Horizontal Curves Virtual Peer Exchange

Introduction and Background

This report provides a summary of a peer-to-peer videoconference sponsored by the Federal Highway Administration (FHWA) Office of Safety. The videoconference was the second in a series of roadway departure-focused peer exchanges sponsored by the Office of Safety as a follow-up to face-to-face peer exchanges held with roadway departure Focus States in 2008 and 2009.

The Office of Safety selected ten States — Alabama, Florida, Indiana, Louisiana, Missouri, Oklahoma, South Carolina, Tennessee, Texas, and West Virginia — to participate in this virtual peer exchange. The selected States were chosen based on the number and percentage of fatal crashes on horizontal curves, as well as geographic location.

The peer exchange provided opportunities for participants to share their experiences on a range of topics including:

- Selecting implementation strategies and countermeasures/treatments to reduce roadway departures on horizontal curves;
- Using data to determine which curves to address;
- Prioritizing and funding projects; and
- Addressing challenges encountered in implementing safety programs and countermeasures.

The event also allowed stakeholders to learn from peers who demonstrated innovative approaches to safety on horizontal curves, including edge line striping and high friction surface treatments (HFST). Peer presentations were made by the Missouri Department of Transportation (MoDOT), the Louisiana Local Transportation Assistance Program (LA LTAP), and the West Virginia Department of Transportation (WV DOT).

Sixty-six participants representing Departments of Transportation (DOT), Local Transportation Assistance Programs (LTAP), and FHWA Division Offices attended the virtual peer exchange (see Appendix A for the complete list of event participants and presenters). The peer exchange discussions and presentations focused on the following topics (see Appendix B for the full agenda):

- Systematic implementation of innovative countermeasures to reduce crashes on curves,
- Identification and treatment of horizontal curves on local roads; and
- Challenges and lessons learned in using high friction surface treatments on curves.

ABOUT THE PEER EXCHANGE

FHWA's RSPCB Peer-to-Peer Program (P2P) supports and sponsors peer exchanges and workshops hosted by agencies.

Date

January 24, 2013

Hosts

FHWA Office of Safety

Key Participants

Alabama Department of Transportation
FHWA Alabama Division Office

Florida Department of Transportation
FHWA Florida Division Office

Indiana Department of Transportation
FHWA Indiana Division Office

Louisiana Department of Transportation and Development
FHWA Louisiana Division Office

Missouri Department of Transportation
FHWA Missouri Division Office

Oklahoma Department of Transportation
FHWA Oklahoma Division Office

South Carolina Department of Transportation
FHWA South Carolina Division Office

Tennessee Department of Transportation
FHWA Tennessee Division Office

Texas Department of Transportation
FHWA Texas Division Office

West Virginia Department of Transportation
FHWA West Virginia Division Office

FHWA Resource Center

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FHWA's Office of Safety sponsors P2P events.
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Facilitated roundtable discussions on each of the topics were a significant component of the event. During the discussion, each State shared its experiences in addressing safety on horizontal curves, including innovative practices and implementation challenges.

Peer Exchange Proceedings

Welcoming Remarks

An FHWA Office of Safety representative welcomed participants to the peer exchange. Attendees then introduced themselves and briefly described what they were hoping to learn from the event.

Peer Presentations

Peers addressed a number of topics related to addressing safety on horizontal curves. The following section provides an overview of their presentations.

Systemic Implementation of Edge Line Striping

John Miller, P.E. - Traffic Safety Engineer, Missouri Department of Transportation

MoDOT's Traffic Safety Engineer discussed the State's initiative on systemic implementation of safety countermeasures. Mr. Miller spoke in detail about Missouri's implementation of edge line striping on rural roads, an initiative which began in 2008, as one example of Missouri's effort to apply systemic approaches to highway safety. Missouri's edge line striping program was initiated in 2008 and was funded through the High Risk Rural Roads Program (HRRRP). This program involved painting shoulder edge lines on roads with Average Daily Traffic (ADT) volumes between 400 and 1,000.

