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## Investigating the Use of a New Universal Breakaway Steel Post --Phase III

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Midwest States Regional Pooled Fund Research Program Fiscal Year 2011 (Year 21) Research Project Number TPF-5(193), Suppl. #35 NDOR Sponsoring Agency Code RPFP-11-BNOSE

# **INVESTIGATING THE USE OF A NEW**

## **UNIVERSAL BREAKAWAY STEEL POST –**

## PHASE 3

Submitted by

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bullnose system. The breaka	away steel post was imple	mented into the thrie beam bullnose barrier							
system and subjected to two f	ull-scale vehicle crash test a	according to the Test Level 3(TL-3) guidelines							
provided in NCHRP Report I	No. 350. Test no. USPBN-3	(test designation no. 3-30) demonstrated that							
the breakaway steel post perfo	ormed in a satisfactory man	ner in the bullnose system as the passenger car							
was captured and safely brou	ight to a controlled stop.	lest no. USPBN-4 (test designation no. 3-31)							
demonstrated that the breaka	way steel post also perform	med in a satisfactory manner in the bullnose							
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This report was performed in part through funding from the Federal Highway Administration, U.S. Department of Transportation. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the state highway departments participating in the Midwest States Regional Pooled Fund Program nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, regulation, product endorsement, or an endorsement of manufacturers.

#### UNCERTAINTY OF MEASUREMENT STATEMENT

The Midwest Roadside Safety Facility (MwRSF) has determined the uncertainty of measurements for several parameters involved in standard full-scale crash testing and non-standard testing of roadside safety features. Information regarding the uncertainty of measurements for critical parameters is available upon request by the sponsor and the Federal Highway Administration.

The Independent Approving Authority (IAA) for the data contained herein was Mr. Scott K. Rosenbaugh, Research Associate Engineer.

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#### **1 INTRODUCTION**

#### **1.1 Background**

From 1997 through 2000, the Midwest Roadside Safety Facility (MwRSF) developed a thrie beam bullnose guardrail system for shielding median hazards found between divided highways [1-3]. The new, non-proprietary bullnose guardrail system was successfully full-scale crash tested and evaluated according to the Test Level 3 (TL-3) safety performance evaluation criteria provided in National Cooperative Highway Research Program (NCHRP) Report No. 350 [4].

Controlled release terminal (CRT) wood posts were used in the original bullnose guardrail system. Although the CRT posts adequately met the TL-3 safety requirements, these wood posts have several drawbacks. First, the properties and performance of wood posts are highly variable due to knots, checks, and splits, thus requiring grading and inspection of posts. Second, two holes are drilled into the CRT posts that allow them to break away upon impact. These holes expose the interior of the wood to the environment, which can accelerate deterioration. Wood posts can also swell under certain environmental conditions, making removal of broken posts from the steel foundation tubes difficult. Further, chemical preservatives used to treat the wood posts have been identified as harmful to the environment by some government agencies. Thus, the treated wood posts may require special consideration during disposal. Due to these concerns, a need existed for a breakaway steel post option for use in the thrie beam bullnose guardrail system.

Existing proprietary steel breakaway posts were investigated in the *Evaluation of an Existing Steel Post Alternative for the Thrie Beam Bullnose Guardrail System* [5]. After several proprietary steel post designs were reviewed and tested, a Road Systems, Inc. (RSI) Hinged Steel Post was chosen as the best option for the bullnose system. Two full-scale tests were performed on the bullnose system with the breakaway hinged steel posts, and both were unsuccessful due to the pickup truck overriding the system.

After the two failed full-scale tests, the focus shifted to the development of a new Universal Breakaway Steel Post (UBSP) to replace the CRT wood posts in the thrie beam bullnose system. While the previously-designed proprietary steel breakaway posts had been successfully used for guardrail end terminals, the bullnose system appeared to be more sensitive to subtle differences between wooden and steel breakaway posts. Thus, the design goal of the new, non-proprietary, UBSP was to mimic the strength and behavior of the wooden CRT post. The new post could also provide a replacement option for the CRT wood post in a wide variety of roadside hardware systems.

Following several rounds of bogie testing with CRT posts and a proposed UBSP, the bullnose system with the UBSP was full-scale crash tested according to test designation no. 3-38 of NCHRP Report No. 350 at the Midwest Roadside Safety Facility (MwRSF) [6]. In test no. USPBN-1, the performance of the UBSP bullnose median barrier was found to be unacceptable according to the NCHRP Report No. 350 criteria due to the pickup truck overriding the guardrail. Two factors were believed to have contributed to this behavior. First, the fracturing bolt posts did not absorb enough energy to safely capture and contain the vehicle. The posts rotated minimally in the soil and broke away quickly, which allowed the pickup to penetrate further into the system. Second, the second post remained intact longer than its wood counterpart, causing the pickup truck to redirect more than what was observed in previous tests on the wood-post bullnose barrier.

The UBSP bullnose median barrier system was modified and tested according to test designation no. 3-38 of NCHRP Report No. 350 [7]. Modifications to the UBSP bullnose median barrier previously tested at MwRSF included changing the second post on each side of the

system from a UBSP to a BCT post, increasing the diameter of the fracturing bolts from  $\frac{3}{4}$  in. (9.5 mm) to  $\frac{7}{16}$  in. (11.1 mm), decreasing the bolt spacing from  $10^{13}/_{16}$  in. x  $2\frac{1}{2}$  in. (275 mm x 64 mm) to 10 in. x  $2\frac{1}{2}$  in. (254 mm x 64 mm), and decreasing the embedment depth of the UBSP base from  $45\frac{3}{8}$  in. (1,153 mm) to 40 in. (1,016 mm). In test no. USPBN-2, the 2000P vehicle was adequately contained and no significant occupant compartment deformation occurred. Thus, test no. USPBN-2 conducted on a bullnose median barrier was determined to be acceptable according to the NCHRP Report No. 350 safety performance criteria for test designation no. 3-38. While test no. USPBN-2 demonstrated acceptable performance of the UBSP for test no. 3-38, two additional crash tests were required to fully evaluate the use of the new post design in the thrie beam bullnose barrier system.

#### **1.2 Objective**

The objective of the research project was to complete the full-scale test matrix required to evaluate the use of the UBSP design in the thrie beam bullnose system. Three full-scale crash tests were required to evaluate the use of the UBSP, test designation nos. 3-30, 3-31, and 3-38. Because the UBSP had previously been successfully tested under test designation no. 3-38, two additional TL-3 full-scale vehicle crash test (test designation nos. 3-30 and 3-31) were planned in order to demonstrate that the UBSP, used in combination with the thrie beam bullnose median barrier system, would meet the NCHRP Report No. 350 safety performance guidelines.

#### **2 DESIGN DETAILS**

The test installation was comprised of a bullnose median barrier system which utilized universal breakaway steel posts, as shown in Figures 1 through 23. Photographs of the test installation are shown in Figures 24 and 25. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

A one-half barrier system was utilized for the testing program in order to reduce costs and construction time. The bullnose system was constructed with twenty-eight posts, with fourteen posts positioned on each side of the system. Each side of the system contained two BCT posts, six UBSP posts, four W6x8.5 (W152x12.6) standard guardrail posts, and two BCT anchorage posts, respectively from the nose of the system. The lower portion of the UBSP consists of a foundation tube with the lower base plate. The upper portion of the UBSP consists of a post with the upper base plate. Although the goal of this study was to develop an all-steel system, previous testing demonstrated that using BCT wood posts in the anchorage system allowed for improved performance and the effective capture of the pickup truck [5].

All of the posts were placed in a compacted coarse, crushed limestone material meeting Grading B of AASHTO M 147-65 as found in NCHRP Report No. 350. The soil was compacted in 2-ft (610-mm) diameter augured holes using 8-in. (203-mm) lifts. Also, the fracturing bolts in the breakaway posts were torqued to 60 to 75 ft-lbs (81.3 to 101.7 N-m) for the full-scale crash testing program.





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	-U.S.																80		в	A	<u>17</u> -	1						UEIAI CALE igin L	N-4
	Face				/4"	/8"	/2"		/2"	/2"	/2"	/2"	/2"	/2"	2"				Side	Side							Å	Ϋ́	SPB
	Rear	×	2'-4'	9'-3'	-2 1,	-3 1,	-2 1,	7'-1'	-2 1,	-11 1	-8 1	-5 1,	-2 1,	11 1	-8 -1	1/2	۲	BB			स न								q Q
A			9	5	56'-	53'-	50'-	4	44'-	37'-	31'-	25'-	19'-	12'-	.9 -	5	9				<b>H</b> -								3 an
Side			$\vdash$								$\vdash$				$\vdash$	$\vdash$					_				Ð				N-N-
			1/8"	1/4"	1/8"	1/4"	3/8"	3/8"	3/8"	3/8"	/8"	/8"	/8"	/8"			۵)				<u></u>			lce	L Edo				ISPI
	Edge	7	2'-3	-11	6 <b>-</b> ,	1'-4	'-2	'-2	'-2	1-2	6 3	6 3	6 3,	6 3	0	0	4	TE	Ļ		B.I.			ar Fe	strean	L.	1:10 ement		os. L
	-D.S.			1	-	-	-	-		-							(7	Þ						Re	Downs				t N
	Face		/8"	<b>'</b> 4"	/8"	/4"	/2"										7	F	3						5		₹∾		Tes
	Rear	×	10 7,	-9 3/	10 3,	11 1,	10 1,	6,-0	3'-9"	7'-6"	1'-3"	0-19	8'-9"	2'-6"	"C-	.0	F		4	z	4	Г		F					ons,
			61'-	58'-	55'-	52'-	49'-	4	4	m	m	2	18	12	l o					Ĵ			N N	E	1	Le	1	о Л	cati
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	ost N		-	2	м	4	5	9	7	80	6	10	11	12	13	14											Rear		Pos
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December 16, 2010









Figure 8. End Rail and Splice Details, Test Nos. USPBN-3 and USPBN-4











Figure 13. W6x9 Post and Blockout Details, Test Nos. USPBN-3 and USPBN-4


















	lide									Offset	Offset																	SHEET: 21 of 22	DATE:	7/26/2010	DRAWN BY: MJW	rev. By: Rwb
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	Har									Blockc	Blockc																	for Thr	ose Me	ISPBN-	<u>s</u>	
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	escriptior			] Anchor	Lower 3	x 19] Up	× 40" [	52] Block	1241	362] Tap	362] Tap	362] Tap	No. 4	ection No	No. 3	ection No	ection No	ection N	ection No	/2" [64]	Hex He	ong Guar	In Hex F	Guardro	long Hex	Guardro						
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		ation Tul	ation Tul	03 × 20:	330 × 17	4" [330	152 × 2(	[152 ×	12.6] ×	[152 ×	[152 ×	[152 ×	rie Bearr	0] Thrie	rie Bearr	rie Bearr	rie Bearr	0] Thrie	0] Thrie	UNC-12	× 10" [2	x 1 1/2	× 1 1/2	× 18" [4	× 7 1/2	× 10" [2	Nail					
		3] Found	J Found	5/8" [2(	1/2" [	/2 × 3/	3/16" [	14 1/4"	V152 × .	14 1/4"	14 1/4"	14 1/4"	5 <b>81</b> 0] Th	-6" [381	5810] Th	5810] Th	5810] Th	-6" [381 - Side A	-6" [381 - Side E	. [11.1]	.9] Dia.	[15.9]	[15.9]	[15.9]	2] Dia.	[15.9]	le Head					
		6" [2438	2" [1829	× 8 ×	3 × 7 ×	3 x 5 1	x 8 x	x 8 x	V6×8.5 [V ubstitute	x 8 x	× 8 ×	x 8 x	2'-6" [3	sent 12'-	2'-6" [3	2'-6" [3	2'-6" [3	sent 12'- 10400]	sent 12'- 10400] -	hreaded)	6/8" [15.	1/8" Dia.	1/8" Dia.	1/8" Dia.	/8" [22.	1/8" Dia.	6D Doub					
	QTY.	2	6 7	9	12 1	12 1	12 6	20 6	12 <sup>V</sup> s	6 6	9	2 6	4	-	2 1	-	-	<u>н</u>	-	48	8	120 5	48 5	14 5	8	20 5	34 1					
	No.	10	22	a3	14	a5	<u> </u>	70	38	60	10	11	51	52	53	54	55	56	57	10	c2	c.3	c4	c5	c6	c7	83					
	Iter									ľ	0	0																				

		UBSP-3 Bull	Se	
ltern No.	QTY.	Description	Material Specification	Hardware Guide
d1	48	7/16" Dia. [11.1] Hex Nut	ASTM A563DH Galvanized	1
d2	12	1" Dia. [25.4] Hex Nut	ASTM A563DH	I
e1	192	7/16" Dia. [11.1] Flat Washer	ASTM F436 Gr. 1 Calvanized	I
e2	118	5/8" [15.9] Dia. Flat Washer	Grade A307	FWC16a
e3	16	7/8" [22.2] Dia. Flat Washer	Grade A307	FWC22a
e4	12	1" Dia. [25.4] Flat Washer	ASTM F436 Gr. 1	FWC24a
f1	80	BCT Thrie Post	SYP Grade No. 1 or better (No knots, 18" [457] abo or below ground line and on tension face)	PDF04
f2	8	W6x8.5 [W152x12.6] × 78" [1981] long (W6x9 [W152 × 13.4] can be substituted)	ASTM A36 (ASTM A992)	I
g <b>1</b>	9	BCT Cable 6'-6" [1981] Long	6x19 or 6x25 Cable IWRC IPS	FCA01
g2	9	2 3/8" [60] 0.D. × 6" [152] long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	FMM02
g3	2	Bullnose Nose Cable 5/8" Dia. [15.9] × 14.4' [4389] Long	"Cold Tuff" Button, S-409 Size No. 12 SB 2 7/8" [7 Stock No. 1040395 for 5/8" [16] Dia. (6x25) wire ro (or any similarly sized swage-grip button ferrules)	1
g <b>4</b>	4	Nose Cable Anchor Plates 12 5/8" [321] x 5 13/16" [148]	ASTM A36	I
g5	9	1/4" Dia. [6.4] U-Bolt Plate Washer	Zinc Coated or Galvanized ASTM A307	I
gɓ	9	1/4" Dia. [6.4] U-Bolt	Zinc Coated or Galvanized ASTM A307	1
97	12	1/4" Dia. [6.4] Hex Nut	Zinc Coated or Galvanized ASTM A307	I
н1	12	UBSP Post – Top Assembly	I	I
h2	12	UBSP Post – Bottom Assembly	L	I
h3	2	Strut and Yoke Assembly	ASTM A36 Galvanized	I
h4	9	Anchor Bracket Assembly	ASTM A36	FPA01
			Midwest Roadside Safety Facility	VICY SHEET: Indie 22 of 22 Action Mate -3 PRAWN BF: NAWN BF:

Figure 23. Bill of Materials, Test Nos. USPBN-3 and USPBN-4





Figure 24. Test Installation Photographs, Test Nos. USPBN-3 and USPBN-4









Figure 25. Test Installation Photographs, Test Nos. USPBN-3 and USPBN-4

# **3 TEST REQUIREMENTS AND EVALUATION CRITERIA**

## **3.1 Test Requirements**

Terminals and crash cushions, such as bullnose median barriers, must satisfy impact safety standards in order to be accepted by the Federal Highway Administration (FHWA) for use on National Highway System (NHS) new construction projects or as a replacement for existing designs not meeting current safety standards. In recent years, these safety standards have consisted of the guidelines and procedures published in NCHRP Report No. 350 [4]. From previous testing [3], the bullnose median barrier was defined as a non-gating barrier, and thus, must fulfill the requirements for a non-gating device. A non-gating device is designed to contain and either redirect or capture a vehicle when impacted downstream from the end of the device. According to Test Level 3 (TL-3) of NCHRP Report No. 350, non-gating terminals and crash cushions must be subjected to eight full-scale vehicle crash tests. The eight full-scale crash tests are as follows:

- 1. Test Designation 3-30 consisting of a 1,808-lb (820-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively, on the tip of the barrier nose with a <sup>1</sup>/<sub>4</sub>-point offset.
- 2. Test Designation 3-31 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively, on the tip of the barrier nose.
- 3. Test Designation 3-32 consisting of a 1,808-lb (820-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively, on the tip of the barrier nose.
- 4. Test Designation 3-33 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively, on the tip of the barrier nose.
- 5. Test Designation 3-36 consisting of a 1,808-lb (820-kg) passenger car impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively, at the beginning of the LON (Length-of-Need).

- 6. Test Designation 3-37 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 20 degrees, respectively, at the beginning of the LON.
- 7. Test Designation 3-38 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 20 degrees at the Critical Impact Point (CIP), respectively.
- 8. Test Designation 3-39 consisting of a 4,409-lb (2,000-kg) pickup truck impacting the system at a nominal speed and angle of 62 mph (100 km/h) and 20 degrees, respectively, in a reverse direction at one half the distance to the LON from the end of the terminal.

The test conditions of TL-3 longitudinal barriers are summarized in Table 1. The Critical Impact Point (CIP) mentioned above is defined for non-gating terminals as the point along the installation where it is unknown whether the guardrail will capture the impacting vehicle or redirect it.

_			Imp	act Condit	ions	Evoluction				
Test	Test	Test Vehicle	Spe	eed	Angle	Evaluation Criteria <sup>1</sup>				
Alticle	Designation	venicie	mph	km/h	(deg)	Cinteria				
	3-30	820C	62	100	0	C,D,F,H,I,K,N				
	3-31	2000P	62	100	0	C,D,F,H,I,K,N				
Non-gating	3-32	820C	62	100	15	C,D,F,H,I,K,N				
Terminals and	3-33	2000P	62	100	15	C,D,F,H,I,K,N				
Crash	3-36	820C	62	100	15	A,D,F,H,I,K,M				
Cusmons	3-37	2000P	62	100	20	A,D,F,K,L,M				
	3-38	2000P	62	100	20	A,D,F,K,L,M				
	3-39	2000P	62	100	20	C,D,F,K,L,M,N				

Table 1. NCHRP Report No. 350 TL-3 Crash Test Conditions

<sup>1</sup> Evaluation criteria explained in Table 2.

