High Friction Surface Treatment

Installation and Inspection Pocket Guide

U.S. Department of Transportation
Federal Highway Administration

ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

Image source: The Transtec Group

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16. Abstract This Guide is a resource for High Friction Surface Treatments and recommendations on applications, site selection, installation, and performance monitoring. This Guide also includes an inspection guide that agencies can use to establish inspection protocols for HFST installation and a resource section.		

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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

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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OVERVIEW OF HFST INSTALLATION

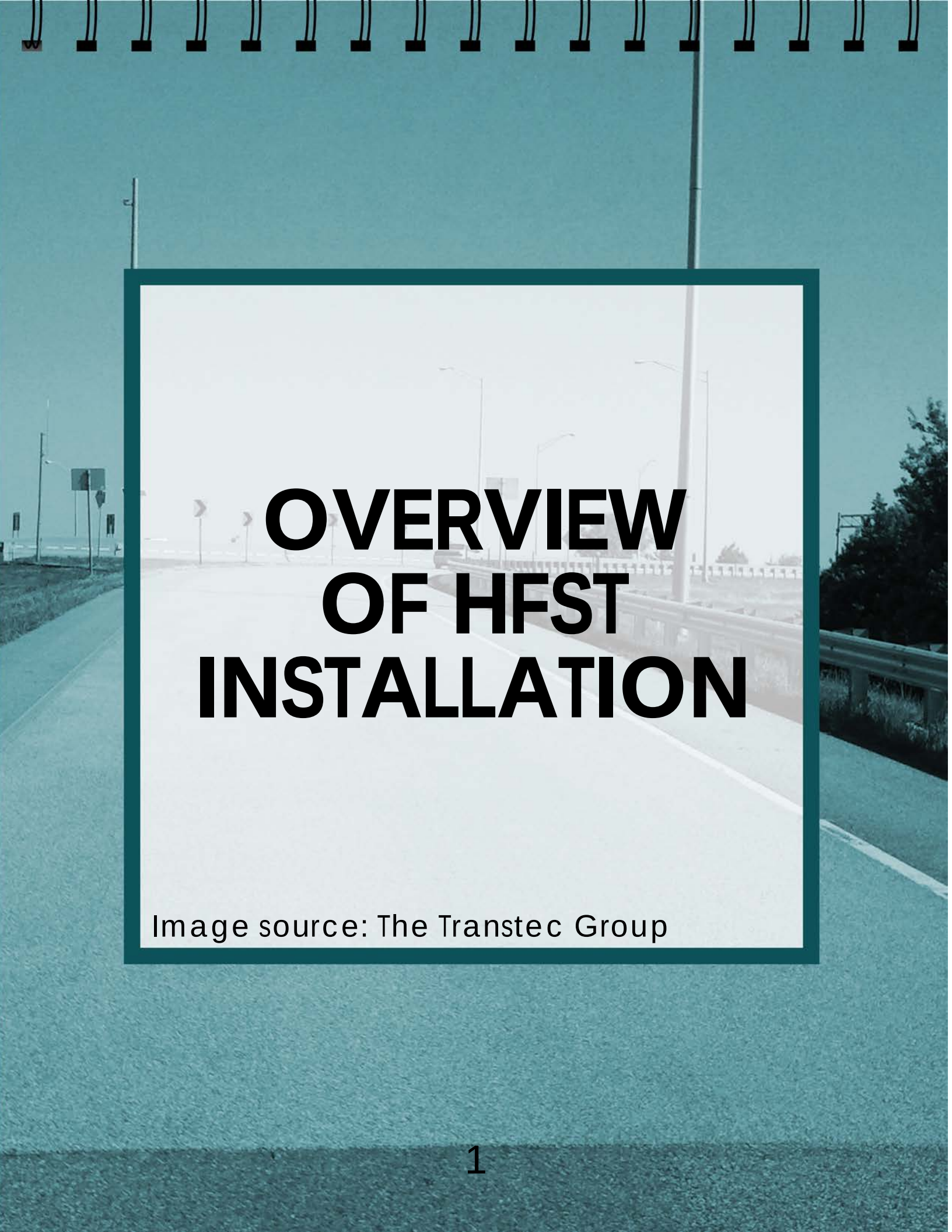

Image source: The Transtec Group

High Friction Surface Treatment (HFST)

HFST is a pavement surface treatment used specifically to dramatically increase the skid resistance of virtually any pavement surface for the purpose of reducing friction-related crashes. HFST is installed by spreading a thin layer of polymeric resin binder (typically epoxy or polyester) over the pavement surface, then broadcasting or dropping a 1-3 mm nominal-size polish and abrasion-resistant aggregate onto the resin layer. The finished surface is a thin, superficial, pavement surface treatment that can be applied during a short closure (e.g., 6-8 hours) of the roadway. Figure 1 shows an

example of HFST placed over a conventional asphalt pavement surface.

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Figure 1. Photograph. HFST placed over a conventional asphalt pavement surface.[1]

[1]Merritt, D. K., Tallon, R., and Watson, R. P. (2020). Developing Crash-Modification Factors for High-Friction Surface Treatments: Friction Change Report. Federal Highway Administration FHWA Research Report FHWA-HRT-20-062. McLean, VA.

Applications and Precautions

- HFST is used for applications where friction demand exceeds friction supply from the existing pavement surface. HFST is effective for reducing both wet and dry weather friction-related crashes.
- Primary usage includes horizontal curves, ramps, and intersections.
- HFST does not provide any pavement preservation benefits – it is used specifically for friction enhancement.
- HFST is different from thin-polymer bridge deck overlays. While the polymeric resin binder and installation methods used for polymer bridge deck overlays are similar to that used for HFST, bridge deck overlays are designed to help seal and preserve the bridge deck

while also enhancing surface friction. Different aggregate materials are typically used for bridge deck overlays.

- HFST performs the best when applied to structurally sound pavement but will still provide immediate safety benefit if short-term performance is acceptable.

HFST Installation

The following are key components of an HFST installation which will be discussed in more detail throughout this Installation and Inspection Pocket Guide:

1. Pre-Construction
2. HFST Materials
3. Surface Preparation
4. HFST Application
5. Aggregate Removal
6. Finished Surface Inspection
7. Acceptance Testing
8. Early-Age Monitoring

PRE-CONSTRUCTION

Image source: The Transtec Group

Quality Control Plan (QCP)

QCPs allow the installer to detail every aspect of their plan for installation of HFST. QCPs are typically approved by the owner agency and allow the agency to provide input on various aspects of the installation before construction begins. QCPs also allow the agency to hold an installer accountable for practices outlined in the plan.

Carefully review the contractor/installer QCP well in advance of installation to verify:

- Schedule for the test strip and full-scale/production of HFST placement (if test strip is to be completed separately).

- Description of equipment for placing HFST.
- Methods for conditioning, metering, blending, and applying resin binder.
- Methods for applying aggregate, including timing of placement onto resin binder.
- Methods for monitoring and documenting material usage.
- Method for protecting areas that will not receive HFST.
- Description of acceptable environmental conditions (temperature and precipitation) for placing HFST.
- Cure time and time to opening to traffic estimates for HFST.
- Storage and handling of HFST materials.
- Disposal and recycling of excess HFST and containers.

- Contingency plan for possible failure during the HFST application.
- Name of the certified independent testing laboratory.
- Key personnel and contact information.
- All project certifications and test results.

QCP Administrator

The installer typically identifies and provides contact information for the QCP administrator who has full authority to institute any action necessary for the successful operation of the QCP. Other key personnel, such as an on-site Lead Technician are also typically identified.

Materials Verification

In advance of installation, verify that materials supplied to the project meet specifications either through agency testing or from certified test results provided by the installer.

If qualified products lists (QPLs) are used for pre-approval of materials, verify that the materials supplied to the project are current on the owner agency's QPL.

If required by the project specification, verify that a resin binder manufacturer's representative is present for the initial/test strip installation.

HFST MATERIALS

Image source: The Transtec Group

HFST consists of two materials: polymeric resin binder and calcined bauxite aggregate. As non-conventional materials, there are special considerations for handling and testing of HFST resin binder and aggregate materials. Key items for inspection of these materials prior to and during installation are discussed below.

