CASE STUDY:

KENTUCKY TRANSPORTATION CABINET'S HIGH FRICTION SURFACE TREATMENT AND FIELD INSTALLATION PROGRAM

U.S. Department of Transportation
Federal Highway Administration

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Roadway departure fatalities account for approximately 65 percent of all fatalities in Kentucky. One of the methods KYTC identified to meet the roadway departure goal was the application of high friction surface treatments (HFST). HFST provides a durable and long-lasting solution to specific and defined roadway locations where a contributing factor in crashes is that the roadway friction demand exceeds the available pavement surface friction. This document provides an overview of Kentucky's efforts to establish an HFST program for reducing roadway crashes and fatalities as well as the State's standards, guidance, and specifications for using this safety treatment strategy as a practice to reduce roadway departures at select road sections. It also identifies and discusses the various elements to consider when selecting candidate roadway segments for placing HFSTs and lists some of the important insights and lessons learned from the Kentucky program.</td></tr>
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Tracy Lovell, KYTC

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Jarrod Stanley, KYTC

Tracy Nowaczyk, KYTC

Tim Scully, UK–Kentucky Transportation Center

Eric Green, UK–Kentucky Transportation Center

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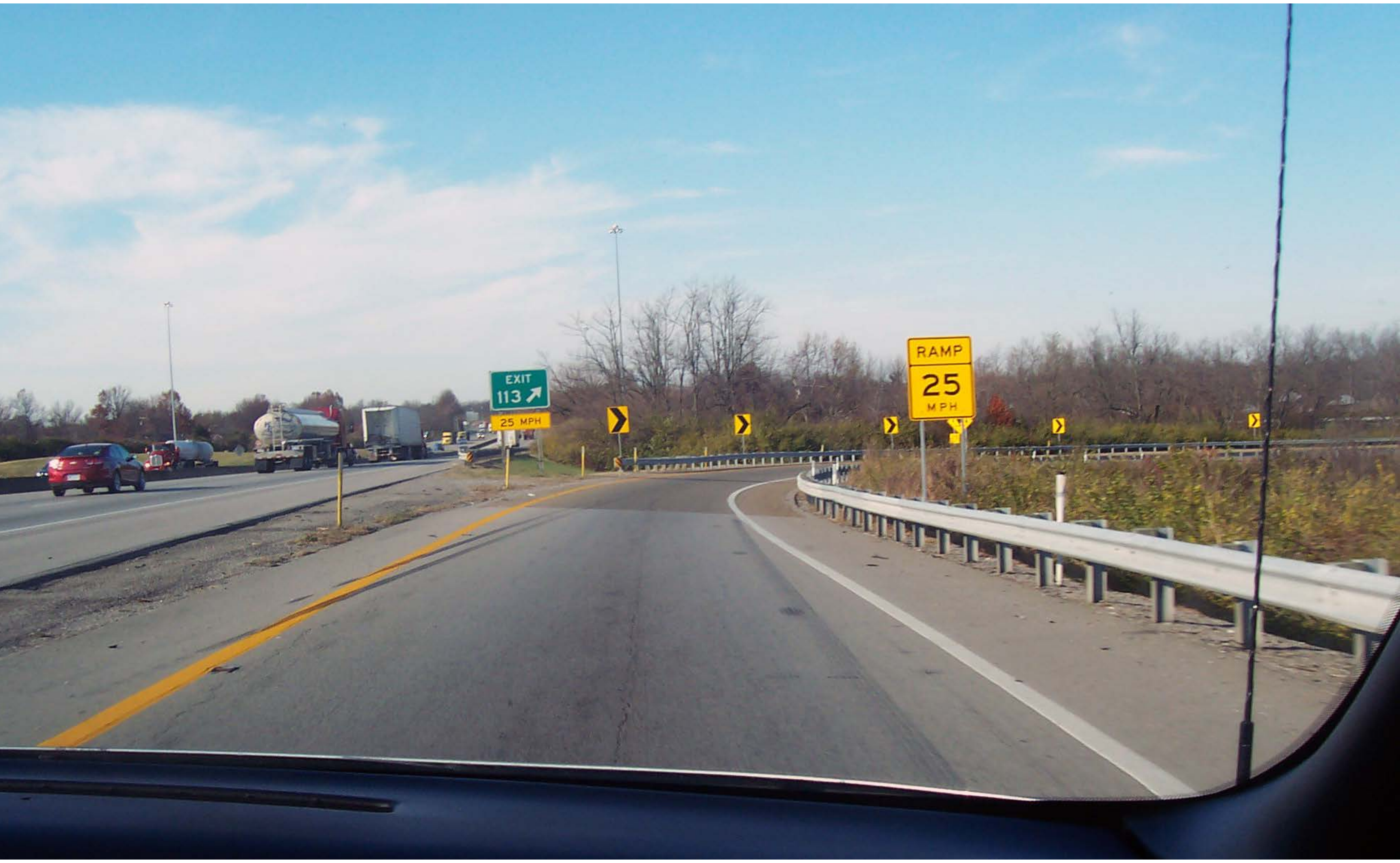
Table of Contents