Previous testing of the bullnose guardrail system successfully passed all of the required tests on the wood-post, thrie beam bullnose system [1-3]. Based on the success of the previous testing, it was believed that the tests required for this project were those that would be affected

by the change from the wood CRT posts to the steel fracturing bolt posts. Researchers determined that three full-scale crash tests would be required to verify that the UBSP provides acceptable safety performance when used in the bullnose median barrier system. The three tests are as follows:

Test Designation 3-38 (2000P at CIP);

Test Designation 3-30 (820C end-on, with ¼-point offset); and

Test Designation 3-31 (2000P end-on to evaluate penetration distance).

The bullnose median barrier system was successfully tested with UBSP posts according to test designation no. 3-38 as detailed in a previous research report [7].

## **3.2 Evaluation Criteria**

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the bullnose median barrier to contain and redirect impacting vehicles. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Vehicle trajectory after collision is a measure of the potential for the post-impact trajectory of the vehicle to result in secondary collisions with other vehicles or fixed objects, thereby increasing the risk of injury to the occupant of the impacting vehicle and to other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in NCHRP Report No. 350. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in NCHRP Report No. 350.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported on the test summary sheet.

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Table 2. NCHRP Report No. 350 Evaluation Criteria for Terminals and Crash Cushions

Structural	А.	Test article should contain should not penetrate, underrid controlled lateral deflection of	and redirect the ve le, or override the in f the test article is acc	hicle; the vehicle stallation although ceptable.									
Adequacy	C.	Acceptable test article per controlled penetration, or cont	rformance may be trolled stopping of th	e by redirection, e vehicle.									
	D.	Detached elements, fragment should not penetrate or show compartment, or present a pedestrians, or personnel in intrusions into, the occupant injuries should not be permit Appendix E of NCHRP Report	s or other debris fro potential for penetra an undue hazard a work zone. De compartment that co ted. See discussion i rt No. 350.	om the test article ating the occupant to other traffic, formations of, or ould cause serious in Section 5.3 and									
	F.	<ul> <li>The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</li> <li>Occupant Impact Velocities (OIV) (see Appendix A, Section A5.3 of NCHRP Report No. 350 for calculation procedure) should satisfy the following:</li> </ul>											
Occupant	H.												
KISK		Occupant Impact Velocity Limits											
		Maximum											
		Longitudinal and Lateral	39.4 ft/s (12 m/s)										
	I.	The Occupant Ridedown Accelerations (ORA) (see Appendix A Section A5.3 of NCHRP Report No. 350 for calculation procedure) should satisfy the following:											
		Occupant Rideo	down Acceleration L	imits									
		Component	Preferred	Maximum									
		Longitudinal and Lateral	15 g's	20 g's									
	K.	After collision it is preferable into adjacent traffic lanes.	that the vehicle's tra	jectory not intrude									
Vehicle	L.	The occupant impact velocity exceed 39.4 ft/s (12 m/s) and longitudinal direction should r	in the longitudinal d the occupant ridedo tot exceed 20 g's.	irection should not wn acceleration in									
Trajectory	М.	The exit angle from the test at percent of the test impact ang contact with test device.	rticle preferably should be a should be should be should be a should be a should be a shou	ald be less than 60 of vehicle loss of									
	N.	Vehicle trajectory behind the test article is acceptable.											

### **4 TEST CONDITIONS**

### 4.1 Test Facility

The testing facility is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 5 miles (8.0 km) northwest of the University of Nebraska-Lincoln.

### 4.2 Vehicle Tow and Guidance System

A reverse cable tow system with a 1:2 mechanical advantage was used to propel the test vehicles. The distance traveled and the speed of the tow vehicle were one-half that of the test vehicle. The test vehicle was released from the tow cable before impact with the barrier system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [8] was used to steer the test vehicles. A guide-flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The <sup>3</sup>/<sub>8</sub>-in. (9.5-mm) diameter guide cable was tensioned to approximately 3,500 lb (15.6 kN) and supported both laterally and vertically every 100 ft (30.48 m) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide-flag struck and knocked each stanchion to the ground.

### 4.3 Test Vehicles

For test no. USPBN-3, a 2000 Suzuki Swift passenger car was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 1,857 lb (842 kg), 1,854 lb (841 kg), and 2,024 lb (918 kg), respectively. The test vehicle is shown in Figure 26, and vehicle dimensions are shown in Figure 27.







Figure 26. Test Vehicle, Test No. USPBN-3



\*(All Measurements Refer to Impacting Side)





	١	ehicle Geon	etry	in. (mn	1)
a	61.25	(1556)	Ь	55.75	(1416)
C .	149.5	(3797)	d	24.25	(616)
e	93	(2362)	f	32.25	(819)
g	21.5	(546)	h	33.67	(855)
ι.	8.25	(210)	j	21	(533)
k .	12.25	(311)	1	26.5	(673)
m	54.5	(1384)	n	53.25	(1353)
۰.	22	(559)	р	4.5	(114)
٩.	22.5	(572)	r	14.25	(362)
<b>s</b> .	12.75	(324)	t	61.5	(1562)
Wh	eel Cente	er Height Fro	nt	10.25	(260)
WI	neel Cent	er Height Re	ar	10.625	(270)
Wh	eel Well	Clearance (F	R)	25	(635)
Whe	el Well (	Clearance (R	R)	25.75	(654)

				Engine Type	4 cyl.
				Engine Size	1.3
				Transmission Type	
Weights					Automatic
lb (kg)	Curb	Test Inertial	Gross Static		FWD
W-front	1197 (543)	1184 (537)	1269 (576)		
W-rear	660 (299)	671 (304)	755 (342)		
W-total	1857 (842)	1854 (841)	2024 (918)		
Note any	damage prior to test:	None			

Figure 27. Vehicle Dimensions, Test No. USPBN-3

For test no. USPBN-4, a 2000 GMC C2500 pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,581 lb (2,078 kg), 4,429 lb (2,009 kg), and 4,429 lb (2,009 kg), respectively. The test vehicle is shown in Figure 28, and vehicle dimensions are shown in Figure 29.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The location of the final c.g. is shown in Figures 27 and 30 for test no. USPBN-3. The location of the final c.g. is show in Figures 29 and 31 for test no. USPBN-4. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicles to aid in the analysis of the high-speed videos, as shown in Figure 30. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicles. The remaining targets were located for references so that they could be viewed from the high-speed cameras for video analysis.

The front wheels of the test vehicles were aligned for camber, caster, and toe-in values of zero so that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted at the center of the vehicles' dashes and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed videos. A remote controlled brake system was installed in the test vehicles so the vehicles could be brought safely to a stop after the tests.







Figure 28. Test Vehicle, Test No. USPBN-4



\*(All Measurements Refer to Impacting Side)



Figure 29. Vehicle Dimensions, Test No. USPBN-4



		Т	ARGI	EST #:_ ET GEON	USPBN-3 IETRY in.	( <b>mm</b> )	)	
A _	42.625	(1083)	_ E_	116.25	(2953)	_ I_	30	(762)
B_	16.5	(419)	F	33.25	(845)	J	30.625	(778)
C_	30.625	(778)	G	28.625	(727)	-		
D	28.625	(727)	н	21.5	(546)			

Figure 30. Target Geometry, Test No. USPBN-3





			TH	EST #: 1	USPBN-4			
		Т	ARGI	ET GEON	IETRY in	. (mm)		
A	52	(1321)	_ E	84.75	(2153)	_ I _	39.875	(1013)
B	89.25	(2267)	F	38	(965)	_ J_	42	(1067)
C	48	(1219)	_ G_	54.25	(1378)	_ K_	26.25	(667)
D	84.75	(2153)	_ н	77.25	(1962)	_		

Figure 31. Target Geometry, Test No. USPBN-4

#### **4.4 Simulated Occupant**

For test no USPBN-3, A Hybrid II 50<sup>th</sup> Percentile Adult Male Dummy, equipped with clothing and footwear, was placed in the left-front seat of the test vehicle with the seat belt fastened. The dummy, which had a final weight of 166 lb (75 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH, the dummy was not included in calculating the c.g location.

### 4.5 Data Acquisition Systems

#### **4.5.1 Accelerometers**

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometers were mounted near the center of gravity of the test vehicles.

One accelerometer system was a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. Three accelerometers were used to measure each of the longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. Two additional accelerometers were used to measure longitudinal and lateral accelerations independently at the same sample rate. The accelerometers were configured and controlled using a system developed and manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM memory and 8 sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The second system, Model EDR-3, was a triaxial piezoresistive accelerometer system manufactured by IST of Okemos, Michigan. The EDR-3 was configured with 256 kB of RAM memory, a range of  $\pm 200$  g's, a sample rate of 3,200 Hz, and a 1,120 Hz low-pass filter. The "DynaMax 1 (DM-1)" computer software program and a customized Microsoft Excel worksheet were used to analyzed and plot the accelerometer data.

### 4.5.2 Rate Transducers

An angle rate sensor, the ARS-1500, with a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of rotation of the test vehicles. The angular rate sensor was mounted on an aluminum block inside the test vehicle near the center of gravity and recorded data at 10,000 Hz to the SIM. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

An additional angle rate sensor, an Analog Systems 3-axis rate transducer with a range of 1,200 degrees/sec in each of the three directions (roll, pitch, and yaw), was used to measure the rates of motion of the test vehicles. The rate transducer was mounted inside the body of the EDR-4 6DOF-500/1200 and recorded data at 10,000 Hz to a second data acquisition board inside the EDR-4 6DOF-500/1200 housing. The raw data measurements were then downloaded, converted to the appropriate Euler angles for analysis, and plotted. The "EDR4COM" and "DynaMax Suite" computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate transducer data.

#### **4.5.3 Pressure Tape Switches**

For test nos. USPBN-3 and USPBN-4, five pressure-activated tape switches, spaced at approximately 6.56 ft (2 m) intervals, were used to determine the speed of the vehicles before

impact. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the right-front tire of the test vehicle passed over it. Test vehicle speeds were determined from electronic timing mark data recorded using TestPoint and LabVIEW computer software programs. Strobe lights and high-speed video analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

## 4.5.4 Digital Cameras

Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were utilized to film test no. USPBN-3. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 32.

Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were utilized to film test no. USPBN-4. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 33.

The high-speed videos were analyzed using ImageExpress MotionPlus and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. Also, a Nikon D50 digital still camera was used to document pre- and post-test conditions for the tests.

	ļ	Aos 地6 UVC 市3	Ì	Lens Setting	-	24	,	67	50						
				Lens	Cosmicar 12.5 mm fixed	Sigma Zoom 24-70	Fujinon 50 mm fixed	TV Zoom 17-102	Sigma Zoom 24-135						
Aos #7			——————————————————————————————————————	Operating Speed (frames/sec)	500	500	500	500	500	29.97	29.97	29.97	29.97	29.97	29.97
	85' [25.9 m] 	mt m state A s	m]'	Type	AOS Vitcam CTM	AOS Vitcam CTM	AOS X-PRI Gigabit	AOS X-PRI Gigabit	AOS X-PRI Gigabit	JVC – GZ-MC500 (Everio)	JVC – GZ-MG27u (Everio)	JVC – GZ-MG27u (Everio)	JVC – GZ-MG27u (Everio)	Canon ZR90	Canon ZR10
AOS #5	[23:09 [25:09 [25:09]	Overhead Heig 58"-5" [17.8 AOS 業2 DV #1	s #1 25 [7.6	No.	2	4	5	6	7	1	2	3	4	1	2
·	75' [2		AOS		F	o beed	l <mark>S-ι</mark>	lgił V	ł		oət	νi	lsti	giU	

									Lens Setting	-	24	-	102	24							
				•					Lens	Cosmicar 12.5 mm fixed	Sigma Zoom 24-70	Fujinon 50 mm fixed	TV Zoom 17-102	Sigma Zoom 24-135							
A B ANG \$3								•DV #2	Operating Speed (frames/sec)	500	500	500	500	500	29.97	29.97	29.97	29.97	29.97	29.97	11CDBN A
	2 23' [7.0 m]	92'-6' [28.2 m]	-e" [22.1 m]	Overhead Height: Set-10 <sup>6</sup> [17:3 m] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 AGS 20 17:3 m] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 AGS 20 10 10 10 10 10 10 10 10 10 10 10 10 10	6" (3.9 m)	54 <sup>*</sup> [16.5 m]	eo <sup>1</sup> [180 m]		Type	AOS Vitcam CTM	AOS Vitcam CTM	AOS X-PRI Gigabit	AOS X-PRI Gigabit	AOS X-PRI Gigabit	JVC – GZ-MC500 (Everio)	JVC – GZ-MG27u (Everio)	JVC – GZ-MG27u (Everio)	JVC – GZ-MG27u (Everio)	Canon ZR90	Canon ZR10	tions Chaads and Lans Cattings T
	AOS		73		-	AOS			No.	2	4	5	9	7	1	2	3	4	1	2	noor I oromo
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### 5 FULL-SCALE CRASH TEST NO. USPBN-3

## 5.1 Test No. USPBN-3

The 2,024-lb (918-kg) passenger car with a simulated occupant in the driver's seat impacted the bullnose median barrier at a speed of 63.3 mph (101.9 km/h) and at an angle of 0 degrees. A summary of the test results and sequential photographs are shown in Figure 34. Additional sequential photographs are shown in Figures 35 and 36. Documentary photographs of the crash test are shown in Figure 37.

## **5.2 Weather Conditions**

Test no. USPBN-3 was conducted on September 13, 2010 at approximately 2:30 pm. The weather conditions, as per the National Oceanic and Atmospheric Administration (station 14939/LNK), were reported and are shown in Table 3.

Temperature	82°F
Humidity	65%
Wind Speed	10 mph
Wind Direction	140° from True North
Sky Conditions	Overcast
Visibility	9 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.03 in.
Previous 7-Day Precipitation	0.04 in.

Table 3. Weather Conditions, Test No. USPBN-3

# **5.3 Test Description**

Initial vehicle impact was to occur with the passenger's side quarter point of the vehicle at the center of the bullnose, as shown in Figure 38. The actual point of impact was at the quarter point. A sequential description of the impact events is contained in Table 4. The vehicle came to rest 20 ft – 11 in. (6.4 m) downstream and 9 in. (0.2 m) to the left of the center of the bullnose. The vehicle trajectory and final position are shown in Figures 34 and 39.

TIME	EVENT
(sec)	
0.000	The right-side bumper impacted the face of the thrie-beam nose.
0.016	Post nos. A1 and B1 deflected forward (away from the center of the system), and the left side of the bumper disengaged.
0.026	The rail kinked near the center of the nose.
0.036	Post nos. A1 and B1 deflected backward (toward the center of the system).
0.042	The rail buckled upstream of post no. B1.
0.046	The rail buckled upstream of post no A1.
0.072	The base of post no. B1 fractured.
0.078	The rail kinked at post no. B2.
0.080	The rail disengaged from post nos. B2 and B3.
0.094	The rail disengaged from post no. B4, and post no. B5 deflected forward (away
0.074	from the center of the system).
0.118	The rail impacted post no. B2.
0.120	The base of post no. B2 fractured.
0.128	The base of post no. A1 fractured.
0.158	Post no. B2 impacted post no. B3.
0.176	The vehicle yawed towards the right.
0.176	The bottom corrugation ruptured at the impact point.
0.188	The rail kinked at post no. B3.
0.232	The base of post no. A2 fractured.
0.260	Post no. B3 broke away.
0.302	The rail buckled downstream of post no. A3.
0.316	The rail buckled at post no. B4.
0.414	Post no. B4 broke away.
0.426	Post no. A3 broke away.
0.530	The rail kinked downstream of post no. B5.
0.632	The vehicle reached maximum displacement.

Table 4. Sequential Description of Impact Events, Test No. USPBN-3

# **5.4 Barrier Damage**

Damage to the barrier was severe, as shown in Figures 40 through 42. Barrier damage consisted of guardrail buckling and flattening, deformation of the guardrail around the front of the car, and post fracture and disengagement on both sides of the bullnose. Deformation to the rail occurred from 11 in. (279 mm) downstream of post no. 3 on Side A to 7½ in. (191 mm) downstream of post no. 5 on Side B.

The first three posts on Side A were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. The universal steel breakaway post no. 3 disengaged from the foundation tube and lower base plate when the bolts fractured. Post no. 3 was slightly twisted downstream in relation to the upper base plate, and there was some slight chipping on the blockout. Post no. 4 was slightly twisted upstream in relation to the upper base plate. Post nos. 1 and 3 had a ¼-in. (6-mm) soil gap and a ½-in. (13-mm) soil gap on the front side of the bases, respectively. There was no visible damage to post nos. 5 through 14 on Side A.

The first four posts on Side B were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. Post no. 1 was split on the upstream face, and the cable bearing sleeve disengaged. UBSP nos. 3 and 4 were slightly twisted upstream in relation to their upper base plates and were disengaged from the foundation tube and lower base plate when the bolts fractured. The blockouts on post no. 5 were rotated downstream. A <sup>1</sup>/<sub>2</sub>-in. (13-mm) soil gap was found on the downstream side of post no. 3 with an approximate 12-in. (30- mm) diameter by 2-in. (51-mm) high soil heave. The rail-to-post bolt was pulled out at post no. 6. There was no visible damage to post nos. 7 though 14 on Side B. There was no visible damage to the foundation tubes or lower base plates on either side of the system.

