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Tech Brief:

High Friction Surface Treatment

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16. Abstract This Technical Brief provides an overview of the benefits, limitations, and applications of high friction surface treatments. Considerations for specifications, contracting, construction, and maintenance are discussed. It addresses the use of High Friction Surface Treatment to address crashes at curves and intersections that are due to wet weather or polished pavements.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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The Challenge

The lack of pavement friction can contribute to serious crashes. The tires and pavement, measured as a friction number or coefficient, is significantly reduced under wet weather conditions or on polished pavement surfaces and can lead to an increase in crashes. While resurfacing a road through the application of new pavement or chip seals can improve friction demand, these methods can take a long time to apply and the improved friction may not last many years. In addition, realigning a road to improve the geometrics at a curvature or intersection can be time-consuming and costly due to environmental clearances and right-of-way needs.

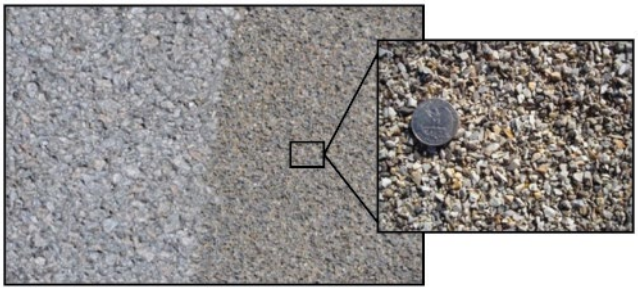

Figure 1: Side by Side of Pavement and High Friction Surface Treatment, with Close-up of High Friction Surface Treatment

Source: National Park Service

High Friction Surface Treatment (HFST) is a surfacing technology that has been shown to reduce run-off-road crashes by 20 to 80 percent and has an average benefit cost ratio of 24:1. When applied per specification, HFST can reduce the number or the severity of crashes, especially wet weather-related crashes, through the application of a binder and aggregate that helps vehicle tires stick to the pavement. HFST is typically limited to spot treatments such as curves or intersections, but may be applied at locations up to 1/2-mile in length based on the extent of known crash locations or locations selected as part of a systemic safety highway program.

Figure 2: Loose Aggregate

Source: National Park Service

Figure 3: Binder in Totes

Source: National Park Service

Executive Summary

Innovation

Demonstrate High Friction Surface Treatment (HFST) is a viable option on roads to through Federal lands to address crashes at curves and intersections that are related to wet weather or polished pavements.

Key and Results

HFST results in increased pavement friction and can be deployed as a stand-alone project or as part of a construction project.

Potential Impact

Instead of realigning a single curve, HFST can be applied to multiple curves on the same route or in the same area for less money per treatment.

Challenges

- Abbreviated Schedule: 12–14 months instead of 24 months.
- Few Qualified Contractors in the locations chosen for HFST installation.
- Limited Funds.

The Journey

HFST has been around for some time and was a Federal Highway Administration (FHWA) Every Day Counts (EDC) effort in 2012. Federal Lands Highway Division (FLHD) involvement at that time included creating specifications for contracting HFST and developing a process for identifying locations that could benefit from HFST; however, no installations were completed on any Federal Lands projects during that round of EDC. In March 2015, the FLHD Safety Team submitted a Coordinated Technology Implementation Program (CTIP) project proposal to install HFST in at least two different geographic areas. The sites selected included:

- A Grays Harbor County road in Washington State that provides access to National Forest and National Park lands.
- A Grand Teton National Park road in Wyoming that is also a National Highway System route.
- An optional Great Smoky Mountains National Park road in the southeast, if funding allowed.

In April 2015, the FLHD Safety Team submitted the project workplan for a 2-year program that would allow time for HFST installation in early 2016 if all sites could not be installed in 2015. FHWA accepted as a CTIP project in May 2015, but no funding was available throughout the remainder of Fiscal Year 2015. After several months of waiting, in March 2016 a project agreement was drafted to secure funding. Unfortunately, the Great Smoky location was no longer a viable option, so the FLHD Safety Team identified an alternate location on a Natchez Trace Parkway project outside of Tupelo, Mississippi. FHWA signed the project agreement in April 2016 and funding was transferred to Western Federal Lands Highway Division (WFLHD) in early May 2016. Now, the only challenge was to complete a 2-year program within 12 to 14 months!

The project budget of $300,000 was split into two portions:

- $50,000 for Federal Lands Highway (FLH), a division of FHWA, staff time and other non-construction charges.
- $250,000 for the construction of HFST via standalone contracts or by modification to existing construction contracts.

Given that the installed HFST cost per square yard depends on the amount of surfacing, geographic location, traffic control, and mobilization, the FLHD Safety Team decided to focus on the delivery of two projects with the available construction funds. So, work began in

Budget

- $300,000 total.
  - $250,000 for at least two installations.
  - $50,000 for staff hours.

Materials

- Aggregate (3–4 mm) with a high resistance to polishing, primarily calcined bauxite.
  - May be subject to Buy American Act and/or Buy America Act.
- Proprietary blend binders using epoxy, polyester, and other resins.

Site Verification

Verify site locations for pavement condition and better estimate of location of HFST application. Examine road for polished surfaces and run-off-road crash evidence.

Environmental Clearance

Determine what environmental clearance is necessary for HFST application: Just because the work is limited to the pavement surface doesn't mean State Historic Preservation Office (SHPO) won't be involved.

earnest on putting together a statement of work and project plans for the Grays Harbor and Grand Teton locations soon after funding was received. After discussions with WFLHD Acquisitions staff, the team determined that:

- The cost for each site should not be more than $150,000 in order to follow the simplified acquisitions process.
- Each would have a fixed price contract to ensure the CTIP project did not exceed the available budget.

Given the specialized material and equipment needed for installing HFST per specifications, there are few companies that install HFST at this time. While the initial proposal and work plan estimated $25 per square yard for installation, the remote sites selected for this CTIP project increased the cost to around $60–$70 per square yard. This higher cost included mobilization, set-up, temporary traffic control, and clean-up.

Wynoochee Valley Road Project

The first project tackled was in Grays Harbor County on Wynoochee Valley Road, near Montesano, Washington. One spot location was initially flagged for HFST since it was part of a Federal Lands Access Program project request, in both 2014 and 2016, for a 1/2-mile-long curve realignment at an estimated cost of $2.6 million dollars. The county identified a nearby curve with a crash history as a second spot location. Besides each curve having a run-off-road crash history (two run-off-road injury crashes between 2009–2013 at the milepost (MP) 1.4 site), there was also evidence of significant pavement polishing. Average daily traffic (ADT) volumes range from 1,200–1,500 vehicles per day (VPD), of which 15 percent is truck traffic (logging and rock material) and 20 percent is Federal Lands-related (accessing the Olympic National Forest and the backcountry of Olympic National Park). On May 7, 2016, experts from the FHWA Resource Center and a representative from the county conducted a field visit to verify the location of the HFST installation. During the review, the HFST application limits were determined for each lane at each curve, resulting in four sites for a total of 2,255 square yards (see Figure 4). Environmental clearance work began soon after. The team completed the final environmental clearance in late June because SHPO clearance was needed from the State even though nothing was being adjusted, altered, or impacted in the road structure or its geometrics.

Wynoochee Valley Road

- Functioned as a lump sum bid project, resulting in:
  - Quicker contracting process.
  - Fixed price so no surprises.
- Still required the National Environmental Policy Act (NEPA).
- Completed work under traffic.
- Proceeded with crack-sealing occurring before HFST placement.
- Adjusted daylight work hours due to slow application rate.
- Protected existing pavement markings with tape but still had some overflow of the binder and aggregate.
- Dealt with unexpected weather and the contractor was unprepared.

Buy American Act vs. Buy America Act

- The Buy American Act applies to any material used in direct Federal procurement contracts (those handled by a Federal agency) using Federal Acquisition Regulations.

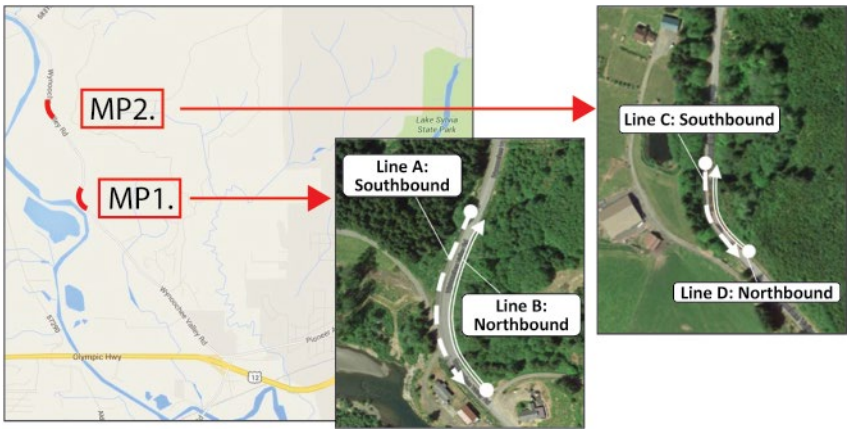

Figure 4: Wynoochee Valley Road High Friction Surface Treatment Locations
Source: National Park Service

We did not include gathering pre-HFST and post-HFST friction test results for the Wynoochee project as part of the contract package because that would entail more work by the contractor and would also require them to be onsite during the week(s) before and after the installation to gather test results. Fortunately, we learned of two opportunities for gathering friction information:

1. An FHWA pavement friction test equipment training opportunity.
2. An FHWA-sponsored friction testing by Washington DOT (WSDOT), which utilized a skid trailer.