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EXECUTIVE SUMMARY

Roadway departure fatalities account for approximately 65 percent of all traffic-related fatalities in Kentucky. The Kentucky Strategic Highway Safety Plan (SHSP) established a safety goal for reducing the number of annual roadway fatalities within the State to no more than 700 by the end of 2008. The Kentucky Transportation Cabinet's (KYTC) tentative updated goal was to reduce fatalities from 2008 levels by 15 percent by 2012. The agency merged a data analysis package, along with a set of roadway departure countermeasures, to identify a set of cost-effective countermeasures, deployment levels, and the funds needed to achieve the 15 percent roadway departure fatality reduction goal.

One of the methods KYTC identified to meet the roadway departure goal was the application of high friction surface treatments (HFST). HFST provides a durable and long-lasting solution to specific and defined roadway locations where a contributing factor in crashes is that the roadway friction demand exceeds the available pavement surface friction; HFST is more than a pavement resurfacing, it is a safety countermeasure.

Experience and data from Kentucky show HFST can be used where most needed, such as on ramps and freeways, two-lane urban or rural roads at horizontal curves, areas near steep grades, areas at or near lane changes, and rural and urban intersections. More importantly, Kentucky's HFST program is considered a major success and is one of the techniques or methods used to achieve the goal of reducing the number of roadway departures and fatalities in Kentucky.

This document provides an overview of Kentucky's efforts to establish an HFST program for reducing roadway departure crashes and fatalities as well as the State's standards, guidance, and specifications for using this safety treatment strategy as a practice to reduce roadway departures at select road sections. It also identifies and discusses the various elements to consider when selecting candidate roadway segments for placing HFSTs and lists some of the important insights and lessons learned from the Kentucky program.

SECTION 1: Introduction

1.1. BACKGROUND

Single and multi-vehicle crashes are the leading cause of fatalities and major injuries in the United States, particularly in rural areas. Roughly 25 to 50 percent of all fatal crashes occur at intersections or on horizontal curves.[1,2] The probability of crashes during vehicle stopping and turning movements is influenced by the friction between the tires and pavement surface.

In horizontal curves, vehicle speed and curve geometry create a "friction demand" that can be higher than adjacent sections of road. Crashes can also occur at intersections when errors in driver judgment create an unexpected need for increased friction due to excessive speed, lateral movement, or both.

Highway safety starts with the driver's ability to control the vehicle. The combination of: 1) the judgment needed to negotiate a horizontal curve, 2) pavement surface wear, and 3) the higher friction demand of a vehicle moving through a horizontal curve compared to the rest of the road results in increased potential for crashes. Adequate surface characteristics, particularly for friction, at critical locations are an effective means to increase traffic safety and reduce crashes. Maintaining an appropriate level of friction is critical for safe driving. One low-cost approach that has been shown to be effective in addressing high "friction demand" locations is the installation of a High Friction Surface Treatment (HFST).

Highway safety starts with the driver's ability to control the vehicle.

1.2 HIGH FRICTION SURFACE TREATMENT DEFINED

HFSTs are pavement surface treatments with exceptional skid-resistant properties that are composed of extremely hard, polish- and abrasion-resistant aggregates bonded to the pavement that greatly enhance the frictional characteristics of a road surface. The high-adhesive and tensile properties of the binder lock the aggregates in place. This creates a durable surface capable of providing long-lasting surface friction on road sections with high friction demands, such as those that experience excessive and heavy braking, contain sharp horizontal curves, or feature a vertical grade in combination with a horizontal curve.

HFSTs address two speed-related crash conditions: (1) where there is low to marginal friction (further reduced by weather), and (2) where the available friction is incompatible with approach speeds and roadway geometry (friction demand). In general, HFSTs assist in keeping vehicles in their lane around curves and allow vehicles to stop in shorter distances at intersections. For details on the HFST material requirements and test methods, the reader is referred to the list of references at the end of this document.

1.3 KENTUCKY TRANSPORTATION CABINET'S HIGH FRICTION SURFACE TREATMENT PROGRAM

Although multiple agencies have installed HFST, the KYTC was one of the first organizations in the United States to establish a formal HFST program—a program considered to be one of the best in the country. The KYTC program was developed in the mid- to late-2000s. One reason for the success of the Kentucky program is the effectiveness of the data analysis processes the State uses in identifying areas where HFST application will maximize the benefit. This benefit has been validated or confirmed through the use of a crash monitoring program prior to and after HFST installation.

