Midwest States Pooled Fund Program
Quarterly Progress Report – First Quarter 2016
December 1, 2015 to March 31, 2016

DRAFT REPORTS – POOL FUND

Kohtz, J.E., Bielenberg, R.W., Rosenbaugh, S.K., Faller, R.K., Lechtenberg, K.A., and Reid, J.D., *MASH Test Nos. 3-11 and 3-10 on a Non-Proprietary Cable Median Barrier*, Draft Report to the Midwest States Pooled Fund Program, MwRSF Research Report No. TRP-03-327-16, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 17, 2016.

Rosenbaugh, S.K., Bielenberg, R.W., Lingenfelter, J.L., Faller, R.K., Reid, J.D., and Lechtenberg, K.A., *Cable-to-Post Attachments for a Non-Proprietary High-Tension Cable Barrier – Phase III*, Draft Report to the Midwest States Pooled Fund Program, MwRSF Research Report No. TRP-03-323-16, Project Nos. TPF-5(193) Supplement Nos. 44 & 64, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, January 25, 2016.

FINAL REPORTS – POOL FUND

Rosenbaugh, S.K., Bielenberg, R.W., Lingenfelter, J.L., Faller, R.K., Reid, J.D., and Lechtenberg, K.A., *Cable-to-Post Attachments for a Non-Proprietary High-Tension Cable Barrier – Phase III*, Final Report to the Midwest States Pooled Fund Program, MwRSF Research Report No. TRP-03-323-16, Project Nos. TPF-5(193) Supplement Nos. 44 & 64, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 24, 2016.

Lingenfelter, J.L., Rosenbaugh, S.K., Bielenberg, R.W., Lechtenberg, K.A., Faller, R.K., and Reid, J.D., *Midwest Guardrail System (MGS) with an Omitted Post*, Final Report to the Midwest States Pooled Fund Program, MwRSF Research Report No. TRP-03-326-16, Project Nos. TPF-5(193) Supplement No. 80, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, February 22, 2016.

Rosenbaugh, S.K., Faller, R.K., Lechtenberg, K.A., and Holloway, J.C., *Development and Evaluation of Weak-Post W-Beam Guardrail in Mow Strips*, Final Report to the Midwest States Pooled Fund Program and Mid-America Transportation Center, MATC Report No. MATC-UNL: 206 and MwRSF Research Report No. TRP-03-322-15, Project Nos. TPF-5(193) Supplement No. 57, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 1, 2015.

DRAFT REPORTS – PROJECT RUN THROUGH POOL FUND, FUNDED BY INDIVIDUAL STATE

Lechtenberg, K.A., Schmidt, J.D., Faller, R.K., Guajardo, A.L., Bielenberg, R.W., and Reid, J.D., *Development of a Crashworthy Pedestrian Rail*, Draft Report to the Wisconsin Department of

Transportation, MwRSF Research Report No. TRP-03-321-15, Project Nos. TPF-5(193) Supplement No. 41, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, November 24, 2015.

FINAL REPORTS – PROJECT RUN THROUGH POOL FUND, FUNDED BY INDIVIDUAL STATE

None

DRAFT REPORTS – FHWA PROJECT

Winkelbauer, B.J., Faller, R.K., Bielenberg, R.W., Rosenbaugh, S.K., Reid, J.D., and Schmidt, J.D., *Phase I Evaluation of Selected Concrete Material in LS-DYNA*, Draft Report to the Nebraska Department of Roads and Federal Highway Administration, Nebraska Division, MwRSF Research Report No. TRP-03-330-16, Project No. DPS-STWD(118), Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, January 26, 2016.

FINAL REPORTS – FHWA PROJECT

None

DRAFT REPORTS – FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE PROJECT

Lechtenberg, K.A., Faller, R.K., Rosenbaugh, S.K., and Reid, J.D., *Phase III Demonstration of Ponderosa Pine Round Posts as Alternative to Rectangular SYP Posts in G4(2W) Guardrail Systems*, Draft Report to the Arizona State Forestry Division, Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, and Arizona Log & Timberworks, MwRSF Research Report No. TRP-03-329-15, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, January 27, 2016.

FINAL REPORTS – FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE PROJECT

None

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): NE Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl.#21	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:
Additional Funding to Complete Development of a Crash-Worthy Terminal for Midwest Four-Cable, HT, Barrier System

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Sicking, Faller	402-472-3084	jreid@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
RPFP-10-CABLE-3	2611211028001	July 1, 2009
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
July 31, 2012	April 30, 2016	4

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ☑ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$159,193	$155,955	98%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$4,834	

Project Description:

Objective: Redesign the cable release mechanism and foundation of the three cable end terminal to accommodate four high tension cables.

Original Tasks
1. Background and literature review - completed
2. Design and analysis, including bogie testing part 1 - completed
3. Report part 1 - completed
4. Design and analysis, including bogie testing part 2 - in-progress
5. Full-scale testing
6. Report

This is Phase II of the project. Phase I was funded in Year 17: SPR-3(017) Suppl.#38 - "Testing of Cable Terminal for High Tension Cable (1100C & 2270P)"

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 6.
The third report (TRP-03-332-16) was finalized on April 28, 2016.

Anticipated work next quarter:

The final reports will be shipped.

Significant Results:

Report TRP-03-268-12 documenting part 1 of this project was published July 17, 2012.
"Development and Recommendations for a Non-Proprietary, High-Tension Cable End Terminal System"

History of cable terminal design changes were documented in a Midwest Roadside Safety Facility internal document, June 2013.

Report TRP-03-294-14 documenting part 2 of this project was published March 21, 2014.

Simulations of a bogie vehicle impacting the end terminal system at 0 and 15 degrees released the cables quickly and easily with minimal damage to the cable anchor bracket and cable release lever.

Simulations of small cars impacting in the reverse direction near the cable anchor bracket indicated potential problems of excessive vehicle deceleration and vehicle stability. New concepts were brainstormed to release the cables in the reverse direction to mitigate these potential problems.

Report TRP-03-332-16 was finalized on April 28, 2016.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Final design details and full-scale testing for this project cannot be conducted until the High Tension Cable Barrier System is completed. Because of timing in that project, this project is behind schedule.

$64,736 of the project funds have been re-allocated to PF-Yr 24 Cable Project. $64,736 of that re-allocation has been reflected on page 1 of this quarter report under "Total Amount of Funds Expended This Quarter".

The bogie testing in Task 4 and the full-scale testing in Task 5 that were originally budgeted will not be completed as the scope and funds of this project have changed. Further design and evaluation of the cable end terminal system was funded during Year 26 of Midwest States Regional Pooled Fund Program.

Potential Implementation:

The revised terminal will provide a non-proprietary end terminal for high tension barrier cable systems once the design is finalized and a full-scale crash testing program has been successfully completed.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Wisconsin Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl. #41	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:		
Crashworthy Pedestrian Rail		
Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Sicking, Faller, Bielenberg, Lechtenberg	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211061001		7/1/2011
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
6/30/2014	12/31/2015	3

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$234,629	$281,292	100%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$14,273	

Project Description:

Situations arise on the roadside where a barrier or rail is required to prevent pedestrians from crossing into a certain area which may be acceptable for an errant vehicle. Although these rails would not need to redirect or stop an errant vehicle, they must also not present additional hazards to the motoring public. These rails/fences should not cause excessive decelerations, vehicle snag points, vehicle instabilities, or produce fragments that may cause harm to other motorists when impacted. In addition, pedestrian rail systems must comply with the Americans with Disabilities Act (ADA). Therefore, a need may exist for a crashworthy pedestrian rail to protect pedestrians and prevent improper street crossings.

The objective of this research effort is development of a pedestrian rail to be ADA compliant and crashworthy. The objectives will be to identify the highest priority, crashworthy pedestrian rail need, to develop viable design concepts to meet that need, to finalize development of the crashworthy pedestrian rail system, and to perform the necessary MASH compliance tests for the system.

Objectives / Tasks

1. Literature review
2. Identification of rail needs and design criteria
3. Pedestrian rail design concepts
4. Component testing of design concepts
5. Summary report of design concepts
6. Finalize system details
7. Full-scale crash testing (MASH 2-91)
8. Full-scale crash testing (MASH 2-90)
9. Written report documenting design, testing, and conclusions

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Final report published and disseminated to the sponsor.

Project was completed.

Anticipated work next quarter:

None as all work has been completed and project is closed.

Significant Results:

Based on the results of the six bogie tests, the critical impact orientation is believed to be the end-on orientation. All of the systems when impacted at a 25 degree angle broke away and did not exhibit much potential for vehicle intrusion. A system that has the posts, rails, and spindles welded appeared to perform better than if they are held together with a set screw or just inserted into the rail.

On October 24, 2014, the Pedestrian Rail system was subjected to AASHTO MASH TL-2 longitudinal channelizer test conditions using a 1100C small car vehicle (test designation 2-90). In test no. APR-1, the small car impacted the system at a speed and angle of 45.2 mph and 25.1 degrees, respectively, resulting in an impact severity of 29.7 kip-ft. The system fractured as intended and the vehicle penetrated through the system as anticipated with five panels fracturing away during the impact. The occupant impact velocities and occupant ridedown accelerations were within the suggested limits provided in MASH. The test was acceptable according to the safety performance criteria of AASHTO MASH for test designation no. 2-90.

On November 12, 2014, the Pedestrian Rail system was subjected to AASHTO MASH TL-2 longitudinal channelizer test conditions using a 1100C small car vehicle (test designation 2-90). In test no. APR-2, the small car impacted the system at a speed and angle of 44 mph and 90 degrees (end-on impact), respectively. The vehicle traversed through the first five panels with the panels fracturing but not as quickly as intended. When the vehicle encountered the sixth panel, the panel was actually leaning on the seventh panel which caused the vehicle to experience high decelerations. Since the numbers obtained from the two different accelerometer units straddled the maximum limits in MASH, FHWA was contacted to determine how to interpret/choose the value to report.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

The 2010 version of the Aluminum Design Manual introduced new welded factors which had to be taken into consideration during the connection design development.

Fabrication of the aluminum systems is taking much longer than anticipated due to limited local aluminum fabricators and the small quantity.

Seven bogie tests were conducted and only four were initially budgeted. These were necessary in order to evaluate the concepts prior to selecting the most promising design for full-scale testing.

$46,663 of project funds was posted to Project No. TPF-5(193) Supplement #43.

Potential Implementation:

The results from this research will provide a cost effective, ADA compliant, crashworthy, pedestrian rail that prevents foot traffic from crossing but does not pose as a hazard to errant vehicles.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): NE Department of Roads

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #51		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Annual LS-DYNA Modeling Enhancement Support		
Name of Project Manager(s): Reid, Sicking, Faller, Bielenberg	**Phone Number:** 402-472-3084	**E-Mail** jreid@unl.edu
Lead Agency Project ID: RPFP-12-LSDYNA	**Other Project ID (i.e., contract #):** 2611211071001	**Project Start Date:** July 1, 2011
Original Project End Date: June 30, 2014	**Current Project End Date:** September 30, 2016	**Number of Extensions:** 2

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ☑ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$36,543	$32,616	90%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
0	$3,225	0

Project Description:

The objective of this research effort is to maintain a modeling enhancement program funded by the Pooled Fund Program States to address specific modeling needs shared by many safety programs. Funding from this project would go towards advancement of LS-DYNA modeling capabilities at MwRSF. The exact nature of the issues to be studied would be determined by the most pressing simulation problems associated with current Pooled Fund projects.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

A two-hour discussion on friction in LS-DYNA roadside safety simulations was conducted by MwRSF researchers at the January 2016, TRB meeting in Washington D.C. Information used in this discussion had been accumulating for many years during various LS-DYNA projects.

The 2012 detailed Yaris model was fitted with the MwRSF developed detailed tire model. The detailed tires will significantly improve tire interaction on several projects including hitting curbs and rock ditch liners. This effort was much more complicated than it might appear. The detailed tire model MwRSF developed was for a pickup truck, the Yaris has considerably different type and size of tires. The model could not simply be scaled to fit.

A report documenting some of the LS-Dyna enhancements made over the years using the multiple LS-DYNA Modeling Enhancement Support project funds was started.

Anticipated work next quarter:

A draft of the report documenting some of the LS-Dyna enhancements made over the years using the multiple LS-DYNA Modeling Enhancement Support project funds will be completed.

Significant Results:

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Due to the nature of this project, this project is worked on when the need arises or when there is a slack in other project priorities. Thus, the funds were not expended in the original project period.

Potential Implementation:

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #56		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Increased Span Length of the MGS Long Span		
Name of Project Manager(s): Reid, Sicking, Faller, Bielenberg, Lechtenberg	**Phone Number:** 402-472-3084	**E-Mail** jreid@unl.edu
Lead Agency Project ID: RPFP-13-MGS-3	**Other Project ID (i.e., contract #):** 2611211082001	**Project Start Date:** 7/1/2012
Original Project End Date: 6/30/2015	**Current Project End Date:** 6/30/2016	**Number of Extensions:** 1

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ☑ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$212,730 + suppl $36,605	$195,980	85%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$15,753	

Project Description:

The current MGS long-span guardrail system provides the capability to span unsupported lengths up 25 ft. While this span length has many useful applications, many culvert structures exceed the span length of the MGS long-span system. Other solutions for mounting guardrail to culverts exist, but mounting hardware to culverts can also cause difficulties. If the long span can be adjusted to accommodate longer spans, the difficulties associated with mounting hardware to the culvert can be avoided.

The objective of this research effort is to design and evaluate the MGS long-span design for use with unsupported spans greater than 25 ft. The research effort could be focused in one of two directions. The research could focus on determination of the maximum unsupported span length for the current long-span design or it could focus on evaluating potential modifications that may allow for significantly longer unsupported spans. The increased unsupported span design would be designed to meet the TL-3 safety criteria set forth in MASH.

Objectives / Tasks

1. Literature review of previous long-span systems - completed
2. Simulation of both original and any new long-span system designs - completed
3. Design modifications to extend unsupported length - completed
4. Full scale crash testing of new design (two MASH 3-11 tests) - completed
5. Data analysis and evaluation - completed
6. Written report documenting all design work, simulation, testing, and conclusions - in-progress

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 5.
Data analysis and evaluation of both tests were completed and presented at the Annual Pooled Fund Meeting on April 19, 2016.

Task 6.
Final test report writing began.

Anticipated work next quarter:

Task 6.
A first draft of the final test report is anticipated.

Significant Results:

Simulations of an increased span length indicated possible successful redirection at a span length of 31.25-ft and 37.5-ft. The 43.75-ft and 50-ft span lengths were ruled out as potential span lengths for future full-scale crash testing due to questionable vehicle capture and severe impacts with the downstream wing wall.

Based on Pooled Fund member states preferences, the following was selected for testing: Span length of 31.25-ft and replace the wood CRT posts with universal breakaway steel posts.

Impacting at CIP-1, test no. mgsls-1 successfully crash tested the increased span length MGS system on May 18, 2015.

Impacting at CIP-2, test no. mgsls-2 unsuccessfully crash tested the increased span length MGS system on June 30, 2015. The downstream anchorage disconnected relatively early in the event, allowing for the truck to pass through the system.

Objectives / Tasks	% Complete
1. Literature review of previous long-span systems	100%
2. Simulation of both original and any new long-span system designs	100%
3. Design modifications to extend unsupported length	100%
4. Full scale crash testing of new design (two MASH 3-11 tests)	100%
5. Data analysis and evaluation	100%
6. Written report documenting all design work, simulation, testing, and conclusions	50%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

This project has a cost of $249,335. There was insufficient funding in Pool Fund Year 23 to fund this entire amount. Thus, the budget for Year 23 is $212,730, and the remaining is being funded by contingency funds in Pool Fund Year 23.

Due to the higher than normal rainy season, the full-scale testing program was delayed, resulting in an overall project delay. A no-cost time extension was granted.

Potential Implementation:

The MGS long-span system has the ability to perform safely without nested rail and with a minimal barrier offset. These features make the barrier a very functional, efficient, and safe option for protection of low-fill culverts. Development of an increased unsupported span length for the MGS long-span system will add to the flexibility of the design and provide for improved protection of culvert headwalls and vertical dropoffs with a length greater than 25 ft.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl. #57	☑ Quarter 1 (January 1 – March 31) ☐ Quarter 2 (April 1 – June 30) ☐ Quarter 3 (July 1 – September 30) ☐ Quarter 4 (October 4 – December 31)

Project Title:		
Weak-Post W-beam Guardrail Installed in Mow Strips		
Name of Project Manager(s): Reid, Sicking, Faller, Bielenberg, Lechtenberg	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211083001	**Other Project ID (i.e., contract #):** RPFP-13-MGS-5	**Project Start Date:** 7/1/2012
Original Project End Date: 6/30/2015	**Current Project End Date:** 6/30/2016	**Number of Extensions:** 1

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$162,896	$108,956	99%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$2,822	

Project Description:

Over the years, it has become desirable to place a longitudinal concrete slab or continuous asphalt pavement under W-beam guardrail systems in order to reduce the time and costs for mowing operations around guardrail posts. Likewise, many times guardrail posts must be installed in un-yielding pavements. Unfortunately, the placement of guardrail posts in pavement restricts energy dissipation by restricting the posts from rotating through the soil. Thus, installations in pavements have incorporated a blocked-out area or "leave-out" that surrounds each post. These leave-outs allow post rotation in the soil and result in acceptable safety performances for standard W-beam guardrails.

Recently, the MGS Bridge Rail was developed and successfully crash tested under the TL-3 MASH guidelines. This system utilized weak steel posts placed in tubular steel sockets that were side-mounted to a concrete bridge deck. The energy dissipation mechanism for this system was designed as bending of the weak posts instead of post rotation through soil. Since the posts are installed in rigid sleeves, MwRSF believes that the MGS Bridge Rail could be adapted for use in guardrail applications where mow strips are required. In this situation, it would be unnecessary to provide large leave-outs around the posts of guardrail systems installed in un-yielding pavements. Thus, The objective of this research effort is to adapt the MGS Bridge Rail system for use in mow strips and other pavements.

Objectives / Tasks

1. State survey of existing mow strip practices
2. System design and analysis
3. Dynamic bogie component testing
4. Full scale crash testing (MASH 3-10 and 3-11 tests)
5. Data analysis and evaluation
6. Written report documenting all design work, simulation, testing, and conclusions

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The draft report was reviewed and edited by MATC as they provided $60,000 of additional funding to conduct extra component tests of posts within various mow strips. The draft report was edited according to their comments and finalized. The report was then published and distributed to the project sponsors on 2/19/2016. The report was also placed on the MwRSF website.

Work has also began on creating the Hardware Guide drawings and assembling the FHWA eligibility letter.

Anticipated work next quarter:

The Hardware Guide drawings and the eligibility letter will be completed and submitted to FHWA for qualify for federal reimbursement. Upon completion of the FHWA letter, the project will be closed.

Significant Results:

A survey of the Pooled Fund States revealed the critical mow strip to be 4 in. thick and 4 ft wide. Both asphalt and concrete versions of the mow strip shall be investigated through dynamic component tests. Component testing testing demonstrated that a 4" concrete pad has sufficient strength to withstand the impact loads without damage. However, testing within the asphalt mow strips illustrated that the posts will push through the asphalt and displace up to 3 inches.

When a 10" wide shear plate was welded to the back of 24"-30" deep sockets, both lateral and longitudinal tests resulted in minimal damage to the 4" asphalt mow strip and minimal displacements to the socket. However, an impact of dual 24" sockets spaced at 37.5" within 4" of asphalt resulted in asphalt fracture socket rotations.

A full-scale test was conducted on the weak-post guardrail system placed within 30" deep sockets spaced at 17.5" along the centerline of a 4' wide, 6" deep asphalt mow strip. The system successfully redirected the 2270P vehicle, but the asphalt behind the posts was damaged. A 2"-3" crack opened along the post line throughout the impact region of the system and the asphalt behind it was pushed back and cracked further.

Another dual post test was conducted, this time with the posts installed in a 4" thick by 4-ft wide concrete pad. During the test, the posts bend over and the concrete pad remained undamaged. Thus, if a mow strip is desired that won't require pavement repairs after impacts, a 4" concrete mow strip is recommended for use in combination with the weak-post guardrail system.

Objectives / Tasks	% Complete
1. State survey of existing mow strip practices	100%
2. System design and analysis	100%
3. Dynamic bogie component testing	100%
4. Full-scale crash testing (MASH 3-10 and 3-11 tests)	100%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Matching funding in the amount of $60,000 was obtained through the Mid-American Transportation Center. Thus, additional component testing was conducted to explore various options for installing the S3x5.7 posts within both concrete and asphalt mow strips. Thus, the project is currently running behind the original schedule.

Potential Implementation:

Adapting the MGS bridge rail to be placed in various pavements will allow designers to install the weak post, MGS system in mow strips without requiring leave-outs, breakaway posts, or other additional hardware. It is anticipated that the new post foundation design will significantly reduce labor and system costs associated with installation, repair, and maintenance of guardrail installed in mow strips and other pavements. Insight will also be gained regarding the potential performance of other weak post guardrail systems when installed in mow strips.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Wisconsin DOT

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**	
TPF-5(193) Suppl # 62	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)	
Project Title: Safety Investigation & Design Guidance for Curb & Gutter Near Energy-Absorbing Terminals		
Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Schmidt, Bielenberg, Faller, Reid	(402) 472-0870	jennifer.schmidt@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211094001		7/1/2013
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
6/30/2016	6/30/2016	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$173,716	$110,094	70%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$19,645	

Project Description:

AASHTO highway design policies discourage the use of curbs along high-speed roadways. This guidance is largely based on the fact that curbs may cause impacting vehicles to become airborne, thus resulting in loss of control by the driver. In the case of a laterally skidding vehicle, a rollover may also be induced upon striking the curb (i.e., tripping). However, safety appurtenances, such as guardrail end terminals and crash cushions, are often placed in combination with curbs. Nonetheless, curbs are often installed along high-speed roadways for several reasons, including restricted right-of-way, drainage considerations, access control and other curb function requirements. In these situations, eliminating existing curbs or laterally offsetting curbs away from the traveled way may represent an expensive or unattainable alternative.

Historically, the safety performance of energy-absorbing guardrail end terminals has been based on the results of full-scale crash tests performed on level terrain. However, very limited research has been performed to investigate the safety performance of these features when installed in combination with curbs. Thus, there is a need to investigate whether curb placement in advance of guardrail end terminals significantly degrades barrier performance as a result of the changes in vehicle trajectory prior to impact. In addition, design recommendations are necessary for determining the safe placement of curb and gutter installed adjacent to energy-absorbing guardrail end terminals.

The objective of this research effort is to develop guidance for the safe placement of curbs adjacent to energy-absorbing guardrail end terminals. A combination of computer simulation and full-scale crash tests will be used to identify potential safety hazards, define critical curb and terminal impact scenarios, and select optimal curb placement. The effort will focus on a single, representative energy-absorbing, guardrail end terminal configuration that is selected during the study effort. In addition, the impact conditions for the simulation and crash testing programs will correspond with those published for Test Level 3 (TL-3) in the MASH impact safety standards.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Writing continued on the report to document the models and results. All simulations with curbs have been completed that include 2", 4", and 6" tall wedge-shaped and vertical curbs at 0" and 6" offsets from the face of the guardrail (74 models total). MASH test designations 3-30, 3-31, 3-32, and 3-33 were completed on each configuration. The results of these simulations are being processed and a large summary table was created to compare trends. The results in the summary table include: impact conditions, curb configurations, guardrail feed length, lateral and longitudinal OIV, lateral and longitudinal ORA, roll, pitch, yaw, change in bumper height, time and velocity of impact and end of rail extrusion, and various measures of energy and average force exerted on the rail.

Anticipated work next quarter:

All of the current simulation results will be processed, documented, and summarized. A meeting will be held with the sponsor to determine if other curb configurations, such as more gently sloping curbs or with a flared end terminal, may be considered. Writing will continue on the report.

Significant Results:

Baseline simulations were completed.

End terminal models with the G4(1S) and MGS were developed. Twelve impact conditions were simulated for both the G4 (1S) and MGS models, and the results were reasonable when compared to full-scale crash testing.

Simulations with all curb configurations were completed.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

The development of design guidelines for the safe placement of energy-absorbing guardrail end terminals behind curbs will provide beneficial information for highway designers and engineers and reduce the risk of highway agencies adopting inadequate and potentially unsafe curb-barrier combinations. These guidelines would also serve to reduce inconsistencies in the recommendations from one highway agency to the next, inconsistencies which could be the source of significant tort risk. These guidelines could potentially reduce highway agency expenses associated with curb removal in front of guardrail end terminals if certain combinations are found to be safe and no longer prohibited. In addition to being costly, curb removal is hazardous to both workers who are exposed to highway traffic in construction zones and the motorists who must traverse a restricted travel way. Any funds which can be saved by avoiding curb removal could be used for implementing other cost-beneficial safety improvements.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Supplement #64	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:
Continued Development of the Midwest Four-Cable, High-Tension, Median Barrier (Continuation Funding)

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Faller, Lechtenberg, Bielenberg	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211096001	RPFP-14-CABLE1	7/1/13
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
6/30/16	6/30/16	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$375,513 (+$264,372 from Yrs 20 & 22)	$501,984 ($294,745 R&D/Reporting	20

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$19,679 ($27,285 R&D/Reporting Cc	

Project Description:

The Midwest Roadside Safety Facility (MwRSF) has been conducting research for the Midwest States Regional Pooled Fund Program to develop a non-proprietary, high-tension, four-cable, median barrier that is capable of being used anywhere in a V-ditch with 4H:1V side slopes. Three tests still remain to complete the test matrix of the cable barrier system in a V-ditch. In addition, the four-cable, high-tension, median barrier has never been tested on level terrain. There is a concern that FHWA may not approve this design without testing on flat ground, especially when considering the wide cable spacing and increased cable heights. Further, the barrier deflections observed in crash tests performed in a 4H:1V V-ditch are likely higher than would be observed on flat ground. Crash testing of the barrier installed on level terrain would identify barrier deflections and working widths that can be expected when the barrier is used in narrow medians with gentle slopes and would allow for better performance comparisons between the Midwest four-cable barrier and other proprietary systems.

Objective: To complete the development, testing, and evaluation of the four-cable, high-tension, median barrier system for use on level terrain.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The report containing the component testing of the non-bolted connection concepts was disseminated to the sponsors.