Due to schedule conflicts, FLHD staff were not able to take advantage of the test equipment training opportunity in June 2016, but WSDOT was still available to collect before and after data at the sites identified on Wynoochee Valley Road. Because this project contract fell under the Federal Acquisition Regulation (FAR) contracting rules, a review of the Buy American Act was needed on the HFST aggregate material before a pre-solicitation notice could be posted. While there are suppliers of the calcined bauxite aggregate in the United States, the raw material comes from foreign sources from around the world. FHWA made a class non-availability determination, which meant that domestic sources can only meet 50 percent or less of total U.S. Government and nongovernment demand. In other words, the calcined bauxite aggregate complies with FAR contracting rules and could be included in this project contract.

The Buy American Act determination allowed for the posting of the pre-solicitation notice by early July 2016, and before the end of July the Statement of Work (SOW) language for the project was converted into a Request for Quotations (RFQ), with a due date of August 12, 2016. During the solicitation period, the FHWA Contracting Officer and

- The Buy America Act applies to iron and steel products used in Federal-aid projects (those contracts handled by a State or local agency).

Friction Testing

Testing the skid resistance (pavement friction in terms of macrotexture and microtexture) of pavement conditions can be done at the option of the road agency and can provide valuable information in determining where to apply the HFST. If testing isn't available, polished pavements with low skid resistance look smooth and uniform in texture, and can be found in curves or at intersection approaches, which are areas of high friction demand.

Macrotexture

Macrotexture depends on asphalt mixture properties (shape, size, and gradation of aggregates) or the texturing method used on concrete pavement surfaces. It provides surface drainage channels for water to move from the contact area between a tire and the pavement.

Contracting Officer's Representative made some updates to the RFQ language to make the binder material references less restrictive, and these changes will be incorporated into recommend contract language.

While waiting for contractors to bid on this fixed price project, work on the Grand Teton project documents began and training for the friction equipment was offered up again. An FLHD-only training was arranged at Penn State for the end of August so that staff could learn how to use the equipment so that the equipment could be transferred from FHWA to FLHD. Staff from Western and Eastern FLHD offices received training on how to operate two machines that measure macrotexture and microtexture, from which a friction number can be calculated. The Circular Track Meter (CTM) is used to obtain the macrotexture of a surface from a spinning laser, while the Dynamic Friction Tester (DFT) is used to estimate the microtexture of a surface through the coefficient of friction where a rotating disk with rubber pads spins around on a wet surface. The CTM and DFT measurements are then taken at the same locations for both before and after HFST readings (see Figures 5 through 8). Once set up, it takes approximately 5 minutes to run both tests per location.

Circular Track Meter (CTM) *Macrotexture*

Figure 5: CTM Circular Track Meter Test
Source: National Park Service

Figure 6: Circular Track Meter CTM Base
Source: National Park Service

Dynamic Friction Tester (DFT) *Microtexture*

Figure 7: Dynamic Friction Tester Test
Source: National Park Service

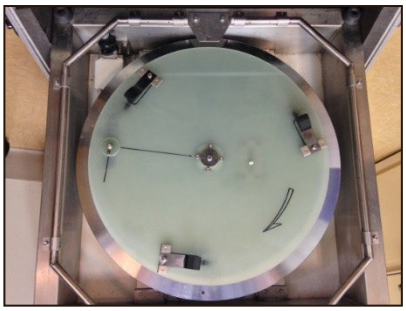

Figure 8: Dynamic Friction Tester Base
Source: National Park Service

Microtexture

Microtexture is related to the amount of fine aggregate and polishing resistance of coarse aggregate in a wearing course. It disrupts the continuity of the water film and produces frictional resistance between a tire and the pavement.

Application Methods

- Mechanical application of binder and aggregate with some handwork needed for spreading the binder and aggregate.
- Manual application in which the binder is mixed in drums and applied by hand and the aggregate is tossed on top of the binder or spread by hand.

Natchez Trace Parkway

- Project was a con-struction modification project.
- Work was completed under full road closure.
- Cracks were not sealed prior to HFST placement.

  Workers walked across binder without spiked shoes.
- Existing pavement markings were not protected with tape but left a clean edge of binder.

By the end of August, just 4 months after receiving funding for this CTIP project, the following items were accomplished:

- The Wynoochee project contractor was selected from two equal bid proposals by the flip of a coin.
- The Grand Teton site fell through and Natchez Trace Parkway in Eastern Federal Lands (EFL) was approached to be the second HFST installation site.
- FLH staff were trained in the use of friction test equipment and could conduct friction testing on the CTIP project sites.
- Friction equipment was transferred from FHWA to FLH.

In early September, a notice to proceed was sent to the Wynoochee contractor so that they could start work after September 14, but needed to complete the project by September 30. The team held a pre-work conference call with the contractor and an initial date of September 22–23 was set for the installation, with the northbound lanes being completed on the first day and the southbound lanes being finished on the second day. But being in the Pacific Northwest means that temperatures and humidity levels are unpredictable, and because of heavy rain in the forecast, the installation was shifted to September 27–28.

Arrangements were made for WFLHD staff to be onsite to take before tests (Figure 5 and Figure 7) under flagger-controlled traffic while the contractor was prepping the road for HFST by doing some sweeping, crack sealing, and taping over the pavement markings to protect the stripes from the binder. The contractor used a mechanical method in a self-contained truck for applying the binder and aggregate (Figure 9). The two-part epoxy resin binder was mixed in the truck and then a tube distributed it to the road, after which a laborer spread it manually, wearing spiked shoes and using a notched squeegee to get coverage up to the duct tape on the pavement markings. The aggregate traveled along a belt from a hopper to a rotary spreader (a larger version of what's used to spread lawn fertilizer or seeds) and additional aggregate was tossed across spots that needed more coverage (Figure 10). Representatives from Olin/Poly-Carb operated the truck and controlled the amount of binder and aggregate released, and they also monitored the contractor's work on spreading the binder and aggregate for adequate coverage.

Specifications

FLH developed HFST specifications under EDC-2 but never applied them until this CTIP project. Practices have changed slightly and work observed in the field will lead to a revision of the specifications for better quality control of the material and installation work on future projects.

Friction Testing

- Testing the before and after pavement friction conditions can be done at the option of the road agency and can provide valuable information in determining where to apply the HFST.
- FLH has equipment that can provide friction information at spot locations while some State DOTs have skid trailers which can measure friction continuously along a road segment.

Figure 9: High Friction Surface Treatment Mechanical Application Truck
Source: National Park Service

Figure 10: Distributing Aggregate
Source: National Park Service

After the binder had time to cure, laborers ran a sweeper across the segment to sweep up and remove loose aggregate (Figure 11), which was then removed from the site. Finally, the contractor removed the tape from the pavement markings and opened the lane to traffic (Figure 12).

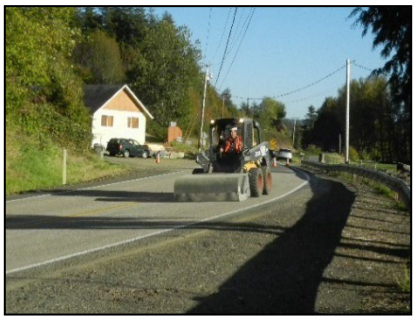

Figure 11: Sweeper Vehicle
Source: National Park Service

Figure 12: Completed High Friction Surface Treatment on Wynoochee at Milepost 1.4
Source: National Park Service

The first day of installation was delayed because of rainy weather conditions and only one northbound lane (Line B) was completed. On the second day, the remaining northbound lane (Line D) and two southbound lanes (Line A and Line C) were completed (Figure 4). The length of application at some sites increased a bit in the field because of the lanes not being quite 11-feet wide and the contractor wanting to use up the material, so the total estimated 2,255 square yards of material was installed. As seen in Figure 12, the HFST is slightly lighter in color than the original chip-sealed pavement.

WFLHD staff gathered pre-HFST friction data at all the sites with a CTM and DFT, but were not able to finish gathering complete post-HFST friction data for the final southbound curve because of the need to open both lanes of the road to traffic by sunset. The WLFHD project manager decided that the spot location data collected by WFLHD staff were adequate since the WSDOT pre-HFST (July 2016) and post-HFST (October

Contracting

HFST can be included in existing construction contracts through a modification or contracted out as a stand-alone project for specific sites on a route or in a region. Bundling multiple sites into one contract will yield better pricing.

Other recommendations for contracting include:

- Need to verify contractor capability BEFORE award.
- Need to ensure that proper construction techniques are used for the application of the binder.

More Information:

FHWA HFST
EDC HFST
ATSSA HFST

Agency Contact:

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Highway Safety Engineer,
Western Federal Lands,
FHWA
tori.brinkly@dot.gov
360-619-7885

2016) skid trailer test results would have complete friction data. Friction results are discussed in the Results section and are included in Appendix A of this Technical Brief.