1 ATSSA, *Safety Opportunities in High Friction Surfacing*, American Traffic Safety Services Association, February 2013.

2 Federal Highway Administration, *Horizontal Curve Safety,* U.S. Department of Transportation, Washington, DC, February 2012, available at: *http://www-nrd.nhtsa.dot.gov/Pubs/811552.pdf*

1.4 PURPOSE OF THE DOCUMENT

The Federal Highway Administration (FHWA) works with States to accelerate the use of innovative technologies and programs, especially those where the proof of the concept has been validated with field data, under the Every Day Counts 2 Program.[3] In 2012 under this program, HFST was selected as one of the safety initiatives. FHWA aims to mainstream HFST as a safety countermeasure on the Nation's highway to decrease serious injuries and fatalities. This document is a case study on the Kentucky HFST program from inception to full-scale deployment.

The FHWA partnered with the American Traffic Safety Service Association, Inc. (ATSSA) and the American Association of State Highway and Transportation Officials (AASHTO) to develop material and performance standards to help State departments of transportation (DOT) and local transportation agencies to implement and use HFST. The standard was published in 2014 as PP79, High Friction Surface Treatment for Asphalt and Concrete Pavements. This case study on the Kentucky HFST program was prepared as part of this assistance and documentation so that other agencies interested in deploying their own programs can benefit from the insights garnered from Kentucky's experiences.

This document summarizes Kentucky's efforts to set up and establish a HFST program for reducing roadway crashes and fatalities and outlines Kentucky's standards, guidance, and specifications for using this safety treatment strategy as a practice for reducing roadway departure crashes in critical areas of the roadway. It also identifies and discusses various elements to consider when selecting roadway segments that are candidates for HFST applications and lists some of the important insights and lessons learned from the Kentucky program. The case study document also includes experiences and lessons learned from HFST installation.

1.5 SCOPE OF THE DOCUMENT

The information for this case study document is based on experiences obtained from Kentucky's formal program to identify and select roadway segments that would be expected to improve roadway departure safety by increasing the available pavement surface friction. Including this Introduction, this case study is organized into seven sections:

- Section two presents a brief overview on the history of HFSTs, including the successful application of HFSTs made throughout the United States and other areas of the world to address crash issues. It also summarizes the main reasons why Kentucky selected HFST.
- Section three presents an overview of the development and deployment of Kentucky's HFST program as an element of its overall Strategic Highway Safety Plan. This section also addresses the level of effort and budget needed to deploy this program.
- Section four focuses on Kentucky's site selection process to maximize the benefit of applying HFSTs.
- Section five focuses on Kentucky's data analysis in support of selecting high-potential locations that were most likely to see the greatest benefit from using HFST to reduce roadway departure crashes and single and multi-vehicle collisions at intersections.
- Section six includes information on materials and construction practices used in Kentucky for placing HFSTs and how changes were made in contracting and construction based on the lessons learned from the early years deploying this technology. This section also addresses Kentucky's post construction assessment friction testing methodology.
- Section seven provides a listing and summary of selected Kentucky HFST projects that document the benefit from using HFST in optimal locations.
- The final section is the list of references cited throughout the document as well as additional reference material.

3 For more information on the Every Day Counts 2 Program, please visit *http://www.fhwa.dot.gov/everydaycounts/*

SECTION 2: Brief History of High Friction Surface Treatments and Their Benefit

HFSTs were originally developed in the United States during the 1950s using epoxy resin, but their use has increased in recent years. An HFST wearing surface has been successfully used in Europe and Asia for decades, including on a wide scale in London in the early 1970's. HFST wearing surface has also been tried and proven at a wide variety of sites as part of the FHWA's Surface Enhancements at Horizontal Curves (SEAHC) demonstration program. State-of-the-art friction measurement equipment has been used to verify the improved friction available after installation as well as to determine how well treated surfaces retain that friction over time.

Kentucky decided to use HFST to assist in effectively reducing highway fatalities. The following are other benefits for using this safety treatment:

- HFST provides a durable and long-lasting solution for specific and defined roadway locations where a contributing factor in crashes is that the roadway friction demand exceeds the available pavement surface friction. HFST is a safety treatment that happens to be a pavement treatment.
- The reported service life of HFST is approximately 10 years based on European experience and the oldest projects in the United States. Based on the performance of the initial projects placed in Kentucky since 2009, it is believed KYTC will realize a similar service life.
- The benefit-cost ratio is many times higher for HFST when compared with other alternatives because the crash reductions continue for many years and the cost of other solutions—such as straightening horizontal curves—can be cost prohibitive and include significant environmental and right-of-way impacts.
- Experience and data from Kentucky show HFST can be used where most needed, such as ramps and freeways, two-lane urban or rural roads at horizontal curves, areas near steep grades, areas at or near lane changes, and at rural and urban intersections.
- Project lengths can be short, and because the HFST sets up quickly, the treatment can be applied in hours, resulting in minimal construction work zone impacts on local traffic.
- HFST can be applied by equipment at a similar speed to other paving surface treatments, or it can be applied with hand tools.
- HFST can be installed on both asphalt and portland cement concrete surfaces. The pavement, however, must be in fair condition to realize the desired service life.

