Kwik Bond Polymers® High Friction Surface Treatment

WA-RD 851.1

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December 2015

Washington State Department of Transportation
Office of Research & Library Services

WSDOT Research Report

Final Report
Experimental Feature 15-01

Kwik Bond Polymers® High Friction Surface Treatment

QE9982
I-5 and I-90 High Friction Surface Treatment
SR 526 EB to I-5 SB and 148th Avenue SE to I-90 WB




Washington State Department of Transportation

Engineering and Regional Operations
Construction Division
State Materials Laboratory

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15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

High friction surface treatment (HFST) was applied to two on-ramps in the Seattle urban area to improve friction resistance. The ramps were high accident locations. The system applied was polyester resin binder and calcined bauxite aggregate. Testing of the completed HFST resulted in average friction numbers (FN40R) ranging from 75 to 86 with no individual value below 72.

An evaluation period of five years is planned to monitor the performance of the HFST. At the end of the five-year period, a final report will be written which summarizes the friction and performance characteristics of the application, its effectiveness at reducing collisions, its cost effectiveness and recommendations on the future use of the high friction surface treatments.

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DISCLAIMER

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Introduction

Sharp curves can lead to higher than normal accident rates if the friction between tires and the pavement is not sufficient to keep the car from skidding. Measures are taken to reduce the number of accidents such as special warning signs and lowered speed limits. If these measures are not effective the characteristics of the pavement are improved to increase friction. The friction properties can be improved by replacing the pavement, placing a surface treatment such as a chip seal over the existing pavement, or by grooving the pavement using diamond grinding (concrete pavements). Replacing the pavement or diamond grinding are expensive fixes. Chip seals are a less expensive solution than replacing the pavement or diamond grinding, but may be prone to aggregate loss if applied on sharp curves due to a loss of bond between the aggregate and binder. The alternative is to apply a thin, high friction surface treatment (HFST) on the existing pavement. The special binders used for HFS treatments have higher bond strengths than the asphalt binders used for chip seals. This is the alternative taken to improve the friction resistance of two on-ramps in the Seattle urban area. HFST was part of FHWA's Center for Accelerated Innovation Every Day Counts program for 2012-2013(FHWA Every Day Counts).

Project Objectives

The three objectives of the study are:

- To measure the long-term performance of the HFST with respect to friction resistance, wear and aggregate retention.
- To measure any reduction in collisions.
- To develop a recommendation regarding the use of Kwik Bond PPC™HFST on WSDOT roadways.

Project Location

The two ramps are located on I-90 and I-5. The I-90 HFST was applied to the on-ramp from 148th Avenue SE to westbound I-90 in Eastgate (Figure 1). The I-5 HFST was applied to the on-ramp from SR 526 eastbound to I-5 southbound south of Everett (Figure 2).

Figure 1. HFST installation on SB 148th Avenue SE on- ramp to WB I-90.

Figure 2. HFST installation on EB SR 526 on-ramp to SB I-5.

Product Description

The HFST system selected for this project was provided by Kwik Bond Polymers, Benicia, CA. The system consists of a polyester resin binder and calcined bauxite aggregate. Great Lakes Minerals, Wurtland, KT was the source of the bauxite aggregate. Kwik Bond's PPC™HFST is a polymer-based resin binder system designed specifically to get into the pores of high friction aggregates and bond to various pavement substrates. The system can be mixed by hand and applied with serrated squeegees, or with automated installation equipment which was used on this project. The binder gains strength very quickly, so it can be applied to a roadway and returned to traffic within a normal production shift. The specifications and actual test results for the HRST are noted in Table 1 (see Appendix B for additional information).

Table 1. Physical properties of Kwik Bond PPC™HFST.

Test	Specification	Test Result
Viscosity	1,000 – 2,000 cps	1,390 cps
Tensile Strength (ASTM D-638)	2,650 – 3,900 psi	4,888 psi
Tensile Elongation at Break (ASTM D-638)	>30% min	52%
Compressive Strength (ASTM C-579)	5,000 psi at 24 hrs.	7,852 psi at 3 hrs.

Bauxite is composed of aluminum oxide, silicon oxide, titanium oxide and iron oxide, and is the source mineral for aluminum. Calcined bauxite is formed from a heating process that removes the crystalline water. The heat transforms the bauxite rock from a hardness of between 1.0 and 3.0 on the Mohs scale to a hardness of 9.0 (Mohs scale of mineral hardness runs from talc at 1.0 to diamond at 10.0, with 9.0 being corundum, Wikipedia). The physical properties of calcined bauxite are listed in Table 2 (Bond Minerals, 2015).

Table 2. Physical properties of calcined bauxite.	
Property	**Value**
Particle Shape	Angular
Color	Cream to Dark Grey
Specific Gravity lb/ft^3	3.70
Bulk Density lb/ft^3	2.75 – 3.10
Hardness (Mohs scale)	9.0
Moisture Content	0.5 – 1.0%
Polished Stone Value (1-3 mm)	70 minimum
Aggregate Abrasion Value	10 maximum

Construction Process

The HFST was installed on the two ramps in the last two weeks of June, 2015. The process is captured in a series of photographs. Figures 3-6 show the preparation prior to the application of the HFST. The pavement receiving the HFST was cleaned to remove all dirt, sand, oils and other debris using a combination of street sweepers and brooms. The paint stripes were removed by diamond grinding if they were in the center of the roadway, or if they were the edge stripes they were left in place or covered with duct tape. If the stripes were of the thermal variety with raised lane marker bumps, duct tape was applied to prevent covering by the HFST.

Figure 3. Inlet covered prior to HFST.

Figure 4. Lane line taped prior to HFST.

Figure 5. Taped expansion joint.

Figure 6. Diamond grinding to remove centerline stripe.

The application process is shown in Figures 7-18. The starting area is covered with plastic to prevent spills from contaminating the existing pavement and to provide a starting point for the HFST. The aggregate from the storage tank on the application vehicle is fed by a conveyer to a central bucket (Figure 9). Augers distribute the aggregate across the width of the paver (Figure 10). The two part binder, also carried on the paver (Figure 11), is distributed through a series of hoses to a ribbed plate (Figure 12). The ribbing on the plate distributes the liquid binder evenly across its width. A replaceable plastic squeegee is attached to the bottom of the ribbed plate to prevent wear on the plate (Figure 13). The binder is distributed onto the pavement followed by a curtain of aggregate (Figure 13). Additional aggregate is broadcast by hand onto the HRST to cover any wet spots of binder (Figure 14).

Figure 7. Application vehicle.

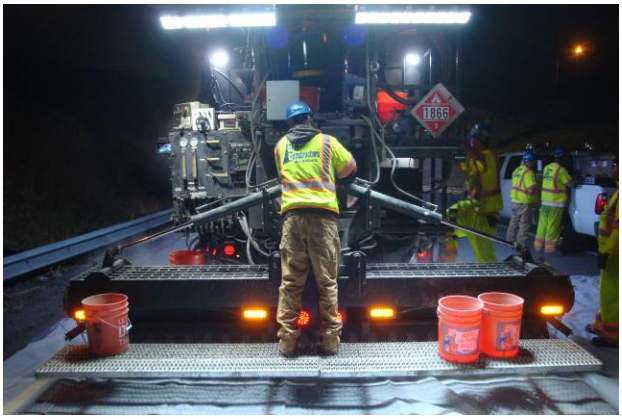


Figure 8. Application vehicle, rear view.

