Make the following Section a part of the Standard Specifications:

"SECTION 421 – HIGH FRICTION SURFACE TREATMENT

421.01 Description. This section describes furnishing and applying a high friction surface treatment (HFST) system on a prepared surface as specified and in conformity with the lines and details shown on the plans.

421.02 Materials.

(A) General. Use a two-part modified exothermic epoxy or polymer resin binder treatment containing epoxy or polymer binder capable of retaining a bauxite aggregate topping under vehicle conditions. Reference to epoxy binder herein refer also to polymer binder unless otherwise specified.

(B) Epoxy or Polymer Binder: The epoxy binder shall consist of a thermosetting modified epoxy compound which holds the aggregate firmly in position. The epoxy binder shall meet the requirements in TABLE 421.02-1 EPOXY OR POLYMER BINDER requirements.

TABLE 421.02-1 EPOXY OR POLYMER BINDER

Property	Requirements	Test Method
Ultimate Tensile Strength	2,500 psi min.	ASTM D638
Compressive Strength	1,600 psi min.	ASTM D695
Gel Time	10 minutes min.	ASTM D2471
Water Absorption	Less than 0.50%	ASTM D570
Shore Hardness	65 min.	ASTM D2240
Viscosity	3,000 Mpa	ISO 2555
Cure Rate	3 hours max.	Thin Film @ 75 ºF
Mixing Ratio	*	n/a

*As recommended by the Manufacturer

Two-part epoxy materials which are not exothermic in curing and do not meet the viscosity requirements will not be allowed. Independent laboratory report documents shall be current, not older than 12 months old, and shall provide documentation that the epoxy binder meets the requirements in this section.

(C) Aggregate Topping: The aggregate topping shall be a calcined bauxite consisting of a 1-3 mm nominal-size polish- and abrasion-resistant aggregate. The aggregate will be delivered to the construction site in plastic wrapped bags or super sacks, with Manufacturer's information clearly labeled. Wrapping shall protect from moisture and contamination to

maintain aggregates clean, dry, and free from foreign matter. The aggregate shall meet the requirements in TABLE 421.02-2 AGGREGATE REQUIREMENTS.

TABLE 421.02-2 AGGREGATE REQUIREMENTS		
Property	**Requirement**	**Test Methods**
Aggregate Abrasion Value	10% max.	LA Abrasion Test
Moisture Content	0.2% max.	AASHTO T255
Aluminum Oxide	87% min.	ASTM C25
	Sieve Designation	**Requirement**
Aggregate Gradation	No. 6 Sieve Size	95 % min. Passing
	No. 16 Sieve Size	5% max. Passing

(D) Certification. Submit certification from the manufacturer that the aggregate meets the above requirements. Submit documentation of the in-place friction characteristics (minimum 65 FN40R in accordance with ASTM E274) of aggregate bonded to a vehicular bearing surface using the modified epoxy binder. Submit a list of projects with owner contact information on which a minimum of 3,000 square yards of HFST has been placed within the past three years. Records shall show binder, equipment and operator shall be the same as applied in those years as well as it being the same for this project.

(E) Storage of material. Materials shall be stored in accordance to the manufacturer's recommendations.

Safety Data Sheet (SDS), Product Data Sheet, and other information pertaining to the safe practices for the storage, handling, and disposal of the materials, and to their health hazards shall be obtained from the manufacturer and posted at storage areas and shall be submitted to the Engineer.

421.03 Construction.

(A) General: Submit a project-specific QC plan with the following:

- Surface preparation methods for areas where HFST is to be placed.
- Method of protecting areas and exposed facilities not to receive HFST.
- Method of protecting and reestablishing existing longitudinal and transverse joints and working cracks in concrete pavements and structures.
- Type of binder to be used.
- Certified instruments to assure that the ambient conditions are compliant. Wet film thickness gauge to make thickness measurements of the binder.

- Binder manufacturer's recommended mixing and placement instructions, including mixing ratios and temperatures.
- Binder manufacturer's estimated cure times for resin binder to be used using anticipated local ambient temperatures.
- Method for safe storage and handling of HFST components.
- Disposal methods for excess HFST, debris, and containers for HFST components.
- Contingency plan that describes corrective actions to be taken in the event of equipment failure or material issues, etc. during HFST placement
- Corrective actions to address irregularities or unsatisfactory final surface.

