must be above 70% for the first 24 hours; otherwise, the surface must be moist cured for 72 hours.

Mortar 12 is a commercially available shrinkage-compensated, fiber-reinforced 100% calcium aluminate-based cementitious resurfacer. According to the product data sheet, this material is recommended for the repair of concrete or masonry structures, including sanitary sewer manholes, sanitary sewer lift stations, pipelines and tunnels, clarifiers, digesters, wastewater treatment plants, water treatment facilities, and locks and dams. The mortar can be applied by trowel or with low-pressure spray equipment to a minimum thickness of 1/2". Curing recommendations not listed on the product data sheet.

APPENDIX B

Table B1: Mortar 1, Epoxy-modified

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 1	C	No	15 hrs	None	**554**	25% A, 75% B	80% A, 20% B	50% A, 50%, B	A 521
Concrete / Mortar 1	D	Yes	15 hrs	None	**481**	60% A, 40% B	25% A, 75% B	50% A, 50%, B	A 521
Concrete / Mortar 1/ 100% Solids EP	E	No	15 hrs	None	**550**	85% A, 15% B	50% A, 50% B	50% A, 50%, B	B 538
Concrete / Mortar 1/ 100% Solids EP	F	Yes	15 hrs	None	**456**	60% A, 40% B	25% A, 75% B	50% A, 50% B	B 538
Concrete / Mortar 1/ 100% Solids EP	G	No	15 hrs	ICRI-CSP3	**553**	60% A/B, 40% B	25% A/B, 50% B, 25% Y	25% A/B, 75% B	B 538
Concrete / Mortar 1/ 100% Solids EP	H	Yes	15 hrs	ICRI-CSP3	**554**	25% A, 75% B	25% A, 75% B	25% A/B, 75% B	B 538
Concrete / Mortar 1	I	No	15 hrs	ICRI-CSP3	**546**	40% A/B, 60% B	50% A/B, 50% B	70% A/B, 30% B	A 521
Concrete / Mortar 1	J	Yes	15 hrs	ICRI-CSP3	**551**	70% A/B, 30% B	60% A/B, 40% B	75% A/B, 25% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 1	K	No	15 hrs	None	**537**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 1	L	Yes	15 hrs	None	**528**	100% B	100% B	100% B	A 521
Concrete / Mortar 1/ 100% Solids EP	M	No	15 hrs	None	**544**	100% B	100% B	100% B	B 538
Concrete / Mortar 1/ 100% Solids EP	N	Yes	15 hrs	None	**503**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B2: Mortar 2, Epoxy-modified

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 2	C	No	24 hrs	None	**560**	100% A	100% A	100% A	A 521
Concrete / Mortar 2	D	Yes	24 hrs	None	**540**	100% A	100% A	100% A	A 521
Concrete / Mortar 2/ 100% Solids EP	E	No	24 hrs	None	**560**	80% A, 20% B	25% A, 75% B	20% A, 80%, B	B 538
Concrete / Mortar 2/ 100% Solids EP	F	Yes	24 hrs	None	**560**	50% A, 50% B	30% A, 70% B	50% A, 50% B	B 538
Concrete / Mortar 2/ 100% Solids EP	G	No	24 hrs	ICRI-CSP3	**560**	50% A/B, 50% B	90% A, 10% B	25% A/B, 75% B	B 538
Concrete / Mortar 2/ 100% Solids EP	H	Yes	24 hrs	ICRI-CSP3	**560**	70% A, 30% B	70% A, 30% B	50% A, 50% B	B 538
Concrete / Mortar 2	I	No	24 hrs	ICRI-CSP3	**560**	100% A	100% A	100% A	A 521
Concrete / Mortar 2	J	Yes	24 hrs	ICRI-CSP3	**560**	60% A, 40% B	90% A, 10% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 2	K	No	24 hrs	None	**560**	100 % A	100 % A	100% A	A 521
Concrete / Mortar 2	L	Yes	24 hrs	None	**560**	90% A, 10% B	40% A, 60% B	100% A	A 521
Concrete / Mortar 2/ 100% Solids EP	M	No	24 hrs	None	**560**	100% A	90% A, 10% B	100% A	B 538
Concrete / Mortar 2/ 100% Solids EP	N	Yes	24 hrs	None	**560**	100% A	100% A	100% A	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B3: Mortar 3, Epoxy-modified

