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MASH-16 Compliance Assessment

Sponsor Information

Date:	June 23, 2020
Name:	Roadside Safety Pooled Fund
Company:	N/A
Address:	N/A
City, ST Zip:	N/A
Country:	United States of America

Texas A&M Transportation Institute (TTI) evaluated the product described below and found it to meet the appropriate evaluation criteria in MASH-16.

Device & Testing Criterion

System Type	Device Name/Variant	Testing Criterion	Test Level
Longitudinal Barriers	UDOT 42-inch 10.8 Degree Single Face Cast-in-Place (CIP) Parapet	MASH-16	TL4

Disclosure of Financial Interest

☒ TTI has no financial interest beyond payment for services for design and/or evaluation of this product.

☐ Other (describe):

Product Description

○ New Hardware ○ Significant Modification to Existing Hardware ◉ Non-significant Modification to Existing Hardware

The UDOT 42-inch 10.8 Degree Single Face CIP Parapet is a solid concrete parapet bridge rail system. The barrier has a total height of 42 inches. Number 4 Grade 60 rebar is used for longitudinal reinforcement and Number 4 Grade 60 rebar is used for transverse reinforcement. Attachment A shows a detailed drawing of the UDOT 42-inch 10.8 Degree Single Face CIP Parapet.

Evaluation Results

Any full-scale crash testing performed by TTI as part of this evaluation was done in compliance with MASH-16.

MASH Test Number	Description/Justification	Evaluation Results
4-10 (1100C)	Rail geometry has a direct influence on MASH occupant risk criteria. For concrete barriers, rail geometry is defined by the barrier shape or profile. MASH Test 4-10 has not been conducted on the UDOT 42-inch 10.8 Degree Single Face CIP Parapet. However, MASH Test 4-10 was successfully performed on the Type 60 Median Barrier and is documented in Research Report FHWA/CA17-2654, "Compliance Crash Testing of the Type 60 Median Barrier, Test 140MASH3C16-04." The Type 60 Median Barrier is a CIP single slope concrete median barrier. Since the Type 60 Median Barrier has been found to satisfy MASH Test 4-10 occupant risk criteria, the UDOT 42-inch 10.8 Degree Single Face CIP Parapet is considered satisfactory according to MASH Test 4-10 evaluation criteria.	Non-critical, not performed
4-11 (2270P)	Rail geometry has a direct influence on MASH occupant risk criteria. For concrete barriers, rail geometry is defined by the barrier shape or profile. MASH Test 4-11 has not been conducted on the UDOT 42-inch 10.8 Degree Single Face CIP Parapet. However, MASH Test 4-11 was successfully performed on a single slope CIP barrier and is documented in Research Report 405160-13-1, "Development and Testing of a Concrete Barrier Design for Use in Front of Slope or on MSE Wall." Therefore, since a single slope CIP barrier has been found to satisfy MASH Test 4-11 occupant risk criteria, the UDOT 42-inch 10.8 Degree Single Face CIP Parapet is considered satisfactory according to MASH Test 4-11 evaluation criteria.	Non-critical, not performed
4-12 (10000S)	To evaluate the structural adequacy of the UDOT 42-inch 10.8 Degree Single Face CIP Parapet without performing MASH Test 4-12 or Finite Element (FE) impact simulations, a strength analysis must be conducted using the procedure described in AASHTO LRFD Bridge Design Specifications, Section 13. The calculated	Non-critical, not performed

