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. #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:** 8/31/18	**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
$124,345	$53,668	55%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$9,186	

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:

In the upcoming quarter, MwRSF will work on simulation of variations of the proposed cable barrier adjacent to slope in order to determine the optimal design configuration. Variations may include posts spacing, cable heights, offset from slope, and cable-to-post attachments. Simulation models of the modified cable system will be conducted 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 has shifted to a tubular steel post. Simulation of proposed designs is underway.

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	100%
4. LS-DYNA model development, validation, and calibration	80%
5. LS-DYNA simulation of various cable barrier modifications	20%
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 that extends the project completion date to 12/31/16.

Due to the continued wait for resolution of the high-tension cable median barrier post design and evaluation. An additional no-cost extension was requested and received extending the project end date to 8/31/18.

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

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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. #81 MwRSF Project No. RPFP-15-AGT-1	☑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):	**Phone Number:**	**E-Mail**
Reid, Faller, Bielenberg, Rosenbaugh	402-472-9324	srosenbaugh2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611211113001	RPFP-15-AGT-1	8/1/2014
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
7/31/2017	7/31/2018	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
$125,906	$117,711	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
	$5,650	

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.):
Work continued to complete the summary report, which will detail all design and testing of the standardized buttress along with guidance and recommendations for installing the buttress in real world AGTs.

Anticipated work next quarter:

The project summary report will be written.

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.

Following the unsuccessful full-scale crash test, the geometry of the standardized buttress was redesigned to improve the performance of the system. The size of the lower taper was increase from a 4"12" taper to a 4.5"x18" taper. Also, the height of this lower taper was increased from 11" to 14". these changes were done to reduce wheel snag and loads into the axle of the vehicle. the upper taper was changed from 4"x4" to a 3"x4". this reduction in slope was intended to

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).

Extra data analysis was conducted in an attempt to validate the differing data traces obtained from the accelerometers and the high speed video for test no. AGTB-1. Unfortunately, none of the analysis methods converged.

A continuation study/project was funded in 2016 as part f the Year 27 Pooled Fund Program. This new project was aimed at redesigning the buttress and re-testing the system (MASH 3-21). As this effort is advanced, labor and materials will be charged to this Year 25 project until the funds are exhausted. The test charges were still applied to the YR 27 project instead of the original YR 25 project.

After the project had begun, FHWA issued a new memo/policy stating that it would only grant eligibility letters to systems that had completed the full test matrix as recommended in MASH. Since the project did not include testing with the small car (deemed non critical), the standardized buttress will not meet the criteria for FHWA eligibility letters. Thus, a submission will not be completed. Instead, MwRSF's opinion on the crashworthiness of the buttress will be explicitly written in the report and supported with details and references.

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

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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.#82	☑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):	**Phone Number:**	**E-Mail**
Reid, Faller, Lechtenberg, Bielenberg	402-472-6864	rfaller1@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
RPFP-15-TREE-1	26112110114001	August 1, 2014
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
July 31, 2017	July 31, 2018	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
$80,815 (+15,000 Yr 25 Contingency)	$80,815 (+18,477 Yr 25 Contingency	97%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$1,375	

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.):

Report internal revision completed.

Anticipated work next quarter:

Draft report will be sent to state DOTs for review and revision. State DOT comments will be implemented and the draft report will be published.

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. Marketing ideas, approaches, and items of interested were identified, discussed, and implemented into sample ideas.

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

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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. #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:** 8/31/2018	**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
$256,184	$115,810	57%

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:

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.):

Previously, MwRSF tested the high-capacity energy absorber prototype and capture net supplied by Impact Absorption in late March of 2016.

In test no. DBT-1, MwRSF impacted the net attenuator with one high-capacity energy absorber on each side of the net mounted near the center of the net height on rigid frames. The 4,908 heavy bogie vehicle impacted the center of the net at an angle of 90 degrees and a speed of 56.5 mph. The net attenuator captured the bogie and brought it to a controlled stop approximately 34 ft from impact. Peak deceleration forces were 23.6 kips, which correlated to a peak deceleration of 4.81 g's. The longitudinal OIV and ORA values were calculated to be 5.8 m/s and 4.7 g's, respectively. Lateral OIV and ORA values were negligible.

The tape feed length on the left and right side were 148.25 in. and 153.75 in., respectively. MwRSF also ran an analysis to check the estimated deceleration levels for the 1100C small car vehicle. Estimated longitudinal OIV and ORA values were calculated to be 7.5 m/s and 8.5 g's, respectively. These values are well within the MASH limits.

The results from the test showed that the high capacity absorber and net had promise, but that higher force levels were needed. In addition, future versions must be ground mounted to work in the hybrid end terminal/crash cushion and net attenuator system while meeting stub height requirements of 4" or less.

For the next step, MwRSF plans to evaluate the system with higher force levels and ground mounted to determine if the system can be setup and function properly when mounted at grade. Impact Absorption is working on supplying an energy absorber with 17 kip sustained pull force. Additionally, MwRSF is working on mounting the system at ground line and low enough to meet stub height requirements. A subsequent test is planned to evaluate the increased capacity energy

Anticipated work next quarter:

In the upcoming quarter, MwRSF will conduct one additional test on each net attenuation prototype at the 1/4 offset point.

Progress will also continue on the summary report.

Significant Results:

Fabrication of high-performance energy absorber for feasibility testing and development of a second potential energy absorber concept. Five dynamic component test were conducted on two net attenuation systems and the results were used to push for a revised designs that will be evaluated next in two subsequent bogie tests.

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).

Due to complications arising from the timing and response of the private industry partners in this effort, the development of the new treatment for intersecting roadways is currently behind schedule. This was discussed with the TAC in the October 2016 meeting and it was agreed that it was worthwhile to extend the research effort to allow for further net attenuator development and the use of potential Zodiac Aerospace technologies. Thus, a no-cost time extension will be requested and received for this project prior which extended the end date to 8/31/2018.

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): New Jersey Department of Transportation

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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. #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): Faller, Lechtenberg, Bielenberg, Rosenbaugh,	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611130095001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 4/1/2015
Original Project End Date: 6/30/2016	**Current Project End Date:** 3/31/2018	**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
$702,369	$591,045	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
	$83,723	

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.):

Internal draft reports for test nos. NJPCB-5 through NJPCB-9 were completed. Internal review of draft reports for test no. NJPCB-5 through NJPCB-9 was completed. Draft reports for test nos. NJPCB-5 through 9 were sent to sponsor for review and comment.

Construction of the NJDOT PCB system with a pinned configuration in asphalt with pins in every pin anchor pocket. This system corresponds to the system specified as test no. 9 in the proposal.

On January 19 in test no. NJPCB-9, the NJDOT PCB configuration with alternating barriers pinned on both sides through an 8-in. layer of asphalt was subjected to AASHTO MASH TL-3 test conditions using a 2270P pickup truck vehicle (test designation 3-11). The system had pins placed in every pin anchor location in every other barrier segments. These threaded rods were driven into pre-drilled holes in the asphalt. In test no. NJPCB-9, the pickup truck impacted the system at a speed and angle of 61.6 mph and 25.6 degrees, respectively, resulting in an impact severity of 118.6 kip-ft. The system did not adequately contain and redirected the pickup truck as it rolled over. 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 14.6 in. (which included tipping of the top of the barrier and concrete fracture) and 53.1 in., respectively. The occupant crush measurements found a maximum of 8.375 in. of deformation in the side door below the seat location which did not exceed the limit provided in MASH. Therefore, due to vehicle snag and rollover, test no. NJPCB-9 was unacceptable according to the safety performance criteria of AASHTO MASH for test designation no. 3-11.

Anticipated work next quarter:

Finalized reports for test nos. NJPCB-1, NJPCB-2, NJPCB-3, NJPCB-4, NJPCB-5, NJPCB-6, NJPCB-7, NJPCB-8, and NJPCB-9.

Significant Results:

None

Objectives / Tasks	% Complete
1. Test no. 1 - Full-scale crash testing (MASH 3-11) - NJPCB-3	100%
1a. Test no. 1 Report - NJPCB-3	95%
2. Test no. 2 - Full-scale crash testing (MASH 3-11) - NJPCB-4	100%
2a. Test no. 2 Report - NJPCB-4	95%
3. Test no. 3 - Full-scale crash testing (MASH 3-11) - NJPCB-1	100%
3a. Test no. 3 Report - NJPBC-1	95%
4. Test no. 4 - Full-scale crash testing (MASH 3-11) - NJPCB-2	100%
4a. Test no. 3 Report - NJPBC-2	95%
5. Test no. 5 - Full-scale crash testing (MASH 3-11) - NJPCB-5	100%
5a. Test no. 5 Report - NJPCB-5	90%
6. Test no. 6 - Full-scale crash testing (MASH 3-11)	100%
6a. Test no. 6 Report - NJPCB-6	90%
7. Test no. 7 - Full-scale crash testing (MASH 3-11)	100%
6a. Test no. 6 Report - NJPCB-7	90%
8. Test no. 8 - Full-scale crash testing (MASH 3-11)	100%
6a. Test no. 6 Report - NJPCB-8	90%
9. Test no. 9 - Full-scale crash testing (MASH 3-11)	100%
6a. Test no. 6 Report - NJPCB-9	90%

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.

A no-cost extension will be requested to continue the project since funding has been delayed.

The additional funds to reach the $702,369 total project budget was received in September 2016. Therefore, the project plan may be shifted 6 months to account for the delay in funding.

A 6-month no-cost extension was requested on September 28, 2017.

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): Nebraska Department of Transportation

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.#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**
Reid, Faller, Lechtenberg, Bielenberg, Rosenk	402-472-9070	kpolivka2@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	$39,414	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
	$22,610	

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

New Project Description -
The Midwest Roadside Safety Facility (MwRSF) has been conducting research for the Midwest States Regional Pooled

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):
Internal review of the draft report of the final 5 component tests evaluating the addition of a cap to the top of the post to prevent cutting of the floorboard completed. Draft report sent to the member states for review on February 5, 2018.

Internal review of the draft report of test no. MWP-9 completed. Draft report sent to the member states for review on February 15, 2018.

One dynamic component test for the selected post section was conducted with the floorpan bogie to evaluate the potential for floorpan cutting. The selected post section, HSS 3x2x1/8, did not impart any floor pan damage.

Continue brainstorming design concepts for the clean-slate high-tension cable median barrier.

Initiate draft report on the nineteen dynamic component tests and one floorpan cutting dynamic component test on the closed post sections.

Anticipated work next quarter:

Implement member state review comments in the report of the final 5 component tests evaluating the addition of a cap to the top of the post to prevent cutting of the floorboard. Publish and disseminate the final report to the member states for review.

Implement member state review comments in the report of test no. MWP-9. Publish and disseminate the final report to the member states for review.

Draft report on the nineteen dynamic component tests and one floorpan cutting dynamic component test on the closed post sections will continue to be written.

Continue brainstorming design concepts for the clean-slate high-tension cable median barrier. Investigate a sleeve nut design for connecting the tabbed bracket to the new post design.

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. The Pooled Fund States decided to explore new median barrier design concepts, and the funds in this project will be utilized for the median barrier design.

Project funds from Project No. TPF-5(193) Supplement #79 - RPFP-15-CABLE-1 were exhausted in Quarter 4 of 2017. Thus continued development of the cable median barrier will be reported under this project.

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.

New 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. #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): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9064	**E-Mail** srosenbaugh2@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	$118,925 + $77,337 (contingency)	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
	$31,919	

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.):
Previously, simulated impacts illustrated that vehicles impacting the thrie beam downstream of the gap may be subjected to significant roll displacements, possibly even rollover. As such, one CIP location was identified ay 1 ft downstream of a 3-ft gap in the PCB system. This quarter, the CIP study was completed on the system and included impacts within the gap and upstream of the gap.

LS-DYNA simulations were conducted to evaluate MASH TL-3 impact with the 2270P pickup truck. Impacts upstream of the PCB gap showed no evidence of pocketing, vehicle snag, or vehicle instabilities resulting from the increase in system stiffness around the PCB gap spanning hardware. As such, no full-scale testing was recommended upstream of the gap.

Simulated impacts were also conducted at 1-ft increments within the maximum 12.5-ft long PCB gap. Although none of the simulations resulted in vehicle rollover, impacts on the downstream half did have significant roll (i.e., 20-50 degrees). Loading to the thrie beam segments and the toe plates was maximized when the impact occurred 6 ft from the downstream end of the gap. Thus, the 2nd CIP was determined to be 6 ft from the downstream end of the gap to evaluate critical loading to the attachment components and possible vehicle instability.

After the completion of the CIP study, work began on the CAD details of the system, including both critical impact scenarios.

Additionally, work on the project summary report continued.

Anticipated work next quarter:

CAD details for the thrie beam attachment concept will be completed. Additionally, work will continue to complete the project summary report.

Significant Results:

A literature review was completed on State DOT standards, private manufacturer hardware, and a patent search. Next, 7 different conceptual designs were shown to the project sponsors for consideration. The sponsors voted to proceed with designing 2 concepts, a 2-piece end plate concept and a thrie beam with toe plate concept, through structural analysis and LS-DYNA simulations.

Simulations on the 2-piece cover plate design illustrated that the cover plate had to be 3/8" - 1/2" thick to prevent the cover plate from hinging and creating a snag point at the upstream end of the PCB. Adding 1/4" thick stiffening plates spaced at about 2 ft intervals allowed the cover plate thickness to be reduced to 1/4". these stiffeners would have to be bolted in place or removed depending on the actual gap width between PCBs. Finally, the end plate would need to be 5/8" thick in order to prevent failure at the connection between loops and the end plate of the cover plates.

Simulations with the thrie beam and toe plate concept illustrated that single ply thrie beams would not be sufficient to prevent vehicle snag on the PCBs. Thus, nested 12-gauge thrie beam was selected for the design. 10-gauge terminal end connectors are used to connect the beams to the PCBs. Spacer blocks were placed at 37.5" intervals to connect the beams on the front and back sides of the system and to provide added strength. the spacers had to be extended all the way to the ground and connected to the toe plate in order to prevent excessive deformations of the toe plate and the associated risk of vehicle snag on the toe of the PCB. The spacers will be fabricated from 1/4" thick steel and resemble the cross section of an F-shape barrier.

A presentation was given in October to the project sponsors detailing the LS-DYNA simulation and design efforts on both design concepts. The sponsors voted unanimously to proceed with the thrie beam and toe plate concept. As such

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 project funds were depleted early in the 4th quarter of 2017. In order to complete the CIP study and assemble the project summary report, multiple contingency funds (or remaining funds from completed Midwest Pooled Fund projects) were designated for use on the PCB gap connection hardware project:

- project code 2611211112003, $8,344, funds moved to contingency from Year 25 project - "MGS with Omitted Post"
- project code 2611130126001, $39,100, contingency funds from Year 28 of the pooled fund program
- project code 2611211138001, $29,893, contingency funds from Year 27 of the pooled fund program

Note, Phase II of this project was selected for funding as part of the Year 28 pooled fund research program, so testing of the system will begin in 2018.

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:
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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. #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 l	**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	$18,852	45%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$1,426	

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.):

Previously, MwRSF conducted a literature search to compile and summarize research related to the MGS adjacent to slopes. This effort collected 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.

The data from the literature search was reviewed and additional research related to barrier placement adjacent to slopes was added included additional bogie testing of posts on both level terrain and slopes. The literature review was reviewed and edited for use as part of the final report.

In November of 2016, MwRSF had a Midwest Pooled Fund progress update meeting. In that meeting, the scope of this project was reviewed in light of the MGS successfully meeting MASH TL-3 criteria when installed in its standard configuration adjacent to a 2:1 slope. In that meeting, it was decided that the use of standard post length MGS systems on 2:1 slope would greatly simplify the required guidance and scope of this report. Thus, it was agreed to simplify the guidance to denote the allowable configuration under MASH and provide relevant implementation guidance in terms of issues such as working width, special MGS applications, and soil strength considerations. Thus, the scope has been revised to a more simple approach.

MWRSF has developed simplified guidance for the MGS placed adjacent to slopes. Additionally, estimated deflections

Anticipated work next quarter:

In the upcoming quarter, MwRSF will work on completion of the summary report.

Significant Results:

State survey completed and the literature search was completed.

Scope of project guidance simplified based on recent MASH testing.

Simplified guidance for the MGS adjacent to slope was developed.

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 Transportation

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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. #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 (+$39,100 Yr 28 Contingency)	$162,186 (+$3,051 Yr 28 Contingenc	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
	$3,676	

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.):

Draft report on the literature review, patent search, and concept development continued to be reviewed. Documentation of the component tests in the report continued.

Design of a breaker bar and modified groundline strut to eliminate the small car snag potential on the cable and the construct-ability of the system, respectively, was initiated.

Anticipated work next quarter:

Design of a breaker bar and modified groundline strut to eliminate the small car snag potential on the cable and the construct-ability of the system, respectively, will be completed.

Findings and recommended system will be presented to the member states for feedback and comment. The preferred design concept will be further developed.

Internal review of the literature review, patent search, concept development, and component test documentation will continue.

Significant Results:

Five design concepts were developed and component tested.

Objectives / Tasks:	% Complete
1. Literature Review	95%
2. Development of Design Concepts	95%
3. Design and Analysis	95%
4. CAD Details	95%
5. Component Fabrication	100%
6. Component Testing	100%
7. Data Analysis	100%
8. CAD Details of Recommended System Design	0%
9. Summary Report	60%

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

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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	$74,787	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
	$435	

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.):

Work continued on assembling the project summary report.

Anticipated work next quarter:

The draft of the project report will be completed. Also, drawings will be developed to illustrate the recommended system installations for top-mounted sockets for weak-post MGS on culverts.

Significant Results:

A literature review was completed covering all previous crash-testing of related weak-post systems and top-mounted culvert guardrail systems. Following some initial conceptual designs, discussions with the project sponsors led to the selection of 3 socket design options for evaluation: 1) a steel socket, 2) a cylindrical concrete foundation, and 3) sockets encased in a concrete slab.

The reinforced steel socket option was evaluated through both the strong and weak axis of the post at impact heights of 25" and 12", respectively. The sockets were placed on the slope break point of a 2:1 slope, and the culvert soil fill depth was at its maximum of 36 inches. This configuration was considered critical to maximize the potential for socket damage and displacement. Both tests resulted in virtually no damage to the socket, and permanent deflections of the socket was less than 0.5" (as measured at the top of the socket.

A dynamic component test was also conducted on the cylindrical concrete foundation. Since this concept has already proven to resist movement in soil with a 30" embedment depth, the shallowest embedment depth (12') was selected as the critical soil depth to evaluate the anchorage of the foundation to the top of the culvert. The test was conducted through the strong axis of the post with a 25" impact height. The test resulted in virtually no damage or displacement of the concrete foundation. A second cylindrical concrete foundation was installed at the maximum fill depth of 36" and subjected to a weak-axis impact at a height of 12" above ground line. The post bent over and the bogie eventually overrode the top of the post. the foundation sustained no damage and had only 1/16" of permanent displacement.

A 9-ft long x 3 ft wide x 4" thick concrete slab was poured with its back edge at the slope break point of a 2:1 slope. Two sockets spaced 27.5" apart were placed within the concrete slab 24" from the back edge of the slab. The test was

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. #93 MwRSF Project No. RPFP-16-MGS-4		**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: Top Mounted Socket for Weak Post Bridge Rail		
Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211123001	**Other Project ID (i.e., contract #):** RPFP-16-MGS-4	**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**
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	$435	

Project Description:

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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.):

Work continued on assembling the project summary report.

Anticipated work next quarter:

The draft of the project report will be completed. Also, drawings will be developed to illustrate the recommended system installations for top-mounted sockets for weak-post MGS on culverts.

Significant Results:

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A 9-ft long x 3 ft wide x 4" thick concrete slab was poured with its back edge at the slope break point of a 2:1 slope. Two

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 May 2017, the FHWA issued a memo that stated that only systems that had been evaluated to the entire suite of tests within the MASH crash testing matrix would receive an eligibility letter. Since this project incorporated only component testing, these socketed designs will not have the opportunity to receive letters. Thus, an application for an FHWA letter will not be submitted.

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:
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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 # 94	**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 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
$123,057	$118,646	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
	$4,157	

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
4. Component Testing

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

Two reports were completed. The first report was published on February 6, 2018 and is only published internally within MwRSF. Sponsors may view the report in person at the MwRSF main office in Lincoln, NE. This report details the other terminal concepts that were brainstormed by the research team. The second report details the patent and background review and the design and analysis of the terminal concept that was selected by the sponsors. This report was sent for sponsor review on February 1, 2018. Not all sponsor comments have been received.

Anticipated work next quarter:

The second report will be made final.

Significant Results:

The background and patents on all current end terminals has been documented. Several concepts have been brainstormed. The States voted to pursue the path of a new end terminal design. The new end terminal impact head was designed and preliminary simulation with LS-DYNA was 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).

Initially, $70,000 was funded to begin the project and determine the course of direction. In December 2016, the majority of the Pooled Fund States voted to utilize $53,057 in Year 23 contingency funds from TPF-5(193) Suppl #57 to continue with component testing and possibly simulation in this Phase I effort. Thus, the total project budget was increased from $70,000 to $123,057 in the 2016 Quarter 4 quarterly progress report.

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 Transportation

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. #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: Enhancements to MwRSF Hub Website		
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	$22,661	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
	$806	

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.):

Uploading videos to the research hub and archiving the converted videos with the original videos continued. Approximately 90% have been uploaded and archived.

Anticipated work next quarter:

Continue uploading videos to the research hub and archiving the converted videos with the original videos.

Continue the verification process of verifying that all videos, CAD, and reports have been uploaded for each of the Pooled Fund reports located on the research hub.

Significant Results:

Task	% Complete
1. Identify projects needing wmv videos uploaded	100%
2. Locate full-scale crash test videos	100%
3. Convert videos to wmv format	100%
4. Upload the wmv videos and archive converted videos	90%
5. Verify videos have been uploaded	85%

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

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

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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. #93 MwRSF Project No. RPFP-16-MGS-4	**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:
Top Mounted Socket for Weak Post Bridge Rail

Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211123001	**Other Project ID (i.e., contract #):** RPFP-16-MGS-4	**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:

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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
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Work continued on assembling the project summary report.

Anticipated work next quarter:

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Significant Results:

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TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

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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 # 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
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Project Description:

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Anticipated work next quarter:

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Significant Results:

The background and patents on all current end terminals has been documented. Several concepts have been brainstormed. The States voted to pursue the path of a new end terminal design. The new end terminal impact head was designed and preliminary simulation with LS-DYNA was completed.

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TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska 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. #95	☑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:

Enhancements to MwRSF Hub Website

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:**
2611211125001	RPFP-16-WEB-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**
$30,102	$22,661	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**
	$806	

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.):

Uploading videos to the research hub and archiving the converted videos with the original videos continued. Approximately 90% have been uploaded and archived.

Anticipated work next quarter:

Continue uploading videos to the research hub and archiving the converted videos with the original videos.

Continue the verification process of verifying that all videos, CAD, and reports have been uploaded for each of the Pooled Fund reports located on the research hub.

Significant Results:

Task	% Complete
1. Identify projects needing wmv videos uploaded	100%
2. Locate full-scale crash test videos	100%
3. Convert videos to wmv format	100%
4. Upload the wmv videos and archive converted videos	90%
5. Verify videos have been uploaded	85%

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): 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	$9,813	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
0	$8	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.):

Due to other project priorities no work was done on this project.

Anticipated work next quarter:

The 2018 version of the MGS model will be completed and made available for usage in various projects. An initial model of the approach guardrail terminal (AGT) will be constructed. The AGT model is expected to be useful on several project in the near future.

