Roadside Safety Pooled Fund

Texas A&M Transportation Institute

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SUMMARY REPORT FOR POOLED FUND PROGRAM TPF 5(343)

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The results reported herein apply only to the article tested. The full-scale crash tests were performed according to TTI Proving Ground quality procedures and American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) guidelines and standards.

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16. Abstract

Established in 2016, the Roadside Safety Pooled Fund Program TPF 5(343) facilitated collaborative research among State Departments of Transportation (DOTs) to address challenges related to roadside safety features. The program prioritized research to support State DOTs in the implementation of the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH).

Research addressing shared roadside safety concerns of the participating DOTs was performed under the pooled fund program. This report provides brief summaries of the research projects carried out under the pooled fund program, along with links to the final reports documenting the details of the individual research projects.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in2	square inches	645.2	square millimeters	mm2
ft2	square feet	0.093	square meters	m2
yd2	square yards	0.836	square meters	m2
ac	acres	0.405	hectares	ha
mi2	square miles	2.59	square kilometers	km2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft3	cubic feet	0.028	cubic meters	m3
yd3	cubic yards	0.765	cubic meters	m3
	NOTE: volumes greater than 1000L shall be shown in m3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm2	square millimeters	0.0016	square inches	in2
m2	square meters	10.764	square feet	ft2
m2	square meters	1.195	square yards	yd2
ha	hectares	2.47	acres	ac
km2	Square kilometers	0.386	square miles	mi2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m3	cubic meters	35.314	cubic feet	ft3
m3	cubic meters	1.307	cubic yards	yd3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in2

*SI is the symbol for the International System of Units

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TABLE OF CONTENTS

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Chapter 1. INTRODUCTION

The Roadside Safety Pooled Fund Program TPF 5(343) was established in 2016 to provide State Departments of Transportation (DOT) a cooperative means for conducting research to resolve issues regarding roadside safety features. Emphasis was placed on assisting State DOTs with their implementation of the AASHTO Manual for Assessing Safety Hardware (MASH) and addressing other roadside safety needs of common interest.

Washington Department of Transportation (WSDOT) served as the lead state agency for the TPF 5(343) program and Texas A&M Transportation Institute (TTI) was the research partner for funded projects. Other State DOTs joined as member states with an annual financial contribution towards the pooled funds for the research program. The number of member states changed over the years, ranging from 18 states to 28 states, as shown in Figure 1.1. Each State DOT was represented by one to two voting representatives, which comprised the Technical Advisory Committee (TAC) for the program. The TAC also included two non-voting members from the Federal Highway Administration (FHWA). Appendix A provides a list of all representatives from the various states from year 2016 to 2022. The annual program funds also varied each year based on the number of states in the program and the level of funds committed by each state member. Figure 1.2 shows the total funds available for each year of the program.

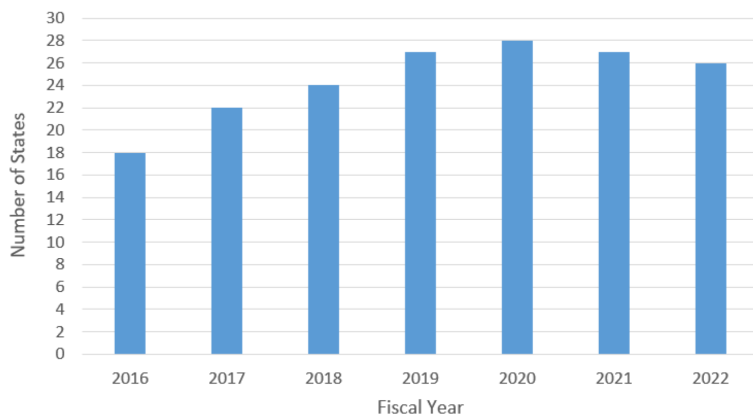


Figure 1.1. Number of Participating States Over the Duration of the Program.

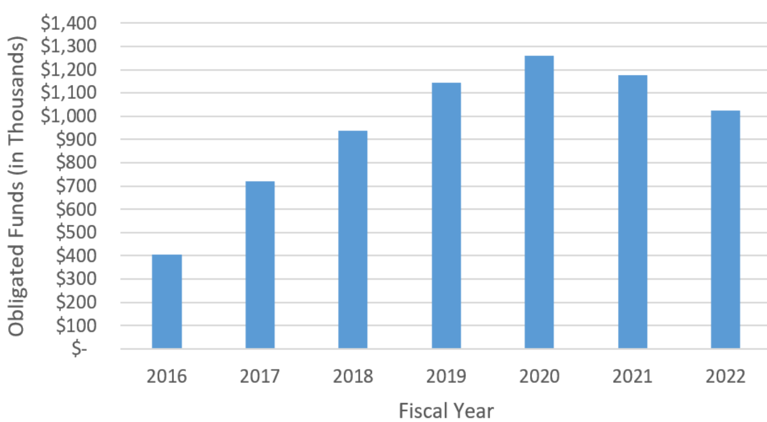


Figure 1.2. Annual Obligated Funds for TPF 5(343).

The members of the pooled fund program submitted new research problem statements each year and met at an annual meeting to discuss and prioritize the statements. To avoid duplication of research, literature search was conducted for each problem statement to identify relevant past or ongoing research. Research problem statements and ongoing research projects were also coordinated with the Midwest Roadside Safety Pooled Fund Program at the University of Nebraska to avoid duplication of research in either of the programs. The FHWA TAC members also provided information on other relevant ongoing or upcoming research to guide the problem statement selection and prioritization process. Once the new problem statements were prioritized, the projects for the upcoming year were funded in the order of priority until the total annual amount of available funds were exhausted.

In addition to the prioritized research projects, the TPF 5(343) program provided means for individual state DOTs to carry out supplemental research projects with additional funds provided by the state. This allowed a state to carry out research projects that were specific to that state which may not have had a broader interest of the member states to be prioritized through the pooled fund prioritization process. Various supplemental projects were carried out under the TPF 5(343) which are also included in this report.

In addition to new research, the TPF 5(343) program provided means for the state DOT safety engineers to collaborate with each other to discuss best practices, new regulatory issues, risk management strategies, and other matters pertaining to roadside safety. A recurring project setup via the TPF 5(343) program provided means for the state members to seek professional engineering opinions from TTI researchers regarding implementation and MASH compliance of roadside safety hardware. The program also provided means for participating DOT members to ask questions from TTI researchers regarding site or state specific design and implementation scenarios. Finally, the TPF 5(343) program established and maintained a database of MASH compliant devices which is still being actively maintained. This interactive database is searchable and filterable to allow for efficient search of roadside safety devices.

Over its eight years duration, the TPF 5(343) program prioritized and conducted 59 research projects and supporting tasks totaling $6.35m. In addition, the TPF 5(343) program conducted 17 projects for individual member states through bilateral agreements and supplemental contracts worth over $2.64m. With an average of 22 states participating in the program at an average of $44.45k obligated per state per year, the TPF 5(343) program rendered a rate of return of $18 in research for every dollar contributed by the participating states for the prioritized research projects.

