NCHRP Project 22-35

Evaluation of Bridge Rail Systems to Confirm AASHTO MASH Compliance

Appendices A–H

Appendices A–H are supplemental to *NCHRP Research Report 1024: Evaluation of Bridge Rail Systems to Confirm AASHTO MASH Compliance* (NCHRP Project 22-35). The full report can be found by searching for the report title on the National Academies Press website (nap.nationalacademies.org).

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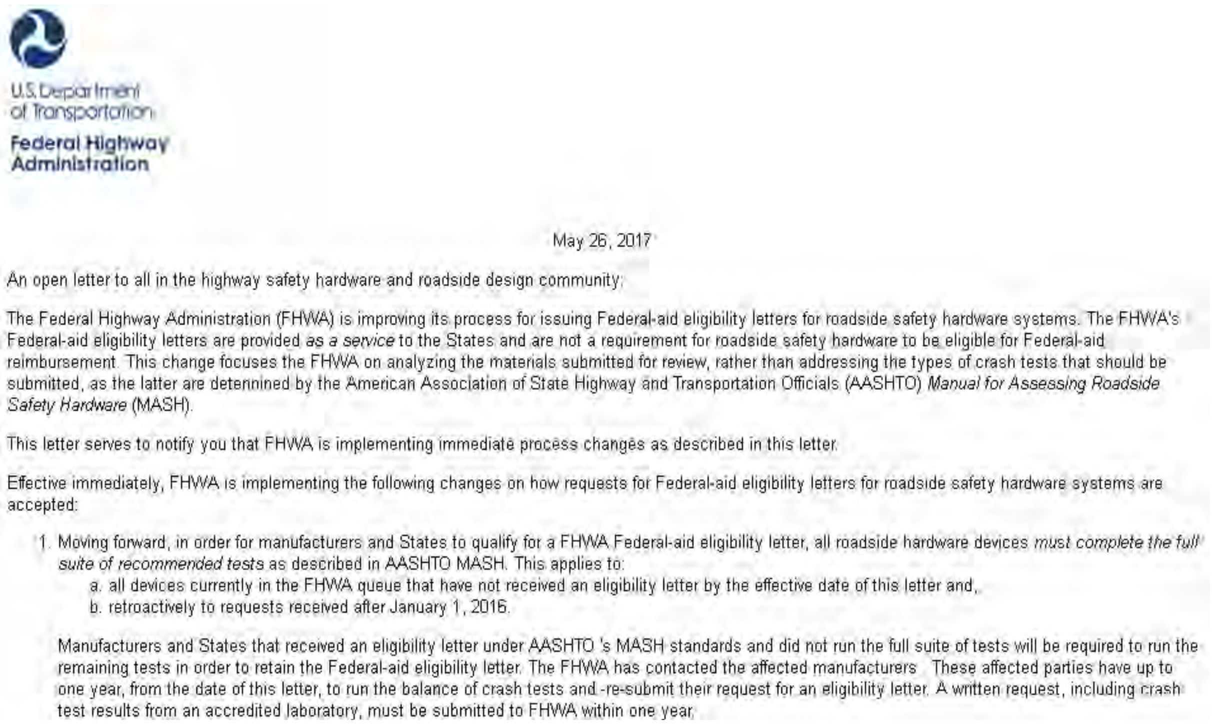
APPENDIX A

FHWA OPEN LETTER



U.S. Department of Transportation
Federal Highway Administration

May 26, 2017

An open letter to all in the highway safety hardware and roadside design community:

The Federal Highway Administration (FHWA) is improving its process for issuing Federal-aid eligibility letters for roadside safety hardware systems. The FHWA's Federal-aid eligibility letters are provided *as a service* to the States and are not a requirement for roadside safety hardware to be eligible for Federal-aid reimbursement. This change focuses the FHWA on analyzing the materials submitted for review, rather than addressing the types of crash tests that should be submitted, as the latter are detennined by the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Roadside Safety Hardware* (MASH).

This letter serves to notify you that FHWA is implementing immediate process changes as described in this letter.

Effective immediately, FHWA is implementing the following changes on how requests for Federal-aid eligibility letters for roadside safety hardware systems are accepted:

1. Moving forward, in order for manufacturers and States to qualify for a FHWA Federal-aid eligibility letter, all roadside hardware devices *must complete the full suite of recommended tests* as described in AASHTO MASH. This applies to:
    a. all devices currently in the FHWA queue that have not received an eligibility letter by the effective date of this letter and,
    b. retroactively to requests received after January 1, 2016.

   Manufacturers and States that received an eligibility letter under AASHTO 's MASH standards and did not run the full suite of tests will be required to run the remaining tests in order to retain the Federal-aid eligibility letter. The FHWA has contacted the affected manufacturers. These affected parties have up to one year, from the date of this letter, to run the balance of crash tests and re-submit their request for an eligibility letter. A written request, including crash test results from an accredited laboratory, must be submitted to FHWA within one year.

   The retroactive date of January 1, 2016, corresponds to the official implementation date balloted by AASHTO and the date FHWA began issuing Federal-aid eligibility letters using standards from AASHTO 's MASH only, i.e., when FHWA ceased issuing eligibility letters using National Cooperative Highway Research Program (NCHRP) Report 350 guidance.

2. FHWA will no longer provide Federal-aid eligibility letters for modifications made to an AASHTO MASH-crash tested device. Manufacturers who have submitted requests for eligibility letters based on modifications have been notified .

These changes are based on several important factors. The transition from guidance in the NCHRP Report 350 to standards in the AASHTO MASH continues per the FHWA– AASHTO Implementation Agreement balloted by AASHTO. Since its official launch, questions about the AASHTO MASH criteria have been identified by a range of stakeholders. Until such time these questions are answered and the transportation community has more experience with AASHTO MASH requirements, FHWA will require manufacturers and States to run all AASHTO MASH recommended crash tests in order to qualify for a FHWA Federal-aid eligibility letter.

This is a prudent action to support highway safety for the traveling public. This opportunity for improvement and consistency was noted in the Government Accountability Office's (GAO) final report dated June 2016, "Highway Safety: More Robust DOT Oversight of Guardrails and Other Roadside Hardware Could Further Enhance Safety, " GA0-16-575 and Evaluation of the Roadside Safety Hardware Process – Prepared for the FHWA's Office of Policy by the John A. Volpe National Transportation Systems Center.

The changes promote efficiency of Federal resources while advancing our Federal role to support public safety and ensuring that decision-making is at the State and local level.

The FHWA will address the initial "entry" of a device into the possibility for Federal-aid reimbursement , through examining crash testing, but the final decisions on selection and modifications to devices will be at the State and local level.

States and manufacturers will now have an outstanding opportunity to collaborate and deploy manufacturers' innovative modifications in a timely manner and/or respond to State-specific needs requiring significant and non-significant modifications - without the need of another Federal-aid eligibility letter from FHWA.

APPENDIX B

PRELIMINARY EVALUATION OF AASHTO GEOMETRICS

KEY DIMENSIONS OF BRIDGE RAIL SYSTEMS

With this information gathered for the various dimensions, the configurations for the bridge rail systems were determined. In order to distinguish the various bridge rail configurations, the following naming convention was used:

- CPB-SP = Concrete Post-and-Beam Snag Potential
- CPB-PS = Concrete Post-and-Beam Post Setback
- MPBD-SP = Metal Post-and-Beam Deck-Mounted Snag Potential
- MPBD-PS = Metal Post-and-Beam Deck-Mounted Post Setback
- MPBC-SP = Metal Post-and-Beam Curb-Mounted Snag Potential
- MPBC-PS = Metal Post-and-Beam Curb-Mounted Post Setback
- MPBP-SP = Metal Post-and-Beam Parapet-Mounted Snag Potential
- MPBP-PS = Metal Post-and-Beam Parapet-Mounted Post Setback

Table B.1 shows the concrete post-and-beam systems that were used to evaluate the snag potential figure geometric relationships, and Table B.2 shows the concrete post-and-beam systems that were used to evaluate the post setback figure geometric relationships.

Table B.1. Concrete post-and-beam systems evaluated for snag potential cases.

Snag Potential Cases				
	Post Setback Distance (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)
CPB-SP-System01	1.25	13	0.606	33
CPB-SP-System02	2	13	0.552	29
CPB-SP-System03	3	13	0.552	29
CPB-SP-System04	4.25	13	0.552	29
CPB-SP-System05	4.75	14	0.517	29
CPB-SP-System06	5.25	15	0.483	29
CPB-SP-System07	6	15	0.483	29
CPB-SP-System08	1.25	10.75	0.629	29
CPB-SP-System09	2	11.25	0.612	29
CPB-SP-System10	3	12	0.586	29
CPB-SP-System11	4.25	12	0.586	29
CPB-SP-System12	4.75	12	0.586	29
CPB-SP-System13	5.25	12	0.586	29
CPB-SP-System14	6	12	0.586	29

Table B.2. Concrete post-and-beam systems evaluated for post setback cases.

Post Setback Cases				
	Post Setback Distance (in.)	**Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**
CPB-PS-System01	1.25	13	0.606	33
CPB-PS-System02	2	13	0.552	29
CPB-PS-System03	2.5	13	0.552	29
CPB-PS-System04	3	13	0.552	29
CPB-PS-System05	3.5	13	0.552	29
CPB-PS-System06	4	13	0.552	29
CPB-PS-System07	2.5	6.5	0.803	33
CPB-PS-System08	3	9	0.727	33
CPB-PS-System09	3.5	11	0.667	33
CPB-PS-System10	4	11.5	0.603	29
CPB-PS-System11	4.5	13	0.552	29
CPB-PS-System12	5	14.5	0.500	29

Table B.3 shows the deck-mounted metal post-and-beam systems that were used to evaluate the snag potential figure geometric relationships, and Table B.4 shows the deck-mounted metal post-and-beam systems that were used to evaluate the post setback figure geometric relationships.

Table B.3. Deck-mounted metal post-and-beam systems evaluated for snag potential cases.

Snag Potential Cases								
	Post Setback Distance (in.)	Total Clear Opening (in.)	First Vertical Clear Opening (in.)	Second Vertical Clear Opening (in.)	First Rail Size	Second Rail Size	Ratio of Contact Width to Height	Height (in.)
MPBD-SP-System01	3	18	13	5	HSS6x3x1/4	HSS6x3x1/4	0.400	30
MPBD-SP-System02	4	21	13	8	HSS5x4x1/4	HSS5x4x1/4	0.323	31
MPBD-SP-System03	4.5	21	13.5	7.5	HSS4x4.5x1.4	HSS5x4.5x1/4	0.300	30
MPBD-SP-System04	5	23	14.5	8.5	HSS4x5x1/4	HSS5x5x1/4	0.281	32
MPBD-SP-System05	6	22	15	7	HSS4x6x1/4	HSS4x6x1/4	0.267	30
MPBD-SP-System06	7	23	15	8	HSS4x7x1/4	HSS4x7x1/4	0.258	31
MPBD-SP-System07	3	18	12	6	HSS6x3x1/4	HSS6x3x1/4	0.400	30
MPBD-SP-System08	4	21	12	9	HSS5x4x1/4	HSS5x4x1/4	0.323	31
MPBD-SP-System09	4.5	21	12	9	HSS4x4.5x1.4	HSS5x4.5x1/4	0.300	30
MPBD-SP-System10	5	23	12	11	HSS4x5x1/4	HSS5x5x1/4	0.281	32
MPBD-SP-System11	6	22	12	10	HSS4x6x1/4	HSS4x6x1/4	0.267	30
MPBD-SP-System12	7	23	12	11	HSS4x7x1/4	HSS4x7x1/4	0.258	31

Table B.4. Deck-mounted metal post-and-beam systems evaluated for post setback cases.

Post Setback Cases								
	Post Setback Distance (in.)	Total Clear Opening (in.)	First Vertical Clear Opening (in.)	Second Vertical Clear Opening (in.)	First Rail Size	Second Rail Size	Ratio of Contact Width to Height	Height (in.)
MPBD-PS-System01	3	18	13	5	HSS6x3x1/4	HSS6x3x1/4	0.400	30
MPBD-PS-System02	4	21	13	8	HSS5x4x1/4	HSS5x4x1/4	0.323	31
MPBD-PS-System03	4.5	21	13.5	7.5	HSS4x4.5x1.4	HSS5x4.5x1/4	0.300	30
MPBD-PS-System04	5	23	14.5	8.5	HSS4x5x1/4	HSS5x5x1/4	0.281	32
MPBD-PS-System05	6	22	15	7	HSS4x6x1/4	HSS4x6x1/4	0.267	30
MPBD-PS-System06	7	23	15	8	HSS4x7x1/4	HSS4x7x1/4	0.258	31
MPBD-PS-System07	3	8	4	4	HSS11x3x1/4	HSS11x3x1/4	0.733	30
MPBD-PS-System08	4	12	6	6	HSS9x4x1/4	HSS9x4x1/4	0.600	30
MPBD-PS-System09	4.5	14	7	7	HSS8x4.5x1/4	HSS9x4.5x1/4	0.548	31
MPBD-PS-System10	5	15	8	7	HSS7x5x1/4	HSS8x5x1/4	0.500	30
MPBD-PS-System11	6	16	8	8	HSS7x6x1/4	HSS7x6x1/4	0.467	30
MPBD-PS-System 12	7	17	9	8	HSS6x7x1/4	HSS7x7x1/4	0.433	30

Table B.5 shows the curb-mounted metal post-and-beam systems that were used to evaluate the snag potential figure geometric relationships, and Table B.6 shows the curb-mounted metal post-and-beam systems that were used to evaluate the post setback figure geometric relationships.

Table B.5. Curb-mounted metal post-and-beam systems evaluated for snag potential cases.

Snag Potential Cases								
	Post Setback Distance (in.)	Total Clear Opening (in.)	First Vertical Clear Opening (in.)	Second Vertical Clear Opening (in.)	First Rail Size	Second Rail Size	Ratio of Contact Width to Height	Height (in.)
MPBC-SP-System01	3	18	13	5	HSS3x3x1/4	HSS3x3x1/4	0.400	30
MPBC-SP-System02	4	21	13	8	HSS2x4x1/4	HSS2x4x1/4	0.323	31
MPBC-SP-System03	5	23	14.5	8.5	HSS2x5x1/4	HSS2x5x1/4	0.303	33
MPBC-SP-System04	6	22	15	7	HSS2x6x1/4	HSS2x6x1/4	0.313	32
MPBC-SP-System05	7	23	15	8	HSS2x7x1/4	HSS2x7x1/4	0.303	33
MPBC-SP-System06	8	23	15	8	HSS2x8x1/4	HSS2x8x1/4	0.303	33
MPBC-SP-System07	3	18	12	6	HSS3x3x1/4	HSS3x3x1/4	0.400	30
MPBC-SP-System08	4	21	12	9	HSS2x4x1/4	HSS2x4x1/4	0.323	31
MPBC-SP-System09	5	23	12	11	HSS2x5x1/4	HSS2x5x1/4	0.303	33
MPBC-SP-System10	6	22	12	10	HSS2x6x1/4	HSS2x6x1/4	0.313	32
MPBC-SP-System11	7	23	12	11	HSS2x7x1/4	HSS2x7x1/4	0.303	33
MPBC-SP-System12	8	23	12	11	HSS2x8x1/4	HSS2x8x1/4	0.303	33

Table B.6. Curb-mounted metal post-and-beam systems evaluated for post setback cases.

Post Setback Cases								
	Post Setback Distance (in.)	Total Clear Opening (in.)	First Vertical Clear Opening (in.)	Second Vertical Clear Opening (in.)	First Rail Size	Second Rail Size	Ratio of Contact Width to Height	Height (in.)
MPBC-PS-System01	3	18	13	5	HSS3x3x1/4	HSS3x3x1/4	0.400	30
MPBC-PS-System02	4	21	13	8	HSS2x4x1/4	HSS2x4x1/4	0.323	31
MPBC-PS-System03	5	26	14.5	11.5	HSS2x5x1/4	HSS2x5x1/4	0.278	36
MPBC-PS-System04	6	27	15	12	HSS2x6x1/4	HSS2x6x1/4	0.270	37
MPBC-PS-System05	7	28	15	13	HSS2x7x1/4	HSS2x7x1/4	0.263	38
MPBC-PS-System06	8	29	15	14	HSS2x8x1/4	HSS2x8x1/4	0.256	39
MPBC-PS-System07	3	8	4	4	HSS8x3x1/4	HSS8x3x1/4	0.733	30
MPBC-PS-System08	4	12	6	6	HSS6x4x1/4	HSS6x4x1/4	0.600	30
MPBC-PS-System09	5	15	8	7	HSS4x5x1/4	HSS5x5x1/4	0.500	30
MPBC-PS-System10	6	16	8	8	HSS4x6x1/4	HSS4x6x1/4	0.467	30
MPBC-PS-System11	7	17	9	8	HSS3x7x1/4	HSS4x7x1/4	0.433	30
MPBC-PS-System12	8	17	9	8	HSS3x8x1/4	HSS4x8x1/4	0.433	30

Table B.7 shows the parapet-mounted metal post-and-beam systems that were used to evaluate the snag potential figure geometric relationships, and Table B.8 shows the parapet-mounted metal post-and-beam systems that were used to evaluate the post setback figure geometric relationships.

Table B.7. Parapet-mounted metal post-and-beam systems evaluated for snag potential cases.

Snag Potential Cases								
	Post Setback Distance (in.)	Total Clear Opening (in.)	First Vertical Clear Opening (in.)	Second Vertical Clear Opening (in.)	First Rail Size	Second Rail Size	Ratio of Contact Width to Height	Height (in.)
MPBP-SP-System01	3	13	13	-	HSS2x3x1/4	-	0.606	33
MPBP-SP-System02	4	13	13	-	HSS2x4x1/4	-	0.606	33
MPBP-SP-System03	5	14.5	14.5	-	HSS2x5x1/4	-	0.580	34.5
MPBP-SP-System04	6	15	15	-	HSS2x6x1/4	-	0.571	35
MPBP-SP-System05	7	15	15	-	HSS2x7x1/4	-	0.571	35
MPBP-SP-System06	8	15	15	-	HSS2x8x1/4	-	0.571	35
MPBP-SP-System07	3	12	12	-	HSS2x3x1/4	-	0.625	32
MPBP-SP-System08	4	12	12	-	HSS2x4x1/4	-	0.625	32
MPBP-SP-System09	5	12	12	-	HSS2x5x1/4	-	0.625	32
MPBP-SP-System10	6	12	12	-	HSS2x6x1/4	-	0.625	32
MPBP-SP-System11	7	12	12	-	HSS2x7x1/4	-	0.625	32
MPBP-SP-System12	8	12	12	-	HSS2x8x1/4	-	0.625	32

Table B.8. Parapet-mounted metal post-and-beam systems evaluated for post setback cases.

Post Setback Potential Cases								
	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**First Vertical Clear Opening (in.)**	**Second Vertical Clear Opening (in.)**	**First Rail Size**	**Second Rail Size**	**Ratio of Contact Width to Height**	**Height (in.)**
MPBP-PS-System01	2	20	10	10	HSS2x2x1/4	HSS2x2x1/4	0.524	42
MPBP-PS-System02	3	26	13	13	HSS2x3x1/4	HSS2x3x1/4	0.458	48
MPBP-PS-System03	4	26	13	13	HSS2x4x1/4	HSS2x4x1/4	0.458	48
MPBP-PS-System04	5	29	14.5	14.5	HSS2x5x1/4	HSS2x5x1/4	0.431	51
MPBP-PS-System05	6	30	15	15	HSS2x6x1/4	HSS2x6x1/4	0.423	52
MPBP-PS-System06	7	30	15	15	HSS2x7x1/4	HSS2x7x1/4	0.423	52
MPBP-PS-System07	3	13	7	6	HSS7x3x1/4	HSS8x3x1/4	0.717	46
MPBP-PS-System08	4	18	9	9	HSS5x4x1/4	HSS5x4x1/4	0.609	46
MPBP-PS-System09	5	23	12	11	HSS2x5x1/4	HSS3x5x1/4	0.500	46
MPBP-PS-System10	6	26	13	13	HSS2x6x1/4	HSS2x6x1/4	0.458	48
MPBP-PS-System11	7	28	14	14	HSS2x7x1/4	HSS2x7x1/4	0.440	50
MPBP-PS-System12	8	30	15	15	HSS2x8x1/4	HSS2x8x1/4	0.423	52

OCCUPANT RISK RESULTS

Tables B.9–B.12 present the FE computer simulation results for the concrete post-and-beam systems.

Tables B.13–B.16 present the FE computer simulation results for the deck-mounted metal post-and-beam systems.

Tables B.17–B.20 present the FE computer simulation results for the curb-mounted metal post-and-beam systems.

Tables B.21–B.24 present the FE computer simulation results for the parapet-mounted metal post-and-beam systems.

Table B.9. Concrete post-and-beam results for snag potential cases (Test 3-10).

	Post Setback Distance (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height(in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
					x-dir	**y-dir**	**x-dir**	**y-dir**		
CPB-SP-System01	1.25	13	0.6061	33	9.3	-8.2	-8.0	10.3	**Yes**	**No**
CPB-SP-System02	2	13	0.5517	29	9.4	-8.2	-5.5	7.7	**Yes**	**No**
CPB-SP-System03	3	13	0.5517	29	9.1	-8.9	-4.7	6.0	**Yes**	**No**
CPB-SP-System04	4.25	13	0.5517	29	8.3	-9.0	-4.2	10.6	**Yes**	**Yes**
CPB-SP-System05	4.75	14	0.5172	29	10.2	-8.9	-7.4	-4.8	**Yes**	**No**
CPB-SP-System06	5.25	15	0.4828	29	11.1	-7.9	-3.7	3.5	**Yes**	**No**
CPB-SP-System07	6	15	0.4828	29	10.0	-8.5	-4.1	4.4	**Yes**	**No**
CPB-SP-System08	1.25	10.75	0.6293	29	8.1	-9.2	-3.2	9.5	**Yes**	**No**
CPB-SP-System09	2	11.25	0.6121	29	8.9	-9.0	-4.6	-3.7	**Yes**	**Yes**
CPB-SP-System10	3	12	0.5862	29	8.1	-9.2	-2.3	9.2	**Yes**	**No**
CPB-SP-System11	4.25	12	0.5862	29	8.1	-9.6	3.0	9.5	**Yes**	**No**
CPB-SP-System12	4.75	12	0.5862	29	8.6	-9.1	-2.7	9.4	**Yes**	**No**
CPB-SP-System13	5.25	12	0.5862	29	6.4	-9.5	-3.7	14.5	**Yes**	**No**
CPB-SP-System14	6	12	0.5862	29	7.0	-9.6	-2.6	14.4	**Yes**	**No**

Table B.10. Concrete post-and-beam results for post setback cases (Test 3-10).

	Post Setback Distance (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
					x-dir	**y-dir**	**x-dir**	**y-dir**		
CPB-PS-System01	1.25	13	0.6061	33	9.3	-8.2	-8.0	10.3	**Yes**	**No**
CPB-PS-System02	2	13	0.5517	29	9.4	-8.2	-5.5	7.7	**Yes**	**No**
CPB-PS-System03	2.5	13	0.5517	29	9.4	-8.3	-6.0	5.6	**Yes**	**No**
CPB-PS-System04	3	13	0.5517	29	9.1	-8.9	-4.7	6.0	**Yes**	**No**
CPB-PS-System05	3.5	13	0.5517	29	8.6	-9.0	-3.3	8.1	**Yes**	**Yes**
CPB-PS-System06	4	13	0.5517	29	8.6	-9.0	-3.8	7.7	**Yes**	**Yes**
CPB-PS-System07	2.5	6.5	0.8030	33	5.4	-9.8	-3.0	20.7	**No**	**No**
CPB-PS-System08	3	9	0.7273	33	5.8	-9.8	-2.8	16.9	**Yes**	**No**
CPB-PS-System09	3.5	11	0.6667	33	6.2	-9.6	-4.6	14.2	**Yes**	**No**
CPB-PS-System10	4	11.5	0.6034	29	7.3	-9.6	-2.9	13.2	**Yes**	**No**
CPB-PS-System11	4.5	13	0.5517	29	8.9	-9.2	-3.4	8.6	**Yes**	**No**
CPB-PS-System12	5	14.5	0.5000	29	9.4	-8.6	-4.9	3.8	**Yes**	**No**

Table B.11. Concrete post-and-beam results for snag potential cases (Test 3-11).

	Post Setback Distance (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
					x-dir	y-dir	x-dir	y-dir		
CPB-SP-System01	1.25	13	0.6061	33	5.9	-7.5	-5.0	15.4	**Yes**	**No**
CPB-SP-System02	2	13	0.5517	29	5.4	-7.6	-5.3	12.5	**Yes**	**Yes**
CPB-SP-System03	3	13	0.5517	29	5.3	-7.6	-4.2	12.5	**Yes**	**Yes**
CPB-SP-System04	4.25	13	0.5517	29	5.2	-7.7	-5.6	12.5	**Yes**	**Yes**
CPB-SP-System05	4.75	14	0.5172	29	5.4	-7.6	-4.8	13.7	**Yes**	**Yes**
CPB-SP-System06	5.25	15	0.4828	29	5.4	-7.4	-7.2	11.4	**Yes**	**Yes**
CPB-SP-System07	6	15	0.4828	29	5.3	-7.5	-4.9	13.8	**Yes**	**Yes**
CPB-SP-System08	1.25	10.75	0.6293	29	5.0	-7.7	-5.1	16.6	**Yes**	**No**
CPB-SP-System09	2	11.25	0.6121	29	4.8	-7.5	4.7	14.7	**Yes**	**Yes**
CPB-SP-System10	3	12	0.5862	29	4.9	-7.5	-5.2	14.1	**Yes**	**Yes**
CPB-SP-System11	4.25	12	0.5862	29	4.9	-7.4	-4.4	14.8	**Yes**	**Yes**
CPB-SP-System12	4.75	12	0.5862	29	4.8	-7.5	4.6	15.6	**Yes**	**No**
CPB-SP-System13	5.25	12	0.5862	29	4.5	-7.4	-4.6	14.0	**Yes**	**Yes**
CPB-SP-System14	6	12	0.5862	29	4.5	-7.5	-5.2	15.3	**Yes**	**No**

Table B.12. Concrete post-and-beam results for post setback cases (Test 3-11).

	Post Setback Distance (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
					x-dir	y-dir	x-dir	y-dir		
CPB-PS-System01	1.25	13	0.6061	33	5.9	-7.5	-5.0	15.4	**Yes**	**No**
CPB-PS-System02	2	13	0.5517	29	5.4	-7.6	-5.3	12.5	**Yes**	**Yes**
CPB-PS-System03	2.5	13	0.5517	29	5.3	-7.6	-5.7	12.6	**Yes**	**Yes**
CPB-PS-System04	3	13	0.5517	29	5.3	-7.6	-4.2	12.5	**Yes**	**Yes**
CPB-PS-System05	3.5	13	0.5517	29	5.2	-7.6	-5.2	12.1	**Yes**	**Yes**
CPB-PS-System06	4	13	0.5517	29	5.1	-7.6	-6.5	13.1	**Yes**	**Yes**
CPB-PS-System07	2.5	6.5	0.8030	33	4.6	-7.5	4.3	17.2	**Yes**	**No**
CPB-PS-System08	3	9	0.7273	33	4.6	-7.5	-5.1	17.2	**Yes**	**No**
CPB-PS-System09	3.5	11	0.6667	33	4.9	-7.5	-4.6	16.4	**Yes**	**No**
CPB-PS-System10	4	11.5	0.6034	29	4.8	-7.5	5.8	15.8	**Yes**	**No**
CPB-PS-System11	4.5	13	0.5517	29	5.1	-7.7	-4.9	12.9	**Yes**	**Yes**
CPB-PS-System12	5	14.5	0.5000	29	5.5	-7.5	-4.8	12.5	**Yes**	**Yes**

Table B.13. Deck-mounted metal post-and-beam results for snag potential cases (Test 3-10).

	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**1st Vertical Clear Opening (in.)**	**2nd Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**	**OIV (m/s)**		**RDA (g's)**		**Pass OIV/RDA Max Limits?**	**Pass OIV/RDA Preferred Limits?**
							x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBD-SP-System01	3	18	13	5	0.4000	30	8.3	-9.4	-7.7	12.0	**Yes**	**No**
MPBD-SP-System02	4	21	13	8	0.3226	31	7.7	-9.6	-6.0	12.8	**Yes**	**No**
MPBD-SP-System03	4.5	21	13.5	7.5	0.3000	30	7.1	-9.4	-3.6	11.7	**Yes**	**No**
MPBD-SP-System04	5	23	14.5	8.5	0.2813	32	9.3	-7.5	-12.4	22.7	**No**	**No**
MPBD-SP-System05	6	22	15	7	0.2667	30	9.0	-7.9	-10.3	15.9	**Yes**	**No**
MPBD-SP-System06	7	23	15	8	0.2581	31	8.2	-8.8	-8.0	7.9	**Yes**	**Yes**
MPBD-SP-System07	3	18	12	6	0.4000	30	6.3	-9.5	-4.5	14.6	**Yes**	**No**
MPBD-SP-System08	4	21	12	9	0.3226	31	6.8	-9.5	-3.1	14.3	**Yes**	**No**
MPBD-SP-System09	4.5	21	12	9	0.3000	30	7.0	-9.3	-3.2	13.1	**Yes**	**No**
MPBD-SP-System10	5	23	12	11	0.2813	32	7.1	-9.4	-3.8	14.0	**Yes**	**No**
MPBD-SP-System11	6	22	12	10	0.2667	30	6.9	-9.3	-3.2	12.3	**Yes**	**No**
MPBD-SP-System12	7	23	12	11	0.2581	31	6.9	-9.4	-4.9	13.2	**Yes**	**No**

Table B.14. Deck-mounted metal post-and-beam results for post setback cases (Test 3-10).

	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**1st Vertical Clear Opening (in.)**	**2nd Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**	**OIV (m/s)**		**RDA (g's)**		**Pass OIV/RDA Max Limits?**	**Pass OIV/RDA Preferred Limits?**
							x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBD-PS-System01	3	18	13	5	0.4000	30	8.3	-9.4	-7.7	12.0	**Yes**	**No**
MPBD-PS-System02	4	21	13	8	0.3226	31	7.7	-9.6	-6.0	12.8	**Yes**	**No**
MPBD-PS-System03	4.5	21	13.5	7.5	0.3000	30	7.1	-9.4	-3.6	11.7	**Yes**	**No**
MPBD-PS-System04	5	23	14.5	8.5	0.2813	32	9.3	-7.5	-12.4	22.7	**No**	**No**
MPBD-PS-System05	6	22	15	7	0.2667	30	9.0	-7.9	-10.3	15.9	**Yes**	**No**
MPBD-PS-System06	7	23	15	8	0.2581	31	8.2	-8.8	-8.0	7.9	**Yes**	**Yes**
MPBD-PS-System07	3	8	4	4	0.7333	30	5.4	-9.7	-3.2	18.6	**Yes**	**No**
MPBD-PS-System08	4	12	6	6	0.6000	30	5.7	-9.6	-3.4	17.2	**Yes**	**No**
MPBD-PS-System09	4.5	14	7	7	0.5484	31	5.8	-9.7	-4.4	16.3	**Yes**	**No**
MPBD-PS-System10	5	15	8	7	0.5000	30	5.9	-9.6	-4.3	16.0	**Yes**	**No**
MPBD-PS-System11	6	16	8	8	0.4667	30	6.1	-9.6	-4.4	14.6	**Yes**	**No**
MPBD-PS-System12	7	17	9	8	0.4333	30	5.9	-9.6	-4.7	14.2	**Yes**	**No**

Table B.15. Deck-mounted metal post-and-beam results for snag potential cases (Test 3-11).

	Post Setback Distance (in.)	Total Clear Opening (in.)	1st Vertical Clear Opening (in.)	2nd Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
							x-dir	y-dir	x-dir	y-dir		
MPBD-SP-System01	3	18	13	5	0.4000	30	5.6	-7.0	-4.0	12.3	**Yes**	**Yes**
MPBD-SP-System02	4	21	13	8	0.3226	31	5.8	-7.1	-4.4	12.9	**Yes**	**Yes**
MPBD-SP-System03	4.5	21	13.5	7.5	0.3000	30	5.5	-7.2	-4.3	11.9	**Yes**	**Yes**
MPBD-SP-System04	5	23	14.5	8.5	0.2813	32	7.6	-6.9	-3.9	7.9	**Yes**	**Yes**
MPBD-SP-System05	6	22	15	7	0.2667	30	5.8	-7.4	7.4	11.6	**Yes**	**Yes**
MPBD-SP-System06	7	23	15	8	0.2581	31	5.6	-7.4	-7.4	11.6	**Yes**	**Yes**
MPBD-SP-System07	3	18	12	6	0.4000	30	4.9	-7.1	-5.1	14.5	**Yes**	**Yes**
MPBD-SP-System08	4	21	12	9	0.3226	31	5.8	-7.0	-3.6	12.3	**Yes**	**Yes**
MPBD-SP-System09	4.5	21	12	9	0.3000	30	5.8	-6.9	-4.8	12.3	**Yes**	**Yes**
MPBD-SP-System10	5	23	12	11	0.2813	32	7.2	-6.8	-4.5	6.9	**Yes**	**Yes**
MPBD-SP-System11	6	22	12	10	0.2667	30	5.9	-7.0	-4.0	13.1	**Yes**	**Yes**
MPBD-SP-System12	7	23	12	11	0.2581	31	6.2	-7.1	-7.0	11.5	**Yes**	**Yes**

Table B.16. Deck-mounted metal post-and-beam results for post setback cases (Test 3-11).

	Post Setback Distance (in.)	Total Clear Opening (in.)	1st Vertical Clear Opening (in.)	2nd Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
							x-dir	y-dir	x-dir	y-dir		
MPBD-PS-System01	3	18	13	5	0.4000	30	5.6	-7.0	-4.0	12.3	**Yes**	**Yes**
MPBD-PS-System02	4	21	13	8	0.3226	31	5.8	-7.1	-4.4	12.9	**Yes**	**Yes**
MPBD-PS-System03	4.5	21	13.5	7.5	0.3000	30	5.5	-7.2	-4.3	11.9	**Yes**	**Yes**
MPBD-PS-System04	5	23	14.5	8.5	0.2813	32	7.6	-6.9	-3.9	7.9	**Yes**	**Yes**
MPBD-PS-System05	6	22	15	7	0.2667	30	5.8	-7.4	7.4	11.6	**Yes**	**Yes**
MPBD-PS-System06	7	23	15	8	0.2581	31	5.6	-7.4	-7.4	11.6	**Yes**	**Yes**
MPBD-PS-System07	3	8	4	4	0.7333	30	4.2	-7.0	5.4	17.4	**Yes**	**No**
MPBD-PS-System08	4	12	6	6	0.6000	30	4.3	-7.1	-6.1	17.0	**Yes**	**No**
MPBD-PS-System09	4.5	14	7	7	0.5484	31	4.7	-7.2	4.7	16.0	**Yes**	**No**
MPBD-PS-System10	5	15	8	7	0.5000	30	4.8	-7.0	5.2	14.1	**Yes**	**Yes**
MPBD-PS-System11	6	16	8	8	0.4667	30	4.9	-7.2	-4.7	13.4	**Yes**	**Yes**
MPBD-PS-System12	7	17	9	8	0.4333	30	4.9	-7.2	4.4	13.6	**Yes**	**Yes**

Table B.17. Curb-mounted metal post-and-beam results for snag potential cases (Test 3-10).

	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**1st Vertical Clear Opening (in.)**	**2nd Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**	**OIV (m/s)**		**RDA (g's)**		**Pass OIV/RDA Max Limits?**	**Pass OIV/RDA Preferred Limits?**
							x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBC-SP-System01	3	18	13	5	0.4000	30	12.1	-7.5	-10.0	-12.5	**Yes**	**No**
MPBC-SP-System02	4	21	13	8	0.3226	31	11.7	-7.4	-13.2	26.1	**No**	**No**
MPBC-SP-System03	5	23	14.5	8.5	0.3030	33	12.3	-5.9	-11.9	13.3	**No**	**No**
MPBC-SP-System04	6	22	15	7	0.3125	32	11.7	-6.4	-13.5	13.0	**Yes**	**No**
MPBC-SP-System05	7	23	15	8	0.3030	33	11.3	-6.9	-12.5	18.8	**Yes**	**No**
MPBC-SP-System06	8	23	15	8	0.3030	33	10.5	-6.7	-15.5	19.9	**Yes**	**No**
MPBC-SP-System07	3	18	12	6	0.4000	30	10.4	-9.4	-11.9	-11.7	**Yes**	**No**
MPBC-SP-System08	4	21	12	9	0.3226	31	8.3	-9.1	-11.7	9.4	**Yes**	**Yes**
MPBC-SP-System09	5	23	12	11	0.3030	33	8.7	-9.3	-9.8	8.7	**Yes**	**No**
MPBC-SP-System10	6	22	12	10	0.3125	32	7.4	-8.9	-7.4	10.7	**Yes**	**Yes**
MPBC-SP-System11	7	23	12	11	0.3030	33	7.2	-9.1	-3.2	10.3	**Yes**	**Yes**
MPBC-SP-System12	8	23	12	11	0.3030	33	7.1	-9.2	-2.8	11.2	**Yes**	**No**

Table B.18. Curb-mounted metal post-and-beam results for post setback cases (Test 3-10).

	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**1st Vertical Clear Opening (in.)**	**2nd Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**	**OIV (m/s)**		**RDA (g's)**		**Pass OIV/RDA Max Limits?**	**Pass OIV/RDA Preferred Limits?**
							x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBC-PS-System01	3	18	13	5	0.4000	30	12.1	-7.5	-10.0	-12.5	**Yes**	**No**
MPBC-PS-System02	4	21	13	8	0.3226	31	11.7	-7.4	-13.2	26.1	**No**	**No**
MPBC-PS-System03	5	26	14.5	11.5	0.2778	36	12.7	-6.1	-13.7	19.5	**No**	**No**
MPBC-PS-System04	6	27	15	12	0.2703	37	13.5	-6.4	-23.9	-14.2	**No**	**No**
MPBC-PS-System05	7	28	15	13	0.2632	38	12.7	-6.4	-19.1	-10.4	**No**	**No**
MPBC-PS-System06	8	29	15	14	0.2564	39	11.1	-7.0	-14.2	20.6	**No**	**No**
MPBC-PS-System07	3	8	4	4	0.7333	30	5.8	-9.7	-4.0	15.7	**Yes**	**No**
MPBC-PS-System08	4	12	6	6	0.6000	30	6.3	-9.5	-3.4	14.6	**Yes**	**No**
MPBC-PS-System09	5	15	8	7	0.5000	30	7.2	-9.5	-2.8	11.0	**Yes**	**No**
MPBC-PS-System10	6	16	8	8	0.4667	30	6.4	-9.7	-3.8	14.7	**Yes**	**No**
MPBC-PS-System11	7	17	9	8	0.4333	30	6.8	-9.6	-3.2	13.3	**Yes**	**No**
MPBC-PS-System12	8	17	9	8	0.4333	30	6.5	-9.6	-4.6	13.4	**Yes**	**No**

Table B.19. Curb-mounted metal post-and-beam results for snag potential cases (Test 3-11).

	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**1st Vertical Clear Opening (in.)**	**2nd Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**	**OIV (m/s)**		**RDA (g's)**		**Pass OIV/RDA Max Limits?**	**Pass OIV/RDA Preferred Limits?**
							x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBC-SP-System01	3	18	13	5	0.4000	30	7.0	-6.8	5.5	10.2	**Yes**	**Yes**
MPBC-SP-System02	4	21	13	8	0.3226	31	9.0	-6.8	-5.6	6.5	**Yes**	**Yes**
MPBC-SP-System03	5	23	14.5	8.5	0.3030	33	9.8	-6.5	-5.9	6.3	**Yes**	**No**
MPBC-SP-System04	6	22	15	7	0.3125	32	6.3	-7.5	-6.1	12.5	**Yes**	**Yes**
MPBC-SP-System05	7	23	15	8	0.3030	33	7.0	-7.4	-5.7	12.2	**Yes**	**Yes**
MPBC-SP-System06	8	23	15	8	0.3030	33	6.1	-7.5	-6.8	11.8	**Yes**	**Yes**
MPBC-SP-System07	3	18	12	6	0.4000	30	8.7	-6.7	-4.6	7.6	**Yes**	**Yes**
MPBC-SP-System08	4	21	12	9	0.3226	31	8.1	-6.9	-4.2	7.5	**Yes**	**Yes**
MPBC-SP-System09	5	23	12	11	0.3030	33	8.4	-7.0	-5.8	7.2	**Yes**	**Yes**
MPBC-SP-System10	6	22	12	10	0.3125	32	8.1	-6.8	-9.2	6.3	**Yes**	**Yes**
MPBC-SP-System11	7	23	12	11	0.3030	33	8.1	-6.6	-5.1	7.2	**Yes**	**Yes**
MPBC-SP-System12	8	23	12	11	0.3030	33	7.9	-6.5	-4.0	8.6	**Yes**	**Yes**

Table B.20. Curb-mounted metal post-and-beam results for post setback cases (Test 3-11).

	Post Setback Distance (in.)	**Total Clear Opening (in.)**	**1st Vertical Clear Opening (in.)**	**2nd Vertical Clear Opening (in.)**	**Ratio of Contact Width to Height**	**Height (in.)**	**OIV (m/s)**		**RDA (g's)**		**Pass OIV/RDA Max Limits?**	**Pass OIV/RDA Preferred Limits?**
							x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBC-PS-System01	3	18	13	5	0.4000	30	7.0	-6.8	5.5	10.2	**Yes**	**Yes**
MPBC-PS-System02	4	21	13	8	0.3226	31	9.0	-6.8	-5.6	6.5	**Yes**	**Yes**
MPBC-PS-System03	5	26	14.5	11.5	0.2778	36	9.3	-7.0	-5.8	7.2	**Yes**	**No**
MPBC-PS-System04	6	27	15	12	0.2703	37	7.1	-7.5	5.5	15.5	**Yes**	**No**
MPBC-PS-System05	7	28	15	13	0.2632	38	7.3	-7.4	-6.1	15.0	**Yes**	**No**
MPBC-PS-System06	8	29	15	14	0.2564	39	7.1	-7.4	-6.0	16.3	**Yes**	**No**
MPBC-PS-System07	3	8	4	4	0.7333	30	4.5	-7.0	-5.2	16.8	**Yes**	**No**
MPBC-PS-System08	4	12	6	6	0.6000	30	5.0	-6.9	-5.0	13.8	**Yes**	**Yes**
MPBC-PS-System09	5	15	8	7	0.5000	30	5.3	-7.1	-5.0	13.5	**Yes**	**Yes**
MPBC-PS-System10	6	16	8	8	0.4667	30	5.3	-7.2	-4.0	12.7	**Yes**	**Yes**
MPBC-PS-System11	7	17	9	8	0.4333	30	5.3	-7.2	-5.5	12.7	**Yes**	**Yes**
MPBC-PS-System12	8	17	9	8	0.4333	30	5.3	-7.2	-5.0	11.9	**Yes**	**Yes**

Table B.21. Parapet-mounted metal post-and-beam results for snag potential cases (Test 3-10).

	Post Setback Distance (in.)	Total Clear Opening (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
						x-dir	y-dir	x-dir	y-dir		
MPBP-SP-System01	3	13	13	0.6061	33	6.7	-9.5	-3.6	16.0	**Yes**	**No**
MPBP-SP-System02	4	13	13	0.6061	33	6.0	-9.6	-3.9	16.4	**Yes**	**No**
MPBP-SP-System03	5	14.5	14.5	0.5797	34.5	6.1	-9.5	-3.6	15.6	**Yes**	**No**
MPBP-SP-System04	6	15	15	0.5714	35	5.9	-9.5	-4.8	16.7	**Yes**	**No**
MPBP-SP-System05	7	15	15	0.5714	35	5.9	-9.5	-4.9	15.7	**Yes**	**No**
MPBP-SP-System06	8	15	15	0.5714	35	5.8	-9.7	-3.6	16.6	**Yes**	**No**
MPBP-SP-System07	3	12	12	0.6250	32	6.1	-9.7	-6.0	15.1	**Yes**	**No**
MPBP-SP-System08	4	12	12	0.6250	32	5.8	-9.7	-4.2	16.1	**Yes**	**No**
MPBP-SP-System09	5	12	12	0.6250	32	5.8	-9.7	-3.8	16.2	**Yes**	**No**
MPBP-SP-System10	6	12	12	0.6250	32	5.5	-9.7	-4.1	18.0	**Yes**	**No**
MPBP-SP-System11	7	12	12	0.6250	32	5.4	-9.7	-2.8	18.3	**Yes**	**No**
MPBP-SP-System12	8	12	12	0.6250	32	5.6	-9.8	-3.7	16.7	**Yes**	**No**

Table B.22. Parapet-mounted metal post-and-beam results for post setback cases (Test 3-10).

	Post Setback Distance (in.)	Total Clear Opening (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
						x-dir	y-dir	x-dir	y-dir		
MPBP-PS-System01	2	20	10	0.5238	42	8.1	-8.9	-8.1	6.2	**Yes**	**Yes**
MPBP-PS-System02	3	26	13	0.4583	48	6.5	-9.6	-3.9	15.8	**Yes**	**No**
MPBP-PS-System03	4	26	13	0.4583	48	6.1	-9.6	-7.2	16.5	**Yes**	**No**
MPBP-PS-System04	5	29	14.5	0.4314	51	6.0	-9.5	-3.4	15.3	**Yes**	**No**
MPBP-PS-System05	6	30	15	0.4231	52	6.0	-9.5	-4.6	16.4	**Yes**	**No**
MPBP-PS-System06	7	30	15	0.4231	52	5.9	-9.5	-5.4	15.8	**Yes**	**No**
MPBP-PS-System07	3	13	7	0.7174	46	5.4	-9.7	-3.6	19.0	**Yes**	**No**
MPBP-PS-System08	4	18	9	0.6087	46	5.6	-9.8	-3.5	18.1	**Yes**	**No**
MPBP-PS-System09	5	23	12	0.5000	46	5.9	-9.6	-4.2	16.4	**Yes**	**No**
MPBP-PS-System10	6	26	13	0.4583	48	6.0	-9.6	-3.8	16.5	**Yes**	**No**
MPBP-PS-System11	7	28	14	0.4400	50	5.7	-9.6	-3.6	16.6	**Yes**	**No**
MPBP-PS-System12	8	30	15	0.4231	52	5.7	-9.7	-4.7	18.3	**Yes**	**No**

Table B.23. Parapet-mounted metal post-and-beam results for snag potential cases (Test 3-11).