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. #101	☑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:
Iowa DOT Combination Bridge Separation Barrier with Bicycle Railing

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Faller, Bielenberg, Reid, Rosenbaugh	(402) 472-9064	rbielenberg2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611130099001		7/01/2016
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
12/31/2018	12/31/2018	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
$254,445.00	$72,652	50

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$7,663	

Project Description:

The objective of this research is to develop a MASH TL-2 crashworthy, low-height, vertical-face traffic barrier with an attached crashworthy bicycle railing. It is desired that the low-height, vertical-face traffic barrier be applicable for standard applications and that the crashworthy bicycle railing attachment can be added as desired. The barrier system should minimize the height of the concrete barrier portion of the system and provide improved visibility and sightlines, including when the bicycle railing attachment is used. In addition, the new railing system should comply with current AASHTO LRFD guidance for bicycle railings with respect to the parapet and/or the parapet and combination railing.

The research effort to develop a MASH TL-2 crashworthy, low-height, vertical-face traffic barrier and attached crashworthy bicycle railing will proceed in two phases. Phase I will consist of the development and analysis of design concepts, and Phase II will consist of evaluation and full-scale crash testing of the proposed design.

Phase I

The Phase I research effort will begin with a literature search to review crash tested vertical parapets and bicycle/pedestrian rails. The information will be reviewed to suggest potential vertical concrete parapet geometries and designs as well as provide background information on existing crashworthy combination railings. Following the literature search, the researchers will estimate the lowest vertical-faced concrete barrier height that is sufficient to meet AASHTO MASH TL-2 crash testing requirements and can also be used with a pedestrian/bicycle railing. A 24-in. minimum height will be the lowest potential parapet height based on the AASHTO LRFD guidance for a pedestrian separation barrier, as noted previously. However, no rigid parapets have been evaluated at that height under the MASH TL-2 criteria.

LS-DYNA simulation with the 2270P vehicle will be used to evaluate potential minimum rail heights for the vertical parapet of 24 in. or greater. A baseline simulation model will be created and validated against the best available relevant crash

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

To date a literature search has been performed on previous crash testing and development of TL-2 and TL-3 vertical concrete parapets as well as combination bridge rails. Information has also been collected regarding low-height TL-2 and TL-1 barriers that includes portable concrete barriers as well. Information on the Zone of Intrusion and occupant head ejection that may be relevant to the project was collected as well.

The researchers used the materials from the literature search to begin simulation analysis of the minimum TL-2 parapet height. MwRSF has developed models of recent vertical parapet tests for calibration and is conducting the height analysis. The researchers also reviewed critical vehicle components relative to the barrier height in existing tests to help establish the minimum barrier height. The literature review data and simulation will then be applied to select the minimum height.

The effort to determine the minimum TL-2 concrete parapet height was continued. Simulation of a MASH TL-3 test of the Texas T-222 vertical bridge rail was conducted to validate simulation of the 2270P vehicle into a vertical concrete parapet. Analysis of the simulation results found that the simulation tended to overestimate vehicle pitch and roll values. Attempts were made to adjust vehicle to barrier friction and the deflection of the barrier to better match the physical crash test, but improvement was minimal. Further analysis simulated TL-2 impacts of the 2270P vehicle into extremely low height parapets with heights of 14 in. and 18 in. The simulation models tended to suggest vehicle redirection for both of these impacts, but previous testing has indicated that 18 in. barrier heights are not sufficient to redirect pickup trucks. Thus, it was determined that the tire and suspension models for the 2270P vehicle may not be sufficient to predict vehicle interaction with the low height parapet.

A second analysis of existing vehicle testing on low height parapets was undertaken that compared critical points on the

Anticipated work next quarter:

MwRSF will schedule a meeting with Iowa to review the proposed design and finalize the details for full-scale testing. Once details are finalized, MwRSF will begin planning for fabrication and testing. This effort and the summary report will extend into the second quarter of 2018, which would be approximately 6 months behind the proposal timeline.

Fabrication and testing would be still be planned for 2018.

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).

Currently, Phase I design of the combination rail is approximately 3-6 months behind the intended project plan. Funding is not an issue. MwRSF will make an attempt to make additional progress to get closer to the intended deadlines.

Testing in 2018 is still planned.

Potential Implementation:

Investigation and evaluation of a MASH TL-2 crashworthy, low-height, vertical-face traffic barrier and an attached crashworthy bicycle railing will provide IaDOT with a safe option for shielding bicycle facilities and also may be used without a railing for pedestrian separation.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): New York State 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. #102	☑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:
Dynamic Testing & Evaluation of a New York DOT Prototype Box Beam Guardrail End Terminal System Under AASHTO M

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Faller, Lechtenberg, Reid, Schmidt	402-472-9070	kpolivka2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
261113010001		8/15/2016
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
10/30/2017	7/31/2018	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
$265,250	$94,571	30%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$619	

Project Description:
The New York State Department of Transportation (NYSDOT) has designed a a prototype box beam guardrail end terminal system. They have a desire to preliminarily evaluate it with the more critical MASH tests.

The objective of this research effort is to investigate the performance of a prototype box beam guardrail end terminal system through MASH-compliant crash testing (three preliminary tests).

Objectives / Tasks
1. System CAD details - test no. 1
2. System construction - test no. 1
3. Full-scale crash testing (MASH 3-31) - test no. 1
4. System CAD details - test no. 2
5. System construction - test no. 2
6. Full-scale crash testing (MASH 3-30) - test no. 2
7. System CAD details - test no. 3
8. System construction - test no. 3
9. Full-scale crash testing (MASH 3-36) - test no. 3
10. Written report documenting design, testing, and conclusions

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):
Continued to write report for NYT-1.

A no-cost extension was requested.

Anticipated work next quarter:

Complete draft report for test no. NYT-1. Initiate internal review of the draft report. Potentially send draft report to sponsor for review and comment.

Significant Results:

None

Objectives / Tasks	% Complete
1. System CAD details - test no. 1	100%
2. System construction - test no. 1	100%
3. Full-scale crash testing (MASH 3-31) - test no. 1	100%
4. System CAD details - test no. 2	
5. System construction - test no. 2	
6. Full-scale crash testing (MASH 3-30) - test no. 2	
7. System CAD details - test no. 3	
8. System construction - test no. 3	
9. Full-scale crash testing (MASH 3-36) - test no. 3	
10. Written report documenting design, testing, and conclusions	
10a. Report - Test no. 1	45%

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:

Investigation and evaluation of the box beam end terminal would provide for MASH TL-3 acceptance of a box beam end terminal.

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. #103		**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: 34" Tall Thrie-Beam Approach Guardrail Transition		
Name of Project Manager(s): Rosenbaugh, Faller, Faller, and Reid	**Phone Number:** 402-472-9327	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611130101001	**Other Project ID (i.e., contract #):** RHE-17M	**Project Start Date:** 9/7/2016
Original Project End Date: 3/31/18	**Current Project End Date:** 9/30/18	**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
$179,936	$104,166	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
	$6,233	

Project Description:

A taller rail height approach guardrail transition (AGT) is desired to allow for future roadway overlays without modifications or retrofits to the thrie beam AGT. Ideally, a 3" overlay could be placed in front of a 34" tall AGT, thereby making it a standard 31" tall AGT. Thus, the objective of this research is to evaluate the safety performance of NDOR's approach guardrail transition (AGT) with the top mounting height of the thrie beam increased from 31" to 34". The 34" tall AGT will be evaluated according to MASH TL-3 safety performance criteria. The concrete buttress at the downstream end of the the transition will be selected to fit the needs of NDOR and ensure a crashworthy system after a 3" overlay. Finally, connection details for the MGS upstream of the thrie-beam AGT will be developed for both pre- and post-overlay situations.

Major Task List:

1. Project Planning and Correspondence
2. Design/Selection of Concrete Buttress
3. Design of MGS to 34" Transition
4. CAD Details
5. Construction of Test Article
6. Full-Scale Crash Testing - MASH 3-20
7. Full-Scale Crash Testing - MASH 3-21
8. System Removal
9. Data Analysis
10. Summary Report
11. Technical Brief and Presentation for NDOR
12. Submission of FHWA Eligibility Letter

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

Efforts focused on writing the summary report documenting all testing and results.

Anticipated work next quarter:

Continued work on the summary report documenting all testing and results for the project. Also, work will begin on the assembly and validation of an LS-DYNA AGT model.

Significant Results:

Through multiple meetings and discussions between MwRSF and NDOR, the concrete buttress design and the upstream transition from 31" MGS to 34" AGT were finalized. The concrete buttress is a taller version of the Standardized Transition Buttress being developed through the Midwest States Pooled Fund (39" instead of 36"). The upstream MGS will connect to a symmetrical W-to-thrie transition segment that will take the top rail height from 31" to 34". Once an overlay is paved, the symmetric segment will be replaced with an asymmetrical W-to-thrie segment, and the W-beam rail and blockouts upstream of the the transition will be raised 3" to match the top rail height of the AGT (was 34" now 31" relative to the top of the roadway). Extra bolt holes were placed in the posts to accommodate the different transition segments and the raising of the W-beam.

CAD details for the system were developed and the 34" AGT system with 39" standardized buttress was constructed at the MwRSF test site. The first full-scale crash test, 34AGT-1, resulted in the 2270P being smoothly redirected with only minor contact between the vehicle and the buttress. All occupant safety criteria was satisfied, so the test passed all saftey performance criteria of MASH 3-21.

The second full-scale test, test no. 34AGT-2, was conducted on the transition system according to MASH 3-20. The small car was contained and redirected, but.the front tire extended under the thrie beam rail and snagged on the upstream face of the buttress. This snag resulted in significant crush to the floorpan and toe pan. However, these deformations were within the MASH limits. The windshield was cracked and torn, which is not allowed under MASH criteria. However, the windshield damage was the result of deformations of the vehicle hood, fender, and A-frame. The test article never contacted the windshield, so the potential for penetration is negligible. Thus, this tearing was not deemed a safety hazard. Finally, the driver side door opened during the test as a result if the contact between the door and the thrie beam. MASH

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 initial project proposal was written with an end date of June 2018. However, the timeline listed on the agreement between NDOT and UNL had shifted the completion date forward to March 31, 2018, thus resulting in 3 months of lost time to complete the study and finalize all project deliverables. Additionally, the MwRSF wanted to prepare a technical journal paper on the project to disseminate the project's findings and conclusions throughout the country. As such, a 6 month, no-cost extension was granted to this project.

Through discussions Phil TenHulzen, NDOR expressed interest in using the test data to construct and validate a computer model for use in further study of AGTs. Specifically, an LS-DYNA model of an approach guardrail transition could aid in the study of other guardrail heights, various transition post and post spacing configurations, and transition flare rates. After the full-scale crash testing and evaluation of this project was completed, there were significant funds remaining in the project budget. Therefore, LS-DYNA modeling was added to the project scope, and a validated AGT model will be constructed as part of this project.

Potential Implementation:

The successful testing of the 34" tall AGT will allow NDOR to install both their bridge rails and their adjacent AGTs in anticipation of future overlays. Both of these barrier types will now be crashworthy at the time of initial installation as well as after a 3" roadway overlay. Not having to remove and replace the AGTs after an overlay should result in significant savings in both cost and labor.

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 #104		☑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: Optimized TL-4 Concrete Bridge Rail		
Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211133001	**Other Project ID (i.e., contract #):** RPFP-17-CONC-2	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2019	**Current Project End Date:** 9/30/2019	**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**
$247,654	$71,533	35%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$9,368	

Project Description:
Historically, rigid concrete barriers satisfying TL-4 criteria have typically been 32 in. tall. However, with the adoption of MASH and an increase in both mass and impact speed for the single-unit truck, TL-4 tests on 32-in. tall barriers have repeatedly resulted in the 10000S vehicle rolling over the barrier. As such, barriers taller than 32 in. are now required to meet the MASH TL-4 criteria.
Past research has indicated that certain barrier shapes, such as safety-shapes, increase the propensity for vehicle climb, instability, and rollover. An optimized barrier shape would minimize vehicle instabilities by utilizing a flat, near vertical face. However, tall vertical faced barriers pose the risk of occupant head slap during impact events. Thus, an optimized geometric shape that considers vehicle containment, vehicle stability, and occupant head ejection is desired for new taller TL-4 barriers. Additionally, the increased impact severity associated with MASH TL-4 criteria will increase impact loads to the deck and could lead to deck damage. Retrofitting stronger barriers onto existing bridge decks not designed for these increased loads may lead to deck damage during severe impacts.
The objective of this research effort is to develop a MASH-compliant TL-4 bridge railing. The railing will be optimized for strength, vehicle stability, installation costs, and head slap mitigation. Efforts will also be made to minimize load transfer into the deck and determine the minimum deck capacity, thereby minimizing the risk of deck damage.

Objectives / Tasks:
1. Literature Review
2. State Survey of TL-4 deck designs
3. Barrier Design and Structural Analysis
4. Deck Design and Structural Analysis
5. CAD Details
6. Development of Barrier End Sections and Transitions

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):
Previously, an optimized barrier configuration was designed to incorporate a single slope front face angled 3 degrees from vertical, an 8" top width, and an installation height of 39". The barrier was reinforced with (8) #5 longitudinal rebar and #4 stirrups spaced at 12" intervals. A bridge deck was also configured for the full-scale test based on existing deck designs from the sponsor DOTs.

Details for the full-scale crash test of the selected bridge rail and deck designs were detailed in CAD. Construction of the test installation began at the MwRSF test site.

Anticipated work next quarter:

The test installation will be completed, and a full scale crash test will be conducted on the system according to MASH test designation 4-12 with the 10000S single unit truck.

Significant Results:

Multiple contractors and slipformers were contacted and surveyed concerning the cost to install concrete bridge rails. Specifically, the material and labor costs for the steel rebar and concrete were obtained. Average values for these costs will be utilized to optimize the barrier design.

A single slope barrier shape measuring 2-3 degrees from vertical was selected for the bridge rail to maximize vehicle containment and stability while also remaining constructible through slipforming. General reinforcement patterns were selected to provide cage stability during casting/slipforming and efficiently strengthen the barrier. Various barrier width and rebar configuration combinations were first analyzed using Yield Line Analysis to ensure a minimum strength capacity of 80 kips to satisfy MASH TL-4 impact loads. The material and labor costs associated with both concrete and the steel reinforcement were estimated for each barrier configuration. A table of the lowest cost configurations to satisfy the 80 kip capacity was created for selection of the optimized system. This analysis was completed twice, once for a single slope barrier configuration, and a second time for a barrier shape which contains large chamfer on the top-front corner to minimize the risk of head slap.

An update meeting was held in October with the project sponsors. At this meeting, various barrier design configurations that satisfied the design criteria were discussed. The states were then asked to vote for their most desired barrier configurations. The selected configuration incorporated a single slope front face angled 3 degrees from vertical, an 8" top width, and an installation height of 39". The barrier was reinforced with (8) #5 longitudinal rebar and #4 stirrups spaced at 12" intervals.

A bridge deck was also configured for the full scale test based on existing deck designs from the sponsor DOTs. Details

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 a May 2017 memo, the FHWA declared that eligibility letters will now only be granted to systems that have completed the entire suite of tests within the MASH testing matrix. Since the small car and pickup truck tests (MASH 3-10 and 3-11) were previously deemed non-critical by MwRSF and the Pooled Fund States, they will not be conducted as part of this project. Thus, the concrete bridge rail will not meet FHWA's new criteria to qualify for a letter, and an application for a letter will not be submitted.

Potential Implementation:

Successful development of this optimized bridge railing would provide states with a MASH TL-4 bridge rail option when constructing new bridges or upgrading existing bridges. The barrier will provide unique benefits in that it will be optimized for vehicle containment and stability, load distribution into the deck, head slap mitigation, and cost while also allowing for future roadway overlays.

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 #105	☑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 with Curb and an Omitted Post		
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:**
2611211134001	RPFP-17-MGS-1	10/1/2016
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
9/30/2019	9/30/2019	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
$164,855	$66,560	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
	$8,107	

Project Description:

Curbs located along roadways can adversely affect the interaction of errant vehicles with roadside barriers. Although the two are commonly used in combination, when curbs are placed near guardrail systems, the propensity for vehicle underride, override, and instability increases. The MGS with a curb offset 6 in. from the front face of the guardrail was successfully crash tested to NCHRP Report No. 350 TL-3 requirements. However, the MGS with curb has not yet been evaluated to MASH TL-3.

In addition, roadside obstructions may frequently occur that prevent proper post placement within a run of guardrail. To avoid small obstructions, a single post may be left out of system creating a single enlarged span length of 12.5 feet. The MGS with an omitted post was crash tested to MASH test no. 3-11 and adequately redirected the 2270P pickup truck. However, the introduction of a curb below to the elongated span of an omitted post length may lead to vehicle capture and/or stability issues. omitted posts has never been crash tested to the safety performance criteria of MASH.

Thus, the objective of this research is to evaluate the performance of the MGS with a single omitted post installed with the face of the rail offset 6-in. from the face of the 6-in. tall AASHTO Type B curb. The evaluation of the barrier system behind curb will be undertaken according to the MASH TL-3 safety criteria through two full-scale crash tests with both the 1100C and 2270P vehicles.

Objectives / Tasks:

1. Determination of CIPs
2. CAD Details
3. Construction of test article
4. Full-Scale Testing - MASH 3-10
5. Full-Scale Testing - MASH 3-11
6. Data Analysis
7. System Removal

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

Previously, full-scale crash test, test no. MGSCO-1, was conducted on the MGS with an omitted post placed 6" behind a 6" curb. The test was conducted in accordance with MASH test 3-10 with the 1100C small car. During impact, the W-beam rail was torn at the splice located within the elongated span length created by the omitted post. As a result, the vehicle penetrated through the barrier system. After review, the sponsors decided to change the scope of the project to include a second MASH 3-10 test on the MGS with curb and an omitted post - only this time nested w-beam rail would be placed in the region of the omitted post.

The second full-scale crash test, test MGSCO-1, was conducted according to MASH TL-3 with the 1100C car impacting the MGS with an omitted post placed 6" behind the face of a 6" tall curb. The MGS included 37.5 ft of nested guardrail encompassing the unsupported span length and 2 adjacent posts on each side. During the test, the vehicle was captured and redirected without any evidence of guardrail tearing. Thus, the test passed MASH 3-10 evaluation criteria.

Since the pickup truck test (MASH 3-11) remains to be conducted, a continuation proposal was submitted to the Midwest States Pooled Fund for consideration as part of the 2018 program.

Anticipated work next quarter:

Work will be focused on completing the summary report documenting all testing and conclusions.

Significant Results:

BARRIER VII analyses were utilized to determine the CIPs for MASH TL-3 impacts on the MGS placed 6" behind a 6" curb and with an omitted post. The CIP for the 1100C was determined to be 122" upstream of the first post downstream of the elongated span, while the CIP for the 2270P was determined to be 131" upstream of the first post downstream of the elongated span.

Full-scale crash test, test no. MGSCO-1, was conducted on the MGS with an omitted post placed 6" behind a 6" curb. The test was conducted in accordance with MASH test 3-10 with the 1100C small car. During impact, the W-beam rail was torn at the splice located within the elongated span length created by the omitted post. As a result, the vehicle was not captured, but instead penetrated through the barrier system.

A number of possible retrofits for the system were discussed with the sponsoring DOTs. Through a survey of the Pooled Fund members, the project scope was changed to include a second MASH 3-10 test on the MGS with curb and an omitted post - only this time nested W-beam rail would be placed in the region of the omitted post. The damaged system was then rebuilt with 37.5-ft of nested rail around the omitted post location.

The second full-scale crash test, test MGSCO-1, was conducted according to MASH TL-3 with the 1100C car impacting the MGS with an omitted post placed 6" behind the face of a 6" tall curb. The MGS included 37.5 ft of nested guardrail encompassing the unsupported span length and 2 adjacent posts on each side. During the test, the vehicle was captured and redirected without any evidence of guardrail tearing. Thus, the test passed MASH 3-10 evaluation criteria.

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 failure of test MGSCO-1, the project scope was changed. The second budgeted crash test (MASH 3-11 with the 2270P) was changed to a 2nd MASH 3-10 test on the nested rail retrofit to the system. To complete the evaluation of the MGS with curb and an omitted post (pickup truck test), a continuation project was funded as part of the Year 29 (2018) Midwest States Pooled Fund Program. Since the MASH 3-11 test will not be conducted as part of this project, hardware guide drawings and an FHWA eligibility letter will not be completed as part of this project, but will take place as part of the Year 29 continuation project.

Also, test MGSCO-2 was conducted in March, but the test charges have not been processed. Those charges will be included in the 2018 2nd quarter progress report.

Potential Implementation:

The successful testing and evaluation of an MGS guardrail system with curb and omitted post will allow state DOTs to eliminate one post to avoid an obstruction in a guardrail run installed adjacent to curbs and ensures that its safety performance remains adequate with respect to the current vehicle fleet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

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

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Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(193) Supplement #106	**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 with Curb		
Name of Project Manager(s): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211135001	**Other Project ID (i.e., contract #):** RPFP-17-MGS-2	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2019	**Current Project End Date:** 9/30/2019	**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
$161,926	$68,454	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
	$8,924	

Project Description:

Curbs located along roadways can adversely affect the interaction of errant vehicles with roadside barriers. Although the two are commonly used in combination, when curbs are placed near guardrail systems, the propensity for vehicle underride, override, and instability increases. The MGS with a curb offset 6 in. from the front face of the guardrail was successfully crash tested to NCHRP Report No. 350 TL-3 requirements. However, the MGS with curb has not yet been evaluated to MASH TL-3.

Thus, the objective of this research is to evaluate the performance of the MGS installed with the face of the rail offset 6-in. from the face of the 6-in. tall AASHTO Type B curb. The evaluation of the barrier system behind curb will be undertaken according to the MASH TL-3 safety criteria through two full-scale crash tests with both the 1100C and 2270P vehicles.

Objectives / Tasks:

1. CAD Details
2. Construction of test article
3. Full-Scale Testing - MASH 3-10
4. Full-Scale Testing - MASH 3-11
5. Data Analysis
6. System Removal
7. Summary Report
8. TF13 Hardware Guide Drawings
9. FHWA Eligibility Letter

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

Previously, two full-scale crash tests were successfully conducted on the MGS with curb test installation in accordance with MASH TL-3 evaluation criteria.

This quarter, the data and video analyses of the full-scale tests were completed. Also, the system was removed from the test site, and components were disposed of. Finally, work began on compiling the project summary report.

Anticipated work next quarter:

Work will continue on the summary report documenting the full-scale testing and the recommended guidelines for installation.

Significant Results:

Two full-scale crash tests were conducted on the MGS with curb test installation. The first test, test no. MGSC-7, was conducted according to MASH 3-10 with the 1100C small car. During the test, the barrier captured and redirected the vehicle with controlled system deflections. The W-beam rail was partially torn at the location of the critically loaded splice. This is the same location as the complete rail rupture observed during testing of the MGS with curb and an omitted post. Thus, the standard system (i.e., no omitted posts) provides enough support and strength to prevent the tearing previously observed.

The second full-scale test, test no. MGSC-8, was conducted according to MASH 3-11 with the 2270P pickup truck. during the test the vehicle was captured and smoothly redirected. The impact event caused the guardrail to detail from every post downstream of impact, though the cable anchorage was still intact. After the vehicle lost contact with the the system, it steered back toward the system eventually coming to a stop on top of the downstream anchorage. Although the front tires overrode the guardrail, this was not seen as grounds for failure of the system for multiple reasons. 1) the vehicle had already safely exited the system, so the tire rolling over the downstream end would be a secondary impact on a damaged system. 2) the trailing end anchorage utilized during the test is expected to gate for impacts located downstream of the 6th post form the downstream end, and the secondary impact clearly impacted near post 3. Thus, the system is supposed to gate at this location. 3.) rail release from posts all the way through the anchor posts has been observed in other successful tests on versions of the MGS. This was just the first occurrence of a secondary impact. Thus, test MGSC-8 was deemed a PASS to be consistent with previous testing evaluations.