Natchez Trace Parkway Project

In early September, the Natchez Trace Parkway (Natchez) paving project near MP 266 (9 miles northeast of Tupelo, Mississippi) explored adding the HFST work to their contract through a construction contract modification. The project team used Google Maps and StreetView to identify three sites (Line A, Line C, and Line B Figure 13) on two curves at the Mississippi State Highway 145 (MS-145) interchange, for an estimated total of 2,450 square yards. From NPS crash data, there was one wet weather run-off-road crash on each ramp in the last 10 years, with one being an injury crash and the other a non-injury crash; however, the direction of travel for these crashes is unknown. According to Mississippi DOT traffic counts, the ADT on the Parkway near this location are around 4,600 VPD, with the bi-directional volume being 850 VPD (Line A and Line B) and 1,400 VPD (Line C).

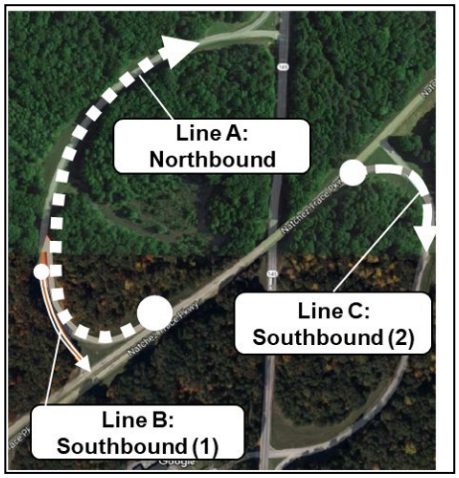


Figure 13: Natchez Trace (Milepost 266) High Friction Surface Treatment Locations

Source: National Park Service

A list of HFST providers and installers were shared with project staff, but by the end of September no one was interested in the application of such a small quantity. One last ditch effort was made to get something under contract, and despite challenges with finding contractors, the EFL project engineer for the construction project negotiated the work with one contractor and an agreement for the HFST installation was signed by October 7, 2016. However, there were still challenges on how to get funds or the funding account transferred to EFL for use in their existing construction contract, and it took until the end of the month before CTIP funds assigned to WFLHD were released and reassigned to the Natchez Trace Parkway project. Luckily, that happened just in time for the work to be added to the project during the week of November 7, 2016.

Figure 14: Semi-Mechanical High Friction Surface Treatment Application

Source: National Park Service

Arrangements were made for EFLHD staff to be onsite to conduct pre-construction CTM and DFT tests the day before the HFST was placed. Because of multiple access routes to MS-145 in the area, both directions of the ramp were closed so that work could be conducted without having to accommodate traffic. The contractor used a semi-mechanical method for applying the binder and aggregate from a flatbed truck (Figure 14). The two-part epoxy urethane binder traveled by tube from containers and was metered on to the road surface before being spread by a laborer in sneakers using a toothed squeegee to distribute the binder up to the pavement markings

Figure 15: Spreading the Binder

Source: National Park Service

(Figure 15). The contractor used a hanging bucket to catch binder from the applicator and dispose of the binder that had aged in the applicator tube prior to being placed on the roadway. Laborers controlled binder thickness by constantly monitoring the application depths from the ridges of toothed squeegee, application quantities, and the traveling speed.

The calcined bauxite aggregate was fed from super-sacks on the truck and was dispersed by a blower hose held up by a laborer, who was also standing on the binder in sneakers, while other laborers tossed additional aggregate from wheelbarrows onto thin spots (Figure 16). The contractor placed super-sacks of aggregate strategically along the project length for a quick resupplying of the aggregate on the flatbed truck. After the binder had time to cure, laborers ran a sweeper across the segment to pick up loose aggregate, which was then screened and reused farther down the project (Figure 17).

Figure 16: Applying the Aggregate
Source: National Park Service

Figure 17: Sweeper Truck
Source: National Park Service

The contractor completed the HFST work over the course of one day, working from the end of the off-ramp towards the Natchez Trace Parkway. EFLHD staff performed post-construction CTM later that day and DFT testing the following day. Due to one of the curves (Line C in Figure 13) being recently paved as part of the primary Natchez contract, along with lane closure limitations, Line A off-ramp curve was treated for a longer distance on the final application of HFST, resulting in a revised length of 2,100 feet and a total of 2,339 square yards of material being installed. As seen in Figure 18, the HFST is slightly darker in color than the existing pavement.

EFLHD staff gathered pre-and post-HFST friction data at numerous locations at this site with a CTM and DFT. Friction results are discussed in the Results section and are included in Appendix A of this Technical Brief.

The Results

Friction Tests

Testing the before and after conditions of the sites was not budgeted for in this CTIP project and may be costly to put on a contractor to complete. Luckily, one project could utilize an existing FHWA contract with the State DOT to conduct skid testing, while both Wynoochee and Natchez used equipment FLH acquired to do tests at spot locations.

After the completion of both projects, it was found that the friction numbers for the post-HFST increased by an average of 93 percent from the pre-HFST F60 friction values and an average of 70 percent from the pre-HFST SN40R friction values for the Wynoochee project.

Figure 12: Completed High Friction Surface Treatment on Natchez Trace
Source: National Park Service

Table 1 summarizes the average F60 friction numbers from the FLH readings and the SN40R friction numbers from the WSDOT readings on the Wynoochee project. The F60 friction values showed an increase from around 0.3 up to 0.6 for all the sites (Wynoochee and Natchez), and the SN40R friction values on the Wynoochee project showed an increase from around 48 to 82.

Table 1: Average Pre- and Post-Friction Values

Site	Pre-HFST Average Friction	Post-HFST Average Friction	Average Increase in Friction
Wynoochee Site 1 (MP 1.4 NB)	0.312 F60	0.603 F60	93%
	50.6 SN40R	86.2 SN40R	70%
Wynoochee Site 2 (MP 2.1 SB)	0.325 F60	0.625 F60	92%
	44.2 SN40R	79.6 SN40R	80%
Wynoochee Site 3 (MP 1.4 SB)	0.333 F60	0.609 F60	83%
	53.6 SN40R	79.1 SN40R	47%
Wynoochee Site 4 (MP 2.1 NB)	0.296 F60	0.615 F60	108%
	46.0 SN40R	83.4 SN40R	81%
Natchez Trace MP 266 SB off-ramp to MS-145	0.317 F60	0.611 F60	92%

Charts are included in Appendix A on the calculated F60 friction results for both sites, with the Wynoochee project also including the WSDOT skid trailer SN40R readings. The F60 friction number is calculated from the CTM and DFT readings at each site, while the SN40R friction number was provided by WSDOT for the Wynoochee sites. Further explanation of these friction numbers can be found in the ASTM International and the American Association of State Highway and Transportation Officials (AASHTO) testing procedures referenced in the example SOW in Appendix B.

FLH tests at both the Wynoochee and Natchez projects were collected just before the HFST application and soon after the HFST cured. However, collecting data 3 or more days, or even months, *after* the application is more ideal since the HFST binder continues to harden over time. While testing is the ideal way to determine the friction characteristics of a road, HFST can be installed without gathering before and after friction data. However, including testing as part of an HFST contract may increase the time and cost for a project because of the specialized work and additional days needed to gather data.

Safety Benefits

Because of the timeframe of this CTIP, an evaluation of post-HFST installation crash data is not available as we would need at least 3 years of data to show any safety effects from the HFST installation. However, FLH plans to monitor these project sites into the future given the proximity of Wynoochee Valley Road to the WFLHD office and continued involvement of EFLHD with projects on the Natchez Trace Parkway.

For quantifying the safety benefits of HFST, the FHWA Crash Modification Factor Clearinghouse (**http://www.cmfclearinghouse.org**) offers several pavement condition and friction countermeasures, including some factors related to high friction surfacing. From the Clearinghouse FAQs, “A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. A CMF reflects the safety effect of a countermeasure, whether it is a

decrease in crashes (CMF below 1.0), increase in crashes (CMF above 1.0), or no change in crashes (CMF of 1.0).” A CMF can also be converted into a crash reduction factor (CRF) to provide an estimate of the percentage reduction in crashes, which may be easier to communicate than a CMF.

Table 2 summarizes CMFs from the Clearinghouse on a variety of pavement surfaces for all severities, all roadway types with two lanes, and shows the CMF for all crash types and wet road crash types. The benefits of HFST are quite evident with the lowest CMF for all crash types (0.653, or a CRF of 34.7 percent) and wet road crash types (0.139, or a CRF of 86.1 percent).

Table 2: Crash Modification Factor Comparison

Countermeasure	All Crash Types	Wet Road Crash Types	Improve Safety?
High Friction Surfacing	0.653	0.139	Yes/Yes
Chip Seal	0.939	0.950	Slightly/Slightly
Microsurfacing	1.090	0.867	No/Yes
Open Graded Friction Course	1.109	1.038	No/No
Slurry Seal	0.931	0.802	Slightly/Yes
Thin Hot Mix Asphalt (≤ 2”)	1.194	1.256	No/No

Contracting Methods

Installing HFST to improve friction at spot locations can be cost-effective when compared to realigning or even resurfacing a road when considering the time and funding necessary for the development and construction of these types of work. The time needed to develop a contract and install HFST is demonstrated fairly well with the two sites in this CTIP project; however, costs for these installations are higher than what other agencies have experienced with their HFST contracts. It should be noted that bundling multiple locations together on future projects should result in a lower cost per square yard than what was experienced as part of this CTIP project.