The damage to the thrie beam guardrail consisted of buckling, tearing, and flattening of the guardrail. Flattening occurred in the thrie beam from post no. 3 on Side A to post no. 4 on Side B. The Side B cable end anchorage threads fractured at the post no. 1 BCT anchorage. A buckle formed 11 in. (279 mm) downstream of post no. 3 on Side A with an 8-in. (203-mm) long horizontal tear in the upper slot. Another buckle formed at post no. 3 on Side A. A 2¼-in. (57-mm) long vertical tear was located 9 in. (229 mm) upstream of the Side A quarter point in rail section no. 1. The guardrail buckled 19 in. downstream of the center of the system towards Side A. Rail section no. 1 at the lower slot was torn completely through from 18½ in. (470 mm)

downstream of the center of the system towards Side A through 10 in. (254 mm) downstream of the Side B quarter point on the nose. A 1<sup>1</sup>/<sub>4</sub>-in. (32-mm) long vertical tear was located at the upper slot 14 in. (356 mm) downstream of the center of the system towards Side A. The guardrail buckled 10 in. (254 mm) downstream of the center of the system towards Side B. A 4<sup>1</sup>/<sub>2</sub>-in. (114-mm) long vertical tear in the upper slot and a buckle were located 10 in. (254 mm) downstream of the Side B quarter point on the nose. 10 in. (254 mm) downstream of the Side B quarter point. A 2<sup>3</sup>/<sub>4</sub>-in. (70-mm) long horizontal tear was located at the lower slot at post no. 2 on Side B. A buckle formed at post no. 4 on Side B, with a <sup>7</sup>/<sub>8</sub>-in. (22-mm) long vertical tear in the upper slot and a 2<sup>1</sup>/<sub>4</sub>-in. (57-mm) long vertical tear in the lower slot. The guardrail was kinked 7<sup>1</sup>/<sub>2</sub> in. (191 mm) downstream of post no. 5 on Side B.

The working width envelope of the system was found to be 22 ft – 9 in. (6.9 m) longitudinally and 14 ft –  $9\frac{1}{4}$  in. (4.5 m) laterally and is shown in Figure 44.

#### **5.5 Vehicle Damage**

The damage to the vehicle was moderate, as shown in Figure 45. Deformations to the vehicle's floorboard were relatively minor, with maximum longitudinal and vertical deflections of <sup>1</sup>/<sub>2</sub> in. (13 mm) and <sup>1</sup>/<sub>4</sub> in. (6 mm), respectively. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C.

The left door was dented and crushed. A dent was found between the left door and quarter panel. The left-fender was crushed inward and backward. The left-front strut attachment was fractured and the steering rod was bent. The left-front CV joint was pulled out, and both ends of the half shaft were damaged or pulled out. A dent was found in the left-front rim. The left mirror was disengaged. The radiator was crushed inward and shifted to the right. Both headlights were fractured. The left bumper mount was fractured. The bumper fractured near its

center. Minor cracking occurred in the lower left windshield in an area approximately 15 in. (381 mm) by 13 in. (330 mm). The hood was crushed backward and upward. The right side of the bumper cover was dented and torn. The right fender was crushed inward. The front of the right door was crushed and dented, and the door was ajar. The fuel tank was punctured, and small scrapes were found on the rear lower control arms. The roof and window glass remained undamaged.

## 5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 5. It is noted that the OIVs and ORAs were within the suggested limits provided in NCHRP Report No. 350. The calculated THIV, PHD, and ASI values are also shown in Table 5. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 34. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix D.

Evaluation Criteria		Trans	NCHRP Report				
		EDR-3	DTS	No. 350 Limits			
OIV	Longitudinal	-33.63 (-10.25)	-32.18 (-9.81)	$\leq 39.4$ (12)			
ft/s (m/s)	Lateral	3.60 (1.10)	4.08 (1.24)	$\leq 39.4$ (12)			
ORA	Longitudinal	-7.70	-7.70	$\leq 20$			
g's	Lateral	5.01	-5.75	$\leq 20$			
THIV ft/s (m/s)		-	32.58 (9.93)	not required			
I	PHD g's	-	8.62	not required			
	ASI	0.93	0.88	not required			

Table 5. Summary of OIV, ORA, THIV, and PHD Values, Test No. USPBN-3

# 5.7 Discussion

The analysis of the test results for test no. USPBN-3 showed that the bullnose median barrier adequately contained and safely decelerated the 820C vehicle. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, as shown in Appendix D, and were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle was contained by the bullnose median barrier. Therefore, test no. USPBN-3 conducted on a bullnose median barrier was determined to be acceptable according to the NCHRP Report No. 350 safety performance criteria for test designation no. 3-30.

2 sec	NA NA Pass	Satisfactory tream of impact	he left of center Moderate	12-FD-5 12FDEW3	1/2 in. (13 mm)					NCHKE KEPOFI No. 350	≤ 39.4 (12)	≤ 39.4 (12)	$\leq 20$	< 20	not required	not required	not required
		- 11 in. (6.4 m) downs	9 in. (0.2 m) to 1			22 ft – 9 in. (6.9 n 14 ft – 9¼ in.				1ucer DTS	-32.18 (-9.81)	4.08 (1.24)	-7.70	-5.75	32.58 (9.93)	8.62	0.88
366 sec		- 10 ft -			Deformation		ements (DTS)		E	EDR-3	-33.63 (-10.25)	3.60 (1.10)	-7.70	5.01		,	0.93
	onditions Speed	e Stability	e Damage	VDS <sup>[9]</sup>	Maximum Interior L	rucie Damage ng Width Envelope	num Angular Displac Roll	Pitch	ucer Data	tion Criteria	Longitudinal	Lateral	Longitudinal	Lateral	THIV //s (m/s)	PHD o's	ASI
.212 sec	Exit C     Exit B	Vehicl     Vehicl	Vehicl		E	Test A     Vorki	<ul> <li>Maxin</li> </ul>		• Transc	Evalu	AIO	ft/s (m/s)	ORA	g's	f		
			6 mm) Thrie Beam	. 31% in. (803 mm) th, bent and slotted	1 m) length, slotted m) length, standard	e BCT Wood Posts	el Breakaway Posts	4 mm) bolt spacing	3 x 4.8 x 1016 mm)	l Thrie Beam Posts	5x8.5 (W152x12.6)	U M14/-05 (1990) Swift nassenger car	1,857 lb (842 kg)	1,854 lb (841 kg)	2,024 lb (918 kg)	mph (101.9 km/h)	quarter point offset
0.112 sec	Side A	ationBullno		12 ft – 6 in. (3.81 m) leng	12  ft - 6  in. (3.8]	14 Thrie	Universal Stee		x 8 x <sup>3/16</sup> x 40 in. (152 x 203	Standard	M M						passenger's side e
		Report No. 350 Test Design:	ponent – Rail pe	p Mounting Height	ction No. 3 ction Nos. 4-5	ponent – Post Nos. 1-2, 13- pe	ponent – Post Nos. 3-8 pe	ape	se Tubes	ponent – Post Nos. 9-12 pe	ape	/ake /Model	rb.	st Inertial	oss Static	eed	pact Location
00:00	<ul> <li>Test Age</li> <li>Test Nurr</li> <li>Date</li> </ul>	NCHRP1     Test Artic	Key Com     Ty	To	S &	Key Com     Ty,	Key Com     Ty     Ty	Ba Frr	Ba	Key Com     Ty	Sh	Soul Type     Vehicle N	Cu	Te	<ul> <li>Impact Co</li> </ul>	Sp An	Ш

Figure 34. Summary of Test Results and Sequential Photographs, Test No. USPBN-3

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0.526 sec

0.000 sec



0.080 sec



0.128 sec



0.260 sec



0.414 sec



0.632 sec

Figure 35. Additional Sequential Photographs, Test No. USPBN-3



0.000 sec



0.072 sec



0.126 sec



0.248 sec



0.426 sec



0.528 sec



0.000 sec



0.126 sec



0.196 sec



0.348 sec



0.512 sec



0.634 sec

Figure 36. Additional Sequential Photographs, Test No. USPBN-3











Figure 37. Documentary Photographs, Test No. USPBN-3



Figure 38. Impact Location, Test No. USPBN-3



Figure 39. Vehicle Final Position and Trajectory Marks, Test No. USPBN-3



Figure 40. System Damage, Test No. USPBN-3





Figure 41. System Damage, Test No. USPBN-3


Figure 42. System Damage, Test No. USPBN-3



Figure 43. System Damage, Test No. USPBN-3



Figure 44. Working Width Envelope, Test No. USPBN-3



Figure 45. Vehicle Damage, Test No. USPBN-3

### 6 FULL-SCALE CRASH TEST NO. USPBN-4

### 6.1 Test No. USPBN-4

The 4,429-lb (2,009-kg) pickup truck impacted the bullnose median barrier at a speed of 64.5 mph (103.7 km/h) and at an angle of 0 degrees. A summary of the test results and sequential photographs are shown in Figure 46. Additional sequential photographs are shown in Figures 47 and 48.

# **6.2 Weather Conditions**

Test no. USPBN-4 was conducted on October 6, 2010 at approximately 12:15 pm. The weather conditions, as per the National Oceanic and Atmospheric Administration (station 14939/LNK), were reported and are shown in Table 6.

Temperature	74°F
Humidity	50%
Wind Speed	8 mph
Wind Direction	330° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.0 in.
Previous 7-Day Precipitation	0.0 in.

Table 6. Weather Conditions, Test No. USPBN-4

# 6.3 Test Description

Initial vehicle impact was to occur at the centerline of the system, as shown in Figure 38. The actual point of impact was at the centerline of the system. A sequential description of the impact events is contained in Table 7. The vehicle came to rest 50 ft - 10 in. (15.5 m) downstream and 2 ft - 7 in. (0.8 m) to the left of the initial impact. The vehicle trajectory and final position are shown in Figures 46 and 50.

TIME	EVENT
(sec)	
0	The bumper impacted the face of the thrie beam nose.
0.012	Kink formed in rail upstream of post no A1.
0.014	Kink formed in rail upstream of post no. Bl
0.018	Hood, right-front quarter panel, and left-front quarter panel deflected.
0.060	The base of post no. A1 fractured, and the rail kinked at the midspan between post nos. A1 and A2 and at the midspan between post nos. B1 and B2.
0.070	The base of post no. B1 fractured.
0.098	Kink formed in rail at post no. B2.
0.104	Kink formed in rail at post no. A2.
0.136	The base of post no. B2 fractured.
0.152	Kink formed in rail at post no. B3.
0.154	Kink formed in rail at post no. A3.
0.190	Post no. A3 broke away.
0.202	Post no. B3 broke away.
0.240	Kink formed in rail at post no. B4.
0.248	Kink formed in rail upstream of post no. A4.
0.286	Post no. A4 broke away.
0.288	Post no. B4 broke away.
0.328	Kink formed in rail upstream of post no. A5.
0.336	The right-rear tire ruptured.
0.366	Kink formed in rail downstream of post no. B5.
0.382	Post no. A5 broke away.
0.384	Post no. B5 broke away.
0.390	Kink formed in rail at midspan between post nos. A5 and A6.
0.472	Kink formed in rail at post no. B6.
0.496	Kink formed in rail upstream of post no. A6.
0.522	Post no. B6 broke away.
0.568	Kink formed in rail downstream of post no. A7.
0.596	Kink formed in rail at midspan between post nos. B6 and B7.
0.616	Kink formed in rail at post no. B7.
0.656	Kink formed in rail downstream of post no. B7.
0.696	Post no. B7 broke away.
0.794	Kink formed in rail at midspan of post nos. B7 and B8.
0.860	Kink formed in rail upstream of midspan between post nos. A7 and A8.
0.982	Kink formed in rail upstream of post no. A8.
1.182	Vehicle reached maximum displacement into system.

Table 7. Sequential Description of Impact Events, Test No. USPBN-4

### 6.4 Barrier Damage

Damage to the barrier was severe, as shown in Figures 51 through 53. Barrier damage consisted of guardrail buckling and flattening, deformation of the guardrail around the front of the pickup truck, and post fracture and disengagement on both sides of the bullnose. Deformation to the rail occurred from 13 in. (330 mm) upstream of post no. 8 on Side A to 15 in. (381 mm) upstream of post no. 8 on Side B.

Post nos. 1 through 6 and post no. 8 on Side A were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. The majority of post no. 1 remained attached to the guardrail connected through the bottom bolt. The universal steel breakaway post nos. 3 through 6 and post no. 8 disengaged from the foundation tube and lower base plate when the bolts fractured. The top portion of post no. 3 was slightly twisted in relation to the upper base plate. The back blockout was disengaged from post no. 4 and the front flange was bent. The back blockout was disengaged from post no. 5, and the front blockout was partially disengaged. The weld at the base plate of post no. 7 fractured at the front flange on the upstream side. Post no. 7 was also bent and twisted downstream in relation to the upper base plate with the rear flange buckled 2 in. (51 mm) at the lower portion of the post. There was also a <sup>3</sup>/<sub>8</sub>-in. (10-mm) soil gap on the upstream face of the foundation tube at post no. 7. Post no. 8 was twisted upstream in relation to the upper base plate, and the back flange and web were bent at the top of the post. Post nos. 9 and 10 had <sup>1</sup>/<sub>2</sub>-in. (13-mm) soil gaps on the backside and frontside of the foundation tubes, respectively. There was no visible damage to post nos. 11 through 14 on Side A.

The first seven posts on Side B were fractured and disengaged. BCT post nos. 1 and 2 fractured through the hole at ground level. Post no. 1 was split on the upstream face. The universal steel breakaway post nos. 3 through 7 disengaged from the foundation tubes and lower base plates as the bolts fractured. Post no. 3 was slightly twisted downstream in relation to the

upper base plate, and the back flange was bent and gouged. Post no. 4 was wedged underneath the left-rear tire. The front blockout on post no. 5 was fractured. The back flange was bent and the front blockout was split on post no. 7. A <sup>1</sup>/<sub>2</sub>-in. (13-mm) soil gap was found on the upstream side of the foundation tube of post no. 8. The two upstream base plate bolts fractured on post no. 8, and the post was bent slightly downstream but still in its original location. There was no visible damage to post nos. 9 though 14 on Side B. There was no visible damage to the foundation tubes or lower base plates on either side of the system.

The damage to the Side B thrie beam guardrail consisted of buckling, tearing and flattening of the guardrail. Folding and flattening occurred downstream of the center of the nose on Side B. A 2-in. (51-mm) long vertical tear was located 20 in. (508 mm) upstream of post no. 1. A 3-in. (76-mm) long vertical tear and a 4-in. (102-mm) long vertical tear were located at the

lower slot 13 in. (330 mm) and 11 in. (279 mm) upstream of post no. 1, respectively. The guardrail was torn completely through at the lower slots 17 in. (432 mm) downstream of post no. 1. A 2-in. (51-mm) long vertical tear was found 7 in. (178 mm) upstream of post no. 2 at the upper slot. Another 1-in. (25-mm) long tear was found 4 in. (102 mm) downstream of post no. 3. A 3-in. (76-mm) long horizontal tear was located 43 in. (1,092 mm) downstream of post no. 7. The guardrail was buckled 15 in. (381 mm) upstream of post no. 8.

The working width envelope of the system was found to be 54 ft  $-\frac{1}{2}$  in. (16.5 m) longitudinally and 14 ft  $-\frac{91}{4}$  in. (4.5 m) laterally and is shown in Figure 54.

### 6.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figure 55. Deformations to the vehicle's floorboard were relatively minor, with maximum longitudinal, lateral, and vertical deflections of  $\frac{1}{2}$  in. (13 mm) located at the right side of the right-side floorboard near the dashboard,  $\frac{1}{2}$  in. (13 mm) located near the middle of the left-side floorboard, and  $\frac{1}{2}$  in. (13 mm) located at the right floorboard near the dashboard, respectively. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C.

The left-rear quarter panel was crushed approximately 3 in. (76 mm). The left-front fender was crushed backward due to contact with the cable, and a 4-in. (102-mm) long tear occurred. The left headlight was disengaged. The left side of the hood was ajar. Scrape marks occurred along the bottom edge of the longitudinal frame members. Folding occurred in the left side of the front bumper, and the bumper was significantly crushed. The grill was crushed inward due to contact with the cable. The radiator was punctured and was leaking. The right headlight was crushed inward. The right-front fender was crushed inward approximately 5 in. (127 mm), and the fender was folded. The right side of the hood was ajar. The right-front tire had a 4-in.

(102-mm) long tear in the side wall, and the hub cap was fractured. The right-rear tire had a 13in. (330-mm) long tear in the side wall. The roof and window glass remained undamaged.

### 6.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 5. It is noted that the OIVs and ORAs were within the suggested limits provided in NCHRP Report No. 350. The calculated THIV, PHD, and ASI values are also shown in Table 8. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 46. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix D.

		Trans	sducer	NCHRP Report
Evaluati	ion Criteria	EDR-3	DTS	No. 350 Limits
	Longitudinal	-21.82	-21.75	≤ 39.4
OIV	201181100	(-6.65)	(-6.63)	(12)
ft/s (m/s)	Lateral	0.19	0.21	≤ 39.4
	Lateral	(0.06)	(0.06)	(12)
ORA	Longitudinal	-7.97	-7.84	$\leq 20$
g's	Lateral	7.46	7.34	$\leq 20$
T ft/s	THIV s (m/s)	_	21.75 (6.63)	not required
I	PHD g's	-	8.99	not required
	ASI	0.44	0.43	not required

Table 8. Summary of OIV, ORA, THIV, and PHD Values, Test No. USPBN-4

# 6.7 Discussion

The analysis of the test results for test no. USPBN-4 showed that the bullnose median barrier adequately contained and safely decelerated the 2000P vehicle. There were no detached

elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, as shown in Appendix D, and were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle was contained by the bullnose median barrier. Therefore, test no. USPBN-4 conducted on a bullnose median barrier was determined to be acceptable according to the NCHRP Report No. 350 safety performance criteria for test designation no. 3-31.