This report presents a summary of the research projects carried out under TPF 5(343). The summaries provide a brief synopsis of the research along with a link to the final report. The research projects are organized into eight chapters in accordance with the roadside safety device category. These categories are Guardrails (Chapter 2), Bridge Rails (Chapter 3), Concrete Barriers (Chapter 4), Portable Concrete Barriers (Chapter 5), Terminals (Chapter 6), Transitions (Chapter 7), Support Structures (Chapter 8), and Work Zone Devices (Chapter 9).

Chapter 2. GUARDRAILS

Guardrails are intended to shield motorists from non-traversable terrain or fixed objects on the roadside within the clear recovery area. Guardrails function by containing and redirecting vehicles within the performance criteria prescribed in MASH. Different guardrail configurations are often developed to address specific roadside conditions. Under this pooled fund program, numerous guardrail systems were tested and evaluated for specific applications such as placement on different slopes and within different vegetation mow strips. Various guardrail stiffening options to reduce the deflection of guardrail in close proximity to roadside obstacles were also evaluated. Other projects included a retrofit treatment for raising the height of existing guardrail, evaluation of flared guardrail to reduce length of need, assessment of the crashworthiness of fall protection fence behind a long-span guardrail system, and testing of an aesthetic steel-backed timber guardrail. Summaries of these projects are presented below.

2.1. MASH TEST 3-11 OF 28-INCH W-BEAM GUARDRAIL SYSTEM WITH 8-INCH COMPOSITE BLOCKOUTS RAISED 4-INCHES ON STEEL POSTS (TRP# 608421-1)

Principal Investigator: Chiara S. Dobrovolny
Technical Representative: Ali Hangul (TDOT)

The purpose of this research was to evaluate the performance of W-beam guardrail with raised blockouts on steel posts as an economical method of adjusting rail height. MASH Test 3-11 was successfully performed on a W-beam guardrail with rail splices at the posts and with composite blockouts raised 4 inches on the posts to provide a rail mounting height of 28 inches. Use of this practice on guardrails with taller rail heights, offset rail splices, and blockouts raised 0-4 inches on the posts are considered acceptable based on the results of this more critical test. The practice can be used to raise the height of deficient guardrail to an acceptable height (i.e., 28 inches or greater) or an existing guardrail to a greater height (e.g., 31 inches) to improve performance.

2.2. MASH TL-3 EVALUATION OF GUARDRAIL ON 6H:1V SLOPE (TRP# 613011-01)

Principal Investigator: Akram Y. Abu-Odeh
Technical Representative: John Donahue (WSDOT)

For guardrails installed adjacent to a slope, the AASHTO Roadside Design Guide recommends the guardrail to be installed with the back flange of the guardrail post at 2-ft from the slope break point. However, in many mountainous areas, or in locations with tight environmental conditions, 2 ft is difficult to provide. Therefore, the research team investigated vehicular trajectory profiles and different offset options for 31-inch steel-post W-beam guardrail system. A 72-in offset system was tested on a 6H:1V slope. The guardrail did not meet the performance criteria for MASH TL-3 longitudinal barriers due to penetration of the guardrail by the 2270P vehicle in MASH Test 3-11. Anchorage failure was observed during the test and using a different end-anchor technology was recommended in future evaluation of this system.

2.3. [MASH TESTING OF A GUARDRAIL SYSTEM ON 1H:1V SLOPE (TRP# 617771-01&02)]

Principal Investigator: Akram Y. Abu-Odeh
Technical Representative: Ted Whitmore (WVDOT)

In many areas with tight environmental constraints, the shoulder width of minimum 2-ft from a slope break can be difficult to provide. A W-beam guardrail solution performed unsatisfactory when evaluated using MASH 3-10 test condition. Subsequently, thrie-beam guardrail system options were developed and investigated by TTI researchers. In this project, MASH TL-3 crash tests were conducted on a thrie-beam guardrail system on 1H:1V slope and the system met the performance criteria for MASH evaluation conditions.

2.4. [MASH TL-3 EVALUATION OF 31-INCH W-BEAM GUARDRAIL WITH WOOD AND STEEL POSTS IN CONCRETE MOW STRIP (TRP# 608551-01-1-5)]

Principal Investigator: Nauman M. Sheikh
Technical Representative: Michael Elle (MNDOT)

This project evaluated the performance of the 31-inch tall W-beam guardrail system installed in a concrete mow-strip to reduce maintenance of the guardrail system by preventing growth of vegetation around the posts. Wood post and steel post W-beam guardrail systems were evaluated by full-scale crash testing. The wood post system did not pass the MASH TL-3 testing criteria. However, the steel post guardrail system passed the MASH TL-3 testing criteria for longitudinal barriers.

2.5. [DESIGN AND EVALUATION OF ASPHALT VEGETATION CONTROL TREATMENT FOR STEEL-POST W-BEAM GUARDRAIL SYSTEM (TRP# 619441-01 09&10)]

Principal Investigator: Nauman M. Sheikh
Technical Representative: Christopher Lindsey (TXDOT)

This project designed and developed an asphalt vegetation control treatment that allows installing the steel-post W-beam guardrail system with posts directly driven in asphalt. The asphalt vegetation control design was developed using a series of bogie vehicle and full-scale crash tests. The final design allows installation of the guardrail in a 2-inch thick asphalt pad with an 8-inch offset from the edge of the asphalt pad and the back of the guardrail posts. The design met the evaluation criteria for MASH TL-3 for longitudinal barriers.

2.6. TESTING AND EVALUATION OF FLARED MGS SYSTEM AT MASH TEST LEVEL 3 CONDITIONS (TRP# 609971-01)

Principal Investigator: Chiara S. Dobrovolny
Technical Representative: Mary McRae (AKDOT)

Flared guardrail can reduce guardrail length of need and reduced impact frequency. Full-scale crash tests were performed to evaluate the impact performance of the Midwest Guardrail System (MGS) installed on a flare. MASH Test 3-10 on an MGS installed on a 7H:1V flare resulted in rail rupture. A subsequent test on an 11H:1V flare following MASH Test 3-11 impact conditions also failed due to rail rupture. A finite element simulation effort was then performed to investigate reduced flare rates and retrofit design configurations and provide recommendations for future research.

2.7. MASH CRASH TESTING AND EVALUATION OF THE MGS WITH REDUCED POST SPACING (TRP# 610211-01, REV 1)

Principal Investigator: James Kovar
Technical Representative: Joe Hall (WVDOT)

The objective of this research project was to evaluate reduced post spacing variations of the Midwest Guardrail System (MGS) for MASH compliance. A quarter-post spacing system successfully met MASH evaluation criteria for Tests 3-11 and 3-10. A modified half-post spacing system with shortened blockouts successfully met MASH evaluation criteria for Test 3-11. A transition between full- and quarter-post spacing successfully met MASH evaluation criteria for Test 3-21. The research team determined these systems to be MASH compliant based on a combination of full-scale crash testing and previous research.