1. **Training.** QC plan must be submitted to the Engineer and accepted before training can be held. The HFST manufacturer's representative, who must be knowledgeable about the components of the HFST and its installation must train HDOT, the contractor's personnel, e.g., supervisor, foreman, operator, workers who will be involved in the HFST installation. Handouts shall be provided. The manufacturer's representative shall report to the construction site prior to surface treatment and shall be present during preparation and application for the test strip and first full location. Complete training a minimum of seven days ahead of the first installation of HFST. Topics of the training to include:
    - Surface Preparation
    - Treatment of cracks and protection of working joints and cracks
    - Acceptable vs unacceptable surface conditions,
    - Acceptable ambient weather conditions, etc.
    - Mixing of the binder
    - Distribution of the HFST binder and HFST aggregate
    - QC procedures to be taken, e.g., wet film thickness measurements, ambient weather conditions, pavement temperature.

2. **Test Strip.** At a location chosen by the Engineer install a test strip of the HFST. The Contractor may suggest suitable test strip locations for acceptance. The test strip shall be done before production installation of the HFST is started. The manufacturer's employed representative shall be present at the installation of the test strip. The test strip shall use all the personnel, material, equipment, i.e., means and methods the Contractor intends to use during the production of the HFST. The test strip shall demonstrate the Contractor's ability to do HFST work that meets the requirements of the Contract Documents. The Engineer may reject or deem the test strip acceptable with comments. Adjust means and methods to address the engineer's comments, or if considered extra work requiring a contract change order and additional cost or contract

time or both inform the Engineer in writing.

Construct test strips of 50-linear feet minimum length by one lane minimum width of the lanes within the project area. The test strip shall demonstrate the hand or mechanical application method or both if both application method is to be used and for application on AC and PCC pavements. In those cases, four test strips shall be constructed. When a mechanical method is used, check that the machine has been properly calibrated. Verify application rates and cure time. No HFST production installation shall take place until an acceptable test strip for the method used is installed. The test strip will be part of the HFST quantity of the project when accepted by the Engineer. If the test strip is not found acceptable, remove and restore test strip area. This shall be at the Contractor's cost and no additional contract time will be given. Redo the test strip until it is acceptable to the Engineer. Conduct a post-installation meeting with the manufacturer's representatives, HDOT, and the Contractor's personnel after the installed test strip area has been open to traffic, and HDOT has had an opportunity to inspect the test strip area.

3. HFST installation work must not start if any of the following conditions exist:

- Pavement surface preparation is not acceptable to the Engineer
- Pavement surface is wet
- The ambient and/or surface temperature is below 40 ºF or above 105º F, or when the anticipated weather conditions would prevent the proper application of the surface treatment as determined by the manufacturer's representative. Conditions include rain within 6 hours of application, or is forecast over 40%. Recommend waiting at least 24 hours after rain before application.

For unaccepted HFST application, square the end of the accepted HFST making an edge of the last finished HFST. Remove the remaining unfinished HFST material in a manner that will not impact the newly placed HFST or the installation of the HFST that will be placed over the area.

(B) Preparation. Surfaces shall be clean, dry and free of all deleterious materials e.g. dust, oil, debris, tar, prior crack treatment etc. and any other material that might interfere with the bond between the HFST material and existing surface before the start of HFST application.

Use detergent or cleaners, and water to remove oil, remove detergent/cleaner-water liquid from the pavement surface to a degree that it does not affect the bonding properties of the binder to the pavement. A 4,000-psi minimum, hydropower washer, i.e., water blasting system may also be used to clean and remove oil and other deleterious material from the pavement's surface. Allow pavement to dry to the required maximum

allowable pavement moisture, before application of HFST.

The texture of the concrete surface profile of the portland cement concrete surfaces must be achieved by shot blasting or hydrodemolition. Shot blasting and hydrodemolition equipment must be equipped with a fully functioning vacuum recovery of shot or water and debris. When using hydrodemolition the pressure at the nozzle must be approximately 25,000 psi minimum or an Engineer accepted pressure needed to achieve the required textures. The nozzles must be in close proximity to the pavement surface.

Existing asphalt pavement surfaces that have a seal coat or a dense mix design or embedded with dirt or both and pavement with potentially detrimental contaminants must be prepared by shot blasting or water blasting.

