Texas A&M Transportation Institute Proving Ground

Test Report No. 9-1531-R3B

MOTORCYCLE HELMET TESTING FOR ROADSIDE SAFETY CRASHWORTHINESS APPLICATIONS

Sponsored by the
Motorcycle Safety Pooled Fund
and the
Texas Department of Transportation

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ISO 17025 Laboratory
Testing Certificate # 2821.01

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-25/9-1531-R3B		

4. Title and Subtitle	5. Report Date
MOTORCYCLE HELMET TESTING FOR ROADSIDE SAFETY CRASHWORTHINESS APPLICATIONS	Submitted: October 2024
	6. Performing Organization Code
7. Author(s) Nathan D. Schulz, Aniruddha Zalani, Roger Bligh, and Brianna E. Bastin	8. Performing Organization Report No. Report 9-1531-R3B
9. Performing Organization Name and Address Texas A&M Transportation Institute Proving Ground 3135 TAMU College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project 9-1531
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, TX 78701-2483	13. Type of Report and Period Covered Technical Report: July 2024–September 2024 14. Sponsoring Agency Code

15. Supplementary Notes

Project sponsored by the Texas Department of Transportation and the Motorcycle Safety Pooled Fund.
Project Title: Development and Evaluation of Roadside Safety Systems for Motorcyclists
URL: https://tti.tamu.edu/documents/9-1531-R3B.pdf

16. Abstract

The United States currently does not have developed and standardized testing and evaluation criteria for use in the crashworthiness investigation of motorcycle roadside safety systems. Europe, however, has developed and adopted a formalized protocol, CEN/TS 17342:2019. The Texas A&M Transportation Institute previously performed testing according to the CEN/TS 17342:2019 protocol, adopting, however, existing U.S. helmets to adapt to U.S. market characteristics. Because helmet characteristics could potentially influence testing injury outcomes, a review of the impact performance of U.S. motorcycle helmets was conducted.

A testing apparatus was developed to evaluate the impact performance of motorcycle helmets attached to a Hybrid III 50th percentile male anthropomorphic test dummy (ATD) head and neck assembly. The impact replicated a sliding ATD impacting a roadside hardware system.

Thirteen U.S. motorcycle helmets were tested and evaluated. Each helmet was assessed based on measured neck compression force and bending moments. Five of the helmets met the performance criteria for the two injury values. There were no noticeable trends in motorcycle helmet performance based on type, finish, material, or certification.

17. Key Words	18. Distribution Statement
Motorcycle, Helmet, Dummy, ATD, Injury Criteria, Compression Force, Bending Moment, Roadside Safety	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22312 http://www.ntis.gov

19. Security Classification. (of this report)	20. Security Classification. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	54	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

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Report 9-1531-R3B
Project 9-1531
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Texas Department of Transportation

Submitted: October 2024

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DISCLAIMER

ACKNOWLEDGMENTS

This research project was performed under a pooled fund program between the following states and agencies. The authors acknowledge and appreciate their guidance and assistance.

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REVISION LOG

Revision Number	Change(s) Made	Date

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

Chapter 1. INTRODUCTION

The United States currently does not have developed and standardized testing and evaluation criteria for use in the crashworthiness investigation of motorcycle roadside safety systems. Europe, however, has developed and adopted a formalized protocol, CEN/TS 17342:2019, *Road Restraint Systems—Motorcycle Road Restraint Systems Which Reduce the Impact Severity of Motorcyclist Collisions with Safety Barriers*.

Protocol CEN/TS 17342:2019 (*1*) provides test procedures to test and evaluate roadside safety hardware for motorcyclist impacts. The procedures generally describe test setup, test installation, anthropomorphic test dummy (ATD) preparation, post-processing, evaluation criteria, and reporting requirements. One specific element of the procedures discusses the identification and use of motorcycle helmet types. Annex F in CEN/TS 17342:2019 describes a test procedure to determine appropriate motorcycle helmets for use in the testing protocols.

The Texas A&M Transportation Institute (TTI) previously performed testing according to the CEN/TS 17342:2019 protocol, adopting, however, existing U.S. helmets to adapt to U.S. market characteristics (*2, 3*). Because helmet characteristics potentially influence testing injury outcomes, there is a need to objectively and efficiently compare U.S. and European motorcycle helmets and to identify potential design and/or evaluation flaws of U.S. helmets for motorcycle roadside safety system investigation.

The objectives of this project were to (a) develop a laboratory apparatus to conduct calibration testing of motorcycle helmet testing, (b) conduct helmet calibration testing following the procedures included in Annex F of CEN/TS 17342:2019, and (c) provide suggestions of U.S. helmets for consideration in the development of guidelines for motorcycle crash testing.

Chapter 2. BACKGROUND

An increase in motorcycle registrations along with rising safety concerns in recent years has driven a growth in motorcycle helmet sales across the globe. The motorcycle helmet market is predicted to rise by 7 percent globally and 8 percent in the United States by 2030 (*4*). Numerous brands and types of motorcycle helmets are available in the market. Generally, there are four different classifications of motorcycle helmets based on shape: (a) full face, (b) half/open face, (c) modular, and (d) off-road/dual sport. Figure 2.1 shows an example of these motorcycle helmet types. Each type offers various advantages and disadvantages. Some types provide better safety and protection, while other types provide better functionality and comfort. The research under this project focused on full-face motorcycle helmets.

(a) Full Face

(b) Half/Open Face

(c) Modular

(d) Off-Road/Dual Sport

Figure 2.1. Helmet Types.

The U.S. Department of Transportation (DOT) requires that all motorcycle helmets sold in the United States meet Federal Motor Vehicle Safety Standard (FMVSS) 218 (*5*). Under this FMVSS 218 testing standard, helmets are subject to impact attenuation, penetration, and chin strap retention tests. In addition, there are general requirements for such things as the liner, chin strap and rivets, weight, and design/style of the helmet. Helmets with FMVSS 218 certification are marked with a sticker on the back side of the helmet.

Another helmet testing program in the United States is Snell (*6*), which subjects motorcycle helmets to additional tests. The latest versions of the testing certification, M2025D and M2025R, have recently gone into effect for motorcycle helmets on the market. The testing is more rigorous than FMVSS 218 because it incorporates additional tests that must meet specific safety and performance requirements. Thus, helmets that meet the Snell testing requirements are generally more expensive since they incorporate more advanced safety features. Motorcycle helmets sold in the United States are not required to meet Snell testing criteria. The tests included as part of Snell certification are the following:

- Impact management tests:
  - Frontal.
  - Oblique.
- Positional stability test.
- Dynamic retention strength test.
- Chin bar test.
- Helmet shell penetration test.
- Face shield penetration test.
- Removability test.

Additional helmet testing standards have been developed and implemented in international countries. These include European Commission for Europe (ECE) 22.05/22.06, safety helmet assessment and ratings program (SHARP), and FIM. Some similarities exist between the various testing standards. However, some are considered more rigorous than others. Further, implementation of the helmet testing criteria varies. Motorcycles helmets sold in the United States may be listed as certified per some of these international standards. Thus, a helmet could be certified as FMVSS 218 DOT approved, Snell M2025R, and ECE 22.06.

Since the United States has no motorcycle safety testing criteria with respect to roadside hardware, there are no specifications as to which helmets or certifications are suitable for an upright or sliding crash impact against barriers.

The CEN/TS 17342:2019 testing procedure requires the use of a standard helmet for conducting sliding impacts with barriers. The testing standard has a calibration test protocol to ensure consistency when different helmets are used across testing laboratories.

Chapter 3. TEST SETUP

Experimental testing was performed to evaluate the performance of U.S. motorcycle helmets. This chapter describes the test setup, and procedures followed to test and evaluate the motorcycle helmets. The test setup and procedures generally followed those outlined in CEN/TS 17342:2019 Annex F.

3.1. TEST FACILITY

The tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01.

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University.

3.2. TEST APPARATUS

The test apparatus consisted of a table with a sled pulled along a track and impacting an ATD head and neck assembly wearing a motorcycle helmet. The sled weighed 166 lb. A stainless steel plate angled at 30 degrees was used as the impact surface against the motorcycle helmet. It was accelerated by dropping a counterweight that weighed 360 lb.

The back of each helmet was positioned the same for all tests. The center rear of the helmet was resting on the table, and the front of the helmet was placed vertically within 0.2 degrees of rotation. The neck was positioned so that the three lowest vertebrae (closest to shoulder interface point) were within 0.2 degrees of horizontal before each test. Adjustments were made in some cases due to different helmets having different distances between the back of the helmet and the back of the head.

Figure 3.1 presents the overall information on the test apparatus. Figure 3.2 shows the sled in contact with a motorcycle helmet. Appendix A provides further details on the test apparatus. Drawings were provided by the TTI Proving Ground, and construction was performed by TTI Proving Ground personnel.

Figure 3.1. Test Apparatus and ATD Assembly with Motorcycle Helmet.

Figure 3.2. Test Apparatus at Contact Point.

3.3. DATA ACQUISITION SYSTEMS

3.3.1. Anthropomorphic Test Dummy and Instrumentation

The ATD consisted of a standard Hybrid III 50th percentile male head and neck assembly. The assembly was mounted to a steel plate that was welded to the table.

The instrumentation used for the tests was based upon a modified Hybrid III 50th percentile male ATD as described in CEN/TS 17342:2019. All necessary measurements to evaluate the biomechanical indices were carried out with measurement systems that satisfy ISO 6487 requirements or better. The resultant accelerations measured at the center of gravity of the ATD's head were calculated from the tri-axial components of the acceleration recorded with a channel frequency class (CFC) of 1000 and a channel amplitude class (CAC) of 500 g. The neck forces and moments were measured by a six-channel upper neck load cell specifically designed to be fitted to the Hybrid III ATD. These forces and moments were recorded as follows: (a) F_x and F_y with a CAC of 8 kN and a CFC of 1000; (b) F_z with a CAC of 13 kN and a CFC of 1000; and (c) M_x, M_y, and M_z with a CAC of 280 Nm and a CFC of 1000.

3.3.2. Photographic Instrumentation Data Processing

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

- One placed overhead with a field of view perpendicular to the table and directly over the impact point.
- One placed with a perpendicular view of the impact point.

The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the impact and to determine the impact speed. A digital camera recorded and documented conditions of each helmet before and after the test.

3.4. MOTORCYCLE HELMETS

Thirteen U.S. motorcycle helmets were acquired for impact testing. Table 3.1 presents a list of the helmets that were evaluated.

Table 3.1. Motorcycle Helmets.

Test Number	Helmet	Certification
491534-03-1	Bell Qualifier	DOT, ECE 22.05
491534-03-2	Scorpion EXO-R320	DOT
491534-03-3	HJC C70	DOT
491534-03-4	Sedici Strada II Primo Americana	DOT, Snell M2020D
491534-03-5	Shoei RF-SR	DOT, Snell M2020D
491534-03-6	HJC F70	DOT, ECE 22.05, 4 star (orange oblique)
491534-03-7	Bell Qualifier DLX Mips	DOT, ECE 22.05, 3 star (orange oblique)
491534-03-8	Bell Qualifier DLX Mips	DOT, ECE 22.05, 3 star (orange oblique)
491534-03-9	AGV K3	DOT, ECE 22.06, 4 star (orange oblique)
491534-03-10	AGV K6 S	DOT, ECE 22.06, 5 star (green oblique)
491534-03-11	Shoei X-15	DOT, ECE 22.06, Snell M2020R, 5 star (green oblique)
491534-03-12	Arai Regent X	DOT, Snell M2020D
491534-03-13	Icon	DOT, ECE 22.06, PSC–Japan

Chapter 4. TEST RESULTS

This chapter presents the results of the tests conducted on the 13 motorcycle helmets. The test results were used to assess the performance of each motorcycle helmet.

4.1. MOTORCYCLE HELMET IMPACT TESTS

Each motorcycle helmet was impacted with the sled at a target impact speed of 12.3 mi/h. Photographs of the helmets before and after the test were taken to document the damage. Appendix B presents the photographs for each test.