2.8. MASH TL-3 EVALUATION OF LONG-SPAN W-BEAM GUARDRAIL IN FRONT OF FALL-PROTECTION FENCE (SUPPLEMENTAL) (TRP# 617231-01-1&2)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Tim Moeckel (WSDOT)

In this research, the Long-Span Guardrail was evaluated with a fall-protection fence installed behind it. This fence is installed on concrete culverts used for fish passages crossing state highways in Washington. The design was evaluated through finite element modeling and simulation, followed by full-scale crash testing. The Long-Span Guardrail installed in front of the fall-protection fence met the performance criteria for MASH TL-3 for longitudinal barriers.

2.9. MASH TL-3 EVALUATION OF MODIFIED MERRITT PARKWAY GUIDERAIL WITH NO CURB (SUPPLEMENTAL) (TRP# 612061-08-01)

Principal Investigator: Chiara S. Dobrovolny
Technical Representative: David Kilpatrick (CTDOT)

Connecticut DOT uses steel-backed timber guiderail as an aesthetic barrier system on the scenic Merritt Parkway. A MASH compliant version of this rail was needed for inclusion in CTDOT's standards. The existing design installed over a 4-inch curb did not meet MASH criteria for Test 3-11. A modified version of the steel-backed timber guiderail was evaluated and determined to be MASH TL-3 compliant. The modification involved a reduction in post spacing from 10 ft to 5 ft. A transition from the modified steel-backed timber guiderail to a vertical concrete parapet was also successfully crash tested following MASH TL-3 criteria.

2.10. MASH TL-3 TESTING OF A THRIE-BEAM GUARDRAIL SYSTEM IN FRONT OF A FIXED OBJECT (TRP# 614031-01-1&2)

Principal Investigator: James Kovar
Technical Representative: Tim Moeckel (WSDOT)

This project's objective was to develop a stiffened thrie-beam system which could be implemented in close proximity to fixed objects. Both quarter- and half-post spacing versions were evaluated through computer simulation. A quarter post spacing system with a 75-inch gap (accommodating a fixed object's foundation) was evaluated through full-scale crash testing. This system successfully met MASH evaluation criteria. Positive correlation between the computer simulation and physical crash testing led the research team to conclude that both the quarter- and half-post alternatives were suitable for implementation.

2.11. DESIGN AND TESTING OF MASH TL-3 THRIE-BEAM GUARDRAIL SYSTEM (TGS) FOR ROADSIDE AND MEDIAN APPLICATIONS (TRP# 614341-01)

Principal Investigator: Maysam Kiani
Technical Representative: James Danila (MassDOT)

In this research, MASH-compliant thrie-beam median guardrail and thrie-beam roadside guardrail systems were developed using simulation and crash testing. The design of these guardrail systems used only the standard MGS components with the exception of the thrie beam rail element. Based on the full-scale tests and impact simulation analyses performed, it was concluded that both systems meet MASH TL-3 evaluation criteria for longitudinal barriers.

2.12. DETERMINATION OF LENGTH-OF-NEED FOR GUARDRAIL WITHOUT ANCHORAGE (TRP# 614721-01-1&2)

Principal Investigator: James Kovar
Technical Representative: Joe Hall (WVDOT)

This project's objective was to determine the minimum length of an MGS without downstream anchorage required to provide MASH compliant redirective behavior. Computer simulations were performed to predict the minimum length-of-need prior to crash testing. MASH Test 3-11 resulted in the W-beam rail pulling off the posts, which violated the objective of the project. The research team modified the design by adding guardrail washers to the downstream posts. This modification also failed to meet the project objectives due to detachment of the W-beam rail from the posts. Lastly, the research team prepared recommendations for future research efforts.

2.13. ANALYSIS AND TESTING OF F DOT BARRIER SYSTEMS FOR MASH COMPLIANCE – GUARDRAIL ACROSS CONCRETE CURB INLET (SUPPLEMENTAL) (TRP# 611971-01)

Principal Investigator: James Kovar
Technical Representative: Derwood Sheppard (FDOT)

This project evaluated a guardrail system that was mounted to the top of a concrete storm sewer drop inlet and adjacent sidewalk. Various surface-mounted post options were investigated through dynamic pendulum impact testing. The selected post design consisted of an S3×5.7 steel post on a ½-inch thick baseplate. Tubular steel offset blocks were used to offset the posts from the W-beam rail to permit proper anchorage of the posts into the inlet structure. The guardrail system satisfied MASH Test 2-11 criteria and is considered MASH TL-2 compliant.

2.14. ANALYSIS AND TESTING OF FDOT BARRIER SYSTEMS FOR MASH COMPLIANCE – MEDIAN GUARDRAIL WITH RUBRAIL (SUPPLEMENTAL) (TRP# 611971-03)

Principal Investigator: James Kovar
Technical Representative: Derwood Sheppard (FDOT)

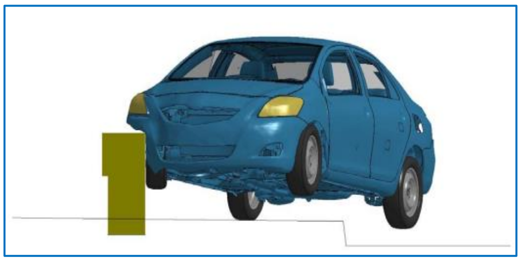
This project evaluated the W-beam median guardrail system with a rubrail mounted below the W-beam rail element on one side of the system. The median guardrail system was evaluated using MASH TL-3 criteria for longitudinal barriers. MASH Tests 3-11 and 3-10 were performed. The median guardrail system with the rubrail passed both tests and is considered MASH TL-3 compliant.

Chapter 3. BRIDGE RAILS

Bridge rails are longitudinal barriers whose primary function is to prevent an errant vehicle from going off the side of a bridge structure. Some bridge rails have a combined function to provide safety for pedestrians and bicyclists crossing the bridge structure in addition to motorists. Bridge rail related projects addressed under this pooled fund program included a retrofit for upgrading obsolete bridge rails, guidelines for joint openings in bridge rails, a combination TL-4 bridge rail system, and investigation of sidewalk width and height for lower test levels. Summaries of these projects are presented below.

3.1. TRAJECTORY VALIDATION SIMULATION WITH THE MNDOT P-1 PARAPET WITH SIDEWALK AND 8-INCH CURB (SUPPLEMENTAL) (TRP# 606881)

Principal Investigator: Akram Y. Abu-Odeh
Technical Representatives: Michael Elle and Paul Rowekamp (MNDOT)



The performance of the Minnesota DOT P-1 28-inch parapet was evaluated using trajectory simulation of both MASH car and pickup truck test vehicles. The MnDOT 28-inch P-1 parapet is considered structurally adequate by MnDOT engineers to resist passenger vehicle impacts. This report concludes that the MnDOT 28-inch P1 parapet on 8-inch sidewalk can successfully redirect both the MASH small car and pickup truck test vehicles at an impact speed of 35 mph and impact angle of 25 degrees. Other impact speeds and taller curb cases were investigated in this study, but the lack of experimental data did not facilitate a conclusion for these cases.

