

Report No.611801-03 & -04 WY2401F



Development of Approach Transition from Box Beam Guardrail to Concrete Parapet

Final Report

Principal Investigator: Roger P. Bligh, Ph.D., P.E. Senior Research Engineer Texas A&M Transportation Institute 3135 TAMU College Station, TX 77843 Phone: 979-317-2703 Email: <u>R-Bligh@tti.tamu.edu</u>

Report Date: November 2023

DISCLAIMER Notice

This document is disseminated under the sponsorship of the Wyoming Department of Transportation ("WYDOT") in the interest of information exchange. The contents of this report reflect the views of the authors, who are solely responsible for the facts and accuracy of the data and the opinions, findings, and conclusions presented herein. The content does not necessarily reflect the official views or policies of WYDOT, The Texas A&M University System ("TAMUS"), or the Texas A&M Transportation Institute ("TTI"). This report does not constitute a standard, specification, or regulation. WYDOT, TAMUS, and TTI do not endorse any products or manufacturers. Trademarks or manufacturers' names appear in this report due to a product's use as part of the objective of the document. WYDOT, TTI, and the Proving Ground Laboratory within TTI's Roadside Safety and Physical Security Division ("TTI Lab") do not assume, either jointly or severally, any liability for the use of the information contained in this document. Further, WYDOT, TTI, and TTI Lab will not be liable for any indirect, incidental, consequential, punitive, or other damages however arising, whether WYDOT, TTI, and TTI Lab knew or should have known of the possibility of such damage, loss, or expense including, without limitation, any claim for damage based, or claimed to be based, upon any negligent act, omission, error, correction of error, delay, or breach of an obligation by the TTI Lab.

Quality Assurance Statement

The Wyoming Department of Transportation (WYDOT) provides high-quality information to serve Government, industry and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility and integrity of its information. WYDOT periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

The results reported herein apply only to the article tested. The full-scale crash tests were performed according to TTI Proving Ground Laboratory with TTI's Roadside Safety and Physical Security Division ("TTI Lab") quality procedures and American Association of State Highway and Transportation Officials ("AASHTO") *Manual for Assessing Safety*

Hardware, Second Edition (MASH) guidelines and standards. The TTI Lab strives for accuracy and completeness in its crash test reports. On rare occasions, unintentional or inadvertent clerical errors, technical errors, omissions, oversights, or misunderstandings (collectively referred to as "errors") may occur and may not be identified for corrective action prior to the final report being published and issued. If, and when, the TTI Lab discovers an error in a published and issued final report, the TTI Lab will promptly disclose such error to WYDOT, and both parties will endeavor in good faith to resolve this situation. The TTI Lab will be responsible for correcting the error that occurred in the report, which may be in the form of errata, amendment, replacement



sections, or up to and including full reissuance of the report. The cost of correcting an error in the report shall be borne by the TTI Lab. Any such errors or inadvertent delays that occur in connection with the performance of the related testing contract will not constitute a breach of the testing contract.

Copyright

No copyrighted material, except that which falls under the "fair use" clause, may be incorporated into a report without permission from the copyright owner if the copyright owner requires such. Prior use of the material in a WYDOT or governmental publication does not necessarily constitute permission to use it in a later publication.

• Courtesy — Acknowledgment or credit will be given by footnote, bibliographic reference, or a statement in the text for use of material contributed or assistance provided even when a copyright notice is not applicable.

• Caveat for Unpublished Work —Some material may be protected under common law or equity even though no copyright notice is displayed on the material. Credit will be given and permission will be obtained as appropriate.

• Proprietary Information — To avoid restrictions on the availability of reports, proprietary information will not be included in reports unless it is critical to the understanding of a report and prior approval is received from WYDOT. Reports containing such proprietary information will contain a statement on the Technical Report Documentation Page restricting availability of the report.

Creative Commons:

The report is covered under a Creative Commons, CC-BY-SA license. When drafting an adaptive report or when using information from this report, ensure you adhere to the following:

Attribution — You must give appropriate credit, provide a link to the license and indicate if changes were made. You may do so in any reasonable manner but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform or build upon the material, you must distribute your contributions under the same license as the original.

No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation.

No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy or moral rights may limit how you use the material.

Any use of this publication to train generative artificial intelligence (AI) technologies to generate text is expressly prohibited. The authors, contractor, and WYDOT reserve all rights to license uses of this work for generative AI training and development of machine learning language models.

| | | | Technical Report | Documentation Page |
|--|---|---|---|--|
| 1. Report No. 2 WY2401F 2 | 2. Government Accession | on No. | 3. Recipient's Catalog | No. |
| 4. Title and Subtitle | | | 5. Report Date | |
| Development of Approach Transition from Box Bea | | am Guardrail | December 2023 | 3 |
| to Concrete Paranet | | | 6. Performing Organiza | ation Code |
| | | | | |
| 7. Author(s) | | | 8. Performing Organiza | ation Report No. |
| Roger P. Bligh (#0000-0001-5699-0 | 070X), Nauman | M. Sheikh | TRNo. 611801- | 03 & -04 |
| (#0000-0003-1718-4881) Nathan [|) Schulz (#000 | 0-0002-7527- | | |
| 9419) William I. L. Schroeder (#00 | 00-0002-8497- | 4659) | | |
| 9 Performing Organization Name and Address | 00 0002 0437 | +000) | 10 Work Unit No. (TRA | (19) |
| Toxas A&M Transportation Institute | | d | | |
| | Froming Groun | iu | <u> </u> | 1 |
| 3135 TAMU | | | 11. Contract or Grant N | 0. |
| College Station, Texas 77843-3135 | 5 | | RS04219 | |
| | | | TPF-5(393) | |
| 12. Sponsoring Agency Name and Address | | | 13. Type of Report and | Period Covered |
| Wyoming Department of Transporta | ation | | Technical Repo | rt: |
| 5300 Bishop Blvd | | | Anril 2022 – De | cember 2023 |
| Chavenne, WV 82000 22404 | | | | |
| | | | 14. Sponsonny Agency | Code |
| 15. Supplementary Notes | | | | |
| Project Title: Pooled Fund for the D | evelopment of | Approach Guard | rail Transitions fo | or Box Beam |
| and MGS (Wyoming, Montana) | | | | |
| WYDOT Project Champion Bill Wil | son | | | |
| | | | | |
| | | · · · · | | |
| This research is a step in the Wyon | ning Departmer | it of Transportati | on's ongoing effo | orts to |
| implement the Manual for Assessin | ig Safety Hardw | <i>/are (MASH</i>) to e | nhance roadside | e safety and |
| reduce the severity of run-off-road of | crashes. The ob | pjective of this re | search was to de | evelop a MASH |
| Test Level 3 (TL-3) compliant stiffne | ess transition fr | om box beam ro | adside quardrail t | to concrete |
| parapet or bridge rail. Shape transit | paranet or bridge rail. Shane transitions were developed to transition the vertical concrete profile to | | | ncrete profile to |
| which the bay been transition is att | cohod to a Nov | | n dene profile | |
| | lached to a nev | | e slope profile. | |
| The Concrete Parapet Shape Trans | sition and box b | eam transition to | o concrete parape | et met the |
| performance criteria for MASH TL-3 | 3 transitions. Bo | oth transition syst | tems are conside | ered MASH |
| compliant. | | , | | |
| | | _ | _ | |
| This report provides details on the c | development of | the Concrete Pa | rapet Shape Tra | nsition and box |
| beam approach transition, the crasl | h tests and resu | ults, and the perf | ormance assessr | ment of the |
| transitions for MASH TL-3 evaluation | on criteria. | | | |
| 47. Key Marda | I | | | |
| In Rey Words | | I. DISTRIBUTION Stateme | er i L | |
| Longituginal Barrier, Crash Lest, Bo | | TI-: | a accallable the second | when the extension of |
| | ox Beam, | This document i | s available throu | gh the National |
| Guardrail, Transition, Concrete Par | ox Beam, apet, | This document i Transportation I | s available throu _ibrary and the W | gh the National /yoming State |
| Guardrail, Transition, Concrete Par Roadside Safety, <i>MASH</i> , Wyoming | ox Beam, apet, | This document i Transportation L Library. Copyrig | s available throu _ibrary and the W ht ©2019. All righ | gh the National /yoming State nts reserved, |
| Guardrail, Transition, Concrete Par Roadside Safety, <i>MASH</i> , Wyoming | ox Beam, apet, | This document i Transportation L Library. Copyrig State of Wvomir | s available throu Library and the W ht ©2019. All righ ng. Wyoming Der | gh the National /yoming State nts reserved, partment of |
| Guardrail, Transition, Concrete Par Roadside Safety, <i>MASH</i> , Wyoming | ox Beam, apet, | This document i Transportation L Library. Copyrig State of Wyomin Transportation | s available throu Library and the W ht ©2019. All righ ng, Wyoming Dep and Texas A&M | gh the National /yoming State nts reserved, partment of Transportation |
| Guardrail, Transition, Concrete Par Roadside Safety, <i>MASH</i> , Wyoming | ox Beam, apet, | This document i Transportation L Library. Copyrig State of Wyomir Transportation, | s available throu Library and the W ht ©2019. All righ ng, Wyoming Dep and Texas A&M | gh the National /yoming State nts reserved, partment of Transportation |
| Guardrail, Transition, Concrete Par Roadside Safety, <i>MASH</i> , Wyoming | ox Beam, apet, | This document i Transportation L Library. Copyrig State of Wyomir Transportation, Institute. | s available throu- Library and the W ht ©2019. All righ ng, Wyoming Dep and Texas A&M | gh the National /yoming State hts reserved, partment of Transportation |
| Guardrail, Transition, Concrete Par Roadside Safety, MASH, Wyoming 19. Security Classif. (of this report) 20 | D. Security Classif. (of t | This document i Transportation L Library. Copyrig State of Wyomir Transportation, Institute. | s available throu- Library and the W ht ©2019. All righ ng, Wyoming Dep and Texas A&M 21. No. of Pages | gh the National /yoming State hts reserved, partment of Transportation |