4.2. ATD INJURY CRITERIA

There were two quantities of interest to analyze the performance of the motorcycle helmets: neck compression force (F_z) and neck bending moment about the x-axis (M_{ocx}). Figure 4.1 and Figure 4.2 show the neck compression force for the motorcycle helmet tests, with the neck compression force presented as a positive value. Figure 4.3 and Figure 4.4 present the neck bending moment about the x-axis for the motorcycle helmet tests.

The ATD neck force and moment varied for each motorcycle helmet. The Bell Qualified helmet had the highest neck compression force at 5533 N. The Sedici Strada II Primo Americana had the lowest neck compression force at 2250 N. The two helmets also had the highest and lowest neck bending moment (x-direction).

The CEN/TS 17342:2019 testing procedure recommends that two criteria be considered when evaluating and selecting candidate motorcycle helmets for full-scale crash testing. First, the neck compression force curve should fit within the bounds of CEN/TS 17342:2019 Figure F.2. Second, the neck bending moment peak value should be between 20 Nm and 80 Nm. To evaluate the first criterion, the neck compression force curve for each motorcycle helmet test was determined, and the detailed results are presented in Appendix C. Ten of the 13 helmets met the criterion. To evaluate the second criterion, the maximum neck bending moment was recorded. Five of the 13 helmets met the criterion.

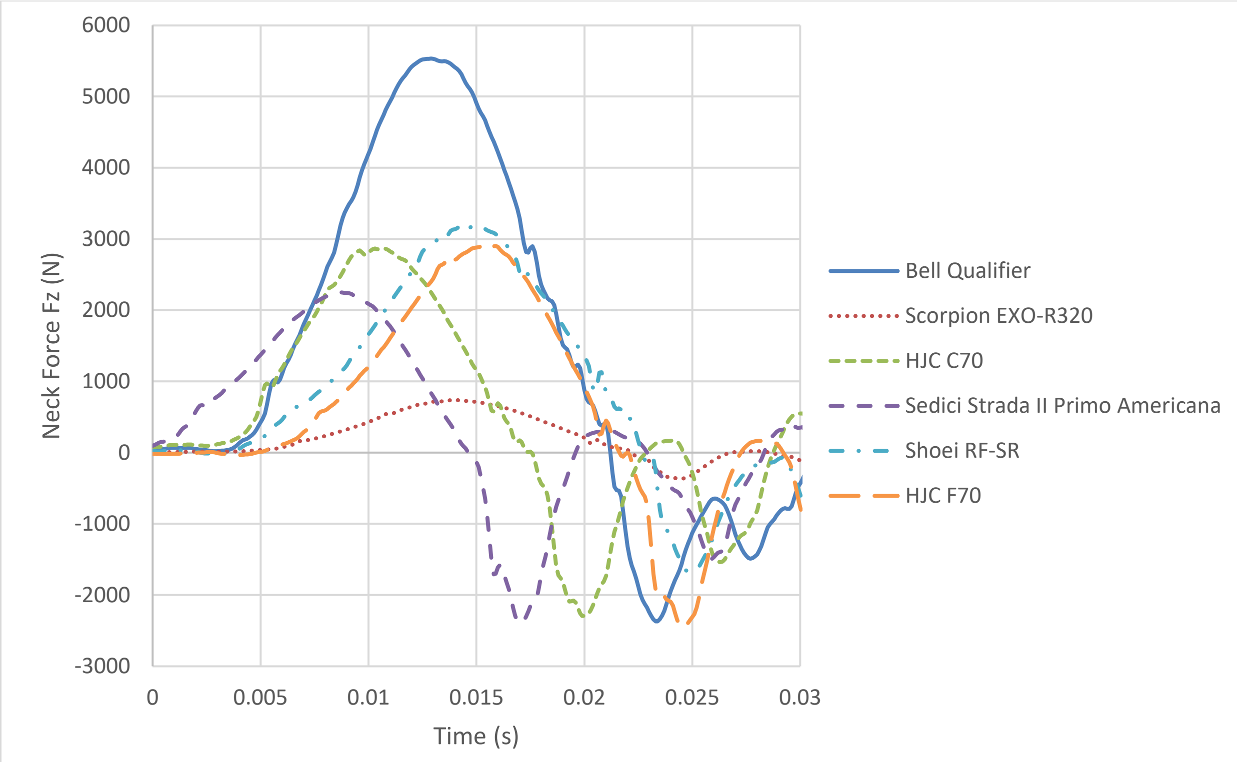

Figure 4.1. Neck Compression Force for Tests 1 through 6.

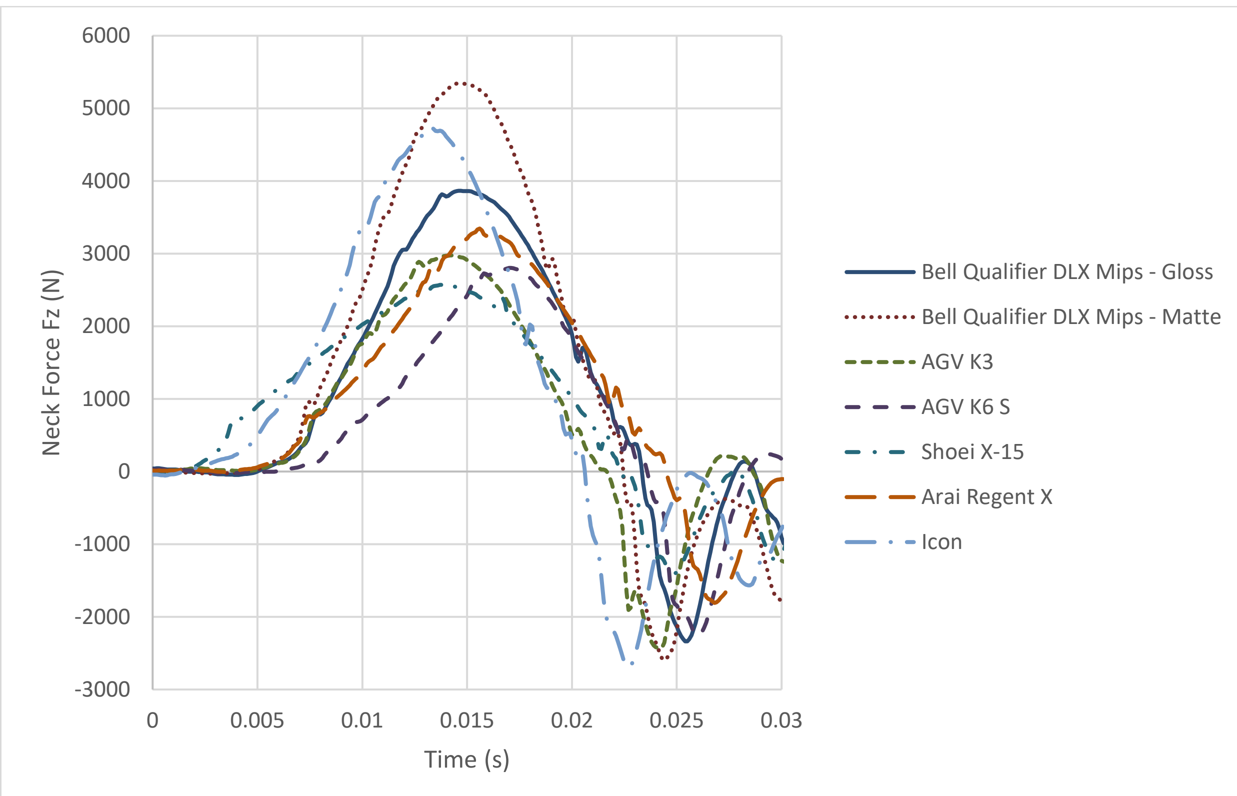

Figure 4.2. Neck Compression Force for Tests 7 through 13.

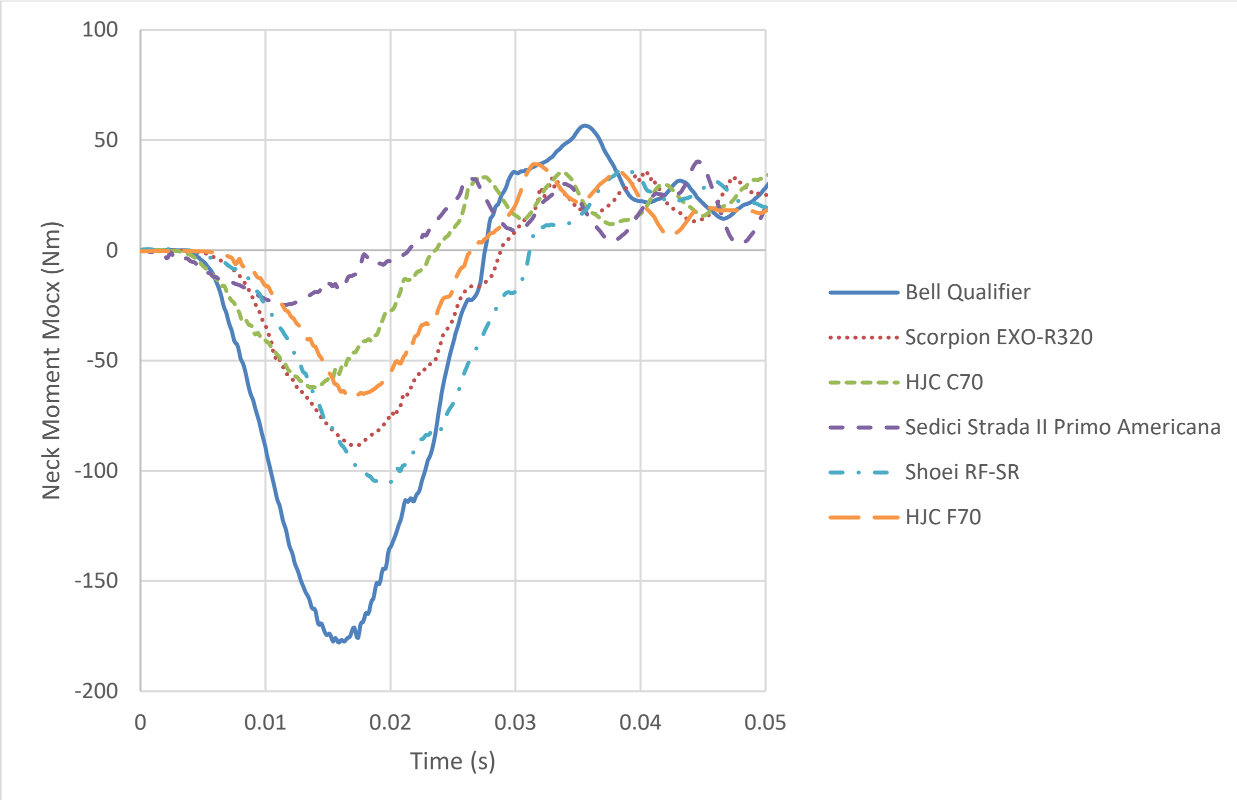

Figure 4.3. Neck Bending Moment for Tests 1 through 6.