The draft report containing the full-scale crash tests (test nos. MWP-4, MWP-6, and MWP-7) was sent to the sponsors for review and comment.

Internal review of the draft report containing the evaluation of floorpan tearing and cable splices was initiated.

Internal review of the draft report containing the full-scale crash test no. MWP-8 was initiated.

Determined potential fixes for the current system to eliminate the floorboard cutting issue seen in test no. MWP-8. Fabricating the concepts in order to test how well they eliminate the cutting issue.

Initiated the R&D path of a complete redesigned system.

Anticipated work next quarter:

Finalized and disseminate the report containing the full-scale crash tests (test nos. MWP-4, MWP-6, and MWP-7) to the sponsors.

Internal review of the draft report containing the evaluation of floorpan tearing and cable splices will continue. There is a potential the draft report may be sent to the member states for review during the next quarter.

Internal review of the draft report containing the full-scale crash test no. MWP-8 will continue. There is a potential the draft report may be sent to the member states for review during the next quarter.

Finalize the fixes for the current system to eliminate the floorboard cutting issue seen in test no. MWP-8. Anticipate preparing, constructing, and conducting a retest of test 3-10.

Continue down the R&D path of a complete redesigned system if so directed by the sponsors.

Significant Results:

On March 26, 2014, MwRSF conducted a 1500A crash test (test no. MWP-1) into the Midwest high-tension cable median barrier with the Midwest Weak Post placed at the slope break point of a 6:1 slope using a 1500-kg Ford Taurus according to the TL-3 safety performance guidelines of MASH, specifically test designation no. 3-17. The vehicle was successfully contained and redirected.

On April 18, 2014, MwRSF conducted one pickup crash test (test no. MWP-2) into the Midwest high-tension cable median barrier with the Midwest Weak Post using a 2270-kg Dodge QuadCab according to the TL-3 safety performance guidelines of MASH, specifically test designation no. 3-11. The pickup was successfully contained and redirected. However, the member states had concerns about the dynamic deflections of the system. Thus, the system was further modified by reducing the post spacing to 8' to attempt to reduce the system deflections and reducing the number of keyways and holes to make the post stronger.

On July 11, 2014, MwRSF conducted one pickup crash test (test no. MWP-3) into the Midwest high-tension cable median barrier with the Midwest Weak Post with 8' post spacing and a reduction in the number of keyways and holes using a 2270-kg Dodge QuadCab according to the TL-3 safety performance guidelines of MASH, specifically test designation no. 3-11. The pickup overrode the cables and eventually rolled over. Hence, the system was further modified by reducing the top cable height to 38", increasing the bottom cable height to 15.5", adjusting the inner cable spacing to 7.5", and increasing the post spacing to 10'.

On October 20, 2014, MwRSF conducted one pickup crash test (test no. MWP-4) into the modified Midwest high-tension cable median barrier with the Midwest Weak Post using a 2270-kg Dodge QuadCab according to the TL-3 safety

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

This project is an extension to previous projects (RPFP-08-02: Four-Cable Median Barrier in 4:1 V-Ditch; RPFP-09-01: New Funding for High-Tension Cable Barrier on Level Terrain with New Cable Attachment; RPFP-10-CABLE-2: Replacement Funding for High-Tension Cable Barrier on Level Terrain; RPFP-12-CABLE1&2: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase I, V-Ditch; and RPFP-12-CABLE1&2: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase II, Level Terrain).

A portion of this project ($264,372 is not included in the project budget shown on page 1) will be funded with the following projects:
$64,746 from Project No.: RPFP-10-CABLE-3 – TPF-5(193) Supplement #21, Project Title: Additional Funds to Complete Development of Crashworthy HT, 4-Cable Barrier Terminal
$199,626 from Project No.: RPFP-12-CABLE1&2 – TPF-5(193) Supplement #46, Project Title: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase III, End Terminal

To date, total funds spent are from the following project funds:
$64,736 from Project No.: RPFP-10-CABLE-3 – TPF-5(193) Supplement #21
$199,626 from Project No.: RPFP-12-CABLE1&2 – TPF-5(193) Supplement #46
$237,622 from this project, Project No.: RPFP-14-CABLE-1 - TPF-5(193) Supplement #64

In addition, Contingency Funds from several prior years have been designated for Cable R&D and Cable Reporting. To date, $294,745 has been posted to the contingency funds for Cable R&D and Cable Reporting.

Potential Implementation:

The successful completion of the development, testing, and evaluation of the Midwest four-cable, high-tension, median barrier on level terrain will allow the member states to implement a non-proprietary, high-tension, cable system along our nation's highways and roadways. In addition, the crash testing of the four-cable, high-tension, median barrier on level terrain would also provide a more complete understanding of barrier performance (i.e., dynamic deflections, working width, etc.) when used in relatively flat, narrow medians. The crash results from the level terrain testing will be used in combination with computer simulation to evaluate the effects of reduced post spacing. The successful completion of this project along with the non-proprietary four-cable, high-tension, median barrier in V-ditch and cable guardrail end terminal would help to assure acceptance by FHWA and improve its chances for widespread implementation.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*		**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Supplement #67		☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans		
Name of Project Manager(s): Reid, Faller, Lechtenberg, Bielenberg	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611211099001	**Other Project ID (i.e., contract #):** RPFP-14-TF13	**Project Start Date:** 7/1/13
Original Project End Date: 6/30/16	**Current Project End Date:** 6/30/16	**Number of Extensions:** 0

Project schedule status:

☐ On schedule ☐ On revised schedule ☑ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$3,695	$3,695	100

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$401	

Project Description:

Each year, the Midwest States Pooled Fund program sponsors several roadside safety studies at the Midwest Roadside Safety Facility (MwRSF) of the University of Nebraska-Lincoln. Some of these research efforts result in the development of new roadside safety features. As part of this effort and on behalf of the member states, MwRSF seeks FHWA acceptance for those devices or systems meeting current impact safety standards. In the future, FHWA will require standard Task Force (TF) 13-format CAD details along the typical system details when requests for hardware acceptance are made.

MwRSF prepares 2-D and/or 3-D CAD details for newly developed roadside safety features that are subjected to full-scale vehicle crash testing. The CAD details used to describe the as-tested systems or components are not always prepared and presented in the same format as now required by AASHTO TF 13 and FHWA. As such, additional CAD details and background information must be prepared when FHWA acceptance is sought under MASH or when the new system or associated components are submitted for inclusion in the electronic version of the barrier hardware guide.

Objective: For all new barrier hardware, the member states request that MwRSF seek formal FHWA acceptance and placement of standardized TF-13 CAD details in the electronic version of the highway barrier guide. This funding shall be used to supplement the preparation of the TF-13 format CAD details.

Tasks:
1. Prepare CAD details for Hardware Guide

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Continue updating the drawings reviewed online by the barrier and component review group during the AASHTO TF-13 meetings.

Funds for this project have been exhausted. This project was closed.

Anticipated work next quarter:

None

Significant Results:

This project is used to supplement the preparation of the TF-13 format CAD details. Previously, it was determined that there are 14 systems and 11 components that need to be prepared in the TF-13 format. During discussions with the AASHTO TF-13 subcommittee in July 2011, new components had to be generated from the existing system drawings. Thus, the original 11 components became 32. Two of the systems and one component had limited work that need to be completed on the drawings as they were to be included in the Bridge Rail Guide and Luminaire Guide, respectively.

In evaluating the separation of the components, it was determined that some could be combined into one drawing based on the same type of component, but just one varying parameter.

Summary of original list created in 2011 of Barrier Drawings through 2014 Quarter 4:
31 systems - 31 approved
41 components - 41 approved
2 systems submitted to Bridge Rail Guide
1 component submitted to Luminaire Guide

Summary of new systems and components since 2014 Quarter 2 to be submitted yet: (Note a majority of the work is being completed under the original system projects):
8 systems
13 components

Task % Complete

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Funding from Project No.: RPFP-13-TF13 – TPF-5(193) Supplement #53, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans will be used prior to starting this project. All funding from previously mentioned project has been exhausted.

Potential Implementation:

Newly-developed highway safety hardware will be contained in the electronic, web-based guide, thus promoting the standardization of barrier hardware across the U.S. and abroad.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #68	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)	
Project Title: Minimum Offset for Standard MGS Adjacent to 2H:1V Slope		
Name of Project Manager(s): Ron Faller, John Reid, Bob Bielenberg	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211100001	**Other Project ID (i.e., contract #):** RPFP-14-MGS-8	**Project Start Date:** 7/1/2013
Original Project End Date: 6/30/16	**Current Project End Date:** 6/30/16	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$89,991.00	$83,190.00	95%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$3,584.00	

Project Description:

W-beam guardrail is often used to protect motorists from steep roadside slopes adjacent to high-speed roadways. A roadside slope placed immediately behind a guardrail system greatly reduces the soil resistance associated with lateral deflection of the barrier. This reduction in the post-soil forces greatly reduces a system's energy-absorption capability, significantly increases dynamic rail deflections, and can potentially produce issues with vehicle capture or vehicle override. Further, when the guardrail extends over the embankment, the gap between the bottom of the rail and the ground will be greatly magnified and thereby increase the risk of severe wheel snag.

The MGS guardrail system has greatly improved the safety performance and stability of guardrail installed at the slope breakpoint of slopes as steep as 2H:1V. However, current MGS installations adjacent to 2H:1V slopes utilize increased length posts in order to provide sufficient embedment to generate the proper soil resistive forces. This requirement creates issues with state DOT hardware inventories and maintenance due to the need to stock and maintain non-standard length posts. In order to reduce hardware inventories, states have chosen in some cases to install the standard MGS system at an offset from the slope. Current guidance requires a minimum offset of 1 ft to 2 ft from the back of the post to the the slope breakpoint for the standard MGS system with 6-ft long posts depending on the slope grade. This large offset maintains the safety performance of the system but creates a great deal of additional expense in terms of earthwork. Thus, a need exists to evaluate a minimum offset for the standard MGS guardrail system adjacent to a 2H:1V fill slope in order to reduce current issues with state hardware inventories and earthwork costs.

The objective of this research effort is to evaluate the minimum offset for installation of the standard MGS guardrail system with 6-ft long W6x9 posts spaced at 75 in. on centers adjacent to a 2H:1V fill slope. The evaluation will focus on a system with the posts installed at the slope break point of a 2H:1V slope. The minimum offset will be evaluated through one full-scale crash test according to the TL-3 impact criteria in MASH for test designation 3-11.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

MwRSF completed the full-scale crash test of the MGS guardrail system with 6-ft long W6x8.5 posts spaced at 75 in. on centers adjacent to a 2H:1V fill slope. On August 14th, the standard MGS (6-ft W6x8.5 posts and 12" blockouts) installed with the centerline of the posts at the slope break point of a 2:1 slope was subjected to AASHTO MASH TL-3 test conditions using a 2270P pickup truck vehicle (test designation 3-11). In test no. MGSS-1, the pickup truck impacted the system at a speed and angle of 61.6 mph and 26.2 degrees, respectively, resulting in an impact severity of 123.7 kip-ft. The system adequately contained and safely redirected the pickup truck. The occupant impact velocities and occupant ridedown accelerations were within the suggested limits provided in MASH. The maximum lateral deflection of the system and working width of the system were approximately 73 in. and 77.5 in., respectively. The test was acceptable according to the safety performance criteria of AASHTO MASH for test designation no. 3-11.

The final documentation of that crash test has been completed and the effort to write the research report is nearly complete. At this time, the initial draft report for the research has been completed, and the report is ready to be submitted to the Midwest Pooled Fund states for comment.

Anticipated work next quarter:

In the upcoming quarter, MwRSF will complete the sponsor edits and finalized the research report. An FHWA eligibility submission for the system and Task Force 13 Hardware Guide drawings will be made by MwRSF.

Significant Results:

One full-scale crash test of the MGS guardrail system with 6-ft long W6x8.5 posts spaced at 75 in. on centers adjacent to a 2H:1V fill slope was completed and the results met the MASH safety requirements.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

Determination of the minimum offset for the standard MGS guardrail system adjacent to a 2H:1V fill slope will result reduced embankment earthwork required for guardrail installations on slopes and reduced state DOT hardware inventories for the MGS system. These benefits will provide for a decrease in project costs to the states while still providing a safe barrier system.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #74		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Redesign of Low-Tension, Cable Barrier Adjacent to Steep Slopes		
Name of Project Manager(s): Faller, Reid, Bielenberg	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211106001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 7/1/2014
Original Project End Date: 12/31/15	**Current Project End Date:** 12/31/2016	**Number of Extensions:** 1

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$124,345	$40,547	40%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$1,484	

Project Description:

Previously, the MwRSF investigated the performance of low-tension cable barrier adjacent to slopes as steep as 1.5H:1V. Full-scale crash testing of the standard, non-proprietary, cable system offset 12" from the slope breakpoint resulted in the 2000P vehicle overriding the barrier and rolling over. Subsequently, the post spacing was reduced from 16' to 4' and the barrier offset was increased to 4'. A second full-scale crash test on this modified system resulted in a successful TL-3 test with the 2000P. While the design modifications provided safe redirection, there were some drawbacks. The closely spaced posts have been difficult and costly to install, and the additional lateral offset from the slope break point can also be difficult to achieve in practice. Thus, a need exists to reconsider the cable barrier adjacent to slope design.

The objective of this study is to review the design of the low-tension cable barrier adjacent to a steep slope and determine design modifications to improve its Implementation, such as increased post spacing and reduced lateral barrier offset. Additionally, cable heights and tensions, attachment hardware, and even system posts may be altered to improve crash performance. Future full-scale vehicle crash testing according to MASH TL-3 criteria would be used to evaluate the modified system in Phase II of the project (currently unfunded)

Major Task List

1. Literature review of cable barrier on/adjacent to slopes
2. Concept Design
3. Component Testing of Post Configurations
4. LS-DYNA model development, validation, and calibration
5. LS-DYNA simulation of various cable barrier modifications
6. CAD details of proposed cable system designs
7. Preparation of research report and recommendations for future research
8. Preparation of Technical Brief for NDOR.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Previously, it was noted that recent research on cable median barriers has indicate that a potential exists for weak post sections with free edges to penetrate the floorboard of small car and sedan vehicles when these vehicles directly override the posts. MwRSF has previously developed a component testing setup with a simulated floorboard to investigate this concern. In order to investigate this potential, a dynamic test of a bogie vehicle with a simulated floorboard was conducted on the weak axis of the S3x5.7 posts proposed for use in the low-tension cable barrier adjacent to slope. The results of this test indicated significant floorboard tearing. This result was discussed with the TAC committee in a July 21st meeting in order to determine how the sponsors wished to proceed.

At the July 21st TAC meeting, MwRSF and the TAC members discussed several options for proceeding with the cable barrier adjacent to slope design in light of the potential for the S3x5.7 post to tear the occupant compartment floorboard.

1. Proceed with current S3x5.7 post, which posed the risk of 1100C test failure in the future.
2. Modify S3x5.7 post through the use of weakening mechanisms or a slip base.
3. Switch to modified MWP post in development as part of parallel research on cable median barrier systems. however, the design of the revised MWP post is not finalized at this time

The second and third options would likely require additional bogie testing adjacent to slope.

Discussion with the TAC members led to the selection of the third option as efforts to redesign the MWP post were alredy underway and the post would likely become a standard inventory part in the future. Currently, the MWP post was redesigned with the addition of two, 3/4" holes at the based of the post in the weak axis flanges. Component testing indicated that this will mitigate floorpan tearing.

Full-scale testing of the MWP post in test no. MWP-8 found that the modified MWP post mitigated tearing initially.

Anticipated work next quarter:

Because the full-scale crash testing of the cable median barrier with the modified MWP post was not successful, the research effort for the cable barrier adjacent to slope is awaiting to see how the MWP post will be modified for the high-tension cable median barrier. At this time, a successful modification has not been developed and evaluated. If the MWP post design issues are resolved, MwRSF will continue with conducting the two remaining bogie tests at reduced slope offsets to determine what the minimum offset to the slope could potentially be. The two remaining tests will focus on slope offset and any potential modifications to the MWP post in terms of embedment and/or soil plates.

Integration of the new post design into a modified cable adjacent to slope system will be required, including consideration of revised system hardware, cable tensions, cable heights, cable attachments, and anchorage. Design changes will be reviewed with the TAC members prior to determining the system configuration.

Following integration of the modified MWP post with the cable barrier adjacent to slope simulation models of the modified cable system will be conducted as originally planned to evaluate the potential for the new design to meet the MASH TL-3 criteria.

Significant Results:

The literature review of all full-scale tests on cable barrier systems adjacent to or within slopes was completed and summarized in a table. A preliminary design was established, and a component testing methodology was determined. The use of the S3x5.7 post was negated due to floorboard penetration concerns and the project is currently awaiting modifications to the MWP post before proceeding. Draft reporting of the first four bogie tests was completed and is awaiting review.

Major Task List	% Complete
1. Literature review of cable barrier on/adjacent to slopes	100%
2. Concept Design	75%
3. Component Testing of Post Configurations	80%
4. LS-DYNA model development, validation, and calibration	5%
5. LS-DYNA simulation of various cable barrier modifications	0%
6. CAD details of proposed cable system designs	0%
7. Preparation of research report and recommendations for future research	15%
8. Preparation of Technical Brief for NDOR.	0%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

The results of the floorboard testing of the S3x5.7 posts has caused delays in the project based on parallel development of the modified MWP post. Funding for the project tasks remains, but a time extension was requested and received this quarter that extends the project completion date to 12/31/16.

Potential Implementation:

Redesign of the low-tension cable barrier adjacent to steep slopes would provide roadway designers with a lower cost and more-easily implemented solution for shielding steep slopes that would still provide safe redirection of errant vehicles.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #75	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title: Length of Need for Free-Standing, F-Shape, Portable 12.5' Concrete Protection Barrier		
Name of Project Manager(s): Ron Faller, Bob Bielenberg, John Reid	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211107001	**Other Project ID (i.e., contract #):** RHE-08	**Project Start Date:** 7/1/2014
Original Project End Date: 12/31/15	**Current Project End Date:** 12/31/16	**Number of Extensions:** 1

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$189,820.00	$61,670.00	65%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$51,762.00	

Project Description:

The objective of this research effort is to investigate and evaluate the safety performance of the previously developed F-shape PCB system in order to determine minimum system length and the number of barriers required for the beginning and end of the length of need. It is proposed that the system be evaluated according to the TL-3 criteria set forth in MASH. Two full-scale crash tests would be conducted to evaluate the performance of PCB system in order to evaluate its safety performance and investigate its dynamic deflection. The research effort will be split into two phases. Phase I, will be conducted to investigate the F-shape PCB system through computer simulation modeling in order to determine minimum system length and the number of barriers required for the beginning and end of the length of need. Phase II, would consist of the full-scale crash testing required to validate the system length and beginning and end of length of need recommendations from Phase I.

Phase I

The research effort for Phase I will begin with LS-DYNA computer simulation of the F-shape PCB system. Previous research efforts at MwRSF involving the F-shape PCB have developed reasonably accurate computer simulation models of the free-standing F-shape PCB system. These models will be used to analyze PCB system length and beginning and end of the length of need requirements. Four cases are proposed for analysis.

1. Simulation of the minimum number of PCB segments required on the upstream end of the barrier installation for a long overall system length.
2. Simulation of the minimum number of PCB segments required on the downstream end of the barrier system for a long overall system length.
3. Simulation of the minimum number of PCB segments required on the upstream end of the barrier system for a minimum overall system length.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Previously, MwRSF completed simulation of impacts on the upstream and downstream ends of the 200 ft long barrier system to determine the length of need. It was determined that three barriers would be recommended for both the beginning and the end of length-of-need for the TCB system, until the results could be further discussed with the TAC.

The next step of the simulation analysis was to conduct impacts at the selected beginning and end of length-of-need lengths for a reduced system length in order to verify that the length-of-need definitions work for shorter lengths and to examine the minimum potential length of the TCB system. Simulation models were evaluated using a seven barrier long TCB system. The results of these models found that the 2270P vehicle was successfully redirected for the seven barrier installation at both the beginning and end of the LON. In both cases, the reduced barrier system increased barrier deflections by approximately 16" over the full-length, 16 barrier system. Additionally, the impact at the end of the LON indicated a potential for the last barrier in the system to rotate rapidly towards the vehicle as it was redirected and impact the vehicle door. Thus, while the vehicle was redirected and the increases in deflections were manageable, the impact of the barrier with the driver side door was a concern.

These findings were discussed in detail at the July 21st TAC meeting in order to determine what the TAC concerns were and what was desired to be investigated through full-scale testing. The TAC indicated that the rotation and impact of the end barrier with the vehicle was a concern and wished to analyze the system with eight barriers, 3 for the beginning of LON, one in the middle, and 4 on the end of the LON. These models were simulated. Again both models successfully redirected the impacting vehicle. The addition of the fourth barrier on the end of LON mitigated the impact of the barriers on the vehicle door. Barrier deflections for impact at the beginning and end of LON for the 8 barrier installation were found to be 94.8 in. and 90 in., respectively. These results were given to the TAC in a meeting on 10-15-15. They concurred that testing should proceed on the 8 barrier installation.

Anticipated work next quarter:

The remaining work for the project will consist of additional simulation analysis and reporting. Simulations of the reduced system length testing will be developed. Next, simulations investigating the 85% impact severity on both the standard length and reduced length systems will be performed as well as simulations of intermediate system lengths under standard TL-3 impact conditions.

The summary report of the research including the analysis, full-scale crash testing, and conclusions and recommendations is currently underway and will continue in the upcoming quarter.

Significant Results:

Simulations of reduced system lengths were completed and a minimum system length of eight barrier segments was recommended for testing.

CAD details were developed and system hardware is ready and waiting in test queue.

Two full-scale crash tests were conducted on the beginning and end of length-of-need on a reduced length PCB system.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Currently, remaining tasks in the project include two full-scale crash tests, additional simulation of reduced length system deflections, and completion of the summary report. Funding for the project tasks remains, but a time extension was requested and received this quarter that extends the project completion date to 12/31/16.

Potential Implementation:

Evaluation of the F-shape PCB minimum system length and the number of barriers required for the beginning and end of the length of need will provide NDOR with improved and validated guidance for their PCB system configurations. These guidelines will improve the safety of PCB installations and may potentially shorten the number of barriers used in these types of installations. This will improve the flexibility of the PCB systems and reduce the number of impacts. The research would also define the increase in barrier deflection for shorter system lengths and better define necessary clear areas behind the PCB segments in work zones.

MwRSF will work closely with NDOR engineers and the TAC committee throughout the evaluation of the LON for PCB systems in order to ensure that the research effort meets the project goals and supplies adequate information to NDOR. This should ensure that the results of the study are viable for NDOR as well as state DOT's across the country.

The dissemination of the research results will be made through the use of a final report describing the computer simulation and investigation of PCB system lengths and the full-scale testing used to evaluate the proposed guidelines. In addition, the results of the research effort will be published as a paper in a refereed journal, if warranted. Following the completion of the study, the results of the study will be disseminated by MwRSF personnel in future NDOR transportation presentations given to State DOTs and to participants of technical engineering conferences, industry meetings, trade shows, and conventions so that dissemination and distribution of the final research results will provide the most significant impact in terms of safety benefit for the motoring public.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #76		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Development of a TL-3 Transition between Temporary Free-Standing, F-Shape 12.5' Concrete Protection Barrier and Gua		
Name of Project Manager(s): Ron Faller, Bob Bielenberg, John Reid	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211108001	**Other Project ID (i.e., contract #):** RHE-11	**Project Start Date:** 7/1/2014
Original Project End Date: 12/31/15	**Current Project End Date:** 12/31/16	**Number of Extensions:** 1

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$213,677.00	$128,788.00	80%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$10,427.00	

Project Description:
The objective of this research is to evaluate the safety performance of the transition between guardrail and free-standing F-shape TCB developed in Phase I of the research effort. The safety performance evaluation is to be conducted according to the TL-3 impact safety standards published in MASH.

The research effort for Phase II would consist of final design, fabrication, and testing of the TL-3 transition between temporary concrete barrier and guardrail selected by the sponsor from Phase I. Design details of the proposed transition would be fully developed in three-dimensional CAD software. Next, fabrication and installation of the transition system would be completed at the MwRSF's full-scale crash test facility. It is anticipated that three full-scale crash tests would be required to fully evaluate the transition system. These tests would include MASH test designation nos. 3-20 and 3-21 which are tests to evaluate the design of the barrier transition with 1100C small car and 2270P pickup truck vehicles. In addition, it is anticipated that a reverse direction impact of test designation no. 3-21 with the 2270P vehicle would be required for evaluation of the transition for installations that require two-way traffic adjacent to the barrier. Following the completion of the full-scale crash testing, a summary report will be completed detailing the evaluation effort as well as providing guidance for implementation of the new transition design. MwRSF will also prepare a technical brief and a PowerPoint presentation of the research results to NDOR at the completion of the project.

Major Task List:

1. Project planning and correspondence
2. Development of design details in 3D CAD and review by TAC
3. Fabrication of hardware and installation at MwRSF test site.
4. Three full-scale crash tests according to TL-3 of MASH.
a. MASH test no. 3-20 with the 1100C small car

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):
Previously, MwRSF conducted all three of the full-scale crash tests for evaluation of the MASH TL-3 guardrail to PCB transition system. The test matrix is listed below.

1. MGSPCB-1 - Test no. 3-21 - Impact of the 2270P vehicle on the centerline of the fifth guardrail post upstream from the end-shoe attachment at a speed of 62 mph and an angle of 25 degrees.
2. MGSPCB-2 - Test no. 3-21R - Reverse direction impact of the 2270P vehicle 12 ft – 6 in. upstream from the end-shoe attachment at a speed of 62 mph and an angle of 25 degrees.
3. MGSPCB-3 - Test no. 3-20 - Impact of the 1100C vehicle on the critical impact point of the guardrail to PCB transition at a speed of 62 mph and an angle of 25 degrees. MASH procedures and engineering analysis will be used to determine the critical impact point.