Resin Binder

- Verify that resin binder type and brand supplied to the project site is what was specified in the QCP and approved for use.
- Verify that resin binder conforms to agency specifications if certified test results were provided by the installer in lieu of agency testing.

- Verify proper storage of materials for ambient conditions.
- Verify that resin binder components are stored in sealed, watertight containers.
- Follow Manufacturer's recommendations for storage of the resin binder (heated/cooled/shaded locations as required).
- Verify resin binder component containers are clearly labeled with: resin component (e.g., Part A, Part B, etc.), brand name, name of manufacturer, lot or batch number, temperature range for storage, expiration date, and quantity of material in container.
- Sample materials for verification testing on-site as called for by specification.

- Verify that adequate quantities of resin binder components for the intended installation are on-site or accessible near the project site.

Calcined Bauxite Aggregate

- Verify that aggregate packaging is clearly labeled with: type of aggregate, manufacturer, and location of processing.
- Verify that aggregate conforms to agency specifications if certified test results were provided by the installer in lieu of agency testing.
- Verify that aggregate is packaged and stored in such a way to protect it from rain.
- Verify that adequate quantity of aggregate for the intended installation is

on-site or accessible near the project site.

- Sample materials for verification testing on-site as called for by specification.
- Assess aggregate cleanliness:
  - Examine aggregate material in packaging or installation vehicle for presence of foreign matter.
  - Observe loading of aggregate into installation vehicle to check for segregation and assess cleanliness (dust generation).
    - Verify aggregate is dry and there is no visible moisture on the stockpile or within the stockpile when sampled by hand. Sample and test for moisture if questionable.
    - If reclaimed aggregate is permitted, verify that reclaimed material has

been remixed with virgin material at the specified minimum ratio (typically 2:1 or 3:1 virgin to reclaimed).

SURFACE PREPARATION

Image source: The Transtec Group

Preparation of the underlying pavement surface is critical for the installation and long-term performance of HFST. The various aspects of surface preparation prior to HFST application are discussed below.

Treatment of Pavement Distresses

The types of underlying pavement distresses to be addressed prior to HFST application are typically outlined in the project plans and specifications. Note that some distresses may need patching or the complete removal and replacement of pavement surfaces, which typically involves 30 days of cure time before HFST can be applied. Most agency specifications require pre-treatment of non-working cracks wider than 0.25 inches

with HFST resin binder, which can be completed just prior to HFST application.

- Verify that all distresses identified for treatment in the project plans have been addressed or will be addressed during installation.
- Verify that bituminous crack sealant material is kept flush with or slightly recessed from the top surface of the pavement (figure 2) and not overbanded onto the pavement surface.
- Allow bituminous crack sealant to cure for at least 30 days prior to HFST application.

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Figure 2. Photograph. Example of bituminous crack sealant in asphalt pavement.

Cleaning and Roughening

These processes are used to thoroughly clean and roughen the pavement surface

to help ensure bond between the resin binder and pavement surface.

- Verify that compressed air wash is completed in accordance with specifications (AASHTO Specification: minimum 180 CFM with tip of lance within 12 inches of surface - note that following this specification is not required by Federal law or regulation) and that the surface is fully covered by the air wash (figure 3).

© The Transtec Group

Figure 3. Photograph. Example of compressed air wash surface preparation.

- Concrete pavement: verify that the specified concrete surface profile (CSP) (AASHTO Specification: minimum CSP of 5 - note that following this specification is not required by Federal law or regulation) has been achieved with the shotblasting process (figure 4). Verify that

entire surface to receive HFST has been shotblasted. Ensure that a compressed air wash has been used to remove latent dust and verify that the prepared surface is free from dust.

- If a power broom or vacuum truck are used to clean the surface, ensure that these are not generating additional dust and are followed by a compressed air wash to remove latent dust.
- For a double layer HFST, verify that all loose aggregate has been removed from the first layer before application of second layer.

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Figure 4. Photograph. Shotblast concrete surface with CSP = 5.

Striping and Pavement Marking Removal and Masking

Most pavement markings and striping within the boundaries of where HFST is to

be applied can be either removed or masked prior to HFST application, as directed by project plans and specifications.

- Removal of markings
  - Verify complete removal of any pavement striping or markings as provided in the project plans and specifications.
  - Check the integrity of the pavement surface where the striping/markings were removed to verify that there is no damage (e.g., raveling) from the removal process (figure 5).
- Protection of markings
  - Verify that any pavement striping or markers to be left in place have been properly masked off as provided in the project plans and specifications.

Figure 5. Photograph. Example of pavement striping removal using milling which has not damaged the underlying pavement.

Protection of Joints and Drainage Structures

Protection of working joints (e.g., concrete pavement or at bridge abutments) and drainage inlets helps prevent intrusion of HFST materials during installation.

- Verify that any pavement joints (e.g., concrete pavement joints, bridge approach joints, etc.) have been masked off as provided in project plans and specifications.
- Verify that any drainage structures (e.g., inlets, manholes, etc.) have been properly masked off as provided in project plans and specifications (figure 6).

Figure 6. Photograph. Example of masking of drainage structures near HFST application.

Protection of the Prepared Surface Prior to Application

Maintaining the integrity of the prepared surface prior to HFST application is critical for helping to ensure proper bond

between the resin binder and pavement surface.

- Verify that the surface is clean and dry prior to HFST application. If the surface has been opened to traffic after cleaning and roughening, verify that the surface has not been affected by traffic.
- Check cracks, joints, and surface pores for dirt and moisture.
- Check moisture content of surface if included in project specifications. A common method for checking moisture content is ASTM D 4263, “Indicating Moisture in Concrete by the Plastic Sheet Method,” modified to a two-hour test.
- Monitor prepared surface prior to and during installation for any contaminants from installation vehicles (oil, hydraulic fluid, air conditioner condensate, etc.).

HFST APPLICATION

Image source: Florida DOT

Application Considerations and Methods

General principles for HFST application inspection, regardless of the method include:

- Ensure resin binder is properly proportioned to manufacturer specifications for installation conditions (pavement and air temperature) and thoroughly blended such that it fully cures after application.
- Ensure resin binder is applied to the appropriate mil thickness, verified using a wet film thickness gage (if appropriate, figure 7) and through a comparison of anticipated to actual coverage rate.

- Ensure aggregate is applied to the resin binder before it gels and that all resin binder is covered.
- Prevent vehicular traffic on the HFST surface before it has cured.

