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GUIDELINES FOR OVERLAPPING PRECAST PORTABLE CONCRETE BARRIERS

Sponsored by

The Roadside Safety Pooled Fund

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16. Abstract

Overlapping free-standing portable concrete barriers (PCBs) are commonly used in work zones. Despite widespread implementation, overlapping configurations have not been evaluated through full-scale crash testing under the Manual for Assessing Safety Hardware (MASH) (1). As a result, transportation agencies rely largely on engineering judgment when deploying overlapping PCBs.

This study evaluated the safety performance of overlapping free-standing F-shape PCBs under MASH Test Level 3 (TL-3) conditions through a combination of survey research, finite element (FE) simulations, and full-scale crash testing. A survey of Roadside Safety Pooled Fund members identified common barrier profiles, connections, and overlap configurations. FE models were developed and validated against prior MASH TL-3 crash tests involving free-standing F-shape barriers (2). The validated models were then used for parametric simulations to evaluate the effects of overlap length, gap size, and impact location, leading to identification of the recommended configuration.

The configuration with 1.5-barrier-segment-length overlap and no gap between parallel barrier runs was selected for full-scale crash testing. MASH tests 3-10 and 3-11 were conducted and met the evaluation criteria. The results establish a practical, crash-tested configuration for overlapping free-standing F-shape PCBs and support safer work zone barrier installations.

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Guidelines for Overlapping Precast Portable Concrete Barriers

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DISCLAIMER

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

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REVISION LOG

Revision Number	Change(s) Made	Date	Approved by

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

CHAPTER 1.
INTRODUCTION

Portable concrete barriers (PCBs) are widely used in temporary traffic control applications to provide positive protection for motorists and roadway workers in work zones. In practice, work zone geometry, staging requirements, and site constraints often necessitate deviations from standard barrier layouts. One common deviation is the use of overlapping free-standing PCBs, in which adjacent barrier runs are offset to provide continuity of protection where standard alignments are not feasible. Overlapping barrier configurations are frequently used to accommodate changes in roadway width, transitions between protected and unprotected areas, construction access openings, and other constrained conditions encountered during work zone operations.

Despite their widespread use, overlapping free-standing PCBs have not been evaluated through full-scale crash testing under the Manual for Assessing Safety Hardware (MASH). As a result, there is limited information available regarding how overlap length, gap between barrier runs, and impact location affect vehicle kinematics, occupant risk, and barrier system performance. While some transportation agencies have developed internal standards or drawings that include overlapping barrier configurations, these recommendations vary considerably and are not supported by crash-testing data.

The absence of research-based guidance for overlapping PCBs creates uncertainty for designers, contractors, and agencies responsible for implementing work zone traffic control plans. To address this gap, the research documented in this report evaluated the safety performance of overlapping free-standing F-shape portable concrete barriers under MASH Test Level 3 conditions. The study combined a survey of current practices, finite element (FE) computer simulations, and full-scale crash testing to identify critical impact conditions, assess system performance, and develop practical recommendations. This report provides recommendations for safer implementation of overlapping PCBs in work zones and identifies areas where additional research may further expand applicable guidance.

CHAPTER 2.

LITERATURE REVIEW AND SURVEY*

The research team conducted a comprehensive search of prior research related to the overlapping of PCBs. No published studies were identified that evaluated overlapping PCBs using computer simulations, full-scale crash testing, or other forms of detailed engineering analysis. Although some research exists on portable concrete barrier performance and barrier terminations, the specific configuration involving overlapping barrier runs has not been directly addressed in the technical literature.

During the literature search, overlapping barriers were identified as a recommended positive protection practice in work zones, particularly in constrained or transitional areas where continuous barrier alignment is not feasible (3). In addition, the literature review identified four standards and guidance documents issued by public transportation agencies that include recommendations for overlapping barrier configurations.

Florida Department of Transportation (FDOT) provides standard drawings illustrating several overlapping configurations using free-standing concrete barriers. A notable recommendation in the FDOT standards is the inclusion of a 2-ft clear space between overlapping barrier runs. Examples of these configurations are shown in Figure 2.1.

The Wisconsin Department of Transportation (WisDOT) also provides standard drawings for overlapping free-standing concrete barriers. WisDOT recommends a minimum overlap of eight barrier segments, corresponding to approximately 100 ft in length, as illustrated in Figure 2.2.

Similarly, the Minnesota Department of Transportation (MnDOT) provides guidance for overlaps involving PCBs and other temporary barrier systems (4). MnDOT recommends a minimum overlap length of 100 ft, with a space between overlapping barrier runs ranging from 6 to 12 inches.

In addition to U.S. practices, Ontario provincial standard drawings include a table specifying minimum overlap lengths and recommended spacing between overlapping barriers, as shown in Figure 2.3. The minimum overlap length is specified as 20 m (65.6 ft) for posted speed limits less than 70 km/h and 32 m (105.0 ft) for posted speed limits of 70

* The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.

km/h or greater, with a recommended gap between overlapping barrier runs ranging from 0.15 m to 0.30 m (6 to 12 in.). For a typical temporary concrete barrier unit measuring approximately 4 m in length, these values correspond to a minimum overlap of five barrier units for speeds below 70 km/h and eight barrier units for speeds of 70 km/h or higher.

Note that none of the standards and recommendations provided by these four states are based on published studies.

The complete standard drawings referenced in this section are provided in Appendix A.

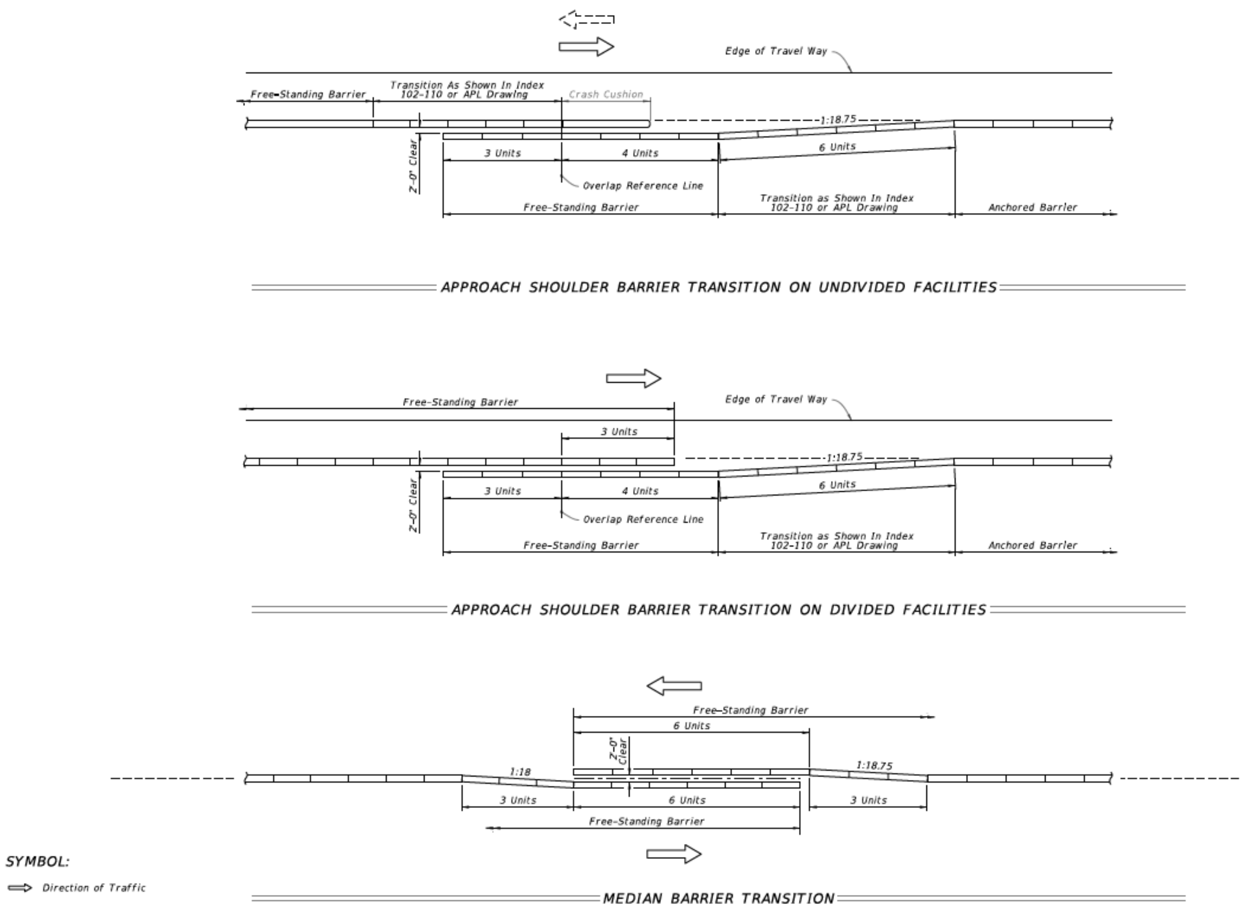


Figure 2.1. FDOT Overlapping PCBs Standards

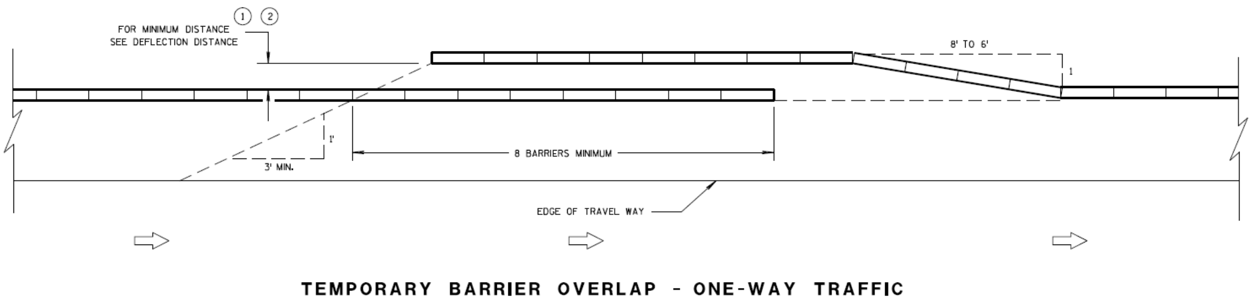


Figure 2.2. WisDOT Overlapping PCBs Standards

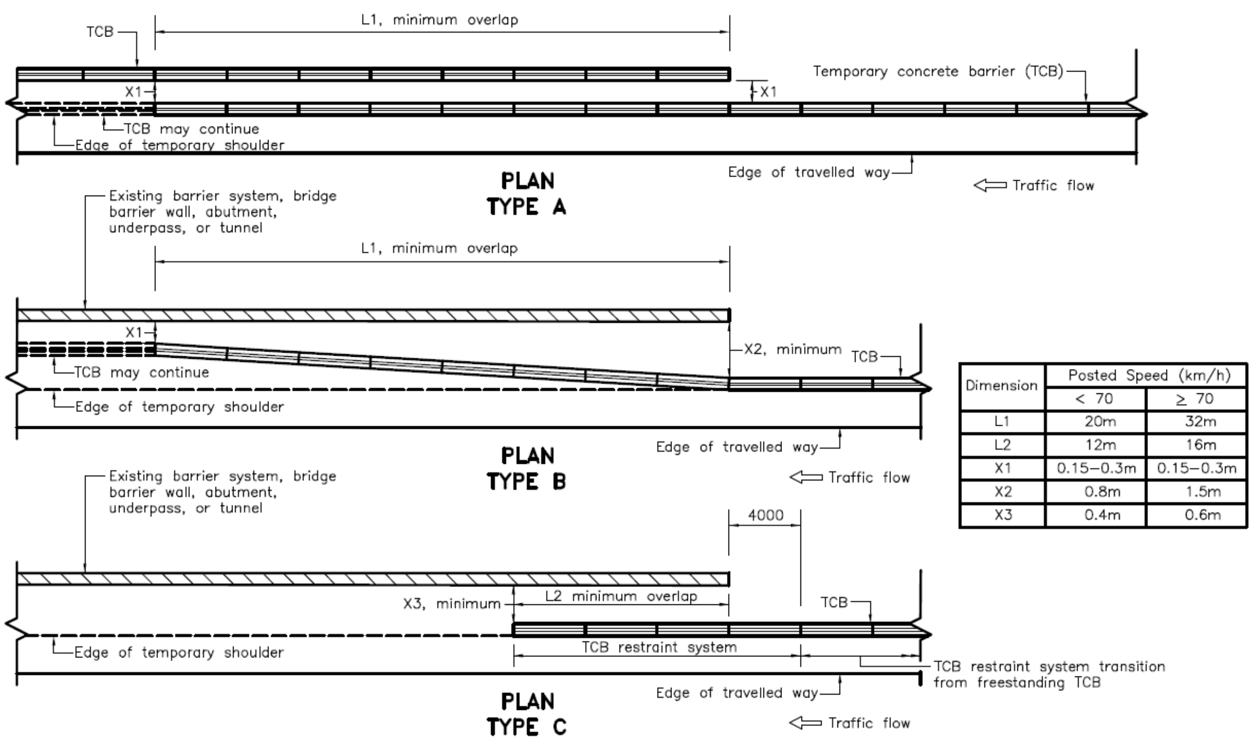


Figure 2.3. Ontario Overlapping PCBs Standards

A survey was conducted with members of the Roadside Safety Pooled Fund to document current state practices related to overlapping PCBs. Technical representatives from participating agencies were asked to provide information regarding the use of overlapping barrier configurations, including whether formal standards exist, the types of barriers and connections typically used, and initial configuration of overlapping barriers runs.

A summary of the key survey questions and responses is presented in Table 2.1. The full survey questionnaire used to collect information is provided in Appendix B.

Survey responses indicated that most responding agencies did not have formal standards specifically addressing overlapping PCB installations. This result highlights the fact that overlapping barrier installations are often implemented based on project-specific considerations or engineering judgment.

Respondents were asked to identify the type of portable concrete barrier most commonly used when overlapping configurations are installed. The majority of agencies reported use of F-shape portable concrete barriers, with 12 responses identifying this barrier profile. Agencies were also asked how overlapping barrier runs are typically configured in the field. Responses showed variability in practice. Five agencies indicated that barrier runs remain parallel when overlapping is used, while seven agencies reported that barrier runs are initially aligned and then laterally offset to create the overlap.

Table 2.1. Summary of Survey Results

State / Province	Does your state have standards for overlapping PCBs?	Which type of PCB does your DOT use when overlapping?	When overlapping is used, are the barrier runs initially in the same line and then offset to make the overlap, or do they initiate and remain in parallel?	What connection type does your DOT typically use for PCBs when overlapping is used?
Alabama	No	F-Shape	N/A	Pin & loop or Proprietary
Alaska	No	F-Shape	Initiate and remain in parallel	Pin & loop
Colorado	No	F-Shape	Nothing specific	N/A
Florida	Yes	F-Shape	Initiate in same line and offset to overlap	Pin & loop and JJ-Hook
Idaho	No	F-Shape, New Jersey	Initiate in same line and offset to overlap	Pin & loop
Michigan	No	Other	Initiate in same line and offset to overlap, Initiate and remain in parallel	Various
Minnesota	Yes	F-Shape	Initiate and remain in parallel	Pin & loop
Ontario	Yes	F-Shape	Initiate and remain in parallel	Standard is not specific
Pennsylvania	No	Other	No overlapping standard	N/A
TDOT	No	F-Shape, New Jersey	Initiate in same line and offset to overlap	Pin & loop
Texas	No	F-Shape, Single Slope Barrier	Mostly Parallel (unsure)	J-J Hook is probably used most often
Utah	No	F-Shape	Initiate in same line and offset to overlap	Pin & loop
Wisconsin	Yes	F-Shape	Initiate in same line and offset to overlap	Pin & loop
Washington	No	F-Shape, New Jersey	Initiate in same line and offset to overlap	Pin & loop
Total	4 Yes / 10 No	12 F-Shape	5 remain in parallel / 7 offset to overlap	9 Pin & loop Connection

With respect to barrier connections, respondents reported that pin-and-loop connections are most commonly used for overlapping PCB installations. Nine agencies identified pin-and-loop connections as their standard connection type when overlapping barriers are installed.

Overall, the survey results demonstrate that overlapping PCB installations are commonly used across multiple agencies despite the limited availability of formal standards or no MASH crash-tested guidance.

Based on the survey results, the F-shape barrier profile, the pin-and-loop connection type, and the configuration in which barrier runs are laterally offset to create the overlap were selected for further evaluation.

CHAPTER 3.
COMPUTER SIMULATIONS*

Computer simulations using FEA were conducted to evaluate the performance of overlapping portable concrete barrier configurations and to inform the selection of configurations for full-scale crash testing. The simulations were performed using LS-DYNA, a commercially available explicit finite element analysis code widely used for impact and crashworthiness applications. All computational analyses were executed using the High Performance Research Computing (HPRC) resources at Texas A&M University, which enabled the efficient execution of large-scale simulations.

3.1. VALIDATION OF FE MODEL

The finite element model of the barrier used in this study and its interaction with the vehicles were validated using results from previous MASH Test Level 3 full-scale crash tests conducted by TTI involving free-standing PCBs (2). Specifically, the validation effort used the crash test results documented in Test Report No. 607911-1&2, which evaluated a free-standing F-shape portable concrete barrier under MASH Tests 3-10 and 3-11.

The barrier consisted of a 32-in. tall free-standing F-shape barrier with pin-and-loop connections, which is the same barrier profile and connection type selected for evaluation in the overlapping barriers configurations examined in this study. The barrier's FE model is shown in Figure 3.1. For the purposes of this study, the researchers modeled the barrier segments with a rigid material, while the barrier connections were modeled using deformable elastic-plastic materials.

* The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.

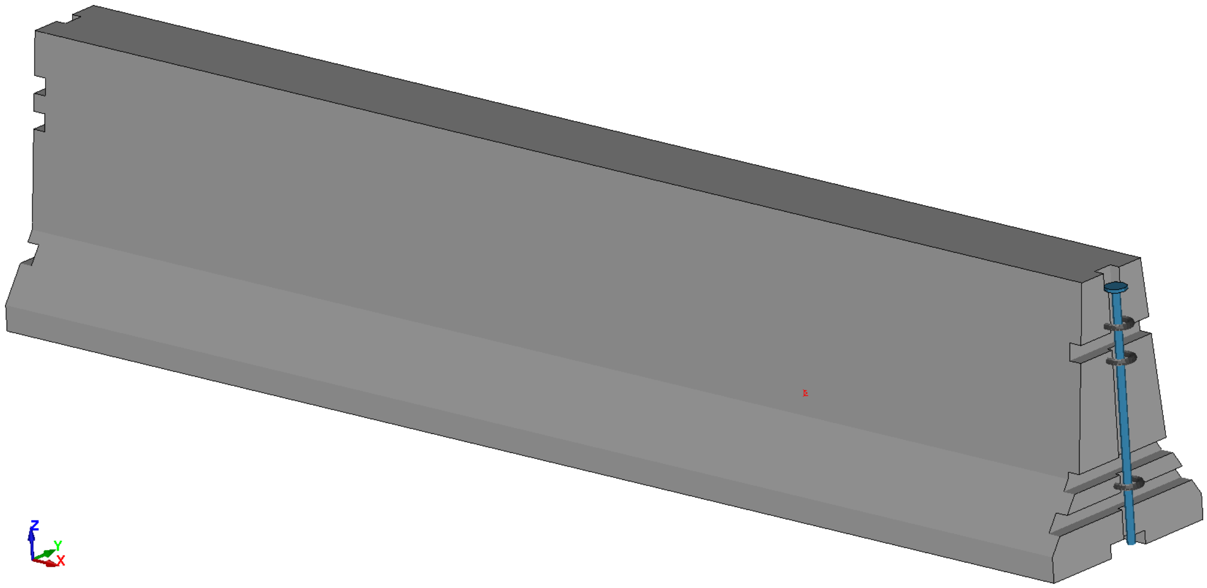


Figure 3.1. FE Model of F-Shape PCB

Researchers performed computer simulations replicating MASH Test 3-10, involving the 1100C small passenger car, and MASH Test 3-11, involving the 2270P pickup truck. Sequential frames from the crash test (Figures Figure 3.2 - Figure 3.5) and the corresponding MASH Test -10 simulation (Figures Figure 3.6 - Figure 3.9) are presented for comparison. A comparison of key simulation results and measured full-scale test data for MASH Test 3-10 and 3-11are presented in Table 3.1 and Table 3.2, respectively.

Figure 3.2. Frame 1 of MASH Crash Test 3-10 (2)

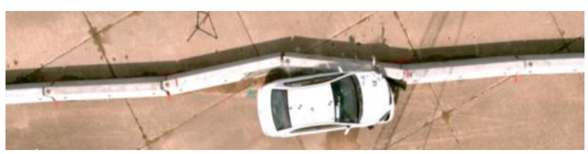


Figure 3.3. Frame 2 of MASH Crash Test 3-10 (2)

Figure 3.4. Frame 3 of MASH Crash Test 3-10 (2)

Figure 3.5. Frame 4 of MASH Crash Test 3-10 (2)

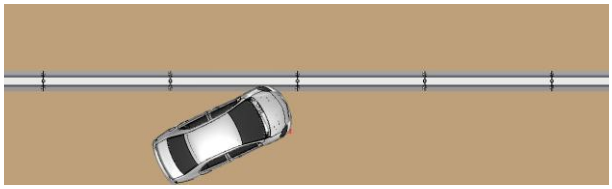


Figure 3.6. Frame 1 of Simulation for MASH Test 3-10

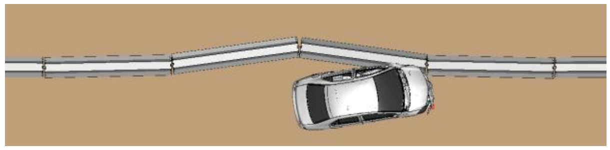


Figure 3.7. Frame 2 of Simulation for MASH Test 3-10

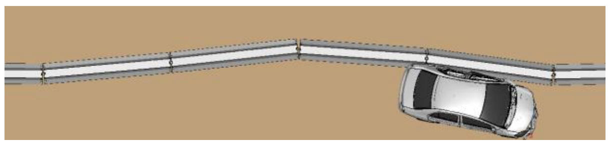


Figure 3.8. Frame 3 of Simulation for MASH Test 3-10

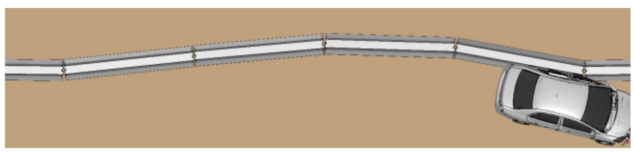


Figure 3.9. Frame 4 of Simulation for MASH Test 3-10

Table 3.1. Comparison of Key Metrics between MASH Test 3-10 Simulation and Crash Test

Parameter	Simulation	Crash Test
Dynamic Deflection	32 in	34 in
Lateral RDA (g)	4.6	4.7
Longitudinal RDA (g)	4.5	9.2
Lateral OIV (ft/s)	22.8	18.4
Longitudinal OIV (ft/s)	28.3	22.6

Table 3.2. Comparison of Key Metrics between MASH Test 3-11 Simulation and Crash Test

Parameter	Simulation	Crash Test
Dynamic Deflection	65 in	63 in
Lateral RDA (g)	12	14.4
Longitudinal RDA (g)	8.8	3.7
Lateral OIV (ft/s)	14.5	18.4
Longitudinal OIV (ft/s)	25.8	12.1

Overall, validation of the system was achieved in a satisfactory manner through comparison of vehicle interaction behavior, with some discrepancies observed, including underprediction of longitudinal RDA for MASH Test 3-10 and longitudinal OIV for MASH Test 3-11.