Clean the concrete or asphalt pavement surfaces by using dry, oil-free compressed air (185 cfm min) and mechanical broom or with vacuum to remove all dust and other loose material. Grind, shot blast, or hydrowash any remaining concerned areas. Perform a final blowdown using 185 cfm dry, oil-free compressed air. Adequate cleaning of all surfaces will must be determined by the manufacturer's employed representative and the Engineer, or the solely the Engineer in the absence of the manufacturer's representative.

Check pavement before and after cleaning for conditions that must be addressed before application of HFST. The conditions to be addressed and recorded only and is not intended to be included within the scope of this project. Conditions include, but are not necessarily limited to:

Asphalt pavement

- Rutting that is 0.25 inches or deeper.
- Raveling of the surface course.
- Bleeding surface mix.
- Cracking in or outside the wheel path that covers 6 percent or more of the surface.

Concrete pavement, slab replacement is required for:

- Any single slab with moderate or severe distress (transverse cracking, longitudinal cracking, patching, spalling, and corner cracking).
- Any single shattered slab in more than 3 pieces.
- Cracking in or outside the wheel path that covers 6 percent or more of the surface.

Slab replacement must be a full-depth repair with dowels and tie-bars. The repair area must be from the existing joint to the existing joint.

Protect utilities, drainage structures, curbs, joints and any other structure within or adjacent to the treatment location against the application of the surface treatment materials.

Remove by grinding or using a high-pressure water blasting/hydro-blasting system with vacuum recovery of water and debris all permanent

and work zone pavement markings that conflict with the surface application.

All wet areas must be left to dry, squeegeed, and if needed, dried with a hot torch air blaster lance/heat lance or similar drying tool, accepted by the Engineer. All drying of the pavement must be completed satisfactorily before the application of HFST starts. Pavement Marking tape may be peeled or burned off; however, all remnants or burn marks must be hydro-blasted.

Remove all pavement markings debris with a mechanical broom with vacuum recovery of water and debris. Fill all depressions caused by the removal of the pavement markings with a binder material, letting it set before proceeding with the application of the HFST. The pavement surface cleaning must be followed by a final blowdown using 185 cfm minimum dry, oil-free compressed air before the start of the HFST application.

Pre-treat joints and cracks, other than Portland cement concrete working joints, greater than 1/4 inches in width and depth, and as directed by the Engineer, with the mixed epoxy specified herein. Treatment of joints and cracks shall be in accordance with the manufacturer's employed representative.

HFST application must not start until the binder in the pre-treated joints and cracks has gelled. Consider, be attentive to, and make accommodations for conditions that may affect gel time of the binder. e.g., long runs, pavement temperature, ambient temperature since gelling can occur faster with warmer temperatures.

The installation of HFST must not start for application on new underlying and adjacent to new asphalt concrete or portland cement concrete pavement surfaces, including patches or repair areas using those materials until a minimum of 30 days after completion of the pavement or repair.

(C) Mixing and Application of Epoxy Binder and Aggregate Wearing Surface. Utilize one of the following methods for application of the binder and aggregate wearing course, as applicable. Use instruments to assure that the ambient conditions are compliant. Take measurements immediately before and during the application of the HFST binder. Using a wet film thickness gauge make thickness measurements during the application of the binder and perform every 50 linear feet.

1. **Hand mixing and application.** Method must be used only for:
   - Low volume application areas, e.g., intersections, areas less than 250 square yards, or
   - Where truck mounted machines cannot be used due to the specified location's logistical restrictions.

Proportion the two-part modified epoxy base binder components, Part A and Part B to the correct ratio as recommended by the Manufacturer and mix using a low speed, high torque drill fitted with a helical stirrer. The stirrer shall be a Jiffy Mixer or an Engineer accepted equivalent.
Manually apply the mixed components onto the prepared pavement surface at a thickness of 60 mil +/- 5 mils Uniformly spread the hand applied base binder onto the substrate. The average wet thickness must be approximately 60 mils. Spread the binder by hand onto the substrate using a method that will generally achieve a uniform thickness of 60 mils. Immediately, spread the high friction surfacing aggregate onto the two part modified epoxy binder, at a minimum rate of 13 lbs/sy and at a saturation state where no wet spots appear. Ensure leveling of HFST liquid is not disturbed. Ensure that the aggregate distribution method leaves no holidays in the aggregate distribution pattern spread and has a uniform look to it. The aggregate application shall cover the entire area of the binder application. Check thickness of HFST liquid using a mil gauge every 50 linear feet.