	Post Setback Distance (in.)	Total Clear Opening (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
						x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBP-SP-System01	3	13	13	0.6061	33	7.4	-7.3	-3.6	10.2	**Yes**	**Yes**
MPBP-SP-System02	4	13	13	0.6061	33	8.1	-6.9	-7.1	4.5	**Yes**	**Yes**
MPBP-SP-System03	5	14.5	14.5	0.5797	34.5	8.5	-7.2	-6.4	5.5	**Yes**	**Yes**
MPBP-SP-System04	6	15	15	0.5714	35	6.8	-7.4	-5.0	13.8	**Yes**	**Yes**
MPBP-SP-System05	7	15	15	0.5714	35	6.9	-7.5	-7.7	14.0	**Yes**	**Yes**
MPBP-SP-System06	8	15	15	0.5714	35	6.6	-7.4	7.3	13.4	**Yes**	**Yes**
MPBP-SP-System07	3	12	12	0.6250	32	8.6	-6.9	-5.3	6.5	**Yes**	**Yes**
MPBP-SP-System08	4	12	12	0.6250	32	8.4	-7.1	-5.0	5.5	**Yes**	**Yes**
MPBP-SP-System09	5	12	12	0.6250	32	6.9	-7.2	-6.4	9.5	**Yes**	**Yes**
MPBP-SP-System10	6	12	12	0.6250	32	7.6	-7.1	-5.0	6.9	**Yes**	**Yes**
MPBP-SP-System11	7	12	12	0.6250	32	6.9	-7.1	-4.1	8.3	**Yes**	**Yes**
MPBP-SP-System12	8	12	12	0.6250	32	6.6	-7.4	-6.0	10.6	**Yes**	**Yes**

Table B.24. Parapet-mounted metal post-and-beam results for post setback cases (Test 3-11).

	Post Setback Distance (in.)	Total Clear Opening (in.)	Vertical Clear Opening (in.)	Ratio of Contact Width to Height	Height (in.)	OIV (m/s)		RDA (g's)		Pass OIV/RDA Max Limits?	Pass OIV/RDA Preferred Limits?
						x-dir	**y-dir**	**x-dir**	**y-dir**		
MPBP-PS-System01	2	20	10	0.5238	42	7.4	-7.4	-5.7	11.7	**Yes**	**Yes**
MPBP-PS-System02	3	26	13	0.4583	48	8.7	-6.7	-6.7	6.7	**Yes**	**Yes**
MPBP-PS-System03	4	26	13	0.4583	48	7.3	-7.5	-4.8	12.4	**Yes**	**Yes**
MPBP-PS-System04	5	29	14.5	0.4314	51	7.9	-7.0	-7.7	7.9	**Yes**	**Yes**
MPBP-PS-System05	6	30	15	0.4231	52	8.4	-7.2	-10.0	5.9	**Yes**	**Yes**
MPBP-PS-System06	7	30	15	0.4231	52	8.4	-7.2	-8.5	8.2	**Yes**	**Yes**
MPBP-PS-System07	3	13	7	0.7174	46	5.4	-7.6	-4.4	18.9	**Yes**	**No**
MPBP-PS-System08	4	18	9	0.6087	46	5.6	-7.6	-5.2	16.5	**Yes**	**No**
MPBP-PS-System09	5	23	12	0.5000	46	6.7	-7.6	8.0	13.1	**Yes**	**Yes**
MPBP-PS-System10	6	26	13	0.4583	48	7.5	-7.2	-8.5	9.8	**Yes**	**Yes**
MPBP-PS-System11	7	28	14	0.4400	50	7.9	-7.1	-9.9	6.4	**Yes**	**Yes**
MPBP-PS-System12	8	30	15	0.4231	52	7.6	-7.6	-5.8	6.8	**Yes**	**Yes**

APPENDIX C

DETAILED EVALUATION OF THE KANSAS CORRAL 32-IN. WITHOUT CURB

DETAILED MODELING OF THE KANSAS CORRAL 32-IN. RAILING

The Kansas Corral barrier system is a concrete post-and-beam bridge rail system anchored to the edge of a concrete bridge deck overhang. One type of the Kansas Corral railing is the 32-in. cast-in-place concrete railing from the Commonwealth of Virginia Department of Transportation (VDOT). Figure C.1 shows an elevation view of the VDOT 32-in. Kansas Corral railing found on Plan No. BCR-4.

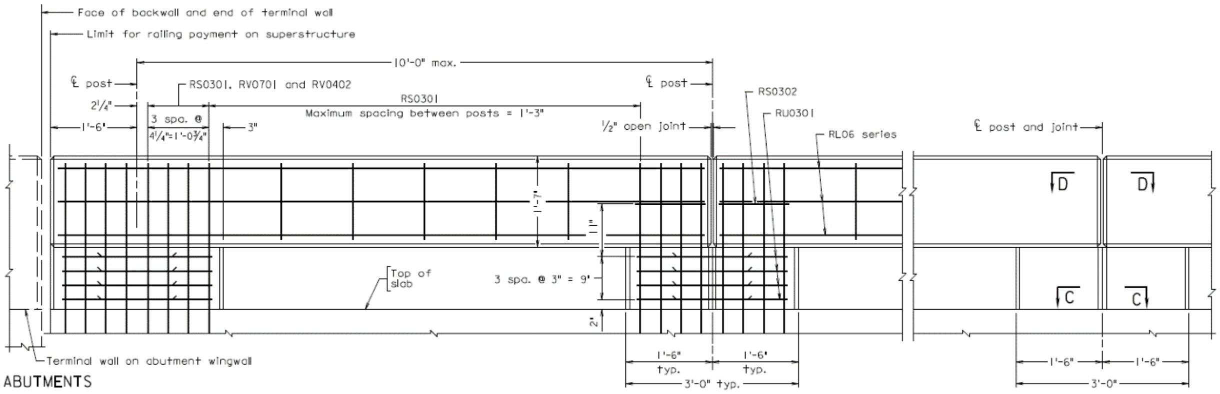


Figure C.1. Elevation view of the VDOT 32-in. Kansas Corral railing.

The Kansas Corral bridge rail element is 1 ft. 2 in. wide with a height of 1 ft. 7 in. This element is anchored on top of the concrete posts, which are located on 10-ft. centers. Each post is 3 ft. wide, 1 ft. deep and has a height of 13 in. Thus, the total system height from the deck surface is 32 in. A cross-section view of the bridge rail is shown in Figure C.2.

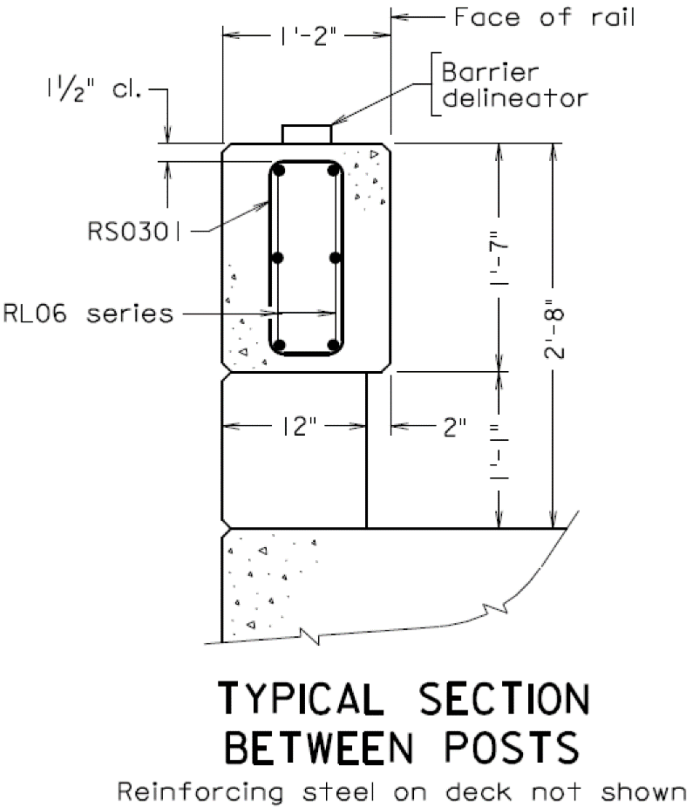


Figure C.2. Typical cross-section view between posts.

The details of the steel reinforcement placement, shapes, and connectivity are shown in Figures C.3, C.4, and C.5. It should be noted that the rail has a fully separated (open) joint at each internal post.

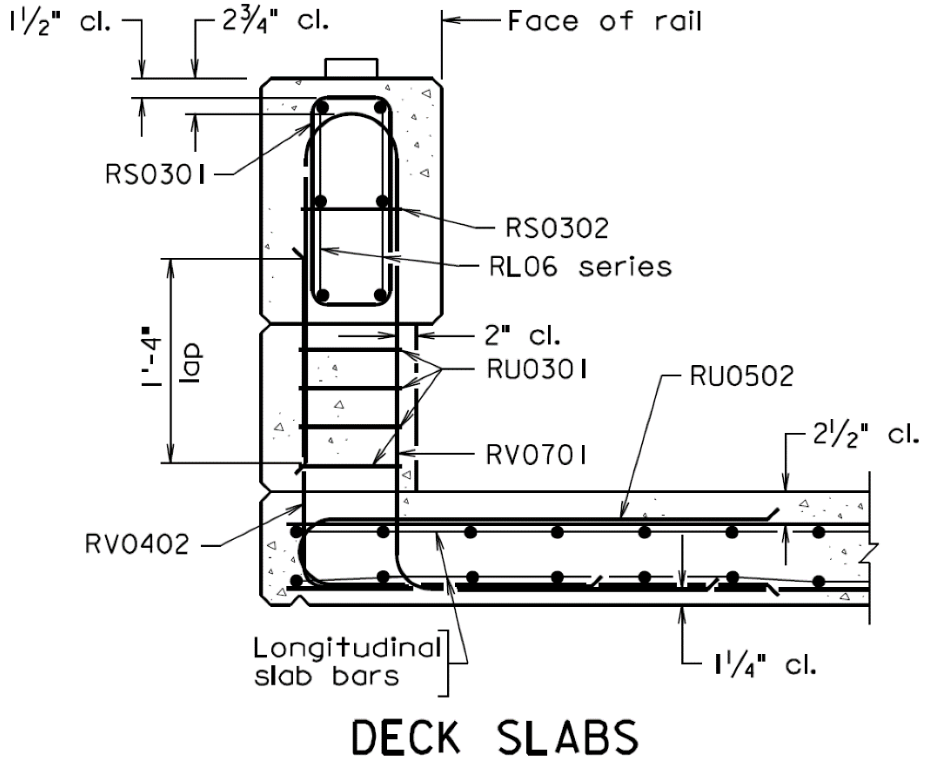


Figure C.3. Cross-section view through posts and the deck overhang.

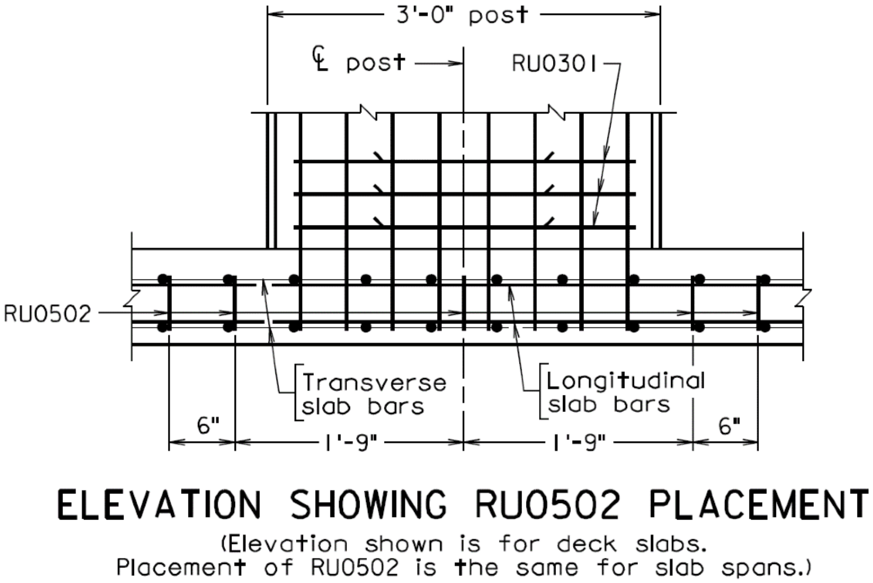
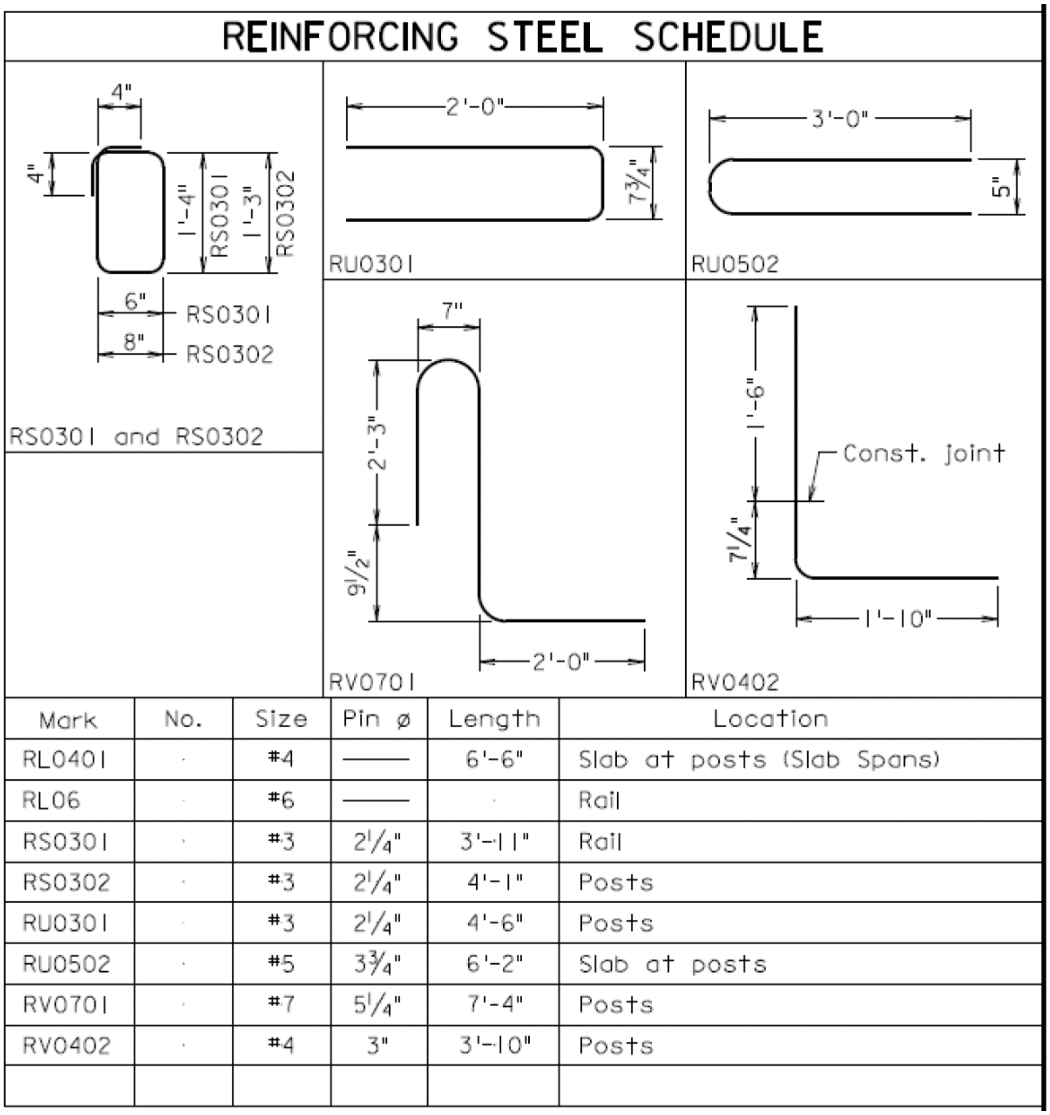


Figure C.4. Elevation at post showing reinforcement details.



Mark	No.	Size	Pin ø	Length	Location
RL0401	·	#4	——	6'-6"	Slab at posts (Slab Spans)
RL06	·	#6	——	·	Rail
RS0301	·	#3	2¼"	3'-11"	Rail
RS0302	·	#3	2¼"	4'-1"	Posts
RU0301	·	#3	2¼"	4'-6"	Posts
RU0502	·	#5	3¾"	6'-2"	Slab at posts
RV0701	·	#7	5¼"	7'-4"	Posts
RV0402	·	#4	3"	3'-10"	Posts

Figure C.5. Reinforcement steel in the VDOT Kansas Corral system.

The FE model of the Kansas Corral rail developed for this project has four rail spans and a 3-ft.-wide deck overhang. The model has three internal posts and two end posts. The overall view of the model is shown in Figure C.6. Figure C.7 shows the meshing scheme used for the model. The steel reinforcement layout of the Kansas Corral rail, post, and overhang deck are shown in Figure C.8.

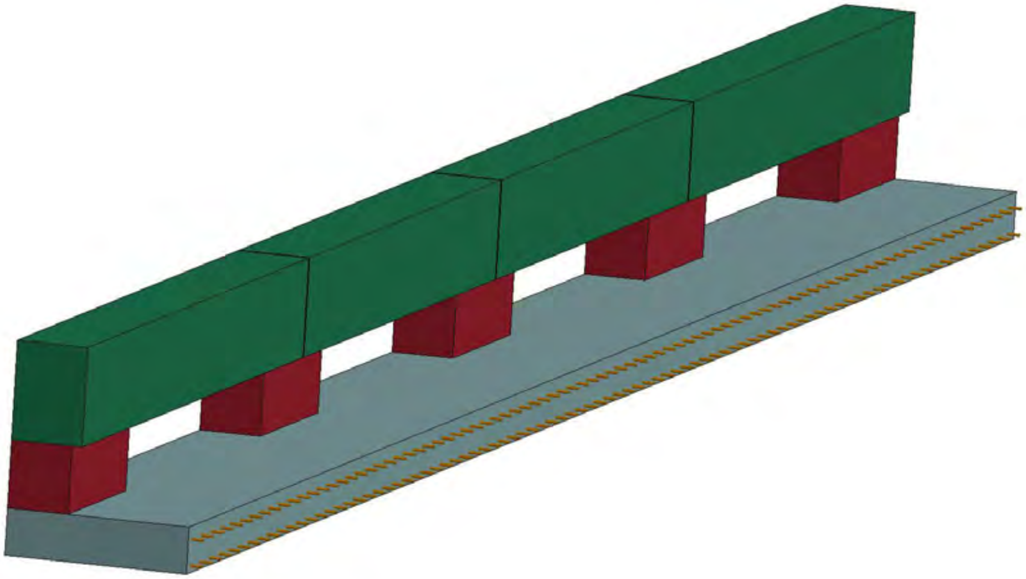


Figure C.6. Overall view of the Kansas Corral FE model.

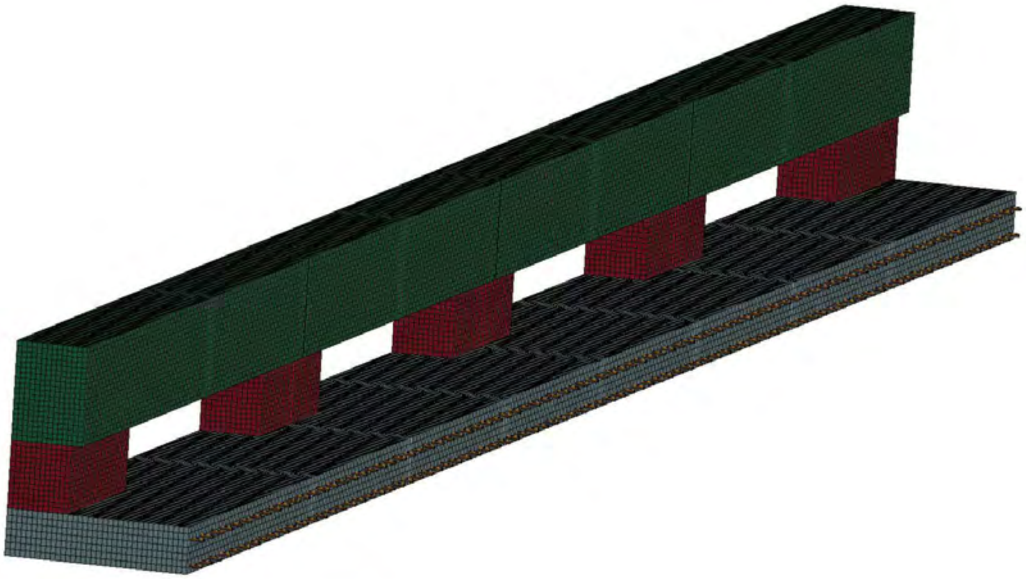


Figure C.7. Meshing scheme of the Kansas Corral model.

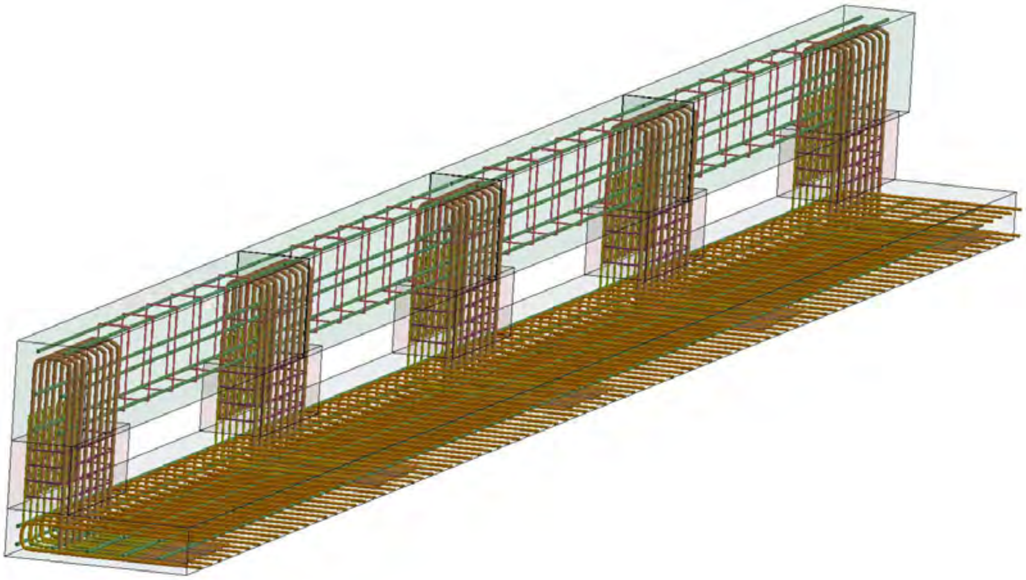


Figure C.8. Detailed view of the steel reinforcement bars (concrete is transparent).

The steel bars were modeled as beam elements and their dimensions were based on the steel schedule in Figure C.5. Figure C.9 depicts the cross-sectional view of the bridge rail system and deck overhang showing the RU0502 (#5) bars, RV0701 (#7) and RV0402 (#4) stirrup bars, RL06 (#6) longitudinal bars, and the RS0301 (#3) and RS0302 (#3) loop bars.

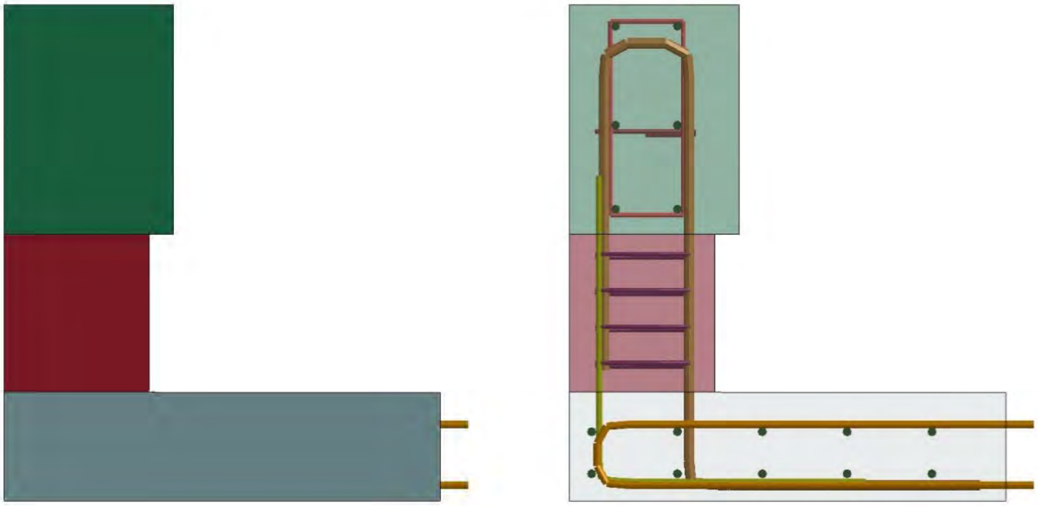


Figure C.9. Cross-section view of the Kansas Corral model showing overall profile (left) and steel bars (right).

The model accounted for the overlap detail in bars and loops as shown in the post detailed view in Figure C.10.

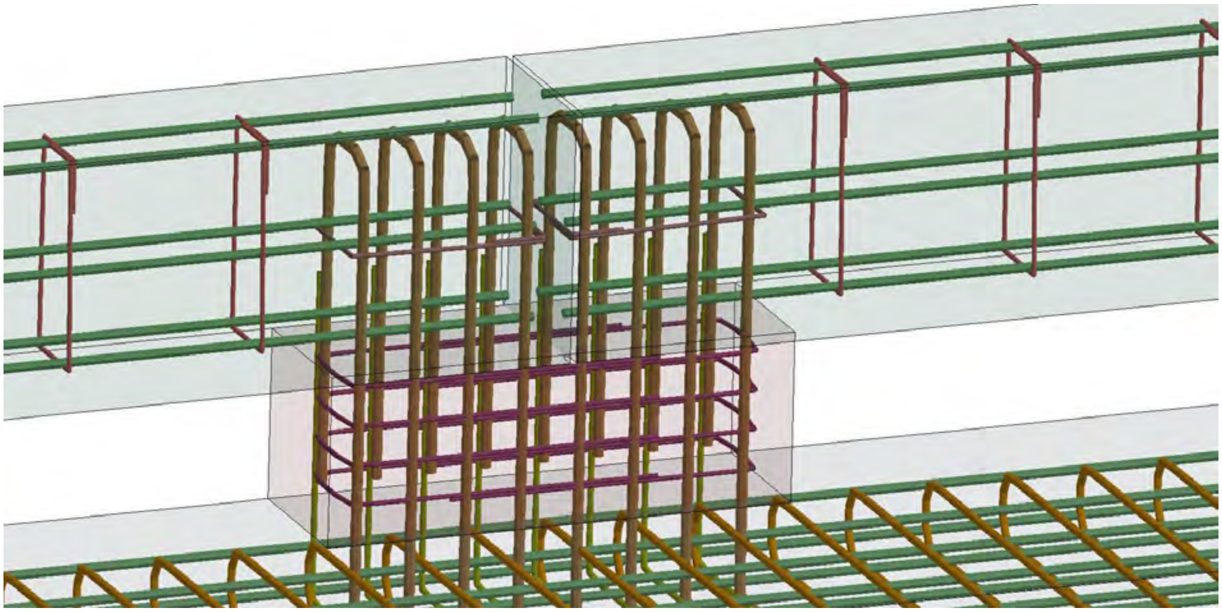


Figure C.10. Detailed view at an internal post showing the placement of steel bars.

Material models used in this system are the full elastic-plastic steel behavior of the Grade 60 reinforcement bars. The model reflected published data and material test reports (MTRs), so it is more realistic than the specification-based properties that are reflective of the minimum yield and strength requirements. However, the last simulation case (#3) used the minimum specification values for the steel bar (Grad 6) as a comparison point. The concrete material is the damage-enabled constitutive material model (*MAT_CSCM/*MAT_159). The target concrete mesh size was 1 in. The model setup for MASH Test 3-11 consisted of the test vehicle (5,000 lb. pickup truck) impacting the CIP at an impact speed and angle of 62 mph and 25 degrees, respectively. The CIP chosen for this analysis was 4.3 ft. upstream of a rail joint per MASH Section 2.2.1, Section 2.3.2, and Figure 2-1.

SIMULATION RESULTS

Simulation Case 1

The first simulation case was for MASH Test 3-11 impact at an internal post. The impact location was upstream from the post centerline to maximize the forces at the internal joint of the Kansas Corral system. The overall vehicular response is shown in Figure C.11 where the pickup truck was redirected as it exited the Kansas Corral system.

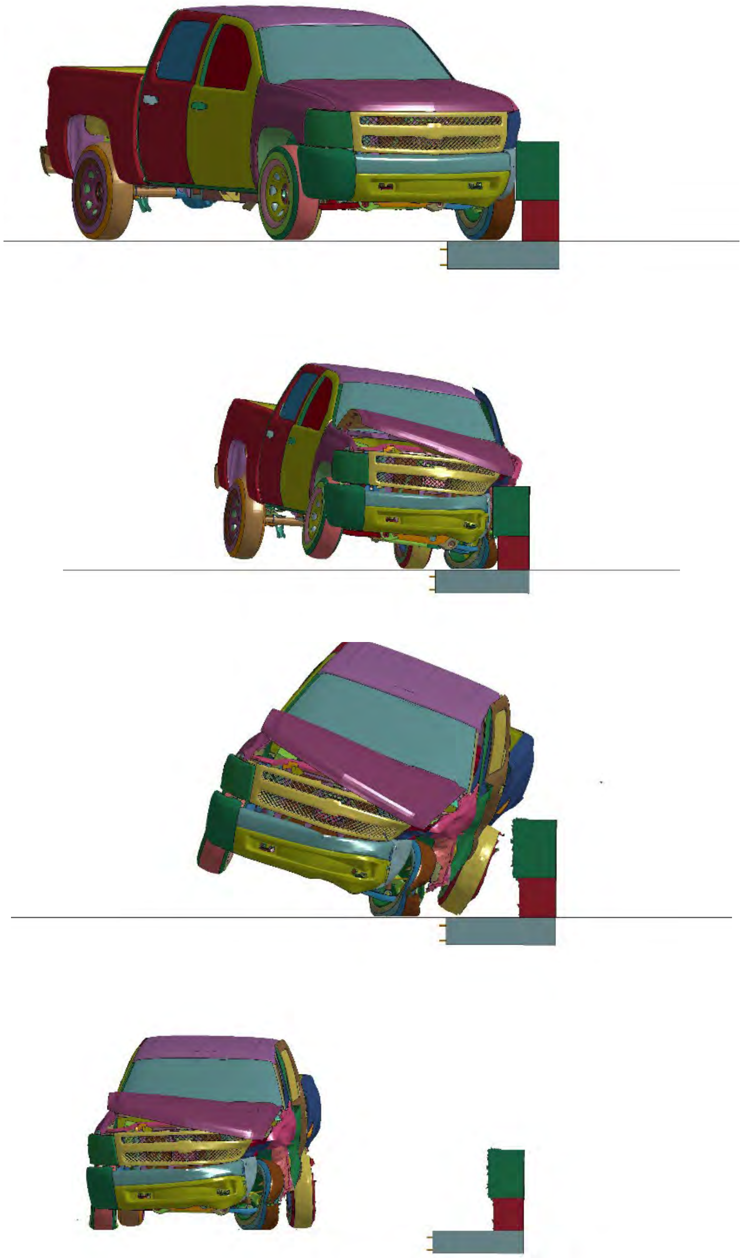


Figure C.11. Key sequential gut view of MASH Test 3-11 on the Kansas Corral system at an internal post.

The extent of damage to the rail and post elements is shown in Figure C.12. This figure presents the damage in terms of spalling and material erosion due to shearing of concrete elements. The rail and the internal post experienced an extensive spalling of concrete.

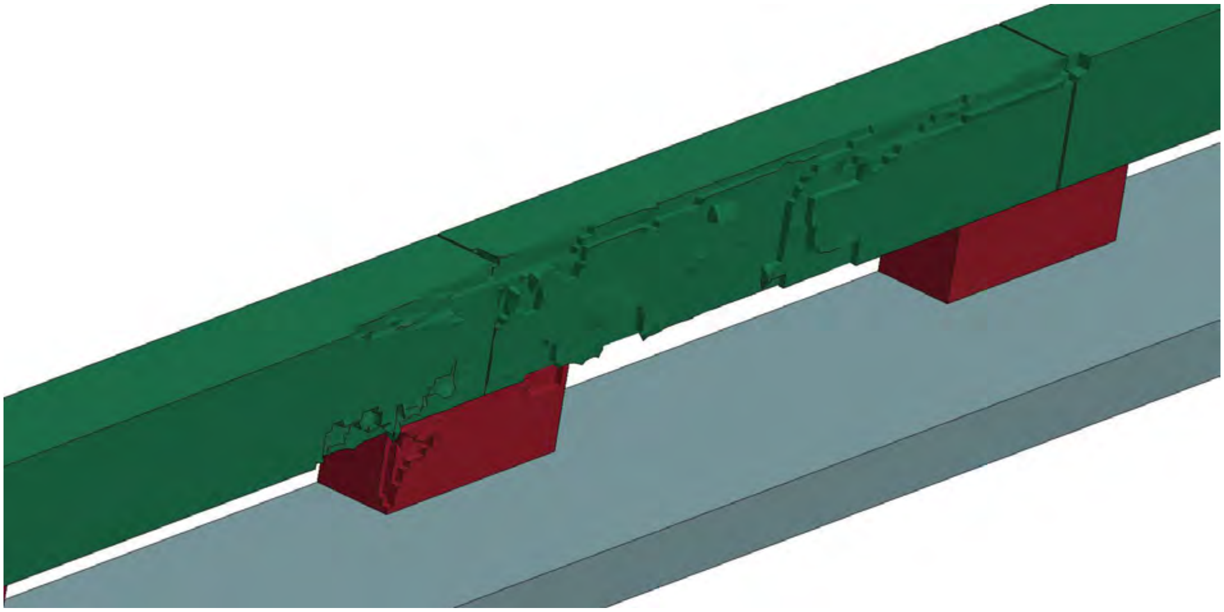


Figure C.12. Scope of spalling damage to railing and post due to MASH Test 3-11.

In Figure C.13 the extent of damage to the concrete is presented as a heat map of the damage function in the material constitute law. Basically, any value close to 1 indicates complete damage to the element, while a value of 0 indicates an undamaged element. The same damage function is presented as an iso-surface through the volume of the concrete parts in Figure C.14. The images indicate a potential of further failure in the post being impacted.

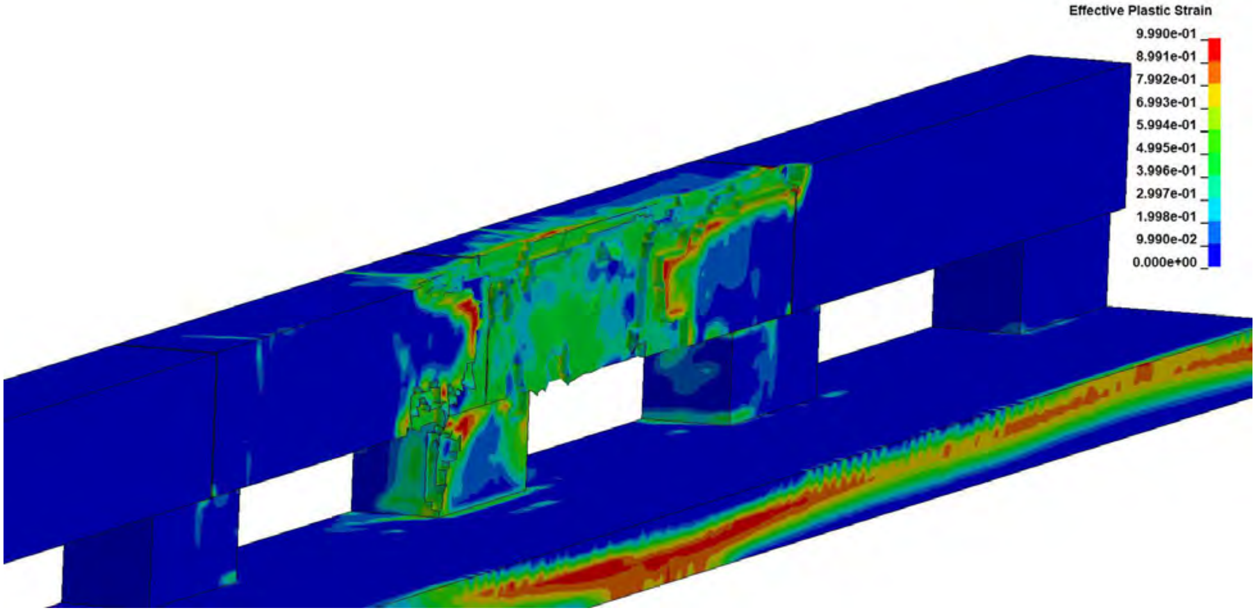


Figure C.13. Contour of material damage function to the rail and post due to MASH Test 3-11.

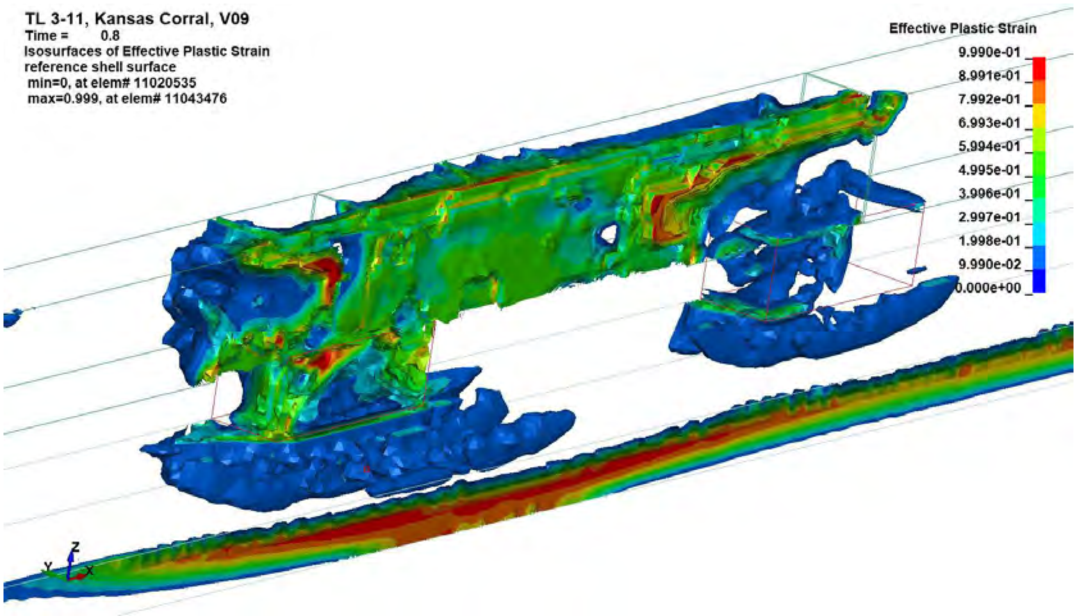


Figure C.14. Iso-surface of material damage function to the rail and post due to MASH Test 3-11.

The deck overhang portion shown in the figures herein exhibits a spread of red contours indicating a damage function of 1 along the boundary edge along the remainder of the bridge deck. This damage level is very narrow to the elements where the boundary is enforced. This thin spread would be more of an indicator of top surface cracking than of full spalling damage due to the rigid assumption of the boundary condition of the continuous deformable deck portion.

Figures C.15 and C.16 show the cross-sectional averaged axial stress in the steel bars. The units are in MPa, and thus the value of 460 MPa is 66.7 ksi. This value is greater than the yield stress specified for steel bars of Grade 60 but is lower than the typical test values reported in MTRs. However, this stress magnitude is an indication for potential plastic hinge development and subsequent post overhang failure.

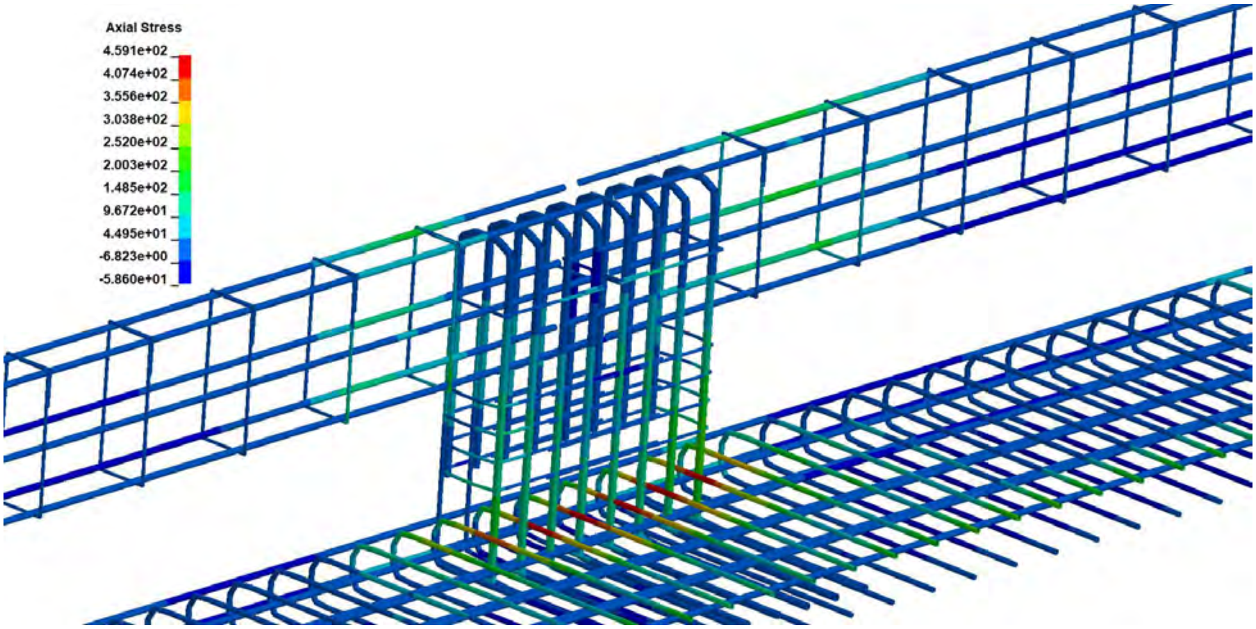


Figure C.15. Maximum (cross-sectional averaged) stress in MPa in the reinforcement steel.

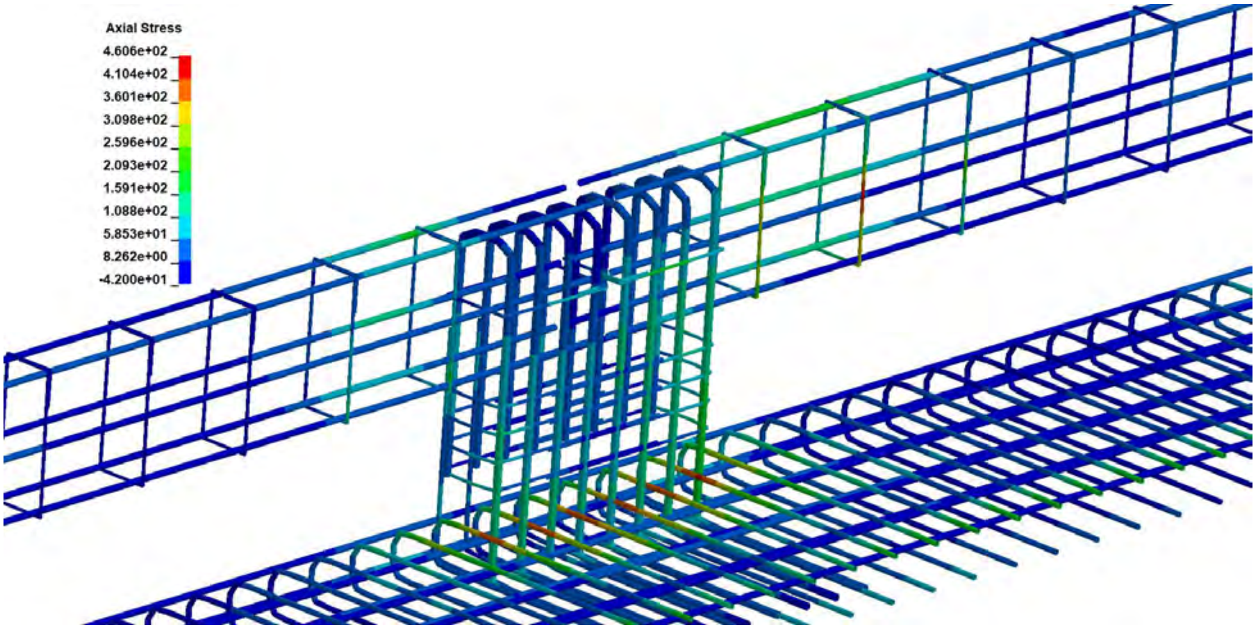


Figure C.16. Maximum (cross-sectional averaged) stress in MPa in the reinforcement steel after pickup truck backslap.

The acceleration signal histories and the angular velocity rates were collected from the center of gravity (CG) of the pickup truck and postprocessed by the TRAP program to calculate occupant risk values. The overall acceleration histories for both the longitudinal (X) and lateral (Y) directions are shown in Figure C.17 and Figure C.18, respectively. The red line is the 50 ms average of the acceleration history.