	resistance of the barrier must be compared to the MASH TL-4 design impact load. The MASH TL-4 design impact load for a barrier with a height of 42 inches is 80 kips located at an effective height of 30 inches above the roadway surface, as determined in NCHRP Project No. 22-20(2), "Design Guidelines for Test Level 3 (TL-3) Through Test Level 5 (TL-5) Roadside Barrier Systems Placed on Mechanically Stabilized Earth (MSE) Retaining Wall." The UDOT 42-inch 10.8 Degree Single Face CIP Parapet has a calculated resistance of 96 kips at an effective height of 30 inches above the roadway surface. Attachment B presents the strength analysis performed on the UDOT 42-inch 10.8 Degree Single Face CIP Parapet. Since the calculated resistance is greater than the design impact load, the UDOT 42-inch 10.8 Degree Single Face CIP Parapet meets the MASH TL-4 structural adequacy criterion. For a bridge rail system to be considered a MASH acceptable barrier, a minimum height must be met to ensure stability of the vehicle and to prevent override of the barrier. The MASH TL-4 minimum rail height is 36 inches, as determined in NCHRP Project No. 22-20(2), "Design Guidelines for Test Level 3 (TL-3) Through Test Level 5 (TL-5) Roadside Barrier Systems Placed on Mechanically Stabilized Earth (MSE) Retaining Wall." The UDOT 42-inch 10.8 Degree Single Face CIP Parapet has a height of 42 inches and, therefore, the UDOT 42-inch 10.8 Degree Single Face CIP Parapet meets the MASH TL-4 minimum height stability criterion. Therefore, since the UDOT 42-inch 10.8 Degree Single Face CIP Parapet meets the MASH TL-4 structural adequacy and minimum height stability criteria, this bridge rail system is considered satisfactory according to MASH Test 4-12 evaluation criteria.	

Signature(s)

☐ *New Hardware or Significant Change to Existing Hardware:* By signature below, the researcher has determined that the critical crash test(s) for this device was (were) conducted in accordance with MASH-16 criteria. The researcher has determined that no additional crash tests are necessary to determine MASH-16 compliance.

☒ *Non-significant Change to Existing Hardware:* By signature below, the researcher has determined that the modification to existing hardware is deemed non-significant.

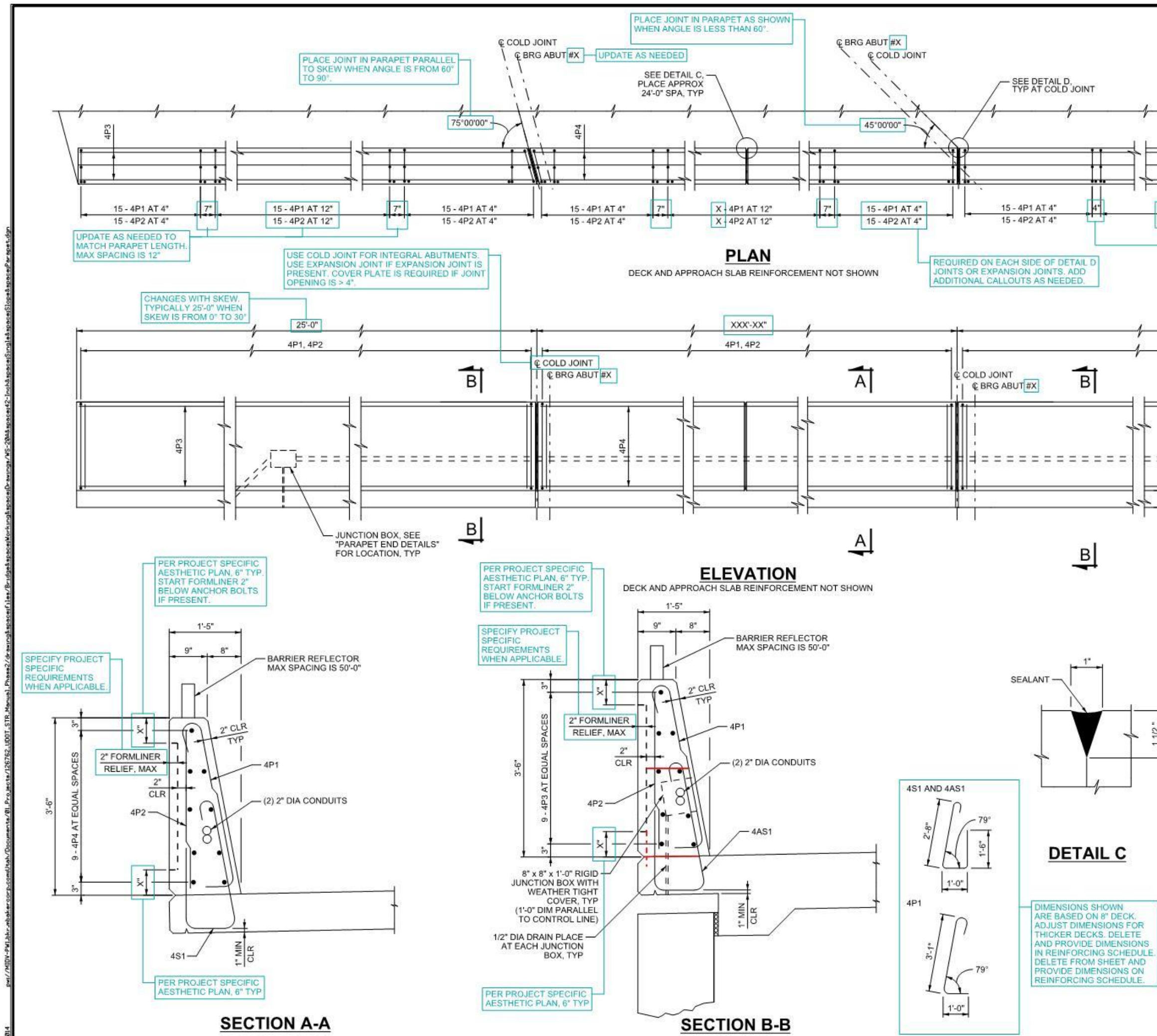
Researcher Name:	Sana Moran, E.I.T.
Researcher Signature:	Sana Moran
Company:	Texas A&M Transportation Institute
Address:	3135 TAMU
City, ST Zip:	College Station, TX 77843-3135
Country:	USA