Objectives / Tasks: % Complete

1. CAD Details 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).

This project was waiting for the testing results of a related project - TPF-5(193) suppl. #105: Testing of the MGS Omitted Post with Curb. The omission of a post is thought to increase the risks of vehicle instabilities and possible capture issues. Thus, it was deemed the more critical of the system installations. If the MGS with Omitted post with curb was successfully tested, this project would likely not be necessary. However, a failure occurred during the evaluation of the omitted post installation. Thus, this project became active after being delayed to observe the results from the related project, TPF-5(193) suppl. #105: "Testing of the MGS Omitted Post with Curb." However, the full-scale crash testing was conducted in a very timely manner, so the project will be completed on time.

Potential Implementation:

The successful testing and evaluation of the MGS guardrail system offset from a 6-in. tall Type B curb would provide state DOTs with a MASH-tested option to install curb adjacent to the MGS. Evaluation of the MGS with curb will allow state DOTs to continue to use this hardware on their roadways and will ensure that its safety performance remains adequate with respect to the current vehicle fleet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

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

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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 #107		☑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): Reid, Faller, Bielenberg, Lechtenberg, Rosenb	**Phone Number:** 402-472-9324	**E-Mail** srosenbaugh2@unl.edu
Lead Agency Project ID: 2611211132001	**Other Project ID (i.e., contract #):** RPFP-17-AGT-3	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2019	**Current Project End Date:** 9/30/2019	**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**
$128,145	$37,956	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**
	$0	

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. A prior project (Pooled Fund YR 25 - TPF-5(193): Development of a Standardized Concrete Parapet for AGTs) ultimately resulted in an unsuccessful full-scale crash test. This project is a continuation of that effort and will utilize the knowledge obtained from the previous crash test.

Objectives / Tasks:

1. Redesign of Standardized Parapet
2. CAD Details
3. Construction of Test Article
4. Full-Scale Crash Testing - MASH 3-21
5. Data Analysis

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

Work continued to complete the summary report, which will detail all design and testing of the standardized buttress along with guidance and recommendations for installing the buttress in real world AGTs.

Anticipated work next quarter:

Work will continue to complete the project summary report.

Significant Results:

Following the unsuccessful full-scale crash test associated with Phase I of this project (Year 25 project), the geometry of the standardized buttress was redesigned to improve the performance of the system. The size of the lower taper was increase from a 4"12" taper to a 4.5"x18" taper. Also, the height of this lower taper was increased from 11" to 14". these changes were done to reduce wheel snag and loads into the axle of the vehicle. the upper taper was changed from 4"x4" to a 3"x4". this reduction in slope was intended to reduce snag on the vehicle bumper and quarter-panel.

The second full-scale crash test, test no. AGTB-2, was conducted on the revised version of the standardized buttress according to MASH 3-21 impact criteria. During the test, the 2270P pickup truck was smoothly redirected by the guardrail transition with limited snag on the standardized concrete buttress. Data analysis showed all accelerations fell within acceptable limits, so the test satisfied the MASH criteria.

A journal paper on the development of the standardized buttress was written and submitted to the Transportation Research Board. The paper submission was presented at the 2018 annual TRB meeting in Washington D.C. and was published in 2018.

Objectives / Tasks:	% Complete
1. Redesign of Standardized Parapet	100%
2. CAD Details	100%
3. Construction of Test Article	100%
4. Full Scale Crash Testing - MASH 3-21	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).

All labor costs are currently being charged to the original project (Pooled Fund YR 25 - TPF-5(193): Development of a Standardized Concrete Parapet for AGTs). Once the YR 25 project funds have been exhausted, charges will be made to this YR 27 continuation project. Test and materials charges were still applied to this YR 27 project.

In a May 2017 memo, the FHWA declared that eligibility letters will now only be granted to systems that have completed the entire suite of tests within the MASH testing matrix. Since the small car test (MASH 3-20) was previously deemed non-critical by MwRSF and the Pooled Fund States, it will not be conducted as part of this project. Thus, the transition buttress will not meet FHWA's new criteria to qualify for a letter, and an application for a letter will not be submitted. Instead, MwRSF's opinion on the crashworthiness of the buttress will be explicitly written in the report and supported with details and references.

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.

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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. #108	**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: MASH Testing of the Thrie Beam Bullnose System – Phase I		
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: 2611211136001	**Other Project ID (i.e., contract #):** RPFP-17-BULLNOSE-1	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2019	**Current Project End Date:** 9/30/2019	**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
$275,477.00	$180,161	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
	$17,923	

Project Description:

The research objective is to conduct full-scale vehicle crash testing on the thrie-beam bullnose median barrier system according to Test Level 3 (TL-3) of the MASH 2016 impact safety standards. The research effort will focus on either the timber CRT post or the UBSP steel-post variation of the barrier system.

The research effort for this study will focus on the evaluation of the thrie-beam bullnose system to the MASH 2016 criteria through a series of full-scale crash tests. The thrie-beam bullnose system is classified as a non-gating crash cushion for the purposes of evaluation. In MASH 2016, as many as ten full-scale crash tests are potentially required to evaluate this type of hardware. Those tests are listed in Table 11.

Out of the ten required crash tests, two tests may potentially be deemed non-critical. Test no. 3-36 on the transition to the rigid structure may not be required as it is assumed that the bullnose will use MASH TL-3 approved thrie-beam approach guardrail transitions for attachment to any rigid structures. Test no. 3-38 is intended to evaluate the performance of mid-sized sedan vehicles with terminals and crash cushions. However, MASH uses an analytical estimation of 1500A vehicle decelerations based on the results of test no. 3-31 to determine whether or not this test is required. Thus, test no. 3-38 may potentially be deemed non-critical as well. MwRSF would need to consult with FHWA officials prior to omitting either test. All ten tests are included herein for completeness.

Due to the extensive number of crash tests required to evaluate the thrie-beam bullnose, MwRSF will phase the full-scale crash testing in order to more efficiently determine the potential for the system to meet the MASH TL-3 criteria. Phase I will consist of evaluation of the bullnose with three of the potentially most critical crash tests, while Phase II will be funded at a later date if the three initial full-scale crash tests are successful.

Phase I

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

MwRSF surveyed the sponsoring states to determine whether they preferred the steel post or timber post version of the bullnose system be evaluated. The responses indicated that steel post version of the system was preferred.

CAD details for the steel post bullnose system were developed and parts were ordered and fabricated. The base plate of the lower portion of the UBSP post was increased in thickness by 1/8" to prevent damage and allow it to be more reusable following an impact. Critical impact points for each of the three tests were also selected.

On March 3, 2017, MwRSF conducted test no. MSPBN-1 according to MASH test designation no. 3-35. For non-gating crash cushions, this test is designed to evaluate a CIP where the crash cushion behavior transitions from capture to redirection with the 2270P vehicle. The critical impact point (CIP) for test designation no. 3-35 was selected at post no. 3, which is halfway between the cable anchor at post no. 1 and the assumed beginning of LON/redirection point at post no. 5. In test no. MSPBN-1, a 5,001 lb. Dodge Ram Quad Cab pickup truck impacted the thrie beam bullnose at a speed of 62.9 mph and an angle of 26.7 degrees. Initial impact occurred, 4 in. downstream of the targeted impact point at post no. 3. After initial impact, the vehicle was captured and safety redirected by the bullnose system. As the vehicle redirected UBSP post nos. 5 through 8 were fractured and disengaged. This created some pocketing and snag at post nos. 9 and 10, which were the first two W6x8.5 posts in the system. However, this behavior did not compromise vehicle capture or stability and did not negatively affect the occupant risk values. Occupant risk values for the test were well below the MASH limits and occupant compartment deformations were minimal. Based on these values and the safe capture and redirection of the 2270P vehicle, this test was deemed acceptable under the MASH TL-3 criteria for test designation no. 3-35.

The second test of the system was conducted on March 22, 2017. Test no. MSPBN-2 was conducted according to MASH

Anticipated work next quarter:

In the upcoming quarter, MwRSF will work towards completion of the summary report of the three full-scale crash tests.

Significant Results:

CAD details of the bullnose system were developed and system fabrication and construction is underway.

Three successful full-scale crash tests were completed 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).

None.Note that because there are two ongoing an related bullnose projects through the Midwest Pooled Fund, MwRSF is depleting the funding from this Year 27 effort prior to charging the Year 28 project.

Potential Implementation:

The thrie-beam bullnose system provides a safe, cost effective, non-proprietary option for shielding of median piers and other median hazards. Evaluation of the barrier system to the MASH 2016 criteria will allow the state DOTs to continue to use this system on their roadways and ensure that its safety performance will remain adequate with respect to the current vehicle fleet.

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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. #109	**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 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: 2611211130001	**Other Project ID (i.e., contract #):** RPFP-16-CONSULT	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/19	**Current Project End Date:** 9/30/19	**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
$56,310.00	$51,109	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
	$6,358	

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/

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.

Midwest States Pooled Fund Program Consulting Quarterly Summary

Midwest Roadside Safety Facility

01-31-2018 to 05-09-2018

Thrie-beam AGT Review

Question
State: NE
Date: 02-02-2018

Anybody,

Our Bridge Approach Section FHWA approval letter is b105

https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/barriers/pdf/b105.htm

Does this bridge approach section meet MASH?

Attachment: https://mwrsf-qa.unl.edu/attachments/55fea7ccf82422547adbdf4a10f9952b.pdf

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Response
Date: 02-07-2018

I have reviewed your Approach Guardrail Transition (AGT) details, specifically the details for the 34" tall transition. I have a few comments:

1. The embedment depth for posts 1 – 8, should be increased by 3". During testing and evaluation, we raised the height of the guardrail and blockout by 3",

but did not shift the post up. We did not want to weaken the stiffness of the transition system by reducing the post embedment depths. Thus, the blockout and rail were extended 3" above the top of the post, and the embedment depths of 54" for the W6x15 posts and 40" for the W6x9 posts were maintained. If desired, you could increase the length of the post so that the tops of the blockout and posts match, but it is not necessary as long as you drill/punch new bolt holes 3" above there typical locations.

2. The 34" tall AGT was tested and evaluated with the standardized buttress. It appears you have the buttress sketched into your details, but I do not see it called out anywhere. Both the 31" and 34" buttresses are only referred to as "concrete rail." . A note on the buttress design should be added to prevent confusion or incorrect installations.
3. Further on the buttress designs – as of now, your AGT attached to the older concrete buttress has not been evaluated to MASH, only NCHRP Report 350. The standardized buttress was tested to MASH criteria win combination with a critically weak AGT, thus it was approved your use will all other thrie-beam AGTs. As such, you should specify the new standardized buttress design for both of the AGT designs. The only difference between the 31" AGT and the 34" AGT would be the height of the buttress. For reference, I have attached 2 drawing sets containing the standardized buttress for both AGT heights.

Attachment: https://mwrsf-qa.unl.edu/attachments/a93f9f013e4028e1bc4ae17902e77a47.pdf

Attachment: https://mwrsf-qa.unl.edu/attachments/01522207b25c61eb05b85f67bad6bb82.pdf

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Kansas Pin and Loop PCB - Transition from freestanding to bolted/permanent on concrete pavement

Question
Date: 02-07-2018

Bob: For Report 350 TL-3 transitions from freestanding PCB on asphalt (2" min) to bolted PCB on concrete, we have specified the Kansas PCB and pinned transition according to details in TRP-03-180-06 (9 steel pins on traffic side over 5 PCBs and nested 12ga thrie beams on front and back at connection to permanent or bolted PCB – Figure 38 on page 63).

We currently need a transition from freestanding PCB on concrete to bolted PCB on concrete, and would appreciate clarification with respect to statements on page 91 of report regarding asphalt and bolt-through concrete tie-down systems are believed to possess similar lateral restraint and thus can be interchanged in the transition design as needed. Would it be acceptable to drill through 8" to 9" thick concrete pavement on the transition and use 9 standard 1-1/2" dia x 38-1/2" long A36 steel pins that are normally used for asphalt as we can't use the 1-1/8" dia A307 threaded rod?

While reviewing this issue, we also reviewed TRP-03-208-10 which has a MASH TL-3 transition from freestanding PCB on asphalt (3" min) to bolted PCB on concrete. We noticed a similar statement on page 109 regarding asphalt pin and bolt-through tie-down systems are believed to possess similar lateral restraint and can thus be interchanged in the transition design as needed. As asked in previous paragraph, would it be acceptable to drill through the concrete and use the steel pins normally used for asphalt.

With respect to the MASH TL-3 transition from freestanding PCB to permanent concrete median barrier, for transitions to bolted or permanent concrete roadside barrier (such as on a bridge with traffic on one side only), are the steel pins needed on both sides of the PCB (9 x 2 = 18 pins over four PCBs) when traffic is on one side only?

Response
Date: 02-08-2018

Good to hear from you. Comments are below in red.

Bob: For Report 350 TL-3 transitions from freestanding PCB on asphalt (2" min) to bolted PCB on concrete, we have specified the Kansas PCB and pinned transition according to details in TRP-03-180-06 (9 steel pins on traffic side over 5 PCBs and nested 12ga thrie beams on front and back at connection to permanent or bolted PCB – Figure 38 on page 63).

We currently need a transition from freestanding PCB on concrete to bolted PCB on concrete, and would appreciate clarification with respect to statements on page 91 of report regarding asphalt and bolt-through concrete tie-down systems are believed to possess similar lateral restraint and thus can be interchanged in the transition design as needed. Would it be acceptable to drill through 8" to 9" thick concrete pavement on the transition and use 9 standard 1-1/2" dia x 38-1/2" long A36 steel pins that are normally used for asphalt as we can't use the 1-1/8" dia A307 threaded rod?

There are a couple of options here. First, I should note that the free-standing PCB to concrete bolted PCB transition for roadside applications has not yet been evaluated to MASH. The median transition was however evaluated to MASH. Both the median and roadside designs were evaluated with the asphalt pins. The roadside and median transitions use similar pin configurations, but the median transition was designed for attachment to taller, concrete median barriers and used pins on both sides of the system. Pins were applied to the both sides of the median transition to prevent the potential for impacting a the barrier in a region that only has pins on the backside of the PCB. Previous research at MwRSF and CALTRANS has suggested that pins on only the backside of the PCBs can promote tipping of the barrier which can increased vehicle climb and instability.

Additionally, you are correct that we have noted in past PCB transition reports that the bolt and pin tie-downs would have similar barrier restraint and that either could be used in the transition.

Previously, we have been asked about installing the 1.5" diameter pins through concrete pavement with an asphalt overlay. At that time, we noted that it was believed that the asphalt pin tie-down could be used with concrete pavement with an asphalt overlay. This would be stiffer that what we originally tested, but we think it is was a viable option. The pins should not fracture, but would tend to bend and pull up. We believed that they will constrain the barriers.

Your request is somewhat similar in that you are installing the pins through 8"-9" of concrete with no overlay. I think that this would fall somewhere between the stiffness of the asphalt pin and bolted anchorages. I would recommend that the drill holes be only 1/16" to 1/8" larger than the pin diameter. This would be a maximum bit size of

1.625". The hole in the pavement needs to be kept as small as possible to make the pin engage as soon as possible during the impact. For installation, it may be easier to set the barriers down and then drill through the existing holes in the barrier as guides to make sure the pins will fit.

A potentially better option would be to use the bolted option with shorter epoxy rod embedment. We recently re-evaluated the bolted tie-down for the F-shape barrier as part of MASH Implementation updates. In this MASH testing, we used 1 1/8" dia. A307 threaded rods similar to the previous NCHRP 350 testing, but we only embedded the rods 5 ¼" into the concrete. This test met MASH TL-3 criteria, but the report is not completed. System drawings are attached. Use of this reduced embedment anchor rod would probably be the best option for you in the transition when installed on a 8"-9" thick concrete pavement.

While reviewing this issue, we also reviewed TRP-03-208-10 which has a MASH TL-3 transition from freestanding PCB on asphalt (3" min) to bolted PCB on concrete. We noticed a similar statement on page 109 regarding asphalt pin and bolt-through tie-down systems are believed to possess similar lateral restraint and can thus be interchanged in the transition design as needed. As asked in previous paragraph, would it be acceptable to drill through the concrete and use the steel pins normally used for asphalt.

The same logic would apply here. The asphalt pins could potentially be used, but the minimal embedment anchors that were recently MASH tested would likely be a better solution.

With respect to the MASH TL-3 transition from freestanding PCB to permanent concrete median barrier, for transitions to bolted or permanent concrete roadside barrier (such as on a bridge with traffic on one side only), are the steel pins needed on both sides of the PCB (9 x 2 = 18 pins over four PCBs) when traffic is on one side only?

If you have traffic on one side only, then the backside pins are not likely needed. As noted above, they are there to provide to prevent barrier tipping during reverse direction traffic impacts. I believe that the stiffness transition from free-standing to fixed barrier would be adequate with only the frontside pins. You would want to follow the snag reduction guidance for PCB alignment with the concrete median barrier and the use of the upper steel cap if the concrete median barrier has increased height.

Attachment: https://mwrsf-qa.unl.edu/attachments/04183f2a6305149e3dd0e8ad5da95111.pdf

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Vertical Taper Rate for Concrete Barrier

Question
State: VA
Date: 02-08-2018

What vertical taper rate would you recommend for concrete barriers?

We have seen vertical tapers as high as 5:1 in some MwRSF research.

Response
Date: 02-09-2018

A vertical taper of 5:1 was used with a steel cap to mitigate vehicle snag on a barrier end above PCBs as they connected to a taller permanent barrier. For vehicle sheet metal to steel cap contact, vehicle performance was acceptable in that crash test.

https://mwrsf.unl.edu/researchhub/files/Report54/TRP-03-208-10.pdf

If vehicle contact to a concrete taper is similar enough, then one may argue to go that route. I do believe the friction and gouging are higher in the later scenario. Although it may be possible to use 5:1, a more conservative route would be to use the 6:1 that Scott had incorporated into the standardized buttress, which demonstrated acceptable crashworthiness in the 2270P transition test.

Trailing End Strut

Question
Date: 02-09-2018

Please see information from Georgia standard plans, provided by Guy Laprade of Trinity Highway

It appears, GDOT is utilizing a C6 x 8.2# Structural Channel Strut in their trailing end terminal. This GDOT terminal is similar to the Downstream Anchorage System that MwRSF tested for WDOT (see link), which incorporated a 10ga x 6" 3 " Formed Channel Strut.

Recognizing that the C6 x 8.2# Structural Channel Strut and the 10ga x 6" x 3" Formed Channel Strut has been somewhat "interchangeable" in the past … would MwRSF offer any guidance as to the acceptability of the 10ga x 6" x 3" Formed Channel Strut in lieu of the C6 x 8.2# Structural Channel Strut of a similar trailing end terminal within MASH Testing and MASH Framework?

We also recognize that Georgia is not a member of the Midwest Pooled Fund Program – we were reaching out to your group in the hopes that you may be aware of testing or such that is available regarding the interchangeability of these struts with the increased loading associated with the vehicles used for testing in NCHRP Report 350 vs. MASH.

Attached is the new GA DOT std of the 31" trailing end showing the C6X8.2# channel strut

The link below shows the MW trailing end with detail showing the 10ga strut…you'll have to scroll down a few pages to see the detail.

https://mwrsf.unl.edu/researchhub/files/Report279/DS-Anchorage-32in_R3.pdf

Thanks

Response
Date: 02-09-2018

As a sample, I did check into our original MASH testing on project no. 22-14(2) with 2270P and 1100C vehicles as well as later MASH testing on MGS Long Span with 2270P vehicles. For that testing, and likely some more after that period, we were using the C6x8.2 channel section for trailing-end anchorage systems that developed the tensile capacity for the guardrail used in those tests.

Years later, we switched to or starting receiving a folded plate design in lieu of the C section. For example, we used the folded plate in the MASH MGS Minimum Length Guardrail Study for the Wisconsin DOT based on photographs, report content, and CAD details. The cert is also attached, although it just says strut and not actual size back in the day. The plans within the report specified a 6x3 by 10 gauge folded section.

Overall, I believe that the C-section would work in trailing-end anchorage terminal based on the many MASH 2270P full-scale crash tests that have been performed over the years and which have loaded up the end anchorages with high tension.

Response
Date: 02-10-2018

Thanks for the preliminary information, we look forward to any other guidance that could be offered and we could share with the Georgia DOT folks.

Would you please clarify this sentence?
"Overall, I believe that the C-section would work in trailing-end anchorage terminal based on the many MASH 2270P full-scale crash tests that have been performed over the years and which have loaded up the end anchorages with high tension."

By "C-Section" are you referring to the C6 x 8.2# Structural Channel Strut or the 10ga x 6" x 3" Formed Channel Strut? Currently the Georgia spec requires the C6 x 8.2# ... and MwRSF has ran several tests with the 10ga x 6" x 3" Formed.

The inquiry was to obtain guidance on whether the 10ga x 3" x 6" Formed Channel Strut could be used instead of the C6 x 8.2# Structural Channel Strut.

Please respond as you time permits and please have a safe and GREAT weekend.

Response
Date: 02-11-2018
I believe that either section can be used interchangeably for the channel strut as they both have been used in MASH crash testing with 2270P vehicles on various MGS guardrail systems.

Response
Date: 03-23-2018

We appreciate your assistance in regards to the "interchangeability" of the Structural C6x8.2# Channel Strut and the 10ga x 6" x 3" Formed (or Folded) Channel Strut – as both have been used in MASH testing with 2270P vehicles in various MGS systems.

We have been approached by another state DOT and asked if we could provide a short listing of relevant MASH tests for each of the two products (struts). Would this be something that we could ask of MwRSF – a listing of a few of the MASH tests in which the two interchangeable channel struts were utilized on?

Trinity's hope is to provide this information to this state (and perhaps others going forward) in an effort to encourage "Standardization" of products which have been MASH tested – instead of each state creating a product (in this case a strut) of their own and which may or may not have been utilized within a MASH test.

In that regard – IF MwRSF can provide us with a few examples of MASH tests which have been conducted using each of these struts – may we in turn supply this information to various DOT agencies? To include this email string?

We understand that MwRSF is NOT endorsing one strut over the other (and we note that both struts are non-proprietary) – instead MwRSF is just providing information that can be utilized by the State DOT specifiers.

Response
Date: 04-25-2018
I am sorry about the late email response regarding this topic. Below, I will list some crash testing examples where each strut type was utilized, including links to reports.

C6x8.2
As a sample, I reviewed MwRSF's original MASH testing on NCHRP Project No. 22-14(2) with 2270P and 1100C vehicles as well as later MASH testing on MwRSF's MGS Long Span with 2270P vehicles. For those crash testing efforts, and likely others after that period, MwRSF used C6x8.2 channel sections for trailing-end anchorage systems to anchor our guardrail systems. These anchorages developed the tensile capacity for the W-beam guardrail elements that were used in those tests.

Test 2214MG-3 (1100C)
https://mwrsf.unl.edu/reportresult.php?reportId=137&search-textbox=22-14

Test 2214MG-1 (2270P)
https://mwrsf.unl.edu/reportresult.php?reportId=138&search-textbox=22-14

Test 2214MG-2 (2270P)
https://mwrsf.unl.edu/reportresult.php?reportId=149&search-textbox=22-14

Test LSC-1 (2270P)
Test LSC-2 (2270P)
https://mwrsf.unl.edu/reportresult.php?reportId=109&search-textbox=long-span

6x3 Bent/Formed Channel

Years later, MwRSF switched to or starting receiving a folded plate design in lieu of the C section. For example, MwRSF used the folded plate in the MASH MGS Minimum Length Guardrail Study for the Wisconsin DOT based on photographs, report content, and CAD details. I have also provide a sample report for the MGS testing with rectangular wood posts.