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

| APPROXIMATE CONVERSIONS TO SI UNITS Symbol When You Know Multiply By To Find Symbol in inches 25.4 millimeters mm in inches 25.4 millimeters mm yd yards 0.914 meters m yd square inches 645.2 square millimeters Km ft ² square inches 645.2 square meters m ² qd square feet 0.033 square meters m ² acras outors 2.55 square kilometers km ² qd square miles 2.57 milliters mL qd square miles 2.57 milliters mL qd galons 3.785 liters L L qd outors 2.835 grams g g outors 0.454 kilograms Kg m ³ outors 0.454 newtons N Mg (r | SI* (MODERN METRIC) CONVERSION FACTORS | | | | | |
|---|---|-----------------------------|----------------------|----------------------------------|------------------------|----------------|
| Symbol When You Know Multiply By To Find Symbol in inches 25.4 millimeters mm in inches 25.4 millimeters m yd yards 0.914 meters m mill miles 1.61 kilometers m in ² square inches 645.2 square meters m ² yd ² square miles 0.036 square meters m ² ac acres 0.405 hectares ha m ² square miles 2.59 square kilometers m ³ m ² cubic vards 0.785 cubic meters m ³ m ⁴ cubic yards 0.785 cubic meters m ³ vd ³ cubic yards 0.454 kilograms kg r short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or "T) r FoRCE and PRESURE r STRESS N lb/in ² poundforce | | APPROXIM | ATE CONVERSIO | NS TO SI UNITS | | |
| In inches 25.4 millimeters mm It feet 0.305 meters m It feet 0.305 meters m yards 0.914 meters m mile 1.61 kilometers km in ² square inches 645.2 square meters m ² galare jetet 0.033 square meters m ² ac acres 0.405 hectares ha m ² square miles 2.59 square meters m ² ac acres 0.405 hectares ha gal galons 3.785 liters L n m ² galons 3.785 liters M NOTE: volumes greater than 1000L shalb be shown in m ³ m ³ ounces 28.35 grams g g/g/g/g/g/g/g/g/g/g/g/g/g/g/g/g/g/g/g/ | Symbol | When You Know | Multiply By | To Find | Symbol | |
| in inches 25.4 millimeters mm it feet 0.305 meters m yards 0.914 meters m miles 1.61 kilometers m in² square inches 645.2 square milers m² yd3 square yards 0.33 square meters m² yd4 square yards 0.836 square meters m² yd3 square miles 2.59 square kilometers m² gal galons 3.785 liters L thi fi od ounces 29.57 milliters m L thi gal galons 3.785 liters L thi fi od ounces 29.57 millitiers mL thi gal galons 0.785 cubic meters m³ ounces 20.35 grams g thi gal galons 0.785 kilograms k | - | | LENGTH | · | | |
| ft feet 0.305 meters m yd yards 0.914 meters m miles 1.61 kilometers km in² square inches 645.2 square meters m² in² square feet 0.036 square meters m² ac acres 0.405 hectares ha ac acres 0.405 hectares ha m² square miles 2.57 millitiers mL gal galons 3.785 litters L galons 3.785 litters M m³ vdbic feet 0.028 cubic meters m³ vdf ⁴ cubic yards 0.765 cubic meters m³ galons 0.784 kilograms g g ounces 28.35 grams g g r bounds 0.454 kilograms m³ vdb/m² pounds 0. | in | inches | 25.4 | millimeters | mm | |
| yd yards 0.914 meters m miles 1.61 kilometers km n² square inches 645.2 square meters m² yd² square feet 0.093 square meters m² yd² square miles 0.405 square meters m² acres 0.405 square incles km² m² square miles 2.59 square kilometers km² fil cubic feet 0.028 cubic meters m³ gal galons 0.785 cubic meters m³ yd³ cubic feet 0.028 garams g oucces 28.35 grams g or oucces 28.35 grams g or short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or *1") "F Fahrenheit 5(F-32)/9 Celsius °C °C or (F-32)/1.8 rewtons N blb/n° poundfor | ft | feet | 0.305 | meters | m | |
| mi miles 1.61 kilometers km in ² square inches 645.2 square meters m ² yd ² square yards 0.836 square meters m ² acres 0.405 hectares ha acres 0.405 hectares ha gal galons 3.785 litters L gal galons 3.785 litters L gal galons 3.785 cubic meters m ³ yd ³ cubic yards 0.765 cubic meters m ³ ounces 28.35 grams g gb pounds 0.454 kilograms g or MASS c c c gal pounds 0.454 kilograms g gal pounds 0.454 kilograms N | yd | yards | 0.914 | meters | m | |
| AREAin²square inchesm²ft²square feet0.093square metersm²yd²square yards0.836square metersm²acres0.405hectaresham²square miles2.59square kilometersm²ft3cubic feet0.028cubic metersm³gailgailons3.785littersLft3cubic feet0.028cubic metersm³vd³cubic grads0.765cubic metersm³NOTE: volumes greater than 1000L shall be shown in m³msm302ounces28.35gramsgjbpounds0.454kilogramskgjcounces28.35gramsgjbpounds0.454kilogramskgjcFoRCE and PRESSURE or STRESSlblb/in²poundforce4.45newtonsNlb/in²poundforce4.45metonsNlb/in²poundforce4.45metonsNmmmillimeters0.039inchesinmmmeters3.28feetftmmmeters0.261milesmilmmsquare meters1.195square inchesin²masquare meters0.036square inchesin²ftpoundforce0.244galuaresgaluaremmmillimeters0.03 | mi | miles | 1.61 | kilometers | km | |
| Inf ⁴ square inches 645.2 square meters m ⁴ yd ² square yards 0.836 square meters m ² ac acres 0.405 hectares ha m ² square miles 2.59 square meters m ² floz fluid ounces 29.57 milliliters mL gal galons 3.785 liters L rd ³ cubic feet 0.028 cubic meters m ³ yd ⁴ cubic yards 0.765 cubic meters m ³ ounces 28.35 grams g g rd ounces 28.35 grams g rd sounds 0.454 klograms kg r sounds 0.454 klograms g r sounds 0.454 klograms g r sounds 0.454 klograms m ³ r sounds 0.454 klograms m ⁴ | | | AREA | | 0 | |
| If* Square feet 0.093 Square meters m ⁴ ac actres 0.405 hectares ha ac actres 0.405 hectares ha m ² square miles 2.59 square kilometers km ² fl oz fluid ounces 29.57 millilliters mL gal galons 3.785 liters L ft ³ cubic feet 0.028 cubic meters m ³ yd ³ cubic yards 0.765 cubic meters m ³ voltic feet 0.028 grams g g ounces 28.35 grams g g ounces 28.35 grams g kg g r short ton (2000 lb) 0.454 kilograms (or metric ton") Mg (or "t") r FERESURE or STRESS kilopaccals kPa lb/in ² poundforce per square inch 6.89 kilopascals kPa b/in ² poundforce | in ² | square inches | 645.2 | square millimeters | mm² | |
| yd* square yards 0.836 square meters m* ac acres 0.405 hectares ha ml* square miles 2.59 square kilometers km² fluid ounces 29.57 milliliters mL L gal gailons 3.785 liters L L gal gailons 3.785 liters L L gal gailons 3.785 cubic meters m³ m² yd* cubic feet 0.028 cubic meters m³ m³ ounces 28.35 grams g gl (or "t") T short tons (2000 lb) 0.454 kilograms kg "C or f(F-32)/18 FORCE and PRESSURE or STRESS N gl (or "t") lb/m² poundforce 4.45 newtons N lb/m² poundforce per square inch 6.89 kilopascals kPa Symbol When You Know Multiply By <td< td=""><td></td><td>square feet</td><td>0.093</td><td>square meters</td><td>m²</td></td<> | | square feet | 0.093 | square meters | m² | |
| ac. actues 0.403 inetuites ina mife square miles 2.59 square kilometers km² iloz galons 3.785 liters L gal galons 0.765 cubic meters m³ yd* cubic yards 0.765 cubic meters kg gal pounds 0.454 kilograms kg T short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or "t") "F Fahrenheit 5(F:32)/9 celsius cC C or (F:32)/1.8 rewtons N kilopascals kPa bifin ² poundforce 4.45 newtons N bifin ² poundforce at the stand ton the stan | yd- | square yards | 0.836 | square meters | m² bo | |
| Init Sequence milling Local fl oz fluid ounces 29,57 milliliters mL fl a gallons 3,785 liters L fl a cubic feet 0,028 cubic meters m³ yd³ cubic feet 0,028 cubic meters m³ NOTE: volumes greater than 1000L shall be shown in m³ 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") T TEMPERATURE (exact degrees) *C *C or (F-32/1.8 *C FORCE and PRESSURE or STRESS N bf poundforce per square inch 6.49 kilopascals kPa Symbol When You Know Multiply By To Find Symbol Mm millimeters 0.039 inches in m meters 1.09 yards yd mm square meters 1.0764 square inches in² mm millimeters 0.386 square square mi² square meters 1.195 square fielet ft² | ac mi ² | square miles | 2 50 | square kilometers | lia km ² | |
| fl oz fluid ounces 29.57 milliliters mL gal galons 3.785 liters L vd ³ cubic feet 0.028 cubic meters m ³ NOTE: volumes greater than 100L shall be shown in m ³ NOTE: volumes greater than 100L 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 Celsius °C FORCE and PRESSURE or STRESS lb poundforce per square inch 6.89 kilopascals kPa klomators kilometers 0.039 inches in meters 3.28 feet ft meters 0.621 miles mi klometers 0.621 miles mi meters 0.621 miles mi mk kilometers 0.621 miles mi mk kilometers 0.621 miles mi m ² square meters 1.195 square feet ft ² m ² square meters 1.195 square feet ft ² m ² square meters 1.195 square feet ft ² m ³ square meters 0.386 square inches in ² m ³ square meters 0.386 square inches m ² klometers 0.336 square feet ft ³ m ³ square meters 0.336 square inches m ³ m ³ square meters 0.336 square inches m ³ klometers 0.336 square inches m ³ m ³ square meters 0.336 square inches m ³ m ³ square meters 0.336 square inches m ³ % square meters 0.336 square miles m ³ % % % % % % % % % % % % % % % % % % % | 1111 | square miles | | square kilometers | NIII | |
| gal gallons 3,785 liters L ft ³ cubic feet 0,028 cubic meters m ³ NOTE: volumes greater than 1000L shall be shown in m ³ MASS oz ounces 28.35 grams g Job pounds 0.454 kilograms kg TEMPERATURE (exact degrees) °C or ("F-32)/1.8 Fahrenheit S(F-32)/9 Celsius °C or ("F-32)/1.8 FORCE and PRESSURE or STRESS Ibf poundforce per square inch 6.89 kitopascals kPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol Maters Maters newtons N m Meters 0.021 meters 0.021 meters 0.021 meters 0.021 meters 0.221 milimeters <td>fl oz</td> <td>fluid ounces</td> <td>29.57</td> <td>milliliters</td> <td>ml</td> | fl oz | fluid ounces | 29.57 | milliliters | ml | |
| Hat Cubic feet 0.028 Cubic meters m³ yd ^a Cubic yards 0.765 Cubic meters m³ NOTE: volumes greater than 1000. shall be shown in m³ MASS g oz ounces 28.35 grams g T short tons (2000 lb) 0.454 kilograms kg "F Fahrenheit 5(F.32)/9 Celsius °C or (F.32)/1.8 °C °C bf poundforce per square inch 6.89 kilopascals N bf/in ² poundforce per square inch 6.89 kilopascals N bf/in ² poundforce per square inch 6.89 kilopascals KPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol mm meters 3.28 feet ft mm square meters 0.621 miles mi maters 0.264 square feet ft ² dare | dal | gallons | 3 785 | liters | 1 | |
| yd³cubic yards0.765cubic metersm³MASSOZOUNCES: volumes greater than 1000L shall be shown in m³MASSozOUNCES: volumes greater than 1000L shall be shown in m³OZOUNCESSTEMPERATURE (exact degrees)"CF FahrenheitS(F-32)/1.8FORCE and PRESSURE or STRESSIbpoundforce4.45newtonsNPORCE and PRESSURE or STRESSIbpoundforce per square inch6.89klippascalskPa ORCE and PRESSURE or STRESS Ibpoundforce per square inch6.89klippascalsNSymbolWhen You KnowMultiply ByTo FindSymbolSymbolLEING KETMmeters3.28feetftmAREAmmadare meters1.09yardsyd2mmAREAmm²square meters1.09yare within "10m² <td colspan<="" td=""><td>ft³</td><td>cubic feet</td><td>0.028</td><td>cubic meters</td><td>m³</td></td> | <td>ft³</td> <td>cubic feet</td> <td>0.028</td> <td>cubic meters</td> <td>m³</td> | ft ³ | cubic feet | 0.028 | cubic meters | m ³ |
| NOTE: volumes greater than 1000L shall be shown in m³ MASS or Start tons (2000 lb) TEMPERATURE (exact degrees) "F Fahrenheit Start tons (2000 lb) TEMPERATURE (exact degrees) "C Celsius "C OPCCE and PRESSURE or STRESS Ibf poundforce 4.45 newtons N Ibf poundforce per square inch 6.89 kilopascals N APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol mm meters 0.039 inches in mm meters 0.039 inches in mm meters 0.039 inches in mm millimeters 0.039 inches in mm millimeters 0.039 inches in mm | vd ³ | cubic vards | 0.765 | cubic meters | m ³ | |
| oz ounces 28.35 grams g ib pounds 0.454 kilograms kg T short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or "t") TEMPERATURE (exact degrees) ** Fahrenheit 5(F-32)/9 Celsius °C or (F-32)/1.8 ** FORCE and PRESSURE or STRESS Ib/ poundforce 4.45 newtons N Ib/ poundforce per square inch 6.89 kilopascals KPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol mm LENGTH mm millimeters 0.039 inches in m meters 1.09 yards yd km kilometers 0.621 miles mile m ² square meters 1.0764 square feet ft ² m ² square meters 1.195 square mile mi ² m ² square meters 0.336 square miles mi ² m ³ | 5 | NOTE: volume | s greater than 1000L | shall be shown in m ³ | | |
| oz ounces 28.35 grams g b pounds 0.454 kilograms kg T short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or "t") "F Fahrenheit 5(F-32)/9 Celsius °C or (F-32)/1.8 FORCE and PRESSURE or STRESS N Ib/in? poundforce 4.45 newtons N Ib/in? poundforce per square inch 6.89 kilopascals KPa Symbol When You Know Multiply By To Find Symbol Meters 0.039 inches in mm meters 3.28 feet ft mm? square meters 0.021 miles mi mm2 square meters 10.764 square feet ft² m2 square meters 0.386 square miles mi² m3 cubic meters 0.344 fuid ounces oz kg grams 0.034 fuid ounces oz m4 square meters 1.195 square feet ft² m4 square meters 1.307 cubic feet ft³ m4 hectares 2.47< | | | MASS | | | |
| b pounds 0.454 kilograms kg T short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or "t") "F Fahrenheit 5(F-32)/9 or (F-32)/1.8 Celsius °C FORCE and PRESSURE or STRESS lbf poundforce per square inch 6.89 kilopascals kPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol m ELENGTH mm meters 3.28 feet ft m meters 0.029 inches in m ² square meters 1.09 yards yd m ² square meters 0.021 miles mi m ² square meters 1.195 square feet ft ² m ² square meters 1.307 acres acc m ³ cubic meters 0.334 fluid ounces oz M ³ cubic meters | oz | ounces | 28.35 | grams | g | |
| T short tons (2000 lb) 0.907 megagrams (or metric ton") Mg (or "t") TEMPERATURE (exact degrees) °F Fahrenheit 5(F-32)/9 Celsius °C °C FORCE and PRESSURE or STRESS Ibf poundforce 4.45 newtons N APPROXIMATE CONVERSIONS Symbol When You Know Multiply By To Find Symbol Symbol When You Know Multiply By To Find Symbol m Celsius °C mm milies in m celsius °C meters 0.039 inches in mm milies mi mm² square milimeters 0.039 inches in² mm² square meters 1.09 yards mm² square meters 1.0764 square square meters mm² square meters 1.195 square meters | lb | pounds | 0.454 | kilograms | kg | |
| TEMPERATURE (exact degrees)°FFahrenheit $5(F-32)/1.8$ °CFORCE and PRESSURE or STRESSlbfpoundforce4.45newtonsNhyperbolic per square inch6.89kilopascalskPaAPPROXIMATE CONVERSIONS FROM SI UNITSSymbolWhen You KnowMultiply ByTo FindSymbolmmmillimeters0.039inchesinmmeters1.09yardsydmmeters0.621milesmimm2square meters1.09yardsydsquare meters0.0016square feetft²m2square meters1.195square feetft²m2square meters1.195square feetft²m2square meters1.307cubic feetft³m3cubic meters0.034fluid ouncesozMASSggrams0.035ouncesozggrams0.035ouncesozkgkilograms2.202poundslbm3cubic meters1.307cubic feetft³m3cubic meters1.307cubic feetft³m3cubic meters1.307cubic feetft³m4millitlers0.035ouncesozggrams0.035ouncesozggrams0.035ouncesoz <th< td=""><td>Т</td><td>short tons (2000 lb)</td><td>0.907</td><td>megagrams (or metric ton")</td><td>Mg (or "t")</td></th<> | Т | short tons (2000 lb) | 0.907 | megagrams (or metric ton") | Mg (or "t") | |
| °F Fahrenheit 5(F-32)/9 Celsius °C or (F-32)/1.8 FORCE and PRESSURE or STRESS lbf poundforce per square inch 6.89 kilopascals kPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol Symbol When You Know Multiply By To Find Symbol meters 0.039 inches in m meters 3.28 feet ft m meters 0.621 miles mil mm² square millimeters 0.6016 square inches in² m² square meters 10.764 square feet ft² m² square kilometers 0.386 square miles mi² km² square kilometers 0.386 square miles mi² m² square kilometers 0.386 square miles mi² m² square meters 1.195 square miles mi² m³ cubic meters | | TEM | PERATURE (exac | t degrees) | | |
| FORCE and PRESSURE or STRESS Ibf poundforce per square inch 6.89 kilopascals N Ibf in 2 PORCE and PRESSURE or STRESS Ibf in 2 N APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol Symbol When You Know Multiply By To Find Symbol Imm Multiply By To Find Symbol meters 0.039 inches in meters 0.621 miles mi MEREA mm AREA mm ² square meters 0.0016 square inches in ² milimeters 0.0016 square meters 10.764 square meters milimeters 0.264 <th col<="" td=""><td>°F</td><td>Fahrenheit</td><td>5(F-32)/9</td><td>Celsius</td><td>°C</td></th> | <td>°F</td> <td>Fahrenheit</td> <td>5(F-32)/9</td> <td>Celsius</td> <td>°C</td> | °F | Fahrenheit | 5(F-32)/9 | Celsius | °C |
| FORCE and PRESSURE or STRESS Ibf poundforce per square inch 6.89 kilopascals N APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol Symbol When You Know Multiply By To Find Symbol mm millimeters 0.039 inches in m meters 3.28 feet ft m meters 0.621 miles miles mm ² square millimeters 0.0016 square inches in ² m ² square meters 1.0764 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 mL milliliters 0.034 fluid ounces oz ubit 0.264 gallons gall g grams 0.035 ounces oz g | | | or (F-32)/1.8 | | | |
| Ibf poundforce 4.45 newtons N Ibf/in² poundforce per square inch 6.89 kilopascals kPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol mm millimeters 0.039 inches in m meters 3.28 feet ft m meters 0.621 miles mil mm² square millimeters 0.0016 square inches in² m² square meters 1.09 yards yd² na AREA mil mil mil m² square meters 1.195 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² mL milliliters 0.034 fluid ounces oz L iters 0.264 gallons gall m³ cubic meters 1.307 cubic yards yd³ g grams 0.035 ounces oz kil | | FORCI | E and PRESSURE | or STRESS | | |
| Ibi/in* poundforce per square inch 6.89 kilopascals kPa APPROXIMATE CONVERSIONS FROM SI UNITS Symbol When You Know Multiply By To Find Symbol mm millimeters 0.039 inches in m meters 3.28 feet ft m meters 1.09 yards yd km kilometers 0.621 miles mil m ² square millimeters 0.0016 square inches in ² m ² square meters 1.0764 square feet ft ² m ² square meters 1.195 square miles mi ² Mathematics 0.386 square miles mi ² Mathematics 0.386 square miles mi ² ML milliliters 0.034 fluid ounces oz L liters 0.264 gallons gal m ³ cubic meters 1.307 cubic feet ft ³ m ³ cubic meters 1.307 cubic feet ft ³ m ⁴ square miles ubic yards yd ³ Mg (or "t") megagrams (or "metric ton") 1.103 short tons (2000lb) </td <td>lbf</td> <td>poundforce</td> <td>4.45</td> <td>newtons</td> <td>N</td> | lbf | poundforce | 4.45 | newtons | N | |
| Symbol When You Know Multiply By To Find Symbol mm millimeters 0.039 inches in m meters 3.28 feet ft m meters 1.09 yards yd km kilometers 0.621 miles mi mm² square meters 10.764 square inches in² m² square meters 1.195 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² m4m² Square kilometers 0.344 fluid ounces oz km² square stillimeters 0.035 ounces oz ma hectares 1.307 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ g grams 0.035 <tdo< td=""><td>Ibt/in²</td><td>poundforce per square inch</td><td>6.89</td><td></td><td>kPa</td></tdo<> | Ibt/in ² | poundforce per square inch | 6.89 | | kPa | |
| Symbol When You know Multiply By To Find Symbol mm millimeters 0.039 inches in m meters 3.28 feet ft m meters 3.28 feet ft m meters 1.09 yards yd km kilometers 0.621 miles mi mm² square meters 10.764 square inches in² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² mL milliliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 1.307 cubic feet ft³ m³ cubic meters 2.202 pounds lb Mg (or "t") megagrams (or "metric tor") 1.103 short to | O and al | | TE CONVERSION | | | |
| LENGTHmmmillimeters0.039inchesinmmeters3.28feetftmmeters1.09yardsydkmkilometers0.621milesmilAREAmm²square millimeters0.0016square feetft²m²square meters10.764square feetft²m²square meters1.195square yardsyd²hahectares2.47acresackm²Square kilometers0.386square milesmi²VOLUMEmLmilliliters0.034fluid ouncesozLliters0.264gallonsgalm³cubic meters1.307cubic feetft³m³cubic meters1.307cubic yardsyd³ggrams0.035ouncesozkgkilograms2.202poundslbMg (or "t")megagrams (or "metric ton")1.103short tons (2000lb)TTEMPERATURE (exact degrees)°CCelsius1.8C+32Fahrenheit°FFORCE and PRESSURE or STRESSNnewtons0.225poundforce per square inchlb/in² | Symbol | When You Know | | TOFING | Symbol | |
| Infinit Infiniteers 0.039 Infiles Infiles m meters 3.28 feet ft m meters 1.09 yards yd km kilometers 0.621 miles mi mm² square millimeters 0.621 miles mi m² square meters 10.764 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² VOLUME mi² volumes mi² mL nilliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 1.307 cubic yards yd³ m³ cubic meters 1.307 cubic yards yd³ g grams 0.035 ounces oz klograms 2.202 pounds lb Mg (or "t") megagrams (or "metric ton") 1.103 short tons (2000lb) T TEMPERATURE (exact degrees) °C | | millimatoro | | inches | in | |
| Interest 3.20 react rt m meters 1.09 yards yd km kilometers 0.621 miles mi mm² square millimeters 0.0016 square inches in² m² square meters 10.764 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² VOLUME VOLUME mi mi² mL milliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ MASS g grams 0.035 ounces oz g grams 0.035 ounces oz pal MASS 2.202 pounds lb psort tos psort tos | m | meters | 0.039 | feet | 111 ft | |
| Initial models 1.00 models yards yards km kilometers 0.621 miles mi mm² square millimeters 0.0016 square inches in² m² square meters 10.764 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² VOLUME m mi² gal mi² mL milliliters 0.024 fluid ounces oz oz L liters 0.264 gallons gal m³ m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ MASS g grams 0.035 ounces oz g grams 0.035 ounces oz oz Mg (or "t") megagrams (or "metric ton") 1.103 short tons (2000lb) T FORCE and PRESSURE or STRESS N newtons 0.225 </td <td>m</td> <td>meters</td> <td>1.00</td> <td>varde</td> <td>vd</td> | m | meters | 1.00 | varde | vd | |
| mm AREA mm mm² square millimeters 0.0016 square inches in² m² square meters 10.764 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² VOLUME VOLUME milliliters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ 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 per square inch lbf N < | km | kilometers | 0.621 | miles | mi | |
| mm² square millimeters 0.016 square inches in² m² square meters 10.764 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² ML milliliters 0.386 square miles oz L liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ MASS g grams 0.035 ounces oz g grams 0.035 ounces oz b 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 per square inch b/in² </td <td></td> <td></td> <td>AREA</td> <td></td> <td></td> | | | AREA | | | |
| m² square meters 10.764 square feet ft² m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² ML milliliters 0.386 square miles mi² VOLUME mi² VOLUME oz ml liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ 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 FORCE and PRESSURE or STRESS N newtons 0.225 poundforce lbf N newtons 0.225 poundforce lbf | mm ² | square millimeters | 0.0016 | square inches | in ² | |
| m² square meters 1.195 square yards yd² ha hectares 2.47 acres ac km² Square kilometers 0.386 square miles mi² mL milliliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ MASS g grams 0.035 ounces oz g grams 0.035 ounces oz z 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 klopascals 0.145 poundforce per square inch lbf/in² | m ² | square meters | 10.764 | square feet | ft 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 per square inch lb/in ² | m ² | square meters | 1.195 | square yards | yd ² | |
| km² Square kilometers 0.386 square miles mi² mL milliliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ MASS g grams 0.035 ounces oz kg kilograms 2.202 pounds lb b 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lbf/in² | ha | hectares | 2.47 | acres | ac | |
| VOLUME mL milliliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lb/in² | km ² | Square kilometers | 0.386 | square miles | mi ² | |
| mL milliliters 0.034 fluid ounces oz L liters 0.264 gallons gal m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ MASS g grams 0.035 ounces oz g grams 0.035 ounces oz bb 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lb/in² | | | VOLUME | | | |
| 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 0z 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 per square inch lb/in ² | mL | milliliters | 0.034 | fluid ounces | OZ | |
| m³ cubic meters 35.314 cubic feet ft³ m³ cubic meters 1.307 cubic yards yd³ 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lbf/in² | L | liters | 0.264 | gallons | gal | |
| m³ cubic meters 1.307 cubic yards yd³ MASS MASS 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lb/in² | m ³ | cubic meters | 35.314 | cubic feet | ft ³ | |
| minos minos 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lb/in ² | m | cubic meters | 1.307 | cubic yards | yas | |
| g grams 0.035 ounces 02 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lb/in ² | | aromo | IVIA55 | 0,0000 | 07 | |
| Ng (or "t") Newtons 2.202 pounds ID 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 per square inch lbf kPa kilopascals 0.145 poundforce per square inch lb/in ² | y ka | yiallis kilograms | 0.030 | nounds | UZ Ih | |
| TEMPERATURE (exact degrees) °C Celsius 1.8C+32 Fahrenheit °F FORCE and PRESSURE or STRESS N newtons 0.225 poundforce per square inch Ibf kPa kilopascals 0.145 poundforce per square inch Ibf | Ma (or "t") | megagrams (or "metric top") | ∠.∠∪∠ 1 103 | short tons (2000lb) | Т | |
| °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 | | TFM | PERATURE (exac | t degrees) | | |
| FORCE and PRESSURE or STRESS N newtons 0.225 poundforce lbf kPa kilopascals 0.145 poundforce per square inch lb/in ² | °C | Celsius | 1 8C+32 | Fahrenheit | °F | |
| N newtons 0.225 poundforce per square inch Ibf | U | FORCI | F and PRESSURE | or STRESS | | |
| kPa kilopascals 0.145 poundforce per square inch Ib/in ² | N | newtons | | poundforce | lhf | |
| | kPa | kilonascals | 0.225 | poundforce per square inch | lb/in ² | |