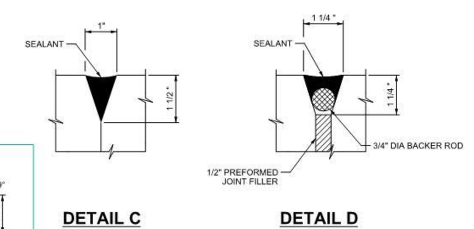
TTI Crash Testing Performed: ☐ Yes (lab signature required) ☒ No (lab signature not required)

Laboratory Name:	
Laboratory Signature:	
Address:	
City, ST Zip:	
Country:	
Accreditation Certificate Number and Dates of Current Accreditation Period:	

Attachment A

Details of UDOT 42-inch 10.8 Degree Single Face CIP Parapet





NOTES

1. ALTERNATE ALL REINFORCING SPLICES.
2. PROVIDE 2" MIN COVER TO REINFORCING UNLESS NOTED OTHERWISE.
3. PLACE CONTRACTION JOINT ON SIDES AND ON TOP OF PARAPET.
4. EXTEND SEALANT AND FOAM BACKER ROD FROM DECK TO TOP OF PARAPET ON THE INSIDE PARAPET FACE AND ACROSS TOP OF PARAPET.
5. LOCATE STRUCTURE NUMBER ON RIGHT-HAND SIDE OF APPROACH PARAPET. SEE "PARAPET END DETAILS" FOR STRUCTURE NUMBER DETAILS.

UTAH DEPARTMENT OF TRANSPORTATION
STRUCTURES DIVISION

PROJECT NAME
STRUCTURE NAME
42-INCH SINGLE SLOPE PARAPET
PROJECT NUMBER

PIN XXXXX

REV NO	DATE	BY	REVISION REMARKS	CHECK

APPROVAL RECOMM. | DATE | SENIOR DESIGN ENGINEER | DESIGN | CHECK
APPROVED FOR USE BY UDOT | DATE | UDOT DESIGN MANAGER | DRAWN | CHECK

XXX
COUNTY
SDDM
STRUCTURE NUMBER
WS-20A
DRAWING NUMBER
SHEET XX OF XXX

Attachment B

Analysis of UDOT 42-inch 10.8 Degree Single Face CIP Parapet

Design Forces for Traffic Railings

Test Level	F_t (kip)	F_L (kip)	F_v (kip)	L_t and L_L (ft)	L_v(ft)	H_e(in)	H_{min}(in)
TL 1	13.5	4.5	4.5	4.0	18.0	18.0	18.0
TL 2	27.0	9.0	4.5	4.0	18.0	20.0	18.0
TL 3	71.0	18.0	4.5	4.0	18.0	19.0	29.0
TL 4 (a)	68.0	22.0	38.0	4.0	18.0	25.0	36.0
TL 4 (b)	80.0	27.0	22.0	5.0	18.0	30.0	36.0
TL 5 (a)	160.0	74.0	160.0	10.0	40.0	35.0	42.0
TL 5 (b)	262.0	75.0	160.0	10.0	40.0	43.0	42.0
TL 6	175.0	58.0	80.0	10.0	40.0	90.0	90.0