All three of the full-scale crash tests successfully met the MASH TL-3 criteria. Thus, the system evaluation was completely successful. Currently, MwRSF is in the process of compiling the test report and recommendations for the implementation of the design. MwRSF was unable to complete the summary report prior to the original project end date of 12/31/15. Thus, a no-cost project extension was requested and granted.

A TAC meeting was held on 10-15-15 to update the project status and review the full-scale crash test results.

During this quarter, MwRSF has continued to compile the research report evaluating the three successful crash tests. Submission of a TRB paper for the 2017 meeting is also planned.

Anticipated work next quarter:

In the upcoming quarter, MwRSF will continue efforts to complete the research report summarizing the testing and evaluation of the guardrail to PCB transition. Additionally, the project team will prepare a technical brief as well as a summary presentation of the research results for the TAC.

Significant Results:

The guardrail to PCB transition design was successfully tested and evaluated to MASH TL-3.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Due to having insufficient time to complete the summary report, MwRSF was not able to complete the research project within the original time frame. Funding for the project tasks remains, but a time extension was requested and received this quarter that extends the project completion date to 12/31/16.

Potential Implementation:

The research study is directed toward improving the safety by minimizing the risk for the motoring public traveling within our nation's work-zones and on our highways and roadways. Since W-beam guardrail has proven to provide better safety performance than temporary concrete barriers, the development of an effective transition between the two can help preserve guardrails outside the immediate work-zone area, thus providing an overall higher level of safety for motorists. The new transition would also eliminate the use of an unproven connection between guardrail and temporary barriers. Further, limiting the use of temporary concrete barriers strictly to the work zone area will also minimize the traffic disruption that these barriers can create to motorists passing in work zones.

MwRSF will work closely with NDOR engineers and the TAC committee throughout the concept development of a MASH TL-3 transition design between TCBs and the MGS in order to ensure that the system is practical, able to be constructed, and cost efficient. This should ensure that the system is viable for NDOR as well as state DOT's across the country.

The dissemination of the research results will be made through the use of a final report describing the transition development and recommendation for full-scale crash testing and publication of a paper in a refereed journal, if warranted. Following the completion of the study, results from this study will be disseminated by MwRSF personnel in future NDOR transportation presentations given to State DOTs and to participants of technical engineering conferences, industry meetings, trade shows, and conventions so that dissemination and distribution of the final research results will provide the most significant impact in terms of safety benefit for the motoring public.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Wisconsin DOT

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl # 77	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:

Phase IIA Vehicle Dynamics Testing, Validation of Vehicle Models & Computer Simulation of Rock Ditch Liners

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Bielenberg, Faller, and Lechtenberg	(402) 472-3084	jreid@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611130089001		6/30/2014
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
6/30/2017	6/30/2017	0

Project schedule status:

☐ On schedule ☐ On revised schedule ☑ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$110,000	$72,696	65%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$4,461	60%

Project Description:

The primary research objective for this study includes the continued development of safety guidelines for use in the design and placement of ditch liners and check dams along highways and roadways. During the Phase I effort and as part of the initial research funding, preliminary safety guidelines were proposed along with a preparation of a research plan for use in their future evaluation. At this time, the Wisconsin Department of Transportation has deemed the preliminary guidelines viable and has requested that continued research be performed to further evaluate and modify the guidelines using computer simulation and full-scale vehicle crash testing.

Due to the significant scope of this ongoing research program, the study has been split into multiple phases. The objective for each specific phase is listed below:

Phase I - Develop preliminary guidelines for the safe construction of rock ditch liners and rock check dams – (Completed 2011)

Phase II - Conduct LS-DYNA computer simulation to develop critical crash testing matrix for evaluating vehicular impacts into rock ditch liners and rock ditch checks.

This current project is a subset of Phase II. This subset is limited to simulation of a 1100c vehicle over a 1:1 slope ground rock ditch liner and one full-scale crash test of such.

Phase III - Perform a series of full-scale crash tests on rock ditch liners and check dams placed in a traversable ditch.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Multiple attempts were made to model the actual rock ditch liner in expanded detail, but all efforts proved to be very challenging. Spatial data cannot be easily reconciled to accurate rock surface depictions with the current technology and software.

A simplified model of the rock ditch liner was utilized and the simulation matrix was expanded to consider more simulation alternatives. Models of a roadside slope with rock ditch liner were constructed.

Anticipated work next quarter:

Simulation will continue with rock ditch liner configurations on slopes and in roadside V-ditch configurations. The vehicle will be tracking without steering control for all of the simulations. Researchers will consult with WSDOT regarding which slope rates and configurations to model.

Real vehicles and drivers may experience instability if vehicles attempt to steer or brake while traversing a rock ditch liner, or the vehicle may be unstable if it encounters the rock ditch liner in a non-tracking skid. At this time, researchers cannot accurately model these types of tests. It may be appropriate to conduct additional tests with the vehicle during steer motion, in a non-tracking condition, or on steep slopes to evaluate the safety of these rock ditch liners. These tests and any associated simulations are beyond the scope of this study.

Significant Results:

None to date.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

Rock ditch liners are a convenient method of controlling erosion and improving water runoff. If rock ditch liners can be proven to be safe and traversable for errant vehicles, these liners may be used in erosion-sensitive locations adjacent to federally-funded highways.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Wisconsin DOT

INSTRUCTIONS:
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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*		**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl # 78		☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Transition from Free-Standing TCB to Reduced Deflection TCB		
Name of Project Manager(s): Schmidt, Bielenberg, Faller, and Reid	**Phone Number:** (402) 472-0870	**E-Mail** jennifer.schmidt@unl.edu
Lead Agency Project ID: 2611130090001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 6/30/2014
Original Project End Date: 6/30/2017	**Current Project End Date:** 6/30/2017	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$95,852	$18,576	25%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$7,707	

Project Description:

Recently, the Wisconsin Department of Transportation sponsored a research project to develop a retrofit design for reducing deflections for temporary concrete barriers (TCB) without anchoring the barriers to the bridge deck or roadway. This research was successful in reducing the deflection of the TCB system, as the addition of steel tubes to both the front and back sides of the barrier reduced the deflection of the TCB system by roughly 50 percent. However, the effort was focused on developing the length-of-need of the system and did not include design of a transition between the reduced deflection TCB system and standard F-shape TCB segments. Thus, a need exists to develop a transition between the new reduced deflection system and free-standing TCB segments.

The objective of this research effort is to develop a MASH TL-3 transition between the recently developed reduced deflection TCB system and free-standing, F-shape TCB segments. The research effort will focus on development of a design that safely transitions between the stiffness and deflection of the two barrier systems while maintaining vehicle stability. The design will also focus on minimizing the length of the transition and additional hardware components. Phase I of this project will involve initial development and computer simulation of the transition design (work described herein). Phase II of the project (currently unfunded) will include full-scale crash testing to evaluate the transition.

Main Objectives/Tasks

1. Literature Review
2. Concept Development
3. Selection of Transition Design
4. LS-DYNA Analysis and Evaluation
5. Project Report

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

An additional 14 impact points were simulated on the first transition concept region with the 2270P vehicle. In each case, the 2270P vehicle model was captured and redirected. Results from the simulations including ORAs, OIVs, roll, pitch, yaw, change in bumper height, and dynamic deflection were calculated and compared to the results of the simulation of test RDTCB-2 (reduced deflection system) and the simulation of test 2214TB-2 (freestanding PCB system). Several of the simulations showed elevated lateral ORAs, increased roll values, or the truck interacting with the "knee" that forms between adjacent barrier segments when deflected. Although these results may not lead to a negative results, a recent crash test resulted in a pickup truck rollover when the knee of PCBs impacted the door of the truck.

A 3.5" x 3.5" tube spacer was modeled and added at the base of adjacent PCBs that form larger angles and can create a "knee". Preliminary results indicated that this tube prevents adjacent PCBs from forming large angles from one another.

Writing continued on the report.

Anticipated work next quarter:

The results of the simulations will be further evaluated. The stiffness of the tube and /or the number of spacers may need to change to get the desired transition behavior. Additional impact points will be simulated. Recommendations about the concept will be provided and modifications or additional concepts may be proposed.

Significant Results:

Initial simulations appear to have an acceptable performance.

Main Objectives/Tasks	% Complete
1. Literature Review	100%
2. Concept Development	60%
3. Selection of Transition Design	60%
4. LS-DYNA Analysis and Evaluation	65%
5. Project Report	14%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

Development of a crashworthy transition system between the reduced-deflection TCB system and freestanding TCBs would provide states with a robust TCB system capable of reducing deflections without anchoring to the road surface. In addition, the system can be used in median applications and could be attached to standard, free-standing TCB segments on each end to allow for easier implementation and integration with existing work zones.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Supplement #79	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title: TL-4 Evaluation of the Midwest High-Tension, 4-Cable Barrier		
Name of Project Manager(s): Reid, Faller, Lechtenberg, Bielenberg, Rosenb	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611211096001 and 2611211111002	**Other Project ID (i.e., contract #):** RPFP-15-CABLE-1	**Project Start Date:** 8/1/14
Original Project End Date: 7/31/17	**Current Project End Date:** 7/31/17	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$408,235	$100,000 for Cable R&D	0

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$0 for Cable R&D	

Project Description:

The Midwest Roadside Safety Facility (MwRSF) has been conducting research for the Midwest States Regional Pooled Fund Program to develop a non-proprietary, high-tension, four-cable, median barrier that is capable of being used anywhere in a V-ditch with 4H:1V side slopes. Three tests still remain to complete the test matrix of the cable barrier system in a V-ditch. In addition, the four-cable, high-tension, median barrier has never been tested on level terrain. There is a concern that FHWA may not approve this design without testing on flat ground, especially when considering the wide cable spacing and increased cable heights. Further, the barrier deflections observed in crash tests performed in a 4H:1V V-ditch are likely higher than would be observed on flat ground. Crash testing of the barrier installed on level terrain would identify barrier deflections and working widths that can be expected when the barrier is used in narrow medians with gentle slopes and would allow for better performance comparisons between the Midwest four-cable barrier and other proprietary systems.

Objective: To complete the development, testing, and evaluation of the four-cable, high-tension, median barrier system for use on level terrain.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

None.

This is additional funding to continue the development of the Midwest Four-Cable, High-Tension, Median Barrier once the funds from the other projects are exhausted (Project No.: RPFP-12-CABLE1&2 – TPF-5(193) Supplement #44, Project Title: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase I, V-ditch, Project No. RPFP-12-CABLE1&2 – TPF-5(193) Supplement #45, Project Title: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase II, Level Terrain, and Project No.: RPFP-14-CABLE-1 - TPF-5(193) Supplement #64, Project Title: Continued Development of the Midwest Four-Cable, HT, Median Barrier (Continuation)).

See Project No.: RPFP-14-CABLE-1 – TPF-5(193) Supplement #64, Project Title: Continued Development of the Midwest Four-Cable, HT, Median Barrier (Continuation) for a detailed explanation of the work completed this quarter.

Anticipated work next quarter:

None

Significant Results:

None

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

This project is an extension to previous projects (RPFP-08-02: Four-Cable Median Barrier in 4:1 V-Ditch; RPFP-09-01: New Funding for High-Tension Cable Barrier on Level Terrain with New Cable Attachment; RPFP-10-CABLE-2: Replacement Funding for High-Tension Cable Barrier on Level Terrain; RPFP-12-CABLE1&2: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase I, V-Ditch; RPFP-12-CABLE1&2: Completion of the Development and Evaluation of the Midwest Four-Cable, High-Tension, Median Barrier Phase II, Level Terrain; RPFP-14-CABLE-1 - TPF-5(193) Supplement #64, Project Title: Continued Development of the Midwest Four-Cable, HT, Median Barrier (Continuation)).

Note, in Quarter 3 of 2015, $100,000 of Project No. RPFP-15-CABLE-1 - TPF-5(193) Supplement #79, Project Title: TL-4 Evaluation of the Midwest High-Tension, 4-Cable Barrier (Yr 24 shortage) was committed to Cable R&D.

Potential Implementation:

The successful completion of the development, testing, and evaluation of the Midwest four-cable, high-tension, median barrier on level terrain will allow the member states to implement a non-proprietary, high-tension, cable system along our nation's highways and roadways. In addition, the crash testing of the four-cable, high-tension, median barrier on level terrain would also provide a more complete understanding of barrier performance (i.e., dynamic deflections, working width, etc.) when used in relatively flat, narrow medians. The crash results from the level terrain testing will be used in combination with computer simulation to evaluate the effects of reduced post spacing. The successful completion of this project along with the non-proprietary four-cable, high-tension, median barrier in V-ditch and cable guardrail end terminal would help to assure acceptance by FHWA and improve its chances for widespread implementation.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #80		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: MGS Guardrail with an Omitted Post		
Name of Project Manager(s): Ron Faller, John Reid, Bob Bielenberg	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211112001	**Other Project ID (i.e., contract #):** RPFP-15-MGS-5	**Project Start Date:** 8/1/2014
Original Project End Date: 7/31/2017	**Current Project End Date:** 7/31/2017	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$99,973.00	$56,074.00	90%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$8,078.00	

Project Description:

The objective of this research effort is to develop guidelines for MGS installations with a single omitted post for clearance of obstacles. The research would attempt to focus on the omission of a post without the use of CRT posts adjacent to the unsupported span. Full-scale crash testing would be conducted to evaluate the use of a single omitted post according to the TL-3 impact safety requirements in MASH. Following successful full-scale crash testing, additional analysis would be conducted to evaluate the potential for omission of a single post in multiple locations in a run of guardrail and the corresponding minimum spacing between the omitted posts.

The research effort will begin with the construction of the MGS with a single omitted post at the MwRSF Outdoor Test Facility for evaluation. The system will be evaluated according to the MASH guidelines for test designation no. 3-11 with the 2270P pickup truck vehicle. It is believed that the 1100C vehicle test can be waived for this system because the 2270P vehicle will provide a more stringent test of the failure modes expected in with the omitted posts such as excessive dynamic deflection, pocketing, vehicle snag, and rail rupture. The CIP for this test will be selected based on maximizing the potential for vehicle pocketing and post snag using the CIP charts in MASH and the researchers engineering judgment. The full-scale vehicle crash test will be conducted, documented, and evaluated by MwRSF personnel and in accordance with the MASH guidelines.

Following the successful full-scale crash testing, results from the crash testing will be applied to estimate potential concerns associate with multiple single omitted posts that are spaced apart in a run of MGS guardrail. Results from the full-scale test would also be analyzed to provide further guidance on allowable spacing between omitted posts based on the behavior of the guardrail system during the test.

After completion of the full-scale crash testing, a summary report of the research project will be completed detailing the tested barrier system, full-scale crash test results, evaluation of barrier performance, additional analysis, and

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Previously, MwRSF began the research effort to investigate the MGS with a single omitted post. Prior to conducting a full-scale crash test, MASH requires selection of a critical impact point (CIP) for the test. In order to determine the CIP for the MGS with a single omitted post, BARRIER VII was used to simulate impacts a various points along an MGS system with a single post removed. The BARRIER VII analysis looked at several factors, including maximum rail deflection, maximum rail tensile forces, vehicle snag on posts, and pocketing of the barrier. Based on this analysis, it was determined that an impact ¾ of the way between post nos. 11 and 12 was critical as it displayed the highest level of vehicle snag and rail deflection and the the second highest rail forces. Pocketing was not significant for any impact point.

On April 29th, 2015, the standard MGS (6-ft W6x8.5 posts and 12" blockouts) with an omitted post was subjected to AASHTO MASH TL-3 test conditions using a 2270P pickup truck vehicle (test designation 3-11). In test no. MGSMP-1, the pickup truck impacted the system at a speed and angle of 63.4 mph and 25.3 degrees, respectively, resulting in an impact severity of 121.3 kip-ft. The system adequately contained and safely redirected the pickup truck. The occupant impact velocities and occupant ridedown accelerations were within the suggested limits provided in MASH. The maximum lateral deflection of the system and working width of the system were approximately 49 in. and 50 in., respectively. The occupant crush measurements were within the limits provided in MASH. Therefore, we can tentatively say that the test was acceptable according to the safety performance criteria of AASHTO MASH for test designation no. 3-11.

The summary report of the research was finalized and completed with state comments. Recommendations were developed for the number and spacing of omitted posts in an MGS guardrail system as well as how close omitted posts can be to special applications of guardrail such as transitions and end terminals.

Anticipated work next quarter:

In the upcoming quarter, MwRSF will complete the submission of the system for an FHWA eligibility letter and the Task Force 13 Hardware Guide drawings in order to close the project.

Significant Results:

Test No. MGSMP-1 was conducted on April 29th, 2015. The MGS system successfully redirected the 2270P vehicle with a single omitted post.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

The successful development and evaluation of a MGS guardrail with omitted posts would provide states with a potentially simpler and less-costly alternative for dealing with post conflicts within a run of guardrail.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #81 MwRSF Project No. RPFP-15-AGT-1		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Standardized Concrete Parapet for Use in Thrie Beam AGT's		
Name of Project Manager(s): Reid, Faller, Bielenberg, Rosenbaugh	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211113001	**Other Project ID (i.e., contract #):** RPFP-15-AGT-1	**Project Start Date:** 8/1/2014
Original Project End Date: 7/31/2017	**Current Project End Date:** 7/31/2017	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$125,906	$81,650	65%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$54,385	

Project Description:

Although most approach guardrail transitions (AGTs) look similar, each AGT has a unique combination of features including rail thickness, post size and spacing, use of a hydraulic curb, and downstream parapet or bridge rail in which it attaches to. However, due to the sensitivity of transition regions, these variables are not interchangeable between AGTs. Thus, each AGT is specific to its own features as well as the bridge railing or parapet to which it is anchored.

Crash testing has illustrated the sensitive nature of these AGT designs with recent failures occurring due to an alteration of an AGT feature (e.g., addition/removal of a curb or changes to the rigid parapet geometry and attachment hardware). The majority of these failures have been the result of excessive vehicle contact on the lower, upstream corner of the rigid parapet. This result indicates that the parapet toe and end geometry may be even more critical than previously believed. Thus, there exists a need to develop a standard concrete parapet end geometry for use with all thrie beam AGTs.

The objective of this research effort is to develop a standardized concrete parapet end section for attachment of various thrie beam AGTs.

Objectives / Tasks:

1. Literature Review
2. Parapet Design and Analysis
3. System CAD Details
4. System Construction
5. Full-scale Crash Test
6. System Removal
7. Data Analysis
8. Design Recommendations

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The full-scale crash test, a MASH 3-21 with a 2270P vehicle, was conducted. During the test, the pickup was contained and redirected. However, the vehicle floor pan and seat were displaced during the impact event - not enough to exceed occupant compartment deformations, but enough to cause erroneous data to be recorded by the accelerometers (which mount to the seat frames). Thus, a -30 g pulse was recorded in the longitudinal direction which exceed MASH ORA limits. The on board ACM recorded only a -20 g pulse, but it too was affected by the motion of the vehicle floor pan. Efforts were made to compare the data trace to high-speed video, but vehicle roll and pitch made tracking of the actual vehicle c.g. very difficult. Consequently, it could not be proven that the ORAs were below the 20.49 g limit in MASH.

The test data and video was analyzed. Work began on the summary report.

Anticipated work next quarter:

Work will continue on the summary report.

Significant Results:

An extensive literature review of all AGTs to concrete parapets was summarized in a reference table. The table was utilized during the design process to develop a buttress that minimizes snag while maximizes vehicle stability. Through a voting process, the states selected a dual taper design over a single taper design. The bottom of the buttress (below the thrie beam) had 4"x12" chamfer to prevent tire snag, while the rest of the buttress had a 4"x4" chamfer to prevent vehicle snag. The length of the buttress was minimized at 7 ft to minimize the system length while also allowing room for geometric shape transitions to match up with various bridge rails. The height of the buttress was selected as 36" to match the height of MASH TL-4 bridge rails. The buttress height tapers down to 32" on the upstream end over a 24" length to prevent snag. Design details for the system including geometric shape and reinforcement were completed.

A test installation was constructed at the MwRSF test site and was subjected to 1 full-scale crash test in accordance with MASH test 3-21 with a 2270P. During the test, the pickup was contained and redirected. However, the vehicle floor pan and seat were displaced during the impact event - not enough to exceed occupant compartment deformations, but enough to cause erroneous data to be recorded by the accelerometers (which mount to the seat frames). Thus, a -30 g pulse was recorded in the longitudinal direction which exceed MASH ORA limits. The on board ACM recorded only a -20 g pulse, but it too was affected by the motion of the vehicle floor pan. Efforts were made to compare the data trace to high-speed video, but vehicle roll and pitch made tracking of the actual vehicle c.g. very difficult. Consequently, it could not be proven that the ORAs were below the 20.49 g limit in MASH.

Objectives / Tasks:	% Complete
1. Literature Review	100%
2. Parapet Design and Analysis	100%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

The test installation was originally built in November. However, heavy precipitation caused the soil around the transition to become too saturated and weak. Thus, the critical area of the transition had to be pulled out and reconstructed in mid-December.

Extra data analysis was conducted in an attempt to validate the differing data traces obtained from the accelerometers and the high speed video. Unfortunately, none of the analysis methods converged.

Potential Implementation:

A single design for the concrete parapet end section at the downstream end of AGTs will simplify state design standards. No longer will transitions be associated with only a single concrete parapet shape. All thrie beam transitions will be able to connect to the new parapet. The designer then only needs to transition the parapet to the proper shape and height of the bridge rail.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): NE Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl.#82	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)	
Project Title: Tree Removal Marketing Program		
Name of Project Manager(s): Reid, Faller, Lechtenberg, Bielenberg	**Phone Number:** 402-472-6864	**E-Mail** rfaller1@unl.edu
Lead Agency Project ID: RPFP-15-TREE-1	**Other Project ID (i.e., contract #):** 26112110114001	**Project Start Date:** August 1, 2014
Original Project End Date: July 31, 2017	**Current Project End Date:** July 31, 2017	**Number of Extensions:** 0

Project schedule status:

☐ On schedule ☐ On revised schedule ☑ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$80,815	$53,591	75%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$9,457	55%

Project Description:

Over the last 30 years, numerous studies have been conducted that resulted in guidance on tree removal and/or protection. However, this information is spread across many research reports. Consequently, decision makers often do not have all of the facts and research when deciding to remove or plant new trees. Thus, they are often making decisions without assessing the involved safety risks.

The objective of this research effort is to develop marketing strategies that would advise state DOTs and the public about the statistics and safety risks associated with roadside trees. In addition, this research should investigate methods for prioritizing treatment of the hazard posed by roadside and median trees.

Task 1 Literature Review: Review prior and ongoing studies addressing guidelines and recommendations related to roadside treatments and collisions with trees or other landscaping as well as risks associated with vehicle-tree collisions.

Task 2 State Crash Data: Review and compile selected state DOT and/or city data related to roadside tree crashes.

Task 3 Survey States: Survey all state DOTs to determine success stories for marketing and involving the use of clear zone concept, implementation of tree removal, and/or tree shielding.

Task 4 Marketing (Revised from previous quarterly updates): Students with marketing expertise were hired and are brainstorming and drafting layouts for advertisements, mailers, and campaign themes for use by DOTs.

Task 5 Summary Report: Compile a summary report of literature search and state DOT survey results. The report will also contain information on potential firms for development of outreach materials.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Draft report undergoing internal editing and expansion with additional data. Additional analysis was started on the crash data obtained during the study.

Anticipated work next quarter:

The draft report will be completed and sent to sponsors during 2Q 2016. Sponsor feedback will be sought and the report will be revised. Depending on available budget and sponsor interest, a conference call may be set up with all of the state DOTs who wish to participate to discuss report results, marketing efforts in the future, and how state DOTs can work together in the future to make progress on safer tree placement guidelines.

Significant Results:

To date, over 450,000 tree or utility pole-related crashes have been collected over 5-year increments from state DOTs. This volume of crash data has never been analyzed in as much detail for any project known to researchers and conclusions will be significant. In addition, 25 state DOTs responded to the request for survey.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

Numerous studies exist which provide recommendations on protection or removal of trees along roadsides. However, state DOTs do not have a good way to disseminate this information to their staff and the public. In addition, there is a need to make the public aware of the statistics involved with tree impacts and the safety issue that roadside and median trees pose. The collection and improved presentation of data would provide states with effective methods for educating designers, politicians, and the driving public as well as advance efforts to reduce the number of roadside trees and the associated hazard they pose to motorists.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**	
TPF-5(193) Suppl. #83	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)	
Project Title: Annual Consulting Services Support		
Name of Project Manager(s): Ron Faller, John Reid, Bob Bielenberg	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211115001	**Other Project ID (i.e., contract #):** RPFP-15-CONSULT	**Project Start Date:** 8/1/2014
Original Project End Date: 7/31/17	**Current Project End Date:** 7/31/17	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$50,001.00	$50,001.00	100%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$3,501.00	

Project Description:

This project allows MwRSF to be a valuable resource for answering questions with regard to roadside safety issues. MwRSF researchers and engineers are able to respond to issues and questions posed by the sponsors during the year. Major issues discussed with the States have been documented in our Quarterly Progress Reports and all questions and support are accessible on a MwRSF Pooled Fund Consulting web site.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

In the past quarter MwRSF has responded to a series of state inquiries. The Quarterly Progress Report summarizing these responses has been attached to this document. The summary will also be available for download at the recently completed MwRSF Pooled Fund Consulting web site - http://mwrsf-qa.unl.edu/

We are continuing to work with and improve the MwRSF Pooled Fund Consulting web site as our experience with it grows. We would ask that all Pooled Fund member states use the new site from this point forward for their inquiries and to contact us with any issues they experience with the web site.

Anticipated work next quarter:

MwRSF will continue to answer questions and provide support to the sponsors during the upcoming quarter.

We would ask that all questions be submitted through the web site so that they can be answered and archived therein.

http://mwrsf-qa.unl.edu/

The funding for the Year 25 Pooled Fund Consulting efforts are expended and this effort has been closed. New questions will be answered using funding allocated in Year 26.