3.2. SIMULATIONS WITH OVERLAPPING BARRIERS

Using the validated FE models described in Section 3.1, the researchers conducted a comprehensive series of simulations to evaluate the performance of overlapping F-shape PCBs configurations. The objective of this effort was to identify configurations that provide acceptable structural performance and occupant safety under MASH TL-3 impact conditions.

The simulation matrix developed for this study included variations in three primary parameters: gap (clearance) between overlapping barrier runs, impact location, and overlap length. Specifically, three different gap sizes were considered, seven impact points were initially evaluated, and overlap lengths ranging from 1.5 barrier segments to 6 barrier segments were investigated. In total, 82 simulations were conducted as part of this study.

The impact locations evaluated are illustrated in Figure 3.10. Early in the simulation effort, it was determined that impact points A, B, and F were not critical for the overlapping configurations examined and were therefore excluded from further analysis. Impact Point C was located 4.3 ft upstream of the connection for MASH Test 3-11 and 3.6 ft upstream for MASH Test 3-10. Impact Point D was located at the same offsets upstream of the closest connection to the center of the overlap. Although Impact Point D was initially considered potentially critical with respect to occupant safety metrics, subsequent simulations indicated that it did not govern system performance. Impact Point E was defined as 4.3 ft (Test 3-11) and 3.6 ft (Test 3-10) upstream of the end of the overlapping barrier, while Impact Point E + 2 ft was positioned 2 ft downstream of Point E. Parametric simulation results demonstrated that Impact Point E + 2 ft was the most critical location for occupant safety metrics for MASH Test 3-10 impacts involving the small car.

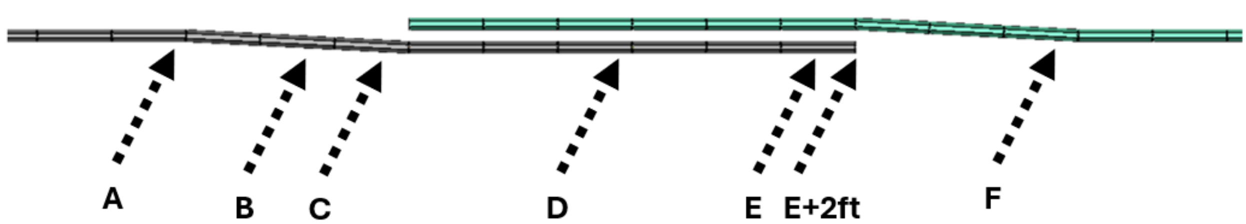


Figure 3.10. Critical Impact Points

For simulations conducted under MASH Test 3-10 conditions with the 1100C small car, the critical response parameters of interest were the occupant risk metrics, particularly ridedown acceleration. The results showed that as the gap between overlapping barrier runs increased from 0 ft to 1 ft and 2 ft, the maximum longitudinal ridedown acceleration increased, exceeding the MASH allowable limit of 20.49 g in all simulations with impact point at E + 2ft. Table 3.3 presents the maximum ridedown acceleration obtained from selected simulations at the most critical impact location. In Table 3.3, simulation results exceeding the MASH allowable limit are shown in *italics*.

Table 3.3. Maximum RDA (g) at Impact Point E+2ft for MASH Test 3-10 Simulations

Gap	Overlap Length of 1.5 Segments	Overlap Length of 2.5 Segments	Overlap Length of 4 Segments	Overlap Length of 6 Segments
2 ft	*25.3*	*27.0*		*25.0*
1 ft	*22.9*	*21.7*	*21.1*	*22.2*
0 ft	14.9	15.5	18.8	19.0

As shown in Table 3.3, maintaining zero gap between overlapping barrier runs is necessary to remain below the MASH allowable ridedown acceleration limit. In addition, the simulation results indicated a general trend in which shorter overlap lengths resulted in lower ridedown accelerations. From a constructability, cost, and operational standpoint, an overlap length of 1.5 barrier segments represents an efficient and desirable configuration for work zone applications. It should be noted that the validation effort demonstrated that the simulations tend to underpredict ridedown acceleration; therefore, based on the observed trends, the range of overlapping configurations that satisfy MASH test 3-10 occupant risk criteria is limited.

For simulations conducted under MASH Test 3-11 conditions with the 2270P pickup truck, the primary performance measures of interest were maximum barrier deflection, working width, and overall vehicle stability. Particular attention was given to assessing any potential vehicle instability as the pickup truck interacted with the overlapping barrier system. The simulation results indicated no stability concerns or occupant risk issues for the pickup truck across the configurations evaluated.

Table 3.4, Table 3.5 and Table 3.6 present the maximum rear-barrier deflection in inches obtained for various overlapping configurations at Impact Point C, E and E+2ft, respectively. Based on the constraints imposed by the small car simulations, which limited acceptable configurations to those with 1.5 barrier segment overlap and zero gap, the pickup truck simulations show that the maximum deflection for this configuration occurs at Impact Point C, with a value of 77 in (Table 3.4).

Table 3.4. Dynamic Deflection (inches) for MASH Test 3-11 Simulations at Impact Point C

Gap	Overlap Length of 1.5 Segments	Overlap Length of 2.5 Segments	Overlap Length of 4 Segments	Overlap Length of 6 Segments
2 ft	47.4		57.3	44.5
1 ft				50.0
0 ft	*77.0*	76.8		63.3

Table 3.5. Dynamic Deflection (inches) for MASH Test 3-11 Simulations at Impact Point E

Gap	Overlap Length of 1.5 Segments	Overlap Length of 2.5 Segments	Overlap Length of 4 Segments	Overlap Length of 6 Segments
2 ft	54.0	56.5	62.6	
1 ft		51.9		
0 ft	46.0	45.0	45.3	39.1

Table 3.6. Dynamic Deflection (inches) for MASH Test 3-11 Simulations at Impact Point E+2ft

Gap	Overlap Length of 1.5 Segments	Overlap Length of 2.5 Segments	Overlap Length of 4 Segments	Overlap Length of 6 Segments
2 ft	54.0	56.5	62.6	
1 ft		51.9		
0 ft	46.0	45.0	45.3	39.1

3.3. RECCOMENDED CONDIFURATION FOR FULL-SCALE CRASH TESTING

Based on the finite element simulation results presented in Section 3.2, the configuration consisting of a 1.5-barrier-length overlap with no gap between parallel barrier runs was selected for full-scale crash testing under MASH TL-3 conditions. For the pickup truck test, Impact Point C was selected to evaluate maximum barrier deflection and working width, while for the small-car test, Impact Point E + 2 ft was selected to assess compliance with MASH occupant safety criteria.

CHAPTER 4.
SYSTEM DETAILS

4.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation was approximately 383 feet and 2 inches long, consisting of thirty-two reinforced concrete barriers. These barriers were F-shape, 32 inches tall and 12.5 feet long. The first sixteen barriers and the last sixteen barriers were connected to adjoining barriers with pin and loop connections. The barriers were free-standing (not secured to the pavement).

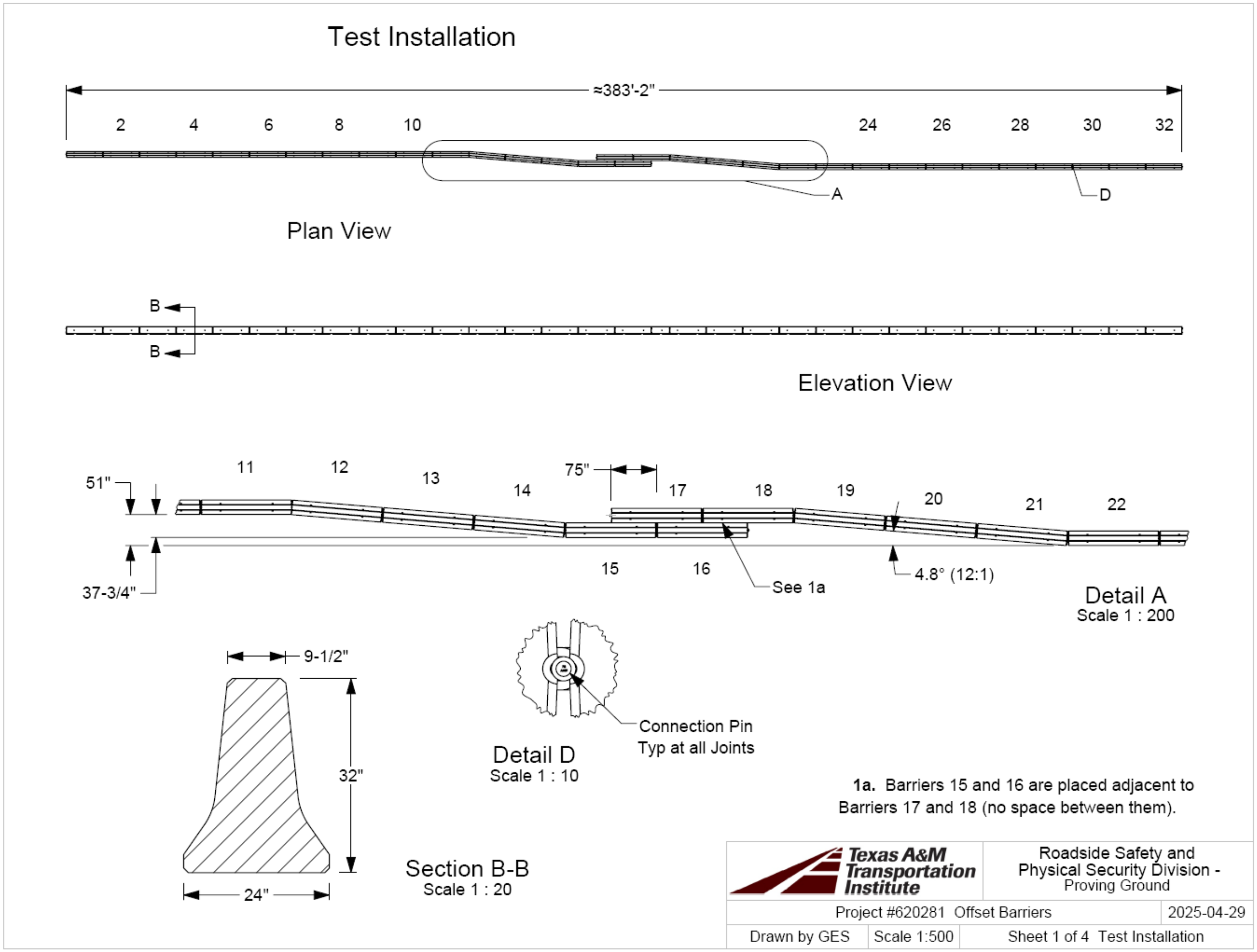
For the first run of barriers, barriers 1 through 11 were placed parallel to traffic, barrier 12 through 13 were placed at a 12:1 lateral offset toward traffic, and barrier 15 and 16 were parallel to traffic. The lateral offset between the first eleven and the last two segments of this run was 37-3/4 inches.

For the second run of barriers, barriers 17 and 18 were placed on the field side of barriers 15 and 16, with the upstream end of barrier 17 aligned with the midpoint of barrier 15. Barriers 19-21 were angled toward the traffic side parallel to barriers 12-14, and barriers 22-32 were parallel to traffic, offset 51 inches toward the traffic side from barriers 1-11.

Figure 4.1 presents the overall information on the Overlapping Precast Portable Concrete Barriers, and Figure 4.2 thru Figure 4.7 provide photographs of the installation. Appendix C provides further details on the Overlapping Precast Portable Concrete Barriers. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and assembly of the barrier configuration was performed by TTI Proving Ground personnel.

4.2. DESIGN MODIFICATIONS DURING TESTS

No modifications were made to the installation during the testing phase.



S:\Accreditation-17025-2017\EIR-000 Project Files\620281 - Overlapping PCB's - Cakalli\Drafting, 620281\620281 Drawing

Figure 4.1. Details of Overlapping Precast Portable Concrete Barriers.

Figure 4.2. Overlapping Precast Portable Concrete Barriers prior to Testing.

Figure 4.3. In-line View of the Overlapping Precast Portable Concrete Barriers prior to Testing.

Figure 4.4. Downstream View of the Overlapping Precast Portable Concrete Barriers prior to Testing.

Figure 4.5. Field-Side of the Overlapping Precast Portable Concrete Barriers prior to Testing.

Figure 4.6. In-line View of the Overlapping Precast Portable Concrete Barriers at the Overlap prior to Testing.

Figure 4.7. Connection Hardware for the Overlapping Precast Portable Concrete Barriers prior to Testing.

4.3. MATERIAL SPECIFICATIONS

Appendix D provides material certification documents for the materials used to install/construct the Overlapping Precast Portable Concrete Barriers. Table 4.1 shows the average compressive strengths of concrete core samples taken on the impacted barriers after testing was completed.

Table 4.1. Concrete Strength

Location	Design Strength (psi)	Avg. Strength (psi)
Two barriers from each test	5000	7668

CHAPTER 5.

TEST REQUIREMENTS AND EVALUATION CRITERIA

5.1. CRASH TEST PERFORMED/MATRIX

Table 5.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for Longitudinal Barrier.

Table 5.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barrier

Test Designation	Test Vehicle	Impact Speed (mi/h)	Impact Angle (°)	Evaluation Criteria
3-10	1100C	62	25	A, D, F, H, I
3-11	2270P	62	25	A, D, F, H, I

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 6 presents brief descriptions of these procedures.

5.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2 and 5-1 of *MASH* were used to evaluate the crash tests reported herein. **Error! Reference source not found.** lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 5.2 provides detailed information on the evaluation criteria.

Table 5.2. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barrier

Evaluation Factors	Evaluation Criteria
A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of *MASH*.
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.

CHAPTER 6.

TEST CONDITIONS

6.1. TEST FACILITY

The full-scale crash tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, as well as *MASH* guidelines and standards.

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 3100-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The sites selected for construction and testing are on an out-of-service apron/runway. The apron/runway consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

6.2. VEHICLE TOW AND GUIDANCE SYSTEM

For the testing utilizing the 1100C and 2270P vehicles, each was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point and through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

6.3. DATA ACQUISITION SYSTEMS

6.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The data acquisition hardware and software conform to the *MASH* recommended version of SAE J211, Instrumentation for Impact Test. Each of the channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a calibration traceable to the International System of Units (SI). Measurement Uncertainties have been determined for critical parameters involved in this testing, and are available upon request by the Sponsor.

TRAP uses the DAS-captured data to compute the occupant to vehicle contact impact velocities, time of occupant to vehicle contact after vehicle impact, and highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. The data from the vehicle-mounted accelerometers are collected and filtered with an SAE Class 180 low-pass digital filter. Various filters to enhance readability are used for plotting acceleration versus time curves for the longitudinal, lateral, and vertical directions using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation being initial impact. Measurement Uncertainties have been determined for critical parameters involved in this testing, and are available upon request by the Sponsor.

6.3.2. Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the front seat on the impact side of the 1100C vehicle. The dummy was not instrumented.

According to *MASH*, use of a dummy in the 2270P vehicle is optional, and no dummy was used in the test.

6.3.3. Photographic Instrumentation Data Processing

Photographic coverage of each test included 3 digital high-speed cameras:

- One placed overhead with a field of view perpendicular to the ground and directly over the impact point.
- One placed with a field of view parallel to and aligned with the installation at the downstream end.
- One placed at an oblique angle upstream from the installation on the field side.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Overlapping Precast Portable Concrete Barriers. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

CHAPTER 7.

MASH TEST 3-10 (CRASH TEST 620281-01-1)

7.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 19.2 inches [1.6 feet] upstream from the downstream edge of barrier 16 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 7.1**Error! Reference source not found.** shows the target CIP for test 620281-01-1. Figure 7.2 and Figure 7.3 depict the vehicle at the CIP prior to test 620281-01-1.

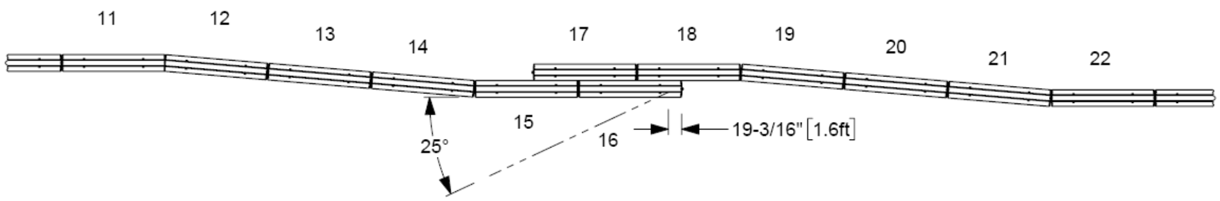


Figure 7.1. Target CIP for *MASH* Test 3-10 on Overlapping Precast Portable Concrete Barriers

Figure 7.2. Overlapping Precast Portable Concrete Barriers/Test Vehicle Geometrics for Test 620281-01-1.

Figure 7.3. Overlapping Precast Portable Concrete Barriers/Test Vehicle Impact Location 620281-01-1.

7.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 7.1 shows the vehicle measurements. Figure 7.4 and Figure 7.5 show the 2018 Nissan Versa used for the crash test. Figure E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.

Table 7.1. Vehicle Measurements for Test 620281-01-1

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	165
Inertial Mass (lb)	2420	±55	2453
Gross Static[a] Mass (lb)	2585	±55	2618
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.6
CG above Ground[c,d] (inches)	N/A	N/A	N/A

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

Figure 7.4. Impact Side of Test Vehicle before Test 620281-01-1.

Figure 7.5. Opposite Impact Side of Test Vehicle before Test 620281-01-1.

7.3. TEST DESCRIPTION

7.3.1. Weather Conditions

Table 7.2 provides the weather conditions for 620281-01-1. Values for wind direction and vehicle travel are in reference to the degrees on a compass, with North being 0 degrees.

Table 7.2. Weather Conditions 620281-01-1

Date of Test	2025-10-16
Wind Speed	2 mi/h
Wind Direction	134°
Temperature	77°F
Relative Humidity	68 %
Vehicle Traveling	325°

7.3.2. Test Events

Table 7.3 lists events that occurred during Test 620281-01-1. The figures in Appendix E.2 present sequential photographs during the test.

Table 7.3. Events during Test 620281-01-1

Time (seconds)	Events
0.0000	Vehicle impacted the installation
0.0250	Vehicle began to redirect
0.0750	Vehicle contacted barrier 18, approximately 12 inches upstream from the joint of barriers 18 and19
0.1100	Vehicle began to push barrier 19 toward the field-side
0.1470	Right front tire began to lift off the ground
0.1580	Right rear tire began to lift off the ground
0.2280	Vehicle was parallel with installation
0.3470	Concrete of upstream traffic-side of Barrier 19 began to spall
0.6140	Left front tire contacted the ground
0.8950	Left rear tire contacted the ground

7.4. TEST ACTUAL IMPACT CONDITIONS

Table 7.4 lists the details of the *MASH* impact conditions for this test and Table 7.5 lists the exit parameters.

Table 7.4. Impact Conditions for *MASH TEST 3-10,* Crash Test 620281-01-1

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	62.2
Impact Angle (°)	25	±1.5	24.7
Impact Severity (kip-ft)	51	≥51	55.4
Impact Location	19.2 inches [1.6 feet] upstream from the downstream edge of barrier 16	±1 foot (12 inches)	17.0 inches [1.4 feet] upstream from the downstream edge of barrier 16

Table 7.5. Exit Parameters for *MASH TEST 3-10,* Crash Test 620281-01-1

Exit Parameter	Measured
Speed	Out of frame - Not measurable
Trajectory	Out of frame - Not measurable
Heading	Out of frame - Not measurable
Brakes applied post impact	Brakes not applied
Vehicle at rest position	190 ft downstream of impact point 45 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle met the exit box criteria[a] by crossing the exit box on the downstream end

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 1100C used in this test was 15.1 ft toward the traffic side as measured from the traffic side toe of the barrier and 32.8 ft downstream from loss of contact.

7.5. DAMAGE TO TEST INSTALLATION

The downstream end of barrier 16 had abrasions and spalling, with a significant spall on the field side of barrier 16 at its base. Barrier 18 had some minor spalling on its upstream end. Barriers 18 and 19 at their joint had spalling at their base on the traffic side, and there was additional spalling on barrier 19 at its upper loop connection. Barriers 20 and 21 at their joint had spalling at their base on the traffic side. Table 7.6 describes the deflection and working width of the Overlapping Precast Portable Concrete Barriers. Figure 7.6 and Figure 7.7 show the damage to the Overlapping Precast Portable Concrete Barriers.

Table 7.6. Deflection and Working Width of the Overlapping Precast Portable Concrete Barriers for Test 620281-01-1

Test Parameter	Measured
Permanent Deflection/Location	29.0 inches toward field side, at the joint of barriers 18 and 19
Dynamic Deflection	29.4 inches toward field side at the top of the upstream field side corner of barrier 19
Working Width [a] and Height	53.5 inches, at a height of 0.0 inches at the field side toe of barrier 19 at the joint of barriers 18 and 19

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 7.6. Overlapping Precast Portable Concrete Barriers at Impact Location after Test 620281-01-1.

Figure 7.7. Upstream View of the Overlapping Precast Portable Concrete Barriers after Test 620281-01-1.

7.6. DAMAGE TO TEST VEHICLE

Figure 7.8 and Figure 7.9 show the damage sustained by the vehicle. Figure 7.10 and Figure 7.11 show the interior of the test vehicle. Table 7.7 and Table 7.8 provide details on the occupant compartment deformation and exterior vehicle damage. Figure E.2 and Figure E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

Figure 7.8.Impact Side of Test Vehicle after Test 620281-01-1.