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 3	C	No	12 hrs	None	**524**	100% B	100% B	100% B	A 521
Concrete / Mortar 3	D	Yes	12 hrs	None	**471**	100% B	100% B	100% B	A 521
Concrete / Mortar 3/ 100% Solids EP	E	No	12 hrs	None	**541**	100% B	100% B	100% B	B 538
Concrete / Mortar 3/ 100% Solids EP	F	Yes	15 hrs	None	**422**	100% B	100% B	100% B	B 538
Concrete / Mortar 3/ 100% Solids EP	G	No	12 hrs	ICRI-CSP3	**560**	50% A, 50% B	70% A, 30% B	10% A, 90% B	B 538
Concrete / Mortar 3/ 100% Solids EP	H	Yes	12 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	B 538
Concrete / Mortar 3	I	No	12 hrs	ICRI-CSP3	**533**	100% B	100% B	100% B	A 521
Concrete / Mortar 3	J	Yes	12 hrs	ICRI-CSP3	**542**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 3	K	No	12 hrs	None	**525**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 3	L	Yes	12 hrs	None	**458**	100% B	100% B	100% B	A 521
Concrete / Mortar 3/ 100% Solids EP	M	No	12 hrs	None	**555**	100% B	100% B	100% B	B 538
Concrete / Mortar 3/ 100% Solids EP	N	Yes	12 hrs	None	**492**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B4: Mortar 4A, Acrylic-modified

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 4A	C	No	72 hrs	None	**258**	100% B	100% B	100% B	A 521
Concrete / Mortar 4A	D	Yes	72 hrs	None	**306**	100% B	100% B	100% B	A 521
Concrete / Mortar 4A/ 100% Solids EP	E	No	72 hrs	None	**269**	100% B	100% B	100% B	B 538
Concrete / Mortar 4A/ 100% Solids EP	F	Yes	72 hrs	None	**274**	100% B	100% B/C	100% B	B 538
Concrete / Mortar 4A/ 100% Solids EP	G	No	72 hrs	ICRI-CSP3	**332**	50% A, 50% B	70% A, 30% B	10% A, 90% B	B 538
Concrete / Mortar 4A/ 100% Solids EP	H	Yes	72 hrs	ICRI-CSP3	**333**	100% B	100% B	100% B	B 538
Concrete / Mortar 4A	I	No	72 hrs	ICRI-CSP3	**312**	100% B	100% B	100% B	A 521
Concrete / Mortar 4A	J	Yes	72 hrs	ICRI-CSP3	**321**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 4A	K	No	72 hrs	None	**227**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 4A	L	Yes	72 hrs	None	**283**	100% B	100% B	100% B	A 521
Concrete / Mortar 4A/ 100% Solids EP	M	No	72 hrs	None	**233**	100% B	100% B	100% B	B 538
Concrete / Mortar 4A/ 100% Solids EP	N	Yes	72 hrs	None	**235**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B5: Mortar 5, Acrylic-modified

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 5	C	No	72 hrs	None	**442**	100% B	100% B	100% B	A 521
Concrete / Mortar 5	D	Yes	72 hrs	None	**474**	100% B	100% B	100% B	A 521
Concrete / Mortar 5/ 100% Solids EP	E	No	72 hrs	None	**388**	100% B	100% B	100% B	B 538
Concrete / Mortar 5/ 100% Solids EP	F	Yes	72 hrs	None	**419**	100% B	100% B	100% B	B 538
Concrete / Mortar 5/ 100% Solids EP	G	No	72 hrs	ICRI-CSP3	**553**	50% A, 50% B	70% A, 30% B	10% A, 90% B	B 538
Concrete / Mortar 5/ 100% Solids EP	H	Yes	72 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	B 538
Concrete / Mortar 5	I	No	72 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	A 521
Concrete / Mortar 5	J	Yes	72 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 5	K	No	72 hrs	None	**346**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 5	L	Yes	72 hrs	None	**387**	100% B	100% B	100% B	A 521
Concrete / Mortar 5/ 100% Solids EP	M	No	72 hrs	None	**372**	100% B	100% B	100% B	B 538
Concrete / Mortar 5/ 100% Solids EP	N	Yes	72 hrs	None	**392**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B6: Mortar 6, Acrylic-modified

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 6	C	No	48 hrs	None	**484**	100% B	100% B	100% B	A 521
Concrete / Mortar 6	D	Yes	48 hrs	None	**559**	100% B	100% B	100% B	A 521
Concrete / Mortar 6/ 100% Solids EP	E	No	48 hrs	None	**506**	100% B	100% B	100% B	B 538
Concrete / Mortar 6/ 100% Solids EP	F	Yes	48 hrs	None	**502**	100% B	100% B	100% B	B 538
Concrete / Mortar 6/ 100% Solids EP	G	No	48 hrs	ICRI-CSP3	**560**	50% A, 50% B	70% A, 30% B	10% A, 90% B	B 538
Concrete / Mortar 6/ 100% Solids EP	H	Yes	48 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	B 538
Concrete / Mortar 6	I	No	48 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	A 521
Concrete / Mortar 6	J	Yes	48 hrs	ICRI-CSP3	**560**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 6	K	No	48 hrs	None	**496**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 6	L	Yes	48 hrs	None	**542**	100% B	100% B	100% B	A 521
Concrete / Mortar 6/ 100% Solids EP	M	No	48 hrs	None	**535**	100% B	100% B	100% B	B 538
Concrete / Mortar 6/ 100% Solids EP	N	Yes	48 hrs	None	**540**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B7: Mortar 7, Portland-based