*SI is the symbol for the International System of Units

REPORT AUTHORIZATION

REPORT REVIEWED BY:

Glen Schoeler

Glenn Schroeder, Research Specialist Drafting & Reporting

adan Mayer

Adam Mayer, Research Specialist Construction

Robert Kocman, Research Specialist Mechanical Instrumentation

eevesen

Ken Reeves, Research Specialist Electronics Instrumentation

Richard Badillo, Research Specialist Photographic Instrumentation

William J. L. Schroeder, Research Engineering Associate Research Evaluation and Reporting

Bill L. Griffith, Research Specialist Quality Manager

Matthew N. Robinson, Research Specialist Test Facility Manager & Technical Manager

Roger P. Bligh, P.E. Senior Research Engineer

TABLE OF CONTENTS

| | | Page |
|---------------|---|-----------------------|
| Chapter 1. | Introduction | 1 |
| 1.1. | Background | 1 |
| 1.2. | Objective | 1 |
| 1.3. | Work Plan | 1 |
| Chapter 2. | Concrete Parapet Shape Transition Design | 3 |
| 2.1. | Introduction | 3 |
| 2.2. | Vertical to Single Slope Transition | 3 |
| 2.2.1. | Pickup Truck Impact Simulations (MASH Test 3-21) | 4 |
| 2.2.2. | Passenger Sedan Impact Simulations (MASH Test 3-20) | 6 |
| 2.3. | Vertical to New Jersey Safety Shape Transition | 7 |
| 2.3.1. | Pickup Truck Impact Simulations (MASH Test 3-21) | 8 |
| 2.3.2. | Small Sedan Impact Simulations (MASH Test 3-20) | 9 |
| 2.4. | CRASH TESTING RECOMMENDATIONS | 10 |
| 2.4.1. | MASH Test 3-21 | 10 |
| 2.4.2. | MASH Test 3-20 | 11 |
| Chapter 3. | Box Beam Transition to Concrete Parapet DEsign | 12 |
| 3.1. | Introduction | 12 |
| 3.2. | Design Modifications | 13 |
| 3.2.1. | Anchor Bolts | 14 |
| 3.2.2. | Additional W6x9 Steel Posts | 15 |
| 3.2.3. | HSS4x3 Rubrail | 16 |
| 3.3. | Final Evaluation and CIP Determination | 17 |
| 3.4. | Upstream Transition Evaluation | 18 |
| 3.5. | Summarv | 25 |
| Chapter 4. | Test Requirements and Evaluation Criteria | 26 |
| 4.1. | Crash Test Matrix | 26 |
| 4.2. | Evaluation Criteria | |
| Chapter 5. | Test Conditions | 30 |
| 5.1. | Test Facility. | 30 |
| 5.2 | Vehicle Tow and Guidance System | |
| 5.3. | Data Acquisition Systems | |
| 531 | Vehicle Instrumentation and Data Processing | 30 |
| 5.3.2 | Anthropomorphic Dummy Instrumentation | |
| 5.3.3. | Photographic Instrumentation Data Processing | |
| Chapter 6. | Crash Testing of Concrete Parapet Shape Transition | |
| 6 1 | Concrete Parapet Shape Transition Details | |
| 611 | Test Article and Installation Details | 34 |
| 612 | Design Modifications during Tests | |
| 613 | Material Specifications | |
| 6.2 | MASH Test 3-20 (Crash Test No. 611801-03-1) | 00 40 |
| 6.2. 6.2.1 | Test Designation and Actual Impact Conditions | 07 10 |
| 0.2.1. 622 | Weather Conditions | 4 0 //2 |
| 623 | Test Vehicle | <u>42</u> 12 |
| 0.2.0. | | ····· ¬∠ |

| 6.2.4. | Test Description | 43 |
|------------|--|-----|
| 6.2.5. | Damage to Test Installation | 44 |
| 6.2.6. | Damage to Test Vehicle | 45 |
| 6.2.7. | Occupant Risk Factors | 48 |
| 6.2.8. | Test Summary | 49 |
| 6.3. | MASH Test 3-21 (Crash Test No. 611801-03-2) | 51 |
| 6.3.1. | Test Designation and Actual Impact Conditions | 51 |
| 6.3.2. | Weather Conditions | 53 |
| 6.3.3. | Test Vehicle | 53 |
| 6.3.4. | Test Description | 54 |
| 6.3.5. | Damage to Test Installation | 55 |
| 6.3.6. | Damage to Test Vehicle | 56 |
| 6.3.7. | Occupant Risk Factors | 59 |
| 6.3.8. | Test Summary | 60 |
| Chapter 7. | Crash Testing of Box Beam Guardrail Transition to Concrete | |
| | Parapet | 62 |
| 7.1. | Concrete Parapet Shape Transition Details | 62 |
| 7.1.1. | Test Article and Installation Details | 62 |
| 7.1.2. | Design Modifications during Tests | 62 |
| 7.1.3. | Material Specifications | 66 |
| 7.1.4. | Soil Conditions | 66 |
| 7.2. | MASH Test 3-20 (Crash Test 611801-04-1) | 67 |
| 7.2.1. | Test Designation and Actual Impact Conditions | 67 |
| 7.2.2. | Weather Conditions | 69 |
| 7.2.3. | Test Vehicle | 69 |
| 7.2.4. | Test Description | 71 |
| 7.2.5. | Damage to Test Installation | 71 |
| 7.2.6. | Damage to Test Vehicle | 73 |
| 7.2.7. | Occupant Risk Factors | 76 |
| 7.2.8. | Test Summary | 76 |
| 7.3. | MASH Test 3-21 (Crash Test 611801-04-2) | 79 |
| 7.3.1. | Test Designation and Actual Impact Conditions | 79 |
| 7.3.2. | Weather Conditions | 81 |
| 7.3.3. | Test Vehicle | 81 |
| 7.3.4. | Test Description | 83 |
| 7.3.5. | Damage to Test Installation | 83 |
| 7.3.6. | Damage to Test Vehicle | 85 |
| 7.3.7. | Occupant Risk Factors | 88 |
| 7.3.8. | Test Summary | 88 |
| Chapter 8. | Summary and Conclusions | 91 |
| 8.1. | Assessment of Test Results and conclusions for the Concrete Para | pet |
| Shape Tra | Insition | 91 |
| 8.2. | Assessment of Test Results and conclusions for the Box Beam | |
| Transition | to Concrete Parapet | 92 |
| Chapter 9. | Implementation | 93 |
| References | | 96 |

| APPENDIX A. | Details of The Concrete Parapet Shape Transition and the Box | |
|-------------|--|------|
| | Beam Transition to Concrete Parapet | . 97 |
| A.1. Detail | s of Concrete Parapet Shape Transition | . 98 |
| A.2. Detail | s of Box Beam Transition to Concrete Parapet | 120 |
| APPENDIX B. | Supporting Certification Documents | 143 |
| APPENDIX C. | MASH Test 3-20 (Crash Test No. 611801-03-1) | 185 |
| C.1. | Vehicle Properties and Information | 185 |
| C.2. | Sequential Photographs | 188 |
| C.3. | Vehicle Angular Displacements | 191 |
| C.4. | Vehicle Accelerations | 192 |
| APPENDIX D. | MASH Test 3-21 (Crash Test No. 611801-03-2) | 195 |
| D.1. | Vehicle Properties and Information | 195 |
| D.2. | Sequential Photographs | 198 |
| D.3. | Vehicle Angular Displacements | 201 |
| D.4. | Vehicle Accelerations | 202 |
| APPENDIX E. | MASH Test 3-20 (Crash Test No. 611801-04-1) | 205 |
| E.1. | Vehicle Properties and Information | 205 |
| E.2. | Sequential Photographs | 208 |
| E.3. | Vehicle Angular Displacements | 211 |
| E.4. | Vehicle Accelerations | 212 |
| APPENDIX F. | MASH Test 3-21 (Crash Test No. 611801-04-2) | 215 |
| F.1. | Vehicle Properties and Information | 215 |
| F.2. | Sequential Photographs | 218 |
| F.3. | Vehicle Angular Displacements | 221 |
| F.4. | Vehicle Accelerations | 222 |
| APPENDIX G. | Details of the Concrete Single Slope Parapet Transition | 225 |

LIST OF FIGURES

| Pa | age |
|---|------------|
| Figure 2.1 Vertical-to-SS Barrier Shape Transition Design and Impact Points | 4 |
| Figure 2.2. FE model prior to vehicle impact with shape transition | 5 |
| Figure 2.3. Vehicles at maximum kinematic instability during simulations of various | |
| impact points | 6 |
| Figure 2.4. Impact Points for Test 3-20 Simulations of the Vertical to SS Barrier | |
| Shape Transition. | 6 |
| Figure 2.5. Vehicles at maximum kinematic instability during simulations of various | |
| impact points. | 7 |
| Figure 2.6. Vertical to NJ Barrier Shape Transition Design and Impact Points. | 8 |
| Figure 2.7. Vehicles at maximum kinematic instability during simulations of various | |
| impact points | 9 |
| Figure 2.8. Vehicles at maximum kinematic instability during simulations of various | - |
| impact points | . 10 |
| Figure 3.1. Box Beam Rail Section – Elevation View. | . 12 |
| Figure 3.2. Box Beam Rail Section – Plan View | . 12 |
| Figure 3.3. Box Beam Transition to Concrete Parapet | 13 |
| Figure 3.4 Box Beam Transition Connection | 13 |
| Figure 3.5 Exposed Anchor Bolts | 14 |
| Figure 3.6 Modified Anchor Bolts | 14 |
| Figure 3.7 Deflection of System with Modified Anchor Bolts | 15 |
| Figure 3.8 Box Beam Transition with 78-inch W6x9 posts | 15 |
| Figure 3.9. Pickup Truck at Maximum Roll Angle | 16 |
| Figure 3.10 Deflection of Box Beam Transition System | 16 |
| Figure 3.11 Box Beam Transition with HSS/v3 Rubrail | 17 |
| Figure 3.12, HSS6v2 (loft) and HSS4v3 (right) Dickup Truck at Maximum | / |
| Poll Andio | 17 |
| Figure 2.12 MASEL 2.20 Simulation Unstroom Section with USS4v2 Pubroil | . 17 |
| Figure 3.15. MASH 3-20 Simulation – Opsilean Section with HSS4x3 Rubrail | 23 |
| Figure 4.1 Target CIP for MASHTL 2 Tests on Concrete Paranet Shane Transition | .24 |
| Figure 4.1. Target CIP for MASHTL-3 Tests on Concrete Parapet Shape Hansilton. | . 21 |
| Concrete Derenet | 27 |
| Figure 6.4. Details of the Constant Descent Change Transition | . Z1 25 |
| Figure 6.1. Details of the Concrete Parapet Shape Transition. | . 30 |
| Figure 6.2. Concrete Parapet Shape Transition prior to Testing 611601-05-1&2 | .37 |
| Figure 6.3. Concrete Parapet Shape Transition at Impact Phor to Testing | 07 |
| 611801-03-1&2. | .37 |
| Figure 6.4. End view of the Concrete Parapet Shape Transition Prior to Testing | ~~ |
| 611801-03-1&2. | . 38 |
| Figure 6.5. Field Side of the Concrete Parapet Shape Transition prior to Testing | ~~ |
| 611801-03-1&2. | 38 |
| Figure 6.6. Concrete Parapet Snape Transition/Test Venicle Geometrics for Test | |
| 611801-03-1 | .41 |
| Figure 6.7. Concrete Parapet Shape Transition/Test Vehicle Impact Location | |
| 611801-03-1 | . 41 |

