High Friction Surface Treatment (HFST) Quick Reference

Source: FHWA.

U.S.Department of Transportation
Federal Highway Administration

DTFH61-13-D-00001, Task B9
April 2020

Contents

- Introduction to HFST.
- Applications for HFST.
- HFST Site Selection.
- HFST Specifications.
- HFST Materials.
- HFST Installation.
- HFST Inspection.
- HFST Testing and Acceptance.
- HFST Performance Monitoring.
- Additional Resources.

Introduction to HFST

HFST is a pavement surface treatment consisting of a *polymer resin binder* used to bond a 1–3 mm nominal-size *polish- and abrasion-resistant aggregate* to the pavement surface.

HFST is a *safety treatment* used specifically to *restore or enhance the friction* of virtually any pavement surface in order to reduce roadway departure crashes.

HFST provides a level of friction generally not achievable with conventional paving materials and *sustains this high level of friction over time*.

HFST friction is provided through *exceptional microtexture* of the aggregate particles and *high macrotexture* of the finished surface.

Source: FHWA.

Introduction to HFST

HFST is typically used as a *spot treatment* to treat targeted *locations with high friction demand*, rather than for longer sections of pavement.

HFST is a *low-cost safety treatment* when compared to the cost of repaving or realignment of curves and ramps. Benefit/cost ratios as high as 18 have been reported for HFST.

HFST is effectively a topical treatment that will *not reduce overhead clearance or change the cross-slope* of a roadway.

HFST can be installed during short lane closures and can enable lanes to *be opened for traffic quickly.*

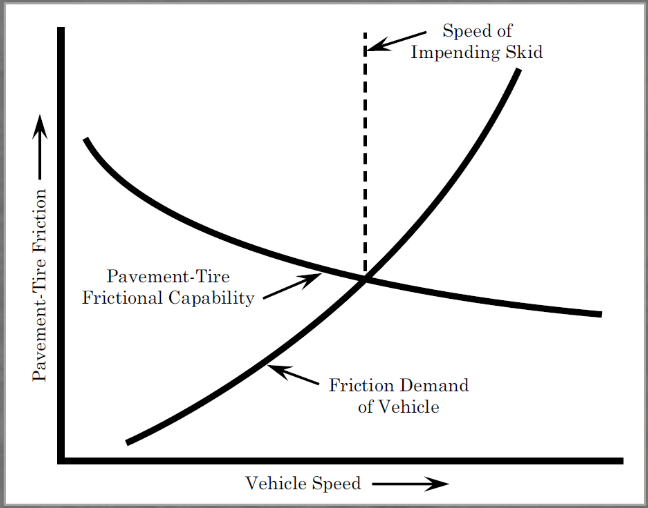
Source: FHWA.

Applications for HFST

HFST provides the most benefit for locations with high friction demand. *Friction demand is the level of friction needed to safely perform braking, steering, and acceleration maneuvers.*[1]

For horizontal curves, *friction demand is affected by vehicle speed, curve radius, and superelevation rate*. Friction demand increases as speed increases and curve radius or superelevation rate decrease.

For noncurve and other high-risk locations (steep grades, intersection approaches, pedestrian crossings, etc.), *friction demand is driven by the ability to perform short-term maneuvers, such as sudden braking, lane changes, and minor changes in direction within a lane.*[2]



Source: FHWA.

Conceptual Relationship Between Friction Demand, Speed, and Friction Availability.[1]

Applications for HFST

Wet weather conditions can significantly reduce a pavement's ability to supply adequate friction at locations with high friction demand.

A water film thickness of 0.002 inches reduces the tire-pavement friction by 20 to 30 percent of the dry surface friction.[3]

From 2007–2016, *12 percent of fatal crashes* (76 percent of weather-related fatal crashes) occurred on wet pavement.[4]

Research conducted by the National Transportation Safety Board and the Federal Highway Administration (FHWA) indicates that up to *70 percent of wet pavement crashes can be prevented or minimized with* improved pavement friction.[5]

Applications for HFST

Primary applications for HFST include:

- Horizontal curves with radii less than 1,500 ft or curves lacking adequate superelevation for prevailing speed.
- Curve ramps with radii less than 1,500 ft or ramps terminating at intersections.
- Approaches to intersections, particularly those with limited stopping sight distances.
- Steep grades (greater than 10 percent).
- Other high-risk locations such as pedestrian crossings, tunnels, etc.