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 7	C	No	7 days	None	**348**	100% B	100% B	100% B	A 521
Concrete / Mortar 7	D	Yes	7 days	None	**392**	100% B	100% B	100% B	A 521
Concrete / Mortar 7/ 100% Solids EP	E	No	7 days	None	**392**	100% B	100% B	100% B	B 538
Concrete / Mortar 7/ 100% Solids EP	F	Yes	7 days	None	**367**	100% B/C	100% B/C	100% B/C	B 538
Concrete / Mortar 7/ 100% Solids EP	G	No	7 days	ICRI-CSP3	**450**	50% A, 50% B	70% A, 30% B	10% A, 90% B	B 538
Concrete / Mortar 7/ 100% Solids EP	H	Yes	7 days	ICRI-CSP3	**548**	100% B	100% B	100% B	B 538
Concrete / Mortar 7	I	No	7 days	ICRI-CSP3	**426**	100% B	100% B	100% B	A 521
Concrete / Mortar 7	J	Yes	7 days	ICRI-CSP3	**540**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 7	K	No	7 days	None	**361**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 7	L	Yes	7 days	None	**392**	100% B	100% B	100% B	A 521
Concrete / Mortar 7/ 100% Solids EP	M	No	7 days	None	**389**	100% B	100% B	100% B	B 538
Concrete / Mortar 7/ 100% Solids EP	N	Yes	7 days	None	**346**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B8: Mortar 8, Portland-based

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 8	C	No	7 days	None	**177**	100% B	100% B	100% B	A 521
Concrete / Mortar 8	D	Yes	7 days	None	**227**	100% B	100% B	100% B	A 521
Concrete / Mortar 8/ 100% Solids EP	E	No	7 days	None	**311**	100% B	100% B	100% B	B 538
Concrete / Mortar 8/ 100% Solids EP	F	Yes	7 days	None	**214**	100% B	100% B/C	100% B	B 538
Concrete / Mortar 8/ 100% Solids EP	G	No	7 days	ICRI-CSP3	**364**	100% B	100% B	100% B	B 538
Concrete / Mortar 8/ 100% Solids EP	H	Yes	7 days	ICRI-CSP3	**404**	100% B	100% B	100% B	B 538
Concrete / Mortar 8	I	No	7 days	ICRI-CSP3	**315**	100% B	100% B	100% B	A 521
Concrete / Mortar 8	J	Yes	7 days	ICRI-CSP3	**335**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 8	K	No	7 days	None	**244**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 8	L	Yes	7 days	None	**291**	100% B	100% B	100% B	A 521
Concrete / Mortar 8/ 100% Solids EP	M	No	7 days	None	**358**	100% B	100% B	100% B	B 538
Concrete / Mortar 8/ 100% Solids EP	N	Yes	7 days	None	**349**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B9: Mortar 9, Portland-based

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 9	C	No	7 days	None	**381**	100% B	100% B	100% B	A 521
Concrete / Mortar 9	D	Yes	7 days	None	**395**	100% B	100% B	100% B	A 521
Concrete / Mortar 9/ 100% Solids EP	E	No	7 days	None	**416**	100% B	100% B	100% B	B 538
Concrete / Mortar 9/ 100% Solids EP	F	Yes	7 days	None	**439**	100% B	100% B/C	100% B	B 538
Concrete / Mortar 9/ 100% Solids EP	G	No	7 days	ICRI-CSP3	**486**	100% B	100% B	100% B	B 538
Concrete / Mortar 9/ 100% Solids EP	H	Yes	7 days	ICRI-CSP3	**538**	100% B	100% B	100% B	B 538
Concrete / Mortar 9	I	No	7 days	ICRI-CSP3	**435**	100% B	100% B	100% B	A 521
Concrete / Mortar 9	J	Yes	7 days	ICRI-CSP3	**535**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 9	K	No	7 days	None	**251**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 9	L	Yes	7 days	None	**369**	100% B	100% B	100% B	A 521
Concrete / Mortar 9/ 100% Solids EP	M	No	7 days	None	**327**	100% B	100% B	100% B	B 538
Concrete / Mortar 9/ 100% Solids EP	N	Yes	7 days	None	**291**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B10: Mortar 10, Calcium Aluminate-based