A birds-eye view of contracting costs and time comparisons are shown in Table 3 for HFST vs. realignment based on the Wynoochee HFST project and a proposed curve realignment project on the same road.

Table 3: Wynoochee Project Example of High Friction Surface Treatment vs. Realignment

Project Specifics	Wynoochee Valley Road, MP 1.4 & MP 2.1	HFST (0.50 mile)	Realignment Project for MP 1.4-1.9
DURATION	Start Work on Contract	May 6, 2016	July 2014 Proposal
	Advertise Contract	July 27, 2016	May 2017 (est.)
	Start Construction Contract	September 9, 2016	August 2017 (est.)
	Finish Construction	September 28, 2016	September 2019 (est.)
	TOTAL	148 days (4 months, 25 days)	1,888 days (5 years, 2 months)
	Time Savings	***1,740 days (92.2%)***	
COST	Development Cost (est.)	$20,000	$310,000
	Construction Cost	$149,000	$2,090,000
	Construction Labor Cost	$6,000	$200,000
	TOTAL COST	$175,000	$2,600,000
	Cost Savings	***$2,425,000 (93.3%)***	

An even higher altitude view of contracting costs comparison is shown in Table 4 for HFST vs. paving based on the Natchez Trace HFST project and a review of resurfacing project costs on the Natchez Trace Parkway. As seen below, installing HFST could potentially result in an around a 30-percent savings in money when compared to the cost of a ½-mile-long paving project.

Table 4: Natchez Trace Project Example of High Friction Surface Treatment vs. Paving

Project Cost Specifics	Natchez Trace MP 266 and MS-145 Off-Ramp	HFST 1,200 ft	Resurfacing Project for ½-mile Segment
COST	Development Cost (est.)	$20,000	$15,000
	Construction Cost	$99,970	$150,000
	Construction Labor Cost (est.)	$6,000	$15,000
	TOTAL COST	$125,970	$180,000
	Cost Savings	***$54,030 (30%)***	

As summarized above, the benefits of installing HFST when compared to a realignment project are significant with HFST being approximately 6 percent of the construction cost and 8 percent of the time to develop, design, and construct a ½-mile-long segment of road. When compared to a pavement resurfacing project, installing HFST to improve friction in a spot location (over an acceptable existing surface) can save around 30 percent in construction costs. Keep in mind that these estimates are just based on these two project sites and that other agencies may see different time and cost savings than FLH experienced as part of this CTIP project.

Due to experiences encountered during both the Wynoochee project and Natchez Trace project, an updated SOW was developed and is included in Appendix B. From both projects, we learned that we need to ensure that contractor experience and references are part of the selection process instead of something checked after the project is awarded. From the Natchez Trace project, we learned that we need to improve the language regarding application requirements, such as wearing spiked shoes to reduce impact on the binder thickness.

And we also believe that the language we've developed so far will continue to evolve as the HFST technology continues to mature.

Road Agency Experience

We made attempts to contact both Grays Harbor County and Natchez Trace Parkway staff to find out how these HFST projects fared over the winter. Unfortunately, we did not hear anything back from these road agencies in time to include it in this report. However, some WFLHD staff visited the Wynoochee project in late July 2017 and found the sections to be intact with no delamination occurring, although the texture had taken on a darker hue because of paving work the county was doing on the road beyond the treated sites.

The Implementation

Implementing HFST can be done through the following methods:

- Incorporate HFST into a larger construction project for a handful of sites, keeping in mind the need to accommodate a minimum of 30 days for the pavement to cure and to consider how pavement markings will be dealt with.
- Identify several sites on the same route or in the same general area to get the best pricing for a project focused only on HFST installation.

A single site in a remote area will be very expensive due to the cost of mobilization of the contractor's crew in addition to the cost of shipping/hauling the material (aggregate and binder).

It should be noted that the specifications for HFST are continuing to evolve and the example provided in this Technical Brief just presents what FLH used for our projects. Several States have HFST specifications they use, and many are available through the American Traffic Safety Services Association website. In addition, there is a standard practice for HFST from AASHTO under designation PP 79-14 (2016).

Q&A

How detailed of a NEPA is required?
Some States have a programmatic clearance for HFST while other locations may need some project-specific environmental clearance work done.

The Buy America requirements applies only to steel products, but how easy is it to meet Buy American (Federal Contracts) requirements?
This may be on a case-by-case basis depending on your contracting/acquisition staff interpretations.

Would a chip seal contractor be able to perform this work?
Potentially, but the contractor would need appropriate equipment to apply the binder and distribute the aggregate.

How long will the HFST last?
That will depend on the conditions present when it was applied and the condition of the pavement beneath it. If applied per specification and manufacturers recommendation, it should last as long as the pavement underneath.

How would I restore it after it diminishes?
HFST does not lend itself to patching.

Is HFST considered a pavement preservation technique?
No, it will only last as long as the pavement surface below it.

For more information visit the FHWA HFST Site:
https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/faqs_links_other/

The Wrap-Up

The deployment of HFST on roads to and through Federal Lands was successful even with some challenges related to contracting, funding, and scheduling, especially with contracts that are small, unique (fixed price), or involve relatively new technology such as HFST. Through this project, we've demonstrated that installing HFST is a cost-effective way to address roadway departure crashes on roads that have high friction demand because of wet weather or polished pavements. Improved friction on these curves and ramps will help reduce run-off-road crashes, and especially those that happen during wet weather. Use the lessons learned from this CTIP project, State DOT experiences, and other agencies that have successfully completed HFST contracts to develop and deploy your own high friction surfacing projects.

More Information:

http://safety.fhwa.dot.gov/roadway_dept/pavement_friction/high_friction/

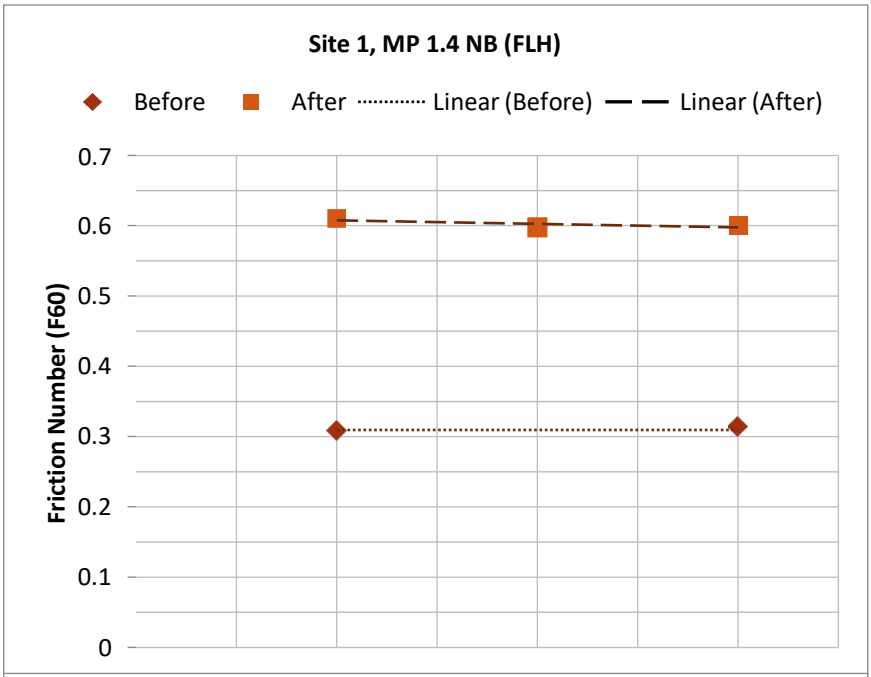
http://www.fhwa.dot.gov/innovation/everydaycounts/edc-2/hfst.cfm

http://www.atssa.com/Resources/HighFrictionSurfacing/FAQs.aspx

Appendix A: High Friction Surface Treatment Test Results

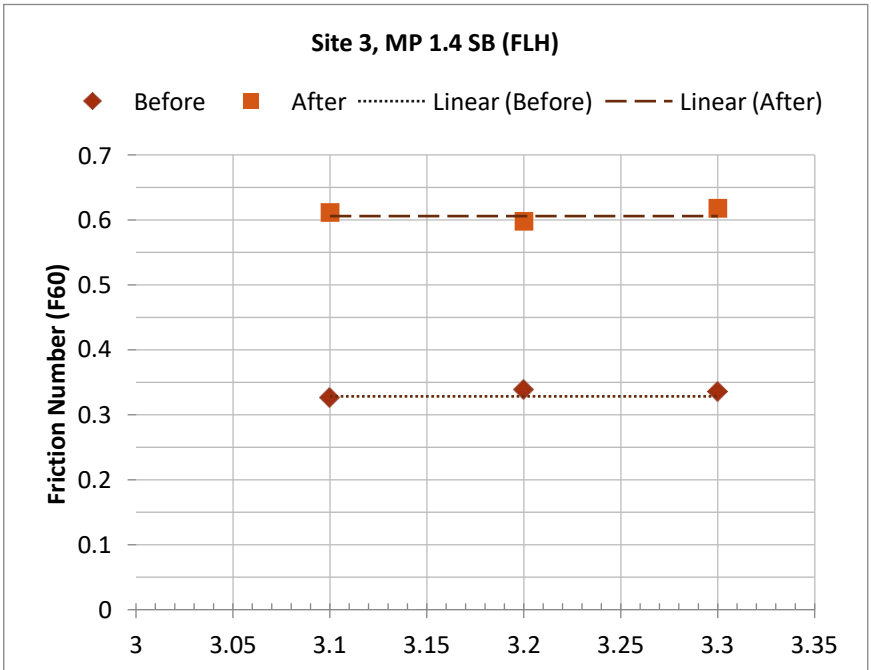
Wynoochee Valley Road Friction Results—Northbound MP 1.4 (Figure 4, Line B)