3.2. DEVELOPMENT OF THRIE-BEAM RETROFIT FOR UPGRADING OBSOLETE BRIDGE RAILS (TRP# 615131-01)

Principal Investigator: William F. Williams
Technical Representative: Carlos Torres (MDOT)

This project designed and tested a new retrofit bridge rail for obsolete bridge rails. The thrie beam retrofit bridge rail designed and tested in this project used posts with baseplates, spaced on 3'-1 ½" on centers, and were anchored to the concrete curb using adhesive anchors. The height of the bridge rail was 34 inches from the roadway surface. The new retrofit design met the performance criteria for MASH TL-3 for longitudinal barriers.

3.3. [EVALUATION OF OPEN JOINTS IN CONCRETE BRIDGE RAIL SYSTEMS (TRP# 619651-01)]

Principal Investigator: Nathan D. Schulz
Technical Representative: Alex Lim (ODOT)

Concrete bridge rail systems tested and evaluated according to MASH typically include joint openings between ½ to 2 inches. Bridge rail systems with larger joint openings have not been evaluated according to MASH. Guidelines were developed for MASH compliant joint opening widths and solutions to protect joint openings that are not MASH compliant.

3.4. [ANALYSIS AND TESTING OF FDOT BARRIER SYSTEMS FOR MASH COMPLIANCE - COMBINATION TRAFFIC-PEDESTRIAN-BICYCLE BRIDGE RAILING (SUPPLEMENTAL) (TRP# 611971-02-1)]

Principal Investigator: James Kovar
Technical Representative: Derwood Sheppard (FDOT)

A combination traffic-pedestrian-bicycle bridge rail system was evaluated following MASH TL-3 conditions. An aluminum bullet-profile rail was mounted on top of a 36-inch-tall single slope bridge parapet to achieve an overall height of 42 inches. The combination bridge rail satisfied MASH TL-3 criteria.

3.5. [A STUDY OF ACCEPTABLE SIDEWALK HEIGHTS AND WIDTHS (TRP# 614091-01)]

Principal Investigator: Akram Y. Abu-Odeh
Technical Representative: Taya Retterer (TXDOT)

The objective of this research was to provide guidance for bridge parapet placement on sidewalks. Under MASH TL-2 conditions, vehicular trajectory tests were conducted on an 8-inch curb. Using the test data, vehicle models were calibrated for parametric simulations. Based on the trajectory profile and parametric simulations, the research team developed bridge parapet placement guidelines for 8-inch-tall curbs under MASH TL-2 impact conditions.

3.6. MASH TL-4 CRASH TESTING OF BICYCLE RAILING ON A CONSTANT SLOPE PARAPET (SUPPLEMENTAL) (TRP# 616221-01)

Principal Investigator: Maysam Kiani
Technical Representative: Tim Craven (ILDOT)

This research project evaluated the MASH TL-4 crashworthiness performance of a combination rail that was comprised of a 39-inch tall constant slope concrete barrier with a 15-inch tall bicycle railing mounted on top. This combination rail was designed by Illinois DOT to accommodate the bicyclist and traffic safety. A MASH Test 4-12 was peformed and the combination rail met the MASH evaluation criteria.

3.7. DETERMINING DECK AND BARRIER LOADS BY STRAIN GAUGING TEST INSTALLATIONS (SUPPLEMENTAL) (TM 09-19-2024)

Principal Investigator: William Williams
Technical Representative: Andy Pott (CODOT)

This research project installed strain gauges in a test installation of a concrete bridge rail that was constructed on a concrete bridge deck. The strain guages were attached to the steel reinforcement of the barrier and the deck to obtain loads during vehicle impact. The bridge rail was impacted under MASH Test 4-12 impact conditions with a 22,000-lb single unit truck. The data collected from the test provides useful loading information for bridge rail and deck design.

Chapter 4. CONCRETE BARRIERS

Concrete barriers are among the most commonly used permanent longitudinal barriers in the United States. They are used as median barriers to prevent vehicles from entering the opposite lanes, and as roadside barriers to prevent vehicles from going off the road. Under the TPF 5(343) Pooled Fund Program, several projects involved research on MASH compliance of concrete barriers. These involved barriers with the single slope and vertical profiles, evaluated to TL-3 or TL-4 of MASH. Summaries of these projects are presented below.

4.1. MASH TEST 4-12 ON KEYED-IN SINGLE-SLOPE BARRIER WITH 40-FT SEGMENT LENGTH (TRP# 610221-01-1)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Kurt Brauner (LADOT)

This research evaluated the MASH TL-4 performance of a 42-inch tall single slope concrete median barrier that was keyed into 1-inch thick asphalt and had a segment length of 40 feet. The barrier was evaluated by performing MASH Test 4-12 and it passed the MASH evaluation criteria. at the time of this research, the 40-ft segment length was the shortest barrier segment length crash tested for the single slope barrier with the 1-inch key-in.

4.2. MASH TL-4 EVALUATION OF FLARED CAST-IN-PLACE CONCRETE BARRIER (TRP# 611901-06)

Principal Investigator: Chiara S. Dobrovolny
Technical Representative: Chris Lindsey (TxDOT)

When fixed objects such as bridge piers, overhead sign structures, or high-mast lighting are located in median of a roadway, there may exist a need to flare a concrete median barrier (CMB) around fixed object to shield it from motorists. The barrier flare increases the effective impact angle with the CMB, resulting in a higher impact severity. The impact performance of a 40-inch-tall single slope CMB was evaluated on a 20H:1V flare rate through full-scale crash testing. The system was found to be MASH TL-4 compliant.

4.3. DETERMINATION OF PEDESTRIAN RAIL OFFSET REQUIREMENTS TO ELIMINATE VEHICLE INTERACTIONS (TRP# 611991-01)

Principal Investigator: James Kovar
Technical Representative: Taya Retterer (TXDOT)

Rails are sometimes installed on concrete barriers to mitigate pedestrians falling over to the other side of the barrier. With this pedestrian rail addition to the top of a barrier, impacting vehicles have a potential for interacting with the pedestrian rail. This project determined the minimum offset required to locate a pedestrian rail on top of a concrete barrier. Videos of past MASH Test 3-11 were analyzed to measure the amount the test vehicle extended over the top traffic side of the concrete barriers. The results of this video analysis are presented in the final report.

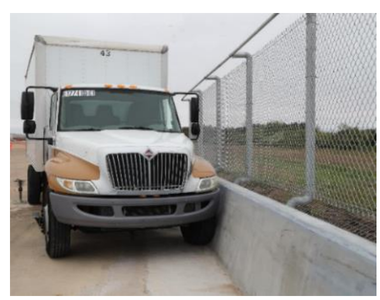
4.4. MASH TL-4 EVALUATION OF CONCRETE MEDIAN BARRIER WITH FENCE MOUNTED ON TOP (TRP# 613131-03-1 & 2)

Principal Investigator: Chiara S. Dobrovolny
Technical Representative: Derwood Sheppard (FDOT)

Occasionally, state DOTs desire to mount chain link fence on top of concrete barrier for various reasons. The addition of a fence can change the impact performance of the barrier. In this project, full-scale crash testing was performed to evaluate the MASH compliance of a 36-inch-tall single slope concrete median barrier with chain link fence mounted on top. MASH Test 4-12 was unsatisfactory due to excessive occupant compartment deformation of the truck cab. However, MASH Test 3-11 passed the MASH criteria, and it was concluded that the system meets MASH TL-3 criteria.