HFST Site Selection

HFST locations are typically selected based on high crash rates, although HFST has also been used as a systemic treatment countermeasure.

HFST is most effective in reducing run-off-road (ROR) and wet-weather crashes (all types), but has also been shown to reduce dry-weather and head-on side-swipe opposite direction (HOSSOD) crashes.

Crash Modification Factors for HFST on Curves from the Current Development of Crash Modification Factors (DCMF) Study

Crash Type	Observed Crashes After Treatment	Empirical Bayes Expected Crashes After Treatment	Crash Modification Factor	
			Estimate	*Standard Error*
Total	329	767.84	0.430	0.028
Injury	106	205.02	0.515	0.037
ROR	92	333.49	0.279	0.032
Wet-Road	82	495.54	0.168	0.020
HOSSOD	59	81.29	0.691	0.105

Source: FHWA.

HFST Site Selection

Friction testing should be used to verify if pavement friction is inadequate for prevailing site conditions (i.e., friction demand).

Pavement friction within curves may be lower than the friction of the abutting tangent and should be evaluated.

Continuous friction measurement equipment (CFME) devices can be used to identify change or variation in friction through curves.

Friction tests with conventional devices, such as the locked-wheel skid trailer (LWST), will only measure friction over approximately 60 ft of pavement at 40 mph test speed, and therefore may not be able to detect variation in friction through curves.

LWST testing can also be a challenge in tight-radius curves, ramps, and intersections.

Source: FHWA.

FHWA's Dynatest Highway Friction Tester CFME.

HFST Site Selection

Pavement condition should be surveyed to determine if a location is a suitable candidate for HFST. In general, HFST should not be applied to highly distressed pavements exhibiting:

- Fatigue-related cracking (alligator and block cracking).
- Deep rutting (> 0.25 inch).
- Raveling or surface bleeding.
- Debonding of surface layers.
- Durability-related cracking or spalling.
- Shattered slabs.

In general, HFST should not be applied to open-graded surfaces unless measures are taken to prevent the HFST from blocking water flow within the pavement surface.

HFST Specifications

Primary components of HFST specifications include:

- Quality control plan requirements.
- Material properties for resin binder and aggregate.
- Sampling and testing methods.
- Packaging and materials certification.
- Surface preparation requirements.
- Resin binder and aggregate installation requirements.
- Acceptance requirements.
- Test strip requirements.

Optional components may include:

- Installation methodology.
- Inspector training requirements.
- Warranty/performance guarantee provision.

Guide specification: American Association of State Highway and Transportation Officials (AASHTO) MP 41-19.[6]

HFST Materials

Resin binder is what bonds the HFST aggregate to the pavement surface. The binder does not provide any frictional properties itself, but securely holds the aggregate in place. Low modulus epoxy and polyester polymeric resins are the primary materials currently used in the United States, but methyl methacrylate (MMA) has also been demonstrated to be effective.

Aggregate is what provides the frictional properties of the HFST. The aggregate must be a hard and durable material that will not polish under traffic over time. Calcined bauxite has a proven record of providing the desired initial and long-term friction necessary for HFST and is also what is required in the current AASHTO and most State highway agency specifications.