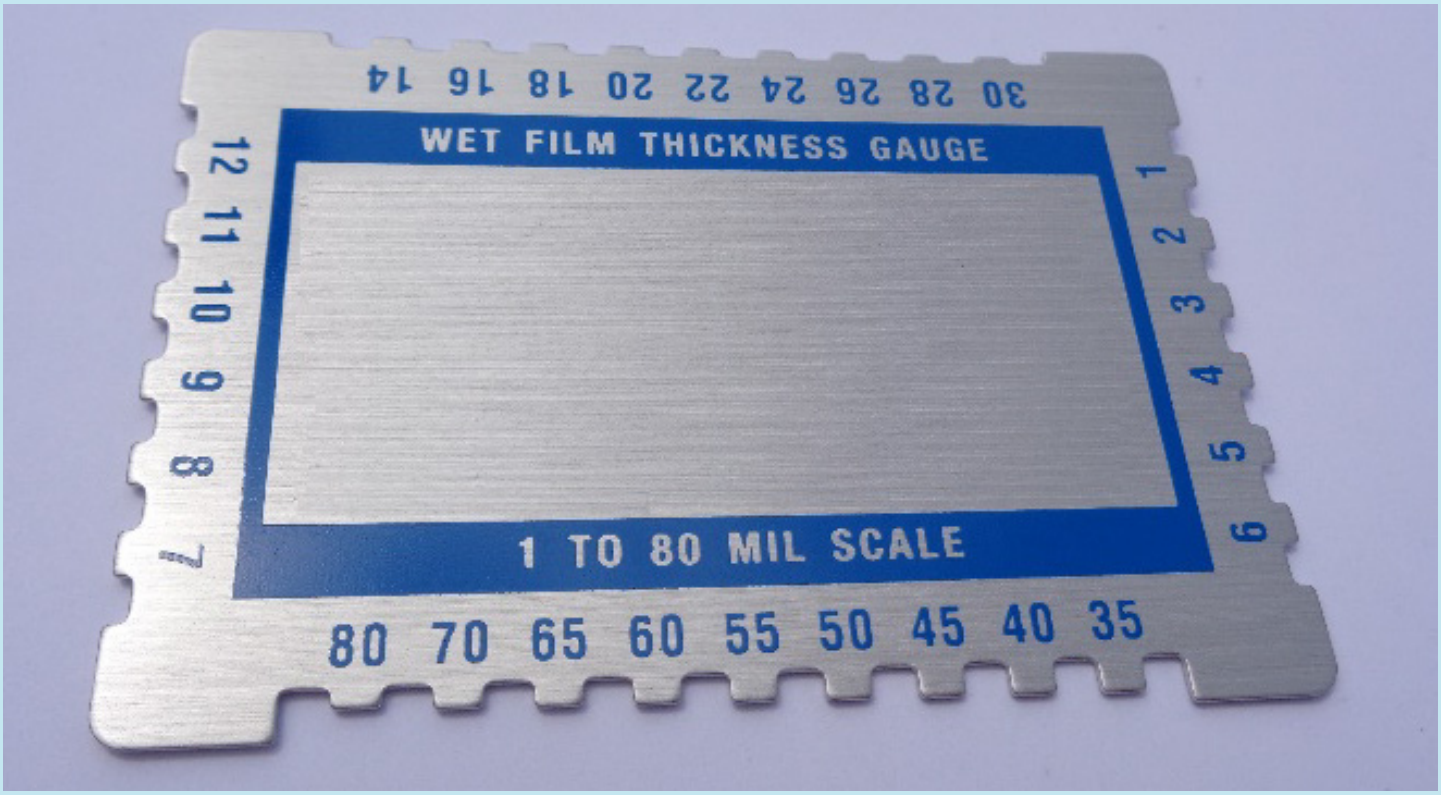

Figure 7. Photograph. Wet film thickness gage used to measure resin binder thickness during application.

The two primary methods for HFST application are *manual* and *fully-automated*. Most agencies require fully-automated HFST installation, with manual application permitted for smaller or irregular areas (less than 200-300 SY) where automated installation is impractical. Installations where lane width varies over the treatment section or irregular areas at tapers or turn pockets are examples where manual application may need to supplement automated installation.

Manual Application

Manual application consists of manual processes for resin binder proportioning, resin binder blending, resin binder application, and aggregate application. While manual installations may utilize

components, such as automated proportioning and blending of resin binder or mechanically-assisted placement of aggregate, application of the resin binder is typically performed with manual labor using notched squeegees to spread the resin binder on the pavement surface (figure 8 through figure 10).

Figure 8. Photograph. Example of mechanically-assisted manual resin binder application.

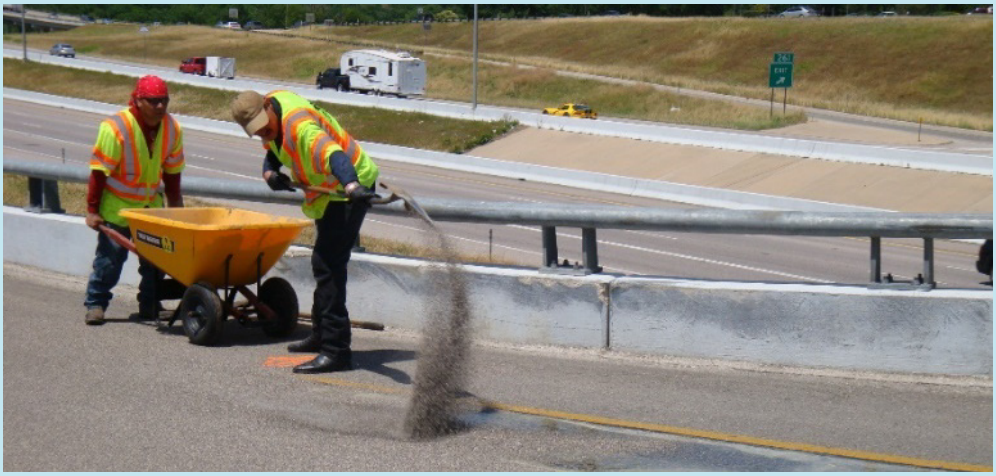

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Figure 9. Photograph. Example of manual application of aggregate, broadcast by hand.

Source: FHWA

Figure 10. Photograph. Example of mechanically-assisted manual aggregate application using a venturi blower.

Resin Binder Proportioning and Blending

General list of tools and equipment for manual resin binder proportioning and blending (figure 11):

- Tarps/plastic sheeting to protect work area.
- Nozzles for resin totes.
- Clean measuring containers (resin type dependent).
- Variable speed drill (primary and backup).
- Generator for mixing drill.
- “Jiffy” style mixer for blending.
- Timer for resin blending.
- Clean mixing container (with wheels if using for transport).
- Rags for clean-up and cleaning spills.

Inspection of manual resin binder proportioning and blending:

- For manual proportioning and blending, verify that resin binder components are proportioned to the correct ratio.
- For mechanically-assisted proportioning and blending, verify the metering process used to proportion the resin binder components to the proper ratio.
- Routinely sample the blended material to ensure that it cures/hardens.

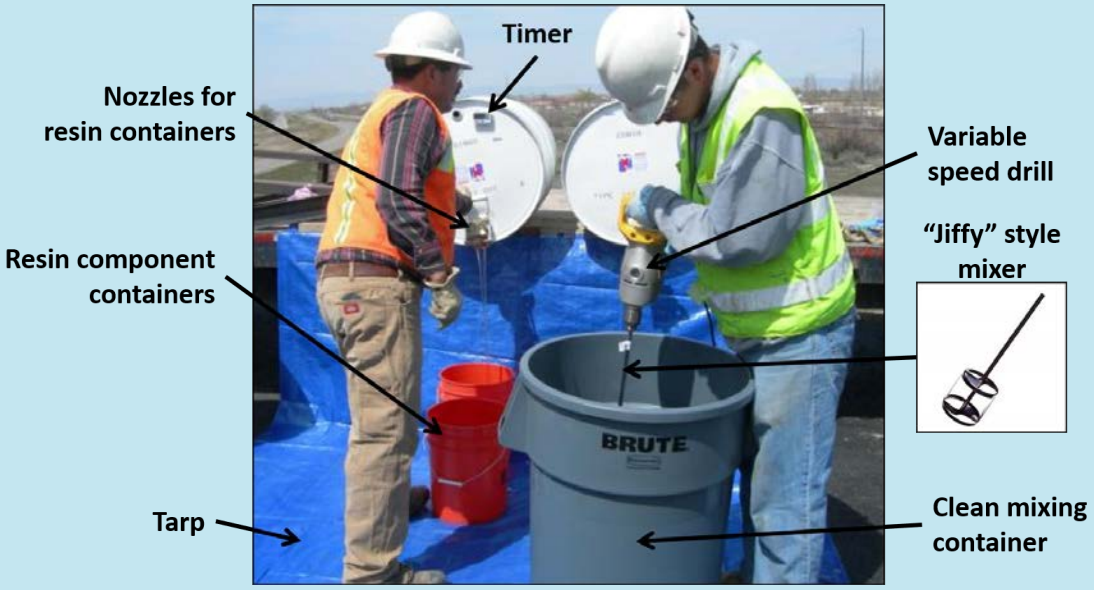


Figure 11. Photograph. Typical tools and equipment for resin binder proportioning and mixing for manual application.

Resin Binder Application

General list of tools and equipment for manual resin binder application:

- Duct tape/tar paper to form start/end joint.
- Wheelbarrow or wheeled mixing container for transporting resin from blending to placement location (may

not be necessary for mechanically-assisted reason binder proportioning and blending).