Figure 9. Aggregate bin and circular bucket that service as the source for the augers which distribute the aggregate.

Figure 10. Augers distributing aggregate across the width of the machine.

Figure 11. Binder storage tanks.

Figure 12. Binder is distributed through a number of rubber hoses to a ribbed plate.

Figure 13. Red plastic squeegee protects ribbed plate from wear. Binder is spread on the pavement followed by a curtain of aggregate.

Figure 14. Casting of aggregate onto wet spots to make sure of full coverage of the pavement.

The clean-up operation is shown in Figures 15 and 16. Organic peroxide is circulated through the hoses to remove the binder. Brushes are used to clean the ribbed plate and plastic squeegee (Figure 15). The peroxide and binder residue is collected in trays and then suctioned into a 55 gallon drum for disposal (Figure 16).

Figure 15. Clean-up operation, brushing excess binder and solvent into plastic trays.

Figure 16. Suctioning excess binder and solvent from the trays.

The finished HFST from the on-ramp to I-5 is shown in Figures 17-19 and the I-90 section in Figure 20. Note the excellent coverage with no streaking. Table 3 lists important facts concerning the installation.

Figure 17. View of the HRST behind the paver on the I-5 section.

Figure 18. Completed HFST, on-ramp to I-5.

Figure 19. Completed HFST on the ramp to I-5.

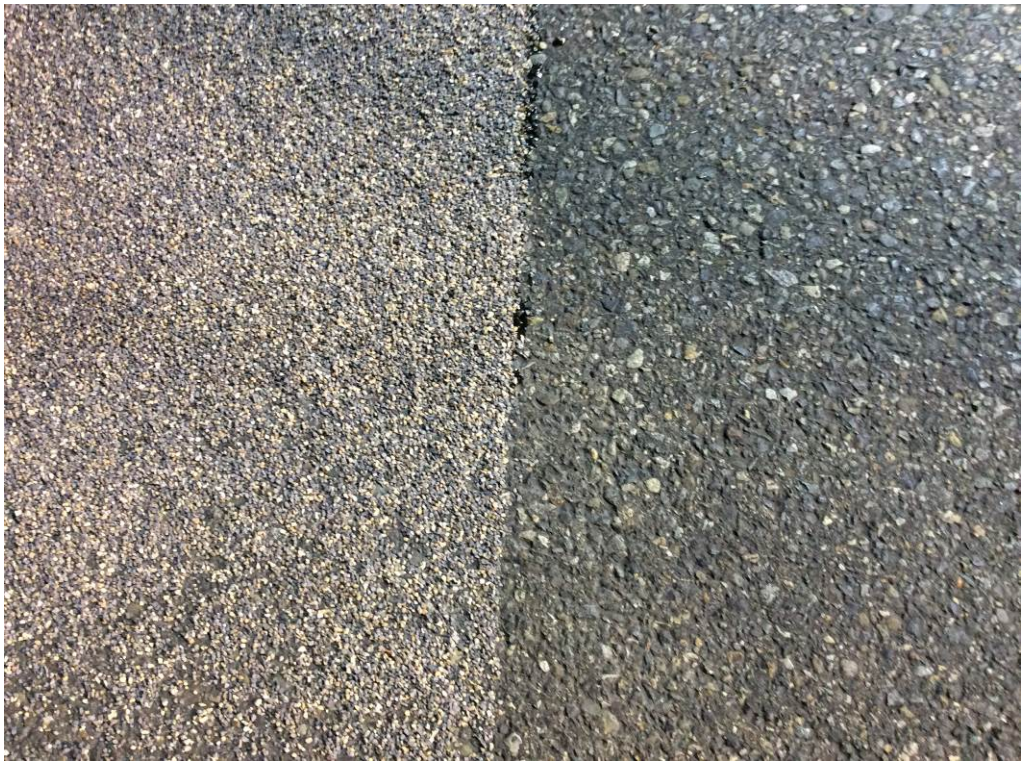


Figure 20. HFST on the left, original HMA on the right, on-ramp to I-90.

Table 3. Project facts.	
State Route	I-90, Eastgate and I-5, Everett
Contract Number	QE9982
Binder Material	Kwik Bond PPC™HFST
Aggregate	Calcined bauxite
Quantity	6605 S.Y.
Bid Price	$35.50 S.Y.
Contractor	American Civil Constructors West Coast, LLC.
Construction Period	June 22 – Jun 30, 2015

Post-Construction Testing

The horizontal curves in each of the ramps and vehicle acceleration maneuvers mandate that the friction resistance of the pavement be higher than tangent sections or areas with steady speeds. Friction testing of the two locations was conducted on May 13, 2015, prior to the application of the HFST, and on July 7, 2015, after completion of the treatment (Table 4). The values for the HMA prior to treatment on both locations average between 38 and 40 with low readings between 34 and 36. Although neither of the ramps had values of 30 or less, which is the threshold at which a review of the location is mandated by the WSDOT Skid Accident Reduction Program guidelines, the values were lower than desired for the ramps.

Table 4. Friction resistance before and after HFS treatment.

Location	Before Treatment (5/13/2015)		After Treatment (7/7/2015)	
	Average	Range	Average	Range
SB 148th Avenue SE on-ramp to WB I-90 Lane 2	39	34 - 42	83	77 – 86
SB 148th Avenue SE on-ramp to WB I-90 HOV	40	36 – 42	86	83 - 90
EB SR 526 on-ramp to SB I-5 Lane 1	38	36 – 41	75	72 – 77

The after treatment results were excellent for both locations with averages between 75 and 86 and low values in the 72 to 77 range. The after treatment values should provide all of the friction needed at both of these locations for traffic.

Cost

The bid price for the HFST was $35.50 per square yard. The original quantity of 6,225 square yards was increased to 6,605 square yards. More material was placed on the I-5, Everett section and a bit less on the I-90, Eastgate section as adjustments were made in the field to make sure that the problem areas at each location were covered. As a result, the total cost of the treatment was $234,477.50. This project was similar to the $36.50 per square yard cost of the Tyregrip® installed on SR 14 in 2010 (Anderson et al, 2012).

Discussion of Results

The HFST treatment was installed according to manufacturer's recommendations in a timely manner and without notable problems. The post-construction friction results are excellent and the visual appearance of the HFST on both ramps is excellent.

Future Research

The ramps will be friction tested and visually evaluated on a yearly basis for a minimum of five years as noted in the Experimental Feature Work Plan (Appendix C). Collision data will be collected and analyzed for the same five year period. At the end of the five-year period, a final report will be written which summarizes the friction and performance characteristics of the application, its effectiveness at reducing collisions, its cost effectiveness and recommendations on the future use of the high friction surface treatments.

References

Anderson, Keith W., Russell, M., Sheets, J., Burkey, D. Uhlmeyer, J.S., Weston, J., "Evaluation of Tyregrip® High-Friction Surfacing", Washington State Department of Transportation, Olympia, WA, June 2012.

Bond Minerals,"Calcined Bauxite Technical Data Sheet", Accessed July 30, 2015.

Appendix A

Contract Special Provisions

Division 5
Surface Treatments and Pavements

(******)
HIGH FRICTION SURFACE TREATMENT

DESCRIPTION

This work consists of constructing a High Friction Surface Treatment (HFST) over an existing asphalt pavement surface.

MATERIALS

The Binder Resin System shall be suitable for use on the intended pavement surface and for the potential range of atmospheric exposure.