HFST Materials

AASHTO specification requirements for refractory grade calcined bauxite aggregate.[6]

Property	Test Method	Requirements
Resistance to Degradation		
Micro-Deval	ASTM D7428	3% Max.
Backup to Micro-Deval (modified Los Angeles Abrasion)	AASHTO T 96	20% Max.
Aggregate Grading	AASHTO T 27	Percent Retained
No. 4 Sieve		0% Max.
No. 6 Sieve		5% Max.
No. 16 Sieve		5% Min.
Moisture Content	AASHTO T 255	0.2% Max.
Aluminum Oxide	ASTM E 1621	87% +/-2%

HFST Materials

AASHTO specification requirements for resin binder vary slightly for epoxy, polyester, and MMA.[6] Key properties for the resin binder are:

- Viscosity.
- Flash Point.
- Gel Time.
- Compressive Strength (3 hours, 24 hours, 7 days).
- Compressive Modulus.
- Tensile Strength (7 days).
- Tensile Elongation.
- Absorption.
- Type D Hardness.
- Thermal Compatibility.
- Infrared Spectrum.

Some agencies require resin binders to be preapproved prior to use on a project.

HFST Materials

Materials-related factors affecting HFST performance:

Resin Binder Formulation and Compatibility:

- Resin binder must have the ability to securely hold the aggregate in place after curing.
- Resin binder must be compatible with the underlying pavement surface, providing a strong bond with the pavement.

Clean and Dry Aggregate:

- Dirty or dust-coated aggregates will not bond well with the resin binder.
- Aggregates must also be at least surface dry in order to properly bond to the resin binder.

HFST Installation

Continuous, fully-automated installation methods are required by most State highway agencies. Automated installation helps ensure proper metering, proportioning, and mixing of resin binder components; uniform placement of the resin binder to the required thickness; and uniform and timely placement of aggregate onto the resin binder.

Most agencies will permit manual application for small areas (< 300 square yards) where it is not practical or possible to use fully-automated installation methods.

Source: FHWA.

HFST Installation

Installation-related factors affecting HFST performance:

Surface Preparation:

- Pavement surface must be clean and dry, and free of any surface moisture and latent dust on the surface prior to placement of the resin binder.
- Pavement surface must have adequate macrotexture, such that a mechanical bond is provided with the resin binder. For concrete surfaces, shotblasting is required to achieve the necessary macrotexture.
- Pavement markings must be removed or masked as required to ensure HFST bond is not inhibited.

Resin Binder Proportioning, Mixing, and Curing:

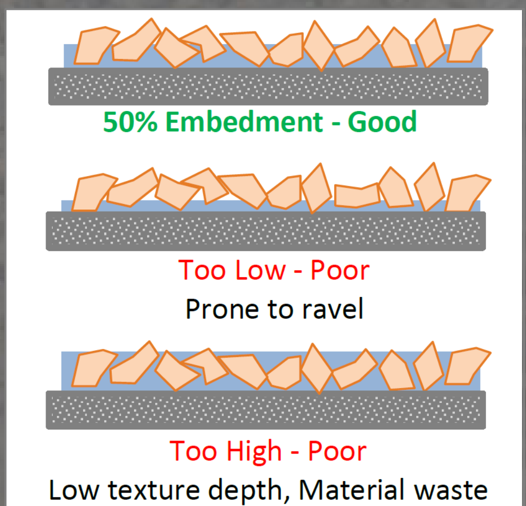
- Resin binder viscosity, gel time, and cure time are highly dependent upon ambient and pavement temperature.
- Resin binder components must be properly proportioned and thoroughly mixed in accordance with the resin binder manufacturer's requirements for prevailing temperature conditions to ensure proper curing.
- Resin binder must thoroughly cure and not exhibit soft areas prior to opening to traffic.

HFST Installation

Installation-related factors affecting HFST performance:

Adequate Resin Binder Thickness:

- Resin binder thickness should be nominally 50 percent of the maximum aggregate size.
- Resin binder thickness is highly dependent on pavement macrotexture with coarse-textured surfaces generally requiring more resin binder to achieve the required thickness.



Importance of proper resin binder thickness and aggregate embedment.[7]

Example of proper resin binder thickness and aggregate embedment.

HFST Installation

Installation-related factors affecting HFST performance:

Aggregate Broadcast Timing:

- Aggregate must be deposited into the resin binder in a timely manner such that the aggregate embeds into the resin binder before it begins to gel.
- Gelled resin binder will resist aggregate penetration, and 50 percent embedment will not be achieved.