| Figure 6.8. Impact Side of Test Vehicle before Test 611801-03-1. | . 42 |
|--|------|
| Figure 6.9. Opposite Impact Side of Test Vehicle before Test 611801-03-1 | . 43 |
| Figure 6.10. Concrete Parapet Shape Transition after Test at Impact Location | |
| 611801-03-1 | . 45 |
| Figure 6.11. Concrete Parapet Shape Transition after Test at the Parapet Joint | |
| 611801-03-1 | . 45 |
| Figure 6.12. Impact Side of Test Vehicle after Test 611801-03-1. | . 46 |
| Figure 6.13. Rear Impact Side of Test Vehicle after Test 611801-03-1 | . 46 |
| Figure 6.14. Overall Interior of Test Vehicle after Test 611801-03-1 | . 47 |
| Figure 6.15. Interior of Test Vehicle on Impact Side after Test 611801-03-1 | . 47 |
| Figure 6.16. Summary of Results for MASH Test 3-20 on Concrete Parapet | |
| Shape Transition. | . 50 |
| Figure 6.17. Concrete Parapet Shape Transition/Test Vehicle Geometrics for Test | |
| 611801-03-2 | . 52 |
| Figure 6.18. Concrete Parapet Shape Transition/Test Vehicle Impact Location | |
| 611801-03-2 | . 52 |
| Figure 6.19. Impact Side of Test Vehicle before Test 611801-03-2. | . 53 |
| Figure 6.20. Opposite Impact Side of Test Vehicle before Test 611801-03-2 | .54 |
| Figure 6.21. Concrete Parapet Shape Transition after Test at Impact Location | |
| 611801-03-2 | 56 |
| Figure 6.22 Concrete Parapet Shape Transition after Test at the Parapet Joint | |
| 611801-03-2 | 56 |
| Figure 6.23 Impact Side of Test Vehicle after Test 611801-03-2 | 57 |
| Figure 6.24 Rear Impact Side of Test Vehicle after Test 611801-03-2 | 57 |
| Figure 6.25 Overall Interior of Test Vehicle after Test 611801-03-2 | 58 |
| Figure 6.26 Interior of Test Vehicle on Impact Side after Test 611801-03-2 | 58 |
| Figure 6.27 Summary of Results for MASH Test 3-21 on Concrete Parapet | |
| Shape Transition | 61 |
| Figure 7.1 Details of Box Beam Guardrail Transition to Concrete Parapet | 63 |
| Figure 7.2 Box Beam Guardrail Transition to Concrete Parapet prior to Testing | . 00 |
| 611801-04-1&2 | 64 |
| Figure 7.3 Box Beam Guardrail Transition to Concrete Paranet at Impact Prior to | . 04 |
| Testing 611801-04-18.2 | 64 |
| Figure 7.4 Box Beam Guardrail Transition to Concrete Paranet at the Box Beam | .04 |
| Transition prior to Testing 611801-04-182 | 65 |
| Figure 7.5. Field Side of the Box Boam Guardrail Transition to Concrete Parapet | .05 |
| prior to Tosting 611901 04 182 | 65 |
| Figure 7.6 Box Boam to Concrete Barrier Transition/Test Vehicle Coometries for | . 05 |
| Toct 611901 04 1 | 60 |
| Figure 7.7 Pay Poom to Congrete Parrier Transition/Test Vahiele Impact Leastion | . 00 |
| Figure 7.7. Box Beam to Concrete Barner Transition/Test Venicle Impact Location | 60 |
| 511801-04-1 | . 68 |
| Figure 7.0. Impact Side of Test Vehicle before Test 011801-04-1. | . 09 |
| Figure 7.9. Opposite impact Side of Test Venicle Defore Test 611801-04-1 | . 70 |
| rigure 7.10. Dox beam to Concrete Damer Transition at Impact Location after Test | 70 |
| 011801-04-1 | . 72 |

| Figure 7.11. Overall View of the Box Beam to Concrete Barrier Transition after Test 611801-04-1 | 72 |
|---|-----|
| Figure 7.12 Impact Side of Test Vehicle after Test 611801-04-1 | 73 |
| Figure 7.13. Door on the Impact Side of Test Vehicle after Test 611801-04-1 | 73 |
| Figure 7.14. Overall Interior of Test Vehicle after Test 611801-04-1 | 74 |
| Figure 7.15. Interior of Test Vehicle on Impact Side after Test 611801-04-1 | 7/ |
| Figure 7.16. Summary of Posults for MASH Tost 3-20 on Box Boam to Concrete | /4 |
| Barrior Transition | 77 |
| Figure 7.17. Box Beam to Concrete Barrier Transition/Test Vehicle Geometrics for | , , |
| Test 611801-04-2 | 80 |
| Figure 7.18. Box Beam to Concrete Barrier Transition/Test Vehicle Impact Location | |
| 611801-04-2 | 80 |
| Figure 7.19. Impact Side of Test Vehicle before Test 611801-04-2. | 81 |
| Figure 7.20. Opposite Impact Side of Test Vehicle before Test 611801-04-2 | 82 |
| Figure 7.21 Box Beam to Concrete Barrier Transition at Impact Location after Test | 02 |
| 611801-04-2 | 84 |
| Figure 7.22 Overall View of the Box Beam to Concrete Barrier Transition after Test | 01 |
| 611801-04-2 | 84 |
| Figure 7.23 Impact Side of Test Vehicle after Test 611801-04-2 | 85 |
| Figure 7.24 Rear Impact Side of Test Vehicle after Test 611801-04-2 | 85 |
| Figure 7.25. Overall Interior of Test Vehicle after Test 611801-04-2 | 86 |
| Figure 7.26. Interior of Test Vehicle on Impact Side after Test 611801-04-2 | 86 |
| Figure 7.27 Summary of Results for MASH Test 3-21 on Boy Beam to Concrete | 00 |
| Barrier Transition | 80 |
| Figure C 1 Vehicle Properties for Test No. 611801_03_1 | 85 |
| Figure C.1. Vehicle Properties for Test No. 011001-03-1 | 86 |
| Figure C.2. Exterior Grush Measurements for Test No. 011001-05-1 | 87 |
| Figure C.4. Sequential Distographs for Test No. 611901 03 1 (Overhead Views) 1 | 00 |
| Figure C.4. Sequential Photographs for Test No. 611801-03-1 (Overhead Views) 1 | 80 |
| Figure C.6. Sequential Photographs for Test No. 611801-03-1 (Poor Views) | 00 |
| Figure C.7. Vehicle Angular Displacements for Test No. 611801-03-1 (Near Views) | 01 |
| Figure C.7. Vehicle Angular Displacements for Test No. 011001-05-1 | 91 |
| (Apple C.o. Vehicle Longitudinal Accelerometer Trace for Test No. 011001-05-1 | 02 |
| Figure C. Q. Vehicle Lateral Accelerometer Trace for Test No. 611901-02-1 | 9Ζ |
| (Applerameter Lageted at Captor of Crowity) | 02 |
| Figure C 10, Vehicle Vertical Appeleremeter Trace for Text No. 611901 02 1 | 9Ζ |
| Figure C. 10. Venicle Venical Accelerometer frace for rest No. 611601-03-1 | 02 |
| (Accelerometer Localed at Center of Gravity) | 93 |
| Figure C.1. Venicle Properties for Test No. 611801-03-2 | 95 |
| Figure D.2. Exterior Grush Measurements for Test No. 611801-03-2. | 96 |
| Figure D.3. Occupant Compartment Measurements for Test No. 611801-03-2 | 97 |
| Figure D.4. Sequential Photographs for Test No. 611801-03-2 (Overnead Views)1 | 98 |
| Figure D.5. Sequential Photographs for Test No. 611801-03-2 (Frontal Views) 1 | 99 |
| Figure D.6. Sequential Photographs for Test No. 611801-03-2 (Rear Views) | 200 |
| Figure D.7. Vehicle Angular Displacements for Test No. 611801-03-2. | :01 |
| Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-03-2 | |
| (Accelerometer Located at Center of Gravity). | 202 |

| Figure D.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-03-2 | |
|---|-----|
| (Accelerometer Located at Center of Gravity). | 202 |
| Figure D.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-03-2 | |
| (Accelerometer Located at Center of Gravity). | 203 |
| Figure E.1. Vehicle Properties for Test No. 611801-04-1 | 205 |
| Figure E.2. Exterior Crush Measurements for Test No. 611801-04-1. | 206 |
| Figure E.3. Occupant Compartment Measurements for Test No. 611801-04-1 | 207 |
| Figure E.4. Sequential Photographs for Test No. 611801-04-1 (Overhead Views) | 208 |
| Figure E.5. Sequential Photographs for Test No. 611801-04-1 (Frontal Views) | 209 |
| Figure E.6. Sequential Photographs for Test No. 611801-04-1 (Rear Views) | 210 |
| Figure E.7. Vehicle Angular Displacements for Test No. 611801-04-1. | 211 |
| Figure E.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-04-1 | |
| (Accelerometer Located at Center of Gravity). | 212 |
| Figure E.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-04-1 | |
| (Accelerometer Located at Center of Gravity). | 212 |
| Figure E.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-04-1 | |
| (Accelerometer Located at Center of Gravity). | 213 |
| Figure F.1. Vehicle Properties for Test No. 611801-04-2. | 215 |
| Figure F.2. Exterior Crush Measurements for Test No. 611801-04-2. | 216 |
| Figure F.3. Occupant Compartment Measurements for Test No. 611801-04-2 | 217 |
| Figure F.4. Sequential Photographs for Test No. 611801-04-2 (Overhead Views) | 218 |
| Figure F.5. Sequential Photographs for Test No. 611801-04-2 (Frontal Views) | 219 |
| Figure F.6. Sequential Photographs for Test No. 611801-04-2 (Rear Views) | 220 |
| Figure F.7. Vehicle Angular Displacements for Test No. 611801-04-2 | 221 |
| Figure F.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-04-2 | |
| (Accelerometer Located at Center of Gravity). | 222 |
| Figure F.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-04-2 | |
| (Accelerometer Located at Center of Gravity). | 222 |
| Figure F.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-04-2 | |
| (Accelerometer Located at Center of Gravity) | 223 |

LIST OF TABLES

| | Page |
|---|------|
| Table 2.1. Results for Test 3-21 Simulation of Transition to SS barrier | 5 |
| Table 2.2. Results for Test 3-20 Simulation of Transition to SS barrier | 7 |
| Table 2.3. Simulation Results of Test 3-21 Impacts with Vertical to NJ Transition | 9 |
| Table 2.4. Simulation Results of Test 3-20 Impacts with Vertical to NJ Transition | 10 |
| Table 3.1. MASH Test 3-20 Occupant Risk Results | 18 |
| Table 3.2. MASH Test 3-21 Occupant Risk Results | 18 |
| Table 4.1. Test Conditions and Evaluation Criteria Specified for MASH TL-3 | |
| Transition System. | 26 |
| Table 4.2. Evaluation Criteria Required for MASH Testing. | 28 |
| Table 6.1. Concrete Strength. | 39 |
| Table 6.2. Impact Conditions for MASH 3-20, 611801-03-1 | 40 |
| Table 6.3. Exit Parameters for MASH 3-20, 611801-03-1 | 40 |
| Table 6.4. Weather Conditions 611801-03-1 | 42 |
| Table 6.5. Vehicle Measurements 611801-03-1 | 43 |
| Table 6.6. Events during Test 611801-03-1. | 44 |
| Table 6.7. Damage to Concrete Parapet Shape Transition 611801-03-1 | 44 |
| Table 6.8. Occupant Compartment Deformation 611801-03-1 | 48 |
| Table 6.9. Exterior Vehicle Damage 611801-03-1. | 48 |
| Table 6.10. Occupant Risk Factors for Test 611801-03-1 | 49 |
| Table 6.11. Impact Conditions for MASH 3-21 611801-03-2 | 51 |
| Table 6.12. Exit Parameters for MASH 3-21 611801-03-2 | 51 |
| Table 6.13. Weather Conditions 611801-03-2 | 53 |
| Table 6.14. Vehicle Measurements 611801-03-2 | 54 |
| Table 6.15. Events during Test 611801-03-2. | 55 |
| Table 6.16. Damage to Concrete Parapet Shape Transition 611801-03-2 | 55 |
| Table 6.17. Occupant Compartment Deformation 611801-03-2 | 59 |
| Table 6.18. Exterior Vehicle Damage 611801-03-2. | 59 |
| Table 6.19. Occupant Risk Factors for Test 611801-03-2 | 60 |
| Table 7.1. Concrete Strength. | 66 |
| Table 7.2. Soil Strength Before Test 611801-04-1. | 66 |
| Table 7.3. Soil Strength Before Test 61801-04-2. | 66 |
| Table 7.4. Impact Conditions for MASH TEST 3-20, Crash Test 611801-04-1 | 67 |
| Table 7.5. Exit Parameters for MASH TEST 3-20, Crash Test 611801-04-1 | 67 |
| Table 7.6. Weather Conditions 611801-04-1 | 69 |
| Table 7.7. Vehicle Measurements for Test 611801-04-1 | 70 |
| Table 7.8. Events during Test 611801-04-1. | 71 |
| Table 7.9. Post Soil Gap and Displacement of the Box Beam to Concrete Barrier | |
| Transition for Test 611801-04-1 | 71 |
| Table 7.10. Deflection and Working Width of the Box Beam to Concrete Barrier | |
| Transition for Test 611801-04-1 | 71 |
| Table 7.11. Occupant Compartment Deformation 611801-04-1 | 75 |
| Table 7.12. Exterior Vehicle Damage 611801-04-1. | 75 |
| Table 7.13. Occupant Risk Factors for Test 611801-04-1 | 76 |
| • | |

| Table 7.14. Impact Conditions for MASH TEST 3-21, Crash Test 611801-04-2 | . 79 |
|--|------|
| Table 7.15. Exit Parameters for MASH TEST 3-21, Crash Test 611801-04-2 | . 79 |
| Table 7.16. Weather Conditions 611801-04-2 | . 81 |
| Table 7.17. Vehicle Measurements 611801-04-2 | . 82 |
| Table 7.18. Events during Test 611801-04-2. | . 83 |
| Table 7.19. Post Soil Gap and Displacement of the Box Beam to Concrete Barrier | |
| Transition for Test 611801-04-2. | . 83 |
| Table 7.20. Deflection and Working Width of the Box Beam to Concrete Barrier | |
| Transition for Test 611801-04-2. | . 83 |
| Table 7.21. Occupant Compartment Deformation 611801-04-2 | . 87 |
| Table 7.22. Exterior Vehicle Damage 611801-04-2. | . 87 |
| Table 7.23. Occupant Risk Factors for Test 611801-04-2 | . 88 |
| Table 9.1. Assessment Summary for MASHTL-3 Tests on the Concrete Parapet | |
| Shape Transition. | . 91 |
| Table 9.1. Assessment Summary for MASH TL-3 Tests on the Box Beam | |
| Transition to Concrete Parapet. | . 92 |

List of Abbreviations

| A2LA | American Association for Laboratory Accreditation |
|--------|--|
| AASHTO | American Association of State Highway and Transportation Officials |
| ASI | Acceleration Severity Index |
| CDC | Collision Deformation Classification |
| CG | Center of Gravity |
| CIP | Critical Impact Point |
| FE | Finite Element |
| FHWA | Federal Highway Administration |
| ft | feet |
| HSS | Hollow Structural Section |
| IS | Impact Severity |
| ISO | International Standards Organization |
| lb | pounds |
| lbf | pounds force |
| kip-ft | thousand foot pounds |
| LON | Length of Need |
| MASH | Manual for Assessing Safety Hardware |
| mi/h | miles per hour |
| NIST | National Institute of Standards Technology |
| OCDI | Occupant Compartment Deformation Index |
| OIV | Occupant Impact Velocity |
| psi | pounds pressure per square inch |
| RA | (Occupant) Ridedown Acceleration |
| TDAS | Tiny Data Acquisition System |
| THIV | Theoretical Head Impact Velocity |
| TL-3 | Test Level 3 |
| TRAP | Test Risk Assessment Program |
| TTI | Texas A&M Transportation Institute |
| VDS | Vehicle Damage Scale |
| WYDOT | Wyoming Department of Transportation |
| х | Longitudinal |
| У | Lateral |
| Z | Vertical |

Chapter 1. INTRODUCTION

1.1. BACKGROUND

The Wyoming Department of Transportation (WYDOT) Mission Statement is to "provide a safe, high quality and efficient transportation system." One of the goals within the mission statement is to "improve safety on the state transportation system." Implementation of roadside safety devices that comply with the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)* is an important part of achieving this goal. *MASH* prescribes the performance criteria that a device must meet when impacted under specified impact conditions (1). Full implementation of *MASH*-compliant roadside safety devices will provide an enhanced level of safety that will help reduce the severity of roadway departure crashes that represent over 75 percent of highway fatalities in Wyoming.