SECTION 3: Kentucky's HFST Program

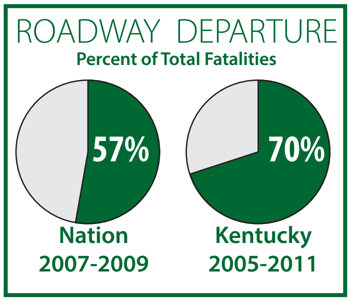
Kentucky, the FHWA, and other agencies have reported significant crash reductions at a number of high-crash sites where an HFST was applied and monitored. While HFST is yet to be known or understood by many practitioners in the United States, that should change in the future with the increased awareness and publicity of Kentucky's successful program. In addition, the American Traffic Safety Services Association (ATSSA) is undertaking an effort to promote a better understanding of the benefits of HFSTs.

This section describes the Kentucky program from inception to full deployment and provides insights into the benefits and challenges overcome during the deployment of Kentucky's HFST program.

3.1 KYTC OVERALL SAFETY PROGRAM

Kentucky's Strategic Highway Safety Plan 2011-2014[4] has the following mission and goal:

- **Mission** – To reduce highway fatalities and serious injuries.
- **Goal** – To reduce the number of highway fatalities and serious injuries toward zero.



The KYTC recognized that it needed to apply improved safety treatments on horizontal curves throughout the State to reduce the number of roadway departure crashes experienced statewide. Nationally, roadway departure crashes account for 57 percent of fatalities; however, in Kentucky, roadway departure crashes have accounted for more than 70 percent of total fatalities since 2005. As a result, the Kentucky Strategic Highway Safety Plan (SHSP) adopted a goal of reducing the number of annual roadway fatalities to no more than 700 by the end of 2008. A tentative updated goal was to reduce fatalities from 2008 levels by a further 15 percent by 2012.

KYTC merged a data analysis package along with a set of roadway departure countermeasures to identify a set of cost effective countermeasures, deployment levels, and funds needed to achieve a 15 percent roadway departure fatality reduction goal. This information is documented in the April 2010 KYTC Roadway Departure Safety Implementation Plan. The data analysis indicated that the roadway departure goal could be achieved with the following enhancements to the safety program:

- The traditional approach of relying primarily on pursuing major improvements at high-crash roadway departure locations would need to be complemented by adopting: (1) a systematic approach that involves deploying large numbers of relatively low-cost, cost-effective countermeasures at many targeted high-crash roadway departure sections; and (2) a comprehensive approach that coordinates an engineering, education, and enforcement (3E) initiative on corridors and in urban areas with large numbers of severe roadway departure crashes.
    - o The systematic improvement categories to be deployed included the following:
        - Sign and marking enhancements on curves with crash histories;
        - Centerline rumble strips on rural two lane highways;
        - Edge line rumble stripes and shoulder rumble strips, predominantly on rural two-lane highways; and
        - Selective rural tree removal program.
    - o The systematic and comprehensive approaches generate a much larger number of roadway departure improvements statewide, and District personnel would need to be trained and take a more active role in identifying the appropriateness of systematic improvements within their Districts.
- The safety program would need to be expanded to incorporate low-cost, cost-effective countermeasures on other types of projects, such as resurfacing and surface transportation projects, when a crash history exists within the area of the work and the countermeasures can reduce future crash potential.

4 *Kentucky Strategic Highway Safety Plan 2011-2014, Toward Zero Deaths*, available at: http://transportation.ky.gov/Highway-Safety/Documents/strategic_plan_draft1.pdf

- The safety program would need to encompass cost-effective treatments on rural roads since a sizeable portion of the statewide roadway departure crash problem occurred on rural roads.
- Additional countermeasures rarely or never used in Kentucky would need to be carefully and judiciously deployed on highway sections that had specific crash problems that these countermeasures could address. These countermeasures included:

  o Florescent yellow warning signs and inlaid pavement markings in advance of curves,

  o High friction surfaces,

  o Traffic calming, and

  o Use of edge line and shoulder rumble stripes/strips on narrow pavements.
- To achieve the roadway departure safety goal, it would take an investment of approximately $48 million over the 5-year period (or $10 million per year) for infrastructure improvements.
- In addition, a substantial pilot program would need to be initiated to improve safe driver behavior on selected corridors and cities that had significant numbers of severe roadway departure crashes. These pilots would involve highly visible active enforcement and, if successful in reducing severe crashes, would be applied to other corridors and cities that had similar crash histories.