NOTE: (a) and (b) denote different TL 4 and TL 5 design force values for bridge rails of different heights.

Stability Criteria

Test Level	4	
H =	42	Bridge Rail Height (in.)
H_{min} =	36	Minimum Height (in.)
CHECK	**OK**	**OK if: $H \geq H_{min}$**

Strength Criteria

Material Properties		
f'_c =	4	Compr. Strength of Concrete (ksi)
f_y =	60	Yield Strength of Steel Rebar (ksi)
E_s =	29000	Modulus of Elasticity of Steel (ksi)
E_c =	3605	Modulus of Elasticity of Concrete (ksi)

Design Forces and Designations		
Test Level	4	
F_t =	80	Transverse Impact Force (kips)
F_L =	27	Longitudinal Impact Force (kips)
F_v =	22	Vertical Impact force (kips)
L_t and L_L =	5	Longitudinal Length of Distribution of Impact Force (ft.)
L_v =	18	ft.
H_e =	30	in.

AASHTO Chapter 13 - LRFD Strength Analysis of Concrete Parapet

Bending Capacity of the Wall About the Longitudinal Axis for Impacts Within a Wall Segment, M_{cmid}		
s_{vp} =	12	Spacing of Parapet Vertical Reinforcement (in.)
A_{vp1} =	0.2	Area of One Parapet Vertical Reinforcement in tension zone (in^2)
d_{cp} =	8.5	Extreme Distance of Parapet Vertical Tensile Reinforcement (in.)
s_{va} =	12	Spacing of Anchorage Bar Reinforcement (in.)
A_{va1} =	0.2	Area of One Anchorage Bar Reinforcement in tension zone (in^2)
d_{ca} =	14.5	Extreme Distance of Anchorage Bar Tensile Reinforcement (in.)
b_c =	12	Unit Width of Wall (in.) - Note: b_c is always 12in
A_{vp} =	0.2	Total Area of Parapet Vert. Reinforcement per 1ft of Wall (in^2/ft)
A_{va} =	0.2	Total Area of Anchorage Bar Reinf. per 1ft of Wall (in^2/ft)
A_{vmid} =	0.2	Total Area of Critical Reinforcement per 1ft of Wall (in^2/ft)
d_{cmid} =	8.5	Extreme Distance of Critical Tensile Reinforcement (in.)
a_{cmid} =	0.294	Whitney Stress Block Depth (in.)
ε_{vtmid} =	0.0707	Strain in Tension most Critical Reinforcement (in./in.)
M_{cmid} =	**8.35**	**Flexural Resistance of Cantilever Wall for Impacts Within a Wall Segment specified in AASTHO Article A13.3.1 (k-ft/ft)**

Bending Capacity of the Wall About the Longitudinal Axis for Impacts at End of Wall or Joint , M_{cend}		
s_{vp} =	4	Spacing of Parapet Vertical Reinforcement (in.)
A_{vp1} =	0.2	Area of One Parapet Vertical Reinforcement in tension zone (in^2)
d_{cp} =	8.5	Extreme Distance of Parapet Vertical Tensile Reinforcement (in.)
s_{va} =	4	Spacing of Anchorage Bar Reinforcement (in.)
A_{va1} =	0.2	Area of One Anchorage Bar Reinforcement in tension zone (in^2)
d_{ca} =	14.5	Extreme Distance of Anchorage Bar Tensile Reinforcement (in.)
b_c =	12	Unit Width of Wall (in.) - Note: b_c is always 12in
A_{vp} =	0.6	Total Area of Parapet Vert. Reinforcement per 1ft of Wall (in^2/ft)
A_{va} =	0.6	Total Area of Anchorage Bar Reinf. per 1ft of Wall (in^2/ft)
A_{vend} =	0.6	Total Area of Critical Reinforcement per 1ft of Wall (in^2/ft)
d_{cend} =	8.5	Extreme Distance of Critical Tensile Reinforcement (in.)
a_{cend} =	0.882	Whitney Stress Block Depth (in.)
ε_{vtend} =	0.0216	Strain in Tension most Critical Reinforcement (in./in.)
M_{cend} =	**24.18**	**Flexural Resistance of Cantilever Wall for Impacts at End of Wall or Joint specified in AASTHO Article A13.3.1 (k-ft/ft)**