Until 2008, MoDOT painted edge line stripes only on roads which had greater than 1,000 ADT; however Missouri has approximately 18,500 centerline miles of potentially eligible HRRRP routes with traffic volumes below 1,000 ADT. A review of the data showed a "Run-off-Road" crash problem, with approximately two-thirds of those occurring in horizontal curves; between 2005 and 2007, approximately 339 fatalities and 2,280 disabling injuries occurred on those roads. However, 65 percent of these fatalities and injuries occurred on the small portion of the roadway system where traffic volumes ranged between 400 and 1,000 ADT (6,800 miles or 37 percent). In 2009, MoDOT's Central District painted edge lines on the majority of its eligible routes, approximately 570 centerline miles on 73 roads. MoDOT performed an Empirical Bayes Analysis using crash data for the three years prior to the project and two years after, and determined that if the project was implemented state wide, 14 fatalities and 95 severe injuries would be prevented each year.

Mr. Miller described the State's initiative on systemic implementation of safety countermeasures. The systemic approach allows the user to address "worst first" problem crash types. MoDOT presented both the benefits and challenges of using a systemic approach for highway safety countermeasures. Benefits include:

- Safety is addressed over a broad area and therefore the State is able to make a noticeable reduction in certain types of crashes; an especially high potential to reduce severe crashes is created.
- A proactive approach reduces the potential for severe crashes at "future" sites.

Challenges to using a systemic approach were also discussed including:

- It requires availability of crash data, traffic volumes and roadway elements to determine which roads are eligible for treatment.
- The systemic approach must also be in line with the priorities and directives of the roadway owner which can be a challenge at the local level.

Systemic projects in Missouri include painting edge lines on the majority of its eligible routes; installing median guard cable on freeways; and installing shoulder rumble strips on major roads on the State system.

Louisiana Local Technical Assistance Program - Horizontal Curve Crash Identification Overview
Marie B. Walsh, Director and Jason Tyler - LA Local Transportation Assistance Program

Representatives from the Louisiana LTAP discussed Louisiana's experience identifying horizontal curve crashes. Louisiana has a higher percentage of roads than average owned by the State as opposed to local municipalities. Approximately 20 to 25 percent of all fatalities occur on local roads in Louisiana and this has spiked in recent years. Louisiana's roadway safety program has faced the challenge of a lack of road data, incomplete crash data, and limited exposure data.

Mr. Tyler discussed how Louisiana identified crashes on horizontal curves which account for 49 percent of all local road fatalities and are 6.5 times more likely to be fatal than other local road crashes. This was a particular challenge as Louisiana has no certified local road database and has incomplete crash and exposure data as well as no ADT counts. Mr. Tyler's team developed a systematic approach using Geographic Information System (GIS) mapping to identify crashes which occurred on horizontal curves. The approach involves visual identification of curves, a process which took three months by a single person. Crashes were then overlapped with the identified curves. Moving forward, the LA LTAP is looking to begin a pilot project with locals. A parish-wide curve improvement project will include signing, pavement markings, and roadway and engineering assessments.

Details on Louisiana's program include:

- Most of the horizontal curve crashes happen on curves with less than a 2,500-foot radius; a GIS tool (coordinate geometry radius tool) identifies the curve radii.
- Several Federal funding sources are used – HRRRP funds, Highway Safety Improvement Program funds, and Section 154/164 transfer funds. Locals must come up with the 10 percent which shows their buy-in to the project.
- Projects have a time limit to go to construction – to date this has not been a problem for locals getting the project to construction because the state process takes so long.
- Projects are funded for a maximum of $500,000. A few projects have been larger and broken into smaller contracts. Because of administrative challenges, the program tries to bundle priorities into a single project.
- Countermeasures used include signing and Chevrons; on multiple crash curves, illuminated beacons are being installed. HFSTs are being investigated. Engineers perform a field review and then provide professional recommendations for improvements.
- Locals own the right-of-way where the signing will be placed; the contract is between the local agency and the Louisiana Department of Transportation and Development (DOTD).
- All data is not yet available, however LA LTAP is working on developing a hierarchy for projects regarding curve radii or ADT or intersections. Roadway safety assessments are used; the current prioritization process targets parishes with the highest numbers of fatalities/injuries weighted by population and other factors.
- An evaluation component to this program is planned.