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 10	C	No	24 hrs	None	**27**	100% B	100% B	100% B	A 521
Concrete / Mortar 10	D	Yes	24 hrs	None	**130**	100% B	100% B	100% B	A 521
Concrete / Mortar 10/ 100% Solids EP	E	No	24 hrs	None	**192**	100% B	100% B	100% B	B 538
Concrete / Mortar 10/ 100% Solids EP	F	Yes	24 hrs	None	**36**	100% B	100% B/C	100% B	B 538
Concrete / Mortar 10/ 100% Solids EP	G	No	24 hrs	ICRI-CSP3	**208**	100% B	100% B	100% B	B 538
Concrete / Mortar 10/ 100% Solids EP	H	Yes	24 hrs	ICRI-CSP3	**282**	100% B	100% B	100% B	B 538
Concrete / Mortar 10	I	No	24 hrs	ICRI-CSP3	**141**	100% B	100% B	100% B	A 521
Concrete / Mortar 10	J	Yes	24 hrs	ICRI-CSP3	**177**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 10	K	No	24 hrs	None	**106**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 10	L	Yes	24 hrs	None	**185**	100% B	100% B	100% B	A 521
Concrete / Mortar 10/ 100% Solids EP	M	No	24 hrs	None	**187**	100% B	100% B	100% B	B 538
Concrete / Mortar 10/ 100% Solids EP	N	Yes	24 hrs	None	**111**	90% B, 10% B/C	100% B	95% B, 5% B/C	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B11: Mortar 11, Calcium Aluminate-based

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 11	C	No	72 hrs	None	**2**	100% B	100% B	100% B	A 521
Concrete / Mortar 11	D	Yes	72 hrs	None	**8**	100% B	100% B	100% B	A 521
Concrete / Mortar 11/ 100% Solids EP	E	No	72 hrs	None	**163**	100% B	100% B	100% B	B 538
Concrete / Mortar 11/ 100% Solids EP	F	Yes	72 hrs	None	**10**	100% B	100% B/C	100% B	B 538
Concrete / Mortar 11/ 100% Solids EP	G	No	72 hrs	ICRI-CSP3	**285**	100% B	100% B	100% B	B 538
Concrete / Mortar 11/ 100% Solids EP	H	Yes	72 hrs	ICRI-CSP3	**471**	100% B	100% B	100% B	B 538
Concrete / Mortar 11	I	No	72 hrs	ICRI-CSP3	**177**	100% B	100% B	100% B	A 521
Concrete / Mortar 11	J	Yes	72 hrs	ICRI-CSP3	**252**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 11	K	No	72 hrs	None	**40**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 11	L	Yes	72 hrs	None	**307**	100% B	100% B	100% B	A 521
Concrete / Mortar 11/ 100% Solids EP	M	No	72 hrs	None	**120**	100% B	100% B	100% B	B 538
Concrete / Mortar 11/ 100% Solids EP	N	Yes	72 hrs	None	**308**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*

Table B12: Mortar 12, Calcium Aluminate-based

System	Panel Section	Membrane Cured	Curing Period	Subsequent Surface Preparation	Avg. psi	Failure Mode *(Pull 1)*	Failure Mode *(Pull 2)*	Failure Mode *(Pull 3)*	Concrete Control Panel (psi)[1]
Bond Strength Matrix: Trowel Finished / Blasted Surface [2]									
Concrete / Mortar 12	C	No	24 hrs	None	**82**	100% B	100% B	100% B	A 521
Concrete / Mortar 12	D	Yes	24 hrs	None	**118**	100% B	100% B	100% B	A 521
Concrete / Mortar 12/ 100% Solids EP	E	No	24 hrs	None	**159**	100% B	100% B	100% B	B 538
Concrete / Mortar 12/ 100% Solids EP	F	Yes	24 hrs	None	**112**	100% B	100% B/C	100% B	B 538
Concrete / Mortar 12/ 100% Solids EP	G	No	24 hrs	ICRI-CSP3	**237**	100% B	100% B	100% B	B 538
Concrete / Mortar 12/ 100% Solids EP	H	Yes	24 hrs	ICRI-CSP3	**246**	100% B	100% B	100% B	B 538
Concrete / Mortar 12	I	No	24 hrs	ICRI-CSP3	**238**	100% B	100% B	100% B	A 521
Concrete / Mortar 12	J	Yes	24 hrs	ICRI-CSP3	**232**	100% B	100% B	100% B	A 521
Bond Strength Matrix: Broom Finished [3]									
Concrete / Mortar 12	K	No	24 hrs	None	**85**	100 % B	100 % B	100% B	A 521
Concrete / Mortar 12	L	Yes	24 hrs	None	**148**	100% B	100% B	100% B	A 521
Concrete / Mortar 12/ 100% Solids EP	M	No	24 hrs	None	**156**	100% B	100% B	100% B	B 538
Concrete / Mortar 12/ 100% Solids EP	N	Yes	24 hrs	None	**128**	100% B	100% B	100% B	B 538

[1] *Refer to Exhibit 1.*
[2] *Refer to Exhibit 2.*
[3] *Refer to Exhibit 3.*