Accelerated Innovation Deployment (AID) Demonstration Project:

HFST in the Oklahoma City Metropolitan Area

Final Report

January 19, 2015

Oklahoma Department of Transportation

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ACKNOWLEDGEMENTS

FHWA Oklahoma Division was extremely helpful during the entire project and played a key role in organizing meetings and ensuring proper tracking of the project.

Dr. Kelvin Wang of Oklahoma State University and his team provided invaluable assistance by collecting friction and macrotexture data *pro bono*.

All the installations of HFST were performed by DBI Services, subcontractor to PBX Corporation. PBX was contracted for work including intersection modification at ramp terminals adjoining the I-40/Air Depot/29 SE HFST installation site, and installation of an overhead sign in that area, as well as the HFST installations which were tied to those jobs. Both contractors cooperated with observation and data collection efforts.

INTRODUCTION

ACCELERATED INNOVATION DEPLOYMENT (AID) DEMONSTRATION GRANTS

The Federal Highway Administration (FHWA) Accelerated Innovation Deployment (AID) Demonstration grant program, which is administered through the FHWA Center for Accelerating Innovation (CAI), provides incentive funding and other resources for eligible entities to offset the risk of trying an innovation and to accelerate the implementation and adoption of that innovation in highway transportation.

The AID program is one aspect of the multi-faceted Technology and Innovation Deployment Program (TIDP) approach, which provides funding and other resources to offset the risk of trying an innovation. The AID Demonstration funds are available for any project eligible for assistance under title 23, United States Code. Projects eligible for funding shall include proven innovative practices or technologies such as those included in the EDC initiative. Innovations may include infrastructure and non-infrastructure strategies or activities, which the award recipient intends to implement and adopt as a significant improvement from their conventional practice.

Projects deemed eligible for funding included proven innovative practices or technologies, including infrastructure and non-infrastructure strategies or activities, which the applicant or sub recipient intends to implement and adopt as a significant improvement from their conventional practice. The AID Demonstration funds are available for any project eligible for assistance under title 23, United States Code.

Entities eligible to apply included State departments of transportation (DOT), Federal Land Management Agencies, and tribal governments as well as metropolitan planning organizations (MPOs) and local governments which applied through the State DOT as sub recipients.

REPORT SCOPE AND ORGANIZATION

This report documents the Oklahoma Department of Transportation demonstration grant award for the installation of High Friction Surface Treatment (HFST) at three metropolitan Interstate sites using fully automated methods. The report presents details relevant to the employed project innovation(s), the overarching TIDP goals, performance metrics measurement and analysis, lessons learned, and the status of activities related to adoption of HFST as conventional practice by Oklahoma Department of Transportation.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

This project constructed High Friction Surfacing Treatment at multiple locations in the Oklahoma City metropolitan area. This project was an example of innovation in improving pavement friction to reduce run-off-the-road crashes. This project addressed the following TIDP goal: "Improve highway efficiency, safety, mobility, reliability, service life, environmental protection, and sustainability." This request for AID demonstration funding comprised 80% of the project budget. Oklahoma was a roadway departure focus state at the time this project was initiated.

The purpose of the project was to improve safety on three curves (including one reverse curve, specifically by providing increased friction to reduce the chances of off-tracking or loss of vehicle control, and to demonstrate the effectiveness, service life, and installation of this treatment for very high traffic Interstate locations.

LESSONS LEARNED

Through this project, the Oklahoma Department of Transportation gained valuable insights with regard to the innovative construction method used. The following were some of the lessons learned:

- Sealing cracks in the pavement prior to the application of the HFST may be counterproductive. It is known from earlier HFST installations on State Highway 20 in Oklahoma that the epoxy will not adhere to the fog seal if a crack is overfilled, leaving gaps in coverage. On the sites for this project, cracks were not sealed. No deleterious effect on the performance of the HFST due to the cracks could be detected.

- In spite of using a fully automated system to apply the HFST, some manual work had to be done at at least one site to correct for interference with the distribution of both epoxy and aggregate by wind. The use of wind guides should be specified for fully automated HFST application, but this alone might not be sufficient to ensure proper application.

- Application of HFST to concrete pavement presented no difficulties or deficiencies although water blasting was required to prepare the surface.

- ODOT lacked an acceptance process for qualification of the epoxy binder.

- Existing lane striping was covered by the HFST and flex tabs were used for weeks after installation. At the Air Depot/29th St. site, the flex tabs did not remain in place as well as desired. Leaving existing striping in place and uncovered by the HFST might be a preferable option.

- At the Airport Road site, loose aggregate remained on the shoulder after installation. Vacuuming followed by sweeping, of the entire paved width, was therefore recommended for this type of application.

- In order to work on the center lane of these sites, it was necessary to close two lanes at a time. Even at off peak times, severe congestion resulted and at one location the queue reached at least six miles in length, with traffic backing up onto adjoining city streets for unknown distances. In the future it may be desirable to allow work only at night.

PROJECT DETAILS

BACKGROUND

The project involved installation of HFST on four curves at three locations in the Oklahoma City metropolitan area. The method of installation was fully automated. Each of the locations included three through lanes in a single direction. One of the locations was a reverse curve. AADT varied from more than 65,000 to more than 125,000.

HFST is relatively new to Oklahoma, with only two prior locations treated. Both of these were curves on two lane rural highways with low ADT (circa 1,000-2,000 or less). Preliminary results from these locations were promising, with high friction numbers and apparent reductions in crash frequency, but they have not been installed long enough to draw reliable conclusions. All of the locations treated were done using fully automated methods. States such as West Virginia have tried manual methods of application, sometimes with mixed results.

Figure 1 below shows the project locations.

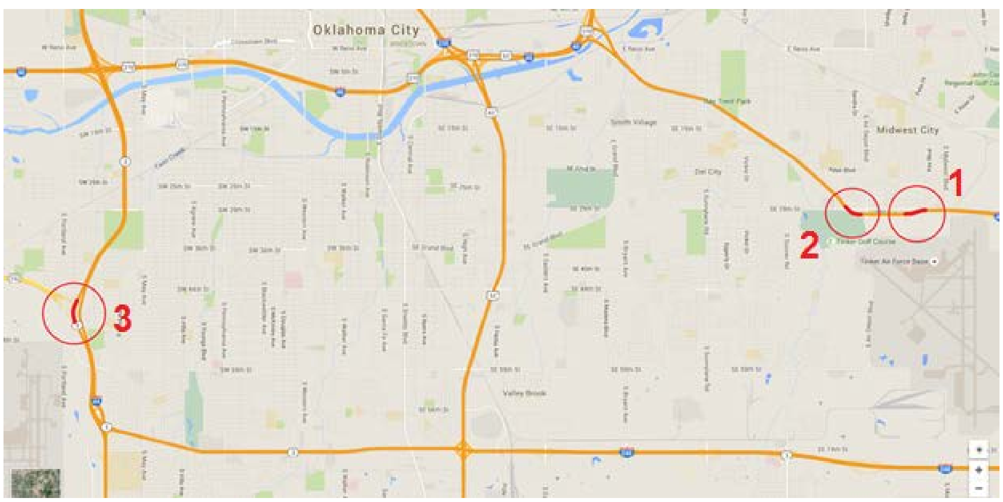

Figure 1. Project locations

Location	On Interstate	Nearby Exits	Direction
1	I-40	157C Town Center Dr./Eaker Gate	Westbound
2	I-40	157B Air Depot Blvd./Tinker Gate & 157A SE 29 St.	Westbound
3	I-44	116B Airport Road/SH-152	Southbound

Table 1. Project Locations

PROJECT DESCRIPTION

Three sites were chosen for the project based on previous crash experience and current pavement condition. One of these sites was the westbound lanes (traveling southbound at this point) of I-44 in the interchange with SH-152 (Airport Road). The other two sites were on I-40 in the Midwest City area, both on the westbound lanes.

Previous applications of HFST in Oklahoma have been limited to two sites on rural two lane highways with low ADT. This project on multi-lane urban interstates will evaluate the durability of HFST under extreme traffic volumes.

HFST was installed on four curves at three locations (including one reverse curve). Each curve had three travel lanes (one direction only). All application was done using a fully automated process. Because of the very high traffic at these locations, work was limited to off-peak hours and weekends, but daylight work was allowed. Only one lane at a time was closed, except when the center lanes were done.

Oklahoma's previous experience with HFST had been exclusively on rural two lane roads with low traffic volume (on State Highway 20 in Mayes County). There were no time restrictions on work at these locations and, due to the brevity of the work, traffic control did not include positive barriers. For the current projects, pavement cracks were not sealed in order to avoid possible loss of aggregate due to failure to adhere to the fog seal material. Except on the concrete bridge deck, the only surface preparation done was sweeping. The concrete bridge deck was water blasted. Existing striping was covered by the HFST without removal, and temporary flex tabs used until the roadways were re-striped.

The following performance measures were established for this project to qualify or quantify the effectiveness of the innovation to inform the AID Demonstration program in working toward best practices, programmatic performance measures, and future decision making guidelines:

1. For each location, crashes will be extracted from the Oklahoma crash database on a yearly basis after installation of the treatment. After a minimum of three years, a picture should begin to emerge that will allow analysts to determine whether a statistically significant reduction in crashes has occurred. It should be noted that due to statistical considerations, no conclusions will be drawn in the six-month report regarding our experience of the efficacy of this treatment. However, the six-month report will be amended as appropriate as crash data are available.
2. Friction numbers will be measured using a skid trailer at the subject locations prior to installation of the HFST.
3. Friction numbers will be similarly measured every six months after installation of the HFST, including immediately thereafter.
4. A visual inspection of the installation will be performed at the same time as friction measurements to monitor any spalling or other dislocation of the aggregate material.

DATA COLLECTION AND ANALYSIS

Performance measures consistent with the project goals were jointly established for this project ODOT and FHWA to qualify, not to quantify, the effectiveness of the innovation to inform the AID Demonstration program in working toward best practices, programmatic performance measures, and future decision making guidelines.

Data was collected to determine the impact of using HFST on pavement friction and traffic safety after installation and demonstrate the ability to:

- Achieve a safer environment for the traveling public and workers
- Reduce overall project delivery time and associated costs
- Reduce life cycle costs through producing a high-quality project
- Reduce impacts to the traveling public and project abutters
- Satisfy the needs and desires of our customers

This section discusses how the Oklahoma Department of Transportation established baseline criteria, monitored and recorded data during the implementation of the innovation, and analyzed and assessed the results for each of the performance measures related to these focus areas.

The ODOT, in coordination with the FHWA OK Division Office, developed this implementation plan for collecting information in support of the identified performance measures.

1. Crash tracking—before installation: Three months after installation crashes will be queried at the subject locations for the previous three and five years. Three months is selected as the initial crash query because there is a lag between crash occurrence and when the crash appears in our database. To ensure lagging crashes aren't skipped, we assume a three-month reporting lag. The criteria for each crash query are listed in item 3.
2. Crash tracking—after installation: At 1 year and 3 months after installation, and for three or more subsequent years thereafter, crashes will be queried at the subject locations.
3. In each case, the crashes queried will be only run-off road and same-direction sideswipe (i.e., lane departure). Note that collisions occurring during icy pavement conditions are excluded, due to the fact that HFST would be completely covered and friction would not be improved. Due to the usual uncertainty in the accuracy of crash locations, the queries extend slightly outside the nominal extent of the curve, but include only crashes reported as occurring on a curve.
4. To ensure consistency in the before and after evaluation of crashes, the query criteria to be used have been saved in SAFE-T using the names "HFST 2015 Site 1 Eaker" etc.
5. Free-flow speed studies will be conducted on the curve at the I-40 & 29th Street location before the project begins, and one month and six months after the installation of an overhead warning sign (with beacons) for the curve. This proposed sign is a complication of the before-and-after HFST study at that location. The purpose of the speed studies is to determine whether the proposed sign is changing driver behavior. It

is hoped that the before-and-after HFST studies may be able to control for the signs with data collected in this step.

6. Friction readings will be collected using standard operating procedure prior to installation, immediately after installation, and subsequently yearly for a minimum of three years. It is intended for friction readings to coincide with the boundaries of the year for which crash data are collected in the event that it is desirable in the future to create a CMF correlated with friction readings.

In addition, friction and macrotexture data were collected by Oklahoma State University using a Grip Tester and an AMES 8300 Survey Pro High Speed Profiler. These data and the skid numbers so far collected by ODOT are presented in Appendix C.

SAFETY DURING CONSTRUCTION

The Oklahoma Department of Transportation is especially concerned with the safety of the workers delivering the project on an Interstate with high traffic and truck volume.

There were no injuries to workers or inspectors during construction. No crashes due to the construction are known. One single-vehicle crash with injury occurred at or near the I-44 site after the completion of the HFST and before replacement of the temporary flex tabs with permanent lane striping. This crash was not reported as being in a work zone and did not involve any workers or work zone appurtenances. The driver admitted to being distracted by a text message.