4.5. MASH TL-4 DESIGN AND EVALUATION OF CONCRETE BRIDGE RAIL WITH FENCE MOUNTED ON TOP (TRP# 617741-01-1)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Derwood Sheppard (FDOT)



In this research, a fence system that can be mounted on top of a 36-inch tall roadside concrete barrier or a bridge rail was designed and crash tested to meet MASH TL-4 criteria. The fence posts were offset away from the centerline of the barrier to prevent negative interaction with the cab of the impacting single unit truck of MASH Test 4-12. The design met the performance criteria for MASH Test 4-12 for longitudinal barriers and is considered MASH TL-4 compliant.

4.6. DESIGN AND EVALUATION OF A MASH TL-2 PERMANENT LOW-PROFILE BARRIER (SUPPLEMENTAL) (TRP# 616151-01)

Principal Investigator: Chiara Silvestri-Dobrovolny
Technical Representative: Derwood Sheppard (FDOT)

Low-profile barriers can offer improved sight distance and provide a barrier option that can more unobtrusively integrate into adjacent urban surroundings. Florida DOT desired to develop a permanent, cast-in-place, low-profile concrete barrier that meets MASH TL-2 criteria. Finite element modeling and simulation was used to recommend a 20-inch-tall, vertical-profile, concrete barrier for full-scale testing. The 20-inch-tall, permanent low-profile concrete barrier met the performance criteria for MASH TL-2 for longitudinal barriers.

4.7. MASH TL-3 EVALUATION OF REDESIGNED BARRIER GAP RAIL (TRP# 610461-01-3&4)

Principal Investigator: William F. Williams
Technical Representative: Michael Elle (MnDOT)

This research redesigned and tested a new tubular barrier gap rail system to use for a 36-inch-high single slope barrier. Report of an earlier phase of this research is available at the Pooled Fund's website. This gap rail is needed in instances where manholes and other features located along the barrier alignment need to be accessed. The new gap rail design was attached flush with the concrete single slope barrier on each side. The gap rail design was tested with the small car (MASH Test 3-10) and the pickup truck (MASH Test 3-11). Both tests were successful with respect to the MASH evaluation criteria.

Chapter 5. PORTABLE CONCRETE BARRIERS

Portable Concrete Barriers (PCB) are precast or prefabricated barrier segments that are connected to each other via a barrier connection to deploy a desired length of a barrier system. PCBs are commonly used in work zones where there is a need to move the barrier around during different phases of the construction. PCBs usually have large deflection when installed unrestrained. When space is limited, PCBs are anchored to the underlying surface using an anchoring mechanism. This chapter summarizes the research projects carried out under the pooled fund program involving various PCB designs. They included free-standing PCB systems, restrained PCB systems, and PCB systems with large scuppers to allow better drainage.

5.1. MASH TL-3 TESTING AND EVALUATION OF FREE STANDING PORTABLE CONCRETE BARRIER (TRP# 607911-1&2)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Jeffery Petterson (WSDOT)

The objective of this research was to test a 32-inch tall, F-shape profile, freestanding PCB system in accordance with the MASH TL-3 evaluation criteria. This barrier system was previously tested under the NCHRP Report 350 evaluation criteria and the new testing was performed to determine its MASH compliance. The free-standing PCB system passed MASH Tests 3-10 and 3-11, and was determined to be MASH TL-3 compliant.

5.2. MASH TEST 3-11 ON F-SHAPE PORTABLE CONCRETE BARRIER PINNED TO CONCRETE (TRP# 610231-01-1)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Jeff Petterson (WSDOT)

The objective of this research was to evaluate the MASH TL-3 performance of a 32-inch-tall F-shape PCB system with the pin-and-loop connection. The barrier system was pinned to 8-inch-thick unreinforced concrete pavement with a 9-inch offset from the edge of the pavement. A MASH Test 3-11 was performed, and the pinned F-shape PCB system met the safety evaluation criteria for MASH.

5.3. MASH EVALUATION OF F-SHAPE & SINGLE SLOPE CONCRETE BARRIER WITH DRAINAGE SCUPPERS (SUPPLEMENTAL) (TRP# 612831-01)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Tim Moeckel (WSDOT)

This project developed and crash tested concrete barrier systems with large drainage scuppers. A 32-inch-tall F-shape PCB system with 6-inch tall and 24-inch-long drainage scuppers was evaluated in free-standing and anchored configurations. Furthermore, a 42-inch-tall single slope barrier with grouted rebar grid connection and large drainage scuppers was evaluated while embedded 4 inches in asphalt, for an effective above-grade height of 38 inches. The F-shape PCB was tested in accordance with MASH TL-3 criteria, and the single slope barrier was evaluated in accordance with MASH TL-4 criteria. Both barrier systems passed the respective evaluation criteria for longitudinal barriers.

5.4. WASHINGTON STATE I-90 SNOQUALMIE PASS BARRIER GAP FULL-SCALE CRASH TESTING (SUPPLEMENTAL) (TM 09-17-2024)

Principal Investigator: William Williams
Technical Representative: Tim Moeckel (WSDOT)

The objective of this research was to develop a barrier gap that could span over drainage inlets and allow snow removal while being connected to adjacent PCB segments. A new barrier gap was designed and tested for this project but did not meet the requirements of MASH TL-3. The connection loops broke at several locations, which contributed to the failure in the crash test. The ultimate strength of the loops was verified to meet material specifications. Further research for improving the barrier connection was recommended.

5.5. DEVELOPMENT OF A MASH TL-3 COMPLIANT ANCHORED PCB SYSTEM WITH VERTICAL ANCHORS (SUPPLEMENTAL) (TRP# 616811-01 1-4)

Principal Investigator: Nauman M. Sheikh
Technical Representative: Bob Meline (Caltrans)

This project developed and crash tested a new PCB system with 12-ft long F-shape barrier segments that were anchored using vertical anchors. The barrier segments were connected with the pin-and-loop connection. Four anchored configurations of the barrier system were crash tested. There were: 1) PCB anchored on asphalt as a roadside barrier, 2) PCB anchored on concrete pavement as a roadside barrier, 3) PCB anchored on asphalt as a median barrier, and 4) PCB anchored on concrete pavement with shallow embedment epoxy anchors. All four anchored configurations of the new PCB system met the performance criteria for MASH TEST 3-11 and the system was determined to be MASH TL-3 compliant.

Chapter 6. TERMINALS

Terminals are attached to the ends of a guardrail to shield errant vehicles from impacting the blunt edge of a guardrail. Most guardrail terminals are proprietary devices and therefore only limited research was performed in this category. There were two projects that performed research on a buried-in-backslope terminal, which is a non-proprietary system. Another project researched installing terminal guardrail posts in metal sleeves to allow easier repair of the terminals during frozen soil conditions. Summaries of these projects are presented below.