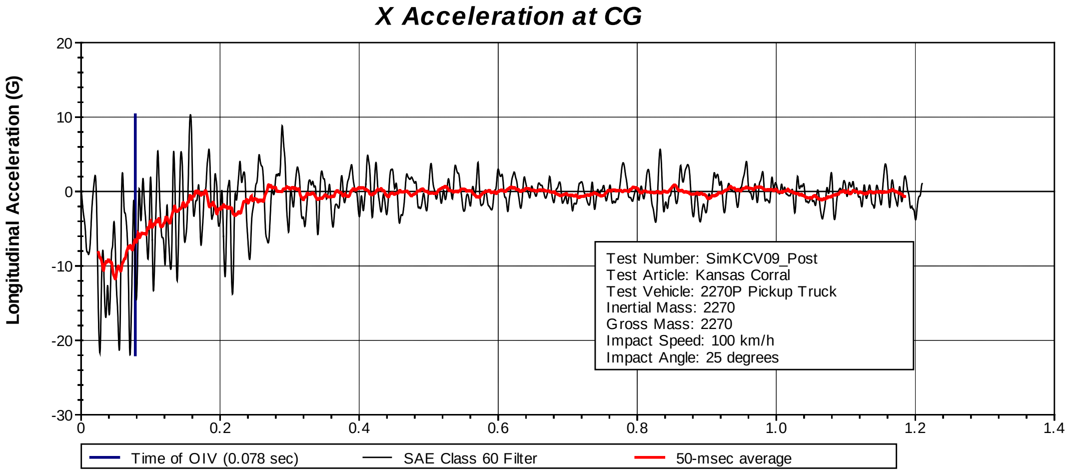


Figure C.17. Longitudinal acceleration history at the CG of the pickup truck.

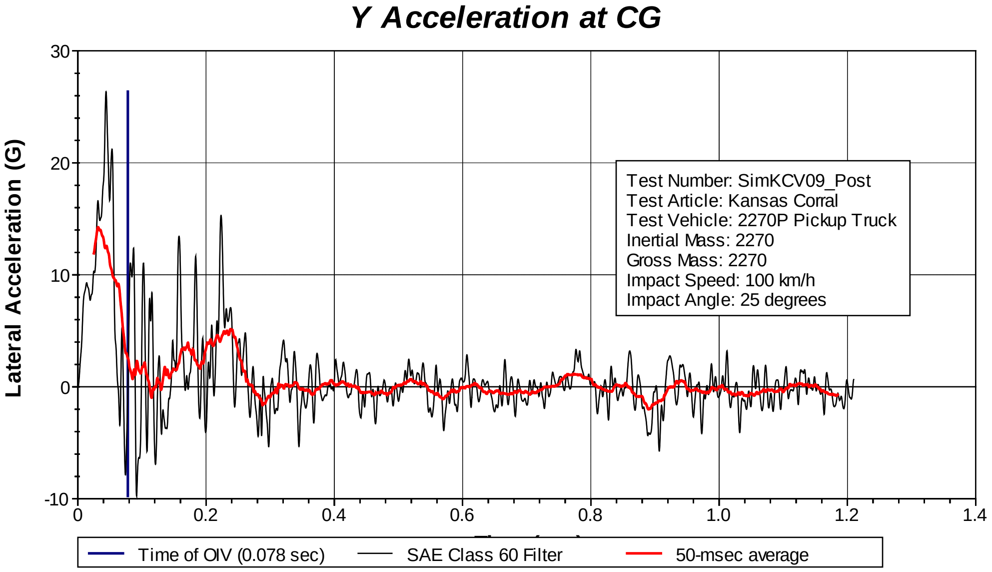


Figure C.18. Lateral acceleration history at the CG of the pickup truck.

As shown in Table C.1, occupant risk factors were within the limits specified in MASH.

Table C.1. Occupant risk factors for the post impact.

Occupant Risk Factors	Occupant Risk Values	Occupant Risk Values (Y-Direction)
Impact Velocity (m/s)	6.6 (X-Direction)	−7.0 (Y-Direction)
Ridedown Accelerations (g's)	−8.3 (X-Direction)	11.3 (Y-Direction)

Maximum Roll (degrees)	−13.9	
Maximum Pitch (degrees)	−4.7	
Maximum Yaw (degrees)	34.4	

Simulation Case 2

The second simulation case was for MASH Test 3-11 impact at the rail span. The impact location was the midspan point of the concrete rail. The overall vehicular response is shown in Figure C.19 where the pickup truck was redirected as it exited the Kansas Corral rail.

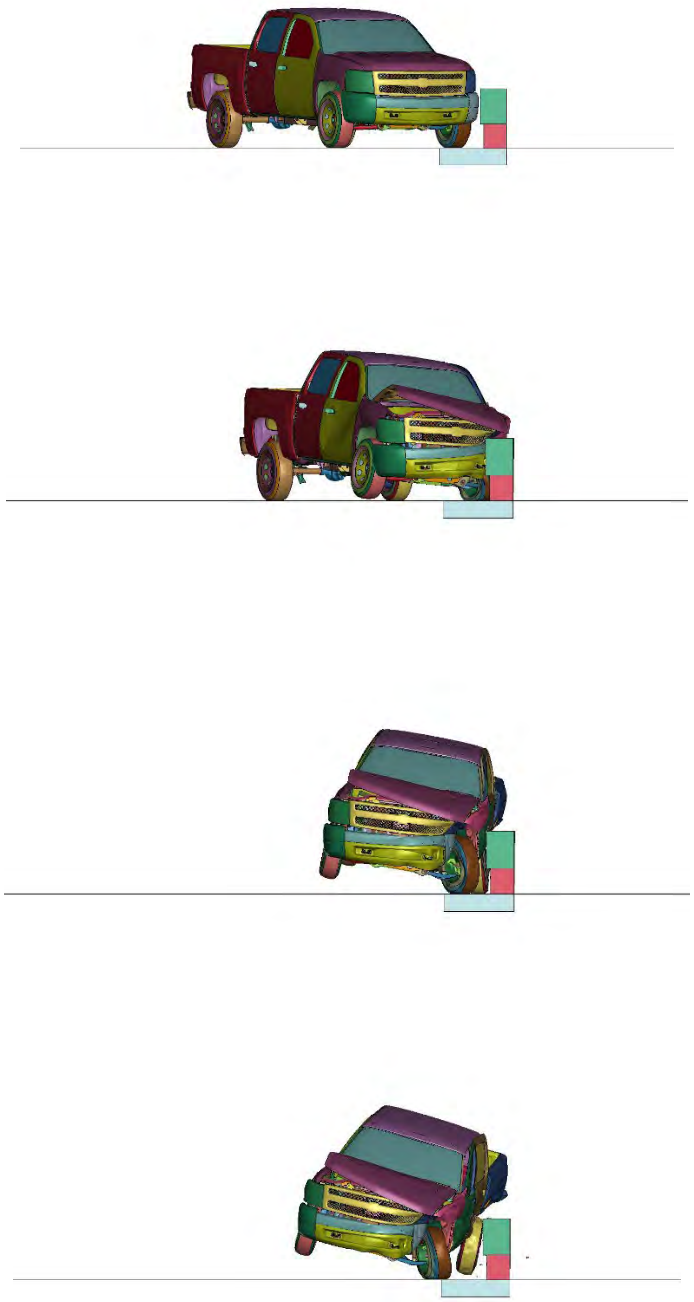


Figure C.19. Key sequential gut view of MASH Test 3-11 on the Kansas Corral system at midspan.

The extent of damage to the rail and post elements is shown in Figure C.20. This figure presents the damage in terms of spalling and material erosion (damage) due to shearing of concrete elements. The rail and the internal post experienced an extensive spalling of concrete starting from the midspan of the rail onward.

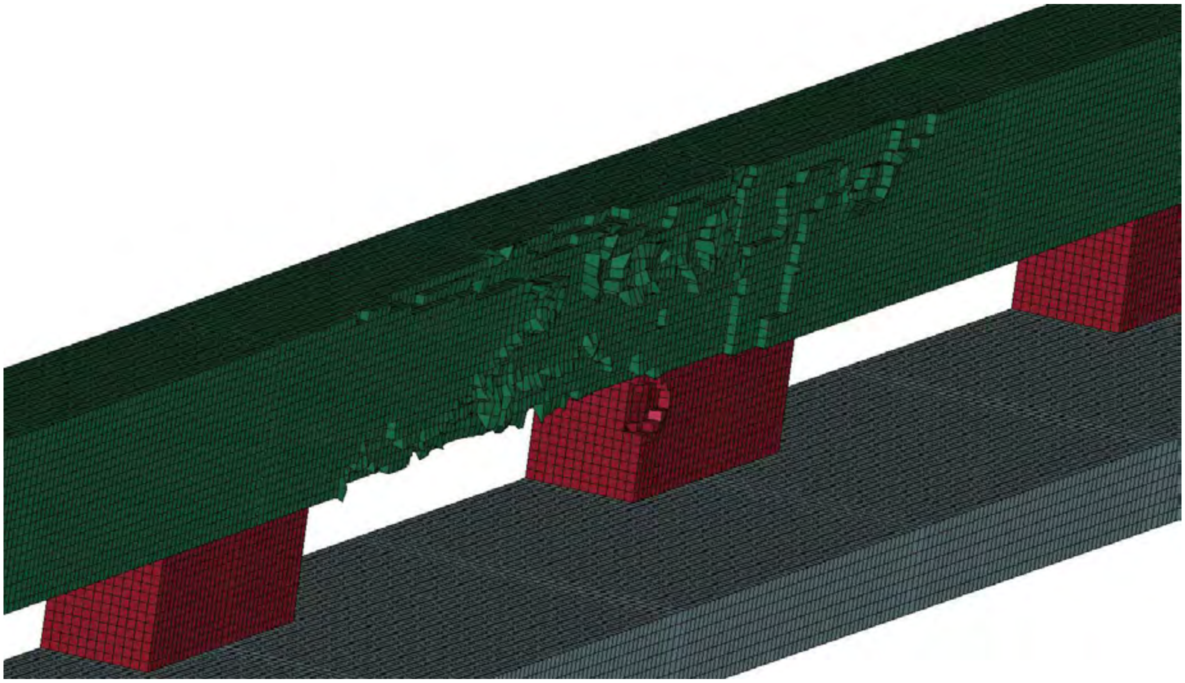


Figure C.20. Scope of spalling damage to railing and post due to MASH Test 3-11.

Like the internal post impact case (Simulation Case 1), the extent of damage to the concrete is presented as a heat map of the damage function in the material constitute law as shown in Figure C.21. Any value close to 1 indicates complete damage to the element, while a value of 0 indicates an undamaged element. The same damage function is presented as an iso-surface through the volume of the concrete parts in Figure C.22. The images indicate a potential of further failure in the rail being impacted.

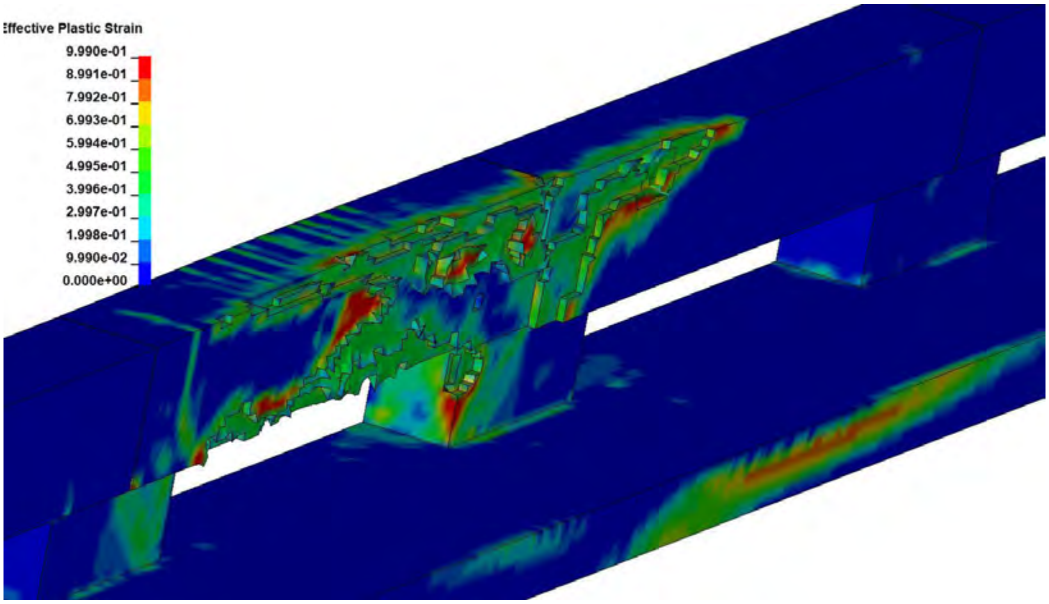


Figure C.21. Contour of material damage function to the rail and post due to MASH Test 3-11.

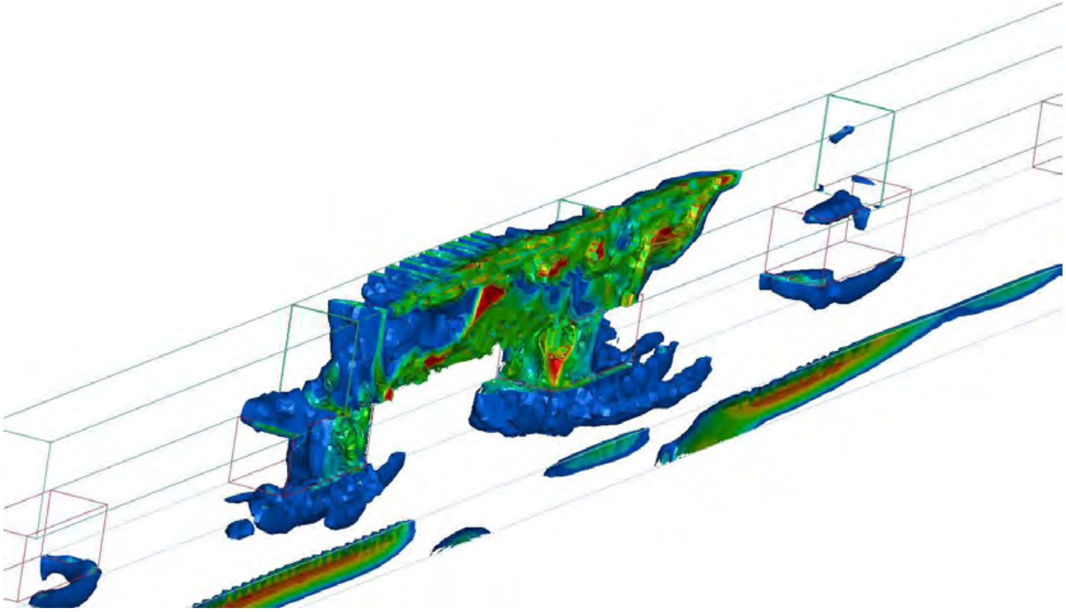


Figure C.22. Iso-surface of material damage function to the rail and post due to MASH Test 3-11.

However, an interesting damage sequence is observed if the iso-surface of damage is presented from the back/field view (Figure C.23). Several through-the-rail damage levels of 0.5 (green) are presented in the rail.

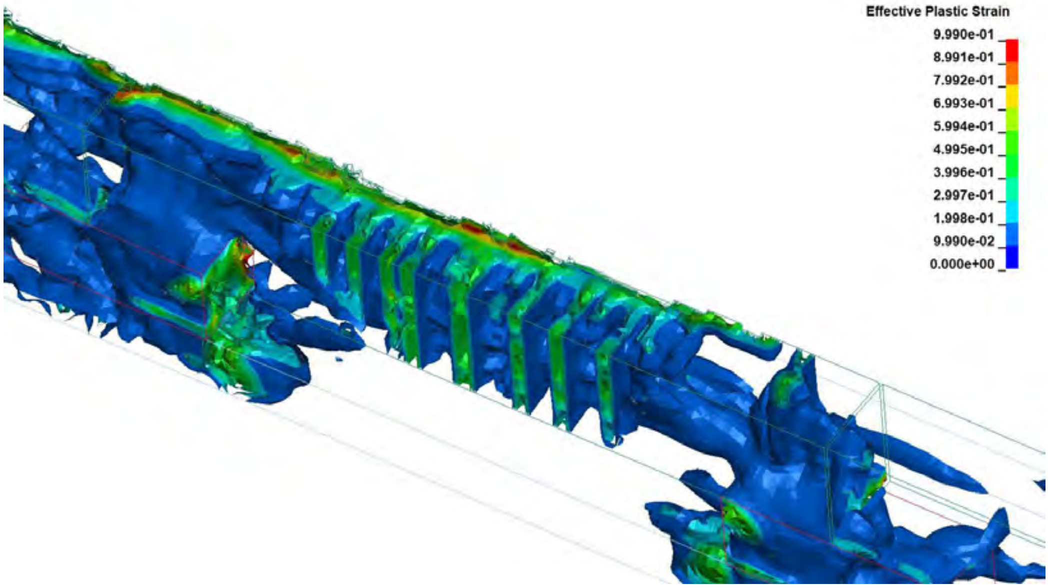


Figure C.23. Field view of the iso-surface of material damage function to the rail and post due to MASH Test 3-11.

Further, Figure C.24 shows the cross-sectional averaged axial stress in the steel reinforcing bars. Again, the units are in MPa and thus the value of 500 MPa is 72.5 ksi. This value is more than the yield stress specified for steel bars of Grade 60 and is close to the typical test values reported in MTRs. This level of axial stress is experienced in the back rail top longitudinal bar as shown in Figure C.24. Thus, due to the stress in the steel reinforcement well above the yield stress of the material, it is a concern that this rail may fracture due to the MASH TL-3 impact load.

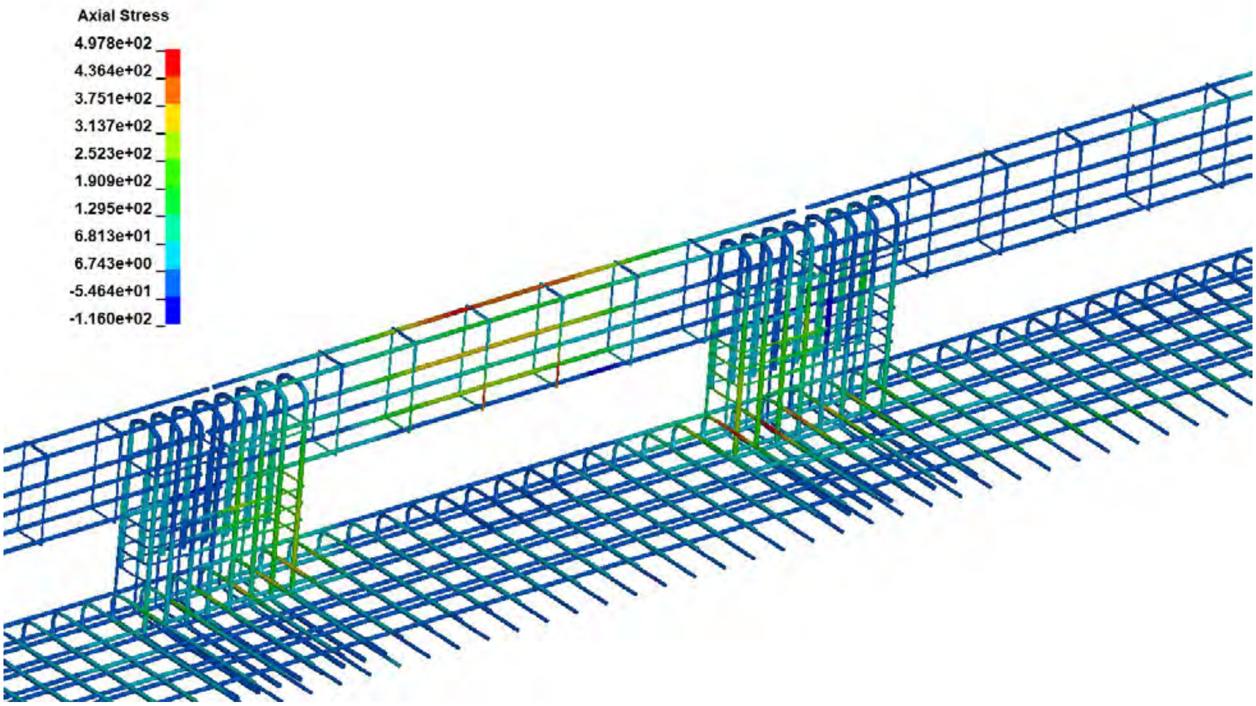


Figure C.24. Maximum (cross-sectional averaged) stress in MPa in the reinforcement steel.

The acceleration signal histories and the angular velocities rates were collected from the accelerometer element located at CG of the pickup truck and postprocessed using the TRAP program to calculate occupant risk values. The overall acceleration histories for both the longitudinal (X) and the lateral (Y) directions are shown in Figures C.25 and C.26, respectively. The red line is the 50 ms average of the acceleration history.

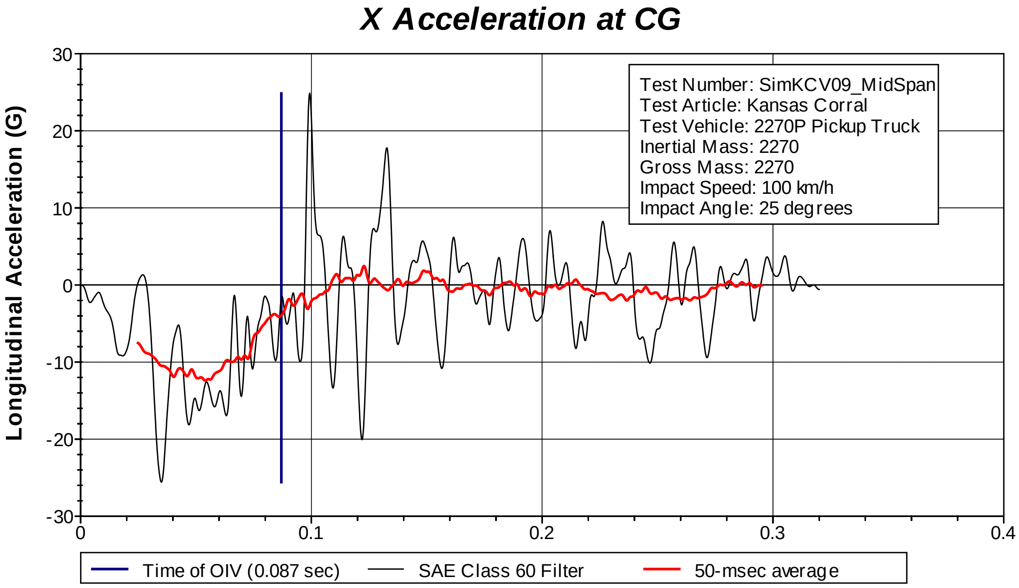


Figure C.25. Longitudinal acceleration history at the CG of the pickup truck.

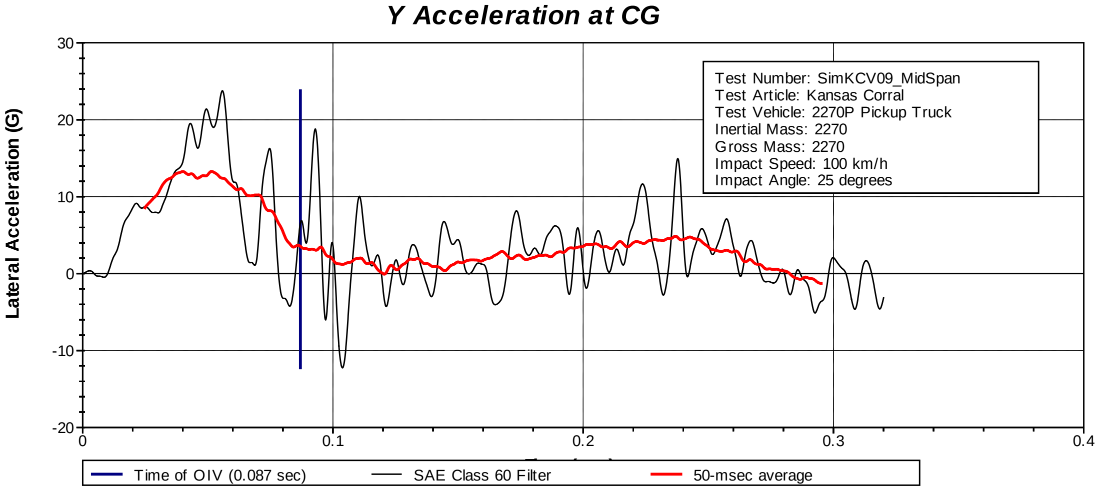


Figure C.26. Lateral acceleration history at the CG of the pickup truck.

As shown in Table C.2, occupant risk factors were within the limits specified in MASH.

Table C.2. Occupant risk factors for midspan impact.

Occupant Risk Factors	Occupant Risk Values	Occupant Risk Values (Y-Direction)
Impact Velocity (m/s)	7.4 (X-Direction)	−7.3 (Y-Direction)
Ridedown Accelerations (g's)	13.7 (X-Direction)	9.1 (Y-Direction)
Maximum Roll (degrees)	−3.0	
Maximum Pitch (degrees)	−1.3	
Maximum Yaw (degrees)	32.8	

Simulation Case 3

The third simulation case was for MASH Test 3-11 impact at the rail span. The difference between this case and Simulation Case 2 is that the steel properties were based on the minimum specification of Grade 60 reinforcement. The impact location was the midspan point of the concrete rail. The overall vehicular response is shown in Figure C.27 where the pickup truck was redirected as it exited the Kansas Corral rail.

Figure C.27. Key sequential gut view of MASH Test 3-11 on the Kansas Corral system at midspan.

The extent of damage to the rail and post elements is shown in Figure C.28. This figure presents the damage in terms of spalling and material erosion (damage) due to shearing of concrete elements. The rail and the internal post experienced an extensive spalling of concrete starting from the midspan of the rail onward.

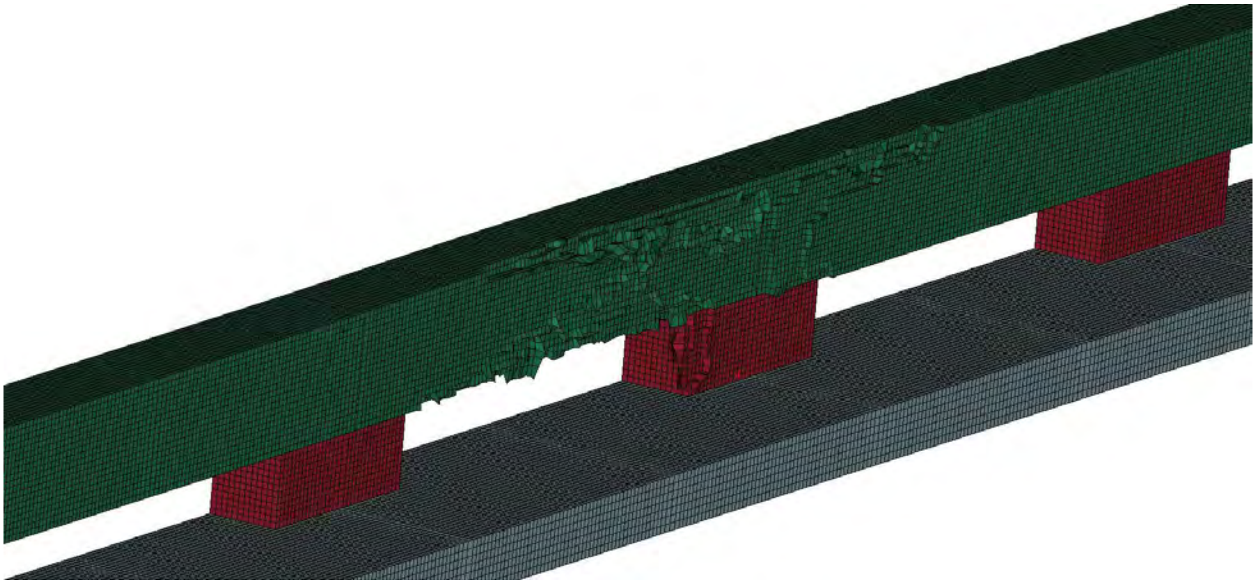


Figure C.28. Scope of spalling damage to railing and post due to MASH Test 3-11.

Like the internal post impact case (Simulation Case 1), the extent of damage to the concrete is presented as a heat map of the damage function in the material constitute law as shown in Figure C.29. Any value close to 1 indicates complete damage to the element, while a value of 0 indicates an undamaged element. The same damage function is presented as an iso-surface through the volume of the concrete parts in Figure C.30. The images indicate a potential of further failure in the rail being impacted.

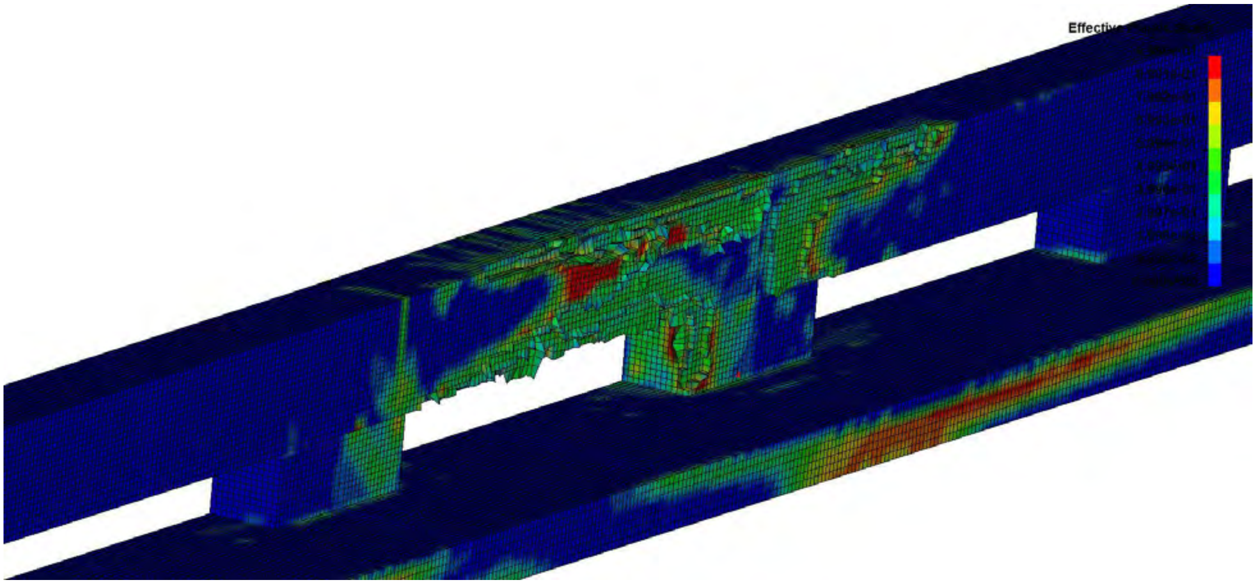


Figure C.29. Contour of material damage function to the rail and post due to MASH Test 3-11.

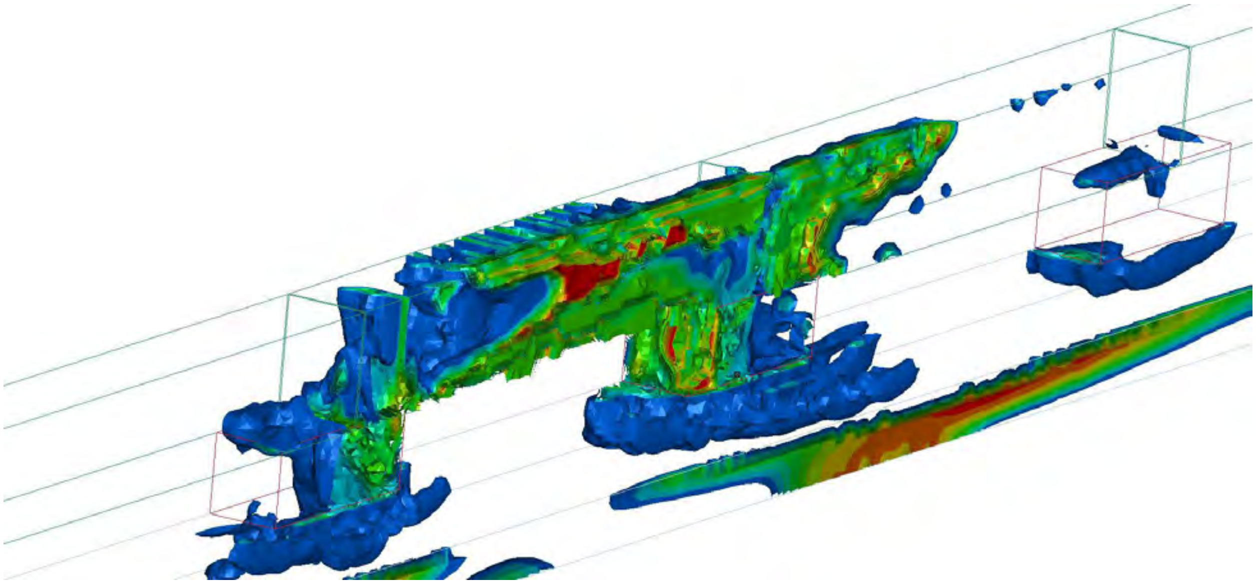


Figure C.30. Iso-surface of material damage function to the rail and post due to MASH Test 3-11.

However, an interesting damage sequence is observed if the iso-surface of damage is presented from the back/field view (Figure C.31). Several through-the-rail damage levels of 0.5 (green) are presented in the rail.

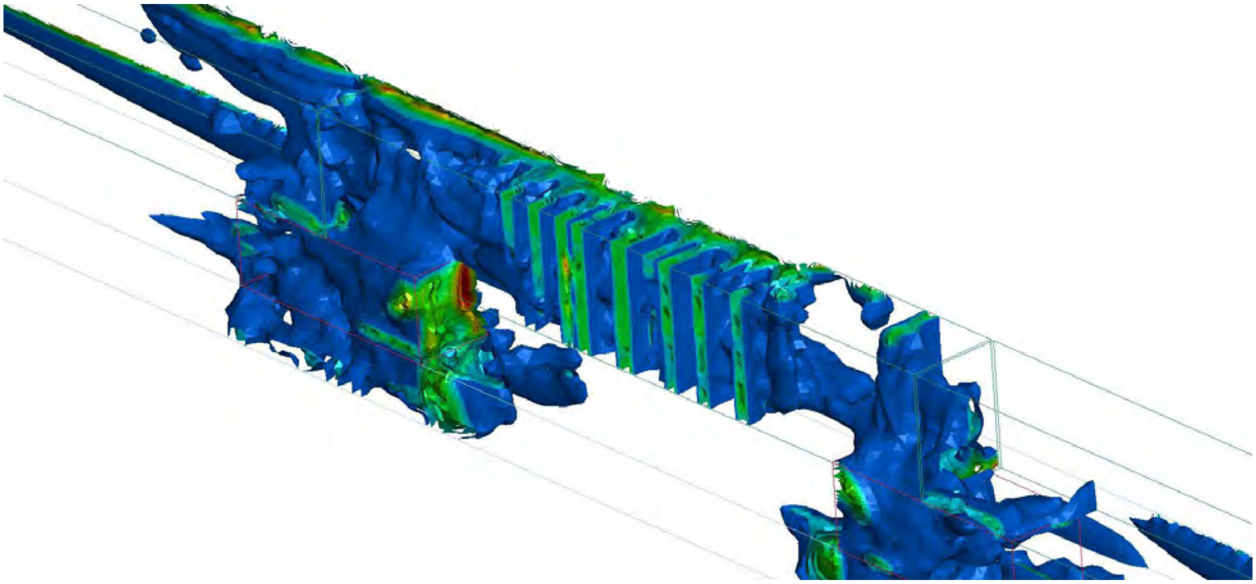


Figure C.31. Field view of the iso-surface of material damage function to the rail and post due to MASH Test 3-11.

Further, Figure C.32 shows the cross-sectional averaged axial stress in the steel reinforcing bars. Again, the units are in MPa and thus the value of 424 MPa is 61.5 ksi. Hence, the red section of the bars has yielded according to the simulation. This level of axial stress is experienced in two longitudinal bars in the back of the rail and several deck rails on each post side as shown in Figure C.32. Thus, due to the stress in the steel reinforcement being well above the yield stress of the material, this rail may potentially fracture due to the MASH Test 3-11 impact load.

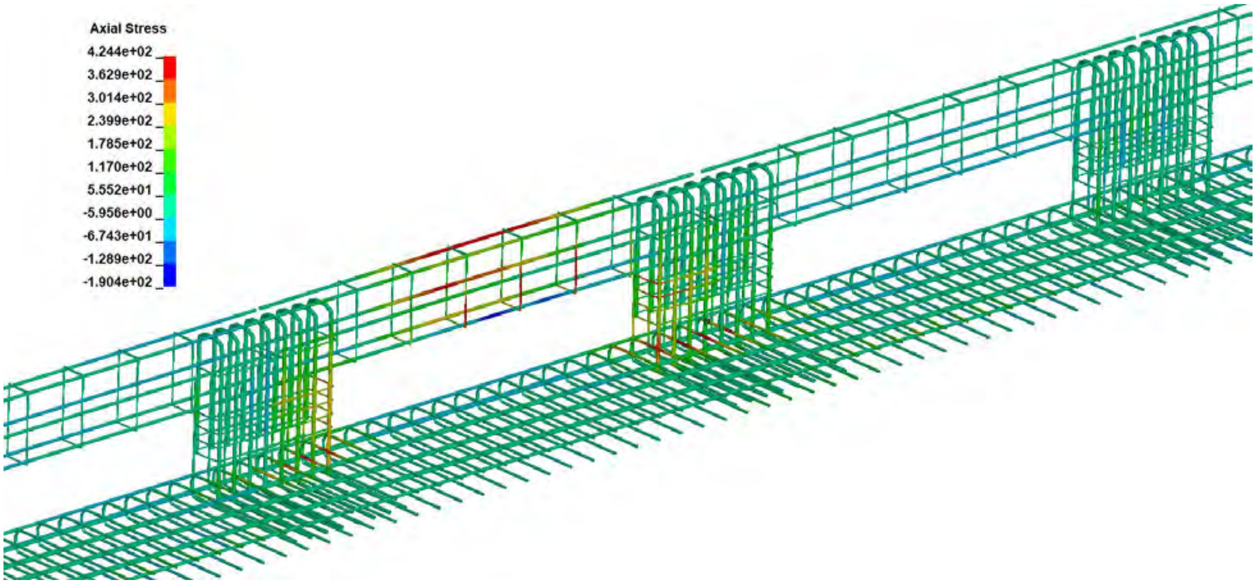


Figure C.32. Maximum (cross-sectional averaged) stress in MPa in the reinforcement steel.

The acceleration signal histories and the angular velocities rates were collected from the CG of the pickup truck and postprocessed using the TRAP program to calculate occupant risk values. The overall acceleration histories for both the longitudinal (X) and the lateral (Y) directions are shown in Figures C.33 and C.34, respectively. The red line is the 50 ms average of the acceleration history.

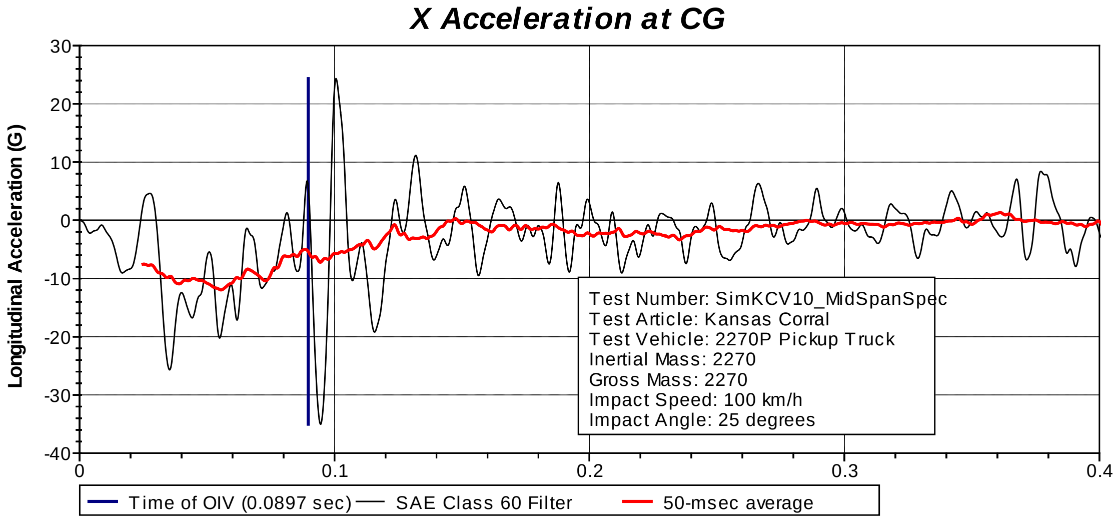


Figure C.33. Longitudinal acceleration history at the CG of the pickup truck.

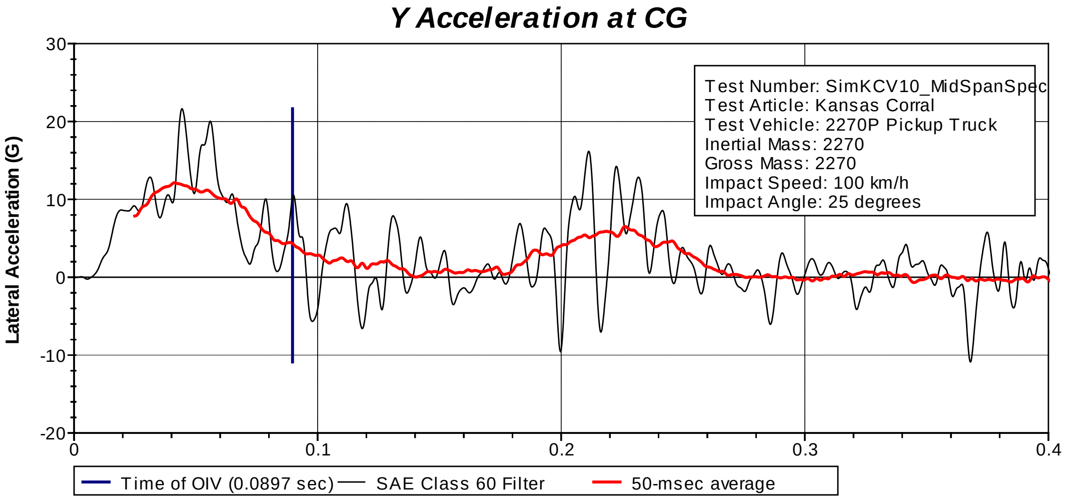


Figure C.34. Lateral acceleration history at the CG of the pickup truck.

As shown in Table C.3, occupant risk factors were within the limits specified in MASH.

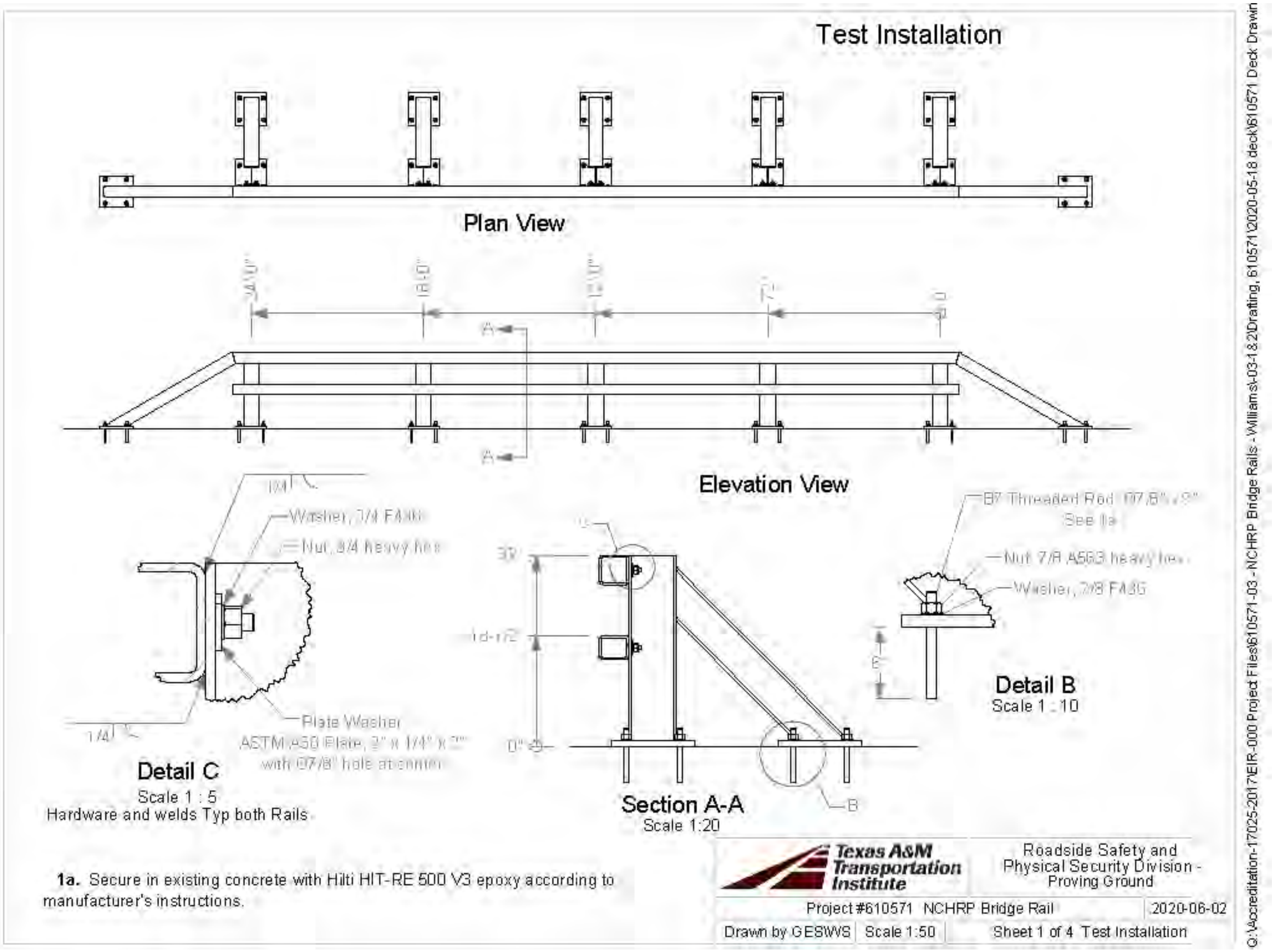
Table C.3. Occupant risk factors for midspan impact.