The Binder Resin System shall conform to the following requirements:

Property	Test Method	Requirements	
		Polymeric Resin	MMA Resin
Viscosity	ASTM D2556 (note 1)	Class C:7-30 poises	Class C 12-20 poises
Gel Time	AASHTO M 235 (note 2)	Class C:10 minutes min.	Class C: 10 minutes min.
Ultimate Tensile Strength	AASHTO M 235 (note 3)	2,500 – 5,000 psi	1,500-5,000 psi
Elongation at break	AASHTO M 235 (note 4)	30-70%	30-70%
Durometer Hardness (Shore D)	ASTM D2240 (note 5)	60-80	40-75
Compressive Strength	ASTM C579 (note 6)	1,000 psi min. @ 3 hrs 5,000 psi min. @ 7 days	1,000 psi min. @ 3 hrs 2,000 psi min. @ 7 days
Cure Rate (Dry through time)	ASTM D1640 (note 7)	3 hours max.	3 hours max.
Water Absorption	AASHTO M 235 (note 8)	1% max.	1% max.
Adhesive Strength @ 24 hr	ASTM C1583 (note 9)	250 psi min. or 100% substrate failure	250 psi min. or 100% substrate failure

Notes:

1. Prepare a one pint sample per manufacturer's recommendation and mix for 2 to 3 minutes before testing. Use X1.1 for Spindle Selection. Perform testing at a temperature of 73 ± 2°F [23 ± 1°C].
2. Prepare a 60g sample per manufacturer's recommendation. Perform testing at a temperature of 73 ± 2°F [23 ± 1°C].
3. Prepare sample as per manufacturer's recommendation. Prepare Type I specimens in accordance with ASTM D638. Cure specimens for 7 days at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

4. Prepare sample as per manufacturer's recommendation. Prepare Type I specimens in accordance with ASTM D638. Cure specimens for 7 days at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.
5. Prepare sample as per manufacturer's recommendation. Prepare Type I specimens in accordance with ASTM D638. Cure specimens for 7 days at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.
6. Prepare sample as per manufacturer's recommendation. Prepare specimen accordance to Method "B", 2" x 2" cube, using 2.75 parts of sand to one part of mixed polymer resin binder by volume. Sand shall meet ASTM C778 20-30 sand. Cure specimens at ASTM D638. Cure specimens at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.
7. Prepare sample as per manufacturer's recommendation. Prepare a specimen at 50-55 wet mil thickness. Cure specimens for 3 hours at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.
8. Prepare sample as per manufacturer's recommendation. Cure specimens for 7 days at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay after immersion.
9. Prepare sample as per manufacturer's recommendation. Use Method D, E, or F with a 2 inch loading fixture. Cure specimens for 24 hours at 73 ± 2°F [23 ± 1°C] and 50 ± 2°F [10 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

Aggregate

The aggregate used for the HFST shall consist of calcined bauxite that is clean, dry, free of foreign matter and conforms to the following requirements:

Gradation

Sieve	Percent Passing
No. 4	99-100
No. 6	95-100
No. 16	0-5

Properties

Polish Stone Value	AASHTO T 279 AASHTO T278	38 min.
LA Wear	AASHTO T 96	20 max.
Moisture Content (at time of placement)	AASHTO T 255	0.2% max.
Aluminum Oxide	ASTM C25	87% min.

Manufacturer's Certificate of Compliance

The Contractor shall submit a Manufacturer's Certificate of Compliance and supporting tests in accordance with Standard Specification 1-06.3 for the Binder Resin System and HFST aggregate demonstrating compliance with these specification requirements 14 calendar days prior to the start of HFST work.

CONSTRUCTION REQUIREMENTS

Contractor Qualifications

A minimum of 10 calendar days prior to the Pre-Activity meeting, the Contractor shall submit these following qualifications: a minimum of 3 projects with the owner's contact information on which the HFST Contractor ahs installed a cumulative minimum of 10,000 square yards of HFST within the past three years demonstrating a friction reading of 65 FH40R or higher when tested in accordance to ASTM E 274. An installer who does not meet this minimum shall be allowed if they are certified by the manufacturer to install and a manufacturer's representative is onsite during all installations.

Resin Binder System Manufacturer's Recommendations
The Contractor shall submit a copy of the manufacturer's application recommendations for the Resin Binder system a minimum of 10 calendar days prior to the Pre-Activity meeting. The application recommendations shall at a minimum include:

Method of surface preparation and required surface conditions for adequate bonding
Crack repair requirements
Weather, moisture and temperature requirements
Mixing ratio and application rates for polymer resin and aggregate
Application methods
Requirements for opening to traffic

The Contractor shall follow the manufacturer's recommendations unless required otherwise by this specification.

Equipment
Application of the Binder Resin System shall be performed using an applicator vehicle equipped with an automated continuous application device approved by the Binder Resin System manufacturer for use with their material. The application device shall mechanically mix, meter, monitor and apply the Binder Resin System and high friction aggregate in one continuous pass.
The application vehicle shall be equipped with volumetric metering pumps that continuously mix, meter, and monitor and apply the resin binder. If recommended by the manufacturer, metering pumps shall be heated. The automated continuous application vehicle shall have continuous pumping and portioning devices that blend the Binder Resin System within a controlled system. The application vehicle shall be capable of applying a uniform application thickness of 50-65 mils (25-32 sf. / gal.).

Weather Limitations
Weather, moisture, and temperature requirements shall be in accordance with the manufacturer's recommendations.

HFST shall not be placed during weather and temperature condition with will not allow the Resin Binder System to adequately cure prior to the required time for opening to traffic.

Surface Preparation

Prior to placement of the HFST, the existing HOV diamond pavement markings and solid wide lane line on the Everett ramp shall be removed from pavement surfaces. Drainage structures, utility covers, and transverse expansion joints, within the enclosed surface area of HFST shall be covered or otherwise protected prior to HFST placement. The surface to receive the HFST shall be thoroughly clean, dry and free of all dust, oil, debris and deleterious other. Pavement surfaces contaminated with oils, greases, or other deleterious materials not removed by the surface preparation shall be washes with a detergent solution, rinsed with clean water, and dried using a hot compressed air lance.

Clean asphalt pavement surfaces using mechanical sweepers and high pressure air wash with sufficient oil traps. Mechanically sweep all surfaces to remove dirt, loose aggregate, debris, and deleterious material. Vacuum sweep or air wash using a minimum of 180 cfm of clean and dry compressed air, all surfaces to remove all dust, debris, and deleterious material. Maintain the tip of the air lance within 12 inches of the surface.

Cracks greater than 1/4 inch in width shall be filled with the mixed Binder Resin System. Prior to HFST application, the Engineer will mark all cracks that require treatment and will review these areas with the Contractor. Once the binder resin in the pre-treated areas has gelled, the installation may proceed.

Application

The Binder Resin System shall be mixed and placed onto the pavement using a Truck Mounted Application machine at a uniform application thickness of 50-65 mils (25-32 sf. /gal.). The Binder Resin System shall be blended and mixed within 2% of the ratio recommended by the manufacturer and shall be continuously applied once blended.

The calcined bauxite aggregate shall be immediately applied using the same integrated application truck and at a uniform rate of 12-15 lbs. per square yard. The aggregate shall completely cover the Binder Resin System to achieve a uniform surface with no exposed resin binder visible on the surface. It is the responsibility of the HFST installer to ensure full embedment of the calcined bauxite aggregate.