6.1. MASH TESTS 3-34 AND 3-35 ON THE 31-INCH BURIED-IN-BACKSLOPE TERMINAL COMPATIBLE WITH MGS GUARDRAIL (TRP# 608431-01-1&2)

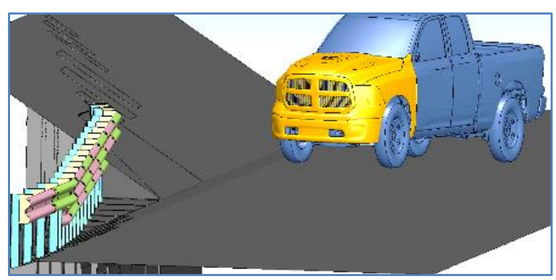
Principal Investigator: Chiara S. Dobrovolny
Technical Representative: Jeff C. Jeffers (AKDOT)

When terrain conditions permit, buried-in-backslope (BIB) terminal designs can be an effective means of terminating and anchoring W-beam guardrail. When properly designed and located, this system can eliminate the possibility of an end-on impact with a guardrail terminal. Under this project, a BIB terminal attached to the 31-inch Midwest Guardrail System was evaluated in accordance with MASH TL-3 criteria. The system traversed a 6H:1V ditch foreslope and was buried in a 2H:1V backslope. The BIB terminal is considered MASH TL-3 compliant and considered suitable for implementation in V-ditches with a 4H:1V or flatter foreslope.

6.2. BURIED-IN-BACKSLOPE TERMINAL VARIATIONS IN TERRAIN CONFIGURATIONS VIA FINITE ELEMENT ANALYSIS (TRP# 617871)

Principal Investigator: Sofokli Cakalli
Technical Representative: Mary McRae (AKDOT)

The BIB terminal has been crash tested for only a selected terrain configuration. The objective of this project was to investigate the crashworthiness of the BIB terminal in different terrain variations via finite element simulations. Three different variations were investigated and the finite element analysis results showed that these BIB terminal configurations are likely to meet MASH evaluation criteria for Tests 3-34 & 3-35.



6.3. EVALUATION OF W-BEAM GUARDRAIL TERMINAL POSTS INSTALLED IN SLEEVES (SUPPLEMENTAL) (TRP# 611011-1)

Principal Investigator: Nauman M. Sheikh
Technical Representative: (AKDOT)

States with extreme winter weather face difficulty in removing and repairing W-beam guardrail and end terminal posts installed in soil due to frozen soil conditions. This project evaluated the performance of the 31-inch W-beam guardrail with a non-proprietary downstream anchor terminal (DAT) with steel posts installed in steel sleeves. The sleeves allow easier removal and installation of the posts. MASH Test 3-35 was determined to be the critical test to evaluate the posts in sleeves. The W-beam guardrail with DAT and steel posts installed in sleeves performed acceptably for this test. It was concluded that W-beam guardrail steel posts installed in buried steel sleeves perform like the direct embedded posts in the guardrail's end terminal region and the length of need.

6.4. REVIEW & INVESTIGATION OF W-BEAM GUARDRAIL TERMINALS WITH CURBS (TRP# 613141-01)

Principal Investigator: James Kovar
Technical Representative: Kurt Brauner (LADOT)

At the time of the research project, there was little guidance on curbs' effects on the impact performance of W-beam guardrail terminals. This project reviewed and documented previous and ongoing research related to W-beam terminals installed near curbs. Additionally, it summarized current state practices for installing W-beam guardrail terminals near curbs.

Chapter 7. TRANSITIONS

Transition systems are used to transition the shape, height, and/or stiffness of one longitudinal barrier system to another. One of the more common applications is a stiffness transition from an approach guardrail to a rigid parapet or bridge rail. Transition projects addressed under this pooled fund program included evaluation of shorter length approach transitions, guidelines for attaching MASH-compliant transitions to parapets different from the one tested, development of a transition between guardrail and anchored portable concrete barrier, and evaluation of a transition from weak-post to strong-post W-beam guardrail. Summaries of these and other transition-related projects are presented below.

7.1. MASH TEST 3-21 EVALUATION OF SHORT W-BEAM TRANSITION (TRP# 613121-01-1)

Principal Investigator: Maysam Kiani
Technical Representative: Joe Hall (WVDOT)

When roadways intersect with restrictive features, it becomes difficult to fit a transition system with proper length. This research project modeled and crash tested a shorter W-beam transition system design for MASH TL-3 evaluation criteria. Due to high ridedown acceleration during the crash test, the short transition did not satisfy the performance criteria for MASH Test 3-21 for transitions.

7.2. MASH TEST LEVEL 3 EVALUATION OF A SHORTER THRIE-BEAM APPROACH TRANSITION (TRP# 618981-01-1)

Principal Investigator: William F. Williams
Technical Representative: Ted Whitmore (WVDOT)

When roadways intersect with restrictive features such as a bridge rail, it becomes difficult to fit a transition system with proper length. It is important in these cases to implement a shorter transition without compromising the integrity of the guardrail system. A new shorter transition was developed for this project. The shorter transition utilized a rubrail that bolted flush with the concrete F-Shape barrier. The new transition met all the requirements of MASH Test 3-21.

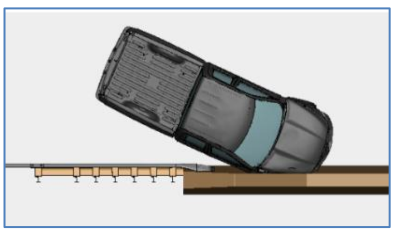
7.3. EVALUATION AND TESTING OF MASH TL-3 TRANSITION DESIGN WITH A STORM DRAIN (TRP# 615251-01)

Principal Investigator: Akram Y. Abu-Odeh
Technical Representative: Derwood C. Sheppard (FDOT)

In this project, a W-beam guardrail to concrete parapet transition design was developed that incorporated a storm inlet in the transition region. The most critical inlet placement and critical impact point for crash testing were determined using finite element modeling and simulation. The new transition design was tested per MASH Test 3-21 impact conditions and met the performance evaluation criteria for MASH.

7.4. GUIDELINES FOR ATTACHING THRIE-BEAM TRANSITIONS TO RIGID CONCRETE BARRIERS DIFFERENT FROM ORIGINAL CRASH TESTING (TRP# 616001-01)

Principal Investigator: Roger Bligh
Technical Representative: Mary McRae (AKDOT)



This project explored the feasibility of attaching MASH compliant thrie-beam transition systems onto rigid concrete barriers other than the one that was tested. The research team used a state survey, literature review, engineering experience, and a limited finite element simulation study to determine the key features associated with the concrete parapet that can influence impact performance of a transition system. Recommendations were developed regarding the application of selected features to permit attachment of a MASH-compliant thrie-beam transition to concrete parapets other than the one tested. Key features enabling use of the tested transition with other parapets included parapet profile, parapet height, parapet toe taper, and curb or rubrail presence.