- Spiked shoes for squeegee operator to prevent shoeprints in resin binder (figure 12).
- Notched rubber squeegee for spreading resin binder with provision of additional squeegees for replacement when notches/serrations become worn (figure 13).
- Wet film thickness gauge (figure 7).

Source: FHWA

Figure 12. Photograph. Example of spiked shoes worn by squeegee operator.

Source: FHWA

Figure 13. Photograph. Notched rubber squeegee for spreading resin binder during manual application.

General list of items for inspection of manual resin binder application (figure 14):

- Note ambient and pavement surface temperatures regularly during application.
- Verify use of tar paper (or similar) masking to create clean construction joints at the beginning and end of the placement.
- Note resin binder viscosity and if it appears too thick or too thin.
  - If resin binder is too thick, it may be difficult to spready uniformly.
  - If resin binder is too thin, watch for resin binder sheeting across the lane or down the pavement grade leaving deficient thickness at the high side.

- Watch for resin binder running off the lane, potentially leaving inadequate thickness.
- Verify complete coverage of the treated area with resin binder before aggregate application.
- Note the method used to operate the squeegee. Squeegees are pulled towards the operator rather than pushed.
- Note any changes in color or consistency of resin binder throughout application and watch for contaminants (e.g., deleterious materials or residual hardened resin binder) as resin binder is deposited onto the pavement surface.
- Verify resin binder mil thickness with a wet film thickness gage at the frequency prescribed in the project specifications.

- Verify total material quantity usage at the end of placement for comparison with expected usage based on necessary mil thickness.

© KwikBond Polymers

Figure 14. Photograph. Example of manual resin binder application.

Aggregate Application

General list of tools and equipment for manual aggregate application:

- Wheelbarrows (2-wheeled preferred).
- Shovels (flat head preferred).
- 5-gallon buckets.
- For mechanically-assisted aggregate application, only 5-gallon buckets may be necessary.

General list of checks for inspection of manual aggregate application (figure 15):

- Verify that aggregate is applied to the resin binder in accordance with the project specifications for timing and broadcast height.
- Verify that aggregate is applied using a method that does not disturb (shove) the resin binder, ideally from the shoulder or adjacent lane.
- Watch for foreign material and significant dust content in aggregate as it is applied.
- Verify that aggregate is applied to the wet resin binder before gelling occurs and within the prescribed timing from project specifications or manufacturer recommendations.

- Verify that all resin binder is completely covered such that no “wet” areas of resin binder show through the aggregate before resin gels.
- Verify that aggregate application remains behind resin binder application such there is no aggregate on the pavement surface before the resin binder.
- Verify uniform thickness of aggregate application.
- Verify total material quantity usage at the end of placement for comparison with expected usage from project specifications

© The Transtec Group

Figure 15. Photograph. Example of manual application of HFST aggregate.

Fully-Automated Application

In general terms, fully-automated application consists of a single vehicle which is capable of placing HFST in a

single pass with minimal manual effort. All materials are contained on the vehicle, and automated systems for conditioning (pre-heating), metering, blending, and placing the resin binder and aggregate materials are utilized for application of HFST (figure 16 and figure 17).

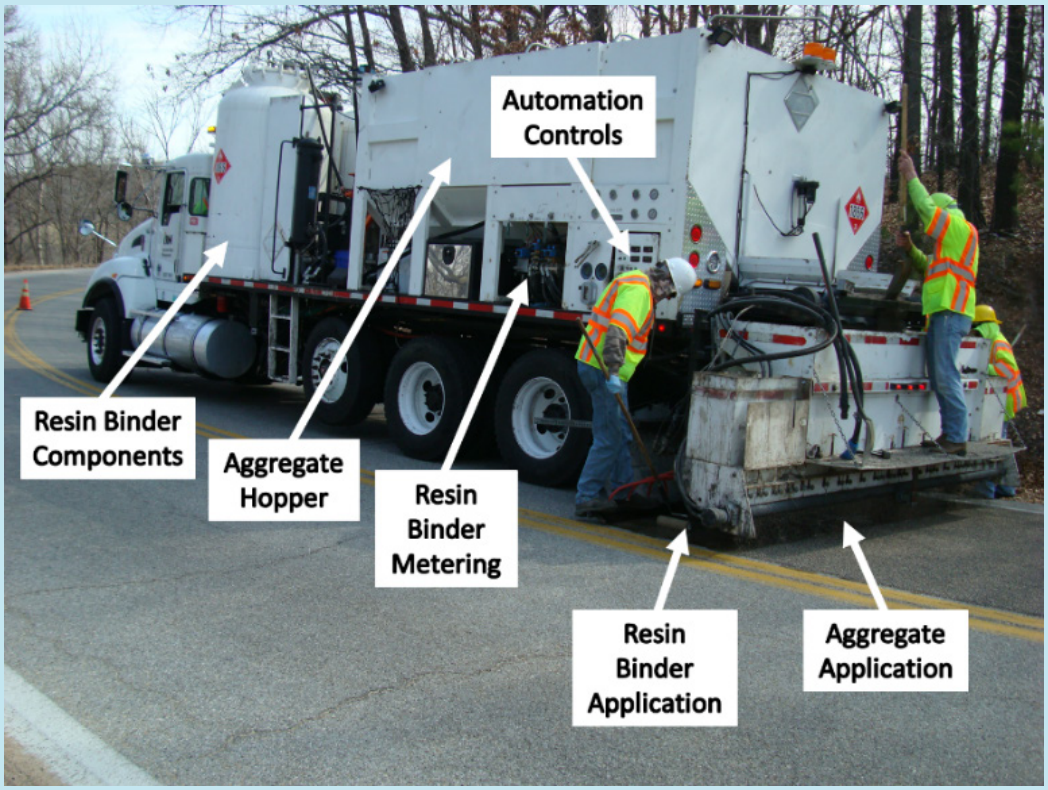


Figure 16. Photograph. Example of a fully-automated installation vehicle.

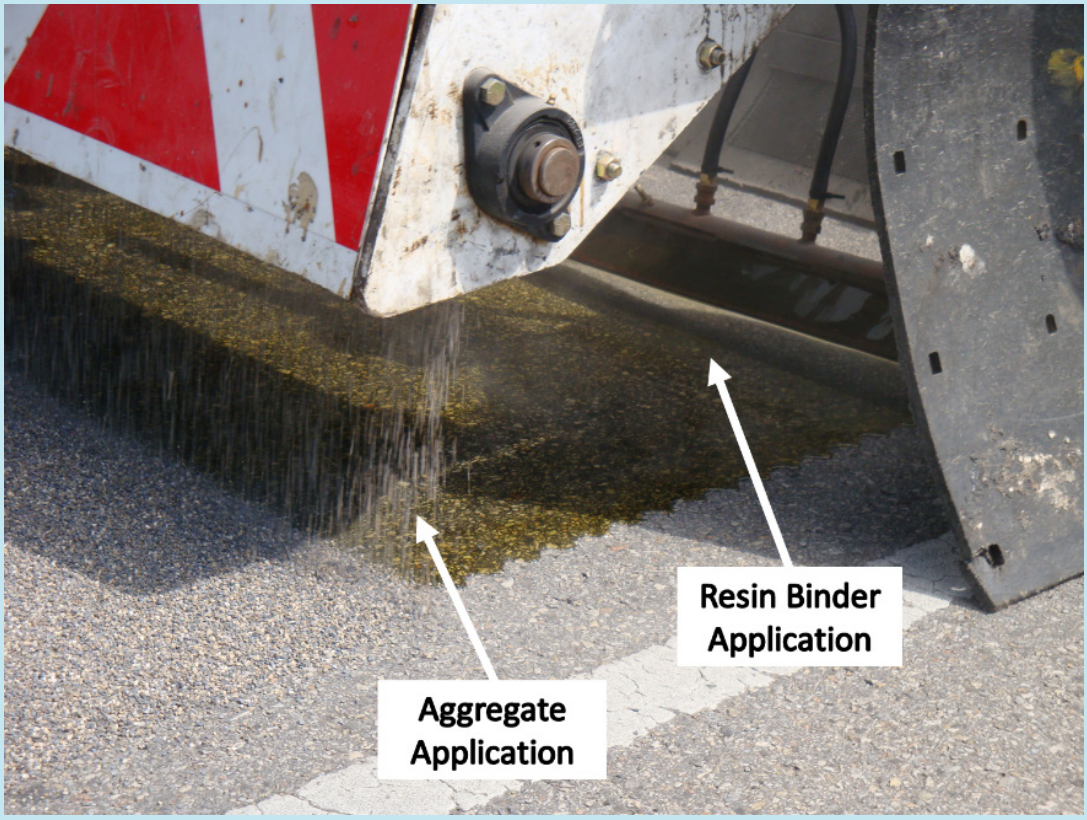


Figure 17. Photograph. Example of resin binder and aggregate placement on a fully-automated installation vehicle.