Irregular areas or areas inaccessible to truck mounted application machine may be placed by hand methods in accordance with the Binder Resin system manufacturer's recommendations. Wet spots must be covered with the aggregate prior to the gelling of the Binder Resin System.

Equipment and traffic shall not be allowed on the HFST until curing is complete.

Opening to Traffic
Prior to opening to traffic the roadway shall be swept clean with loose aggregate removed and disposed of in accordance with Section 2-03.3(7) C.

As shown in the plans, all existing pavement markings either immediately adjacent to, or within the treated lanes, shall be reinstalled after placement of HSFT and roadway sweeping.

All HFST areas, as well as untreated shoulders adjacent to the HFST, shall be re-swept three to five days after the initial installation is completed.

Application of HFST
The finished HFST surface shall have a uniform coverage of aggregate without streaks or areas of exposed polymer resin binder.

After completion of the HFST, the Contractor shall notify the Project Engineer that the HFST is ready for testing. WSDOT State Materials Lab will perform the testing. Conditions permitting: testing will be completed within 30 calendar days of notification. No testing will be done unless the roadway surface temperatures is a minimum of 40°F and rising, and the requirements of ASTM E 274 are satisfied.

The completed HFST shall attain an average friction number (FH40R) of 65 or greater when tested in accordance with ASTM E 274 with no individual test less than a friction number (FH40R) of 60. The average friction number will be based on a minimum of five tests points in each lane.

The Engineer may isolate areas of exposed resin binder, insufficient aggregate of that otherwise appear defective for additional testing. These areas shall attain a friction number (FN40R) of 60 or greater.

If the HFST fails to meet the requirements of this section, the contractor shall remove and replace the defective areas at the Contractor's expense. The areas selected for reinstallation will be retested using the same methods and subject to the acceptance criteria as outlined above.

Measurement

High friction surface treatment shall be measured by the square yard. No deduction will be made for drainage structures or utility appurtenances within the HFST placement area.

Payment

"High Friction Surface Treatment", per square yard.

The area to be paid for will be based on the dimensions shown on the plans. No additional payment will be made for reinstallation of HFST where the initial installation was determined to be defective.

The contract price paid per square yard for high friction surface treatment (HFST) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in HFST, complete in place, including the submittals, surface preparation, roadway sweeping, and other work, all in accordance with the attached Contract Plans, these Contract Provisions, the Standard Specifications, and as directed by the Engineer.

Appendix B

Manufacturer's Certificate of Compliance

Washington State Department of Transportation

Manufacturer's Certificate of Compliance Check List

Instructions: This form is to be completed by the PEO. It is **NOT** required for concrete delivery tickets, asphalt bill of lading, or admixtures.

Contract Number	SR Number	Section	Date
QE9982	I-5 & I-90	I-5 & I-90 High Friction Surface Treatment	5/19/2015

Project Engineer:	Contractor:
Mark Sawyer	American Civil Constructors West Coast, Inc.

The attached Manufacturer's Certificate of Compliance for a quantity of 6225 S.Y. for Bid Item # 4 ;
Material High Friction Surface Treatment, has been checked for conformance to Section 1-06.3 of the *Standard Specifications* per the check list shown below.

	YES	NO
1. Is a Mfg. Cert. proper documentation for this item of Material? *See Note 1*	☒	☐
2. Is the certification being provided PRIOR to the material being installed?	☒	☐
3. If the answer to No. 2 above is "NO," attached is a copy of the contractor's approved request for permission to install prior to providing a Mfg. Cert. for acceptance.	☐	☐
4. Has an approved RAM/QPL been received for this item?	☒	☐
5. Does this Mfg. Cert. identify the name of the manufacturer and/or fabricator?	☒	☐
6. Does the Mfg. Cert. identify the quantity of material being certified and/or placed by type, size, lot, or heat number? *See Note 2*	☒	☐
6a. Does the material being placed match the certification provided?	☒	☐
7. Does the Mfg. Cert. identify the applicable contract specification (i.e., WSDOT, AASHTO, ASTM) that the material is to meet? *See Note 3.*	☒	☐
8. Does the Mfg. Cert. provided show the material conforms to the required specifications ? (i.e., WSDOT, AASHTO, ASTM) *See Note 4*	☒	☐
9. Is the Mfg. Cert. signed by a corporate official?	☒	☐
10. When more than a single delivery is made, are the lot numbers identified?	☐	☐
11. Is a supporting mill test attached showing the physical and chemical test values meeting applicable specifications? *See Note 3.*	☐	☐

Remarks:
MFR-0001

Notes:

1. Check the Record of Materials (ROM), Special Provisions, or the 'Approved' Request for Approval of Material (RAM).
2. Rebar cut sheets may be used in lieu of bill of lading or invoice.
3. Test values required to be supplied with Manufacturer's Certificate for steel reinforcing bars and structural steel. Manufacturer's Certificate for some steel items, such as steel culvert pipe items, may reference heats used.
4. If answer is "NO," submit Manufacturer's Certificate to State Materials Laboratory for approval.

☒ Accepted as proper documentation per Section 1-06.3 of the *Standard Specifications.*
☐ Manufacturer's Certificate of Compliance submitted to State Materials Laboratory for "Approval Action."
☐ Returned to contractor for correction of "NO" answers recorded in items _____

Signed	Date
Dale Delino	5/19/15

DOT Form 350-572 EF
Revised 6/2004

KWIKBOND POLYMERS

923 Teal Drive
Benicia, CA 94510
(866)434-1772
(707) 746-7981 Fax
patti@kwikbondpolymers.com

Certificate of Compliance

Date: May 15, 2015

Contract No: NWR-ELJ201501 High Friction Surface Treatment, Division 5-Surface Treatment & Pavements

Material Quantity – Per Bid Item #4 - 6,225 Sq Yards HFST

Contractor: ACC West Coast

Kwik Bond Polymers, LLC is both a manufacturer and System Provider for Polyester Polymer Concrete Applications. Kwik Bond Polymers, LLC certifies that the components listed below have been tested and/or known to comply with the Special Provisions for the material referenced in the contract number above.

Product	Lot No.	Quantity	Ship Date
PPC HFST	0000912421	8 totes / 3 drums / 3-4 gal pails	6-2-2015
DDM 9		52 gallons	6-2-2015
Zcure		36 gallons	6-2-2015
Great Lakes Calcined Bauxite	031115	24 S/S	6-2-2015

If you have any questions, please contact Patti Fonseca at 707-373-4075. Thank you.

Patti Fonseca
Corporate Secretary
Kwik Bond Polymers
patti@kwikbondpolymers.com

MTL 3766-32 Kwik Bond Polymer

Martin Testing Laboratories, Inc.

P.O. Box 2019
North Highlands, CA 95660
(916) 920-4110
(916) 920-4390 fax

www. martintesting.com

May 14, 2015

Customer: Kwik Bond Polymer
923 Teal Dr.
Benecia, CA 94510

MTL MJO: 3766-32
P.O. No: verbal

Attn: Daniel Tikusis
(7107) 330-9227
(707) 746-7981 fax

RE: Testing of KBP HFST 32042-11, Batch # 912421- 7 day cure

The following are test results for testing of KBP HFST as specified by customer. Testing included:

Water Absorption, Tensile Strength, Compression, and Hardness.

Data sheets for tensile and compression are attached separately. Please call if you have any questions.

Thank you.