Sweeping and Opening to Traffic:

- Excess aggregate should not be swept until the resin binder has cured enough to securely hold the aggregate in place.
- HFST should not be opened to traffic until the resin binder has fully cured and the aggregate will not be dislodged by traffic.
- Inspection.

HFST Inspection

Key inspection items during HFST installation:

Materials:

- Aggregate packaging—material source, properties, batch number, etc.
- Resin binder packaging—component identification, properties, batch number, expiration date, storage requirements, etc.
- Material sampling and testing requirements and/or manufacturer certification.

Surface Preparation:

- Removal of striping/pavement markings as specified in project plans.
- Repair of distresses (crack sealing, etc.) as specified in project plans.
- Cleaning and roughening (e.g., shotblasting) of pavement surface as specified in project plans.
- Protection of prepared surface prior to HFST placement.

HFST Inspection

Key inspection items during HFST installation:

Resin Binder Proportioning and Mixing:

- Metering of the resin binder component materials.
- Thorough mixing of the resin binder components.
- Consistency of the resin binder throughout placement.

Aggregate Placement:

- Aggregate cleanliness and dryness.
- Timing of aggregate placement to ensure embedment in the resin binder.
- Application rate—to refusal—onto the resin binder.
- Covering any resin binder that bleeds through the aggregate layer after initial placement.

Removal of Excess Aggregate:

- Timing of removal to ensure resin has adequately cured.
- Complete removal to ensure no loose material remains.

HFST Inspection

Key inspection items during HFST installation:

Preparation for Opening to Traffic:

- Remove masking from striping, pavement markers, joints, drainage inlets, etc.
- Replace pavement striping/markings (temporary or permanent) as required in project plans.
- Final surface check for uncured resin and loose aggregate.
- Sweep adjacent lanes or paved shoulders to remove loose aggregate.

Repairs:

- Repair any areas where HFST is missing.
- Remove and replace any HFST where resin binder has not cured.

Resweeping:

- Monitor surface for loose aggregate from shedding after opening to traffic as needed and resweeping as needed.

HFST inspection and installation training is available from the American Traffic Safety Services Association (ATSSA).[8]

HFST Testing and Acceptance

Acceptance testing typically consists of friction testing within 30–90 days after installation. Testing immediately after installation can produce artificially high results as the HFST requires a wear-in period under traffic before friction values stabilize.

Friction testing is typically performed with the ASTM E274 LWST or ASTM E1911 Dynamic Friction Tester (DFT).

Some agencies also require testing for macrotexture depth (mean profile depth or mean texture depth).

Acceptance requirements may also include:

- Patching of any areas missing HFST.
- Removal and repair of any defective areas (uncured resin, discolored or nonuniform surface).
- Sweeping of loose aggregate from paved shoulders and adjacent lanes.
- Replacement of striping and other pavement markings prior to opening to traffic.

HFST Performance

A properly installed HFST should last at least 5–7 years under most conditions, and even longer under lower traffic exposure and on newer pavements.

Key performance indicators to monitor over time include:

- Aggregate loss—exposing resin binder and underlying pavement.
- HFST delamination—peeling off pavement surface in sheets.
- Aggregate polishing.
- Surface wear leading to loss of HFST and exposing underlying pavement.
- Friction loss—sustained reduction in friction over time.
- Underlying pavement failure leading to failure of the HFST.