Historical data to establish the expected safety of a work zone of this (or any other) type do not exist due to a lack of records of spatial and temporal work zone limits. The only basis for comparison is the two HFSTs earlier completed on two lane rural sites. These sites did not experience any accidents during construction but the traffic exposure was also less by an extremely large factor.

Based on overall Statewide crash rates for facilities of this type, the average expected number of crashes for the work sites during the whole period of construction (until completion of striping) would have been 0.66 crashes with 0.21 injury crashes. The reported crash history does not show a statistically significant deviation from this amount.

SCHEDULE

ODOT had no established methods, standards or procedures for friction enhancement, which had not been previously done in Oklahoma except for two recent pilot locations of much smaller size and much lower traffic. Comparison with previous methods of delivery is not feasible.

Installation at one location was delayed because it had both asphalt and concrete pavement and it was thus necessary to bring in water blasting equipment.

COST

The direct financial cost associated with delivery of this project using HFST resulted in a cost of $416,612.88 for the actual HFST only. Costs for traffic control and mobilization could not be isolated as this project was tied to another project reconstructing interchange ramp terminal intersections adjoining to one of the curves, both projects being performed simultaneously.

Oklahoma Department of Transportation has limited previous experience with other projects of this type with which the cost could be compared. Total costs for previous pilot projects were about $50 per square yard of HFST. Costs for this project were about $25 per square yard plus traffic control and mobilization. The Oklahoma Department of Transportation expects that total costs per square yard for HFST on high volume metropolitan Interstates will not exceed total costs per square yard for HFST on rural two lane highways.

No lane rental charges or liquidated damages were accrued due to HFST portion of the project.

QUALITY

Oklahoma Department of Transportation has not previously installed HFST by means other than fully automated. Previous projects have not been in place long enough to collect data on long term durability of the friction course.

Initial skid numbers for this project were very high at 80-84, at least comparable with values achieved by HFSTs on two lane rural highways. This was a drastic improvement over pre-construction skid number in the range 31-36. Friction numbers collected by the Grip Tester were predominately 0.4-0.6 on untreated adjacent pavement and 1.0-1.2 on treated pavement, also reflecting a drastic improvement.

USER COSTS

Generally, the three categories of user costs used in an economic/life cycle cost analysis are vehicle operating costs (VOC), delay costs, and safety-related costs/crash costs.
The impacts to the road users, though often underrepresented, are not to be neglected. Generally, user costs are categorized by delay costs, vehicle operating costs, and safety-related costs which incorporate numerous factors including fuel usage, vehicle emissions, distance traveled, point-to-point travel time, accelerated degradation of detour facilities, decreased levels of service along detour routes, and the viability of alternate routes for non-motorized users.

HFST is not expected to affect travel speeds, delay, or traffic volume. No detour routes were provided during these installations and changes in traffic volume during construction were not measured. This was due to the brevity of the installation. However queues of at least six miles were reported at the I-44 location.

USER SATISFACTION

The Oklahoma Department of Transportation has received positive feedback from users of the treated facilities, but no formal or quantitative assessment of stakeholder satisfaction was developed.

SPEED IMPACT

Vehicle speed data were collected at the I-40/SE29/Air Depot location both before and after the project. At this location, a large overhead electronic sign was installed a few weeks after the completion of the HFST. This sign was equipped with flashing beacons, a large right turn arrow over each through lane, and the legend "DANGEROUS CURVE 50 MPH". Speed data were collected at two points on this curve, in 2014 and in December 2015 about three weeks after the installation of this sign.

The 85^{th} percentile speed at this curve showed a 2-4 MPH increase after installation of the HFST and the overhead sign; the mean speed showed a 1-2 MPH increase. The 85^{th} percentile speed is an established measure of the speed at which most drivers are comfortable negotiating a facility. Increased speeds may reflect an increased level of driver comfort allowed by better friction.

RECOMMENDATIONS AND IMPLEMENTATION

RECOMMENDATIONS

The Oklahoma Department of Transportation determined from the preliminary results of our data analysis that installation of HFST on multi-lane high volume highways is practicable and that dramatically improved friction numbers can be achieved. Pending longer term data analysis, we propose adopting the use of HFST on multi-lane high volume highways into our standard operating procedures.

However, we also identified the following areas that could be improved upon in future applications of this innovation:

- The use of wind guides should be required for automated applications.
- Striping should be left in place on high traffic volume locations, where flex tabs may not stay in place long enough.
- Removal of all loose aggregate from roadway, including shoulders, should be ensured.
- ODOT needs some qualification process for approval of epoxy binder.

STATUS OF IMPLEMENTATION AND ADOPTION

Since the completion of HFSTs in the Oklahoma City Metropolitan Area, the Oklahoma Department of Transportation has undertaken the following activities to implement HFST into their standard operating procedures as a significant improvement from our traditional practice for similar type projects:

- Revisions to ODOT standards for the application of HFST are under development.
- A program to systematically apply HFST to a number of selected curves each year has been initiated with tentative funding of $1,000,000 annually using HSIP funds. A list of possible sites has been created and is being scoped to select sites for treatment in FFY 2016.
- Sites have been selected using an adaptation of the Empirical Bayesian predictive method published in the Highway Safety Manual (AASHTO, 2010).

Appendix A: Project Narrative

April 9, 2014

Accelerated Innovation Deployment
Project Narrative

I. Project Abstract.

This project will construct High-Friction Surfacing Treatment (HFST) at multiple locations in the Oklahoma City metropolitan area. This project is a complete project. This project is an example of innovation in improving pavement friction to reduce run-off-the-road crashes. This project addresses the following TIDP goal: "Improve highway efficiency, safety, mobility, reliability, service life, environmental protection, and sustainability." This request for AID demonstration funding will comprise 80% of the project budget. Oklahoma is a roadway departure focus state.

II. Project Description.

The objective of this project is to increase friction between tires and the roadway surface.

The innovation proposed in this project is a high-friction surface treatment, which is an EDC initiative.

The performance goal for this innovation is a statistically-significant drop in crashes. This goal is measurable by reviewing crash data in the future to determine if there is a statistically-significant drop in crashes. It is predicted that a statistically significant determination of success will not be possible for at least three years.

ODOT has no experience with this innovation.

This project does not represent a change to conventional practice. It is the objective of this project to see a crash reduction without resorting to the much less cost-effective option of altering the roadway's geometry.

This project will construct HFST at the following locations:

- I-40 westbound near SE 29th Street. At this location a 4.75-degree curve exists with a posted speed limit of 60 mph and an advisory speed of 50 mph. Existing treatments are advance warning signs, chevrons, and glare fence on the median wall. The curve is hidden by a crest vertical curve. There have been 20 crashes in the last three years at this location, 6 with injury.
- I-40 westbound near Town Center Drive. At this location a reverse curve exists with degrees of 5 and 4.5 and a posted speed of 60 mph. These curves have been treated with doubled-up advance warning signs and glare fence on

the median wall at the first curve. There have been 16 crashes in the last three years at this location, 3 with injury.

- I-44 westbound over Airport Road. At this location a compound 4.75/4-degree curve exists with a posted speed of 60 mph. There have been 11 crashes in the last three years at this location, 3 with injury.

III. Innovation Performance.
This innovation's performance will be monitored via review of crash reports in the future. It is ODOT's goal to review these locations each subsequent year after project completion to see if a statistically significant reduction in crashes results. In addition, every six months, ODOT will measure friction using its skid trailer and will perform a visual inspection for surface raveling. This improvement is part of the Everyday Counts program, and has been used by many other states with significant improvement from the *status quo*. ODOT would like to experiment with this treatment to see if similar results can be achieved in Oklahoma.

IV. Applicant Information and Coordination with Other Entities.
The project point of contact is Faria Emamian, who can be reached at 405-521-2861. ODOT is not engaging in a cooperative effort with other entities for this project. No other entities are involved in this project.

V. Funding Request.
ODOT is requesting $417,696 AID Demonstration funding for this project. The total estimated project cost is $522,120 which is for 17,404 yd^2 of HFST at $30.00/yd^2.

VI. Eligibility and Section Criteria.

- ODOT is eligible to apply for funding.
- ODOT has not received AID funding in the past.
- The project is eligible for Federal Aid assistance under 23 USC.
- The project will be ready to initiate within six months of this application.
- The innovation aligns with TIDP goals as stated in section I above.
- This innovation is part of the Everyday Counts program.
- ODOT does not routinely use this treatment on its highways (in fact, it never has).

- ODOT projects that this innovation will be a significant improvement from the *status quo* at the project location.
- ODOT is willing to (a) participate in monitoring and assessment activities regarding the effectiveness of the innovation and subsequent technology transfer and information dissemination activities associated with the project; (b) accept FHWA oversight of the project; and (c) conduct a before-and-after customer satisfaction determination for construction projects.

Appendix B: Data Collection & Implementation Plan

Technology and Innovation Deployment Program (TIDP)
Accelerated Innovation Deployment (AID) Demonstration
ODOT – High Friction Surface Treatments in the Oklahoma City Metropolitan Area

Data Collection and Implementation Plan

Data Collection and Implementation Plan Purpose

This document will serve as a working document to be used to facilitate the development and implementation of information collection and reporting on the project's performance with respect to the relevant outcomes that are expected to be achieved through the use of the innovation in the project. As a requirement of the AID Demonstration program the award recipient is to work with FHWA on the development and implementation of this plan. Performance indicators need to be identified for each project, and will consider the individual project's stated goals as well as resource constraints of the award recipient. Performance indicators may include formal goals or targets, or at least include baseline measures as well as post-project outputs, and will inform the AID Demonstration program in working toward best practices, programmatic performance measures, and future decision-making guidelines.

Initial information in this template is based on the narrative provided in the application for the AID Demonstration grant.

The DC&I plan should assist in guiding the information that will be included in the final report. The award recipient shall submit a **final report to FHWA within 6 months of project completion** which documents the process, benefits, and lessons learned including development and/or refinement of guidance, specifications or other tools and methods to support rapid adoption of the innovation(s) as standard practice.

Accelerated Innovation Deployment (AID) Demonstration Program Information

The Accelerated Innovation Deployment (AID) program is one aspect of the multi-faceted Technology and Innovation Deployment Program (TIDP) approach, which provides funding and other resources to offset the risk of trying an innovation. The AID Demonstration funds are available for any project eligible for assistance under Title 23, United States Code. Projects eligible for funding shall include proven innovative practices or technologies such as those included in the EDC initiative. Innovations may include infrastructure and non-infrastructure strategies or activities, which the award recipient intends to implement and adopt as a significant improvement from their conventional practice.

- **Project Information**

The Oklahoma Department of Transportation (ODOT) was selected to receive an AID Demonstration grant in the amount of $417,696 to offset the costs of implementing High Friction Surface Treatments (HFST) in the Oklahoma City Metropolitan Area. The AID Demonstration fund award is based on the cost of the innovation in this project, not the total project cost. The awarded AID Demonstration funds will be used in place of other Federal program funds and do not otherwise modify the Federal fund match requirements.

Oklahoma was identified by FHWA as a focus State to improve traffic safety and roadway departure. Under the EDC initiative, the FHWA Oklahoma Division office and the Resource Center provided technical assistance and partnered with Oklahoma Department of Transportation (ODOT) to showcase application of HFST on a low volume road in northeast Oklahoma. From this showcase, ODOT was able to see the benefits of the HFST technology. Application of the HFST technology on high volume Interstate roads in a metropolitan area, as proposed under the AID Demonstration grant application, would provide ODOT with the necessary experience to institutionalize the use of HFST and deploy across the State as appropriate in safety-critical locations.

- **Project Timeline**

FHWA Authorization:	2014-09-15
Project Design Completion:	2014-10-24
Letting (Tentative):	2015-01
Begin Construction (Tentative):	2015-05-04
End Construction (Tentative):	2015-08-24
1st Project Evaluation (Tentative):	2015-11-23
2nd Project Evaluation (Tentative):	2016-11-21
3rd Project Evaluation (Tentative):	2017-11-20

- **Innovation**

High Friction Surface Treatment, an EDC innovation, is being installed using the proceeds from this grant. Prior to this installation, Oklahoma's only known HFST installation is the above-mentioned demonstration project.

- **Performance**

Performance of this innovation will be monitored and assessed for friction, pavement performance, and crash history.

- **Performance Measures**

The following performance measures have been established for this project to qualify or quantify, the effectiveness of the innovation to inform the AID Demonstration program in working toward best practices, programmatic performance measures, and future decision making guidelines:

1. For each location, crashes will be extracted from the Oklahoma crash database on a yearly basis after installation of the treatment. After a minimum of three years, a picture should begin to emerge that will allow analysts to determine whether a statistically significant reduction in crashes has occurred. It should be noted that due to statistical considerations, no conclusions will be drawn in the six-month report regarding our experience of the efficacy of this treatment. However, the six-month report will be amended as appropriate as crash data are available.