0.200 sec	0.324 sec		0.47	2 sec	C	692 sec
15.5 m] 15.5 m] 15.5 m] 15.5 m] 15. m] 15					5	
	•	Exit Condit	ions			
MM.	RSF N 4	Spee	p			NA
10 10	5/10 •	Exit Box C	riterion			Pass
	3-31	Vehicle Sta	bility			Satisfactory
Bullnose Median Ba	rrier •	Vehicle Sto	pping Distance		10 in. $(15.5 \text{ m})$ dov	vnstream of impact o the left of impact
12 ga. (2.66 mm) Thrie F	eam •	Vehicle Da	mage			Moderate
31 <sup>5</sup> / <sub>8</sub> in. (803	nm)	SCIV	[ <b>0</b> ]			
3.81 m) length, bent and sl	tted		(10)			1055 1255 1255 1255 1255 1255 1255 1255
t – 6 in. (3.81 m) length, sl	otted	Max	imim Interior Defo	ormation		12FUEW2 1/5 in (13 mm)
- 6 in. (3.81 m) length, star	dard	Tect Article	Damage		**** *** *** *** **** *** *** ***	(IIIIII C1) .III 2/
Thrie BCT Wood 1	osts	Working W	idth Envelope		54 ft – ½ in. (16.	5 m) longitudinally
			- - -		14 ft – 9¼ j	in. (4.5 m) laterally
iversal Steel Breakaway l	osts	Maximum / Roll	Angular Displacem	ients (D1S)		5 68 deg
W6x8.5 (W152x	2.6)	Pitch	l			-7.02 deg
ın. (64 x 254 mm) bolt spi ) diameter ASTMA325 he	cing tap	Yaw				5.89 deg
n. (152 x 203 x 4.8 x 1016		Transducer	Data	_		
~	<u> </u>	-		Trans	sducer	NCHRP Report
WEVE 5 WITCH	osts	Evalua	иоп Спиена	EDR-3	DTS	Limits
DATE MILLING AND	0.7	OIV	Longitudinal	-21.82 (-6.65)	-21.75 (-6.63)	≤ 39.4 (12)
GMC C2500 nickin	uck mek	ft/s (m/s)	Lateral	0.19(0.06)	0.21 (0.06)	≤ 39.4 (12)
4.581 lb (2.07	ke)	ORA	Longitudinal	-7.97	-7.84	$\leq 20$
4,429 lb (2,000	kg)	g`s	Lateral	7.46	7.34	≤20
4,429 lb (2,00	kg)		THIV THIV		21.75 (6.63)	not required
		1I I	/s (m/s)			-
	n/h)		DHD	ı	8.99	not required
the second secon	ueg		S -		ç	
			AST.	0.44	0.43	not required

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1.1

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Figure 46. Summary of Test Results and Sequential Photographs, Test No. USPBN-4

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Figure 47. Additional Sequential Photographs, Test No. USPBN-4



Figure 48. Additional Sequential Photographs, Test No. USPBN-4







Figure 49. Impact Location, Test No. USPBN-4



Figure 50. Vehicle Final Position and Trajectory Marks, Test No. USPBN-4



Figure 51. System Damage, Test No. USPBN-4



Figure 52. System Damage, Test No. USPBN-4



Figure 53. Post Damage, Test No. USPBN-4



Figure 54. Working Width Envelope, Test No. USPBN-4



Figure 55. Vehicle Damage, Test No. USPBN-4

### 7 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A bullnose median barrier was developed with fracturing bolt, steel posts. The breakaway steel posts were designed to match the cantilevered bending capacities of the existing wood CRT posts about their strong and weak axis, as well as for a biaxial loading condition. The embedded portion of the UBSP was similar to the CRT post to assure comparable rotational resistance in the soil. The mass, general geometry, and the breakaway characteristics of the upper UBSP section were also similar to the CRT wood post. The lower portion of the UBSP consisted of a foundation tube with the lower base plate. The upper portion of the UBSP consisted of a post with the upper base plate. The bullnose system utilized BCT posts for the first two posts as well as for the last two anchorage posts on each side of the barrier. Post nos. 3 through 8 were UBSP, and the remaining posts were standard thrie beam guardrail steel posts. The system was subjected to test designation nos. 3-3- and 3-31 of NCHRP Report No. 350 to determine if it met the TL-3 safety performance criteria.

In full-scale crash test no. USPBN-3, a 2,024-lb (918-kg) passenger car impacted the barrier at the passenger's side quarter point offset of the bullnose at a speed of 63.3 mph (101.9 km/h) and at an angle of 0 degrees. A summary of the safety performance evaluation is provided in Table 9. The vehicle was safely contained and decelerated, and the barrier did not cause vehicle instability.

In full-scale crash test no. USPBN-4, a 4,429-lb (2,009-kg) pickup truck impacted the barrier at the centerline of the bullnose at a speed of 64.5 mph (103.7 km/h) and at an angle of 0 degrees. A summary of the safety performance evaluation is provided in Table 9. The vehicle was safely contained and decelerated, and the barrier did not cause vehicle instability. The

bullnose median barrier with universal breakaway steel posts was determined to be acceptable according to the TL-3 safety performance criteria in NCHRP Report No. 350.

Based on this performance of the UBSP in the tests described herein and those conducted previously, the researchers believe that the UBSP is a suitable alternative for the wood, CRT post used in the original design. Because the performance of the system with the UBSP was nearly identical to the original system with CRT posts, no additional constraints or caveats need to be applied when using the alternative post design. In addition, recommendations made with respect to the design and implementation of the original bullnose median barrier system would still be applicable to the system when the UBSP is used.

It should be noted that the foundation tube and lower base plate of the UBSP was typically undamaged in the full-scale crash tests and could potentially be reused. MwRSF believes that the UBSP foundation tube and lower base plate can be reused if it displays no plastic deformation. In addition, if the UBSP foundation tube and lower base plate have not deflected more than ½ in. (13 mm) in the soil, it would be acceptable to re-compact the soil around the post base and mount a new top section (i.e., post and upper base plate) to the lower base plate to reset the post. Soil deflections greater than ½ in. (13 mm) would require pulling the post base, checking for damage, and resetting the post.

It should also be noted that the bullnose system constructed for use in this test program had dual cable anchorages employed on each side of the downstream end of the system. The function of these cable anchorages was to develop the appropriate rail tension required to simulate a typical field installation of the bullnose which would consist of a closed envelop or attachment of sides of the bullnose to a concrete bridge rail. Thus, for a closed envelope bullnose system or a bullnose that is attached to a bridge rail on both sides, these anchorages are not required. However, some states install the bullnose in a layout that attaches the oncoming traffic side to a bridge rail but leaves the reverse direction traffic side open and unattached. In this type of installation, the researchers would recommend that dual cable anchorages be employed similar to those used in the full-scale testing described herein.

Finally, the satisfactory performance of the UBSP in the bullnose median barrier system would suggest that there is potential for the UBSP as a surrogate in other CRT applications, such as in the long-span guardrail system and guardrail end terminals. However, further analysis and testing would be required to verify its performance in those other guardrail applications.

Evaluation Factors		Evaluation (	Criteria		Test No. USPBN-3	Test No. USPBN-4	
Structural	А.	Test article should contain a vehicle should not penetrate installation although control test article is acceptable.	and redirect the e, underride, or lled lateral defle	vehicle; the override the ection of the	S	S	
Adequacy	C.	Acceptable test article predirection, controlled predirection, stopping of the vehicle.	performance m enetration, or	nay be by controlled	S	S	
	D.	Detached elements, fragmentest article should not penetrating the occupant cundue hazard to other traffinina work zone. Deformation occupant compartment that should not be permitted. See and Appendix E of NCHRP	nts or other deb etrate or show p ompartment, or c, pedestrians, or ns of, or intrusi- could cause ser e discussion in Report No. 350	ris from the potential for present an or personnel ons into, the ious injuries Section 5.3 ).	S	S	
	F.	The vehicle should remain collision although moderate are acceptable.	n upright durin e roll, pitching	g and after and yawing	S	S	
Occupant Risk	H.	Occupant Impact Velocitie Section A5.3 of NCHR calculation procedure) should	s (OIV) (see A P Report No ld satisfy the fol	Appendix A, b. 350 for llowing:			
Risk		Occupant Impac	et Velocity Limi	ts	М	S	
		Component	Maximum				
		Longitudinal and Lateral	29.5 ft/s (9 m/s)	39.4 ft/s (12 m/s)			
	I.	The Occupant Ridedown Appendix A, Section A5.3 for calculation procedure) sh	Accelerations of NCHRP Rep hould satisfy the	(ORA) (see oort No. 350 e following:	~	-	
		Occupant Ridedowr	n Acceleration I	Limits	S	S	
		Component	Preferred	Maximum			
		Longitudinal and Lateral	15 g's	20 g's			
	К.	After collision it is preferable trajectory not intrude into ac	le that the vehic ljacent traffic la	le's nes.	S	S	
Vehicle Trajectorv	L.	The occupant impact velocit direction should not exceed occupant ridedown accelera direction should not exceed	ty in the longitu 39.4 ft/s (12 m/ tion in longitudi 20 g's	dinal s) and the inal	S	S	
	М.	The exit angle from the test less than 60 percent of the te at time of vehicle loss of con	article preferablest impact angle ntact with test d	ly should be , measured evice.	NA	NA	
	N.	Vehicle trajectory behind th	e test article is a	acceptable.	S	S	
S – Sa	atisfa	ctory M – Marginal	U – Unsat	isfactory	NA - Not	Applicable	

Table 9. Summary of Safety Performance Evaluation Results

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# **9 APPENDICES**

# Appendix A. Material Specifications

inity Highway Products , LLC 5 E. O'Connor ma, OH ma, OH istomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097						
5 E. O'Connor ma, OH istomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097						
na, OH ustomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097		Order Number: 1114	1173			
Istomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097		Customer PO: 2209				As of 0/11/00
P.O.BOX 81097		BOL Number: 5103	36			20/11/2/10/20
		Document #: 1				
		Shipped To: NE				
LINCOLN, NE (8501-1097		Use State: NE				
oject: RESALE						
Qty Part# Description S	Spec CL TY Heat Code	/Heat# Yield	TS	Elg C	Mn P S Si C	u Cb Cr Vn ACW
4 2090 112112'0'0'3/S	M-180 A 2 125145	01,860	076,67	23.0 0.190	0.770 0.010 0.004 0.020 0.12	1 0.00 0.030 0.000 4
	M-180 A 2 01138	12 60,600	82,200	24.8 0.210	0.910 0.010 0.010 0.020 0.0	10 0.000 0.020 0.000 4
	M-180 A 2 01138	13 32,200	00.11	70.2 0.220	0.910 0.010 0.010 0.010 0.0	10 0.000 0.020 0.000 4
	M-180 A 2 12514	44 61,890	81,040	26.5 0.190	0.740 0.010 0.000 0.030 0.1	20 0.000 0.050 0.000 4
4 729G TS {X6X3/16X8 <sup>1</sup> .0" SLEEVE	M-180 A 2 12514 A-500 L2848	45 63,120 59,523	81,790	25.2 0.190 28.0 0.147	0.740 0.010 0.000 0.020 0.1 0.648 0.009 0.008 0.023 0.1	10 0.000 0.040 0.000 4 5 0.00 0.091 0.000 4
4 749G TS \$X6X3/16X6'-0" SLEEVE	A-500 L2848	59,523	72,619	28.0 0.147	0.648 0.009 0.008 0.023 0.1	5 0.00 0.091 0.000 4
4 12379G T12/12/6/SPEC/S 34'RCX	M-180 A 2 291920	68,500	73,700	28.0 0.066	0.720 0.010 0.010 0.011 0.0	57 0.04 0.026 0.001 4
Upon delivery, all materials subject to Trinity Hig ALL STEEL USED WAS MELTED AND MANUFA ALL GUALVANIZED MATERIAL CONFORMS BOLTS COMPLY WITH ASTM A-307 SPECIFI NUTS COMPLY WITH ASTM A-363 SPECIFI 34" DIA CABLE 6X19 ZINC COATED SWAGED I STRENGTH - 49100 LB State of Ohio, County of Allen Awon and subscribed Notary Public: Notary Public:	phway Products , LLC Stori CTURED IN USA AND COI LL STRUCTURAL STEE WITH ASTM-123, UNLE ICATIONS AND ARE GAI CATIONS AND ARE GAI SATIONS AND ARE GAI END AISI C-1035 STEEL AI brone me this 11st day of S	age Stain Policy No. LG-0 age Stain Policy No. LG-0 MPLES WITH THE BUY A L MEETS ASTM A36 SS OTHERWISE STATE ALVANIZED IN ACCORD NNEALED STUD 1" DIA , pptember, 2009 Trini certi	02. AMERICA ACT AMERICA ACT 2D. CLDANCE WITH ASTM 449 AA ASTM 449 ASTM 440 ASTM 1564 By:	L ASTM A-1 ASTM A-1 ASTM A-15 AND A-1 ASTM A-15 ASTM A-1	153, UNLESS OTHERWIS 3, UNLESS OTHERWISE 776 II BREAKING	E STATED. STATED. 1 of 8

Figure A-1. Nose Cables

		<b>Certified Analysis</b>	950 POLIA KRIMINI
	Trinity Highway Products , LLC 425 E. O'Connor Lima, OH Custome:: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 P. O. BOX 81097 LINCOLN, NE 68501-1997 Project: RESALE	Order Number: 1121475 Customer PO: 2270 BOL Number: 55149 Document #: 1 Shipped To: NE Use State: KS	As of: 4/26/10
	BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE C 34" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL STRENGTH - 49100 LB State of Ohio, County of Afen. Swom and subscribed before me this 26th day Notary Public:	: GALVANIZED IN ACCORDANCE WITH ASTM / BALVANIZED IN ACCORDANCE WITH ASTM / ANNEALED STUD 1" DIA ASTM 449 AASHTO M3 • of April, 2010 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	A-153, UNLESS OTHERWISE STATED. -153, UNLESS OTHERWISE STATED. 0, TYPE II BREAKING 7. Thirty Highway Products , LLC certified By: Continued for the systemeter of the syst
91			
			3 of 3
Figure A-2.	Nose Cables		

	,													MO	Aay Produ	ice.	
						Cerum	Analys	SI						'UL		s.LLC	
Trinity H	lighway	Products, LLC															
425 E. O'	Connor					Order	Number: 1121496										
Lima, OH						Custo	omer PO: 2269						V	01/0/2			
Customer	MIDV	WEST MACH.& SUPPL	Y CO.			BOL	Number: 54132										
	P. O.	BOX 81097				Doc	sument #: 1										
						Shi	ipped To: NE										
	LINC	OLN, NE 68501-1097				Ω	Ise State: KS										
Project:	RESA	VLE															
Qty	Part #	Description	Spec	-C	YT .	Heat Code/ Heat #	Yield	TS	Elg	CV	P P	S	Si Cu	Cb Cr	Nn Vn	ACW	
70	D607	\$/5.3/0.71/711	001-W	¥	7	/ 17051-	04,020	7 000	1.0 0.1	1.0 0.1	610.0 M	0.0 200.0	061.0 02	0.00 0.060	0.000	4	
			M-180	¥ •	7 6	129151	63,860 8	001,300	26.8 0.	0 061.	710 0.010	0,004 0.	020 0.090	0.000 0.050	0.000	4 4	
			M-180	<	2	129161	63,450 8	1,140	26.0 0.	190 0	730 0.010	0.003 0.	020 0.150	0.000 0.050	0.000	4	
			M-180	۷	2	129162	62,160 7	8,740	25.4 0.	190 0	740 0.014	0.004 0.	020 0.150	0.000 0.070	0.000	4	
			M-180	A	2	130216	63,390 8	1,100	22.9 0.	190 0	730 0.011	0.004 0.	020 0.100	0.000 0.050	0.000	4	
			M-180	A	5	130218	57,750 8.	2,130	22.2 0.	130 0	750 0.011	0.005 0.	020 0.130	0.000 0.050	0.000	4	
1			M-180	¥.	2	130793	63,980 8.	3,300	23.0 0.	200 0	740 0.012	0.003 0.	030 0.120	0.000 0.050	0.000	4	
20	2110	T12/12'6/5'1.5/S	M-180	Υ.	7	129155	61,190 81	,210 2	3.8 0.1	190 0.7	30 0.011	0.003 0.0	20 0.150	0.00 0.060	0.000	4	
			M-180	A	2	129152	62,700 8	0,900	25.2 0.	190 0	.720 0.012	0.004 0.	020 - 0.150	0.000 0.060	0.000	4	
			M-180	¥ ·	0 0	129153	. 63,070 8	0,470	23.8 0.	180 0	730 0.011	0.002 0.	030 0.140	0.000 0.060	0.000	4	
			M-180	A .	2 4	129162	62,160 7	8,740	25.4 0.	0 001	740 0.014	0.004 0.	020 0.150	0.000 0.070	0.000	4 .	
	211G		M-180	× v	5 4	129163	61,760 78	s,730 2	8.0 0.1	190 0.7	40 0.011	0.0 200.0	30 0.140	0.00 0.060	0.000	4 4	
			M-180	A	2	128756	62,920 8	1,360	24.4 0.	.190 0	740 0.012	0.004 0.	020 0.110	0.000 0.060	0.000	4	
			M-180	A	2	129151	63,860 8	1,300	26.8 0.	.190 0	740 0.010	0.004 0.	020 0.090	0.000 0.050	0.000	4	, '
			M-180	A	2	129152	62,700 3	006'0	25.2 0.	.190 0	.720 0.012	0.004 0.	020 0.150	0.000 0.060	0.000	4	
			M-180	A	2	129153	63,070 8	0,470	23.8 0	.180 0	730 0.011	0.002 0.	030 0.140	0.000 0.060	0.000	4	
			M-180	¥.	3	129154	61,190 7	6,690	24.8 0	.180 0	.730 0.012	0.006 0.	020 0.150	0.000 0.060	0.000	4	
			M-180	Ä	2	129155	61,190 8	1,210	23.8 0	.190 0	.730 0.011	0.003 0.	020 0.150	0.000 0.060	0.000	4	
			M-180	A	2	129162	62,160 7	8,740	25.4 0	.190 0	.740 0.014	0.004 .0.	020 0.150	0.000 0.070	0.000	4	
			M-180	A	5	129164	61,140 8	0,290	26.5 0	.190 0	.750 0.011	0.003 0.	020 0.130	0.000 0.050	0.000	4	
. 30	260G	T12/25/63/S	M-180	۷	2	129163	61,760 71	3,730 2	8.0 0.	190 0.7	4) 0.011	0.003 0.0	30 0.140	0.00 0.060	0.000	4	
			M-180	A	2	128756	62,920	1,360	24.4 0	.190 0	.740 0.012	0.004 0.	020 0.110	0.000 0.060	0.000	4	
			M-180	A	5	129151	63,860 3	1,300	26.8 0	0 061.	.740 0.010	0.004 0.	020 0.090	0.000 0.050	0.000	4	
			M-180	A	2	129152	62,700 8	006'0	25.2 0	0 061.	.720 0.012	0.004 0.	020 0.150	0.000 0.060	0.000	4	