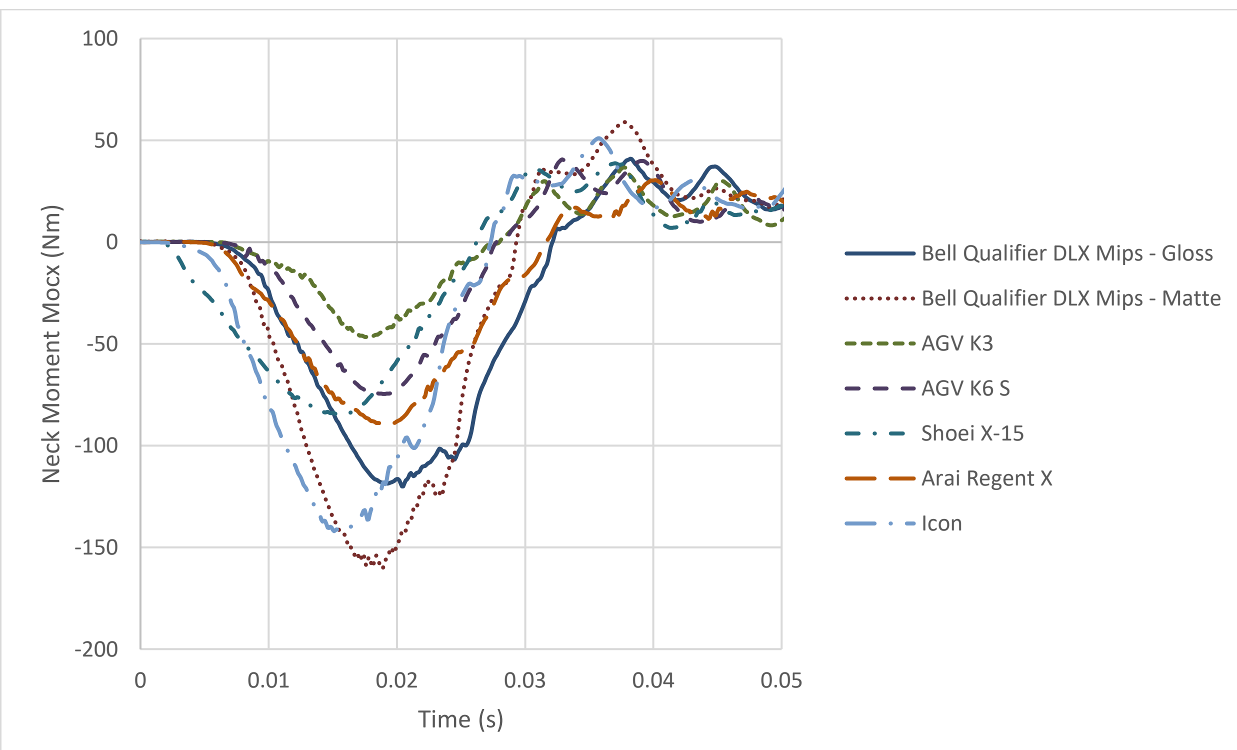

Figure 4.4. Neck Bending Moment for Tests 7 through 13.

4.3. DISCUSSION

Table 4.1 presents a summary of the testing for each of the motorcycle helmets. Five of the 13 helmets met both of the CEN/TS 17342:2019 Annex F criteria. Observances and trends from the helmet tests are as follows:

- The three Bell helmets were among the lower performers.
- The HJC and AGV helmets met both of the criteria.
- None of the helmets with a polycarbonate shell met both of the criteria, with the exception of the HJC C70 helmet, which had a polycarbonate composite shell.
- There was no commonality in performance based on helmet certification levels. Some helmets with lower certification levels met both of the criteria, while some helmets with higher certification levels did not meet the criteria.
- There was no commonality in performance based on the helmet finish.
- Several helmets performed well but were just over the 80 Nm limit for the neck bending moment. Three helmets were in the range of 80 to 90 Nm, which caused them to fail the criteria.
- The Sedici Strada II Primo Americana helmet was the best performer. It is the helmet that has been used in previous full-scale motorcycle crash tests performed at TTI.

Table 4.1. Summary of Motorcycle Helmet Tests.

Test Number	Helmet	Helmet Shell	Helmet Liner	Impact Speed (mi/h)	Certification	Helmet Finish	Max Neck Force F_z—Compression (N)	M_{ocx} (Nm)
1	Bell Qualifier	Lightweight polycarbonate	Unknown	12.13	DOT, ECE 22.05	Matte	**5532.7**	**177.8**
2	Scorpion EXO-R320	Advanced LG polycarbonate	Dual-density EPS	12.79	DOT	Gloss	3299.0	**88.5**
3	HJC C70	Polycarbonate composite	Multi-density EPS	12.39	DOT	Matte	2865.4	62.3
4	Sedici Strada II Primo Americana	Fiberglass and DuPont Kevlar fiber	Dual-density EPS	12.71	DOT, Snell M2020D	Matte	2250.0	24.7
5	Shoei RF-SR	Fiber	Dual-layer EPS	12.73	DOT, Snell M2020D	Gloss	3187.7	**105.8**
6	HJC F70	Fiberglass composite	Multi-density EPS	12.14	DOT, ECE 22.05, 4 star (orange oblique)	Gloss	2934.3	65.7
7	Bell Qualifier DLX Mips	Lightweight polycarbonate	Mips EPS	12.22	DOT, ECE 22.05, 3 star (orange oblique)	Gloss	3863.2	**120.0**
8	Bell Qualifier DLX Mips	Lightweight polycarbonate	Mips EPS	12.37	DOT, ECE 22.05, 3 star (orange oblique)	Matte	**5344.4**	**160.4**
9	AGV K3	High-resistance thermoplastic	Multi-density EPS	12.19	DOT, ECE 22.06, 4 star (orange oblique)	Matte	2973.6	46.7
10	AGV K6 S	Carbon aramid fiber	5-layer density EPS	12.6	DOT, ECE 22.06, 5 star (green oblique)	Matte	2803.4	74.6
11	Shoei X-15	Six-ply matrix of fiberglass	Multi-density EPS	12.69	DOT, ECE 22.06, Snell M2020R, 5 star (green oblique)	Gloss	2571.3	**84.6**
12	Arai Regent X	Super-complex laminate construction	Unknown	12.41	DOT, Snell M2020D	Gloss	3346.4	**89.7**
13	Icon	Polycarbonate shell	Unknown	12.38	DOT, ECE 22.06, PSC–Japan	Matte	**4743.1**	**142.0**

Note: Values with red bold text did not meet the CEN/TS 17342:2019 Annex F criteria. EPS = expanded polystyrene.

Chapter 5. CONCLUSIONS

There is a lack of standardized testing and evaluation criteria to investigate the crashworthiness of motorcycle roadside safety systems in the United States. A testing standard has been developed for use in Europe, CEN/TS 17342:2019. In lieu of existing standards, previous full-scale crash tests have generally followed the CEN/TS 17342:2019 test standards. Other full-scale crash tests have been performed to evaluate upright motorcyclist impacts with roadside safety hardware. One common thread in the testing conditions has been the use of a U.S. motorcycle helmet. The general approach has been to utilize a readily available DOT-approved helmet. Test results have necessitated a review of U.S. motorcycle helmets to assess their range of performance.

In this project, a test apparatus was developed to evaluate the impact performance of motorcycle helmets. The impact was designed to replicate the sliding impact conditions presented in CEN/TS 17342:2019. Further, Annex F in CEN/TS 17342:2019 presents details on the test apparatus setup and impact conditions; these protocols were generally followed in the testing presented in this report. The test apparatus consisted of a table and sled mounted on a sliding track system. The sled impacted a Hybrid III 50th percentile male ATD head and neck assembly and motorcycle helmet mounted to a steel plate.

Thirteen helmets were evaluated with the impact testing. The helmets ranged in manufacturer, price, finish, shell material, and certification. The performance of each helmet was analyzed by determining the ATD neck compression force (F_z) and neck bending moment about the x-axis (M_{ocx}). The F_z and M_{ocx} values for each helmet were compared to thresholds specified in Annex F of CEN/TS 17342:2019.

Five of the 13 helmets met the performance criteria for the neck compression force and bending moment injury values. These five helmets varied in type, certification, and price. There were no general trends observed in the motorcycle helmet performance. Some of the motorcycle helmets with lower certification levels performed at a high level, while others with higher certification levels performed at a lower level. The motorcycle helmet that had been previously used in full-scale crash tests (Sedici Strada II Primo Americana) was one of the best performing helmets.

The results of the testing provide an overview of motorcycle helmet performance for a specific impact condition. Additional research and testing configurations may be needed to better understand trends in U.S. motorcycle helmet performance. This could include conducting repeat tests to identify possible variance in the testing outcomes, altering the impact angle of the sled plate, altering the test procedures, and analyzing additional motorcycle helmets. Until further research is conducting, the five helmets that met both performance criteria should be considered appropriate candidate helmets for full-scale crash testing.

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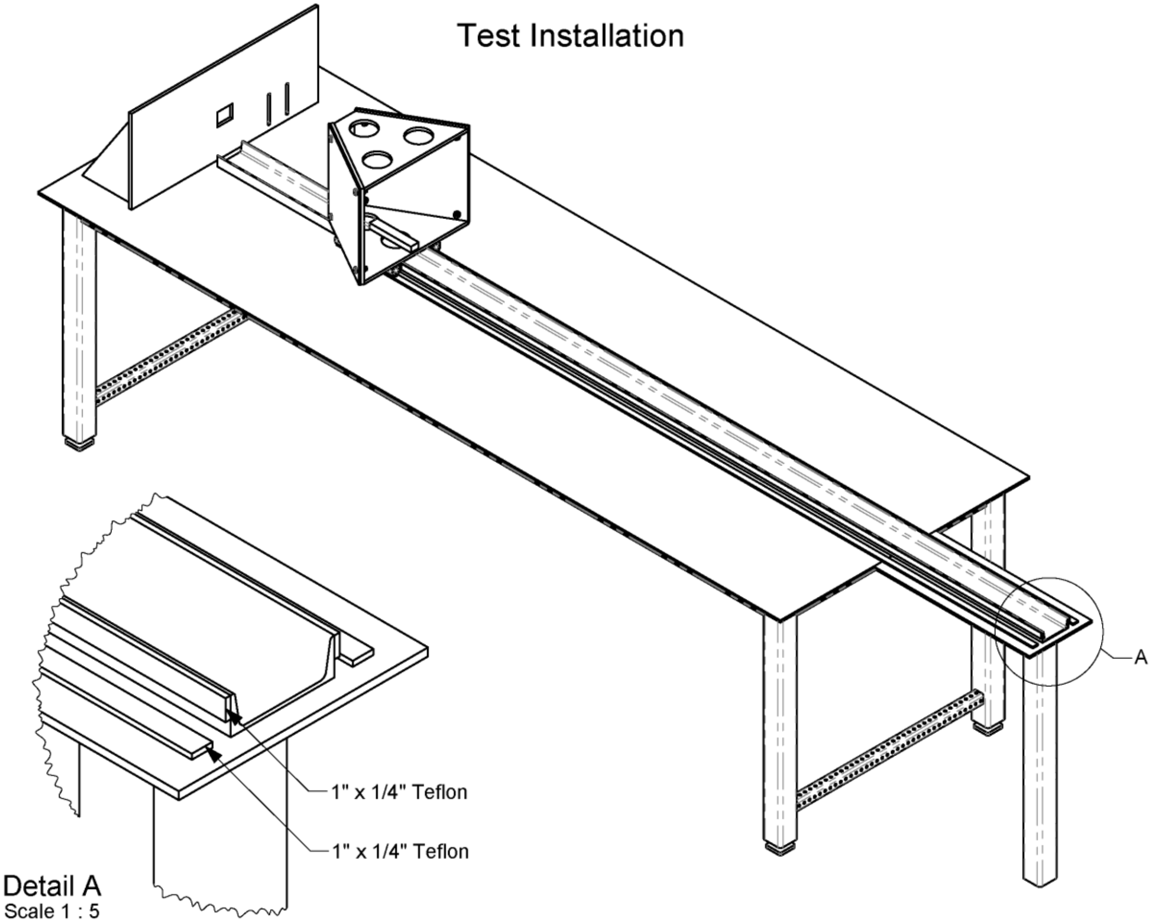
3. Silvestri Dobrovolny, C., Shi, S., Kovar, J., Bligh, R., Kuhn, D., and Griffith, B. *Development and Evaluation of Concrete Barrier Containment Options for Errant Motorcycle Riders.* Report No. 0-6968-R6. Texas A&M Transportation Institute, College Station, TX, 2018.
4. Grand View Research. *Motorcycle Helmet Market Size, Share & Trends Analysis Report By Product (Full Face, Open Face, Off-Road/Racing, Others), By End-User (Rider, Passenger), By Distribution Channel (Offline, Online), By Region, and Segment Forecasts, 2023–2030*. 2022. https://www.grandviewresearch.com/industry-analysis/motorcycle-helmet-market
5. National Highway Traffic Safety Administration. *Federal Motor Vehicle Safety Standards; Motorcycle Helmets.* 49 C.F.R. 571. Washington, DC, 2015.
6. Snell. *2020 Standard for Protective Headgear.* Snell Foundation, North Highlands, CA, 2020.