Test MGSMIN-1 (2270P)
https://mwrsf.unl.edu/reportresult.php?reportId=281&search-textbox=minimum%20length

Test MGSSYP-1 (2270P)
Test MGSSYP-2 (1100C)

https://mwrsf.unl.edu/reportresult.php?reportId=282&search-textbox=mgs

Summary

Overall, I believe that the C-section and C^x8.2 channel section can be used in lieu of one another for anchoring guardrail systems. Both sections would work in the non-proprietary, downstream, trailing-end, anchorage terminal based on the many MASH 2270P full-scale crash tests that have been performed over the years and which have loaded up the end anchorages with high tension.

Please let me know what additional information may be required. Thanks!

Transition from anchored TBR to unanchored TBR

Question
State: IA
Date: 02-13-2018

I have a couple of questions I'm hoping you can answer in less time it would take me to research them. With Khyle Clute and Brian Smith both recently departing our Methods Section, my time to research issues is very limited.

We are developing a detail to show a transition from anchored TBR to unanchored TBR. I have perused TRP-03-180-06 and see a transition was developed for rigid to free-standing TBR (Figure 32 of TRP-03-180-06) based on pinned barrier. Do you know if anything has been (or is being) developed for TBR anchored using tie-down straps?

For an anchored installation with crash cushions to protect the ends, what is the minimum number of TBR sections needed to develop the full strength in the system to limit deflection to the 6 inches shown in our BA-401?

Thank much for your assistance!

Response
Date: 02-13-2018

Hi Daniel,

Responses below in red.

I have a couple of questions I'm hoping you can answer in less time it would take me to research them. With Khyle Clute and Brian Smith both recently departing our Methods Section, my time to research issues is very limited.

- We are developing a detail to show a transition from anchored TBR to unanchored TBR. I have perused TRP-03-180-06 and see a transition was developed for rigid to free-standing TBR (Figure 32 of TRP-03-180-06) based on pinned barrier. Do you know if anything has been (or is being) developed for TBR anchored using tie-down straps?

  No transition design has yet been developed with the tie-down straps. The straps have significantly higher deflections that the other two anchorage systems. It could potentially be done, but has not been attempted at this time.

- For an anchored installation with crash cushions to protect the ends, what is the minimum number of TBR sections needed to develop the full strength in the system to limit deflection to the 6 inches shown in our BA-401?

  This question is a little more involved. First, the roadside PCB to rigid barrier transition has not been tested to MASH at this time. The median version has, but that uses pins/anchors on both sides of the approach PCB segments.

Second, the asphalt pin tie-down shown in the detail was tested to MASH in November and did not pass due to snag on the PCB joint. MwRSF conducted full-scale crash test no. WITD-2 on the asphalt anchorage of the F-shape PCB. In this test a 2270P vehicle impacted the barrier system installed 6" from the a 3-ft deep vertical trench at 62.0 mph and an angle of 25.1 degrees. During the impact, the vehicle was captured and stably redirected. All of the barrier segments were retained on the asphalt and the maximum dynamic deflection of the barrier was 24.5". However, the left front wheel of the pickup truck snagged on a joint between adjacent PCB segments and was pushed back into the floor pan. This resulted in intrusion and opening of the floor pan in the occupant compartment with a small portion of the wheel extending into the occupant compartment. As such, this test was deemed unsuccessful under the MASH TL-3 impact conditions. Potential system design revisions were noted to the sponsor and a follow-on research project was proposed for the Midwest States Pooled Fund Year 29 research program.

Third, the transition designs we have tested were all developed for connection to rigid concrete barriers. They have never been evaluated with crash cushions or their connection to the PCB. This issue has been brought up previously by several states, but it is difficult to develop a transition to all of the proprietary crash cushion systems. Additionally, transitions between PCBs and crash cushions is allowed by many manufacturers, but I am not aware of them being tested in the configuration. The transitions we have developed may potentially work with crash cushions, but I wanted to let you know that we did not design them for that and they have not been evaluated in that manner. Vehicle snag and the transition in stiffness may not be the same.

With regards to the question of the number of PCB segments needed to generate similar deflections to the original anchors PCB adjacent to a drop-off, that question has several aspects. First, the tested system had deflections higher than the 6" shown in your detail. The 6" gap was sufficient for crash testing to maintain all of the barriers on the pavement without falling into the trench. However, the deflection was higher (approximately 21.8" of dynamic deflection at the top of the barrier and 11.1" of permanent set deflection at the base. These deflections were due to rotation of the top of the barrier and disengagement of the soil/asphalt adjacent to the trench. We would expect lower deflections if the trench was not present, but testing of the bolted tie-down anchorage for the F-shape PCB under MASH resulted in a dynamic deflection o 14.1" at the top of the barrier. This is still higher than the 6" in your detail.

The second aspect is how many barriers do you need to develop the tested system deflections. That question is based on a couple of factors, including the overall system length and the distance to the end. This analysis has not been done for anchored PCBs, but we did look at it for free-standing PCBs.

https://mwrsf.unl.edu/researchhub/files/Report331/TRP-03-337-17.pdf

For free-standing PCBs, we found a minimum system length of nine barriers was recommended with three barriers upstream of the beginning of LON and five barriers downstream of the end of LON. For anchored PCBs we would expect system length to have less of an effect on the overall length and the barriers upstream and downstream of the LON, but this has not been analyzed or evaluated. An anchored PCB system would tend to engage the upstream and downstream PCBs much less than free-standing systems and would not require the upstream and downstream barrier mass and friction to restrain barrier motions. It would seem reasonable that the guidance for free-standing barriers would be adequate for anchored installations. The minimum length free-standing PCB system required additional barriers on the downstream end of the system. For an anchored system, this would not likely be necessary as the anchors provide most of the lateral resistance for the barriers. Thus, a more reasonable recommendation for anchored PCBs would be a minimum system length of seven barriers with three barriers upstream of the beginning of LON and three barriers downstream of the end of LON. Again this has not been formally evaluated, but it seems reasonable based on the data we currently have.

Temporary Barrirer-Reinforcement

Question
State: WI
Date: 02-21-2018

A temporary barrier manufacturer is indicating that they can bend the 6A2 bar as one piece. They want to replace the two 6A2 near the barrier anchor holes with one bent bar. Knowing how important that reinforcement is for holding a barrier in place when anchor, I don't know if it is a good idea.
Attachment: https://mwrsf-qa.unl.edu/attachments/997727558417fc8c047901542b85e313.jpg

Attachment: https://mwrsf-qa.unl.edu/attachments/c2de21735821f41aa91d3fb56e86f4a2.jpg

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Response
Date: 02-23-2018
We don't believe that it would be an issue to do the two "U"-shaped bars as a single piece as shown in the attached schematic. We would recommend that the overlap of the single piece bar be at least 10" in order to provide similar development on the non-continuous side as the previous two piece configuration.
Attachment: https://mwrsf-qa.unl.edu/attachments/ec2cb585a8391fe80e30c21f32b1dfaf.jpg

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MASH Bridge Rail Modifications

Question
State: IA
Date: 02-22-2018

I was asked by our Bridge Engineer, how much we can change an existing MASH tested TL-4 bridge barrier rail.

For example, we will probably use stainless steel in our bridge rails instead of epoxy. Would this constitute a big enough change that needs testing under MASH?

We also have a MASH TL-5 tested median barrier (see below left), if I use the face shape on a bridge (half section below right), with the same steel area per foot, would we have to get it crash tested?

Thanks for your help. This MASH stuff is a little confusing.

Attachment: https://mwrsf-qa.unl.edu/attachments/b53178c5bec8cef121f8d091065acbbb.png

Attachment: https://mwrsf-qa.unl.edu/attachments/6426ec23e2c46a45c9aa734d2413db35.png

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Response
Date: 02-23-2018

Hi Stuart

Responses below.

I was asked by our Bridge Engineer, how much we can change an existing MASH tested TL-4 bridge barrier rail.

For example, we will probably use stainless steel in our bridge rails instead of epoxy. Would this constitute a big enough change that needs testing under MASH?

I don't see an issue with changing to stainless steel reinforcement as long as a couple conditions are met. First, you would want to ensure that the stainless steel has a similar grade (yield, UTS, elongation) to the A615 Grade 60 rebar typically used. Second, it would be a good idea to verify that the stainless steel rebar has similar lap and development lengths as the standard rebar. It is likely similar, but worth checking. If you can verify those points, I don't see any big issues with changing the rebar from the current A615 spec in terms of crashworthiness of the rail.

We also have a MASH TL-5 tested median barrier (see below left), if I use the face shape on a bridge (half section below right), with the same steel area per foot, would we have to get it crash tested?

Because you are changing the width of the barrier, you would have to check more than just steel area per foot. The width of the barrier will affect the overall capacity and the anchorage of the barrier. Thus, we would expect the narrower section to potentially need more reinforcement and different anchorage configuration. That said, we believe that you could do that type of analysis with yield line theory to develop an equivalent configuration, and that should not require additional crash testing. Single slope barriers and vertical barriers have previously been tested to MASH with the passenger vehicles. You have not changed the basic barrier geometry and have slightly widened the top of the barrier, so the redirection of the TL-5 tractor trailer would be acceptable. Capacity is the only real issue and that can be confirmed with yield line theory.

Thanks for your help. This MASH stuff is a little confusing.

Yes. Yes it is. We are happy to help.

Bridge Rail Rating Inquiry

Question
State: MO
Date: 02-27-2018

Has this barrier been rated? And, what is it?

4000 psi concrete
60 ksi reinforcement
Grade 50W steel posts @ 6' cts. and rails

Long steel is 6-#4s
Transverse steel is #4 @ 8"

Attachment: https://mwrsf-qa.unl.edu/attachments/a578d0b2a8848447d4fedc57eefa9d52.png

Attachment: https://mwrsf-qa.unl.edu/attachments/2abb73200e056ad625087a845bb88edb.jpg

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Response
Date: 02-28-2018

I have reviewed the report for NCHRP Project No. 20-07 Task 395 to determine if this railing, or something similar to it, has been evaluated against the MASH 2016 safety performance guidelines and estimated design impact loading. Within the report, two bridge railings seem to be somewhat similar: (1) aesthetic parapet tube B-25-J railing from Michigan [pages 102-105 and 180-187] and (2) S-352 series steel tubing concrete combination railing from Vermont [pages 107-109 and 198-208].

From a quick review, it is evident that the two railings in the NCHRP report have an additional, lower railing that has been added between the upper rail and the parapet. Both systems use six No. 4 longitudinal bars with 60 ksi steel. The Grade 60 vertical steel consists of No. 4 bars at 8 in. centers for both systems. The posts and upper rail have similar sizes. Your detail does not depict a lower steel tube rail.

TTI researchers have rated the two systems as expected to meet MASH Test Level 4. At this time, I do not have access to the research that led to the addition of a second steel rail, which was likely added to mitigate vehicle snag on posts with passenger vehicles. I will inquire to my colleagues to see if they know any additional history.

Attachment: https://mwrsf-qa.unl.edu/attachments/2ab288bd577e6a5370e767084a891983.pdf

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TL-4 MINNESOTA COMBINATION TRAFFIC/BICYCLE BRIDGE RAIL - TRP-03-74-98 - November 30, 1998

Question
State: MN
Date: 02-28-2018

With respect to referenced report, page 18 and 19 shows the cycling rail attached to the back of a Report 350 TL-4 NJ bridge rail with a top width of 230mm (9.0"), bottom width of 460mm (18.1"), and height of 810mm (31.9"). Is the 230mm offset from traffic side of top of traffic barrier to the face of the retrofit cycling rail critical for Report 350 TL-3 performance? Our older existing TL-3 NJ traffic barrier that we are proposing to add the Minnesota cycling rail to back of has a top width of 155mm (6.1") and height of 825mm (32.5"). This would result in a reduced offset from top of traffic face of barrier of only 6" to face of cycling rail instead of the crash tested design with an offset of 9". The TL-3 crash test does show the pickup engaging the cycling rail during the TL-3 test, which would result in more engagement during an impact with cycling railing offset only 6" vs 9" (although system brackets are designed to fail with tubes staying connected to bridge via cables).

On page 73, it was "recommended that consideration be given to modifying the design in order to reduce the potential for the vertical spindle bars from releasing from the system and decrease any hazard from flying debris. These design considerations may include the following: (1) increasing the strength or the connection between the tubular rails and the spindle bars; (2) attaching a longitudinal railing member to the traffic-side face of the spindle bars and at the mid-height between the two rails; (3) reducing the mass of the spindle bars by using small tubes; and (4) moving the spindle bars to the back side of the tubular rails to increase the strength of tile welded connection."

Are you aware if any of above considerations have been made implemented for this system, or whether a fifth option would be acceptable involving elimination of the spindles (assuming our code would allow a horizontal gap between the two rails of approximately 15" when placed above a 32" high NJ barrier)? It is my understanding the spindles don't have a structural function.

Attachment: https://mwrsf-qa.unl.edu/attachments/c6a640b398b782f7b44fc8ce2a096a2e.png

Response
Date: 03-01-2018

We do believe that the combination rail offset plays a role in the performance of the bridge rail tested in TRP-03-74-98. Reduction of that offset may adversely affect the performance of the barrier due to increased interaction with the combination rail as you noted below. While the reduced offset may potentially work, we cannot recommend it without further research and/or testing. You can see in the attached report that vehicle interaction with the combination rail can be a significant issue in these tests of a different combination rail that used a single-slope barrier and slightly less offset.

https://mwrsf.unl.edu/researchhub/files/Report136/TRP-03-162-07.pdf

We have discussed placement of the combination rail on a 36" single slope with MnDOT. However, that modification was believed to reduce interaction with the combination railing.

https://mwrsf-qa.unl.edu/view.php?id=1141

We did note in the report that the spindle bars could be modified to reduce disengagement of the spindles. We have not seen those recommendations implemented to the best of my knowledge. MnDOT may have more thoughts on that.

Elimination of the spindles is a potential option. As you noted, they are not structural. They are required to meet pedestrian rail criteria for rail openings.

Thanks

Tolerance on the Length of Wood Guardrail Posts

Question
State: WY
Date: 03-08-2018

Have you ever encountered any established tolerances on the length of wood guardrail posts?

Response
Date: 03-08-2018

I don't believe that I have ever seen established tolerances for wood post lengths, but I have some thoughts.

We generally use a relationship to describe the changes in post-soil forces that varies with the square of the ratio of the embedment depths of the post.

$F_2 = F_1(d_2/d_1)^2$

So, if we increase embedment depth from 40" to 43", we expect the post-soil forces to increase by a factor of 1.156.

The concern with wood post with increased lengths would be that increased length could significantly increase the post-soil forces and lead to fracture of the wood post rather than rotation through the soil. Fracture of the post can lead to pocketing, increased rail loads and fracture, and vehicle instability similar to a system with an omitted post.

Based on these concerns, we would recommend that the post length tolerance for wood posts be around plus or minus 2". For a 40" post embedment, this limits the variation in post soil forces to around 10%. Variation more than this may start to adversely affect barrier performance.

Let me know if you need anything else.

MGS Transition Connector Problems

Question
State: MO
Date: 03-08-2018

We have a couple of problems/requests for expert opinion related to transition section connections to concrete bridge railing.

Problem No. 1

There is a need to retrofit MGS transition section connector plate (which is same as NCHRP 350 Transition section connector plate developed as part of MwRSF Research Report No. TRP-03-69-98, "Two Approach Guardrail Transitions for Concrete Safety Shape Barriers") to fit our earlier/older style concrete bridge rail safety shape (aka Safety Barrier Curb, SBC). The connector plate will only work with some modifications. Is our proposed connector plate modifications acceptable?

See attached:

Proposed_Bridge_Anchor_Field_Modification.pdf The problem and MoDOT's field solution

Proposed_Revised_Bridge_Anchor_Section.pdf Proposed connector plate modification

60660B.pdf MGS transition connector plate (the standard)

60660C04.pdf Modified connector plate (proposed modification to standard)

60660C05.pdf Modified connector plate (proposed modification to standard)

Problem No. 2

There is a need to connect MGS transition section to 29" vertical concrete bridge rail without replacing concrete bridge rail end. This would require transitioning vertically from 31" down to 29". Currently, MoDOT transitions to a double W-Beam terminal connector/transition which is to be upgraded to a MGS transition. We are asking for an acceptable transition connection.

See attached:

Needed_Transition_for_29_Inch_Vertical_Barrier.pdf
Attachment: https://mwrsf-qa.unl.edu/attachments/f51b4a0924597b354d75bb2c5bd65212.jpg

Attachment: https://mwrsf-qa.unl.edu/attachments/131d1af26f3d48d025c0404a41ab7334.jpg

Attachment: https://mwrsf-qa.unl.edu/attachments/a44a8cdebfb6eaf17f9607c3ec6682a4.zip

Attachment: https://mwrsf-qa.unl.edu/attachments/7381ebb0ed030fce7f48399fb7a2dc7f.pdf

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Response
Date: 03-12-2018

Dr. Faller is placing some stacked W-beam reports in a Box folder for you to reference. The design tested at TTI under test 404211-12 has an FHWA eligibility letter, see attached. This transition design was a modified version of a NCHRP Report 230 tested design, which was approved by FHWA in a technical memo – see link below

https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/barriers/techadvs/archive/t504026/

Scott

Response
Date: 03-13-2018

Scott:

Crash test shows metric height from ground to center of top W-rail at 550mm (top of guardrail). Our structures use 21" (533mm). I assume this is acceptable.

In general, are bridge anchor sections still acceptable when approaches are overlaid that would reduce effective height of rail? Specifically, is this transition acceptable when approach is overlaid?

Gregory Sanders, P.E.

Response
Date: 03-15-2018

There are a few small differences between your old transition standard and the one crash tested to NCHRP Report 350 and approved by FHWA. However, I believe the ¾" height difference would have a minimal effect on performance. Thus, you could make the argument that your existing transitions are NCHRP Report 350 TL-3 compliant.

During our conference call this week, you expressed that you will be attaching MGS to the upstream ends of these existing transitions. The bridge railings and parapets in which the transitions are attached to are only 29" tall, so you will not be able to raise the height of the transition rails to match up with MGS. Note, TTI recent conducted a study in which the height of the upper W-beam rail was increased to 31", but the system failed to satisfy MASH criteria during crash testing. Thus, you will need a height transition between 31" MGS and the 27" transition, and your transition section will not be MASH crashworthy.

In order to create a MASH crashworthy transition, you will need to remove/replace the ends of the concrete barrier to match a MASH tested system. This retrofit would be costly. You had stated that you have not observed safety issues with the existing transitions, so upgrading the transitions would have limited benefits as the existing system is NCHRP 350 crashworthy. As such, I recommend leaving the transitions in place (as part of the bridge rail) when the adjacent guardrail is replaced with MGS.

To transition between the existing transitions and MGS, you will need a height transition – from 27" to 31", respectively. MwRSF has been recommending that such height transitions be done gradually over a distance of 50-ft. Additionally, the height transition should start upstream of the stacked w-beam transition, which would include rub rail and reduced post spacing. So, the height transition should begin at the 9^{th} post upstream of the bridge rail.

I do not think these transitions would remain crashworthy if an overlay raised the height of the roadway 2-3 inches. These transitions are already short (at 27"), and further reducing this height could have major effects on the performance of the system. At this time, it is not known if a 31" tall guardrail transition would maintain its crashworthiness if the height was reduced. I have not found any thrie-beam transitions to pass TL-3 criteria (either NCHRP 350 or MASH) with a height less than 31". Most of the shorter height transitions resulted in rollovers. If an overlay is necessary, you may want to grind down the pavement prior to the overlay so that the roadway height remains the same.

For future installations, MwRSF and NDOT are currently finishing a project to develop a 34" tall guardrail transition system – which would make it crashworthy as installed and after a 3" overlay is added. The system has been successfully crash tested to MASH TL-3. The report is not yet completed, but I can supply you with further details if you are interested.

W-beam Adjacent to Slopes with 11' long Posts

Question
State: NE
Date: 03-21-2018

This AASHTIO training refers to 11' posts

Where was this tested?
Attachment: https://mwrsf-qa.unl.edu/attachments/7b615d939c323c9be2529cd381a4edb6.png

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Response
Date: 03-22-2018

I don't believe that this has been tested. This comes from the Washington DOT standards. TTI is currently looking into guardrail on steeper slopes, but the project is not finished.

I would not recommend installations as shown with the 11' posts on steep slopes. Case 5 has not been tested either. Case 4 was evaluated to MASH at TTI.

https://www.roadsidepooledfund.org/placement-of-guardrail-on-slopes-phase-iii-603221-2/

Thanks

Concrete Barrier Connector Plate

Question
State: VA
Date: 03-22-2018

We are reviewing the options for connecting thrie beam to different types of barrier and it appears there are a few different designs that have been used. I have attached the 3 designs I have found and was wondering if any of the designs perform any better than another.

The TRP-03-175-06 version that was used in the 2006 crash tests looks like it was the latest version of the detail. We would like to use this design with both constant slope barrier and F shape barrier with some minor modifications to fit each barrier.

Do you see any issues with the 2006 design being used since the angled plate is shorter? Also would minor modifications to this design to fit specific barriers warrant further crash testing?

Any information or guidance you could provide would be appreciated.

Response
Date: 04-02-2018

TRP-03-47-95

In the mid-1990s, we developed a MoDOT thrie beam median transition to a single-slope concrete median barrier. In the first crash test (MTSS-1) into design no. 1, several barrier behavior problems were observed, which contributed to a failed 2000P crash test. Following this test, several design modifications were incorporated, including a shortened steel thrie beam connector plate to allow thrie beam space to gradually deform backward at end of parapet, shortened blockout to allow lower thrie corrugation to deflect backward, flattened vertical slope for top of barrier at end, and tapered steel blocks and recessed posts at top to reduce vehicle snag.

For the re-test (MTSS-2) on design no. 2, the modified thrie beam median transition to single-slope barrier demonstrated improved safety performance. In your attached pdf, you will note that the steel apparatus was shortened from 50¼ in. to 40 in., and it did not extend to the end of the buttress.

TRP-03-69-98

In the mid-1990s, we developed an IaDOT thrie beam roadside transition to a New Jersey concrete roadside barrier under NCHRP Report No. 350 using four 2000P crash tests. Two unsuccessful and two successful crash tests were performed. Two tests with wood posts, and two tests with steel posts. The NJ Steel connector plate was approximately 32 in. long. Again, the end of the connector plate did not extend to the end of the buttress. The sloped end was 12 in. long versus the 20 in. long due to the narrower lateral top plate width over which to transition the sloped end.

TRP-03-175-06

In the mid-2000s, we retested the Iowa transition under MASH using a 2270P vehicle. The steel connector plate did not change from that used in the 350 testing program.

Lateral Slope Change

For the general configurations, the single-slope connector plate has a lateral slope of 3-13/16 over 20, or 1/5.25. The NJ connector plate has a lateral slope of 2-3/8 over 12, or 1/5.05. These two slopes are approximately equal. To provide similar behavior under reverse-direction crashes, we should maintain this slope or provide an even flatter lateral slope.

Note that we did not crash test the two parts in the reverse-direction. Minor changes may be acceptable. However, a much steeper slope may cause more concern for vehicle snagging on the end or too rapid of the change that may contribute to instability.

When we studied lateral slope changes on the face of concrete barriers with computer simulation, we iterated to a flatter slope. The more gentler slope consisted of a 1:10.

TRP-03-335-17

We completed another study involving a transition from MGS to F-shape PCBs in 2017. A W-beam steel connector plate was attached to PCBs and evaluated under MASH in two directions. For reverse-direction crashes with the 1100C vehicle, the connector plate had a lateral slope of 2-1/2 over 12, or 1/4.80. Again, the slope is close to 1/5 in combination with a PCB system that can translate under lateral loading.