2. Friction numbers will be measured using a skid trailer at the subject locations prior to installation of the HFST.
3. Friction numbers will be similarly measured every six months after installation of the HFST, including immediately thereafter.
4. A visual inspection of the installation will be performed at the same time as friction measurements to monitor any spalling or other dislocation of the aggregate material.

- **Data Collection**

The ODOT, in coordination with the FHWA OK Division Office, developed this implementation plan for collecting information in support of the identified performance measures.

1. Crash tracking—before installation: Three months after installation[1] crashes will be queried at the subject locations for the previous three and five years. The criteria for each crash query are listed in item 3.
2. Crash tracking—after installation: At 1.25 years after installation, and for three or more subsequent years thereafter, crashes will be queried at the subject locations. The criteria for each crash query are listed in item 3.
3. Crash query criteria: To ensure consistency in the before and after evaluation of crashes, the following criteria shall be used at each location:
    a. Exclude Special Features 20 through 59
    b. Exclude Intersection Related
    c. Exclude Icy Road
    d. Road Alignment = { Curve left, curve right }
    e. Collision Types = { Sideswipe Same Direction, Fixed Object, Overturn/Rollover, Other Single Vehicle Crash }
    f. For I-40 at 29th Street Overpass: Control Section 55-68, Range = [0391, 0449], Unit 1 Travel Direction = { W, 1 }
    g. For I-40 at Eaker Gate: Control Section 55-68, Range = [0449, 0497], Unit 1 Travel Direction = "W"
    h. For I-44 at Airport Road: Control Section 55-05, Range = [0115, 0164], Unit 1 Travel Direction = { S, W, 2, 3 }
4. Free-flow speed studies will be conducted on the curve at the I-40 & 29th Street location before the project begins, and one month and six months after the installation of an overhead warning sign (with beacons) for the curve. This proposed sign is a complication of the before-and-after HFST study at that location. The purpose of the speed studies is to determine whether the proposed sign is changing driver behavior. It is hoped that the before-and-after HFST studies may be able to control for the signs with data collected in this step.
5. Friction readings will be collected using standard operating procedure prior to installation, immediately after installation, and subsequently yearly for a minimum of three years. It is

[1] Three months is selected as the initial crash query because there is a lag between crash occurrence and when the crash appears in our database. To ensure lagging crashes aren't skipped, we assume a three-month reporting lag.

intended for friction readings to coincide with the boundaries of the year for which crash data are collected in the event that it is desirable in the future to create a CMF correlated with friction readings.

RECOMMENDATIONS AND IMPLEMENTATION

- **Recommendations**
- **Status of Implementation and Adoption**

(Include discussion on partnering, cooperation, or coordination efforts, if applicable)

Since the completion of the HFST projects the ODOT has undertaken the following activities to implement HFST into our standard operating procedures as a significant improvement from our traditional practice for similar type projects:

- *(list activities and status)*
- *(list any technology transfer activities)*

Our plan for full adoption of (insert Innovation) is as follows:

- *(list timeline and activities necessary for adoption)*

- **Reporting**

The ODOT shall submit a final report to the FHWA CAI within six months of project completion. Project completion is currently projected for August 24, 2015. The report shall document the process, benefits, and lessons learned from implementation of High Friction Surface Treatments (HFST). The report shall include baseline data using traditional methods, observed data from implementation of the innovation, and discussion on the ODOT development and/or refinement of guidance, specifications or other tools and methods to support rapid adoption of the HFST as standard practice.

Appendix C: Pavement Friction & Macrotexture Data

Figure C1 shows Skid Numbers, collected by Oklahoma Dept. of Transportation using the Locked Wheel Skid Trailer method, ASTM E274-06. These numbers compare the same pavement before and after treatment.

Figures C2-C1l show Friction Numbers, collected by Oklahoma State University using the Grip Tester method, ASTM E274-11. These numbers compare treated with adjoining non-treated pavement.

Figure C12 shows the average difference between treated and non-treated Friction Numbers for each site.

Table C1 shows results of the T-test for significance for the difference between treated and non-treated Friction Numbers.

Figures C13-C22 show Mean Profile Depth data collected by OSU using the Model 8300 Survey Pro High Speed Profiler.

Figure C23 shows the average difference between treated and non-treated Mean Profile Depth for each site.

Table C2 shows results of the T-test for significance for the difference between treated and non-treated Mean Profile Depth.

Figures C2-C23 and Tables C1-C2 appear courtesy of Kelvin C. P. Wang, Ph.D., P.E., and Joshua Q. Li, Ph.D. Data from other projects, not addressed by this report, have been removed from these graphs and tables.

HFST SKID NUMBERS						
DATE	I-40 / SE 29TH OL	I-40 / SE 29TH IL	I-40 / TCD OL	I-40 / TCD IL	I-44 OL	I-44 IL
7/30/2015						
9/17/2015						
12/16/2013						
7/30/2015						
12/16/2013						
7/30/2015						
12/16/2013						
7/30/2015						
6/22/2015	34.7 L, 31.2 L, 27.8 L	37.1 L, 29.1 L, 26.8 L				
9/8/2015	83.4L, 84.1 L, 83.2 R	85.8 L, 79.3 L, 86.5 L				
6/22/2015			32.3 R, 31.4 R, 28.1 R	35.5 R, 32.0 R, 31.2 L		
9/8/2015			81.8 R, 82.0 R, 78.0 L	83.8 R, 80.7, R, 81.3 L		
6/22/2015					36.3 R, 32.5 R, 31.1 R	45.0 R, 35.4 R, 28.1 R
9/8/2015					85.4 R, 82.0 R, 83.6 R	86.3 R, 80.4 R, 85.7 R
Pre- Avg.	31.2	31.0	30.6	32.9	33.3	36.2
Post-Avg.	83.6	83.9	80.6	82.0	83.7	84.1