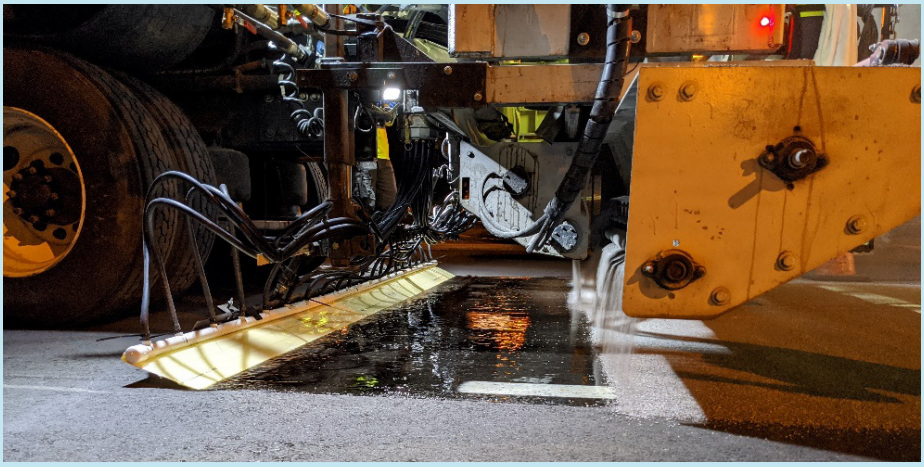
Resin Binder Application

- Verify functionality of resin binder component metering system and proportioning to the proper blending ratio.

- Routinely sample blended material to ensure that it cures/hardens.
- Note ambient and pavement surface temperatures regularly during application.
- Verify use of tar paper (or similar) masking to create clean construction joints at the beginning and end of the placement.
- Observe resin binder application, noting any issues with consistency of the material or uniformity of coverage (figure 18).
- Note any excessive use of rollers and squeegees to correct automated application issues.
- Verify resin binder mil thickness with a wet film thickness gage, if possible, at the

frequency prescribed in the project specifications.

- Verify total material quantity usage at the end of placement for comparison with expected usage based on specified mil thickness.



© Florida DOT

Figure 18. Photograph. Example of fully automated resin binder application followed by automated aggregate application demonstrating uniformity of coverage.

Aggregate Application

- Verify that aggregate is applied to the resin binder in accordance with the project specifications for timing and broadcast height.
- Verify that aggregate application method does not interfere with resin binder application or disturb (shove) the resin binder.
- Watch for foreign material and significant dust content in aggregate as it is deposited.
- Observe aggregate application, noting any issues with uniformity of coverage (figure 18).
- Verify that all resin binder is completely covered such that no “wet” areas of resin binder show through the aggregate before resin gels, using manual

aggregate application to cover these areas as needed.

- Verify total material quantity usage at the end of placement for comparison with expected usage from project specifications.

AGGREGATE REMOVAL

Image source: The Transtec Group

The primary purpose of aggregate removal is to remove the loose excess aggregate from the HFST after the resin binder has cured. A secondary purpose is to loosen and remove lightly bonded aggregate to help minimize the amount of shedding over the first few days and weeks after opening to traffic.

Methods

Removal of excess aggregate is generally completed using some form of a power broom (figure 19), vacuum sweeper (figure 20), or combination broom-vacuum. Power brooms tend to be most effective and efficient, generally only requiring 1 to 2 passes, but may not be possible to use if there is risk of sweeping aggregate into adjacent lanes. Whenever

broom methods are used, only non-metallic, less aggressive broom bristles are recommended. If aggregate reuse is permitted, vacuum sweepers are generally the most efficient method for reclaiming aggregate. However, because vacuum sweepers do not agitate the surface like power brooms, 3 to 4 passes may be necessary to remove all loose aggregate. Agencies may have their own requirements for dust mitigation that will require one method over another.

Figure 19. Photograph. Example of aggregate removal using a power broom.

Figure 20. Photograph. Example of aggregate removal using a vacuum truck.

Timing

Timing of aggregate removal is critical. If sweeping/vacuuming begins before the resin has adequately cured, there is risk of pulling aggregate out of the resin binder, potentially diminishing the frictional properties of the finished surface. Timing of aggregate removal will be based on resin binder manufacturer guidelines based on the manufacturer's cure time requirements and ambient temperature at placement. Deformability of the resin binder is typically used to determine timing of sweeping in the field. Note that cure time needed before sweeping may be different from that needed before opening to traffic.

Reclamation

If aggregate is to be reused, reclaimed aggregate needs to be stored separately from virgin aggregate such that they can be remixed in the proper proportions for future application.

Inspection

- Verify that equipment used for aggregate removal is appropriate and meets project specifications (e.g., non-metallic brush bristles, etc.).
- Verify that the sweeping time is in accordance with the resin binder manufacturer recommendations, and resin cure has been verified before sweeping begins.
- Note any areas where sweeping exposes the resin binder or underlying pavement (figure 21). These areas should be repaired or replaced.
- Verify that all loose aggregate has been removed from the surface of the HFST before opening to traffic.

- Verify that all aggregate which has migrated onto adjacent lanes, paved shoulders, or pavement adjacent to the beginning or end of the HFST section has been removed (figure 22).
- Verify that reclaimed aggregate is stored separately from virgin aggregate.

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Figure 21. Photograph. Example of exposure of underlying pavement after sweeping.

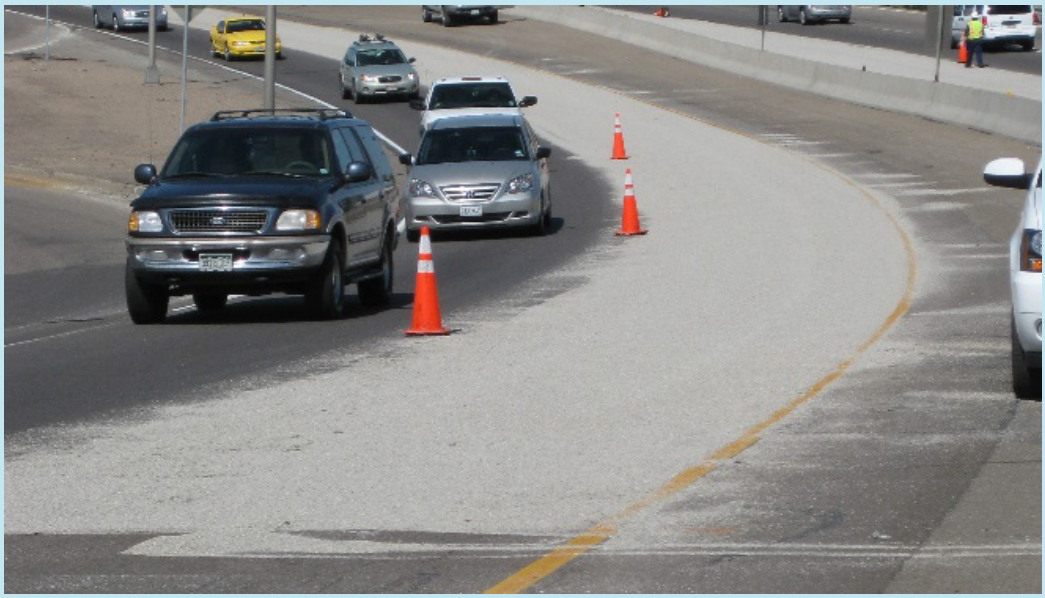

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Figure 22. Photograph. Example of loose aggregate migration onto adjacent lanes and shoulders.