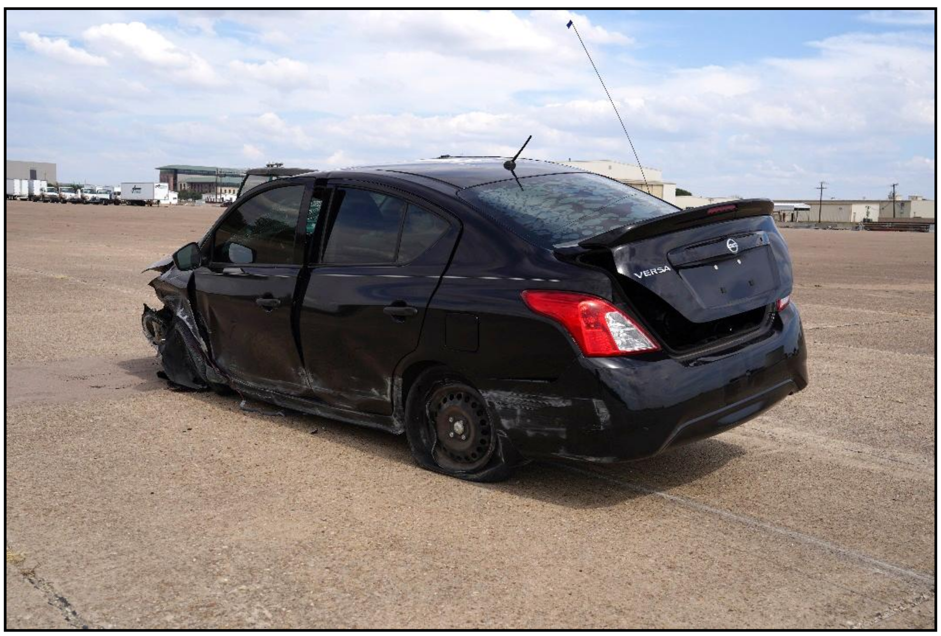


Figure 7.9. Rear Impact Side of Test Vehicle after Test 620281-01-1.

Figure 7.10. Overall Interior of Test Vehicle after Test 620281-01-1.

Figure 7.11. Interior of Test Vehicle on Impact Side after Test 620281-01-1.

Table 7.7. Occupant Compartment Deformation 620281-01-1

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	1.5
Floor Pan/Transmission Tunnel	≤12.0	0.5
Side Front Panel	≤12.0	1.5
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 7.8. Exterior Vehicle Damage 620281-01-1

Test Parameter	Details
Side Windows	The side windows remained intact
Maximum Exterior Deformation	19 inches in the front plane at the left front corner at bumper height
VDS	11LFQ4
CDC	11FLAW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, grill, and left headlight dislodged. The radiator and its support fractured. The left front fender, left front door, left rear door, and left rear quarter panel were deformed. The wheels on the left side deformed and their tires ruptured. The windshield was cracked on the left side, but there were no holes or tears in the laminate. The top of the left front door and left rear door separated from the body of the car creating openings of 3.5 inches and 0.5 inches respectively.

7.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.9. Figure E.7 through Figure E.9 in Appendix E.3 show acceleration versus time traces.

Table 7.9. Occupant Risk Factors for Test 620281-01-1

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *≤30.0*	13.5	0.1282 seconds on left side of interior
OIV, Lateral (ft/s)	≤40.0 *≤30.0*	17.6	0.1282 seconds on left side of interior
Ridedown, Longitudinal (g)	≤20.49 *≤15.0*	9.3	0.1282 - 0.1382 seconds
Ridedown, Lateral (g)	≤20.49 *≤15.0*	19.2	0.1307 - 0.1407 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	5.7	0.1248 seconds on left side of interior
Acceleration Severity Index	N/A	1.6	0.1315 - 0.1815 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-8.0	0.1135 - 0.1635 seconds
50-ms MA Lateral (g)	N/A	10.8	0.1148 - 0.1648 seconds
50-ms MA Vertical (g)	N/A	-4.5	0.1066 - 0.1566 seconds
Roll (°)	≤75	N/A	N/A
Pitch (°)	≤75	N/A	N/A
Yaw (°)	N/A	N/A	N/A

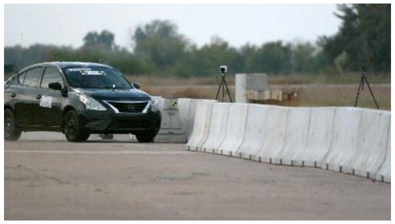
[a.] *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

Due to equipment failure, accurate roll, pitch, and yaw angles could not be calculated. Visual inspection of the high-speed video indicates that roll and pitch never met or exceeded the specified maximum of 75 degrees.

7.8. TEST SUMMARY

Figure 7.12 summarizes the results of *MASH* Test 620281-01-1.



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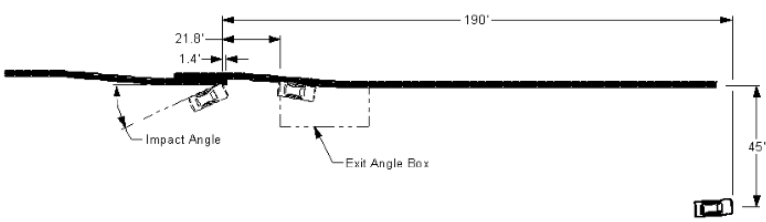
0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-10
Project No.:	620281-01-1
Test Date:	2025-10-16
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Overlapping Precast Portable Concrete Barriers
Length:	383 feet 2 inches
Key Materials:	32 f-shape portable concrete barriers
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2018 Nissan Versa
Inertial Mass:	2453 lb
Dummy Mass:	165 lb
Gross Static Mass:	2618 lb
IMPACT CONDITIONS	
Impact Speed:	62.2 mi/h
Impact Angle:	24.7°
Impact Location:	17.0 inches [1.4 feet] upstream from the downstream edge of barrier 16
Impact Severity:	55.4 kip-ft
EXIT CONDITIONS	
Exit Speed:	Out of frame - Not measurable
Trajectory/Heading Angle:	Out of frame - Not measurable
Exit Box Criteria:	The vehicle met the exit box criteria

Stopping Distance:	190 ft downstream 45 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	29.4 inches
Permanent:	29 inches
Working Width:	53.5 inches
Working Width Height:	0.0 inches
VEHICLE DAMAGE	
VDS:	11LFQ4
CDC:	11FLAW3
Max Exterior Deformation:	19 inches in the front plane at the left front corner at bumper height
Max Occupant Compartment Deformation:	1.5 inches in the foot well/toe pan
OCCUPANT RISK VALUES	
Longitudinal OIV:	13.5 ft/s
Lateral OIV:	17.6 ft/s
Longitudinal Ridedown:	9.3 g
Lateral Ridedown:	19.2 g
THIV:	5.7 m/s
ASI:	1.6
Max 50ms Longitudinal:	-8.0 g
Max 50ms Lateral:	10.8 g
Max 50ms Vertical:	-4.5 g
Max Roll:	Not measurable
Max Pitch:	Not measurable
Max Yaw:	Not measurable



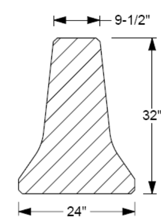


Figure 7.12. Summary of Results for *MASH* Test 3-10 on Overlapping Precast Portable Concrete Barriers.

CHAPTER 8.
MASH TEST 3-11 (CRASH TEST 620281-01-2)

8.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 51.6 inches [4.3 feet] upstream from the joint between barriers 14 and 15 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 8.1 shows the target CIP for test 620281-01-2. Figure 8.2 and Figure 8.3 depict the vehicle at the CIP prior to test 620281-01-2.

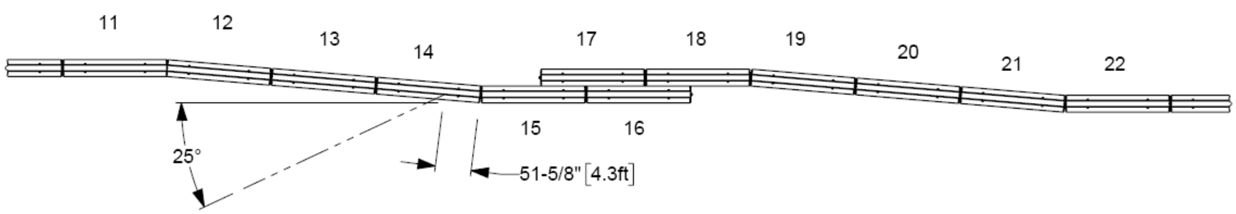


Figure 8.1. Target CIP for *MASH* Test 3-11 on Overlapping Precast Portable Concrete Barriers

Figure 8.2. Overlapping Precast Portable Concrete Barriers/Test Vehicle Geometrics for Test 620281-01-2.

Figure 8.3. Overlapping Precast Portable Concrete Barriers/Test Vehicle Impact Location 620281-01-2.

8.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 8.1 shows the vehicle measurements. Figure 8.4 and Figure 8.5 show the 2019 RAM 1500 used for the crash test. Figure F.1 in Appendix F.1 gives additional dimensions and information on the vehicle.

Table 8.1. Vehicle Measurements for Test 620281-01-2

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	N/A
Inertial Mass (lb)	5000	±110	5044
Gross Static[a] Mass (lb)	5000	±110	5044
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.0
Overall Length (inches)	237	±13	227.5
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	61.4
CG above Ground[c,d] (inches)	≥28	N/A	28.8

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

Figure 8.4. Impact Side of Test Vehicle before Test 620281-01-2.

Figure 8.5. Opposite Impact Side of Test Vehicle before Test 620281-01-2.

8.3. TEST DESCRIPTION

8.3.1. Weather Conditions

Table 8.2 provides the weather conditions for 620281-01-2. Values for wind direction and vehicle travel are in reference to the degrees on a compass, with North being 0 degrees.

Table 8.2. Weather Conditions 620281-01-2

Date of Test	2025-10-23
Wind Speed	3 mi/h
Wind Direction	169°
Temperature	79°F
Relative Humidity	74 %
Vehicle Traveling	325°

8.3.2. Test Events

Table 8.3 lists events that occurred during Test 620281-01-2. The figures in Appendix F.2 present sequential photographs during the test.

Table 8.3. Events during Test 620281-01-2

Time (seconds)	Events
0.0000	Vehicle impacted the installation
0.0240	Barrier 14 began to lean toward the field-side.
0.0290	Vehicle began to redirect
0.0360	Barrier 15 began to move toward the field-side
0.0730	Barrier 17 began to slide toward the field-side
0.0810	Front right tire began to lift off the ground
0.2290	Vehicle was parallel with installation
0.2380	Rear right tire began to lift off the ground

8.4. TEST ACTUAL IMPACT CONDITIONS

Table 8.4 lists the details of the *MASH* impact conditions for this test and Table 8.5 lists the exit parameters.

Table 8.4. Impact Conditions for *MASH TEST 3-11,* Crash Test 620281-01-2

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	62.1
Impact Angle (°)	25	±1.5	25.5
Impact Severity (kip-ft)	106	≥106	120.5
Impact Location	51.6 inches [4.3 feet] upstream from the joint between barriers 14 and 15	±1 foot (12 inches)	53.6 inches [4.5 feet] upstream from the joint between barriers 14 and 15

Table 8.5. Exit Parameters for *MASH TEST 3-11,* Crash Test 620281-01-2

Exit Parameter	Measured
Speed	Out of frame - Not measurable
Trajectory	Out of frame - Not measurable
Heading	Out of frame - Not measurable
Brakes applied post impact	Brakes not applied
Vehicle at rest position	120 ft downstream of impact point 41 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle met the exit box criteria[a] by crossing the exit box on the downstream end

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 2270P used in this test was 16.8 ft toward the traffic side as measured from the traffic side toe of the barrier and 32.8 ft downstream from loss of contact.

8.5. DAMAGE TO TEST INSTALLATION

The field side base of the barriers at the joint of barriers 12 and 13, and 13 and 14 were spalled. The traffic side base of the barriers at the joint of barriers 14 and 15 had large spalls, and barrier 15 had cracks which extended through the barrier at 42 and 72 inches from its upstream end. The traffic and field side base of the barriers at the joint of barriers 15 and 16 were spalled. Barrier 16 had additional spalling on the field side 18 inches from its downstream end. Barrier 17 had spalling with exposed rebar on its traffic side near its downstream end. Barrier 18 had spalling on the field side at both ends, and barrier 19 had spalling on its field side on its upstream end. Table 8.6 describes the deflection and working width of the Overlapping Precast Portable Concrete Barriers. Figure 8.6 and Figure 8.7 show the damage to the Overlapping Precast Portable Concrete Barriers.

Table 8.6. Deflection and Working Width of the Overlapping Precast Portable Concrete Barriers for Test 620281-01-2

Test Parameter	Measured
Permanent Deflection/Location	87.0 inches toward field side, at the joint of barriers 14 and 15
Dynamic Deflection (upstream half of the installation)	88.4 toward field side at the top of barrier 15 at the joint of barriers 14 and 15
Dynamic Deflection (downstream half of the installation)	94.7 inches toward field side at the upstream end of barrier 17
Working Width [a] and Height	159.8 inches, at a height of 0.0 inches at the toe of barrier 17 on the upstream end

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 8.6. Overlapping Precast Portable Concrete Barriers at Impact Location after Test 620281-01-2.

Figure 8.7. Field-Side of the Overlapping Precast Portable Concrete Barriers at Impact after Test 620281-01-2.

8.6. DAMAGE TO TEST VEHICLE

Figure 8.8 and Figure 8.9 show the damage sustained by the vehicle. Figure 8.10 and Figure 8.11 show the interior of the test vehicle. Table 8.7 and Table 8.8 provide details on the occupant compartment deformation and exterior vehicle damage. Figure F.2 and Figure F.3 in Appendix F.1 provide exterior crush and occupant compartment measurements.

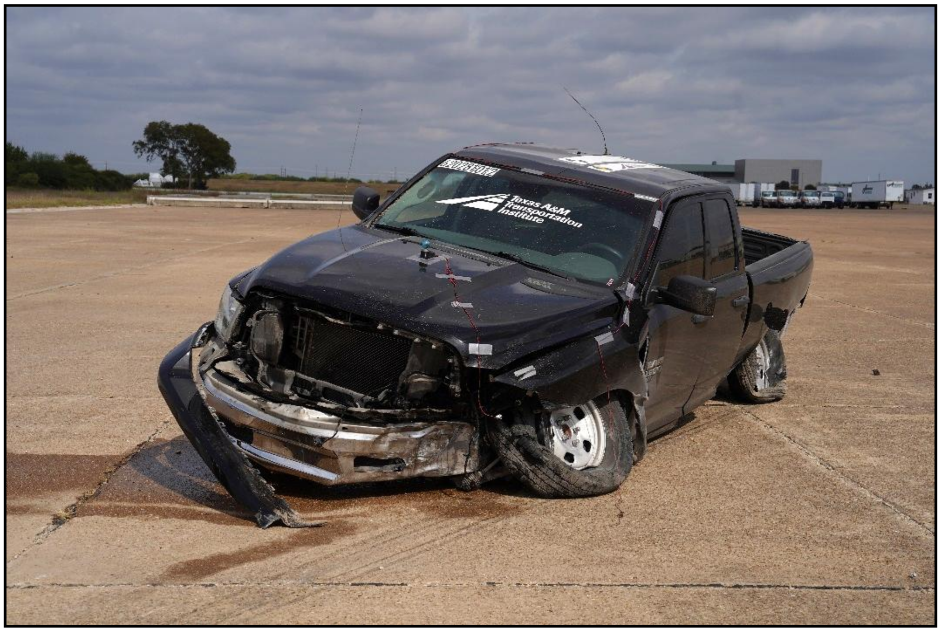


Figure 8.8. Impact Side of Test Vehicle after Test 620281-01-2.

Figure 8.9. Rear Impact Side of Test Vehicle after Test 620281-01-2.

Figure 8.10. Overall Interior of Test Vehicle after Test 620281-01-2.

Figure 8.11. Interior of Test Vehicle on Impact Side after Test 620281-01-2.

Table 8.7. Occupant Compartment Deformation 620281-01-2

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	3.0
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	0.5
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 8.8. Exterior Vehicle Damage 620281-01-2

Test Parameter	Details
Side Windows	The side windows remained intact
Maximum Exterior Deformation	25 inches in the front plane at the left front corner at bumper height
VDS	11LFQ4
CDC	11FLAW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, grill, hood, front left quarter panel, left side lower trim, left rear quarter panel, and rear bumper were deformed. The radiator and its support fractured. The wheels on the left side were deformed and their tires ruptured. The left front headlight released, and the left rear brake light fractured. The left front door deformed, causing a 1.3-inch gap at the top between it and the body of the vehicle, and the left rear door deformed, causing a 2.5-inch gap at its base between it and the body of the vehicle. The windshield had some cracking on the lower left side, due to the flexing of the vehicle during impact. There were no holes or tears in the laminate.

8.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 8.9. Figure F.7 through Figure F.9 in Appendix F.3 show acceleration versus time traces.

Table 8.9. Occupant Risk Factors for Test 620281-01-2

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *≤30.0*	19.3	0.1038 seconds on left side of interior
OIV, Lateral (ft/s)	≤40.0 *≤30.0*	19.3	0.1038 seconds on left side of interior
Ridedown, Longitudinal (g)	≤20.49 *≤15.0*	6.4	0.1673 - 0.1773 seconds
Ridedown, Lateral (g)	≤20.49 *≤15.0*	11.0	0.3456 - 0.3556 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	8.4	0.1000 seconds on left side of interior
Acceleration Severity Index	N/A	1.6	0.0511 - 0.1011 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-9.3	0.0399 - 0.0899 seconds
50-ms MA Lateral (g)	N/A	10.8	0.0231 - 0.0731 seconds
50-ms MA Vertical (g)	N/A	-3.9	0.9422 - 0.9922 seconds
Roll (°)	≤75	N/A	N/A
Pitch (°)	≤75	N/A	N/A
Yaw (°)	N/A	N/A	N/A

[a.] *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

Due to equipment failure, accurate roll, pitch, and yaw angles could not be calculated. Visual inspection of the high-speed video indicates that roll and pitch never reached the specified maximum of 75 degrees.

8.8. TEST SUMMARY

Figure 2.1 summarizes the results of *MASH* Test 620281-01-2.

0.000 s

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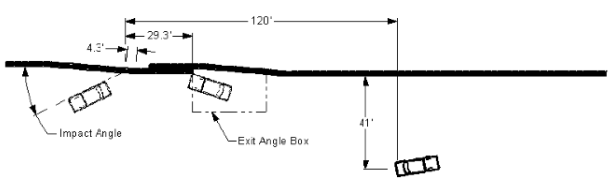
0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-11
Project No.:	620281-01-2
Test Date:	2025-10-23
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Overlapping Precast Portable Concrete Barriers
Length:	383 feet 2 inches
Key Materials:	32 f-shape portable concrete barriers
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2019 RAM 1500
Inertial Mass:	5044 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5044 lb
IMPACT CONDITIONS	
Impact Speed:	62.1 mi/h
Impact Angle:	25.5°
Impact Location:	53.6 inches upstream from the joint between barriers 14 and 15
Impact Severity:	120.5 kip-ft
EXIT CONDITIONS	
Exit Speed:	Out of frame - Not measurable
Trajectory/Heading Angle:	Out of frame - Not measurable
Exit Box Criteria:	The vehicle met the exit box criteria

Stopping Distance:	120 ft downstream 41 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	88.4 / 94.7 inches
Permanent:	87 inches
Working Width:	159.8 inches
Working Width Height:	0.0 inches
VEHICLE DAMAGE	
VDS:	11LFQ4
CDC:	11FLAW3
Max Exterior Deformation:	25 inches in the front plane at the left front corner at bumper height
Max Occupant Compartment Deformation:	3 inches in the foot well/toe pan
OCCUPANT RISK VALUES	
Longitudinal OIV:	19.3 ft/s
Lateral OIV:	19.3 ft/s
Longitudinal Ridedown:	6.4 g
Lateral Ridedown:	11.0 g
THIV:	8.4 m/s
ASI:	1.6
Max 50ms Longitudinal:	-9.3 g
Max 50ms Lateral:	10.8 g
Max 50ms Vertical:	-3.9 g
Max Roll:	Not measurable
Max Pitch:	Not measurable
Max Yaw:	Not measurable



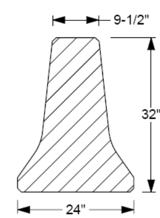


Figure 8.12. Summary of Results for *MASH* Test 3-11 on Overlapping Precast Portable Concrete Barriers.

CHAPTER 9.
RESULTS OF CRASH TESTING

The crash tests reported herein were performed in accordance with *MASH* TL-3, which involves two tests, on the Overlapping Precast Portable Concrete Barriers.

Table 9.1shows that the Overlapping Precast Portable Concrete Barriers met the performance criteria for *MASH* TL-3 Longitudinal Barrier.

Table 9.1. Assessment Summary for *MASH* TL-3 Tests on Overlapping Precast Portable Concrete Barriers.

Evaluation Criteria	**Description[1]**	**Test 620281-01-1** (*MASH* Test 3-10)	**Test 620281-01-2** (*MASH* Test 3-11)
A	Contain, Redirect, or Controlled Stop	S	S
D	No Penetration into Occupant Compartment	S	S
F	Roll and Pitch Limit	S	S
H	OIV Threshold	S	S
I	Ridedown Threshold	S	S
Overall Evaluation		Pass	Pass

Note: S = Satisfactory; N/A = Not Applicable.
[1] See **Error! Reference source not found.** for details

CHAPTER 10.

SUMMARY, IMPLEMENTATION, AND FUTURE RESEARCH*

10.1. SUMMARY

This study addressed the lack of crash-tested guidance for overlapping free-standing portable concrete barriers used in work zone applications. Although overlapping barrier installations are commonly employed in practice, prior to this study there was no validated analytical or experimental basis to assess their safety performance under MASH criteria.

The study began with a literature review and survey of current practice, which confirmed that overlapping PCBs are widely used by transportation agencies. The survey of Roadside Safety Pooled Fund members indicated that F-shape barrier profiles with pin-and-loop connections and laterally offset overlapping configurations are most used in the field.

To address these knowledge gaps, finite element computer simulations were performed using LS-DYNA and executed on the High Performance Research Computing center at Texas A&M University. The FE models of the barrier and the vehicles were first validated using prior MASH TL-3 full-scale crash test results involving free-standing F-shape barriers impacted by the MASH 1100C small car (Test 3-10) and the 2270P pickup truck (Test 3-11). Validation demonstrated satisfactory agreement between simulated and experimental results in terms of vehicle kinematics and barrier deflection, with some discrepancies observed, including underprediction of longitudinal ridedown acceleration for MASH Test 3-10 with the small car.

Following validation, the researchers conducted an extensive parametric simulation study to evaluate the influence of overlap length, gap distance between the overlapping barrier segments, and impact location on system performance. A total of 82 simulations were performed, considering overlap lengths from 1.5 to 6 barrier segments, gap distance ranging from 0 to 2 ft, and seven impact points along the overlapping region. Results identified critical impact locations for the small car and pickup truck.

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* The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.

Simulation results showed that for MASH Test 3-10 with the small car, increasing the gap between overlapping barrier runs significantly increased ridedown acceleration, resulting in exceedance of the MASH allowable limit. Maintaining zero gap between barrier runs is needed to meet MASH occupant risk criteria. The simulations also indicated that shorter overlap lengths resulted in lower ridedown accelerations, making shorter overlaps both safer and more practical for work zone deployment.

For MASH Test 3-11 with the pickup-truck, the parametric simulations showed no vehicle stability concerns for the pickup truck across evaluated configurations. The pickup truck simulations controlled maximum barrier deflection and working width.