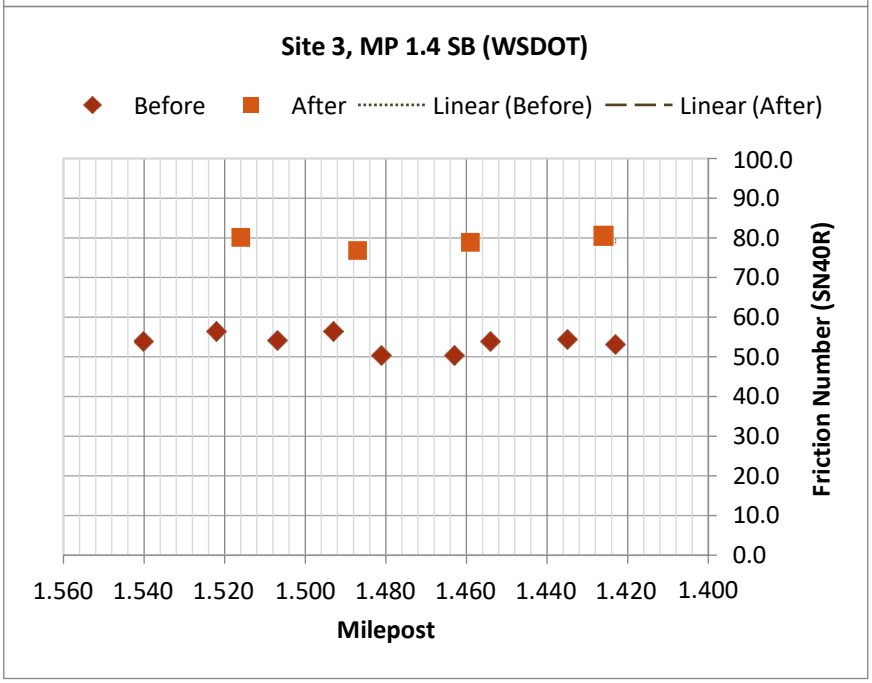
Source: National Park Service



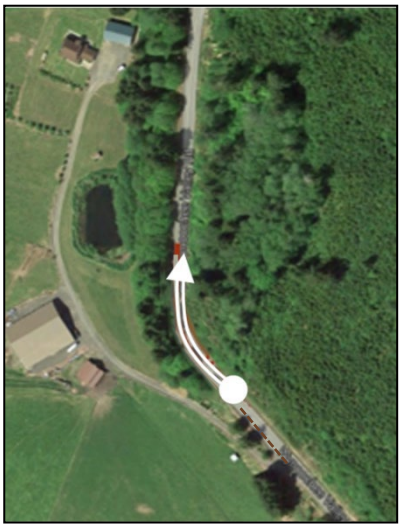
Wynoochee Valley Road Friction Results—Southbound MP 1.4 (Figure 4, Line A)

Source: National Park Service

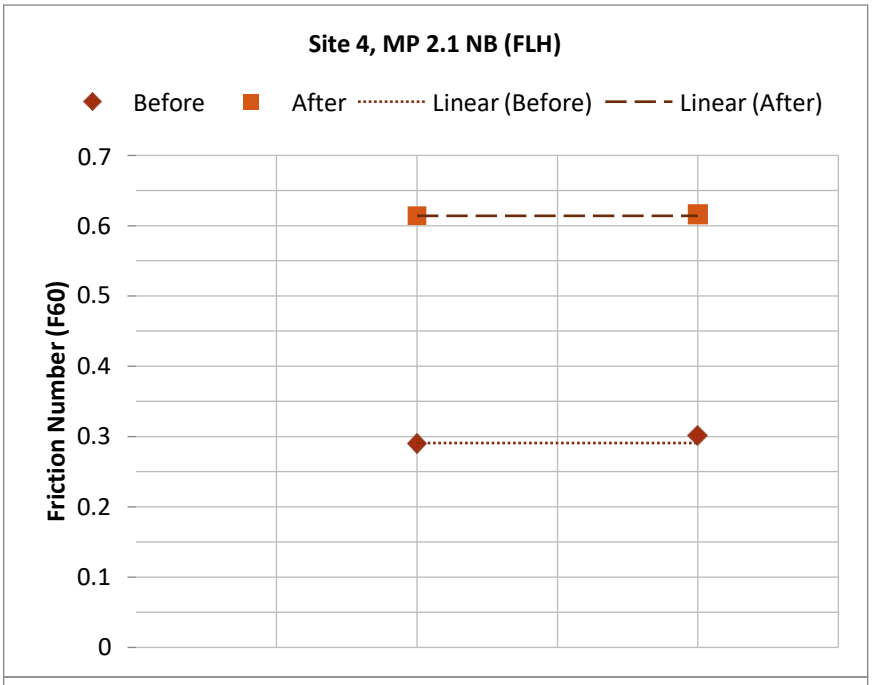


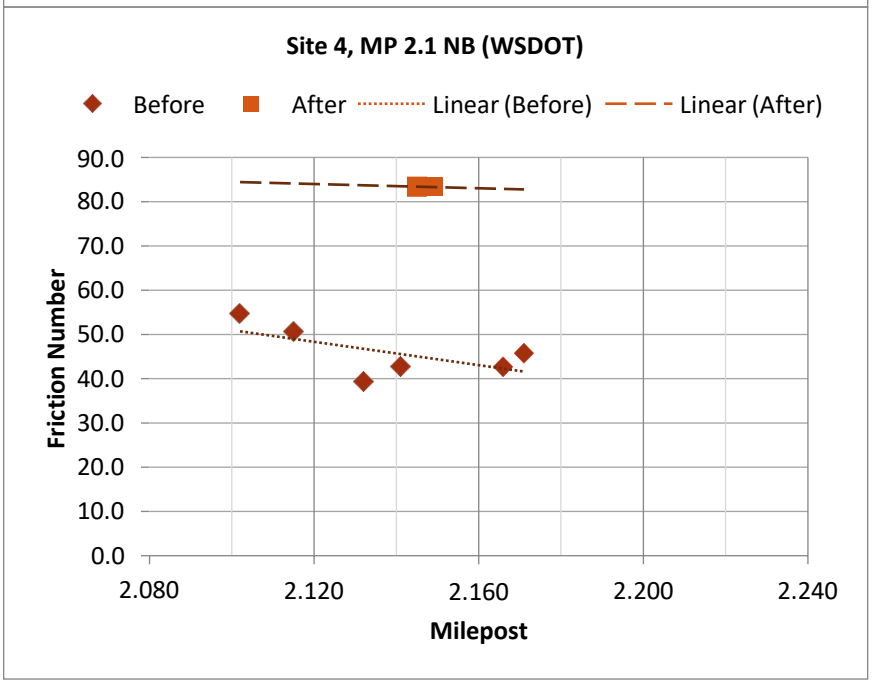


Wynoochee Valley Road Friction Results—Northbound MP 2.1 (Figure 4, Line D)