Martin Testing Labs

Debbie Hu

1

Materials Technology Laboratories

May 06, 2015

Customer: Kwik Bond Polymer
923 Teal Dr.
Benecia, CA 94510

MTL MJO: 3766-29
P.O. No: verbal

Attn: Daniel Tikusis
(707) 330-9227
(707) 746-7981 fax

RE: Testing of KBP HFST 32042-11, Batch 912421

A sample of KBP HFST was submitted for viscosity testing per ASTM D2556. Results are presented below.

Viscosity per ASTM D2556

Sample	Viscosity (cps)
KBP HFST	1390

Sample was tested using a Brookfield RVT Viscosity Tester.
Spindle #3 at 20 rpm @ 25°C.

Please call if you have any questions.

Thank you.

Martin Testing Labs

Debbie Hu

Martin Testing Laboratories
A Division of Materials Technology Laboratories, Inc.
4724 Arnold Ave.
McClellan, CA 95652
Ph: (916) 920-4110; Fx: (916) 920-4390

Materials Technology Laboratories

May 06, 2015

Customer: Kwik Bond Polymer
923 Teal Dr.
Benecia, CA 94510

MTL MJO: 3766-29
P.O. No: verbal

Attn: Daniel Tikusis (707) 330-9227

RE: Testing of KBP HFST 32042-11, Batch 912421

A sample of KBP HFST was submitted for Gel Time and Cure Rate testing.
Results are presented below.

Gel Time per ASTM C881 and AASHTO M 235

Sample	Gel Time
KBP HFST @ 77F/25C	17 min
KBP HFST@ 50F/10C	13 min

Components at 77F/25C: 0.175% Z Cure, 2.0% DDM-9
Components at 50F/10C: 1.5% Z Cure, 2.0% DDM-9

Cure Rate per ASTM D1640

Sample	Cure Rate
KBP HFST @ 77F/25C	<100 min
KBP HFST@ 50F/10C	<80 min

Components at 77F/25C: 0.175% Z Cure, 2.0% DDM-9
Components at 50F/10C: 2.0% Z Cure, 2.0% DDM-9

Please call with any questions.

Debbie Hu

Martin Testing Laboratories
A Division of Materials Technology Laboratories, Inc.
4724 Arnold Ave.
McClellan, CA 95652
Ph: (916) 920-4110; Fx: (916) 920-4390

Martin Testing Laboratories — **May 12, 2015**

Tensile Properties of Plastics (Modulus) — **Report No. 3918**

3966-31

Test Date 12-May-15 Testing Machine Smart Series

Vendor KwikBond
Operator RE — P/N KBP HFST
Description 32042-11 — Batch: 912421

Load Cell S/N (QS4008), Units (Lbs) 1000 — Crosshead Speed (Inches / min) or Rate 0.2
Displacement Sensor XHD_100 (XHD100)

Notes ASTM D638 7 day cure

Test No	Spec ID	Width (in)	Thickness (in)	Tensile (lbs)	Tensile Str. (psi)	Modulus of Elasticity (psi)	Break Elong (%)	Tensile Elong (%)
9483	1-01	0.486	0.127	305.77	4,955.83	3,354,424	47.92	12.34
9484	1-02	0.485	0.126	295.62	4,838.30	4,307,218	38.85	11.05
9485	1-03	0.486	0.128	305.96	4,919.00	4,322,393	63.06	11.01
9486	1-04	0.486	0.131	309.41	4,857.24	4,087,605	52.30	10.73
9487	1-05	0.487	0.134	318.07	4,870.95	4,024,469	59.29	10.75
	Mean	0.486	0.129	306.97	4,888.26	4,019,222	52.28	11.17
	Median	0.486	0.128	305.96	4,870.95		52.30	11.01
	Std Dev	0.001	0.003	8.07	48.14	394,180	9.55	0.67
	Maximum	0.487	0.134	318.07	4,955.83	4,322,393	63.06	12.34
	Minimum	0.485	0.126	295.62	4,838.30	3,354,424	38.85	10.73
	Range	0.002	0.008	22.45	117.53	967,969	24.21	1.60

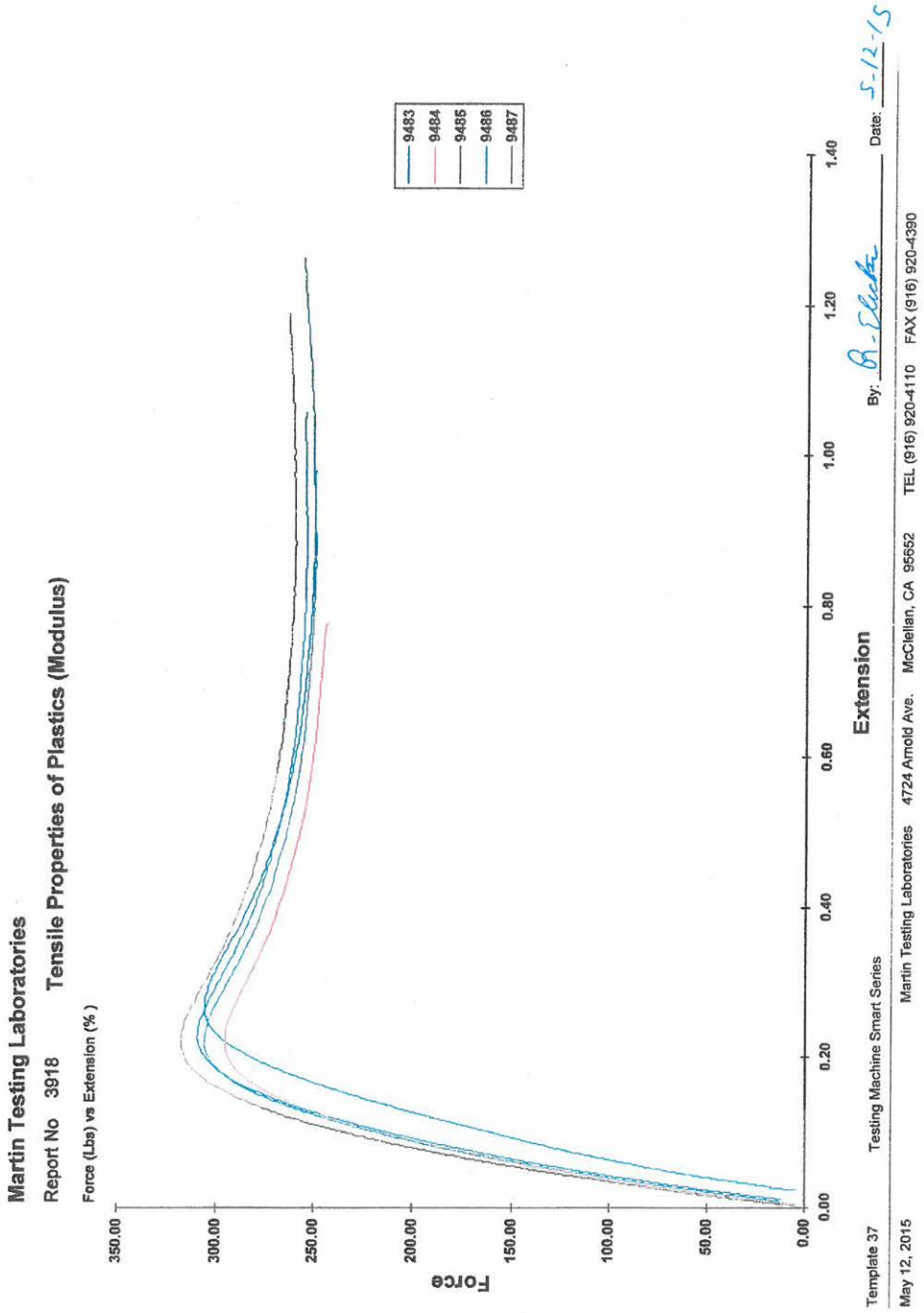
NOTES:

1. Tested per ASTM D638 and AASHTO M235

2. Samples are 7 day cure at 73F

By: R. Elichen Date: 5-12-15

Martin Testing Laboratories 4724 Arnold Ave. McClellan, CA 95652 TEL (916) 920-4110 FAX (916) 920-4390


Martin Testing Laboratories
Report No 3918
Tensile Properties of Plastics (Modulus)
Force (Lbs) vs Extension (%)
Force
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Extension
9483
9484
9485
9486
9487
Template 37
Testing Machine Smart Series
May 12, 2015
Martin Testing Laboratories 4724 Arnold Ave. McClellan, CA 95652 TEL (916) 920-4110 FAX (916) 920-4390
By:
Date: 5-12-15

MTL 3766-32 Kwik Bond Polymer

KBP HFST 32042-11, Batch 912421 5-14-15

1) Water Absorption – 73F (23C) & 50F (10C), 7 day cure

Sample was tested per ASTM D570 and AASHTO M235

Sample	73F Wt. Increase %	50F Wt. Increase %
1	0.478	0.373
2	0.477	0.347
3	0.450	0.364
Average	0.468	0.361

2) Shore D Hardness – 73F (23C) & 50F (10C), 7 day cure

Sample was tested in accordance with ASTM D2240.

Sample	Shore D
KBP HFST	75

2

Martin Testing Laboratories **May 7, 2015**

ASTM C579-01 Compressive Strength of CR Mortars... **Report No. 3912**

Test Date 07-May-15 Testing Machine Smart Series

Customer Name KwikBond
Operator RE
Batch # 912421

Product # KBP PPC HFST
Description: 3 hr @ 50F/10C

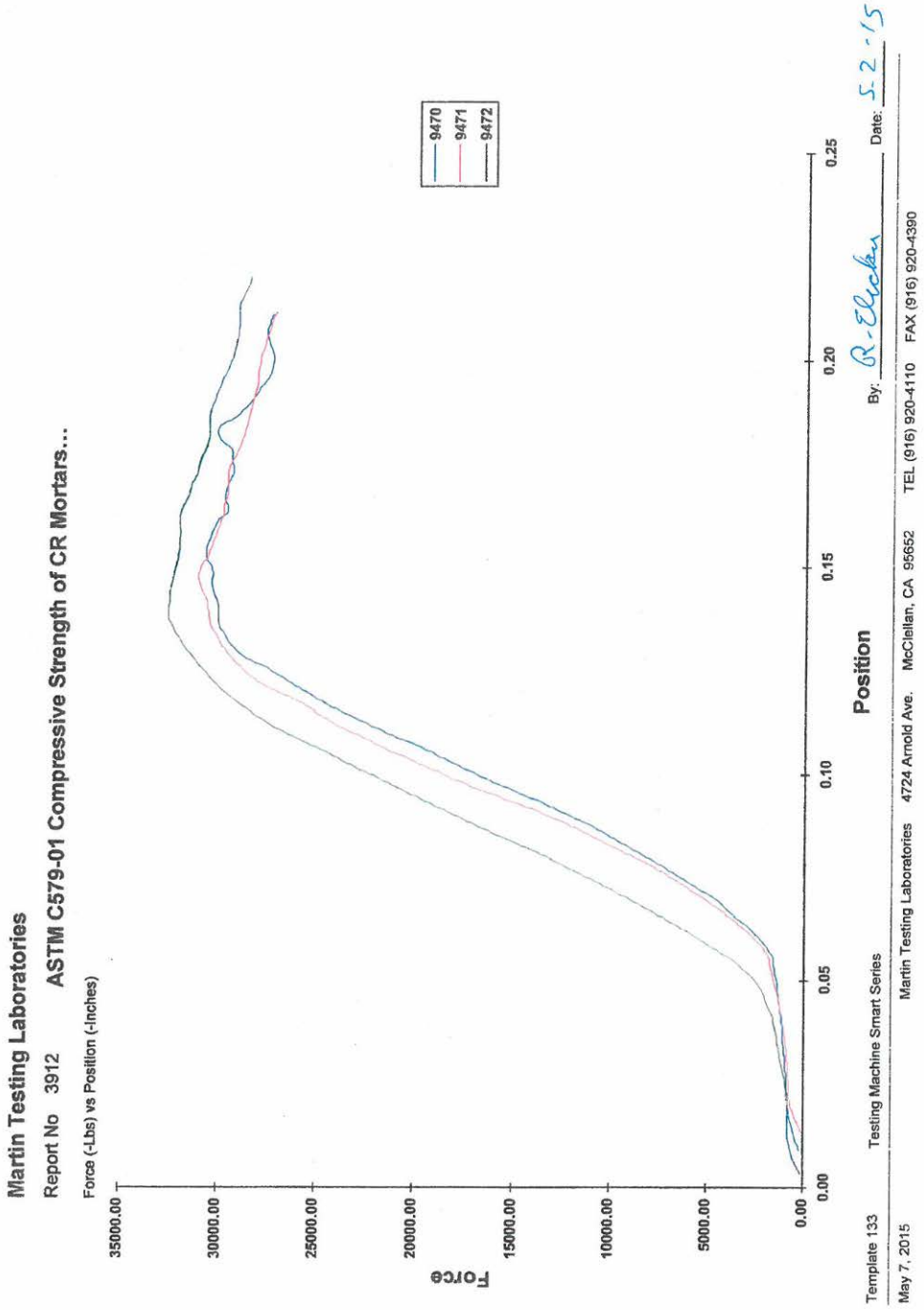
Load Cell S/N (SB188501), Units (Lbs) 110000
Preload Value (-Lbs) 100

Crosshead Speed (-Inches / min) or Rate 0.2
Displacement Sensor XHD_100 (XHD100)

Test No	Spec ID	Width (in)	Length (in)	Max Comp Load (lbs)	Max Comp Stress (psi)
9470	1-01	2.000	2.000	30,649.64	7,662.41
9471	1-02	2.000	2.000	31,029.82	7,757.45
9472	1-03	2.000	2.000	32,547.57	8,136.89
	Mean	2.000	2.000	31,409.01	7,852.25
	Median	2.000	2.000	31,029.82	
	Std Dev	0.000	0.000	1,004.18	251.04
	Maximum	2.000	2.000	32,547.57	8,136.89
	Minimum	2.000	2.000	30,649.64	7,662.41
	Range	0.000	0.000	1,897.93	474.48

By: R. Elisha Date: 5-7-15

Martin Testing Laboratories 4724 Arnold Ave. McClellan, CA 95652 TEL (916) 920-4110 FAX (916) 920-4390


Martin Testing Laboratories
Report No 3912
ASTM C579-01 Compressive Strength of CR Mortars...
Force (-Lbs) vs Position (-Inches)
Force
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
Position
9470
9471
9472
Template 133
Testing Machine Smart Series
May 7, 2015
Martin Testing Laboratories 4724 Arnold Ave. McClellan, CA 95652 TEL (916) 920-4110 FAX (916) 920-4390
By: R-Elucha
Date: 5-2-15