Overall, I think that it may be best to try to maintain the lateral slope that has been used in prior steel connector plates. Of course, some minor deviation in lateral slope would seem to be reasonable. In fact, MoDOT has been developing some revised connector parts to aid in attachment to existing concrete buttresses. It may helpful to see where they wrapped up this work last month. Both Greg Sanders and Boyd Denison were working on this effort. A recent email with contact information is attached. Note that the details in that email may have changed after our conversations.

https://mwrsf-qa.unl.edu/view.php?id=1215

If we need to further discuss this topic in a conference call, please let me know. Thanks!

Attachment: https://mwrsf-qa.unl.edu/attachments/85928705b62925b1734e0fe65373d324.pdf

Attachment: https://mwrsf-qa.unl.edu/attachments/4426268c62f1f340fc675ddd05ca405c.pdf

Attachment: https://mwrsf-

qa.unl.edu/attachments/3ae03b829aa73dac6ccee06c61fcf19f.pdf

Flare Rates for Permanent CSB and Thrie-Beam AGT in Downstream Applications

Question
State: KS
Date: 04-04-2018

KDOT is working on evaluating different alternatives for upgrading an existing Inertial Barrier System at a mainline/ramp gore location (see attached Google Earth KMZ file for existing location). Through our evaluation we have been working with an attenuator manufacturer and have developed the draft layout shown in Attachment 1. Attachment 1 also includes details for the AGT we are planning to use as part of this installation since we will be connecting into existing 4G-1S, 28" w-beam guardrail. Basically we are proposing to construct a special concrete block similar to what is shown on page 3

As we've been evaluating the alternatives we need some guidance on using 8:1 flare rates (as shown in the attached PDF) for permanent CSB and Thrie-Beam AGT at this location. The 8:1 flare rate (relative to the edge of the through lane) matches approximately the existing flare rate of the w-beam at this location. The mainline and ramp posted speed is 65 mph with a traffic volume of ~25K ADT on the mainline movement. KDOT's field staff has indicated the first couple of barrels on the existing IBS installation are hit and have to be replaced 3 to 5 times a year. Any guidance you could provide in using these types of flare rates in downstream, permanent applications would be appreciated. We were hopeful to have some guidance within the next couple of weeks, but let me know what timeframe you think is reasonable.

Call or e-mail me with any questions…

Attachment: https://mwrsf-qa.unl.edu/attachments/9656d15ae49d851535ac6fe576b850e1.pdf

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Response
Date: 04-05-2018
I have a few thoughts/questions for you:

I'm not a huge fan of 8:1 flare rates on concrete and AGTs. So that make me a little nervous if there are ways to reduce that, I would feel better. If not, it may just be an installation site where you have go with the best you have.

How attached are you to the crash cushion you are using? I ask this because a wider crash cushion (at least one that gets wider in the back) would allow for reduced flare rates for the guardrail.

Technically, you shouldn't need AGTs going downstream from the crash cushion. It looks like this is for one-direction traffic, so there shouldn't be any reverse direction hits. As such, you don't need AGTs, and you can just attach guardrail to the concrete as you would the trailing end of a one-way bridge.

Without the need for an AGT, you may want to just install MGS downstream of the concrete. The MGS has been successfully crash tested with up a 5:1 flare rate according to NCHRP TL-3. You could install MGS along any flared section of guardrail and then transition the rail down to 28" along the tangent section of the guardrail installations.

I would also encourage you to utilize the shortest concrete parapet you can, thus minimizing the exposure of flared concrete. Not sure if your concrete parapet at this location is 9 ft or 19 ft long, but it could be much shorter than that if used only to support the crash cushion.

Response
Date: 04-06-2018

Scott – Thanks for the feedback… See my responses below. We'll discuss here again at KDOT and I'll follow up with you and Bob if we have any additional questions.

Tom

I have a few thoughts/questions for you:

- I'm not a huge fan of 8:1 flare rates on concrete and AGTs. So that make me a little nervous if there are ways to reduce that, I would feel better. If not, it may just be an installation site where you have go with the best you have. We did look at an option to reconstruct all the guardrail to flatten the flare rates to 16:1 or flatter, but it pushed the attenuator out farther in the gore approximately 25' closer to traffic. Since the first few barrels in the inertial barrel installation are already being hit fairly regularly we didn't want to move any device closer to traffic.
- How attached are you to the crash cushion you are using? I ask this because a wider crash cushion (at least one that gets wider in the back) would allow for reduced flare rates for the guardrail. We did look at the wider attenuator assemblies, but with the potential maintenance costs for impacts being higher for all the special parts we wanted to select something more typical/standard. We also ran into the same issue with the wider transition for the attenuator pushing the device out closer to traffic.
- Technically, you shouldn't need AGTs going downstream from the crash cushion. It looks like this is for one-direction traffic, so there shouldn't be any reverse direction hits. As such, you don't need AGTs, and you can just attach guardrail to the concrete as you would the trailing end of a one-way bridge.
- Without the need for an AGT, you may want to just install MGS downstream of the concrete. The MGS has been successfully crash tested with up a 5:1 flare rate according to NCHRP TL-3. You could install MGS along any flared section of guardrail and then transition the rail down to 28" along the tangent section of the guardrail installations. I had suggested this, but didn't get much traction. With this feedback from MwRSF I'll bring it up again for discussion.
- I would also encourage you to utilize the shortest concrete parapet you can, thus minimizing the exposure of flared concrete. Not sure if your concrete parapet at this location is 9 ft or 19 ft long, but it could be much shorter than that if used only to support the crash cushion. The 8:1 flared portion of the CSB is approximately 3' in length. Does that alleviate some of your concerns?

Response
Date: 04-26-2018

Scott – We had some additional discussions here internally at KDOT and we have a design we are moving forward with along with some documentation with everything we've investigated within the project/site criteria/constraints… in this situation we feel this proposal is still an improvement from the existing condition and is the best alternative of several we evaluated for this particular site. Would you mind taking one more quick look… I was wanting your thoughts on one item in particular regarding whether or not to nest the first 12'-6" of w-beam off the backside of the concrete block (see attached for details).

Thanks,

Attachment: https://mwrsf-qa.unl.edu/attachments/8624047d97e830868635ae3c99353a05.pdf

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Response
Date: 04-27-2018

I don't think you need to nest the w-beam coming off of the concrete barrier. I'm not sure if it helps much in terms of system performance, but nesting the rail shouldn't hurt in anyway. I guess what I'm saying is that nesting isn't necessary, but if you are concerned about the strength of the barrier in that region, you can nest the rail without negatively affecting performance.

Roadside Concrete Barrier Standard Drawing Review Request

Question
State: UT
Date: 07-11-2017

We
would like to request a review of our Concrete Barrier Standard Drawings to see what needs to be improved upon. I have attached a pdf copy of our standard drawings and calculations used at the time when they were created.

Along
with the entire set, I do have a couple specific concerns as follows:

TL-3
CIP Barrier Design:

- At this time,
  the TL-3 CIP barrier does not have a foundation design for each end of the barrier. In most cases the CIP barrier is placed on 9 inch thick PCCP concrete roadway panels. At a minimum Standards require a 4 inch

thick barrier pad constructed of concrete or asphalt. Will the design as shown on Sheet BA 3A2 require a foundation if placed on concrete of 9 inches or thicker?

- Will the barrier function if placed on asphalt, or no pavement at all?

TL-5
CIP Barrier Design:

- BA 1E & BA BA 301: The TL-5 barrier has an option to use a foundation end block or P1 bars at the end of the barrier depending on the thickness of the concrete pad it is being placed upon. Foundation end blocks are not required when barrier is placed on PCCP of 8 inch thickness or greater. Do you see any issues with this design?

- BA 3O4: Do you see any issues with scuppers used with the TL-5 design?

- BA 2D: This is a short stand alone barrier section. My concern is that it does not have a foundation. Currently this design in most cases is installed on PCCP of 9 inch thickness.

Thank
you for your time,

Attachment: https://mwrsf-qa.unl.edu/attachments/ff63314ca50d07420aa3e23f6b84f621.pdf

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Response
Date: 11-01-2017

Scott and I have reviewed you details. Comments and responses to your questions are located below.

For you PCB standards.

1. On sheet BA 1A2, you show two basic PCB details. One is a 42" constant slope barrier and one is a 32" New Jersey barrier. both are 20' long per segment.
    a. To my knowledge, the 32" tall NJ barrier section has not been tested to MASH TL-3. However, 20' long NJ PCB has been tested to MASH TL-3 with a different barrier connection. Thus, the barrier has the potential to meet MASH TL-3.

        i. The connection loops are denoted as ¾" dia. bar and use a 1" radius loop bend for the connection pin. In previous development of the F-shape barrier, MwRSF found that the bend radius and the grade of the loop steel were critical to developing proper load in the connection loops. That research used a 2 ¾" dia. bend radius and specified an ASTM A709 Gr. 70 or A706 Gr. 60 rebar for the loops in order to prevent fracture of the loops under impact loads.

ii. MwRSF's F-shape PCB also uses double shear loops for the connection loops. This lowers the load in each loop and reduces pin bending. Previous designs of the F-shape PCB found it necessary to use a constraint bolt at the base of the PCB connection pin to prevent the connection pin from bending and pulling through the loops under load. This may be an option to consider for your system as well. You appear to use the double shear loops in the 42" tall single-slope design.

b. For the 42" single-slope, I don't believe this has been tested to MASH either. Again, it may have to potential to meet TL-3 based on comparison to other tested systems. One concern with that system is the vertical cutouts for the anchorage pins. We have observed vertical asperities of 3/8" or more can contribute to vehicle instability when extended from the barrier. TTI conducted research in NCHRP 554 regarding aesthetic barrier design and the size of vertical asperities allowable for concrete barriers. This research found a range of performance for vertical asperities dependent on the angle, depth, and the width between asperities. Crash testing conducted as part of this project found that vertical concrete ridges as deep as ½" could result in failure. Further simulation analysis found that vertical steps of ¼" were acceptable. The height of the vertical cutouts and their depth may lead to similar concerns here.

2. On sheet BA 1A2, details are provided for pinning the barrier to reduce deflection. This approach has been used on several MASH tested PCB systems, but the configuration utilized has been a bit different. Currently, the Utah details denote pinning at two locations on the front and back sides of the barrier near the ends of the barrier segment. Previously MASH tested pinned barrier configurations have used three or more pins. Additionally, we have typically recommended not anchoring to the backside of PCB segments in order to reduce the potential for tipping of the barrier about the backside anchors which can promote vehicle climb and instability. However, we have seen a configurations with pins on both sides of the barrier work with NJDOT's 20' long PCB. The F-shape PCB anchorage we developed used three pins on the front face of each segment and the New Jersey system uses 5 anchor pockets on each face of the barrier. Thus, there is potential for your configuration to work, but I cannot provide any definitive recommendation regarding its MASH compliance. It also difficult to determine what the potential deflection

reduction might be and how the pin configuration affects the structural loading of the barrier.

3. Currently your details show a deflection area of 1' at 10:1 or flatter and 2' of 8:1 or flatter with steep slope after that initial 3'. For your 20' long PCB which is similar to a PCB we have tested for New Jersey, we would expect MASH TL-3 deflections of at least 40" and they may be higher. In the past, we have not recommended the use of slopes steeper than 10:1 in the PCB deflection region due to concerns with the barrier deflection increasing and tipping of the barriers. For your anchored PCBs, I would think that your 1' offset from the slope is sufficient. However, as noted above, I cannot say for sure as I don't know your deflection reduction due to pinning without more investigation.
4. Your details denote flaring of the ends of the PCB runs, but I could not find the specified flare rates on the plans. This has never been fully defined through crash testing or simulation, but NCHRP 358 provides some guidance on PCB flare rates and is what we typically recommend to states.
5. On sheet BA 1D, you show a curved layout for operations outside the clear zone or low speed applications. There may be concerns for high angle impacts in these curved regions due to occupant risk, but your low speed requirement should limit that hazard. I just wanted to note that this type of installation has not been evaluated to any testing criteria to the best of my knowledge.
6. On sheet BA 2B, you show a sloped end section for the concrete, these sloped ends have been tested at lower test levels and heights for some low profile PCBs under current test standards. However, the 32" height and the slope of the sloped end section would likely promote vehicle instability as shown under TL-3 impact conditions and potentially under TL-2 impact conditions. I note that you recommend them for use in areas with speeds less than 40 mph. However, we have seen research suggesting that speeds over 30 mph have been an issue. We looked at this issue for some of the pooled fund states in the past. See Q&A response - http://mwrsf-qa.unl.edu/view.php?id=778

Similar concerns would apply to the slope end treatment shown on sheet BA 3H.

Safe termination of PCB's is a significant safety issue that has not been dealt with over time, and few options are available other than sand barrels and crash cushions. We have done preliminary work on the length of need, but the issue of safe termination of PCBs likely need more research.

Scott looked at your CIP barrier questions and standards. In response to your questions:

TL-3 CIP Barrier Design:

- At this time, the TL-3 CIP barrier does not have a foundation design for each end of the barrier. In most cases the CIP barrier is placed on 9 inch thick PCCP concrete roadway panels. At a minimum Standards require a 4 inch thick barrier pad constructed of concrete or asphalt. Will the design as shown on Sheet BA 3A2 require a foundation if placed on concrete of 9 inches or thicker?
  - Anchorage to the roadway slab is likely acceptable. We would recommend that you place dowels/ties adjacent to all stirrups in the end section (approximately 12', for the sloped end section approximately 26')
- Will the barrier function if placed on asphalt, or no pavement at all?
  - End sections of CIP barrier placed without anchorage are susceptible to excessive cracking and damage and potential failure. We would recommend anchorage of the end sections.

TL-5 CIP Barrier Design:

- BA 1E & BA BA 301: The TL-5 barrier has an option to use a foundation end block or P1 bars at the end of the barrier depending on the thickness of the concrete pad it is being placed upon. Foundation end blocks are not required when barrier is placed on PCCP of 8 inch thickness or greater. Do you see any issues with this design?
  - Anchorage to the roadway slab is likely acceptable. We would recommend that you place dowels/ties adjacent to all stirrups in the end section similar to the footing design.
- BA 3O4: Do you see any issues with scuppers used with the TL-5 design?
  - Scuppers will reduce barrier strength to some degree, but you have limited their use as shown in your plans and not placed them in the end section, so the effect is not likely a big issue as your barrier is well reinforced. You may observe some additional cracking or damage in those areas.

BA 2D: This is a short stand alone barrier section. My concern is that it does not have a foundation. Currently this design in most cases is installed on PCCP of 9 inch thickness.

Let me know if you have any comments or questions.

Response
Date: 04-10-2018

Has there been any testing of cast-in-place barrier anchorage itself? For example, has a physical test or computer analysis been run to see what would happen if a vehicle impacts the last 10 feet of the barrier run to ensure the barrier will not push back or rotate exposing a concrete bridge rail end? That being the pickup for TL-3 and Semi for TL-5.

If not, would Midwest Roadside Safety Facility be willing to run computer analysis on our current design attached?

Another thought if other agencies have similar question, this issue could also be incorporated within the RPFP-19-CONC-1 Evaluation of Permanent Concrete Barriers to MASH 2016?

Thank you for your time,

Response
Date: 04-12-2018

We have conducted TL-3 crash testing on an end section buttress supported by and anchored to reinforced concrete foundations. This crash testing was performed under NCHRP Report No. 350 impact conditions. Lateral impact loading from pickup trucks on buttresses under MASH 2009/2016 would be slightly higher than previously observed under NCHRP 350. I am providing weblinks to reports that utilized a foundation system for the transition system as well as another to anchor a TL-5 barrier. Note that the TL-5 barrier was not impacted at the end but rather designed to anchor the end of the barrier.

https://mwrsf.unl.edu/reportresult.php?reportId=84&search-textbox=transition

https://mwrsf.unl.edu/reportresult.php?reportId=106&search-textbox=tl-5

Further, there exists a TRB journal paper from the late 1980s that provide suggested sizes for anchorage foundations at barrier ends or buttresses where AGTs are often connected.

https://unl.box.com/s/psiose59ebda2mfds3l4zakofyljnufi

https://unl.box.com/s/psiose59ebda2mfds3l4zakofyljnufi

Finally, Scott has already conducted structural analysis and design guidance for this configuration to the Wisconsin DOT. This include included shape and height transitions, interior and end designs, etc. I can ask that Scott either send you his details or details which details now exist in the Wisconsin DOT's plans.

Response
Date: 04-13-2018
The design methodology for foundations at barrier ends is contained within the Appendices of the TL-5 barrier report, TRP-03-194-07 (Dr. Faller provided the link below). The foundation design is dependent upon the barrier you are anchoring, so you will need to utilize the size and strength of your barrier when designing the foundation and each barrier may have its own foundation design to match it.

MGS close to retaining wall

Question
State: OH
Date: 04-10-2018

In this proposed cross section with MGS half post spacing, what do you recommend as minimum spacing between the back for the post and the pile wall? I'm thinking 6 inches shown is too little. If we reduce the shoulder to 3', we could get at least 1.5' behind the post. And we could also try 8" blockouts.

Also, could the distance behind the post be reduced further if MGS with quarter post spacing was used?
Attachment: https://mwrsf-qa.unl.edu/attachments/88d9b5d5c3c42a73a2779393462ae63e.png

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Response
Date: 04-10-2018

We recommend a 2-ft offset between the post and the wall due to a lack of similar testing. There is also the possibility of using non-blocked, standard post-spacing MGS to save on space between the road and the wall (just ensure the working width does not extend over the wall.

Recently, we tested a ½-post spacing MGS that was top-mounted to a culvert to MASH TL-3 for the state of Wisconsin (Bob will be presenting these results next week at the Midwest Pooled Fund meeting). The posts were offset 12" from the headwall, and the system passed. Thus, it would make sense that the posts could be offset 12" from the wall in your situation. A 12" offset would also satisfy the leave out dimensions established for posts-in-rock under NCHRP Report 350.

BR27 Railing

Question
State: VA
Date: 04-11-2018

A question has come up related to the BR27 railing that VDOT uses.

It has been suggested that the anchor bolts should be fully tensioned using turn of the nut tightening (the same tightening we use for beam splices). VDOT uses a 1/8" elastomeric “leveling" pad, so I don't think that will work, but no pad was shown on the crash test. I am 99% sure that no special tightening was used in the crash test and that, in fact, tensioning the connection might even degrade performance, but that 1% say I should get confirmation that snug tight is tight enough and fully tensioned is not desirable or required.

Our detail is at this link:

http://www.virginiadot.org/business/resources/bridge/Manuals/Part3/BR27C-12.pdf

Response
Date: 04-11-2018

I am not aware of any special tightening on these anchor bolts as well. I do not think that it would significantly influence the performance of the system either when anchors are finger tightened or more snugly tightened. I am enclosing a copy and link to a recent report where alternative anchorages were provided.

https://mwrsf.unl.edu/reportresult.php?reportId=313&search-textbox=iowa

https://mwrsf.unl.edu/researchhub/files/Report313/TRP-03-325-15.pdf

Bearing pads may likely be used to deal with uneven concrete surfaces, lower stress concentrations, or better distribute loading.

Since Bob worked on this system a few years ago, I will see if he has additional thoughts.

Response
Date: 04-12-2018

I would concur with run that the amount of torque and associated preload in those anchors is not critical for the bridge rail to function. You would want them tightened and not loose.

One related issue is that you have to be careful with the amount of torque and preload you use if you use an epoxy anchored rail. To much preload in the epoxy anchor can create issues with the epoxy bond capacity and creep. Most manufacturers have recommendations for the torque/preload.

Response
Date: 04-14-2018

Yes, that is why the pad is used. To help eliminate unevenness.

The concern I have with going to a turn of the nut condition is that the intent of turn of the nut is to ensure a consistent clamping force for slip critical connections, we do this by yielding the bolt. In a conditions where we are counting on friction (this is fine), in a condition where a collision would add load, then the bolt which has already yielded would deform until fracture with no additional strength (unless there is a reliance on strain hardening).

The addition concerns with turn of the nut are:

yielding will debond concrete locally near the top of the anchorage

poisons ratio will create tension stresses in the 10 or 12" barrier which may lead to premature failure.

Response
Date: 04-25-2018

I have looked over our last correspondence on the anchor topic for bridge posts. Although I do not have much more to comment, we can further discuss if need be.

I assume that your anchor rods are cast into the parapet. Is this true? I really do not think that finger tight or some moderate torque requirement would negatively impact the post and anchor performance. I am hesitant to think that the poison effect will cause problems in the upper parapet region but have not studied this issue. For anchors epoxied into concrete and subjected to higher long-term dead loading, I believe that there can be concerns for anchor creep within the epoxy resin material. Under those scenarios, anchor failure can occur. If the anchors were installed with epoxy resin, I would suggest that one follows the epoxy manufacturer's guidance. Again and for now, I do not think that the finger tight or moderately tightened would drastically change post and railing performance.

Let us know if we need to further discuss. Thanks!

Thrie Beam lapping at end shoe connection

Question
State: WI
Date: 04-23-2018

Is their a correct way to lap nested thrie beam at the end shoe connection. I have seen different variations.

Response
Date: 04-24-2018

I don't know if I would call it “supposed to be lapped". Rather there may be a benefit to lapping things a certain way for nested guardrail connected to an end shoe.

Typically, we have lapped our end shoe connections with both plies of the nested rail on the outside of the end shoe. This has worked fine structurally, but does allow slightly increased vehicle snag potential on the rail when impacted in the reverse direction.

An alternative is to sandwich the end shoe between the nested thrie sections as shown below. This has the benefit of reduced snag potential and loads the splice bolts in double shear rather than single shear. Thus, this may the best configuration from an engineering perspective.

Attachment: https://mwrsf-qa.unl.edu/attachments/a43f95f712ef0ca4c0284e9097b5caa5.jpg

Attachment: https://mwrsf-

qa.unl.edu/attachments/da2760b95e0ad5fb55d32907ab97f6f5.jpg

Attachment: https://mwrsf-qa.unl.edu/attachments/e82049f263ca19a61a22390e54ba2bf6.jpg

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UBSP Post Base Galvanization Vent Hole

Question
Date: 04-26-2018

Per our discussion on the test track a few minutes ago, please see attachments.

We would like to receive written concurrence from MwRSF that the tube sleeve embedment for the ThrieBeam Bullnose can be manufactured with a 13/16" galvanizing (vent/drain) hole instead of 3/8" as shown. For the following reasons:
o If you try to galvanize the product and drain it using the 3/8" hole, it becomes clogged.
o If you try to galvanize the product and use the 3/8" hole as a venting hole, it isn't large enough to allow the heated air to vent properly. The product tends to float in the zinc kettle.
If you are concerned that another manufacturer would desire a ¾" hole vs a 13/16" hole or such – then you could reply to this email indicating a maximum diameter galvanizing hole.
As 13/16" holes are used extensively in the guardrail product applications and most galvanizing hanging hardware is larger than 5/8" rod, we would ask that at least a 13/16" hole be allowed.

We would appreciate a response within a week, if at all possible. Thanks for your time and effort to consider our request.

Attachment: https://mwrsf-qa.unl.edu/attachments/14781f78e59d95c290e5d0a717b3e0ac.pdf

Attachment: https://mwrsf-qa.unl.edu/attachments/69b41bab5dd5fbe67689268443a6b64d.pdf

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Response
Date: 04-26-2018

I have reviewed the attachments and email you sent regarding the vent/drain holes in the lower section of the UBSP post developed here at MwRSF.

I see no issues with increasing the size of the vent/drain hole to ¾" or 13/16" as need to facilitate better galvanization of the assembly. Additionally, That hole could be relocated on the base plate as needed as long as it was located on the interior of the base tube.

I will update the details in our latest bullnose testing to reflect a larger hole as well and place this note on the MwRSF Q&A site as well to help in disseminating the information to our states.