Significant Results:

A quarterly summary of the consulting effort was provided and users can use the web site to search and find responses as well.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

None.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #84	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)	
Project Title: Pooled Fund Center for Highway Safety		
Name of Project Manager(s): Reid, Faller, Lechtenberg, Bielenberg, Rosenb	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611211116001	**Other Project ID (i.e., contract #):** RPFP-15-PFCHS	**Project Start Date:** 8/1/2014
Original Project End Date: 7/31/2017	**Current Project End Date:** 7/31/2017	**Number of Extensions:** 0

Project schedule status:

☐ On schedule ☐ On revised schedule ☑ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$11,468	$11,468	100%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$3,055	

Project Description:

Many of MwRSF's inquiries from members of the Midwest States Pooled Fund program can be answered based upon prior pooled fund or other research. Further, even though answers to pooled fund inquiries are normally routed to all pooled fund states in the quarterly progress report, there are numerous repeat questions every year. The quarterly summaries are helpful to member states, but they are temporary and not well organized by the type of question or specific topic. Many pooled fund inquiries could be answered through the development of a Center of Highway Safety web site. A dedicated and well-maintained Pooled Fund Center for Highway Safety web site would provide for all of these needs. It would provide for a searchable database of previous MwRSF inquiries and solutions, a searchable online listing of downloadable research reports, and a searchable archive of CAD details for crash tested and/or approved systems and features. This safety center would also be helpful to non-member states with problems or inquiries similar to those identified by the member states.

In Year 22, the Midwest States Pooled Fund states sponsored the development of a Pooled Fund Center for Highway Safety web site. This project allowed for the development of the first phase of the web site and archiving of materials on the web site. In the past year, a web site for the Midwest States Pooled Fund consulting questions and responses was developed and made available. The web site is currently operational and provides functions for submitting questions and inquiries to MwRSF as well as posting of the responses. It also provides a searchable database of previous MwRSF inquiries and solutions. The website is located at http://mwrsf-qa.unl.edu/.

In addition to the consulting web site, a searchable online listing of downloadable research reports, and a searchable archive of CAD details for crash tested and/or approved systems and features has been started. MwRSF is currently in the process of making this web site operational and uploading the archived reports and CAD. MwRSF anticipates that this archive will be fully functional in the near term. The report and CAD archive as well as the Midwest States Pooled Fund consulting web site will be integrated with the main MwRSF web site in the near future as well.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Maintenance, repair, and upkeep of the website continued.

All completed projects through the first quarter 2016 were added to the research archive site.

Continued development and refinement of a page dedicated to the Pooled Fund to include historical information, state contacts, active projects, and problem statement submission. The Pooled Fund page was added to the mwrsf site.

All funds from this project have been exhausted, all remaining work and progress will be reported under Project No.: RPFP-16-PFCHS – TPF-5(193) Supplement #97, Project Title: Pooled Fund Center for Highway Safety

Anticipated work next quarter:

None as all funds have been exhausted, all remaining work and progress will be reported under Project No.: RPFP-16-PFCHS – TPF-5(193) Supplement #97, Project Title: Pooled Fund Center for Highway Safety

This project will be closed.

Significant Results:

Several newly completed projects were added to the research archive.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

This is a continuation of funding for the original project started in Pooled Fund Year 22, Project No.: RPFP-12-PFCHS-1 – TPF-5(193) Supplement #48, Project Title: Pooled Fund for Highway Safety. Funding from Project No.: RPFP-13-PFCHS – TPF-5(193) Supplement #60, Project Title: Pooled Fund for Highway Safety and Project No.: RPFP-14-PFCHS – TPF-5 (193) Supplement #66, Project Title: Pooled Fund for Highway Safety will be used prior to starting this project.

Potential Implementation:

The Pooled Fund Center for Highway Safety web site would provide immediate access to a wide library of roadside safety materials for designers and engineers, including reports, CAD details, etc. It would also provide a searchable database of previous solutions and responses to prior Pooled Fund inquiries and problems. The web site would also be available through controlled access to state DOT's around the country which would promote improved roadside safety.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Supplement #85	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:		
Annual Fee to Finish TF-13 and FHWA Standard Plans		
Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Faller, Lechtenberg, Bielenberg, Rosenb	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211117001	RPFP-15-TF13	8/1/2014
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
7/31/2017	7/31/2017	0

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$3,602	$1,482	40

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$1,482	

Project Description:

Each year, the Midwest States Pooled Fund program sponsors several roadside safety studies at the Midwest Roadside Safety Facility (MwRSF) of the University of Nebraska-Lincoln. Some of these research efforts result in the development of new roadside safety features. As part of this effort and on behalf of the member states, MwRSF seeks FHWA acceptance for those devices or systems meeting current impact safety standards. In the future, FHWA will require standard Task Force (TF) 13-format CAD details along the typical system details when requests for hardware acceptance are made.

MwRSF prepares 2-D and/or 3-D CAD details for newly developed roadside safety features that are subjected to full-scale vehicle crash testing. The CAD details used to describe the as-tested systems or components are not always prepared and presented in the same format as now required by AASHTO TF 13 and FHWA. As such, additional CAD details and background information must be prepared when FHWA acceptance is sought under MASH or when the new system or associated components are submitted for inclusion in the electronic version of the barrier hardware guide.

Objective: For all new barrier hardware, the member states request that MwRSF seek formal FHWA acceptance and placement of standardized TF-13 CAD details in the electronic version of the highway barrier guide. This funding shall be used to supplement the preparation of the TF-13 format CAD details.

Tasks:

1. Prepare CAD details for Hardware Guide

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Continue updating the drawings reviewed online by the barrier and component review group during the AASHTO TF-13 meetings.

Anticipated work next quarter:

Continue to update drawings based on comments received from online review of drawings.

Significant Results:

This project is used to supplement the preparation of the TF-13 format CAD details.

Summary of new systems and components to be submitted yet: (Note a majority of the work is being completed under the original system projects):
8 systems
13 components

Task	% Complete
1. Prepare CAD details for Hardware Guide	40%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Funding from Project No.: RPFP-14-TF13 – TPF-5(193) Supplement #67, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans will be used prior to starting this project. All funding from previously mentioned project has been exhausted.

Potential Implementation:

Newly-developed highway safety hardware will be contained in the electronic, web-based guide, thus promoting the standardization of barrier hardware across the U.S. and abroad.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #86		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Phase II Conceptual Development of an Impact Attenuation System for Intersecting Roadways		
Name of Project Manager(s): Bielenberg, Faller, Reid	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211118001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 7/1/2015
Original Project End Date: 12/31/16	**Current Project End Date:** 12/31/16	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$256,184	$6,092	12%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$3,484	

Project Description:

The Nebraska Department of Roads (NDOR) funded the first phase of this effort (M332 – New Conceptual Development of an Impact Attenuation System for Intersecting Roadways). This Phase I effort consisted of development of design concepts, analysis of those concepts, and recommendations as to their feasibility. The project was proposed as an initial conceptual design effort, allowing NDOR to limit the research funds for this phase until a viable design was identified and a more substantial investment could be made toward compliance testing.

Following the Phase I study, a hybrid end terminal/crash cushion and net attenuator system was for additional research that had several areas in need of further development. First, dynamic component testing of the proposed Dragnet attenuator found that the current force levels were insufficient to maintain stopping distances near the desired length of 30 ft. In fact, component testing with three standard Dragnet energy absorbers on each side of the system resulted in deflections over 40 ft. Thus, redesign of the net attenuator system will be required to increase the resistive force and shorten the stopping distances. This will likely require redesign of the energy-absorbing drums, the capture net, and the anchorage of the energy absorbers. Additionally, it was desired that the hybrid end terminal/crash cushion and net attenuator attempt to accommodate moderate slopes. Thus, additional research is needed to determine what slopes can be safely used with the revised net attenuator. The first phase of the research considered a variety of end terminal and crash cushion systems, but additional research is needed to determine what other systems are optimal based on their geometry and shielding of the bridge rail end. Finally, additional research is needed to determine the exact layout of the hybrid end terminal/crash cushion and net attenuator system in order to ensure that the two systems function properly when used together.

Thus, the current research results indicated a potential for an alternative design to meet the MASH safety criteria. However, further research is needed to complete the design and prepare it for full-scale crash testing and evaluation to MASH TL-3.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

In this quarter of the research project, MwRSF has been working and collaborating with Impact Absorption, Inc. to develop high-performance net attenuation system that incorporates increased capacity energy absorbers and an appropriate capture net. Attempts by Impact Absorption, Inc. to modify their existing Dragnet energy absorber to generate higher loads have failed due to either not reaching desired loads or overloading of the steel tape causing it to fracture. As such, Impact Absorption, Inc. efforts have shifted to investigation of a higher capacity energy absorber they developed previously for high-severity impacts and military applications. This system uses a much thicker tape that plastically deforms to absorb energy and generates approximately 17 kips of force per absorber, which is close to the design target value of 18-25 kips. However, this system has some drawbacks due to its size, and its performance is unknown when the energy absorber and tape are loaded out of plane. Thus, Impact Absorption, Inc. is fabricated a prototype and shipped it to MwRSF for evaluation.

MwRSF received the high-capacity energy absorber prototype and capture net in late March of 2016. A mounting fixture for the energy absorber was designed and a setup of dynamic testing was developed. These details have been completed and have recently been sent to the MwRSF test facility for fabrication and completion of a single dynamic test of the high-capacity energy absorber prototype. The results of that test should provide insight into the feasibility of the prototype design.

Due to the difficulties that have been found in modifying existing energy absorbers, MwRSF also developed a concept for an energy absorber based on capstan friction using a cable that passes around a series of pins. Basic calculations found that the target design loads can be reached with this concept, but additional developmental testing and design efforts would be required. This concept will be placed on hold for now, but may be further developed based on the evaluation of the Impact Absorption, Inc. high-performance energy absorber.

Anticipated work next quarter:

In the upcoming quarter, MwRSF hopes to perform a dynamic component test of the high-performance net attenuation system to evaluate its feasibility.

Depending on the outcome of that test, MwRSF and NDOR will need to determine what path the energy absorber development should take moving forward.

Significant Results:

Fabrication of high-performance energy absorber for feasibility testing and development of a second potential energy absorber concept. A dynamic component test setup to evaluate the system was developed and test preparations have begun.

A literature search of existing terminal and crash cushion designs was completed and preliminary review of the available system was done to consider potential options for use with the hybrid end terminal/crash cushion and net attenuator system. Further recommendations on potential systems will be based on NDOR input and will be dependent on the parameters of the final net attenuator design.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

Currently, no safety treatment has been successfully crash tested using TL-3 conditions under NCHRP Report No. 350 or MASH to resolve the problems posed when intersecting roadways are located near a bridge railing. A design that can safely treat this situation along high-speed roadways is sorely needed. In addition, the development of a new design concept for an attenuation system for intersecting roadways will focus on the site and space restraints associated with intersecting roadways and adapt a design that best meets those constraints.

MwRSF will work closely with NDOR engineers and the TAC committee members throughout the concept development of a new attenuation system for intersecting roadways in order to ensure that the system is practical. This focus should ensure that the system is viable for NDOR as well as other state DOT's.

Once the new, TL-3 attenuation system for intersecting roadways has been crash tested, evaluated, and accepted by FHWA, NDOR and other State DOTs can implement the new design into its Standards and/or Special Plans for intersecting roadways. At the conclusion of this research project, it is recommended that NDOR designate an intersecting roadway location that will use this new technology in order to evaluate a "real-world" installation and make any necessary improvements.

Finally, the publication and dissemination of the research results and demonstration program, in the form of newsletters, research reports, and refereed journal papers, will aid the rapid transfer of this new technology to all interested

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #87	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:
Guidelines for Placement of Breakaway Light Poles Behind MGS

Name of Project Manager(s): Faller, Bielenberg, Reid, Pajouh	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611130094001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 7/10/2015
Original Project End Date: 6/30/17	**Current Project End Date:** 6/30/17	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$262,603	$35,752	25%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$32,920	

Project Description:

Light poles are a commonly found along most highways due to the need to provide proper illumination to critical areas of the road. It is not uncommon for light poles to be placed in areas where guardrail is present as well. In these situations, light poles must be placed sufficiently close to the roadway while not interfering with the performance of the guardrail system. However, several concerns exist when placing light poles in close proximity to guardrail that may affect its ability to safely contain and redirect vehicles. First, interaction between a deflected guardrail system and a pole may create unwanted stiffening or hinging of the barrier system about the pole, which may cause pocketing and increased loading to the guardrail. The pole may also present a snag hazard to impacting vehicles, which may cause increased vehicle decelerations and instabilities. Third, interaction between the guardrail posts and light pole may affect barrier performance. While the use of breakaway light poles may mitigate these concerns to some degree, the interaction between a guardrail system and a closely-positioned light pole requires further investigation.

The Illinois Tollway currently has many instances where light pole placement is desired directly behind W-beam guardrail in order to provide adequate road illumination. Illinois Tollway and Illinois Department of Transportation have recently adopted the Midwest Guardrail System (MGS) as their standard W-beam guardrail design. The current Illinois Tollway standard for light poles is to place the pole no closer than the minimum barrier clearance distance of 28" (standard 6'-3" post spacing), 23" (½-post spacing), and 14" (¼-post spacing), as shown in Figure 1. In order to accommodate poles positioned closer than the minimum barrier clearance distance, an investigation should be conducted to determine if the minimum standard distance for breakaway light poles can be reduced, and if so, determine the optimal position of the light pole with respect to the guardrail system. It is anticipated that computer simulation/modeling with non-linear finite element analysis will be conducted to reduce the number of required crash tests. Crash tests should be conducted according to the AASHTO MASH Test Level 3(TL-3) impact safety criteria.

The objective of this research effort is to develop guidance for safe placement of the Illinois Tollway standard light pole

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

In this quarter of the research project, the focus was on the selection of the critical impact point and the critical location of the light pole through numerical modeling. For this purpose, the baseline model of the MGS system impacted by a 2270P pickup truck was analyzed to find the impact point with the maximum defection of the barrier.

A large number of LS-DYNA simulations were conducted with the pole was placed at different offsets from the face of the guardrail (28" to 16") and at different offsets from the post a long the guardrail (4" to 20"). The results were then compared to the baseline model without pole including ORA/OIV occupant risk values, pocketing angle, vehicle snag, barrier deflection, roll/pitch/yaw angle,rail forces, peak deceleration, and velocity change. Preliminary results indicate that lateral pole offsets in the 16"-18" range may significantly affect barrier performance. Additionally, the simulations indicated that placement of the offset pole slightly downstream of a barrier post was most critical.

Anticipated work next quarter:

In the continue of the project, more scenarios will be investigated numerically to better characterize the effect of a reduced offset pole on the MGS barrier performance. These simulations will further identify the critical pole offsets and the critical impact point for various offsets. MwRSF plans to review and discuss the simulation results with the sponsor and to select which lateral pole offset they wish to investigate through full-scale crash testing. Once the preferred post location has been selected, small car impact simulations will be conducted to determine if the small car interaction with the offset pole is a concern and determine an impact point for the 1100C vehicle test. Documentation and reporting of the simulation analysis will begin in the upcoming quarter as well.

Design details for the first full-scale crash test will be developed in CAD. The first test designation is no. 3-11, which is an impact of the 2270P vehicle with speed of 62 mph and 25 degree angle at the critical impact point determined through simulation. The need for the 1100C test will be evaluated based the outcome of that testing and the small car simulations noted above.

Significant Results:

The MGS impact point downstream of a post was found to be the most critical. It was numerically observed that pole offset behind rail showed potential for increased occupant risk, rail pocketing, increased rail tensile loads, vehicle instability and snag on pole.

Lateral pole offset of 16" may be minimum. The final recommendation can be made after additional analysis.
Longitudinal offset of pole 4"-8" downstream of a post also was observed to produce critical behaviors.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

The successful development and evaluation of a minimal offset for light poles placed adjacent to the MGS would allow the Illinois Tollway and the Illinois DOT to reduce light pole relocations in upcoming construction projects and avoid relocation in projects that are currently underway. Avoiding or reducing light pole relocations when minimum clearance distance is not met would reduce construction costs. In addition, the research could potentially reduce the need for supplemental lighting, planning, and analysis of lighting impacts due to necessary light pole relocation.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): New Jersey Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl. #88	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:		
Evaluation of New Jersey TCB Performance under MASH TL-3		
Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Faller, Lechtenberg, Bielenberg, Rosenbaugh,	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611130095001		4/1/2015
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
6/30/2016	6/30/2016	

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$702,369	$106,471	15%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$74,201	

Project Description:

The New Jersey Department of Transportation (NJDOT) currently uses a New Jersey shape temporary concrete barrier (TCB) design with a I-beam connection piece in their work zones and construction areas. The New Jersey Roadway Design Manual provides guidance on allowable barrier deflections for various classes of TCB joint treatments. The guidance provided in the Roadway Design Manual was based on test data from previous testing standard and needs to be updated to be consistent with current testing standards and the vehicle fleet. MASH TL-3 testing of other TCB systems has indicated that dynamic barrier deflections of these types of barriers can increase significantly when compared to deflections based on older crash test data. Thus, a need exists to investigate the performance of the NJDOT TCB design in its various configurations and provide guidance for updating current design guidance for these systems.

The objective of this research effort is to investigate the performance of the NJDOT TCB design in various configurations in order to evaluate the barrier to the MASH TL-3 safety requirements and to develop information on the barrier performance that can be used by the NJDOT to developed updated and improved guidance for the use of the TCB system.

Objectives / Tasks

1. Test no. 1 - Full-scale crash testing (MASH 3-11)
2. Test no. 2 - Full-scale crash testing (MASH 3-11)
3. Test no. 3 - Full-scale crash testing (MASH 3-11)
4. Test no. 4 - Full-scale crash testing (MASH 3-11)
5. Test no. 5 - Full-scale crash testing (MASH 3-11)
6. Test no. 6 - Full-scale crash testing (MASH 3-11)
7. Test no. 7 - Full-scale crash testing (MASH 3-11)
8. Test no. 8 - Full-scale crash testing (MASH 3-11)

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Procurement of remaining materials for proposal test no. 3. Construction of the NJDOT PCB system in a pinned configuration (every other barrier is pinned in all 9 pin recesses) with grouted barrier toes, corresponding to Joint Class C in the NJDOT Roadway Design Manual. This system corresponds to the system specified as test no. 3 in the proposal.

On February 19th, the NJDOT PCB in a pinned configuration with grouted barrier toes was subjected to AASHTO MASH TL-3 test conditions using a 2270P pickup truck vehicle (test designation 3-11). This system had 1-in. diameter steel pins placed in every pin-hole location in every other barrier segment. This system configuration corresponds to Joint Class C in the NJDOT Roadway Design Manual. In test no. NJPCB-1, the pickup truck impacted the system at a speed and angle of 62.6 mph and 24.7 degrees, respectively, resulting in an impact severity of 114.8 kip-ft. The system adequately contained and safely redirected the pickup truck. The occupant impact velocities and occupant ridedown accelerations were within the suggested limits provided in MASH. The maximum lateral deflection of the system and working width of the system were approximately 14 in. and 38 in., respectively. The occupant crush measurements found a maximum of approximately 5 in. of deformation in any of the required locations which does not exceed the limits provided in MASH. The test was acceptable according to the safety performance criteria of AASHTO MASH for test designation no. 3-11.

Test documentation and analysis of test no. NJPCB-1 was completed.

Preparation of CAD details for proposal test no. 4 and proposal test no. 1. Drawings were sent to the sponsor for review and approval.

Procurement of remaining materials for proposal test no. 4. Construction of the NJDOT PCB system in a bolted

Anticipated work next quarter:

Conduct crash test no. 2 (which is actually test no. 4 from the proposal).

Documentation of crash test no. 2.

Procurement of remaining materials for proposal test no. 1. Setup system and conduct crash test no. 3 (which is actually test no. 1 from the proposal).

Documentation of crash test no. 3.

Continuation of draft report for test no. NJPCB-1. Potentially initiate draft reports for subsequent tests.

Significant Results:

None

Objectives / Tasks	% Complete
1. Test no. 1 - Full-scale crash testing (MASH 3-11)	
1a. Test no. 1 Report	
2. Test no. 2 - Full-scale crash testing (MASH 3-11)	
2a. Test no. 2 Report	
3. Test no. 3 - Full-scale crash testing (MASH 3-11) - NJPCB-1	85%
3a. Test no. 3 Report - NJPBC-1	20%
4. Test no. 4 - Full-scale crash testing (MASH 3-11) - NJPCB-2	5%
3a. Test no. 3 Report - NJPBC-2	
5. Test no. 5 - Full-scale crash testing (MASH 3-11)	
6. Test no. 6 - Full-scale crash testing (MASH 3-11)	
7. Test no. 7 - Full-scale crash testing (MASH 3-11)	
8. Test no. 8 - Full-scale crash testing (MASH 3-11)	
9. Test no. 9 - Full-scale crash testing (MASH 3-11)	
10. LS-DYNA simulation test no. 1	
11. LS-DYNA simulation test no. 5	
12. LS-DYNA simulation reduced system lengths	
13. Written report documenting design, testing, and conclusions	
14. Hardware Guide drawings	

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

In August 2015, MwRSF received authorization to begin work on the project. However, the NJDOT provided $219,500 of project funding initially. In October 2015, NJDOT anticipates providing additional funds to reach $350,000 in total funding. In the fall of 2016, NJDOT anticipates providing the remainder of the funds to reach the $702,369 total project budget. Therefore, the project plan was adjusted to accommodate the staged funding and delayed authorization to proceed.

Note: additional funds to reach the initial $350,000 have not been received as of April 30, 2016. Therefore, the project only has enough funds to conduct 3 tests at this time.

Potential Implementation:

Investigation and evaluation of the proposed NJDOT TCB configurations would provide for MASH TL-3 acceptance of the current NJDOT barrier standard. In addition, the testing and proposed simulation analysis would provide improved data for NJDOT design guidance and standards.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): NE Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl.#89	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:
Continued Development of Midwest High-Tension, Cable Barrier End Terminal - Phase I

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Schmidt, Reid, Faller	402-472-0870	jennifer.schmidt@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211119001	RPFP-16-CABLE-4	10/1/2015
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
9/30/2018	9/30/2018	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$41,230	$55	0%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$55	

Project Description:

MwRSF has been conducting research for the Midwest States Pooled Fund Program to develop a non-proprietary, high-tension, four-cable median barrier. A separate effort was funded in parallel to develop a crashworthy end terminal for that cable barrier design. Previous research efforts resulted in two non-proprietary, high-tension, cable barrier end terminal designs that were subjected to dynamic bogie testing. However, the bogie testing indicated that the two systems did not meet all of the design goals and further design modifications and investigation was deemed necessary. Additionally, during the development of the high-tension, four-cable median barrier, several design modifications were implemented that will likely affect the design of the end terminal, including the post section, the cable height and spacing, cable tension, and the cable-to-post connection hardware. It is desired that the end terminal system be designed to integrate with the high-tension, four-cable median barrier design as seamlessly as possible. Thus, additional effort is needed to update the terminal to the current high-tension, cable median barrier configuration.

The research objective is to continue the development, dynamic component testing, and evaluation of a crashworthy, four-cable end terminal. The system is desired to meet the TL-3 safety performance criteria found in MASH.

Major Task List -

1. LS-DYNA Simulation
2. CAD Drawings
3. Construction of End Terminal
4. Two Bogie Tests and Data Analysis
5. Summary Report

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The Year 20 cable end terminal report was finalized on April 28, 2016. No significant work has begun on this project.

Anticipated work next quarter:

This project is contingent on the direction taken by the high-tension, cable median barrier project. Once the direction of that project is determined, end terminal concepts will be brainstormed that include improving the performance on the end terminal during reverse direction impacts.

Significant Results:

None.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Note: This project was originally funded in Year 26 with a total budget of $106,230. In the November 9 Pooled Fund meeting, it was decided that $65,000 would be reduced from this project RPFP-16-CABLE-4, so the currently funded budget is $41,230 as reflected in 'Total Project Budget' on page 1. The $65,000 deficit was not made up in Year 27. Thus, all tasks in this project will not be completed.

Potential Implementation:

The revised terminal will provide a non-proprietary end terminal for high tension barrier cable systems once the design is finalized and the full-scale crash testing program has been funded and successfully completed.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #90		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Portable Concrete Barrier–Steel Cover Plate for Large Open Joints		
Name of Project Manager(s): John Reid, Ron Faller, Bob Bielenberg, Karla	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211120001	**Other Project ID (i.e., contract #):** RPFP-16-CONC-4	**Project Start Date:** 10/1/2015
Original Project End Date: 9/30/18	**Current Project End Date:** 9/30/18	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$118,925.00	$0.00	5%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$0.00	

Project Description:

Temporary concrete barriers (TCB) are commonly used to protect work zones and to shield motorists from hazards in construction areas. During setup or contractor operations in work zone areas, it is not uncommon to layout, construct, and connect free-standing TCB installations from different ends or to install barriers with a longitudinal gap between adjacent barrier segments. Longitudinal gaps can also be created due to tensioning issues following an impact event. These gaps can range from 6 in. to as long as a full barrier segment length, or 12.5 ft. Gaps in the barrier system pose a serious safety concern, but limited guidance is available for this situation. Overlapping two runs of barriers has been recommended in the past. However, the length of barrier overlap is relatively large and also requires significant lateral offset between the overlapped segments, which reduces available space in constricted work zones. Thus, a need exists to develop crashworthy and efficient methods for treating longitudinal gaps in adjacent runs of free-standing TCBs.

Previous research efforts to investigate gaps between adjacent TCB installations have focused on gate designs for providing emergency or maintenance access through temporary barriers. These devices include the ArmorGuard Gate, the BarrierGuard Gate, and the Vulcan barrier system. All of these gate systems are proprietary with fixed lengths that can be attached to permanent and temporary concrete barrier systems. While these systems have been crash-tested and demonstrated to function adequately, they are fixed-length solutions that would not be effective at spanning variable length gaps. In addition, these gates can be relatively costly to install.

For a more general solution to variable length gaps, the current guidance is to longitudinally overlap two adjacent barrier runs with a minimum of eight TCB segments and provide a minimum lateral offset of 2 ft between adjacent barrier runs. While this solution is adequate in terms of crashworthiness, it is not always manageable in terms of available space in the work zone. A more efficient solution would involve some form of gap-spanning hardware that could be adjusted for a variable gap length, would be easy to install and remove, and would be crashworthy. Crashworthiness of any design solution would require development of continuity (shear, tensile, and flexural loads) across the variable gap length and

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

A literature review was conducted encompassing various related barrier systems including temporary and permanent concrete barriers, barrier gates, cover plates, and PCB transitions. The literature review covered State DOT standard plans, proprietary barriers, and a patent search. Work also began to document the findings of the literature review.