FINISHED SURFACE INSPECTION

Image source: The Transtec Group

Before opening to traffic, perform a visual inspection on the finished surface. Below is a checklist of recommended visual inspection practices.

- Verify that there is no loose aggregate on the HFST surface or adjacent surfaces.
- Verify that there are no areas of discoloration that could indicate uncured resin or moisture beneath the treatment (figure 23).
- Verify that all masking of striping, pavement markers, joints, drainage structures, etc. has been removed.
- Identify any areas where HFST is missing (figure 24) or will need to be removed and replaced for non-conformance.
- Verify that the surface is safe to open to traffic before these repairs are made.

- If surface is not safe to open to traffic, discuss mitigation and repair/replacement plan with installer.
- Verify that all striping has been replaced with temporary or permanent markings in accordance with project plans and specifications.

Figure 23. Photograph. Example of discoloration indicating uncured resin binder.

Figure 24. Photograph. Example of areas where HFST is missing and will need repair.

ACCEPTANCE TESTING

Image source: The Transtec Group

Acceptance testing differs depending on the owner agency. In addition to the visual inspection of the finished surface discussed above, acceptance testing typically includes friction testing, but may also include macrotexture testing and pull-off testing.

Friction Testing

Friction testing may take place before opening to traffic but usually happens 14 to 90 days after opening to traffic to allow a wear-in period. Agencies with performance guarantees may also specify testing during or at the end of the performance period.

Test Methods

The most common methods for friction testing are: ASTM E274/AASHTO T 242

LWST[2,3], which can be performed under traffic, and ASTM E 1911 DFT[4], which will involve a lane closure (note that following these specifications is not required by Federal law or regulation).

Inspection

- Verify the test requirements in the project specifications, including timing, number

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[2]ASTM. (2020). Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire. ASTM E274/E274M-15. ASTM International. West Conshohocken, PA.

[3]AASHTO. (2018). Standard Method of Test for Frictional Properties of Paved Surfaces Using a Full-Scale Tire. AASHTO T 242-18. Washington, D.C.

[4] ASTM. (2020). Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Lose Angeles Machine. ASTM C131/C131M-20. ASTM International. West Conshohocken, PA.

of tests, test speed, and friction value for acceptance.

- Verify that the test is performed in accordance with project specifications and any ASTM/AASHTO/agency-specific procedures (note that following these specifications is not required by Federal law or regulation).

Macrotexture Testing

Macrotexture testing is typically completed at the same time as friction testing and is used to measure texture depth.

Test Methods

The two most common methods for macrotexture testing are stationary methods that will involve a lane closure. The ASTM E 965 “Sand Patch” method uses

a known volume of sand or glass beads to estimate macrotexture depth, reported as mean texture depth or MTD[5]. The ASTM E2157 Circular Track Meter measures macrotexture over a circular path using a laser and reports it as mean profile depth or MPD. Note that following these specifications is not required by Federal law or regulation.

Inspection

- Verify the test requirements in the project specifications, including timing, number of tests required, and friction value for acceptance.

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[5]ASTM. (2019b). Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique. ASTM E965-15. ASTM International. West Conshohocken, PA.

- Verify that the test is performed in accordance with project specifications and any ASTM/AASHTO/agency-specific procedures (note that following these specifications is not required by Federal law or regulation).

Other Testing

Some agencies may have additional acceptance testing procedures, such as the ASTM C1583 pull-off tensile strength test to verify adhesion between the HFST and underlying pavement[6]. This is also a stationary test which will involve a lane closure but can typically be performed after installation, before opening to traffic.

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[6]ASTM. (2020). Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method). ASTM C1583/C1583M-20. ASTM International. West Conshohocken, PA.

EARLY-AGE MONITORING

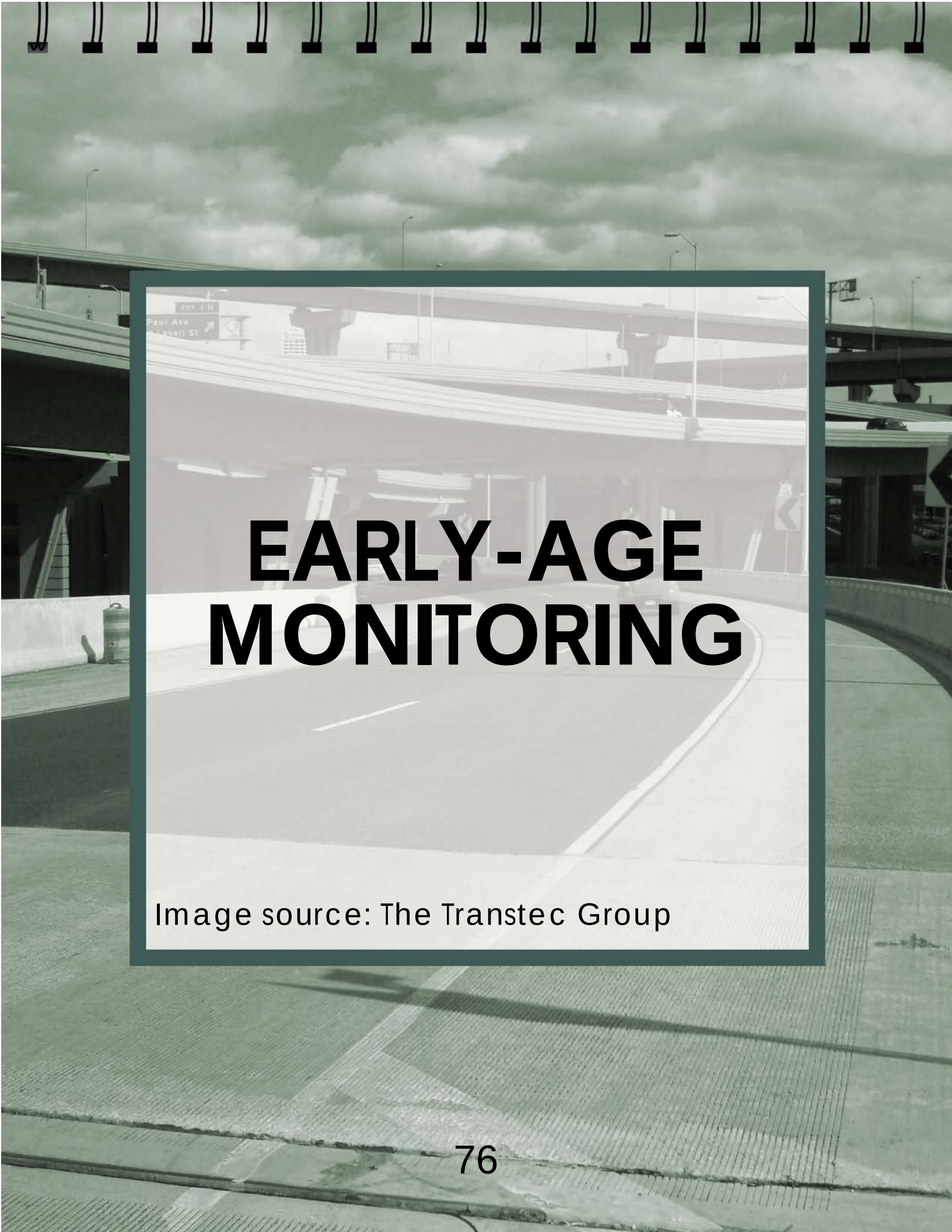

Image source: The Transtec Group

Early-age monitoring will help identify any issues related to materials and installation workmanship. These issues will typically develop within the first 30 to 60 days after installation.

Uncured Resin Binder

Uncured resin binder will normally appear as isolated areas where the HFST is discolored (figure 23) and soft, and will lead to aggregate loss or flushing of the resin binder on the HFST surface. This may not appear immediately and may develop over the first few days after installation. Agencies may investigate discoloration and determine the limits of the resin binder failure as it may not affect the entire application.