Based on the simulation results, the configuration consisting of 1.5 barrier segments of overlap with no gap between the overlapping barrier runs was selected for full-scale crash testing. MASH Tests 3-10 and 3-11 were conducted at the identified critical impact locations. Both crash tests were successfully completed and met the MASH Test Level 3 evaluation criteria for longitudinal barriers.

10.2. IMPLEMENTATION

Based on the results of this study, the following configuration is recommended for overlapping free-standing F-shape portable concrete barriers:

- 0-ft gap between overlapping barrier runs, and
- 1.5 barrier segments of overlap length.

MASH test level 3 crash testing of this configuration resulted in a maximum dynamic barrier deflection of 88.4 in. and a total working width of 159.8 in.

For the evaluated barrier segment length of 12 ft 6 in., this configuration results in an overlap length of approximately 18.8 ft. This provides transportation agencies a practical, cost-effective solution for overlapping portable barriers in work zones when circumstances dictate while maintaining compliance with MASH safety performance requirements.

For barriers with different segment lengths, different connection mechanisms, or alternative installation details, additional research is needed to determine the applicability of these recommendations. However, the researchers believe that for other barrier profiles of similar length, such as single-slope concrete barriers, the findings of this study are likely applicable.

10.3. FUTURE RESEARCH

To provide a complete guide for the overlapping practice of F-shape PCBs, further research is recommended to evaluate an overlap length of 2.5 barrier segments. Providing guidance for an overlapping range from 1.5 to 2.5 barrier segments would cover all possible overlapping scenarios encountered in work zones based on the initial longitudinal gap that exists between the two barrier runs.

Crash testing conducted in this study demonstrated that the small car experienced a lateral ridedown acceleration of 19.2 g, which is close to the MASH allowable limit of 20.49 g. While parametric simulations showed only a small difference in ridedown acceleration between the 1.5-segment and 2.5-segment overlap configurations (only 0.6 g), the model validation indicated that ridedown acceleration tends to be underpredicted in simulations. As a result, definitive conclusions regarding the acceptability of the 2.5-segment overlap configuration cannot be drawn without physical testing.

The researchers believe that the 2.5-barrier overlap configuration is likely to meet MASH TL-3 criteria, but full-scale crash testing is recommended. Future research should conduct MASH Test 3-10 crash testing with the small car at the critical impact point defined in this study to evaluate MASH occupant risk criteria for this configuration.

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1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.

2. Sheikh, N. M., Menges, W. L., and Kuhn, D. L. *MASH TL-3 Testing and Evaluation of Free-Standing Portable Concrete Barrier*. Test Report No. 607911-1&2. Texas A&M Transportation Institute, College Station, TX, May 2017.

3. Bremer, W., Noyce, D. A., Shaw, J. W., Chitturi, M. V., and Bill, A. *Guidelines for Work Zone Designers – Positive Protection*. Traffic Operations & Safety Laboratory, University of Wisconsin–Madison, Madison, WI, May 2019.

4. Minnesota Department of Transportation. *Temporary Barrier Guidance Manual*. MnDOT Office of Traffic Engineering, St. Paul, MN, December 2018.

APPENDIX A.

STANDARDS DRAWINGS

A.1. FDOT STANDARD DRAWINGS

GENERAL NOTES:

1. Temporary barrier systems may be any of the following:

   A. Type K Temporary Concrete Barrier System (Index 102-110) installed as either Free-Standing or Anchored.

   B. Proprietary Temporary Barrier Systems on the Approved Product List (APL).
      a. Concrete Barrier (Free-Standing or Anchored)
      b. Steel Barrier (Anchored)
      c. Water Filled Barrier (Free-Standing)

2. Where existing flexible pavement is not present, construct a minimum 2" thick temporary Asphalt Pad using Miscellaneous Asphalt Pavement in accordance with Specification 339 with the exception that the use of a pre-emergent herbicide is not required.

3. For Barrier Delineators, see Specification 102. Mount on top of temporary barriers. Color must match adjacent longitudinal pavement marking.

4. Remove all grass debris, loose dirt, and sand for the pavement, bridge deck, or asphalt pad surface within the barrier footprint just prior to placement of the temporary barrier.

5. Ensure the setback distance is clear of any grass, construction debris, stockpiled materials, equipment, and objects.

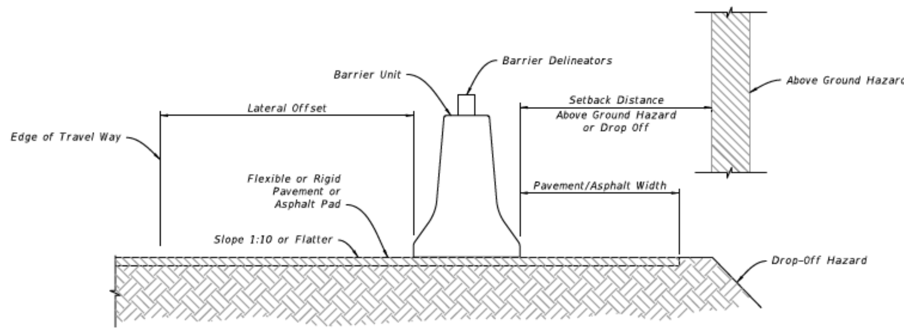
6. Transitions are required between Type K Barrier and free-standing, anchored, back-filled or other types of temporary barrier. See Index 102-110 for transitions between Type K Barrier and permanent bridge or traffic railing. Refer to the APL for transitions allowed for Proprietary Temporary Barrier Systems.

7. Anchoring (Bolting) of temporary barrier or crash cushions is not permitted on bridge superstructures that contain post-tensioned tendons within the concrete deck (top flange of concrete box girders) or on bridge superstructures consisting of longitudinally prestressed, transversely post-tensioned, solid or voided concrete slab units.

8. Anchor abutting segments of temporary barrier terminated with a Crash Cushion as shown in Index 102-110 or the APL.

9. The requirements of this Index do not apply to Temporary Low Profile Barrier, See Index 102-120.

10. Setback requirements below cover most Temporary Barrier options. Provide additional setback distance for APL products that require additional setback (deflection) space.

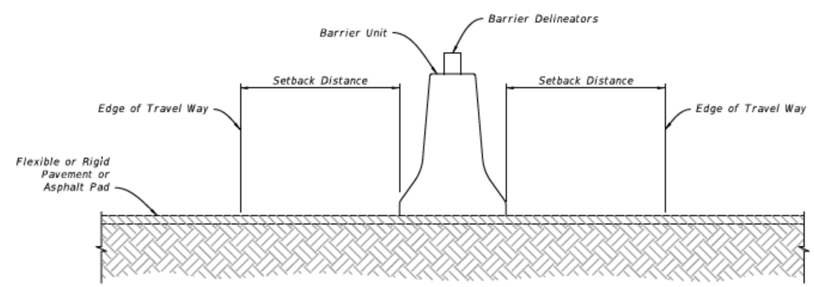


ROADSIDE INSTALLATION

INSTALLATION DATA

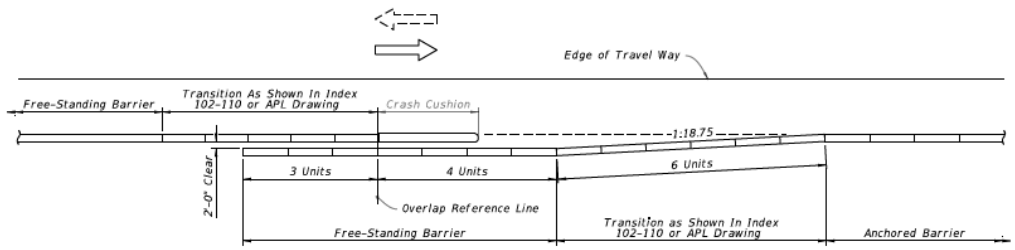
CONDITION	LATERAL OFFSET	SETBACK DISTANCE	PAVEMENT/ ASPHALT WIDTH
Anchored	2' Min.	2' Min. (See Note)	1' Min.
Free-standing	2' Min.	4' Min.	4' Min.

NOTE: For Bridge Decks see Index 102-110 or APL.

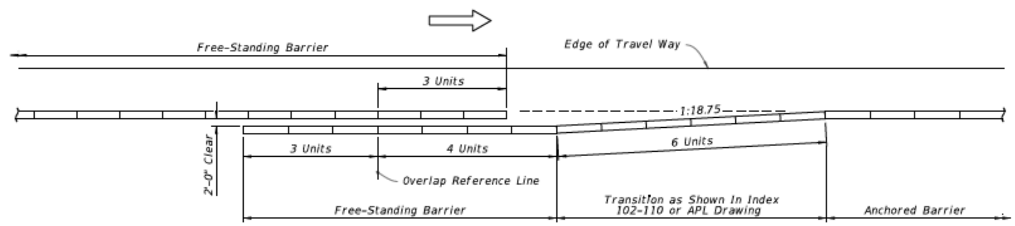


MEDIAN INSTALLATION

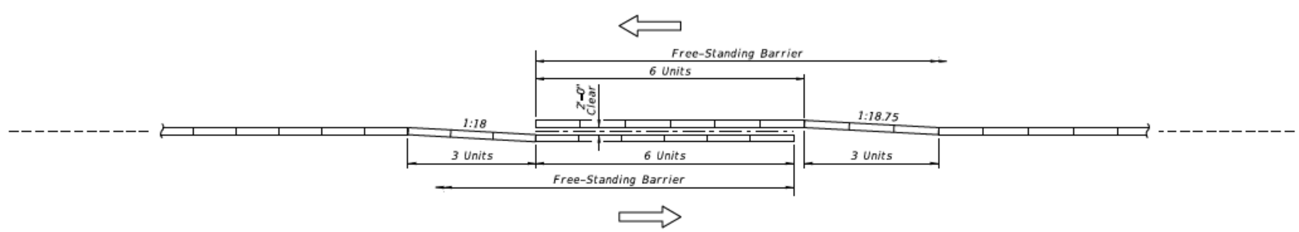
LAST REVISION	REVISION	DESCRIPTION:			INDEX	SHEET
11/01/20			FDOT FY 2024-25 STANDARD PLANS	TEMPORARY BARRIER	102-100	1 of 4



APPROACH SHOULDER BARRIER TRANSITION ON UNDIVIDED FACILITIES



APPROACH SHOULDER BARRIER TRANSITION ON DIVIDED FACILITIES

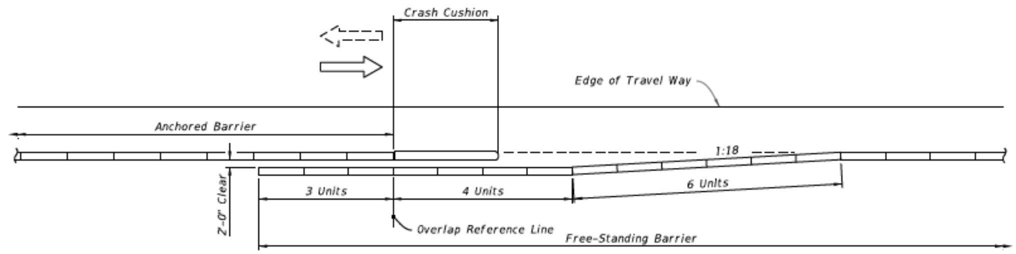


SYMBOL:

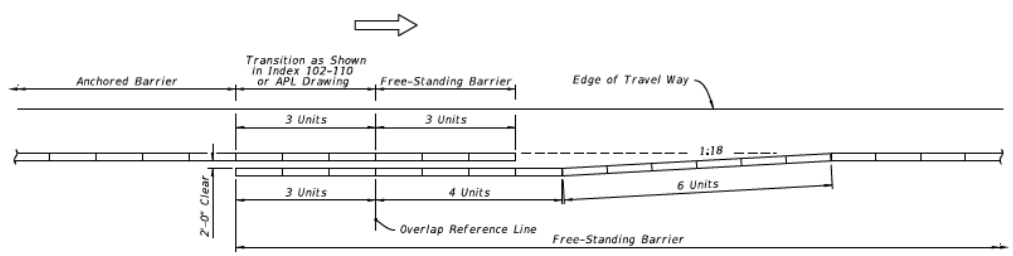
Direction of Traffic

MEDIAN BARRIER TRANSITION

LAST REVISION 11/01/20	REVISION	DESCRIPTION:	FDOT FY 2024-25 STANDARD PLANS	TEMPORARY BARRIER	INDEX 102-100	SHEET 2 of 4



DEPARTURE SHOULDER BARRIER TRANSITION ON UNDIVIDED FACILITIES



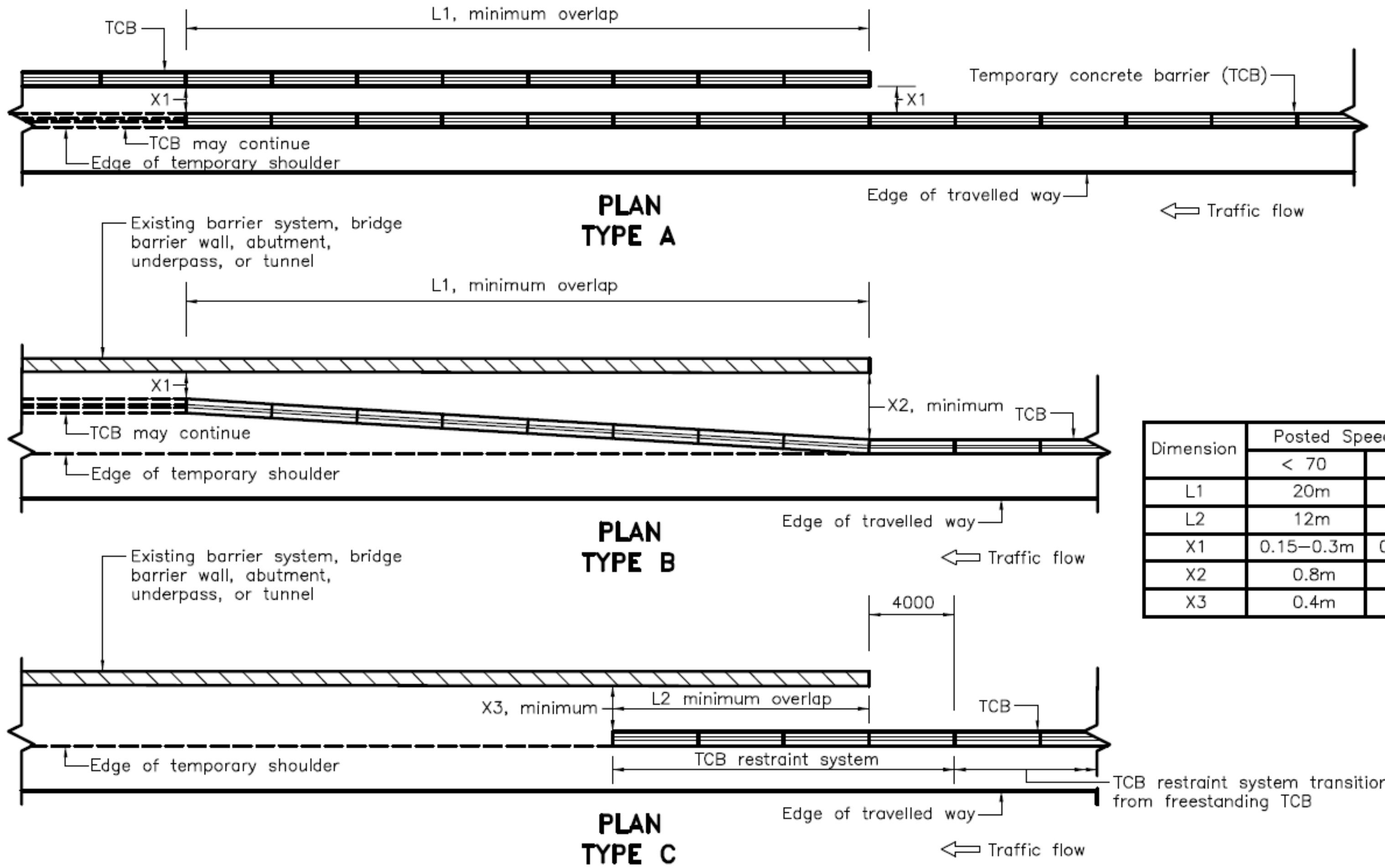
DEPARTURE (TRAILING) SHOULDER BARRIER TRANSITION ON DIVIDED FACILITIES

SYMBOL:

⇨ Direction of Traffic

LAST REVISION	REVISION	DESCRIPTION:	FDOT	FY 2024-25 STANDARD PLANS	TEMPORARY BARRIER	INDEX	SHEET
11/01/20						102-100	3 of 4

A.2. ONTARIO PROVINCIAL STANDARD DRAWING



Dimension	Posted Speed (km/h)	
	< 70	≥ 70
L1	20m	32m
L2	12m	16m
X1	0.15–0.3m	0.15–0.3m
X2	0.8m	1.5m
X3	0.4m	0.6m

NOTES:

A Roadside installation shown. For median application, use a mirror image.

B All dimensions are in millimetres unless otherwise shown.