APPENDIX A. DETAILS OF TEST APPARATUS

Test Installation



1a. The table was anchored to the concrete floor with anchors, via angle iron pieces (not shown here) welded to the legs.

1b. The Teflon strips were secured with flat head machine screws and nuts.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
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Drawn by GES	Scale 1:20	Sheet 1 of 7 Test Installation	

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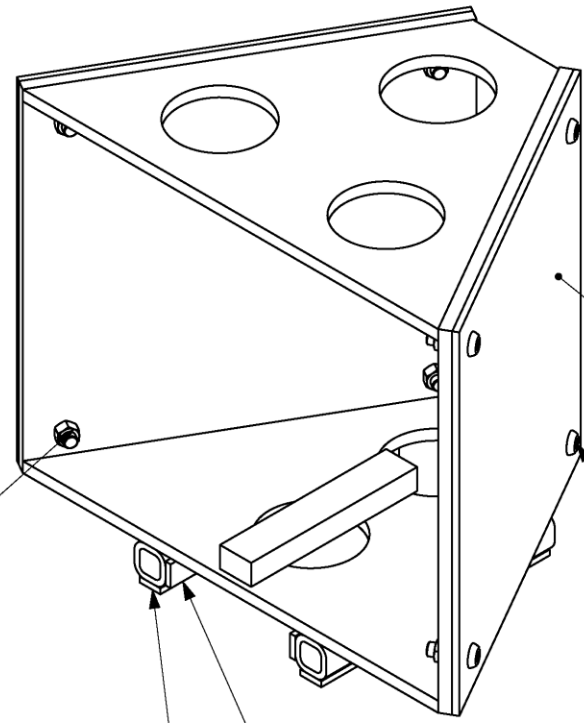
Sled



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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Drawn by GES	Scale 1:5	Sheet 2 of 7 Sled

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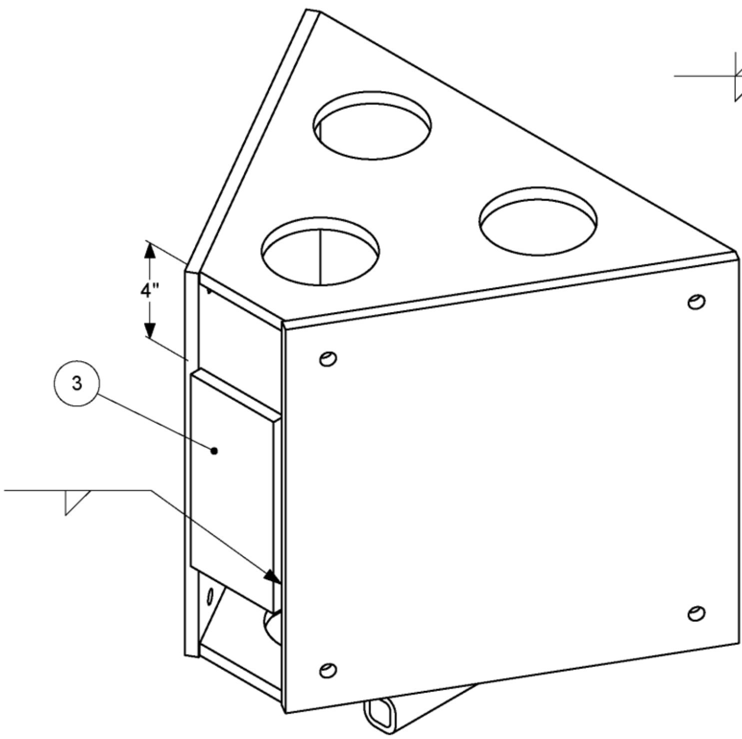
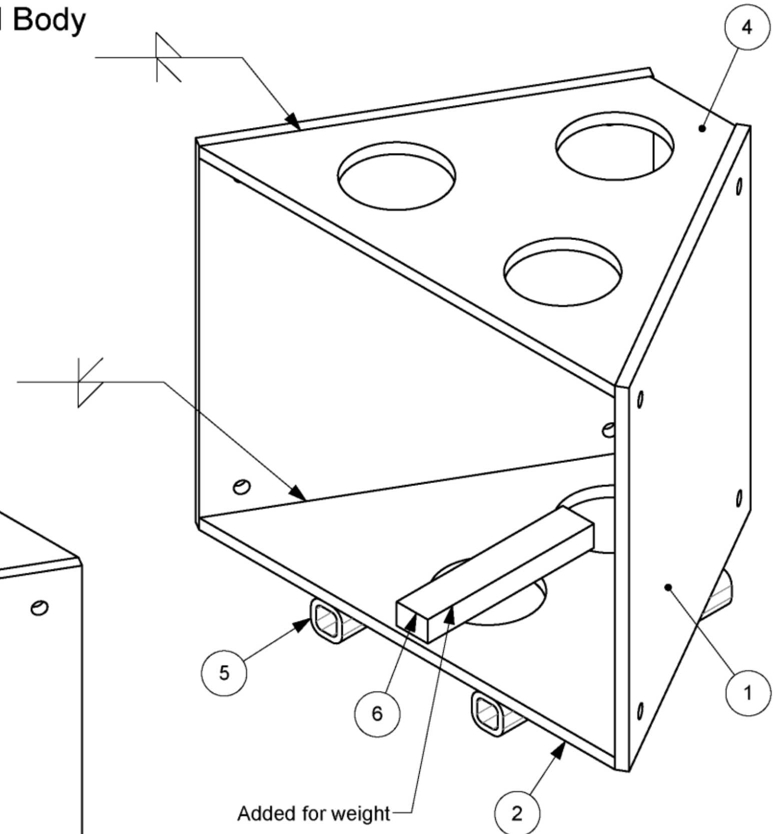
#	Description	Length	Qty
1	Plate, 16" x 1/2"	16"	2
2	Plate, 13 3/4" x 1/2"	20"	1
3	Plate, 4" x 1/2"	8"	1
4	Plate, 13 3/4" x 1/2"	20"	1
5	HSS 1 1/2" x 1 1/2" x 1/4"	11"	2
6	Plate, 1 1/2" x 1"	8"	1

Sled Body





Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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Drawn by GES	Scale 1:5	Sheet 3 of 7 Sled Body

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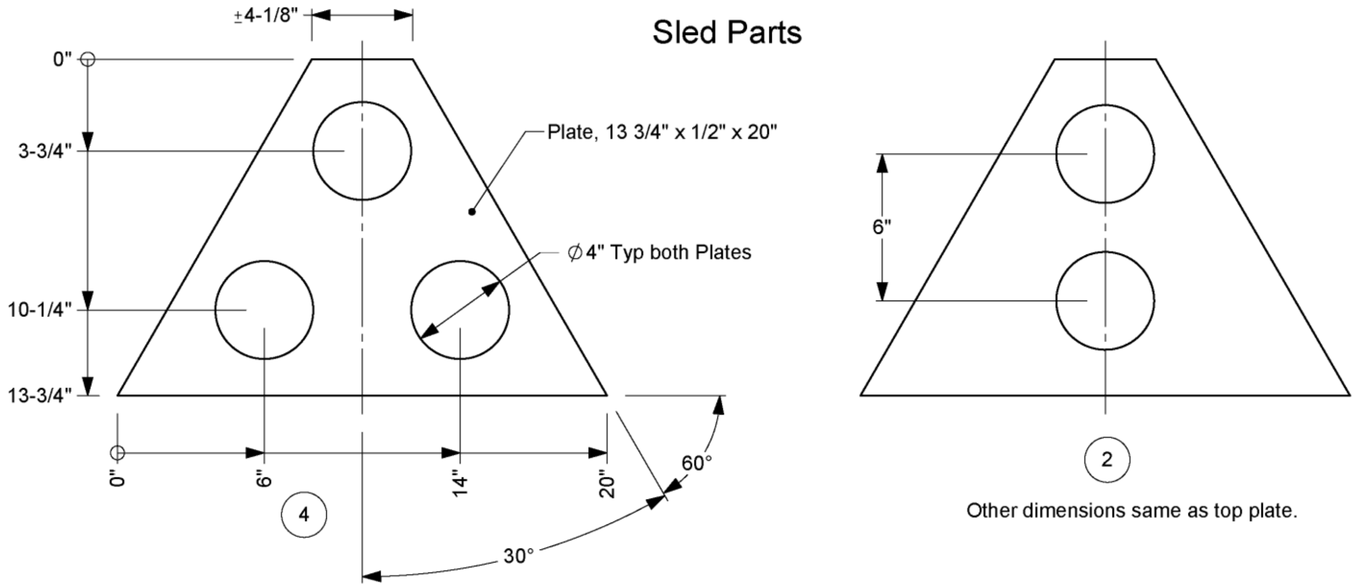
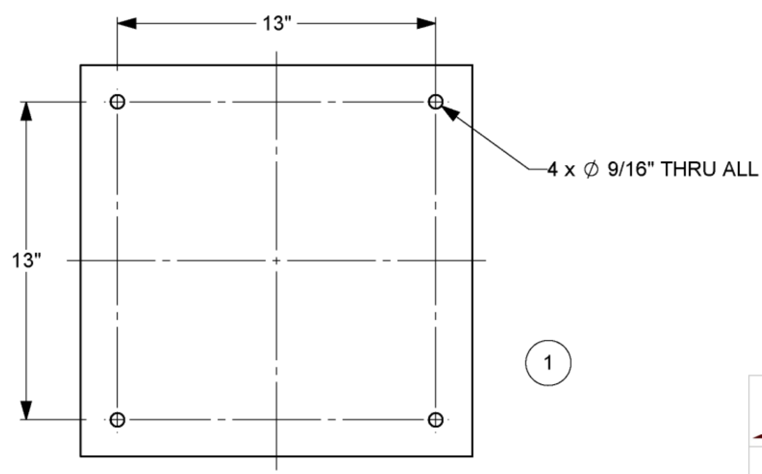
Sled Parts





Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491534-1 Motorcycle Helmet Testing		2024-07-26
Drawn by GES	Scale 1:6	Sheet 4 of 7 Sled Parts