HFST Performance

Friction performance (as measured by the FHWA High Friction Tester CFME device) from the current DCMF study.[9]

State	Number HFST Sites Tested	HFT Friction Range and Average (40 mph)	Age of HFST at Testing (Months)	Annual Average Daily Traffic for HFST Sites	Estimated Total Traffic Exposure (Millions of Vehicles)
AR	17	**0.84–1.0** **Avg. = 0.95**	11–24 Avg. = 16	1,700–30,000 Avg. = 9,635	0.39–5.85 Avg. = 2.62
GA	125	**0.74–1.0** **Avg. = 0.97**	2–27 Avg. = 7	160–15,600 Avg. = 2,540	0.01–5.35 Avg. = 0.51
KY	44	**0.84–1.0** **Avg. = 0.97**	18–78 Avg. = 49	1,024–69,619 Avg. = 7,897	0.51–28.31 Avg. = 5.6
LA	27	**0.89–1.0** **Avg. = 0.97**	< 18	1,190–4,800 Avg. = 2,412	Estimated Range: 0.04–2.59
PA	61	**0.84–1.0** **Avg. = 0.95**	1–119 Avg. = 23	1,080–219,752 Avg. = 10,074	0.04–25.27 Avg. = 2.54
WV	11	**0.77–1.0** **Avg. = 0.90**	5–73 Avg. = 44	2,335–107,000 Avg. = 36,890	0.32–20.33 Avg. = 8.2

Source: FHWA.

Friction values for new HFST (as measured by the HFT device) will typically range from 0.9 to 1.0.

Additional Resources

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 minute version: https://www.youtube.com/watch?v=HVzS-VkABPE

20 minute version: https://www.youtube.com/watch?v=V860pC6ncAY

Additional Resources

FHWA HFST Curve Selection and Installation Guide
https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/faqs_links_other/hfst_guide/

Florida Department of Transportation (DOT) HFST Guidelines: Project Selection, Materials, and Construction
https://www.fdot.gov/docs/default-source/content-docs/materials/pavement/performance/ndt/documents/hfstguidelines.pdf

Case Study: Kentucky Transportation Cabinet's HFST and Field Installation Program
https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/case_studies_noteworthy_prac/kytc/

Texas Curve Margin of Safety (TCMS) Analysis Tool
https://tti.tamu.edu/documents/0-6714-1.pdf

Additional Resources

Pennsylvania DOT Publication 408, Section 659-HFST
https://www.penndot.gov/ProjectAndPrograms/Construction/Pages/ConstructionSpecifications.aspx
This is one example of a mature HFST specification from an agency with a long-standing HFST program.

AASHTO National Transportation Product Evaluation Program (NTPEP) for High Friction and Thin Overlays (HFTO)
https://data.ntpep.org/HFTO/Products

National Center for Asphalt Technology HFST Alternative Aggregates Study
https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep15-04.pdf

References

1. AASHTO. (2008). *Guide for Pavement Friction,* Washington, DC.
2. AASHTO. (2018). *A Policy on Geometric Design of Highways and Streets,* Washington, DC.
3. AASHTO. (2008). *Driving Down Lane-Departure Crashes,* Washington, DC.
4. FHWA. (2019). *Federal Highway Administration*, Road Weather Management Program, Washington, DC, obtained from: https://ops.fhwa.dot.gov/weather/q1_roadimpact.htm, last accessed July 2019.
5. FHWA. (2019). *Federal Highway Administration*, Office of Safety Pavement Friction, Washington, DC, obtained from: https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/index.cfm, last accessed July 2019.

References

6. AASHTO. (2019). *MP 41-19, Standard Specification for High Friction Surface Treatment for Asphalt and Concrete Pavements Using Calcined Bauxite,* Washington, DC.
7. Florida DOT. (2016). *High Friction Surface Treatment Guidelines: Project Selection, Materials, and Construction,* Gainesville, FL.
8. ATTSA. (2019). *ATSSA HFST Inspection and Installation Training,* Fredericksburg, VA, obtained from: https://www.atssa.com/Training/Find-a-Course/High-Friction-Surface-Treatment-Inspection-and-Installation#/webForm/Web_HFS_Events, last accessed August 2019.
9. Merritt, D., R. Tallon, R. Watson. (2019). *Development of Crash Modification Factors for High Friction Surface Treatment: Friction Change Report.* FHWA, Washington, DC, (currently unpublished).

Disclaimer

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers’ names appear in this presentation only because they are considered essential to the objective of the presentation. They are included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.

This research is supported in part by the U.S. Department of Transportation Federal Highway Administration.