The bottom line for a successful plan implementation was that, **once fully implemented over a 10-year period, approximately 21,000 roadway departure crashes and almost 1,500 disabling injury crashes would be prevented, and more than 650 lives would be saved.**

Kentucky's HSIP Investment Plan is documented in a May 10, 2013, letter to FHWA and includes the following information:

"The Federal highway legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21) was enacted in 2012. MAP-21 continues the HSIP with an increase in funding for Kentucky from $22 million per year to $38 million per year to achieve a significant reduction in traffic fatalities and serious injuries on all public roads. Kentucky's HSIP focuses on three areas for improvement: Roadway Departures, Intersections, and Other Strategic Highway Safety Plan (SHSP) measures.

- **Roadway Departures** – Kentucky's HSIP planning for MAP-21 includes a significant investment in the reduction of roadway departure crashes—more than $25 million (66 percent of total HSIP funding) annually. HFSTs are included within this category and represent about $2 million, or 8 percent of the total funding level for the roadway departure plan. KYTC's field experience with HFST, which started in 2009, gave them the confidence to develop an HFST program of this magnitude.
- **Intersections –** Over the past 7 years, intersection-related crashes have accounted for nearly 14 percent of roadway fatalities and 25 percent of injury crashes. Thus, the Governor's Executive Committee on Highway Safety voted in September 2012 to include intersections as an emphasis area in Kentucky's SHSP. An investment of $6.5 million annually, or about 17 percent of the MAP-21 HSIP funding, was directed to intersections. HFSTs were initially not included in this category, but have since been used at selected intersections.
- **Other HSIP Initiatives** – The key component of these initiatives are opportunities to partner with KYTC District personnel and other shareholders to deliver data-driven safety solutions, advance safety culture throughout the KYTC, and obtain safety funding for projects of local importance while still utilizing a data driven approach. An annual investment of $6.5 million in MAP-21 HSIP funding is directed toward these activities. These funds provide for engineering activities to support key strategies within the SHSP…"

Source: Excerpt from the cover letter for the "KYTC HSIP MAP-21 Investment Plan" submitted by KYTC Secretary of Transportation Michael Hancock to FHWA Kentucky Division Administrator Jose Sepulveda, May 10, 2013.

3.2 HFST PROGRAM CONCEPTION AND HISTORY

KYTC's first HFST installations were in 2009 at two locations on KY 22 in District 5 near Louisville. District engineers had assessed various safety countermeasures for reducing roadway departure crashes and selected HFST as a treatment to assess with field installations. Working with local law enforcement and transportation personnel, two locations were selected that had high crash rates. KYTC expected that these crash rates could be reduced if a high friction surface treatment was installed. District 5 engineers assessed the sites in the field and concurred that the locations were good candidates The HFST was applied, and the locations realized a significant reduction in crashes immediately. The two locations had 65 reported wet pavement crashes in the 3 years before the HFST treatment (average 21.7/year) and 15 (average 3.75/year) in the 4-year after period. This initial positive experience was significant in KYTC developing a HFST program.

WET PAVEMENT CRASHES

3 Years Before HFST Treatment	4 Years After HFST Treatment
21.75 avg. /yr.	**3.75** avg. /yr.

In late 2009, KYTC conducted a data analysis that resulted in identifying the 30 highest crash sections that had the potential to benefit from HFST installation. Within this same time frame, KYTC collaborated with FHWA to develop the KYTC Roadway Departure Safety Implementation Plan (RwDIP). The RwDIP also included a data analysis process that resulted in identifying 159 sections that had the potential to benefit from HFST. Both of these data analysis processes are considered reactive since the analysis is driven by crash frequency.

To facilitate application of HFST on these sections and to reduce risk of poor construction practices, KYTC executed a "Master Agreement" contract (i.e., "on-call" contract) with one HFST contractor in 2010. This contracting mechanism allowed KYTC to direct the contractor to place HFST within a few weeks of the order. This contracting method enabled the agency and contractor to develop a strong partnership that led to a high level of satisfaction with product quality at the KYTC, a contractor that responded quickly to any remediation requests, and the foundation for clearer, more exact specifications in future HFST contracts. The Master Agreement has since expired, and KYTC now contracts for HFST installations in a competitive regional area contracting method. The agency's contracting and construction experiences will be detailed further in section six.