Occupant Risk Factors	**Occupant Risk Values**	**Occupant Risk Values (Y-Direction)**
Impact Velocity (m/s)	6.7 (X-Direction)	−7.1 (Y-Direction)
Ridedown Accelerations (g's)	17.7 (X-Direction)	11.9 (Y-Direction)
Maximum Roll (degrees)	−19.0	
Maximum Pitch (degrees)	−8.4	
Maximum Yaw (degrees)	41.0	

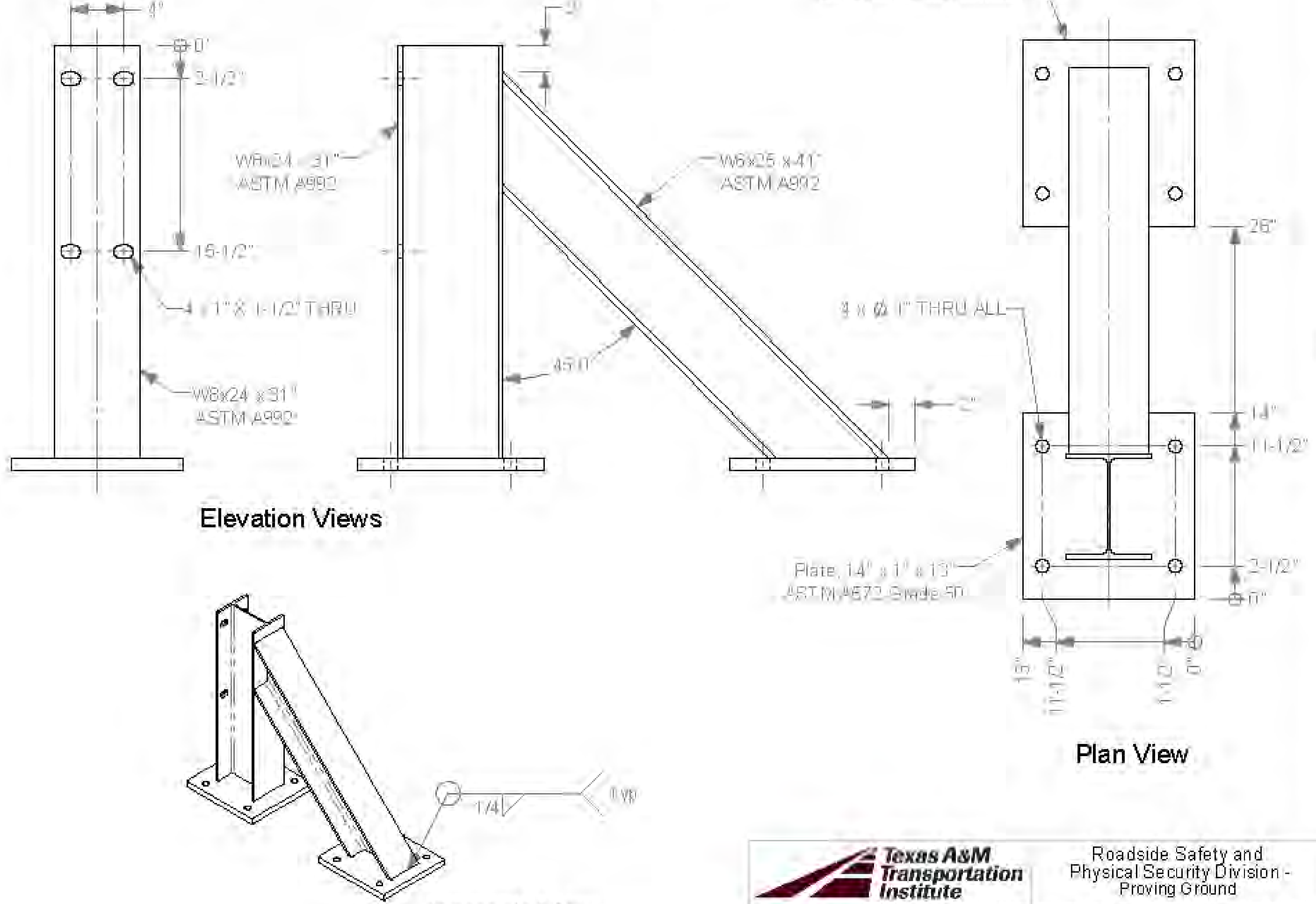
Based on the simulation results for these two impact cases, the Kansas Corral Bridge Rail as shown herein may be able to redirect the MASH TL-3 pickup truck but there is a good likelihood of excessive damage to the rail, the posts, and the deck as illustrated in the concrete damage and bar axial stresses presented above.

APPENDIX D. DETAILS OF BRIDGE RAILS

BRIDGE RAIL ON DECK



Post



Texas A&M Transportation Institute

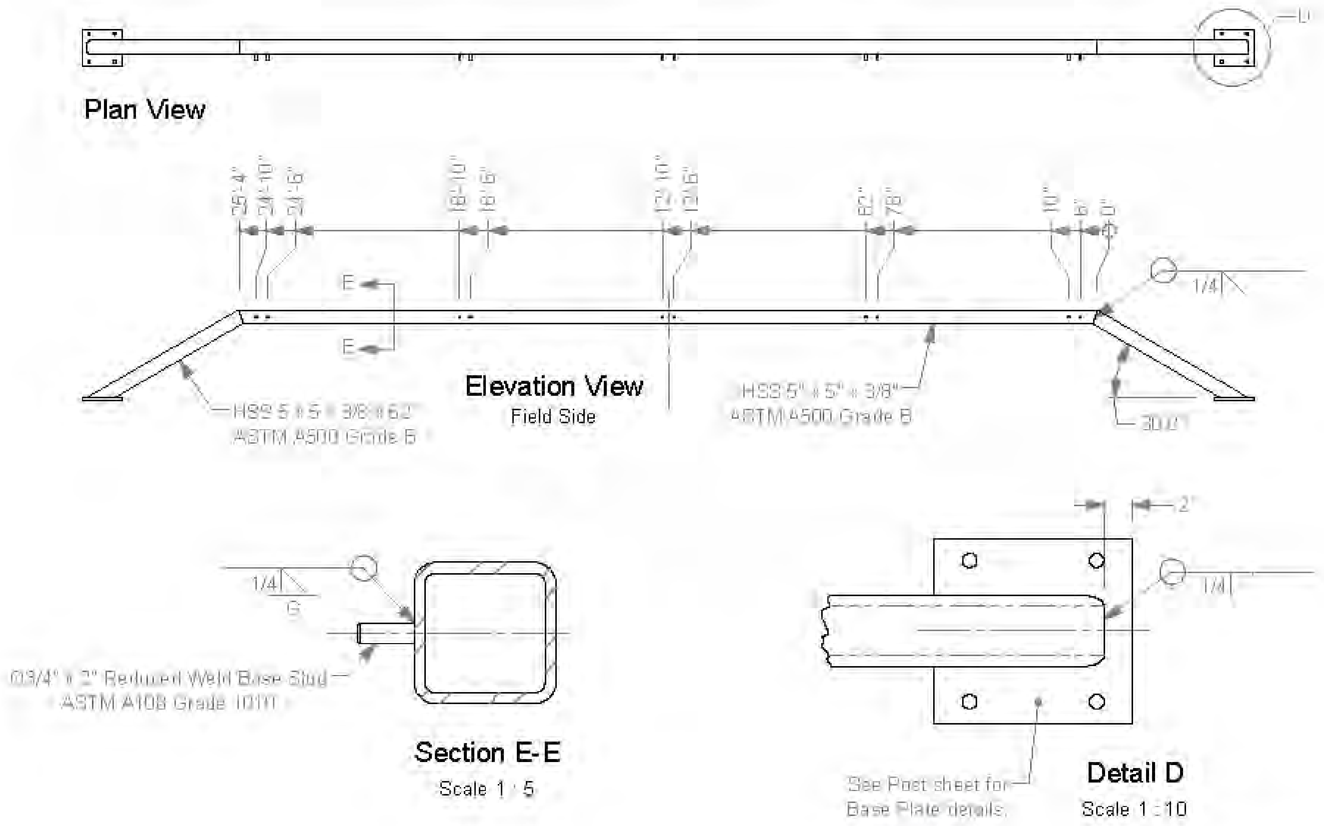
Roadside Safety and
Physical Security Division -
Proving Ground

Project #610571 NCHRP Bridge Rail 2020-06-02

Drawn by GESWS Scale 1:10 Sheet 2 of 4 Post

Q:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 - NCHRP Bridge Rails - Williams\-03-1 & 2\Drafting, 610571\2020-05-18 deck\610571 Deck Drawing

Top Rail



Texas A&M Transportation Institute

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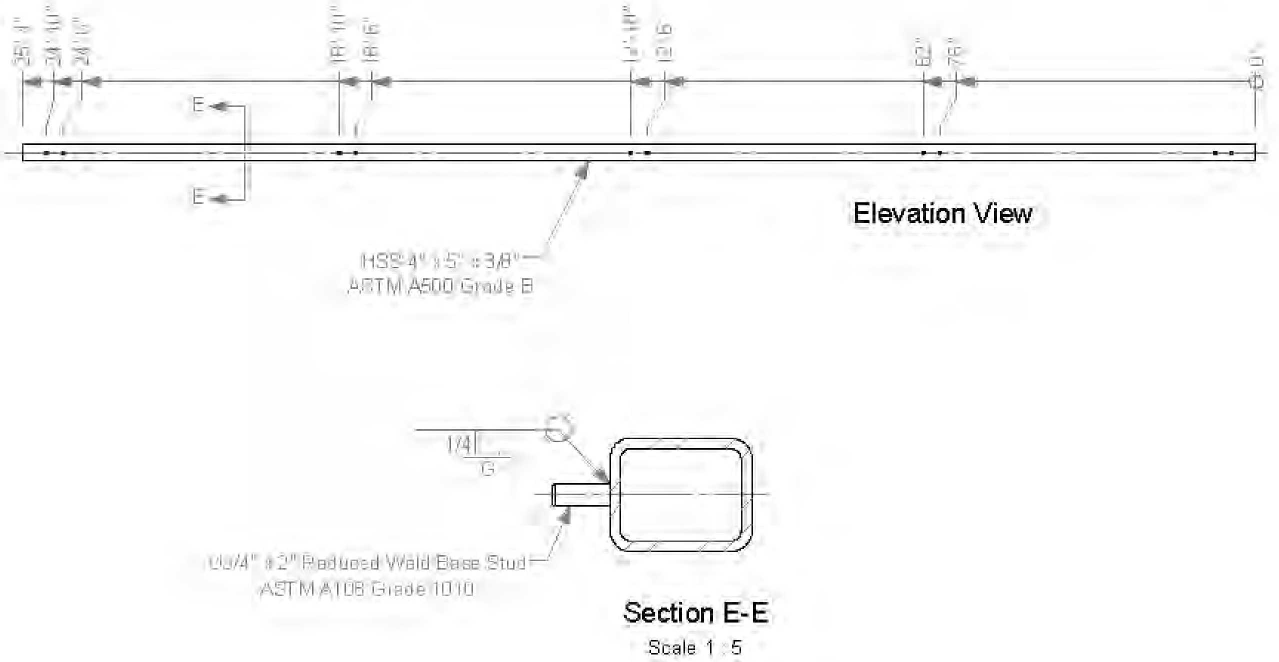
Physical Security Division -
Proving Ground

Project #610571 NCHRP Bridge Rail 2020-06-02

Drawn by GESWS Scale 1:50 Sheet 3 of 4 Top Rail

Q:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 - NCHRP Bridge Rails - Williams\-03-1&2\Drafting, 610571\2020-05-18 deck\610571 Deck Drawing

Bottom Rail



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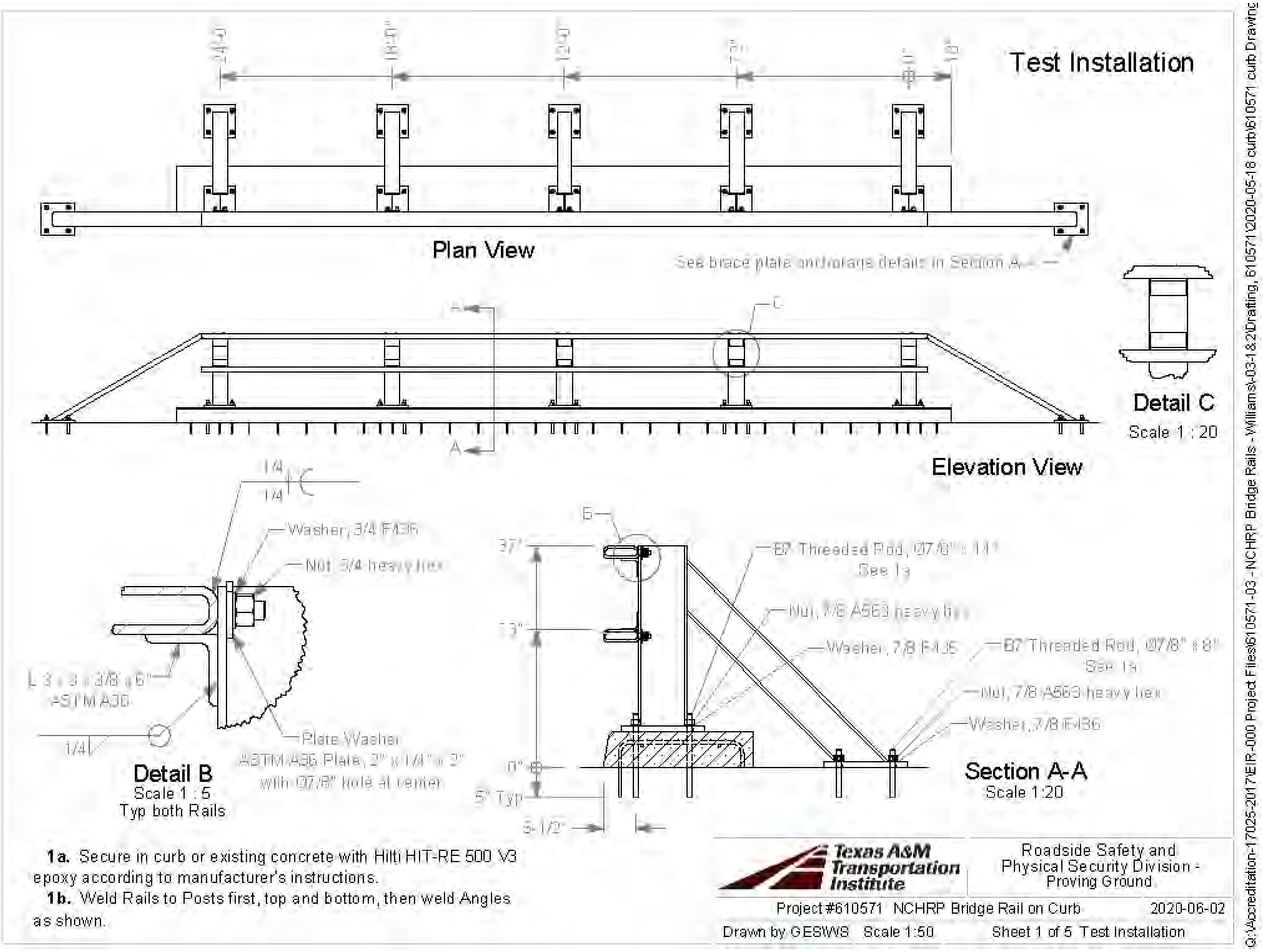
Roadside Safety and
Physical Security Division -
Proving Ground

Project #610571 NCHRP Bridge Rail 2020-06-02

Drawn by GESWS Scale 1:35 Sheet 4 of 4 Bottom Rail

Q:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 - NCHRP Bridge Rails - Williams\-03-1&2\Drafting, 610571\2020-05-18 deck\610571 Deck Drawing

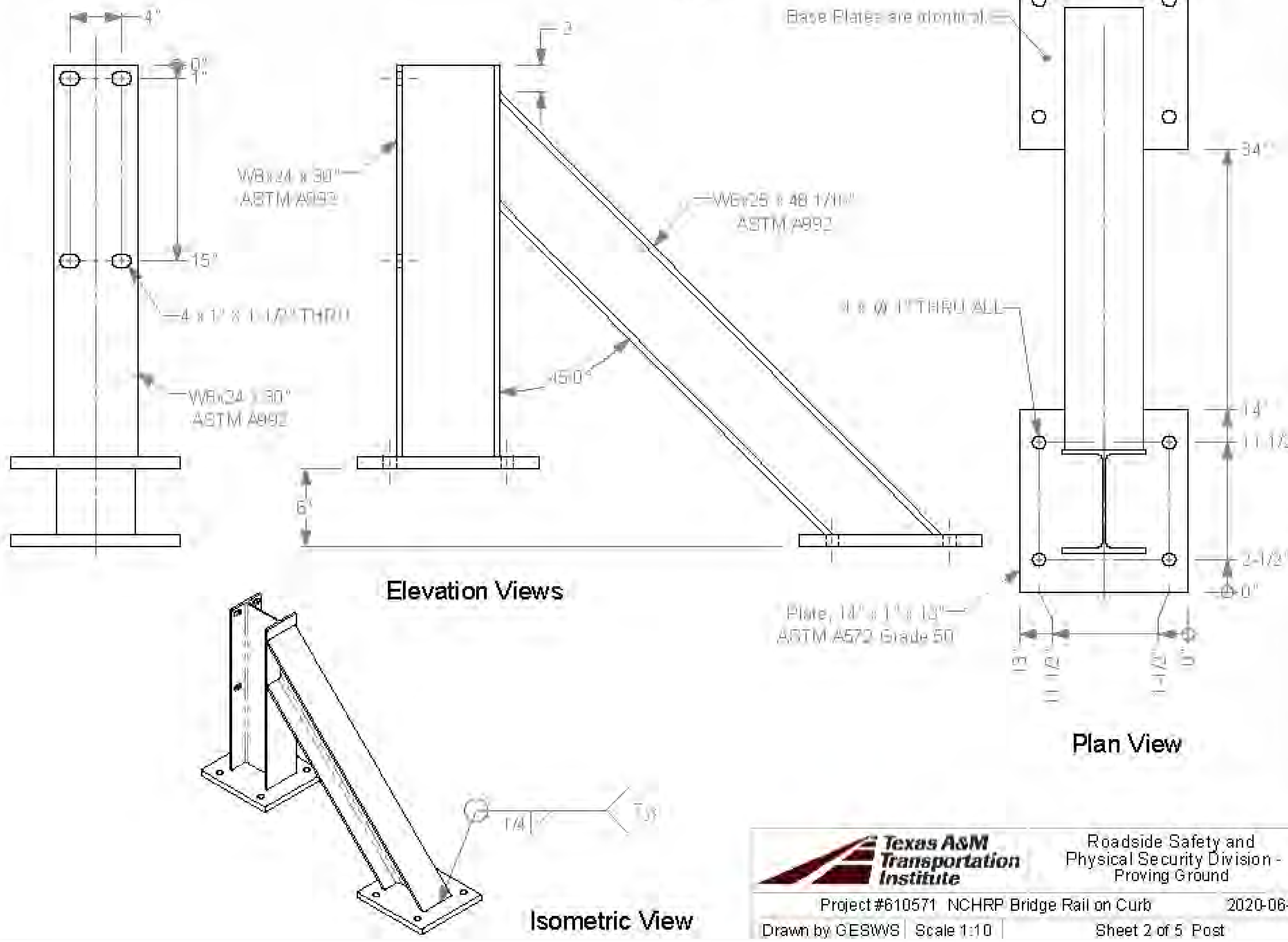
BRIDGE RAIL ON CURB



1a. Secure in curb or existing concrete with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions.

1b. Weld Rails to Posts first, top and bottom, then weld Angles as shown.

Post



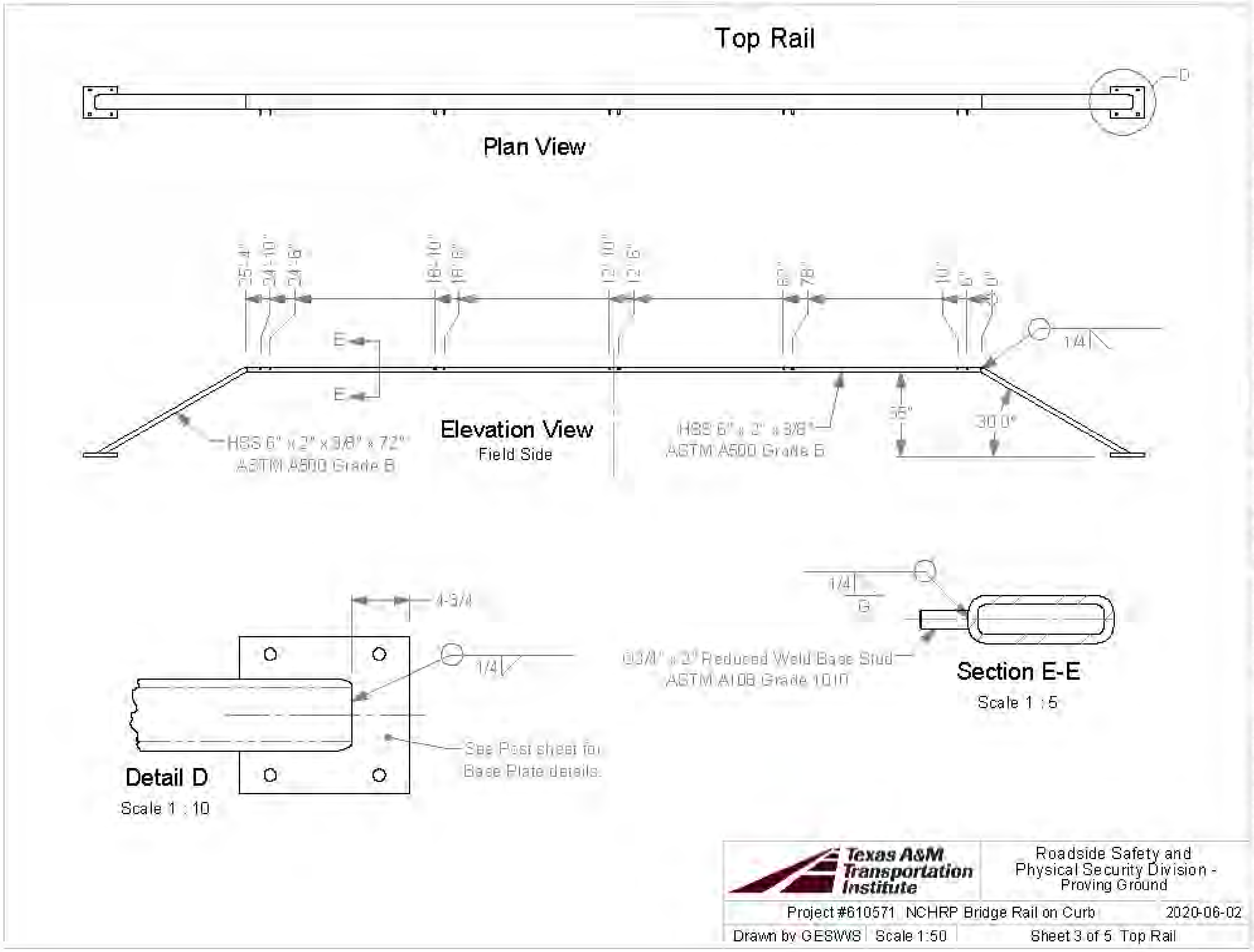
Texas A&M Transportation Institute

Roadside Safety and
Physical Security Division -
Proving Ground

Project #610571 NCHRP Bridge Rail on Curb | 2020-06-02

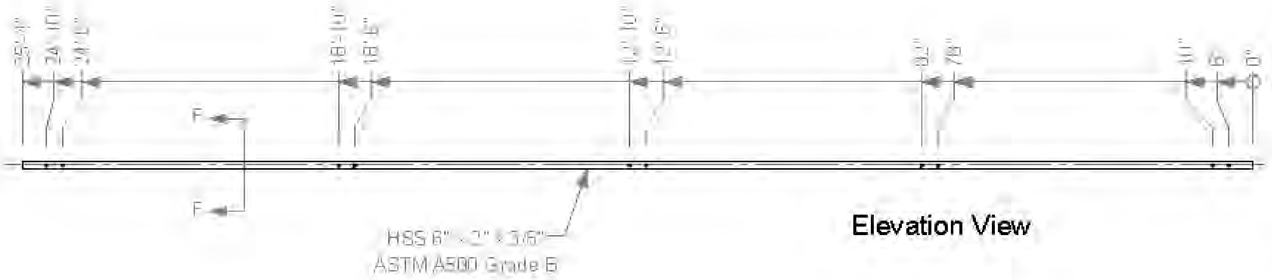
Drawn by GESWS | Scale 1:10 | Sheet 2 of 5 Post

Q:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 -NCHRP Bridge Rails - Williams\-03-1&2\Drafting, 610571\2020-05-18 curb\610571 curb Drawing

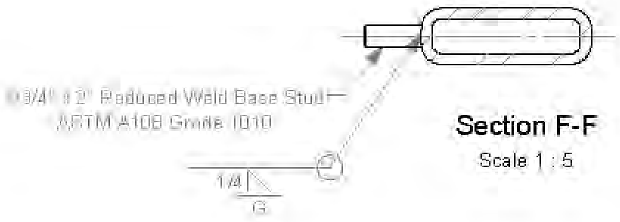


G:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 -NCHRP Bridge Rails - Williams\-03-1&2\Drafting, 610571\2020-05-18 curb\610571 curb Drawing

Bottom Rail



Elevation View



Section F-F

Scale 1 : 5

Texas A&M Transportation Institute

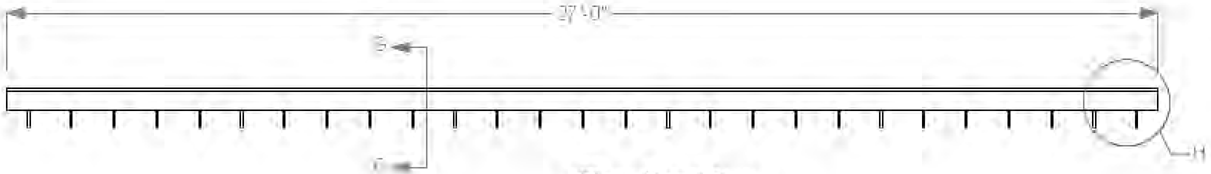
Roadside Safety and Physical Security Division - Proving Ground

Project #610571 NCHRP Bridge Rail on Curb 2020-06-02

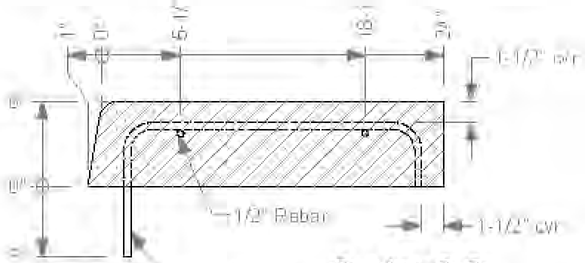
Drawn by GESWS Scale 1:35 Sheet 4 of 5 Bottom Rail

Q:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 - NCHRP Bridge Rails - Williams\-03-1&2\Drafting, 610571\2020-05-18 curb\610571 curb Drawing

Curb Details

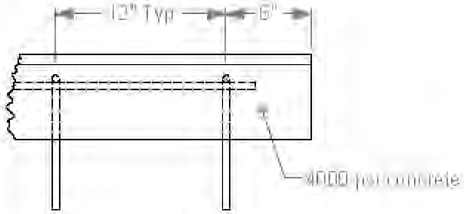


Elevation View



Section G-G

Scale 1 : 10



Detail H

Scale 1 : 10

Curb Stirrup

Ø1/2" Rebar

Scale 1:10

5a. Secure in existing concrete with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions.

5b. Lap length for #4 bars is 15". Chamfer traffic side edge 1" (3/4" each way) as shown.

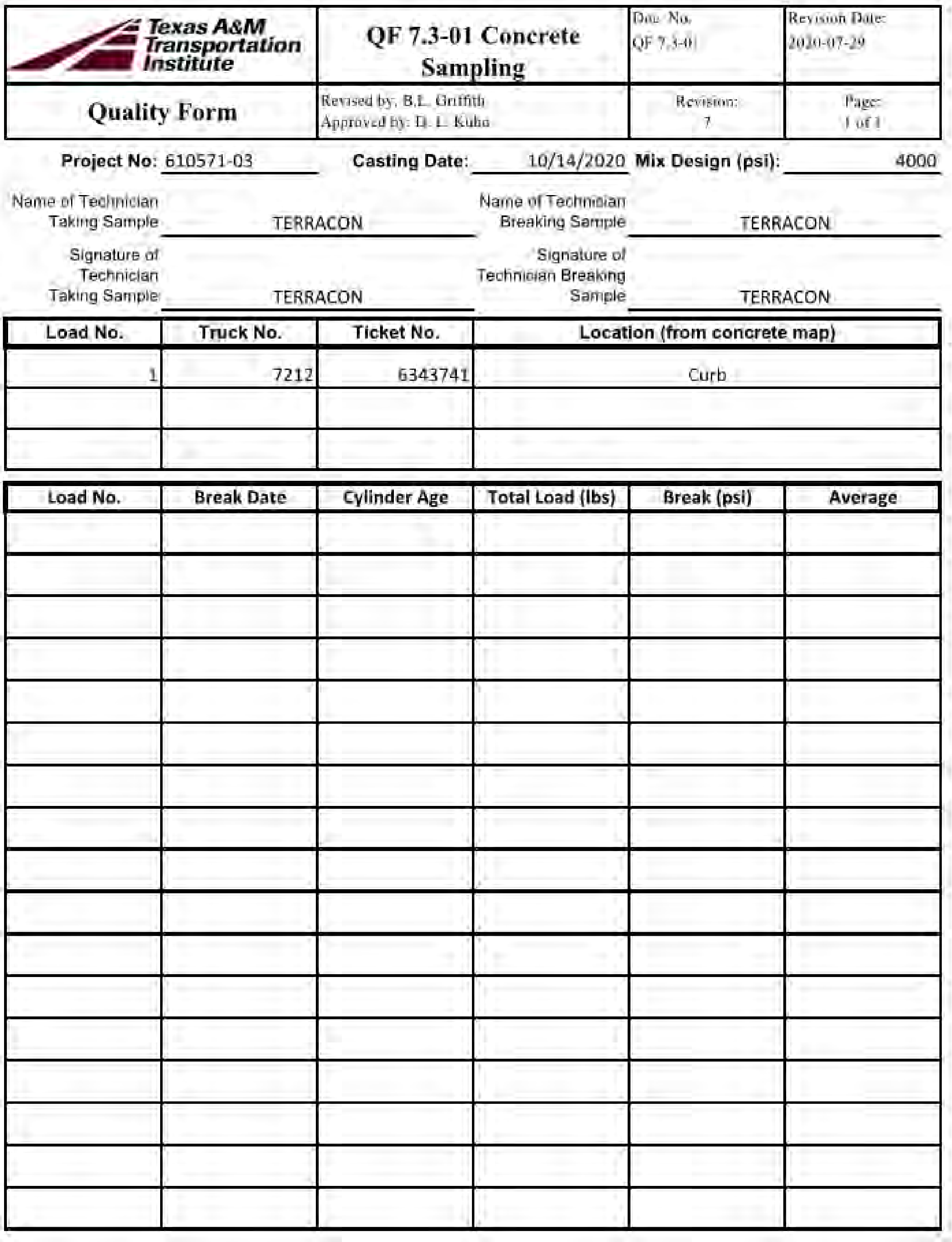
Texas A&M Transportation Institute

Roadside Safety and
Physical Security Division -
Proving Ground

Project #610571	NCHRP Bridge Rail on Curb	2020-06-02
Drawn by GESWS	Scale 1:40	Sheet 5 of 5 Curb Details

G:\Accreditation-17025-2017\EIR-000 Project Files\610571-03 - NCHRP Bridge Rails - Williams\-03-1&2\Drafting, 610571\2020-05-18 curb\610571 curb Drawing

APPENDIX E. SUPPORTING CERTIFICATION DOCUMENTS



Texas A&M Transportation Institute

QF 7.3-01 Concrete Sampling

Doc. No.: QF 7.3-01

Revision Date: 2020-07-29

Quality Form

Revised by: B.L. Griffith
Approved by: D. L. Kuhn

Revision: 7

Page: 1 of 1

Project No: 610571-03 **Casting Date:** 10/14/2020 **Mix Design (psi):** 4000

Name of Technician Taking Sample: TERRACON

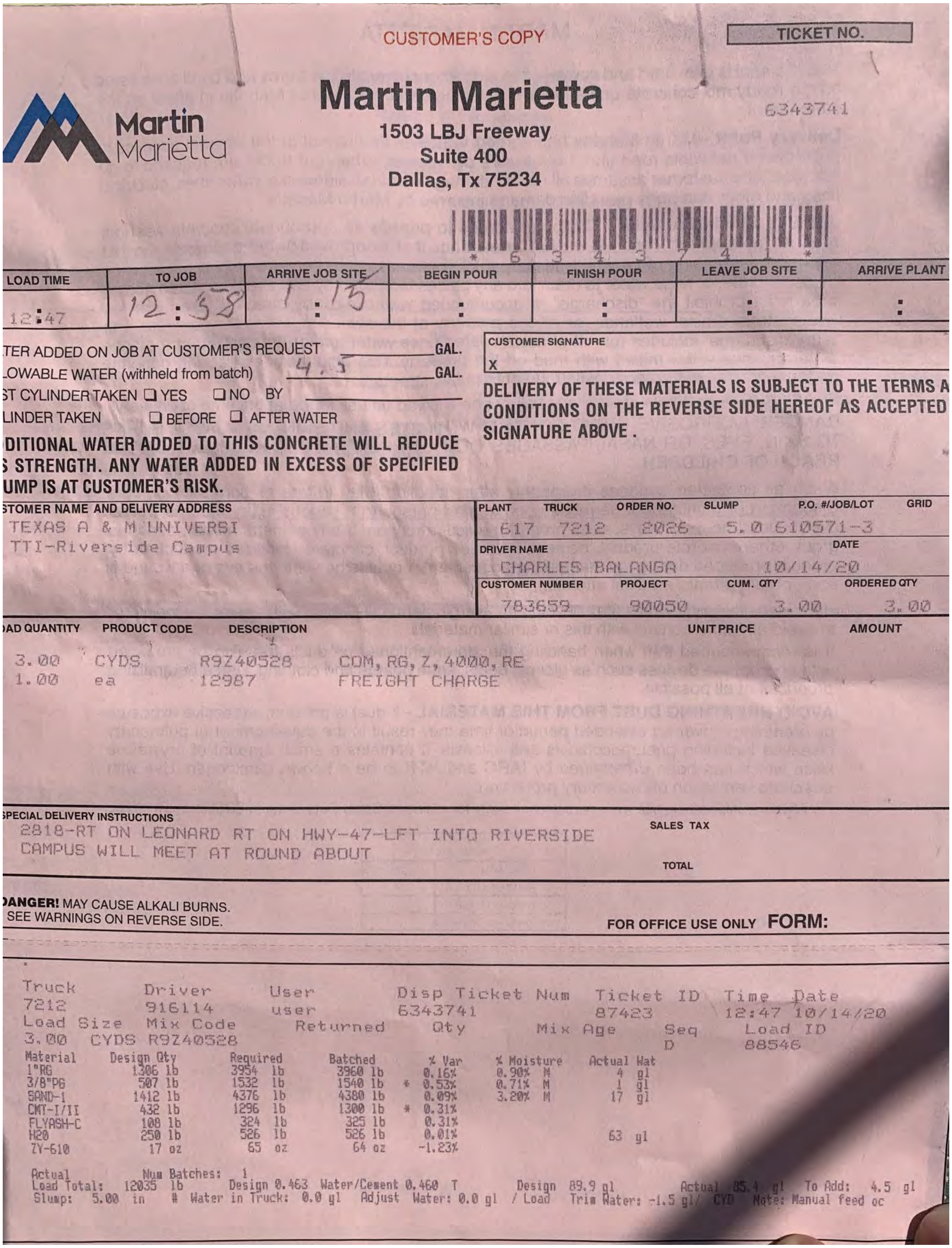
Name of Technician Breaking Sample: TERRACON

Signature of Technician Taking Sample: TERRACON

Signature of Technician Breaking Sample: TERRACON

Load No.	Truck No.	Ticket No.	Location (from concrete map)
1	7212	6343741	Curb

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average



CUSTOMER'S COPY

TICKET NO. 6343741

Martin Marietta
1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:47	12:58	1:15	:	:	:	:

TER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
LOWABLE WATER (withheld from batch) 4.5 GAL.
ST CYLINDER TAKEN ☐ YES ☐ NO BY ________
LINDER TAKEN ☐ BEFORE ☐ AFTER WATER

DITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE S STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED UMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS A CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED SIGNATURE ABOVE .

STOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-Riverside Campus

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7212	2026	5.0	610571-3	

DRIVER NAME	DATE
CHARLES BALANGA	10/14/20

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783659	90050	3.00	3.00

AD QUANTITY	PRODUCT CODE		DESCRIPTION	UNIT PRICE	AMOUNT
3.00	CYDS	R9Z40528	COM,RG,Z,4000,RE		
1.00	ea	12987	FREIGHT CHARGE		

PECIAL DELIVERY INSTRUCTIONS
2818-RT ON LEONARD RT ON HWY-47-LFT INTO RIVERSIDE
CAMPUS WILL MEET AT ROUND ABOUT

SALES TAX

TOTAL

ANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:**

```
Truck         Driver       User          Disp Ticket Num    Ticket ID   Time   Date
7212          916114       user          6343741            87423       12:47  10/14/20
Load Size     Mix Code          Returned       Qty        Mix Age      Seq      Load ID
3.00    CYDS  R9Z40528                                                 D        88546
Material     Design Qty      Required      Batched        % Var     % Moisture    Actual Wat
1"RG            1306 lb      3954  lb      3960 lb        0.16%     0.90%  M          4  gl
3/8"PG           507 lb      1532  lb      1540 lb     *  0.53%     0.71%  M          1  gl
SAND-1          1412 lb      4376  lb      4380 lb        0.09%     3.20%  M         17  gl
CMT-I/II         432 lb      1296  lb      1300 lb     *  0.31%
FLYASH-C         108 lb       324  lb       325 lb        0.31%
H2O              250 lb       526  lb       526 lb        0.01%                      63  gl
ZY-610            17 oz        65  oz        64 oz       -1.23%

Actual          Num Batches:   1
Load Total:   12035  lb      Design 0.463  Water/Cement 0.460  T        Design  89.9 gl         Actual  85.4  gl   To Add:   4.5  gl
Slump:   5.00  in     #  Water in Truck:  0.0 gl   Adjust  Water: 0.0 gl  / Load   Trim Water: -1.5 gl/  CYD   Note: Manual feed oc
```

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0149
Service Date: 10/14/20
Report Date: 12/07/20 Revision 1 - PO Correction
Task: PO #610571-03

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 4,000 psi @ 28 days

Mix ID: R9Z40528
Supplier: Martin Marietta
Batch Time: 1247 **Plant:** 617
Truck No.: 7212 **Ticket No.:** 6343741

Sample Information

Sample Date: 10/14/20 **Sample Time:** 1320
Sampled By: Alexander Dunigan
Weather Conditions: Clear No Wind
Accumulative Yards: 3/3 **Batch Size (cy):** 3
Placement Method: Direct Discharge
Water Added Before (gal):
Water Added After (gal):
Sample Location: North End of Strip
Placement Location: Concrete Strip

Field Test Data

Test	Result	Specification
Slump (in):	5	Not Specified
Air Content (%):	2.1	Not Specified
Concrete Temp. (F):	85	40 - 95
Ambient Temp. (F):	87	40 - 95
Plastic Unit Wt. (pcf):		Not Specified
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.00	28.27		11/09/20	26 F	132,790	4,700	3	AWD
1	B	6.00	28.27		11/09/20	26 F	123,220	4,360	2	AWD
1	C	6.00	28.27		11/09/20	26 F	128,810	4,560	2	AWD
1	D					Hold				

Initial Cure: Outside **Final Cure:** Field Cured

Comments: Not tested for plastic unit weight. F = Field Cured

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Alexander Dunigan **Start/Stop:**
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffin

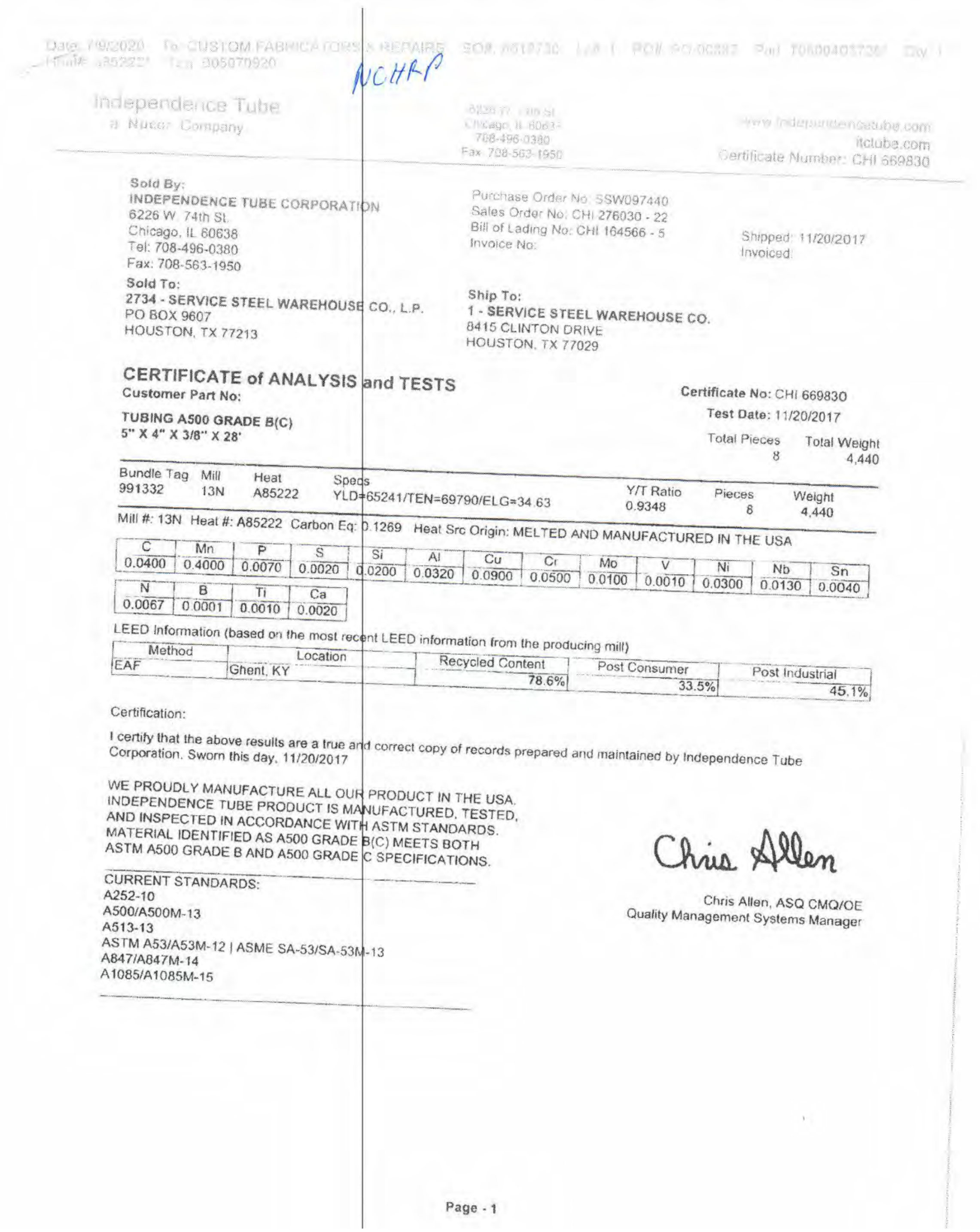
Reviewed By:
Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

Page 1 of 1

CR0001, 11-16-12, Rev 6



Date: 7/9/2020 To: CUSTOM FABRICATORS & REPAIRS SO#: 8519730 Ln#: 1 PO#: PO-00887 Part: T0500403728 Qty: 1
Heat#: A85222' Tag: 005070920

NCHRP

Independence Tube
a Nucor Company

6226 W. 74th St
Chicago, IL 60638
708-496-0380
Fax 708-563-1950

www.independencetube.com
itctube.com
Certificate Number: CHI 669830

Sold By:
INDEPENDENCE TUBE CORPORATION
6226 W. 74th St.
Chicago, IL 60638
Tel: 708-496-0380
Fax: 708-563-1950

Purchase Order No: SSW097440
Sales Order No: CHI 276030 - 22
Bill of Lading No: CHI 164566 - 5
Invoice No:

Shipped: 11/20/2017
Invoiced:

Sold To:
2734 - SERVICE STEEL WAREHOUSE CO., L.P.
PO BOX 9607
HOUSTON, TX 77213

Ship To:
1 - SERVICE STEEL WAREHOUSE CO.
8415 CLINTON DRIVE
HOUSTON, TX 77029

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

TUBING A500 GRADE B(C)
5" X 4" X 3/8" X 28'

Certificate No: CHI 669830
Test Date: 11/20/2017

Total Pieces	Total Weight
8	4,440

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight
991332	13N	A85222	YLD=65241/TEN=69790/ELG=34.63	0.9348	8	4,440

Mill #: 13N Heat #: A85222 Carbon Eq: 0.1269 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Sn
0.0400	0.4000	0.0070	0.0020	0.0200	0.0320	0.0900	0.0500	0.0100	0.0010	0.0300	0.0130	0.0040

N	B	Ti	Ca
0.0067	0.0001	0.0010	0.0020

LEED Information (based on the most recent LEED information from the producing mill)

Method	Location	Recycled Content	Post Consumer	Post Industrial
EAF	Ghent, KY	78.6%	33.5%	45.1%

Certification:

I certify that the above results are a true and correct copy of records prepared and maintained by Independence Tube Corporation. Sworn this day, 11/20/2017

WE PROUDLY MANUFACTURE ALL OUR PRODUCT IN THE USA. INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED, AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS. MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

Chris Allen

Chris Allen, ASQ CMQ/OE
Quality Management Systems Manager

CURRENT STANDARDS:
A252-10
A500/A500M-13
A513-13
ASTM A53/A53M-12 | ASME SA-53/SA-53M-13
A847/A847M-14
A1085/A1085M-15

Page - 1

Fluid Sealing Products, Inc.
GASKETS · FASTENERS · COATINGS

TEXAS BOLT AND NUT

155 SOUTHBELT INDUSTRIAL DRIVE
HOUSTON, TX 77047
Phone: 713-910-1028 Fax: 713-910-1227
www.fluidsealingproducts.com

Certified Material Test Report

Page : 1 of 1

SOLD TO:
MACK BOLT & STEEL
5875 E STATE HIGHWAY
BRYAN, TX 77808

SHIP TO:
MACK BOLT & STEEL
5875 E STATE HIGHWAY
BRYAN, TX 77808

DATE	SALES ORDER #	CUST P.O.#	SPECIFICATION	MATERIAL	FINISH
06/08/2020	573991	36180	ASTM A193	Grade B7	PLAIN

ITEM	QTY	ITEM DESCRIPTION	HEAT #	LOT #	ORIGIN	VENDOR #
1	20	7/8-9 X 14 B7 STUD ✓	10639200	659302	USA	10469

CHEMICAL ANALYSIS

C -	Mn	P -	S -	Si	Cr	Ni	Mo
.4200	.8700	.0110	.0210	.2800	.9500	.0400	.2000

PHYSICAL PROPERTIES

YIELD PSI	TENSILE PSI	ELONGATION	REDUCTION OF AREA %	HARDNESS RC	TEMPERED AT TEMP	MACRO ETCH E381	SPEC DATE
129000	141000	20	62	30	1351 F	S2/R2/C2	19

NCARP
610571

SUPPLEMENTAL INFORMATION

represented above are transference of test data documented by the source of inspection. All test are in
s prescribed in the applicable SAE and/or ASTM specifications and are free from mercury contamination.
, selenium, tellurium or lead was intentionally added have been used to produce the bolts. Fluid Sealing
lity or warranty implied or expressed for the test results represented. Under terms expressed, we hereby
rue representation of information provided by the material supplier and/or our testing laboratory, and under no
information been altered. Original documentation remains on file for review.