1 of 6

Figure A-3. Rail Section No. 3

92

Trinity Highword D					Certified	Analy	sis								· from B	Ullicity	, \ C
I rinity Highway I	roducts, LLC				Order Mr.	01011	-								/		
47) E. O COIIIOI						001711 .10011											
Lima, OH					Custome	er PO: 2252							A	s of: 4/2	8/10		
Customer: MIDW	/EST MACH.& SUPPLY	co.			BOL Nu	umber: 55201											
P. O. F	3OX 81097				Docum	1ent #: 1											
					Shipp	ed To: NE											
TINCC	JLN, NE 68501-1097				Use	State: NE											
Project: RESA	LE																
Otv Part#	Description	Spec	ರೆ	ΤY	Heat Code/ Heat #	Yield	IS	Elg	0	Mn	2 2	Si	Cu	cp	ර්	Vn AC	à
4 209B	T12/12'6/6'3/S	M-180	Ā	2	132181	64,070	81,720	26.2 0.2	0 00:	730 0.01	4 0.003	0.030	0.140	0.00 0	.080 0.0	00	
		M-180	A	2	131905	63,690	81,990	24.1 0	190	0.730 0.	013 0.00	4 0.030	0.120	0.000 (	0.060 0.	000	
		M-180	A	2	132182	60,790	78,680	26.2 0	190	0.730 0.	013 0.00	6 0.020	0.080	0.000 (	0.080 0.	000	
		M-180	A	2	132182	60,790	78,580	26.2 0	190	0.730 0.	013 0.00	6 0.020	0.140	0.000 (	0.080 0.	000	
		M-180	A	2	132183	64,220	82,170	24.8 0	190	0.740 0.	015 0.00	3 0.030	0.140	0.000 (	0.080 0.	000	
		M-180	A	5	132189	62,000	79,120	26.5 0	.190	0.720 0.	012 0.00	4 0.030	0.110	0.000	0.060 0.	000	
20 209G	T12/12'6/6'3/5	M-180	A	5	130794	63,340	81,340	26.6 0.	190 0.	.750 0.0	1 0.00	0.030	0.110	0.00	0.060 0.0	000 4	
		M-180	A	2	128756	62,920	81,360	24.4 0	.190	0.740 0.	012 0.00	4 0.02(	0.110	0.000	0.060 0	000	
		M-180	A	2	129161	63,450	81,140	26.0 0	.190	0.730 0	010 0.00	3 0.02(	0.150	0.000	0.050 0	000	
		M-180	A	2	129162	62,160	78,740	25.4 0	.190	0.740 0	014 0.00	4 0.020	0.150	0.000	0.070 0	000	
		M-180	A	2	130216	63,390	81,100	22.9 0	.190	0.730 0	011 0.00	4 0.02(	0.100	0.000	0.050 0	000	_
		M-180	A	2	130217	64,020	83,600	21.8 0	.190	0.760 0	013 0.00	5 0.02	0.150	0.000	0.060 0	000	-
		M-180	< ,	° °	130715	63,980	83,300	23.0 0	100 0	0.740 0	012 0.00	0.03	0.120	0.000	0.050 0	7 000	
0.607		NA_1 RO	<	4 (	012001	002 69	80 000	0 6.30	100	0 000 000	10 0 0 0 0	070.0 ¥	0.1.00			* 000	
		M-180	. ∢	2	129154	61.190	06962	24.8	180	0.730 0	012 0.00	10 0 00	0 0 150	0000	0 0000	000	
		M-180	A	2	130217	64,020	83,600	21.8 (	061.1	0.760 0	013 0.00	15 0.02	0 0.150	0.000	0.060 0	000	
		M-180	A	2	130793	63,980	83,300	23.0	0.200	0.740 0	.012 0.0	3 0.03	0 0.120	0.000	0.050 0	.000	**
		M-180	V	5	130794	63,340	81,340	26.6 (	0,190	0.750 0	0.0 110.	3 0.03	0 0.110	0.000	0.060 0	000.	**
209G		M-180	A	2	130217	64,020	83,500	21.8 0	190 0	0.760 0.0	13 0.00	5 0.020	0.150	0.00	0.060 0.	000 4	
		M-180	۲	2	129151	63,860	81,300	26.8 (	0.190	0.740 0	.010 0.0	0.02	0 0.090	0.000	0.050 0	000	**
		M-180	A	2	129154	61,190	79,690	24.8 (	0.180	0.730 (	.012 0.0	0.02	0 0.150	0.000	0.060 0	000	**
		M-180	A	2	129161	63,450	81,140	26.0	0.190	0.730 (	.010 0.0	03 0.02	0 0.150	0.000	0.050 0	000	**
		M-180	A	2	129162	62,160	78,740	25.4	0.190	0.740 (	.014 0.0	0.02	0 0.150	0.000	0.070 0	000	4
		M-180	A	2	130216	63,390	81,100	22.9	0.190	0.730 (	0.0 110.0	0.02	0 0.10(	0.000	0.050 0	000	4
		M-180	A	2	130218	57,750	82,130	22.2	0.130	0.750 (	0.0 110.0	05 0.02	0 0.13(	0.000	0.050 0	000	4
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Figure A-4. Rail Section No. 3

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							0	Certified	Analy	sis							in in	- Annula	100 Miles	.10
Trinity Hi	ighwa	iy Products, LLC																		
425 E. O'C	Connt	)r						Order Num	ber: 1121509									7		
Lima, OH								Customer	PO: 2252							As	of 4/2	8/10		
Customer:	IWI :	DWEST MACH.&	E SUPPLY	CO.				BOL Num	ber: 55201									01 10		
	P. (	D. BOX 81097						Documer	nt #: 1											
								Shipped	To: NE											
	LIT	ICOLN, NE 68501-	1 097					Use St	ate: NE											
Project:	RE	SALE																		
Qty	Part	## Description		Spec	5	TY	Heat	Code/ Heat #	Yield	ST	Elg	U	Mn P	s	ŝ	Cu	ට	5	Vn AC	3
				M-180		1 2		130793	63,980	83,300	23.0 0	200	0.740 0.0	2 0.003	0.030	0.120	0.000.0	0.050 0.	000 4	Ì
	209	Ū		M-180	A	2	13218	13	64,070	81,720 2	6.2 0.	200 0.	730 0.014	0.003	0.030	0.140	0.00 0.0	080 0.0	00 4	
				M-180	4	1 2		131905	63,690	065'18	24.1 0	.190	0.730 0.0	3 0.004	0.030	0.120	0.000 0	0.060 0.	000 4	
				M-180		1 2		132182	60,790	78,680	26.2 0	061.	0.730 0.0	3 0.006	0.020	0.080	0.000 0	0.080 0.	000 4	
				M-180	4	1 2		132182	60,790	78,680	26.2 0	.190	0.730 0.0	3 0.006	0.020	0.140	0.000 0	0.080 0.	000 4	
				M-180	4	4 2		132183	64,220	82,170	24.8 0	061.	0.740 0.0	5 0.003	0.030	0.140	0.000 0	0.080 0.	000 4	
				M-180	-	A 2		132189	62,000	79,120	26.5 0	.190	0.720 0.0	12 0.004	0.030	0.110	0.000 0	0.060 0.	000 4	
40	26(	JG T12/25/6'3/S		M-180	۷	2	1302	16	63,390	81,130	22.9 0.	190 0.	730 C.011	0.004	0.020	0.100	0.00 0.	050 0.0	000 4	
				M-180	1	A 2		129152	62,700	80,900	25.2 0	061.	0.720 0.0	12 0.004	0.020	0.150	0.000 0	0.060 0.	000 4	
				M-180		A 2		129154	61,190	069'61	24.8 0	.180	0.730 0.0	12 0.006	0.020	0.150	0.000 0	0.060 0.	000 4	
				M-180		A 2		130217	64,020	83,600	21.8 0	1.190	0.760 0.0	13 0.005	0.020	0.150	0.000 0	0.060 0.	000 4	
				M-180		A 2	<b>c</b> '	130793	63,980	83,300	23.0 0	0.200	0.740 0.0	12 0.003	0.030	0.120	0.000 (	0.050 0.	000 4	
				M-180		A 2	61	130794	63,340	81,340	26.6 0	061.0	0.750 0.0	11 0.003	0.030	0.110	0.000 (	0.060 0.	000 4	
9	135	(9B T12/12'6/6'3/S	35'CX	M-180	۲	2	1302	16	63,390	81,100	22.9 0.	190 0	730 0.01	0.004	0.020	0.100	0.00 0	.050 0.0	000	
				M-180		A		129152	62,700	80,900	25.2 (	061.0	0.720 0.0	12 0.004	0.020	0.150	0.000 (	0.060 0	000	
				M-180		A 2	2	129154	61,190	79,690	24.8 (	0.180	0.730 0.0	12 0.006	0.020	0.150	0.000 (	0.060 0	000	
				M-180		A S	2	130217	64,020	83,500	21.8 (	0.190	0.760 0.0	13 0.005	0.020	0.150	0.000 (	0.060 0	000	
				M-180		A	2	130793	63,980	83,300	23.0 (	0.200	0.740 0.0	12 0.003	0.030	0.120	0.000 (	0.050 0	000	
				M-180		V	2	130794	63,340	81,340	26.6 (	0.190	0.750 0.0	11 0.003	0.030	0.110	0.000 (	0.060 0	000	
3	3 506	94B T12/12'6/6'3/5	5 5'-3" RCX	M-180	A	2	1302	.16	63,390	81,100	22.9 0	.190 0	730 0.01	0.004	0.020	0.100	0.00 0	0.050 0.1	000	
				M-180		¥	2	129152	62,700	80,900	25.2	061.0	0.720 0.0	12 0.004	0.020	0.150	0.000	0.060 0	000	
				M-180		A	2	129154	61,190	79,690	24.8 (	081.C	0.730 0.0	12 0.00	0.020	0.150	0.000	0.060 0	000	
				M-180		A	2	130217	64,020	83,600	21.8	0.190	0.760 0.0	13 0.00	0.020	0.150	0.000	0.060 0	000	
				M-180		¥	2	130793	63,980	83,300	23.0	0.200	0.740 0.0	12 0.00	0:030	0.120	0.000	0.050 0	000'	
				M-180		×	2	130794	63,340	81,340	26.6	0.190	0.750 0.0	11 0.00	0:030	0.110	0.000	0.060 0	000	
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Figure A-5. Rail Section No. 3

Solution of the solution of th		As of: 4/28/10					SS OTHERWISE STATED. S OTHERWISE STATED. AKING MITY HEINWAY Products, LLC	
Certified Analysis	Order Number: 1121509	Customer PO: 2252	BOL Number: 55201	Document #: 1 Shipped To: NE	Use State: NE		LLC Storage Stain Policy No. LG-002. 10SA AND COMPLES WITH THE BUY AMERICA ACT. TURAL STEEL MEETS ASTM A36 TM-123, UNLESS OTHERWISE STATED. AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE this 28th day of April, 2010 Certified By: UNLOCATION CONTRACTION CONTRACTION CONTINUED CONTINUED TO ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BRE 1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE ASTM 449 ASTM	
ŧ,	Trinity Highway Products , LLC 425 E. O'Connor	Lima, OH	Customer: MIDWEST MACH.& SUPPLY CO.	P. O. BOX 81097	LINCOLN, NE 68501-1097	Project: RESALE	Upon delivery, all materials subject to Trinity Highway Prod ALL STEEL USED WAS MEL TEDAND MANUFACTURED IN ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUC ALL GALVANIZED MATERIAL CONFORMS WITH AS: BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS. NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS. 3/4" DIA CABLE 6X19 ZNC COATED SWAGED END AISI C STRENGTH - 49100LB State of Ohio, County of Allen. Svom and subscribed before me State of Ohio, Count of Allen. Svom and subscribed before me Notary Public: SWO-3V Q. MOV Commission Expires 2V 2.0. / 20. V	

Figure A-6. Rail Section No. 3

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CL         TY         Heat Code/Hat #         Yiad         TS         Eig         C         Min         P         S         NI         Cit         Cr         Vin ACVV           80 $\lambda$ 2         13974         63,340         81,340         256         0.190         0.790         0.010         0.000 <th>-1 097</th> <th></th> <th></th> <th></th> <th>Use</th> <th>State: KS</th> <th></th>	-1 097				Use	State: KS										
CL         TY         Heart Cude/Heart#         Yield         TS         Eg         C         M         P         S         I         Cl         TV         Acro         Ci         Ci         Ci         TV         Acro           0         A         2         130795         53,340         81,140         256         0.19         0.746         0.000         0.00	1															
	S	pec C	L	H K	sat Code/ Heat #	Yield	IS	Elg	υ	Mn	P	Si	Cu	ĉ	r Vr	ACV
0         A         2         128756         62,920         81,360         24,4         0.190         0.730         0.110         0.000         0.050         0.000         0.050         0.000 <td></td> <td>M-180 A</td> <td></td> <td>13</td> <td>0794</td> <td>63,340</td> <td>81,340</td> <td>26.6 0</td> <td>.190 0.</td> <td>750 0.0</td> <td>11 0.00</td> <td>0:030</td> <td>0.110</td> <td>0.00 00.06</td> <td>00.000</td> <td>4</td>		M-180 A		13	0794	63,340	81,340	26.6 0	.190 0.	750 0.0	11 0.00	0:030	0.110	0.00 00.06	00.000	4
0         A         2         129161         65,450         81,40         26.0         0.190         0.0730         0.000         0.050         0.000         0.000         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050         0.000         0.050 <td></td> <td>M-180</td> <td>¥</td> <td>5</td> <td>128756</td> <td>62,920</td> <td>81,360</td> <td>24.4 (</td> <td>0.190</td> <td>0.740 0</td> <td>.012 0.00</td> <td>4 0.020</td> <td>0.110</td> <td>0.000 0.0</td> <td>60 0.00</td> <td>4 0</td>		M-180	¥	5	128756	62,920	81,360	24.4 (	0.190	0.740 0	.012 0.00	4 0.020	0.110	0.000 0.0	60 0.00	4 0
0         A         2         129152         62,160         78,740         25,4         0.190         0.740         0.010         0.0000         0.000 <td></td> <td>M-180</td> <td>¥</td> <td>2</td> <td>129161</td> <td>63,450</td> <td>81,140</td> <td>26.0 (</td> <td>0.190</td> <td>0.730 0</td> <td>.010 0.00</td> <td>3 0.020</td> <td>0.150</td> <td>0.000 0.0</td> <td>50 0.00</td> <td>4 0</td>		M-180	¥	2	129161	63,450	81,140	26.0 (	0.190	0.730 0	.010 0.00	3 0.020	0.150	0.000 0.0	50 0.00	4 0
0         A         2         130216         63,390         81,100         229         0.190         0.730         0.000         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500         0.500 <th0.500< th=""> <th0.500< th=""> <th0.500< th=""></th0.500<></th0.500<></th0.500<>		M-180	۷	5	129162	62,160	78,740	25.4	0.190	0.740 (	.014 0.00	4 0.020	0.150	0.000 0.0	70 0.00	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	~	4-180	A	5	130216	63,390	81,100	22.9	0.190	0.730 0	.011 0.00	4 0.020	0.100	0.000 0.0	50 0.00	0 4
0         A         2         130793         65,980         83,500         23.0         0.200         0.740         0.012         0.030         0.000         0.50         0.000         0.	~	A-180	A	5	130217	64,020	83,600	21.8	0.190	0.760 0	.013 0.00	5 0.020	0.150	0.000 0.0	60 0.00	0 4
180         A         2         130217         64,020         83,60C         21.8         0.190         0.740         0.013         0.005         0.000 </td <td>2</td> <td>I-180</td> <td>A</td> <td>2</td> <td>130793</td> <td>63,980</td> <td>83,300</td> <td>23.0</td> <td>0.200</td> <td>0.740 0</td> <td>.012 0.00</td> <td>3 0.030</td> <td>0.120</td> <td>0.000.0</td> <td>50 0.00</td> <td>0 4</td>	2	I-180	A	2	130793	63,980	83,300	23.0	0.200	0.740 0	.012 0.00	3 0.030	0.120	0.000.0	50 0.00	0 4
	4	A-180 A		2 13	0217	64,020	83,600	21.8 0	.190 0.	760 0.6	13 0.00	5 0.020	0.150	0.00 0.00	00.000	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	N	180	A	2	129151	63,860	81,300	26.8	0.190	0.740 (	.010 0.00	4 0.020	060.0 0	0.000 0.0	50 0.00	0 4
	×	180	Y	5	129154	61,190	79,69)	24.8	0.180	0.730 6	.012 0.00	0.020	0.150	0.000 0.0	60 0.00	0 4
$ \begin{array}{lcccccccccccccccccccccccccccccccccccc$	-W	180	٧	2	129161	63,450	81,140	26.0	0.190	0.730 6	.010 0.00	3 0.020	0.150	0.000 0.0	50 0.00	0 4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	I-W	80	Y	2	129162	62,160	78,740	25.4	0.190	0.740 6	.014 0.00	14 0.020	0.150	0.000 0.0	70 0.00	0 4
0         A         2         130218         57,750         82,13)         222         0.130         0.750         0.011<0.005         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.000         0.030         0.00	M-1	80	A	5	130216	63,390	81,100	22.9	0.190	0.730 6	.011 0.00	14 0.020	0.100	0.000 0.0	50 0.00	0 4
0         A         2         130733         65,980         83,300         22.0         0.200         0.740         0.012         0.003         0.000         0.50         0.40         4           180         A         2         130216         63,390         81,100         22.9         0.190         0.730         0.010         0.00         0.50         0.000         4           180         A         2         130216         63,390         81,100         22.9         0.190         0.730         0.011         0.004         0.000         0.50         0.000         4           180         A         2         129152         63,790         80,900         252         0.190         0.750         0.012         0.000         0.50         0.000         4           10         A         2         129154         61,190         79,690         23.8         0.190         0.750         0.012         0.000         0.50         0.000         4           10         A         2         130774         64,020         83,400         73.40         81,400         77.60         0.012         0.000         0.000         60         0.000         0.000         6	M-1	80	¥	5	130218	57,750	82,130	22.2	0.130	0.750 6	.011 0.00	5 0.020	0.130	0.000 0.0	50 0.00	0 4
180         A         2         130216         63,390         81,100         22.9         0.190         0.720         0.011         0.004         0.020         0.000         4           20         A         2         129152         63,700         80,900         252         0.190         0.720         0.012         0.000         0.60         0.000         0.60         0.000         4           80         A         2         129154         61,190         79,690         252         0.190         0.750         0.012         0.000         0.60         0.000         6         0.000         4         2         130217         64,020         83,560         21.8         0.190         0.760         0.012         0.000         0.60         0.000         0.60         0.000         4         4         2         130714         64,020         83,340         21.1         0.190         0.760         0.012         0.000         0.000         0.000         60         0.000         4         6         0.012         0.001         0.000         0.000         0.000         4         0.01         0.000         0.000         0.000         0.000         0.000         6         0.01         <	M-1	80	¥	5	130793	63,980	83,30)	23.0	0.200	0.740 (	.012 0.00	3 0.030	0.120	0.000 0.0	50 0.00	0 4
0         A         2         129152         62,700         80,900         252         0.190         0.720         0.012         0.000         0.050         0.000         0.60         4           80         A         2         129154         61,190         79,690         24.8         0.180         0.730         0.012         0.000         0.60         0.000         0.60         0.000         4           80         A         2         130217         64,020         83,500         21.8         0.190         0.760         0.012         0.000         0.60         0.000         6         0.000         4         4         1         1<130714	'W	180 /		2 13	10216	63,390	81,100	22.9 0	.190 0.	730 0.0	11 0.00	4 0.020	0.100	0.00 00.0	50 0.000	4
0         A         2         129154         61,190         79,690         248         0.180         0.730         0.012         0.006         0.000         0.60         0.40           80         A         2         130217         64,020         83,600         21.8         0.190         0.760         0.013         0.000         0.600         0.000         0.60         4           80         A         2         130793         65,380         83,300         23.10         0.200         0.740         0.012<0.003	I-W	80	A	2	129152	62,700	80,900	25.2	0.190	0.720	.012 0.00	0.020	0.150	0.000 0.0	60 0.00	0 4
30         A         2         132017         64,020         83,600         21.8         0.190         0.760         0.013         0.005         0.000         0.60         0.000 <td>-W</td> <td>80</td> <td>A</td> <td>5</td> <td>129154</td> <td>61,190</td> <td>C69'6L</td> <td>24.8</td> <td>0.180</td> <td>0.730</td> <td>0.012 0.00</td> <td>0.020</td> <td>0.150</td> <td>0.000 0.0</td> <td>60 0.00</td> <td>0 4</td>	-W	80	A	5	129154	61,190	C69'6L	24.8	0.180	0.730	0.012 0.00	0.020	0.150	0.000 0.0	60 0.00	0 4
30         A         2         130793         63,980         83,300         23.0         0.200         0.740         0.012         0.003         0.000         0.50         0.40         0.12         0.003         0.000         0.50         0.40         4           130794         63,340         81,340         26.6         0.190         0.750         0.011         0.003         0.000         0.60         0.000         4           50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.000         0.00         0.000         4           50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.000         0.00         0.00         0.00         0.00         4           50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.000         0.00         0.00         0.00         0.00         4           50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.00         0.00         0.	Y	180	¥	5	130217	64,020	83,600	21.8	0.190	0.760	0.013 0.00	5 0.020	0.150	0.000 0.0	00.0 090	0 4
30         A         2         130794         63,340         81,340         26.6         0.190         0.750         0.011         0.003         0.020         0.000 <td>'W</td> <td>180</td> <td>A</td> <td>5</td> <td>130793</td> <td>63,980</td> <td>83,300</td> <td>23.0</td> <td>0.200</td> <td>0.740</td> <td>0.012 0.00</td> <td>3 0.030</td> <td>0 0.120</td> <td>0.000 0.0</td> <td>50 0.00</td> <td>0 4</td>	'W	180	A	5	130793	63,980	83,300	23.0	0.200	0.740	0.012 0.00	3 0.030	0 0.120	0.000 0.0	50 0.00	0 4
50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.000         0.000         0.000         4           50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.000         0.000         0.000         4           50         N0266         54,007         72,010         29.0         0.057         0.645         0.008         0.014         0.000         0.000         0.000         4           180         A         2         129152         62,700         80,900         25.2         0.190         0.720         0.112         0.004         0.050         0.006         0.000         4	I-W	80	¥	5	130794	63,340	81,340	26.6	0.190	0.750	0.011 0.00	0.030	0 0.110	0.000 0.0	0.00	0 4
50         N0266         54,007         72,010         29,0         0.057         0.645         0.008         0.014         0.000         0.000         0.000         4           180         A         2         129152         62,700         80,900         25.2         0.190         0.720         0.012         0.004         0.050         0.000         4	×	-500		Ż	0266	54,007	72,010	29.0 0	0.057 0	.645 0.1	108 0.00	8 0.014	0.000	0.0 0.0	00.00	4
180 A 2 129152 62,700 80,900 25.2 0,190 0.720 0.012 0,004 0,020 0.150 0.060 0.000 4	A	-500		Z	0266	54,007	72,010	29.0 0	0.057 0	.645 0.1	08 0.00	8 0.014	0.000	0.00 0.0	00.00	4
	M	-180	_	2 12	19152	62,700	80,900	25.2 0	0.190 0	.720 0.	112 0.00	4 0.020	0.150	0.00 0.0	50 0.000	4