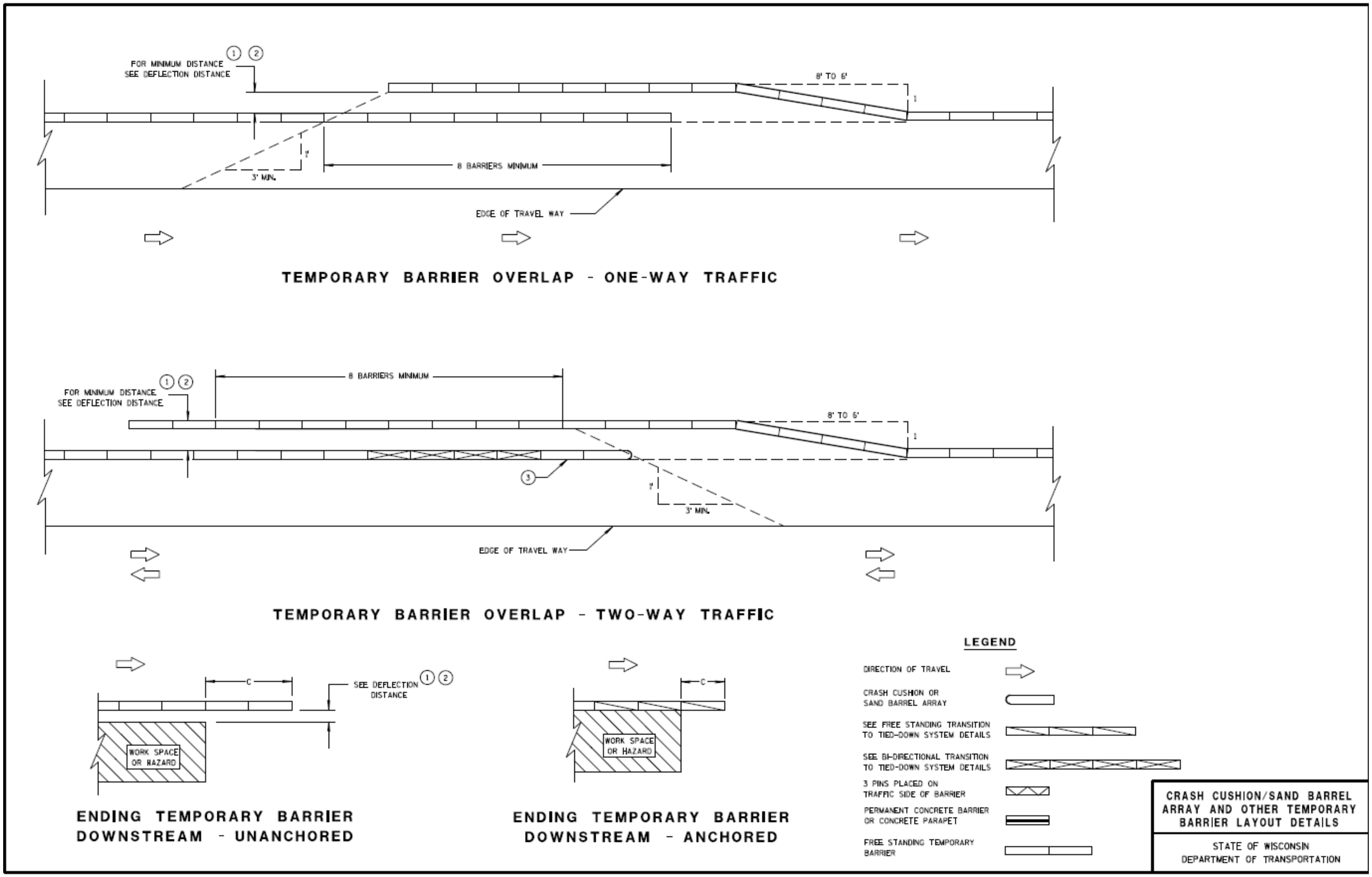
ONTARIO PROVINCIAL STANDARD DRAWING

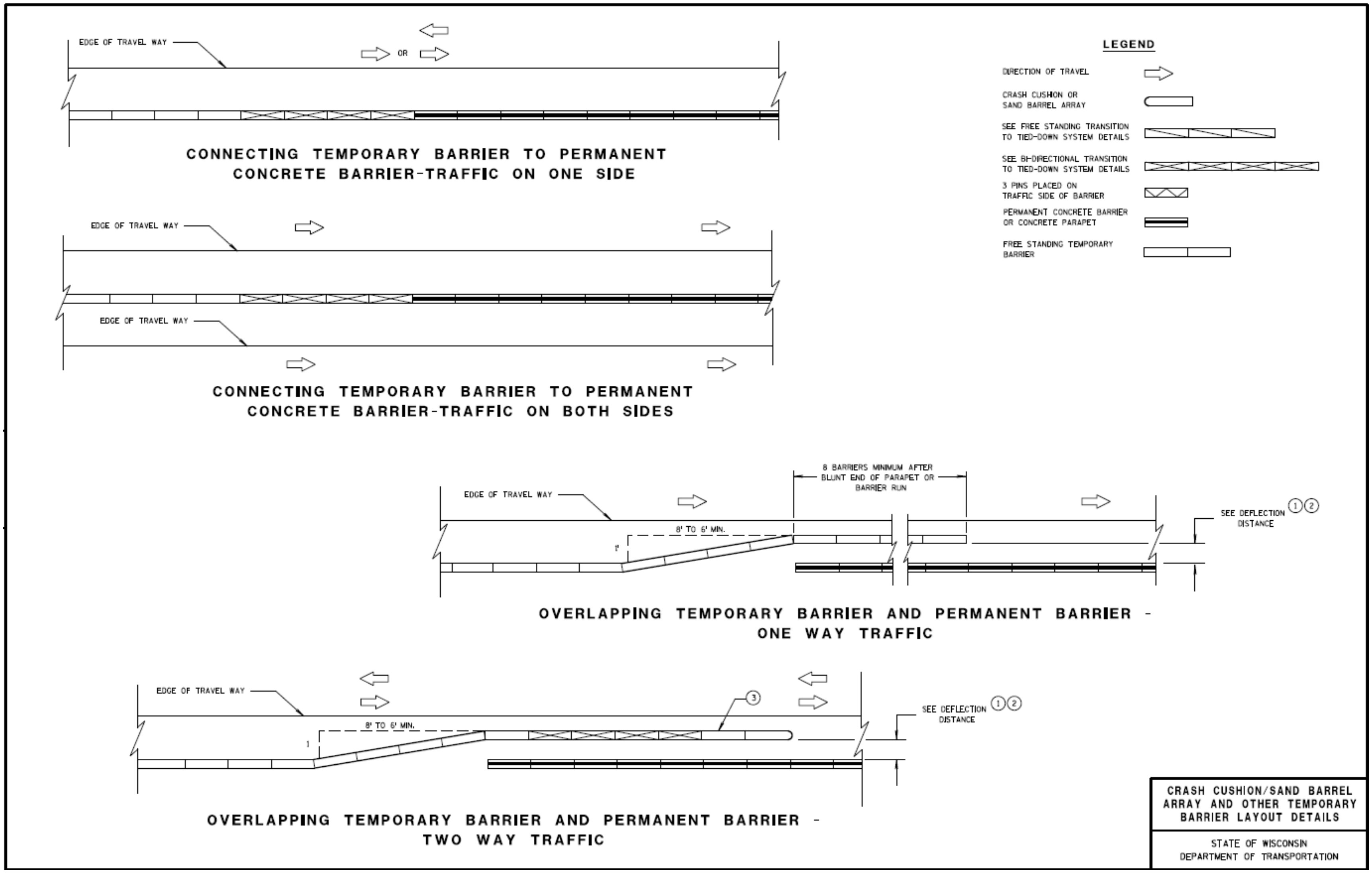
Nov 2015 | Rev 1

GUIDE RAIL SYSTEM, CONCRETE BARRIER TEMPORARY – LEAVING END TREATMENT INSTALLATION – DIVIDED HIGHWAY

OPSD 911.430

A.3. WISDOT STANDARD DRAWINGS




EDGE OF TRAVEL WAY
OR
CONNECTING TEMPORARY BARRIER TO PERMANENT CONCRETE BARRIER-TRAFFIC ON ONE SIDE
LEGEND
DIRECTION OF TRAVEL
CRASH CUSHION OR SAND BARREL ARRAY
SEE FREE STANDING TRANSITION TO TIED-DOWN SYSTEM DETAILS
SEE BI-DIRECTIONAL TRANSITION TO TIED-DOWN SYSTEM DETAILS
3 PINS PLACED ON TRAFFIC SIDE OF BARRIER
PERMANENT CONCRETE BARRIER OR CONCRETE PARAPET
FREE STANDING TEMPORARY BARRIER
EDGE OF TRAVEL WAY
EDGE OF TRAVEL WAY
CONNECTING TEMPORARY BARRIER TO PERMANENT CONCRETE BARRIER-TRAFFIC ON BOTH SIDES
8 BARRIERS MINIMUM AFTER BLUNT END OF PARAPET OR BARRIER RUN
EDGE OF TRAVEL WAY
8' TO 6' MIN.
1'
SEE DEFLECTION DISTANCE 1 2
OVERLAPPING TEMPORARY BARRIER AND PERMANENT BARRIER - ONE WAY TRAFFIC
EDGE OF TRAVEL WAY
3
8' TO 6' MIN.
1
SEE DEFLECTION DISTANCE 1 2
OVERLAPPING TEMPORARY BARRIER AND PERMANENT BARRIER - TWO WAY TRAFFIC
CRASH CUSHION/SAND BARREL ARRAY AND OTHER TEMPORARY BARRIER LAYOUT DETAILS
STATE OF WISCONSIN DEPARTMENT OF TRANSPORTATION

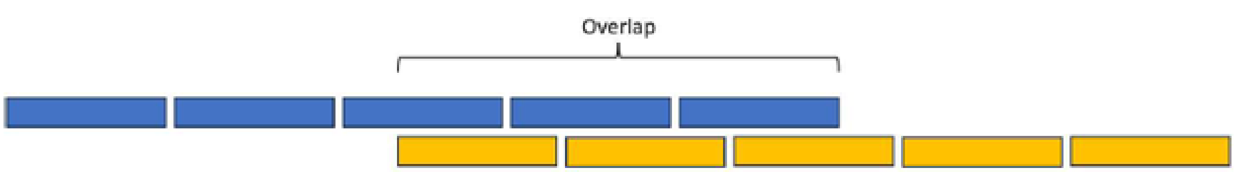
APPENDIX B.
SURVEY TEMPLATE

Introduction

Researching Guidelines for Overlapping Precast Concrete Portable Barriers

Overlapping of PCBs is a commonly used practice to terminate exposed barrier ends in work zones by many DOTs. Current practices and standards are not crash tested and not based in research. This survey aims to collect information about the current state of practice and use it to better address the research objectives. The goal of this project is to develop MASH compliant guidelines for overlapping precast concrete portable barriers.

The overlapping mentioned is as follows:



1.) Please enter your contact information below:

Name
DOT
Email
Phone

Questions

2.) Does your State DOT have standards, drawings or guidelines for the overlapping barriers practice?

No

Yes

3.) Please attach the standards, drawings, or guidelines of your State.

Attach additional files

Attach additional files

Attach additional files

4.) Which portable barrier profile does your State DOT typically use when overlapping is used?

F-shape
Single Slope Concrete Barrier (SSCB)
Other (please define):

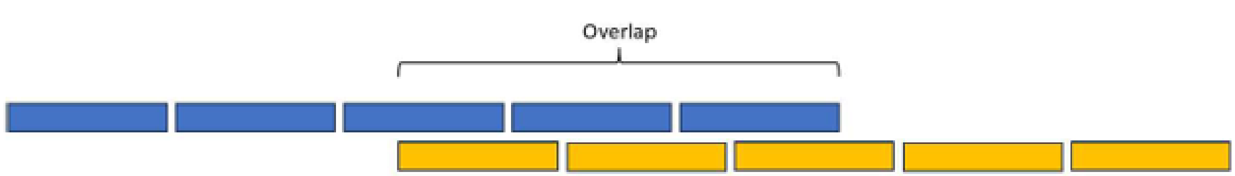
5.) Please attach the standards or drawings for the selected barrier profile.

Attach additional files

Attach additional files

Attach additional files

6.) What is the typical barriers overlapping length used by your State DOT? You may provide a range.



Length (or range) of overlap (ft):

7.) When overlapping is used, are the barrier runs initially in the same line and then offset to make the overlap, or do they initiate and remain in parallel?

Initiate and remain in parallel

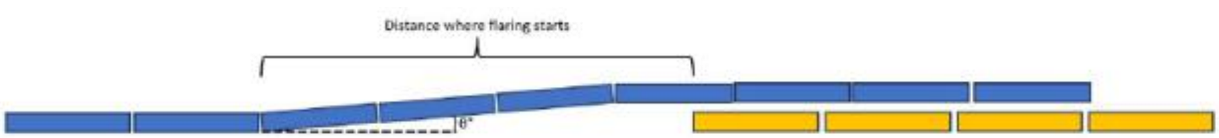
Initiate in same line and offset to overlap

Initiate in same line and offset to overlap

Initiate and remain in parallel

Other: Please comment below

8.) In what distance to the barriers make the flare and at approximately what angle?



Distance where flaring starts (ft):

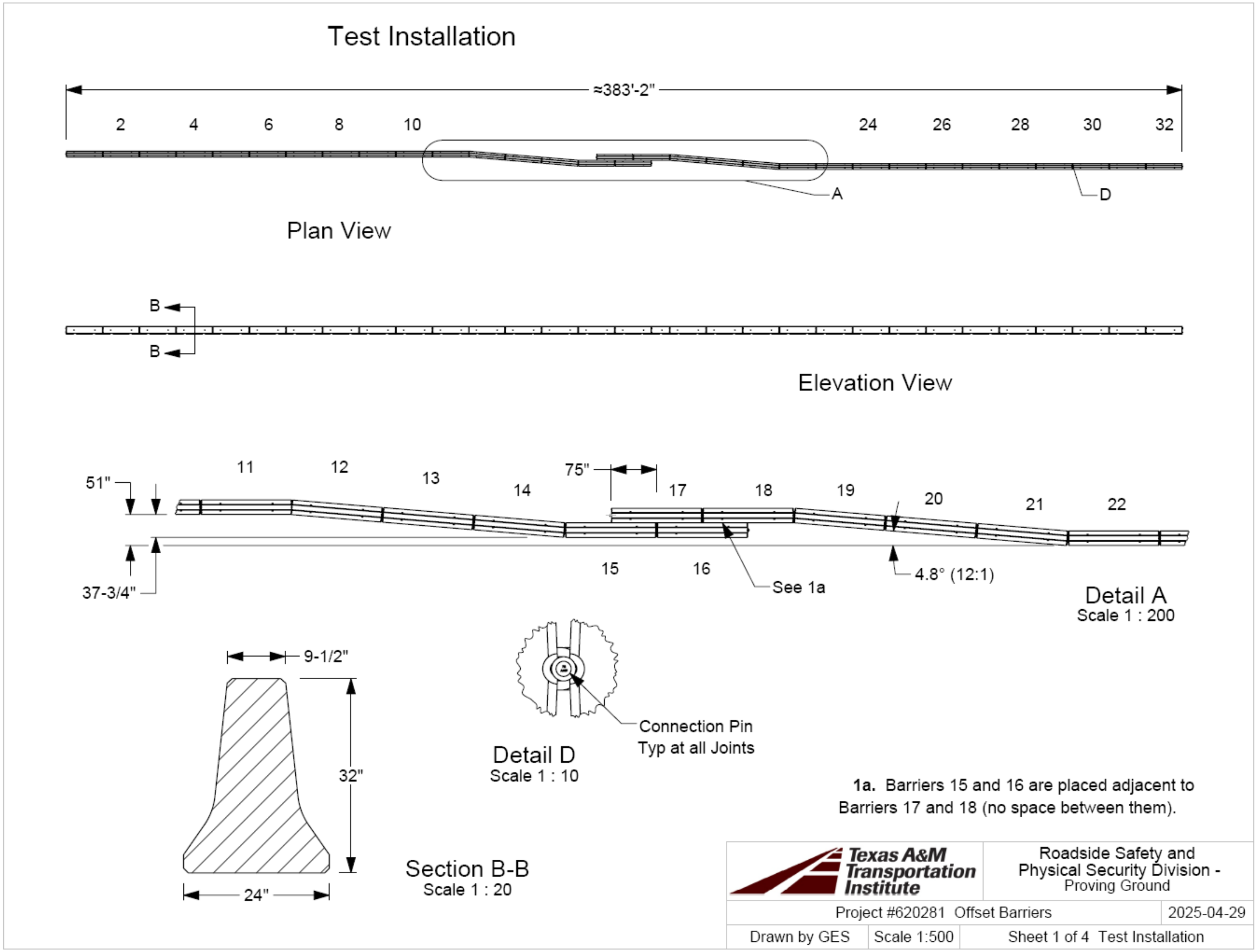
Angle (or rate) of flare:

Other Comments:

9.) In what other instances does your State use the overlapping barriers practice?

APPENDIX C.

DETAILS OF OVERLAPPING PRECAST PORTABLE CONCRETE BARRIERS



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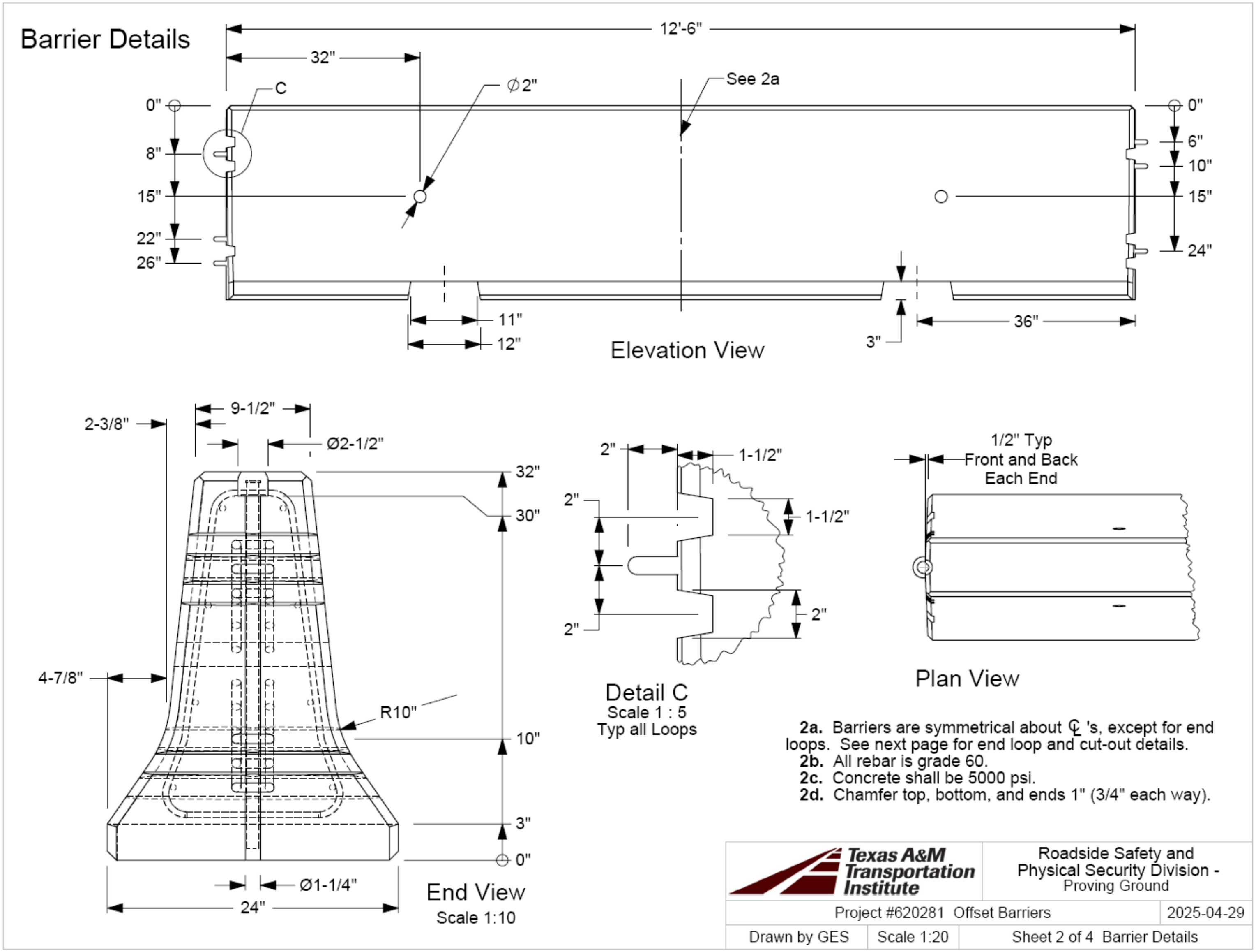

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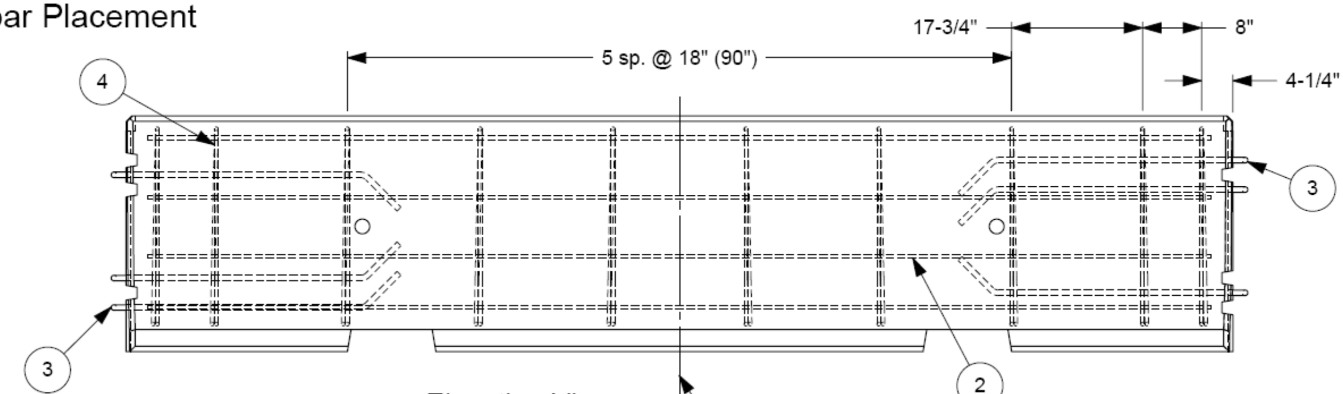
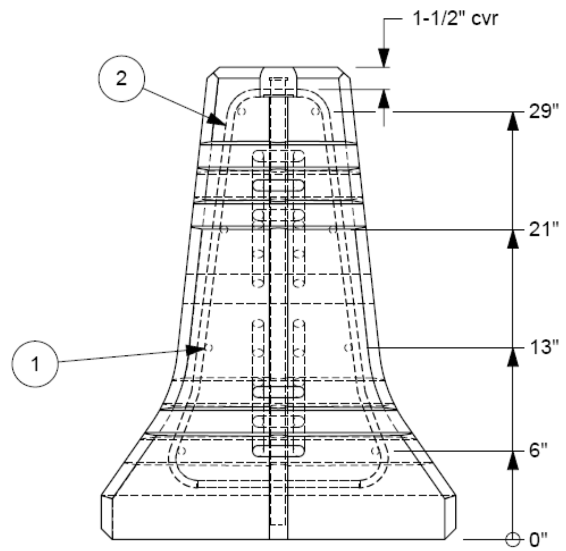
Rebar Placement



Elevation View



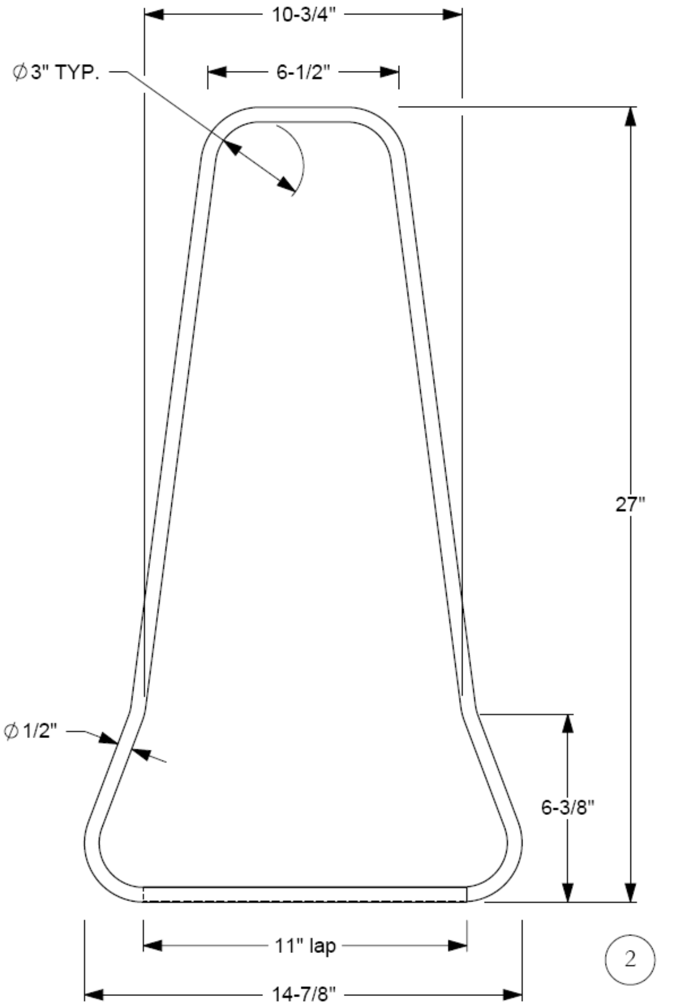
End View
Scale 1:10

#	PART NAME	QTY.
1	Rebar, #4 x 144"	8
2	Stirrup	10
3	End Loops	6

3a. All rebar is grade 60.
3b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

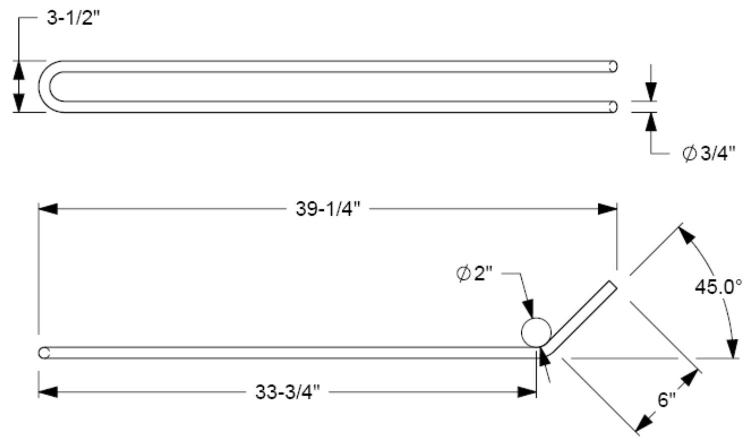
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620281 Offset Barriers		2025-04-29
Drawn by GES	Scale 1:20	Sheet 3 of 4 Rebar Placement

S:\Accreditation-17025-2017\EIR-000 Project Files\620281 - Overlapping PCB's - Cakalli\Drafting, 620281\620281 Drawing



2

Stirrup
Gr. 60 Rebar



3

End Loop
Ø 3/4" - A36 Cold Roll

Texas A&M Transportation Institute

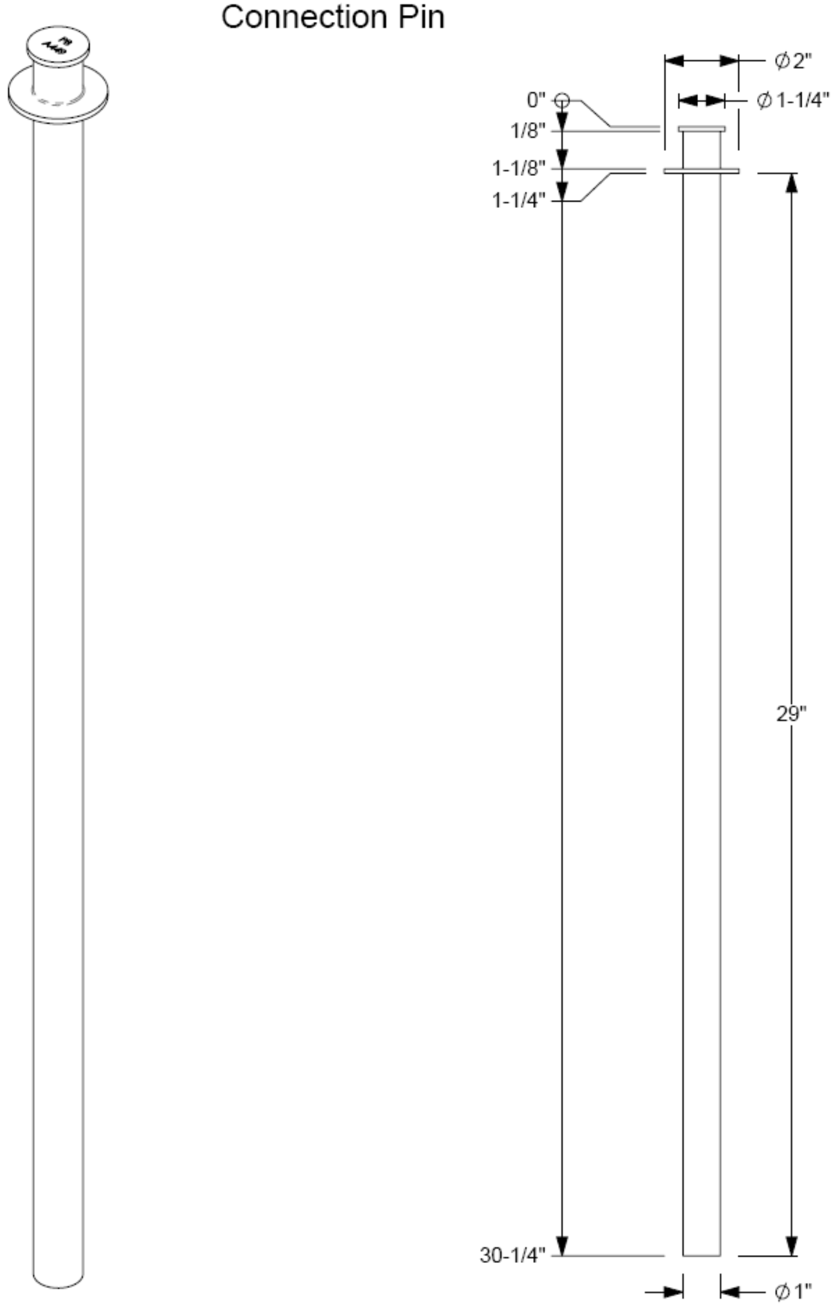
Roadside Safety and Physical Security Division - Proving Ground

Project #620281 Offset Barriers	2025-04-29

Drawn by GES	Scale 1:10	Sheet 4 of 4 Stirrup and End Loop

S:\Accreditation-17025-2017\EIR-000 Project Files\620281 - Overlapping PCB's - Cakalli\Drafting, 620281\620281 Drawing

Connection Pin



1a. Pin is forged by Portland Bolt Company (Part #18241), with no welding, and galvanized per ASTM F2329 and A153.
1b. Material is ASTM A449.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Forged Connection Pin		2022-10-06
Drawn by GES	Scale 1:4	Sheet 1 of 1

S:\Accreditation-17025-2017\Drafting Department\Solidworks\Standard Parts\Concrete Barriers\Forged Connection Pin

APPENDIX D.