Dennis Galati

Dennis Galati - Q.A. Manager

MH

Fluid Sealing Products, Inc.
GASKETS · FASTENERS · COATINGS

TEXAS BOLT AND NUT

155 SOUTHBELT INDUSTRIAL DRIVE
HOUSTON, TX 77047
Phone: 713-910-1028 Fax: 713-910-1227
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Certified Material Test Report

Page : 1 of 1

SOLD TO:
MACK BOLT & STEEL
5875 E STATE HIGHWAY
BRYAN, TX 77808

SHIP TO:
MACK BOLT & STEEL
5875 E STATE HIGHWAY
BRYAN, TX 77808

DATE	SALES ORDER #	CUST P.O.#	SPECIFICATION	MATERIAL	FINISH
06/08/2020	573991	36180	ASTM A193	Grade B7	PLAIN

ITEM	QTY	ITEM DESCRIPTION	HEAT #	LOT #	ORIGIN	VENDOR #
2	48	7/8-9 X 9 B7 STUD ✓	58040469/02	CLZU	USA	10107

CHEMICAL ANALYSIS

C -	Mn	P -	S -	Si	Cr	Mo
.4200	.9800	.0130	.0250	.3000	1.070	.2180

PHYSICAL PROPERTIES

YIELD PSI	TENSILE PSI	ELONGATION	REDUCTION OF AREA %	HARDNESS BRINELL	TEMPERED AT TEMP	MACRO ETCH E381	SPEC DATE
135470	145860	23.78	61.64	309	1100 F	S1/R1/C1	17

REF. NUMBER:

SUPPLEMENTAL INFORMATION

The physical characteristics represented above are transference of test data documented by the source of inspection. All test are in
e with the methods prescribed in the applicable SAE and/or ASTM specifications and are free from mercury contamination.
to which bismuth, selenium, tellurium or lead was intentionally added have been used to produce the bolts. Fluid Sealing
Inc. defers liability or warranty implied or expressed for the test results represented. Under terms expressed, we hereby
this data is a true representation of information provided by the material supplier and/or our testing laboratory, and under no
ces has the information been altered. Original documentation remains on file for review.

Dennis Galati

Dennis Galati - Q.A. Manager

MH

Fluid Sealing Products, Inc.
GASKETS · FASTENERS · COATINGS

TEXAS BOLT AND NUT

155 SOUTHBELT INDUSTRIAL DRIVE
HOUSTON, TX 77047
Phone: 713-910-1028 Fax: 713-910-1227
www.fluidsealingproducts.com

Certified Material Test Report

Page : 1 of 1

SOLD TO:
MACK BOLT & STEEL
5875 E STATE HIGHWAY
BRYAN, TX 77808

SHIP TO:
MACK BOLT & STEEL
5875 E STATE HIGHWAY
BRYAN, TX 77808

DATE	SALES ORDER #	CUST P.O.#	SPECIFICATION	MATERIAL	FINISH
06/08/2020	573991	36180	ASTM A193	Grade B7	PLAIN

ITEM	QTY	ITEM DESCRIPTION	HEAT #	LOT #	ORIGIN	VENDOR #
3	28	7/8-9 X 8 B7 STUD ✓	18B703046	2-181116-2	CHI	10373

CHEMICAL ANALYSIS

C -	Mn	P -	S -	Si	Cr	Mo
.4100	.8000	.0120	.0050	.2000	.8400	.1900

PHYSICAL PROPERTIES

YIELD PSI	TENSILE PSI	ELONGATION	REDUCTION OF AREA %	HARDNESS RC	TEMPERED AT TEMP	MACRO ETCH E381	SPEC DATE
123000	134000	23	63	29.5	1166 F	S2/R2/C3	17

REF. NUMBER:

SUPPLEMENTAL INFORMATION

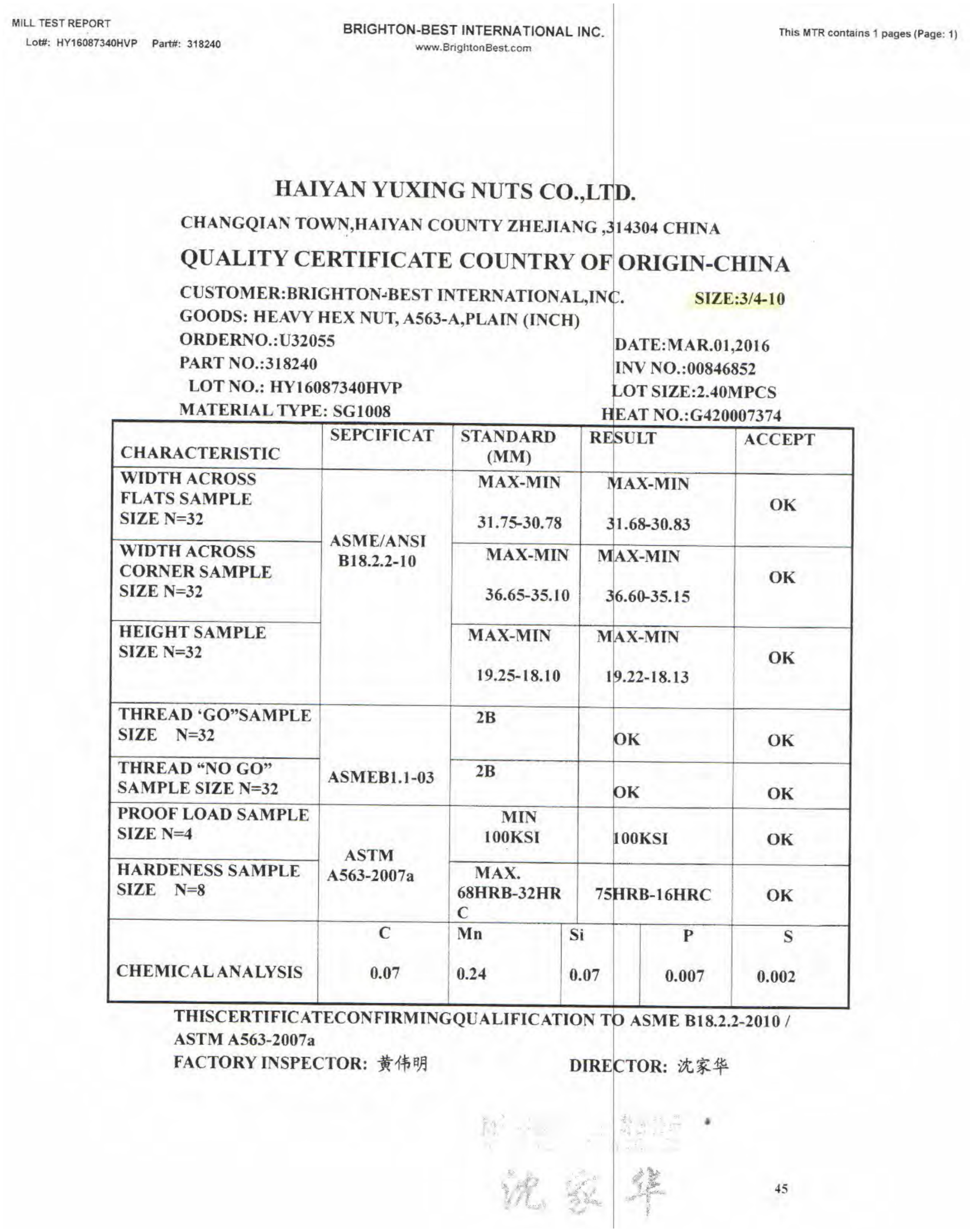
The physical characteristics represented above are transference of test data documented by the source of inspection. All test are in accordance with the methods prescribed in the applicable SAE and/or ASTM specifications and are free from mercury contamination. No heats to which bismuth, selenium, tellurium or lead was intentionally added have been used to produce the bolts. Fluid Sealing Products, Inc. defers liability or warranty implied or expressed for the test results represented. Under terms expressed, we hereby certify that this data is a true representation of information provided by the material supplier and/or our testing laboratory, and under no circumstances has the information been altered. Original documentation remains on file for review.

Vd CO 6-15-20

Dennis Galati

MH

Dennis Galati - Q.A. Manager



MILL TEST REPORT
Lot#: HY16087340HVP Part#: 318240

BRIGHTON-BEST INTERNATIONAL INC.
www.BrightonBest.com

This MTR contains 1 pages (Page: 1)

HAIYAN YUXING NUTS CO.,LTD.

CHANGQIAN TOWN,HAIYAN COUNTY ZHEJIANG ,314304 CHINA

QUALITY CERTIFICATE COUNTRY OF ORIGIN-CHINA

CUSTOMER:BRIGHTON-BEST INTERNATIONAL,INC. **SIZE:3/4-10**
GOODS: HEAVY HEX NUT, A563-A,PLAIN (INCH)
ORDERNO.:U32055 **DATE:MAR.01,2016**
PART NO.:318240 **INV NO.:00846852**
LOT NO.: HY16087340HVP **LOT SIZE:2.40MPCS**
MATERIAL TYPE: SG1008 **HEAT NO.:G420007374**

CHARACTERISTIC	SEPCIFICAT	STANDARD (MM)	RESULT	ACCEPT
WIDTH ACROSS FLATS SAMPLE SIZE N=32	ASME/ANSI B18.2.2-10	MAX-MIN 31.75-30.78	MAX-MIN 31.68-30.83	OK
WIDTH ACROSS CORNER SAMPLE SIZE N=32		MAX-MIN 36.65-35.10	MAX-MIN 36.60-35.15	OK
HEIGHT SAMPLE SIZE N=32		MAX-MIN 19.25-18.10	MAX-MIN 19.22-18.13	OK
THREAD 'GO"SAMPLE SIZE N=32	ASMEB1.1-03	2B	OK	OK
THREAD "NO GO" SAMPLE SIZE N=32		2B	OK	OK
PROOF LOAD SAMPLE SIZE N=4	ASTM A563-2007a	MIN 100KSI	100KSI	OK
HARDENESS SAMPLE SIZE N=8		MAX. 68HRB-32HRC	75HRB-16HRC	OK

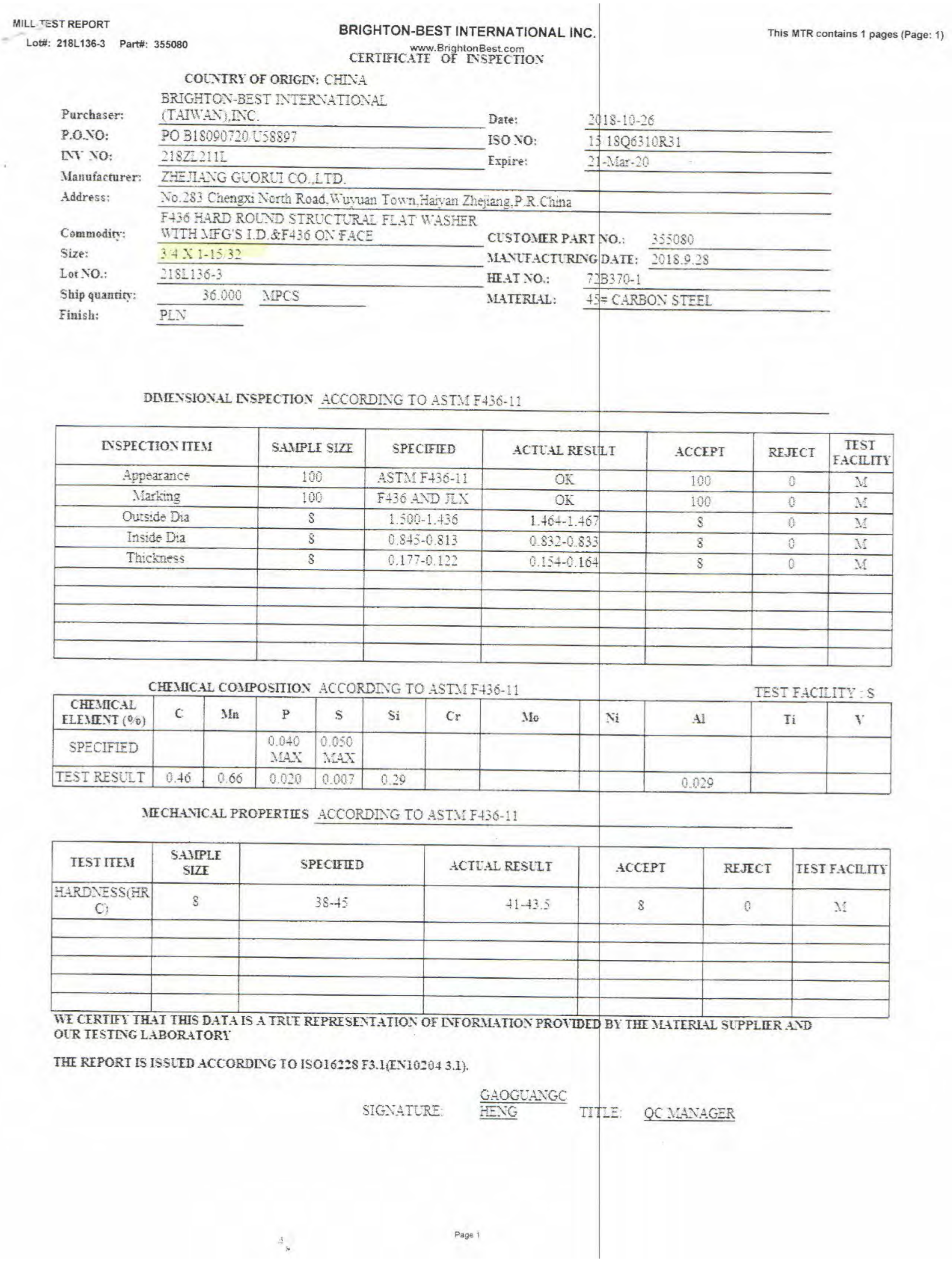
	C	Mn	Si	P	S
CHEMICAL ANALYSIS	0.07	0.24	0.07	0.007	0.002

THISCERTIFICATECONFIRMINGQUALIFICATION TO ASME B18.2.2-2010 / ASTM A563-2007a

FACTORY INSPECTOR: 黄伟明 **DIRECTOR:** 沈家华

沈家华

45



MILL TEST REPORT

Lot#: 218L136-3 Part#: 355080

BRIGHTON-BEST INTERNATIONAL INC.

www.BrightonBest.com

This MTR contains 1 pages (Page: 1)

CERTIFICATE OF INSPECTION

COUNTRY OF ORIGIN: CHINA

Purchaser: BRIGHTON-BEST INTERNATIONAL (TAIWAN),INC.
Date: 2018-10-26
P.O.NO: PO B18090720 U58897
ISO NO: 15 18Q6310R31
INV NO: 218ZL211L
Expire: 21-Mar-20
Manufacturer: ZHEJIANG GUORUI CO.,LTD.
Address: No.283 Chengxi North Road,Wuyuan Town,Haiyan Zhejiang,P.R.China
Commodity: F436 HARD ROUND STRUCTURAL FLAT WASHER WITH MFG'S I.D.&F436 ON FACE
CUSTOMER PART NO.: 355080
Size: 3/4 X 1-15/32
MANUFACTURING DATE: 2018.9.28
Lot NO.: 218L136-3
HEAT NO.: 72B370-1
Ship quantity: 36.000 MPCS
MATERIAL: 45= CARBON STEEL
Finish: PLN

DIMENSIONAL INSPECTION ACCORDING TO ASTM F436-11

INSPECTION ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	ACCEPT	REJECT	TEST FACILITY
Appearance	100	ASTM F436-11	OK	100	0	M
Marking	100	F436 AND JLX	OK	100	0	M
Outside Dia	8	1.500-1.436	1.464-1.467	8	0	M
Inside Dia	8	0.845-0.813	0.832-0.833	8	0	M
Thickness	8	0.177-0.122	0.154-0.164	8	0	M

CHEMICAL COMPOSITION ACCORDING TO ASTM F436-11

TEST FACILITY : S

CHEMICAL ELEMENT (%)	C	Mn	P	S	Si	Cr	Mo	Ni	Al	Ti	V
SPECIFIED			0.040 MAX	0.050 MAX							
TEST RESULT	0.46	0.66	0.020	0.007	0.29				0.029		

MECHANICAL PROPERTIES ACCORDING TO ASTM F436-11

TEST ITEM	SAMPLE SIZE	SPECIFIED	ACTUAL RESULT	ACCEPT	REJECT	TEST FACILITY
HARDNESS(HRC)	8	38-45	41-43.5	8	0	M

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY

THE REPORT IS ISSUED ACCORDING TO ISO16228 F3.1(EN10204 3.1).

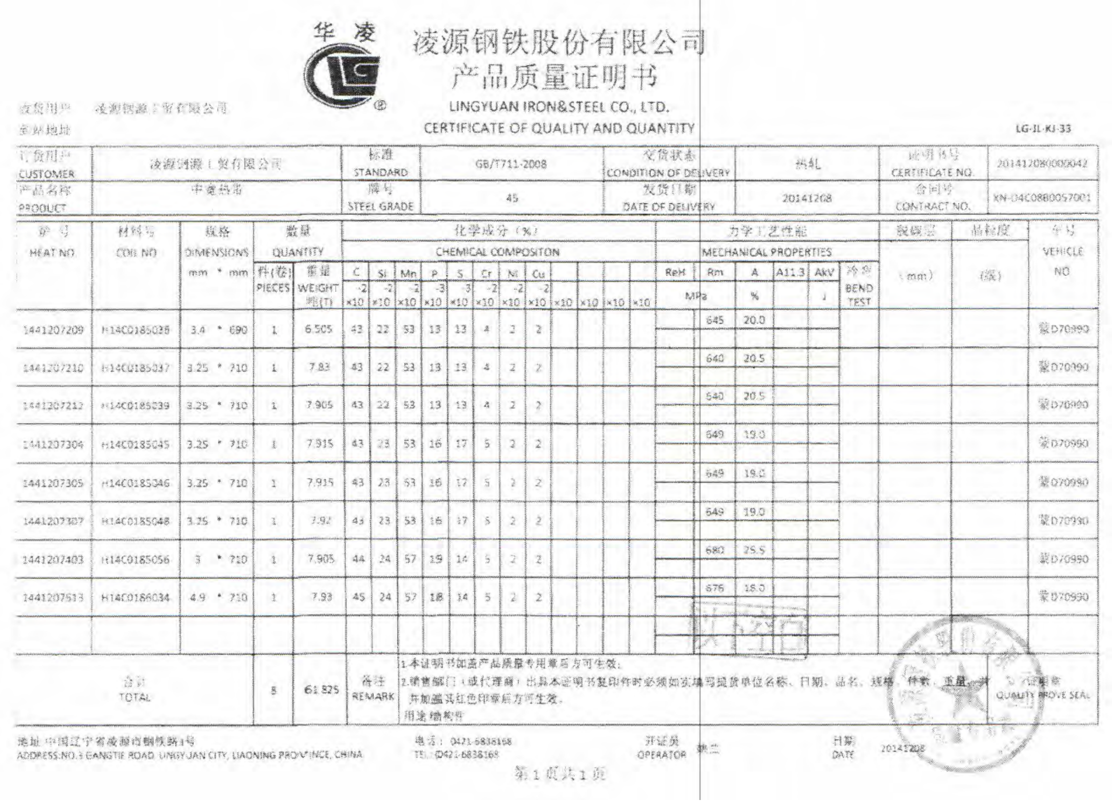
SIGNATURE: GAOGUANGCHENG   TITLE: QC MANAGER

Page 1

MILL TEST REPORT
Lot#: 54219050015 Part#: 355092

BRIGHTON-BEST INTERNATIONAL INC.
www.BrightonBest.com

This MTR contains 1 pages (Page: 1)



华凌

凌源钢铁股份有限公司
产品质量证明书

LINGYUAN IRON&STEEL CO., LTD.
CERTIFICATE OF QUALITY AND QUANTITY

LG-IL-KJ-33

收货用户 凌源钢源工贸有限公司
邮寄地址

订货用户 CUSTOMER	凌源钢源工贸有限公司	标准 STANDARD	GB/T711-2008	交货状态 CONDITION OF DELIVERY	热轧	证明书号 CERTIFICATE NO.	20141208000042
产品名称 PRODUCT	中宽热带	牌号 STEEL GRADE	45	发货日期 DATE OF DELIVERY	20141208	合同号 CONTRACT NO.	XN-04C0880057001

炉号 HEAT NO	材料号 COIL NO	规格 DIMENSIONS	数量 QUANTITY		化学成分（%） CHEMICAL COMPOSITON												力学工艺性能 MECHANICAL PROPERTIES						脱碳层	晶粒度	车号 VEHICLE NO
		mm * mm	件(卷) PIECES	重量 WEIGHT 吨(T)	C	Si	Mn	P	S	Cr	Ni	Cu					ReH	Rm	A	A11.3	AkV	冷弯 BEND TEST	(mm)	(级)	
					×10-2	×10-2	×10-2	×10-3	×10-3	×10-2	×10-2	×10-2	×10	×10	×10	×10	MPa		%		J				
1441207209	H14C0185036	3.4 * 690	1	6.505	43	22	53	13	13	4	2	2						645	20.0						蒙D70990
1441207210	H14C0185037	3.25 * 710	1	7.83	43	22	53	13	13	4	2	2						640	20.5						蒙D70990
1441207212	H14C0185039	3.25 * 710	1	7.905	43	22	53	13	13	4	2	2						640	20.5						蒙D70990
1441207304	H14C0185045	3.25 * 710	1	7.915	43	23	53	16	17	5	2	2						649	19.0						蒙D70990
1441207305	H14C0185046	3.25 * 710	1	7.915	43	23	53	16	17	5	2	2						649	19.0						蒙D70990
1441207307	H14C0185048	3.25 * 710	1	7.92	43	23	53	16	17	5	2	2						649	19.0						蒙D70930
1441207403	H14C0185056	3 * 710	1	7.905	44	24	57	19	14	5	2	2						680	25.5						蒙D70990
1441207613	H14C0186034	4.9 * 710	1	7.93	45	24	57	18	14	5	2	2						676	18.0						蒙D70990
合计 TOTAL			8	61.825	备注 REMARK	1.本证明书加盖产品质量专用章后方可生效； 2.销售部门（或代理商）出具本证明书复印件时必须如实填写提货单位名称、日期、品名、规格、件数、重量、并加盖其红色印章后方可生效。 用途 结构件																			质量证明章 QUALITY PROVE SEAL

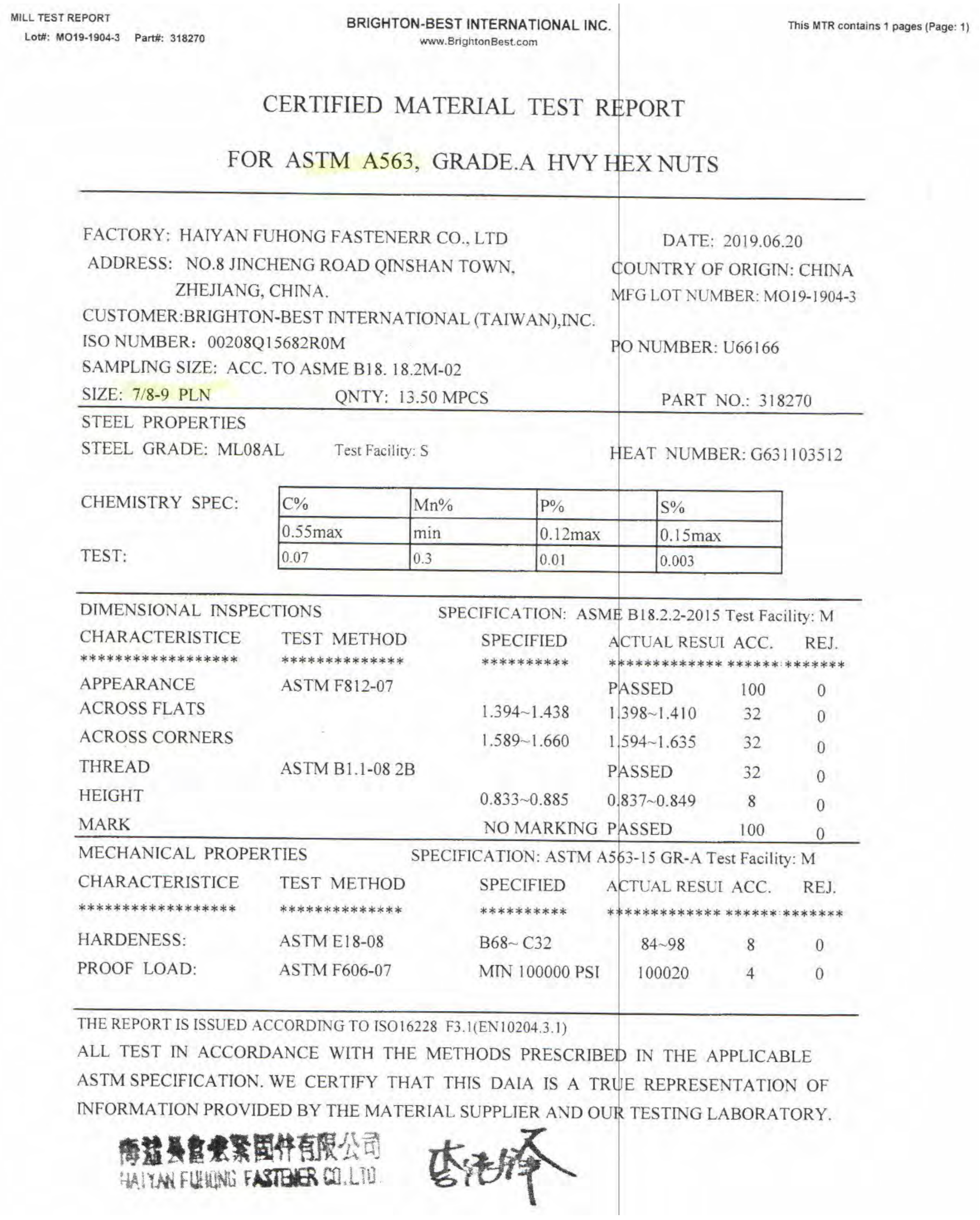
地址 中国辽宁省凌源市钢铁路3号
ADDRESS:NO.3 GANGTIE ROAD, LINGYUAN CITY, LIAONING PROVINCE, CHINA

电话：0421-6838168
TEL: 0421-6838168

开证员 OPERATOR 魏兰

日期 DATE 20141208

第1页共1页



MILL TEST REPORT
Lot#: MO19-1904-3 Part#: 318270

BRIGHTON-BEST INTERNATIONAL INC.
www.BrightonBest.com

This MTR contains 1 pages (Page: 1)

CERTIFIED MATERIAL TEST REPORT

FOR ASTM A563, GRADE.A HVY HEX NUTS

FACTORY: HAIYAN FUHONG FASTENERR CO., LTD
ADDRESS: NO.8 JINCHENG ROAD QINSHAN TOWN,
ZHEJIANG, CHINA.
CUSTOMER:BRIGHTON-BEST INTERNATIONAL (TAIWAN),INC.
ISO NUMBER：00208Q15682R0M
SAMPLING SIZE: ACC. TO ASME B18. 18.2M-02
SIZE: 7/8-9 PLN QNTY: 13.50 MPCS

DATE: 2019.06.20
COUNTRY OF ORIGIN: CHINA
MFG LOT NUMBER: MO19-1904-3
PO NUMBER: U66166
PART NO.: 318270

STEEL PROPERTIES
STEEL GRADE: ML08AL Test Facility: S
HEAT NUMBER: G631103512

	C%	Mn%	P%	S%
CHEMISTRY SPEC:	0.55max	min	0.12max	0.15max
TEST:	0.07	0.3	0.01	0.003

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME B18.2.2-2015 Test Facility: M

CHARACTERISTICE	TEST METHOD	SPECIFIED	ACTUAL RESUI	ACC.	REJ.
******************	**************	**********	*************	******	*******
APPEARANCE	ASTM F812-07		PASSED	100	0
ACROSS FLATS		1.394~1.438	1.398~1.410	32	0
ACROSS CORNERS		1.589~1.660	1.594~1.635	32	0
THREAD	ASTM B1.1-08 2B		PASSED	32	0
HEIGHT		0.833~0.885	0.837~0.849	8	0
MARK		NO MARKING	PASSED	100	0

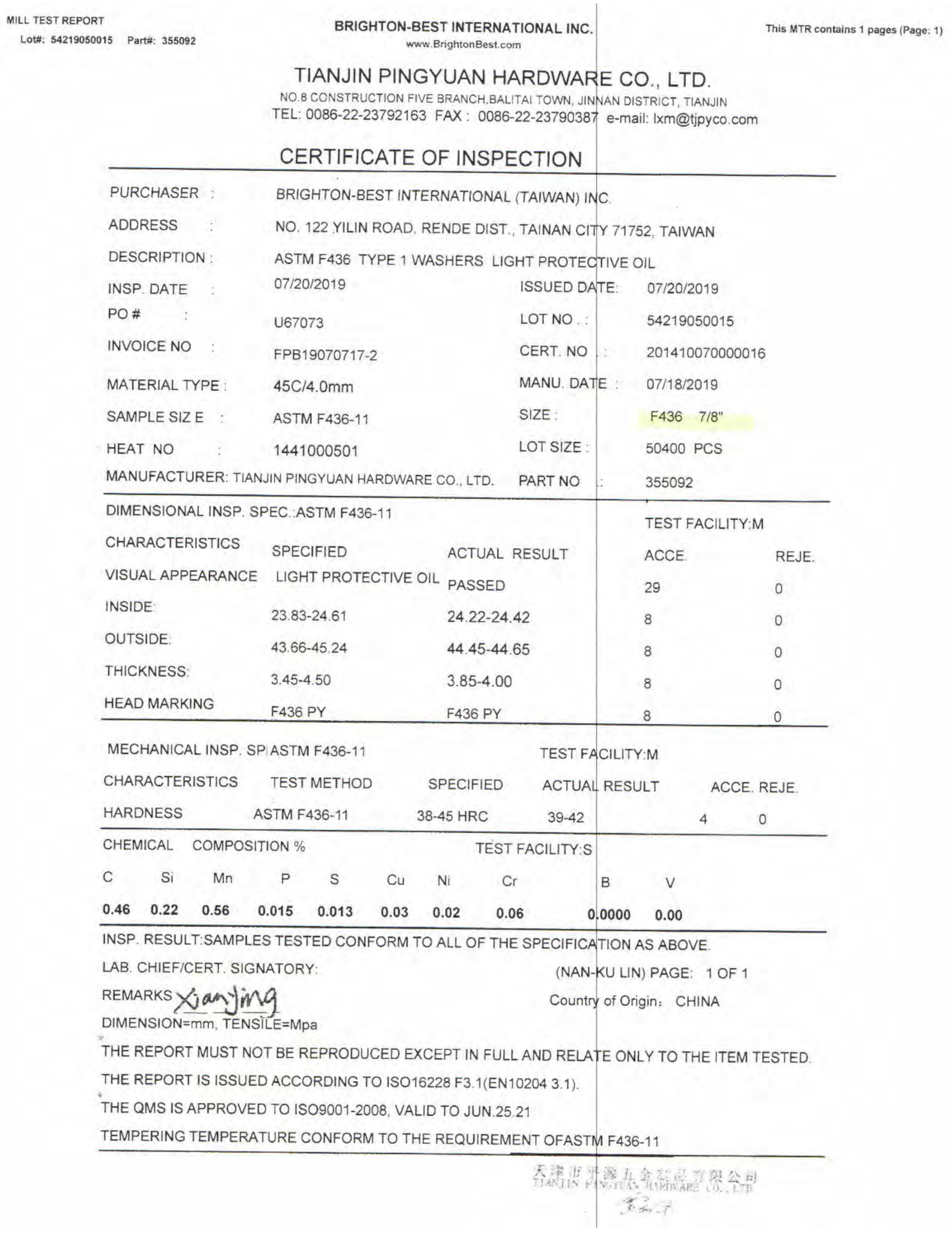
MECHANICAL PROPERTIES SPECIFICATION: ASTM A563-15 GR-A Test Facility: M

CHARACTERISTICE	TEST METHOD	SPECIFIED	ACTUAL RESUI	ACC.	REJ.
******************	**************	**********	*************	******	*******
HARDENESS:	ASTM E18-08	B68~ C32	84~98	8	0
PROOF LOAD:	ASTM F606-07	MIN 100000 PSI	100020	4	0

THE REPORT IS ISSUED ACCORDING TO ISO16228 F3.1(EN10204.3.1)

ALL TEST IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

海盐县富鸿紧固件有限公司
HAIYAN FUHONG FASTENER CO.,LTD



MILL TEST REPORT
Lot#: 54219050015 Part#: 355092

BRIGHTON-BEST INTERNATIONAL INC.
www.BrightonBest.com

This MTR contains 1 pages (Page: 1)

TIANJIN PINGYUAN HARDWARE CO., LTD.

NO.8 CONSTRUCTION FIVE BRANCH,BALITAI TOWN, JINNAN DISTRICT, TIANJIN
TEL: 0086-22-23792163 FAX : 0086-22-23790387 e-mail: lxm@tjpyco.com

CERTIFICATE OF INSPECTION

PURCHASER :	BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC.		
ADDRESS :	NO. 122 YILIN ROAD, RENDE DIST., TAINAN CITY 71752, TAIWAN		
DESCRIPTION :	ASTM F436 TYPE 1 WASHERS LIGHT PROTECTIVE OIL		
INSP. DATE :	07/20/2019	ISSUED DATE:	07/20/2019
PO # :	U67073	LOT NO. :	54219050015
INVOICE NO :	FPB19070717-2	CERT. NO :	201410070000016
MATERIAL TYPE :	45C/4.0mm	MANU. DATE :	07/18/2019
SAMPLE SIZ E :	ASTM F436-11	SIZE :	F436 7/8"
HEAT NO :	1441000501	LOT SIZE :	50400 PCS
MANUFACTURER:	TIANJIN PINGYUAN HARDWARE CO., LTD.	PART NO :	355092

DIMENSIONAL INSP. SPEC.:ASTM F436-11 TEST FACILITY:M

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACCE.	REJE.
VISUAL APPEARANCE	LIGHT PROTECTIVE OIL	PASSED	29	0
INSIDE:	23.83-24.61	24.22-24.42	8	0
OUTSIDE:	43.66-45.24	44.45-44.65	8	0
THICKNESS:	3.45-4.50	3.85-4.00	8	0
HEAD MARKING	F436 PY	F436 PY	8	0

MECHANICAL INSP. SP ASTM F436-11 TEST FACILITY:M

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACCE.	REJE.
HARDNESS	ASTM F436-11	38-45 HRC	39-42	4	0

CHEMICAL COMPOSITION % TEST FACILITY:S

C	Si	Mn	P	S	Cu	Ni	Cr	B	V
0.46	**0.22**	**0.56**	**0.015**	**0.013**	**0.03**	**0.02**	**0.06**	**0.0000**	**0.00**

INSP. RESULT:SAMPLES TESTED CONFORM TO ALL OF THE SPECIFICATION AS ABOVE.

LAB. CHIEF/CERT. SIGNATORY: (NAN-KU LIN) PAGE: 1 OF 1

REMARKS Xianjing Country of Origin: CHINA

DIMENSION=mm, TENSILE=Mpa

THE REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL AND RELATE ONLY TO THE ITEM TESTED.

THE REPORT IS ISSUED ACCORDING TO ISO16228 F3.1(EN10204 3.1).

THE QMS IS APPROVED TO ISO9001-2008, VALID TO JUN.25.21

TEMPERING TEMPERATURE CONFORM TO THE REQUIREMENT OFASTM F436-11

天津市平源五金制品有限公司
TIANJIN PINGYUAN HARDWARE CO., LTD

Metals 2 Go

MATERIAL TEST REPORT COVER SHEET

224 N HEWITT DR
HEWITT TX 76643
254-235-7700
FAX 254-235-7703
MTR@METALS2GO.COM

MACK MANUFACTURING & MACHINE

PO #	36186		EXPECTED DELIVERY	060920
TICKET #	200549			

```
18May20 15:40            T E S T    C E R T I F I C A T E          No: HO  308791
     PLATEPLUS INC



                                                 MJ LATHERN CO INC
                                                 DBA METALS 2 GO
                                                 224 NORTH HEWITT DRIVE
                                                 HEWITT TX   76643
     MJ LATHERN CO INC
     DBA METALS 2 GO
     PO BOX 20425
     WACO  TX  76702


     Tel: 254-235-7700 Fax: 254 235-7703
--------------------------------------------------------------------------------
                CERTIFICATE of ANALYSIS and TESTS           Cert. No: HO  308791
                                                                          18May20
Part No
HR BLK PLATE CORRECT LV ASTM A-36/ASME SA-36
1/4 X 48.0000" X 96.0000"                                             Pcs     Wgt
                                                                       53  17,318

Heat Number     Tag No     Mill Tag                                   Pcs     Wgt
92843C          108331     HSM 00252461                                 5   1,634
                    MILL=<USS>/CNTRY=<USA>/MELT=<USA>/MFG=<USA>/YLDH=46.4
                    TENSH=69.6/ELONH=30/YLDC=43.1/TENSC=66.6/ELONC=31.5
93374C          108458     HSM 00260600                                12   3,921
                    MILL=<USS>/CNTRY=<USA>/MELT=<USA>/MFG=<USA>/YLDH=45.2
                    TENSH=67.4/ELONH=31.5/YLDC=43.3/TENSC=64.4/ELONC=32.5
93374C          108459     HSM 00260600                                12   3,921
                    MILL=<USS>/CNTRY=<USA>/MELT=<USA>/MFG=<USA>/YLDH=45.2
                    TENSH=67.4/ELONH=31.5/YLDC=43.3/TENSC=64.4/ELONC=32.5
93374C          108460     HSM 00260600                                12   3,921
                    MILL=<USS>/CNTRY=<USA>/MELT=<USA>/MFG=<USA>/YLDH=45.2
                    TENSH=67.4/ELONH=31.5/YLDC=43.3/TENSC=64.4/ELONC=32.5
93374C          108461     HSM 00260600                                12   3,921
                    MILL=<USS>/CNTRY=<USA>/MELT=<USA>/MFG=<USA>/YLDH=45.2
                    TENSH=67.4/ELONH=31.5/YLDC=43.3/TENSC=64.4/ELONC=32.5


Heat Number          *** Chemical Analysis ***
US STEEL
92843C          C=0.2000 Mn=0.7800 P=0.0130 S=0.0110 Si=0.0130 Cu=0.0500
                Al=0.0370 Cb=0.0000 V=0.0000 Ni=0.0200 Cr=0.0500 Ti=0.0000
                N=0.0040 Mo=0.0100 B=0.0000 Zr=0.0000 Sn=0.0000 Sb=0.0000
                Ca=0.0000
93374C          C=0.2000 Mn=0.7500 P=0.0120 S=0.0060 Si=0.0110 Cu=0.0300
                Al=0.0520 Cb=0.0000 V=0.0000 Ni=0.0100 Cr=0.0500 Ti=0.0010
                N=0.0030 Mo=0.0000 B=0.0000 Zr=0.0000 Sn=0.0100 Sb=0.0000
                Ca=0.0000

ELEMENTS NOT LISTED TEST BELOW DETECTABLE LEVELS
ALL ASTM PLATE PRODUCTS ARE PRODUCED FROM COIL
CENTER TESTS AVAILABLE AT PLATEPLUS
THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED
  HEREIN WAS SAMPLED AND TESTED IN ACCORDANCE
  WITH THE SPECIFICATION, TO OUR KNOWLEDGE,
  AND FULFILLS REQUIREMENTS IN SUCH RESPECT.
ALL PRODUCT IS PRODUCED FROM COIL. ELONGATION
IS MEASURED FROM A TWO INCH GAGE LENGTH UNLESS

    Page:  1 ....Continued
```

18May20 15:40 TEST CERTIFICATE No: HO 308791

PLATEPLUS INC

MJ LATHERN CO INC
DBA METALS 2 GO
224 NORTH HEWITT DRIVE
HEWITT TX 76643

MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO TX 76702

Tel: 254-235-7700 Fax: 254 235-7703

CERTIFICATE of ANALYSIS and TESTS Cert. No: HO 308791
18May20

OTHERWISE NOTED.