Anticipated work next quarter:

Multiple design concepts will be developed and presented to the sponsors for review and feedback. Once the most desired concept is selected, work will begin to further develop the concept and flesh out the system components.

Significant Results:

A literature review was completed on State DOT standards, private manufacturer hardware, and a patent search.

Objectives / Tasks	% Complete
1. Literature Review	75%
2. Concept Development and Analysis	0%
3. CAD details	0%
4. (Sponsor) Design Selection	0%
5. Computer Simulation	0%
6. CIP Study	0%
7. Project Summary Report	0%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

Development of a crashworthy system for spanning variable gaps in adjacent runs of TCBs would provide states with increased safety through removal of the hazard posed by interruption of the barrier continuity and would improve the flexibility of work zone operations by making it easier to move or coordinate TCB installations.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #91		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Design Guidance for MGS Placed on or near Slopes		
Name of Project Manager(s): John Reid, Ron Faller, Bob Bielenberg, Karla	**Phone Number:** 402-472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611211120001	**Other Project ID (i.e., contract #):** RPFP-16-MGS-2	**Project Start Date:** 10/1/2015
Original Project End Date: 9/30/18	**Current Project End Date:** 9/30/18	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$54,309.00	$0.00	5%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$0.00	

Project Description:

The MGS has shown to be a high performance, adaptable system that can be installed on or near slopes. Variations of the MGS have been tested under these conditions, with differing post spacing, post lengths, and blockout depths, depending on the degree of the slope and the guardrail offset in front of the slope. However, gaps in the guidance still exist for some ranges of slopes and offsets, and existing guidance is contained in various documents as well as on the Midwest Pooled Fund Q/A website.

The need exists to fill the gaps in guidance regarding MGS installed near slopes. For example, there is currently limited guidance for: (1) posts installed 1 ft to 2 ft adjacent to a 3H:1V or steeper slope; (2) posts installed less than 1 ft adjacent to a 3H:1V to 6H:1V slope; and (3) posts installed less than 1 ft adjacent to a 6H:1V or flatter slope. In addition, a single document that provides clear, concise guidance on all options available to designers when installing MGS near slopes would be extremely valuable.

The research objectives are to: (1) develop recommendations for MGS installed with slopes and offsets that have not been provided previously and (2) combine all recommendations regarding MGS installed near slopes into a selection guide which clearly presents all options available to designers when placing MGS near slopes.

Major Task List

Literature Review: Review literature pertaining to MGS in combination with slopes.

Selection of Options: Determine slope and barrier combinations requiring guidance, followed by sponsor review and feedback

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

In this quarter, MwRSF has initiated a literature search to compile and summarize research related to the MGS adjacent to slopes. This effort will collect information regarding:

1. Collect all previous MASH testing of the MGS adjacent to slopes including MwRSF 2:1 slope testing, MwRSF gabion wall testing on 3:1 slopes, and TTI testing of 31" tall guardrail on 2:1 slopes.
2. Collect bogie testing efforts at MwRSF and others related to guardrail adjacent to slopes.
3. Review current research related to guardrail on slopes including ongoing projects.
4. Review previous guidance on guardrail adjacent to slopes provided by MwRSF through the Midwest Pooled Fund Consulting efforts.

This data is currently being collected and will be reviewed and summarized as part of the final report.

MwRSF also contacted the states regarding the parameters for the MGS adjacent to slope guidance. The sponsoring states were asked the following questions.

1. Keeping in mind that 10:1 slopes or flatter slopes are generally accepted adjacent to guardrail, we are currently anticipating providing guidance for 8:1, 6:1, 4:1, 3:1, and 2:1 slopes. If there are other slopes in use by the state DOT's please let us know so they can be considered in the guidance.
2. In the past, offsets of 2 ft more from the back of the post to the slope have been allowed for most installations. Currently, we are considering providing guidance for offsets between 2 ft from the back of the post to the slope break point to the face of the guardrail installed at the slope break point in 6 in. intervals. Please respond if you require offsets that do not fall into this range or spacing.
3. Finally, one option for the guidance would be to varying the post spacing adjacent to the slope. Would your state prefer to have guidance only for standard 6 ft – 3in. post spacing or would you need guidance for ½ and ¼ post spacing as well? Keep in mind that reduced post spacing is only an option and may not be required.

Anticipated work next quarter:

In the upcoming quarter, MwRSF will continue to compile and review the literature search related to MGS adjacent to slopes. Once that literature has been compiled and reviewed, MwRSF will begin the process of developing guidance for intermediate slopes and barrier offsets.

Potential alternatives with respect to the format of the guidance will be taken into consideration as well. Depending on state DOT desires, the guidance could be a table or a spreadsheet that allows one to look up or determine appropriate MGS configurations based on the slope and offset of the barrier.

Significant Results:

State survey completed and the literature search was initiated.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

This research would develop a selection guide that presents installation options of the MGS placed near a slope. It would be slope-based such that for a given slope, all allowable variations and locations of the MGS would be presented.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #92 MwRSF Project No. RPFP-16-MGS-3	**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title: Steel Post Version of Downstream Anchorage System		
Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611211122001	**Other Project ID (i.e., contract #):** RPFP-16-MGS-3	**Project Start Date:** 10/1/2015
Original Project End Date: 9/30/2018	**Current Project End Date:** 9/30/2018	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$162,219	$0	5%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$0	

Project Description:

Component testing has shown that the performance of the new Universal Breakaway Steel Post (UBSP) compares very well with that of the wood CRT post. As a result, the MwRSF concluded that the UBSP may be a viable option to replace CRT posts in various systems including bullnose systems, long-span guardrail systems, and guardrail end terminals. Although most guardrail end terminals are proprietary, MwRSF has recently developed a non-proprietary downstream anchorage system for the MGS that utilizes two wood Breakaway Cable Terminal (BCT) posts. For state DOTs that primarily utilize steel posts, it is desirable to find a steel post alternative for BCT posts utilized in the MGS downstream anchorage. Although BCT posts differ in function and design from CRT posts, they have similar cross sections and weakening holes at groundline. Thus, modifications to the UBSP may result in performances similar to that of a BCT post. Therefore, an adaptation of the UBSP is desired for use in a new steel post version of the MGS downstream anchorage system.

The objective of this research effort is to develop a steel post version of the MGS downstream anchorage system that satisfies the MASH TL-3 safety performance requirements. Note, this project was divided into two phases. Phase II has yet to be funded, and only Phase I is shown herein.

Objectives / Tasks:

1. Literature Review
2. Development of Design Concepts
3. Design and Analysis
4. CAD Details
5. Component Fabrication
6. Component Testing
7. Data Analysis
8. CAD Details of Recommended System Design

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Work indirectly began for this project as information being gathered in Project No.: RPFP-16-TERM-1 – TPF-5(193) Supplement #94, Project Title: Development of Generic Energy End Terminal will be utilized for the initial patent search for post patents including mailboxes and traffic standards since they are subsumed under terminal and barrier patents.

Anticipated work next quarter:

Continue and potentially complete the patent search. Document the findings of the patent search.

Initiate concept development.

Significant Results:

Objectives / Tasks:	% Complete
1. Literature Review	5%
2. Development of Design Concepts	0%
3. Design and Analysis	0%
4. CAD Details	0%
5. Component Fabrication	0%
6. Component Testing	0%
7. Data Analysis	0%
8. CAD Details of Recommended System Design	0%
9. Summary Report	0%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

The successful development of a steel post downstream anchorage system would provide states with a second non-proprietary option for the downstream anchorage of MGS. State DOTs that regularly use steel posts instead of wood posts would find implementation of the new system much easier than having to justify wood post use for this special application.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl. #93 MwRSF Project No. RPFP-16-MGS-4	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:

Top Mounted Socket for Weak Post Bridge Rail

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Faller, Bielenberg, Lechtenberg, Rosenb	402-472-9324	srosenbaugh2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211123001	RPFP-16-MGS-4	10/1/2015
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
9/30/2018	9/30/2018	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$130,538	$84	5%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$84	

Project Description:

Numerous box culverts across the country utilize low-fill soil above the top slab, typically in the range of 1 to 3 ft. Because these fill heights do not permit full guardrail post embedment (i.e., 40 inches), alternative post attachment/anchorage options are required to protect the culvert drop-off. Top-mounted post systems have been developed to bolt to the top culvert slab. Unfortunately, when the guardrail system is impacted and posts need to be repaired and/or replaced, maintenance personnel are required to dig up the roadway and/or fill soil to access the attachment bolts and base of posts. This effort adds significant time and costs to system repairs.

Recently, a side-mounted socket system for weak-post MGS was developed for attachment to the outside face of culvert headwall. The system posts are inserted into steel sockets that remain undamaged during impacts. Thus, damaged posts can be replaced without any soil removal or the need for a post driver. However, there are many installations where the culvert or roadway geometry is not compatible with this side-mounted system. For example, the culvert headwall may be farther from the roadway than the adjacent guardrail system. Additionally, there may be a fill slope between the edge of the roadway and the culvert headwall, and the side-mounted guardrail system was only recommended for level terrain applications. The ideal guardrail system for use on low-fill culverts would combine the benefits of a top-mounted system with that of a socketed system. Utilizing sockets would allow for quick and easy repairs to damaged posts, while mounting the sockets to the top of the culvert slab would allow the system to be installed on virtually all culverts.

The objective of this project is to develop a top-mounted socket to attach the weak-post W-beam guardrail system to the top slab of low-fill (1-3 ft) box culverts.

Objectives / Tasks:

1. Literature Review
2. Conceptual Design and Analysis

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The literature review was completed. All previous crash-testing of related weak-post systems and top-mounted culvert guardrail systems was reviewed.

Anticipated work next quarter:

Preliminary design concepts will be developed and presented to the states for review and selection of desired concept.

Significant Results:

A literature review was completed covering all previous crash-testing of related weak-post systems and top-mounted culvert guardrail systems.

Objectives / Tasks:	% Complete
1. Literature Review	100%
2. Conceptual Design and Analysis	0%
3. Selection of Preferred Concepts	0%
4. CAD Details	0%
5. Component Fabrication and Construction	0%
6. Dynamic Component Testing	0%
7. Data Analysis	0%
8. Removal and Disposal	0%
9. TF 13 Hardware Guide Drawings	0%
10. Project Summary Report	0%
11. FWHA Eligibility Letter	0%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

With the successful completion of this project, state DOTs will have a crashworthy, top-mounted, socketed guardrail system for use on low-fill culverts. The use of sockets to support the guardrail posts will minimize maintenance and repair costs, while having a top mounted system will allow the guardrail system to be placed anywhere on the culvert.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): NDOR

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl # 94	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:

Development of a Generic Energy-Absorbing, Approach End Terminal for MGS

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Schmidt, Reid, Faller	(402) 472-0870	jennifer.schmidt@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211124001	RPFP-16-TERM-1	10/1/2015
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
9/30/2018	9/30/2018	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$70,000	$4,511	10%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$4,511	

Project Description:

Several crashworthy end terminals exist for W-beam guardrail, including energy-absorbing and non-energy absorbing options. According to the FHWA resource charts for roadside terminals, the currently available generic W-beam guardrail end terminals are all classified as non-energy absorbing [1]. Seven proprietary, energy-absorbing, end terminals exist for W-beam guardrail. However, only one of those systems has been evaluated according to MASH safety performance criteria. Several of the other end terminals were evaluated with 27¾-in. high guardrail and had limited full-scale crash testing with 31-in. high MGS. Only one proprietary, energy-absorbing W-beam guardrail end terminal has been evaluated according to MASH safety performance criteria. Therefore, state DOTs desire a generic, energy-absorbing, tangent end terminal for the MGS that meets the MASH TL-3 safety performance criteria.

The research objective is to synthesize information regarding existing end terminal designs and begin development of design concepts for a generic, tangent, energy-absorbing end terminal for use with the MGS.

Major Task List

1. Literature Review
2. Brainstorming
3. Concept Development and Preliminary Design

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The literature and patent began, and approximately half of the applicable patents have been downloaded and reviewed. Several patents associated with current energy-absorbing and non-energy absorbing end terminals were identified as being expired.

Anticipated work next quarter:

The literature and patent review will be completed. Initial brainstorming efforts will begin.

Significant Results:

Several expired end terminal patents were determined.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

At the completion of this multiple phase project, State DOTs will have a tangent approach end terminal for MGS that is generic,energy-absorbing, and meets MASH safety performance criteria. Additionally, State DOTs will better understand the performance of energy-absorbing end terminals, will have an alternative to proprietary products, and could easily explore special applications (i.e. with a curb) that are beyond the current state-of-the-practice.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #95		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Pooled Fund Center for Highway Safety		
Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611211125001	**Other Project ID (i.e., contract #):** RPFP-16-WEB-1	**Project Start Date:** 10/1/2015
Original Project End Date: 9/30/2018	**Current Project End Date:** 9/30/2018	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$30,102	$1,908	5%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$1,908	

Project Description:

The Midwest States Pooled Fund states sponsored the development of a Pooled Fund Center for Highway Safety website. This project has allowed for the development of the website and archiving of materials on the website. Previously, a website for the Midwest States Pooled Fund consulting questions and responses was developed and made available. The website is currently operational and provides functions for submitting questions and inquiries to MwRSF as well as posting of the responses. It also provides a searchable database of previous MwRSF inquiries and solutions. The website is located at http://mwrsf-qa.unl.edu/.

In addition to the consulting website, a searchable online listing of downloadable research reports and a searchable archive of CAD details for crash-tested and/or approved systems and features has been created. The research archive contains all of MwRSF's archived research reports in a searchable format. The archive of the CAD details for the research efforts has been generated and is currently being uploaded beginning with newer projects and proceeding to older research. Additionally, Midwest Pooled Fund members have requested inclusion of videos files from full-scale crash testing to the archive. These are currently being added to the site for the newer projects and as requests for older videos are made. The research archive as well as the Midwest States Pooled Fund consulting website is integrated with the main MwRSF website.

Tasks

(1) Identify projects needing wmv videos uploaded to the Research Hub
(2) Locate full-scale crash test videos for publicly funded projects completed at MwRSF
(3) Convert videos to wmv format
(4) Upload the wmv videos to the Research Hub and archive converted videos with the original videos
(5) Verify videos have been uploaded

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Identified projects with videos that need converting. Creating a tracking list.

Located full-scale crash test videos from publicly funded projects that need to be converted.

Anticipated work next quarter:
Initiate video conversion to wmv format.

Significant Results:
None.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

Making the videos available in wmv format will benefit the DOTs involved in training designs, field inspectors, and maintenance personnel on the various roadside safety concepts and devices.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*		**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl. #97		☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Pooled Fund Center for Highway Safety		
Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Faller, Bielenberg, Lechtenberg, Rosenb	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211127001	RPFP-16-PFCHS	10/1/2015
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
9/30/2018	9/30/2018	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$11,848	$1,052	10%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$1,052	

Project Description:

Many of MwRSF's inquiries from members of the Midwest States Pooled Fund program can be answered based upon prior pooled fund or other research. Further, even though answers to pooled fund inquiries are normally routed to all pooled fund states in the quarterly progress report, there are numerous repeat questions every year. The quarterly summaries are helpful to member states, but they are temporary and not well organized by the type of question or specific topic. Many pooled fund inquiries could be answered through the development of a Center of Highway Safety web site. A dedicated and well-maintained Pooled Fund Center for Highway Safety web site would provide for all of these needs. It would provide for a searchable database of previous MwRSF inquiries and solutions, a searchable online listing of downloadable research reports, and a searchable archive of CAD details for crash tested and/or approved systems and features. This safety center would also be helpful to non-member states with problems or inquiries similar to those identified by the member states.

In Year 22, the Midwest States Pooled Fund states sponsored the development of a Pooled Fund Center for Highway Safety web site. This project allowed for the development of the first phase of the web site and archiving of materials on the web site. In the past year, a web site for the Midwest States Pooled Fund consulting questions and responses was developed and made available. The web site is currently operational and provides functions for submitting questions and inquiries to MwRSF as well as posting of the responses. It also provides a searchable database of previous MwRSF inquiries and solutions. The website is located at http://mwrsf-qa.unl.edu/.

In addition to the consulting web site, a searchable online listing of downloadable research reports, and a searchable archive of CAD details for crash tested and/or approved systems and features has been started. MwRSF is currently in the process of making this web site operational and uploading the archived reports and CAD. MwRSF anticipates that this archive will be fully functional in the near term. The report and CAD archive as well as the Midwest States Pooled Fund consulting web site will be integrated with the main MwRSF web site in the near future as well.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

See progress in Project No.: RPFP-15-PFCHS – TPF-5(193) Supplement #84, Project Title: Pooled Fund for Highway Safety.

Anticipated work next quarter:

Continue maintenance, repair, and upkeep of the website.

Continue updating the archive with completed projects as they are completed.

Continue the refinement of the dedicated Pooled Fund page.

Significant Results:

Several newly completed projects were added to the research archive.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

This is a continuation of funding for the original project started in Pooled Fund Year 22, Project No.: RPFP-12-PFCHS-1 – TPF-5(193) Supplement #48, Project Title: Pooled Fund for Highway Safety; Project No.: RPFP-13-PFCHS – TPF-5(193) Supplement #60, Project Title: Pooled Fund for Highway Safety; and Project No.: RPFP-14-PFCHS – TPF-5(193) Supplement #66, Project Title: Pooled Fund for Highway Safety. Funding from Project No.: RPFP-15-PFCHS – TPF-5 (193) Supplement #84, Project Title: Pooled Fund for Highway Safety will be used prior to starting this project.

Potential Implementation:

The Pooled Fund Center for Highway Safety web site would provide immediate access to a wide library of roadside safety materials for designers and engineers, including reports, CAD details, etc. It would also provide a searchable database of previous solutions and responses to prior Pooled Fund inquiries and problems. The web site would also be available through controlled access to state DOT's around the country which would promote improved roadside safety.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Supplement #98	☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:

Annual Fee to Finish TF-13 and FHWA Standard Plans

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Reid, Faller, Lechtenberg, Bielenberg, Rosenb	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211128001	RPFP-16-TF13	10/1/2015
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
9/30/2018	9/30/2018	0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$3,686	$0	0

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$0	

Project Description:

Each year, the Midwest States Pooled Fund program sponsors several roadside safety studies at the Midwest Roadside Safety Facility (MwRSF) of the University of Nebraska-Lincoln. Some of these research efforts result in the development of new roadside safety features. As part of this effort and on behalf of the member states, MwRSF seeks FHWA acceptance for those devices or systems meeting current impact safety standards. In the future, FHWA will require standard Task Force (TF) 13-format CAD details along the typical system details when requests for hardware acceptance are made.

MwRSF prepares 2-D and/or 3-D CAD details for newly developed roadside safety features that are subjected to full-scale vehicle crash testing. The CAD details used to describe the as-tested systems or components are not always prepared and presented in the same format as now required by AASHTO TF 13 and FHWA. As such, additional CAD details and background information must be prepared when FHWA acceptance is sought under MASH or when the new system or associated components are submitted for inclusion in the electronic version of the barrier hardware guide.

Objective: For all new barrier hardware, the member states request that MwRSF seek formal FHWA acceptance and placement of standardized TF-13 CAD details in the electronic version of the highway barrier guide. This funding shall be used to supplement the preparation of the TF-13 format CAD details.

Tasks:

1. Prepare CAD details for Hardware Guide

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

None

This project will not be started until the completion of Project No.: RPFP-15-TF13 – TPF-5(193) Supplement #85, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans.

Anticipated work next quarter:

None

Significant Results:

This project is used to supplement the preparation of the TF-13 format CAD details.

Task	% Complete
1. Prepare CAD details for Hardware Guide	0%

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Funding from Project No.: RPFP-15-TF13 – TPF-5(193) Supplement #85, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans will be used prior to starting this project.

Potential Implementation:

Newly-developed highway safety hardware will be contained in the electronic, web-based guide, thus promoting the standardization of barrier hardware across the U.S. and abroad.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): NE Department of Roads

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Suppl. #99		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: LS-DYNA Modeling Enhancement Support		
Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-3084	**E-Mail** jreid@unl.edu
Lead Agency Project ID: RPFP-16-LSDYNA	**Other Project ID (i.e., contract #):** 2611211129001	**Project Start Date:** October 1, 2015
Original Project End Date: September 30, 2018	**Current Project End Date:** September 30, 2018	**Number of Extensions:** 0

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ☑ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$41,114	$0	0%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
0	$0	0

Project Description:

The objective of this research effort is to maintain a modeling enhancement program funded by the Pooled Fund Program States to address specific modeling needs shared by many safety programs. Funding from this project would go towards advancement of LS-DYNA modeling capabilities at MwRSF. The exact nature of the issues to be studied would be determined by the most pressing simulation problems associated with current Pooled Fund projects.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

This is a continuation of TPF-5(193) Suppl. #51, "Annual LS-DYNA Modeling Enhancement Support" and thus, no progress to report until funds are exhausted in that project.

Anticipated work next quarter:

Significant Results:

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Potential Implementation:

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Iowa DOT

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*		**Transportation Pooled Fund Program - Report Period:**
TPF-5(193) Suppl. #100		☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Attachment of Combination Rails to Concrete Parapets Utilizing Epoxy Adhesive Anchors - Phase IB		
Name of Project Manager(s): Bielenberg, Faller, Reid, Rosenbaugh	**Phone Number:** (402) 472-9064	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611130097001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 9/23/2015
Original Project End Date: 11/30/2015	**Current Project End Date:** 11/30/2015	**Number of Extensions:** 0

Project schedule status:

☑ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$33,488.00	$2,997.00	100

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$2,213.00	

Project Description:

The research objective is to design and evaluate alternative epoxy adhesive anchorages for use in the IaDOT BR27C combination bridge rail system. The alternative epoxy adhesive anchorages would be developed to have equal or greater capacity than the current cast-in-place anchorage, so that they can be used in new construction or as a retrofit to modify existing bridge railings. The proposed epoxy attachment designs will be evaluated through dynamic component testing.

The research effort will consist of redesign, testing, and evaluation of alternative epoxy adhesive anchorage systems for attaching the beam and post system to the concrete parapet according to the details for the BR27C combination bridge railing. This first task in this effort would be for MwRSF to review the current cast-in-place anchorage design and develop alternative epoxy adhesive anchorage configurations. This effort could include an inline anchor system and/or a four anchor system similar to the cast in place configuration but with spacing more compatible with the clearances required for a drill in system. The alternative epoxy adhesive anchorage systems would be submitted to IaDOT for review and selection of the one or two preferred systems to be tested and evaluated.

Dynamic component testing will be used to evaluate the proposed epoxy adhesive anchorages and to demonstrate that the capacity of the proposed epoxy anchorages was equal to or greater than the existing cast-in-place anchorage system. The capacity of the current cast-in-place anchorage has not been fully quantified with testing. Thus, one dynamic component test would be performed on the post using the current cast-in-place anchorage configuration. Additional dynamic component tests would also be performed on the proposed alternative epoxy adhesive anchorage systems. The target impact conditions for all tests would be identical. The tests would be configured so that the applied impact load would occur at a height on the post/rail in order to produce a bending moment in the post and combined loading on the anchorage system similar to that provided during vehicle crash events. The force versus deflection, energy dissipated versus deflection, and failure modes would be documented for each test and compared to one another. These comparisons would be used to verify that the proposed anchorages provided equal or greater capacity than the current

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

This project is supplemental funding provided by IaDOT to account for a revision in project scope and a need for additional funding in project Attachment of Combination Rails to Concrete Parapets Utilizing Epoxy Adhesive Anchors - Phase I.

As noted in the previous progress reports for Attachemnt of Combination Rails to Concrete Parapets Utilizing Epoxy Adhesive Anchors - Phase I, the testing of the original BR27C attachment and the three proposed epoxy anchorage configurations was analyzed, compared and sent to the sponsors. Force versus deflection curves from all four tests were compared. All of the alternative anchorages exceeded the capacity of the cast-in-place anchorage. Thus, all three of the alternatives should be acceptable.

MwRSF is completed the summary report for this research and submitted it to IaDOT for review. IaDOT was unable to complete the report review by the end of October 2015 to correspond with the revised project deadline. As such, a no-cost extension of the project was provided until November 30, 2015.

Additionally, the project funding was depleted and the additional funding requested in April was needed to complete the project. MwRSF received the supplemental funds as part of a second project, Attachment of Combination Rails to Concrete Parapets Utilizing Epoxy Adhesive Anchors - Phase IB.

The summary report was completed and the project was closed using the supplemental funds.

Anticipated work next quarter:

The project has closed.

Significant Results:

None.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

As noted previously, changes to the project scope have affected the budget of the original research to some degree. However, IaDOT agreed to the revised scope and budget changes.

IaDOT provided additional funds through a supplemental research effort, Attachment of Combination Rails to Concrete Parapets Utilizing Epoxy Adhesive Anchors - Phase IB, to address the revised scope and budget. A time extension was granted by IaDOT to extend the project close date to November 30, 2015.

Potential Implementation:

The development of alternative epoxy adhesive anchorage systems for use in IaDOT combination bridge rails would provide for simpler and more cost-effective construction of combination bridge rails. The new designs would also provide more effective options for new and retrofit construction.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska Department of Roads

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*		**Transportation Pooled Fund Program - Report Period:** ☑Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Adaptation of the SAFER Barrier for Roadside and Median Applications		
Name of Project Manager(s): Ron Faller, John Reid, & Jennifer Schmidt	**Phone Number:** 402-472-6864	**E-Mail** rfaller1@unl.edu
Lead Agency Project ID: 2611211036001	**Other Project ID (i.e., contract #):** DPU-TWD(94)	**Project Start Date:** 7/1/2009
Original Project End Date: 6/30/2011	**Current Project End Date:** 6/30/2016	**Number of Extensions:** 5

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$990,000.00	$890,409	90%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
$34,505(3.5%)	$34,505	90%

Project Description:

Concrete barriers have gained widespread application along our nation's highways and roadways, primarily as median barriers and bridge railings. Most of these barriers are largely maintenance free and can provide the capacity to contain high-energy truck impacts at much lower construction costs than metal barriers. However, accident data has shown that impacts with these barriers cause more fatalities than observed with flexible guardrails. Vehicular impacts into rigid concrete barriers often impart high decelerations to vehicles and their occupants. Thus, there is a need for an energy-absorbing roadside/median barrier that lowers vehicle decelerations but still has the capacity to contain high-energy truck impacts without significant increases in cost. The objectives of the research are to identify the most promising highway application for SAFER Barrier technology and adapt the barrier system to this highway application. The adapted barrier design must provide optimized energy management for highway vehicles, consider construction costs in comparison to existing barrier technologies, be more damage resistant, and require no to limited routine maintenance and repair. The research will be accomplished through the following tasks.