SUPPORTING CERTIFICATION DOCUMENTS

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #6 (19MM)	0001258246

LENGTH	WEIGHT	HEAT / BATCH
40'00"	23,552 LB	58065334/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
15042266/000010		ASTM A615/A615M-24

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
Yard 051925	1327-0000628316	05/20/2025

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqyA706 (%)
0.48	1.01	0.019	0.019	0.22	0.25	0.11	0.19	0.027	0.009	0.028	0.003	0.003	0.67

MECHANICAL PROPERTIES

YS (PSI)	YS (MPa)	UTS (PSI)	UTS (MPa)	G/L (Inches)	G/L (mm)	Elong. (%)	BendTest
83057	573	122296	843	8.000	200.0	12.40	OK

MECHANICAL PROPERTIES

UTS / YS
1.47

COMMENTS / NOTES

Gerdau's steel is 100% recyclable. Support the circular economy through our Metals Recycling Partnership. For details, visit www2.gerdau.com/metals-recycling, or contact metalsrecycling@gerdau.com.

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau's possession. For all products other than billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) and produced (Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

WADE LUMPKINS
QUALITY ASSURANCE MGR.
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

CERTIFIED MATERIAL TEST REPORT

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #5 (16MM)	0001246867
		LENGTH 40'00"	WEIGHT 23,781 LB	HEAT / BATCH 58064838/02
SALES ORDER 14965591/000010	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION ASTM A615/A615M-24		

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
A4643	1327-0000624394	04/25/2025

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqyA706 (%)
0.45	1.00	0.014	0.024	0.24	0.24	0.09	0.19	0.028	0.009	0.004	0.020	0.002	0.64

MECHANICAL PROPERTIES

YS (PSI)	YS (MPa)	UTS (PSI)	UTS (MPa)	G/L (Inches)	G/L (mm)	Elong. (%)	BendTest
71717	494	111968	772	8.000	200.0	11.50	OK

MECHANICAL PROPERTIES

UTS / YS
1.56

COMMENTS / NOTES

Gerdau's steel is 100% recyclable. Support the circular economy through our Metals Recycling Partnership. For details, visit www2.gerdau.com/metals-recycling, or contact metalsrecycling@gerdau.com.

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau's possession. For all products other than billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) and produced (Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) in the USA. CMTR complies with EN 10204 3.1.

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NUCOR

Mill Certification

06/16/2025

MTR#:2016295-3
Lot #:380005685820
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN YARD ORDER	Sales Order #	38031490 - 1.4
Product Group	Rebar	Product #	2110230
Grade	A615 Gr 60/AASHTO M31	Lot #	380005685820
Size	#5	Heat #	3800056858
BOL #	BOL-2065805	Load #	2016295
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 40' 0" [480"] 4001-8000 lbs	Customer Part #	
Production Date	06/05/2025	Qty Shipped LBS	20024
Product Country Of Origin	United States	Qty Shipped EA	480
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States
Melting Date: 05/23/2025

Roll Country of Origin : United States
Rolling Date: 06/05/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.37	0.82	0.020	0.023	0.172	0.11	0.20	0.02	0.37	0.023	0.000

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.042	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	70600	100100	15.6

Other Test Results

Weight Percent Variance (%) : -3.72 Tensile / Yield Ratio : 1.42

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess

Nolan Guess, Quality Supervisor

Page 1 of 1

NUCOR

Mill Certification

06/12/2025

MTR#:2019965-2
Lot #:380005707120
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN 60' YARD	Sales Order #	38031545 - 1.3
Product Group	Rebar	Product #	2110206
Grade	A615 Gr 60/AASHTO M31	Lot #	380005707120
Size	#4	Heat #	3800057071
BOL #	BOL-2062986	Load #	2019965
Description	Rebar #4/13mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	06/01/2025	Qty Shipped LBS	36072
Product Country Of Origin	United States	Qty Shipped EA	900
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States
Roll Country of Origin : United States

Melting Date: 05/31/2025
Rolling Date: 06/01/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.38	0.80	0.013	0.030	0.220	0.12	0.17	0.04	0.31	0.023	0.000

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.032	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	69800	99700	12.5

Other Test Results

Weight Percent Variance (%) : -4.14 Tensile / Yield Ratio : 1.43

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess

Nolan Guess, Quality Supervisor

Page 1 of 1

NUCOR

Mill Certification

06/03/2025

MTR#:1990406-1
Lot #:110006817020
8812 HWY 79 W
Jewett, TX 75846 US
903 626-4461
Fax: 903 626-6290

Sold To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	YARD LOAD 5/16	Sales Order #	11086983 - 3.5
Product Group	Rebar	Product #	2110200
Grade	A615 Gr 60/AASHTO M31	Lot #	110006817020
Size	#4	Heat #	1100068170
BOL #	BOL-2050229	Load #	1990406
Description	Rebar #4/13mm A615 Gr 60/AASHTO M31 40' 0" [480"] 2001-4000 lbs	Customer Part #	
Production Date	04/15/2025	Qty Shipped LBS	48096
Product Country Of Origin	United States	Qty Shipped EA	1800
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 04/12/2025
Roll Country of Origin : United States — Rolling Date: 04/15/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.38	1.03	0.017	0.019	0.212	0.11	0.22	0.03	0.28	0.005	0.003

Mechanical

	Bend Test
(1)	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	68300	104900	10.0

Other Test Results

Tensile / Yield Ratio : 1.54

Comments:

1. All manufacturing processes of the steel, including melting, casting & hot rolling, have been performed in U.S.A
2. Mercury not intentionally added at any point during manufacturing or testing of this material.
3. Welding or weld repair was not performed on this material.
4. This material conforms to the specifications described on this document and may not be reproduced, except in full, without written approval of Nucor Corporation.
5. Results reported ASTM E45 (Inclusion content) and ASTM E381 (Macro-etch) are provided as interpretation of ASTM procedures.

Ramon Vigil, Quality Supervisor

Page 1 of 1

NUCOR

Mill Certification

06/12/2025

MTR#:2019968-2
Lot #:380005692420
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN 60' YARD	Sales Order #	38031545 - 1.2
Product Group	Rebar	Product #	2110206
Grade	A615 Gr 60/AASHTO M31	Lot #	380005692420
Size	#4	Heat #	3800056924
BOL #	BOL-2061592	Load #	2019968
Description	Rebar #4/13mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	06/01/2025	Qty Shipped LBS	27054
Product Country Of Origin	United States	Qty Shipped EA	675
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/25/2025

Roll Country of Origin : United States — Rolling Date: 06/01/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.40	0.83	0.007	0.023	0.185	0.13	0.12	0.03	0.33	0.023	0.001

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.034	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	71300	102500	12.5

Other Test Results

Weight Percent Variance (%) : -1.81 Tensile / Yield Ratio : 1.44

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess

Nolan Guess, Quality Supervisor

Page 1 of 1

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #4 (13MM)	0001216063

LENGTH	WEIGHT	HEAT / BATCH
60'00"	24,048 LB	58064077/02

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
14783780/000030		ASTM A615/A615M-24

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
Yard 021725	1327-0000614176	02/20/2025

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqyA706 (%)
0.45	0.97	0.010	0.026	0.22	0.24	0.11	0.17	0.028	0.005	0.003	0.001	0.001	0.64

MECHANICAL PROPERTIES

YS (PSI)	YS (MPa)	UTS (PSI)	UTS (MPa)	G/L (Inches)	G/L (mm)	Elong. (%)	BendTest
74432	513	114450	789	8.000	200.0	16.90	OK

MECHANICAL PROPERTIES

UTS / YS
1.54

COMMENTS / NOTES

Gerdau's steel is 100% recyclable. Support the circular economy through our Metals Recycling Partnership. For details, visit www2.gerdau.com/metals-recycling, or contact metalsrecycling@gerdau.com.

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau's possession. For all products other than billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) and produced (Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Wade A. L
WADE LUMPKINS
QUALITY ASSURANCE MGR.
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

NUCOR

Mill Certification

06/16/2025

MTR#:2019971-2
Lot #:380005688920
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN 60' YARD	Sales Order #	38031545 - 2.6
Product Group	Rebar	Product #	3019447
Grade	A615 Gr 60/AASHTO M31	Lot #	380005688920
Size	#5	Heat #	3800056889
BOL #	BOL-2066549	Load #	2019971
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	05/29/2025	Qty Shipped LBS	36048
Product Country Of Origin	United States	Qty Shipped EA	576
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States
Roll Country of Origin : United States

Melting Date: 05/24/2025
Rolling Date: 05/29/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.40	0.85	0.009	0.026	0.206	0.10	0.13	0.02	0.31	0.023	0.001

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.039	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	66400	99200	21.2

Other Test Results

Weight Percent Variance (%) : -3.79   Tensile / Yield Ratio : 1.50

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess

Nolan Guess, Quality Supervisor

Page 1 of 1

Mi

NUCOR

Mill Certification

02/18/2025

MTR#:1889269-2
Lot #:110006605720
8812 HWY 79 W
Jewett, TX 75846 US
903 626-4461
Fax: 903 626-6290

Sold To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	YARD LOAD 2/10	Sales Order #	11080199 - 7.9
Product Group	Rebar	Product #	2110320
Grade	A615 Gr 60/AASHTO M31	Lot #	110006605720
Size	#8	Heat #	1100066057
BOL #	BOL-1939407	Load #	1889269
Description	Rebar #8/25mm A615 Gr 60/AASHTO M31 40' 0" [480"] 2001-6000 lbs	Customer Part #	
Production Date	02/11/2025	Qty Shipped LBS	12816
Product Country Of Origin	United States	Qty Shipped EA	120
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 02/09/2025

Roll Country of Origin : United States — Rolling Date: 02/11/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.36	0.97	0.017	0.014	0.201	0.16	0.28	0.05	0.23	0.004	0.022

Mechanical

	Bend Test
(1)	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	70300	104800	11.0

Other Test Results

Tensile / Yield Ratio : 1.49

Comments:

1. All manufacturing processes of the steel, including melting, casting & hot rolling, have been performed in U.S.A
2. Mercury not intentionally added at any point during manufacturing or testing of this material.
3. Welding or weld repair was not performed on this material.
4. This material conforms to the specifications described on this document and may not be reproduced, except in full, without written approval of Nucor Corporation.
5. Results reported ASTM E45 (Inclusion content) and ASTM E381 (Macro-etch) are provided as interpretation of ASTM procedures.

Robert E. Fortson, Quality Assurance

Page 1 of 1

NUCOR

Mill Certification

05/30/2025

MTR#:2005651-2
Lot #:380005631820
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN 2 NOW 2 LATER	Sales Order #	38031249 - 1.3
Product Group	Rebar	Product #	2110265
Grade	A615 Gr 60/AASHTO M31	Lot #	380005631820
Size	#6	Heat #	3800056318
BOL #	BOL-2047185	Load #	2005651
Description	Rebar #6/19mm A615 Gr 60/AASHTO M31 40' 0" [480"] 2001-6000 lbs	Customer Part #	
Production Date	05/06/2025	Qty Shipped LBS	30282
Product Country Of Origin	United States	Qty Shipped EA	504
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/01/2025

Roll Country of Origin : United States — Rolling Date: 05/06/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)	Sn (%)
0.36	0.79	0.014	0.028	0.227	0.22	0.23	0.05	0.33	0.021	0.002	0.012

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.049	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	69900	106500	13.8

Other Test Results

Weight Percent Variance (%) : -3.40 Tensile / Yield Ratio : 1.52

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess, Quality Supervisor

Page 1 of 1

NUCOR

Mill Certification

06/16/2025

MTR#:2019971-2
Lot #:380005688920
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN 60' YARD	Sales Order #	38031545 - 2.6
Product Group	Rebar	Product #	3019447
Grade	A615 Gr 60/AASHTO M31	Lot #	380005688920
Size	#5	Heat #	3800056889
BOL #	BOL-2066549	Load #	2019971
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	05/29/2025	Qty Shipped LBS	36048
Product Country Of Origin	United States	Qty Shipped EA	576
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/24/2025

Roll Country of Origin : United States — Rolling Date: 05/29/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.40	0.85	0.009	0.026	0.206	0.10	0.13	0.02	0.31	0.023	0.001

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.039	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	66400	99200	21.2

Other Test Results

Weight Percent Variance (%) : -3.79 Tensile / Yield Ratio : 1.50

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess, Quality Supervisor

NUCOR

Mill Certification

06/05/2025

MTR#:2011246-2
Lot #:380005688820
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	YARD LOADS	Sales Order #	38031356 - 1.3
Product Group	Rebar	Product #	3019447
Grade	A615 Gr 60/AASHTO M31	Lot #	380005688820
Size	#5	Heat #	3800056888
BOL #	BOL-2053669	Load #	2011246
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	05/29/2025	Qty Shipped LBS	36048
Product Country Of Origin	United States	Qty Shipped EA	576
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/24/2025

Roll Country of Origin : United States — Rolling Date: 05/29/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.40	0.76	0.010	0.026	0.199	0.10	0.13	0.02	0.29	0.022	0.002

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.038	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	64200	96400	17.5

Other Test Results

Weight Percent Variance (%) : -3.16 Tensile / Yield Ratio : 1.50

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess, Quality Supervisor

Page 1 of 1

NUCOR

Mill Certification

06/18/2025

MTR#:2027805-2
Lot #:110006976920
8812 HWY 79 W
Jewett, TX 75846 US
903 626-4461
Fax: 903 626-6290

Sold To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	YARD LOAD 6/16	Sales Order #	11088570 - 2.2
Product Group	Rebar	Product #	2110230
Grade	A615 Gr 60/AASHTO M31	Lot #	110006976920
Size	#5	Heat #	1100069769
BOL #	BOL-2069005	Load #	2027805
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 40' 0" [480"] 4001-8000 lbs	Customer Part #	
Production Date	06/01/2025	Qty Shipped LBS	40050
Product Country Of Origin	United States	Qty Shipped EA	960
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/30/2025

Roll Country of Origin : United States — Rolling Date: 06/01/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.35	1.08	0.019	0.017	0.197	0.16	0.30	0.04	0.31	0.004	0.001

Mechanical

	Bend Test
(1)	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	65000	101700	12.0

Other Test Results

Tensile / Yield Ratio : 1.56

Comments:

1. All manufacturing processes of the steel, including melting, casting & hot rolling, have been performed in U.S.A
2. Mercury not intentionally added at any point during manufacturing or testing of this material.
3. Welding or weld repair was not performed on this material.
4. This material conforms to the specifications described on this document and may not be reproduced, except in full, without written approval of Nucor Corporation.
5. Results reported ASTM E45 (inclusion content) and ASTM E381 (Macro-etch) are provided as interpretation of ASTM procedures.

Ramon Vigil, Quality Supervisor

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #4 (13MM)	0001216063

LENGTH	WEIGHT	HEAT / BATCH
60'00"	24,048 LB	58064077/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
14783780/000030		ASTM A615/A615M-24

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
Yard 021725	1327-0000614176	02/20/2025

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqyA706 (%)
0.45	0.97	0.010	0.026	0.22	0.24	0.11	0.17	0.028	0.005	0.003	0.001	0.001	0.64

MECHANICAL PROPERTIES

YS (PSI)	YS (MPa)	UTS (PSI)	UTS (MPa)	G/L (Inches)	G/L (mm)	Elong. (%)	BendTest
74432	513	114450	789	8.000	200.0	16.90	OK

MECHANICAL PROPERTIES

UTS / YS
1.54

COMMENTS / NOTES

Gerdau's steel is 100% recyclable. Support the circular economy through our Metals Recycling Partnership. For details, visit www2.gerdau.com/metals-recycling, or contact metalsrecycling@gerdau.com.

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau's possession. For all products other than billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) and produced (Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Wade L. [illegible]
WADE LUMPKINS
QUALITY ASSURANCE MGR.
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

Sentry 25-186

NUCOR

Mill Certification

06/12/2025

MTR#:2019969-3
Lot #:380005692320
3630 Fourth Street
Flowood, MS 39232 US
601 939-1623
Fax: 601 936-6202

Sold To: REGAL METALS
207 SENTRY DR
MANSFIELD, TX 76063 US

Ship To: REGAL METALS INTERNATIONAL
207 SENTRY DR
MANSFIELD, TX 76063 US

Customer PO	BRIAN 60' YARD	Sales Order #	38031545 - 1.4
Product Group	Rebar	Product #	2110206
Grade	A615 Gr 60/AASHTO M31	Lot #	380005692320
Size	#4	Heat #	3800056923
BOL #	BOL-2062325	Load #	2019969
Description	Rebar #4/13mm A615 Gr 60/AASHTO M31 60' 0" [720"] 6001-10000 lbs	Customer Part #	
Production Date	06/01/2025	Qty Shipped LBS	27054
Product Country Of Origin	United States	Qty Shipped EA	675
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/25/2025

Roll Country of Origin : United States — Rolling Date: 06/01/2025

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.41	0.79	0.008	0.028	0.203	0.12	0.13	0.02	0.34	0.027	0.002

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.024	Pass

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	68300	101100	15.0

Other Test Results

Weight Percent Variance (%) : -4.43   Tensile / Yield Ratio : 1.48

Comments:

Nucor Steel Jackson, Inc. is in compliance with and certified to: ISO 9001:2015, ISO 14001:2015, ABS Quality Assurance Program & AASHTO's NTPEP Reinforcing Steel and Wire (REBAR) Technical Committee Work Plan. All manufacturing processes for this product, including melting, casting, and hot rolling, were performed in the United States of America.
Mercury not intentionally added at any point during manufacturing or testing of this material. No weld repair was performed.
Material and Mill Certification are in full compliance with the American Iron and Steel requirement as mandated in EPA's State Revolving Fund Programs and complies with the Buy American Act, (FTA) Buy America Requirements (49 CFR part 661), and (FHWA) Buy America Requirements (23 CFR part 635.410)
This material was tested using full-section samples.