SECTION 4: HFST Site Selection Process

As mentioned in section 3.2, the initial selection of two high-crash locations with high friction demand served Kentucky well in launching their HFST program. The significant after treatment crash reductions were realized immediately, which led to the selection of additional sites to more clearly prove the benefit. To develop an effective HFST program, however, KYTC needed a process to screen for the most appropriate locations to be treated. This section describes the evolution of KYTC's site selection screening processes.

4.1 CRASH DATABASE - KYOPS

KYTC uses the Kentucky Collision Analysis for the Public (KYOPS) database that was developed and is maintained by the Kentucky State Police. This Kentucky crash database is considered comprehensive and of high quality for the KYTC road network. It is also considered a key asset for the agency's safety program. The crash database and information are available to the public at *www.crashinformationky.org*. The Kentucky State Police has continuously improved KYOPS in terms of both data quality and detail since 2000. Thus, KYTC has a high level of confidence in the data from 2008 and forward. To reduce errors and increase quality, the majority of data is collected electronically. Another quality element of the data collection system is that crash locations are generated automatically by the electronic data collection system.

4.2 HFST SITE SELECTION SCREENING PROCESS I – THE 30 WORST

In 2009, at the time the first two HFST installations were ongoing, KYTC developed its first HFST site selection screening process. Since HFST was in its infancy, the process was designed to find sections that had a high probability of realizing benefits (i.e., crash reductions) in a short time frame as a means of continuing to gain support from KYTC personnel. Thus it was a reactive type screening process.

The process included an analysis of 3 years of roadway departure crash data (total crashes and total wet weather crashes) on the two-lane, two-way (TLTW) rural State road system, curves,[5] and ramps (section lengths varied as a horizontal curve database was the source). The definition of roadway departure crash includes the following crash types in the Kentucky crash data base: non-intersection, non-parking lot, non-private property, single vehicle, fixed object, non-fixed object, head on, overturn/rollover, ran off road left/right/straight, sideswipe/opposite direction.

KYTC identified the 30 highest crash sections (i.e., those that had greater than 50 percent wet/dry crash ratio) as priority candidate sites for HFST. Because the two 2009 HFST installation sections were identified within these 30, KYTC had greater confidence that the screening process was reasonable.

4.3 HFST SITE SELECTION SCREENING PROCESS II – 2010 RWDIP

In 2009/2010 KYTC collaborated with FHWA to develop the KYTC Roadway Departure Safety Implementation Plan (RwDIP) discussed in detail above in section 3.1. The HFST site selection screening process incorporated in the RwDIP included 4 years of crash data (2004-2008) on the rural State road system, including roadway departure crashes (defined in section 4.1) (total crashes and total wet weather crashes). The road system analyzed was segregated into 3,000 foot sections (curve database was not utilized for this analysis) and identified by county, route, and milepoint. The threshold value to be considered a candidate HFST site was 8 wet total crashes (8 was selected due to data showing high return on investment) and a minimum wet to total crash ratio of 0.35.

The RwDIP site selection process identified 227 candidate HFST sections. All of the "Worst 30" were included in the RwDIP process. All 227 candidate sections have been field assessed (see section 4.4) to determine if HFST is appropriate treatment, and of these, approximately 160 of the candidate sections were determined to be appropriate for HFST installation. HFST installations based on the RwDIP process started in 2010, and by Fall 2012 approximately 160 sections had been constructed or programmed for construction.

5 A curve is defined as a section of road with a curvature of 3.4° or greater.

4.4 HFST SITE SELECTION SCREENING PROCESS III – USING THE EMPIRICAL BAYES METHODOLOGY

KYTC is currently developing a more advanced screening process with assistance from the Kentucky Transportation Center (KTC) at the University of Kentucky.

A regression model incorporating Empirical Bayes methodology is currently being used to screen the network for candidate segments to be treated with HFST. The Empirical Bayes methodology is a data-driven, science-based approach and is described in detail in the Part C of the AASHTO *Highway Safety Manual*.

The Empirical Bayes methodology is used to more precisely estimate the number of crashes that would have occurred at an individual treated site in the after period had a treatment not been implemented. The effect of the safety treatment is approximated by comparing the sum of the predicted number of crashes in the after period for all treated sites with the number of crashes, corrected using Empirical Bayes, recorded after the safety treatment was installed. The advantage of the Empirical Bayes approach is that it correctly accounts for observed changes in crash frequencies before and after a treatment that may be due to regression-to-the-mean.

The steps below outline the process specific to this application for HFST.