7.5. AN EXPLORATION INTO VARIATIONS IN GUARDRAIL APPROACH TRANSITIONS TO RIGID BARRIERS (TRP# 615991-01)

Principal Investigator: Maysam Kiani
Technical Representative: Erik Emerson (WIDOT)

This research project analyzed installation deficiencies in approach transitions using computer modeling and simulation. The researchers conducted an extensive literature review, identified a representative approach guardrail transition, created a computer model for it, and evaluated common field variations using finite element simulation analysis. The research presented several findings emanating from the simulation analysis of the various field variations evaluated.

7.6. [DESIGN AND MASH EVALUATION OF TRANSITION BETWEEN GUARDRAIL TO ANCHORED PORTABLE CONCRETE BARRIER (TRP# 616391-01)]

Principal Investigator: Nauman M. Sheikh
Technical Representative: Shawn Debenham (UDOT)

In limited-space situations, especially in mountainous areas, there is a need to place anchored PCB systems adjacent to steep slopes and attach them to a W-beam guardrail system. This research project developed a guardrail transition design that allows attaching the W-beam guardrail system to an anchored F-shape PCB system. The design was developed using finite element simulations and full-scale MASH Tests 3-21 and 3-20. The transition design passed MASH TL-3 requirements and is ready for field implementation.

7.7. [EVALUATION OF A MEDIAN GUARDRAIL TRANSITION TO MEDIAN F-SHAPE CONCRETE BARRIER (TRP# 618851-01-1)]

Principal Investigator: Nathan D. Schulz
Technical Representative: Evan Pursel (PDOT)

The purpose of the research reported herein was to assess the performance of median guardrail transition to median F-shape barrier according to MASH. The project evaluated the performance of the transition using simulation and developed guidelines for a MASH compliant transition from strong post median guardrail to various heights of precast/cast-in-place median F-shape barrier. A critical configuration of the median guardrail transition to median F-shape barrier was crash tested but did not meet the performance criteria for MASH TL-3.

7.8. [CRASH TESTING AND EVALUATION OF TRANSITION FROM 32-INCH TALL WEAK POST GUARDRAIL SYSTEM TO MGS STRONG POST SYSTEM (TRP# 612051-4)]

Principal Investigator: Chiara S. Dobrovolny
Technical Representative: David Kilpatrick (CTDOT)

This project developed a transition from the weak-post W-beam guardrail to strong-post MGS guardrail system. It utilized reduced post spacing of the S3×5.7 weak steel posts to achieve a stiffness similar to the MGS with the standard post spacing. The transition system met MASH TL-3 performance criteria.

Chapter 8. SUPPORT STRUCTURES

Support structures include sign supports, mailbox supports, luminaire supports, and other similar systems. When placed within the roadside clear recovery area, these support structures incorporate a breakaway mechanism if they are not shielded using a barrier. Under the pooled fund program, various breakaway support structures were evaluated. These included slip base luminaire supports, large guide sign supports, small sign supports, enhanced highway sign assemblies, pedestrian traffic signals, and a mailbox support. Summaries of these projects are provided below.

8.1. TESTING AND EVALUATION OF LARGE SIGNS SLIP BASE SUPPORT ON SLOPE AT MASH TEST LEVEL 3 IMPACT CONDITIONS (TRP# 612261-04-1, -05-1, & -05-2)

Principal Investigator: Chiara Silvestri-Dobrovolny
Technical Representative: Mustafa Mohamedali (WSDOT)

This report assesses the performance of the large sign slip base support according to AASHTO MASH safety-performance guidelines. The crash test was performed in accordance with MASH Test 3-62. The large sign slip base support meets the performance criteria for MASH 3-62 support structures.

8.2. EVALUATION OF A NON-PROPRIETARY SIGN SUPPORT SYSTEM (TRP# 616011-01) (TRP# 616011-01)

Principal Investigator: Nathan D. Schulz
Technical Representative: Carlos Torres (MDOT)

The initial objective was to evaluate the U-Channel Sign Support System according to the complete MASH TL-3 matrix. However, only MASH Test 3-62 was performed on the system due to excessive vehicle deformation observed during the crash test. The U-Channel Sign Support system did not meet the performance criteria for MASH tl-3 Support structures.

8.3. EVALUATION OF CRASHWORTHY ENHANCED HIGHWAY SIGN ASSEMBLIES (SUPPLEMENTAL) (TRP# 616161-01)

Principal Investigator: Maysam Kiani
Technical Representative: Derwood Sheppard (FDOT)

In this project, the researchers assessed the crashworthiness of Florida DOT's Enhanced Highway Sign Assemblies using full-scale crash testing in accordance with MASH evaluation criteria for support structures. The Enhanced Highway Sign Assemblies were comprised of solar panel and battery combinations attached to the sign support. A preliminary analysis was performed to determine the critical weight and height of the various solar panel and battery combination options. MASH Tests 3-60 and 3-62 were performed with the critical design, which passed the MASH evaluation criteria in both tests.

8.4. MASH EVALUATION OF PEDESTRIAN TRAFFIC SIGNALS (TRP# 617891-01 1-4)

Principal Investigator: Sofokli Cakalli
Technical Representative: Derwood Sheppard (FDOT)

The purpose of this project was to assess the performance of the MUTCD standard pedestrian signal assemblies according to MASH criteria. A total of three different pedestrian signal assemblies were crash tested. The first two configurations did not meet MASH Test 3-62 evaluation criteria. The third configuration was investigated through research and development (R&D) tests with previously crash tested vehicles using the impact conditions of MASH Tests 3-61 & 3-62. These R&D tests passed the MASH metrics that could be evaluated in the tests, indicating the third configuration is likely to meet the full MASH evaluation criteria. Further testing was recommended in accordance with the MASH evaluation criteria.

8.5. EVALUATION OF MODIFIED MINNESOTA SWING-AWAY MAILBOX (SUPPLEMENTAL) (TRP# 609731-5&6)

Principal Investigator: Roger P. Bligh
Technical Representative: Michael Elle (MNDOT)

The Minnesota DOT desired a swing-away mailbox support for use in locations where snow and ice removal during the winter presents a problem for conventional mailbox supports. The design utilizes a cantilevered arm that can rotate relative to its anchorage during snowplow operation, thereby reducing the potential for damage to the mailbox support. Crash tests were performed to evaluate two different impact scenarios associated with the cantilevered design of the swing-away mailbox: an impact on the cantilever arm and mailbox assembly, and an impact on the vertical portion of the mailbox support and its anchorage. The modified Minnesota swing-away mailbox support is considered MASH TL-3 compliant.