Page: 2 .... Last

Metals 2 Go

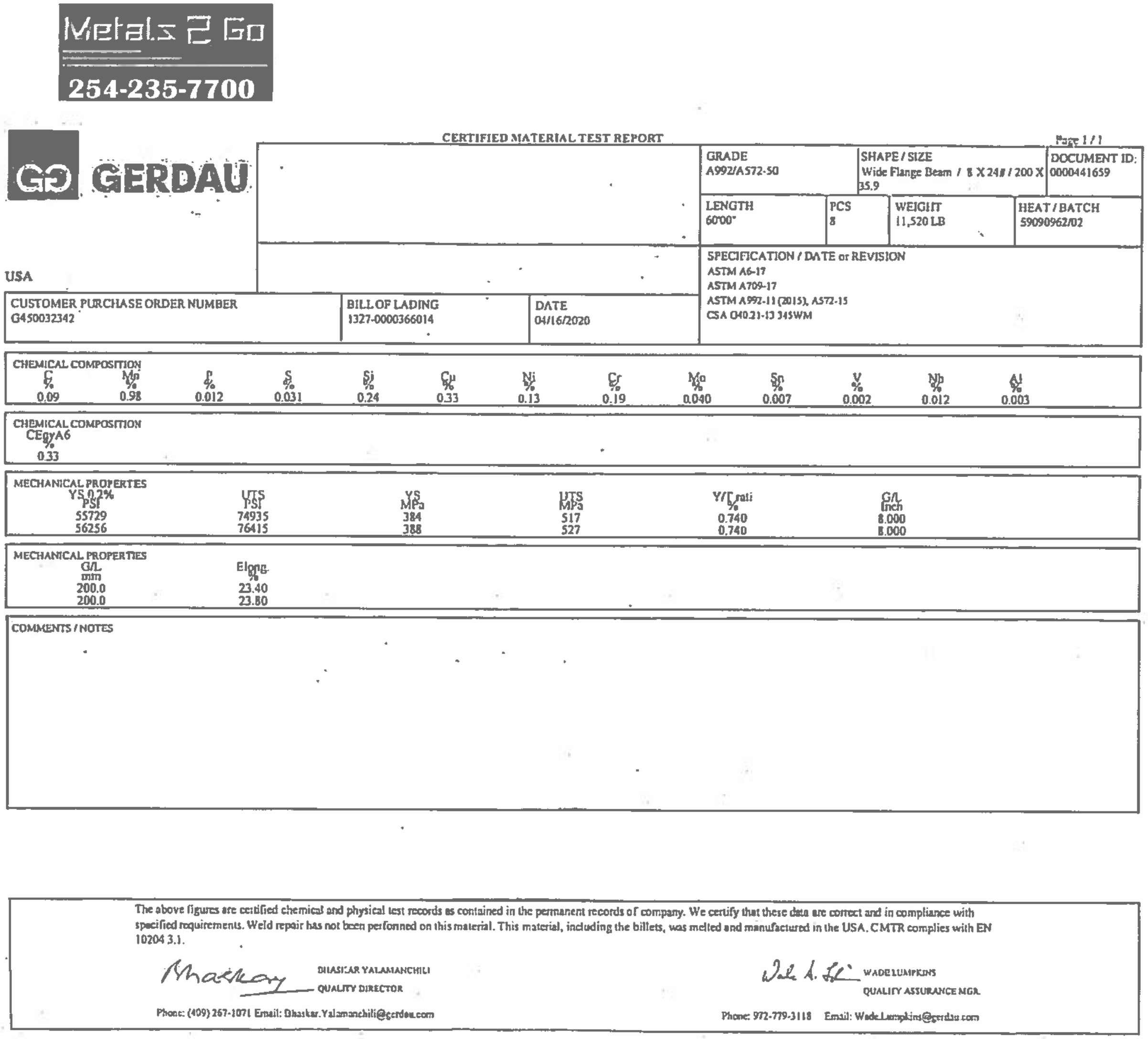
MATERIAL TEST REPORT COVER SHEET

224 N HEWITT DR
HEWITT TX 76643
254-235-7700
FAX 254-235-7703
MTR@METALS2GO.COM

MACK MANUFACTURING & MACHINE

PO #	36179		EXPECTED DELIVERY	060920
TICKET #	200456			

Metals 2 Go
Customer PO: 43090
Heat: 59090962
Shipment: 0020015119



Metals 2 Go
254-235-7700

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
A992/A572-50	Wide Flange Beam / 8 X 24# / 200 X 35.9	0000441659

LENGTH	PCS	WEIGHT	HEAT / BATCH
60'00"	8	11,520 LB	59090962/02

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
G450032342	1327-0000366014	04/16/2020

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.09	0.98	0.012	0.031	0.24	0.33	0.13	0.19	0.040	0.007	0.002	0.012	0.003

CHEMICAL COMPOSITION

CEqyA6 %
0.33

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T rati %	G/L Inch
55729	74935	384	517	0.740	8.000
56256	76415	388	527	0.740	8.000

MECHANICAL PROPERTIES

G/L mm	Elong. %
200.0	23.40
200.0	23.80

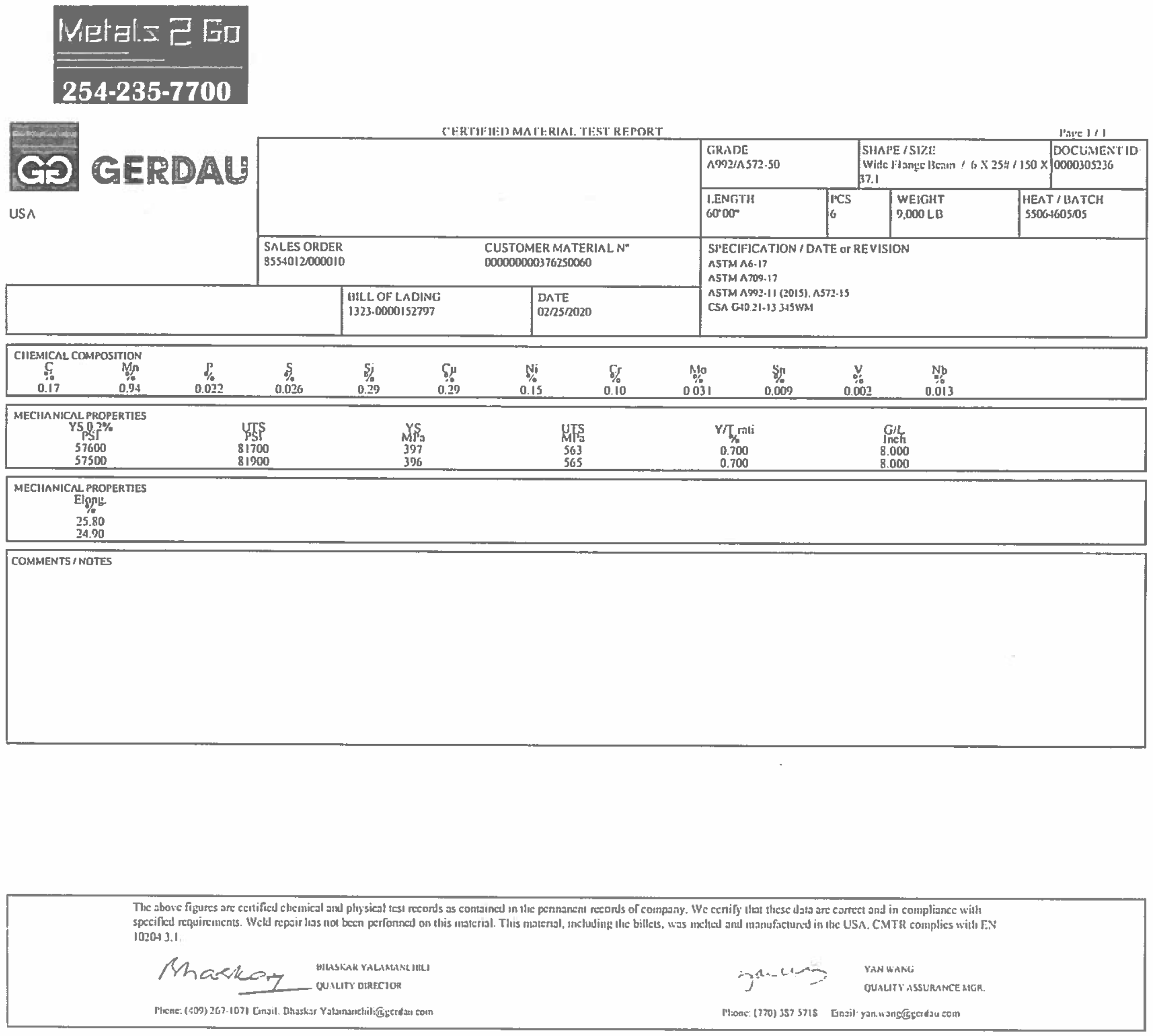
COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured 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

Metals 2 Go
Customer PO: 43198
Heat: 55064605
Shipment: 0020017371



Metals 2 Go
254-235-7700

GERDAU
USA

CERTIFIED MATERIAL TEST REPORT

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GRADE A992/A572-50		SHAPE / SIZE Wide Flange Beam / 6 X 25# / 150 X 37.1		DOCUMENT ID 0000305236
LENGTH 60'00"	PCS 6	WEIGHT 9,000 LB		HEAT / BATCH 55064605/05

SALES ORDER 8554012/000010	CUSTOMER MATERIAL N° 000000000376250060
BILL OF LADING 1323-0000152797	DATE 02/25/2020

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.17	0.94	0.022	0.026	0.29	0.29	0.15	0.10	0.031	0.009	0.002	0.013

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	Y/T ratio %	G/L Inch
57600	81700	397	563	0.700	8.000
57500	81900	396	565	0.700	8.000

MECHANICAL PROPERTIES

Elong. %
25.80
24.90

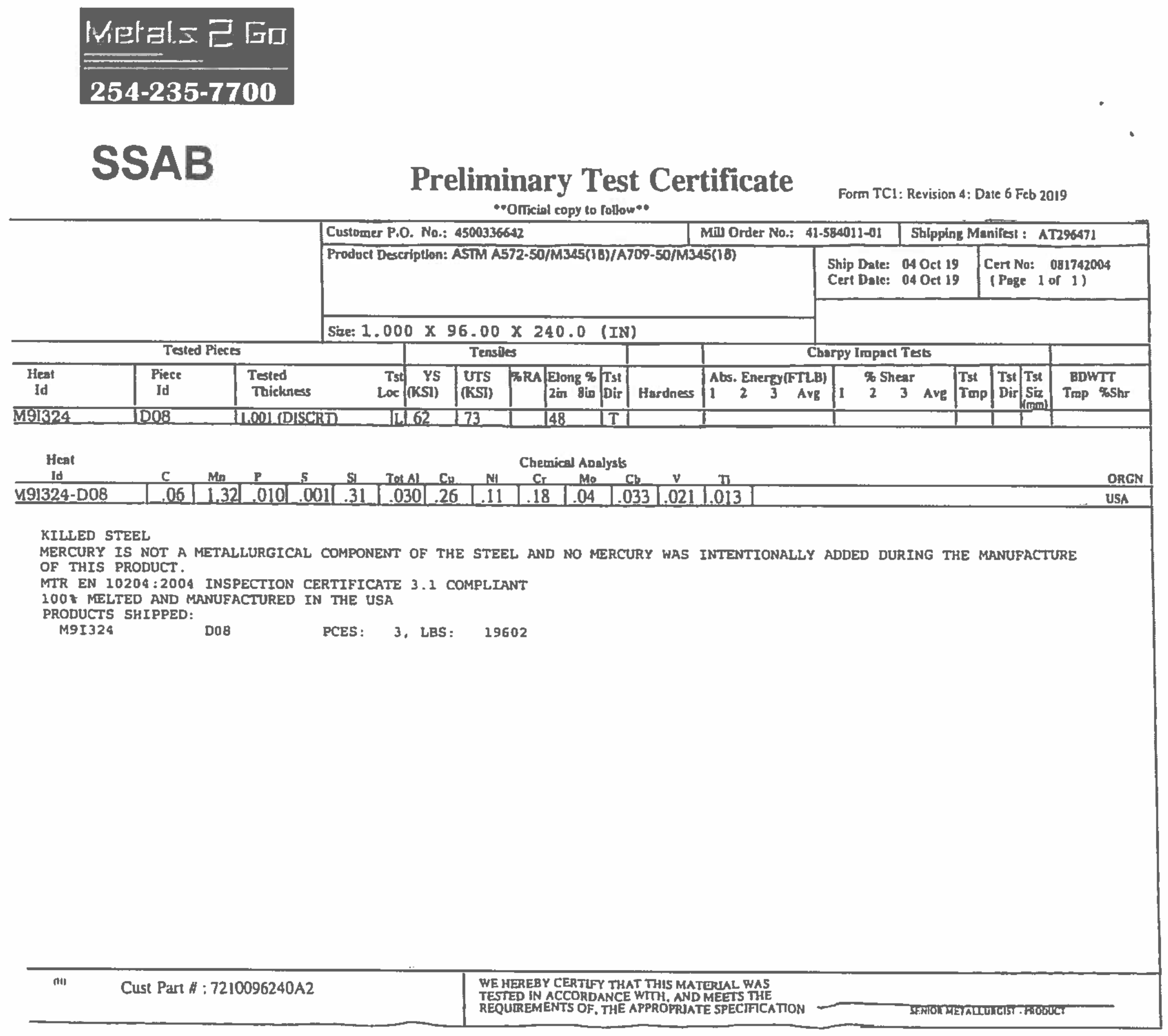
COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

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

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Metals 2 Go
Customer PO: 42233
Heat: M9I324
Shipment: 0019041614



Metals 2 Go
254-235-7700

SSAB

Preliminary Test Certificate

Official copy to follow

Form TC1: Revision 4: Date 6 Feb 2019

Customer P.O. No.: 4500336642
Mill Order No.: 41-584011-01
Shipping Manifest : AT296471
Product Description: ASTM A572-50/M345(18)/A709-50/M345(18)
Ship Date: 04 Oct 19
Cert Date: 04 Oct 19
Cert No: 081742004
(Page 1 of 1)
Size: 1.000 X 96.00 X 240.0 (IN)

Tested Pieces				Tensiles							Charpy Impact Tests													
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1	Abs. Energy(FTLB) 2	Abs. Energy(FTLB) 3	Abs. Energy(FTLB) Avg	% Shear 1	% Shear 2	% Shear 3	% Shear Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp	BDWTT %Shr
M9I324	D08	1.001 (DISCRT)	L	62	73		48		T														

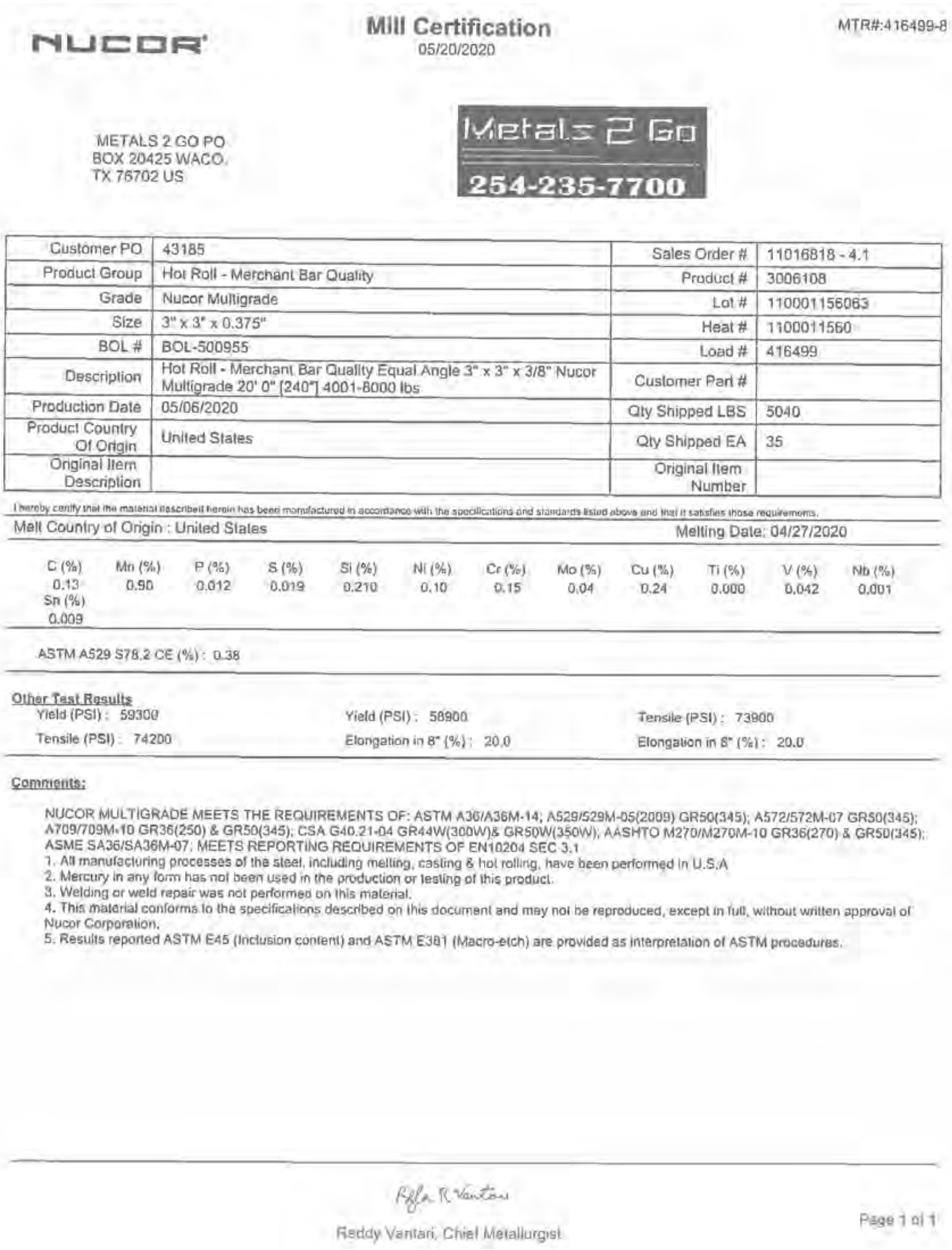
Heat Id	Chemical Analysis													
	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	ORGN
M9I324-D08	.06	1.32	.010	.001	.31	.030	.26	.11	.18	.04	.033	.021	.013	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA
PRODUCTS SHIPPED:
M9I324 D08 PCES: 3, LBS: 19602

Cust Part # : 7210096240A2

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

SENIOR METALLURGIST - PRODUCT



NUCOR

Mill Certification

05/20/2020

MTR#:416499-8

METALS 2 GO PO
BOX 20425 WACO,
TX 76702 US

Metals 2 Go
254-235-7700

Customer PO	43185	Sales Order #	11016818 - 4.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3006108
Grade	Nucor Multigrade	Lot #	110001156063
Size	3" x 3" x 0.375"	Heat #	1100011560
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Equal Angle 3" x 3" x 3/8" Nucor Multigrade 20' 0" [240"] 4001-8000 lbs	Customer Part #	
Production Date	05/06/2020	Qty Shipped LBS	5040
Product Country Of Origin	United States	Qty Shipped EA	35
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: 04/27/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.13	0.90	0.012	0.019	0.210	0.10	0.15	0.04	0.24	0.000	0.042	0.001
Sn (%)											
0.009											

ASTM A529 S78.2 CE (%) : 0.38

Other Test Results

Yield (PSI) : 59300	Yield (PSI) : 58900	Tensile (PSI) : 73900
Tensile (PSI) : 74200	Elongation in 8" (%) : 20.0	Elongation in 8" (%) : 20.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

1. All manufacturing processes of the steel, including melting, casting & hot rolling, have been performed in U.S.A
2. Mercury in any form has not been used in the production or testing of this product.
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.

Reddy R Vantari

Reddy Vantari, Chief Metallurgist

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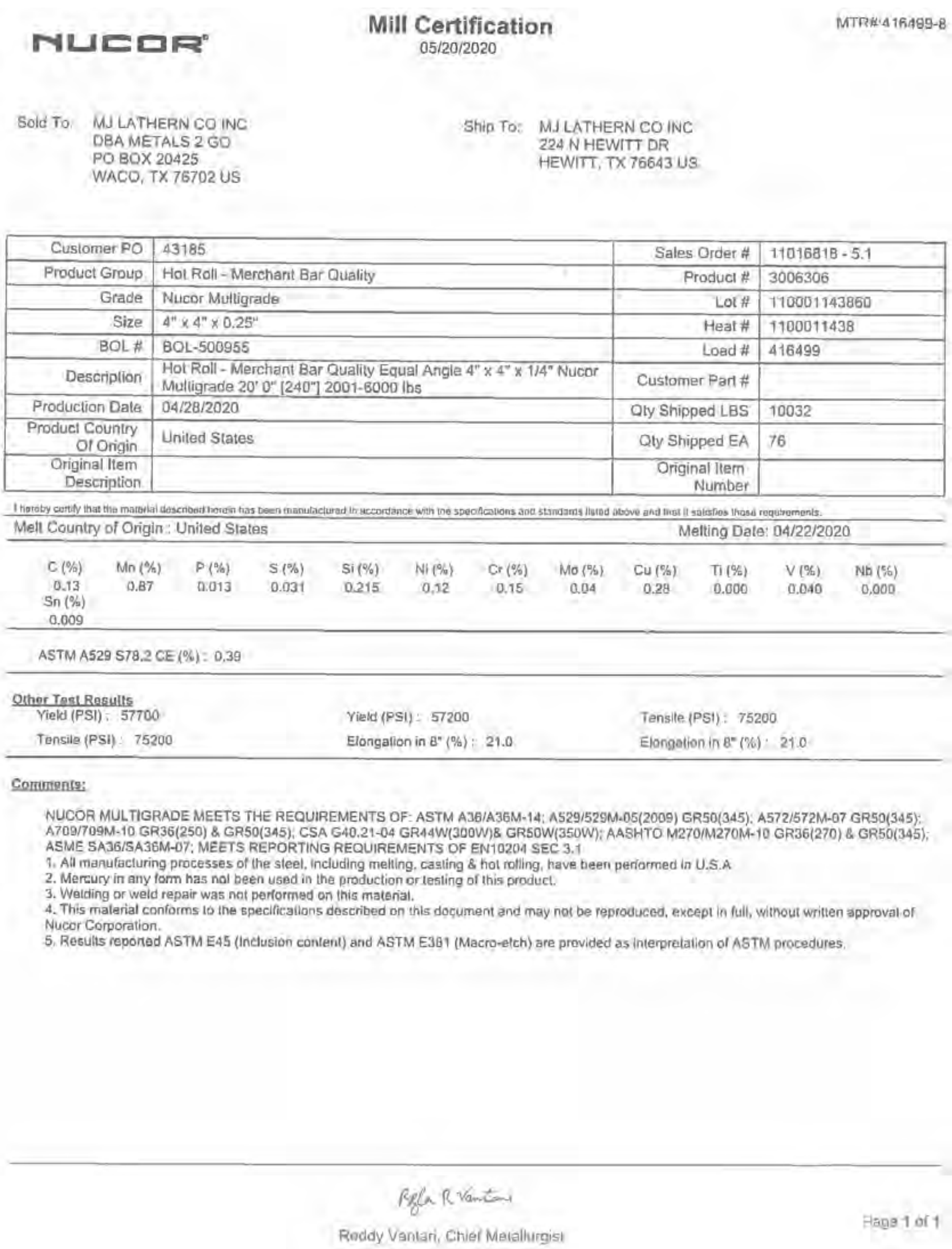

NUCOR

Mill Certification

05/20/2020

MTR#:416499-8

Sold To: MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO, TX 76702 US

Ship To: MJ LATHERN CO INC
224 N HEWITT DR
HEWITT, TX 76643 US

Customer PO	43185	Sales Order #	11016818 - 5.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3006306
Grade	Nucor Multigrade	Lot #	110001143860
Size	4" x 4" x 0.25"	Heat #	1100011438
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Equal Angle 4" x 4" x 1/4" Nucor Multigrade 20' 0" [240"] 2001-6000 lbs	Customer Part #	
Production Date	04/28/2020	Qty Shipped LBS	10032
Product Country Of Origin	United States	Qty Shipped EA	76
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: 04/22/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.13	0.87	0.013	0.031	0.215	0.12	0.15	0.04	0.28	0.000	0.040	0.000
Sn (%)											
0.009											

ASTM A529 S78.2 CE (%) : 0.39

Other Test Results

Yield (PSI) : 57700

Tensile (PSI) : 75200

Yield (PSI) : 57200

Elongation in 8" (%) : 21.0

Tensile (PSI) : 75200

Elongation in 8" (%) : 21.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

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Reddy Vantari, Chief Metallurgist

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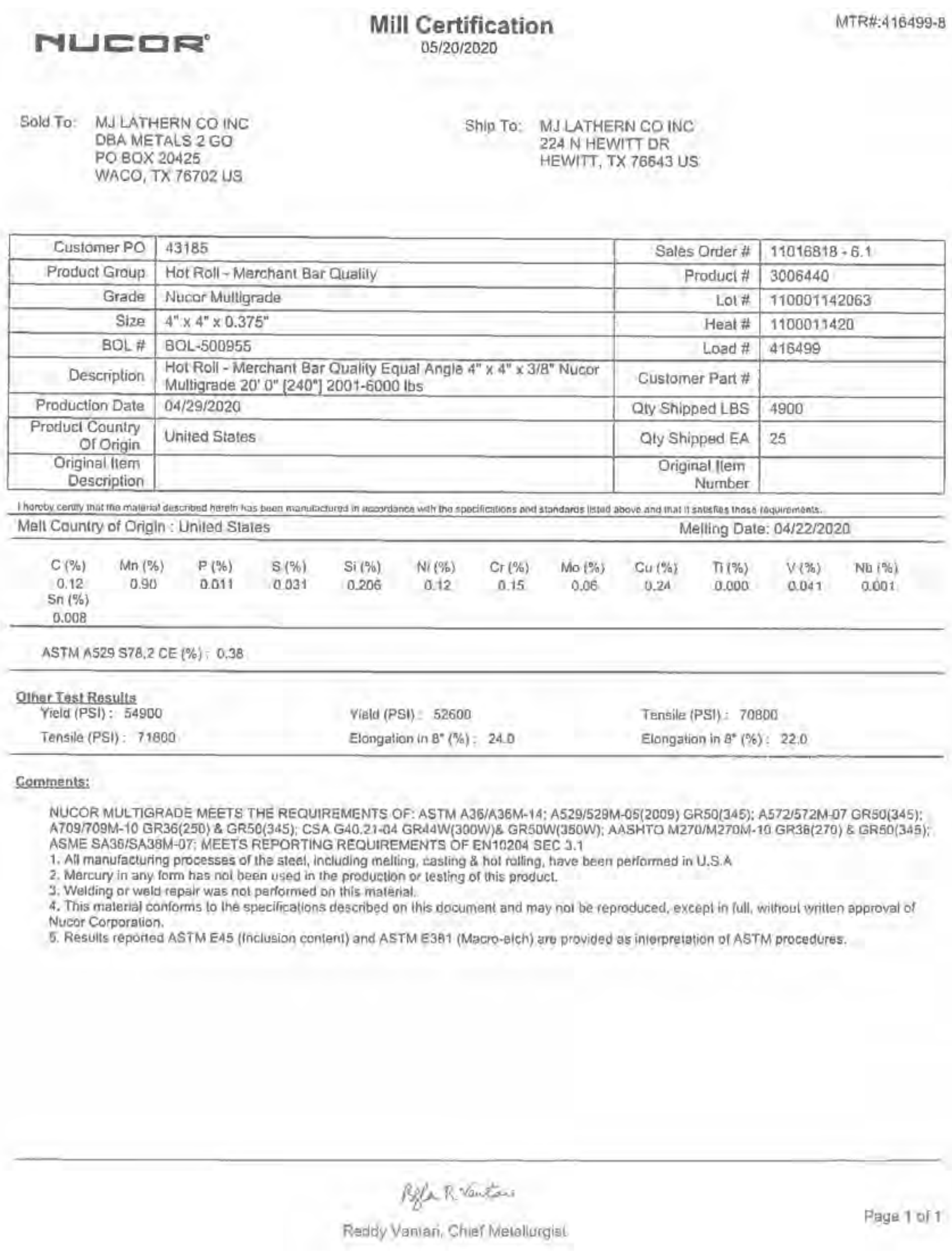

Mill Certification

05/20/2020

MTR#:416499-8

Sold To:
MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO, TX 76702 US

Ship To:
MJ LATHERN CO INC
224 N HEWITT DR
HEWITT, TX 76643 US

Customer PO	43185	Sales Order #	11016818 - 6.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3006440
Grade	Nucor Multigrade	Lot #	110001142063
Size	4" x 4" x 0.375"	Heat #	1100011420
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Equal Angle 4" x 4" x 3/8" Nucor Multigrade 20' 0" [240"] 2001-6000 lbs	Customer Part #	
Production Date	04/29/2020	Qty Shipped LBS	4900
Product Country Of Origin	United States	Qty Shipped EA	25
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: 04/22/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.12	0.90	0.011	0.031	0.206	0.12	0.15	0.06	0.24	0.000	0.041	0.001

Sn (%)
0.008

ASTM A529 S78.2 CE (%) : 0.38

Other Test Results

Yield (PSI) : 54900	Yield (PSI) : 52600	Tensile (PSI) : 70800
Tensile (PSI) : 71800	Elongation in 8" (%) : 24.0	Elongation in 8" (%) : 22.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

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Reddy Vantari, Chief Metallurgist

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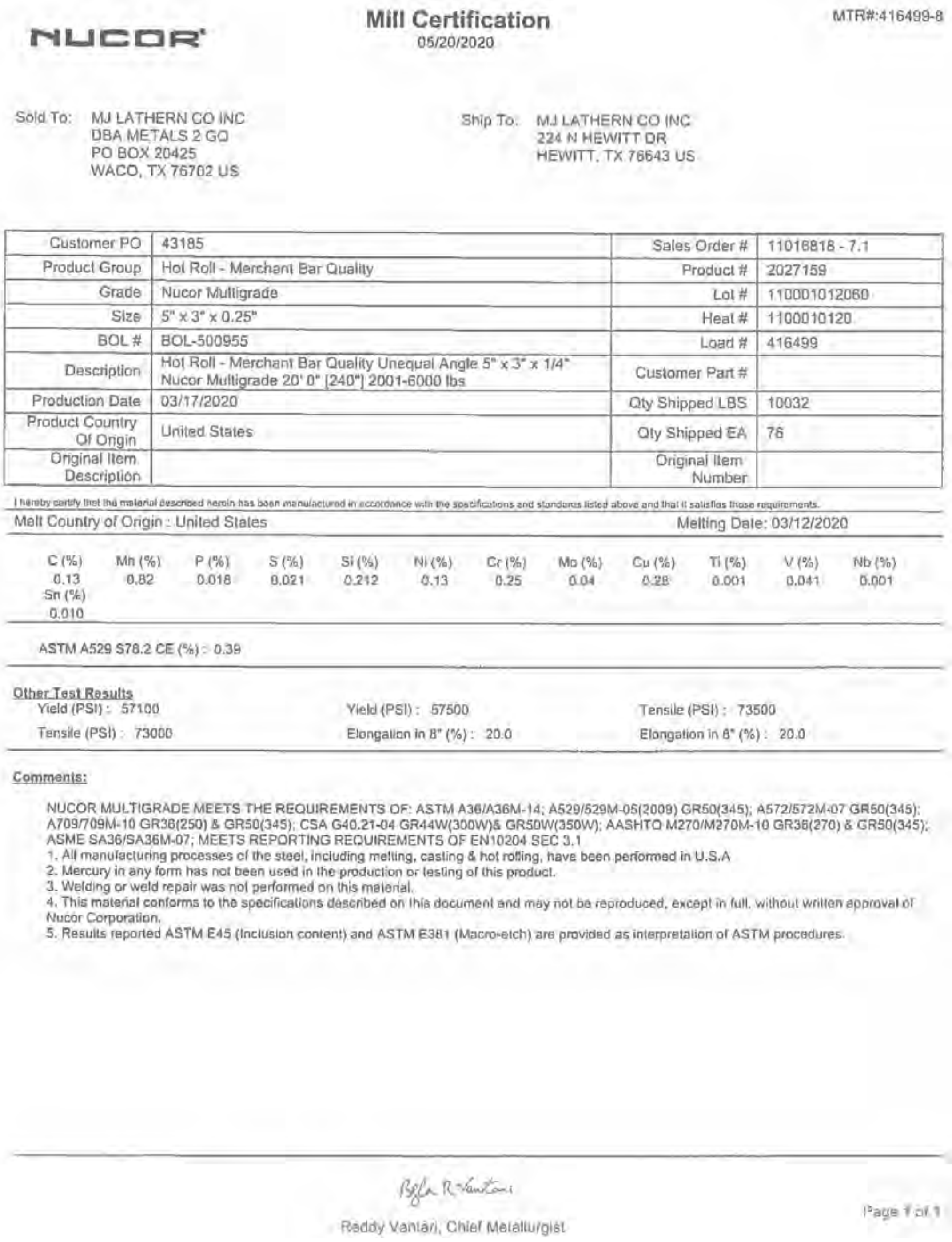

NUCOR

Mill Certification

05/20/2020

MTR#:416499-8

Sold To: MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO, TX 76702 US

Ship To: MJ LATHERN CO INC
224 N HEWITT DR
HEWITT, TX 76643 US

Customer PO	43185	Sales Order #	11016818 - 7.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	2027159
Grade	Nucor Multigrade	Lot #	110001012060
Size	5" x 3" x 0.25"	Heat #	1100010120
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Unequal Angle 5" x 3" x 1/4" Nucor Multigrade 20' 0" [240"] 2001-6000 lbs	Customer Part #	
Production Date	03/17/2020	Qty Shipped LBS	10032
Product Country Of Origin	United States	Qty Shipped EA	76
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: 03/12/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.13	0.82	0.018	0.021	0.212	0.13	0.25	0.04	0.28	0.001	0.041	0.001

Sn (%)
0.010

ASTM A529 S78.2 CE (%) : 0.39

Other Test Results

Yield (PSI) : 57100

Tensile (PSI) : 73000

Yield (PSI) : 57500

Elongation in 8" (%) : 20.0

Tensile (PSI) : 73500

Elongation in 8" (%) : 20.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

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Reddy Vantari, Chief Metallurgist

Page 1 of 1

NUCOR

Mill Certification

05/20/2020

MTR#:416499-8

Sold To: MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO, TX 76702 US

Ship To. MJ LATHERN CO INC
224 N HEWITT DR
HEWITT, TX 76643 US

Customer PO	43185	Sales Order #	11016818 - 8.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3007378
Grade	Nucor Multigrade	Lot #	110001068061
Size	6" x 4" x 0.3125"	Heat #	1100010680
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Unequal Angle 6" x 4" x 5/16" Nucor Multigrade 20' 0" [240"] 2001-6000 lbs	Customer Part #	
Production Date	04/07/2020	Qty Shipped LBS	4738
Product Country Of Origin	United States	Qty Shipped EA	23
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: 03/28/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.13	0.89	0.017	0.027	0.208	0.12	0.27	0.04	0.28	0.001	0.042	0.002
Sn (%)											
0.010											

ASTM A529 S78.2 CE (%) : 0.41

Other Test Results

Yield (PSI) : 58100	Yield (PSI) : 58100	Tensile (PSI) : 78200
Tensile (PSI) : 76800	Elongation in 8" (%) : 21.0	Elongation in 8" (%) : 23.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

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Reddy R Vantari

Reddy Vantari, Chief Metallurgist

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NUCOR

Mill Certification

05/20/2020

MTR#:416499-8

Sold To: MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO, TX 76702 US

Ship To: MJ LATHERN CO INC
224 N HEWITT DR
HEWITT, TX 76643 US

Customer PO	43185	Sales Order #	11016818 - 11.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3007482
Grade	Nucor Multigrade	Lot #	120202214720
Size	10" x 15.3#	Heat #	1202022147
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Structural Channel 10" x 15.3# Nucor Multigrade 20' 0" [240"] 2001-6000 lbs	Customer Part #	
Production Date	05/10/2020	Qty Shipped LBS	3672
Product Country Of Origin	United States	Qty Shipped EA	12
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: 04/27/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.15	0.85	0.013	0.020	0.24	0.09	0.14	0.02	0.23	0.001	0.014	0.001
Sn (%)											
0.018											

ASTM A529 S78,2 CE (%) : 0.39

ASTM A992 5.4 CE (%) : 0.35

Other Test Results

Yield (PSI) : 59200
Tensile (PSI) : 79300

Yield (PSI) : 59200
Elongation in 8" (%) : 27.0

Tensile (PSI) : 79400
Elongation in 8" (%) : 26.0

Comments:

ASTM A36/A36M-19, ASTM A529/A529M-19 GR50, ASTM A572/A572M-18 GR50, CSA G40.21-13(R2018) 44W(300W)/50W(350W), ASTM A709/A709M-18 GR36/GR50 (NO CVN), AASHTO M 270/M 270M-19 GR36/GR50, ASME SA36/SA36M-17

Material is certified to the most recent revision level of the specification and grade indicated at time of production/testing.

Nucor-Plymouth is an ISO-9001:2015 and an ABS certified mill. CMTR complies with DIN EN 10204 – 3.1 All manufacturing processes of the steel materials in this product, including melting, casting, and hot rolling have occurred in the United States of America. All products produced are weld free. Mercury, in any form, has not been used in the production or testing of this material.

Bryden Morris, Chief Metallurgist

Page 1 of 1

NUCOR

Mill Certification

05/20/2020

Sold To: MJ LATHERN CO INC
DBA METALS 2 GO
PO BOX 20425
WACO, TX 76702 US

Ship To: MJ LATHERN CO INC
224 N HEWITT DR
HEWITT, TX 76643 US

Customer PO	43185	Sales Order #	11016818 - 12.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3016420
Grade	Nucor Multigrade	Lot #	110001101160
Size	0.25" x 4"	Heat #	1100011011
BOL #	BOL-500955	Load #	416499
Description	Hot Roll - Merchant Bar Quality Flat 1/4" x 4" Nucor Multigrade 20' 0" [240"] 4001-8000 lbs	Customer Part #	
Production Date	04/21/2020	Qty Shipped LBS	4900
Product Country Of Origin	United States	Qty Shipped EA	72
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: 04/07/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Sn (%)
0.14	0.86	0.016	0.020	0.225	0.14	0.24	0.05	0.32	0.001	0.041	0.010

ASTM A529 S78.2 CE (%) : 0.42

Other Test Results

Yield (PSI) : 62200	Yield (PSI) : 61100	Tensile (PSI) : 77600
Tensile (PSI) : 78400	Elongation in 8" (%) : 22.0	Elongation in 8" (%) : 24.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

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Reddy Vantari, Chief Metallurgist

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PERFILES COMERCIALES SIGOSA S.A. DE . C.V.

SIGOSA

Metals 2 Go
254-235-7700

Certificado de Calidad de Pruebas Físicas y Químicas
(Mill Test Report)

Información del Cliente / Client Information : | **Orden / Order:63884** | **Certificado / Certificate: B67987**

METALS 2 GO

* 0 0 0 0 8 6 7 9 8 7 *

Fecha / Date:02/06/2020 17:56 PM
Fecha Impresión / Print Date:02/06/2020 17:57 PM

SERIE SERIAL	PRODUCTO PRODUCT	COLADA HEAT	GRADO GRADE	*LE *YS	*UT *TS	PE %EL	LE/UT (YS/TS)	C	Mn	Si	P	S	Cu	Cr	Ni	Mo	Sn	V	Nb	Al	CEQ
2202002121084	CAN 6 (8.2Lb/12.2K) 20ft	000000200273	A36/A529-50	51100	74900	33	0.68	.184	.882	.19	.02	.033	.381	.159	.123	.036	.015	.001	.005	.002	.436
1202005271026	ANG 2 x 3/16 20ft	000000200358	A36/A529-50	52100	74500	30	0.7	.182	.87	.182	.023	.028	.269	.145	.109	.018	.016	.001	.022	.004	.415
1202005271023	ANG 2 x 3/16 20ft	000000200358	A36/A529-50	52100	74500	30	0.7	.182	.87	.182	.023	.028	.269	.145	.109	.018	.016	.001	.022	.004	.415
1202005271033	ANG 2 x 3/16 20ft	000000200358	A36/A529-50	52100	74500	30	0.7	.182	.87	.182	.023	.028	.269	.145	.109	.018	.016	.001	.022	.004	.415

*Las unidades expresadas en L.E. y U.T son en PSI. La composición química esta expresada en % en peso.
The units expressed in L.E and U.T are in PSI. The chemical composition is expressed in % in weight.

Certificamos que el producto aquí descrito, cumple y ha sido fabricado, muestreado, probado e inspeccionado de acuerdo con los requisitos aplicables de la especificación:
2013: ASME SA36;ASME SA-6/SA-6M;A36;
2014: ASTM A6/ A6 M-13;A529 / A529M; ASTM A370 – 12a
Rebar - ASTM A615

We certify that the product above mentioned accomplishes and has been manufactured, sampled, tested and inspected in accordance with applicable requirements of specifications:
ASTM A6/ A6 M-13 a (2014); A36; A529 / A529M;
ASME SA-6/SA-6M; ASTM A370 – 12a (2014); ASME SA36.
Rebar - ASTM A615

Gerente de Aseguramiento de Calidad

En SIGOSA, SA DE CV nos comprometemos a satisfacer las expectativas y requerimientos de nuestros clientes, Mediante un sistema de Gestión de Calidad, la mejora continua de nuestros productos, el uso eficiente de los recursos, y la participación individual y de equipo de todo su personal.

FOR-CAL-CAL-001 REV. 4 OCTUBRE 2014.

19Jun18 13:22 TEST CERTIFICATE No: MAR 803862

INDEPENDENCE TUBE CORPORATION

Metals 2 Go
254-235-7700

Metals 2 Go
Customer PO: 70460
Heat: C86155
Shipment: D018028674

CERTIFICATE of ANALYSIS and TESTS

Cert. No: MAR 803862
12Jun18

Part No		Pcs	Wgt
TUBING A500 GRADE B(C) 3" SQ X 3/8" X 20'		40	9,728

Heat Number	Tag No	Pcs	Wgt
C86155	223796 YLD=78560/TEN=82690/ELG=25.8	20	4,864
C86155	223797	20	4,864

Heat Number
C86155

*** Chemical Analysis ***

C=0.0500 Mn=0.3900 P=0.0090 S=0.0030 Si=0.0200 Al=0.0420
Cu=0.1400 Cr=0.0500 Mo=0.0100 V=0.0010 Ni=0.0500 Nb=0.0120
Sn=0.0100 N=0.0066 B=0.0001 Ti=0.0020 Ca=0.0015
MELTED AND MANUFACTURED IN THE USA

WE PROUDLY MANUFACTURE ALL OUR PRODUCT IN THE USA. INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED, AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS. MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

CURRENT STANDARDS:
A252-10
A500/A500M-18
A513/A513M-15
ASTM A53/A53M-12 | ASME SA-53/SA-53M-13
A847/A847M-14
A1085/A1085M-15

Metals 2 Go
Customer PO: 42687
Heat: W85348
Shipment: 0020005276

Atlas Tube Corp. Chicago

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Metals 2 Go
254-235-7700

MATERIAL TEST REPORT

Material: 5.0x5.0x375x40'0"0(4x2).
Material No: 500503754000
Made in: USA
Melted in: USA
Sales Order: 1452209
Purchase Order: C450008084
Cust Material#: 6550037540

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
W85348	0.220	0.750	0.012	0.011	0.020	0.038	0.030	0.004	0.007	0.010	0.060	0.001	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M800901564	8	061528 Psi	077323 Psi	31 %	ASTM A500-18 GRADE B&C	CE: 0.36

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)
W85348	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%

Material Note:
Sales Or. Note:

Material: 5.0x5.0x375x40'0"0(4x2).
Material No: 500503754000
Made in: USA
Melted in: USA
Sales Order: 1452648
Purchase Order: C450008087
Cust Material#: 6550037540

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
W85348	0.220	0.750	0.012	0.011	0.020	0.038	0.030	0.004	0.007	0.010	0.060	0.001	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M800901563	8	061528 Psi	077323 Psi	31 %	ASTM A500-18 GRADE B&C	CE: 0.36

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)
W85348	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%

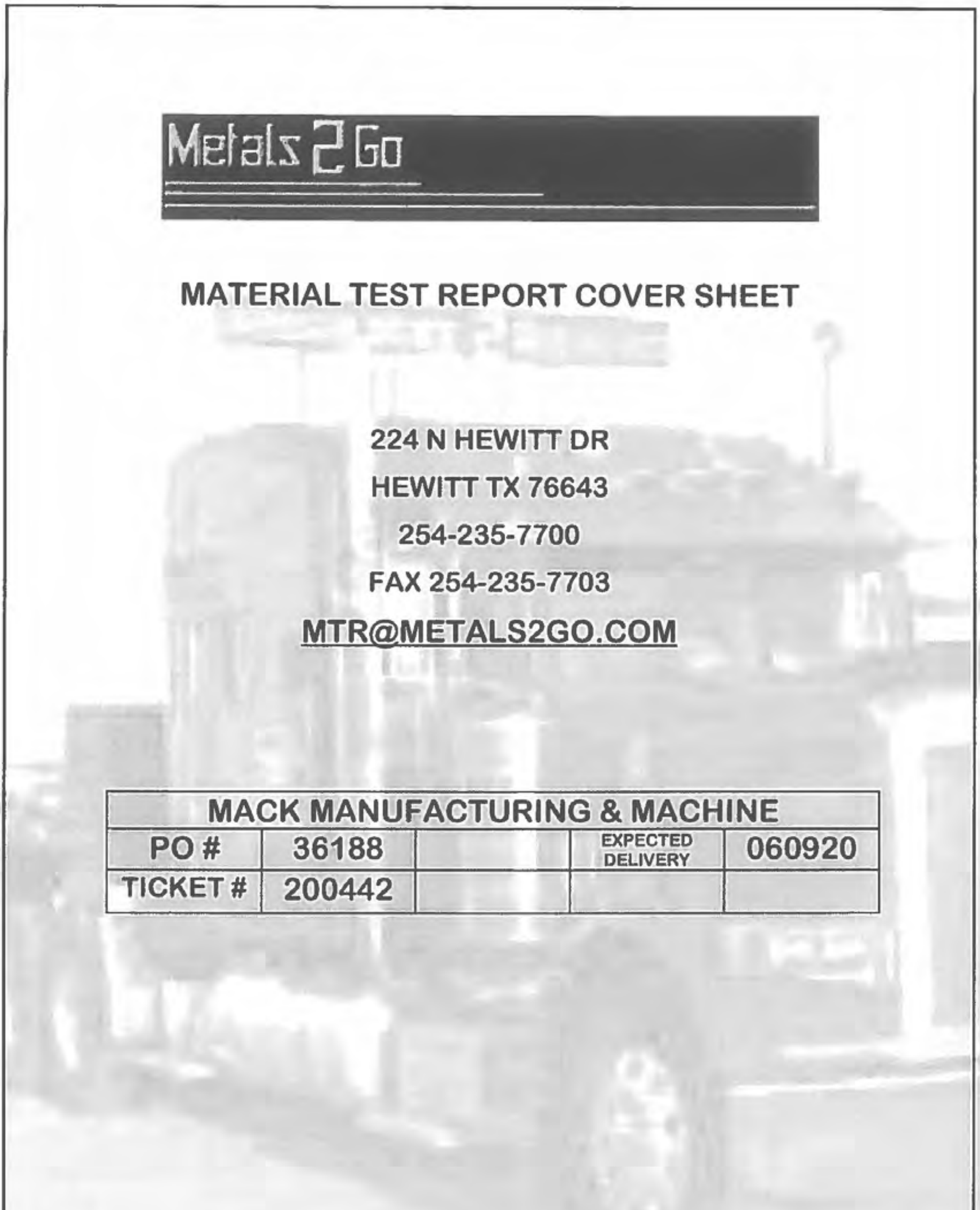
Material Note:
Sales Or. Note:

Authorized by Quality Assurance:

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute
OF NORTH AMERICA

Metals Service Center Institute

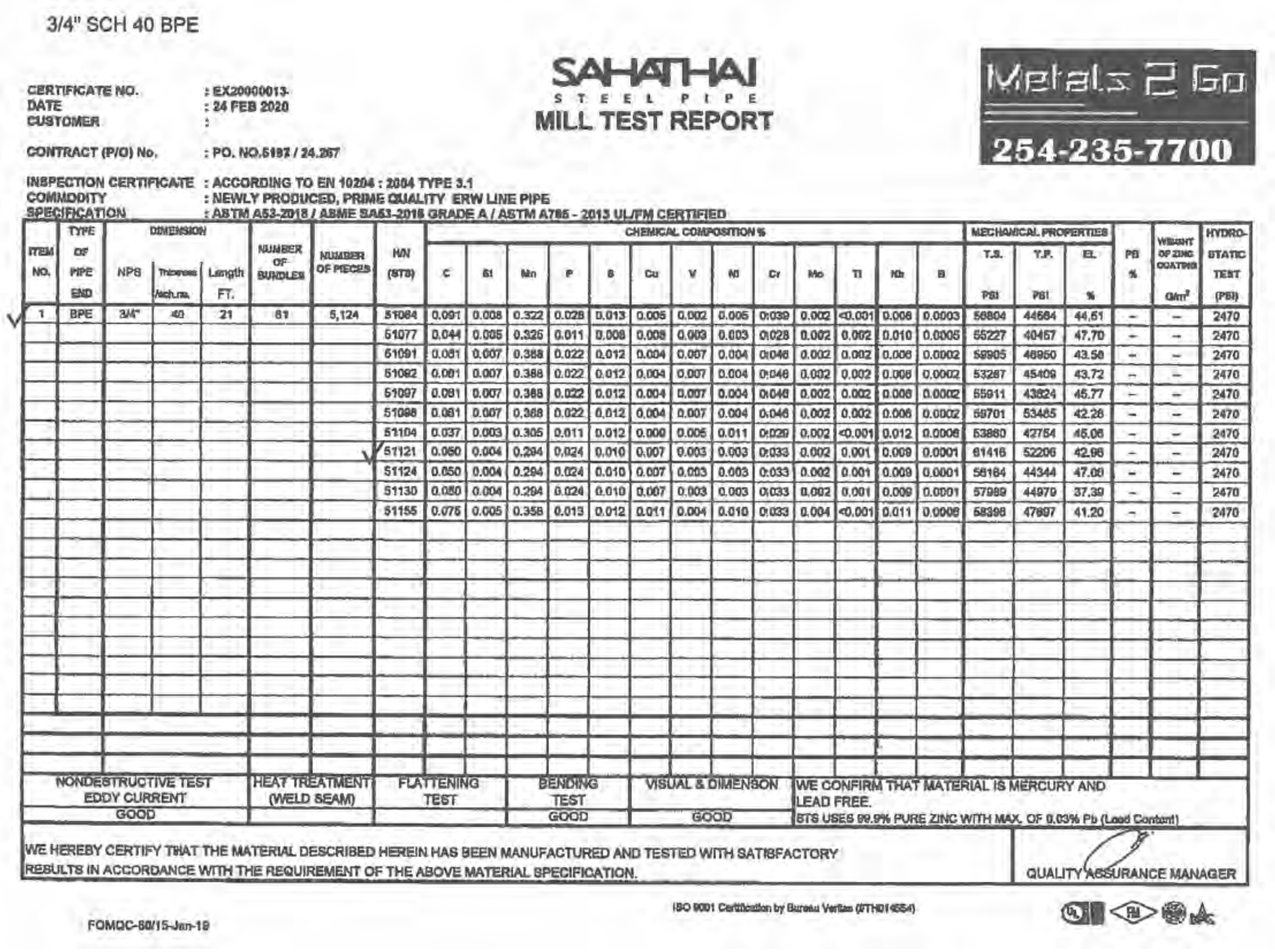


Metals 2 Go

MATERIAL TEST REPORT COVER SHEET

224 N HEWITT DR
HEWITT TX 76643
254-235-7700
FAX 254-235-7703
MTR@METALS2GO.COM

MACK MANUFACTURING & MACHINE				
PO #	36188		EXPECTED DELIVERY	060920
TICKET #	200442			



3/4" SCH 40 BPE

Metals 2 Go

254-235-7700

SAHATHAI
S T E E L P I P E

MILL TEST REPORT

CERTIFICATE NO. : EX20000013-
DATE : 24 FEB 2020
CUSTOMER :

CONTRACT (P/O) No. : PO. NO.5197 / 24.267

INSPECTION CERTIFICATE : ACCORDING TO EN 10204 : 2004 TYPE 3.1
COMMODITY : NEWLY PRODUCED, PRIME QUALITY ERW LINE PIPE
SPECIFICATION : ASTM A53-2018 / ASME SA53-2018 GRADE A / ASTM A795 - 2013 UL/FM CERTIFIED

ITEM NO.	TYPE OF PIPE END	DIMENSION			NUMBER OF BUNDLES	NUMBER OF PIECES	H/N (STS)	CHEMICAL COMPOSITION %													MECHANICAL PROPERTIES			PB %	WEIGHT OF ZINC COATING G/m²	HYDRO-STATIC TEST (PSI)
		NPS	Thickness Sch.no.	Length FT.				C	Si	Mn	P	S	Cu	V	Ni	Cr	Mo	Ti	Nb	B	T.S. PSI	Y.P. PSI	EL. %			
1	BPE	3/4"	40	21	61	5,124	51084	0.091	0.008	0.322	0.028	0.013	0.005	0.002	0.005	0.039	0.002	<0.001	0.006	0.0003	56804	44684	44,61	–	–	2470
							51077	0.044	0.005	0.325	0.011	0.008	0.008	0.003	0.003	0.028	0.002	0.002	0.010	0.0005	55227	40457	47.70	–	–	2470
							51091	0.081	0.007	0.388	0.022	0.012	0.004	0.007	0.004	0.046	0.002	0.002	0.006	0.0002	59905	46950	43.58	–	–	2470
							51092	0.081	0.007	0.388	0.022	0.012	0.004	0.007	0.004	0.046	0.002	0.002	0.006	0.0002	53287	45409	43,72	–	–	2470
							51097	0.081	0.007	0.388	0.022	0.012	0.004	0.007	0.004	0.046	0.002	0.002	0.006	0.0002	55911	43824	45.77	–	–	2470
							51098	0.081	0.007	0.388	0.022	0.012	0.004	0.007	0.004	0.046	0.002	0.002	0.006	0.0002	59701	53465	42.28	–	–	2470
							51104	0.037	0.003	0.305	0.011	0.012	0.000	0.005	0.011	0.029	0.002	<0.001	0.012	0.0008	53860	42754	45.08	–	–	2470
							51121	0.050	0.004	0.294	0.024	0.010	0.007	0.003	0.003	0.033	0.002	0.001	0.009	0.0001	61416	52206	42.98	–	–	2470
							51124	0.050	0.004	0.294	0.024	0.010	0.007	0.003	0.003	0.033	0.002	0.001	0.009	0.0001	58184	44344	47.08	–	–	2470
							51130	0.050	0.004	0.294	0.024	0.010	0.007	0.003	0.003	0.033	0.002	0.001	0.009	0.0001	57989	44979	37,39	–	–	2470
							51155	0.075	0.005	0.358	0.013	0.012	0.011	0.004	0.010	0.033	0.004	<0.001	0.011	0.0008	58398	47697	41.20	–	–	2470

NONDESTRUCTIVE TEST EDDY CURRENT	HEAT TREATMENT (WELD SEAM)	FLATTENING TEST	BENDING TEST	VISUAL & DIMENSON	WE CONFIRM THAT MATERIAL IS MERCURY AND LEAD FREE.
GOOD			GOOD	GOOD	STS USES 99.9% PURE ZINC WITH MAX. OF 0.03% Pb (Lead Content)

WE HEREBY CERTIFY THAT THE MATERIAL DESCRIBED HEREIN HAS BEEN MANUFACTURED AND TESTED WITH SATISFACTORY RESULTS IN ACCORDANCE WITH THE REQUIREMENT OF THE ABOVE MATERIAL SPECIFICATION.

QUALITY ASSURANCE MANAGER

ISO 9001 Certification by Bureau Veritas (#TH014554)

FOMQC-60/15-Jan-19

APPENDIX F. MASH-2016 TEST 3-10 ON NCHRP BRIDGE RAIL ON DECK

VEHICLE PROPERTIES AND INFORMATION

Figure F.1. Vehicle properties for test no. 610571-03-2.

Date: 2020-10-29 Test No.: 610571-03-2 VIN No.: 3N1CN7AP5FL881103

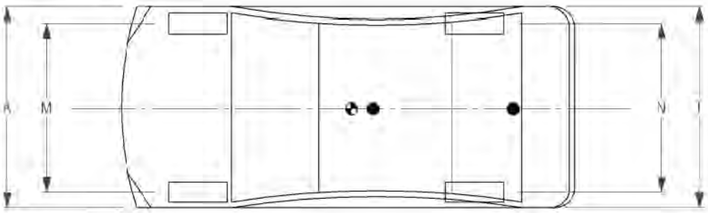
Year: 2015 Make: NISSAN Model: VERSA

Tire Inflation Pressure: 36 PSI Odometer: 80538 Tire Size: P185/65R15

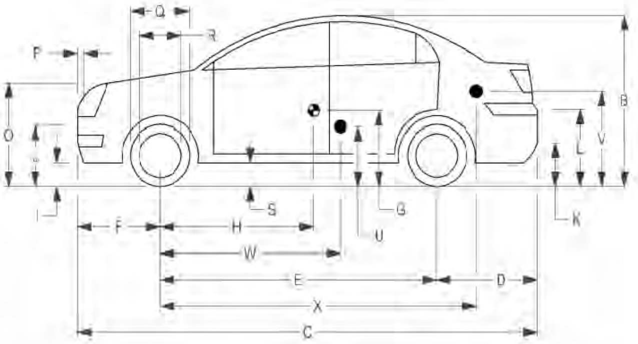
Describe any damage to the vehicle prior to test: None

● 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: IMPACT SIDE

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	40.85	M	58.30	R	16.25	W	40.80
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.25	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.05

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}	1444	1461	1546
Back	1687	M_{rear}	956	970	1050
Total	3389	M_{Total}	2400	2431	2596

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

Mass Distribution:
lb LF: 752 RF: 709 LR: 463 RR: 507

Figure F.2. Exterior crush measurements for test no. 610571-03-2.

Date: 2020-10-29 Test No.: 610571-03-2 VIN No.: 3N1CN7AP5FL881103

Year: 2015 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	Front plane at bmp ht	15	12	24	-	-	-	-	-	-	-16
2	Side plane above bmp ht	15	14	40	-	-	-	-	-	-	60
	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).

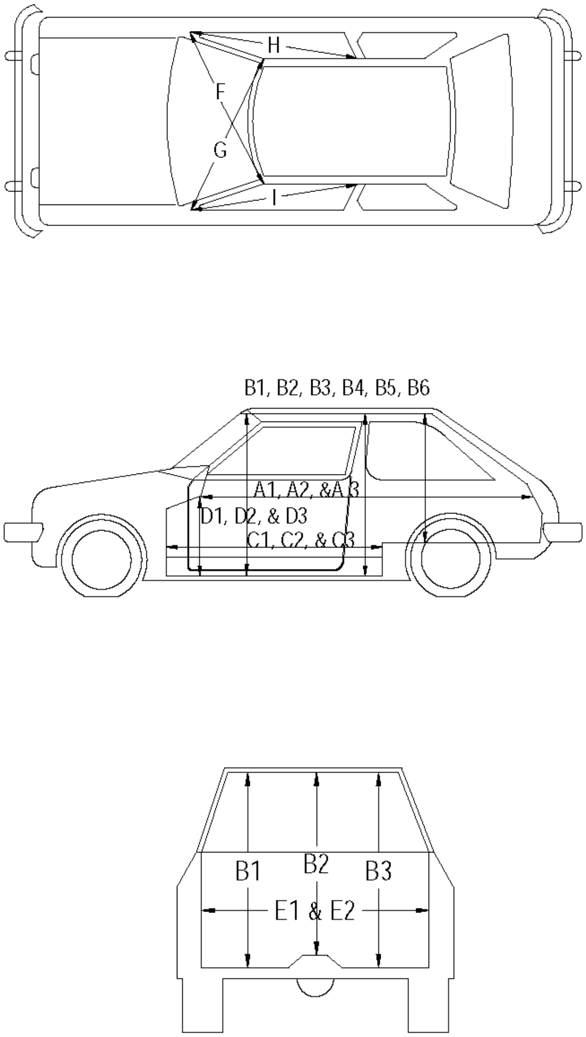
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Figure F.3. Occupant compartment measurements for test no. 610571-03-2.

Date: 2020-10-29 Test No.: 610571-03-2 VIN No.: 3N1CN7AP5FL881103

Year: 2015 Make: NISSAN Model: VERSA

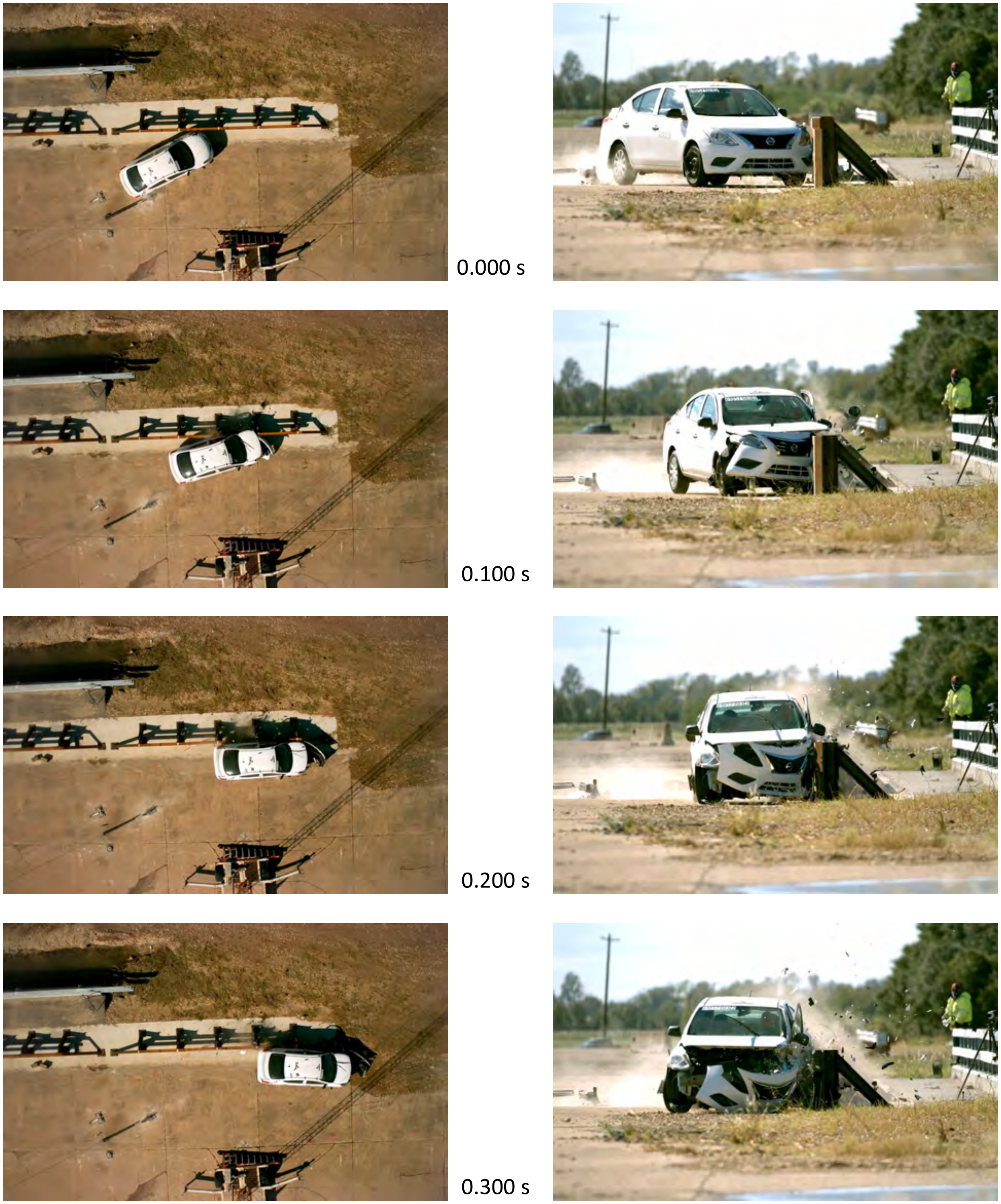


OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	75.00	75.00	0.00
A2	74.00	74.00	0.00
A3	74.00	74.00	0.00
B1	43.00	43.00	0.00
B2	37.00	37.00	0.00
B3	43.00	43.00	0.00
B4	46.50	46.50	0.00
B5	42.50	42.50	0.00
B6	46.50	46.50	0.00
C1	26.00	23.00	-3.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	12.50	14.25	1.75
D2	0.00	0.00	0.00
D3	10.00	10.00	0.00
E1	48.00	41.50	-6.50
E2	48.75	50.50	1.75
F	47.50	47.50	0.00
G	47.50	45.25	-2.25
H	39.00	39.00	0.00
I	39.00	39.00	0.00
J*	48.50	41.50	-7.00

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

SEQUENTIAL PHOTOGRAPHS



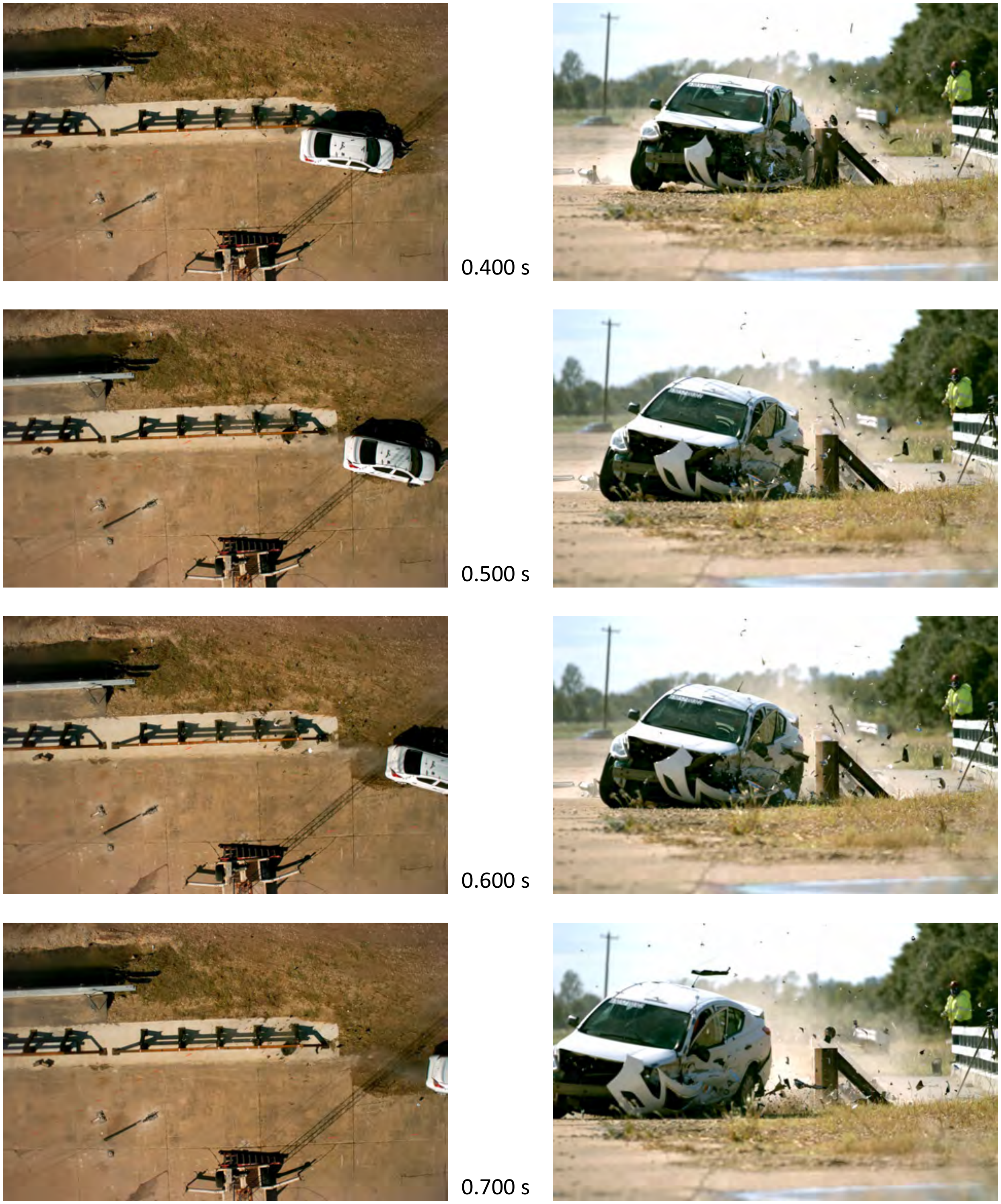
0.000 s

0.100 s

0.200 s

0.300 s

Figure F.4. Sequential photographs for test no. 610571-03-2 (overhead and frontal views).

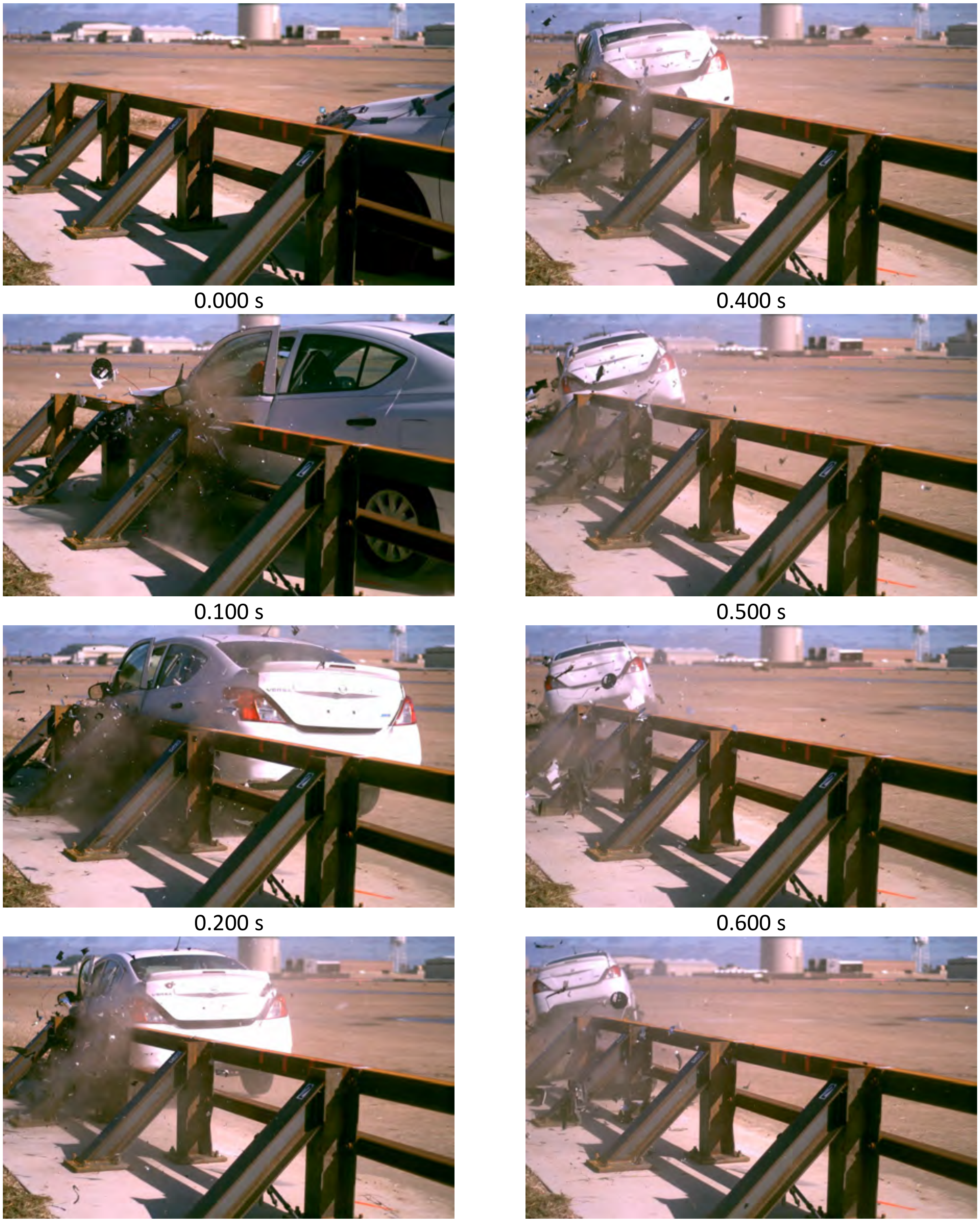

0.400 s

0.500 s

0.600 s

0.700 s

Figure F.5. Sequential photographs for test no. 610571-03-2 (overhead and frontal views, ctd.).



0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

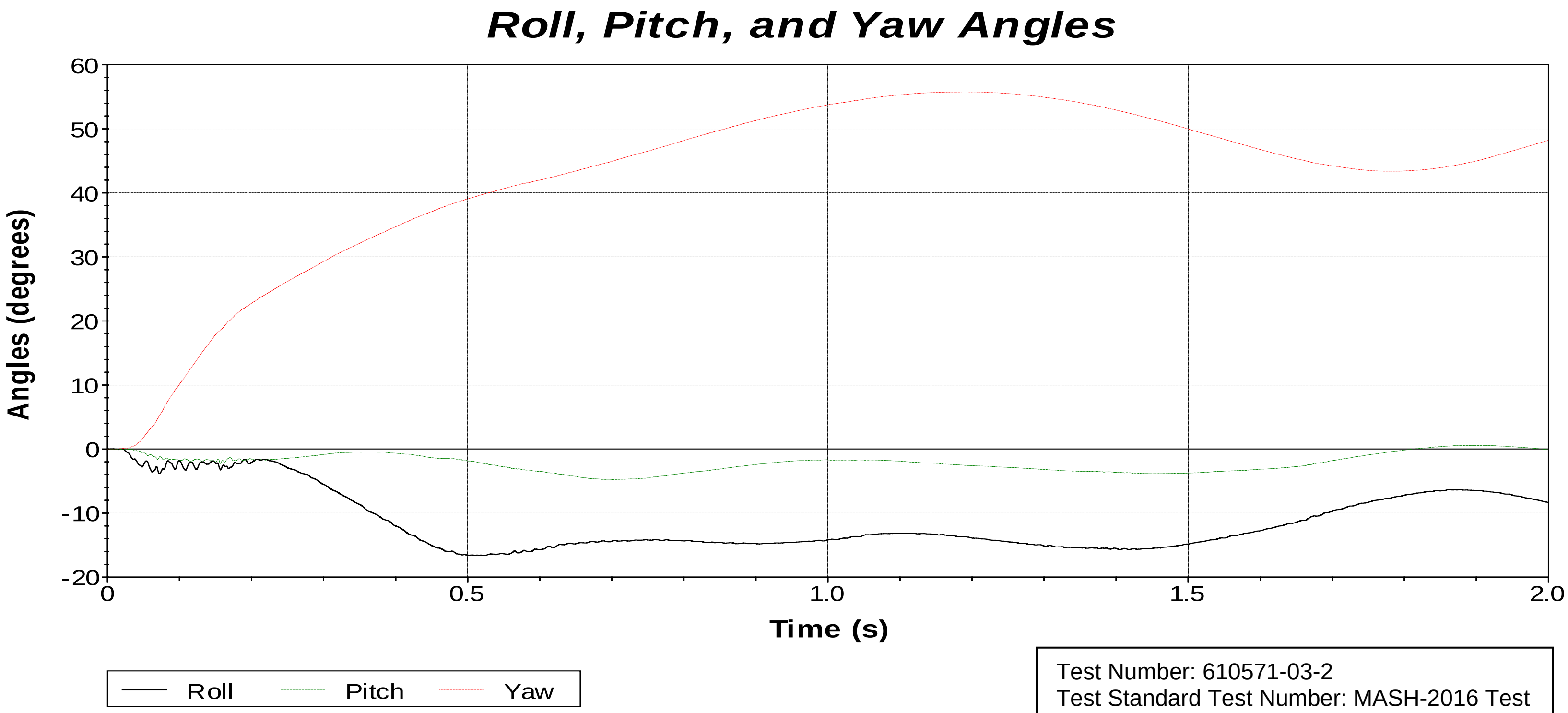
0.500 s

0.600 s

0.700 s

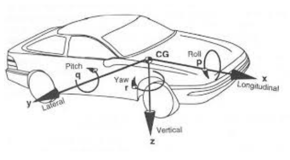
Figure F.6. Sequential photographs for test no. 610571-03-2 (rear view).

VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle fixed.
Sequence for determining orientation:

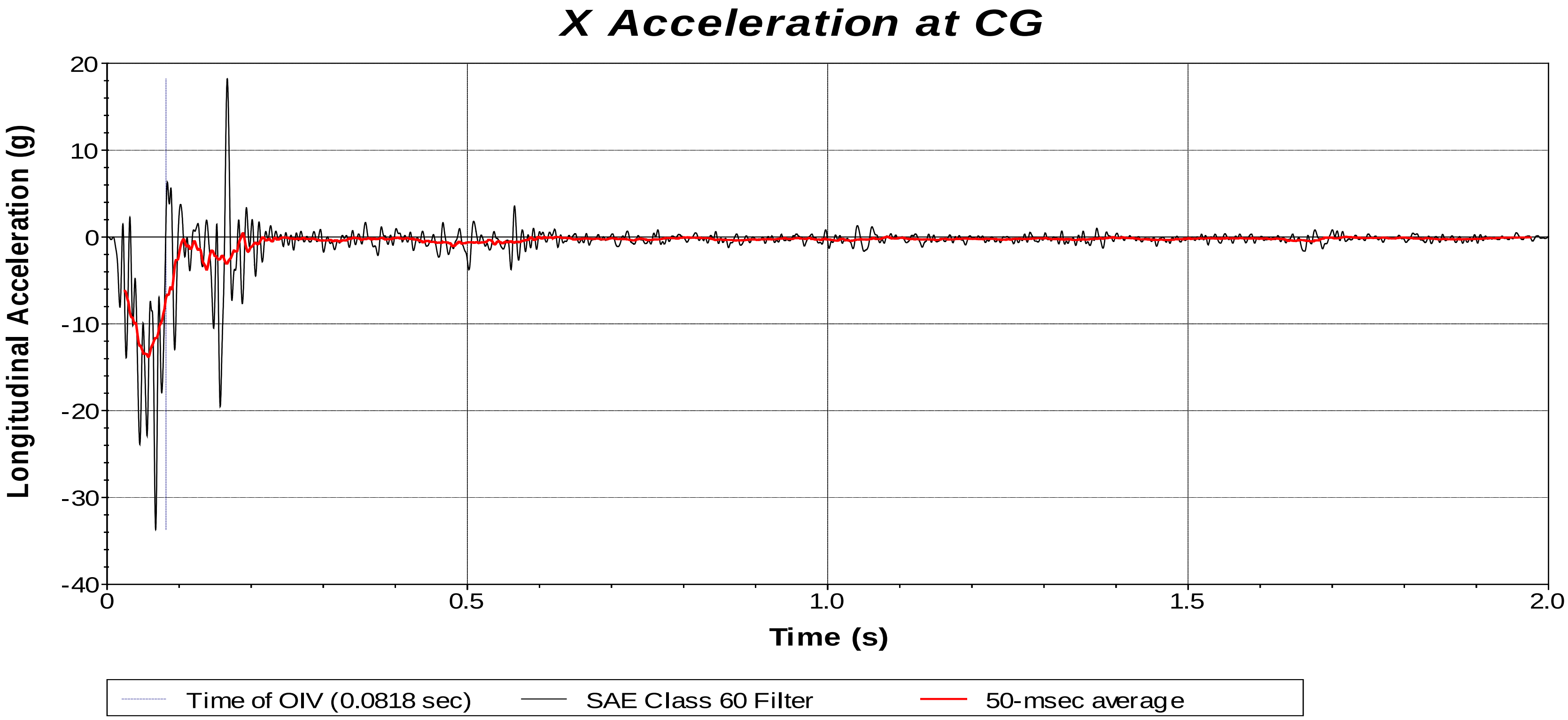
1. Yaw.
2. Pitch.
3. Roll.



Test Number: 610571-03-2
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Deck
Test Vehicle: 2015 Nissan Versa
Inertial Mass: 2,431 lb.
Gross Mass: 2,596 lb.
Impact Speed: 63.2 mph
Impact Angle: 24.2°

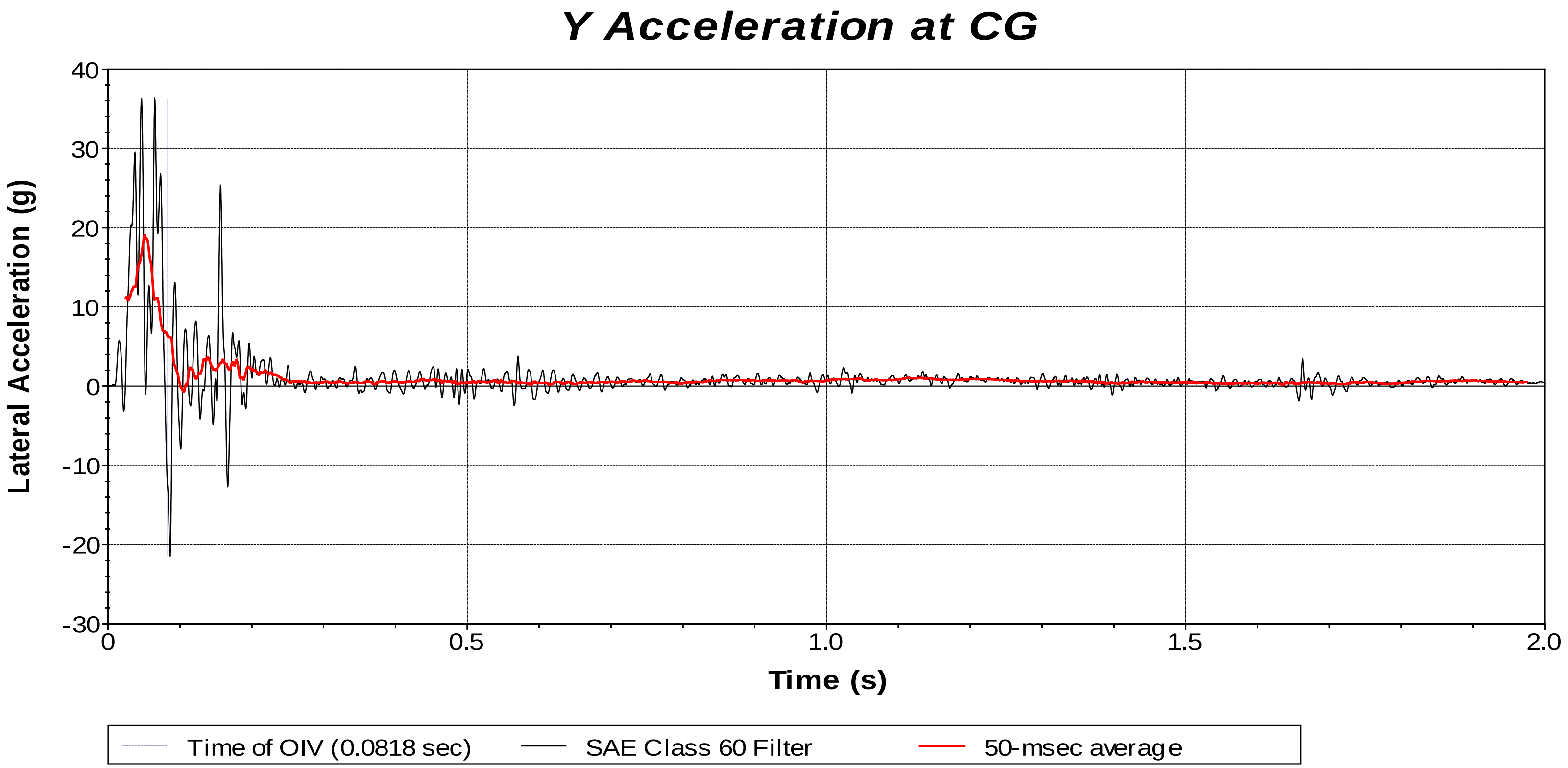
Figure F.7. Vehicle angular displacements for test no. 610571-03-2.

VEHICLE ACCELERATIONS



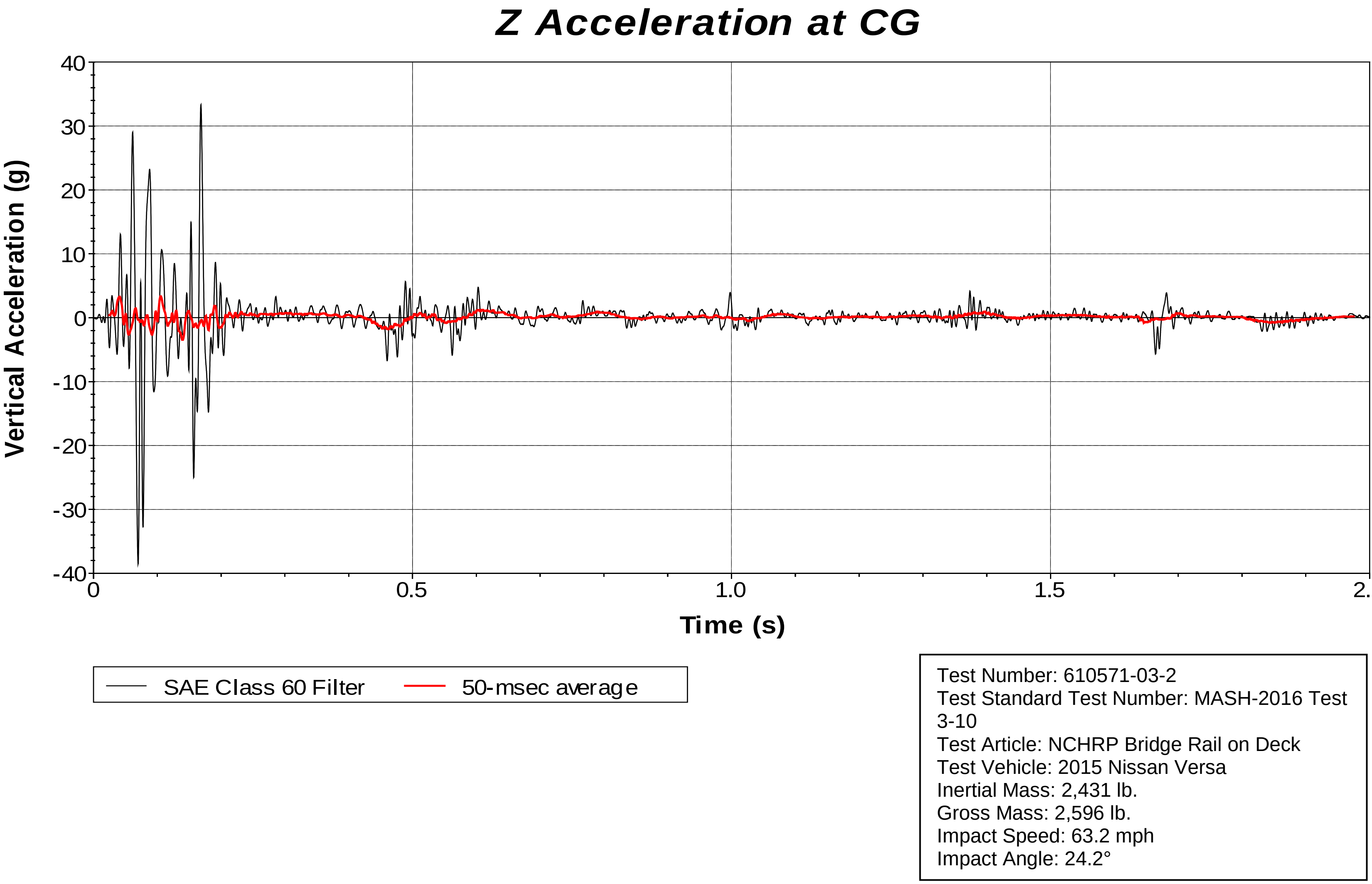
Test Number: 610571-03-2
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Deck
Test Vehicle: 2015 Nissan Versa
Inertial Mass: 2,431 lb.
Gross Mass: 2,596 lb.
Impact Speed: 63.2 mph
Impact Angle: 24.2°

Figure F.8. Vehicle longitudinal accelerometer trace for test no. 610571-03-2 (accelerometer located at center of gravity).



Test Number: 610571-03-2
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Deck
Test Vehicle: 2015 Nissan Versa
Inertial Mass: 2,431 lb.
Gross Mass: 2,596 lb.
Impact Speed: 63.2 mph
Impact Angle: 24.2°

Figure F.9. Vehicle lateral accelerometer trace for test no. 610571-03-2 (accelerometer located at center of gravity).



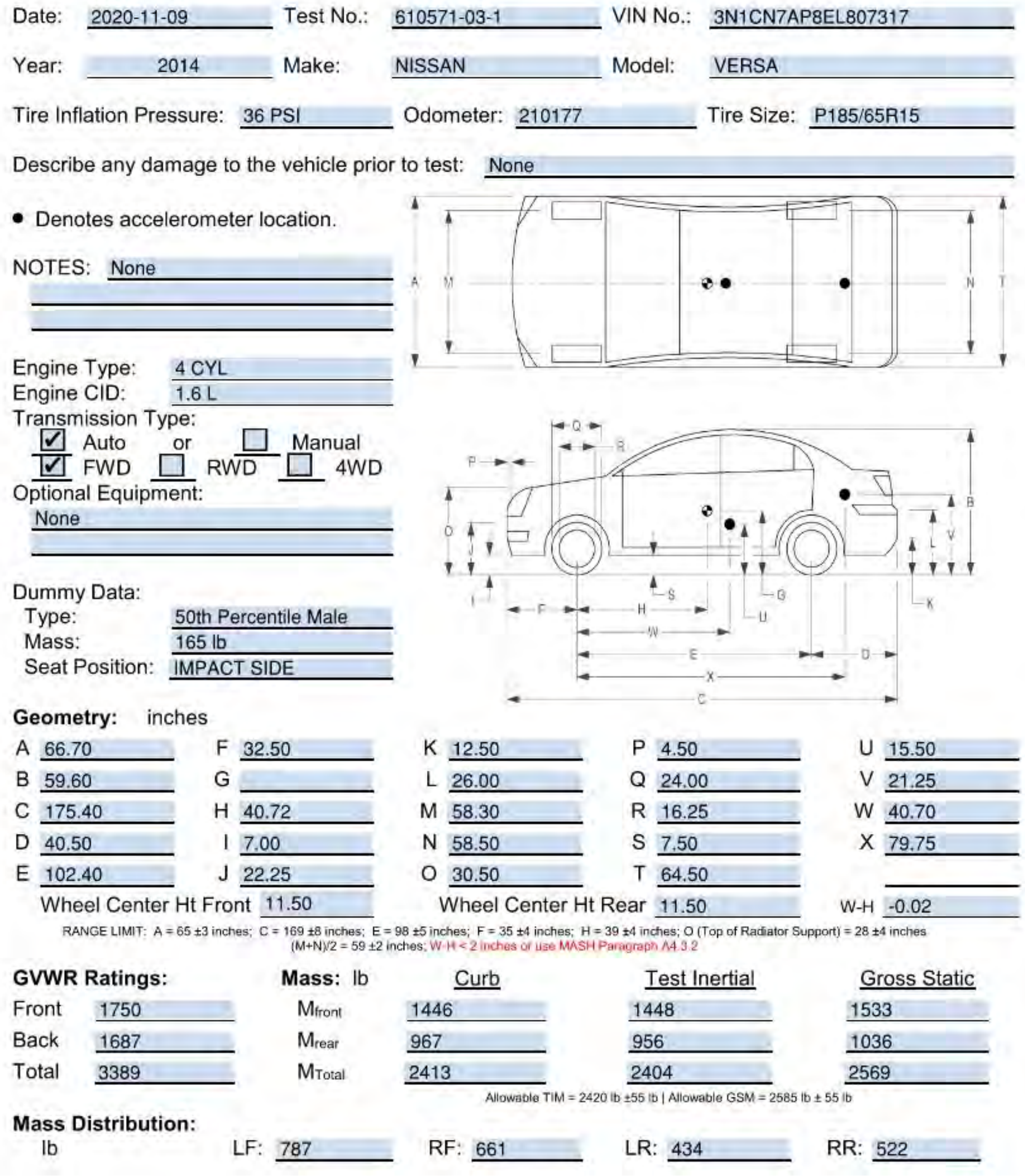
Test Number: 610571-03-2
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Deck
Test Vehicle: 2015 Nissan Versa
Inertial Mass: 2,431 lb.
Gross Mass: 2,596 lb.
Impact Speed: 63.2 mph
Impact Angle: 24.2°

Figure F.10. Vehicle vertical accelerometer trace for test no. 610571-03-2 (accelerometer located at center of gravity).

APPENDIX G. MASH-2016 TEST 3-10 ON NCHRP BRIDGE RAIL ON CURB

VEHICLE PROPERTIES AND INFORMATION

Figure G.1. Vehicle properties for test no. 610571-03-1.