Bending Capacity of the Wall About the Vertical Axis for Impacts Within a Wall Segment, M_{wmid}		
A_{wmid} =	1	Area of Longitudinal Reinforcement in tension zone (in^2)
h_w =	42	Height of Wall (in.)
d_{wmid} =	8.25	Average Distance of Longitudinal Tensile Reinforcement (in.)
a_{wmid} =	0.420	Whitney Stress Block Depth (in.)
ε_{wtmid} =	0.0471	Strain in Tension most Long. Reinf. (in./in.)
ϕ_{wmid} =	1.0	Strength Reduction Factor
M_{wmid} =	**40.20**	**Flexural Resistance of Wall about its Vertical Axis for Impacts Within a Wall Segment specified in AASTHO Article A13.3.1 (k-ft)**

Bending Capacity of the Wall About the Vertical Axis for Impacts at End of Wall or Joint, M_{wend}		
A_{wend} =	1	Area of Longitudinal Reinforcement in tension zone (in^2)
h_w =	42	Height of Wall (in.)
d_{wend} =	8.25	Average Distance of Longitudinal Tensile Reinforcement (in.)
a_{wend} =	0.420	Whitney Stress Block Depth (in.)
ε_{wtend} =	0.0471	Strain in Tension most Long. Reinf. (in./in.)
ϕ_{wend} =	1.0	Strength Reduction Factor
M_{wend} =	**40.20**	**Flexural Resistance of Wall about its Vertical Axis specified in AASTHO Article A13.3.1 (k-ft)**

Nominal Railing Resistance to Transverse Load for Impacts Within a Wall Segment, R_{wmid}		
L_t =	5	Longitudinal Length of Distribution of Impact Force (in.)
H =	3.50	Height of Wall (ft.)
M_{cmid} =	8.35	Flexural Resistance of Cantilever Wall (k-ft/ft)
M_{wmid} =	40.20	Flexural Resistance of Wall about its Vertical Axis (k-ft)
M_b =	0.00	Add. Flex. Resist. of Wall about its Vertical Axis (k-ft)
L_{cmid} =	14.37	Critical Length of Yield Line Failure Pattern (ft.)
F_t =	80	Ultimate Transverse Force (kips)
H_e =	30	Height of Equivalent Transverse Load (in)
R_{wmid} =	**96.06**	**Total Transverse Resistance of the Railing at midspan specified in AASHTO Article A13.3.1 Located at H_e (kips)**
CHECK	**OK**	**OK if: $R_{wmid} \geq F_t$**

Nominal Railing Resistance to Transverse Load for Impacts at End of Wall or at Joint, R_{wend}		
L_t =	5	Longitudinal Length of Distribution of Impact Force (in.)
H =	3.50	Height of Wall (ft.)
M_{cend} =	24.18	Flexural Resistance of Cantilever Wall (k-ft/ft)
M_{wend} =	40.20	Flexural Resistance of Wall about its Vertical Axis (k-ft/ft)
M_b =	0.00	Add. Flex. Resist. of Wall about its Vertical Axis (k-ft/ft)
L_{cend} =	5.97	Critical Length of Yield Line Failure Pattern (ft.)
F_t =	80	Ultimate Transverse Force (kips)
H_e =	30	Height of Equivalent Transverse Load (in)
R_{wend} =	**115.55**	**Total Transverse Resistance of the Railing at end of wall or joint specified in AASHTO Article A13.3.1 (kips)**
CHECK	**OK**	**OK if: $R_{wend} \geq F_t$**