- In assigning crashes to specific segments, KTC used 0.3 mile lengths that did not overlap.
- KTC developed one safety performance function (SPF)[6] for all wet crashes and one for serious wet crashes (fatal, incapacitating and evident injuries). The SPFs use both segment length and traffic volume as variables.
- To apply the model to homogeneous sections, an SPF was developed for each highway type (e.g. rural two-lane, urban four-lane divided). The form of the equation is

$$y = L \times e^{a} \times V^{b}$$

where: **y = predicted crashes**
L = segment length
V = average annual traffic volume, and
a and b are coefficients that describe the behavior between length, volume, and the predicted number of crashes.

4.5 HFST FIELD SITE ASSESSMENT

After the site selection screening process has identified candidate sections, a field site assessment is conducted to determine if HFST is an appropriate treatment. One of greatest time and cost factors of implementing HFST, but considered highly critical to KYTC success to date, is that one of the three HQ KYTC traffic engineers led each of the field assessments. Items considered during the field assessment included but were not limited to:

- Drainage
- Superelevation
- Driveways
- Coordinate future planned work on road section by the district
- Sight distances
- Crash analysis
- HFST treatment for one or both directions of road

6 An SPF is a mathematical model that predicts the mean crash frequency for similar locations with the same characteristics. These characteristics typically include traffic volume and may include other variables such as traffic control and geometric characteristics. This SPF is then used to derive the second source of information for the empirical Bayes estimation, the number of crashes predicted at treated sites based on sites with similar operational and geometric characteristics.

- HFST limits
- Confirm ponding water condition is not present
- Constructability
- Existing pavement condition has expected life of greater than about 3 years.

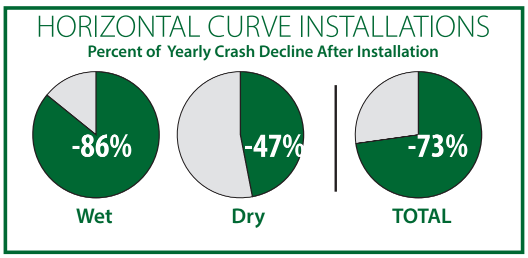
The value of having a small pool of personnel to lead each field assessment is consistency in conducting the field assessment and improving future field assessments by incorporating lessons learned from previous assessments. The major challenge of having a small pool of personnel is the time and cost to conduct the field assessment.

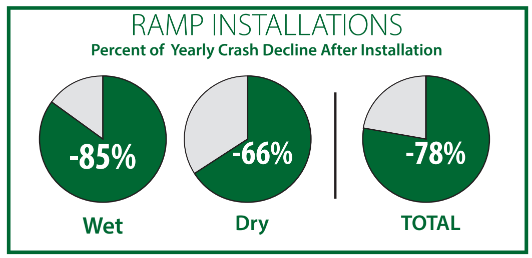
SECTION 5: Data Collection and Analysis in Support of the HFST Program

This section discusses the data collection and analysis used for site selection and monitoring after HFST placement to assess the impact on crashes and HFST friction characteristics.

5.1 HFST POST-INSTALLATION CRASH ANALYSIS

To assess the value of HFST, KYTC performed a post-installation crash analysis. The latest HFST crash analysis, conducted in October 2013, included 43 uniquely identified HFST installations on ramps and horizontal curves that were constructed between July 2009 and October 2012. Since the post HFST installation time frame is not adequate in length to perform a more rigorous analysis, a simple 3 year "before" installation to 1 to 4 years "after" installation[7] crash comparison was performed. For horizontal curve installations yearly wet crash averages declined by 86 percent, yearly dry crash averages declined by 47 percent, and yearly total crashes declined by 73 percent. For ramp installations yearly wet crash averages declined by 85 percent, yearly dry crash averages declined by 66 percent, and yearly total crashes declined by 78 percent.





5.2 HFST POST-INSTALLATION FRICTION MONITORING

As part of KYTC HFST post-installation assessment, there was interest in testing pavement friction on the HFST installations. KYTC conducts friction measurements with a conventional locked wheel skid trailer, but does not perform network-level friction testing. Friction testing is conducted for special requests and materials assessments. The majority of the HFST sites are in sharp horizontal curves, which are not conducive to testing with the locked wheel skid trailer.

KYTC selected the Dynamic Friction Tester (DFT) as the pavement friction testing device for HFST assessment. The Kentucky Transportation Center (KTC) was selected to provide the DFT testing services and prepare a written report. The DFT is a portable device that is suitable for testing pavement friction, but requires a lane closure. Friction data is collected in the inner and outer wheel paths as well as between the wheel paths. Testing is conducted at three locations per site: the beginning, the middle, and the end of the HFST installation. KTC personnel also document pavement distress and take photographs of each site. Unpublished reports documenting the testing conducted in 2012 and 2013 were developed. Some sites have little to no distress, while others display some raveling of the HFST aggregate and delamination of the epoxy-resin. Existing pavement transverse and longitudinal cracking have reflected through the HFST, which is expected. No moisture-trapping-related distresses have been observed. DFT values are consistent for most of the projects and are considered adequate. In 2012, the first year of DFT testing, approximately 80 sites were tested.