Figure C1: Skid Numbers

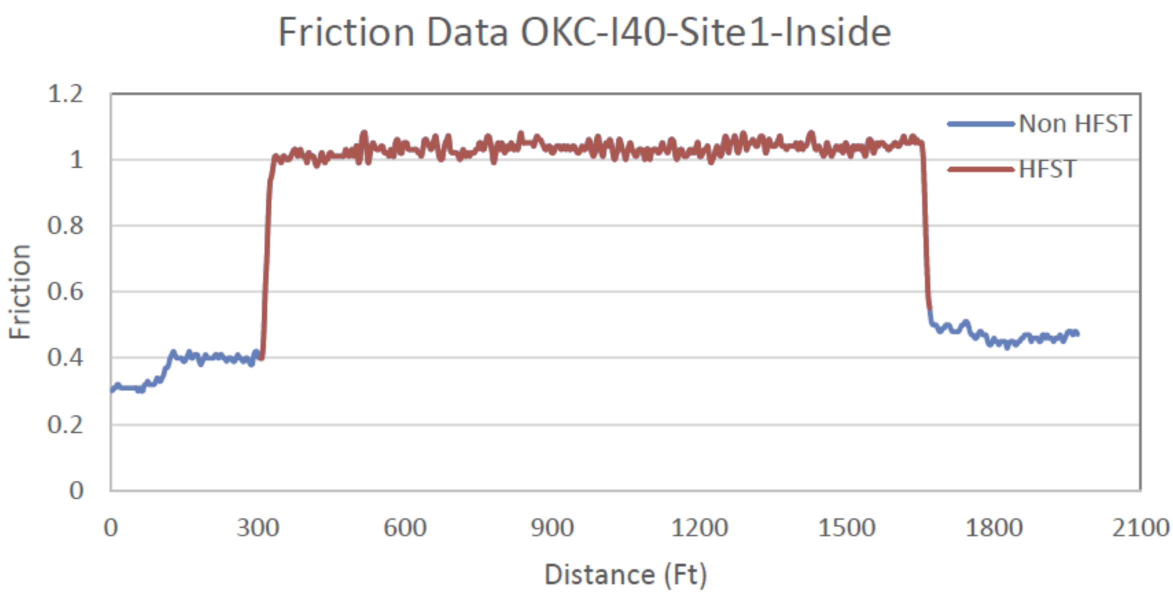

Figure C2: Friction Numbers, Site 1, Inside Lane

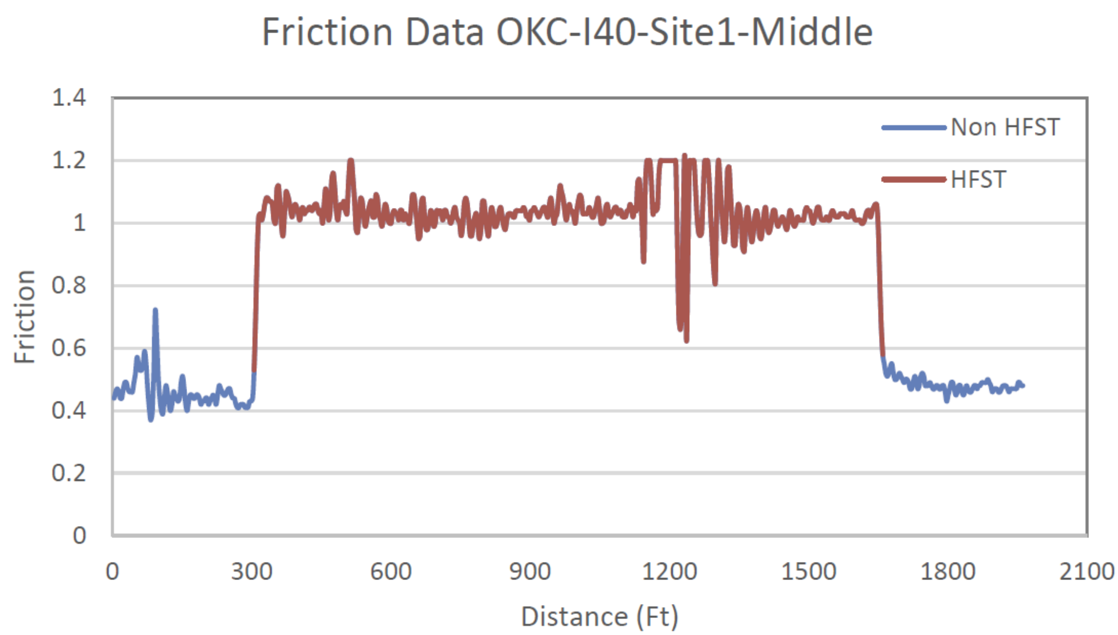

Figure C3: Friction Numbers, Site 1, Middle Lane

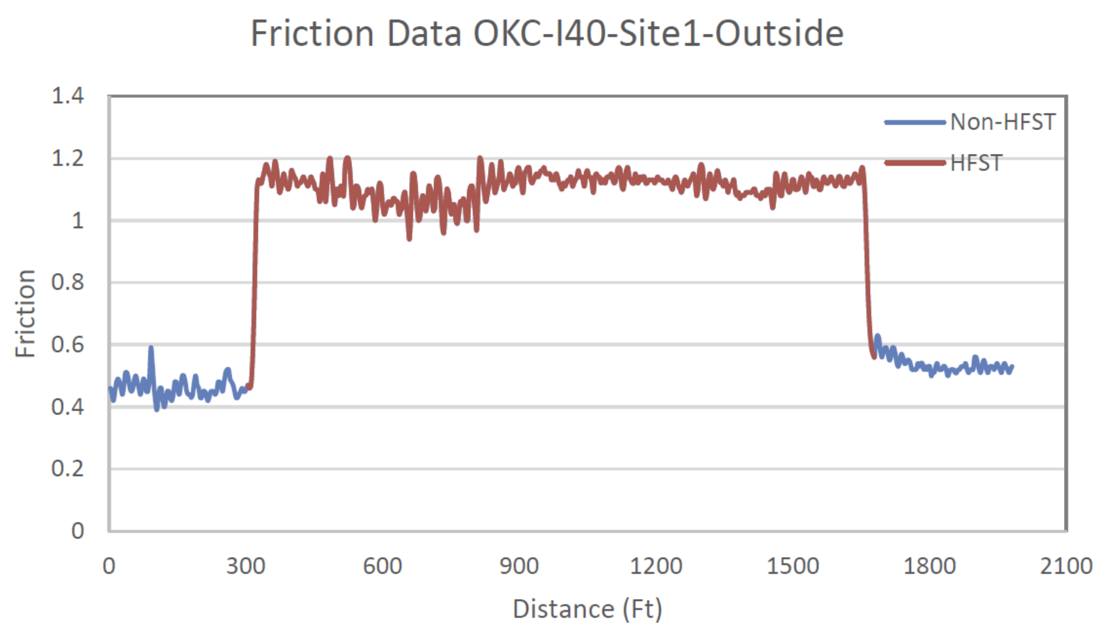

Figure C4: Friction Numbers, Site 1, Outside Lane

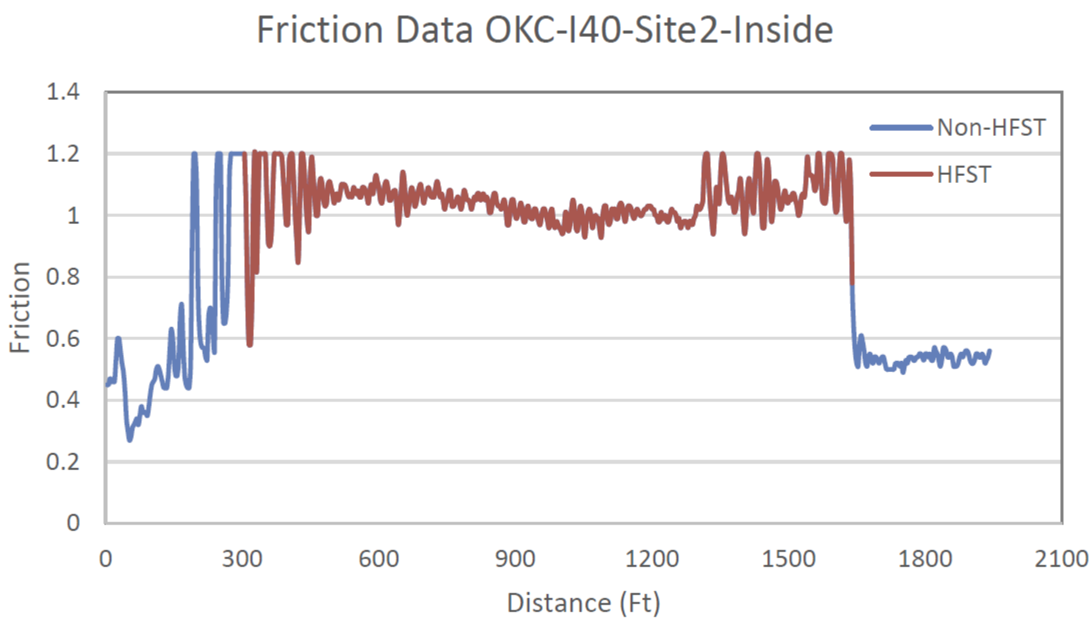

Figure C5: Friction Numbers, Site 2, Inside Lane

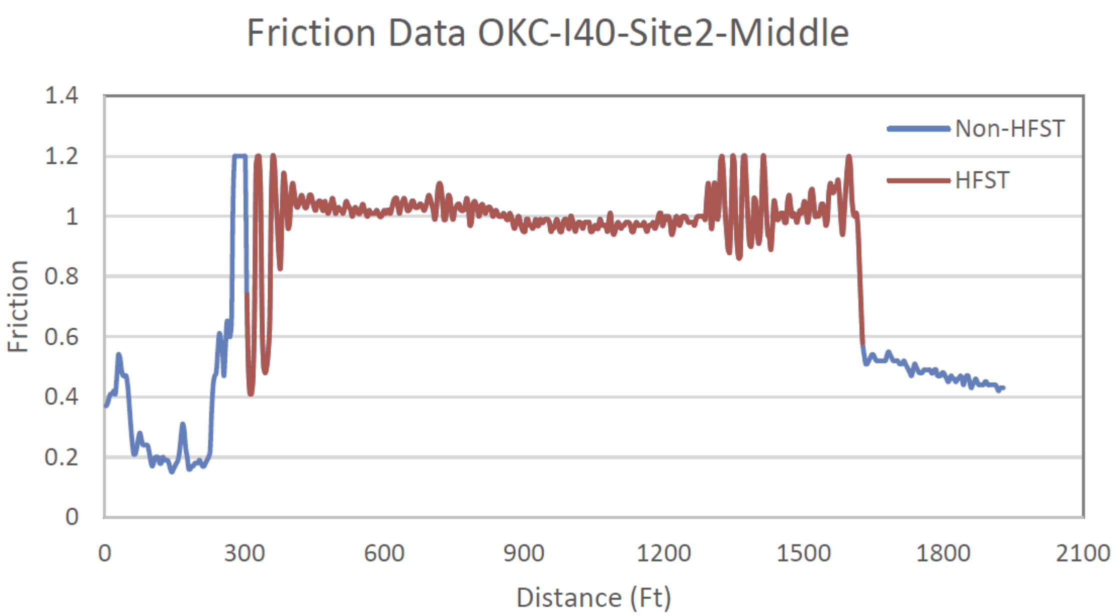

Figure C6: Friction Numbers, Site 2, Middle Lane

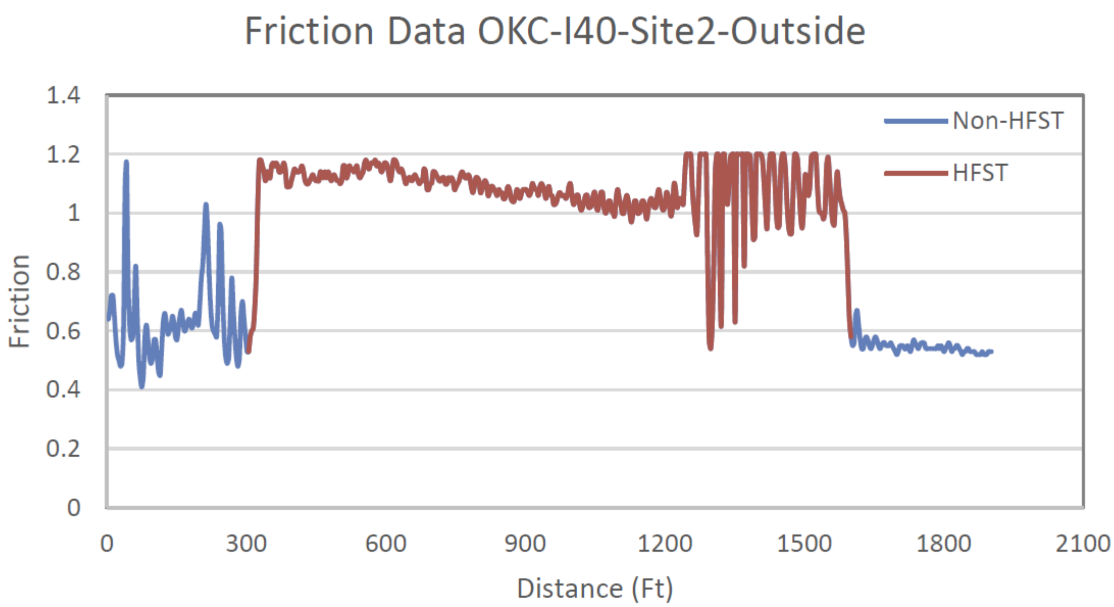

Figure C7: Friction Numbers, Site 2, Outside Lane

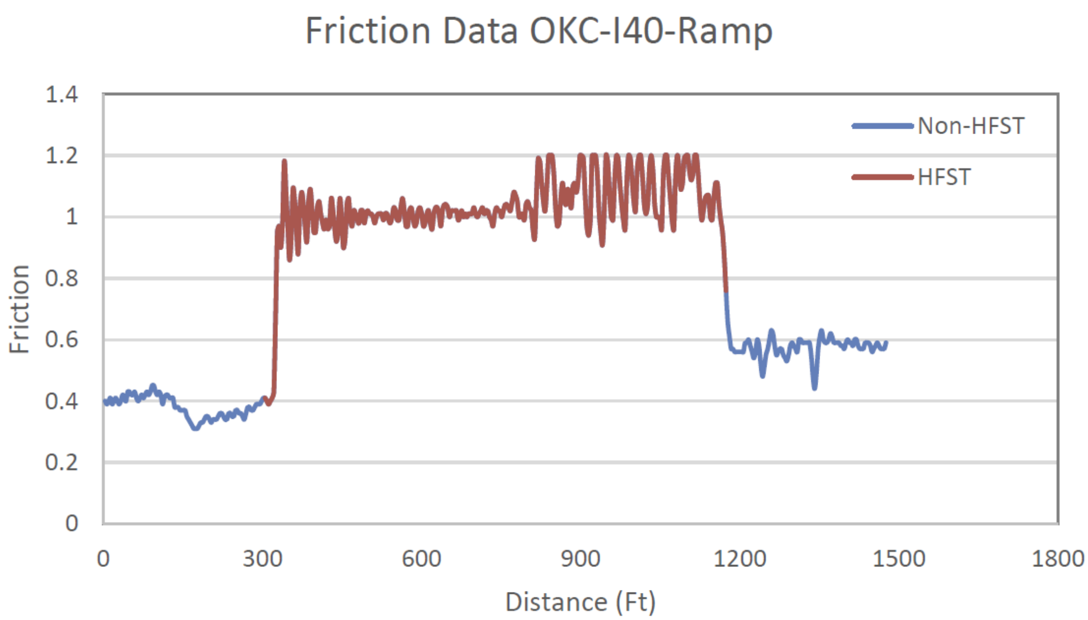

Figure C8: Friction Numbers, Site 2, Entrance Ramp

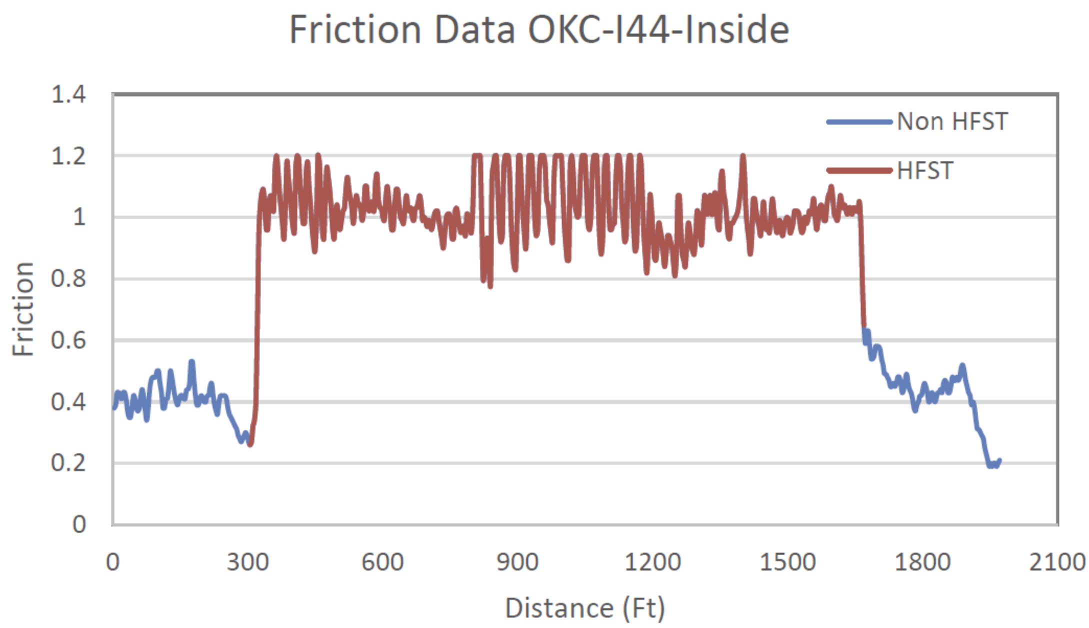

Figure C9: Friction Numbers, Site 3, Inside Lane

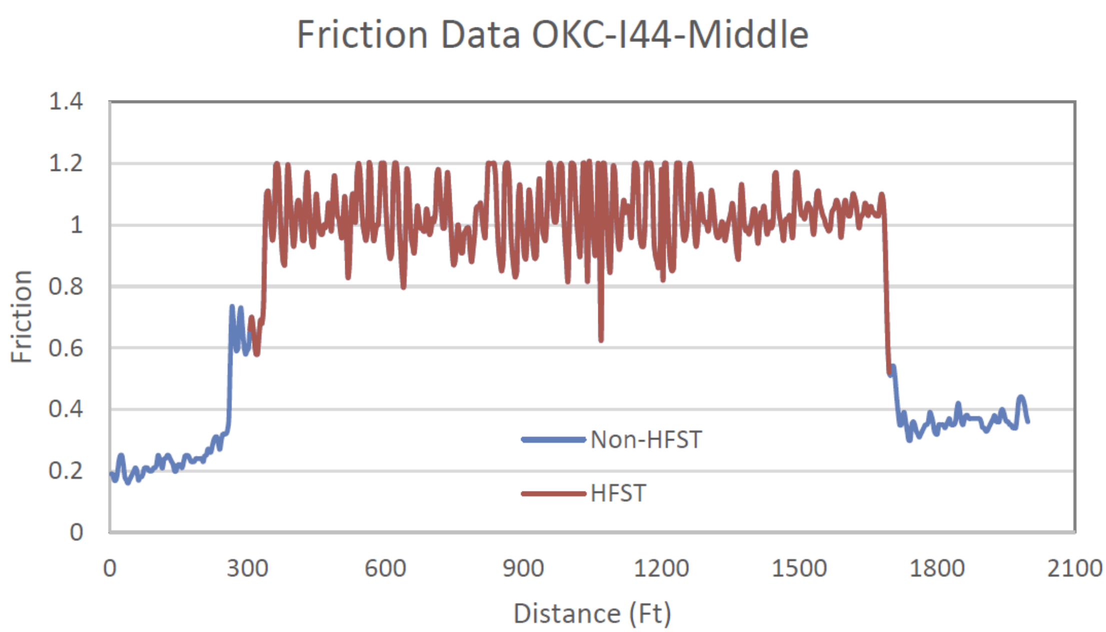

Figure C10: Friction Numbers, Site 3, Middle Lane

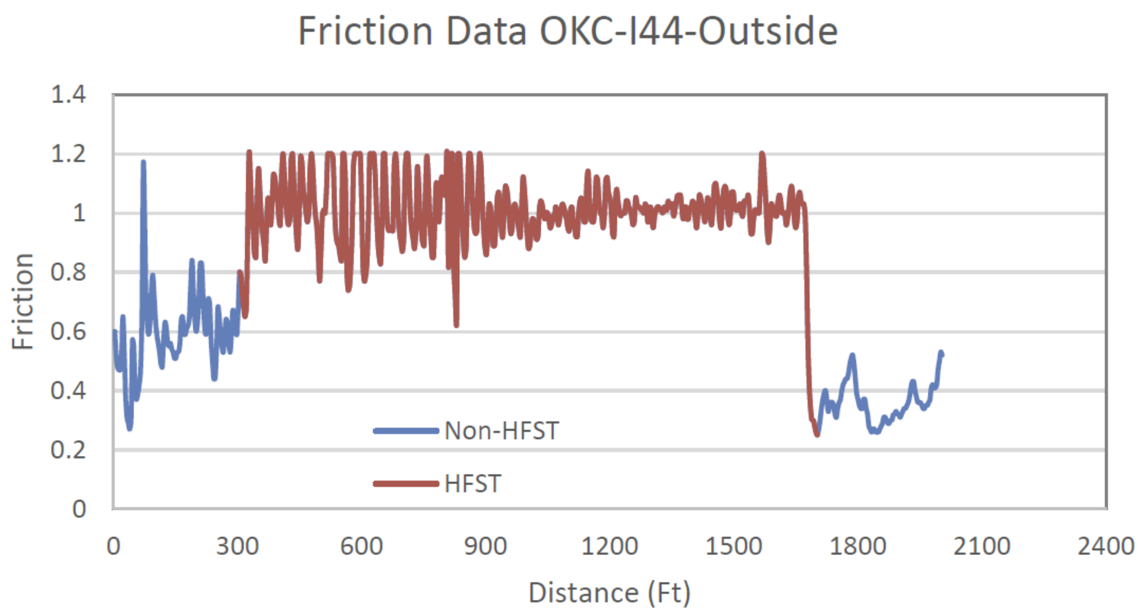

Figure C11: Friction Numbers, Site 3, Outside Lane