This research addresses one important element of roadside safety design—the transition from an approach roadside guardrail to a bridge rail. The purpose of the transition section is to transition the stiffness from the more flexible approach guardrail to the more rigid bridge rail. Stiffness transitions provide continuity of motorist safety from *MASH* guardrail systems to *MASH* bridge rail systems. A stiffness transition has two distinct transition points that need to be considered in the design process. The first is the transition from the approach guardrail to the upstream end of the transition section. The second is the transition from the downstream end of the transition section to the bridge rail. A transition design and its connection details must include consideration of strength to resist impact loads and geometry to reduce vehicle snagging potential from both directions of travel (i.e., onto and off the bridge structure). Variables in transition design include the size and thickness of the rail element(s), post size, post spacing, and post embedment depth. A lower rub-rail or curb element below the primary transition rail is another design consideration.

1.2. OBJECTIVE

This project was jointly funded by WYDOT and Montana DOT with the objective of developing MASH Test Level 3 (TL-3) compliant nonproprietary approach guardrail transition systems. The objective of this phase of the project was to develop a *MASH* Test Level 3 (TL-3) compliant transition from box beam approach guardrail to a vertical concrete parapet. Shape transitions were developed to transition the vertical concrete parapet to which the transition was attached to other concrete barrier profiles that have been used or are planned for use by WYDOT.

1.3. WORK PLAN

The work plan for this phase of the project consisted of five tasks that relate to the design, analysis, testing, evaluation, and documentation of Concrete Parapet Shape Transitions and box beam guardrail transition to concrete parapet. Tasks included transition conceptualization and design, finite element (FE) modeling and impact

simulations, test installation construction, full-scale crash testing in accordance with *MASH* TL-3 criteria, and deliverable preparation. Details of this research are described herein.

Chapter 2. CONCRETE PARAPET SHAPE TRANSITION DESIGN

2.1. INTRODUCTION

WYDOT desired to use the box-beam guardrail transition to vertical parapet with 42inch-tall single slope (SS) and the 32-inch-tall New Jersey (NJ) profile concrete barriers. Due to the differences in heights and shapes of these concrete bridge rails, special shape transitions were needed. The slopes on the traffic face of the SS and NJ profiles result in wider barriers compared to the vertical parapet profile. Furthermore, there is a 10-inch height difference between the vertical parapet and the SS barrier profile. Shape transitions were needed to allow stable redirection of a vehicle impacting the concrete parapet.

The researchers developed designs for transitioning from the vertical concrete parapet to both the SS barrier profile and NJ profile concrete barriers. One of the design objectives was to minimize the length of the concrete transition parapet, with a goal of 10 ft or less. The researchers used finite element (FE) modeling and simulation to evaluate transition design concepts and determine critical impact points for crash testing. This chapter presents details of the modeling and simulation effort related to the development of the Concrete Parapet Shape Transition designs.

2.2. VERTICAL TO SINGLE SLOPE TRANSITION

The researchers developed a design to transition the shape of a vertical parapet to a SS concrete barrier. The conceptualized transition design is shown in Figure 2.1. The vertical parapet is 32 inches tall and transitions to a 42-inch-tall SS barrier. The box beam transition rails are intended to be attached to the vertical parapet. To allow sufficient room for this connection, the length of the vertical portion of the concrete parapet was selected to be 36 inches. The shape transition section was selected to be 72 inches long, providing an overall parapet length of 9 ft. The height transitioned 10 inches from 32 inches at the vertical parapet end to 42 inches at the SS barrier end. The shape transition from vertical to SS profile was achieved by using two triangular planes on the traffic side, as shown in Figure 2.1.



Figure 2.1 Vertical-to-SS Barrier Shape Transition Design and Impact Points.

2.2.1. Pickup Truck Impact Simulations (MASH Test 3-21)

To evaluate the performance of the Concrete Parapet Shape Transition, the researchers developed a model of the transition parapet and adjacent single slope barrier. All simulations were performed using the finite element (FE) method. LS-DYNA, which is a commercially available general purpose FE software, was used for all the analyses.

The transition section and adjacent barrier were modeled using rigid material representation. A 5,000-lb Dodge RAM pickup truck model was used for the impact simulations. Figure 2.1 shows the three impact points at which the impact simulations were performed. The direction of the vehicle and the location of the impact points was as follows:

- **Vertical to SS:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **SS to Vertical CIP1:** Vehicle impacting the SS barrier at the point where the shape transition begins.
- **SS to Vertical CIP2:** Vehicle impacting the SS barrier 2 ft upstream of the point where the shape transition begins.

Figure 2.2 shows the model of the vehicle positioned to impact the barrier and the shape transition for SS to Vertical – CIP2.



Figure 2.2. FE model prior to vehicle impact with shape transition.

The researchers performed impact simulations using MASH Test 3-21 impact conditions for all three impact points described above. This test involves the pickup truck model impacting the barrier system at an impact speed and angle of 62 mi/h and 25 degrees. In all three simulations, the vehicle was successfully contained and redirected. Table 2.1 shows the maximum Occupant Impact Velocity (OIV) and Ridedown Acceleration (RA) values calculated from the simulation data for all three impact points, along with the maximum vehicle roll angle in each simulation. Figure 2.3 shows the vehicles at the point of maximum kinematic instability for each of the impact points simulated.

All three simulations satisfied MASH criteria. The impact from the direction of the vertical parapet to the SS barrier was determined to be the critical impact point for Test 3-21 for this shape transition. This impact point resulted in maximum climb of the vehicle and also had the highest RA value.

| Direction of Impact and Impact Point | Max. Ridedown Acceleration (g) | Maximum Occupant Impact Velocity (ft/s) | Maximum Vehicle Roll (degrees) | |
|---|--------------------------------------|---|---|--|
| Vertical to SS | 13.2 | 28.3 | 7.2 | |
| SS to Vertical – CIP1 | 9.9 | 29.5 | 8.5 | |
| SS to Vertical – CIP2 | 9.4 | 28.0 | 5.7 | |

 Table 2.1. Results for Test 3-21 Simulation of Transition to SS barrier.



Figure 2.3. Vehicles at maximum kinematic instability during simulations of various impact points.

2.2.2. Passenger Sedan Impact Simulations (MASH Test 3-20)

The researchers performed impact simulations on the shape transition from the vertical parapet to SS barrier with a small passenger sedan using the impact conditions of MASH Test 3-20. This test involves impacting the transition with a 2,420-lb passenger sedan at an impact speed and angle of 62 mph and 25 degrees. The vehicle model used in the simulations was a Toyota Yaris model.



PLAN VIEW

Figure 2.4. Impact Points for Test 3-20 Simulations of the Vertical to SS Barrier Shape Transition.

Figure 2.4 shows the three impact points at which the impact simulations with MASH Test 3-20 conditions were performed. The direction of the vehicle and the location of the impact points were as follows:

- **Vertical to SS:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **SS to Vertical CIP1:** Vehicle impacting the SS barrier at the point where the shape transition begins.
- **SS to Vertical CIP2:** Vehicle impacting the SS barrier 1.5 ft upstream of the point where the shape transition begins.

In all three simulations, the vehicle was successfully contained and redirected. Table 2.2 shows the results of the maximum Occupant Impact Velocity (OIV), Ridedown Acceleration (RA), and vehicle roll angle in each simulation.

| Direction of Impact and Impact Point | Max. Ridedown Acceleration (g) | Maximum Occupant Impact Velocity (ft/s) | Maximum Vehicle Roll (degrees) | |
|---|--------------------------------------|---|---|--|
| Vertical to SS | 6.4 | 40.3 | 12.8 | |
| SS to Vertical – CIP1 | 15.0 | 30.6 | 8.4 | |
| SS to Vertical – CIP2 | 12.1 | 29.2 | 10.4 | |

Table 2.2. Results for Test 3-20 Simulation of Transition to SS barrier.

Figure 2.5 shows the vehicles at the point of maximum kinematic instability for each of the impact points simulated for the passenger sedan. The impact from the direction of the vertical parapet to the SS barrier resulted in slightly greater vehicle instability. It also had the highest OIV and vehicle roll, and was thus selected to be the critical impact point for Test 3-20 for this shape transition.







Single Slope to Vertical - CIP2

Figure 2.5. Vehicles at maximum kinematic instability during simulations of various impact points.

2.3. VERTICAL TO NEW JERSEY SAFETY SHAPE TRANSITION

The researchers also developed a design to transition the shape between a vertical parapet and a NJ profile concrete barrier. This transition design is shown in Figure 2.6. The 32-inch-tall vertical parapet transitioned to a 32-inch-tall NJ profile barrier. The length of the vertical parapet was selected to be 36 inches to allow connection of the box beam approach transition. The shape transition section was 72 inches long, providing an overall parapet length of 9 ft. The shape transition from vertical to NJ profile was achieved using triangular planes on the traffic side, as shown in Figure 2.6.



Figure 2.6. Vertical to NJ Barrier Shape Transition Design and Impact Points.

2.3.1. Pickup Truck Impact Simulations (MASH Test 3-21)

The researchers performed impact simulations with the shape transition from vertical to NJ profile barrier with a pickup truck model using the impact conditions of MASH Test 3-21. This test involves a 5,000-lb pickup truck impacting the transition at an impact speed and angle of 62 mph and 25 degrees. Figure 2.6 shows the three impact points at which the impact simulations were performed. The direction of the vehicle and the location of the impact points were as follows:

- **Vertical to NJ:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **NJ to Vertical CIP1:** Vehicle impacting the NJ barrier at the point where the shape transition begins.
- **NJ to Vertical CIP2:** Vehicle impacting the NJ barrier 2 ft upstream of the point where the shape transition begins.

In all three simulations, the vehicle was successfully contained and redirected and MASH criteria were satisfied. Table 2.3 shows the maximum OIV, RA, and vehicle roll angle from each simulation.

| Direction of Impact and Impact Point | Maximum Occupant Impact Velocity (ft/s) | Maximum Ride Down Acceleration (g) | Maximum Vehicle Roll (deg.) | |
|---|---|---|-----------------------------------|--|
| Vertical to NJ | 27.6 | 12.2 | 15.4 | |
| NJ to Vertical – CIP1 | 29.4 | 9.6 | 11.2 | |
| NJ to Vertical – CIP2 | 29.9 | 11.0 | 10.3 | |





Figure 2.7. Vehicles at maximum kinematic instability during simulations of various impact points.

Figure 2.7 shows the vehicles at their approximate points of maximum kinematic instability for each of the impact points simulated. The overall stability of the vehicle and its kinematics during and after the impact were similar for all three impact points. The impact from the direction of the vertical parapet to the NJ barrier resulted in slightly greater vehicle instability. It also had the highest RA and vehicle roll, and was thus selected to be the critical impact point for Test 3-21 for this shape transition.

2.3.2. Small Sedan Impact Simulations (MASH Test 3-20)

The researchers also performed impact simulations with the shape transition from the vertical parapet to the NJ profile barrier with a small passenger sedan using the impact conditions of MASH Test 3-20. Figure 2.6 shows the three impact points at which the impact simulations with MASH Test 3-20 conditions were performed. The direction of the vehicle and the location of the impact points were as follows.

- **Vertical to NJ:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **NJ to Vertical CIP1:** Vehicle impacting the NJ barrier at the point where the shape transition begins.
- **NJ to Vertical CIP2:** Vehicle impacting the NJ barrier 1.5 ft upstream of the point where the shape transition begins.

In all three simulations, the vehicle was successfully contained and redirected, and MASH criteria were satisfied. Table 2.4 shows the maximum OIV, RA, and vehicle roll for each simulation.

| Direction of Impact and Impact Point | Maximum Occupant Impact Velocity (ft/s) | Maximum Ride Down Acceleration (g) | Maximum Vehicle Roll (deg.) | | |
|---|---|--|-----------------------------------|--|--|
| Vertical to NJ | 30.4 | 5.6 | 20.7 | | |
| NJ to Vertical – CIP1 | 31.2 | 9.5 | 10.0 | | |
| NJ to Vertical – CIP2 | 30.6 | 12.2 | 17.1 | | |

Table 2.4. Simulation Results of Test 3-20 Impacts with Vertical to NJ Transition.



NJ to Vertical – CIP2

Figure 2.8. Vehicles at maximum kinematic instability during simulations of various impact points.

Figure 2.8 shows the vehicles at their approximate points of maximum kinematic instability for each of the impact points simulated. The overall stability of the vehicle and its kinematics during and after the impact were similar for all three impact points. The impact from the direction of the vertical parapet to the NJ barrier resulted in slightly greater vehicle instability and also had the highest vehicle roll. In comparison, the impact "NJ to Vertical – CIP2" had slightly less roll angle, about same OIV, and higher RA. While both impact points were contenders for the critical impact point and direction, the researchers believe that vehicle stability should be given precedence over occupant risk in the case of the shape transition. Since the impact from the vertical to NJ barrier resulted in higher roll, the researchers selected this location to be the critical impact point and direction for Test 3-20 for this shape transition.

2.4. **CRASH TESTING RECOMMENDATIONS**

Ideally, both shape transition systems could be crash tested for MASH Test 3-20 and Test 3-21. However, the scope of the current project included testing one of the two shape transition systems. Subject to this constraint, the research team developed the recommendations for crash testing presented below.

2.4.1. MASH Test 3-21

For Test 3-21 with a pickup truck, the research team considered the transition from vertical to NJ barrier to be more critical since it had higher maximum vehicle roll and similar maximum OIV and RA to the transition from vertical to SS barrier. Even though the OIV and RA of the vertical to SS transition were slightly higher, vehicle stability was considered a more important factor for the shape transitions. Therefore, for Test 3-21, the researchers recommended testing the vertical to NJ barrier transition. The critical impact point, as discussed previously, was the point where the vertical parapet starts transitioning to the NJ profile barrier. The direction of impact for this point was from the vertical parapet to the NJ profile barrier.

2.4.2. MASH Test 3-20

For Test 3-20 with a small passenger sedan, the point on the vertical parapet at the beginning of the SS shape transition had an OIV that was at the MASH threshold of 40 ft/s. On the other hand, the vehicle roll angle for the transition from vertical to NJ barrier was 7.9 degrees higher than the vehicle roll for the vertical to SS barrier transition.

The small car simulation model is known to be conservative in predicting OIV values. Thus, even though the OIV value for the vertical to SS transition was at the MASH threshold, it was expected to stay within the MASH limits in a crash test. Furthermore, as mentioned previously, vehicle stability is usually a more critical design factor compared to occupant risk for rigid concrete barrier shape transitions. Therefore, the research team recommended testing the vertical to NJ profile barrier transition for Test 3-20. The critical impact point was where the shape transition starts at the end of the vertical parapet. The direction of impact was from the vertical parapet to the NJ profile barrier.

Chapter 3. BOX BEAM TRANSITION TO CONCRETE PARAPET DESIGN

3.1. INTRODUCTION

The research team utilized finite element computer simulations to design and investigate the impact performance of an approach transition from box beam guardrail to a vertical concrete parapet. The transition system was evaluated in accordance with *MASH* TL-3 impact conditions and criteria.

The box beam guardrail transition to vertical concrete parapet consists of components and details similar to those utilized in the box beam guardrail transition to C2P bridge rail (2). Figure 3.1 and Figure 3.2 show elevation view and plan views of the box beam transition concept, respectively. The box beam rail is supported by strong steel posts, and the spacing of the posts decreases as the concrete parapet is approached. A rub rail is present below the box beam rail to help reduce vehicle snagging on the strong transition posts and parapet end. The box beam transition is connected to a 32-inch vertical concrete parapet. The shape transition on the concrete parapet was not included in these simulations as the purpose was to investigate the transition from the box beam rail to the vertical concrete parapet. Figure 3.3 shows the entire transition system including the parapet.