# **Certified** Analysis

Order Number: 1121475 Customer PO: 2270 BOL Number: 55149 Document #: 1 Shipped To: NE

Customer: MIDWEST MACH.& SUPPLY CO.

P. O. BOX 81097

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Trinity Highway Products, LLC

425 E. O'Connor Lima, OH

Sonord Kenner

As of: 4/26/10

December 16, 2010 MwRSF Report No. TRP-03-244-10
Trinity Hi	ghway Pri	oducts, LLC													- Br		
425 E. O'C	onnor					Order Nu	umber: 1121475										
Lima, OH						Custom	er PO: 2270							As	of: 4/26/1	0	
Customer:	MIDWE	SST MACH.& SUPPLY C	Ö			BOL NI	umber: 55149										
	P. O. B(	ZX 81097				Docun	nent #: 1										
						Shipp	ed To: NE										
	LINCOL	LN, NE 68501-1097				Use	State: KS										
Project:	RESAL	Ë															
											,						
Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS F	cla	CN	In	S	Si	Cu	Cb Cr	r Vn	ACW
			M-180	A	2	129155	61,190	81,210 2	3.8 0.1	90 06	.730 0.0	11 0.003	0.020	0.150	0.000 0.06	0 0.000	4
			M-180	A	2	129163	61,760	78,730 2	8.0 0.1	0 06	.740 0.0	11 0.003	0.030	0.140	0.000 0.06	000.0 0	4
20	12383G	T12/12'6/6'3/SPEC SLOTS/S	M-180	A	2	130216	63,390	81,100 22	2.9 0.19	90 0.7	30 0.0	1 0.004	0.020	0.100	0.00 0.050	0000 0	4
			M-180	¥	2	129152	62,700	80,900	5.2 0.1	0 061	.720 0.0	12 0.004	0.020	0.150	0.000 0.06	000.0 000	4
			M-180	A	5	129154	61,190	79,690 2	4.8 0.1	180 0	.730 0.0	112 0.006	0.020	0.150	0.000 0.06	00000	4
			M-180	A	5	130217	64,020	83,600 2	21.8 0.1	190 0	760 0.0	113 0.005	0.020	0.150	0.000 0.06	000.000	4
			M-180	A	5	130793	63,980	83,300 2	23.0 0.2	200 0	.740 0.0	112 0.003	0.030	0.120	0.000 0.05	50 0.000	4
			M-180	A	5	130794	63,340	81,340 2	26.6 0.1	190 0	1.750 0(	011 0.003	0:030	0.110	0.000.0	50 0.000	4
10	12385G	T12/12/6/SPEC/S 5'RCX	M-180	A	5	130794	63,340	81,340 2	6.6 0.1	0.0 06	750 0.01	1 0.003	0.030	0.110	0.00 0.06	0 0.000	4
			M-180	A	5	128756	62,920	81,360	24.4 0.	190 0	.740 0.0	012 0.007	t 0.020	0.110	0.000 0.06	50 0.000	4
			M-180	A	5	129161	63,450	81,140	26.0 0.	190 0	0.730 0.1	010 0.00	3 0.020	0.150	0.0 000.0	50 0.000	4
			M-180	A	5	129162	62,160	78,740	25.4 0.	190 0	0.740 0.1	014 0.00	4 0.020	0.150	0.0 000.0	70 0.000	4
			M-180	A	5	130216	63,390	81,100	22.9 0.	190 (	0.730 0.	011 0.00	4 0.020	0.100	0.000 0.0	50 0.00(	4
			M-180	A	2	130217	64,020	83,600	21.8 0.	190 (	0.760 0.	013 0.00	5 0.020	0.150	0.000 0.0	60 0.000	4
			M-180	A	5	130793	63,980	83,30)	23.0 0.	200 (	0.740 0.	012 0.00	3 0.030	0.120	0.000 0.0	50 0.000	4
40	19361G	BNT PL 3/16XI2-5/8X5-1/2	A-36			60747	66,820	75,200	0.0 0.62	1.1 870	220 0.0	2 0.006	0.021	0.010	0.05 0.02	5 0.003	4
Upon del	ivery, all	materials subject to Trinity	'Highway	Produ	cts, I	LC Storage Stain Poli	icy No. LG-002.										
ALL STE ALL GU	EL USED ARDRAI	WAS MELTEDAND MAN L MEETS AASHTO M-18	UFACTUF 30, ALL S	LED IN TRUC	USA	AND COMPLIES WITH	H THE BUY AME STM A36	RICA ACT.									
ALL GA	LVANIZ	ED MATERIAL CONFOR	TIW SMD	H AST	M-12	3, UNLESS OTHERV	VISE STATED.										