8.6. EVALUATION OF FOUR BOLT SLIP BASE FOR BREAKAWAY LUMINAIRE SUPPORTS FOR VARIOUS POLE CONFIGURATIONS (TRP# 618911-01-1-3)

Principal Investigator: James Kovar
Technical Representative: Shawn Debenham (UDOT)

Limited MASH testing has been performed on luminaire supports. The tests that have been conducted incorporated cast aluminum transformer bases. This project evaluated different luminaire pole configurations on a four-bolt slip base assembly. Standards from the member states were reviewed to select representative pole configurations. MASH Test 3-60 is considered the critical test for evaluating occupant compartment deformation and intrusion. A 40-ft steel pole configuration with dual 15-ft long arms and a 30-ft steel pole configuration with dual 15-ft long arms both failed to meet MASH Test 3-60 criteria. A 40-ft steel pole configuration with single 15-ft long arm satisfied MASH Test 3-60 criteria.

8.7. MULTI-DIRECTIONAL BASE DESIGN FOR STEEL BEAM NON-PROPRIETARY LARGE SIGN SUPPORTS (TRP# 616401-01)

Principal Investigator: James Kovar
Technical Representative: Ted Whitmore (WVDOT)

This project evaluated two different sign configurations on a retrofit multi-directional breakaway mechanism. These included a dual support multi-route marker assembly and a dual support guide sign. Fuse plates were incorporated into the supports below the sign panels. The existing uni-directional rectangular slip base was retrofit onto an omni-directional triangular slip base assembly. The route-marker assembly met MASH criteria for Test 3-60 at zero degrees and Test 3-61 at 90 degrees. The guide sign system was tested at 90 degrees in several configurations following MASH Test 3-62 conditions. Variations included different fuse plate design and increased mounting height. The large guide sign did not satisfy MASH criteria in these tests. Recommendations were made for future research.

Chapter 9. WORK ZONE TRAFFIC CONTROL DEVICES

Work zone traffic control devices are used to inform, guide, and control traffic near, around, or through construction zones. Because these devices may be placed near traffic and work-zone personnel, their impact performance is evaluated. Under the pooled fund program, a project evaluated the crashworthiness of Type III barricades with attached signs. A summary of this project is provided below.

9.1. EVALUATION OF TYPE III BARRICADES WITH MOUNTED SIGNS (TRP# 616411-01)

Principal Investigator: James Kovar
Technical Representative: Brian Crossley (PennDOT)

This research project's objective was to develop a MASH compliant design for mounting a sign panel on top of a Type III barricade. The research team first reviewed relevant research and state standards to lay a foundation for the design efforts. A design was developed and crash tested in accordance with the impact conditions of MASH Tests 3-71 and 3-72. The design successfully met the evaluation criteria for both tests.

APPENDIX A

Following is the list of the Pooled Fund member states and their representing members during the duration of the TPF 5(343) Pooled Fund Program from 2016 to 2022.

State	Member	Years Involved
AK	Mary McRae	2016-2022
AK	Cole Carnahan	2022
AK	Jeff Jeffers	2016-2021
AL	Ron Johnson	2018-2019
AL	Stanley Biddick	2018-2022
AL	Steven Walker	2018-2020
AL	Wade Henry	2022
CA	John Jewell	2016-2022
CA	Bob Meline	2018-2022
CO	Joshua Keith	2017-2022
CO	Joshua Palmer	2019-2020
CO	Chih (Shawn) Yu	2018-2020
CO	Andrew Pott	2019-2020
CO	Steve Yip	2021-2022
CT	David Kilpatrick	2016-2022
DE	Michael DuRoss	2019-2022
DE	Mark Buckalew	2017-2018
DE	Jeffrey Van Horn	2019-2021
DE	Cassidy Blowers	2021-2022
DE	James Osborne	2022
FHWA	Richard Albin	2016-2022
FHWA	William Longstreet	2016 & 2018
FHWA	Eduardo Aspire	2018-2022
FHWA	Greg Schertz	2018-2020
FHWA	Christine Black	2021-2022
FHWA	Matt Hinshaw	2021-2022
FHWA	Isbel Ramos-Reyes	2021-2022
FL	Derwood Sheppard	2016-2022
FL	Richard Stepp	2022
IA	Daniel Harness	2019-2022
IA	Zac Abrams	2021
IA	Chris Poole	2022
ID	Gary Sanderson	2016-2017
ID	Kevin Sablan	2018-2022
ID	Rick Jensen	2018-2020
ID	Shanon M. Murgoitio	2018-2020
ID	Marc Danley	2016-2022

State	Member	Years Involved
IL	Timothy J. Sheehan	2016
IL	Filiberto Sotelo	2017-2020
IL	Martha Brown	2018-2022
IL	Tim Craven	2018-2020
IL	Jon McCormick	2018-2020
IL	Edgar Galofre	2021-2022
LA	Chris Guidry	2016 & 2018-2022
LA	Kurt Brauner	2016-2022
LA	Steven Mazur	2018-2020
LA	Brian Allen.	2019-2020
LA	Carl Gaudry	2022
MA	James Danila	2016-2022
MA	Neil Boudreau	2017 & 2019-2022
MA	Alex Bardow	2018-2022
MD	Jeff Robert	2018-2021
MD	Rodney Wynn	2019-2022
MD	Sharon D. Hawkins	2018-2020
MD	Matamba Kabengele	2021-2022
MI	Carlos Torres	2016-2022
MN	Michael Elle	2016-2021
MN	Michelle Moser	2018-2020
MN	Khamsai Yang	2020-2022
MN	Brian Tang	2022
MO	Ronald Effland	2018-2022
MO	Sarah Kleinschmit	2019-2022
MO	Nick Voltenburg	2021
MO	Kaitlyn Bower	2022
MS	Heath Patterson	2019-2021
NM	David Quintana	2019-2020
NM	Afshin Jian	2021
NM	Brad Julian	2022-2022
OK	Hebret Bokhru	2017-2019
OH	Don Fisher	2019-2022
ON	Mark Ayton	2017-2018
ON	Kenneth Shannon	2018-2022
OR	Heidi Shoblom	2017-2022
OR	Christopher Henson	2016-2022
PA	Mark Burkhead	2016
PA	Divyang Pathak	2017-2018
PA	Guozhou Li	2018-2022
PA	Hassan Raza	2018-2021
PA	Evan Pursel	2018-2022

State	Member	Years Involved
PA	Nina Ertel	2018-2022
PA	Brian Crossley	2021-2022
TTI	Lance Bullard	2016-2022
TTI	Roger Bligh	2016-2022
TTI	Chiara Silvestri Dobrovonly	2016-2022
TTI	Ariel Sheil	2021-2022
TX	Chris Lindsey	2016-2022
TX	Taya Retterer	2018-2022
TX	Wade Odell	2018-2020
TN	Ali Hangul	2016-2022
UT	Matt Luker	2018-2022
UT	Shawn Debenham	2018-2022
WA	Jeff Petterson	2016-2018
WA	John Donahue	2018-2022
WA	Mustafa Mohamedali	2018-2022
WA	Rhonda Brooks	2016-2018
WA	Anne Freeman	2019
WA	Tim Moeckel	2018-2022
WI	Erik Emerson	2016-2022
WV	Donna Hardy	2016-2022
WV	Joe Hall	2016-2021
WV	Ted Whitmore	2018-2022