Figure 3.1. Box Beam Rail Section – Elevation View.



Figure 3.2. Box Beam Rail Section – Plan View.



Figure 3.3. Box Beam Transition to Concrete Parapet.

The box beam rail and lower rub rail are attached to the concrete parapet using two anchors on each rail. The first anchor for each rail is located 6 inches from the parapet edge and the second anchor for each rail is located 12 inches from the parapet edge. Each rail has a tapered end to mitigate snagging in a reverse direction impact. The tapered end of the wider upper box beam rail is additionally covered with a plate. Figure 3.4 shows the transition connection at the parapet. The anchors are not shown.



Figure 3.4. Box Beam Transition Connection.

3.2. DESIGN MODIFICATIONS

Design changes were made to the box beam transition section to address performance issues identified during the computer simulation effort. Details of these modifications are documented below. After the box beam transition design was finalized, simulations were performed at different locations on the final design to determine the critical impact locations for *MASH* testing.

3.2.1. Anchor Bolts

The initial computer simulations indicated satisfactory performance for MASH Test 3-20 and Test 3-21 evaluation criteria. However, deformation of the box beam rail led to exposed connection bolts that could snag the impacting vehicle. Figure 3.5 shows the exposed bolts resulting from local deformation of the box beam rail during one of the MASH Test 3-21 simulation runs.



Figure 3.5. Exposed Anchor Bolts.

To mitigate the potential for bolt head snagging, the bolt anchors going into the concrete parapet were modified. The bolt heads were moved off the traffic face of the box beam rail to the inside of the box beam rail. Figure 3.6 shows the modified anchor bolt with the head of the bolt located inside the rail. This eliminates the potential for vehicle snagging on the bolts.



Figure 3.6. Modified Anchor Bolts.

The modification of the bolted connection did prevent vehicle snagging. However, the new connection detail permitted more rotational movement and deflection of the box beam rail. This additional deflection resulted in rollover of the pickup truck vehicle. Figure 3.7 shows the deflection of the box beam rail after the pickup truck impact.



Figure 3.7. Deflection of System with Modified Anchor Bolts.

3.2.2. Additional W6x9 Steel Posts

The box beam transition section was stiffened to reduce the dynamic deflection through the addition of a W6x9 post in the downstream transition region. Additionally, the length of the W6x9 posts was increased from 72 inches to 78 inches. Figure 3.8 shows the modified transition system.



Figure 3.8. Box Beam Transition with 78-inch W6x9 posts.

In the subsequent MASH Test 3-21 simulation, the pickup truck did not roll over onto its side, but the roll of the pickup truck was significant as it exited the system. Figure 3.9 shows an image from the simulation at the time the pickup truck is at its maximum roll angle.



Figure 3.9. Pickup Truck at Maximum Roll Angle.

3.2.3. HSS4x3 Rubrail

It was desired to further reduce this roll angle to increase confidence in the impact performance of the transition system prior to performing full-scale crash tests. It was observed that during the deflection of the transition system, the rubrail extends beyond the main box beam rail in the lateral direction. Figure 3.10 shows the deflection of the transition system from overhead.

The box beam transition design was further modified by changing the rubrail from an HSS6x2 rail member to an HSS4x3 rail member. The traffic face of this rubrail section is inset two inches from the traffic face of the box beam rail. In addition to the modified rubrail, a smaller HSS tube was placed inside the main rail and spanned from the end of the rail at the parapet to the first steel post. Part of this added HSS tube was the addition of a third anchor bolt for the main rail. Figure 3.11 shows the updated overall transition system.



Figure 3.10. Deflection of Box Beam Transition System.



Figure 3.11. Box Beam Transition with HSS4x3 Rubrail.

The stability of the pickup truck was improved in the simulation with the HSS4x3 rubrail. Figure 3.12 shows a comparison of the maximum pickup truck roll angle for the HSS6x2 rubrail and HSS4x3 rubrail.



Figure 3.12. HSS6x2 (left) and HSS4x3 (right) Pickup Truck at Maximum Roll Angle.

3.3. FINAL EVALUATION AND CIP DETERMINATION

Simulations were conducted on the final transition design to verify performance of the system for MASH Tests 3-20 and 3-21 evaluation criteria. Additionally, simulations were conducted at different impact locations for each test condition to determine the critical impact location for full-scale crash testing.

The two primary MASH evaluation factors are structural adequacy and occupant risk. In all simulations, the vehicle was successfully contained and redirected. Table 3.1 and Table 3.2 show the occupant risk values for the simulations of MASH Tests 3-20 and 3-21, respectively.

| CIP Location | OIV-x (m/s) | OIV-y (m/s) | RDA-x (g's) | RDA-y (g's) | Roll (°) | Pitch (°) | Yaw (°) |
|--|----------------|----------------|----------------|----------------|-------------|--------------|------------|
| 2ft upstream of Parapet End | 5.2 | 8.9 | -4 | -14.2 | 6.3 | -4.1 | -27.4 |
| <i>3ft upstream of Parapet End</i> | 5.8 | 8.8 | -4.5 | -8.9 | 7.2 | -4.6 | -35.9 |
| 4ft upstream of Parapet End | 6.5 | 9.4 | -3.9 | -13.3 | 9 | -5.2 | -39.8 |
| 5ft upstream of Parapet End | 6.7 | 9.8 | -4.6 | -15.1 | 10.4 | -5.2 | -44.8 |
| 6ft upstream of Parapet End | 7 | 9.8 | -5.3 | -16.2 | 9.9 | -4.6 | -44.5 |

Table 3.1. MASH Test 3-20 Occupant Risk Results.

| CIP Location | OIV-x (m/s) | OIV-y (m/s) | RDA- x (g's) | RDA- y (g's) | Roll (°) | Pitch (°) | Yaw (°) |
|---------------------------------|----------------|----------------|--------------------|--------------------|-------------|--------------|------------|
| 6ft upstream of Parapet End | 7 | 9.2 | -5.8 | -10.8 | 24.8 | -18.5 | - 38.5 |
| 7ft upstream of Parapet End | 7.1 | 9.5 | -7.3 | -10.1 | 34.9 | -19 | - 55.2 |
| 8ft upstream of Parapet End | 6.6 | 8.9 | -8.2 | 10 | 43 | -11.3 | - 59.9 |
| 9ft upstream of Parapet End | 6.2 | 8.6 | -7.5 | -10.1 | 35.3 | -11.1 | - 43.4 |
| 10ft upstream of Parapet End | 5.9 | 8.3 | 8 | -9.6 | 36.2 | -12.8 | - 43.9 |

Table 3.2. MASH Test 3-21 Occupant Risk Results.

For MASH Test 3-20, the CIP was determined to be 5 ft upstream of the parapet end. This simulation resulted in one of the higher OIV and RDA metrics and had the highest roll angle. The impact point 6 ft upstream of the parapet end had similar high OIV and RDA metrics, but there was less potential for vehicle interaction with the parapet end.

For MASH Test 3-21, the CIP was determined to be 7 ft upstream of the parapet end. This simulation resulted in the highest OIV, roll angle, and pitch angle.

3.4. UPSTREAM TRANSITION EVALUATION

It was initially planned for the design details of the upstream end of the box beam approach guardrail transition to vertical concrete parapet to be similar to those of the MASH compliant box beam transition to C2P bridge rail that was developed under Phase I of this research (2). This system incorporated an HSS6×2 rubrail, and specific termination details for that rubrail at the upstream end of the transition. However, as described above, the rubrail in the box beam transition to vertical concrete parapet was
changed to an HSS4×3 to address stability concerns with the pickup truck observed in the impact simulations.

Consequently, a decision was made to evaluate the MASH impact performance of the upstream end of the transition with the HSS4x3 rubrail modification using computer simulation. MASH Test 3-20 and Test 3-21 computer simulations were performed on the upstream end of the transition system with the HSS4x3 rubrail and associated termination details.



0.00 s



0.25 s



0.50 s









0.25 s



0.50 s



0.75 s

Figure 3.14 show sequential images for Test 3-20 and Test 3-21 impact simulations, respectively. The impact locations were the same as those conducted in the previous crash tests (2).

For both simulations, the occupant risk values were below the MASH limits. In the MASH Test 3-20 impact simulation, the vehicle interacted longer with the transition system and did not exit as quickly compared to the original HSS6×2 rubrail system. However, the 1100C passenger car remained stable throughout the impact event, and the research team considered the performance of the upstream transition system with an HSS4×3 rubrail to be satisfactory.



0.00 s



0.25 s



0.50 s



Figure 3.13. MASH 3-20 Simulation – Upstream Section with HSS4x3 Rubrail.



Figure 3.14. MASH 3-21 Simulation – Upstream Section with HSS4x3 Rubrail.

3.5. SUMMARY

Finite element computer simulations were performed to analyze the crashworthiness of a transition system from box beam approach guardrail to a vertical concrete parapet. The impact simulations of the initial transition system concept showed significant snagging potential with the anchor bolts attaching the box beam rail to the concrete parapets. Design modifications were made to the system to improve its impact performance.

After the design was finalized, *MASH* Test 3-20 and Test 3-21 impact simulations were conducted on both the upstream and downstream end to evaluate the transition system according to *MASH* TL-3 criteria and select critical impact points for crash testing.

Overall, the modified box beam transition design to vertical concrete parapet performed acceptably for MASH TL-3 evaluation criteria.

Chapter 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST MATRIX

Table 4.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for transitions. The target critical impact points (CIPs) for each test were determined using finite element simulation. Figure 4.1 shows the target CIPs for *MASH* Tests 3-20 and 3-21 on the concrete parapet shape transition. Figure 4.2 shows the target CIPs for *MASH* Tests 3-20 and 3-21 on the box beam guardrail transition to concrete parapet.

| Table 4.1. Test Conditions and Evaluation Criteria Specified for MAS | <i>SH</i> TL-3 |
|--|----------------|
| Transition System. | |

| Test Designation | Test Vehicle | Impact Speed | Impact Angle | Evaluation Criteria |
|---------------------|-----------------|-----------------|-----------------|---------------------|
| 3-20 | 1100C | 62 mi/h | 25° | A, D, F, H, I |
| 3-21 | 2270P | 62 mi/h | 25° | A, D, F, H, I |



Figure 4.1. Target CIP for *MASH* TL-3 Tests on Concrete Parapet Shape Transition.



Figure 4.2. Target CIP for MASH TL-3 Tests on Box Beam Guardrail Transition to Concrete Parapet.

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 5 presents brief descriptions of these procedures.

4.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2A and 5-1 of *MASH* were used to evaluate the crash tests reported herein. Table 4.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 4.2 provides detailed information on these evaluation criteria.

| Evaluation Factors | Evaluation Criteria |
|-----------------------|--|
| A. | Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable. |
| D. | Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of <i>MASH</i> . |
| F. | The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees. |
| H. | Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s. |
| 1. | The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g. |

Table 4.2. Evaluation Criteria Required for MASH Testing.

Chapter 5. TEST CONDITIONS

5.1. TEST FACILITY

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

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The site selected for construction and testing of the transitions was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

5.2. VEHICLE TOW AND GUIDANCE SYSTEM

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

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a 16-channel Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors,

measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each of the TDAS Pro units is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCOTM 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive calibration via a Genisco Rate-of-Turn table. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel per SAE J211. Calibrations and evaluations are also made anytime data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

TRAP uses the data from the TDAS Pro to compute the occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with an SAE Class 180-Hz low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation being initial impact. Rate of rotation data is measured with an expanded uncertainty of ± 0.7 percent at a confidence factor of 95 percent (k = 2).

5.3.2. Anthropomorphic Dummy Instrumentation

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

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

5.3.3. Photographic Instrumentation Data Processing

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

- One located overhead with a field of view perpendicular to the ground and directly over the impact point.
- One placed upstream from the installation at an angle to have a field of view of the interaction of the rear of the vehicle with the installation.
- A third placed with a field of view parallel to and aligned with the installation at the downstream end.

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

Chapter 6. CRASH TESTING OF CONCRETE PARAPET SHAPE TRANSITION

6.1. CONCRETE PARAPET SHAPE TRANSITION DETAILS

6.1.1. Test Article and Installation Details

The test installation consisted of two independent 9-ft long concrete parapets with a 2inch open joint between them. The upstream parapet had a vertical profile over the first 3 ft of length followed by a shape transition from a vertical to New Jersey profile over the last 6 ft. The downstream parapet had a New Jersey profile throughout its length. Both parapets were anchored to a separate steel reinforced concrete approach slab.

Figure 6.1 presents overall information on the Concrete Parapet Shape Transition, and Figure 6.2 thru Figure 6.5 provide photographs of the installation for crash tests 611801-03-1 and 611801-03-2. Section A.1. in Appendix A provides further details on the Concrete Parapet Shape Transition. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

6.1.2. Design Modifications during Tests

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



Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing

Figure 6.1. Details of the Concrete Parapet Shape Transition.



Figure 6.2. Concrete Parapet Shape Transition prior to Testing 611801-03-1&2.



Figure 6.3. Concrete Parapet Shape Transition at Impact Prior to Testing 611801-03-1&2.



Figure 6.4. End View of the Concrete Parapet Shape Transition Prior to Testing 611801-03-1&2.



Figure 6.5. Field Side of the Concrete Parapet Shape Transition prior to Testing 611801-03-1&2.

6.1.3. Material Specifications

Appendix B provides material certification documents for the materials used to install/construct the Concrete Parapet Shape Transition. Table 6.1 shows the average compressive strengths of both the parapet and approach slab concrete on the day of the first test (2022-09-15).

| Location | Design Strength (psi) | Avg. Strength (psi) | Age (days) | Detailed Location |
|---------------|-----------------------------|---------------------------|---------------|-------------------|
| Approach Slab | 4000 | 4070 | 93 | 100% of Deck |
| Parapet | 4000 | 4367 | 77 | 100% of Parapet |

Table 6.1. Concrete Strength.

6.2. MASH TEST 3-20 (CRASH TEST NO. 611801-03-1)

6.2.1. Test Designation and Actual Impact Conditions

See Table 6.2 for details on impact conditions for this test, and Table 6.3 for the exit parameters. Figure 6.6 and Figure 6.7 depict the target impact setup.

| Test Parameter | Specification | Tolerance | Measured |
|--------------------------|--|-------------|--|
| Impact Speed (mi/h) | 62 | ±2.5 mi/h | 62.1 |
| Impact Angle (deg) | 25 | ±1.5° | 24.9 |
| Impact Severity (kip-ft) | 51 | ≥51 kip-ft | 55.7 |
| Impact Location | 36 inches downstream from the upstream end of the concrete parapet. | ± 12 inches | 36 inches downstream from the upstream end of the concrete parapet. |

Table 6.2. Impact Conditions for MASH 3-20, 611801-03-1.

Table 6.3. Exit Parameters for *MASH* 3-20, 611801-03-1.

| Exit Parameter | Measured |
|--------------------------------|--|
| Speed (mi/h) | 52.7 |
| Trajectory angle (deg) | 5 |
| Heading angle (deg) | 9 |
| Brakes applied post impact (s) | Not applied |
| Vehicle at rest position | 155 ft downstream of impact point74 ft to the traffic side90° counter-clockwise rotation |
| Comments: | Vehicle remained upright and stable. Vehicle crossed exit box ^a 62 ft downstream from loss of contact. |

^a Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.



Figure 6.6. Concrete Parapet Shape Transition/Test Vehicle Geometrics for Test 611801-03-1.



Figure 6.7. Concrete Parapet Shape Transition/Test Vehicle Impact Location 611801-03-1.

6.2.2. Weather Conditions

Table 6.4 provides the weather conditions for 611801-03-1.

| Date of Test | 2022-09-15 AM |
|-------------------------|---------------|
| Wind Speed (mi/h) | 4 |
| Wind Direction (deg) | 100 |
| Temperature (°F) | 84 |
| Relative Humidity (%) | 63 |
| Vehicle Traveling (deg) | 195 |

Table 6.4. Weather Conditions 611801-03-1.

6.2.3. Test Vehicle

Figure 6.8 and Figure 6.9 show the 2016 Nissan Versa used for the crash test. Table 6.5 shows key vehicle measurements. Table C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.



Figure 6.8. Impact Side of Test Vehicle before Test 611801-03-1.