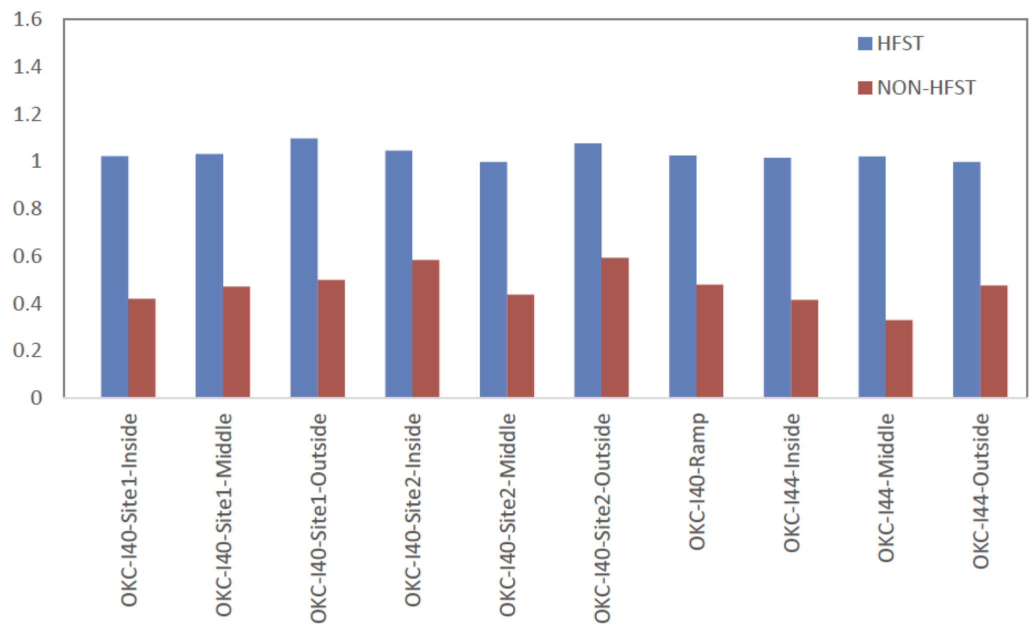

Figure C12: Comparison of Average Friction Numbers, All Sites

State Abb.	HFST Section	Friction (11/2015 Grip Tester Data)							
		Mean - HFST	Mean - Non HFST	Standard Deviation – HFST	Standard Deviation – Non HFST	t value	df	P value	Sig. Diff?
IOKC	OKC-I40-Site1-Inside	1.0219	0.4192	0.0052	0.0035	99.74	599	0.00	Yes
	OKC-I40-Site1-Middle	1.0316	0.4704	0.0065	0.0018	89.39	596	0.00	Yes
	OKC-I40-Site1-Outside	1.0967	0.4989	0.0088	0.0022	82.10	602	0.00	Yes
	OKC-I40-Site2-Inside	1.0451	0.5832	0.0062	0.0444	38.71	590	0.00	Yes
	OKC-I40-Site2-Middle	0.9971	0.4373	0.0105	0.0467	42.58	586	0.00	Yes
	OKC-I40-Site2-Outside	1.0762	0.5915	0.0124	0.0121	48.99	578	0.00	Yes
	OKC-I40-Ramp	1.0243	0.4782	0.0152	0.0106	49.29	448	0.00	Yes
	OKC-I44-Inside	1.0141	0.4137	0.0151	0.0072	60.31	599	0.00	Yes
	OKC-I44-Middle	1.0200	0.3291	0.0133	0.0136	67.68	607	0.00	Yes
	OKC-I44-Outside	0.9971	0.4749	0.0186	0.0244	41.56	609	0.00	Yes