Thanks

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska 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)* TPF-5(193) Suppl. #110		**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: 2611211131001	**Other Project ID (i.e., contract #):** RPFP-17-PFCHS	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2019	**Current Project End Date:** 9/30/2019	**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
$12,668	$8,398	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
	$464	

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.

Updated research hub with new completed projects.

Anticipated work next quarter:

Continue maintenance, repair, and upkeep of the website.

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

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; and Project No.: RPFP-15-PFCHS – TPF-5(193) Supplement #84, Project Title: Pooled Fund for Highway Safety; and Project No.: RPFP-16-PFCHS – TPF-5(193) Supplement #97, Project Title: Pooled Fund for Highway Safety. Funding from Project No.: RPFP-16-PFCHS – TPF-5 (193) Supplement #97, Project Title: Pooled Fund for Highway Safety was 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.

There are a few small differences between your old transition standard and the one crash tested to NCHRP Report 350 and approved by FHWA. However, I believe the ¾" height difference would have a minimal effect on performance. Thus, you could make the argument that your existing transitions are NCHRP Report 350 TL-3 compliant.

During our conference call this week, you expressed that you will be attaching MGS to the upstream ends of these existing transitions. The bridge railings and parapets in which the transitions are attached to are only 29" tall, so you will not be able to raise the height of the transition rails to match up with MGS. Note, TTI recent conducted a study in which the height of the upper W-beam rail was increased to 31", but the system failed to satisfy MASH criteria during crash testing. Thus, you will need a height transition between 31" MGS and the 27" transition, and your transition section will not be MASH crashworthy.

In order to create a MASH crashworthy transition, you will need to remove/replace the ends of the concrete barrier to match a MASH tested system. This retrofit would be costly. You had stated that you have not observed safety issues with the existing transitions, so upgrading the transitions would have limited benefits as the existing system is NCHRP 350 crashworthy. As such, I recommend leaving the transitions in place (as part of the bridge rail) when the adjacent guardrail is replaced with MGS.

To transition between the existing transitions and MGS, you will need a height transition – from 27" to 31", respectively. MwRSF has been recommending that such height transitions be done gradually over a distance of 50-ft. Additionally, the height transition should start upstream of the stacked w-beam transition, which would include rub rail and reduced post spacing. So, the height transition should begin at the 9th post upstream of the bridge rail.

I do not think these transitions would remain crashworthy if an overlay raised the height of the roadway 2-3 inches. These transitions are already short (at 27"), and further reducing this height could have major effects on the performance of the system. At this time, it is not known if a 31" tall guardrail transition would maintain its crashworthiness if the height was reduced. I have not found any thrie-beam transitions to pass TL-3 criteria (either NCHRP 350 or MASH) with a height less than 31". Most of the shorter height transitions resulted in rollovers. If an overlay is necessary, you may want to grind down the pavement prior to the overlay so that the roadway height remains the same.

For future installations, MwRSF and NDOT are currently finishing a project to develop a 34" tall guardrail transition system – which would make it crashworthy as installed and after a 3" overlay is added. The system has been successfully crash tested to MASH TL-3. The report is not yet completed, but I can supply you with further details if you are interested.

W-beam Adjacent to Slopes with 11' long Posts

Question
State: NE
Date: 03-21-2018

This AASHTIO training refers to 11' posts

Where was this tested?
Attachment: https://mwrsf-qa.unl.edu/attachments/7b615d939c323c9be2529cd381a4edb6.png

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Response
Date: 03-22-2018

I don't believe that this has been tested. This comes from the Washington DOT standards. TTI is currently looking into guardrail on steeper slopes, but the project is not finished.

I would not recommend installations as shown with the 11' posts on steep slopes. Case 5 has not been tested either. Case 4 was evaluated to MASH at TTI.

https://www.roadsidepooledfund.org/placement-of-guardrail-on-slopes-phase-iii-603221-2/

Thanks

Concrete Barrier Connector Plate

Question
State: VA
Date: 03-22-2018

We are reviewing the options for connecting thrie beam to different types of barrier and it appears there are a few different designs that have been used. I have attached the 3 designs I have found and was wondering if any of the designs perform any better than another.

The TRP-03-175-06 version that was used in the 2006 crash tests looks like it was the latest version of the detail. We would like to use this design with both constant slope barrier and F shape barrier with some minor modifications to fit each barrier.

Do you see any issues with the 2006 design being used since the angled plate is shorter? Also would minor modifications to this design to fit specific barriers warrant further crash testing?

Any information or guidance you could provide would be appreciated.

Response
Date: 04-02-2018

TRP-03-47-95

In the mid-1990s, we developed a MoDOT thrie beam median transition to a single-slope concrete median barrier. In the first crash test (MTSS-1) into design no. 1, several barrier behavior problems were observed, which contributed to a failed 2000P crash test. Following this test, several design modifications were incorporated, including a shortened steel thrie beam connector plate to allow thrie beam space to gradually deform backward at end of parapet, shortened blockout to allow lower thrie corrugation to deflect backward, flattened vertical slope for top of barrier at end, and tapered steel blocks and recessed posts at top to reduce vehicle snag.

For the re-test (MTSS-2) on design no. 2, the modified thrie beam median transition to single-slope barrier demonstrated improved safety performance. In your attached pdf, you will note that the steel apparatus was shortened from 50¼ in. to 40 in., and it did not extend to the end of the buttress.

TRP-03-69-98

In the mid-1990s, we developed an IaDOT thrie beam roadside transition to a New Jersey concrete roadside barrier under NCHRP Report No. 350 using four 2000P crash tests. Two unsuccessful and two successful crash tests were performed. Two tests with wood posts, and two tests with steel posts. The NJ Steel connector plate was approximately 32 in. long. Again, the end of the connector plate did not extend to the end of the buttress. The sloped end was 12 in. long versus the 20 in. long due to the narrower lateral top plate width over which to transition the sloped end.

TRP-03-175-06

In the mid-2000s, we retested the Iowa transition under MASH using a 2270P vehicle. The steel connector plate did not change from that used in the 350 testing program.

Lateral Slope Change

For the general configurations, the single-slope connector plate has a lateral slope of 3-13/16 over 20, or 1/5.25. The NJ connector plate has a lateral slope of 2-3/8 over 12, or 1/5.05. These two slopes are approximately equal. To provide similar behavior under reverse-direction crashes, we should maintain this slope or provide an even flatter lateral slope.

Note that we did not crash test the two parts in the reverse-direction. Minor changes may be acceptable. However, a much steeper slope may cause more concern for vehicle snagging on the end or too rapid of the change that may contribute to instability.

When we studied lateral slope changes on the face of concrete barriers with computer simulation, we iterated to a flatter slope. The more gentler slope consisted of a 1:10.

TRP-03-335-17

We completed another study involving a transition from MGS to F-shape PCBs in 2017. A W-beam steel connector plate was attached to PCBs and evaluated under MASH in two directions. For reverse-direction crashes with the 1100C vehicle, the connector plate had a lateral slope of 2-1/2 over 12, or 1/4.80. Again, the slope is close to 1/5 in combination with a PCB system that can translate under lateral loading.

Overall, I think that it may be best to try to maintain the lateral slope that has been used in prior steel connector plates. Of course, some minor deviation in lateral slope would seem to be reasonable. In fact, MoDOT has been developing some revised connector parts to aid in attachment to existing concrete buttresses. It may helpful to see where they wrapped up this work last month. Both Greg Sanders and Boyd Denison were working on this effort. A recent email with contact information is attached. Note that the details in that email may have changed after our conversations.

https://mwrsf-qa.unl.edu/view.php?id=1215

If we need to further discuss this topic in a conference call, please let me know. Thanks!

Attachment: https://mwrsf-qa.unl.edu/attachments/85928705b62925b1734e0fe65373d324.pdf

Attachment: https://mwrsf-qa.unl.edu/attachments/4426268c62f1f340fc675ddd05ca405c.pdf

Attachment: https://mwrsf-

qa.unl.edu/attachments/3ae03b829aa73dac6ccee06c61fcf19f.pdf

Flare Rates for Permanent CSB and Thrie-Beam AGT in Downstream Applications

Question
State: KS
Date: 04-04-2018

KDOT is working on evaluating different alternatives for upgrading an existing Inertial Barrier System at a mainline/ramp gore location (see attached Google Earth KMZ file for existing location). Through our evaluation we have been working with an attenuator manufacturer and have developed the draft layout shown in Attachment 1. Attachment 1 also includes details for the AGT we are planning to use as part of this installation since we will be connecting into existing 4G-1S, 28" w-beam guardrail. Basically we are proposing to construct a special concrete block similar to what is shown on page 3

As we've been evaluating the alternatives we need some guidance on using 8:1 flare rates (as shown in the attached PDF) for permanent CSB and Thrie-Beam AGT at this location. The 8:1 flare rate (relative to the edge of the through lane) matches approximately the existing flare rate of the w-beam at this location. The mainline and ramp posted speed is 65 mph with a traffic volume of ~25K ADT on the mainline movement. KDOT's field staff has indicated the first couple of barrels on the existing IBS installation are hit and have to be replaced 3 to 5 times a year. Any guidance you could provide in using these types of flare rates in downstream, permanent applications would be appreciated. We were hopeful to have some guidance within the next couple of weeks, but let me know what timeframe you think is reasonable.

Call or e-mail me with any questions…

Attachment: https://mwrsf-qa.unl.edu/attachments/9656d15ae49d851535ac6fe576b850e1.pdf

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Response
Date: 04-05-2018
I have a few thoughts/questions for you:

I'm not a huge fan of 8:1 flare rates on concrete and AGTs. So that make me a little nervous if there are ways to reduce that, I would feel better. If not, it may just be an installation site where you have go with the best you have.

How attached are you to the crash cushion you are using? I ask this because a wider crash cushion (at least one that gets wider in the back) would allow for reduced flare rates for the guardrail.

Technically, you shouldn't need AGTs going downstream from the crash cushion. It looks like this is for one-direction traffic, so there shouldn't be any reverse direction hits. As such, you don't need AGTs, and you can just attach guardrail to the concrete as you would the trailing end of a one-way bridge.

Without the need for an AGT, you may want to just install MGS downstream of the concrete. The MGS has been successfully crash tested with up a 5:1 flare rate according to NCHRP TL-3. You could install MGS along any flared section of guardrail and then transition the rail down to 28" along the tangent section of the guardrail installations.

I would also encourage you to utilize the shortest concrete parapet you can, thus minimizing the exposure of flared concrete. Not sure if your concrete parapet at this location is 9 ft or 19 ft long, but it could be much shorter than that if used only to support the crash cushion.

Response
Date: 04-06-2018

Scott – Thanks for the feedback… See my responses below. We'll discuss here again at KDOT and I'll follow up with you and Bob if we have any additional questions.

Tom

I have a few thoughts/questions for you:

- I'm not a huge fan of 8:1 flare rates on concrete and AGTs. So that make me a little nervous if there are ways to reduce that, I would feel better. If not, it may just be an installation site where you have go with the best you have. We did look at an option to reconstruct all the guardrail to flatten the flare rates to 16:1 or flatter, but it pushed the attenuator out farther in the gore approximately 25' closer to traffic. Since the first few barrels in the inertial barrel installation are already being hit fairly regularly we didn't want to move any device closer to traffic.
- How attached are you to the crash cushion you are using? I ask this because a wider crash cushion (at least one that gets wider in the back) would allow for reduced flare rates for the guardrail. We did look at the wider attenuator assemblies, but with the potential maintenance costs for impacts being higher for all the special parts we wanted to select something more typical/standard. We also ran into the same issue with the wider transition for the attenuator pushing the device out closer to traffic.
- Technically, you shouldn't need AGTs going downstream from the crash cushion. It looks like this is for one-direction traffic, so there shouldn't be any reverse direction hits. As such, you don't need AGTs, and you can just attach guardrail to the concrete as you would the trailing end of a one-way bridge.
- Without the need for an AGT, you may want to just install MGS downstream of the concrete. The MGS has been successfully crash tested with up a 5:1 flare rate according to NCHRP TL-3. You could install MGS along any flared section of guardrail and then transition the rail down to 28" along the tangent section of the guardrail installations. I had suggested this, but didn't get much traction. With this feedback from MwRSF I'll bring it up again for discussion.
- I would also encourage you to utilize the shortest concrete parapet you can, thus minimizing the exposure of flared concrete. Not sure if your concrete parapet at this location is 9 ft or 19 ft long, but it could be much shorter than that if used only to support the crash cushion. The 8:1 flared portion of the CSB is approximately 3' in length. Does that alleviate some of your concerns?

Response
Date: 04-26-2018

Scott – We had some additional discussions here internally at KDOT and we have a design we are moving forward with along with some documentation with everything we've investigated within the project/site criteria/constraints… in this situation we feel this proposal is still an improvement from the existing condition and is the best alternative of several we evaluated for this particular site. Would you mind taking one more quick look… I was wanting your thoughts on one item in particular regarding whether or not to nest the first 12'-6" of w-beam off the backside of the concrete block (see attached for details).

Thanks,

Attachment: https://mwrsf-qa.unl.edu/attachments/8624047d97e830868635ae3c99353a05.pdf

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Response
Date: 04-27-2018

I don't think you need to nest the w-beam coming off of the concrete barrier. I'm not sure if it helps much in terms of system performance, but nesting the rail shouldn't hurt in anyway. I guess what I'm saying is that nesting isn't necessary, but if you are concerned about the strength of the barrier in that region, you can nest the rail without negatively affecting performance.

Roadside Concrete Barrier Standard Drawing Review Request

Question
State: UT
Date: 07-11-2017

We
would like to request a review of our Concrete Barrier Standard Drawings to see what needs to be improved upon. I have attached a pdf copy of our standard drawings and calculations used at the time when they were created.

Along
with the entire set, I do have a couple specific concerns as follows:

TL-3
CIP Barrier Design:

- At this time,
  the TL-3 CIP barrier does not have a foundation design for each end of the barrier. In most cases the CIP barrier is placed on 9 inch thick PCCP concrete roadway panels. At a minimum Standards require a 4 inch

thick barrier pad constructed of concrete or asphalt. Will the design as shown on Sheet BA 3A2 require a foundation if placed on concrete of 9 inches or thicker?

- Will the barrier function if placed on asphalt, or no pavement at all?

TL-5
CIP Barrier Design:

- BA 1E &
  BA BA 301: The TL-5 barrier has an option to use a foundation end block or P1 bars at the end of the barrier depending on the thickness of the concrete pad it is being placed upon. Foundation end blocks are not required when barrier is placed on PCCP of 8 inch thickness or greater. Do you see any issues with this design?

- BA 3O4:
  Do you see any issues with scuppers used with the TL-5 design?

- BA 2D: This is a short stand alone barrier section. My concern is that it does not have a foundation. Currently this design in most cases is installed on PCCP of 9 inch thickness.

Thank
you for your time,

Attachment: https://mwrsf-qa.unl.edu/attachments/ff63314ca50d07420aa3e23f6b84f621.pdf

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Response
Date: 11-01-2017

Scott and I have reviewed you details. Comments and responses to your questions are located below.

For you PCB standards.

1. On sheet BA 1A2, you show two basic PCB details. One is a 42" constant slope barrier and one is a 32" New Jersey barrier. both are 20' long per segment.
    a. To my knowledge, the 32" tall NJ barrier section has not been tested to MASH TL-3. However, 20' long NJ PCB has been tested to MASH TL-3 with a different barrier connection. Thus, the barrier has the potential to meet MASH TL-3.

        i. The connection loops are denoted as ¾" dia. bar and use a 1" radius loop bend for the connection pin. In previous development of the F-shape barrier, MwRSF found that the bend radius and the grade of the loop steel were critical to developing proper load in the connection loops. That research used a 2 ¾" dia. bend radius and specified an ASTM A709 Gr. 70 or A706 Gr. 60 rebar for the loops in order to prevent fracture of the loops under impact loads.

ii. MwRSF's F-shape PCB also uses double shear loops for the connection loops. This lowers the load in each loop and reduces pin bending. Previous designs of the F-shape PCB found it necessary to use a constraint bolt at the base of the PCB connection pin to prevent the connection pin from bending and pulling through the loops under load. This may be an option to consider for your system as well. You appear to use the double shear loops in the 42" tall single-slope design.

b. For the 42" single-slope, I don't believe this has been tested to MASH either. Again, it may have to potential to meet TL-3 based on comparison to other tested systems. One concern with that system is the vertical cutouts for the anchorage pins. We have observed vertical asperities of 3/8" or more can contribute to vehicle instability when extended from the barrier. TTI conducted research in NCHRP 554 regarding aesthetic barrier design and the size of vertical asperities allowable for concrete barriers. This research found a range of performance for vertical asperities dependent on the angle, depth, and the width between asperities. Crash testing conducted as part of this project found that vertical concrete ridges as deep as ½" could result in failure. Further simulation analysis found that vertical steps of ¼" were acceptable. The height of the vertical cutouts and their depth may lead to similar concerns here.

2. On sheet BA 1A2, details are provided for pinning the barrier to reduce deflection. This approach has been used on several MASH tested PCB systems, but the configuration utilized has been a bit different. Currently, the Utah details denote pinning at two locations on the front and back sides of the barrier near the ends of the barrier segment. Previously MASH tested pinned barrier configurations have used three or more pins. Additionally, we have typically recommended not anchoring to the backside of PCB segments in order to reduce the potential for tipping of the barrier about the backside anchors which can promote vehicle climb and instability. However, we have seen a configurations with pins on both sides of the barrier work with NJDOT's 20' long PCB. The F-shape PCB anchorage we developed used three pins on the front face of each segment and the New Jersey system uses 5 anchor pockets on each face of the barrier. Thus, there is potential for your configuration to work, but I cannot provide any definitive recommendation regarding its MASH compliance. It also difficult to determine what the potential deflection

reduction might be and how the pin configuration affects the structural loading of the barrier.

3. Currently your details show a deflection area of 1' at 10:1 or flatter and 2' of 8:1 or flatter with steep slope after that initial 3'. For your 20' long PCB which is similar to a PCB we have tested for New Jersey, we would expect MASH TL-3 deflections of at least 40" and they may be higher. In the past, we have not recommended the use of slopes steeper than 10:1 in the PCB deflection region due to concerns with the barrier deflection increasing and tipping of the barriers. For your anchored PCBs, I would think that your 1' offset from the slope is sufficient. However, as noted above, I cannot say for sure as I don't know your deflection reduction due to pinning without more investigation.
4. Your details denote flaring of the ends of the PCB runs, but I could not find the specified flare rates on the plans. This has never been fully defined through crash testing or simulation, but NCHRP 358 provides some guidance on PCB flare rates and is what we typically recommend to states.
5. On sheet BA 1D, you show a curved layout for operations outside the clear zone or low speed applications. There may be concerns for high angle impacts in these curved regions due to occupant risk, but your low speed requirement should limit that hazard. I just wanted to note that this type of installation has not been evaluated to any testing criteria to the best of my knowledge.
6. On sheet BA 2B, you show a sloped end section for the concrete, these sloped ends have been tested at lower test levels and heights for some low profile PCBs under current test standards. However, the 32" height and the slope of the sloped end section would likely promote vehicle instability as shown under TL-3 impact conditions and potentially under TL-2 impact conditions. I note that you recommend them for use in areas with speeds less than 40 mph. However, we have seen research suggesting that speeds over 30 mph have been an issue. We looked at this issue for some of the pooled fund states in the past. See Q&A response - http://mwrsf-qa.unl.edu/view.php?id=778

Similar concerns would apply to the slope end treatment shown on sheet BA 3H.

Safe termination of PCB's is a significant safety issue that has not been dealt with over time, and few options are available other than sand barrels and crash cushions. We have done preliminary work on the length of need, but the issue of safe termination of PCBs likely need more research.

Scott looked at your CIP barrier questions and standards. In response to your questions:

TL-3 CIP Barrier Design:

- At this time, the TL-3 CIP barrier does not have a foundation design for each end of the barrier. In most cases the CIP barrier is placed on 9 inch thick PCCP concrete roadway panels. At a minimum Standards require a 4 inch thick barrier pad constructed of concrete or asphalt. Will the design as shown on Sheet BA 3A2 require a foundation if placed on concrete of 9 inches or thicker?
    - Anchorage to the roadway slab is likely acceptable. We would recommend that you place dowels/ties adjacent to all stirrups in the end section (approximately 12', for the sloped end section approximately 26')
- Will the barrier function if placed on asphalt, or no pavement at all?
    - End sections of CIP barrier placed without anchorage are susceptible to excessive cracking and damage and potential failure. We would recommend anchorage of the end sections.

TL-5 CIP Barrier Design:

- BA 1E & BA BA 301: The TL-5 barrier has an option to use a foundation end block or P1 bars at the end of the barrier depending on the thickness of the concrete pad it is being placed upon. Foundation end blocks are not required when barrier is placed on PCCP of 8 inch thickness or greater. Do you see any issues with this design?
    - Anchorage to the roadway slab is likely acceptable. We would recommend that you place dowels/ties adjacent to all stirrups in the end section similar to the footing design.
- BA 3O4: Do you see any issues with scuppers used with the TL-5 design?
    - Scuppers will reduce barrier strength to some degree, but you have limited their use as shown in your plans and not placed them in the end section, so the effect is not likely a big issue as your barrier is well reinforced. You may observe some additional cracking or damage in those areas.

BA 2D: This is a short stand alone barrier section. My concern is that it does not have a foundation. Currently this design in most cases is installed on PCCP of 9 inch thickness.

Let me know if you have any comments or questions.

Response
Date: 04-10-2018

Has there been any testing of cast-in-place barrier anchorage itself? For example, has a physical test or computer analysis been run to see what would happen if a vehicle impacts the last 10 feet of the barrier run to ensure the barrier will not push back or rotate exposing a concrete bridge rail end? That being the pickup for TL-3 and Semi for TL-5.

If not, would Midwest Roadside Safety Facility be willing to run computer analysis on our current design attached?

Another thought if other agencies have similar question, this issue could also be incorporated within the RPFP-19-CONC-1 Evaluation of Permanent Concrete Barriers to MASH 2016?

Thank you for your time,

Response
Date: 04-12-2018

We have conducted TL-3 crash testing on an end section buttress supported by and anchored to reinforced concrete foundations. This crash testing was performed under NCHRP Report No. 350 impact conditions. Lateral impact loading from pickup trucks on buttresses under MASH 2009/2016 would be slightly higher than previously observed under NCHRP 350. I am providing weblinks to reports that utilized a foundation system for the transition system as well as another to anchor a TL-5 barrier. Note that the TL-5 barrier was not impacted at the end but rather designed to anchor the end of the barrier.

https://mwrsf.unl.edu/reportresult.php?reportId=84&search-textbox=transition

https://mwrsf.unl.edu/reportresult.php?reportId=106&search-textbox=tl-5

Further, there exists a TRB journal paper from the late 1980s that provide suggested sizes for anchorage foundations at barrier ends or buttresses where AGTs are often connected.

https://unl.box.com/s/psiose59ebda2mfds3l4zakofyljnufi

https://unl.box.com/s/psiose59ebda2mfds3l4zakofyljnufi

Finally, Scott has already conducted structural analysis and design guidance for this configuration to the Wisconsin DOT. This include included shape and height transitions, interior and end designs, etc. I can ask that Scott either send you his details or details which details now exist in the Wisconsin DOT's plans.

Response
Date: 04-13-2018
The design methodology for foundations at barrier ends is contained within the Appendices of the TL-5 barrier report, TRP-03-194-07 (Dr. Faller provided the link below). The foundation design is dependent upon the barrier you are anchoring, so you will need to utilize the size and strength of your barrier when designing the foundation and each barrier may have its own foundation design to match it.