Agencies may remove and reapply the HFST in the affected area(s) to correct the resin binder failure.

Aggregate Loss and Re-Sweeping

HFST will naturally shed aggregate that is only lightly bonded to the resin binder under traffic wear. Normal shedding will generally be heaviest during the first 24 to 72 hours, tapering off over time, depending on traffic volume. Shed aggregate will generally accumulate along the edges of the lane and possibly in adjacent lanes and paved shoulders (figure 25). Re-sweeping is typically included in project specifications to remove this loose material within the first 2 to 4 weeks of installation.

If significant aggregate loss continues beyond the first 30 to 60 days, this may indicate an issue with materials and installation and the cause should be investigated further, particularly if the resin binder or underlying pavement becomes exposed.

Corrective action for aggregate loss is removal and reapplication of the affected area(s).

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Figure 25. Photograph. Example of aggregate shedding and accumulation along lane edge and on paved shoulder.

Delamination

Delamination is the separation of the HFST from the underlying pavement due to a lack of bond. Delamination generally manifests as “sheets” of HFST peeling away

from the surface, commonly in small, localized areas, but can spread to much larger areas (figure 26).

Delamination is not obvious until the HFST peels away, leaving exposed pavement, but may still be occurring. Sounding techniques can be used to identify delamination if there is evidence that this may be occurring.

Corrective action for delamination is removal of all affected areas and reapplication of HFST. Widespread delamination may necessitate complete removal and reapplication, ensuring that any possible causes of the delamination (e.g., surface preparation) are addressed before reapplication.

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Figure 26. Photograph. Example of delamination of HFST from underlying pavement surface.

Aggregate Polishing

Aggregate polishing is the result of aggregate particles being worn away under traffic, leaving a smooth HFST surface where the aggregate may be worn flush with the resin binder (figure 27).

While this is not likely to occur if calcined bauxite aggregate meeting specifications is used, if it does occur, further investigation with laboratory testing is warranted.

Corrective action for aggregate polishing will be removal and reapplication of the HFST.

Figure 27. Photograph. Example of polished HFST surface in wheelpaths.

Discoloration

Discoloration is a visible difference in color of localized areas of HFST from the surrounding surface (figure 28). Discoloration does not necessarily indicate a problem with the HFST but may be an indicator of the presence of moisture trapped beneath the HFST. Continue monitoring over time to note any changes in discoloration or appearance of localized distresses. Corrective action may be needed if the condition leads to distresses.

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Figure 28. Photograph. Example of HFST discoloration likely caused by moisture.

Surface Wear Loss of HFST

Surface wear loss of HFST occurs when both the aggregate and resin binder wear off under traffic. This generally occurs when the aggregate polishes or breaks away from the resin binder, exposing the

resin binder which quickly wears off, exposing underlying pavement (figure 29). While wear-off is expected at the end of HFST service life, premature wear-off is a cause for concern that should be investigated further, as it may indicate that the resin binder layer was placed too thin.

Corrective action for wear-off is reapplication of HFST either over the existing surface (if recommended by the resin binder manufacturer) or after removal of the worn layer.

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Figure 29. Photograph. Example of HFST worn off in the wheelpaths.

Friction Loss

Friction loss is defined as a sustained decrease in friction over time. While there will naturally be some loss of friction over the first year after installation as the surface is worn in under traffic, continued

loss of friction (e.g., 10 percent or more) year after year, should be investigated further. Generally, this condition is caused by polishing or loss of aggregate.

Corrective action for friction loss is reapplication of HFST either over the existing surface (if recommended by the resin binder manufacturer) or after removal of the existing surface.

Failure of Underlying Pavement

Failure of the underlying pavement will cause a loss of HFST. Failures typically manifest as small, isolated areas (e.g., potholes) which can progress to much larger areas (figure 30). This type of failure is more common in asphalt pavements and may be the result of a cohesive failure within a weak asphalt layer or due to

stripping of the asphalt layer due to trapped moisture.

Corrective action for failure of the underlying pavement will involve removal of the affected area, proper repair of the underlying pavement, and reapplication of HFST.

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Figure 30. Photograph. Example of failure of underlying pavement leading to isolated failures (potholes) of HFST.

INSPECTION CHECKLIST

Image source: The Transtec Group

1 Pre-Construction

Item	Item Description	Status
1.1	Review contractor Quality Control Plan (QCP) to verify provisions for: a) Test strip and full-scale/production of HFST placement schedule (if test strip is to be completed separately). b) Description of equipment for placing HFST. c) Methods for conditioning, metering, blending, and applying resin binder. d) Methods for applying aggregate, including timing of placement onto resin binder. e) Methods for monitoring and documenting material usage. f) Method for protecting areas that will not receive HFST. g) Description of acceptable environmental conditions (temperature and precipitation) for placing HFST. h) Cure time and time to opening to traffic estimates for HFST. i) Storage and handling of HFST materials. j) Disposal and recycling of excess HFST and containers.	

	k) Contingency plan for possible failure during the HFST application. l) Name of the certified independent testing laboratory. m) Key personnel and contact information. n) All project certifications and test results.	
1.2	Verify name and contact information for contractor QCP administrator.	
1.3	Check that materials supplied to the project meet project specification requirements (through agency testing or from certified test results from the installer).	
1.4	Verify that a resin binder manufacturer's representative is present for initial/test strip installation.	

2 Materials

Item	Item Description	Status
2.1	Check that resin binder is type and brand specified in the QCP.	
2.2	Check that aggregate material is type and brand specified in QCP.	
2.3	For reclaimed aggregate only: verify that reclaimed material had been blended with new/virgin material at the specified ratio (e.g., two parts new to one part reclaimed).	
2.4	Check resin binder and aggregate stockpiles to verify proper packaging and storage of materials.	
2.5	Check that aggregate is clean (minimal dust content and no foreign materials) and dry (subjective assessment).	
2.6	Check that adequate quantities of resin binder and aggregate materials for the intended installation area are on-site or accessible near the project site.	
2.7	Sample materials for verification testing on-site as provided by specification.	

3 Surface Preparation

Item	Item Description	Status
3.1	Check that all distresses identified for pre-treatment in the project plans have been addressed.	
3.2	Check that all striping and pavement markings have been removed or masked as required in project plans and specifications.	
3.3	Check that all drainage inlets, manhole and valve covers, and other utilities and structures have been masked as required in project plans and specifications.	
3.4	Shotblasting: Verify that surface has been shotblast to concrete surface profile (CSP) of 5, as required in project specifications, followed by compressed air wash.	
3.5	Check that entire surface has been cleaned with a mechanical sweeper and/or a compressed air wash as required in the project plans.	

3.6	Check that all pavement surfaces to be covered with HFST are dry and free of oils, grease, dust (including latent dust from shotblasting) and foreign material prior to HFST placement.	

4 Pre-Application

Item	Item Description	Status
4.1	Verify test strip placement procedure (i.e., separate test strip or as part of initial production installation).	
4.2	Check that equipment for placing HFST is as outlined in the QCP.	
4.3	Document width of placement based on installation vehicle setup.	
4.4	Check for masked-off areas at beginning and end of placement to ensure clean termination joints.	
4.5	Verify that resin binder metering devices are fully functional.	
4.6	Document ambient and surface temperatures at start and end of application (minimum) and routinely throughout application if necessary.	

5 Resin Binder Application

Item	Item Description	Status
5.1	Check for changes in coloration and consistency of resin binder throughout application.	
5.2	Check uniformity of resin binder film across the lane (e.g., no gaps or tearing of the film or variations in thickness).	
5.3	Check thickness of resin binder on pavement surface as it is placed using a mil thickness gage as required in project specifications.	
5.4	Document total quantity of material used from metering devices on installation vehicle. Verify if quantity of material used corresponds to anticipated quantity based on placement area and mil thickness requirement.	
5.5	Manual application of small areas: a) Check that resin binder is properly proportioned and thoroughly blended before being deposited on pavement surface. b) Check that resin binder is spread with notched squeegees to the uniform thickness	

	specified in the project requirements over the placement area. c) Check that resin binder is not sheeting or running across the lane or down the pavement grade before aggregate is applied. d) Check that no foot traffic other than spiked shoes are allowed on uncovered resin binder.	
5.6	Check that no vehicular traffic is allowed onto the surface prior to curing of the resin binder.	