Martin Testing Laboratories **May 13, 2015**

ASTM C579-01 Compressive Strength of CR Mortars... **Report No. 3920**

Test Date 13-May-15 Testing Machine Smart Series

Customer Name KwikBond
Operator RE
Batch # 912421

Product # KBP HFST
Description: 7 Day @ 50F/10C

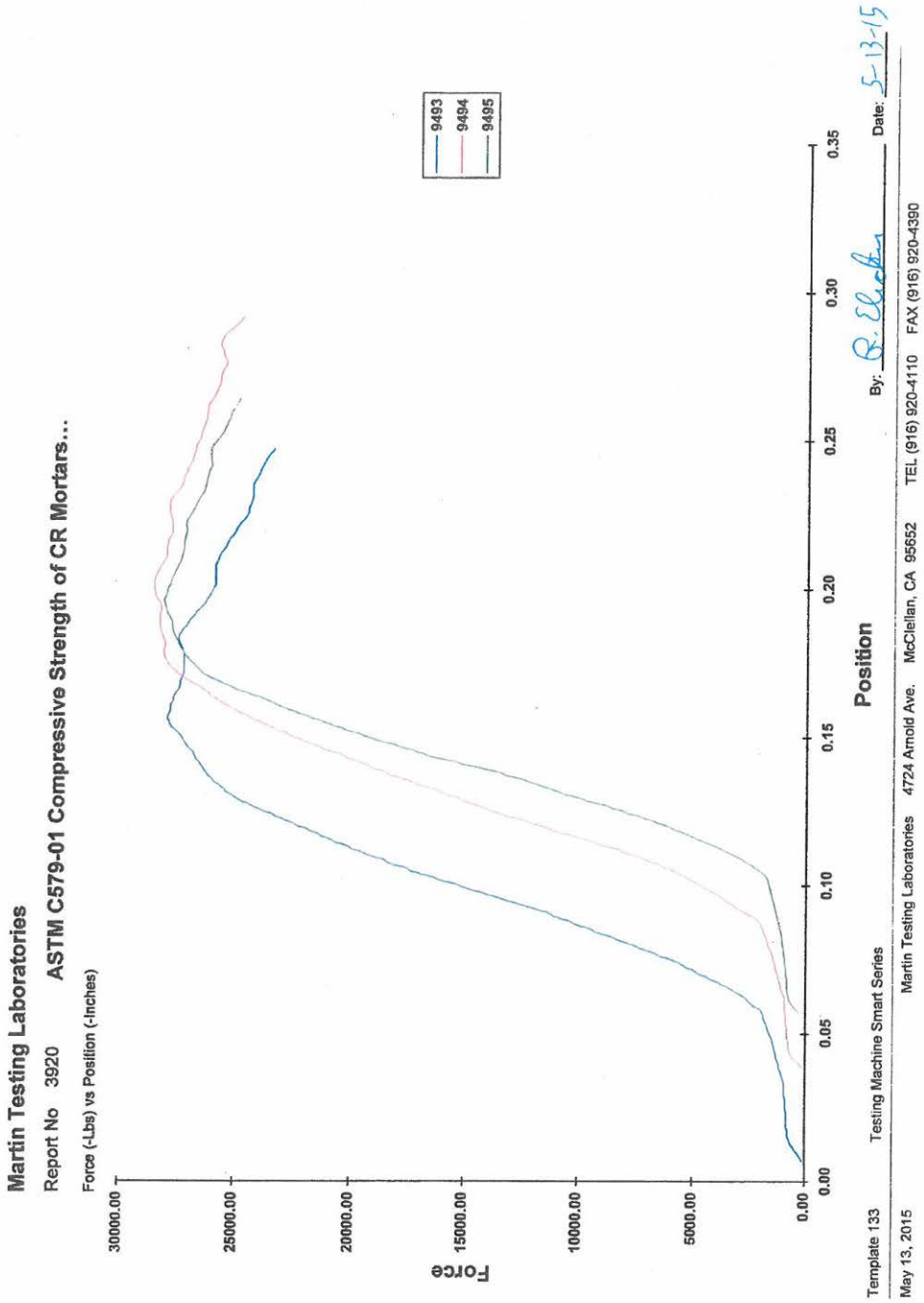
Load Cell S/N (SB188501), Units (Lbs) 110000
Preload Value (-Lbs) 100

Crosshead Speed (-Inches / min) or Rate 0.2
Displacement Sensor XHD_100 (XHD100)

Test No	Spec ID	Width (in)	Length (in)	Max Comp Load (lbs)	Max Comp Stress (psi)
9493	1-01	2.000	2.000	27,869.26	6,967.32
9494	1-02	2.000	2.000	28,486.52	7,121.63
9495	1-03	2.000	2.000	28,072.78	7,018.19
	Mean	2.000	2.000	28,142.85	7,035.71
	Median	2.000	2.000	28,072.78	
	Std Dev	0.000	0.000	314.54	78.63
	Maximum	2.000	2.000	28,486.52	7,121.63
	Minimum	2.000	2.000	27,869.26	6,967.32
	Range	0.000	0.000	617.26	154.31

By: R. Elicson Date: 5-13-15

Martin Testing Laboratories 4724 Arnold Ave. McClellan, CA 95652 TEL (916) 920-4110 FAX (916) 920-4390


Martin Testing Laboratories
Report No 3920
ASTM C579-01 Compressive Strength of CR Mortars...
Force (-Lbs) vs Position (-Inches)
Force
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Position
9493
9494
9495
Template 133
Testing Machine Smart Series
May 13, 2015
Martin Testing Laboratories 4724 Arnold Ave. McClellan, CA 95652 TEL (916) 920-4110 FAX (916) 920-4390
By:
Date: 5-13-15

Materials Technology Laboratories

May 7, 2015

MJO: 3766-30

Customer: Kwik Bond Polymers
923 Teal Drive
Benecia, CA 94510

Daniel Tikusis (707) 330-9227

RE: Testing of KBP HFST 32042-11, Batch 912421 for Adhesive Strength per ASTM C1583

24 hr cure at 77F/25C

Sample No.	Bond Strength, psi	Mode of Failure
1	469.4	Epoxy/Adh. Failure
2	533.3	Concrete Failure
3	478.9	Epoxy/Adh. Failure

24 hr cure at 50F/10C

Sample No.	Bond Strength, psi	Mode of Failure
1	435.0	Concrete Failure
2	370.9	Adhesive Failure
3	427.0	90% Adh Failure/ 10% Concrete Failure

Samples: Three 2" dia. cored concrete samples with bonded gravel overlay for each set of testing performed.

Please call with any questions.