MGS close to retaining wall

Question
State: OH
Date: 04-10-2018

In this proposed cross section with MGS half post spacing, what do you recommend as minimum spacing between the back for the post and the pile wall? I'm thinking 6 inches shown is too little. If we reduce the shoulder to 3', we could get at least 1.5' behind the post. And we could also try 8" blockouts.

Also, could the distance behind the post be reduced further if MGS with quarter post spacing was used?
Attachment: https://mwrsf-qa.unl.edu/attachments/88d9b5d5c3c42a73a2779393462ae63e.png

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Response
Date: 04-10-2018

We recommend a 2-ft offset between the post and the wall due to a lack of similar testing. There is also the possibility of using non-blocked, standard post-spacing MGS to save on space between the road and the wall (just ensure the working width does not extend over the wall.

Recently, we tested a ½-post spacing MGS that was top-mounted to a culvert to MASH TL-3 for the state of Wisconsin (Bob will be presenting these results next week at the Midwest Pooled Fund meeting). The posts were offset 12" from the headwall, and the system passed. Thus, it would make sense that the posts could be offset 12" from the wall in your situation. A 12" offset would also satisfy the leave out dimensions established for posts-in-rock under NCHRP Report 350.

BR27 Railing

Question
State: VA
Date: 04-11-2018

A question has come up related to the BR27 railing that VDOT uses.

It has been suggested that the anchor bolts should be fully tensioned using turn of the nut tightening (the same tightening we use for beam splices). VDOT uses a 1/8" elastomeric "leveling" pad, so I don't think that will work, but no pad was shown on the crash test. I am 99% sure that no special tightening was used in the crash test and that, in fact, tensioning the connection might even degrade performance, but that 1% say I should get confirmation that snug tight is tight enough and fully tensioned is not desirable or required.

Our detail is at this link:

http://www.virginiadot.org/business/resources/bridge/Manuals/Part3/BR27C-12.pdf

Response
Date: 04-11-2018

I am not aware of any special tightening on these anchor bolts as well. I do not think that it would significantly influence the performance of the system either when anchors are finger tightened or more snugly tightened. I am enclosing a copy and link to a recent report where alternative anchorages were provided.

https://mwrsf.unl.edu/reportresult.php?reportId=313&search-textbox=iowa

https://mwrsf.unl.edu/researchhub/files/Report313/TRP-03-325-15.pdf

Bearing pads may likely be used to deal with uneven concrete surfaces, lower stress concentrations, or better distribute loading.

Since Bob worked on this system a few years ago, I will see if he has additional thoughts.

Response
Date: 04-12-2018

I would concur with run that the amount of torque and associated preload in those anchors is not critical for the bridge rail to function. You would want them tightened and not loose.

One related issue is that you have to be careful with the amount of torque and preload you use if you use an epoxy anchored rail. To much preload in the epoxy anchor can create issues with the epoxy bond capacity and creep. Most manufacturers have recommendations for the torque/preload.

Response
Date: 04-14-2018

Yes, that is why the pad is used. To help eliminate unevenness.

The concern I have with going to a turn of the nut condition is that the intent of turn of the nut is to ensure a consistent clamping force for slip critical connections, we do this by yielding the bolt. In a conditions where we are counting on friction (this is fine), in a condition where a collision would add load, then the bolt which has already yielded would deform until fracture with no additional strength (unless there is a reliance on strain hardening).

The addition concerns with turn of the nut are:

yielding will debond concrete locally near the top of the anchorage

poisons ratio will create tension stresses in the 10 or 12" barrier which may lead to premature failure.

Response
Date: 04-25-2018

I have looked over our last correspondence on the anchor topic for bridge posts. Although I do not have much more to comment, we can further discuss if need be.

I assume that your anchor rods are cast into the parapet. Is this true? I really do not think that finger tight or some moderate torque requirement would negatively impact the post and anchor performance. I am hesitant to think that the poison effect will cause problems in the upper parapet region but have not studied this issue. For anchors epoxied into concrete and subjected to higher long-term dead loading, I believe that there can be concerns for anchor creep within the epoxy resin material. Under those scenarios, anchor failure can occur. If the anchors were installed with epoxy resin, I would suggest that one follows the epoxy manufacturer's guidance. Again and for now, I do not think that the finger tight or moderately tightened would drastically change post and railing performance.

Let us know if we need to further discuss. Thanks!

Thrie Beam lapping at end shoe connection

Question
State: WI
Date: 04-23-2018

Is their a correct way to lap nested thrie beam at the end shoe connection. I have seen different variations.

Response
Date: 04-24-2018

I don't know if I would call it “supposed to be lapped". Rather there may be a benefit to lapping things a certain way for nested guardrail connected to an end shoe.

Typically, we have lapped our end shoe connections with both plies of the nested rail on the outside of the end shoe. This has worked fine structurally, but does allow slightly increased vehicle snag potential on the rail when impacted in the reverse direction.

An alternative is to sandwich the end shoe between the nested thrie sections as shown below. This has the benefit of reduced snag potential and loads the splice bolts in double shear rather than single shear. Thus, this may the best configuration from an engineering perspective.

Attachment: https://mwrsf-qa.unl.edu/attachments/a43f95f712ef0ca4c0284e9097b5caa5.jpg

Attachment: https://mwrsf-

qa.unl.edu/attachments/da2760b95e0ad5fb55d32907ab97f6f5.jpg

Attachment: https://mwrsf-qa.unl.edu/attachments/e82049f263ca19a61a22390e54ba2bf6.jpg

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UBSP Post Base Galvanization Vent Hole

Question
Date: 04-26-2018

Per our discussion on the test track a few minutes ago, please see attachments.

We would like to receive written concurrence from MwRSF that the tube sleeve embedment for the ThrieBeam Bullnose can be manufactured with a 13/16" galvanizing (vent/drain) hole instead of 3/8" as shown. For the following reasons:
o If you try to galvanize the product and drain it using the 3/8" hole, it becomes clogged.
o If you try to galvanize the product and use the 3/8" hole as a venting hole, it isn't large enough to allow the heated air to vent properly. The product tends to float in the zinc kettle.
If you are concerned that another manufacturer would desire a ¾" hole vs a 13/16" hole or such – then you could reply to this email indicating a maximum diameter galvanizing hole.
As 13/16" holes are used extensively in the guardrail product applications and most galvanizing hanging hardware is larger than 5/8" rod, we would ask that at least a 13/16" hole be allowed.

We would appreciate a response within a week, if at all possible. Thanks for your time and effort to consider our request.

Attachment: https://mwrsf-qa.unl.edu/attachments/14781f78e59d95c290e5d0a717b3e0ac.pdf

Attachment: https://mwrsf-qa.unl.edu/attachments/69b41bab5dd5fbe67689268443a6b64d.pdf

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Response
Date: 04-26-2018

I have reviewed the attachments and email you sent regarding the vent/drain holes in the lower section of the UBSP post developed here at MwRSF.

I see no issues with increasing the size of the vent/drain hole to ¾" or 13/16" as need to facilitate better galvanization of the assembly. Additionally, That hole could be relocated on the base plate as needed as long as it was located on the interior of the base tube.

I will update the details in our latest bullnose testing to reflect a larger hole as well and place this note on the MwRSF Q&A site as well to help in disseminating the information to our states.

Thanks

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Nebraska 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)* TPF-5(193) Suppl. #110		**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: 2611211131001	**Other Project ID (i.e., contract #):** RPFP-17-PFCHS	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2019	**Current Project End Date:** 9/30/2019	**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
$12,668	$8,398	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
	$464	

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.

Updated research hub with new completed projects.

Anticipated work next quarter:

Continue maintenance, repair, and upkeep of the website.

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

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; and Project No.: RPFP-15-PFCHS – TPF-5(193) Supplement #84, Project Title: Pooled Fund for Highway Safety; and Project No.: RPFP-16-PFCHS – TPF-5(193) Supplement #97, Project Title: Pooled Fund for Highway Safety. Funding from Project No.: RPFP-16-PFCHS – TPF-5 (193) Supplement #97, Project Title: Pooled Fund for Highway Safety was 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 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)* TPF-5(193) Supplement #111		**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 Fee to Finish TF-13 and FHWA Standard Plans		
Name of Project Manager(s): Reid, Faller, Lechtenberg, Bielenberg, Rosenb	**Phone Number:** 402-472-9070	**E-Mail** kpolivka2@unl.edu
Lead Agency Project ID: 2611211137001	**Other Project ID (i.e., contract #):** RPFP-17-TF13	**Project Start Date:** 10/1/2016
Original Project End Date: 9/30/2018	**Current Project End Date:** 9/30/2019	**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
$3,686	$123	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

Anticipated work next quarter:

Anticipate receiving comments from reviews. Will update drawings based on comments received from online review of drawings as they are obtained.

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-16-TF13 – TPF-5(193) Supplement #98, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans will be used prior to starting this project. As of the 2nd quarter of 2017, 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): 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)* TPF-5(193) Suppl. #113		**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: Dynamic Testing & Evaluation of a Culvert-Mounted, Strong-Post MGS to TL-3 Guidelines		
Name of Project Manager(s): Bielenberg, Faller, Reid, Rosenbaugh	**Phone Number:** (402) 472-9070	**E-Mail** rbielenberg2@unl.edu
Lead Agency Project ID: 2611130103001	**Other Project ID (i.e., contract #):**	**Project Start Date:** 10/01/2016
Original Project End Date: 3/31/2018	**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
$233,945	$147,199	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
	$65,878	

Project Description:

Based on previous NCHRP Report No. 350 and MASH testing of culvert mounted guardrail systems, the WisDOT desires to evaluate the MGS installed on a culvert with the MwRSF version of the strong-post attachment, half-post spacing, and a 12-in. offset from the back of the post to the culvert headwall. WisDOT also desires evaluation of the culvert mounted posts using an epoxy anchorage rather than the through-bolt system used in the original design. It is believed that if the epoxy anchorage performs adequately, then through-bolted option posts would work equally as well.

The research objective is to conduct full-scale vehicle crash testing on the MGS installed on a culvert with the MwRSF version of the strong-post attachment with epoxy anchorage, half-post spacing, and a 12-in. offset from the back of the post to the culvert headwall. All testing will be performed according to the Test Level 3 (TL-3) impact safety standards found in MASH 2016.

Objectives / Tasks

1. Simulated culvert CAD details
2. Simulated culvert construction
3. System CAD details - test no. 1
4. System construction - test no. 1
5. Full-scale crash testing & data analysis (MASH 3-11) - test no. 1
6. System CAD details - test no. 2
7. System construction - test no. 2
8. Full-scale crash testing & data analysis (MASH 3-10) - test no. 2
9. System removal
10. Transition analysis and guidance
11. Written report documenting design, testing, and conclusions

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

MwRSF conducted the first of the two full-scale crash tests on the MGS system installed on culvert. Test no. CMGS-1 on 12/1/2017. In this test, a 1100C small car vehicle impacted the barrier system at a speed of at 61.3 mph and an angle of 25.1 degrees. During the impact, the vehicle was captured and stably redirected. Occupant risk criteria were within the MASH limits. It should be noted that a partial tear of the rail splice downstream of impact was noted during the test. This type of rail tearing has been observed in other small car tests of increased stiffness MGS systems and is believed to be due to combined loading of the rail splice by the small car. However, the integrity of the rail was not compromised nor did the tear adversely affect the performance of the barrier in the test. This test was deemed successful under the MASH TL-3 impact conditions.

In this quarter, MwRSF conducted the second full-scale crash test on the strong post MGS mounted on culvert. In test CMGS-2, a 5,013 lbs. Ram 1500 Quad Cab pickup truck impacted the barrier at a speed of 62.8 mph and an angle of 25.7 degrees. During the test, the vehicle was captured and smoothly redirected by the culvert mounted guardrail. Some wheel snag was observed on the posts, but the vehicle stability and occupant risk evaluation were well within the MASH TL-3 criteria. No evidence of high rail loads or the potential for rail rupture were observed. The MASH TL-3 test evaluation criteria values were all found to be acceptable. Barrier damage was moderate and consisted of damaged W-beam and deformed posts. Two of the posts were disengaged from their base plates due to fracture at the base of the post. Static and dynamic barrier deflections are still being evaluated but will not affect the test outcome. Vehicle damage was moderate and occupant compartment deformations were well within limits. MwRSF believes that test no. CMGS-2 met the MASH TL-3 criteria.

Work towards the summary report for the research effort and testing was continued, and LS-DYNA analysis of the

Anticipated work next quarter:

In the next quarter, MwRSF plans to continue working towards completion of the summary report and the LS-DYNA transition analysis.

Significant Results:

None.

Task	% Completed
1. Simulated culvert CAD details	100%
2. Simulated culvert construction	100%
3. System CAD details - test no. 1	100%
4. System construction - test no. 1	100%
5. Full-scale crash testing & data analysis (MASH 3-11) - test no. 1	100%
6. System CAD details - test no. 2	100%
7. System construction - test no. 2	100%
8. Full-scale crash testing & data analysis (MASH 3-10) - test no. 2	100%
9. System removal	100%
10. Transition analysis and guidance	30%
11. Written report documenting design, testing, and conclusions	40%
12. Hardware Guide drawings	0%
13. FHWA eligibility application	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).

Due to the timing of the full-scale crash testing and the need to complete the transition analysis, MwRSF requested and received a six month, no-cost extension for this research.

Potential Implementation:

A strong-post attachment for mounting the MGS on low-fill culverts will provide a safe, cost effective, non-proprietary option for the placement of guardrail across culverts that are too wide for current long-span guardrail systems. Evaluation of the barrier system to the MASH 2016 criteria will allow state DOTs to continue to use this systems on roadways and ensure that its safety performance will remain adequate with respect to the current vehicle fleet. Full-scale crash testing will also identify the dynamic deflection and working width of the barrier system with respect to the current vehicle fleet.

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)* TPF-5(193) Suppl. #114	**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:
Evaluation of Anchored Temporary Concrete Barrier to MASH 2016 TL-3

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
Faller, Bielenberg, Reid	(402) 472-9064	rbielenberg2@unl.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
2611130104001		10/01/2016
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
5/31/2018	5/31/2018	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
$190,745.00	$119,854	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
	$4,352	

Project Description:

The research objective is to conduct full-scale vehicle crash testing on both the bolt-through, tie-down anchorage system for concrete road surfaces with a reduced embedment epoxy anchorage as well as the steel pin tie-down anchorage system for asphalt surfaces. All testing will be performed on F-shape PCB according to the Test Level 3 (TL-3) impact safety standards found in MASH 2016.

The research effort for this study will test and evaluate the bolt-through, tie-down system for concrete road surfaces and the steel pin tie-down system for asphalt surfaces for use with F-shape PCBs to MASH 2016. MASH 2016 requires two full-scale crash tests to evaluate the length-of-need of longitudinal barriers.

Test no. 3-10 with the 1100C vehicle may be omitted as it is not deemed critical for evaluation of the barrier system. Previous full-scale crash tests of rigid safety-shape concrete barriers under both NCHRP Report No. 350 and MASH have found that safety-shape barriers can safely redirect small car vehicles. Additionally, small car testing of New Jersey shape PCB systems found that deflections during small car impacts are generally minor, and that the small car performance with respect to the PCB was similar to the rigid barrier testing. Based on these previous tests, it is believed that the small car testing would not be necessary to evaluate the tie-down anchorages for use with F-shape PCBs. Test no. 3-11 is more critical due to concerns for increased barrier loading during 2270P impacts, the need to evaluate the barrier restraint system, and determine dynamic deflection and working width. It should be noted that it may be worthy to consider evaluation of the system with the 1100C vehicle in order to build further confidence in the safety performance of these systems based on the recent switch to new vehicle types as part of the implementation of the MASH criteria and the lack of experience and knowledge regarding the performance of the new vehicle types with certain types of hardware. Additionally, it should be noted that any tests within the evaluation matrix deemed non-critical may eventually need to be evaluated based on additional knowledge gained over time or additional FHWA eligibility letter requirements.

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

Preliminary discussions with the sponsor were held this quarter concerning the potential to modify the anchors used in the bolt-through, tie-down system for concrete road surfaces. There has been some concern in the past regarding the use of plain steel anchor rods epoxied into bridge decks due to the potential for corrosion if left in place. In order to remove these rods, they must be cored out of the deck which is problematic. Thus, the potential to replace the A307 rods fro the original system with stainless steel rods of equivalent strength was discussed. This would allow the rods to remain in place after use.

MwRSF has began research of potential stainless steel rod materials for use in the bolt-through, tie-down system for concrete road surfaces. Once an appropriate material is identified, MwRSF will review the material with WisDOT to get t heir feed back prior to developing CAD details and fabrication of a test system.

In this quarter, MwRSF finalized the details for the full-scale test setups. For the concrete anchorage, review of the potential stainless steel anchors indicated that 300 series stainless steels should provide the best corrosion resistance and comes ins several grades with greater strength and ductility than A307 Grade A. If the test was conducted with a 316 stainless anchor with greater capacity than the original A307 anchor and the test passes MASH TL-3, the A307 anchor may no longer be considered crashworthy as it has lower capacity. Thus, there were two potential options for moving forward.

1. Test with the original A307 anchor and then use engineering analysis to justify the 316 stainless anchors as an alternative based on the material strength.
2. Test with the 316 stainless anchors. Then we may need to specify a stronger (a449 or A193 B7) plain steel threaded rod as an equivalent.

After discussion with WisDOT, it was decided to pursue option 1.

Anticipated work next quarter:

In the upcoming quarter, MwRSF will continue work on the summary report of the two full-scale crash tests.

Significant Results:

CAD details for both of the PCB anchorage tests were completed.

Test no. WITD-1 on the concrete anchored PCB was successful under MASH TL-3.

Test no. WITD-2 on the asphalt anchored PCB was unsuccessful under 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).

None.

Potential Implementation:

The tie-down anchorages for use with F-shape PCBs provide a safe, cost effective, non-proprietary option for reducing the deflection of free-standing PCBs and retaining PCB segments installed adjacent to drop-offs and bridge deck edges. Evaluation of the barrier systems to the MASH 2016 criteria will allow state DOTs to continue to use these systems on roadways and ensure that their safety performance will remain adequate with respect to the current vehicle fleet. Full-scale crash testing will also identify the dynamic deflection and working width of the barrier systems with respect to the current vehicle fleet.

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl #115

Project Title: Minnesota DOT Evaluation of MnDOT's Noise Wall System Under MASH TL-3

Principal Investigator: Ronald K. Faller

Principal Contact Information Email: rfaller1@unl.edu **Phone:** (402) 472-6864

Project Start Date: 4/6/2017 **Project Completion Date:** 9/30/2018

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☐ **On Schedule**
- ☒ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

	Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1.	Project Planning and Correspondence	$14,635.00	4%	$635.00	98%	$300.00
2.	Phase I Full-Scale Testing	$185,692.00	50%	$69,264.00	67%	$90,613.00
3.	Phase II Full-Scale Testing	$79,788.00	0%	$1,000.00	2%	$78,788.00
4.	Reporting and FHWA letter	$25,000.00	8%	$2,000.00	30%	$17,269.00
5.						
6.						
7.						
8.						
9.	Total	$305,115.00		$71,899.00		$118,145.00

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

Materials for the three crash tests were obtained, and construction began on the first system. The sponsor provided details on several variations of the noisewall system that may occur during field installations including using longer rail elements, utilizing hex-head bolts with counterboring in leiu of dome-head bolts, and installation of the noisewall planks on the front side of the posts. Draft test plans were created for the third full-scale crash tests which utilizes noisewall planks on the front side of the posts and hex head bolts. Writing continued on the draft report.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

The projected timeline included in the proposal including the project starting in January 2017 and extending through March 31, 2018 (5 quarters total). The contract was not approved until April 6, 2017. Thus, the project started over a quarter behind. As of April 6, 2018, all three full-scale crash tests have been completed. However, not all of charges have been applied to the project and are not reflected in this progress report. An extension was requested and approved to extend the project to September 30, 2018 to allow sufficient time to process all of the test data as well as prepare and review the summary report.

Anticipated Work Next Quarter:

Analysis of the test data will be completed. Writing will continue on the report

Total Percentage of Project Completion:

60%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl#116

Project Title: Illinois DOT and Ohio DOT MASH TL-4 Steel Tube Bridge Rail and Guardrail Transition

Principal Investigator: Ronald K. Faller

Principal Contact Information Email: rfaller1@unl.edu **Phone:** (402) 472-6864

Project Start Date: 5/4/2017 **Project Completion Date:** 9/30/2019

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☐ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☒ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Bridge Rail Planning, Literature Review, Design	$53,131.00	1%	$500.00	99%	$0.00
2. Bridge Rail Full-Scale Testing	$344,162.00	2%	$3,500.00	4%	$337,162.00
3. Bridge Rail Reporting	$30,000.00	5%	$2,000.00	10%	$26,000.00
4. Bridge Deck Component Testing	$187,956.00	9%	$17,603.00	34%	$121,656.00
5. Transition Planning	$13,859.00	0	$0.00	0	$13,859.00
6. Transition Analysis and Design	$67,261.00	0	$0.00	0	$67,261.00
7. Transition Full-Scale Testing	$200,482.00	0	$0.00	0	$200,482.00
8. Transition Reporting	$30,000.00	0	$0.00	0	$30,000.00
9. Total	$926,851.00		$23,603.00		$796,420.00

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

A meeting was held with the sponsors on March 14 to discuss the progress on the project. Several internal meetings have been held between members of the research team, and several discussions were held via email with the sponsors.

Several tube rail splice options were discussed with the sponsors over the course of several meetings and emails. Ohio and Illinois have recommended testing the HSS splice tube with welded plates to connect adjacent rails, although both a HSS splice tube and and equivalent built-up splice tube would be acceptable for use. Additionally, a plate will be attached to the top of the post with 4 bolts (2 bolts on each side of the post) attaching the post to the top rail.

After many rounds of discussions with the sponsors, both Illinois DOT and Ohio DOT favored Concept #1D (thick plate welded to post with HSS5x4x3/8 spacers). Vertical tolerance of 3⅛ in. is included in the connection on the post side. Several different variations of this concepts were drawn in preparation for the 6 dynamic bogie tests. The first bogie test will be Concept #1D as-is. Depending on the results of the first test, other alternative could be tested such as thinner plates, thicker tubes, alternative washers, smaller anchors, and more reinforcement in the box girder. If too much deck damage occurs or if Concept #1D does not perform well, Illinois DOT recommended utilizing Concept #1A (double angles with tubes). The 42-in. tall box girder with the built-in anchorage hardware was fabricated by an external supplier for component testing, but it has yet to be delivered. Of note, the anchor rods utilized in the box girder were specified to be all-thread. However, the fabricator utilized straight bar with only threaded ends. Thus, the full capacity of the anchor rods may not be developed due to less bond between the rods and concrete.

The capacities of both the Illinois DOT and Ohio DOT slab decks were evaluated. All slab deck configurations have more than sufficient capacity for the design loads. Thus, the team determined that the slab deck configurations should all experience less damage than the box girder.

Writing continued on the summary reports.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

The original gantt chart in the proposal had the project starting in April 2017. Due to the time it took to get the contract in place (May 4, 2017), the project timeline will be shifted by approximately 1 month. Along with the initial delay, design and optimization of the connections and rails has taken longer than expected. Part of these delays are due to the mutliple rounds of design that were required to meet the sponsors' desires, especially with the rail sizes, post spacing, connections, and post-to-deck connection spacer. This level of design was not anticipated, and we have spent more funds than originally budgeted. The component and full-scale crash tests have not begun as early as anticipated and are delayed several months from the gantt chart. Every effort will be made to get the project completed by its original end date (September 30, 2019). The project is currently behind on its proposed budget, but the project team will work to make up for these additional funds.

Anticipated Work Next Quarter:

All material for the component tests will be ordered. Dynamic bogie testing will be conducted once all materials are received.