1. Identify target applications.
2. Analyze energy management and deformation of current SAFER barrier during high-speed impacts to guide selection of new highway barrier.
3. Brainstorm and develop concepts for the design of the new barrier and energy absorbers.
4. Evaluate the best concepts and energy absorbers with finite element analysis and static, dynamic, and durability tests.
5. Develop and simulate a preferred final design concept.
6. Construct barrier prototypes for full-scale crash tests and refine finite element simulations & designs as needed:
a. MASH TL-3 with 2270P vehicle; b. MASH TL-3 with 1100C vehicle; c. MASH TL-3 with either 2270P or 1100C vehicle if re-design is necessary; d. MASH TL-4 with 10000S vehicle; & e. retests as needed.
7. Prepare final report to document the research, development, testing, and evaluation effort.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Writing continued on a fifth report, which details the initial background and development of a future stiffness transition to a rigid concrete parapet.

A stiffness transition between the deformable barrier and a TL-4 rigid concrete parapet end or buttress was designed and simulated using LS-DYNA. The transition design was simulated at several impact points with the 1100C, 2270P, and 10000S vehicles.

A series of four component tests were conducted to evaluate the damage that occurs at the current concrete beam splice and three configurations where an elastomer padding is added at the splice, normal strength concrete is utilized, and a steel end cap is added at the ends of the concrete beams. The test results are still being processed, but some of the refinements reduced the concrete fracture and spalling that occurred at the concrete beam splices in full-scale crash testing.

Anticipated work next quarter:

The simulation results of the 1100C, 2270P, and 10000S vehicles impacting the prototype transition will be processed and documented. Additional analysis, design, and LS-DYNA computer simulation may be conducted if further design refinements are explored. Future design revisions to transition prototype are likely needed based on initial results. At this time, crash tests to evaluate potential barrier modifications/refinements are recommended in the future with additional project funding and include 1100C, 2270P, or 10000S vehicles.

The results of the four component tests will be processed and documented in a draft report.

Significant Results:

With the results of all three crash tests, the barrier satisfactory safety performance according to the MASH TL-4 evaluation criteria for longitudinal barriers. The reductions in lateral acceleration for the passenger vehicles met the desired levels. During both of the passenger vehicle impacts, more damage occurred to the barrier than desired, which included concrete spalling at the beam joints, gouging on the front faces of the beams, and two rubber posts were cut by the small car. Damage also occurred to the concrete beams and top metal rail during the impact with the single-unit truck, although some damage was permissible during the larger truck impacts.

Report TRP-03-318-15 documenting phase 4 of this project was published on November 3, 2015.
Report TRP-03-317-15 documenting phase 3 of this project was published on July 29, 2015.
Report TRP-03-280-13 documenting phase 2 of this project was published February 6, 2014.
Report TRP-03-281-13 documenting phase 1 of this project was published July 16, 2013.

Test no. SFH-3 was conducted on March 13, 2015 and was successful.
Test no. SFH-2 was conducted on August 11, 2014 and was successful.
Test no. SFH-1 was conducted on July 2, 2014 and was successful.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Throughout the project, several concerns regarding the use of rubber posts have arose and have been addressed. The barrier was redesigned multiple times in advance of the first crash test in order to obtain a more successful performance in a variety of environmental conditions, to optimize the concrete and steel rail, and to have greater confidence for a successful crash test result. Installation concerns were also addressed, which will allow the barrier to be installed in a larger range of conditions in the real world. Therefore, the start of the full-scale crash testing program was delayed. All required full-scale crash tests have been successfully completed on the length-of-need longitudinal barrier system. Additional design refinements are recommended to reduce damage to the barrier and maintenance costs. A transition from the length-of-need longitudinal barrier to a rigid concrete barrier is also desired before the system could be installed on roadways. Therefore, the project has received multiple extensions. The budget of the project has not been affected.

Potential Implementation:

Study findings on rubber material models under high-velocity impacts are available to future researchers to use in other investigative efforts. The rubber post, open concrete median barrier concept has demonstrated a significant reduction in lateral vehicle accelerations and occupant risk values for passenger vehicles, and the barrier also has demonstrated the ability to contain TL-4 single-unit truck impacts under MASH test conditions. The barrier demonstrated restorability during full-scale crash testing. However, some damage occurred in the impacts with passenger vehicles and the single-unit truck. Note that the damage should not affect the structural integrity of the barrier as the barrier should be reusable after impact events. With further design refinements, the barrier could have very low maintenance requirements for TL-4 impact events. It is anticipated that severe injuries and fatalities could be reduced with the RESTORE barrier installed in lieu of current rigid concrete median barriers along urban, high-speed roadways.

Midwest States Pooled Fund Program Consulting Quarterly Summary

Midwest Roadside Safety Facility

12-10-2015 to 04-30-2016

MGS transition on 2:1

Question
State: OH
Date: 12-21-2015

ODOT is upgrading existing guardrail to MGS on an Interstate route. For the attached location, the District would like to use long posts (7.5' -8') for posts 7-13 of the attached drawing and also for the transition at the trailing end of the structure. Previous research for Wisconsin addressed a retrofit option by placing additional posts behind the existing posts. I didn't see any guidance for new installations. Can an MGS transition be installed on a 2:1 with long posts? Are longer posts an option for posts 1-6 of the bridge transition?
Thanks!

Attachment: http://mwrsf-qa.unl.edu/attachments/ffd733cfe7fd5af1e64b2581e8e5691d.JPG

Attachment: http://mwrsf-qa.unl.edu/attachments/0a035519941ccd171fea2f4ccf9b3e12.JPG

Response
Date: 12-21-2015

I need to start this response by clarifying that evaluation of this transition placed on slopes has never been performed (testing or numerical analysis). The report you referred to on retrofitting transitions (TRP-03-266-12) was focused on two different transitions utilized by the the state of Wisconsin. Additionally, that project only focused on the downstream end of the transition. Evaluation of the w-to-thrie beam stiffness transition has never been performed on sloped terrain. Thus, a crashworthy transition system has never been developed for use on or adjacent to fill slopes. In order to ensure system crashworthiness, you would need to provide 2-ft of level grading behind the transition posts. Of course, it would be costly and labor intensive to add the required soil to the roadside. If you chose to install a transition without the required grading, the recommendations below are our best guess at what it would take to make the transition perform as intended. Please do not take these recommendations as a standard for new construction. Rather, these should only be utilized to improve existing systems without the possibility of significant grading work to the site.

Report TRP-03-266-12 provided guidance pertaining to additional posts to be driven behind existing 7-ft transition posts. These replacement posts were conservatively designed assuming the original posts would provide no additional resistance compared to the new post. Thus, the same "additional" posts would be recommended as replacement posts. As described in the report, the size and embedment depth of the replacement posts depends on the slope of the roadside. Steeper slopes will require larger posts. So, an 8.5-ft long W6x12 post was recommended for 3:1 slopes, while a 12-ft long W6x16 was recommended for 2:1 slopes. Please use this report to guide your selection of post for use as Post nos. 1-6 depending on the terrain slope on site.

The MGS has been successfully crash tested on 2:1 slopes with 6-ft, 8-ft, and 9-ft posts. Due to the lack of grading behind the posts, working widths and system deflection were increased due to the slope. However, increasing post lengths and embedment depths helped reduce the working width of the system back near values obtained for MGS on level terrain testing. Because transitions are sensitive to changes in lateral stiffness and can result in vehicle snag and pocketing when not designed properly, you want to install a post that best replicated the stiffness of a 6-ft W6x9 on level terrain. Therefore, we would recommend using the longer 9-ft posts to replace the standard 6-ft W6x9 posts in the transition region. This increased post length should be carried all the way through the transition region (post nos. 7-13 on your drawing set) and for the next 25 ft of MGS upstream of the w-to-thrie transition element.

Long Span Question

Question
State: WI
Date: 12-23-2015

Please review questions in the PDF. I have a region that does not like having water flow over the top of the box culvert. They are wondering if it is possible to do something like what I have attached.

What I have is a situation where there is a significant elevation difference between the shoulder by the beam guard long span and where the culvert headwall is located. The region staff wants to keep the headwall to prevent water from flowing over the head wall (I don't know why.).

The truck or car can only drop so much during an impact into a long span. For the sake of illustration, I'll pick an imaginary number of 2' of vehicle drop during a crash test. If the culverts headwall is 3' below the shoulder surface, the vehicle cannot interact with the headwall during an impact. It should be O.K. for the head wall to remain in place.

The question becomes, What is the truck or car's drop during an impact into a long-span. I pick the imaginary number of 2' out of a hat for the sake of illustration. But you smart people have the slow motion cameras, computer models, and other sorts of wizardry and probably could actually come up with a more accurate, scientific guess than I could.

Attachment: http://mwrsf-qa.unl.edu/attachments/5d6b008e826752b7be41b471c92b47dd.pdf

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Response
Date: 01-04-2016

If I understand correctly, you are wanting to install the long span at an offset from the head wall larger than what we tested, but with a slope and drop to the head wall behind it.

I don't see this as much of an issue as the long span was tested with a vertical drop off approximately 34" behind the face of the rail. I believe that we require the long span to have 24" behind the posts prior to a 2:1 slope. Assuming that you have continue that grading behind the unsupported span prior to the slope and head wall, I don't see this installation as more severe than what was tested. I believe that the slope to the head wall would only provide additional vertical support to the vehicle and improve stability.

If you plan to start the slope closer to the rail face we may need to discuss it further.

Response
Date: 01-05-2016

2' of grading behind the post is not a problem. But where the span is plan to be the 2:1 starts close to the back of rail.

Attachment: http://mwrsf-qa.unl.edu/attachments/62c828a478a7e0f5fd6cee01be5d938c.jpg

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Response
Date: 01-06-2016

I don't believe we can recommend the system as shown due to concerns with the drop of the slope relative to the rail position in the unsupported span.

In the long span testing, the posts were aligned with the back of the post flush with the face of the headwall. This placed the face of the guardrail in the unsupported span area approximately 34" in front of the headwall. Thus, during an impact in the unsupported span, the ground was supporting the wheels of the vehicle for approximately 3' prior to the vehicle dropping behind the headwall.

In the installation you have shown below, the slope begins directly behind the face of the guardrail. This would allow wheel drop much earlier than the tested system. Beginning of the wheel drop sooner may allow the vehicle to fall farther as it extends over the culvert which could compromise vehicle capture, vehicle stability, and cause issues with the vehicle climbing back over the headwall as the vehicle is redirected.

As such, we cannot recommend the installation shown below.

Break away work zone sign

Question
State: WI
Date: 01-04-2016

I have been asked to review a sign design. I believe that TTI tested the design to NCHRP 350. But they only ran the truck tests. They way I see the testing and what

TxDOT has in their drawings, I'm concerned about the sand bags and 4" on a 5ft chord issue.

I have indicated that the drawings may not meet the MASH requirements because they would likely need a small car test.

If you could review this it would help.

Thanks

Attachment: http://mwrsf-qa.unl.edu/attachments/ad6c23b5078c487bd177ee4a51832cd9.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/44a8785312784bba4977d52025c584b6.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/ab1ddf84b80b8c9b2438eb2ba56ffb7e.pdf

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Response
Date: 01-11-2016

The sign support from test 453360-3 is documented in TTI Report No. 5388-1F.

A temporary, skid-mounted temporary sign with a mounting height of 7 ft that was recently tested to MASH with a small car at the Texas A&M Transportation Institute had an unsuccessful performance due to excessive occupant impact velocity (test no. 467824-2 in report 0-6782-2). However, with some modifications to the breakaway features of the system, the system performed satisfactorily with the both the small car (test 467824-4) and pickup truck (test 467824-3). Also, additional guidelines were developed based on wind loads to design temporary sign systems to select sign supports based on the sign size desired.

This MASH testing indicated that the breakaway mechanism of sign supports is critical to a successful small car performance. As such, it unknown how the small car would interact with the particular sign support you are inquiring about and how that system would break away. An alternative would be to utilize the skid-mounted, temporary sign support evaluated to MASH safety performance criteria and the guidelines based on wind loads (TTI Report No. 0-6782-2).

Attachment: http://mwrsf-qa.unl.edu/attachments/d71876eeac78fc01c5a5eb69cb8cee78.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/e234f579d647b40851beea7211cc24c5.pdf

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Signs

Question
State: WI
Date: 01-04-2016

I have been asked to review some more signs for crashworthiness. Please review the attached signs and provide comments.

Attachment: http://mwrsf-qa.unl.edu/attachments/e9a7f75c02928bd050e1d4bcd099d680.jpg

Attachment: http://mwrsf-qa.unl.edu/attachments/ecbda2783a4c0a73e1348c72c7d3cc61.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/318cf1689cb46784778965403992e32f.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/d176bc23345d5c6f858e026a83a18953.jpg

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Response
Date: 01-11-2016

There are some design variations between the photos shown. It does not appear that there are breakaway holes or another breakaway mechanism in the posts in any of the designs. With a variety of signs and mounting heights, as well as multiple vertical wood posts and sometimes horizontal wood beams, it is unknown how the system will fracture and deform upon impact. Sign systems can be sensitive to minor design changes that may present a problem for windshield and occupant compartment deformation and penetration, depending on the how the system fractures upon impact. At this time, we would recommend crash testing to evaluate crashworthiness of this sign.

Portable Barrier and Rock Fall

Question
State: MN
Date: 01-05-2016

We have a temporary work zone situation, where the designer would like to use portable concrete barrier for a potential rock fall concern. Most of the rock fall (95%) will be contained within the ditch section, but 5% could make it to the traveled lane.

The designer understands the concern over pinning barrier on the opposite side of traffic. But feel that it will be placed far enough away from the 30 mph work zone traffic to be a concern.

This is an interesting question and would appreciated you guidance on how the barrier would react to the forces describe below.

Currently our rock fall analysis is finding that a maximum of 5000 ft/lbs of total kinetic energy (translational plus rotational) could impact the barrier at 90°, typically at the base of the barrier or as high as 1' above the base of the barrier. Would J-barrier, which is pinned on the side being impacted, be able to withhold that impact? If it was not pinned what would the deflection be?

Response
Date: 01-25-2016

I have briefly reviewed the inquiry regarding the rockfall concerns near roadways and the use of PCBs for debris containment. Below, it was noted that the impact energy for the design scenario would be approximately 5 kip-ft (6.8 kJ) when applied perpendicular to a portable concrete barrier (PCB) system. Initially, this kinetic energy seems to be rather low. However, I would like to give some perspective to a known quantity that is similar to the roadside safety community.

Let us for the moment consider the AASHTO MASH impact conditions for evaluating roadside barrier hardware. A Test Level 1 (TL-1) impact condition involving a small car would provide an impact severity of 14.0 kip-ft (18.9 kJ), which consists of a 2,425-lb sedan striking at 31.1 mph and 25 degrees. Normally, a TL-1 condition would also include a 5,000-lb pickup truck impact event as well, which is of course the strength test. Most PCB systems are tested and evaluated at a TL-3 condition, which includes a 62 mph (100 kph) impact speed at a 25-degree angle. PCBs are designed to meet the TL-3 impact condition, which provides an impact severity of 115 kip-ft (156 kJ) for the pickup truck with up to 80 in. of dynamic displacement.

It should be noted that the design condition of 5 kip-ft (6.8 kJ) is significantly lower than that provided by the lower of two impact scenarios for TL-1. The design condition would be somewhat represented by a 2,425-lb small car impact the PCBs at a speed of 18.6 mph (30 kph) and 25 degrees.

Based on this fundamental comparison and knowledge of PCB performance under impact events, I believe that existing PCB systems could contain the rockfall material under design conditions when un-pinned to a foundation. Further, dynamic deflections would be estimated as 3.5 in. for this design condition.

In addition, I also reviewed a research report that was conducted by the University of Akron for the Ohio DOT, titled Rockfall Concrete Barrier Evaluation and Design Criteria. Within this study, the OHIO DOT PCB system was evaluated. Researchers determined that the Ohio PCB system could contain rockfall material with a kinetic energy of 18.2 kip-ft (24.7 kJ) with observed sliding of approximately 12 to 15 in. Since the Ohio PCB is similar to that used by the MnDOT, this research confirms that a rockfall slide with material having 5 kip-ft of energy would be safely contained. For a reduced impact energy, deflections may be estimated as 3.3 to 4.1 in.

Using both methods, I can confidently state that the deflections should be less than 6 to 8 in. when un-pinned and connections pulled taught. Also, I do not see a need to pin the barriers to a foundation due to this low estimated deflection.

Please let me know if you have any questions or comments regarding the information contained above. Thanks!

MGS Long Span Deflections

Question
State: IA
Date: 01-05-2016

I'm working on a project where the designer would like to consider whether to use a long-span system (attached eba211.pdf) or connect to the culvert (attached eba210.pdf). There are a number of culvert locations containing a mixture of headwall heights and widths and the designer has inquired about the deflection distances for each of the long-span layouts. I've attached what I could find from recent research, as well as a thought on how we might find another, but I don't have any inclination as to what deflection distances should be used for the two post layout.

Please review and comment on what I could find and provide guidance on what I couldn't.

As always, thank you!

Attachment: http://mwrsf-qa.unl.edu/attachments/d5d6020093c77313c249f96d08097d9f.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/0c145a28afa0c2862c15c6c4f4f49788.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/f8a2aa8c66f6a8a855779a766cbad5a9.pdf

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Response
Date: 01-07-2016

We have not done any detailed analysis of intermediate working widths for the MGS system. However, we do have data points at the 25 ft unsupported span as you noted in your table and data points for the standard MGS system. It seems reasonable that our best path to estimating these working width values would be to linearly interpolate between the know values.

I have added a table below that does just that. For the MGS with standard post spacing, I have assumed a working width of 60.3 in. based on the highest working width value we have observed for an MGS system (this is test MGSDF-1 of the MGS with Douglas Fir posts). This should provide a conservative starting value and better represent the CRT posts used in the long span in terms of system stiffness and barrier deflections. I then used your suggested upper bound of 96 in. based on the results of test no. LSC-1. The results come out relatively nice in that the recommended working widths are essentially even foot values.

While this analysis is not substitute for testing, it should provide you with reasonable guidance given our best available information.

Thanks

Attachment: http://mwrsf-qa.unl.edu/attachments/41089e587c27ab9118e7d47a08c0d4ff.jpg

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Response
Date: 01-08-2016

Looks like a reasonable approach. Thank you.

As a follow-up question – in the TRP-03-187-07 report on page 101 where it mentions a 2" max height, why would this value be lower than the typical 4" height where we start to view an object as a hazard per Roadside Design Guide?

Response
Date: 01-09-2016

The 4" you mention below is a stub height requirement that is intended to prevent/reduce damage to the vehicle undercarriage and the underside of the occupant compartment if the vehicle drives over.

The 2" height for the headwall noted in the long span research is listed for a different reason. The is some concern that interaction of the impacting vehicle with headwalls taller than 2" may affect vehicle stability it is redirected. Previous research with curbs have found that 2" curbs affect vehicle motion significantly less than 4" or 6" curbs. Thus, we limited the headwall extension above grade to 2" or less to improve vehicle stability.

Hope that answers your question. Let me know if you need anything else.

Thrie-beam connection to twin steel tube bridge railing

Question
State: OH
Date: 01-06-2016

I believe you worked with our group on standard drawing MGS-3.1. From past e-mails, I see that she used Iowa's standard drawing as a template. I looked at the Iowa website, but didn't see a connection detail like the one shown below. This is the MGS thrie-beam connection to twin steel tube bridge railing. I received a call from a contractor asking if the washers (highlighted below) are necessary. Do you know if this connection detail was based on research from Midwest Pooled Fund or another state? I would normally assume that the washers are necessary, but this particular contractor does a large amount of work for us and his question makes me wonder whether I'm missing something.

Thanks,

http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/roadway/Standard%20Construct%20Drawings/MGS-3.1_7-18-2014.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/31c23aa168a137dc8cc1e93d7b318036.jpg

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Response
Date: 01-07-2016

This issue has come up in the past regarding the use of the washers underneath the end shoe and nested thrie beam attachment. We have been recommending that washers be used based on the size and length of the slots in the current thrie beam end shoe pieces. We have some concerns that the size of the slots in the end shoe might allow the nuts to pull through. TTI has been using washers as well based on similar concerns. I believe that they have been using rectangular washers, but I do not have the spec.

In our recent tests, we have been using 5/8" F844 washers on the backside of the end shoe. That has worked fine to date. These are more standard parts and are easier to obtain.

http://www.portlandbolt.com/products/washers/standard-flat/

Thanks

Attachment: http://mwrsf-qa.unl.edu/attachments/305ffe7ebae49c4a49642d43ea1fe963.jpg

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TRP-03-277-14

Question
State: WI
Date: 01-14-2016

Can I get the CADD for the hardware in TRP-03-277-14

The box that we are planning to attach to had some concrete surface issues. Is it possible to increase the embedment of the connection to account for concrete surface issues?

Response
Date: 01-22-2016
I have attached a ZIP file containing CADD file of the final system drawings.

If your culvert has concrete surface damage, increase the embedment depth of the anchor rods by the depth of the surface damage:

New EMB = Design EMB + Surface Damage Depth.

Attachment: http://mwrsf-qa.unl.edu/attachments/ba9431ed592a46c36f93ae644babf4ee.zip

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TRP-03-226-10

Question
State: WI
Date: 01-22-2016

We are interested in use the MGS bridge rail in TRP-03-226-10

Is it possible to install blocks between the post and rail to minimize the likelihood of a plow snagging the bolt on the deck?

My guess adding a block would likely improve performance. It would also get rid of the possibility of rail tearing on the steel post.

Response
Date: 01-25-2016
We have looked into this question previously. See below.

http://mwrsf-qa.unl.edu/view.php?id=760

I don't believe that the response has changed.

Thanks

Triple Blockouts

Question
State: OH
Date: 12-01-2015

We have a guardrail replacement project that is wrapping up on Interstate 70 in Columbus. Because of an inlet, the contractor has used triple 12" blockouts at several approach locations to a structure. The inlet is in poor condition and the project engineer is concerned that the structure is too weak to properly support the load of an impact. From past questions I see that a triple 8" blockout can be used under certain conditions. Is a triple 12" blockout ever an option? If so, can it be used at a transition section such as this? Could some combination of triple blockout and steel post attached to the inlet be used? Is the only option in this case to remove the old inlet and use steel posts attached to the top of the new inlet? Thanks!

Attachment: http://mwrsf-qa.unl.edu/attachments/cb4b50311442ec93e99e898dbcb36188.JPG

Attachment: http://mwrsf-qa.unl.edu/attachments/acd0ce95fff7f85ff91908655a94eceb.JPG

Attachment: http://mwrsf-qa.unl.edu/attachments/2134370d30a7a9f7d5859cff9cac2a9e.JPG

Attachment: http://mwrsf-qa.unl.edu/attachments/cd11ed3a2b8e7b5f549c8b978ca7078d.JPG

Attachment: http://mwrsf-qa.unl.edu/attachments/c5c6cc210086ce2a99b5771a37c00c48.JPG

Response

Date: 01-25-2016

In the past, we have recommended no more than one triple 8" blockout installation very 50' for guardrail installations. This is based on concerns that the ability of the triple blockout to transmit load to the post would be compromised for large deflections. With regards to transitions, we have used a similar rationale and have limited the installation of triple blockouts to a single post in the transition at limited locations. For your installation shown, we believe that the number of consecutive triple blockouts is likely too many.

The MGS utilizes 12-in.deep blocks for standard applications as well as for special applications. For example, the MGS long span design utilizes one 12-in. wood block with three CRT posts instead of two stacked 12-in. deep blocks. For the MGS, it would seem reasonable that the use of two 12-in. deep stacked blocks could be accommodated at a few locations as well, thus also resulting in a rail offset of 24 in. However, it is uncertain as to whether the use of two 12-in. deep blocks may be too excessive when used continuously with the MGS.

Thus, based on previous testing of systems with deep or extended blockouts and an analysis of the contact lengths of typical MGS testing, MwRSF would recommend the following:

1. Double standard blockouts or combinations of blockouts up to 16-in. deep may be used continuously in a guardrail system.
2. Triple standard blockouts or combinations of blockouts up to 24-in. deep should be limited to one in any 75 ft of guardrail.

There is currently a problem statement in the Year 27 Pooled Fund Program to address this issue specifically, "Additional Options for Post Conflicts within the Approach Guardrail Transition".

With respect to attachment to the top of the inlet, that would depend on the connection to the inlet and the relative stiffness of that post configuration. One would also need to be sure that the inlet attachment had sufficient structural capacity as the short, stiff post may overload the top of the inlet.

MGS Rail stiffness transition with Curb

Question
State: MO
Date: 01-26-2016

In the email below is a question on the amount of curb required along the transition area from a bridge end thru the thrie beam, transition section and into the MGS. Basically, our new bridge end design will likely have curb extended into the transition section area or just past that into the nested MGS. But as we read report TRP-03-291-14, the design has curbing that ends either before post 11 OR extends past the first section of MGS that has been double nested with W beam to between posts 4 and 5 (Fig 54, pg 74). The question comes, is there any way to have a curb from the bridge end that ends within the transition section or within the nested MGS section that has been found as acceptable? This only saves a few feet of curbing at each approach, but multiplied over and over at locations around the state, it adds up.

The recommendations on pages 135 and 136 include nesting the W-beam rail at the upstream end of the W-to-thrie transition AND carries the curb past that nested section into the normal MGS. If that is the option, we will go with it. But, if there is some other design option that allows curbing to end in the thrie-to-W beam transition area, please let us know where to look for recommendations and design guidance. If there is nothing, please confirm that the design in Figure 54 with curb extended into the normal MGS rail in report TRP-03-291-14 is current and the best practice for this transitional area with curb.