2. Mechanical mixing and application. Apply the binder by a truck mounted application machine. The binder must be applied onto the pavement section to be treated across the entire lane width and at a uniform compliant application thickness. Do not allow the epoxy base binder material to separate in the mixing lines, cure, dry, or otherwise impair retention bonding or depth of the high friction surfacing aggregate. Apply the mixed components mechanically onto the prepared pavement surface with a uniform thickness of 60 mil +/- 5 mils onto the pavement surface. Within 2 minutes of the binder being applied, mechanically spread the high friction surfacing aggregate onto the installed binder, at a minimum rate of 13 lbs/sy coverage across the full lane width in a uniform continuous application and until saturation such that no wet spots appear. Ensure that the aggregate distribution method leaves no holidays in the aggregate distribution pattern spread and has a uniform look to it. Aggregate application shall cover the entire area of the epoxy binder application without disturbing the leveling of HFST liquid. Check thickness of HFST liquid using a mil gauge every 50 linear feet.

3. For either method hand or mechanical, Do not compact aggregate after placement. Completely cover the wet epoxy binder with aggregate to achieve a uniform surface. No exposed wet spots shall be visible once the aggregate is placed. Wet spots indicate insufficient aggregate being applied; if wet spots are present, add more aggregate to the wet spot immediately upon discovery.

Check thickness of epoxy base binder every 50 linear feet using a mil gauge.

(D) Curing. Allow the binder topped with high friction to cure in accordance with the manufacturer recommendations. Refer to Manufacturer's data/charts for cure times vs temperature. Protect treated surfaces from traffic and environmental effects until the area has cured. The new HFST area must not be open to traffic until it has cured and swept clean of all loose HFST aggregate.

Once cured, remove excess aggregate by mechanical broom, mechanical sweeper with a vacuum followed by compressed air (minimum 185 cfm compressor) before opening to traffic. Excess aggregate can be reused for one reuse time only, provided the aggregate is kept clean, dry and free from contaminants. Recovered aggregate must be blended with new aggregate at a rate of 2:1 (two parts of new HFST aggregate to one part of recovered HFST aggregate). Remove and dispose excess aggregate from project site.

The Engineer may require additional mechanical broom, sweep or vacuum as necessary after the system fully cures and the treated surface is open to traffic. Broom or vacuum immediately before opening to traffic and perform a final sweep 7 to 14 days after opening. Provide traffic control during the cleaning operation.

(E) Pavement Markings. All pavement markings shall be at the height specified in the Contract Documents measured from the HFST surface. Temporary pavement markings must comply with the size and shape shown in the MUTCD and must be in place before the pavement is open to public traffic. Flexible temporary raised pavement markers must not be used in place of raised markers that are shown on Standard Plans TE-26.

(F) Additional Signs. Install traffic warning signage "Loose Gravel", and "Motorcycles Use Caution" or both should conditions require the warning. Maintain signs until street sweep is no longer required by the Contract Documents and the Engineer.

(G) Acceptance and Warranty. Ninety (90) days after construction is completed all HFST applications require a minimum 1.5-year warranty from surface defects. At the end of the warranty period, the Contractor must in the presence of the Engineer inspect for any surface defects attributable to materials, equipment or workmanship. The warranty will comply with Subsection 108.17 Guarantee of Work.

421.04 Measurement. The quantities to be paid for will be the plan quantity, in square yards, completed and accepted. No deduction will be made for the areas occupied by manholes, inlets, drainage structures, pavement markings or by any public utility appurtenances within the area.

421.05 Payment. The Engineer will pay for the accepted high friction surface

treatment at the contract price per square yard as shown on the proposal schedule. All work will be full compensation for the work prescribed in this section and the contract documents.

The Engineer will pay for the following pay item when included in proposal schedule:

Pay Item	**Pay Unit**
High Friction Surface Treatment	Square Yard

Partial Payment Schedule for High Friction Surface Treatment. The Engineer will pay for:

(A) 72 percent of the contract unit bid price upon completion of the installation of the High Friction Surface Treatment and the second sweep of the High Friction Surface Treatment installation performed one week after its installation.

(B) 18 percent of the contract unit bid price in eighteen monthly payment of 1 percent for satisfactory progress during the High Friction Surface Treatment warranty period.

(C) 10 percent of the contract unit bid price at the final acceptance of the High Friction Surface Treatment and the end of the warranty period."

END OF SECTION 421