Table C1: Statistical Significance of Difference in Friction Numbers

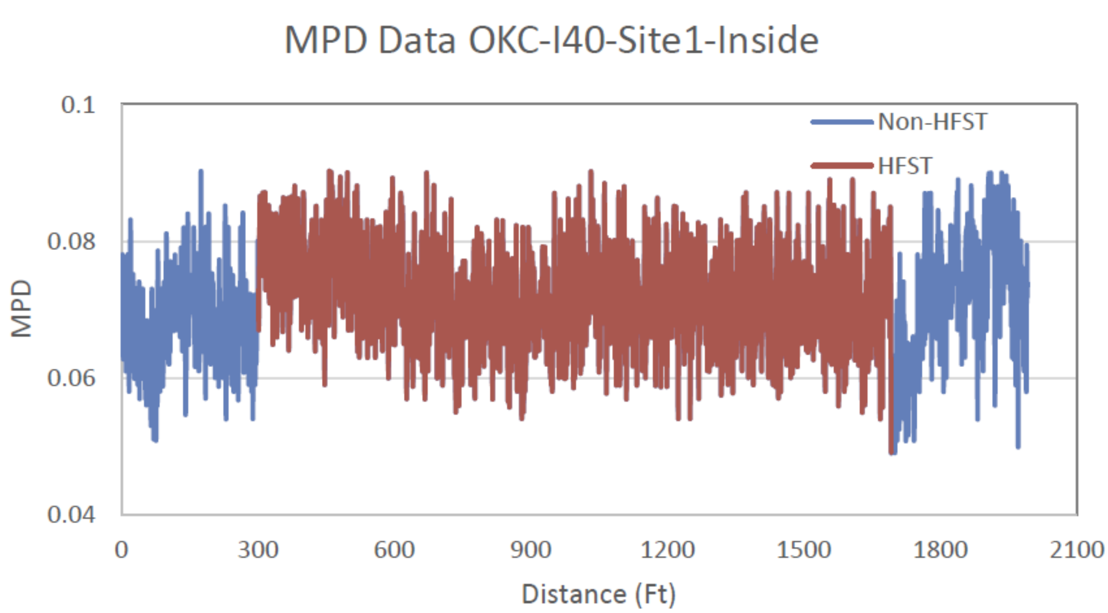

Figure C13: Mean Profile Depth, Site 1, Inside Lane

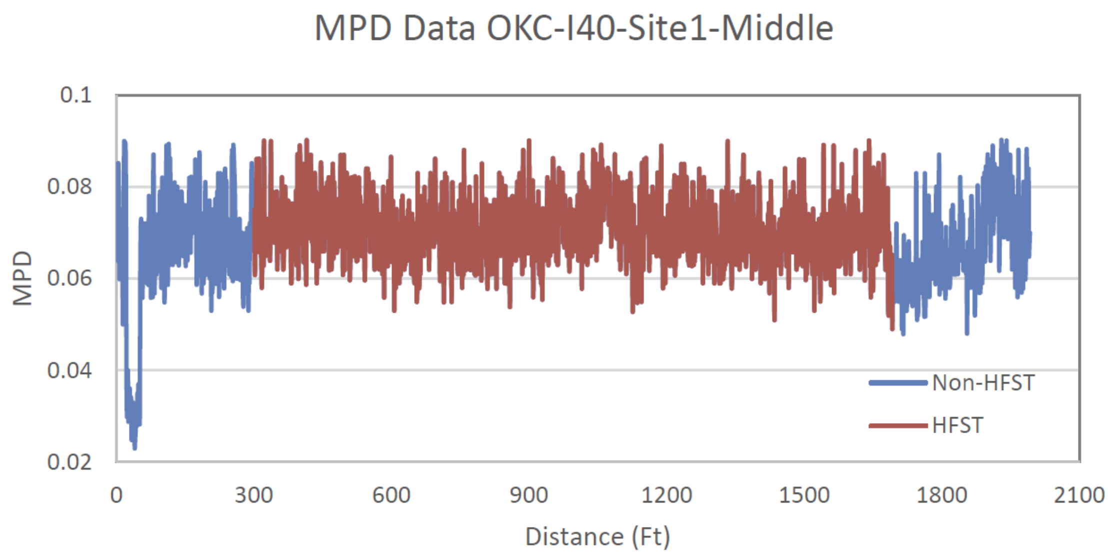

Figure C14: Mean Profile Depth, Site 1, Middle Lane

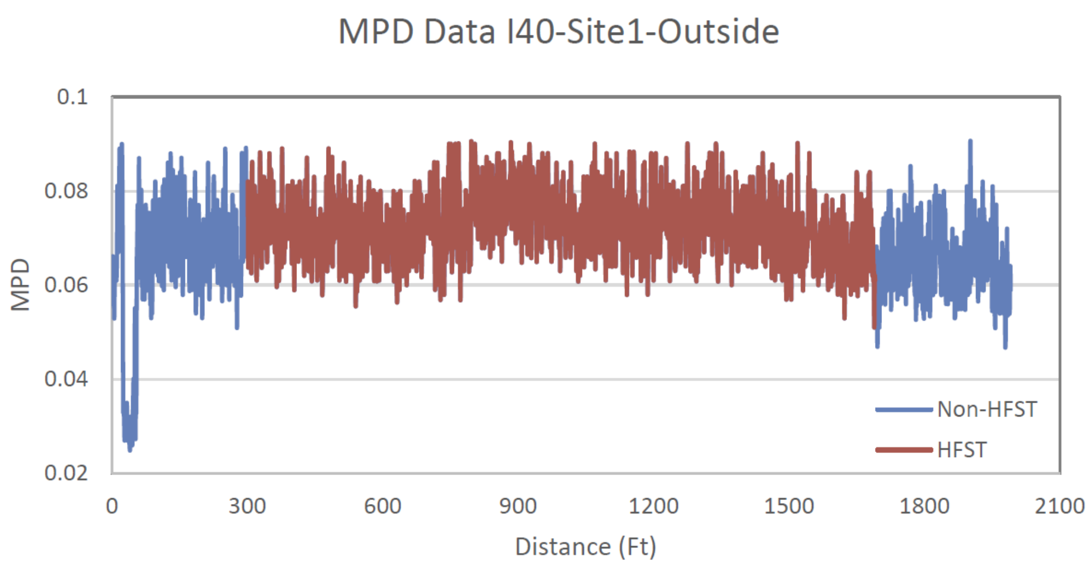

Figure C15: Mean Profile Depth, Site 1, Outside Lane

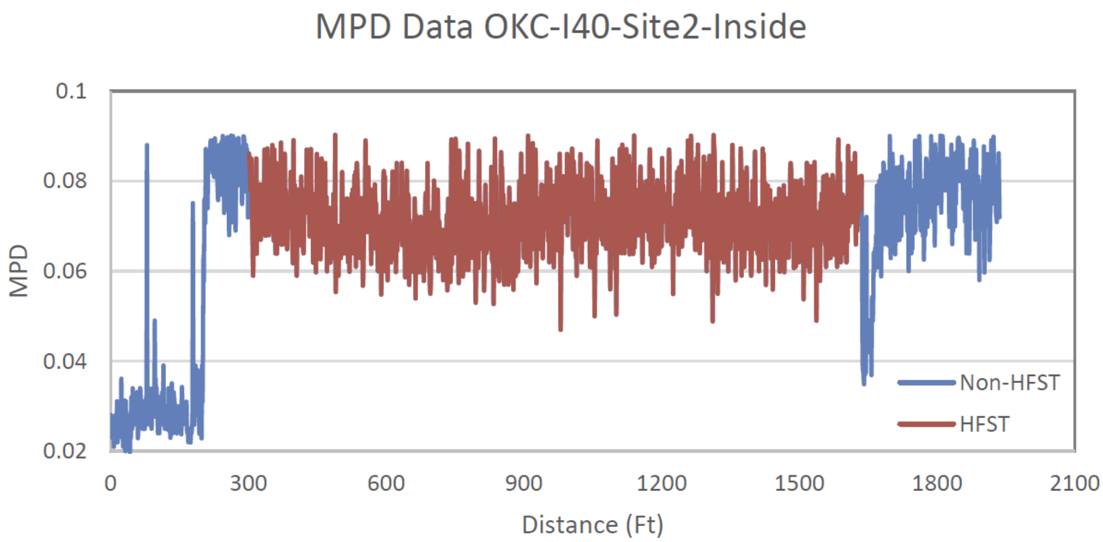

Figure C16: Mean Profile Depth, Site 2, Inside Lane

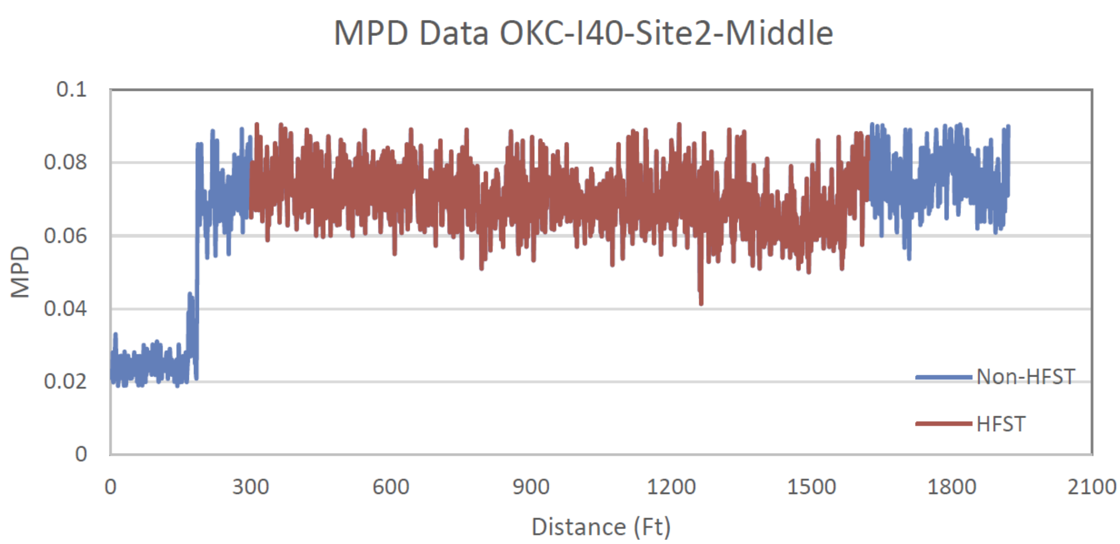

Figure C17: Mean Profile Depth, Site 2, Middle Lane

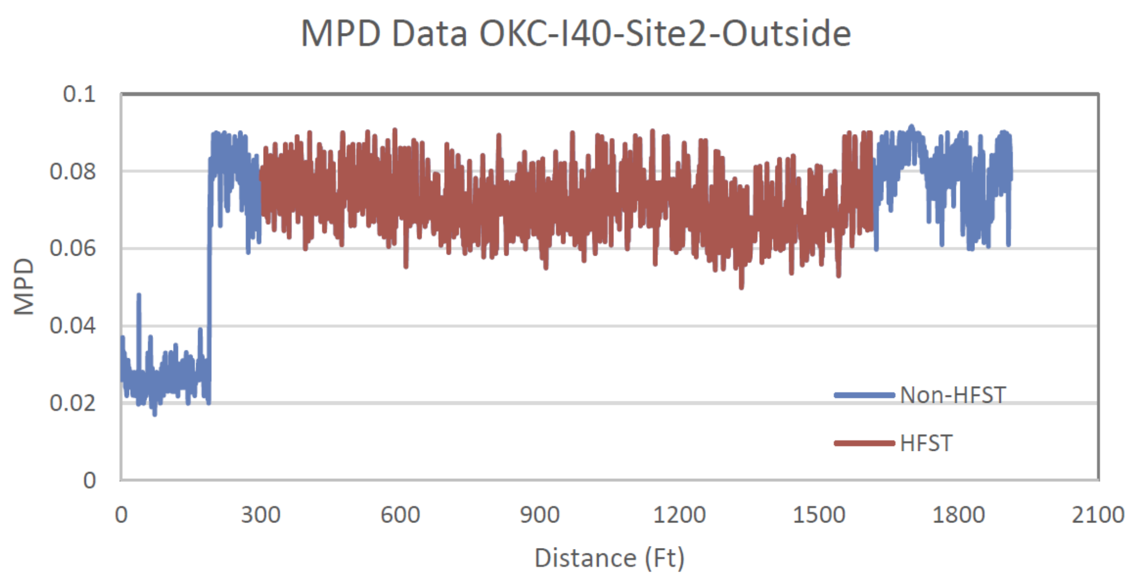

Figure C18: Mean Profile Depth, Site 2, Outside Lane

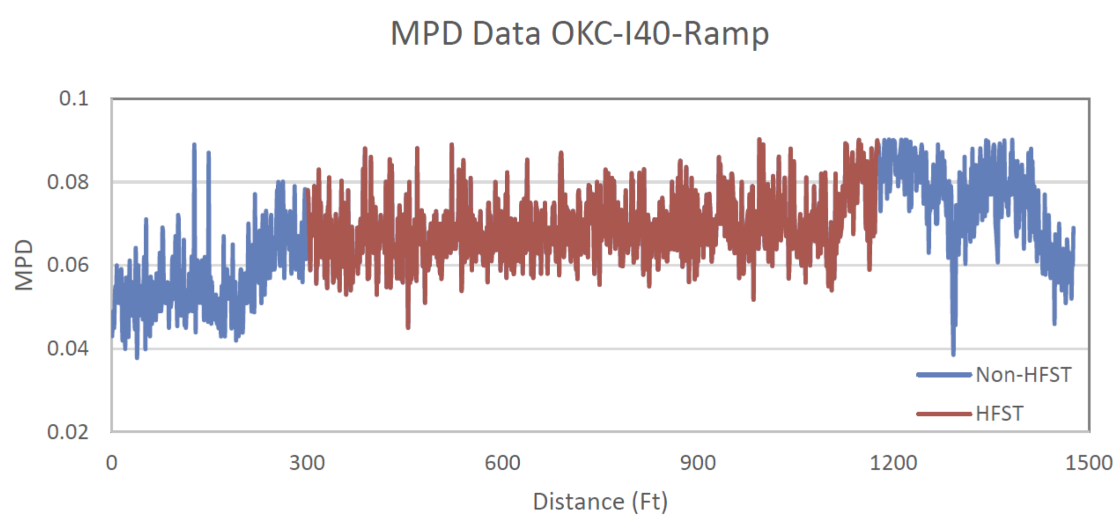

Figure C19: Mean Profile Depth, Site 2, Entrance Ramp

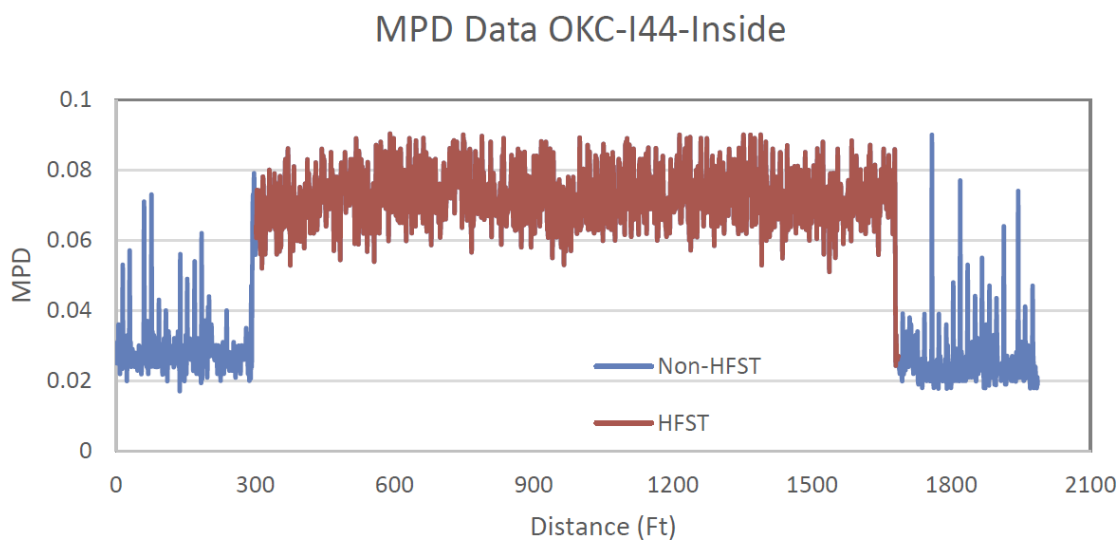

Figure C20: Mean Profile Depth, Site 3, Inside Lane

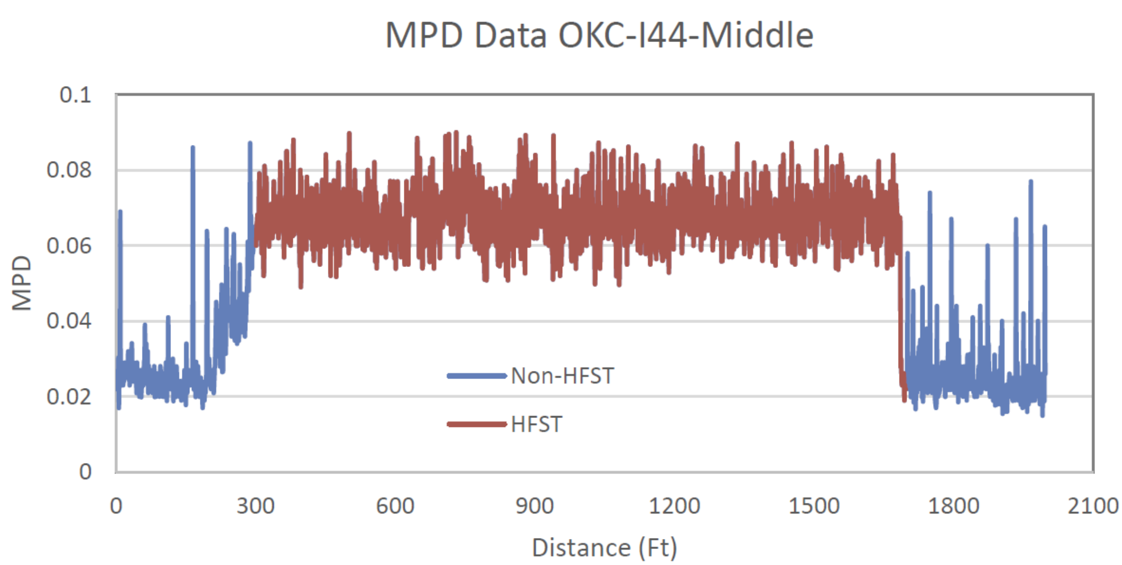

Figure C21: Mean Profile Depth, Site 3, Middle Lane

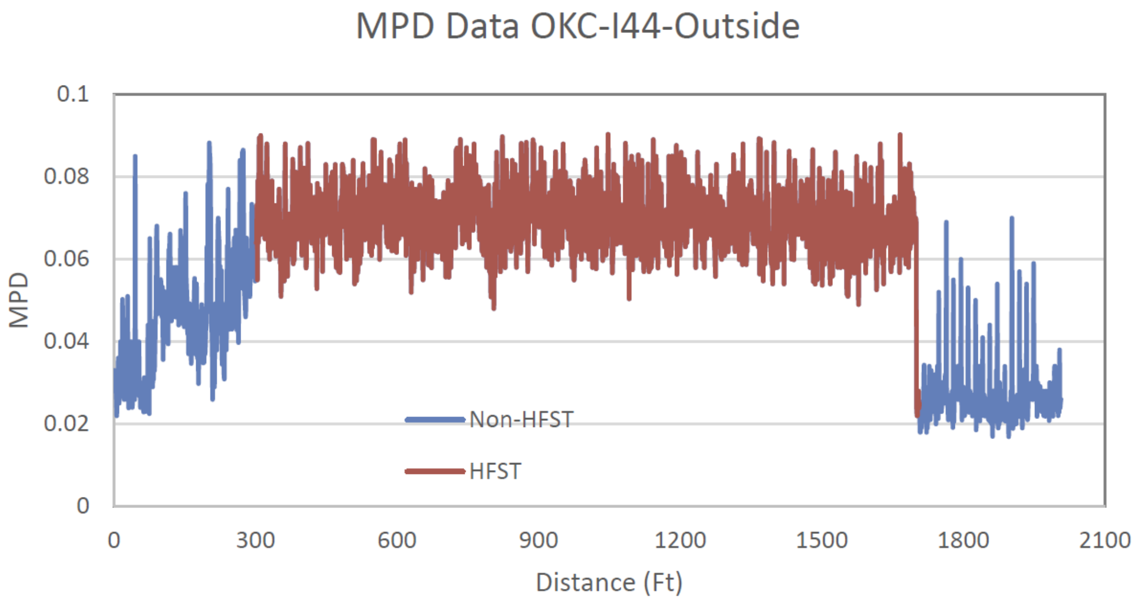

Figure C22: Mean Profile Depth, Site 3, Outside Lane

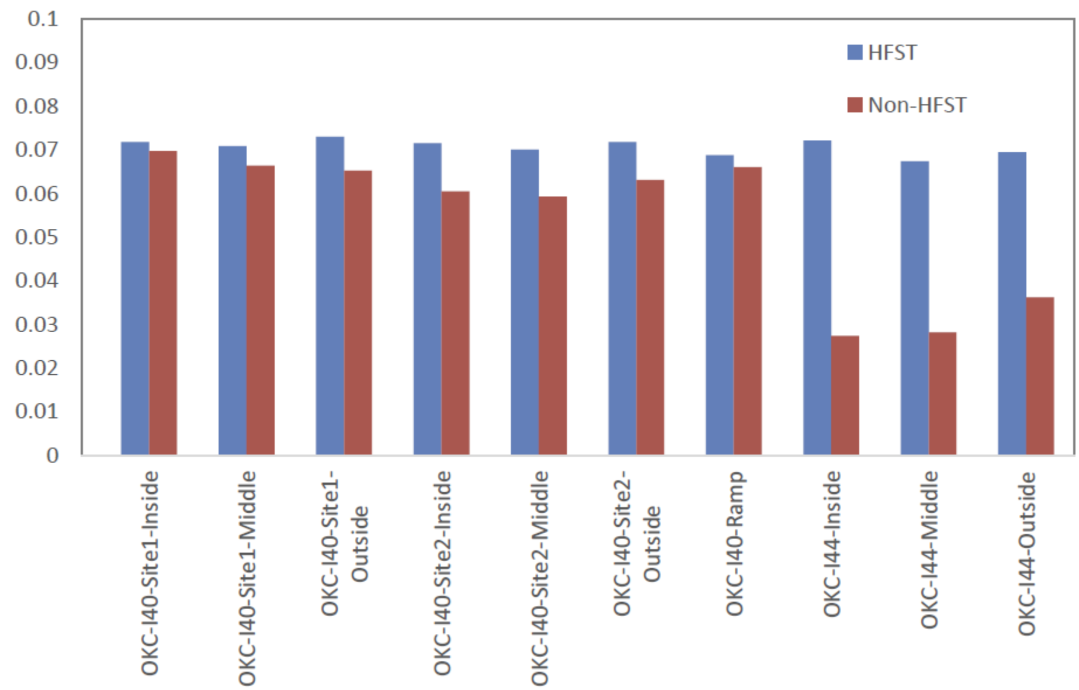

Figure C23: Comparison of Mean Profile Depth, All Sites

State Abb.	HFST Section	MPD (11/2015)							
		Mean - HFST	Mean - Non HFST	Standard Deviation – HFST	Standard Deviation – Non HFST	t value	df	P value	Sig. Diff?
IOKC	OKC-I40-Site1-Inside	0.0718	0.0698	0.0000	0.0001	5.47	1990	0.00	Yes
	OKC-I40-Site1-Middle	0.0709	0.0664	0.0000	0.0001	10.72	1990	0.00	Yes
	OKC-I40-Site1-Outside	0.0730	0.0653	0.0000	0.0001	18.68	1989	0.00	Yes
	OKC-I40-Site2-Inside	0.0716	0.0605	0.0001	0.0006	15.10	1934	0.00	Yes
	OKC-I40-Site2-Middle	0.0701	0.0593	0.0001	0.0006	14.79	1919	0.00	Yes
	OKC-I40-Site2-Outside	0.0718	0.0631	0.0001	0.0007	11.17	1910	0.00	Yes
	OKC-I40-Ramp	0.0688	0.0661	0.0001	0.0002	4.98	1474	0.00	Yes
	OKC-I44-Inside	0.0722	0.0274	0.0001	0.0001	111.83	1984	0.00	Yes
	OKC-I44-Middle	0.0674	0.0282	0.0001	0.0001	88.96	1995	0.00	Yes
	OKC-I44-Outside	0.0695	0.0362	0.0001	0.0002	63.83	2005	0.00	Yes

Table C2: Statistical Significance of Difference in Mean Profile Depth

CONTRACTOR SHALL USE SHOT BLASTING ON CONCRETE PAVEMENT AND CLEAN ANY LARGE OIL SPILLS.

ALL CONCRETE JOINTS AND BRIDGE JOINTS MUST BE MASKED OFF PRIOR TO APPLYING THE HFST TREATMENT.

HFST SHALL BE APPLIED TO ASPHALT PAVEMENT WITH NORMAL CRACKING AFTER PERFORMANCE OF CRACK SEAL OPERATIONS IN 1/4” OR LARGER CRACKS. ROUTER AND BLOWOUT AS NECESSARY. DO NOT USE HFST ON ASPHALT SURFACES WITH BLOCK CRACKING, ALLIGATOR CRACKING, OR DEEP RUTTING.

DO NOT ALLOW CRACK SEAL ABOVE THE PAVEMENT SURFACE.

THE CONTRACTOR SHALL ENSURE THAT A QUALIFIED FIELD TECHNICIAN CERTIFIED BY THE MANUFACTURER WILL BE ON SITE TO ASSIST AND SUPERVISE THE INSTALLATION OF HIGH FRICTION SURFACE AT EACHY LOCATION. THE COST FOR THE FIELD TECHNICIAN WILL BE INCLUDED IN THE PRICE BID FOR THE HFST PAY ITEM.

CONTRACTOR SHALL REMOVE ALL STRIPE PRIOR TO INSTALLING HFST.

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
HIGH FRICTION SURFACE TREATMENT (HFST)

These Special Provisions revise, amend, and where in conflict, supersede applicable sections of the 2009 Standard Specification for Highway Construction, English and Metric.

(Add the following:)

404.01 DESCRIPTION

High friction surface treatment (HFST) is a spot surface treatment that improves the coefficient of friction of an asphalt or concrete pavement. The HFST is comprised of a minimum single layer using a binder resin system and surface applied aggregates. The binder resin system includes polymeric or methyl methacrylate (MMA) resins.

404.02 MATERIALS

See Special Provision 707-1, "Materials for High Friction Surface Treatment (HFST)"

404.03 EQUIPMENT

A. Truck Mounted Application Machine

Use an ODOT approved self-propelled, truck mounted application machine capable of continuously and thoroughly mixing the resin binder system to the ratio recommended by the manufacturer at a minimum coverage rate of 15 gal/min. Ensure that the machine includes an aggregate drop spreader capable of continuously spreading aggregates in varying widths. Ensure the machine is capable of applying a minimum width of 12 ft in a single pass, and achieving a proper uniform spread of the aggregates.

B. Regenerative Air Sweeper

Use a self-propelled regenerative sweeper and/or power brooms capable of cleaning the existing pavement and removing loose aggregates without dislodging the bonded HFST aggregates. Ensure that the vacuum head is wide enough to span at least half of the lane width. The regenerative air sweeper must be capable of being used without water for dust suppression to ensure a dry surface will be maintained.