Thanks for the help with this question and for providing a written reply that we can share with other staff to assure we have considered the options with lesser curb. Please call or email with questions.

Through my research and understanding of the MGS guardrail system and transitions related to the system, I have ran across report TRP-03-291-14 "Dynamic Evaluation of MGS Stiffness Transition with Curb." This report details the testing of MGS rail and the stiffness transition to thrie-beam where a mountable curb exists. The report summary indicates the need for nesting of the first 12'-6" section of MGS rail when curb extends upstream of post No. 11 (beginning of the thrie-beam transition section to w beam). The report also goes on to indicate that if curb is present beyond post No. 11 then it should be extended to the end of the 12'-6" stiffness transition. This distance is stated to be approximately 37.5' from the vertical parapet connection (Bridge end).

My question for MwRSF is – is this still a valid issue? Has there been any additional developments related to stiffness transitions with curb that does not require extending the curb 37.5' from the bridge end. MoDOT has recently modified our designs for Bridge Approach Slabs and Concrete Approach pavements which will cause the curb to fall within this zone. If we can just double nest the first 12'-6" of w-beam MGS then keep our standard curb lengths that's great, but if we must extend that curb to the end of the double nested MGS section that is something I would like to see in writing from MwRSF. This will affect every major road we modify if this is the case.

Response
Date: 01-29-2016

The introduction or removal of roadway geometric features has shown to cause critical differences in safety performances for some barrier systems. Approach guardrail transitions (AGTs) in particular have been shown to fail crash tests after a curb is either introduced or removed from otherwise crashworthy systems, as demonstrated in the noted report (TRP-03-291-14) and in other AGT tests. In addition, the termination or transition between adjacent features can cause their own issues with system crashworthiness. Thus, to be conservative and avoid any potential snag and/or stability issues, we have recommended that the curb (or lack thereof) be consistent through the critical area of this MGS stiffness transition – specifically the area under and upstream of the W-to-thrie transition segment. That has produced the following recommendations:

- If you want to terminate the curb within the AGT system, we recommend doing so prior to the W-to-thrie transition element (or as you stated, before post 11 – from TRP-03-291-14 page 74).

- If the curb needs to be carried further than this location, we recommend carrying it past the entire AGT system. This extends another 18 ft – 9 in. to the upstream end of the nested W-beam rail (or the mid-span between post 6 and 7 from trp-03-291-14 page 74).

Terminating or transitioning within this 18.5-ft region of the AGT may be crashworthy, but we simply don't have the research or testing to confirm that.

MGS Long Span installed on 2:1 Slopes

Question
State: WI
Date: 01-26-2016

We are currently looking at options for installation of the MGS long span at the slop-break-point of a 2:1 slope.

What are your recommendations regarding this type of installation?

Response
Date: 01-26-2016

I looked through past guidance we have given regarding the MGS long span and its use adjacent to slopes.

In the past, we have fielded inquiries regarding the use of the long span at the slope break point. In those discussions, we have noted that the previous testing of the MGS with steel and wood posts suggests that there is potential to use the long span installed at the slope break point if 8 or 9 ft W6x8.5 steel posts are used or 7.5 ft SYP posts are used. Both of these options previously were evaluated to MASH and believed to be acceptable for use on 2:1 slopes. Similarly, we have recommended that the CRT posts used in the long span be extended to 7.5 ft long posts to ensure their proper breakaway function similar to the previously tested systems. All of this guidance assumed standard post spacing and assumed that the lateral offset between the back of the post and the culvert head wall and the height of the headwall relative to the unsupported span section was maintained. It should be noted that this guidance was provided using our best engineering judgment in the absence of full-scale crash testing, computer simulation, dynamic component testing, or combination thereof. If new information becomes available, MwRSF may deem it necessary to revise this guidance.

You had inquired about the potential to a half post spacing MGS long span system in a similar manner. Previous research at MwRSF has suggested that 7' long posts at half post spacing adjacent to a 2:1 slope should perform in a similar manner to the standard posts and spacing on level terrain. Thus, from a stiffness standpoint, the use of half post spacing seems reasonable. The issue with half post spacing comes from the CRT posts. In order to maintain similar stiffness and deflection of the system, we would likely need to extend the half post spacing to the CRT's. However, the use of energy dissipating CRT posts at half post spacing may affect the function of the long span. The extra CRT's may provide similar deflection, but they may also change the behavior of the CRT's in terms of preventing pocketing and how the CRT's affect the entry and exit of the vehicle with respect to the unsupported span. Without further study, it is difficult to assess how much of an affect the half post spacing of the CRT's may have. Thus, while there is potential for a half post spacing pf the MGS long span to work it would likely require further study.

Thanks

Response
Date: 03-29-2016

I was working with you about a long-span issue the region put together some drawings (see attached). I was wondering about the holes for the CRT posts. Are they located correctly? I'll probably need to call to explain.

Attachment: http://mwrsf-qa.unl.edu/attachments/31c0984173ee05a799316bc706bcd60c.pdf

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Response
Date: 03-31-2016

We don't have a definitive answer for you question regarding the holes in the CRT post. It is true that the lower hole in the CRT post is designed to fracture to post below grade for weaker soils. However, our previous discussion recommended increased post embedment to account for the reduced soil forces due to the slope. Thus, it is currently our best guidance to leave the holes in their standard location.

While it may be possible to optimize that hole location when used adjacent to slopes, determining that hole location would require further research.

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w-beam back-up plate

Question
State: WI
Date: 01-29-2016

In TRP-03-226-10 Development of a Low-Cost Energy-Absorbing Bridge Rail, the back up plate shown is 6" wide.

I believe that at a pooled fund meeting there was some discussion about the need to make the back up plate wider. What width should the back-up plate be?

Response
Date: 01-29-2016

You are correct that recent testing as part of the MGS installed in mow strips project led us to recommend revised backup plates for weak post MGS systems using the S3x5.7 post. The use of 12-in. (305-mm) long backup plates behind the rail was recommended. The partial rail tearing observed during test no. MGSMS-1 was caused when the test vehicle impacted a post and caused it to deflect downstream and twist such that its flange contacted the bottom of the rail directly below the downstream splice bolts. Then, as the vehicle's right-front bumper and fender loaded the splice, the tear propagated to span half of the rail height. If a long backup plate had been installed at this location, the tear may have never occurred.

The original MGS bridge rail utilized 6-in. (152-mm) long backup plates at every post, including splice locations since the splice bolts are 8 in. (203 mm) apart. Unfortunately, the design drawings for the full-scale test specified 12-in. (305-mm) backup plates (taken from the non-blocked MGS drawings) instead of the 6-in. (152 mm) backup plates, and these larger backup plates could not be installed over the splice bolts, which are 8½ in. (216 mm) apart, without additional holes in the plate. As such, backup plates were not installed at locations where posts coincided with rail splices. The lack of backup plate material may have contributed to the partial rail tearing in test no. MGSMS-1. However, the tearing would have likely still occurred had 6-in. (152-mm) backup plates been utilized, because the 6-in. (152-mm) backup plates do not extend below the splice bolts where the tear initiated. Similar rail tearing has been observed in other 2270P testing on S3x5.7 (S76x8.5) weak-post guardrail systems that utilized 5⅝-in (143-mm) backup plates at all post locations.

To prevent rail tearing due to post contact near rail splices, a longer backup should be utilized to protect the rail around all posts, especially at splice locations. Therefore, the utilization of a 12-in. (305-mm) long backup plate is recommended for the MGS weak-post guardrail systems, including the original MGS bridge rail and the weak-post guardrail attached to culverts.

Since 12-in. (305-mm) long backup plates are unable to be installed at guardrail splices, holes or slots need to be cut into the backup plate to allow the guardrail bolts to pass through the plate. The backup plates could utilize the same splice bolt slot pattern that is currently punched into the ends of every guardrail segment. Utilizing this design, the backup plate could be attached to the guardrail and assembled as a part of the splice. Alternatively, a backup plate could be configured to fit over the back of assembled guardrail splices at the time of mounting the rail to a post. Under these conditions, the slots would need to be enlarged to fit around the splice bolts and nuts. Both of these design options are shown in the attached figure and should be equally effective in reducing the risk of rail tearing.
Attachment: http://mwrsf-qa.unl.edu/attachments/c41092b4068e1c81e23d4cabf813c2ed.jpg

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Weak-post guardrail on culverts installation issues

Question
State: IL

Date: 01-29-2016

We are dealing with a few installation/compatibility issues with the weak-post guardrail attachment to culvert system described in TRP-03-277-14. Without compromising MASH compatibility with the system, and without introducing a stiffness transition between the MGS and the socketed weak post system:

1. How can the weak post socket system be modified to fit culvert installations where the thickness of the top slab plus the height of the headwall (T+H) is as little as 13 inches? Note the socket would extend past the top of the culvert in these installations.

2. If this is not feasible, how can the required T+H dimension be reduced, and by how much?

3. Our standards dictate that a 6" radius be used of the bottom edge of the top culvert slab on the upstream side of the culvert. How can the weak post socket system be adapted to our rounded top slab detail? For the as-designed T+H value of 17 inches? For some reduced T+H values as noted above.

4. For precast culverts, the headwall is often part of the band or collar joining the wings and barrel of the culvert. What concerns or constraints arise?

5. Are there constraints on how close bolt holes could be placed to the barrel/headwall horizontal joint when the headwall is part of the band or collar joining the wings and precast barrel.

Please see the attached file for details

Attachment: http://mwrsf-qa.unl.edu/attachments/211f47bd7ff2608164f89afbac6d26ef.docx

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Response
Date: 01-29-2016

Questions 1 &2:

This weak post attachment to culvert design was adapted from a bridge rail design that was previously developed here at MwRSF [reference report TRP-03-226-10]. In that design, the bridge deck was only 8" thick, so the socket extended past the bottom of the deck. To anchor the base of the socket, a steel angle was bolted to the inside face of the socket and to the bottom of the deck (see pages 162 – 164 of the report). I think utilizing this concept would work perfectly for culverts with short headwalls. ½" diameter bolts can be used to attach the socket baseplate to one side of the angle, while the 3/4" diameter anchor rods should be used to anchor into the bottom of the culvert slab. The anchor rods should be increased in size because they now transfer all the load in shear (as opposed to the base plate bearing directly to the culvert headwall. The angle should be at least 3" high (matches base plate), 6" wide (to extend under the culvert), 3/8" thick (to match original bridge rail angle), and 8" long (matches base plate). Also, the 3/4" anchor rods should remain 6" apart – same as the original base plate attachment. A gusset plat similar to the one utilized in the original bridge rail should be welded in the angle to prevent deformations. Note, the exact height and/or orientation of the angle would change based on the actual height of the headwall (the angle could be flipped around to open toward the culvert for headwall heights near or just exceeding the depth of the socket).

Question 3:

We have come up with 2 reasonable options to retrofit these curved edges at the bottom of the culvert slab. Simple sketches of these options are shown in the attached file.

Option 1 utilizes a bent plate with an inside radius of 6" to match the radius of the culvert edge. This bent plate could also be cut from a pipe with an inside radius of 6". The plate would contain two holes that would allow ¾" anchor rods to be inserted through the plate and into the curved face of the culvert, thus attaching the plate to the culvert. A gusset plate would need to be used to bridge the gap and attach the outside of the plate to the inside face of the socket. The gusset plate would be welded to both the socket and the plate.

Option 2 (preferred) utilizes the steel angle concept discussed above. The only difference would be that the steel angle would need to be wide enough to extend past the curved portion of the culvert and few inches into the flat section of the slab. The ¾" dimeter anchors should be utilized to attach the angle to the flat portion of the culvert slab. Note, the angle could also be fabricated from a bent plate to obtain the desired dimensions. The same ½" diameter bolts can be used to connect the angle to the socket base plate, and a gusset should be welded within the angle/bent plate as noted above. Dimensions and orientation of the angle/bent plate would be dependent upon the culvert dimensions.

Question 4:

I believe all dimensional concerns were discussed in the previous questions and answers, so I assume that the sockets have the space needed to be mounted on the headwalls. As you have stated, if no headwall is present, then another barrier option needs to be utilized. Additionally, you would want to avoid any rebar/bolts/rods/etc. critical to joining these components together. Thus, the holes for the epoxied anchor rods should be drilled with care as to not cut through any critical connection hardware.

Question 5:

Anchor bolts/rods do lose capacity when placed adjacent to the edge of a concrete member. However, none of the anchors should be loaded in shear in a direction toward a horizontal joint. Thus, there would be minimal effect. Anchors could be placed within a few inches of a joint – as long as the concrete isn't damaged/split/spalled when the holes are drilled.

Attachment: http://mwrsf-qa.unl.edu/attachments/0b432155d6ca6af7dfacd021af2c03fa.pdf

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Response

Date: 04-05-2016

We are working on updating Illinois Department of Transportation Highway Standards related to guardrail, and have a few questions to resolve in order to finalize the draft highway standards to forward to Design and Environment.

MGS Attached to Culverts

Q1: For the MGS attached to culverts (weak post), in Option 2, provided by Scott, (see attached "socket to culvert attachment sketchs.pdf") there is a leg of the bent angle that goes under the culvert top slab radius. Because the radius at the inlet end of the top slab can be about 6 inches, the leg of the angle into the culvert could be 10 inches or so. In the original design referenced by the MGS attached to a bridge deck, the corresponding leg of the angle was just 7 inches. The thickness of the original angle with a 7 inch leg was 3/8". For a 10 inch leg should the material be thicker?

Q2: What is the minimum bend radius we should use for this bent angle? The radius used here slightly affects the bottom plate gusset dimension. See the following related question.

Q3: Please review the attached weld type and dimension we've shown for the bottom plate gusset.

For questions 2 and 3, please see the "MGS attach culvert bottom bracket assembly.pdf" and "MGS attach culvert bottom bracket parts.pdf" attachments.

Q4. Please review the IDOT spec for "Chemical Adhesive" and the related materials testing procedures (attached "TestingChemicalAdhesives.pdf"), and advise us if this satisfies the intent and requirements of the adhesive used in testing the MGS attached to culverts. Our current list of approved materials ("chemicaladhesives.pdf") is also attached. We note that the AC 100+ Gold by Powers Fasteners is listed, but the AC 50 Silver, apparently a lower grade, is also listed. (Or we might refer this to our Bureau of Bridges and Structures, and/or to our Bureau of Materials, but we need to understand the "bond strength" definition and requirements.)

Note: We do need to look at threaded rod embedment, because IDOT culverts use 3500 psi concrete, while the MwRSF testing used 4000 psi pcc. Also, we need to investigate if any special spec is required for the overhead use of chemical adhesive.

SECTION 1027. CHEMICAL ADHESIVE

1027.01 Chemical Adhesive Resin System. The chemical adhesive resin system shall consist of a two part, fast-setting resin and filler/hardener. The system shall meet the requirements of the ITP for Chemical Adhesives and be on the Department's qualified product list.

Attachment: http://mwrsf-qa.unl.edu/attachments/6b0cf602b9d2bd19b5770e794b57d38d.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/243428957985c6e527af9e1cb2748cab.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/2502fa9b62de5f4a6a4f40debf80e8c2.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/05d09be50da796f4ce6be7e9b73f6346.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/a50a22b9988cb40e4e2550652f4ab9bb.pdf

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Response
Date: 04-05-2016

Q1: The thickness of the bottom angle can remain at 3/8". The compression force the socket transfers to the angle should be equivalent to the bridge rail system, so the same material thickness and cross section seems reasonable.

Q2: Typically, the minimum bend radius for a steel plate is considered to be equal to the plate thickness. 3/8" is getting pretty difficult to bend, so I understand if a fabricator wanted a larger radius. The gusset can handle a radius as large as ¾" without needing modifications, so I would place the maximum bending radius at ¾", or 2 times the plate thickness.

Another option would be to turn this bent plate into a welded assembly of two flat plates (eliminates the bend if you are having difficulty with it). A welded angle assembly should also work just fine.

Q3: The weld and gusset appear to have the same specifications and dimensions as the original bridge rail attachment. I see no issues here

Q4. The strength of an epoxied anchor can be calculated through procedures provided in ACI-138 (Appendix D in 2011 version, or Chapter 17 in 2014 version). Using the equations provided in these sections along with the anchor size and strength, concrete strength, embedment depth, and adhesive bond strength, you can calculate the tensile and shear strengths of a particular anchor. The strength of the epoxy will only be applicable anchors loaded in tension. The anchors on the under-side of the culvert slab (overhead installation) would be loaded in shear and therefore only critical for concrete breakout and steel failure. The top mounted socket designs for culvert attachment also load the headwall anchors in shear, so again the adhesive is not critical.

Only the epoxy anchored version of the side-mounted sockets (originally design concept D2 in report TRP-03-277-14) for culvert attachment are loaded directly in tension. So, if you are utilizing that particular attachment design, you should check your anchorage strength (embedment and bond strength) against those of the tested design.

Since your culverts were constructed with a 3500 psi concrete, you will want to utilize the noted ACI-318 sections to ensure that the embedment of the anchors will develop sufficient concrete breakout strength and concrete pry out strength (tension and shear loading) for all anchors.

Curb termination in MGS stiffness transition

Question
State: MO
Date: 01-29-2016

We have a question on the amount of curb required along the transition area from a bridge end thru the thrie beam, transition section and into the MGS. Basically, our new bridge end design will likely have curb extended into the transition section area or just past that into the nested MGS. But as we read report TRP-03-291-14, the design has curbing that ends either before post 11 OR extends past the first section of MGS that has been double nested with W beam to between posts 4 and 5 (Fig 54, pg 74). The question comes, is there any way to have a curb from the bridge end that ends within the transition section or within the nested MGS section that has been found as acceptable? This only saves a few feet of curbing at each approach, but multiplied over and over at locations around the state, it adds up.

The recommendations on pages 135 and 136 include nesting the W-beam rail at the upstream end of the W-to-thrie transition AND carries the curb past that nested section into the normal MGS. If that is the option, we will go with it. But, if there is some other design option that allows curbing to end in the thrie-to-W beam transition area, please let us know where to look for recommendations and design guidance. If there is nothing, please confirm that the design in Figure 54 with curb extended into the normal MGS rail in report TRP-03-291-14 is current and the best practice for this transitional area with curb.

Response
Date: 01-29-2016

The introduction or removal of roadway geometric features has shown to cause critical differences in safety performances for some barrier systems. Approach guardrail transitions (AGTs) in particular have been shown to fail crash tests after a curb is either introduced or removed from otherwise crashworthy systems, as demonstrated in the noted report (TRP-03-291-14) and in other AGT tests. In addition, the termination or transition between adjacent features can cause their own issues with system crashworthiness. Thus, to be conservative and avoid any potential snag and/or stability issues, we have recommended that the curb (or lack thereof) be consistent through the critical area of this MGS stiffness transition – specifically the area under and upstream of the W-to-thrie transition segment. That has produced the following recommendations:

1. If you want to terminate the curb within the AGT system, we recommend doing so prior to the W-to-thrie transition element (or as you stated, before post 11 – from TRP-03-291-14 page 74).

2. If the curb needs to be carried further than this location, we recommend carrying it past the entire AGT system. This extends another 18 ft – 9 in. to the upstream end of the nested W-beam rail (or the mid-span between post 6 and 7 from trp-03-291-14 page 74).

Terminating or transitioning within this 18.5-ft region of the AGT may be crashworthy, but we simply don't have the research or testing to confirm that.

Weak post culvert mount

Question
State: WI
Date: 02-03-2016

Attachment: http://mwrsf-qa.unl.edu/attachments/26acd91bf9c4443074ece153eb77ce77.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/95371badd78b1ff4a1746d91c4578e1d.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/a876ccd14d537f20609c33463363ad5d.pdf

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Response
Date: 02-12-2016
I reviewed the details you provided.

The modification to the post to prevent the post from dropping through the socket during installation should pose not performance issues.

In terms of how to address limited post deflection area for strong posts adjacent to the culvert mounted rail, we would recommend that you extend the use of S3x5.7 posts at half post spacing past the end of the culvert. The S3x5.7 posts will not be affected by lack of soil displacement as they typically yield at groundline. You could use soil plates or post with extended embedment to ensure sufficient resistance of the post-soil forces to yield the post.

TL-2 minimum installation length

Question
State: IA
Date: 02-25-2016

We are working on putting together standard drawings for our lower speed (45mph or under) as well as our lower volume (400 vpd or under) roadways. Doing so potentially involves aspects of both TTI and MwRSF research, so I'd like to address this as a shared conversation.

For the bridge connection, we would like to go with TTI's MASH 31" TL-2 transition (Report 9-1002-8).

For the tangent w-beam section, we would like to go with MwRSF's nested w-beam recommendation (borrowed from their TL-3 test 03-291-14) to cover all cases regardless if there is a curb or not, as we would rather nest when it wasn't needed than not nest when it was.

For the end terminal, we are looking at the MASH TL-2 Softstop (38'-3.5" long) as well as NCHRP 350 TL-2 ET-Plus and SKT (25') options.

My questions to both research groups are: What is the minimum length needed for a TL-2 system to function when attached to a bridge? What would it be if it was a free standing installation, say protecting a point hazard?

My question to MwRSF research group is: Does a TL-2 situation pose the same rupture risk with a curb under the transition/w-beam connection?

Potential installations would then be the following:
1. Assuming curb is not present at all, ends before transition/w-beam connection, or does not pose rupture risk:
a. System length of approximately 35' (10' transition + X' of w-beam to meet minimum length + 25' terminal)
b. System length of approximately 48' (10' transition + X' of w-beam to meet minimum length + 38' terminal)
2. Assuming curb is under transition/w-beam connection and does pose a risk:
a. System length of approximately 48' (10' transition + 12.5' nested w-beam + X' of w-beam to meet minimum length + 25' terminal)
b. System length of approximately 60' (10' transition + 12.5' nested w-beam + X' of w-beam to meet minimum length + 38' terminal)

Please let me know if you have any questions. Thank you for your assistance.

Response
Date: 02-26-2016

You have several good questions below. I will try to give you my best response based on our current knowledge.

1. Your first question seems to be what is the minimum system length for a the TL-2 approach guardrail transition system. For the TL-3 system, we made several recommendations related to the upstream system length based on our testing and interaction with terminals for both the transition with and without the curb. The placement of the upstream end anchorage too close to the stiffness transition may negatively affect system performance, thus potentially resulting in excessive barrier deflections, vehicle pocketing, wheel snagging on posts, vehicle-to barrier override, or other vehicle instabilities. For the transition without the curb, we recommended:

A recommended minimum length of 12 ft – 6 in. for standard MGS is to be installed between the upstream end of the asymmetrical W-beam to thrie beam transition section and the interior end of an acceptable TL-3 guardrail end terminal.

Or

A recommended minimum barrier length of 46 ft – 10½ in. is to be installed beyond the upstream end of the asymmetrical W-beam to thrie beam transition section, which includes standard MGS, a crashworthy guardrail end terminal, and an acceptable anchorage system.

For the transition without the curb, we made similar recommendations:

The length of W-beam guardrail installed upstream of the nested W-beam section is recommended to be greater than or equal to the total system length of an acceptable TL-3 guardrail end terminal. Thus, the guardrail terminal's interior end (identified by stoke length) should not intrude into the nested W-beam section of the modified MGS stiffness transition.

A recommended minimum barrier length of 34 ft – 4½ in. is to be installed beyond the upstream end of the nested W-beam section, which includes standard MGS, a crashworthy guardrail end terminal, and an acceptable anchorage system.

With respect to the TL-2 transition tested by TTI, the system used the same 46 ft – 10½ in. length upstream of the asymmetrical W-beam to thrie beam transition section. Thus, while the overall system length was shorter due to the simplified transition section, the amount of guardrail upstream of the asymmetrical W-beam to thrie beam transition section and the corresponding distance to the upstream anchor was identical.

While we would expect that anchor loads are lower for the TL-2 system, we do not have data that confirms the anchor loads and the effect of a shorter system length at this time. Thus, we cannot shorten these length recommendations at this time. It seems reasonable that one could reduce the distance between the asymmetrical W-beam to thrie beam transition section and the end anchorage by 6 ft – 3 in. or 12 ft – 6 in. and still have acceptable system performance. However, that cannot be verified without further analysis and/or testing.

2. Your second question is what is the minimum system length for a standard TL-2 MGS system. We have conducted previous research into minimum system lengths for the MGS under TL-3 (http://mwrsf.unl.edu/researchhub/files/Report281/MGSLENGTH_R8.pdf). In that study we successfully evaluated a 75' long MGS system. Although the 75-ft MGS performed successfully, several factors, including Lateral Extent of the Area of Concern and the Guardrail Runout Length, must be considered when determining the overall barrier length for shielding a roadside hazard. Only a few roadside hazards can be properly shielded by short guardrail installations. Thus, longer guardrail installations are still required for shielding many hazards.

BARRIER VII simulations were conducted to investigate system lengths of 62 ft – 6 in. and 50 ft. The 62-ft 6-in. model showed promising results with rail forces, barrier deflections, vehicle behavior, cable anchor forces, and anchor displacements similar to those observed in the validated 75-ft MGS model. Thus, a 62-ft 6-in. MGS showed potential for successfully meeting MASH TL-3 standards. BARRIER VII simulations of the 50-ft system produced erratic results and model instabilities once the vehicle contacted end anchorage posts. It was concluded that the simplified BARRIER VII models of the end anchorages were limited in their ability to accurately simulate BCT posts during vehicle contact.

The 50-ft MGS was further investigated with LS-DYNA simulations. The LS-DYNA simulations provided more realistic wood post fracture behavior and insight into vehicle roll and pitch tendencies. The simulations showed successful redirection of the 2270P vehicle for impacts between post nos. 3 and 4, while the system gated for impacts at post nos. 5 through 8. The 62-ft 6-in. and 50-ft models both exhibited the potential for successfully redirecting an errant vehicle at the MASH TL-3 test conditions. However, these reduced-length systems would have a narrow window for redirecting vehicles and would only be able to shield limited size hazards. Due to limitations associated with the computer simulations, full-scale crash testing is recommended before these shorter systems are installed.