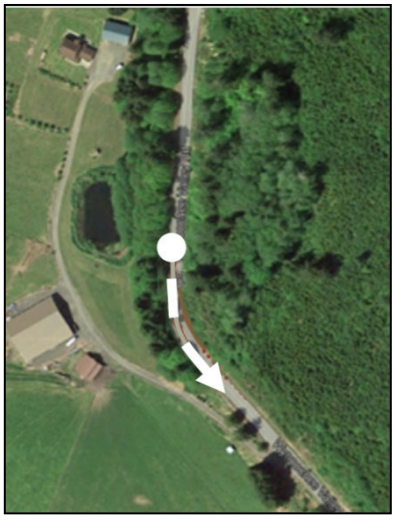


Source: National Park Service

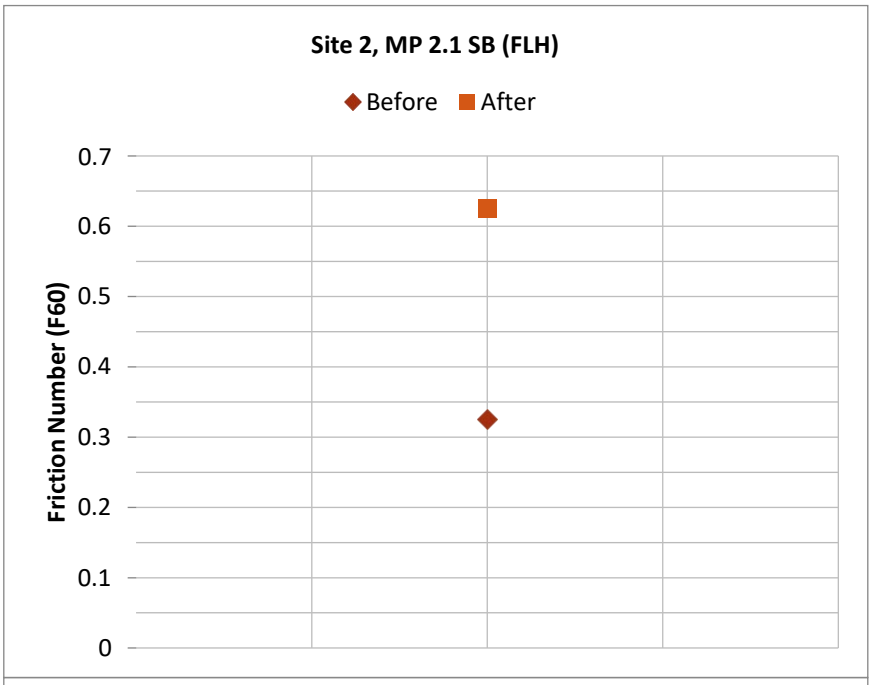


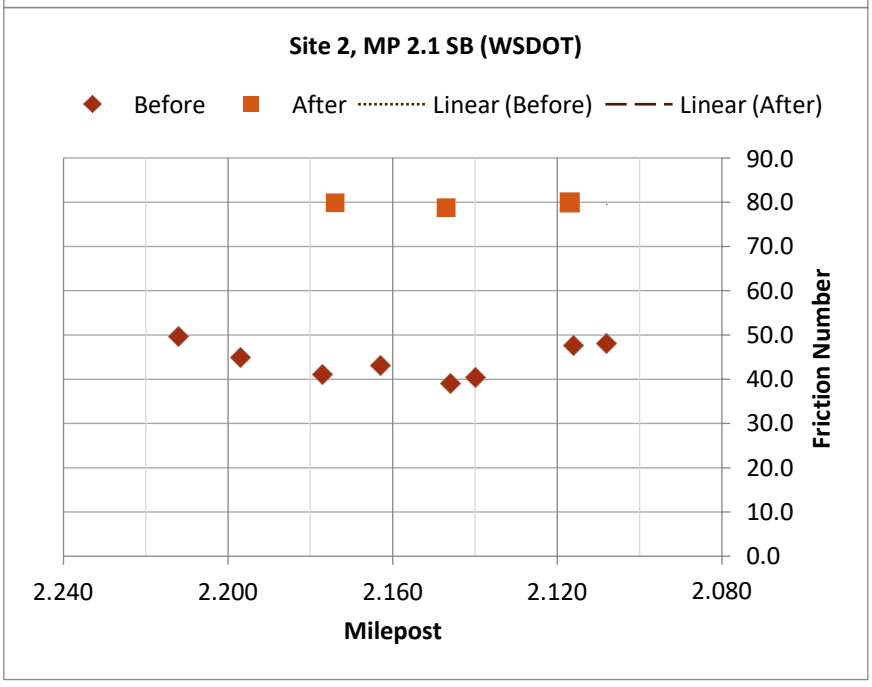


Wynoochee Valley Road Friction Results—Southbound MP 2.1 (Figure 4, Line C)

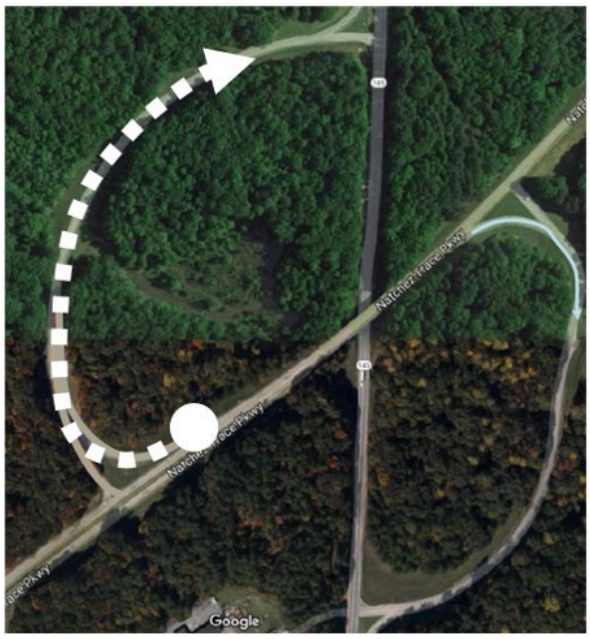


Source: National Park Service

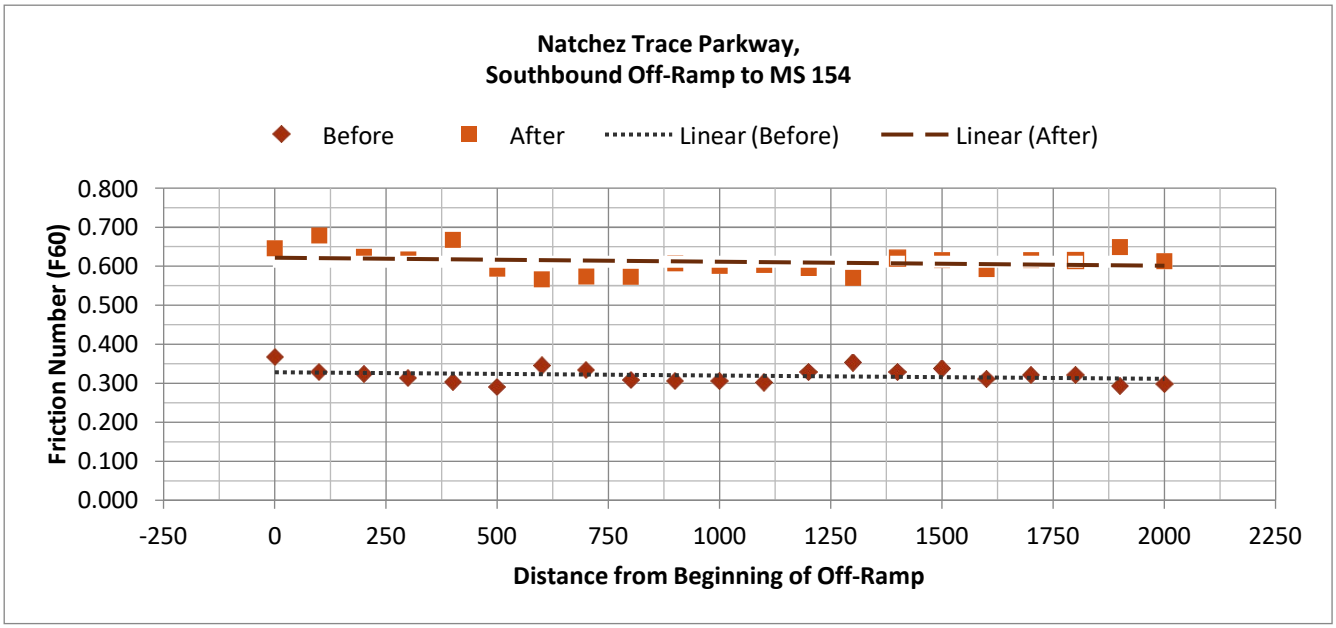




Natchez Trace Friction Results



Source: National Park Service



Appendix B: Example Statement of Work for Contracting High Friction Surface Treatment Projects

Legend:
Bracketed words should be edited for the project location.

Italicized text should be edited for the transportation agency's construction and contracting policies and procedures.

[Project Number]

High Friction Surface Treatment

STATEMENT OF WORK

1. DESCRIPTION OF WORK

This work consists of installing high friction surface treatments (HFST) consisting of polymeric binder resin and aggregate on [road] in [county], [State]. *This work also includes the installation of temporary pavement markers on the centerline of the locations after the high friction surface treatment is installed with permanent pavement markings to be installed by the county.*

Locations of the high friction surface treatment include *in priority order, and as shown in the plans*:

- [Description of locations]

The [road] high friction surface treatment includes up to [amount] square yards of high friction material consisting of up to [number] separate applications of [width] feet wide by [length] feet long sections at the locations noted in the plans. Widths and lengths noted are estimated and can be field adjusted as needed.

No new features will be added to the roadway.

2. QUALIFICATIONS

Submit the following with the proposal:

A. A minimum of three projects with the owner's contact information on which a cumulative minimum of 10,000 square yards (4,180 square meters) of HFST meeting a State DOT's friction property requirements (per AASHTO T 242 or ASTM E 1911) have been placed within the past 3 years demonstrating a friction reading of 65 FN40R or better when test in accordance to T 242; or

B. Proof the contractor is certified by the manufacturer to install and a manufacturer's representative is onsite during all installations.

3. CONTRACTOR'S USE OF PREMISES

A. Protection and Restoration of Property and Landscape. *Follow the requirements of FAR Clause 52.236-9 Protection of Existing Vegetation, Structures, Equipment, Utilities, and Improvements.*

Preserve public and private property, and protect monuments established for the purpose of perpetuating horizontal, vertical, cadastral, or boundary control. When necessary to destroy a monument, reestablish the monument according to applicable State statute or by the direction of the agency or individual who established the monument.