Figure 6.9. Opposite Impact Side of Test Vehicle before Test 611801-03-1.

| Test Parameter | MASH | Allowed Tolerance | Measured |
|--|------|----------------------|----------|
| Dummy (if applicable) ^a (lb) | 165 | N/A | 165 |
| Test Inertial Weight (lb) | 2420 | ±55 | 2437 |
| Gross Static Weight ^a (lb) | 2585 | ±55 | 2602 |
| Wheelbase (inches) | 98 | ±5 | 102.4 |
| Front Overhang (inches) | 35 | ±4 | 32.5 |
| Overall Length (inches) | 169 | ±8 | 175.4 |
| Overall Width (inches) | 65 | ±3 | 66.7 |
| Hood Height (inches) | 28 | ±4 | 30.5 |
| Track Width ^b (inches) | 59 | ±2 | 58.4 |
| CG aft of Front Axle ^c (inches) | 39 | ±4 | 41.2 |
| CG above Ground ^{c,d} (inches) | N/A | N/A | N/A |

Table 6.5. Vehicle Measurements 611801-03-1.

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

^b Average of front and rear axles.

^c For test inertial mass.

^d 2270P vehicle must meet minimum CG height requirement.

6.2.4. Test Description

Table 6.6 lists events that occurred during Test No. 611801-03-1. Figures C.1 and C.2 in Appendix C.2 present sequential photographs during the test.

| Time (s) | Events |
|----------|---|
| 0.0000 | Vehicle impacted installation |
| 0.0330 | Vehicle began to redirect |
| 0.0390 | Barrier began to lean toward field side |
| 0.0460 | Windshield began to fracture due to body flexing and torsion from impact |
| 0.0600 | Barrier leaned maximum amount (1 inch) to field side |
| 0.0740 | Front and rear driver's side tires left the pavement |
| 0.1660 | Vehicle was parallel with installation |
| 0.1830 | Rear passenger bumper impacted barrier |
| 0.2740 | Vehicle exited the installation at 52.7mi/h with a heading angle of 8.8 degrees and a trajectory angle of 4.9 degrees |

Table 6.6. Events during Test 611801-03-1.

6.2.5. Damage to Test Installation

There was a crack along the traffic side toe of the upstream parapet at the deck, and there was some scuffing at the impact point. Table 6.7 describes the damage to the Concrete Parapet Shape Transition. Figure 6.10 and Figure 6.11 show the damage to the Concrete Parapet Shape Transition.

Table 6.7. Damage to Concrete Parapet Shape Transition 611801-03-1.

| Test Parameter | Measured |
|-------------------------------|---|
| Permanent Deflection/Location | 3% inches toward field side, at the parapet joint |
| Dynamic Deflection | 1 inch toward field side |
| Working Width a and Height | 21.6 inches, at a height of 36.6 inches |

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



Figure 6.10. Concrete Parapet Shape Transition after Test at Impact Location 611801-03-1.



Figure 6.11. Concrete Parapet Shape Transition after Test at the Parapet Joint 611801-03-1.

6.2.6. Damage to Test Vehicle

Figure 6.12 and Figure 6.13 show the damage sustained by the vehicle. Figure 6.14 and Figure 6.15 show the interior of the test vehicle. Table 6.8 and Table 6.9 provide details on the occupant compartment deformation and exterior vehicle damage. Tables

C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.



Figure 6.12. Impact Side of Test Vehicle after Test 611801-03-1.



Figure 6.13. Rear Impact Side of Test Vehicle after Test 611801-03-1.



Figure 6.14. Overall Interior of Test Vehicle after Test 611801-03-1.



Figure 6.15. Interior of Test Vehicle on Impact Side after Test 611801-03-1.

| Test Parameter | Specification | Measured |
|-------------------------------|----------------------------------|------------|
| Roof | ≤4.0 inches | 0 inches |
| Windshield | ≤3.0 inches | 2.3 inches |
| A and B Pillars | ≤5.0 overall/≤3.0 inches lateral | 0 inches |
| Foot Well/Toe Pan | ≤9.0 inches | 2 inches |
| Floor Pan/Transmission Tunnel | ≤12.0 inches | 0 inches |
| Side Front Panel | ≤12.0 inches | 5 inches |
| Front Door (above Seat) | ≤9.0 inches | 5 inches |
| Front Door (below Seat) | ≤12.0 inches | 0 inches |

 Table 6.8. Occupant Compartment Deformation 611801-03-1.

Table 6.9. Exterior Vehicle Damage 611801-03-1.

| Side Windows | The right front window shattered due to stresses from the flexing of the car door during impact. |
|--------------------------------------|--|
| Maximum Exterior | 8 inches in the front plane at the right front corner just above |
| Deformation | bumper neight |
| VDS | 01RFQ4 |
| CDC | 01FREW3 |
| Fuel Tank Damage | None |
| Description of Damage to Vehicle: | The front bumper, hood, grill, radiator and support, right front strut and tower, right front tire and rim, right front quarter fender, windshield, right A-pillar, right front door and glass, right front floor pan, roof, right rear door, right rear rim, right rear quarter fender, right tail light, and rear bumper were all damaged. The windshield had a 46-inch by 28-inch break that had a maximum depth of 2.3 inches which was caused by the flexing of the vehicle during impact and not due to penetration of the test article. The right front door had a 6-inch gap at the top. The roof had two dents at the B-pillar. One measured 5 inches by 8 inches by 0.5 inches deep, and the other 6 inches square and 0.5 inches deep. |

6.2.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.10. Figure C.3 in Appendix C.3 shows the vehicle angular displacements, and Figures C.4 through C.6 in Appendix C.4 show acceleration versus time traces.

| Test Parameter | MASH ^a | Measured | Time |
|----------------------------|-------------------|----------|--|
| OIV, Longitudinal (ft/s) | ≤40.0 | 21.4 | 0.0771 seconds on right side of interior |
| | 30.0 | | |
| OIV, Lateral (ft/s) | ≤40.0 | 31.2 | 0.0771 seconds on right side of interior |
| | 30.0 | | |
| Ridedown, Longitudinal (g) | ≤20.49 | 3.2 | 0.0771 - 0.0871 seconds |
| | 15.0 | | |
| Ridedown, Lateral (g) | ≤20.49 | 9.0 | 0.1994 - 0.2094 seconds |
| | 15.0 | | |
| THIV (m/s) | N/A | 11.6 | 0.0756 seconds on right side of interior |
| ASI | N/A | 2.6 | 0.0484 - 0.0984 seconds |
| 50-ms MA Longitudinal (g) | N/A | -12.2 | 0.0188 - 0.0688 seconds |
| 50-ms MA Lateral (g) | N/A | -19.5 | 0.0240 - 0.0740 seconds |
| 50-ms MA Vertical (g) | N/A | 3.5 | 0.0000 - 0.0500 seconds |
| Roll (deg) | ≤75 | 20 | 0.4740 seconds |
| Pitch (deg) | ≤75 | 17 | 0.7250 seconds |
| Yaw (deg) | N/A | 104 | 4.9999 seconds |

 Table 6.10. Occupant Risk Factors for Test 611801-03-1.

F. Values in italics are the preferred MASH values

6.2.8. Test Summary

Figure 6.16 summarizes the results of *MASH* Test 611801-03-1.

| Test | | | | Test Agency | Texas | exas A&M Transportation Institute (TTI) | | | | |
|---|--|------------------------|----------------------------|---|---------------------|---|---|--|--------------|--|
| the Martin | | | Test Standard/Test No. MAS | | | | H 2016, Test 3-20 | | | |
| States and | | | TTI Project No. 6 | | | | 1801-03-1 | | | |
| | SH- | 1 | Test Date 2022 | | | | -09-15 | | | |
| | | | TEST ARTICLE | | | | | | | |
| | | | Type Tra | | | Trans | ition Syst | em | | |
| | | | | | Name | Concr | ete Para | pet Shape Transition | | |
| a la se participation and | | | Length 18 fe | | | | et | | | |
| 0.00 | 00 s | | Key Materials | | | 32-inc wide o | 32-inch-high concrete parapet and 60-inch wide concrete deck | | | |
| alkia. | | | Soil Type and Condition C | | | Concr | Concrete, damp | | | |
| March Cont | | | TEST VEHICLE | | | | | | | |
| | an | bolly-Mill | Type/Designation 1100 | | | | С | | | |
| AND | | - | Year, Make and Model 2016 | | | | Nissan Versa | | | |
| | Carl Trans | - And | | In | ertial Weight (lb) | 2437 | | | | |
| | | a series of the series | | | Dummy (lb) | 165 | | | | |
| | | | | | Gross Static (lb) | 2602 | | | | |
| 0.20 | 0 s | | IMPACT | CONDI | TIONS | | | | | |
| | | | | Impa | act Speed (mi/h) | 62.1 | | | | |
| | | | | Im | pact Angle (deg) | 24.9 | | | | |
| | | | Impact Location 36 i | | | | nches downstream from the upstream end the concrete parapet. | | | |
| | to a | | | Impac | t Severity (kip-ft) | 55.7 | | | | |
| | | | EXIT CONDITIONS | | | | | | | |
| Aria | | | Exit Speed (mi/h) 52.7 | | | | | | | |
| 1-1- Star | | | Trajecto | ory/Head | ding Angle (deg) | 5/9 | 9 | | | |
| E | | | Exit Box Criteria | Vehic | Vehicle crossed | | | | | |
| | | | | St | opping Distance | 155 ft 74 ft t | downstre | eam fic side | | |
| 0.40 | 0 s | | TEST AR | TICLE | DEFLECTIONS | • | | | | |
| | - Xilay - | | | D | ynamic (inches) | 1 | | | | |
| | | | Permanent (inches) 3/8 | | | | ∛8 | | | |
| | and the second s | 0 | Working | g Width | /Height (inches) | 21.6/36.6 | | | | |
| | in the set | | VEHICLE | VEHICLE DAMAGE | | | | | | |
| | | | VDS 01 | | | 01RF | 01RFQ4 | | | |
| | | | CDC | | | 01FREW3 | | | | |
| | | | | Max. B | Ext. Deformation | 8 | | | | |
| 0.600 s Max Occupant Compartment Deformation 5 in | | | 5 inch | inches at the side panel and in the door. | | | | | | |
| | | | OC | CUPAN | T RISK VALUES | | | | | |
| Long. OIV (ft/s) | 21.4 | Long. Ride | down (g) | 3.2 | Max 50-ms Lon | g. (g) | -12.2 | Max Roll (deg) | 20 | |
| Lat. OIV (ft/s) | 31.2 | Lat. Rided | own (g) | 9.0 | Max 50-ms Lat. | (g) | -19.5 | Max Pitch (deg) | 17 | |
| THIV (m/s) | 11.6 | ASI | | 2.6 | Max 50-ms Ver | t. (g) | 3.5 | Max Yaw (deg) | 104 | |
| - | 1 | 155' — | | | | | | -10- | r 1-1/2 | |
| | | ↓ ↓ <u>_</u> = | 11.7' Exit Angle | | - ⊢ 3.0' | | | | ** 32* | |
| Impact Angle | | | | RIO | | | | | | |
| 74' Heading Angle Exit Angle Box | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | -[]] | | / ľ | | | |
| ↓ 8 | | | | | | | | <u>9////////////////////////////////////</u> | ∠///t₁o- | |
| L | | | | | | | - | 50 | | |

Figure 6.16. Summary of Results for *MASH* Test 3-20 on Concrete Parapet Shape Transition.

6.3. MASH TEST 3-21 (CRASH TEST NO. 611801-03-2)

6.3.1. Test Designation and Actual Impact Conditions

See Table 6.11 for details on impact conditions for this test, and Table 6.12 for the exit parameters. Figure 6.17 and Figure 6.18 depict the target impact setup.

| Test Parameter | Specification | Tolerance | Measured |
|--------------------------|--|-------------|--|
| Impact Speed (mi/h) | 62 mi/h | ± 2.5 mi/h | 62.6 |
| Impact Angle (deg) | 25° | ± 1.5° | 24.3 |
| Impact Severity (kip-ft) | 106 kip-ft | ≥106 kip-ft | 111.2 |
| Impact Location | 36 inches downstream from the upstream end of the concrete parapet. | ± 12 inches | 43.2 inches downstream from the upstream end of the concrete parapet. |

Table 6.11. Impact Conditions for MASH 3-21 611801-03-2.

Table 6.12. Exit Parameters for *MASH* 3-21 611801-03-2.

| Exit Parameter | Measured |
|--------------------------------|---|
| Speed (mi/h) | 49.4 |
| Trajectory angle (deg) | 2 |
| Heading angle (deg) | 7 |
| Brakes applied post impact (s) | 2.4 |
| Vehicle at rest position | 189 ft downstream of impact point7 ft to the field side90° clockwise rotation |
| Comments: | Vehicle remained upright and stable. Vehicle crossed exit box a 101 ft downstream from loss of contact. |

^a Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.



Figure 6.17. Concrete Parapet Shape Transition/Test Vehicle Geometrics for Test 611801-03-2.



Figure 6.18. Concrete Parapet Shape Transition/Test Vehicle Impact Location 611801-03-2.

6.3.2. Weather Conditions

Table 6.13 provides the weather conditions for 611801-03-2.

| Date of Test | 2022-09-28 AM |
|-------------------------|---------------|
| Wind Speed (mi/h) | 5 |
| Wind Direction (deg) | 137 |
| Temperature (°F) | 81 |
| Relative Humidity (%) | 37 |
| Vehicle Traveling (deg) | 195 |

Table 6.13. Weather Conditions 611801-03-2.

6.3.3. Test Vehicle

Figure 6.19 and Figure 6.20 show the 2016 RAM 1500 used for the crash test. Table 6.14 shows key vehicle measurements. Table D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.



Figure 6.19. Impact Side of Test Vehicle before Test 611801-03-2.



Figure 6.20. Opposite Impact Side of Test Vehicle before Test 611801-03-2.

| Test Parameter | MASH | Allowed Tolerance | Measured |
|--|------|----------------------|----------|
| Dummy (if applicable) ^a (lb) | 165 | N/A | N/A |
| Test Inertial Weight (lb) | 5000 | ± 110 | 5011 |
| Gross Static Weight ^a (lb) | 5000 | ± 110 | 5011 |
| Wheelbase (inches) | 148 | ±12 | 140.5 |
| Front Overhang (inches) | 39 | ±3 | 40.0 |
| Overall Length (inches) | 237 | ±13 | 227.5 |
| Overall Width (inches) | 78 | ±2 | 78.5 |
| Hood Height (inches) | 43 | ±4 | 46.0 |
| Track Width ^b (inches) | 67 | ±1.5 | 68.25 |
| CG aft of Front Axle ^c (inches) | 63 | ±4 | 61.29 |
| CG above Ground ^{c,d} (inches) | 28 | ≥28 | 28.5 |

 Table 6.14. Vehicle Measurements 611801-03-2.

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

^b Average of front and rear axles.

^c For test inertial mass.

^d 2270P vehicle must meet minimum CG height requirement.

6.3.4. Test Description

Table 6.15 lists events that occurred during Test No. 611801-03-2. Figures D.1 and D.2 in Appendix D.2 present sequential photographs during the test.
| Time (s) | Events | | |
|----------|--|--|--|
| 0.0000 | Vehicle impacted installation | | |
| 0.0250 | Concrete Barrier began to lean toward field side | | |
| 0.0470 | Vehicle began to redirect | | |
| 0.0830 | Front drivers side tires left the pavement | | |
| 0.1030 | Barrier leaned maximum amount (3.7 inches) to field side | | |
| 0.1170 | Rear drivers side tires left the pavement | | |
| 0.2080 | Vehicle was parallel with installation | | |
| 0.2100 | Rear passenger bumper impacted barrier | | |
| 0.4150 | Vehicle exited the installation at 49.4 mi/h with a heading angle of 7.5 degrees and a trajectory angle of 1.9 degrees | | |

Table 6.15. Events during Test 611801-03-2.

6.3.5. Damage to Test Installation

The upstream parapet was leaning 0.3° back from vertical prior to impact. After impact, it was leaning 3.0° back. The offset of the two parapets along the top field side edge enlarged from $\frac{3}{8}$ -inch to $2\frac{5}{8}$ inches. There was significant damage to the concrete at the top of the joint with rebar exposed on the upstream end of the downstream parapet. The impacted parapet was pushed back $\frac{1}{2}$ -inch at grade and was raised up $\frac{1}{2}$ -inch at the joint on the traffic side.