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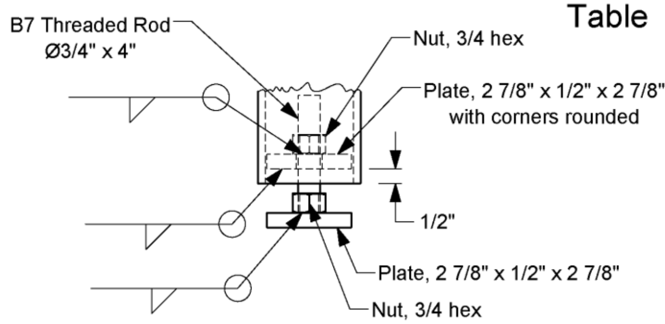
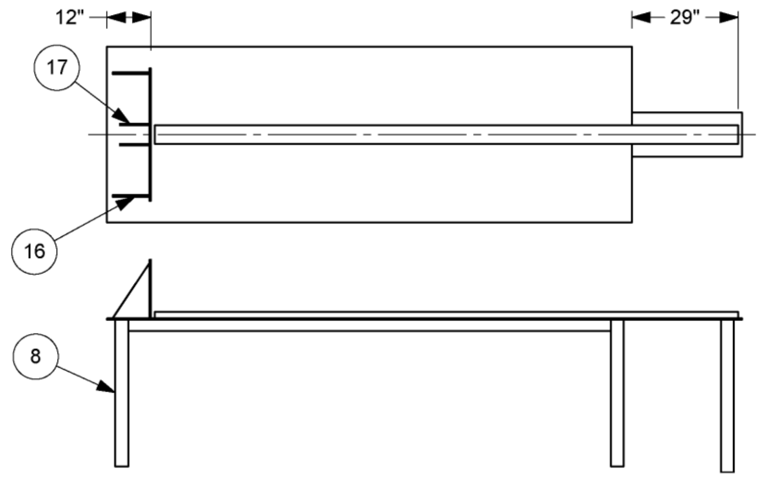
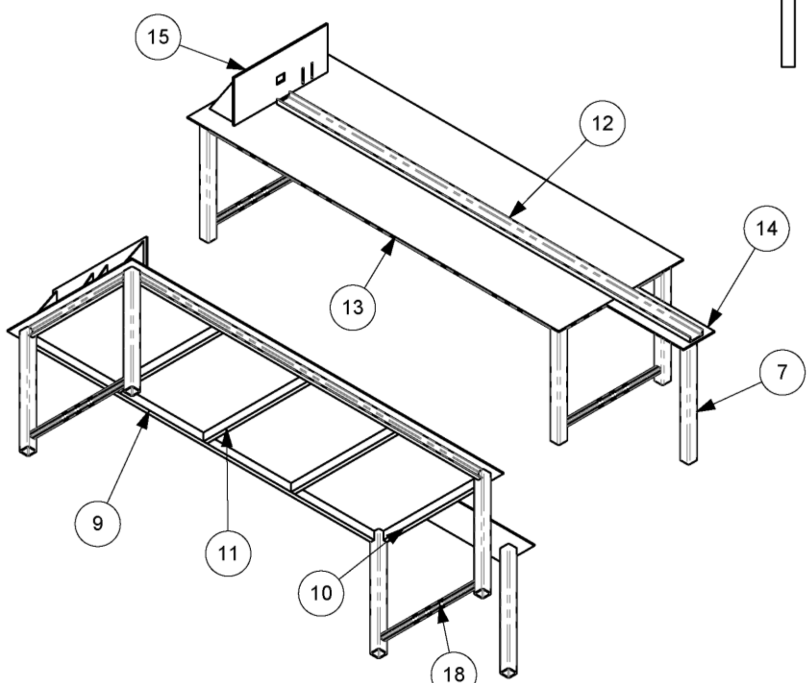
Table







#	Description	Length	Qty
7	HSS 3-1/2 x 3-1/2 x 1/4	41 1/2"	1
8	HSS 3-1/2 x 3-1/2 x 1/4	40"	4
9	C 3 x 4.1	10'-11 1/2"	2
10	C 3 x 4.1	36 1/2"	2
11	C 3 x 4.1	40"	3
12	C 5 x 6.7	13'-4"	1
13	Plate, 48" x 3/8"	12'-0"	1
14	Plate, 12" x 3/8"	30"	1
15	Plate, 16" x 1/2"	36"	1
16	Plate, 15" x 1/2"	10"	2
17	Plate, 15" x 1/2"	8"	2
18	1-3/4" Perforated Steel Tubing	36 1/2"	2

Texas A&M Transportation Institute

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Drawn by GES Scale 1:40 Sheet 5 of 7 Table

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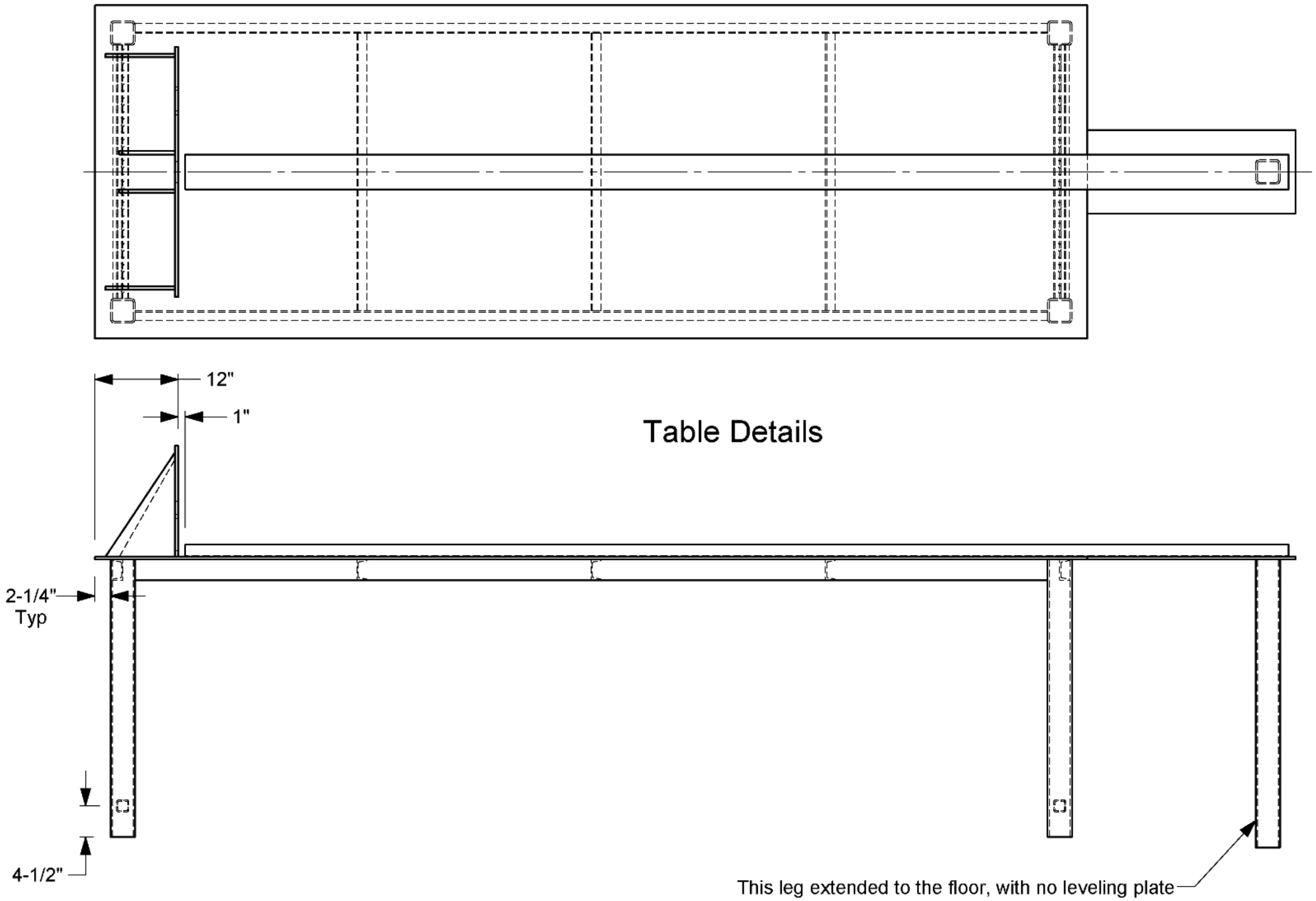
Table Details



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491534-1 Motorcycle Helmet Testing		2024-07-26
Drawn by GES	Scale 1:20	Sheet 6 of 7 Table Details

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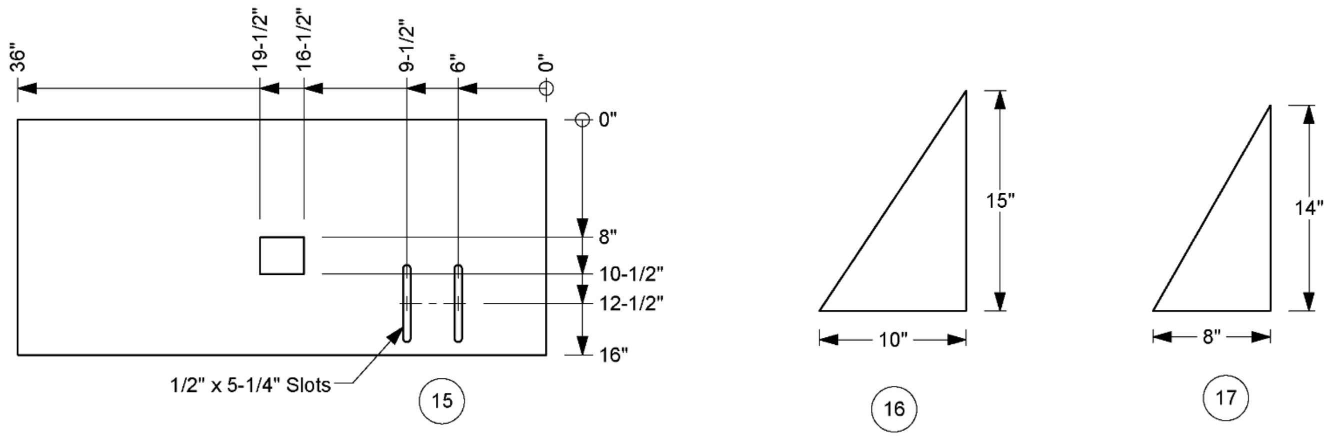
Table Parts



7a. Parts not detailed here have 90° cuts at each end, with no holes or other features.

7b. The rectangular hole in the plate was for the pull cable. The slots were for attaching the bracket holding the dummy head in place.

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

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Drawn by GES | Scale 1:10 | Sheet 7 of 7 Table Parts

S:\Accreditation-17025-2017\EIR-000 Project Files\491534-TxDOT Pooled Fund Guardrail-Schulz\-03 Motorcycle Helmet\Drafting, 491534-3\2023-12-14\491534-3 Drawing

APPENDIX B. MOTORCYCLE HELMET IMPACT TESTS—BEFORE AND AFTER PHOTOS

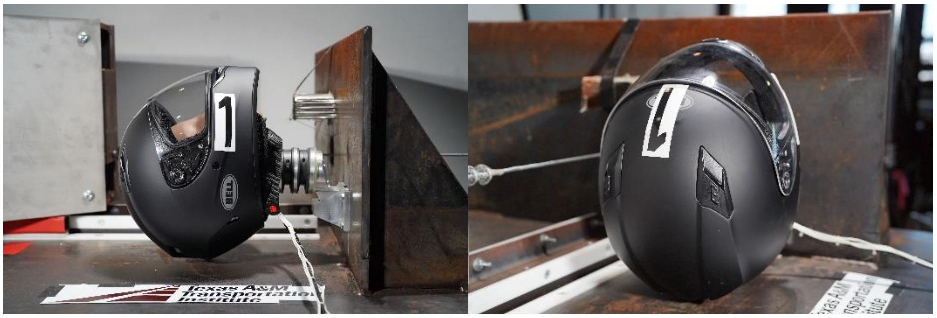

Figure B.1. 491534-03-1 prior to Testing.

Figure B.2. 491534-03-1 after Testing.

Figure B.3. 491534-03-2 prior to Testing.

Figure B.4. 491534-03-2 after Testing.

Figure B.5. 491534-03-3 prior to Testing.

Figure B.6. 491534-03-3 after Testing.

Figure B.7. 491534-03-4 prior to Testing.

Figure B.8. 491534-03-4 after Testing.

Figure B.9. 491534-03-5 prior to Testing.

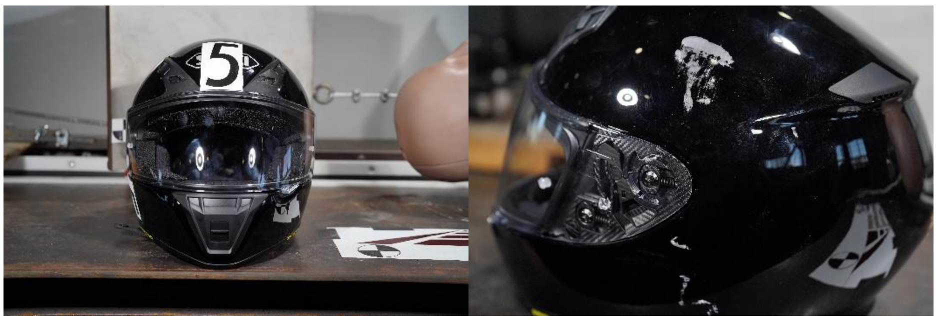

Figure B.10. 491534-03-5 after Testing.