Do not disturb any area outside the construction limits unless authorized by the *Contracting Officer (CO).* Construction limits are defined as any existing hardened surfaces along the striping corridors. Replace trees, shrubs, or vegetated areas outside the construction limits damaged by construction operations as directed and at no cost to *the Government*. Only remove damaged limbs of existing trees when directed by an approved arborist.

Do not excavate, remove, damage, alter, or deface any archeological or paleontological remains or specimens. Control the actions of employees and subcontractors on the project to ensure that protected sites are not disturbed or damaged. Should any of these items be encountered, suspend operations at the discovery site, notify the CO, and continue operations in other areas. The CO will inform the Contractor when operations may resume at the discovery site.

B. Protection of Forests, Parks, and Public Lands. *Comply with all regulations of the State fire marshal, conservation commission, Forest Service, National Park Service, Bureau of Land Management, Fish & Wildlife Service, Bureau of Indian Affairs, or other authority having jurisdiction governing the protection of land including or adjacent to the project.*

Comply with the following:

(1) *Limit parking of equipment and private vehicles to hardened surfaces. Parking is restricted to hardened surfaces, such as pullouts and closed lanes of the roadway to limit disturbance of roadside vegetation. This includes no driving or parking on vegetated shoulders.*

(2) *Confine all operations to disturbed areas within the construction limits.*

(3) *Do not allow equipment to idle longer than 15 minutes when not in use.*

(4) *Equip all motor vehicles and equipment at all times with mufflers conforming to original manufacturers specifications. Ensure that they are in good working order and that in constant operations to prevent excessive or unusual noise, fumes, or smoke.*

(5) *Stage equipment and materials on existing hardened surfaces.*

(6) *Remove trash and food waste daily generated by contractor.*

(7) *Do not clean or fuel equipment within 300 feet of any waterway. Provide fuel containment at all fueling locations.*

C. ***Limitations on Construction Operations.*** *When the roadway is open to public traffic, restrict operations as follows:*

(1) Operate equipment in the direction of traffic, where practical.

(2) Locate staging areas at least 30 feet from the traveled way or behind acceptable traffic barriers. Obtain CO approval of the location and access to staging areas. Store unused traffic control devices at staging areas.

(3) Park equipment at least 30 feet from the traveled way or behind acceptable traffic barriers.

(4) Provide parking areas for employees' personal vehicles in areas approved by the CO.

(5) Provide two-way radio communications between flaggers and between flaggers and pilot cars unless flaggers can see each other and communicate. Citizen band radios are not acceptable. Make radio equipment available to the CO, as necessary.

(6) Where switching traffic to a completed lane, provide adequate personnel and equipment to set or relocate traffic control devices.

(7) Limit construction-caused delays to public traffic to a maximum of 10 minutes per passage through the project.

(8) Perform construction operations during the hours of daylight (one-half hour after sunrise to one-half hour before sunset).

D. Spill Prevention. Provide a safety plan addressing spill preservation. Submit safety plan to CO for approval prior to beginning work. Immediately address spills on roadways, parking areas, sidewalks, and staging areas. Immediately notify the *CO* of any spills or leaks and mitigate any damage to county resources and clean up spill at no additional cost to the Government.

4. PRODUCTS

A. Aggregate for high friction surface treatment. Furnish calcined bauxite aggregate that is clean, dry, free from foreign matter. Conform to properties in Table 1:

Table 1: Material Properties for Polymeric Binder Resin System

Property	Test Method	Specifications
Resistance to Degradation	AASHTO T 96	20% maximum
Aggregate Grading	AASHTO T 27	Finer than the No. 200 (75 µm) sieve
	Sieve Designation	Mass % Passing
	No. 4 (4.75 mm)	100% minimum passing
	No. 6 (3.35 mm)	95% minimum passing
	No. 16 (1.18 mm)	5% maximum passing
Moisture Content	AASHTO T 255	0.2% maximum
Aluminum Oxide	ASTM C 25, as per Section 15	87% minimum

B. Polymeric binder resin. Furnish a two-component polymeric binder resin system for bonding skid-resistant aggregate to hot-mix asphalt or chip seal asphalt. Conform to the properties listed in Table 2:

Table 2: Material Properties for Polymeric Binder Resin System

Property	Test Method	Specifications
Ultimate tensile strength(1)	AASHTO M 235	2,500–5,000 psi
Elongation at break point(2)		30–70%
Water absorption(3)		1% maximum
Gel time(4)		10 minutes, minimum
Viscosity(5)	ASTM D2556	7–30 poises
Durometer hardness (Shore D)(6)	ASTM D2240	60–80
Compressive strength(7)	ASTM C579	1,000 psi, minimum @ 3 hours
		5,000 psi, minimum @ 7 days
Cure rate (dry-through time)(8)	ASTM D1640	3 hours, maximum
Adhesive strength @ 24 hours(9)	ASTM D4541	250 psi minimum or 100% substrate failure

(1) Ultimate Tensile Strength: 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]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

(2) Elongation at break point: 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]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

(3) Water Absorption: Prepare sample as per manufacturer's recommendation. Cure specimens for 7 days at 73 ± 2°F [23 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay after immersion.

(4) Gel time: Prepare a 60g sample per manufacturer's recommendation. Perform testing at a temperature of 73 ± 2°F [23 ± 1°C].

(5) Viscosity: 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].

(6) Durometer Hardness: Prepare sample as per manufacturer's recommendation. Use the Type 1 Precision—Type D Durometer Method. Cure specimens for 7 days at 73 ± 2°F [23 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

(7) Compressive Strength: Prepare sample as per manufacturer's recommendation. Prepare specimen according 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 for 3 hours and for 7 days at 73 ± 2°F [23 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

(8) Cure Rate (Dry-through Time): Prepare sample as per manufacturer's recommendation. Prepare a specimen of 50–55 wet mil thickness. Cure specimens for 3 hours max at 73 ± 2°F [23 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

(9) Adhesive Strength @ 24hours: Prepare sample as per manufacturer's recommendation. Use method D, E, or F with a 2" loading fixture. Cure specimens for 24 hours at 73 ± 2°F [23 ± 1°C]. Test specimens at 73 ± 2°F [23 ± 1°C] without delay.

5. APPLICATION

Provide 48-hour notice to the *CO* prior to beginning work.

At least 7 days before applying high friction surface treatment, furnish a written copy of the manufacturer's recommendations for use and the following:

A. Aggregate sample. 80-pound (35 kilograms) sample including supplier name, location of source, proposed gradation, and proposed application rate.

B. Polymeric binder resin. Type and proposed application rate. Per the manufacturer's recommendations, include the ratio of the components to be mixed by volume including any special instructions regarding mixing. When a prime coat is required by the polymeric binder resin manufacturer, include the type, manufacturer, and application procedures.

Ship material in appropriate containers plainly marked with the following information, as appropriate, for the material being furnished:

- Manufacturer's name and address.
- Name of product.
- Lot/batch numbers.
- Net mass and volume of contents.
- Date of manufacture.
- Date of expiration.
- Statement of contents (if mixing of components is required).
- Mixing proportions and instructions.
- Safety information.

Store aggregate and polymeric binder resin in a clean, dry environment. Do not allow the aggregate to be exposed to rain or moisture. Provide to the *CO* a copy of the Material Safety Data Sheet (MSDS), Product Data Sheet, and other information from the manufacturer pertaining to the safe practices for the storage, handling, and disposal of the materials, as to their health hazards.

Clean the existing surface of loose material, dust, grease, and other deleterious substances that will interfere with the bond between the existing surface and polymeric binder resin. Remove raised or recessed pavement markers. Cover existing edge and center line pavement markings with two layers of duct tape to protect from the application of surface treatment materials. Protect service entrances such as manholes, valve boxes, and drop inlets. Protect concrete work, rock walls, and other objects adjacent to the work.

Use mechanical or vacuum sweepers and oil-and-water-free high pressure air wash (180 cfm) to clean surface. Surface must be clean and dry before application of HFST may begin.

Pre-treat cracks and joints greater than 1/4 inch (6 mm) in width and depth by cleaning and filling with the mixed polymeric binder resin. Once the binder resin in the pre-treated areas has gelled, proceed with the installation of the HFST.

Apply the HFST when the air temperature in the shade and the surface temperature are at least 50°F (10 °C) and rising, the surface is dry, and the weather is not foggy or rainy. Refer to manufacturer's recommendations for maximum temperature and wind limitations. Do not place if rain is forecasted with 24 hours of application or when the anticipated weather conditions would prevent the proper application of the surface treatment as determined by the *CO.*

Ensure full embedment of the aggregate and complete coverage of the lane or area being treated. If necessary, construction staff may traverse the polymeric binder treated area using spiked shoes. Otherwise, do not allow any form of contact or contamination with the wet uncured binder resin prior to application of the aggregate. Remove and replace at the Contractor's expense all areas that have been contacted or contaminated prior to application of the aggregate.

Provide straight lines along curbs and shoulders and do not allow runoff onto these areas. Provide straight and neat starting and ending joints by masking surfaces at the start, end, and other locations as directed by the *CO.*

For longitudinal joints, place joints on lane lines. Overlap longitudinal joints no more than 2 inches (50 millimeters).