High Friction Surface Treatment - West Virginia's Plan to Reduce Roadway Departure Crashes
Donna J Hardy, PE - Mobility & Safety Engineer, WV Division of Highways, Traffic Engineering Division

The Mobility and Safety Engineer from the West Virginia Division of Highways (WVDOH) discussed the State's experience using HFST on its roadways. West Virginia has applied HFST at 26 sites with an additional 17 sites programmed and 8 more planned as of December 2012. HFST has been used to address roadway departure issues primarily on horizontal curves, but was also used on a vertical curve project; its use is being expanded to bridge decks and roads near springs and rivers which are more susceptible to freezing and black ice.

WVDOH presented important information regarding HFST installation including:

- The product can be applied to the roadway using either manual or mechanical methods; a determination is made based on terrain, roadway shoulders and storage areas for materials. Other placement requirements relate to weather conditions and roadway surface condition.
- The application must be installed in temperatures above 40 degrees Fahrenheit and during low humidity.

- The roadway surface must be clean and dry and free of potholes and subsurface failure.
- After completion of a project, it must be monitored for loss of aggregate and damage from snow plows. Completed projects are measured and sites with a skid friction rating below 70 are not accepted; the contractor must correct the treatment.

HFSTs are comprised of two components, a polymer and an aggregate. West Virginia only allows Bauxite for use as an aggregate. To date, WVDOH has used three vendors for HSFTs: Tyregrip (23 sites), Ebond Epoxy and Bauxite Materials (2 sites), and Safe T Grip (1 site).

West Virginia's first project was a demonstration on WV 3 in Boone County. The Tyregrip product was applied mechanically and WVDOH paid only for the materials. The project resulted in a drastic reduction in roadway departure crashes. Similar success has been demonstrated at most of the other projects as well. Nine of WVDOH's ten districts have completed at least one project and are requesting additional installations.

Of the 26 completed sites, there were application issues at three sites. Two of those sites have been corrected at no cost to WVDOH and they are in negotiations on the third site. The projects in the table below highlight potential challenges and how they can be addressed for future projects.

Project Location/Existing Conditions	Issues with HFST Installation	Solutions Implemented
WV 20 – Mercer County • Existing road has many horizontal and vertical curves	• Shortage of binder material – job delayed. • Binder and aggregate were applied manually. • Heat and humidity were a problem for curing times. • Aggregate stockpile was too far from application and aggregate did not adhere. • Holes appeared in aggregate – loose aggregate on shoulders.	• Treatment was re-applied mechanically with success.
I-77 – Mercer County • Road was listed in Transparency 5% reports. • Heavy truck traffic, vertical grade issues and many horizontal curves. • Numerous median crossover crashes; cable median was frequently being repaired. • Material was applied mechanically with a single lane closure.	• Truck traffic was too close to the installation, "blowing" the epoxy and preventing the aggregate from binding. • The application truck was travelling at a higher speed than what is recommended.	• The HFST was re-installed with lane closures to prevent truck traffic in the adjacent lane. • Speed of application truck was lowered.

Lessons learned from completed projects include:

- Bids averaged 144 percent above engineers' estimates due to contractor unfamiliarity with the products and initial difficulty finding Bauxite.
- Vacuum sweeping is preferred over mechanical sweeping to prep roadway surface.
- The letting schedule should be limited to ensure adequate temperatures for the material to cure.
- HFST cannot be applied over magnesium.
- The roadway surface must be repaired before application to prevent delamination or spot failures.