6 Aggregate Application

Item	Item Description	Status
6.1	Check that aggregate is applied onto the resin binder within the time required in the project specifications.	
6.2	Check that aggregate is applied in a manner that it does not disturb the resin binder	
6.3	Check for dryness and cleanliness (substantially free of dust and foreign matter) of aggregate as it is deposited.	
6.4	Check for uniformity of placement across the lane.	
6.5	Check for aggregate placement until refusal over resin binder.	
6.6	Check that any exposed resin binder and “wet” areas that appear are covered.	
6.7	Document total quantity of material used from installer records. Verify if quantity of material used corresponds to anticipated quantity based on placement area.	

6.8	Manual Placement of small areas: a) Check that aggregate is deposited onto the exposed resin binder within the time required in the project specifications. b) Check that aggregate is broadcast such that it does not disturb the resin binder.	

7 Aggregate Removal

Item	Item Description	Status
7.1	Check that resin binder has reached adequate cure prior to sweeping (verify that resin binder is not soft and that aggregate does not pull out of resin binder).	
7.2	Document timing of aggregate removal with respect to completion of HFST placement.	
7.3	Check that aggregate removal using a vacuum or power brooms is not damaging the HFST surface and exposing the underlying pavement.	
7.4	Check that surface is free of loose aggregate after completion of all aggregate removal.	
7.5	Check for and document any areas where underlying pavement is exposed after aggregate removal.	

8 Opening to Traffic and Acceptance Testing

Item	Item Description	Status
8.1	Check for any remaining loose aggregate.	
8.2	Check for any “soft” areas in the HFST surface where resin binder may not have fully cured.	
8.3	Check for and document any discolored areas in HFST surface.	
8.4	Check for and document any areas where HFST is missing and needs to be patched.	
8.5	Check for replacement of pavement markings (temporary or permanent) as required in the project plans and specifications.	
8.6	Verify that masking has been removed from drainage inlets, manhole and valve covers.	
8.7	Check for loose aggregate on any adjacent untreated lanes and paved shoulders, and untreated pavement before and after the treated area.	
8.8	Verify the plan for acceptance testing and check that acceptance testing is performed in accordance with project specifications.	

8.9	Check acceptance testing result for conformance with project specifications.	

9 Post-Installation

Item	Item Description	Status
9.1	Monitor aggregate shedding over the first several days after installation and note any excessive build-up of loose aggregate within the treated lanes or on adjacent surfaces. Ensure loose aggregate is promptly removed if it presents a safety hazard.	
9.2	Check that surface is re-swept within two weeks after initial placement to remove loose aggregate.	
9.3	Monitor the HFST surface for discoloration, delamination, cracking, and other distresses.	

ADDITIONAL RESOURCES

Image source: The Transtec Group

FHWA Frequently Asked Questions for HFST
https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/faqs_links_other/hfst_faqs/

FHWA Technical Advisory for Pavement Friction Management (T 5040.38)
https://www.fhwa.dot.gov/pavement/t504038.cfm

FHWA Office of Safety HFST website
https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/high_friction/

FHWA/ATSSA Videos
6 min. version: https://www.youtube.com/watch?v=HVzS-VkABPE
20 min. version: https://www.youtube.com/watch?v=V860pC6ncAY

ATSSA HFST Technical Services
https://www.atssa.com/Technical-Services/High-Friction-Surface-Treatment

ATSSA HFST Inspection and Installation Training Course

https://www.atssa.com/Training/Find-a-Course/High-Friction-Surface-Treatment-Inspection-and-Installation#/qbeld/Web_HFS_Events

Pennsylvania DOT HFST Videos

https://www.youtube.com/watch?v=YE5N8WiAp24

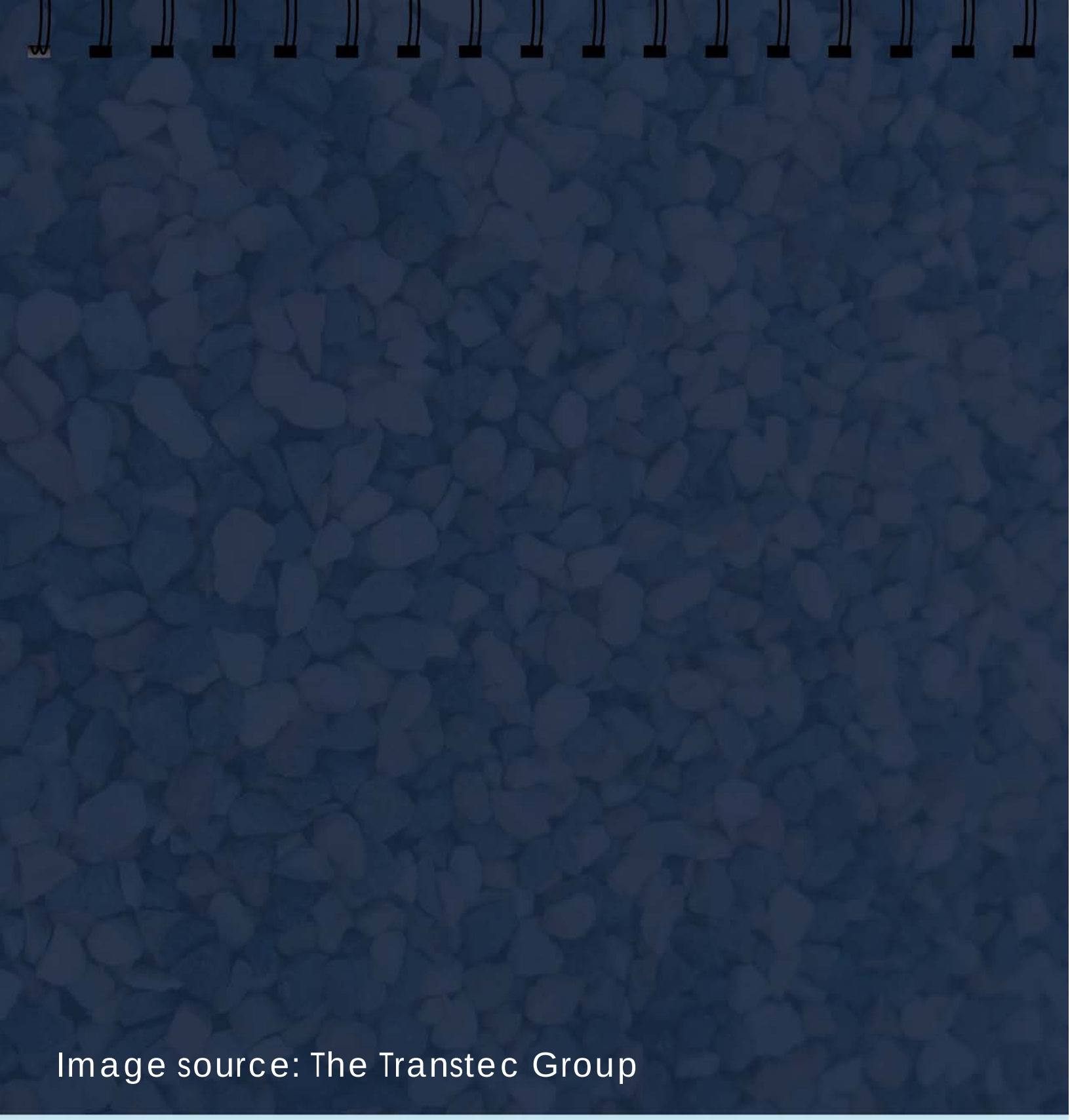
https://www.youtube.com/watch?v=Sn34DAynjCE

Oklahoma DOT HFST Video

https://www.youtube.com/watch?v=gWajb4Vz38Q

Florida DOT High Friction Surface Treatment Guidelines

https://www.fdot.gov/docs/default-source/materials/pavement/performance/ndt/documents/hfstguidelines.pdf



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