The scope of the research did not include evaluation of the performance of end terminals on a reduced-length guardrail system. Further study may be needed to evaluate reduced system length in conjunction with guardrail end terminals in redirective impacts as well as end-on terminal impacts. Guardrail end terminals may have different post sections and/or anchorage than what was utilized in test no. MGSMIN-1. Thus, shorter guardrail lengths may not have the same redirection envelope found in this study. Additionally, for compression based terminals, the system post must develop the compressive forces required for the terminal to function. Very short systems may not provide sufficient resistance to the rail forces in end-on impacts.

Thus, our current recommendation for TL-2 MGS lengths would still be the 75 ft length until further research can be conducted.

3. Your third question was whether a TL-2 situation pose the same rupture risk with a curb under the transition/w-beam connection. We believe that the rail rupture potential would still exist if a curb was used with the transition. During the testing of the MGS transition system with a curb to TL-3, the rail rupture appeared to occur due to a

combination of to heavy upward and lateral forces on the lower region of the guardrail in advance of the splice between the W-beam and asymmetrical transition segments. While a TL-2 impact would result in lower lateral guardrail forces, there is concern that the upward forces produced by the vehicle wedging between the curb and the W-beam could be very similar in a TL-2 impact. In fact, if you look at the TL-2 transition test conducted at TTI, it appears that the 1100C vehicle did extend underneath the W-beam and lift up on the rail, and similar behavior would thus be expected when the curb was present.

As a side note, we have had several states that have simply incorporated the nested rail in the transition when the curb is present or not as you noted above. This, may be prudent as a means to ensure the transition always is within the tested limits.

Thus, from your email and based on the comments above, I would get the following installation lengths (shown in red). I should note that here and in the discussion above we are referring to maximum of the tested end terminal stroke lengths or the paid system length quoted by the manufacturer. We are concerned with interaction of the terminal with the transition and paid lengths may be shorter than the actual head travel. Thus, the lengths below are assuming the 25 ft and 38 ft terminal lengths you mention reflect the maximum of the head travel or terminal length. Thus, the lengths may change slightly based on the terminal lengths. Again, there may be potential to shorten these somewhat as noted above, but these values are based on our current guidance.

Potential installations would then be the following:

1. Assuming curb is not present at all, ends before transition/w-beam connection, or does not pose rupture risk:
    a. System length of approximately 35' (10' transition + X' of w-beam to meet minimum length + 25' terminal)
        i. For a 25' terminal length (8.67 ft from end of bridge to end of W-thrie section + 46.875 ft including 25 ft terminal = 55.545 ft)

b. System length of approximately 48' (10' transition + X' of w-beam to meet minimum length + 38' terminal)

    i. For a 38' terminal length (8.67 ft from end of bridge to end of W-thrie section + 12.5 ft of standard MGS + 38 ft terminal = 59.17 ft)

2. Assuming curb is under transition/w-beam connection and does pose a risk:

    a. System length of approximately 48' (10' transition + 12.5' nested w-beam + X' of w-beam to meet minimum length + 25' terminal)

        i. For a 25' terminal length (8.67 ft from end of bridge to end of W-thrie section + 46.875 ft including 25 ft terminal = 55.545 ft)

    b. System length of approximately 60' (10' transition + 12.5' nested w-beam + X' of w-beam to meet minimum length + 38' terminal)

        i. For a 38' terminal length (8.67 ft from end of bridge to end of W-thrie section + 12.5 ft of nested MGS + 38 ft terminal = 59.17 ft)

Lance, if you have further thoughts on this, feel free to chime in. We are being conservative based on lack of more knowledge on minimum length systems, and you may have arguments for revising what I have here.

Response
Date: 02-27-2016

In case I forgot to send it along, thank you for that response.

Attached are three of our initial markups based on that information.

1. els-tl2-250 will detail a situation where we are protecting a point hazard with minimal to no concern regarding a secondary hazard.

2. eba-tl2-250 will detail a situation where there is concern for a secondary hazard.

3. eba-tl2 transition will detail the Barrier Transition Section shown in both layouts. This includes the short thrie-beam, asymmetrical section, and nested w-beam.

My question today is related to eba-tl2-250. In report TRP-03-291-14 (page 137 – statement 3) it mentions that when a TL-3 installation is flared, there needs to be an additional 12.5' section of single w-beam added upstream of the nested w-beam before the flare (as stated in our current BA-250 circle note 5). What I'm wondering is whether or not that remains true for our TL-2 situations.

Attachment: http://mwrsf-qa.unl.edu/attachments/f60dfb82ddfb97f24eafa67e2681f63e.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/79b9f9895976d2ad8034c90181709e63.pdf

Attachment: http://mwrsf-qa.unl.edu/attachments/9420f303d45d7ac0efbd055a8c35012a.pdf

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Response
Date: 02-28-2016

We would recommend keeping that 12.5' tangent section upstream of the nested section for TL-2. The two concerns are:

1. Having a flared section directly adjacent to a stiffened region of the barrier may increase pocketing, rail loading, and vehicle instability.

2. We are somewhat concerned that small cars impacting in the flared region upstream of the transition could extend further under the stiffened transition. This may cause increased underride, vehicle snag on posts, increased vehicle decelerations, and increased rail loads.

While we would agree that this potential should be reduced for TL-2, without further analysis or testing, we want to take a more conservative approach.

Thanks

MGS Weak Post Questions

Question
State: WI
Date: 03-01-2016

We would like to add small anti-drop plates to the MGS weak post bridge rail system to prevent the posts from falling through the sockets during installation.

Is what I am showing acceptable for the welding that anti-drop plates to the s3x5.7

Attachment: http://mwrsf-qa.unl.edu/attachments/3182e65e0d790ab3706489211f2128b8.jpg

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Response
Date: 03-02-2016

I think the welding you have listed is fine. I did not realize that you had plates on the front and back side of the S3x5.7. Welding plates to both sides effectively makes the base of the post a tube. This may potentially stiffen the base of the post and change the location that the post yields at.

Do you have any issues with just welding one plate across the back flange? See Below. This would keep things out of the way and still support the post while limiting the effect on the post behavior.
Attachment: http://mwrsf-qa.unl.edu/attachments/7e3cdcd1c98f295e1abcebd7fe29af1c.jpg

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Response
Date: 03-03-2016

More questions for the side mounted assembly. See attached.

Attachment: http://mwrsf-qa.unl.edu/attachments/0a9018e6b6b3113fd3d1dc0a432372da.pdf

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Response
Date: 03-04-2016

Answers to your questions.

1. In terms of minimum headwall thickness for bolting through, there is no minimum thickness. Instead, we would recommend that the headwall have equal or greater capacity to the design we evaluated. We selected a headwall that was on the lower end of headwall strengths.

2. In terms of clear cover for the end of the rod, the main concern would be blowout of the back side. The effect of end cover on epoxy would be minimal. We would recommend that the embedment depth is met. If you were referring to the clear cover of to the top of the headwall, that would be defined by the geometry of the headwall and the attachment bracket and should not change.

3. In terms of the post length and embedment, we would recommend that a post without a soil plate as shown have a minimum of 42" of embedment. We have used this embedment in the cable median barrier work and it has proven to develop proper soil resistance without the soil plate. If you use the soil plate version of the post, the post can be 36" long I believe.

4. In terms of distance from a slope, we recently did testing of S3x5.7 posts with the soil plate adjacent to steep slopes for NDOR. In that work, it was found that offsets as low as 1' were acceptable, but a 6" offset resulted in blowout of the post through the slope. Thus, we would recommend a minimum offset of 1'. We also believe that the 1' offset would be acceptable with the 42" embedded post without the soil plate.

5. For the post installed 4" from the wingwall, the wingwall will provide additional resistance and help develop the forces to yield the post. As the posts in the weak post MGS system are intended to yield at groundline with minimal rotation in the soil, this should not be an issue.

Thanks

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bridge rai on a timber bridge

Question
State: WI

Date: 03-01-2016

We have road project going past an existing timber bridge.

1. Has MwRSF see a bridge rail like this crash tested?

2. Project staff are asking if they should nest the beam guard on the bridge.

Attachment: http://mwrsf-qa.unl.edu/attachments/24301b56d685dac0d1421d95f2bce130.docx

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Response
Date: 03-03-2016
We have observed similar post and beam bridge rails in use in the past, but we do not have knowledge of them being crash tested to any recent standard.

Nesting the beam would be a positive step in terms of reducing the potential for rail rupture. However, it may not guarantee the crashworthiness of the barrier system.

New Bridge / 2" overlay the following year

Question
State: NE
Date: 03-07-2016

Do you have a good solution for a new Bridge w/ 2" overlay the following year

A: Could we build the bridge approach section at 34" the first year?

or

B: Could we place a steel plate with a 2" offset below the bolts into the bridge where the 5 bolt pattern is.

then remove the following year when the overlay is placed

Response
Date: 03-08-2016

On new construction, it would seem reasonable that one could install a concrete buttress with two different anchor patterns for the five end shoe bolts or studs, which allow for a 2" height adjustment. Some consideration could be given toward mitigating vehicle engine hood/quarter panel snag on the end of the new buttress after the approach thrie beam is lowered by 2" after one year of service. As such, there could be a downward slope or taper to reduce snag on the concrete corner. I like this option more than option A.

There also could be an option where a steel plate is used to make the switch, similar to the options discussed last winter.

Transition between G4(1S) and MGS.

Question
State: MI
Date: 03-11-2016

Per our phone conversation earlier today, I've attached a file containing MDOT's proposed MGS details. If you refer to sheet 10, I've highlighted our proposed details for transitioning from MGS guardrail to conventional (28" tall) strong-post, w-beam guardrail and thrie-beam guardrail, respectively. We would like to introduce a single

3'-1.5" post spacing in order to transition from the splice being located between posts (MGS style) to the splice being located at post locations (conventional guardrail style). By using a single 3'-1.5" post spacing, we can use standard 13'-6.5" long beam elements throughout the entire transition. We are trying to avoid the use of w-beam elements that do not have a standard length (13'-6.5") for ease of maintenance.

Do you foresee any issues with these details, or do you have any comments or suggestions concerning these details?
Attachment: http://mwrsf-qa.unl.edu/attachments/8203ce243d3cc31f446e822f8797388b.pdf

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Response
Date: 03-29-2016

Ron asked me to look at you details and provide some guidance regarding the transitioning from the older G4 type W-beam systems to the 31" tall MGS and dealing with the movement of the splice location. Your plans current show a height transition of the W-beam from the old G4 barrier height to the MGS height over 25'. We have previously recommended that this transition occur over a distance between 25'-50'. Thus, you plan looks acceptable there. We have more concern with the use of the additional post when relocating the splice to the midspan. Adding the post directly downstream of the splice location will tend to increase barrier stiffness and rail loads near the splice location. In previous testing, this has been shown to create a potential for rail rupture. Thus, this would not be our first choice in this area.

We believe that there are two options for transitioning the splice that may work better.

1. As you noted, there is the option to use a non-standard rail section. This would work well, but as you noted can be undesirable in terms of inventory and maintenance.
2. A better solution may be to proceed with the posts at the splices for one full 12.5' rail section at 31" height. Then rather than add an extra post, we would recommend omitting the post at the next splice to make a 9.375' long span between posts. This should place the posts in the correct spacing for the midspan splices used in the MGS.

We believe this can be done because we recently conducted a successful MASH TL-3 test on the MGS with a single omitted post which created a 12.5' long span between posts. This would suggest that using a 9.375' long span to get the correct post alignment for the MGS should not be an issue. However, as noted previously, we would recommend not omitting the post until a full 12.5' of 31" tall barrier is in place. See the sketch below.

Please let me know if you have any questions about this. We can provide more thoughts if needed.

Attachment: http://mwrsf-qa.unl.edu/attachments/a34293ed02c903241 1dfe885dbca3f5b.jpg

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Response
Date: 03-30-2016

Thanks for looking into this and replying to my request. I agree that your suggested approach of omitting a post and creating a 9.375' long clear span is advantageous, and MDOT will definitely look into this option.

Has your group prepared a report for the MASH TL-3 test where a post was omitted resulting in a 12.5' long clear span? If so, could you share that report? Did your group use 12" or 8" offset blocks when you conducted the test? If your group used 12" offset blocks in your recent test, do you believe the same treatment could be applied to MGS with 8" offset blocks without jeopardizing the crashworthiness of the system?

Response
Date: 03-31-2016

We have not quite completed the omitted post report at this time. I can send you a link to the document when it is complete. As a side note, all of our research reports are currently archived online at the link below. You can always look there for any of our completed research.

http://mwrsf.unl.edu/researchhub.php

As for you question regarding the use of 8" blockouts, we did evaluate the system with 12" blockouts as we feel that they improve vehicle capture and stability. That said, we do not believe that the use of 8" blockouts would degrade the performance of the omitted post system sufficiently to jeopardize the crashworthiness of the system.

31" Guide Rail Curb Offsets

Question
State: NJ
Date: 04-04-2016

What criteria do you have on the 31" MGS placement behind curb? This is what I have so far:

NCHRP TL-3 used 6" Type B Curb (type of vertical curb) which passed 6" behind curb for 31" height measured from gutter line. The designer can use the lay down curb as shown in the Roadside Design Guide Figure 5-35(b) (see Section 5.6.2.1.2 2nd paragraph) in lieu of the 6" AASHTO Type B curb.

TRP-03-221-09 concluded for MASH TL-3 that an 8' offset is not acceptable.

TRP-03-237-10 concluded that for MASH TL-2 that 4' to 12' max is acceptable.

Can we use the sloping curb offsets shown in the 2011 Roadside Design Guide, Section 5.6.2.1.1 which is:

· Design speed less than 45 MPH: Set flush or at least 8 feet behind the face of curb. Use 6" high or shorter sloping-faced curbs.

· Design Speed 45 to 50 MPH: Set flush or at least 13 feet behind the gutter. Use 4" high or shorter sloping curbs.

· Design Speed greater than 50 MPH: Set flush with gutter. Design speeds above 50 MPH, use 4" or shorter sloping face curb. For design speeds above 60 MPH, the sloping face should be 3:1 or flatter and no taller than 4" high.

Response
Date: 04-07-2016

I have added some comments below regarding curbs.

What criteria do you have on the 31" MGS placement behind curb? This is what I have so far:

NCHRP TL-3 used 6" Type B Curb (type of vertical curb) which passed 6" behind curb for 31" height measured from gutter line. The designer can use the lay down curb as shown in the Roadside Design Guide Figure 5-35(b) (see Section 5.6.2.1.2 2nd paragraph) in lieu of the 6" AASHTO Type B curb.

This is correct, and we believe that less severe curbs such as the one sloped curb you note would be acceptable to NCHRP Report 350 as well. The MGS with curb in this configuration has not been evaluated to MASH TL-3 at this time. There is a proposal in the Year 27 Pooled Fund to evaluate this to MASH.

TRP-03-221-09 concluded for MASH TL-3 that an 8' offset is **not** acceptable.

True. We did test this as we believed it was a critical configuration, and found that the 2270P vehicle became unstable and rolled.

TRP-03-237-10 concluded that for MASH TL-2 that 4' to 12' max is acceptable.

We did do additional analysis for larger curb offsets at TL-2 and had a single test of a MGS offset 6 ft from the curb that was successful. I should note that the 6 ft offset test used a MGS installed with a height of 37 in. from the gutter line. Based on this test and our LS-DYNA work, it was concluded that the 37 in. high MGS was acceptable for curb offsets between 4'-12'.

Can we use the sloping curb offsets shown in the 2011 Roadside Design Guide, Section 5.6.2.1.1 which is:

This guidance is based on slightly older research and pertains to the G4(1S) guardrail system and mounting heights. We would expect the MGS to perform as well or better than the G4(1S) systems in almost all circumstances. Thus, the RDG guidance is likely acceptable for the MGS unless we have the previous research noted above to alter it.

Note that none of the RDG guidance appears to consider alteration of the rail height relative to the gutter as we did in our previous studies.

- Design speed less than 45 MPH: Set flush or at least 8 feet behind the face of curb. Use 6" high or shorter sloping-faced curbs.

- Design Speed 45 to 50 MPH: Set flush or at least 13 feet behind the gutter. Use 4" high or shorter sloping curbs.

- Design Speed greater than 50 MPH: Set flush with gutter. Design speeds above 50 MPH, use 4" or shorter sloping face curb. For design speeds above 60 MPH, the sloping face should be 3:1 or flatter and no taller than 4" high.

BCT for MGS Long Span

Question
State: IL
Date: 04-05-2016

For long-span guardrail would it
be acceptable to use steel tubes and CRT drop-in wood posts rather than the full length wood CRT posts? What would be a minimum length of the steel tubes?

Our Highway Standard 631011 uses
steel tubes and posts, adapted to anchor the w-beam. (Attached "218-631011-09 TrafBarTermType2.pdf)

Attachment: http://mwrsf-qa.unl.edu/attachments/aa12632cee9ad968a195d03e8399ba90.pdf

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Response
Date: 04-05-2016

CRT posts have two weakening holes in them, one at ground line and one 16" below ground line. Thus, CRT can break at two different locations – and did so at various post locations during the evaluation of the MGS Long Span system. Placing them in steel foundation tubes would prevent fracture at the bottom hole and may change the performance of the system.

BCT end terminal posts are typically placed in steel foundation tubes. However, BCTs have a slightly different cross section and only one weakening hole. We do not recommend utilizing BCTs in place of CRTs for the Long Span system.

Use of flared, non-blocked, MGS

Question
State: IL
Date: 04-05-2016

Is it acceptable to flare the
non-blocked MGS? If so, do we use the same guidance as for the MGS with blockouts? I don't find any mention of this in the report or in the consulting questions.

Response
Date: 04-05-2016

MwRSF has never evaluated a flared, non-blocked, MGS installation. Both the flared MGS and non-blocked MGS illustrated significant increases in vehicle snag, rail loading, and vehicle instability when evaluated as independent systems. If the two were combined into a single system, these negative characteristics may further increase to unsatisfactory levels. So, without further evaluation, we do not currently recommend installing a flared, non-blocked, MGS.

Departing End Structure for MGS with Curb

Question
State: IL
Date: 04-05-2016

IDOT uses a guardrail attachment
to the downstream end of a structure on a one-way road that attaches the w-beam
to 1 inch diameter by ~2 ft anchor bolts cast into the concrete
structure. Is it acceptable to use a curb with this guardrail near and up
to the structure? (See attached Highway Standard "218-631026-06
TrafBarTermType5.pdf").

Attachment: http://mwrsf-qa.unl.edu/attachments/a7fdd9c6d0136ff81d20e449853744e8.pdf

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Response
Date: 04-05-2016

To my knowledge, guardrail anchorages such as this have never been crash tested. As such, I will comment on the system assuming that the upstream anchorage is crashworthy and wouldn't negatively affect the guardrail system.

The MGS placed 6" behind a 6" tall curb was successfully evaluated to NCHRP 350 standards – see report TRP-03-139-04. Assuming your upstream anchorage doesn't affect the performance of the guardrail system, then the behavior of the MGS with curb should also be crashworthy to NCHRP 350 standards.

One side note here – recent testing with MASH small cars has raised concerns about possible rail tearing when small vehicles impact a curbed MGS installation (the NCHRP 350 evaluation did not include a small car). This issue has been brought to the Pooled Fund Sponsors' attention, and a MASH evaluation (including the small car) is currently a potential project for the 2016 Pooled Fund Program. Thus, we may learn more about the crashworthiness of the MGS with curbs in the near future. Until then, I can only say that the MGS with curbs has been NCHRP 350 approved.

MASH 2016 Bridge Rail Loads

Question
State: IL
Date: 04-06-2016

I appreciated the opportunity to discuss this subject with you yesterday by phone. Illinois is still attempting to understand all of the issues involved with MASH 2016 so we can meet the deadlines and make some informative decisions moving forward with a standard barrier shape. Currently we use both a 34" and a 42" F Shape barrier and the reinforcement we use is designed per Chapter 13 Appendix of the AASHTO LRFD Bridge Design Specifications. We know that any barriers under MASH 2016 need to be a minimum of 36" tall plus any additional future wearing thickness. In Illinois this means we would need a minimum 39" tall barrier. We were considering just using our 42" F Shape barrier for possibly the MASH 2016 TL-4 load but it would likely require a crash test to assure that it could handle the 57% increase in impact severity. You also brought to my attention that while the TL-5 impact severity did not increase from NCHRP 350 to MASH 2016, it is anticipated that the 124 k and other design values for TL-5 will increase significantly because these design values were apparently calibrated way to low.

Ideally AASHTO will publish a revised load chart soon to replace the current chart shown below with MASH 2016 loads. The 2015 FALL presentation showed the 2nd chart below but there aren't any values for the other Test Levels as there currently is in AASHTO. You noted that you have a Manitoba 49" TL-5 barrier test coming up next week and that you anticipated learning a lot towards better TL-5 design values from that test. If there are any new developments regarding the TL-5 design loads I would appreciate if you could send me a link to that information.

Illinois is leaning towards switching to a constant 11 degree slope barrier, but we don't know what height yet.For TL-5, it may likely be 45" tall, but we don't have design values for that yet.

Attachment: http://mwrsf-qa.unl.edu/attachments/7a9b4021c788c481765291553e03fc96.jpg

Attachment: http://mwrsf-qa.unl.edu/attachments/0ce35426e51b2200c54a0a28eed2abcc.jpg

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Response
Date: 04-07-2016

I have dug out some information from a few quarterly progress reports on NCHRP Project No. 22-20. During that effort as well a few others, TTI researchers utilized modeling to investigate barrier loading. I have provided details in the attached PDF regarding their suggested design forces for analyzing and designing bridge railings. As I recall, existing procedures largely use the application height at the top of the barrier when considering prior 32" TL-4 and 42" TL-5 barrier heights. Now, they have offered revised loads and application heights based on barrier heights. Note that one design load and application height was suggested for TL-4 to cover a range of barrier heights.

Next, it is not yet clear as to what the minimum barrier height would be required for all TL-4 rigid barriers. Barrier front face shape and top width may impact the minimum height. TTI had a success at 36 in., while failures were observed at 32". We know from past experience that rectangular shapes (vertical faces) allowed a lower height parapet to redirect a 8000S vehicle at TL-4 of NCHRP 350 as compared to safety shapes (sloped front faces). We have conducted LS-DYNA modeling around a decade ago that suggested that a 34.5" tall vertical face barrier may actually be capable of containing a MASH TL-4 10000S SUT vehicle. Testing would be needed to confirm. Thus, the 36" minimum is based on a TTI test on a particular barrier shape and top width. Depending on shape, it may be possible to actually use a 37.5" barrier to account for a 3" overlay for later field use of 34.5" (if proven with testing). If overlays are considered, then the barrier and deck design should consider the increased barrier height and load application height from asphalt surfacing.

I suspect that we will learn more with the Manitoba TL-5 test next week. We also plan to investigate and evaluate existing guidance for deck design based on barrier capacity at base. We will let you know of those results as they are obtained from the crash testing and follow-on analyses.

Finally, several of the topics discussed above are actually addressed in a few proposals under consideration at the April Pooled Fund meeting.

Attachment: http://mwrsf-qa.unl.edu/attachments/ea247f56f6e6f37a1909ab0b8712d6a4.pdf

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Thrie-beam height tolerances

Question
State: IA
Date: 04-06-2016

As a follow-up
to Question #288, was a
decision ever reached about thrie-beam height tolerances for MASH TL-3 levels?
We currently show 32" at the concrete bridge end post and then transition down
to 31" at the w-beam connection on our BA-201,
but a question has come in about an older bridge rail that is lower than 32"
and we're not sure how low the thire-beam connection can be.

Response
Date: 04-07-2016

We have addressed this issue in the past for several states. You may want to look at the responses below and see if they address your question. The short answer is that little research has been done on thrie beam transitions at heights below 31". Thus, there are concerns with the performance as the thrie beam AGT height is reduced.

http://mwrsf-qa.unl.edu/view.php?id=1029

http://mwrsf-qa.unl.edu/view.php?id=246

http://mwrsf-qa.unl.edu/view.php?id=908

Let me know if this helps.

Thanks

AGT Special Curb Design, under the Thrie-beam section

Question
State: MN
Date: 04-14-2016

We have been looking into a new single slope barrier, AGT design
option, with a back taper at the bottom to reduce snagging. However, this option is not preferred because
of constructability and water drainage (curb flow line consistency) concerns.

One alternative design has recently been proposed. It uses an 8-inch high curb with a front face at the same slope as the single slope barrier.
The gap between the top of the 8-inch curb and the bottom of the thrie-beam would be 3-inches. The curb would tapper to a 4-inch curb (or to zero) before the W-to-thrie transition element.

Attached is a draft drawing showing this design approach. We would like to know if this would reduce the snagging issues at the concrete end, similar to a back tapper design.

Let me know if you need any further information.

Thank you

Attachment: http://mwrsf-qa.unl.edu/attachments/4d2093376bb7b469d8fddf16774e19cb.pdf

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Response

Date: 04-25-2016

Previous full-scale testing has shown that the addition of a curb has generally reduced the amount of snag on the rigid buttress. That being said, the face of the buttress has typically been tapered back in conjunction with the curb. I don't believe any AGT has been successfully tested without a taper of the rigid buttress (of the toe or the entire front face). Thus, snagging may still be an issue. The smallest taper that i could find that was successfully tested on a SS buttress was 4" laterally, by 22" longitudinally - reference TRP-03-47-95. That AGT configuration did not utilize a curb, so there is a chance that adding a curb could help reduce snag, but it has not been tested/evaluated.

My biggest concern with the proposed idea is a potential for vehicle instability with an 8" tall curb. All of the previously crash tested (350 and MASH) AGT designs utilized 4 inch tall curbs. Testing of W-beam guardrail with a curb has used curb heights up to 6". There is no data available on vehicle interactions with an 8" tall curb. As such, my concerns are that excessive climbing and rolling may occur during vehicle impacts. Again, there is no data proving that this is a problem, but there is also no data demonstrating the crashworthiness of an 8" curb. However, I would feel better about leaving the curb height at 4 inches throughout its length - the curb height typical of AGT's that has been shown to be crashworthy.

If you do decide to utilize a taller curb, you are correct in transitioning it down to a 4" tall curb prior to the curb extending below the W-to-thrie beam transition element. Previous testing has demonstrated the sensitivity of this region of the AGT, and we would not want to induce further vertical climb and increased vertical rail loads.