- Selecting the correct HFST application method is essential. Mechanical application is preferred over manual as it gives better results.
- The temperature requirement was modified to at least 50 degrees - at the lower temperatures it took hours to cure.
- Some issues occur when applying paint to HFST; other striping methods including tape are being investigated. Other research includes the use of HFST on manholes and steel bridge deck components and the addition of an electrified grid or induction heating to melt snow and ice.
- The roadway surface needs to be clean; if not, the problems are immediate. The positive side to this is that it enables issues to be resolved under the same contract. Specifications require contractors to return if there is a problem. An HFST product will be banned from the state if it doesn't work.

WVDOH's Mobility and Safety section is performing a three year post evaluation of crashes occurring at HFST sites.

Group discussion regarding HFSTs:

FHWA is working with the American Traffic Safety Services Association (ATSSA) and the American Association of State Highway and Transportation Officials (AASHTO) to develop a specification for HFST. A long term specification will take significant time to get approval through AASHTO; there are plans to provide an interim specification, since the process is still evolving. California, Tennessee and Maryland were noted as states that have good specifications.

The group discussed whether increasing superelevation or applying HFSTs was a better way of decreasing roadway departures on curves. Some noted that increased superelevation may cause people to drive faster and not actually improve the safety. HFST won't cause people to drive faster but has been shown to increase safety.

Roundtable Discussion

A number of key topics were discussed during the roundtable discussions.

Does your state have a program to address horizontal curves?

- Alabama has reviewed its crash history from the past five years. The crash reports allow them to identify if crashes take place near or on horizontal curves including prior to, within, or beyond the curve as well as how severe the curve is. The State is prioritizing locations and evaluating approximately 1,600 miles per year for signage upgrades.
- Florida does not presently have a system but would like one soon. They have good data for the State system (10 percent of total roadways); however face the challenge of acquiring data for the 90 percent of the roadways in the State that are locally owned.
- Indiana is developing a systematic curve program as well as a system of countermeasures. The State's current challenge is identifying the curves. Crash reports identify if the crash occurs on a curve but is not very accurate. They are currently working to put crash locations into a GIS database.
- Louisiana checks its curve and crash locations by hand. They have a project - Systemic Low Cost Safety Improvements - with three districts, and have identified all locations that have roadway departure issues. Every two years, a data collection van is used to collect pavement data and can record the locations of curves, though this is often not accurate as the van cannot differentiate between turns and curves.
- Missouri is in year four of a ten year Chevron program. Chevrons are installed on curves where the advisory speed is 15 miles per hour below the speed limit. They have a "top 100" curves program to identify severe curves and apply additional treatments. Missouri is a data rich state and wants to develop a more comprehensive system with curve data and crash locations. All curves in the State have been ball banked.
- Oklahoma is just beginning a horizontal curve program but does not have much detail yet. They maintain a roadway inventory but face the challenge of identifying curves.
- South Carolina does not currently have a program but would like one. They have crash data and locations but are struggling with overlaying roadway inventory to locate curves.

- Tennessee has completed a horizontal curve database. Its roadway departure action plan is currently in the pilot phase; curves have been identified and projects will soon be going to construction. It is a two-year process and the action plan is expected to be completed in 2014. They are also looking at wet weather crashes to identify locations for application of HFST.
- Texas previously evaluated curves across the state and established standards for how to move forward. Thermoplastic striping, raised pavement markings and delineators/Chevrons were used based on the difference between the posted speed and the advisory speed. Texas has adopted a new system called Texas Curve Advisory Speed (TCAS) for curves which uses a global positioning system technology combined with a ball bank indicator to measure superelevation. The technology measures the critical component of the curve and develops an advisory speed. District offices have been trained in how to use the device and are currently using it to evaluate curves. The software for the device was developed through a Texas Transportation Institute research project and has been supplied to other states and countries.
- West Virginia is currently updating all of its systems so that all state data systems will eventually be integrated. The new system will provide curve locations and radii. Rumble strips are being added to all center and edge lines, Safety Edge^{SM} is being applied, and fluorescent signs and additional delineation is being considered.
- Mississippi does not have a horizontal curve program. They are currently working on improving roadway data elements. Rumble strips have been incorporated for many years and the State addresses curves as necessary in conjunction with other projects.