Figure B.11. 491534-03-6 prior to Testing.

Figure B.12. 491534-03-6 after Testing.

Figure B.13. 491534-03-7 prior to Testing.

Figure B.14. 491534-03-7 after Testing.

Figure B.15. 491534-03-8 prior to Testing.

Figure B.16. 491534-03-8 after Testing.

Figure B.17. 491534-03-9 prior to Testing.

Figure B.18. 491534-03-9 after Testing.

Figure B.19. 491534-03-10 prior to Testing.

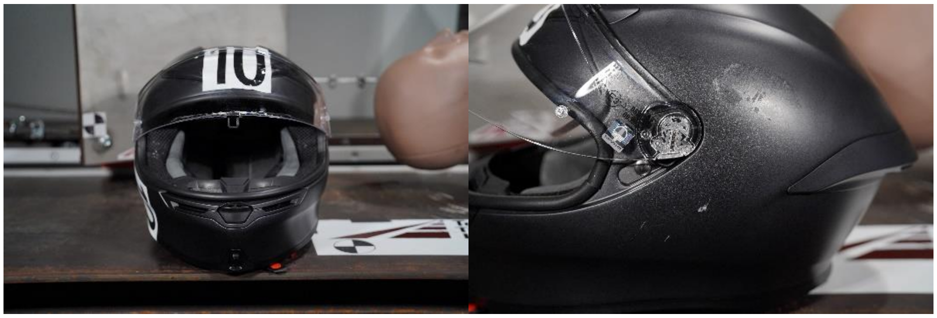

Figure B.20. 491534-03-10 after Testing.

Figure B.21. 491534-03-11 prior to Testing.

Figure B.22. 491534-03-11 after Testing.

Figure B.23. 491534-03-12 prior to Testing.

Figure B.24. 491534-03-12 after Testing.

Figure B.25. 491534-03-13 prior to Testing.

Figure B.26. 491534-03-13 after Testing.

APPENDIX C. NECK COMPRESSION FORCE CURVES

C.1. TEST 491534-03-1—BELL QUALIFIER

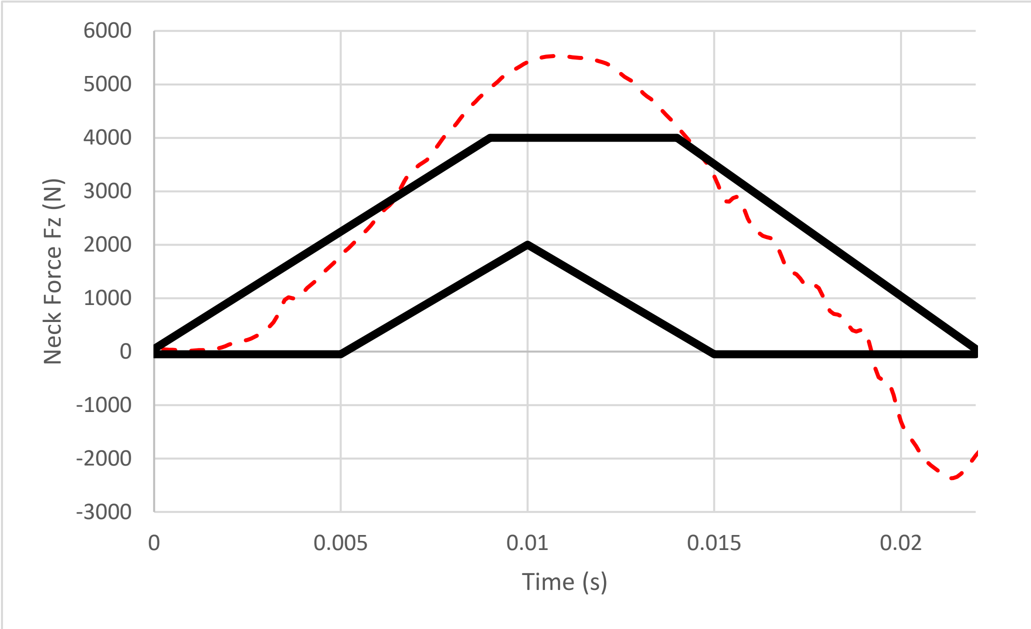

Figure C.1. Neck Compression Force Curve—Test 491534-03-1.

C.2. TEST 491534-03-2—SCORPION EXO-R320

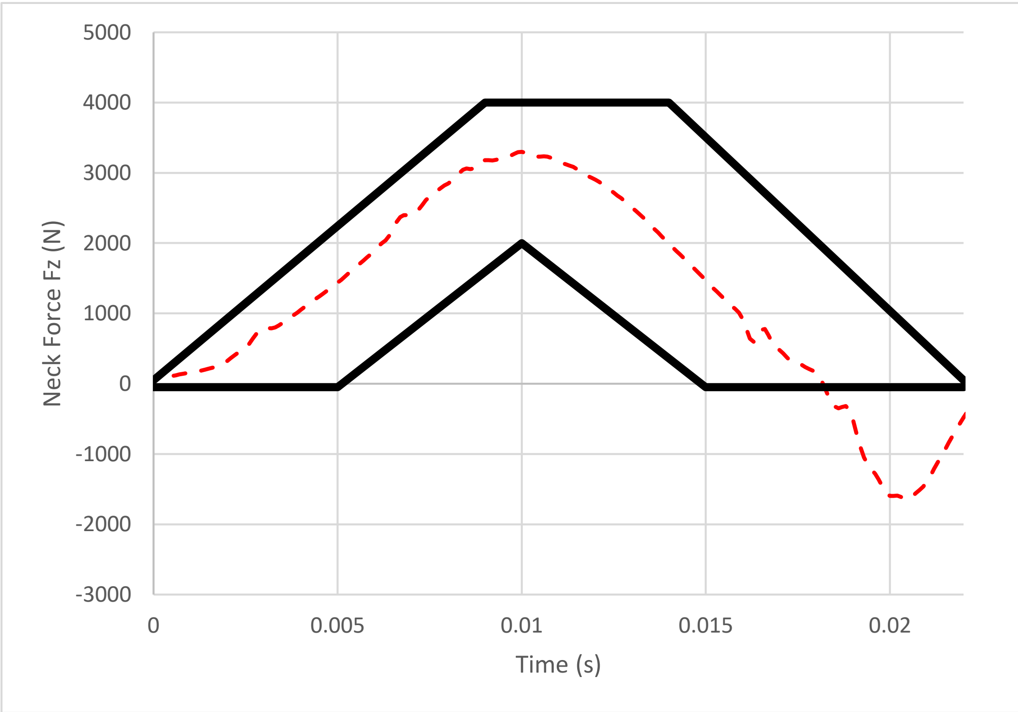

Figure C.2. Neck Compression Force Curve—Test 491534-03-2.

C.3. TEST 491534-03-3—HJC C70

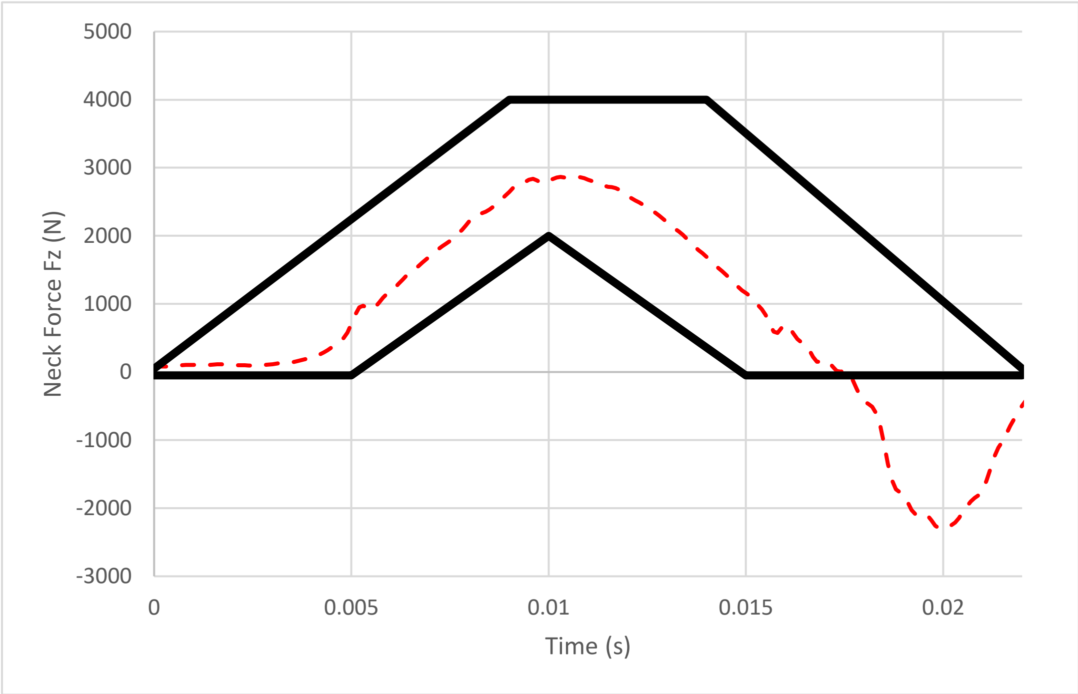

Figure C.3. Neck Compression Force Curve—Test 491534-03-3.

C.4. TEST 491534-03-4—SEDICI STRADA II PRIMO AMERICANA

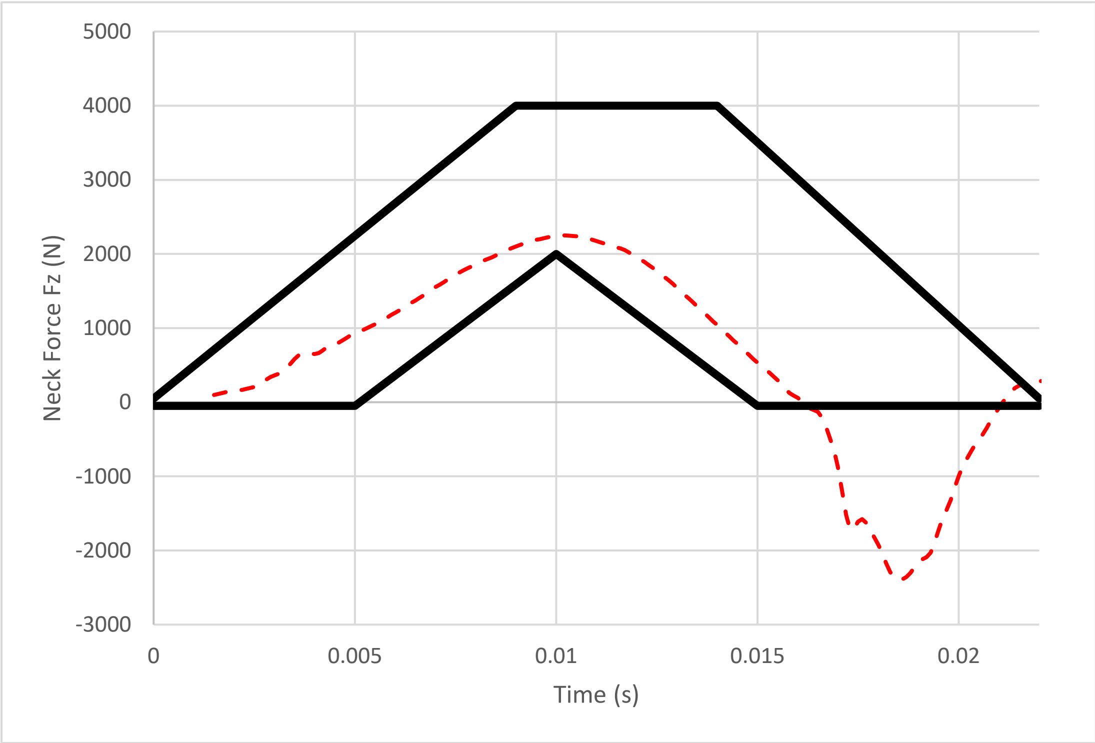

Figure C.4. Neck Compression Force Curve—Test 491534-03-4.