Nolan Guess

Nolan Guess, Quality Supervisor

Page 1 of 1

BL HOU-91227-1 8/1/2025
Order HOU-626887-1 Page:1

CMC

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
800-227-6489

We hereby certify that the test results presented here,
are accurate and conform to the reported grade specification

Drew Fischer
Drew M Fischer
Quality Assurance Manager

1SERIES-BPS ®

EAT NO.:3137924 ECTION: ROUND 3/4 x 20'0" A36/52950 RADE: ASTM A36-19/A529-19 Gr 50 RD OLL DATE: 04/04/2025 ELT DATE: 03/20/2025 ert. No.: 86392384 / 137924A457	SOLD TO	Triple S Steel Supply Co 6000 JENSEN DR HOUSTON TX US 77026-1113 7136977105	SHIP TO	Triple S Steel- Jensen 6000 Jensen Dr Houston TX US 77026-1113 7136977105	Delivery#: 86392384 BOL#: 76682884 CUST PO#: HOU-213284 CUST P/N: DLVRY LBS / HEAT: 22830.000 LB DLVRY PCS / HEAT: 760 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.10%	Elongation Gage Lgth test 1	8IN		
Mn	1.09%	Reduction of Area test 1	61%		
P	0.014%	Yield to tensile ratio test1	0.74		
S	0.024%	Yield Strength test 2	55.6ksi		
Si	0.19%	Tensile Strength test 2	75.6ksi		
Cu	0.26%	Elongation test 2	46%		
Cr	0.06%	Elongation Gage Lgth test 2	2IN		
Ni	0.08%	Reduction of Area test 2	57%		
Mo	0.019%	Yield to tensile ratio test2	0.74		
V	0.000%	BHN @ Surface test 1	0BHN		
Cb	0.009%				
Sn	0.009%				
Al	0.002%				
N	0.0106%				
Carbon Eq F1554	0.30%				
Carbon Eq A529	0.35%				
Yield Strength test 1	55.2ksi				
Tensile Strength test 1	74.6ksi				
Elongation test 1	28%				

The Following is true of the material represented by this MTR:
*Material is fully killed and is Hot Rolled Steel
*100% melted, rolled, and manufactured in the USA
*EN10204:2004 3.1 compliant *Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov
*THE RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHABLE AS A FELONY UNDER FEDERAL STATUTE

PO/REL HOU-4255?
HEAT: 3137924

ARKS : ALSO MEETS ASTM GRADE A36, A529-50, A572-50, A709-36, A709-50, A992, AASHTO M270-36, M270-50, CSA G40.21-04 44W, 50W
O MEETS THE REQUIREMENTS OF F1554 GRADE 36 SUPPLEMENT S1

ROUND BAR A-36/A 529 GR50
3/4 X 20'

SUMMIT PRECAST CONCRETE
PO: 25-188
PART: 250548 TTI LOOP CONN
END LOOPS HDG

UF461D

Page 1 OF 1 07/29/2025 17:28:34

CMC

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
800-227-6489

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Drew M Fischer
Quality Assurance Manager

1SERIES-BPS ®

AT NO.:3133243
CTION: ROUND 3/4 x 20'0" A36/52950
ADE: ASTM A36-19/A529-19 Gr 50 RD
LL DATE: 04/04/2025
LT DATE: 08/26/2024
t. No.: 86279742 / 133243A457

SOLD TO: O'Neal Steel Inc
4530 MESSER AIRPORT HWY
BIRMINGHAM AL
US 35222-1627
2055998000

SHIP TO: O'Neal Steel
4005 Grand Lakes Way
Grand Prairie TX
US 75050-0000
9724027946

Delivery#: 86279742
BOL#: 76557623
CUST PO#: 722550
CUST P/N: 834718
DLVRY LBS / HEAT: 4566.000 LB
DLVRY PCS / HEAT: 152 EA

Characteristic	Value	Characteristic	Value
C	0.16%	Elongation Gage Lgth test 1	8IN
Mn	0.75%	Reduction of Area test 1	51%
P	0.009%	Yield to tensile ratio test1	0.72
S	0.023%	Yield Strength test 2	52.4ksi
Si	0.21%	Tensile Strength test 2	73.4ksi
Cu	0.41%	Elongation test 2	50%
Cr	0.05%	Elongation Gage Lgth test 2	2IN
Ni	0.09%	Reduction of Area test 2	57%
Mo	0.020%	Yield to tensile ratio test2	0.71
V	0.014%	BHN @ Surface test 1	149BHN
Cb	0.001%		
Sn	0.010%		
Al	0.005%		
N	0.0154%		
Carbon Eq F1554	0.30%		
Carbon Eq A529	0.37%		
Yield Strength test 1	52.6ksi		
Tensile Strength test 1	72.8ksi		
Elongation test 1	26%		

The Following is true of the material represented by this MTR:
*Material is fully killed and is Hot Rolled Steel
*100% melted, rolled, and manufactured in the USA
*EN10204:2004 3.1 compliant *Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manua
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov
*THE RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHABL AS A FELONY UNDER FEDERAL STATUTE

RKS : ALSO MEETS ASTM GRADE A36, A529-50, A572-50, A709-36, A709-50, A992, AASHTO M270-36, M270-50, CSA G40.21-04 44W, 50W
MEETS THE REQUIREMENTS OF F1554 GRADE 36 SUPPLEMENT S1

Page 1 OF 1 05/22/2025 12:53:35

SUMMIT PRECAST CONCRETE
PO: 25-188
PART: 250548 TTI LOOP CONN
END LOOPS HDG

UF4547

UNIFAB
MACHINE & FABRICATION

UNI-FAB

CERTIFICATE OF MATERIAL

SPECIFICATIONS AND WORKMANSHIP

DATE: 8/6/25

PO# 144173

JOB: 73592

PART NUMBER: 250548 TTI LOOP CONN   PART DESCRIPTION: END LOOPS HDG

CUST PO: 25-188 LINE 1
S/N: TRACER 1 -210
Material: A36
HL: UF4547 /HT# 3133243, UF4610 /HT# 3137924

QUANTITY: 210

SPECIAL PROCESS: MANUFACTURED PER PRINT

COUNTRY OF ORIGIN: United States of America

The materials, processes, and workmanship all conform to the requirements of all applicable specifications, drawings, and the purchase order supplied to Uni-Fab. The appropriate documentation providing traceablity is on file at Uni-Fab. It is available for review by authorized customer representatives.

Serial No.	25-188-1-71, 25-188-1-72, 25-188-1-73, 25-188-1-74, 25-188-1-75
Serial No.	25-188-1-76, 25-188-1-77, 25-188-1-78, 25-188-1-79, 25-188-1-80
Serial No.	25-188-1-81, 25-188-1-82, 25-188-1-83, 25-188-1-84, 25-188-1-85
Serial No.	25-188-1-86, 25-188-1-87, 25-188-1-88, 25-188-1-89, 25-188-1-90
Serial No.	25-188-1-91, 25-188-1-92, 25-188-1-93, 25-188-1-94, 25-188-1-95
Serial No.	25-188-1-96, 25-188-1-97, 25-188-1-98, 25-188-1-99, 25-188-1-100
Serial No.	25-188-1-101, 25-188-1-102, 25-188-1-103, 25-188-1-104, 25-188-1-105
Serial No.	25-188-1-106, 25-188-1-107, 25-188-1-108, 25-188-1-109, 25-188-1-110
Serial No.	25-188-1-111, 25-188-1-112, 25-188-1-113, 25-188-1-114, 25-188-1-115
Serial No.	25-188-1-116, 25-188-1-117, 25-188-1-118, 25-188-1-119, 25-188-1-120
Serial No.	25-188-1-121, 25-188-1-122, 25-188-1-123, 25-188-1-124, 25-188-1-125
Serial No.	25-188-1-126, 25-188-1-127, 25-188-1-128, 25-188-1-129, 25-188-1-130
Serial No.	25-188-1-131, 25-188-1-132, 25-188-1-133, 25-188-1-134, 25-188-1-135
Serial No.	25-188-1-136, 25-188-1-137, 25-188-1-138, 25-188-1-139, 25-188-1-140
Serial No.	25-188-1-141, 25-188-1-142, 25-188-1-143, 25-188-1-144, 25-188-1-145
Serial No.	25-188-1-146, 25-188-1-147, 25-188-1-148, 25-188-1-149, 25-188-1-150
Serial No.	25-188-1-151, 25-188-1-152, 25-188-1-153, 25-188-1-154, 25-188-1-155
Serial No.	25-188-1-156, 25-188-1-157, 25-188-1-158, 25-188-1-159, 25-188-1-160
Serial No.	25-188-1-161, 25-188-1-162, 25-188-1-163, 25-188-1-164, 25-188-1-165
Serial No.	25-188-1-166, 25-188-1-167, 25-188-1-168, 25-188-1-169, 25-188-1-170
Serial No.	25-188-1-171, 25-188-1-172, 25-188-1-173, 25-188-1-174, 25-188-1-175
Serial No.	25-188-1-176, 25-188-1-177, 25-188-1-178, 25-188-1-179, 25-188-1-180
Serial No.	25-188-1-181, 25-188-1-182, 25-188-1-183, 25-188-1-184, 25-188-1-185
Serial No.	25-188-1-186, 25-188-1-187, 25-188-1-188, 25-188-1-189, 25-188-1-190
Serial No.	25-188-1-191, 25-188-1-192, 25-188-1-193, 25-188-1-194, 25-188-1-195
Serial No.	25-188-1-196, 25-188-1-197, 25-188-1-198, 25-188-1-199, 25-188-1-200
Serial No.	25-188-1-201, 25-188-1-202, 25-188-1-203, 25-188-1-204, 25-188-1-205
Serial No.	25-188-1-206, 25-188-1-207, 25-188-1-208, 25-188-1-209, 25-188-1-210
	CERT ENVELOPE

COUNTRY OF ORIGIN: USA

The materials, processes, and workmanship all conform to the requirements of all applicable specifications, drawings, and the purchase order supplied to Craig Godwin, Inc. dba. The appropriate documentation providing traceability is on file at Craig Godwin, Inc. dba. It is available for review by authorized customer representatives.

Anthony Bennett

Authorized Signature
Craig Godwin, Inc. dba

UMW PO 25-188

Craig Godwin, Inc. dba

EST
1972

United Machine Works

Certificate of Conformance

To: SUMMIT PRECAST CONCRETE, LP
9930 INDUSTRIAL DR
Navasota, TX 77868
USA

From: United Machine Works
P O Box 525
New Waverly, TX 77358
USA

Packing List No: 146058
Shipping Date: 08/06/2025
Today's Date: 08/06/2025
PO Number: 25-188

CERTIFICATION DOCUMENTS

PO Line No.	Number	Revision	Description	Job No.	Unit	Shipped	Ordered	Back Ordered
1	250548 TTI LOOP CONN		END LOOPS HDG	73592	EA	210	210	0
	Serial No.	25-188-1-1, 25-188-1-2, 25-188-1-3, 25-188-1-4, 25-188-1-5						
	Serial No.	25-188-1-6, 25-188-1-7, 25-188-1-8, 25-188-1-9, 25-188-1-10						
	Serial No.	25-188-1-11, 25-188-1-12, 25-188-1-13, 25-188-1-14, 25-188-1-15						
	Serial No.	25-188-1-16, 25-188-1-17, 25-188-1-18, 25-188-1-19, 25-188-1-20						
	Serial No.	25-188-1-21, 25-188-1-22, 25-188-1-23, 25-188-1-24, 25-188-1-25						
	Serial No.	25-188-1-26, 25-188-1-27, 25-188-1-28, 25-188-1-29, 25-188-1-30						
	Serial No.	25-188-1-31, 25-188-1-32, 25-188-1-33, 25-188-1-34, 25-188-1-35						
	Serial No.	25-188-1-36, 25-188-1-37, 25-188-1-38, 25-188-1-39, 25-188-1-40						
	Serial No.	25-188-1-41, 25-188-1-42, 25-188-1-43, 25-188-1-44, 25-188-1-45						
	Serial No.	25-188-1-46, 25-188-1-47, 25-188-1-48, 25-188-1-49, 25-188-1-50						
	Serial No.	25-188-1-51, 25-188-1-52, 25-188-1-53, 25-188-1-54, 25-188-1-55						
	Serial No.	25-188-1-56, 25-188-1-57, 25-188-1-58, 25-188-1-59, 25-188-1-60						
	Serial No.	25-188-1-61, 25-188-1-62, 25-188-1-63, 25-188-1-64, 25-188-1-65						
	Serial No.	25-188-1-66, 25-188-1-67, 25-188-1-68, 25-188-1-69, 25-188-1-70						

Sales Order No. 185017

www.portlandbolt.com
sales@portlandbolt.com

Date	6/24/2025
Salesperson	Dan Karpan
Email	dan@portlandbolt.com
Phone	800.599.0538

PB Northwest
800.547.6758
3441 NW Guam St.
Portland, OR 97210

PB Southeast
800.631.2076
890 W Five Notch Rd.
North Augusta, SC 29860

PB Northeast
833.701.4125
12 Elbridge St.
Jordan, NY 13080

Sold To
936.701.1977
SUMMIT PRECAST CONCRETE
15349 SUMMIT PARK DR.
SUITE 101
MONTGOMERY, TX 77356

Ship To
SUMMIT PRECAST CONCRETE
9930 Industrial Drive
Navasota, TX 77868

Attention	Terms	Customer PO
Toby<toby@summitprecast.com>	Full Payment Before shipping	Credit Card

Ship Date (scheduled)	Delivery	Certs
7/30/2025	Best Way (Prepaid)	Emailed Mill Test Reports

Comments

No.	Qty	UOM	Description
1	34	EA	1 X 29 galv. A449 [OR] barrier pin with 2" ring
2	0	EA	FREIGHT CHARGES

Total Weight (lbs.) 236.66

Page: 1 of 1

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
PLAINFIELD 14636 S DEPOT DRIVE PLAINFIELD,IL 60544 USA	R L PERLOW CORPORATION 14636 S DEPOT DRIVE PLAINFIELD,IL 60544-7709 USA	4140HR2	Round Bar / 1"	0001220752

LENGTH	WEIGHT	HEAT / BATCH
21'06"	6,659 LB	**58064340/06**

SALES ORDER	CUSTOMER MATERIAL N°
14613390/000010	A1.0004140GAS A

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
P5454	1327-0000615677	03/01/2025

SPECIFICATION / DATE or REVISION
ASTM A29-23
ASTM A304-20
ASTM A322-18

COMMENTS / NOTES

Meets or exceeds SAE J422: S-5, O-5

Gerdau's steel is 100% recyclable. Support the circular economy through our Metals Recycling Partnership. For details, visit www2.gerdau.com/metals-recycling, or contact metalsrecycling@gerdau.com.

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau's possession. For all products other than billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) and produced (Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

WADE LUMPKINS
QUALITY ASSURANCE MGR.
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

18173 2858375

CERTIFIED MATERIAL TEST REPORT

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
PLAINFIELD 14636 S DEPOT DRIVE PLAINFIELD,IL 60544 USA	R L PERLOW CORPORATION 14636 S DEPOT DRIVE PLAINFIELD,IL 60544-7709 USA	4140HR2	Round Bar / 1"	0001220752

LENGTH	WEIGHT	HEAT / BATCH
21'06"	6,659 LB	**58064340**/06

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
14613390/000010	A1.0004140GAS A	ASTM A29-23 ASTM A304-20 ASTM A322-18

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
P5454	1327-0000615677	03/01/2025

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	Ti (%)	B (%)
0.41	0.88	0.009	0.028	0.24	0.30	0.09	0.92	0.228	0.008	0.028	0.000	0.001	0.003	0.0000

GEOMETRIC CHARACTERISTICS

R:R
53.8

METALURGICAL CHARACTERISTICS

FineGr	E381 S	E381 R	E381-C
OK	1	1	1

HARDENABILITY

DI A255 (Inches)	J1 (HRC)	J2 (HRC)	J3 (HRC)	J4 (HRC)	J5 (HRC)	J6 (HRC)	J7 (HRC)	J8 (HRC)	J9 (HRC)	J10 (HRC)	J12 (HRC)	J14 (HRC)
6.02	56	56	56	56	56	56	56	56	56	56	53	51

HARDENABILITY

J16 (HRC)	J18 (HRC)	J20 (HRC)	J24 (HRC)	J28 (HRC)	J32 (HRC)
50	50	49	46	45	42

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau's possession. For all products other than billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) and produced (Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was Melted & Poured (via Electric Arc Furnace and Continuous Caster) in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Wade A. L.
WADE LUMPKINS
QUALITY ASSURANCE MGR.
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

FOR	SUMMIT PRECAST CONCRETE
PB INVOICE	185017
CUSTOMER PO	Credit Card
SHIP DATE	07/29/2025

Certificate of Conformance

We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.

1 X 29 GALV. A449 [OR] BARRIER PIN WITH 2" RING

HEAT	58064340	BASE STEEL	4140AR	DIAMETER	1.000	SOURCE	PERLOW STEEL CORP	
C	CR	CU	MN	MO	NI	P	S	SI
0.410	0.920	0.300	0.880	0.228	0.090	0.009	0.028	0.240

Coatings

- ASTM F2329 and A153 cl.C Hot Dip Galvanizing

Certification Department Quality Assurance
Dane McKinnon

APPENDIX E.

MASH TEST 3-10 (CRASH TEST 620281-01-1)

E.1. VEHICLE PROPERTIES AND INFORMATION

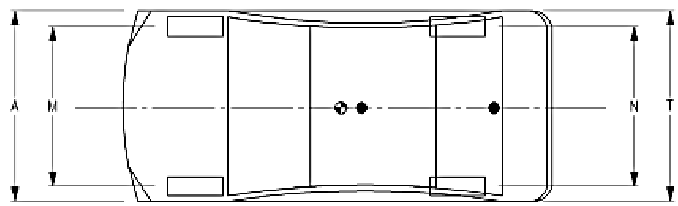
Date: 2025-10-16 Test No.: 620281-01-1 VIN No.: 3N1CN7AP2JL818260

Year: 2018 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 46,373 Tire Size: P185/65R15

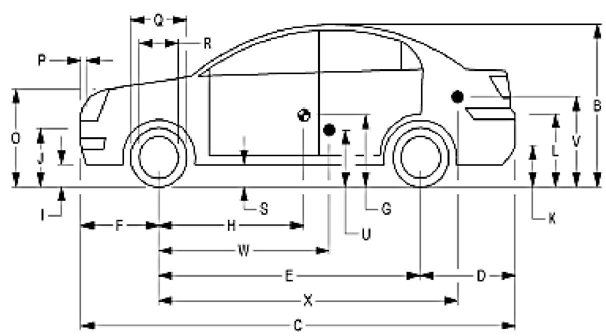
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.



NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position:

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	41.60	M	58.30	R	16.25	W	
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -41.60

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1434	1455	
Back	1687	M_{rear}	988	998	
Total	3389	M_{Total}	2422	2453	0

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 735 RF: 720 LR: 510 RR: 488

Figure E.1. Vehicle Properties for Test 620281-01-1.

Date:	2025-10-16	Test No.:	620281-01-1	VIN No.:	3N1CN7AP2JL81826
Year:	2018	Make:	Nissan	Model:	Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	**Side Damage**
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	AFB	9	19	14							-21
1	AFB	21	12	48							88
	Measurements recorded										
	☑ inches or ☐ mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

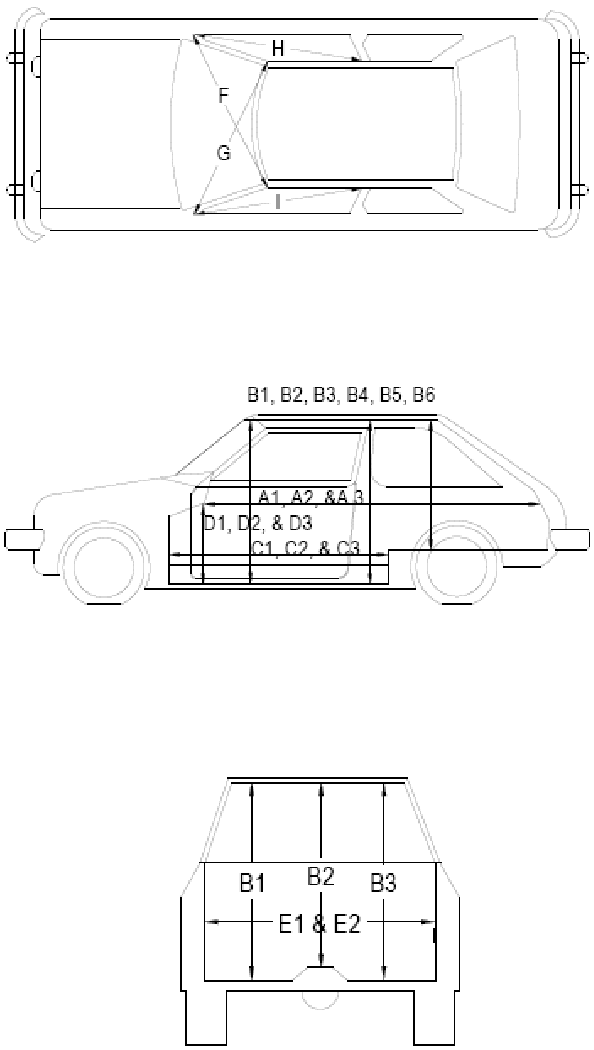
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure E.2. Exterior Crush Measurements for Test 620281-01-1.

Date:	2025-10-16	Test No.:	620281-01-1	VIN No.:	3N1CN7AP2JL81826
Year:	2018	Make:	Nissan	Model:	Versa



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	24.50	-1.50
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.00	-0.50
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.50	0.00
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	49.50	-1.50

*Lateral area across the cab from driver's side kick panel to passenger's side kick panel.

Figure E.3. Occupant Compartment Measurements for Test 620281-01-1.

E.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

Figure E.4. Sequential Photographs for Test 620281-01-1 (Overhead Views).

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

Figure E.5. Sequential Photographs for Test 620281-01-1 (Downstream In-line Views).

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

Figure E.6. Sequential Photographs for Test 620281-01-1 (Upstream Field Side Oblique Views).

E.3. VEHICLE ACCELERATIONS

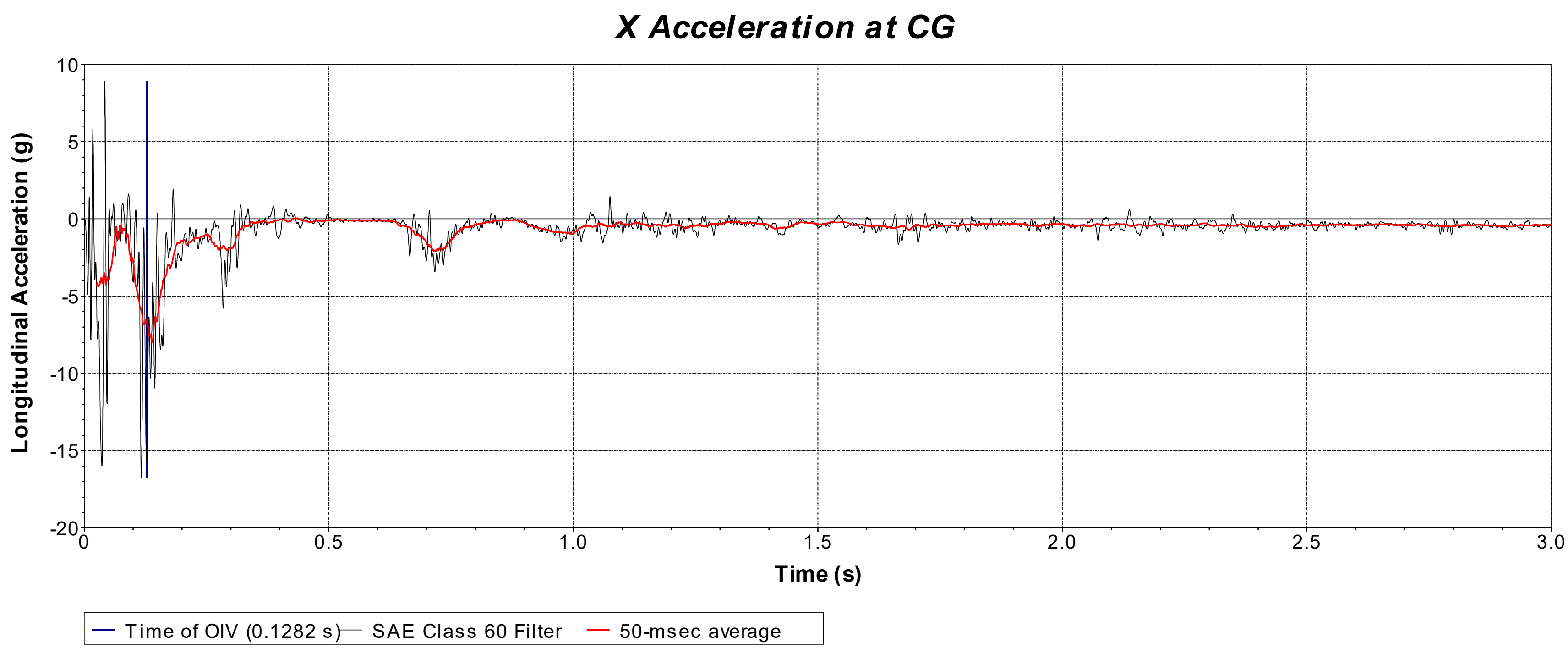


Figure E.7. Vehicle Longitudinal Accelerometer Trace for Test 620281-01-1 (Accelerometer Located at Center of Gravity).