Q. What new ideas and techniques is your state using for horizontal curves?

As an example of a new idea, a pavement marking developed and used in Pennsylvania and installed experimentally in Iowa was shown to the group. The treatment is a turn arrow with the word "SLOW" on the pavement in advance of curves. (See photo below). The Pennsylvania Department of Transportation (PennDOT) installed this at a few hundred locations and noted significant reductions in crashes initially. They were unable to determine its long-term effects due to difficulties in tracking maintenance of the markings. Note the treatment is considered experimental per the Manual on Uniform Traffic Control Devices (MUTCD), because the arrow symbol is specifically designated for turn lanes.

Other feedback from the participating states included:

- Alabama currently has a proposal through the product evaluation board to evaluate thermoplastic discs melted into roadway stripes on horizontal curves and along edge and centerlines instead of scoring/rumble strips. The discs include an audible component – raised ¼ to ½ inches. Alabama DOT will do a noise study looking at both nuisance noise and audible noise to the driver. They are also re-signing all their horizontal curves per the horizontal curve signing table in the MUTCD and will work with locals when the State system is complete. Alabama LTAP is also looking at additional efforts to address safety on the local system.
- Florida has implemented some test sections with rumble stripes and Intelligent Transportation System (ITS) countermeasures. The State has 5-foot shoulders on state roads in rural areas for bicycles. They are looking to reach out

to locals and partner with LTAP centers for safety projects. Many locals may not have engineering staff or data but the LTAP will assist with these issues.

- Indiana is bringing their roadway inventory in line with the Minimum Inventory of Roadway Elements (MIRE) and tying that inventory to the crash data. They also have plans to use high-intensity fluorescent signs near curves and are looking into most of the other ideas discussed.
- Louisiana is a Focus State for roadway departure and has developed an action plan for curves in its Strategic Highway Safety Plan (SHSP).
- Missouri adopted fluorescent sign sheeting two years ago. They are also trying illuminated Chevrons and other signs activated by vehicle detection or speed detection. They have completed some tree removal, but this is not easy to do because it is unpopular with residents. They have installed stacked Chevrons on combined vertical/horizontal curves and are looking to test HFSTs.
- Oklahoma is just starting to look at prioritizing their curves for mitigation.
- South Carolina is identifying curves and overlaying the crash data. They are looking for new treatments and have tried reducing the spacing of raised pavement markings on curves from 80 feet to 40 feet and adding retro-reflective strips on sign posts.
- Tennessee is rolling out HFST for horizontal and vertical curves. They are also considering how they can increase the funding for these projects to 100% federal-aid for local agencies.
- Texas is using a type of striping which includes a noise component similar to the product used in Alabama. It is created through a method of placing thermoplastic. The thermoplastic striping has a series of raised bumps spaced transversely to the wheel. Texas is also using profile markings and speed activated sign beacons.
- West Virginia is putting together a task force to specifically look at roadway departures because they are such a high percentage of its severe crashes.

Key Areas of Interest and Next Steps

At the conclusion of the roundtable discussion, states discussed key areas of interest based on information that emerged from the peer exchange, as well as topics that they intend to explore in the future:

- Several states expressed interest in learning more HFST.
    - Texas and Tennessee plan to evaluate HFST for curves and will investigate best practices for developing HFST projects.
    - South Carolina has a better understanding of where other states are with HFST and plans to follow up with contacts gained from the event.
    - Missouri plans to learn more about HFST, particularly identifying the best curves for the treatment; they will look into applying HFST on curves rather than adjusting superelevation.
    - Louisiana would like to pursue HFSTs and would like to coordinate with West Virginia regarding its program.
- States are interested in learning about effective outreach mechanisms to reach other stakeholders, particularly county and local agencies; focusing on better coordination of safety programs; and making more comprehensive, systematic improvements.
- Participants from West Virginia may reconsider how different funding sources are used.
- Oklahoma is just beginning their program, but now has a better idea of what to consider. They are considering the PennDOT advance curve warning pavement marking for their horizontal curve program. Referring to the discussion about superelevation correction versus HFST, they would like to correct superelevation first but don't know which treatment is best.
- Mississippi has tried speed feedback signs but experienced vandalism problems; they would like to approach curves systemically which is not being done currently.
- Indiana plans to look at additional countermeasures for curves including warning markings and radar detection signs; they have been on the fence with HFSTs but now see the value.