7 Installations occurred over a period of 3 years, so some assessed installations were older than others.

PHOTO: Andy Mergenmeier

SECTION 6: Contracting and Constructing HFST

As noted above, HFST is a spot treatment that is applied to an existing roadway surface that increases the surface friction characteristics, allowing for better traction. This application consists of a binder resin system combined with polish- and abrasion-resistant aggregates. Different aggregate and binder resin system materials are available to use when applying an HFST. The following paragraphs briefly identify and explain the contracting process that was used and the materials selected for use by KYTC.

6.1 CONTRACTING PROCESS

At the onset of using HFST, KYTC executed a "Master Agreement" contract (i.e., "on-call" contract) with one HFST contractor in 2010. KYTC elected to adopt this method to enhance the probability for success by contracting with what essentially worked as an incentive: if the contractor performed well and was cooperative, then future work could be expected. As a result, KYTC realized the benefits as desired—both KYTC and the contractor learned in a cooperative manner how to develop and execute an effective HFST program. When issues did arise, the contractor remedied them on site or repaired the area quickly.

Upon expiration of the Master Agreement, KYTC now contracts for HFST installations in a competitive regional area contracting method. The regional area contracts generally cover one construction season. Based on KYTC's experiences from the original Master Agreement, current specifications have been enhanced. To date, two installations were removed and replaced shortly after placement by the contractor due to construction-related concerns that were recognized during application. In addition, three other locations have required spot repairs. A lesson learned from the initial HFST experiences with the Master Agreement contract was it required centerline and edge line striping to be preserved (HFST is not placed over the striping) to reduce costs. New contracts will generally include HFST placement over the entire lane width and new striping.

6.2 CONSTRUCTION

To date all HFST installations have included a two-part epoxy binder with calcined bauxite aggregate, although KYTC is assessing other binder materials for future applications. To date, all HFSTs have been placed on dense graded asphalt mixes.

Some lessons learned about construction efforts include the following:

- Aggregate shedding does occur, and the specifications need to require sweeping both immediately after installation and 3 days after installation.
- The inspector needs to clearly identify the application starting and stopping points for HFST application (for horizontal curves - generally 50-100' before point of curvature (beginning of curve) and 50-100' after point of tangency (end of curve) to try and capture some initial braking area.
- If not covering up centerline or edge line striping with HFST, the inspector needs to ensure HFST is placed adjacent to the stripe.

SECTION 7: Project Examples of HFST Application

This section of the document provides some specific examples where an HFST was placed to reduce wet-weather roadway departures and crashes. A total of four projects are included in this section.

Location 1: Madison County, Kentucky; KY-21, MP 6.7-6.9
Installation: November 2010

Two horizontal curves were located within these mileposts. Prior to the HFST installation, nine wet weather crashes and eight dry weather crashes were recorded at this location over 3 years.

After the installation, over a period of 2.9 years, one wet-weather crashes and three dry-weather crashes were recorded.

PHOTO: KYTC

Location 2: Madison County, Kentucky; KY-21, MP 11.3-13.5
Installation: April 2011

The roadway within this segment was divided into five sections, each containing a horizontal curve. During the 3 years prior to the HFST installation, 37 wet-weather crashes and 6 dry-weather crashes were recorded.

After the treatment, over a period of 2.5 years, 4 wet-weather crashes and 10 dry weather crashes were recorded.

PHOTO: KYTC

Location 3: Fayette County, Kentucky; Ramp from I-75/I-64 to US-68/US-27
Installation: November 2010

An HFST was placed on the ramp from I-75/I-64 to US-68/US-27. The 3-year before-treatment period included 17 wet-weather and 8 dry crashes in the ramp area.

The HFST was placed from the guardrail to the edge strip along the shoulder. During the 3-year post-treatment period only one dry weather crash has been reported.

PHOTO: KYTC

Location 4: Fayette County, Kentucky; KY-922; MP 7.8 to 7.9
Installation: November 2010

During the 3 years prior to the HFST installation, eight wet-weather crashes and five dry-weather crashes were recorded.

After the treatment, over a period of 3 years, one wet-weather crash has been recorded.

PHOTO: KYTC

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PHOTO: Andy Mergenmeier

For More Information:

For more information, visit *http://www.safety.fhwa.dot.gov*

FHWA Office of Safety

Joseph Cheung
joseph.cheung@dot.gov

FHWA Resource Center

Andy Mergenmeier
andy.mergenmeier@dot.gov

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