C.5. TEST 491534-03-5—SHOEI RF-SR

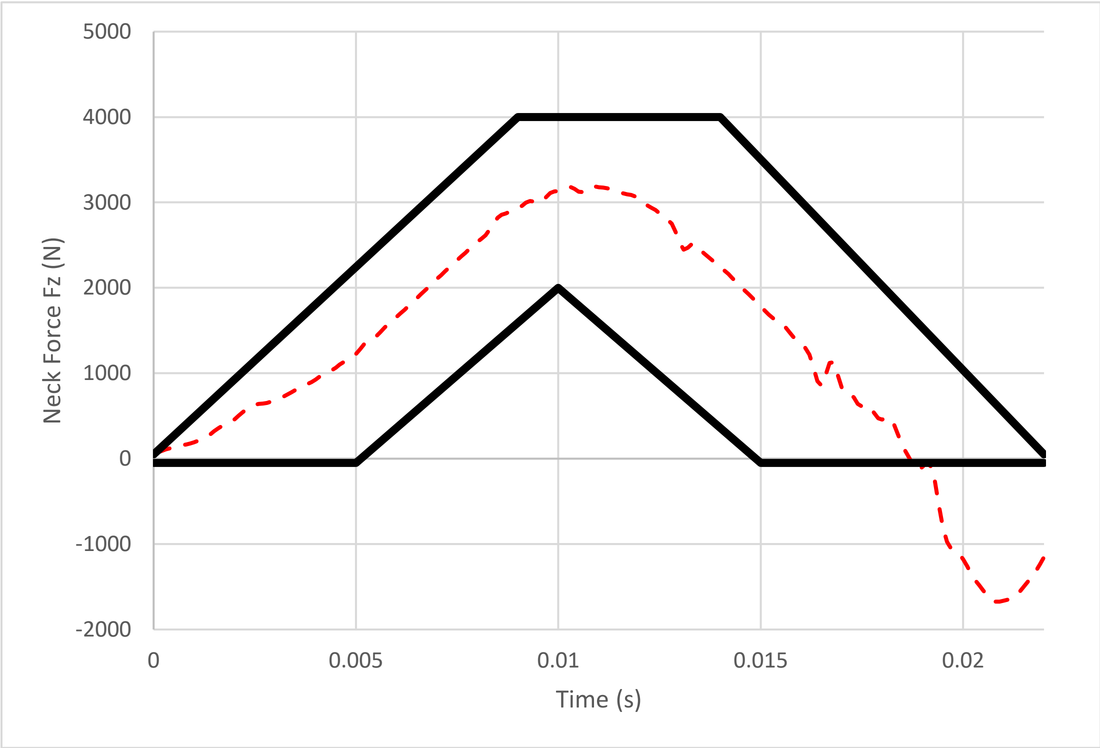

Figure C.5. Neck Compression Force Curve—Test 491534-03-5.

C.6. TEST 491534-03-6—HJC F70

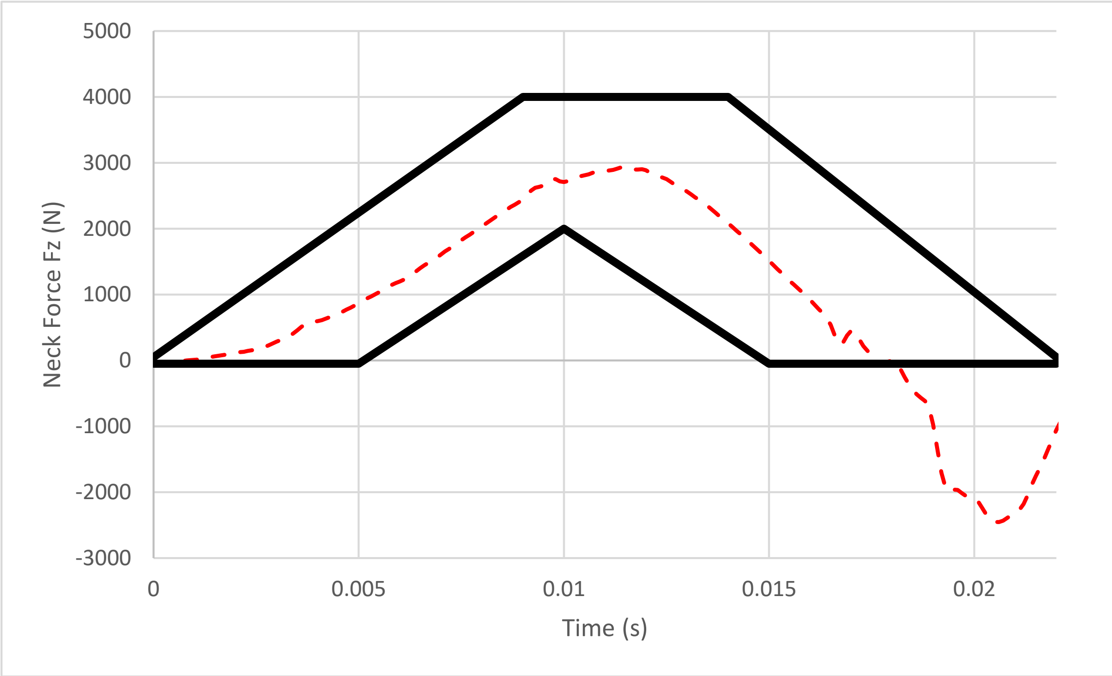

Figure C.6. Neck Compression Force Curve—Test 491534-03-6.

C.7. TEST 491534-03-7—BELL QUALIFIER DLX MIPS (GLOSS)

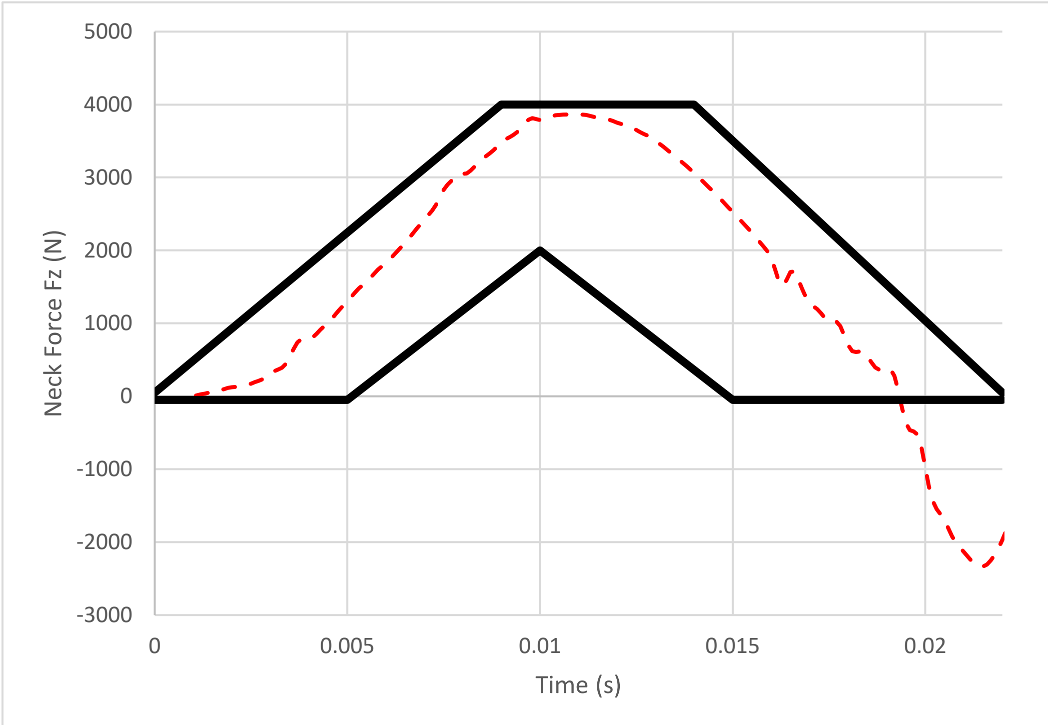

Figure C.7. Neck Compression Force Curve—Test 491534-03-7.

C.8. TEST 491534-03-8—BELL QUALIFIER DLX MIPS (MATTE)

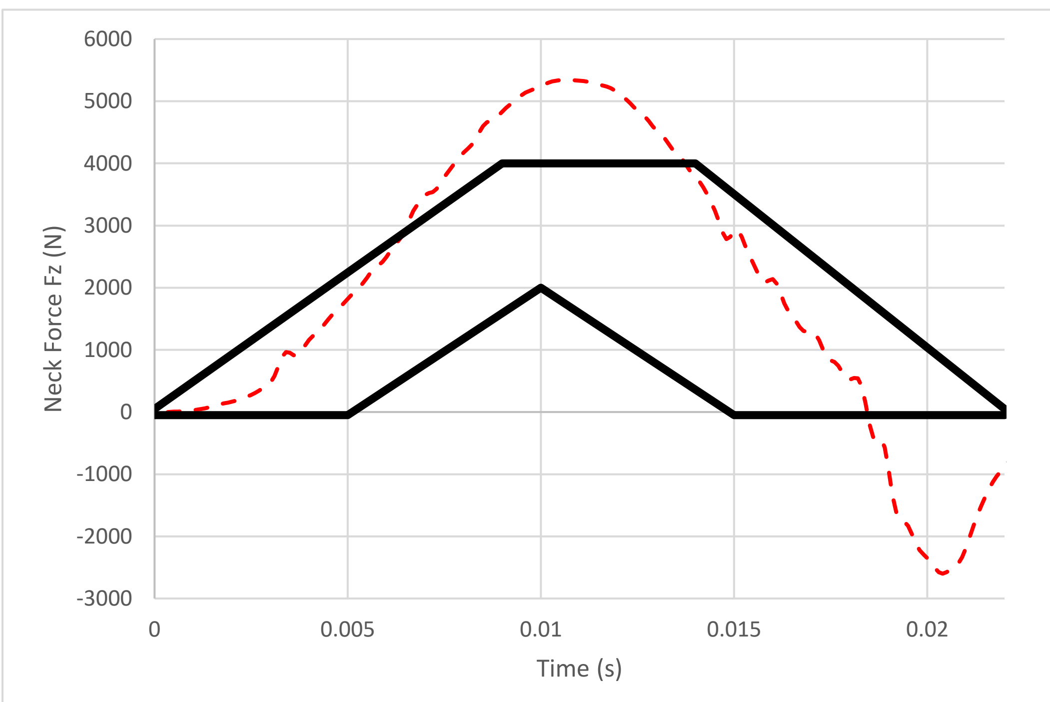

Figure C.8. Neck Compression Force Curve—Test 491534-03-8.