- Florida plans to look more seriously at HFSTs. They currently have intensive programs for data collection related to implementing the Highway Safety Manual and plan to use systematic approach for addressing curves.
- Alabama liked the PennDOT pavement markings and plans to look into 100 percent funding since many counties can't provide the 10 percent match. They will also look into the profile markings used in Texas.

Feedback and Suggestions

Participants noted that the peer exchange went smoothly with good discussions and that it was appropriate in time and scope. General comments included: "exceeded my expectations" and "worth the time spent." All of the states indicated that they left the peer exchange with better knowledge of the subject matter and many plan to follow up with contacts gained during the exchange and implement some of the new ideas they heard. Highlights identified by the participants included:

- Lessons learned on HFST applications;
- Variety of treatments available for horizontal curves;
- Funding low cost countermeasures using HSIP funds;
- Unique contracting processes for low cost countermeasure implementation; and
- New and innovative technology for measuring horizontal curves and tracking horizontal curve crashes.

Suggestions on how the event could have been improved included:

- Add a discussion on SHSPs including specific strategies used in SHSPs to address curves.
- Provide a more detailed presentation on curve signage with all signage options and costs. The discussion on MUTCD changes regarding advisory speeds and Chevron placement could have been stressed better.
- Poll other states in advance for their expertise and include those leaders as presenters so other states can learn from their experience.
- Present methods of data analysis to identify and prioritize candidate intersections, as well as delineation methods to improve safety on horizontal curves with an emphasis on low-cost treatments.

Overall, the group consensus was that the peer exchange was very helpful. One participant noted, "The pace was good and the presenters were knowledgeable. It was great to catch up on the emerging state of the practice from other locations." Other attendees said that the "greatest benefit of the event was hearing the different challenges that others are going through" and "learning about countermeasures that worked, didn't work, and might work". States appreciated the opportunity to spend time with staff from the FHWA Division Office, LTAP, and State DOT.

Appendix A: Event Participants

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Appendix B: Event Agenda

Horizontal Curve Peer Exchange

Agenda

Thursday, January 24, 2013

10:30am to 3:00 pm Eastern Time

10:30 Welcome and Introductions

Presentations and Q&A

Systemic Implementation of Edge Line Striping, John Miller, MoDOT
Identifying and Treating Horizontal Curves on Local Roads, Marie Walsh, LA LTAP

Roundtable Discussion

- Selecting implementation strategies – Systemic, Hot Spot, other
- Using data to determine which curves to treat
    - Crash Data – state, national, and local sources and issues
    - Roadway Data – widths, intersections, degree of curve
    - Other Data
- Selecting treatments/countermeasures
- Efficient means of gathering necessary info for implementation
- Prioritizing projects

12:30 Working Lunch

Local discussion at each site on Addressing Safety on Curves

Presentation and Q&A

High Friction Surface Treatments on Curves, Donna Hardy, WVDOH

Roundtable Discussion

- Challenges to treating local roads – including where they were never engineered
- Funding projects – HSIP and beyond (funding match, etc.)
- Implementation concern with pavement countermeasures (friction, rumble strips, etc.)
- Taking risks – why or why not?

Take-Away Items

- Where do we go from here?
    - What will you do differently
    - What concerns still need to be resolved
    - Future peer-to-peer opportunities

3:00 Close

Appendix C: Web Sites

- The list below provides links to websites discussed during the peer exchange.

HFST Specifications
Site: High Friction Roads **Link:** www.highfrictionroads.com
Texas Profile Marking Standard
Site: TXDOT Profile Marking Standard **Link:** bit.ly/WpnhHc