Certified Analysis

Figure A-8. Radius Guardrail

2 of 3

rinty Highway Products , 11d 25 E. O'Comer 25 E. O'Comer 26 Comer 26 Comer 27 D. Manues 20 Ma	rinity Highway Products , LLC 25 E. O'Connor ima, OH batomet: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 P. O. BOX 81097 LINCOLN, NE 63501-1097 roject: RESALE	Order Cussi BOL Do Shi Shi TY Heat Code/Reat# 2 125143 A 2 0113812 A 2 0113812 A 2 0113812 A 2 0113813 A 2 0013813 A 2 0000 A 2 00000 A 2 00000 A 2 00000 A 2 00000 A 2 000000 A 2 00000 A 2 000000 A 2 0	Number: 111417. mmer PO: 2209 Number: 51036 sument #: 1 iped To: NE vise State: NE vise State: NE 61,860 61,800 61,800 61,800 61,890 61,890 61,890 61,890 61,890 61,80	3 IS 77,700 177,700 81,040 81,040 81,040 81,040 77,700 77,619 72,619	Elg. C 23.0 0.190 24.8 0.210 24.8 0.210 26.5 0.190 26.5 0.190 28.0 0.147 28.0 0.147 28.0 0.147	Mn         F           0.770         0.010           0.770         0.010           0.740         0.011           0.740         0.011           0.744         0.024           0.0548         0.020           0.0548         0.020	S 0.004 0.020 0. 0.020 0.020 0 0.020 0.030 0 0.030 0.000 0.030 0.030 0.000 0.030 0.030 0.030 0.030 0.000 0.030 0.0000 0.000 0.000 0.00	As of: 9/ As of: 9/ 121 0.00 0.010 0.000 0.010 0.000 0.110 0.000 0.110 0.000	11/09 11/09 <b>Cr Vn A</b> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
21 E O'Contra     Coter Number: 11113     Acc 90100       Brainer: MONEST MACHA & SUPELY CG.     BOL Number: 11185     Acc 90100       Brainer: MONEST MACHA & SUPELY CG.     BOL Number: 11185     Acc 90100       Brainer: MONEST MACHA & SUPELY CG.     BOL Number: 1118     Acc 90100       Proper: BALL     Deventant #: 1     Support Te: NE     Bol Number: 1118       Proper: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Deventant #: 1     Support Te: NE     Deventant #: 1       Nope: BALL     Nope: BALL     Deventant #: 1     Support Te: NE       Nope: BALL     Nope: BALL     Support Te: NE     Deventant #: 1       Nope: BALL     Support Te: NE     Support Te: NE     Deventant #: 1       Nope: BALL     Support Te: NE     Support Te: NE     Deventant #: 1       Nope: BALL     Support Te: NE     Support Te: NE     Deventant #: 1	25 E. O'Connor .ima, OH Dustomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 I.O. BOX 81097 LINCOLN, NE 63501-1097 roject: RESALE	Order Custa BOL Doc Shi Shi Custa 2 1 2 1 2 1 2 1 2 1 2 1 2 1 3 8 2 1 2 1 3 8 1 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Number: 1114177 omer PO: 2209 Number: 51036 ument #: 1 ipped To: NE ise State: NE fise State: NE fise State: NE fise State: State fise State: State fise S	3 IS IS IS IS IS IS IS IS IS IS IS IS IS	Elg C 2.50 0.190 2.48 0.210 2.62 0.220 2.65 0.190 2.62 0.190 2.62 0.147 2.80 0.147 2.80 0.147	Mn P 0.770 0.010 0.740 0.010 0.041 0.01 0.041 0.001 0.048 0.009	S Si 0.004 0.020 0. 0.010 0.020 0 0.010 0.020 0 0.000 0.030 0 0.000 0.030 0 0.000 0.030 0 0.000 0.032 0.	As off 9/ As off 9/ 121 0.00 ( 1.121 0.00 0.000 0.010 0.000 0.110 0.000 0.110 0.000	11/09 11/09 <b>Cr Vn A</b> 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
mu, OH         Constant PD: 239         And 91109           Submet:         Mod SUP         Document H:         1           P. O. DOX 8109*/         Expont To: NE         Document H:         1           P. O. DOX 8109*/         Sipped To: NE         Sipped To: NE         Sipped To: NE           Process:         REALE         Use State: NE         Verial Participation         Sipped To: NE           Process:         REALE         Use State: NE         Verial Participation         Sipped To: NE         Verial Participation         Out on 2000 000 000 000 000 000 000 000 000 0	.ima, OH Dustomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 LINCOLN, NE 63501-1097 Project: RESALE	Clisti BOL Do Do Shi Shi Shi T T Heat Codo/ Heat# 2 125143 A 2 0113812 A 2 0113812 A 2 0113812 A 2 0113813 A 2 0113813 A 2 013812 A 2 012645 A 2 0125645 A 2 0100000000000000000000000000000000000	mumber: 51036 Number: 51036 cument #: 1 ipped To: NE ise State: NE fise State: NE fise State: NE fise State: State fise State: NE fise State: State fise Sta	ZT ZZ ZZ ZZ ZZ ZZ ZZ ZZ ZZ ZZ ZZ ZZ ZZ Z	Elg C 23.0 0.190 24.8 0.210 26.2 0.190 26.2 0.190 26.2 0.190 28.0 0.147 28.0 0.147 28.0 0.147	Mm P 0.070 0.010 0.770 0.010 0.0410 001 0.0410 001 0.048 0.00 0.058 0.00	S Si 0.004 0.020 0. 0.010 0.020 0 0.0.010 0.010 0.020 0 0.0.000 0.020 0 0.0.000 0.020 0.020 0.0000 0.020 0.0000 0.020 0.0000 0.020 0.00000 0.00000 0.0000 0.00000 0.0000 0.000000	As off. 9/ Ca Ch 121 0.00 0.010 0.000 0.010 0.000 0.110 0.000	11/09 <b>Cr Vn A</b> 0.020 0.000 0.020 0.000 0.020 0.000 0.020 0.000 0.000
Datasere         MJD WEST MA/CH & SUPPLY CO.         BOL Number         E105           P. 0. DOX 8109         Downant H: 1         Downant H: 1         Downant H: 1           Project         Exact         Downant H: 1         Downant H: 1           Project         LLNOCLN, NE 6601-1097         Downant H: 1         Downant H: 1           Project         ZISAJJE         Las Stats:         NE         Las Stats:         NE           Project         ZISAJJE         Las Stats:         NE         Las Stats:         NE         Downant H: 1         Downant H: 1           Project:         ZISAJJE         Las Stats:         NE         ZISAJJE         Downant H: 1         Downant H: 1 <t< td=""><td>Dustomer: MIDWEST MACH.&amp; SUPPLY CO. P. O. BOX 81097 LINCOLN, NE 63501-1097 Project: RESALE</td><td>BDL Do Shi TY Heat Code/Heat# 2, 125143 A 2 0113812 A 2 0113813 A 2 0113813 A 2 125144 A 2 12848 A 2 12848</td><td>Number: 51036 sument #: 1 ipped To: NE ise State: NE fise State: NE 61,860 60,600 51,200 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,80</td><td><b>TS</b> 79,520 82,230 81,040 81,070 72,619 72,619 72,619</td><td>Elg C 23.0 0.190 24.8 0.210 26.2 0.220 26.5 0.190 26.5 0.190 28.0 0.147 28.0 0.147 28.0 0.147</td><td>Min P 0.770 0.010 0.770 0.011 0.240 001 0.648 0.009</td><td>s si 0.004 0.020 0. 0.010 0.020 0. 0.010 0.010 0.020 0 0.0000 0.020 0.020 0.000 0.020 0.020 0.0000 0.020 0.0.000 0.020 0.0.000 0.0000 0.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0</td><td>Cu Ch Ch</td><td>Cr Vn A </td></t<>	Dustomer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 LINCOLN, NE 63501-1097 Project: RESALE	BDL Do Shi TY Heat Code/Heat# 2, 125143 A 2 0113812 A 2 0113813 A 2 0113813 A 2 125144 A 2 12848 A 2 12848	Number: 51036 sument #: 1 ipped To: NE ise State: NE fise State: NE 61,860 60,600 51,200 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,890 61,80	<b>TS</b> 79,520 82,230 81,040 81,070 72,619 72,619 72,619	Elg C 23.0 0.190 24.8 0.210 26.2 0.220 26.5 0.190 26.5 0.190 28.0 0.147 28.0 0.147 28.0 0.147	Min P 0.770 0.010 0.770 0.011 0.240 001 0.648 0.009	s si 0.004 0.020 0. 0.010 0.020 0. 0.010 0.010 0.020 0 0.0000 0.020 0.020 0.000 0.020 0.020 0.0000 0.020 0.0.000 0.020 0.0.000 0.0000 0.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0	Cu Ch	Cr Vn A 
P. O. BOX 81001       Document if: 1 LINCOLN NE 6801-107       Document if: 1 LINCOLN NE 6801-107 <thdocum 6801-107<="" ne="" th="">       Do</thdocum>	P. O. BOX 81097 LINCOLN, NE 63501-1097 Project: RESALE	Dot Shi TY Hent Code/Heat# 2 125143 A 2 0113812 A 2 0113813 A 2 125144 A 2 125144 A 2 125144 A 2 125144 A 2 125145 A 2 125155 A 2 1251555 A 2 12515555 A 2 12515555555555555555555555555555	ument #: 1 ipped To: NE ise State: NE viald 61,860 60,600 53,120 61,890 61,890 63,120 63,223 59,523	TS 77,920 82,220 81,700 81,700 72,619 72,619 72,619	Elg C 235.0 0.190 245.0 0.190 265.0 1.900 265.0 1.901 265.0 0.147 285.0 0.147 285.0 0.147	Mn P 0.770 0.010 0.770 0.010 0.0740 001 0.0548 0.009	s si 0.004 0.020 0. 0.020 0.020 0 0.02010 0.020 0 0.02010 0.020 0 0.0200 0.020 0.020 0.020 0.0000 0.020 0.0000 0.020 0.000000	Cu Ch	Cr Vn A 2030 0.000 - 0.020 0.000 0.020 0.000 0.020 0.000 0.020 0.000 0.000
Stipped To: NE LINCOLA, NE 6500-1097       Stipped To: NE LINCOLA, NE 6500-1097       Use State: NE Use State: NE Applie: REAALE         Uper: REAALE       Use State: NE Applie: REAALE         OP       Trincollar, NE REAALE         OP       Nation of the Net of the	LINCOLN, NE 635 01-1 097 Project: RESALE	Shi TY Heat Code/Heat# 2 125143 A 2 0113812 A 2 0113812 A 2 125144 A 2 125144 A 2 125144 A 2 125144 A 2 125145 A 2 125145 A 2 125145 A 2 125448 A 2 125468 A 2 1254688 A 2 1254688848 A 2 1254688588 A 2 1254688568856888568	tise State: NE fise State: NE vield 61,860 60,600 53,220 61,890 61,890 61,20 59,223 59,223 59,223	<b>TS</b> 77,920 82,220 81,790 81,790 72,6:9 72,6:9	Elg C 23.0 0.190 24.8 0.210 24.8 0.210 26.2 0.190 26.2 0.190 28.0 0.147 28.0 0.147 28.0 0.147	Mn         P           0.770         0.010           0.770         0.010           0.740         0.011           0.740         0.011           0.744         0.0048           0.648         0.005	S Si 0.004 0.020 0. 0.010 0.020 0 0.0.010 0.020 0 0.0.000 0.030 0 0.0.000 0.020 0 0.0.000 0.020 0	Cu Cb 121 0.00 0 0.010 0.000 0.010 0.000 0.110 0.000 0.115 0.000	Cr Vn A 0.000 0.0
Incoluling       Lucoluling       Luculing       Luculing <th< td=""><td>LINCOLN, NE 63501-1097 Project: RESALE</td><td>TY Heat Code/ Heat# 2. 125143 A 2 0113812 A 2 0113813 A 2 0113813 A 2 125144 A 2 125144 A 2 125144 A 2 125144</td><td>ise State: NE Vield 61,860 60,600 52,200 61,890 61,890 63,120 59,523 59,523</td><td>TS 79,920 77,700 81,040 81,040 81,040 72,619 72,619 73,700</td><td>Elg. C 23.0 0.190 24.8 0.210 24.8 0.210 26.2 0.220 26.2 0.190 28.0 0.147 28.0 0.147 28.0 0.147</td><td>Мп Р 0.770 0.010 0.910 001 0.740 001 0.548 0.009 0.548 0.009</td><td>s si 0.004 0.020 0. 0.010 0.020 0 0.010 0.010 0 0.000 0.020 0 0.000 0.020 0 0.000 0.020 0 0.000 0.020 0</td><td>Cu Cb </td><td>Cr Va A </td></th<>	LINCOLN, NE 63501-1097 Project: RESALE	TY Heat Code/ Heat# 2. 125143 A 2 0113812 A 2 0113813 A 2 0113813 A 2 125144 A 2 125144 A 2 125144 A 2 125144	ise State: NE Vield 61,860 60,600 52,200 61,890 61,890 63,120 59,523 59,523	TS 79,920 77,700 81,040 81,040 81,040 72,619 72,619 73,700	Elg. C 23.0 0.190 24.8 0.210 24.8 0.210 26.2 0.220 26.2 0.190 28.0 0.147 28.0 0.147 28.0 0.147	Мп Р 0.770 0.010 0.910 001 0.740 001 0.548 0.009 0.548 0.009	s si 0.004 0.020 0. 0.010 0.020 0 0.010 0.010 0 0.000 0.020 0 0.000 0.020 0 0.000 0.020 0 0.000 0.020 0	Cu Cb 	Cr Va A 
Update:         REALE           Opdag:         Terrel Discription         See: CL         TY Hart Code/Hart i         Yelda         TS         Si         CG         CY         Yelda         Yelda<	rojeet: RESALE	TY Heat Code/ Heat# 2. 125143 A 2. 0113812 A 2. 0113813 A 2. 125144 A 2. 125144 A 2. 125144 A 2. 125144 A 2. 125145 A 2. 125145 A 2. 125145 A 2. 125145 A 3. 2. 125145 A 3. 2. 125145 A 4. 2. 125145 A 4. 2. 125145 A 5. 125145 A 6. 125145 A 7. 12515 A 7. 1	Yiteld 61,860 60,6,00 61,890 61,890 61,890 63,720 59,523 59,523	TS 79,920 77,70 81,040 81,040 81,040 72,619 72,619 73,700	Elg C 23.0 0.190 24.8 0.210 26.5 0.190 26.5 0.190 25.2 0.190 25.2 0.147 28.0 0.147 28.0 0.066	Mn         P           0.770         0.010           0.710         0.010           0.710         0.010           0.740         0.010           0.740         0.010           0.740         0.010           0.740         0.010           0.648         0.009           0.648         0.009	s si 0.004 0.020 0. 0.010 0.022 0. 0.021 0.010 0. 0.020 0.022 0. 0.008 0.022 0.	Cu Cb 	Cr Vn A 0.030 0.000 - 0.020 0.000 - 0.020 0.000 0.020 0.000 0.020 0.000 0.040 0.000 0.041 0.000
Op         Territ Dencipiia         Sec Cl.         TV         Hercrotional         Kind         TS         Rg         C         Min         F         S         Ci.         O         O         V         Min         F         S         Ci.         O         C         V         Min           4         2004         112/200533         413813         2030         233<		TY Heat Code/ Heat# 2, 125143 A 2 0113812 A 2 0113813 A 2 0113813 A 2 125144 A 2 125144 A 2 125144 A 2 125144 A 2 013813 A 3 2 0000000000000000000000000000000000	Yield 61,860 60,6,060 60,8,800 61,890 61,890 63,120 59,523 59,523 68,500	TS 79,920 82,2200 81,790 81,790 81,790 72,619 72,619 72,619	Elg         C           23:0         0.190           24:8         0.210           26:2         0.220           26:5         0.190           26:5         0.190           28:0         0.147           28:0         0.147           28:0         0.147	Mn P 0.770 0.010 0.910 0.01 0.910 0.01 0.914 0.01 0.548 0.009 0.548 0.009	S Si 0.004 0.020 0. 0.010 0.020 0 0.0.010 0.010 0 0.0.00 0.030 0 0.000 0.023 0.	Cu Cb Cb	Cr Vn A 0.030 0.000 - 0.020 0.000 0.020 0.000 0.050 0.000 0.040 0.000 0.041 0.000 0.091 0.000
4         2007         T12/T56675         M-18/A         2         13313         6,180         79,50         230         107         000         00000         0000000	Qty Part # Description Spec CL	2. 125143 A 2 0113812 A 2 0113813 A 2 125144 A 2 125144 L2848 L2848	61,860 60,600 52,200 61,890 61,290 59,223 59,223 59,223	79,920 82,220 81,040 81,040 81,790 72,6:9 72,6:9	23.0 0.190 24.8 0.210 26.5 0.220 26.5 0.190 25.2 0.197 28.0 0.147 28.0 0.147 28.0 0.066	0.770 0.010 0.910 0.01 0.910 0.01 0.740 0.01 0.740 0.01 0.648 0.009 0.648 0.009	0.004 0.020 0. 0.0.010 0.020 0 0.0.010 0.010 0 0.000 0.030 0 0.000 0.023 0. 0.008 0.023 0.	.121 0.00 0 .010 0.000 .010 0.000 .110 0.000 .175 0.00 0	0.020 0.000 0.020 0.000 0.020 0.000 0.050 0.000 0.040 0.000
Mile         2         013313         0.000         8.200         73,700         54         8.2010         0.00	4 209G T12//2'6/6'3/S M-180 A	A 2 0113812 A 2 0113813 A 2 125144 A 2 125145 L2848 L2848	60,600 32,200 61,890 59,223 59,223 68,500	82,220 77,77 81,040 81,790 72,6:9 72,6:9 73,700	24.8 0.210 26.2 0.220 26.5 0.190 25.2 0.190 28.0 0.147 28.0 0.147 28.0 0.147 28.0 0.066	0.910 001 0.910 001 0.740 001 0.648 0.009 0.648 0.009	0 0.010 0.020 0 0 0.010 0.010 0 0 0.000 0.030 0 0 0.000 0.023 0 0 0.008 0.023 0	0.010         0.000           0.120         0.000           0.110         0.000           0.175         0.000	0.020 0.000 0.020 0.000 0.050 0.000 0.040 0.000 0.091 0.000
Mile A         2         11313         52.200         77,700         252         0590         00000.000         0000.000         00000         00000         0000 <td>M-180 /</td> <td>A 2 0113813 A 2 125144 A 2 125145 L2848 L2848</td> <td>52,200 61,890 63,120 59,523 59,523 68,500</td> <td>77,700 81,040 81,790 72,619 72,619 73,700</td> <td>26.2 0.220 26.5 0.1900 25.2 0.197 28.0 0.147 28.0 0.147 28.0 0.066</td> <td>0.910 001 0.740 001 0.748 0.009 0.648 0.009 0.648 0.009</td> <td>0 0.010 0.010 0 0 0.000 0.030 0 0 0.000 0.020 0 0.008 0.023 0.</td> <td>0.010 0.000 0.120 0.000 0.110 0.000 175 0.00 (</td> <td>0.020 0.000 0.050 0.000 0.040 0.000 0.091 0.000</td>	M-180 /	A 2 0113813 A 2 125144 A 2 125145 L2848 L2848	52,200 61,890 63,120 59,523 59,523 68,500	77,700 81,040 81,790 72,619 72,619 73,700	26.2 0.220 26.5 0.1900 25.2 0.197 28.0 0.147 28.0 0.147 28.0 0.066	0.910 001 0.740 001 0.748 0.009 0.648 0.009 0.648 0.009	0 0.010 0.010 0 0 0.000 0.030 0 0 0.000 0.020 0 0.008 0.023 0.	0.010 0.000 0.120 0.000 0.110 0.000 175 0.00 (	0.020 0.000 0.050 0.000 0.040 0.000 0.091 0.000
Milon         2         13114         61300         81,000         255         0100         00000         0000         00000         00000	M-180 /	A 2 125144 A 2 125145 L2848 L2848	61,890 63,120 59,523 59,523 68,500	81,040 81,790 72,619 72,619 73,700	26.5 0.190 25.2 0.190 28.0 0.147 28.0 0.147 28.0 0.147 28.0 0.066	0.740 001 0.740 001 0.648 0.009 0.648 0.009	0 0.000 0.030 0 0 0.000 0.020 0 0.008 0.023 0.	0.120 0.000 0.110 0.000 .175 0.00 (	0.050 0.000 0.040 0.000 0.000 0.000
4         750 T3 & KGZUJGKW* SLEDYE         M-100 A         2         12145         63,120         8,120         8,7,30         53,20         90,000 0.000         0.000 0.000         0.000	M-180 J	A 2 125145 12848 1.2848	63,120 59,523 59,523 68,500	81,790 72,619 73,619 73,700	25.2 0.190 28.0 0.147 28.0 0.147 28.0 0.066	0.648 0.009	0 0.000 0.020 0 0.008 0.023 0.	0.110 0.000 (175 0.00 (	0.040 0.000
4         736         736         736         736         736         0.047         0.668         0.003         0.000	M-180 J	L2848 L2848	59,523 59,523 68,500	72,6:9 72,6:9 73,700	28.0 0.147 28.0 0.147 28.0 0.066	0.648 0.009 0.648 0.009	0.008 0.023 0.	.175 0.00 (	0.001 0.000
4         7969         75,69         25,00         73,70         25,00         0.147         0.648         0.005         0.014         0.648         0.000         4           7         713795         712/1265FECS 3/RCX         M.180         2         29190         65,00         73,700         280         0.014         0.648         0.006         0.010         0.011         0.010 </td <td>4 729G TS 8X6X3/16X8-0" SLEEVE A-500</td> <td>L2848</td> <td>59,523 68,500</td> <td>72,6:9 73,700</td> <td>28.0 0.147 28.0 0.066</td> <td>0.648 0.009</td> <td></td> <td></td> <td></td>	4 729G TS 8X6X3/16X8-0" SLEEVE A-500	L2848	59,523 68,500	72,6:9 73,700	28.0 0.147 28.0 0.066	0.648 0.009			
4 10705 T1276SFEC53FRCX       M-180 A       2       29100       06,000       0.000       0.001       0.0	4 749G TS 8X6X3/16X6-0" SLEEVE A-500		68,500	73,700	28.0 0.066		0.008 0.023 0.	.175 0.00 (	000.0 160.0
Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002. ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLES WITH THE BUY AMERICA ACT. ALL GUADRALL MEETS AASHTO M-180, ALL STRUCTURED IN USA AND COMPLES WITH THE BUY AMERICA ACT. ALL GUADRALL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM 36 ALL GALVANIZED MATERIAL CONFORMS WITH ASTN-123, UNLESS OTHERWISE STATED. BOLTS COMPLY WITH ASTNA -360 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA -153, UNLESS OTHERWISE STATED. NUCTS COMPLY WITH ASTMA -360 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA -153, UNLESS OTHERWISE STATED. NUCTS COMPLY WITH ASTMA -360 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA -153, UNLESS OTHERWISE STATED. NUCTS COMPLY WITH ASTMA -360 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA -153, UNLESS OTHERWISE STATED. NUCTS COMPACIENT OF A DATE OF A DA	4 12379G T12/12/6/SPEC/S 34'RCX M-180 A	076167 7				0.720 0.010	0.010 0.011 0.	.067 0.04 (	0.026 0.001
Upon delivery, all materials subject to Trinity Highway Products, LLC Storage Stain Policy No. LG-002. ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT. ALL GUARDRAIL MEETS AASHTO M.180, ALL STRUCTURAL STEEL MEETS ASTM 366 ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-133, UNLESS OTHERWISE STATED. BOLTS COMPLY WITH ASTM -3-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUST COMPLY WITH ASTM -563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. 34" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 ASHTTO M30, TYPE II BREAKING STRENGTH -49100 LB State of Obio, County of Allen 5wom and subscribed bries mether, 2009 Trinity HighMoProducts, LLC Notary Public: Commission Expires Commission Expires									
ALL STEEL USED WAS MELTED AND MANUF ACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT. ALL GUARDRAIL MEETS ASSHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED. BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTM A-363 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTM A-369 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTM A-369 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTM A-369 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTM A-369 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. SUBSTOCHT-49100LB State of Obio, County of Allen & Wom and subscribed by fore methis 11st day of September, 2009 Trinity High Maproduds , LLO Notary Public: Notary Public: Ocumission Expires	Upon delivery, all materials subject to Trinity Highway Pro	oducts, LLC Storage Stain	Policy No. LG-002.						
State of Olici, County of Allen Swom and subscribed byfore me this 11st day of September, 2009 Trinity High MeyProducts , LLA Control of Allen Swom and subscribed byfore me this first day of September, 2009 Certified By. Onlicity Assurance Commission Expires	ALL STEEL USED WAS MELTED AND MANUFACTURED ALL GUARDRAIL MEETS AASHTO M-180, ALL STRL ALL GALVANIZED MATERIAL CONFORMS WITH A, BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS NUTS COMPLY WITH ASTM A-363 SPECIFICATIONS 3,4" ID CABLE 6012 ZINC COATED SWAGED END AISI STRPMATT	IN USA AND COMPLIES V UCTURAL STEEL MEET (STM-123, UNLESS OTHI STM-123, UNLESS OTHI STM-123, UNLESS OTHI STM-123, UNLESS OTHI STEEL ANNEALEI I C-1035 STEEL ANNEALEI	VITH THE BUY AM S ASTM A36 SRWISE STATED. SRWISE STATED. ZED IN ACCORDAN ED IN ACCORDAN STUD I" DIA AS	ERICA ACT. ANCE WITH / ICE WITH / TM419 AASI	ASTM A- STM A-15 ATO M30, 1	153, UNLE 83, UNLESS YPE II BRE	SS OTHERWI S OTHERWISI AKING	ISE STATE E STATED	
Commission Expires / 287 2012 1 of 8	State of Ohio, County of Allen & wom and subscribed before me	e this 11st day of September,	2009 Trinity	HighwayPro	ducts , LLO	C	P		
	Notary Publics: North Commission Expires / N DU/2	9	Cerutie	d By. A	All Assessment	And			1 of 8