C. Portable Shot Blasting Equipment

Use ODOT approved portable shot blast equipment capable of removing any curing compound and any oil and rubber deposits on Portland cement concrete surfaces without damaging the existing aggregates or cement bond.

404.04 CONSTRUCTION METHODS

A. Qualification

Provide documentation which verifies that the Contractor placing the HFST, or equivalent process, has had successful experience on at least three projects with a cumulative minimum of 10,000 yd^2 placement on state agency highway projects.

B. Quality Control (QC) Plan

Submit a QC plan to the Engineer for approval at the time of pre-construction. In addition to showing proposed methods to control equipment, materials, mixing construction operations, include the following information in the QC plan to ensure conformance with these specifications:

- Key personnel and contact information
- Calibration record of equipment
- Materials sources and their technical and MSDS sheets
- Moisture control method of aggregates
- Corrective actions for unsatisfactory work

Provide an expert technical representative from the resin manufacturer at the construction site to supervise application and handling of the materials.

C. Weather Restrictions

Apply the HSFT on dry surfaces (including no condensation moisture from construction vehicles) when the temperature is 55 °F and rising unless the resin manufacturer can provide test data to support installation at a lower temperature. Do not place HFST when rain is expected within 24 hours of application.

D. Storage of Materials

Store materials in a clean, dry environment and in accordance with the manufacturer's recommendations. Do not allow the aggregates to be exposed to rain or moisture.

E. Traffic Control

Submit a detailed Traffic Control Plan (TCP) and corresponding sequence of operation for the application of the HFST and sweeping of the finished surface. Obtain approval of the TCP from the Department before performing this work.

F. Surface Preparation

Clean asphalt pavement surfaces using mechanical sweepers and high pressure air wash with sufficient oil traps. Mechanically sweep all surfaces to remove dirt, loose aggregate, debris, and deleterious material. Vacuum sweep or air wash all surfaces to remove dust, debris, and deleterious material using a minimum of 125 psi of clean, dry compressed air. While in use, keep the air lance perpendicular to the paving surface with the tip within 12 inches of the paving surface.

For applications on new asphalt pavements, allow the pavement to cure for thirty (30) days prior to installing the HFST.

Clean concrete pavement surfaces by shot blasting and vacuum sweeping. Shot blast all surfaces to remove all curing compounds, loosely bonded mortar, surface carbonation, and deleterious material. After shot blasting, vacuum sweep or air wash all surfaces as described above.

G. Binder Application

Mix the resin binder components in accordance with the manufacturer's recommended ratio. Use a truck mounted application machine to apply the two part polymeric or methacrylate (MMA) resin binder to the prepared pavement section. Apply the resin at a uniform rate of 2.8 to 3.6 yd^2/gal and a uniform thickness of 55 to 65 mils. To ensure the retention bonding of surface aggregates do not allow the binder to cure, dry, chill, set up, or separate in the mixing lines.

After application of surface aggregates, ensure that no seems are visible in the middle of the traffic lanes of the finished work. Binder may be placed by hand in sections that are less than 300 yd^2, located in a corner, in an area difficult to pave with the machine, or as approved the Engineer. For hand application, apply the binder resin with a squeegee brush to the required application rate and thickness recommended by the manufacturer.

When recommended by the technical expert or the ODOT Materials Division, apply a layer of prime coat before application of the binder resin system.

H. Aggregates Application

Using a truck mounted application machine, apply the aggregates at a uniform rate of 12 to 15 lb/yd^2 immediately after placing the binder resin. Completely cover the "wet" binder resin with aggregate to achieve a uniform surface with no exposed binder resin visible on the surface. Open-graded friction course (OGFC), permeable friction course (PFC), and ultrathin bonded overlays may need two applications to achieve the required thickness.