Allow treated areas to cure completely in accordance with the polymeric resin binder manufacturer recommendations before opening to traffic. Do not allow construction equipment, vehicular traffic, or foot traffic on the HFST until it is fully cured. Remove excess aggregate by hand brooms, mechanical sweeping, or vacuum sweeping before opening to traffic. Excess aggregate can be reused, provided the aggregate is reclaimed by a vacuum sweeper, clean, uncontaminated, and dry.

At the end of each day's production, provide the *CO* with documentation for calibrations and application rates.

6. APPLICATION EQUIPMENT

Apply HFST in accordance with the manufacturer's recommendations. The HFST can be applied by either the mechanical or manual method as described below:

A. Mechanical and Automated Application. Use application equipment approved by the polymeric binder resin manufacturer and the *CO* with the following capabilities:

(1) Is self-propelled.

(2) Has a proportioning device that can continuously pump and blend the two-part polymeric binder resin within 2 percent by volume of the manufacture's recommended ratio.

(3) Can mechanically mix, meter, and monitor the application of the polymeric binder resin and aggregate in one continuous pass.

(4) Has volumetric metering pumps that continuously meter, monitor, and apply the binder resin. If recommended by the manufacturer, supply heated metering pumps.

(5) Can apply a uniform thickness of polymeric binder resin across variable widths up to 16 feet (3.7 m).

(6) Can apply aggregate at a controlled and metered rate without disrupting the leveled binder resin.

Apply the polymeric binder resin uniformly at a rate of 0.28 to 0.36 gal/yd^2 (1.3 to 1.6 l/m^2) to achieve an application thickness of 50 to 65 mils (1.3 to 1.7 mm). Do not allow the binder resin to separate, cure, dry, or harden in such a way to impair retention and bonding of the aggregate. The aggregate shall be uniformly applied within 5 minutes of the binder application onto the pavement section. Apply the aggregate mechanically at a rate of 12 to 15 lbs/yd^2 (6.5 to 8.2 kg/m^2) in such a manner that there is no disruption to the binder.

B. Hand Mixing and Application. Hand mixing and application are allowed at individual sites where the total quantity for HFST is less than 200 yd^2 (165 m$^{2)}$. Use hand mixing and application in areas not accessible to the mechanical and automated application equipment in 6.A such as radius areas in an intersection or small tapered areas.

Proportion the two-part polymeric binder resin to the correct ratio and mix using a low-speed, high-torque drill fitted with a helical stirrer; or use another mixing procedure as approved by the manufacturer and *CO*. Use a continuous V-notch serrated-edge squeegee to apply the resin binder uniformly across the area treated. Apply the polymeric binder resin uniformly at a rate of 0.28 to 0.36 gal/yd^2 (1.3 to 1.6 l/m^2) to achieve an application thickness of 50 to 65 mils (1.3 to 1.7 mm). Within 2 minutes of the binder application, apply the aggregate in a uniform manner at a rate of 12 to 15 lbs/yd^2 (6.5 to 8.2 kg/m^2).

7. DISPOSING OF MATERIAL

Remove and dispose of material spills and associated debris at the end of each shift as follows:

A. Remove material from the project by recycling or disposing of legally off the project. Submit a statement documenting the nature and quantity of material processed or sold for recycling. Otherwise, submit a signed copy of the disposal agreement before disposal begins.

B. Submit a copy of hazardous material disposal permits. Dispose of material according to Federal, State, and local regulations.

(1) Submit a detail disposal plan that includes how material will be handled, loaded, and transported to the disposal facility. Include the name and address of the facility where the material will be taken.

(2) Include the MSDS with the material to the disposal facility. Ensure that loads transported from the site are adequately contained and covered to prevent dispersion on route to the disposal facility.

8. CONSTRUCTION SCHEDULE

Conduct a pre-surfacing preparatory phase meeting. Coordinate attendance with the *CO* and appropriate subcontractors. Be prepared to discuss the following:

A. Contract requirements for the work, including acceptance procedures, schedule, and control strip.

B. Process and equipment for constructing the work.

C. Plan for inspection, process control, testing, measuring, and reporting the work.

D. Capabilities of the equipment, material, and personnel.

E. Equipment calibration of metering devices and application rate monitoring devices.

F. Specific procedures for placement of the HFST.

G. Curing requirements for the HFST.

9. TRAFFIC CONTROL

Install and maintain temporary traffic control devices adjacent to and within the project as required by the Manual on Uniform Traffic Control Devices. Provide a traffic control plan for *CO* approval prior to beginning work. Install and maintain traffic control devices as follows:

- Furnish and install traffic control devices before the start of construction operations.
- Install only those traffic control devices needed for each stage or phase.
- Relocate temporary traffic control devices, as necessary.
- Remove devices that no longer apply to the existing conditions.
- Immediately replace any device that is lost, stolen, destroyed, or inoperative.
- Keep temporary traffic control devices clean.
- Furnish and maintain traffic control devices that meet the “acceptable” standard described in Quality Standards for Work Zone Traffic Control Devices published by ATSSA. Amend the ATSSA standards as follows:
  - Repair or remove and replace “marginal” devices within 48 hours.
  - Repair or remove and replace “unacceptable” devices immediately.
  - Furnish temporary traffic control devices that meet the NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features, for crashworthiness standards as applicable.

10. MEASUREMENT

Mobilization, schedules, surface preparation, including cleaning, sweeping, protection of pavement markings, protection or removal of pavement markers, pre-treatment of joints and cracks, and removing and disposing of sweepings and debris, traffic control and installation of temporary pavement markers will not be measured for payment, but shall be incidental to this work.

Acceptance is based on visual inspection of the work for compliance with the specific contract requirements. In the absence of specific contract requirements or tolerances, prevailing industry standards may be used.

Check certifications, before incorporating the materials into the work to ensure that the requirements of the contract have been met. Mark the certifications with the following information: project name, project number, contract item number, item description, contractor's signature, and date.

Submit a completed [certification of compliance] with each material requiring a certification. *An electronic form may be found at [xxx].*

Submit all certifications to the *CO* 3 days before incorporating materials into work.

For each day of work, prepare a [Daily Record of Construction Operations] or an approved alternate form. Detail inspection results including deficiencies observed and corrective actions taken. Include the following certification signed by the person with overall responsibility for the inspection system:

> "It is hereby certified that the information contained in this record is accurate and that all work documented herein complies with the requirements of the contract. Any exceptions to this certification are documented as a part of this record."

Submit the record and certification within 1 working day of the work being performed. If the record is incomplete, in error, or otherwise misleading, a copy of the record will be returned with corrections noted. When chronic errors or omissions occur, correct the procedures by which the records are produced.

11. PAYMENT

Payment for all contract work is provided under the lump sum bid amount.

Compensation is full payment for performing all contract work in a complete and acceptable manner. All risk, loss, damage, or expense arising out of the nature or prosecution of the work is included in the compensation provided by *the lump sum bid amount.*

Method of Billing and Proper Submission of Invoices:

All invoices and final payments should reference the contract number [number], project reference/title, and the *CO's* name and be sent to one of the following addresses:

[ADDRESS(ES)]

Invoices may also be sent in .PDF format by electronic mail to [email]. The subject line of the message must include Contract Number, project reference/title, and invoice number, and [other].

In accordance with [contracting clause], the following correct information constitutes a proper invoice and is required as payment documentation:

Name and Address of Contractor Invoice

Date and Number Contract Number

Invoice Amount

Description and quantity of goods and services rendered during Performance Period

Delivery and payment terms

Other substantiating documentation required by the Agreement

Final Payment *The Contractor will submit to the [Agency] support data and one final and complete billing marked Final Invoice of all eligible costs incurred [not later than 180 days] after satisfactory completion of the work pursuant to the provisions of [regulation].*

12. CONTRACTOR FURNISHED ITEMS

All materials shall be Contractor furnished.

Hauling Materials on Public Roads*: Load restrictions on county roads are identical to the State load restrictions. A special permit will not relieve the Contractor of liability for damage, which may result from moving of equipment.*

13. OTHER CONTRACTS

Follow the requirements of [regulatory clauses].

14. INSURANCE REQUIREMENTS

The successful offeror will be required to procure and maintain until final acceptance of the contract, liability insurance of the types and limits specified below. The successful offeror shall obtain insurance from companies authorized to do business in [State] and shall cover all operations under the contract whether performed by the Contractor or by subcontractors.

Before work begins, furnish "certificates of insurance" certifying that the policies will not be changed or canceled until 30 days written notice has been given to the [Agency]. Insurance coverage in the minimum amounts set forth below shall not relieve the Contractor of liability in excess of the coverage.

Carry insurance meeting the following minimums:

A. Worker's compensation insurance. Minimum required by law.

B. Comprehensive or commercial general liability insurance:

- **(1)** Personal injury and property damage coverage.
- **(2)** Contractual liability coverage.
- **(3)** Completed operations liability coverage.
- **(4)** $1,000,000 combined single limit for each occurrence.
- **(5)** $2,000,000 general aggregate limit.

C. Automobile liability insurance. $1,000,000 combined single limit for each occurrence.

FOR FURTHER INFORMATION, CONTACT:

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