Figure A-9. Straight Slotted Guardrail

State of Ohio, County of Allen, Swom and subscribed before methins 11st day of September, 2009 Trinity Highwhreoduefer, JLC	BULTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTM A-363 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED. 34" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH - 49100 LB	Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002. ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT. ALL GUARDRAIL MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHER WISE STATED.	M-180 A 2 191995 70,400 75,100 26.0 0.060 0.710 0.010 0.010 0.040 0.000 0.020 0.000 M-180 A 2 191997 68,000 73,700 27.0 0.060 0.720 0.010 0.010 0.010 0.000 0.030 0.000	M-180 A 2 0153048 51,000 76,000 25.0 0.210 0.809 0.010 0.010 0.010 0.000 0.020 0.000 M-180 A 2 191996 67,500 73,300 28.0 0.066 0.740 0.007 0.011 0.055 0.04 0.020 0.002	M-180 A 2 0153031 54,100 77,500 25.2 0.2910 0.010 0.010 0.020 0.000 0.020 0.020 0.000 0.020 0.00	M-180 A 2 0113813 52,200 77,700 26.2 0.220 0.910 0.010 0.010 0.010 0.000 0.020 0.000	4 12383G T12/126/65/SPECSLOTS/S M-180 A 2 .0113811 61,700 84,700 22.4 0.220 0.940 0.015 0.007 0.010 0.010 0.020 0.000 4 M-180 A 2 0113812 60,600 82,200 24.8 0.210 0.910 0.010 0.020 0.010 0.000 0.020 0.000 0.020 0.000 0.020 0.000 4	oject: RESALE • QV Fart# Description Spee CL TY Heat Code/Heat# Yield TS Elg C Mn P S Si Cu Cb Cr Vn AC	Shipped To: NE LINCOLN, NE 68:01-1097 USe State: NE	P. O. BOX 81097 Document #: 1	As of: 9/11/09 BOL Number: 51036 BOL Number: 51036	ma, OH Customer PO: 2209	is E. O'Connor	Certified Analysis	As off 9/11/09 As off 9/11/09	Elg C 22.4 0.220 24.8 0.211 24.8 0.211 24.8 0.212 25.0 0.006 25.0 0.006 25.0 0.006 27.0 0.006 27.000	14173 99 036 75,000 77,000 77,000 77,000 77,000 73,000 74,0000 74,0000 74,0000 74,0000 74,0000 74,0000 74,0000 74,	<ul> <li>r Number: 11</li> <li>tormer PO: 220</li> <li>Number: 51</li> <li>ipped To: NE</li> <li>Use State: NE</li> <li>yield         <ul> <li>a,1,700</li> <li>60,600</li> <li>51,000</li> <li>54,100</li> <li>54,100</li> <li>54,100</li> <li>54,100</li> <li>54,000</li> <li>60,600</li> <li>60,600</li> <li>60,600</li> <li>60,600</li> <li>60,600</li> <li>60,600</li> <li>61,700</li> <li>60,600</li> <li>61,000</li> <li>62,000</li> <li>61,000</li> <li>61,000</li></ul></li></ul>	Order Cust BOL Do Do Sh U TY Hent Codo Heat # 2 0113811 2 0113812 2 0113813 2 0113812 2 011381 2 0113812 2 00000000000000000000000000000000000	CO. Spee CL Ss M-180 A M-180 A M-18	Products, LLC VEST MACH & SUPPLY ( BOX 81097 DLN, NE 68501-1097 LLE S33G T12/1566535PEC SLOT 333G T12/1566535PEC SLOT 333G T12/1566535PEC SLOT 333G T12/1566535PEC SLOT 333G T12/1266535PEC SLOT 333G T12/12665355PEC SLOT 333G T12/1266535PEC SLOT 333G T12/1266535FEC SLOT 350 T12/12665555FEC SLOT 350 T12/1266555555555555555555555555555555555	<ul> <li>inity Highwayl</li> <li>E. O'Connor</li> <li>ma, OH</li> <li>astomer: MIDV</li> <li>P. O. J</li> <li>P. D. D</li> <li>P. D</li></ul>
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Figure A-10. Straight Slotted Guardrail





# Appendix B. Vehicle Center of Gravity Determination

Test:	USPBN-3		Vehicle:	820C/Swift			
		Vehicle	CG Deter	mination			
		Weight	Long CG			HOR M	
VEHICLE	Equipment	(lb)	(in.)			(lb-in.)	
+	- Unbalasted Car	1857	33.05	5		6138	80
+	- Brake receivers/wires	6	115	5		69	0
+	- Brake Frame	5	28	3		14	0
+	- Brake Cylinder	28	62.5	5		175	50
+	<ul> <li>Strobe Battery</li> </ul>	5	55	5		27	'5
+	- Hub	18	0	)			0
+	<ul> <li>CG Plate (EDRs)</li> </ul>	5	39	9		19	15
63	- Battery	-26	-12	2		31	2
6.	- Oil	-4	-6	5		2	24
6.	- Interior	-22	46	5		-101	2
5.	- Spare Tire	-32	99	9		-316	8
29	- Coolant	-7	-17	7		11	9
19	- Washer fluid	-5	-16.5	5		82.	.5
BALLAST	Water (fuel tank)						0
	Misc. DTS Unit	18	28	3		50	)4
	Misc.						0
wheelbase	TOTAL WEIGHT	1846	]іь	CG L	ocation (in.)	61291. ) 33.6	5
Wilcolbabe	NCHRP 350 Targets			CURRENT		Difference	•
	Test Inertial Weight	1808	(+/- 55)	1846		38	0
	Long CG	31.5	(+/- 6)	33.67		2.1700	
	Note, Long, CG is me	asured from f	ront axle of te	est vehicle			
					Dummer		
	Cruck Mainh4 (lb)			1	Dummy =	166 10	valacht (lb)
	Curb weight (ib)				Gross Sta	ttic wheel v	veight (ID)
		Left	Right			Left	Right
	Front	581	616	2	Front	66	61 6
	Rear	369	291		Rear	39	97  3
	FRONT	1197			FRONT	126	9
	REAR	660			REAR	75	5
	TOTAL	1857	D.		TOTAL	202	24

Figure B-1. Vehicle Mass Distribution, Test No. USPBN-3

	USPBN-4		11	Vehicle:	C2500/2000P	
		Veh	nicle	CG Deter	mination	
				Long CG		HOR M (lb-
VEHICLE	Equipment	Weight	(lb)	(in.)		in.)
+	Unbalasted Truck	-	4581	54.51	]	249718.5
+	Brake receivers/wires		9	80		720
+	Brake Frame		5	41	]	205
+	Brake Cylinder		27	54	Ī	1458
+	Strobe Battery		4	70	)	280
+	Hub		29	C	)	0
+	CG Plate (EDRs)		12	58	3	696
-	Battery		-30	-15	5	450
-	Oil		-6	10	)	-60
-	Interior		-110	54	Į.	-5940
-	Fuel		-52	97	7	-5044
-	Coolant		-13	-20.5	5	266.5
-	Washer fluid		-5	-18.5	5	92.5
-	Exhuast		-35	108	3	-3780
BALLAST	DTS Rack		18	70	)	1260
	EDR		7	58	3	406
	Misc.			_	]	0
	TOTAL WEIGHT		4441	b	CG location (ir	240728.5 n.) 54.30

NCHRP 350 Targets		CURRENT	Difference
Test Inertial Weight (Ib	4410 (+/-)100	4441	31.0
Long CG (in.)	55 (+/-)6	54.30	-0.70000

Note, Long. CG is measured from front axle of test vehicle

Curb Weight			
	Left	Rig	ght
Front		1383	1299
Rear		949	950
FRONT		2682 lb	
REAR		1899 lb	
TOTAL		4581 lb	

Actual te	st iner	tial wei	ght	
(from scales)				
8	Left		Right	
Front		1359	1920	1241
Rear	<i></i>	910		919
FRONT		2600	lb	
REAR		1829	lb	
TOTAL	5.0 	4429	lb	

Figure B-2. Vehicle Mass Distribution, Test No. USPBN-4

# Appendix C. Vehicle Deformation Records

# Occupant Compartment Deformation Index (OCDI)

Test No. USPBN-3 Vehicle Type: 820C/Swift

### OCDI = XXABCDEFGHI

XX = location of occupant compartment deformation

A = distance between the dashboard and a reference point at the rear of the occupant compartment, such as the top of the rear seat or the rear of the cab on a pickup

- B = distance between the roof and the floor panel
- C = distance between a reference point at the rear of the occupant compartment and the motor panel

D = distance between the lower dashboard and the floor panel

E = interior width

F = distance between the lower edge of right window and the upper edge of left window

G = distance between the lower edge of left window and the upper edge of right window

H= distance between bottom front corner and top rear corner of the passenger side window

I= distance between bottom front corner and top rear corner of the driver side window

# Severity Indices

0 - if the reduction is less than 3%

1 - if the reduction is greater than 3% and less than or equal to 10 % 2 - if the reduction is greater than 10% and less than or equal to 20 %

3 - if the reduction is greater than 20% and less than or equal to 30 % 4 - if the reduction is greater than 30% and less than or equal to 40 %



where.

1 = Passenger Side

2 = Middle

3 = Driver Side

# Location:

Measurement	Pre-Test (in.)	Post-Test (in.)	Change (in.)	% Difference	Severity Index
A1	44.50	44.75	0.25	0.56	0
A2	45.50	45.50	0.00	0.00	0
A3	44.00	44.25	0.25	0.57	0
B1	38.75	39.00	0.25	0.65	0
B2	37.00	37.25	0.25	0.68	0
B3	39.00	39.00	0.00	0.00	0
C1	54.50	54.25	-0.25	-0.46	0
C2	59.25	58.75	-0.50	-0.84	0
C3	56.00	56.00	0.00	0.00	0
D1	18.25	18.50	0.25	1.37	0
D2	20.00	20.00	0.00	0.00	0
D3	19.25	19.25	0.00	0.00	0
E1	49.25	49.25	0.00	0.00	0
E3	49.50	49.50	0.00	0.00	0
F	44.25	44.25	0.00	0.00	0
G	44.00	43.75	-0.25	-0.57	0
н	38.50	38.50	0.00	0.00	0
1	43.50	43.50	0.00	0.00	0

Note: Maximum sevrity index for each variable (A-I) is used for determination of final OCDI value

XX A B C D E F G H I LF 0 0 0 0 0 0 0 0 0 Final OCDI:

Figure C-1. Occupant Compartment Deformation Index, Test No. USPBN-3

# VEHICLE PRE/POST CRUSH INFO Set-1

TEST: USPBN-4 VEHICLE: C2500/2000P

# Note: If impact is on driver side need to enter negative number for Y

POINT	Х	Y	Z	X'	Y	Z'	DEL X	DEL Y	DEL Z
1	31.25	-26.25	-3.5	31.25	-26.25	-3.5	0	0	0
2	31.25	-19.5	-4.25	31.25	-19.25	-4	0	0.25	0.25
3	30.5	-14.5	-4.5	30.5	-14.25	-4.25	0	0.25	0.25
4	25.75	-5.25	-0.75	25.75	-5	-0.5	0	0.25	0.25
5	28	-27	-6.25	28	-27.25	-6.25	0	-0.25	0
6	28	-21	-6.5	28	-21	-6.25	0	0	0.25
7	27.5	-14	-6.5	27.5	-13.75	-6.25	0	0.25	0.25
8	22.75	-4.75	-1.75	22.75	-4.75	-1.5	0	0	0.25
9	21.75	-29	-8.75	22	-29	-8.5	0.25	0	0.25
10	22.25	-21.75	-8.5	22.5	-22	-8.5	0.25	-0.25	0
11	22.25	-13	-8	22.25	-13	-7.75	0	0	0.25
12	18.5	-2.25	-2.25	18.5	-2.5	-1.75	0	-0.25	0.5
13	16.5	-27.75	-9.25	16.5	-27.75	-9	0	0	0.25
14	16.5	-21	-9	16.75	-21	-8.75	0.25	0	0.25
15	17	-13.25	-8.75	17	-13	-8.5	0	0.25	0.25
16	14.25	-4	-2.75	14	-4	-2.5	-0.25	0	0.25
17	11.25	-28.25	-9.75	11.5	-28.5	-9.5	0.25	-0.25	0.25
18	12.5	-19.75	-9.25	12.5	-19.5	-9	0	0.25	0.25
19	13	-12.75	-9	12.75	-12.5	-8.75	-0.25	0.25	0.25
20	11.5	-3.75	-3.25	11.5	-3.75	-3	0	0	0.25
21	25.25	7.25	-1	25.75	7.25	-0.75	0.5	0	0.25
22	30.75	19	-3.75	30.75	18.5	-3.25	0	-0.5	0.5
23	30.5	27.75	-4	30.5	27.25	-3.5	0	-0.5	0.5
24	18.75	6.25	-2.5	18.5	6.25	-2	-0.25	0	0.5
25	21.75	17.5	-8.25	21.75	17.5	-7.75	0	0	0.5
26	21.5	26	-8.25	21.5	25.75	-8	0	-0.25	0.25
27	12.5	10	-7.75	12.75	10	-7.5	0.25	0	0.25
28	12.5	20.5	-8.25	12.5	20.25	-8	0	-0.25	0.25
29							0	0	0
30									



Figure C-2. Floor Pan Deformation Data – Set 1, Test No. USPBN-4

# VEHICLE PRE/POST CRUSH INFO Set-2

TEST: USPBN-4 VEHICLE: C2500/2000P Note: If impact is on driver side need to enter negative number for Y

POINT	Х	Y	Z	X'	Y'	Z'	DEL X	DEL Y	DELZ
1	57	-17.75	-3.25	57.25	-18	-3.25	0.25	-0.25	0
2	57.75	-11	-4	57.75	-10.5	-4	0	0.5	0
3	57	-6.5	-4	57	-6	-4	0	0.5	0
4	52.25	3.5	-0.25	52.25	3.5	0	0	0	0.25
5	54.5	-18.75	-6.25	54	-18.75	-6.25	-0.5	0	0
6	54.5	-12.75	-6.25	54.75	-12.5	-6.25	0.25	0.25	0
7	54	-5.5	-6	54	-5.25	-6	0	0.25	0
8	49.25	3.75	-1.25	49.25	4	-1	0	0.25	0.25
9	48.75	-20.75	-8.75	48.25	-21	-8.75	-0.5	-0.25	0
10	49	-13.5	-8.5	49.25	-13.5	-8.25	0.25	0	0.25
11	49	-4.75	-7.5	49	-4.5	-7.5	0	0.25	0
12	45	6.25	-1.5	45	6.5	-1.5	0	0.25	0
13	43.25	-19.25	-9.25	43	-19.5	-9.25	-0.25	-0.25	0
14	43.5	-12.5	-8.5	43.5	-12.5	-8.5	0	0	0
15	43.75	-5	-8.5	44	-4.75	-8.25	0.25	0.25	0.25
16	40.75	4.5	-2.25	40.75	4.75	-2.25	0	0.25	0
17	38.25	-20	-9.5	38	-20	-9.5	-0.25	0	0
18	39.25	-11.25	-8.75	39.25	-11	-8.75	0	0.25	0
19	39.75	-4.25	-8.5	39.75	-4.25	-8.5	0	0	0
20	38	4.75	-2.5	38	5	-2.5	0	0.25	0
21	51.75	15.5	-0.25	51.75	15.5	0	0	0	0.25
22	57	27.25	-2.25	57	27.25	-2.25	0	0	0
23	56.25	36	-2.25	56.75	36.25	-2.25	0.5	0.25	0
24	45	14.5	-1.5	45	14.5	-1.25	0	0	0.25
25	48.5	25.5	-7	48.5	26	-6.75	0	0.5	0.25
26	48	34	-6.75	48.25	34.5	-6.75	0.25	0.5	0
27	39.5	18.25	-6.75	39.5	18.5	-6.75	0	0.25	0
28	39.25	28.5	-7	39.25	29	-7	0	0.5	0
29							0	0	0
30									



Figure C-3. Floor Pan Deformation Data – Set 2, Test No. USPBN-4

### Occupant Compartment Deformation Index (OCDI)

USPBN-4 Test No. Vehicle Type: C2500/2000P

OCDI = XXABCDEFGHI

XX = location of occupant compartment deformation

A = distance between the dashboard and a reference point at the rear of the occupant compartment, such as the top of the rear seat or the rear of the cab on a pickup

B = distance between the roof and the floor panel

C = distance between a reference point at the rear of the occupant compartment and the motor panel

D = distance between the lower dashboard and the floor panel

E = interior width

F = distance between the lower edge of right window and the upper edge of left window

G = distance between the lower edge of left window and the upper edge of right window

H= distance between bottom front corner and top rear corner of the passenger side window

I= distance between bottom front corner and top rear corner of the driver side window

#### Severity Indices

0 - if the reduction is less than 3%

1 - if the reduction is greater than 3% and less than or equal to 10 % 2 - if the reduction is greater than 10% and less than or equal to 20 %

3 - if the reduction is greater than 20% and less than or equal to 30 %

4 - if the reduction is greater than 30% and less than or equal to 40 %



where,

1 = Passenger Side

2 = Middle

3 = Driver Side

## Location:

Measurement	Pre-Test (in.)	Post-Test (in.)	Change (in.)	% Difference	Severity Index
A1	36.75	36.75	0.00	0.00	0
A2	39.25	39.00	-0.25	-0.64	0
A3	38.75	38.75	0.00	0.00	0
B1	44.00	44.00	0.00	0.00	0
B2	39.75	39.75	0.00	0.00	0
B3	44.25	44.25	0.00	0.00	0
C1	58.75	58.75	0.00	0.00	0
C2	51.50	51.50	0.00	0.00	0
C3	57.00	57.00	0.00	0.00	0
D1	21.50	21.50	0.00	0.00	0
D2	16.50	16.50	0.00	0.00	0
D3	22.75	22.50	-0.25	-1.10	0
E1	62.50	62.25	-0.25	-0.40	0
E3	63.50	63.50	0.00	0.00	0
F	56.00	56.00	0.00	0.00	0
G	56.00	55.75	-0.25	-0.45	0
н	40.75	40.75	0.00	0.00	0
1	40.75	40.75	0.00	0.00	0

Note: Maximum sevrity index for each variable (A-I) is used for determination of final OCDI value

XX A B C D E F G H I LF 0 0 0 0 0 0 0 0 0 0 Final OCDI:



Appendix D. Accelerometer and Rate Transducer Data Plots, Test No. USPBN-3

















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Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. USPBN-4





Figure E-2. Longitudinal Occupant Impact Velocity (DTS), Test No. USPBN-4


















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