Debbie Hu

Martin Testing Laboratories
A Division of Materials Technology Laboratories, Inc.
4724 Arnold Ave.
McClellan, CA 95652
Ph: (916) 920-4110; Fx: (916) 920-4390

PaveTex Engineering & Testing, Inc.
3989 HWY 290 East
Dripping Springs, Texas, 78620
PH 512-858 2993 Fax 512-858 2921

Client:
Attn:

Report No: 17561-R3
Date: 11/13/2014

Report of: Particle Size Analysis of Soils, Aggregate Acid Insoluability, LA Abrasion, Polish Value & Na Soundness
Test Method: CTM 202, ASTM D 3042, AASHTO T 96, CTM 211, ASTM D 3319 & ASTM C88

Sample ID: NP
Sampled By: Client
Sample Location: High Friction Surfacing Project- CA
Producer: Great Lakes Minerals
Material Description: Calcined Bauxite Mineral Aggregate

Lab No: 143789
Production/ Sampled Date: NP
Project No: NP
Received Date: 11/7/2014
Test Performed By: Phillip New, CET

Results:

Sieve Size	Cumulative % Passing	% Passing Limit
#4	100.0	100
#6	100.0	>95
#8	64.5	
#10	38.3	
#16	0.9	<5
#30	0.2	
#50	0.1	

Acid Insoluability (%):	99.1	>90%

La Abrasion (D grading) @100rev (%):	3.0	<20%

British Pendulum No.	
Prior to Polishing	After 10 Hrs Polishing
58	41

Magnesium Soundness (%):	1.0	<30%

STATE OF TEXAS
DALE A. RAND
73810
LICENSED
PROFESSIONAL ENGINEER

PaveTex Engineering and Testing
F-961

Report Reviewed by:

Dale A Rand

PaveTex Engineering and Testing, Inc.
Firm Registration No. F-961

The results shown on this report are for the exclusive use of the client for whom they were obtained and apply only to the samples tested and/or inspected. They are not planned to be indicative of apparently identical products.

Great Lakes Minerals, LLC

CERTIFICATE OF ANALYSIS

Date: 5/15/2015
Customer: Kwik Bond
P.O. #
BOL# RD11385, RD11386, RD11387
Pallets#

Material: RD88
Size: GripGrain
Lot# 031115

Chemistry Analysis (%)

Al2O3 88% min	Fe2O3 2.0% max	SiO2 7.5% max	TiO2 3.75% max	Na2O + K2O 0.25% max	CaO + MgO 0.60% max	Bulk Density 3.25 gm/cc	Moisture 0.5% max
89.10	1.51	5.07	3.11	0.11	0.42	3.26	0.1

Sieve Analysis

US STD Sieve/Inch		4	6	16	Pan		
min / max %		0	0 - 5		0 - 5	-	-
		0.0	1.1	97.1	1.8		

INSPECTORATE

Great Lakes Minerals, LLC
1200 Port Road, Suite B
Wurtland, KY 41144

Certificate of Analysis

Job: Submitted Samples - October
Product : Bauxite
Sample I.D.: RD-88 6X6 Grip Grain Bauxite
Terminal: Submitted
Job ID : 14-60111-4366
Lab Ref: 14-601-00194-01-001

Sample Submitted By : Great Lakes Minerals
Analysis Performed By : IAC New Orleans M&M Operations
Date Received : October 21, 2014
Date Reported : November 6, 2014
Submission ID : 14-601-00194-01

RD-88 6X6 Grip Grain Bauxite

Method	Test	Result
ASTM C566, AASHTO T-255	Loss on drying (Moisture), %	0.01
ASTM C25	Alumina, %	88.11

Particle Size Distribution
ASTM C136, AASHTO T-27

Screen Size	Weight, %
+ 4 mesh	Nil
+ 6 mesh	0.3
+ 16 mesh	99.5
- 16 mesh	0.2

Renisha Singh, Technical Manager

5051 Taravella Road
Marrero, Louisiana 70072 U.S.A.
Tel: +1-504-392-7660
Fax: +1-504-392-5185
www.inspectorate.com

Appendix C

Work Plan

Washington State Department of Transportation

WORK PLAN

High Friction Surface Treatment

QE9982
Interstate 90
SB 148th Avenue SE on-ramp to I-90 Westbound
I-5
SR 526 Eastbound on-ramp to I-5 Southbound

Keith W. Anderson
Experimental Features Engineer
Washington State Department of Transportation

Introduction

Two ramps, one on I-90 and one on I-5, will have a High Friction Surface (HFS) applied to the ramps to improve the frictional properties of the pavement. The I-90 section is the on-ramp from 148th Avenue SE to westbound I-90 in Eastgate (Figure 1). The I-5 section is the on-ramp from SR 526 eastbound to I-5 southbound south of Everett (Figure 2). Both on-ramps are high accident locations. WSDOT installed warning signs to alert motorists to the hazard but there is still a high occurrence of accidents. The ramp geometry and type of accidents indicate that increasing the pavement friction may reduce the number of accidents.

There are several methods to increase friction on an existing pavement. These include replacing the pavement, placing a surface treatment such as a chip seal over the existing pavement or grooving the pavement by diamond grinding (PCC pavements). These methods are costly and the existing HMA pavement on the subject ramps is not due for rehabilitation. A less costly solution is to install a thin high-friction laminate surface over the existing pavement.

The HFS system selected for this project was provided by Kwik Bond Polymers, Benicia, CA. The system consists of a polyester resin binder and calcined bauxite aggregate. Great Lakes Minerals, Wurtland, KT was the source of the bauxite aggregate. The system can be applied by machine or by hand depending on the size of the project.

Scope

Kwik Bond HFS will be installed on the curved portions of the two ramps. The amount of HFS to be installed is 6,225 square yards, 1520 ft. by 24 ft. on SR 526 and 1055 ft. by 16 ft. on 148th Avenue SE. The contract special provisions require that the method of application be by a mechanical device that mixes, monitors and applies the binder resin system and high friction aggregate in one continuous pass.

Figure 1. HFST installation on SB 148th Avenue SE on-ramp to I-90 WB.

Figure 2. HFST installation on SR 526 eastbound to I-5 SB.

Staffing

This installation will be constructed as a Northwest Region Traffic Office low cost enhancement project. Representatives from and WSDOT Materials Laboratory (1 – 2 people) will be involved in monitoring the installation to collect data and photos for the post-construction report.

Contacts and Report Author

Mark Russell
State Pavement Design Engineer
Washington State DOT
(360) 709-5479
russelm@wsdot.wa.gov

Keith Anderson
Experimental Features Engineer
Washington State DOT
(360) 584-8648
anderke@wsdot.wa.gov

Testing

Pavement performance will be monitored by the following methods:

- Friction will be measured before and after construction then annually.
- Accident data will be gathered by the Northwest Region Traffic Office
- Visual inspections will be conducted to collect data on cracking, delaminations (potholes) and other pavement distress.

Reporting

A "Post Construction Report" will be written following completion of the ramps. This report will include construction details, cost of the treatment, construction test results, and other details concerning the overall process. Friction testing will be conducted annually and any problems with the friction values or condition of the HFS reported to the NWR. At the end of the five-year period, a final report will be written which summarizes the performance

characteristics, effectiveness at reducing accidents and future recommendations for use of this process.

Cost Estimate

Construction Costs

No additional construction costs are required. This project will be constructed as a Region HAL enhancement (QE program) project.

Testing Costs

Pre and post-construction friction testing will be conducted as part of the Region Q program project (estimated cost $2,500). Annual friction testing will be conducted in conjunction with the annual post-construction testing of HMA preservation projects. Annual inspections will be conducted to assess the condition of the HFS at a cost of approximately $3,000.

Report Writing Costs

Initial Report – 16 hours = $2,112

Final Report – 32 hours = $4,224

Total Cost = $9,336

Schedule

Construction: June – July 2015

Date	Friction (Annual)	Post Construction Report	Visual Inspection	Final Report
July 2015	X			
Summer 2015		X		
Fall 2016	X		X	
Fall 2017	X		X	
Fall 2018	X		X	
Fall 2019	X		X	
Spring 2020			X	X