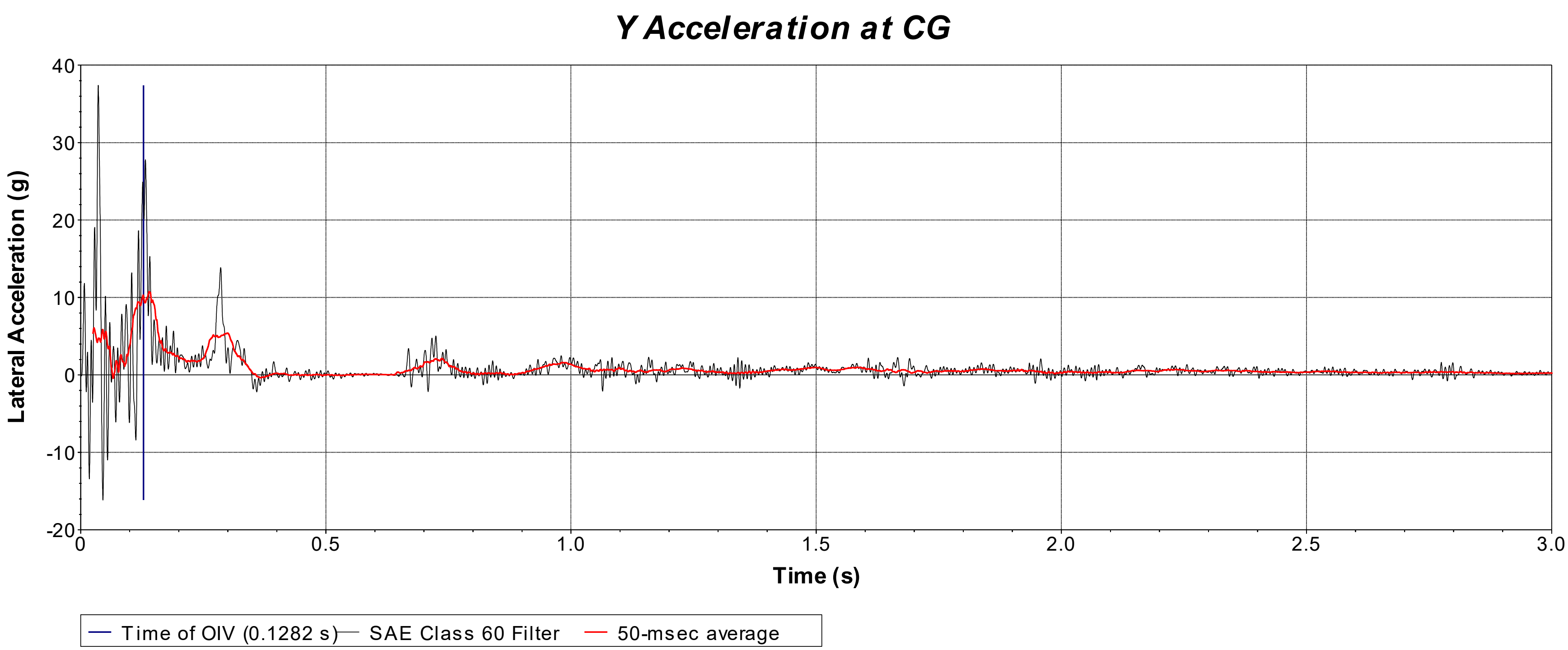


Figure E.8. Vehicle Lateral Accelerometer Trace for Test 620281-01-1 (Accelerometer Located at Center of Gravity).

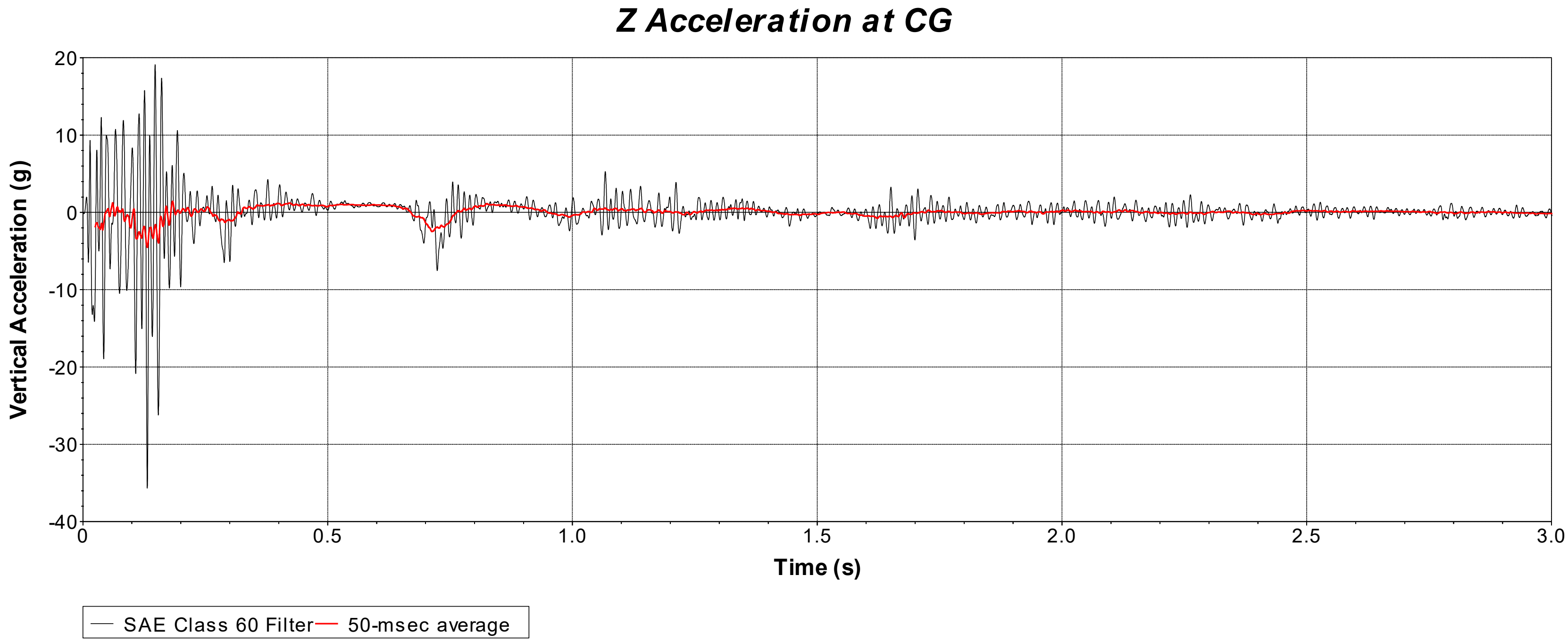


Figure E.9. Vehicle Vertical Accelerometer Trace for Test 620281-01-1 (Accelerometer Located at Center of Gravity).

APPENDIX F.

MASH TEST 3-11 (CRASH TEST 620281-01-2)

F.1. VEHICLE PROPERTIES AND INFORMATION

Date:	2025-10-23	Test No.:	620281-01-2	VIN No.:	1C6RR6FT2K5745736
Year:	2019	Make:	RAM	Model:	1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 133,830

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

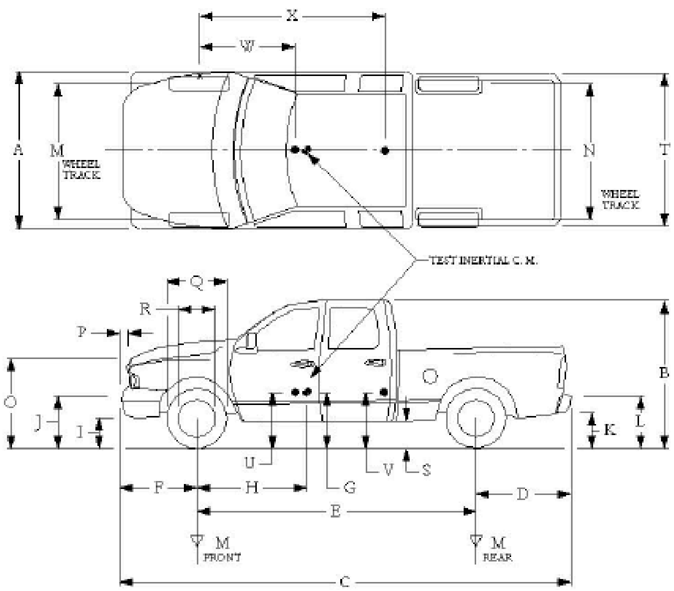
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.75	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.40	M	68.50	R	18.00	W	0.00
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2921	2839	
Back	3900	M_{rear}	2051	2205	
Total	6700	M_{Total}	4972	5044	5209

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1459 RF: 1380 LR: 1080 RR: 1125

Figure F.1. Vehicle Properties for Test 620281-01-2.

Date:	2025-10-23	Test No.:	620281-01-2	VIN No.:	1C6RR6FT2K5745736
Year:	2019	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AFB	30	25	27							-17
1	AFB	34	18	60							-71
	Measurements recorded										
	☑ inches or ☐ mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

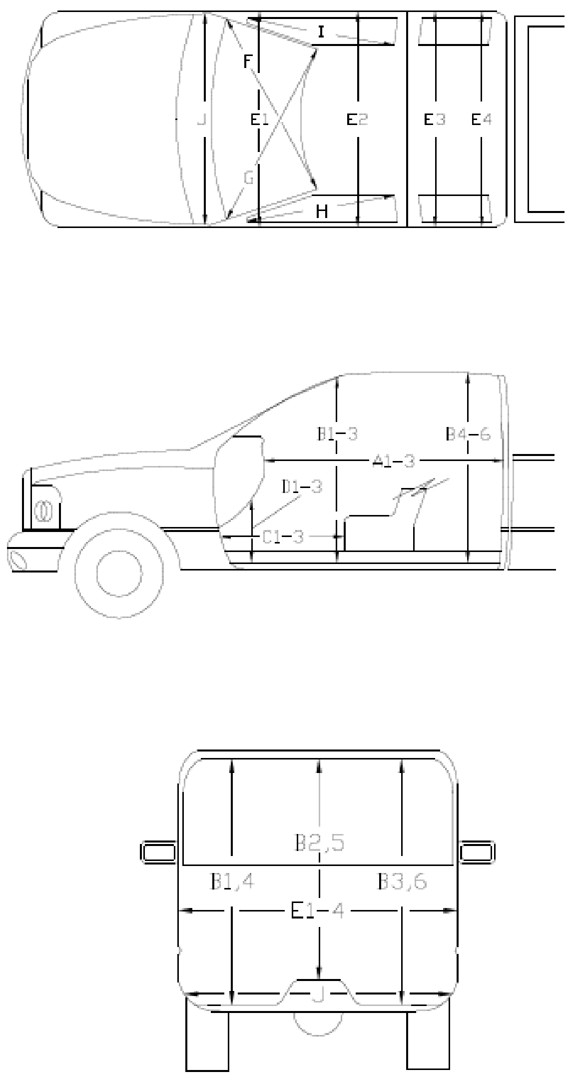
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure F.2. Exterior Crush Measurements for Test 620281-01-2.

Date:	2025-10-23	Test No.:	620281-01-2	VIN No.:	1C6RR6FT2K5745736
Year:	2019	Make:	RAM	Model:	1500



*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	23.00	-3.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	64.75	1.25
E3	63.50	63.50	0.00
E4	63.50	66.00	2.50
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	24.50	-0.50

Figure F.3. Occupant Compartment Measurements for Test 620281-01-2.

F.2. SEQUENTIAL PHOTOGRAPHS


(a) 0.000 s | (b) 0.1000 s


(c) 0.2000 s | (d) 0.3000 s

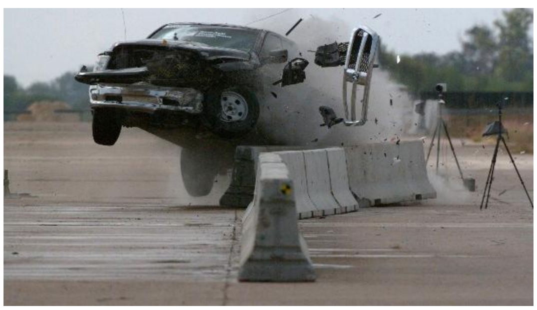

(e) 0.4000 s | (f) 0.5000 s


(g) 0.6000 s | (h) 0.7000 s

Figure F.4. Sequential Photographs for Test 620281-01-2 (Overhead Views).


(a) 0.000 s (b) 0.1000 s


(c) 0.2000 s (d) 0.3000 s




(e) 0.4000 s (f) 0.5000 s


(g) 0.6000 s (h) 0.7000 s

Figure F.5. Sequential Photographs for Test 620281-01-2 (Downstream In-line Views).

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

Figure F.6. Sequential Photographs for Test 620281-01-2 (Upstream Field Side Oblique Views).

F.3. VEHICLE ACCELERATIONS

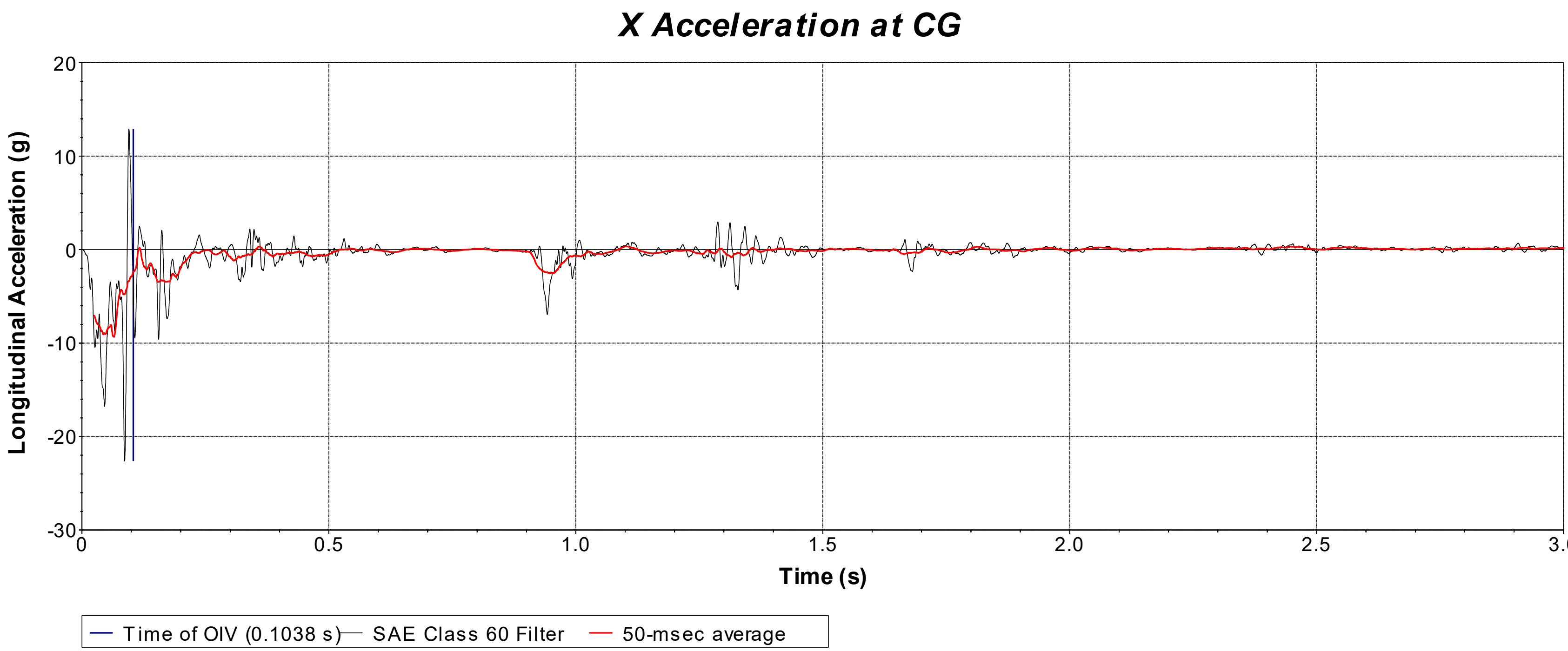


Figure F.7. Vehicle Longitudinal Accelerometer Trace for Test 620281-01-2 (Accelerometer Located at Center of Gravity).

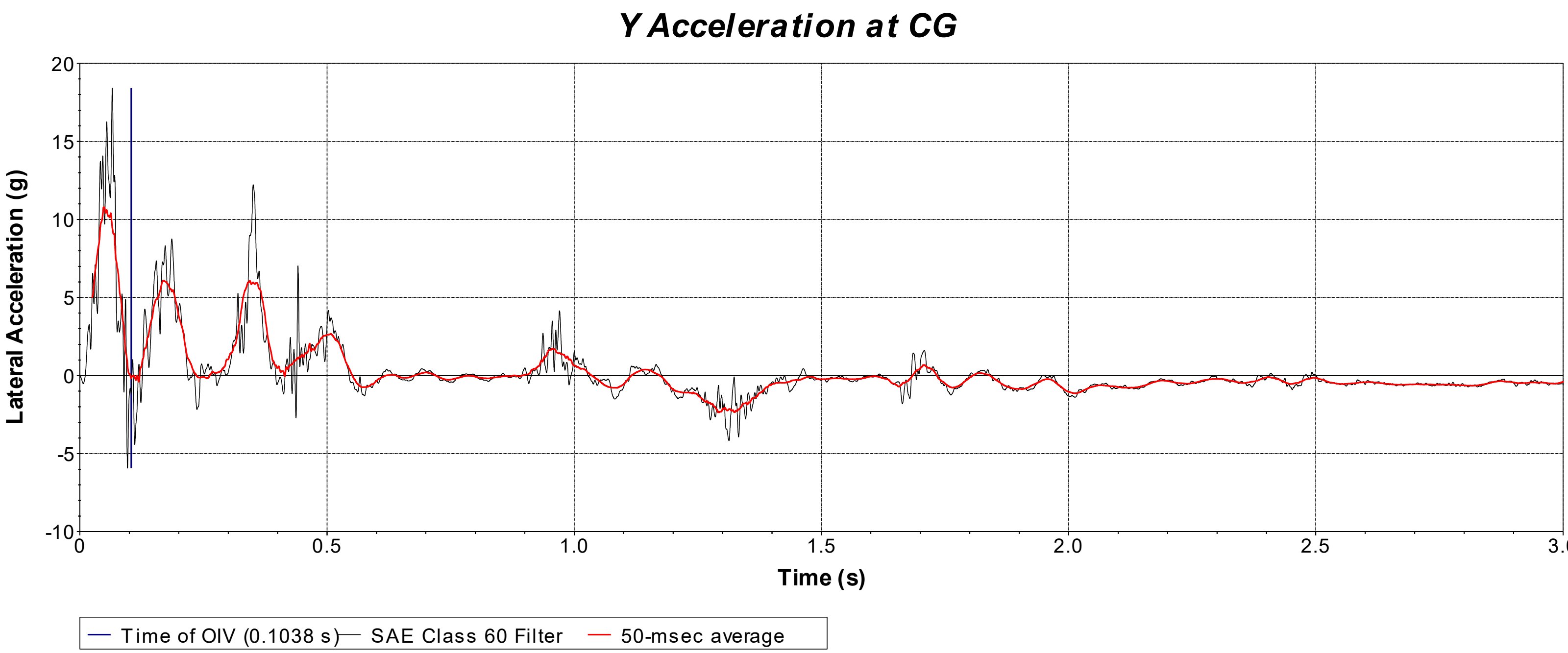


Figure F.8. Vehicle Lateral Accelerometer Trace for Test 620281-01-2 (Accelerometer Located at Center of Gravity).

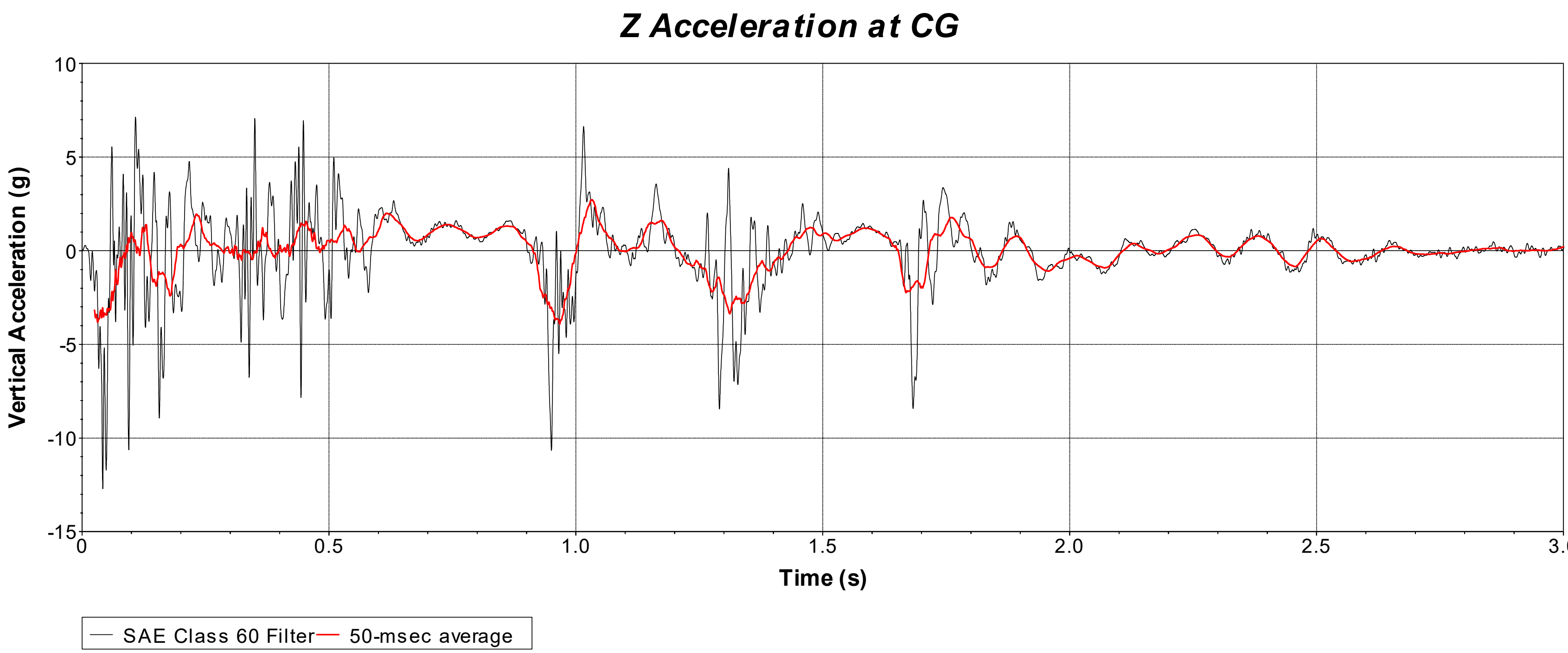


Figure F.9. Vehicle Vertical Accelerometer Trace for Test 620281-01-2 (Accelerometer Located at Center of Gravity).

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