The connections between the post and rail as well as the rail splices will be finalized after sponsor review. Drawings will be prepared for the full-scale crash tests. A meeting will be held with the sponsors to discuss the full-scale crash testing plan.

Writing will continue on the summary reports.

Total Percentage of Project Completion:
14%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl #117_OHIOSS-1

Project Title: MASH TL-3 Evaluation of the Ohio Single-Slope Concrete Barrier

Principal Investigator: Dr. Ronald K. Faller and Mr. Robert W. Bielenberg

Principal Contact Information Email: rbielenberg2@unl.edu **Phone:** (402) 472-9064

Project Start Date: 7/1/2017 **Project Completion Date:** 6/31/2018

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ----------------- October 31
- ☐ Quarter 2 (October 1 – December 31) ------------- January 31
- ☒ Quarter 3 (January 1 – March 31) ------------------ April 30
- ☐ Quarter 4 (April 1 – June 30) ------------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Project Planning and Correspondence	$5,000.00	25%	$0.00	25%	$3,500.00
2. Full-Scale Crash Testing	$116,259.00	0%	$19,023.00	90%	$56,633.00
3. Reporting and Project Deliverables	$14,155.00	50%	$2,000.00	0%	$12,155.00
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

Test, no. OSSB-1 was conducted on 12/13/17. In test OSSB-1, a 5,001 lbs. Ram 1500 Quad Cab pickup truck impacted the barrier at a speed of 101.0 mph and an angle of 24.8 degrees. During the test, the vehicle was captured and smoothly redirected by the single slope barrier. Some wheel snag was observed at the vertical separation in the barriers that was included to represent through cracking of the unreinforced barrier, but the vehicle stability and occupant risk evaluation were well within the MASH TL-3 criteria.

Occupant risk criteria are shown below. Note that OIV must be less than 40 ft/s and ORA must be ≤ 20.49 g's. All of the values were acceptable.

PRIMARY UNIT: SLICE2

Longitudinal	MASH			
ORA	-9.3566148	g's	@	0.0841 sec
OIV	-19.179486	ft/s		
Time	0.0791 sec			

Lateral	MASH			
ORA	10.4034925	g's	@	0.2125 sec
OIV	26.9061463	ft/s		
Time	0.0791 sec			

Vehicle stability was also acceptable vehicle remained upright and stable during the impact and the maximum roll angle of the vehicle was 20.0 degrees and the maximum pitch angle was 6.6 degrees. Barrier damage was minimal and was limited to minor spalling and cracking of the barrier. Dynamic barrier deflections were less than 1" at the top of the first impacted barrier segment, and permanent set deflections were negligible.

Vehicle damage was moderate. Detailed occupant compartment deformations have not been measured, but visual inspection of the vehicle floorboard and interior suggested that they were well below the MASH limits as well. There was a small tear at the floor seam, about an inch long. We don't believe this is an issue based on MASH recommendations. MwRSF believes that the minimal floorboard seam in this test falls under the safe limits noted in MASH. Thus, test OSSB-1 was successful under MASH TL-3 impact conditions.

In this quarter, MwRSF has worked on the summary report of this research. A preliminary draft has been completed and is in interal review and editing.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

None

Anticipated Work Next Quarter: Completion of the summary report.
Total Percentage of Project Completion: 80%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #118, RPFP-18-CABLE-1

Project Title: Redesign of the High-Tension Cable Median Barrier (Continuation)

Principal Investigator: Reid, Faller, Bielenberg, Lechtenberg, Rosenbaugh, Schmidt

Principal Contact Information Email: kpolivka2@unl.edu **Phone:** (402) 472-9070

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Correspondence & Reporting	$29,614.00	0%	$0.00	0%	$0.00
2. Design and Analysis	$20,386.00	15%	$3,120.00	15%	$17,266.00
3. Bogie Testing	$0.00	0%	$0.00	0%	$0.00
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:
(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)
None.

This is supplemental funding of the ongoing cable median barrier development project. Only $50,000 was funded of the total project costs. This effort will be conducted to the extent possible using these funds and existing funding from previous years noted.

These project funds are to be utilized for the development of the cable median barrier. These funds will be used after the funds in TPF-5(193) Supplement #89, RPFP-16-CABLE-4 are exhausted. The funds in the aforementioned project were exhausted in Quarter 1 of 2018. All progress was noted under the previous project and further progress will be noted herein starting in Quarter 2 of 2018.

Circumstances Affecting Project, Scope, or Budget:
(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)
This project will not be started until the original project funds (Project No. TPF-5(193) Supplement #89 - RPFP-16-CABLE-4) have been exhausted. Only $50,000 was funded of the total project costs. This effort will be conducted to the extent possible using these funds and existing funding from previous years noted.

Anticipated Work Next Quarter:
None.

Total Percentage of Project Completion:
6%

Research Project Quarterly Progress Report

Date: 12/31/2017 **Project Number:** TPF-5(193) Suppl. #119 or RPFP-18-CONC-1

Project Title: PCB Steel Cover Plate for Large Open Joints - PHASE II

Principal Investigator: Rosenbaugh, S.K., Reid, J.D., Bielenberg, R.W., Faller, R.K., & Lechtenberg, K.A.

Principal Contact Information Email: srosenabugh2@unl.edu **Phone:** (402) 472-9324

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31) ------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. **Project Planning and CAD**	$15,299.00	0%	$0.00	0%	$15,299.00
2. **Full-Scale Crash Testing**	$132,517.00	0%	$0.00	0%	$132,517.00
3. **Reporting and Project Deliverables**	$25,000.00	0%	$0.00	0%	$25,000.00
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

This project has not begun, since Phase I of the project is still ongoing. Details are provided below.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

This project will not be started until the Phase I project (Pooled FUnd Year 26 project TPF-5(193) Suppl. #82) is completed, as Phase I contains the full design, analysis, and selection of the critical impact points required for full-scale testing. This Phase II was funded with this understanding as the project plan (Gantt chart) did not anticipate work to begin on this project until spring of 2018. The project is still anticipated to be completed on time.

Anticipated Work Next Quarter:

Efforts will begin to detail the system in CAD and the test plan will be put together illustrating the test vehicles and impact points needed for testing.

Total Percentage of Project Completion:

0%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #120, RPFP-18-MGS-1

Project Title: Steel Post Version of Downstream Anchorage System Phase II

Principal Investigator: Reid, Faller, Bielenberg, Lechtenberg, Rosenbaugh, Schmidt

Principal Contact Information Email: kpolivka2@unl.edu **Phone:** (402) 472-9070

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31) ------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30) ---------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Project Planning & Correspondence	$21,027.00	0%	$0.00	0%	$21,027.00
2. Full-Scall Crash Testing	$128,945.00	0%	$0.00	0%	$128,945.00
3. Reporting & Project Deliverables	$25,000.00	0%	$0.00	0%	$25,000.00
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:
(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)
None.

This is the Phase II of an ongoing project.

Circumstances Affecting Project, Scope, or Budget:
(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)
This project will not be started until the Phase I project (Project No. TPF-5(193) Supplement #92 - RPFP-16-MGS-3, Project Title: Steel Post Version of Downstream Anchorage System) is completed, as Phase I contains the full design and analysis required for full-scale testing. This Phase II was funded with this understanding as the project plan (Gantt chart) did not anticipate work to begin on this project until spring of 2018. The project is still anticipated to be completed on time.

Anticipated Work Next Quarter:
None.

Total Percentage of Project Completion:
0%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #122; FPFP-18-SIGN-1

Project Title: MASH Testing of Single-Post, U-Channel Sign Supports

Principal Investigator: Jennifer Schmidt, J. Reid, R. Faller, R. Bielenberg, K. Lechtenberg, S. Rosenbaugh

Principal Contact Information Email: jennifer.schmidt@unl.edu **Phone:** (402) 472-870

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Project Planning & Reporting	$28,506.00	7%	$1,863.00	7%	$26,643.00
2. Analysis & Selection of Configurations	$24,396.00	0%	$0.00	0%	$24,396.00
3. Develop Bogie, Install and Remove Signs	$51,348.00	0%	$0.00	0%	$51,348.00
4. Dynamic Bogie Tests	$90,988.00	0%	$0.00	0%	$90,988.00
5.					
6.					
7.					
8.					
9. Total	$195,238.00		$1,863.00		$193,375.00

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

Internal meetings discussing the project plan were held. The literature review was conducted on existing U-channel sign supports tested to NCHRP Report 350 or MASH. Twenty-two crash tests were summarized and documented. There are a few remaining tests to be added to the crash test summary of single, U-channel sign supports.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

None

Anticipated Work Next Quarter:

The literature review of crash tests on single, U-channel sign supports will be completed. A survey, which will be sent to State DOTs to garner their U-channel sign support usage, will be prepared.

Total Percentage of Project Completion:

1%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #123 RPFP-18-

Project Title: MASH Testing of the Thrie Beam Bullnose System – Phase II

Principal Investigator: Jennifer Schmidt, J. Reid, R. Faller, R. Bielenberg, K. Lechtenberg, S. Rosenbaugh

Principal Contact Information Email: rbielenberg2@unl.edu **Phone:** (402) 472-9064

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Project Planning and Correspondence	$19,019.00	25%	$0.00	25%	$19,019.00
2. Full-Scale Crash Testing	$364,028.00	25%	$0.00	25%	$364,028.00
3. Reporting and Project Deliverables	$27,719.00	0%	$0.00	0%	$27,719.00
4.					
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Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

Test no. MSPBN-4 was conducted under the MASH TL-3 guidelines for test no. 3-30. Test no. 3-30 is an impact of the 1100C vehicle at 62 mph and 0 degrees on the nose of the system with a ¼ vehicle offset. In test no. MSPBN-4, a 2,429 lbs. Kia Rio sedan impacted the barrier at a speed of 62.1 mph and an angle of 1.3 degrees. During the test, the vehicle was initially captured by the thrie beam nose of the system. However, as the vehicle proceeded into the system, the slot between the upper two corrugations of thrie beam and the lowest corrugation opened. This allowed the top two thrie beam corrugations to push upward and the lower thrie beam corrugations to move downward and rupture. This compromised the capture of the vehicle front end and allowed the vehicle to penetrate the system. Thus, the system was not acceptable under the MASH TL-3 criteria.

Barrier damage was moderate and consisted of deformed and torn thrie beam and disengaged posts. The bottom two thrie beam corrugations were fractured and three of the BCT posts were disengaged. The four BCT post on the left side of the system was partially fractured. The limited disengagement of the breakaway posts would indicate that capture was lost prior to the vehicle being significantly decelerated. High speed video confirms this. Static and dynamic barrier deflections are still being evaluated but will not affect the test outcome. Vehicle damage was extensive and windshield deformation due to the top two thrie corrugations passing up and over the vehicle exceeded the MASH limits.

We have reviewed the test data along with data from previous 820C testing and have determined that three factors contributed to the failure of this test.

1. Increased vehicle mass and energy (25% increase) as compared to previous 820 testing. Mass increased from 1,808 lb to 2,425 lb.
2. 1100C front end geometry and structure is significantly different than the 820C vehicle tested previously which may have altered the engagement with the nose rail and changed the nose rail slot tab tearing and corrugation separation. Additionally, it was noted that the behavior of the vehicle hood was different as compared to the previous 820C testing.
3. The previous two factors led to more rapid rupture of the thrie beam slot tabs in the nose section, opening of the thrie beam of between the middle and lower rail corrugations, upward movement of the upper two rail corrugations, and rupture of the lower rail corrugation which allowed the vehicle to penetrate the system.

After reviewing the test results, it has been determined that the best option for improving the system performance would be to add a third nose cable behind the lowest thrie beam corrugation. Recall that the current bullnose system has reinforcing cable elements behind the top two rail corrugations that are used to retain the pickup truck vehicle when the thrie beam rail in the nose section ruptures during impact on the end of the system. It is believed adding a third cable to the lowest corrugation could provide similar capture benefits for the 1100C vehicle now that it has been observed to fracture the rail in the nose section. Additional modification of the slot tabs in the nose section and/or the use of additional capture elements were considered, but these would significantly modify the system and require additional analysis.

It should be noted that the opening and separation of the lower corrugation from the upper two corrugations in test no. MSPBN-4 leads to some concern that capture of the front end of the 1100C may not be optimal even with the addition of aa third nose cable. In MSPBN-4, the lower corrugation is riding below the apex or middle of the vehicle bumper prior to rupturing. The addition of the third nose cable will prevent loss of tension across the front of the vehicle, but the position of that capture element may not be as positive as observed in previous 820C testing. However, we believe that this is the best step moving forward. If the addition of the third nose cable is unsuccessful, additional R&D using LS-DYNA would likely be required to develop modifications necessary to improve capture.

Currently, we plan to proceed with retesting the bullnose system under test no. 3-30 with the additional nose cable. The addition of a third nose cable is not expected to affect the system relative to the three previous, successful MASH crash tests (test nos. 3-32, 2-34, and 3-35), and these tests would not need to be rerun if this modification is successful.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

Note that because there are two ongoing an related bullnose projects through the Midwest Pooled Fund, MwRSF is depleting the funding from the Year 27 effort prior to charging this Year 28 project.

Anticipated Work Next Quarter:

Full-scale crash testing should continue with a retest of test no. MSPBN-4. Subsequent testing will follow dependent on the outcome of that test.

Total Percentage of Project Completion:

25%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #124 RPFP-18-CONSULT

Project Title: Annual Consulting Services Support

Principal Investigator: Jennifer Schmidt, J. Reid, R. Faller, R. Bielenberg, K. Lechtenberg, S. Rosenbaugh

Principal Contact Information Email: rbielenberg2@unl.edu **Phone:** (402) 472-9064

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31) ------------- January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30) ------------------------ July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Project Planning and Correspondence	$56,310.00	0%	$0.00	0%	$56,310.00
2.					
3.					
4.					
5.					
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8.					
9.					

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

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.

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.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

None

Anticipated Work Next Quarter:

Full-scale crash 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/ should begin on the four planned full-scale crash tests..

Total Percentage of Project Completion:

0%

Research Project Quarterly Progress Report

Date: 3/31/2018 **Project Number:** TPF-5(193) Suppl. #125, RPFP-18-PFCHS

Project Title: Pooled Fund Center for Highway Safety

Principal Investigator: Reid, Faller, Bielenberg, Lechtenberg, Rosenbaugh, Schmidt

Principal Contact Information Email: kpolivka2@unl.edu **Phone:** (402) 472-9070

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Website Develop, Populate, and Host	$12,669.00	0%	$0.00	0%	$12,669.00
2.					
3.					
4.					
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8.					
9.					

Progress and Accomplishments this Quarter:
(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)
None.

This is continuation funding for the original project. Funds from Project Title: Pooled Fund for Highway Safety. Funding from Project No.: RPFP-17-PFCHS – TPF-5(193) Supplement #110, Project Title: Pooled Fund for Highway Safety will be used prior to starting this project.

Circumstances Affecting Project, Scope, or Budget:
(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)
This is continuation funding untill the funds from Project No.: RPFP-17-PFCHS – TPF-5(193) Supplement #110, Project Title: Pooled Fund for Highway Safety have been exhaused.

Anticipated Work Next Quarter:
None until funds from previous project have been exhausted.

Total Percentage of Project Completion:
0%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #126, RPFP-18-TF13

Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans

Principal Investigator: Reid, Faller, Bielenberg, Lechtenberg, Rosenbaugh, Schmidt

Principal Contact Information Email: kpolivka2@unl.edu **Phone:** (402) 472-9070

Project Start Date: 9/15/2017 **Project Completion Date:** 12/31/2020

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31) ------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ---------------- April 30
- ☐ Quarter 4 (April 1 – June 30) -------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. Annual CAD Services Support	$3,999.00	0%	$0.00	0%	$3,999.00
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

None.

This is continuation funding for the original project. Funds from Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans. Funding from Project No.: RPFP-17-TF13 – TPF-5(193) Supplement #111, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans will be used prior to starting this project.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

This is continuation funding untill the funds from Project No.: RPFP-17-TF13 – TPF-5(193) Supplement #111, Project Title: Annual Fee to Finish TF-13 and FHWA Standard Plans have been exhaused.

Anticipated Work Next Quarter:

None until funds from previous project have been exhausted.

Total Percentage of Project Completion:

0%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #128

Project Title: Crash Testing of Transition between Box Beam and Corrugated Beam Guide Rail

Principal Investigator: Faller, Lechtenberg, Holloway, Asadollahipajouh, Ranjha

Principal Contact Information Email: kpolivka2@unl.edu **Phone:** (402) 472-9070

Project Start Date: 10/18/2017 **Project Completion Date:** 10/17/2018

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ---------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☒ **On Schedule**
- ☐ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. **Project Planning & Correspondence**	$10,985.00	70%	$7,807.00	70%	$3,178.00
2. **Full-Scale Crash Testing**	$200,641.00	0%	$0.00	0%	$0.00
3. **Reporting & Project Deliverables**	$25,000.00	0%	$0.00	0%	$0.00
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:
(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)
Create tests plan for first system.

Begin ordering and acquire materials for first system.

Circumstances Affecting Project, Scope, or Budget:
(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)
None

Anticipated Work Next Quarter:
Acquire materials for first system.

Construction of first system.
Conduct test on first system.
Potentially rebuild and conduct test on second system.

Total Percentage of Project Completion:
3%

Research Project Quarterly Progress Report

Date: 4/30/2018 **Project Number:** TPF-5(193) Suppl. #129

Project Title: Crash Testing MoDOT Devices

Principal Investigator: Lechtenberg, Faller, Holloway, Schmidt

Principal Contact Information Email: kpolivka2@unl.edu **Phone:** (402) 472-9070

Project Start Date: 3/1/2018 **Project Completion Date:** 2/28/2019

Report Period: **Due Date:**

- ☐ Quarter 1 (July 1 – September 30) ---------------- October 31
- ☐ Quarter 2 (October 1 – December 31)------------ January 31
- ☒ Quarter 3 (January 1 – March 31) ----------------- April 30
- ☐ Quarter 4 (April 1 – June 30)----------------------- July 31

Project Schedule Status:

- ☐ **On Schedule**
- ☒ **On Approved Revised Schedule**
- ☐ **Ahead of Schedule**
- ☐ **Behind Schedule**

Progress:

Task	Total Budget	% work Completed This Quarter	Expenses This Quarter	Total % of Task Completed	Remaining Budget
1. System #1 - X-Foot Signs with Trim-line Bases	$109,634.00	0%	$619.00	0%	$109,015.00
2. System #2 - Crash System with 2 bolts instead of 4	$157,099.00	0%	$0.00	0%	$157,099.00
3. System #4 - Sign Modification with PSST Base	$109,634.00	0%	$0.00	0%	$109,634.00
4.					
5.					
6.					
7.					
8.					
9.					

Progress and Accomplishments this Quarter:

(Provide an informative summary of tasks/activities that occurred this quarter includes meetings, work plan status, significant progress, etc.)

Begin correspondence of setting up a kickoff meeting.

Circumstances Affecting Project, Scope, or Budget:

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints, along with recommended solution to those problems.)

Note project dates were originally 12/27/17 through 12/26/18 but not approved until later.

Anticipated Work Next Quarter:

Hold kickoff meeting to determine exactly what systems will be crash testing. Potentially obtain system material if decision is made on what systems will be crash tested.

Total Percentage of Project Completion:

0%

Midwest States Pooled Fund Program
Quarterly Progress Report – First Quarter 2018
January 1, 2018 to March 31, 2018

DRAFT REPORTS – POOL FUND

Wipf, J.T., Schmidt, J.D., Faller, R.K., Stolle, C.S., Bielenberg, R.W., Rosenbaugh, S.K., and Lechtenberg, K.A., *Development of a Generic Energy-Absorbing Approach End Terminal for MGS*, CONFIDENTIAL Draft Report to the Midwest Pooled Fund Program, MwRSF Research Report No. TRP-03-379-18, Project No. TPF-5(193) Supplement No. 94, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, January 29, 2018.

Asadollahi Pajouh, M., Lechtenberg, K.A., Faller, R.K., Holloway, J.C., Bielenberg, R.W., Rosenbaugh, S.K., and Reid, J.D., *MASH Test No. 3-10 of a Non-Proprietary, High-Tension, Cable Median Barrier for Use in 6H:1V V-Ditch (Test No. MWP-9)*, Draft Report to the Midwest Pooled Fund Program, MwRSF Research Report No. TRP-03-360-18, Project No. TPF-5(193) Supplement Nos. 64 and 79, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, February 15, 2018.

Meyer, D.T., Asadollahi Pajouh, M., Lechtenberg, K.A., Faller, R.K., Bielenberg, R.W., and Holloway, J.C., *Phase II Evaluation of Floor Pan Tearing for Cable Barrier Systems*, Draft Report to the Midwest Pooled Fund Program, MwRSF Research Report No. TRP-03-359-18, Project No. TPF-5(193) Supplement Nos. 64 and 79, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, February 2, 2018.

FINAL REPORTS – POOL FUND

None

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

Stolle, C.S., Lechtenberg, K.A., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Urbank, E.L., *Performance Evaluation of New Jersey's Portable Concrete Barrier with a Pinned Configuration in Asphalt [Type 4 – Alternative B – Modified Joint Class C] – Test No. NJPCB-9*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-385-18, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 13, 2018.

Stolle, C.S., Lechtenberg, K.A., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Urbank, E.L., *Performance Evaluation of New Jersey's Portable Concrete Barrier with a Grouted Bolted Configuration in Asphalt [Type 4 – Alternative B – Modified Joint Class D] – Test No. NJPCB-8*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-384-18, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 13, 2018.

Bhakta, S.K., Lechtenberg, K.A., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Urbank, E.L., *Performance Evaluation of New Jersey's Portable Concrete Barrier with a Traffic-side Pinned Configuration and Grouted Toes [Type 4 – Alternative B] – Test No. NJPCB-7*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-374-18, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 13, 2018.

Bhakta, S.K., Lechtenberg, K.A., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Urbank, E.L., *Performance Evaluation of New Jersey's Portable Concrete Barrier with a Back-side Pinned Configuration and Grouted Toes [Type 4 – Alternative B] – Test No. NJPCB-6*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-373-18, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 13, 2018.

Bhakta, S.K., Lechtenberg, K.A., Fang, C., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Urbank, E.L., *Performance Evaluation of New Jersey's Portable Concrete Barrier with a Box-Beam Stiffened configuration and Grouted Toes [Type 4 – Alternative B – Stiffened] – Test No. NJPCB-5*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-372-18, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 13, 2018.

Bhakta, S.K., Lechtenberg, K.A., Faller, R.K., Reid, J.D., and Bielenberg, R.W., *Performance Investigation of New Jersey's Portable Concrete Barriers in a Free-Standing Configuration with Grout – Test No. NJPCB-4*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-371-17, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 3, 2017.

Bhakta, S.K., Lechtenberg, K.A., Faller, R.K., Reid, J.D., and Bielenberg, R.W., *Performance Investigation of New Jersey's Portable Concrete Barriers in a Free-Standing Configuration – Test No. NJPCB-3*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-355-17, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 3, 2017.

Bhakta, S.K., Lechtenberg, K.A., Faller, R.K., Reid, J.D., and Bielenberg, R.W., *Performance Investigation of New Jersey's Portable Concrete Barriers in a Bolted Configuration – Test No. NJPCB-2*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-340-17, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 3, 2017.

Bhakta, S.K., Lechtenberg, K.A., Faller, R.K., Reid, J.D., and Bielenberg, R.W., *Performance Investigation of New Jersey's Portable Concrete Barriers in a Pinned Configuration – Test No. NJPCB-1*, Draft Report to the New Jersey Department of Transportation, MwRSF Research Report No. TRP-03-338-17, Project No. TPF-5(193) Supplement No. 88, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, July 26, 2017.

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

None

DRAFT REPORTS – FHWA PROJECT

None

FINAL REPORTS – FHWA PROJECT

None