In areas less than 300 yd^2, obtain approval from the Engineer to apply the aggregates using an alternate method.

I. Curing and Removal of Aggregates

Allow the HFST to cure in accordance with the binder resin system manufacturer's recommendation; typically 4 to 6 hours.

Before opening to traffic, remove excess aggregates with a vacuum sweeper and/or power broom. (Reclaimed excess aggregates can be reused. The reused aggregate must be clean, dry, and uncontaminated.)

When HFST is placed on routes with a posted speed limit greater than 55 mph, perform an additional sweeping of the finished surface (including ramps) three (3) days after the initial application.

J. Acceptance of Material

Acceptance of HFST is based on visual inspection and the Contractor's certifications. Provide the letter of certification(s) for the applied binder resin system and calcined bauxite or mine chat to the Engineer. During installation, random samples of the binder resins (one gallon per component) and aggregate (40 lbs) shall be taken by the ODOT Materials Division for verification.

404.05 METHOD OF MEASUREMENT

Accepted quantities of HFST will be measured and paid by the square yard of material in place.

404.06 BASIS OF PAYMENT

The Department will pay for accepted quantities of HFST in place at the contract unit price per the specified pay unit as follows:

Pay Item:	Pay Unit:
HIGH FRICTION SURFACE TREATMENT	Square Yard

Payment for High Friction Surface Treatment includes compensation for all materials, equipment, labor, technical expertise, sampling, all traffic control, and removal and replacement of existing pavement markings necessary to perform the work as specified.

The Department will pay for prime coat in accordance with Section 408, "Prime Coat."

Include the cost of repairing pavement cracks for HFST application in other items of work.

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
MATERIALS FOR HIGH FRICTION SURFACE TREATMENT (HFST)

These Special Provisions revise, amend, and where in conflict, supersede applicable sections of the 2009 Standard Specification for Highway Construction, English and Metric.

(Add the following:)

707.05 HIGH FRICTION SURFACE TREATMENT (HFST)

A. Binder Resin Systems

Provide a binder resin system that is either two-part polymeric or methacrylate (MMA). Ensure that the binder resin system is recommended by the manufacturer as suitable for use on the intended pavement surface, and for the potential range of environmental and/or atmospheric exposures. The binder resin system must meet the requirements of Table 707:6.

Table 707:6
Physical Requirements of the Binder Resin System

Property	Test Method	Requirements	
		Polymeric Resin	MMA Resin
Viscosity	ASTM D-2556	Class C: 7-30 poises	Class C: 12-20 poises
Gel Time (minimum)	AASHTO M-235	Class C: 10 minutes	Class C: 10 minutes
Ultimate Tensile Strength	AASHTO M-235	2,500 - 5,000 psi	1,500 - 5,000 psi
Elongation at Break Point	AASHTO M-235	30 - 70 %	30 - 70 %
Durometer Hardness (Shore D)	ASTM D-2240	60 - 80	40 - 75
Compressive Strength (minimum)	ASTM C-579	1,000 psi @ 3 hrs 5,000 psi @ 7 days	1,000 psi @ 3 hrs 2,000 psi @ 7 days
Cure Rate (dry through time)	ASTM D-1640	3 hrs max	3 hrs max
Water Absorption	AASHTO M-235	1% max	1% max
Adhesive Strength @ 24 hrs	ASTM D-4541	250 psi min, or 100% substrate failure	250 psi min, or 100% substrate failure

Obtain approval of the binder resin system from the ODOT Materials Division before its use.

B. Calcined Bauxite

Provide calcined bauxite aggregate that is clean, dry, and free from foreign materials meeting the requirements of Table 707:7. Before use, ensure that the aggregate source is approved by the ODOT Materials Division.

Table 707:7 Physical and Chemical Requirements of the Aggregate		
Property	**Test Method**	**Requirements**
Resistance to Degradation	AASHTO T-96	20% max
Moisture Content	AASHTO T-255	0.2% max
Aluminum Oxide	ASTM C-25	87% min
Aggregate Grading	AASHTO T-27	-
Sieve Designation	Mass Percent Passing	
No. 4 Sieve Size	100% min	
No. ~~6~~ 8 Sieve Size	95% min	
No. 16 Sieve Size	5% max	

C. Mine Chat

Provide mine chat aggregate that is clean, dry, and free from foreign materials meeting the requirements of Table 707:8. Before use, ensure that the aggregate source is approved by the ODOT Materials Division.

Table 707:8 Physical and Chemical Requirements of the Aggregate		
Property	**Test Method**	**Requirements**
Resistance to Degradation	AASHTO T-96	22% max
Moisture Content	AASHTO T-255	0.2% max
Aggregate Grading	AASHTO T-27	-
Sieve Designation	Mass Percent Passing	
No. 4 Sieve Size	100	
No. ~~6~~ 8 Sieve Size	30 - 60	
No. 16 Sieve Size	0 - 5.0	
No. 30 Sieve Size	0.0 - 1.0	

Appendix E: Aggregate Test Data

Bauxite (HFST)

/09

OKLAHOMA DEPARTMENT OF TRANSPORTATION

Materials Division, 200 N. E. 21st Street, Okla. City, OK 73105-3204

FINE AGGREGATE

(T-11) (T-19) (T-21) (T-27) (T-84)

69416

Project No.: 46209115081114 00 **County:** OK **Div.** 4 **Report No.:**

Source: OKC **Material:** F. A. # Bauxite **ID Number**

Sieve Size	Acc. Wt. Retained	Acc. % Retained	Total % Passing	Specific Gravity		1996 Specifications	Required	Found
3/8" (9.5 mm)	0	0	100	O D WT.		Pass 3/8" (9.5 mm)	100%	100
No. 4 (4.75mm)	0	0	100	Pyc. + H_2O		Pass #4 (4.75 mm)	95 - 100%	100
No. 6 (2.36 mm)	2.5	0.4	99.6	Pyc. + H_2O + Sam.		Pass # 6	95% min	100
No. 16 (1.18 mm)	596.7	94.1	5.9	SSD WT.		Pass #16 (1.18 mm)	5%	67
				Spec. Gravity		[illegible]	0.02	
						Beginning	500	
				Unit Weight		Ending	499.9	
				Weight of Sand				
TOTAL	633.5			Measure Factor	0.022018			
Wash Weight	631.7			Final Weight		Colorimetric Test No.	<3	
Wash Loss	1.8					Specific Gravity	N / A	
Pan Material	34.8			Fineness Modulus		Unit Weight	N / A	
Total Minus Material	36.6			Init. Source Value		Fineness Modulus	± 0.20	

Tested by ______________________ **Checked by** ______________________ **Date** ______________________

OKLAHOMA DEPARTMENT OF TRANSPORTATION

Form DT-260C Rev. 05/13

Materials Division, 200 N. E. 21st Street, Okla. City, OK 73105-3204

COARSE AGGREGATE

(T-11) (T-19) (T-27) (T-85) (T-96) (T-210)

69416

Project No.: 4620911508111400 **County:** ______ **Div.** ______ **Report No.:** ______

Source: ______ **Material:** C. A. # ______ **ID Number** ______

Sieve Size	Acc. Wt. Retained	Acc. % Retained	Total % Passing	Wt. in Air, dry		Size #57		Required	Found
1/2" (37.5 mm)				Wt. in Air, Sat.		Pass 1 1/2"	(37.5 mm)	100%	
1" (25.0 mm)				Wt. in Water		Pass 1"	(25.0 mm)	95 - 100%	
3/4" (19.0 mm)				Specific Gravity -		Pass 1/2"	(12.5 mm)	25 - 60%	
1/2" (12.5 mm)				Absorption -		Pass #4	(4.75 mm)	0 - 10%	
3/8" (9.5 mm)				Unit Weight -		Pass #8	(2.36 mm)	0 - 5%	
No. 4 (4.75mm)				Durability		Pass #200	(0.75 mm)	0 - 2.0%	
No. 8 (2.36 mm)						Size #67			
No. 200 (0.075mm)				L. A. Abrasion	Meth. D	Pass 1"	(25.0 mm)	100%	
TOTAL				Initial Weight	5000	Pass 3/4"	(19.0) mm)	90 - 100%	
Wash Weight				Final Weight	4375	Pass 3/8"	(9.5 mm)	20 - 55%	
Wash Loss				Loss	625	Pass #4	(4.75 mm)	0 - 10%	
Pan Material				Percent Wear	13%	Pass #8	(2.36 mm)	0 - 5%	
Total Minus Material		TYPE D	L.A.	Required	20% Max.	Pass #200	(0.075 mm)	0.0 - 2.0%	

Tested by ______________________ Checked by ______________________ Date ______________________

HFST

OKLAHOMA DEPARTMENT OF TRANSPORTATION

Materials Division, 200 N. E. 21st Street, Okla. City, OK 73105-3204

FINE AGGREGATE

(T-11) (T-19) (T-21) (T-27) (T-84)

DT-260B Rev. 12/09

683~~24~~24

Project No.: 9434281507240730 **County:** OK **Div.** 4 **Report No.:**

Source: **Material:** F. A. # Bauxite **ID Number**

Sieve Size	Acc. Wt. Retained	Acc. % Retained	Total % Passing	Specific Gravity		1996 Specifications	Required	Found
3/8" (9.5 mm)	Ø	Ø	100	O D WT.		Pass 3/8" (9.5 mm)	100%	100%
No. 4 (4.75mm)	Ø	Ø	100	Pyc. + H_2O		Pass #4 (4.75 mm)	- 100%	100%
No. ~~8~~ 6 (~~2.36 mm~~)	2.5	0.49	99.51	Pyc. + H_2O + Sam.		Pass # 6 (~~2.36 mm~~)	95%	96%
No. 16 (1.18 mm)	495.1	96.23	3.77	SSD WT.		Pass #16 (1.18 mm)	15%	4%
No. 30 (0.60 mm)	Ø			Spec. Gravity				
No. 50 (0.30mm)						Moisture Cont.	0%	
No.100 (0.150 mm)				Unit Weight		Beginning	500.0	
No. 200 (0.075mm)				Weight of Sand		Ending	500.0	
TOTAL	514.5			Measure Factor	0.022018			
Wash Weight	513.8			Final Weight		Colorimetric Test No.	<3	
Wash Loss	0.7					Specific Gravity	N / A	
Pan Material	18.7			Fineness Modulus		Unit Weight	N / A	
Total Minus Material	19.4			Init. Source Value		Fineness Modulus	± 0.20	

Tested by ______ **Checked by** ______ **Date** ______

HFST

OKLAHOMA DEPARTMENT OF TRANSPORTATION

Materials Division, 200 N. E. 21st Street, Okla. City, OK 73105-3204

COARSE AGGREGATE

(T-11) (T-19) (T-27) (T-85) (T-96) (T-210)

Form DT-260C Rev. 05/13

68324

Project No.: 9434281507240730 **County:** OK **Div.** 4 **Report No.:**

Source: **Material:** C. A. # Bauxite **ID Number**

Sieve Size	Acc. Wt. Retained	Acc. % Retained	Total % Passing	Wt. in Air, dry		Size #57		Required	Found
1/2" (37.5 mm)				Wt. in Air, Sat.		Pass 1 1/2"	(37.5 mm)	100%	
1" (25.0 mm)				Wt. in Water		Pass 1"	(25.0 mm)	95 - 100%	
3/4" (19.0 mm)				Specific Gravity -		Pass 1/2"	(12.5 mm)	25 - 60%	
1/2" (12.5 mm)				Absorption -		Pass #4	(4.75 mm)	0 - 10%	
3/8" (9.5 mm)				Unit Weight -		Pass #8	(2.36 mm)	0 - 5%	
No. 4 (4.75mm)				Durability		Pass #200	(0.75 mm)	0 - 2.0%	
No. 8 (2.36 mm)						Size #67			
No. 200 (0.075mm)				L. A. Abrasion		Pass 1"	(25.0 mm)	100%	
TOTAL				Initial Weight	5001	Pass 3/4"	(19.0) mm)	90 - 100%	
Wash Weight				Final Weight	4576	Pass 3/8"	(9.5 mm)	20 - 55%	
Wash Loss				Loss	425	Pass #4	(4.75 mm)	0 - 10%	
Pan Material				Percent Wear	8.50	Pass #8	(2.36 mm)	0 - 5%	
Total Minus Material		TYPE D L.A.		Required	20% Max.	Pass #200	(0.075 mm)	0.0 - 2.0%	

Tested by ______ Checked by ______ Date ______

References

Wang, Kelvin et al. 3D Laser Imaging Based Pavement Surface Evaluation for High Friction Surfacing Treatments (HFST) in Oklahoma. School of Civil and Environmental Engineering, Oklahoma State University, Stillwater. Dec 2015.