Date: 2020-11-09 Test No.: 610571-03-1 VIN No.: 3N1CN7AP8EL807317

Year: 2014 Make: NISSAN Model: VERSA

Tire Inflation Pressure: 36 PSI Odometer: 210177 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: IMPACT SIDE

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	40.72	M	58.30	R	16.25	W	40.70
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.25	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.02

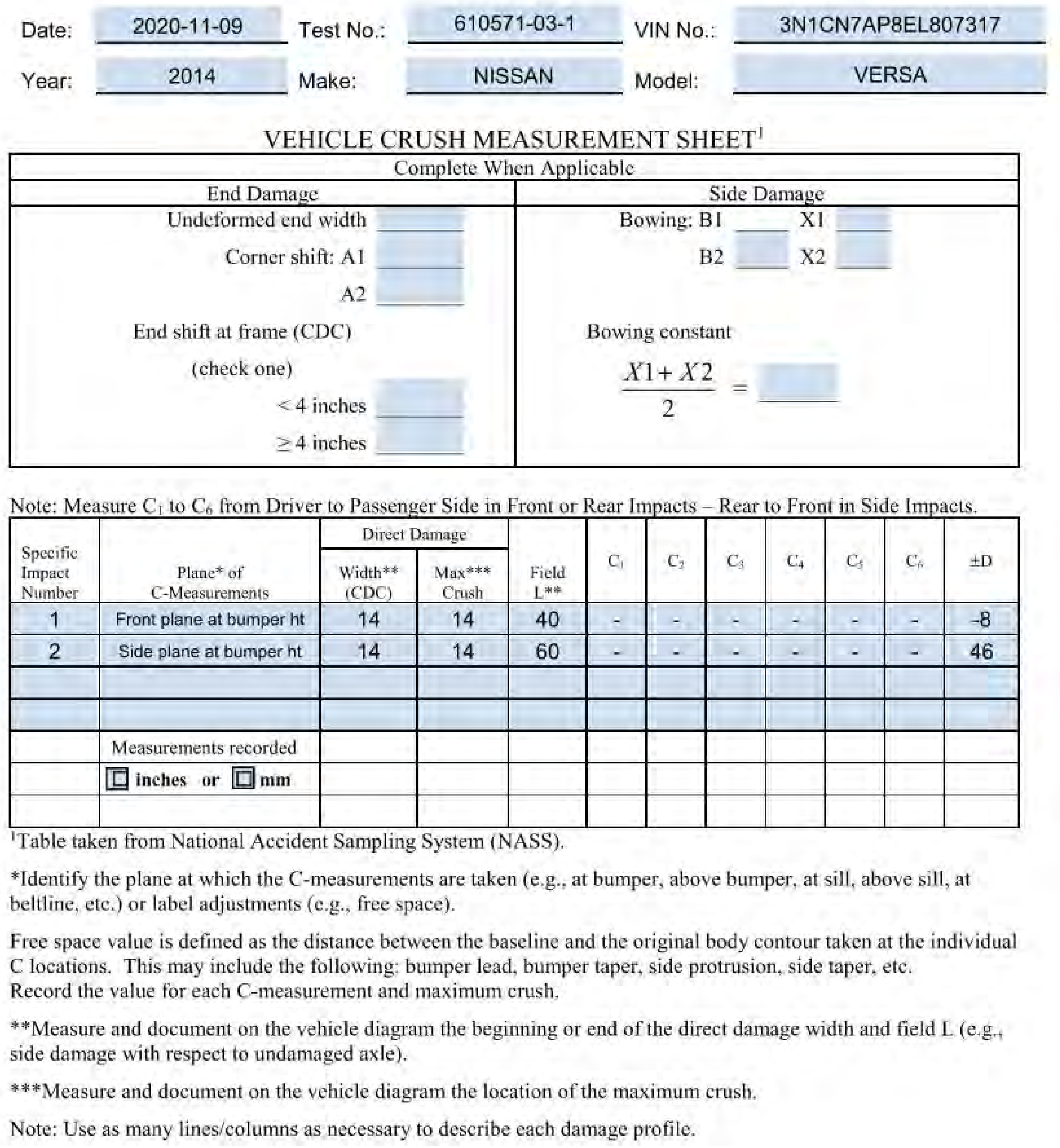
RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches of use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1446	1448	1533
Back	1687	M_{rear}	967	956	1036
Total	3389	M_{Total}	2413	2404	2569

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

Mass Distribution:
lb LF: 787 RF: 661 LR: 434 RR: 522

Figure G.2. Exterior crush measurements for test no. 610571-03-1.



Date: 2020-11-09 Test No.: 610571-03-1 VIN No.: 3N1CN7AP8EL807317

Year: 2014 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	Front plane at bumper ht	14	14	40	-	-	-	-	-	-	-8
2	Side plane at bumper ht	14	14	60	-	-	-	-	-	-	46
	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).

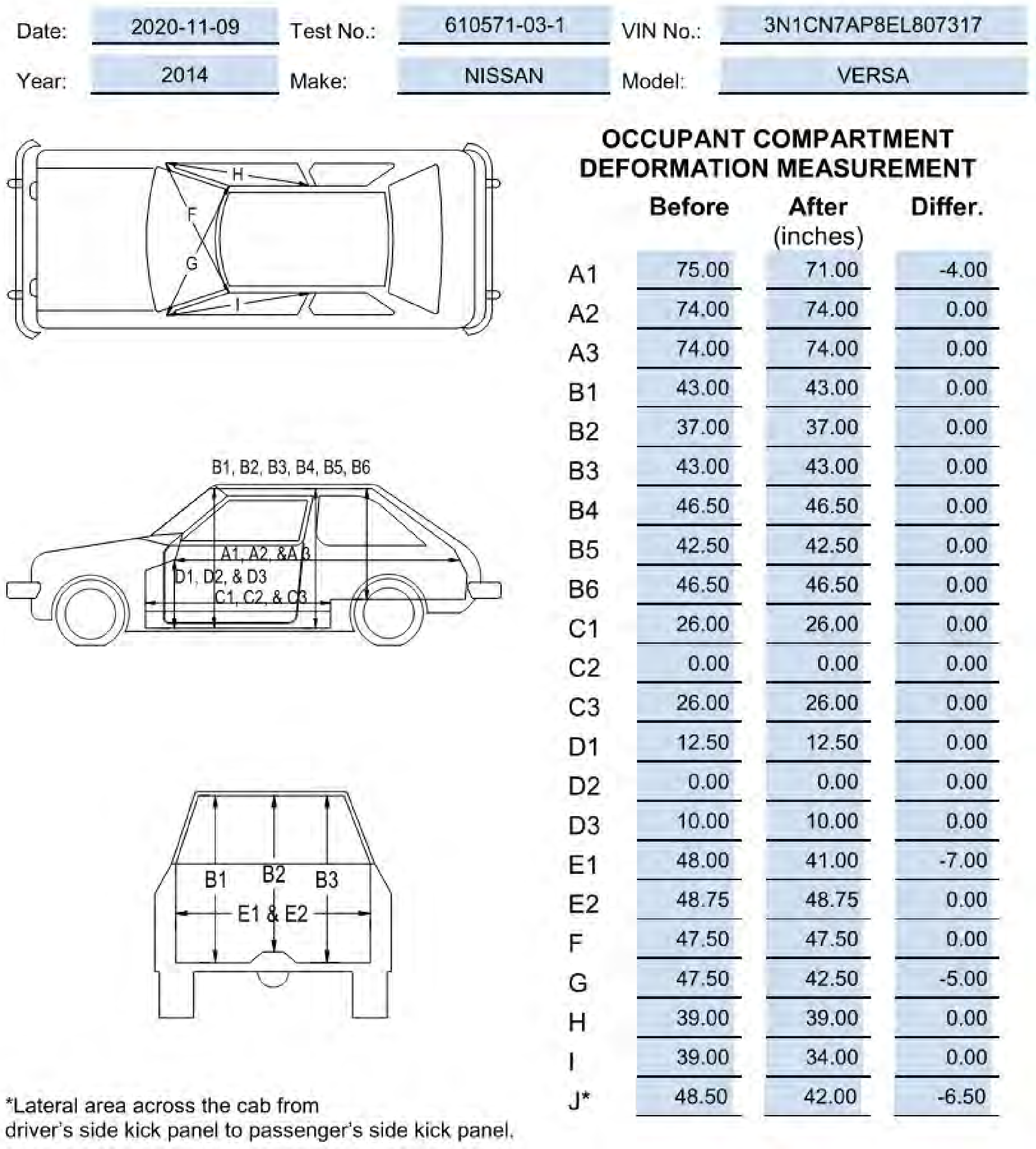
Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**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 G.3. Occupant compartment measurements for test no. 610571-03-1.



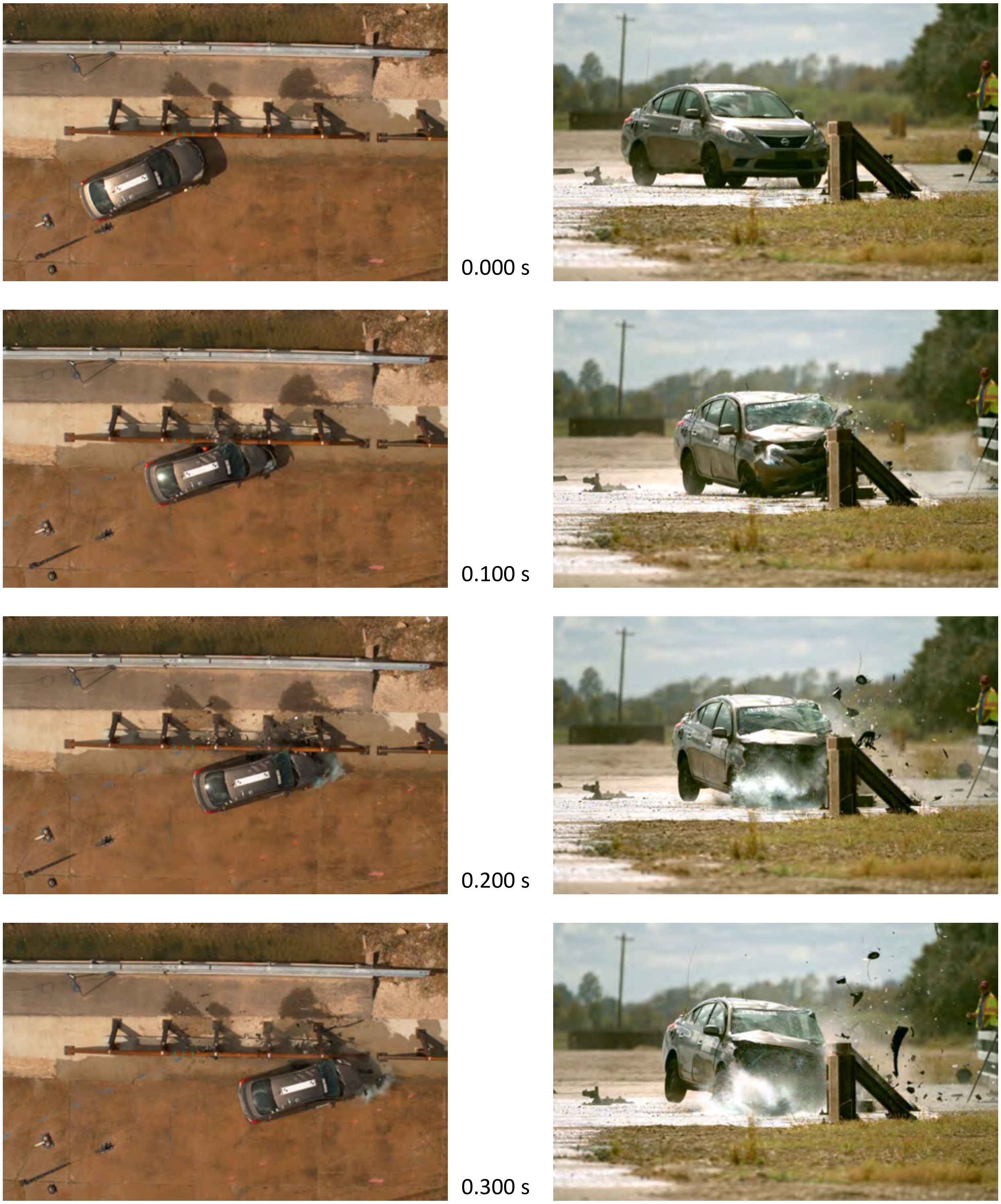
Date:	2020-11-09	Test No.:	610571-03-1	VIN No.:	3N1CN7AP8EL807317
Year:	2014	Make:	NISSAN	Model:	VERSA

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	75.00	71.00	-4.00
A2	74.00	74.00	0.00
A3	74.00	74.00	0.00
B1	43.00	43.00	0.00
B2	37.00	37.00	0.00
B3	43.00	43.00	0.00
B4	46.50	46.50	0.00
B5	42.50	42.50	0.00
B6	46.50	46.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	12.50	12.50	0.00
D2	0.00	0.00	0.00
D3	10.00	10.00	0.00
E1	48.00	41.00	-7.00
E2	48.75	48.75	0.00
F	47.50	47.50	0.00
G	47.50	42.50	-5.00
H	39.00	39.00	0.00
I	39.00	34.00	0.00
J*	48.50	42.00	-6.50

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

SEQUENTIAL PHOTOGRAPHS



0.000 s

0.100 s

0.200 s

0.300 s

Figure G.4. Sequential photographs for test no. 610571-03-1 (overhead and frontal views).

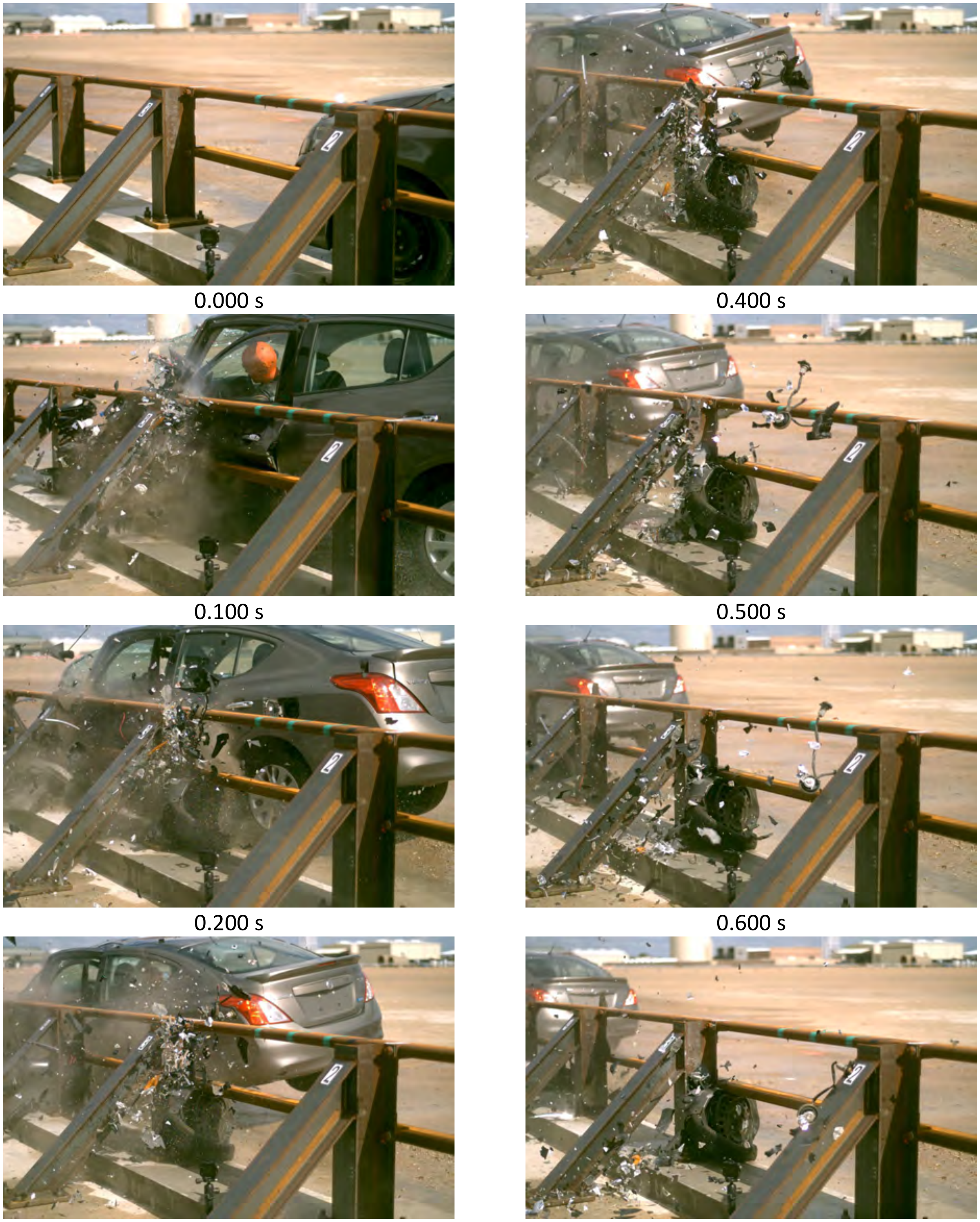
0.400 s

0.500 s

0.600 s

0.700 s

Figure G.5. Sequential photographs for test no. 610571-03-1 (overhead and frontal views, ctd.).



0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

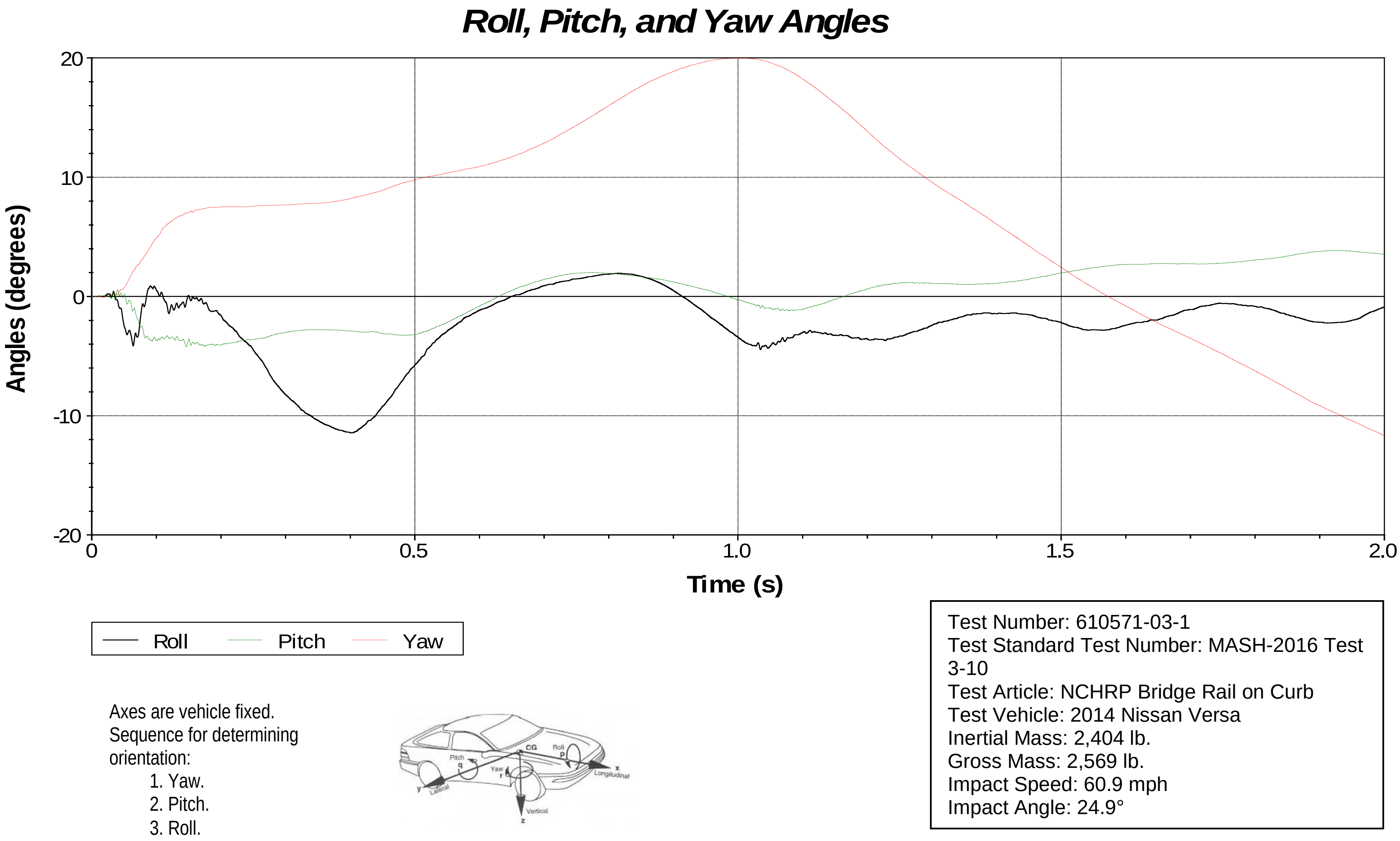
0.500 s

0.600 s

0.700 s

Figure G.6. Sequential photographs for test no. 610571-03-1 (rear view).

VEHICLE ANGULAR DISPLACEMENTS



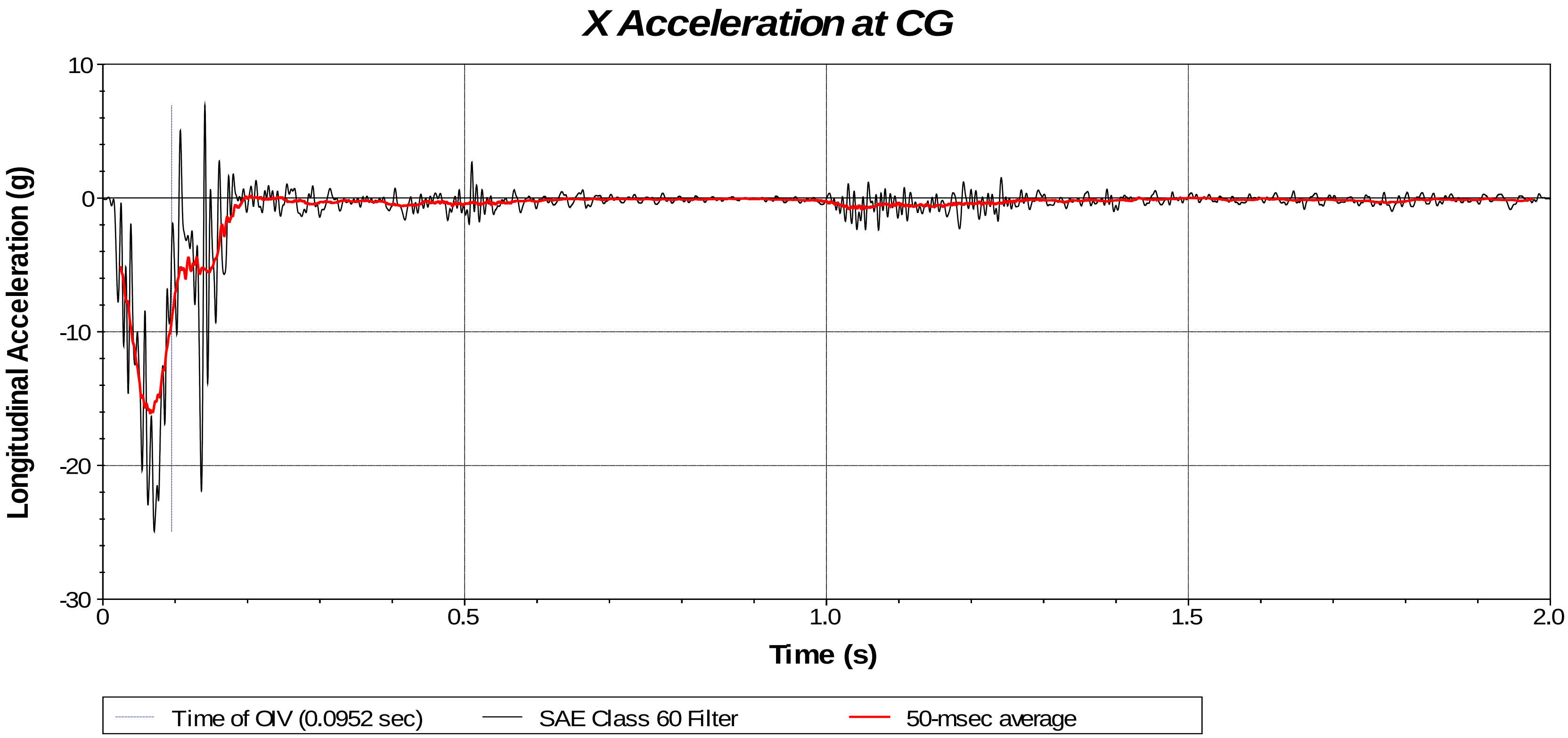
Axes are vehicle fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.

Test Number: 610571-03-1
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Curb
Test Vehicle: 2014 Nissan Versa
Inertial Mass: 2,404 lb.
Gross Mass: 2,569 lb.
Impact Speed: 60.9 mph
Impact Angle: 24.9°

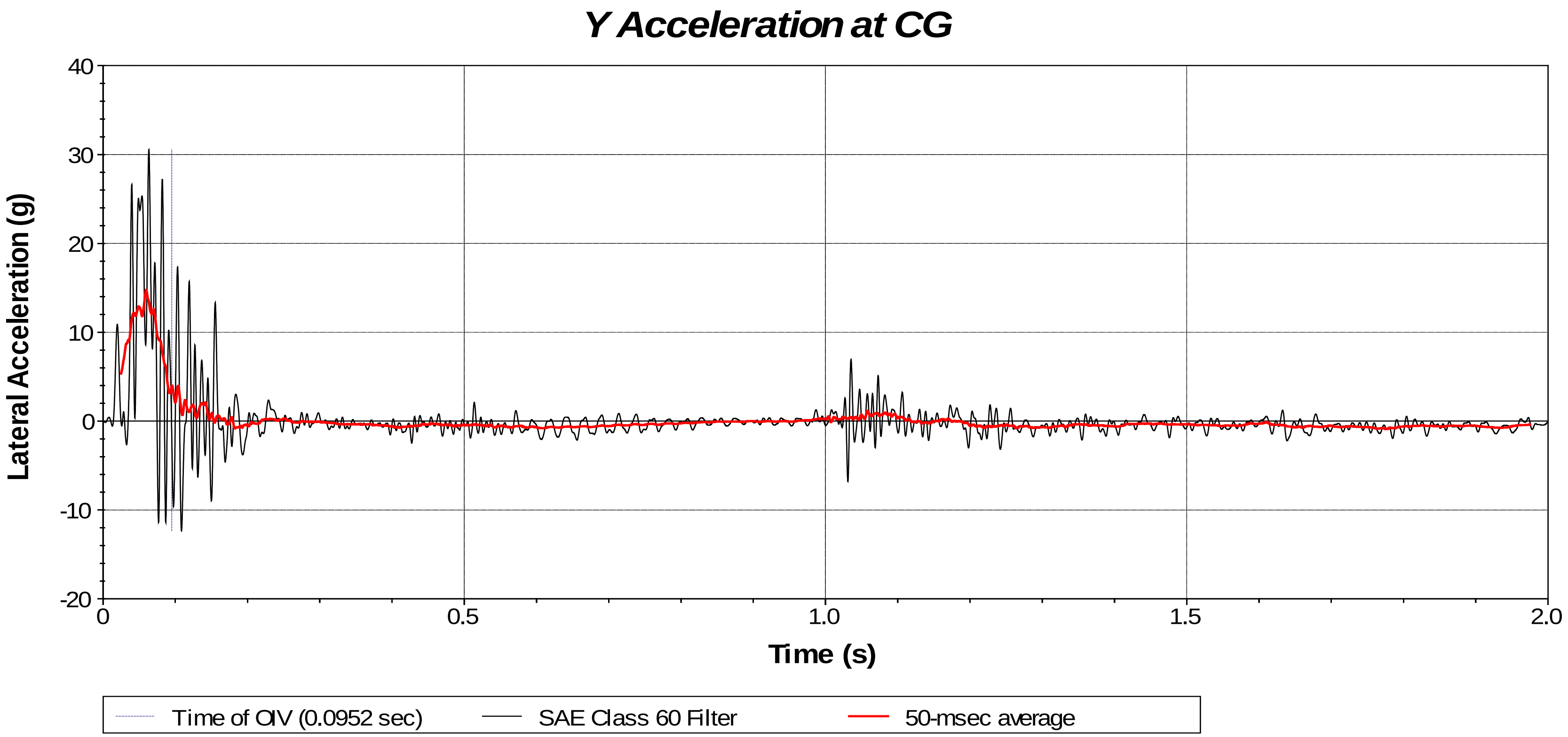
Figure G.7. Vehicle angular displacements for test no. 610571-03-1.

VEHICLE ACCELERATIONS



Test Number: 610571-03-1
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Curb
Test Vehicle: 2014 Nissan Versa
Inertial Mass: 2,404 lb.
Gross Mass: 2,569 lb.
Impact Speed: 60.9 mph
Impact Angle: 24.9°

Figure G.8. Vehicle longitudinal accelerometer trace for test no. 610571-03-1 (accelerometer located at center of gravity).



Test Number: 610571-03-1
Test Standard Test Number: MASH-2016 Test 3-10
Test Article: NCHRP Bridge Rail on Curb
Test Vehicle: 2014 Nissan Versa
Inertial Mass: 2,404 lb.
Gross Mass: 2,569 lb.
Impact Speed: 60.9 mph
Impact Angle: 24.9°

Figure G.9. Vehicle lateral accelerometer trace for test no. 610571-03-1 (accelerometer located at center of gravity).

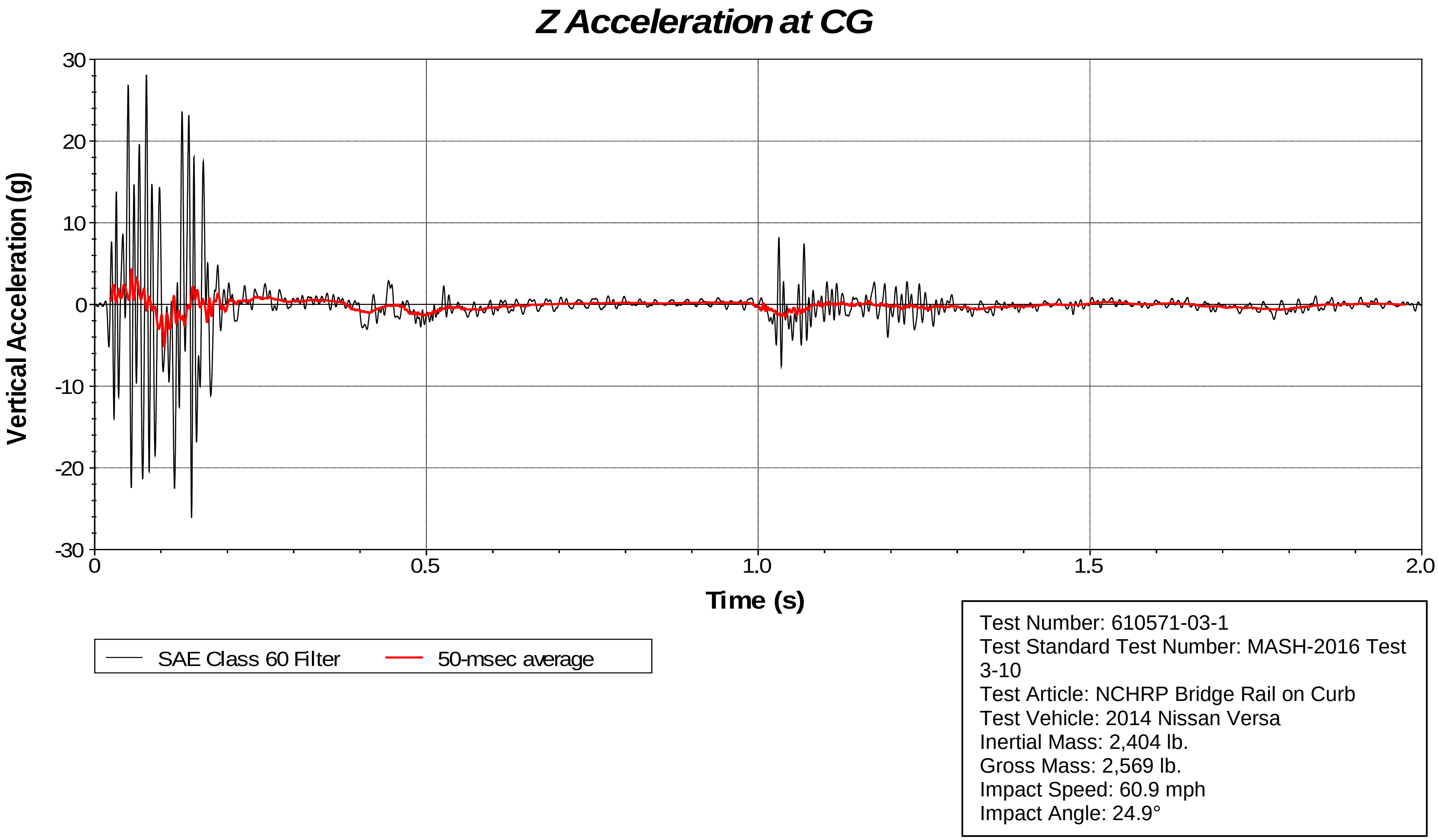


Figure G.10. Vehicle vertical accelerometer trace for test no. 610571-03-1 (accelerometer located at center of gravity).

APPENDIX H. NCHRP PROJECT 20-07 MARGINAL BRIDGE RAIL SYSTEMS

Profile views for the NCHRP Project 20-07 bridge rail systems listed in Chapter 5 are provided in this appendix.

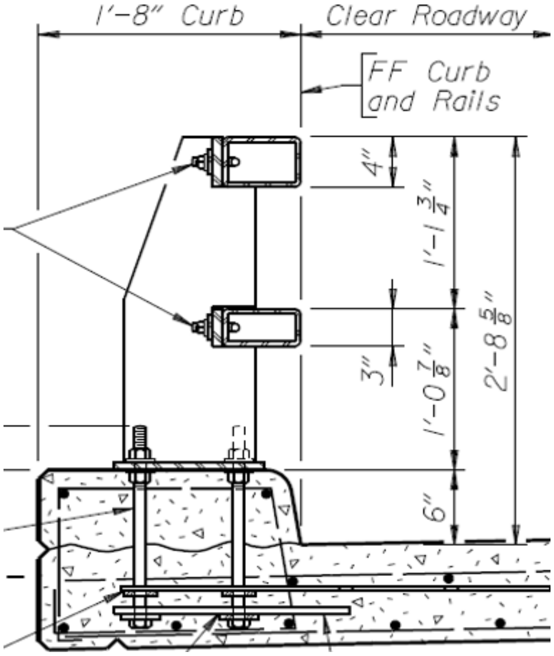


Figure H.1. Two-tube railing 36d (Wyoming).

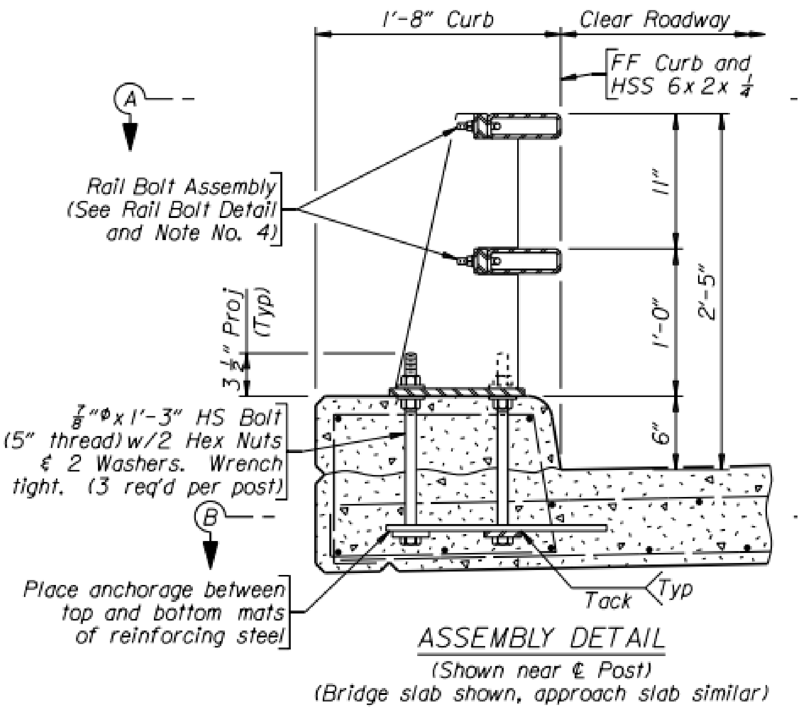


Figure H.2. Two-tube TL-3 SBB36c railing (Wyoming).

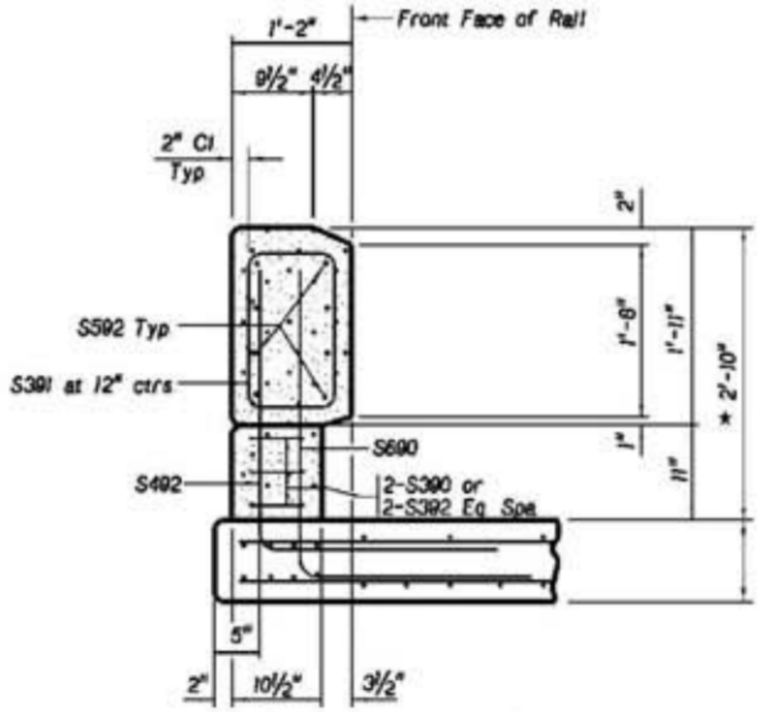
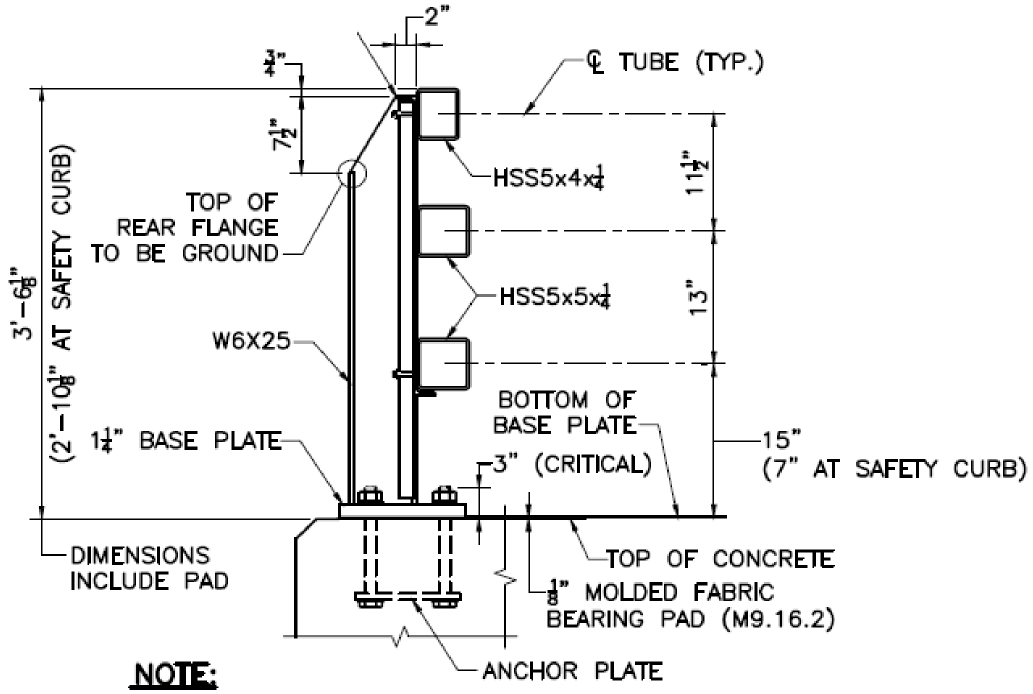


Figure H.3. Open concrete rail with 34 in. height (Nebraska).



NOTE:

SECTION AT SIDEWALK SHOWN. SECTION AT
SAFETY CURB SIMILAR, EXCEPT AS NOTED.

Figure H.4. S3-TL4 (Massachusetts).

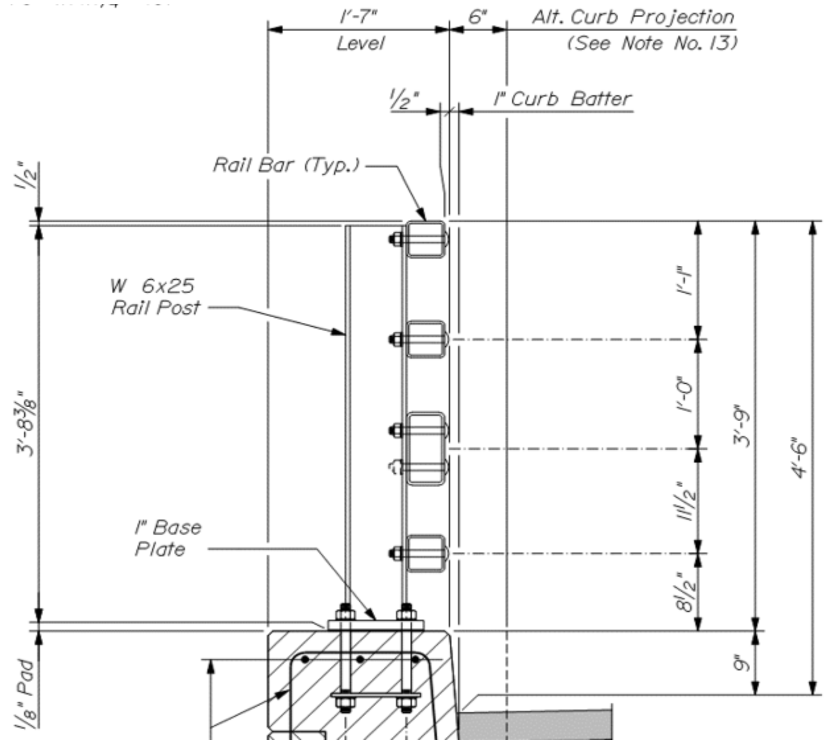


Figure H.5. Four-bar steel traffic/bicycle railing on curb (Maine).

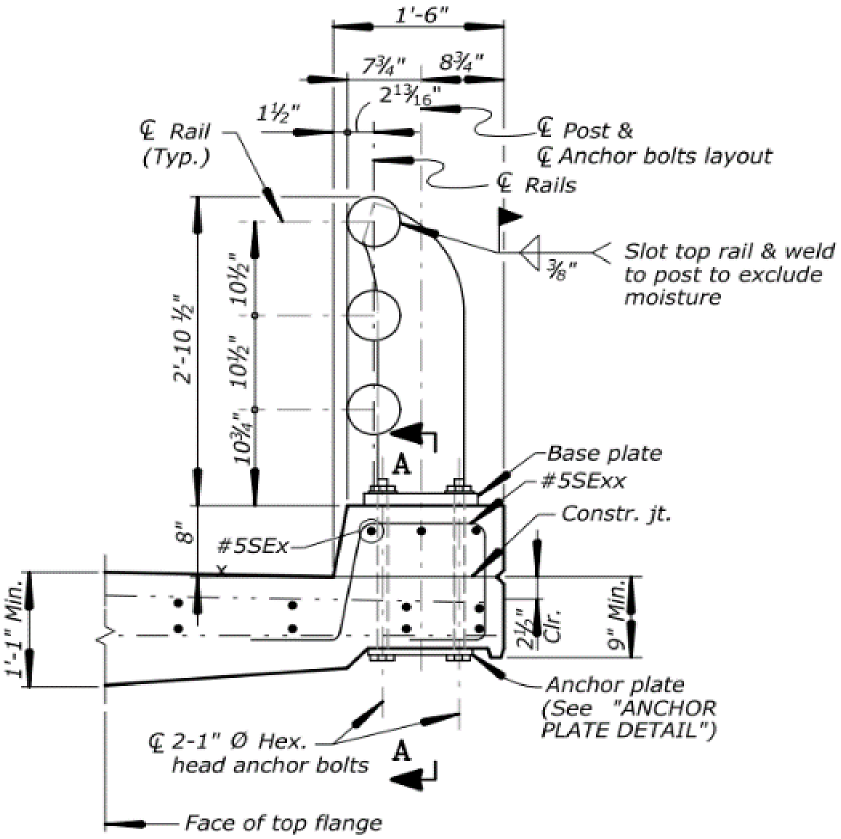


Figure H.6. George Washington Memorial Parkway railing (Federal Lands).

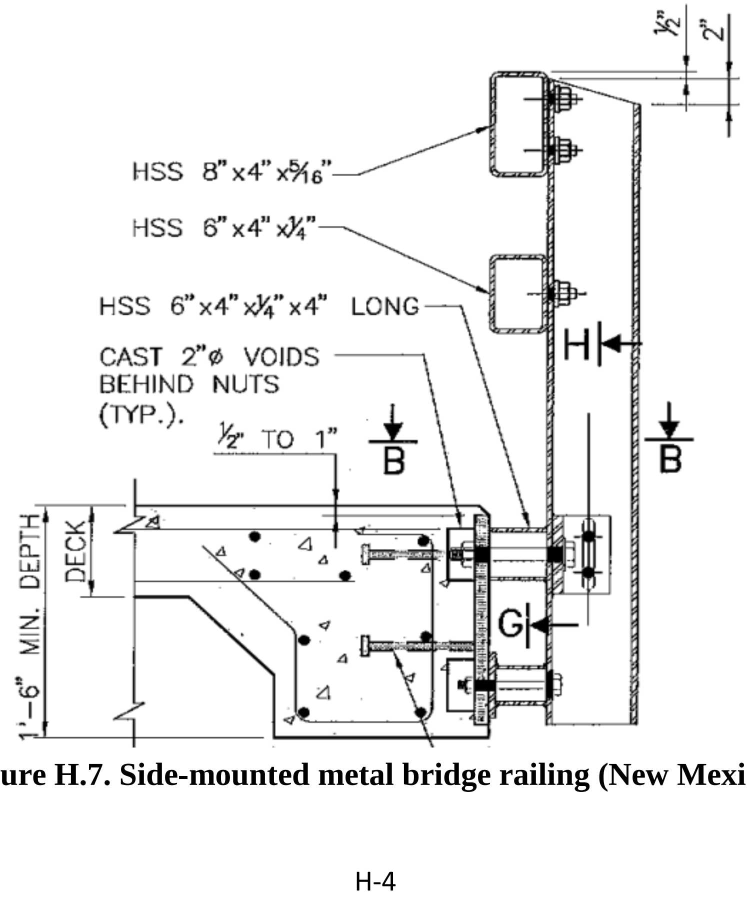


Figure H.7. Side-mounted metal bridge railing (New Mexico).