C.9. TEST 491534-03-9—AGV K3

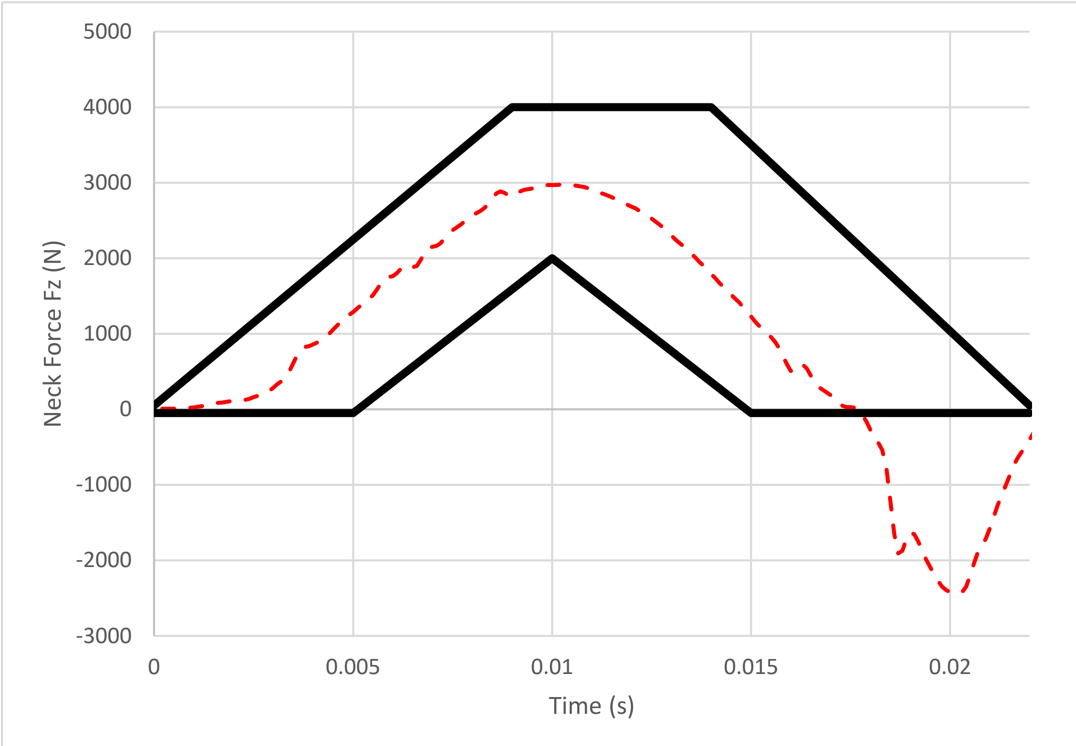

Figure C.9. Neck Compression Force Curve—Test 491534-03-9.

C.10. TEST 491534-03-10—AGV K6 S

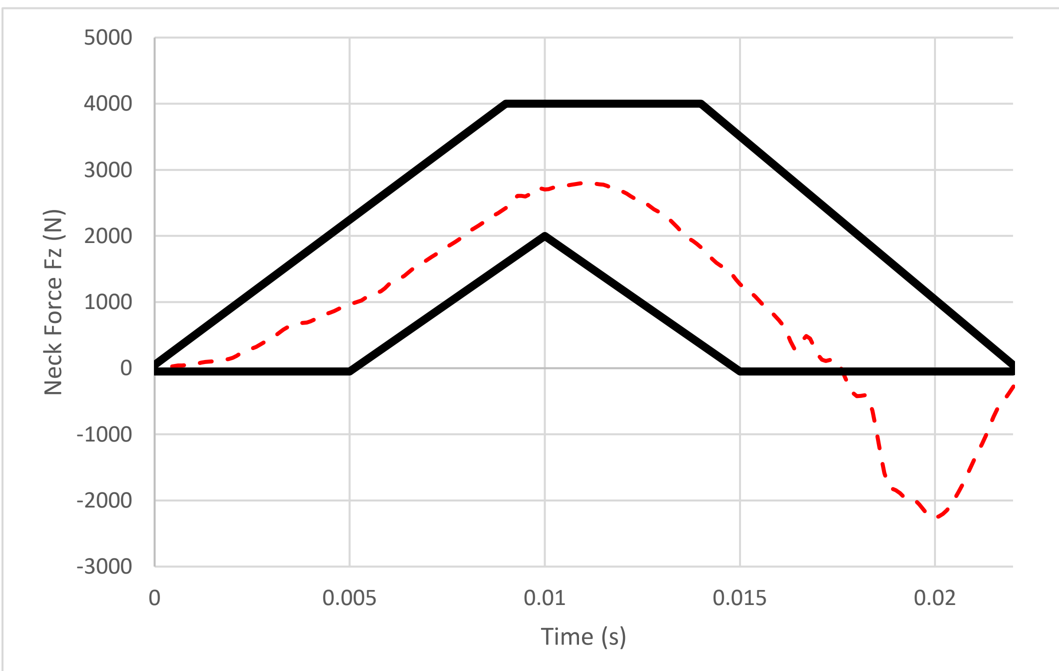

Figure C.10. Neck Compression Force Curve—Test 491534-03-10.

C.11. TEST 491534-03-11—SHOEI X-15

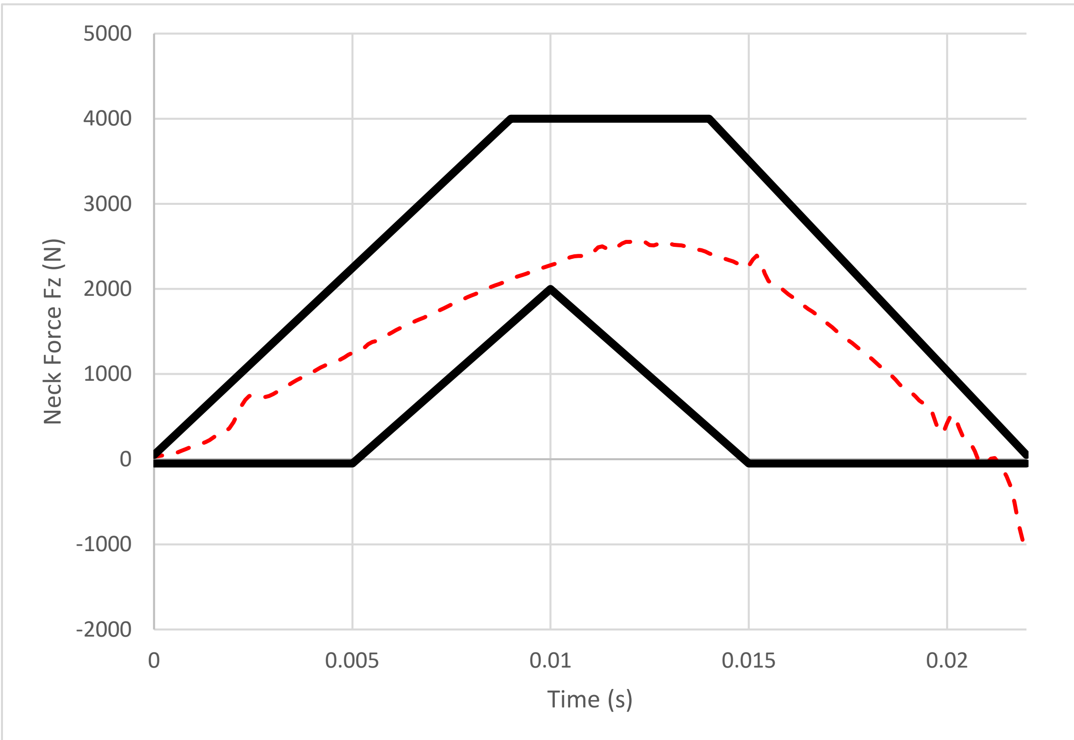

Figure C.11. Neck Compression Force Curve—Test 491534-03-11.

C.12. TEST 491534-03-12—ARAI REGENT X

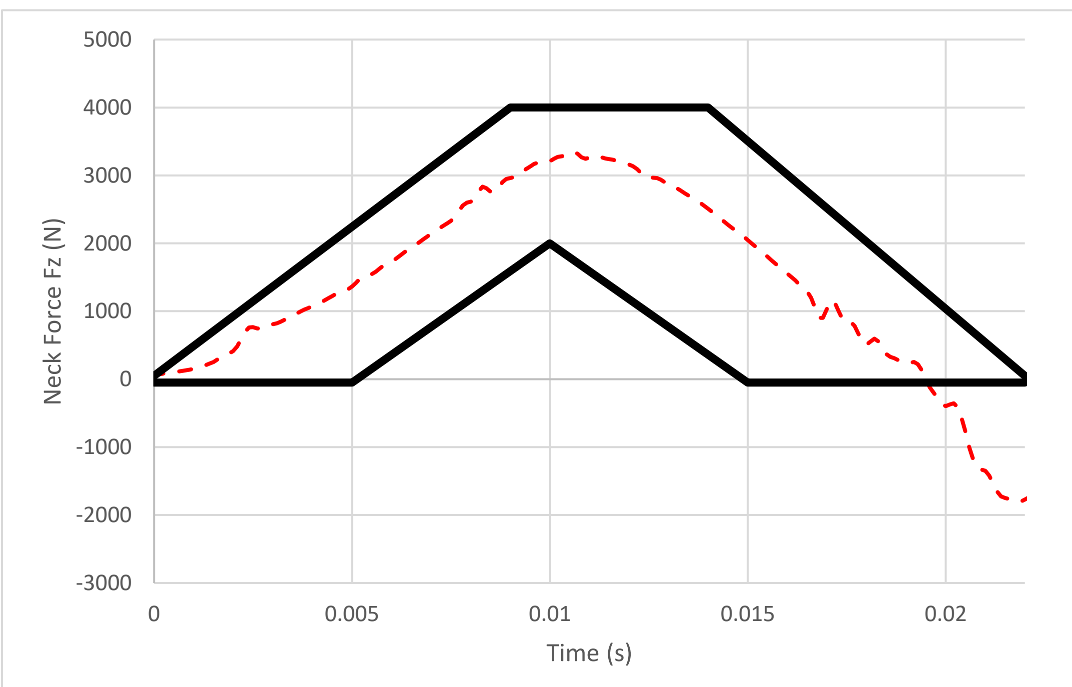

Figure C.12. Neck Compression Force Curve—Test 491534-03-12.

C.13. TEST 491534-03-13—ICON

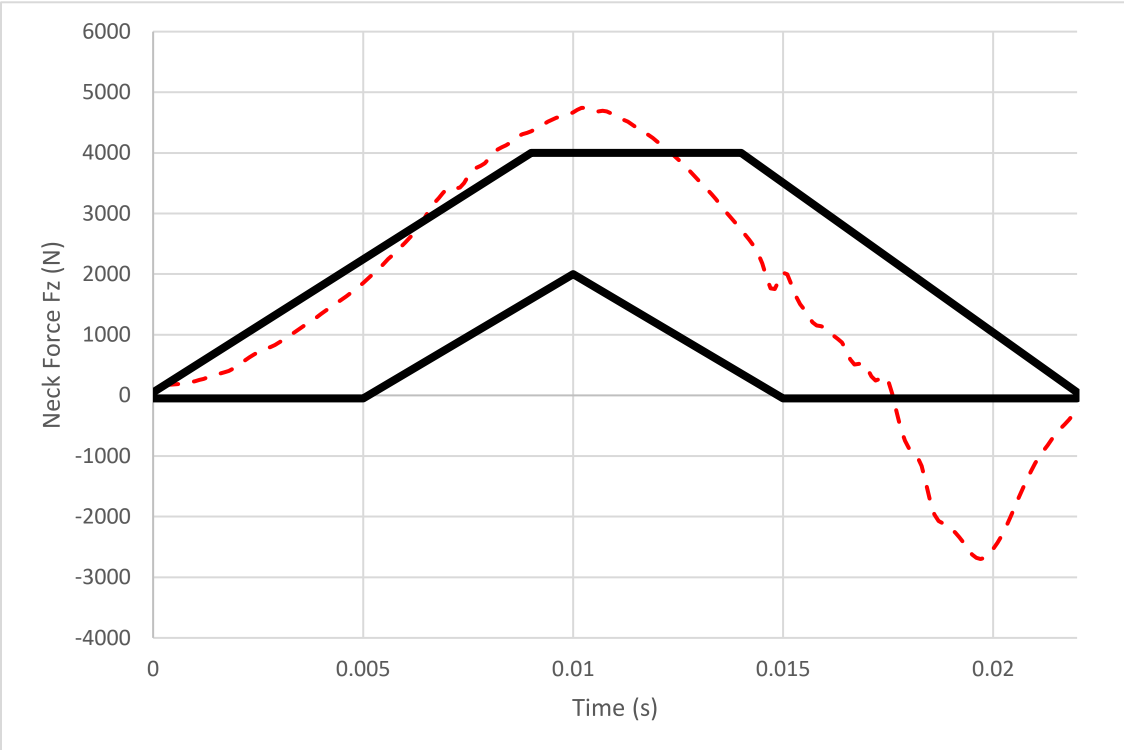

Figure C.13. Neck Compression Force Curve—Test 491534-03-13.