Table 6.16 describes the damage to the Concrete Parapet Shape Transition. Figure 6.21 and Figure 6.22 show the damage to the Concrete Parapet Shape Transition.

 Table 6.16. Damage to Concrete Parapet Shape Transition 611801-03-2.

| Test Parameter | Measured | | |
|---------------------------------------|---|--|--|
| Permanent Deflection/Location | 2.25 inches toward field side, at the downstream end of the upstream parapet. | | |
| Dynamic Deflection | 3.7 inches toward field side, at the downstream end of the upstream parapet. | | |
| Working Width ^a and Height | 29.6 inches, at a height of 62.2 inches (corresponding to the right-side mirror of the vehicle) | | |

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



Figure 6.21. Concrete Parapet Shape Transition after Test at Impact Location 611801-03-2.



Figure 6.22. Concrete Parapet Shape Transition after Test at the Parapet Joint 611801-03-2.

6.3.6. Damage to Test Vehicle

Figure 6.23 and Figure 6.24 show the damage sustained by the vehicle. Figure 6.25 and Figure 6.26 show the interior of the test vehicle. Table 6.17 and Table 6.18 provide details on the occupant compartment deformation and exterior vehicle damage. Tables

D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.



Figure 6.23. Impact Side of Test Vehicle after Test 611801-03-2.



Figure 6.24. Rear Impact Side of Test Vehicle after Test 611801-03-2.



Figure 6.25. Overall Interior of Test Vehicle after Test 611801-03-2.



Figure 6.26. Interior of Test Vehicle on Impact Side after Test 611801-03-2.

| Test Parameter | Specification | Measured |
|-------------------------------|----------------------------------|------------|
| Roof | ≤4.0 inches | 0.0 inches |
| Windshield | ≤3.0 inches | 0.0 inches |
| A and B Pillars | ≤5.0 overall/≤3.0 inches lateral | 0.0 inches |
| Foot Well/Toe Pan | ≤9.0 inches | 3.5 inches |
| Floor Pan/Transmission Tunnel | ≤12.0 inches | 0.0 inches |
| Side Front Panel | ≤12.0 inches | 2.5 inches |
| Front Door (above Seat) | ≤9.0 inches | 1.5 inches |
| Front Door (below Seat) | ≤12.0 inches | 0.0 inches |

 Table 6.17. Occupant Compartment Deformation 611801-03-2.

Table 6.18. Exterior Vehicle Damage 611801-03-2.

| Side Windows | Side windows remained intact | | |
|--------------------------------------|---|--|--|
| Maximum Exterior | 12 inches in the front plane at the right front corner at bumper | | |
| Deformation | height | | |
| VDS | 01RFQ4 | | |
| CDC | 01FREW3 | | |
| Fuel Tank Damage | None | | |
| Description of Damage to Vehicle: | The front bumper, grill, right and left headlight, right front quarter fender, windshield, right front door, right front floor pan, right front tire and rim, right rear door, right cab corner, right rear quarter fender, right rear tire and rim, and rear bumper were damaged. The windshield had some minor stress fractures, which were caused by the flexing of the vehicle during impact and not due to penetration of the test article, and the right front door had a 4-inch gap at the top. | | |

6.3.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.19. Figure D.3 in Appendix D.3 shows the vehicle angular displacements, and Figures D.4 through D.6 in Appendix D.4 show acceleration versus time traces.

| Test Parameter | MASH ^a | Measured | Time |
|----------------------------|-------------------|----------|--|
| OIV, Longitudinal (ft/s) | ≤40.0 | 23.9 | 0.0957 seconds on right side of interior |
| | 30.0 | | |
| OIV, Lateral (ft/s) | ≤40.0 | 25.2 | 0.0957 seconds on right side of interior |
| | 30.0 | | |
| Ridedown, Longitudinal (g) | ≤20.49 | 4.4 | 0.1019 - 0.1119 s |
| | 15.0 | | |
| Ridedown, Lateral (g) | ≤20.49 | 7.2 | 0.2417 - 0.2517 s |
| | 15.0 | | |
| THIV (m/s) | N/A | 9.7 | 0.0932 seconds on right side of interior |
| ASI | N/A | 1.8 | 0.0576 - 0.1076 s |
| 50-ms MA Longitudinal (g) | N/A | -11.0 | 0.0470 - 0.0970 s |
| 50-ms MA Lateral (g) | N/A | -13.2 | 0.0322 - 0.0822 s |
| 50-ms MA Vertical (g) | N/A | -2.6 | 0.0030 - 0.0530 s |
| Roll (deg) | ≤75 | 36 | 0.6788 s |
| Pitch (deg) | ≤75 | 10 | 0.6729 s |
| Yaw (deg) | N/A | 45 | 1.0096 s |

 Table 6.19. Occupant Risk Factors for Test 611801-03-2.

F. Values in italics are the preferred MASH values

6.3.8. Test Summary

Figure 6.27 summarizes the results of *MASH* Test 611801-03-2.

| | | | 1 | | | | | | |
|---|------------------|--|---|-------------------|---------------------|-------------------|--|---|--|
| Test Agency | | | Texas A&M Transportation Institute (TTI) | | | | | | |
| | | | Test Standard/Test No. MAS | | | MASH | H 2016, Test 3-21 | | |
| | | | TTI Project No. 61180 | | | 01-03-2 | | | |
| | | | Test Date 2022-0 | | | | 09-28 | | |
| | | | TEST AR | TICLE | | ī | | | |
| | | the state of the s | | | Туре | Transition System | | | |
| | - | | Name | | | Concr | Concrete Parapet Shape Transition | | |
| Production of the second second | | | Length 18 | | | 18 | 8 | | |
| 0.00 | 00 s | | | | Key Materials | 32-inc wide o | h-high co concrete | oncrete parapet and 60 deck | <i>i</i> -inch |
| | 50 | | Soil Type and Condition Cor | | | Concr | ncrete, damp | | |
| A | E | | TEST VE | HICLE | | ī | | | |
| A A A A A A A A A A A A A A A A A A A | | | | Т | ype/Designation | 2270 | P | | |
| | | RE | | Year, I | Make and Model | 2016 | RAM 150 | 0 | |
| Chinkland Strange | 11.00 | Sarding . | | In | ertial Weight (lb) | 5011 | | | |
| State Contractor and | | - | | | Dummy (lb) | N/A | | | |
| and the second se | 1 | | | | Gross Static (lb) | 5011 | | | |
| 0.20 |)0 s | | IMPACT | CONDI | TIONS | ī | | | |
| | | | | Imp | act Speed (mi/h) | 62.6 | | | |
| | | | | Im | pact Angle (deg) | 24.3 | | | |
| | Min an | | | | Impact Location | 43.2 ii end o | inches downstream from the upstream of the concrete parapet. | | |
| A UP | | | | Impac | t Severity (kip-ft) | 111.2 | | | |
| | Ser. 1 1 | 2. 4 | EXIT CO | NDITIO | NS | ī | | | |
| | Steeling - March | <u> </u> | | E | xit Speed (mi/h) | 49.4 | | | |
| Contraction of the second | | a landad | Trajecto | ory/Hea | ding Angle (deg) | 2/7 | | | |
| and the second second | | | Exit Box Criteria Cross | | | ed | | | |
| ALC: NOT THE OWNER OF THE OWNER OWNER OF THE OWNER OWNE | 1 | and a second | Stopping Distance 189 | | | 189 ft | ft downstream | | |
| | | | 7 ft t | | | 7 ft to | the field | side | |
| 0.40 | JUS | | Dynamic (inches) 3.7 | | | 07 | | | |
| | anonen | | Dynamic (inches) 3.7 | | | 3.7 | | | |
| | 1 | | Permanent (Inches) 21/4 | | | | | | |
| 1 | 1. Ja | | Working Width / Height (inches) 29.6 | | | 29.67 | 62.2 | | |
| | | The - | | | | 0405 | 2.4 | | |
| | | | VDS 01F | | | 01RF | | | |
| Contraction Contraction | | a series and a series of the s | | | | 01FR | 01FREW3 | | |
| and the second | - | | Max. Ext. Deformation 12 | | | 12 Inc | nes | | |
| 0.60 | 00 s | | Max Occupant Compartment Deformation 3 inc | | | 3 inch | es in the | kick panel | |
| | | | 000 | CUPAN | T RISK VALUES | | | | |
| Long. OIV (ft/s) | 23.9 | Long. Ride | down (g) | 4.4 | Max 50-ms Long | g. (g) | -11.0 | Max Roll (deg) | 36 |
| Lat. OIV (ft/s) | 25.2 | Lat. Rided | own (g) | 7.2 | Max 50-ms Lat. | (g) | -13.2 | Max Pitch (deg) | 10 |
| THIV (m/s) | 9.7 | ASI | | 1.8 | Max 50-ms Vert | . (g) | -2.6 | Max Yaw (deg) | 45 |
| | | —————————————————————————————————————— | Ex | 14.6' it Angle | 3.6' | | | F F F | 5 5 5 7 7 7 7 8 8 7 7 8 8 8 8 8 8 8 8 8 |
| | | | Ī | RID | | | | | |
| | | | 1 | | | | | | |
| | | | - | -77 | | 3" 0" | | | |
| | | | | | └─ Exit Angle | | | <u> 14 14 14 14 14 14 14 14 14 14 14 14 14 </u> | 1 0" |
| | | | | | | | - | 60" | → |

Figure 6.27. Summary of Results for *MASH* Test 3-21 on Concrete Parapet Shape Transition.

Chapter 7. CRASH TESTING OF BOX BEAM GUARDRAIL TRANSITION TO CONCRETE PARAPET

7.1. CONCRETE PARAPET SHAPE TRANSITION DETAILS

7.1.1. Test Article and Installation Details

The test installation consisted of the previously described concrete transition parapet, box beam stiffness transition, box beam guardrail, and box beam guardrail anchorage. The upstream concrete transition parapet was reconstructed prior to the box beam transition tests. The spacing of the anchorage bars was reduced from 6 inches to 5 inches to increase strength and reduce maintenance for direct impacts.

The box beam stiffness transition consisted of an HSS $6 \times 6 \times 3/16$ -inch upper traffic rail and an HSS $4 \times 3 \times 1/4$ -inch lower rub-rail mounted on steel posts of different sizes and spacing using steel angle brackets. The top of the traffic rail was 28 inches above grade, and the top of the rub-rail was at 14 inches above grade. The rub-rail turned back and down at post 17 and was secured to the field side of post 16 near grade level. The transition rails were bolted to the vertical portion of the concrete transition parapet. The ends of the rails were tapered to mitigate vehicle snagging in reverse-direction impacts. A 36-inch long, HSS $5 \times 5 \times 1/4$ -inch stiffening sleeve was inserted inside the downstream end of the HSS $6 \times 6 \times 3/16$ -inch upper traffic rail.

The 72 ft of box beam guardrail attached to the upstream end of the transition was comprised of an HSS $6\times6\times3/16$ -inch rail mounted 28 inches above grade and attached to S3x5.7 posts with 8x24-inch soil plates using L5x3½-inch angle brackets. The 23-ft 5-inch-long terminal section was comprised of a single HSS $6\times6\times3/16$ -inch rail that turned down between posts 1 and 2 and was anchored to an unreinforced concrete block via anchor bolts cast into the block.

Figure 7.1 presents overall information on the Box Beam Guardrail Transition to Concrete Parapet, and Figure 7.2 thru Figure 7.5 provide photographs of the installation for crash tests 611801-04-1 and 6110801-04-2 prior to testing. Section A.2. in Appendix A provides further details on the Box Beam Guardrail Transition to Concrete Parapet. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

7.1.2. Design Modifications during Tests

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



Figure 7.1. Details of Box Beam Guardrail Transition to Concrete Parapet.



Figure 7.2. Box Beam Guardrail Transition to Concrete Parapet prior to Testing 611801-04-1&2.



Figure 7.3. Box Beam Guardrail Transition to Concrete Parapet at Impact Prior to Testing 611801-04-1&2.



Figure 7.4. Box Beam Guardrail Transition to Concrete Parapet at the Box Beam Transition prior to Testing 611801-04-1&2.



Figure 7.5. Field Side of the Box Beam Guardrail Transition to Concrete Parapet prior to Testing 611801-04-1&2.

7.1.3. Material Specifications

Appendix B provides material certification documents for the materials used to install/construct the Box Beam Guardrail Transition to Concrete Parapet. Table 7.1 shows the average compressive strengths of the reconstructed concrete transition parapet and approach slab on the day of the first box beam transition test (2023-03-23).

| Location | Design Strength (psi) | Avg. Strength (psi) | Age (days) | Detailed Location |
|-----------------------------|-----------------------------|---------------------------|---------------|----------------------|
| Reconstructed Approach Slab | 4000 | 5657 | 44 | 100% of Deck |
| Reconstructed Parapet | 4000 | 5083 | 33 | 100% of Parapet |

| Table 7.1 | . Concrete | Strength. |
|-----------|------------|-----------|
|-----------|------------|-----------|

7.1.4. Soil Conditions

The test installation was installed in standard soil meeting Type 1 Grade D of AASHTO standard specification M147-17 "Materials for Aggregate and Soil Aggregate Subbase, Base, and Surface Courses."

In accordance with Appendix B of *MASH*, soil strength was measured the day of each crash test. During installation of the Box Beam Guardrail Transition to Concrete Parapet for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the Box Beam Guardrail Transition to Concrete Parapet using the same fill materials and installation procedures used in the test installation and the standard dynamic test.

The minimum post loads are shown in and

On the day of Test 3-20, 2023-03-23, loads obtained from the post pull test are shown in Table 7.2. The soil in which the Box Beam Guardrail Transition to Concrete Parapet was installed met minimum *MASH* requirements for soil strength.

| Displacement (in) | Minimum Load (Ib) | Actual Load (Ib) |
|-------------------|-------------------|------------------|
| 5 | 4420 | 10,242 |
| 10 | 4981 | 10,060 |
| 15 | 5282 | 10,152 |

| Table 7.2. Soil Strength Bef | ore Test 611801-04-1. |
|------------------------------|-----------------------|
|------------------------------|-----------------------|

On the day of Test 3-21, 2023-03-30, loads obtained from the post pull test are shown in Table 7.3. The soil in which the Box Beam Guardrail Transition to Concrete Parapet was installed met minimum *MASH* requirements for soil strength.

| Displacement (in) | Minimum Load (Ib) | Actual Load (lb) | | | | |
|-------------------|-------------------|------------------|--|--|--|--|
| 5 | 4420 | 8545 | | | | |
| 10 | 4981 | 9515 | | | | |
| 15 | 5282 | 10,181 | | | | |

7.2. MASH TEST 3-20 (CRASH TEST 611801-04-1)

7.2.1. Test Designation and Actual Impact Conditions

See Table 7.4 for details of impact conditions for this test and Table 7.5 for the exit parameters. Figure 7.6 and Figure 7.7 depict the target impact setup.

Table 7.4. Impact Conditions for MASH TEST 3-20, Crash Test 611801-04-1.

| Test Parameter | Specification | Tolerance | Measured |
|--|---------------|------------|---|
| Impact Speed (mi/h) | 62 | ±2.5 mi/h | 61.8 |
| Impact Angle (deg) | 25 | ±1.5° | 25.0 |
| Impact Severity (kip-ft) | 51 | ≥51 kip-ft | 55.8 |
| Impact Location60 inches upstream from the end of the concrete parapet | | ±12 inches | 59.7 inches upstream from the end of the concrete parapet |

| Exit Parameter | Measured |
|--------------------------------|--|
| Speed (mi/h) | 48.0 |
| Trajectory angle (deg) | 4.5 |
| Heading angle (deg) | 5.9 |
| Brakes applied post impact (s) | 1.6 |
| Vehicle at rest position | 118 ft downstream of impact point7 ft to the traffic side175° left |
| Comments: | Vehicle remained upright and stable. Vehicle did not cross the exit box. |

| Table 7.5. EXIT Parameters for MASH TEST 3-20, Grash Test 611801-04-1 |
|---|
|---|

^a Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.



Figure 7.6. Box Beam to Concrete Barrier Transition/Test Vehicle Geometrics for Test 611801-04-1.



Figure 7.7. Box Beam to Concrete Barrier Transition/Test Vehicle Impact Location 611801-04-1.

7.2.2. Weather Conditions

Table 7.6 provides the weather conditions for 611801-04-1.

| Date of Test | 2023-03-23 AM |
|-------------------------|---------------|
| Wind Speed (mi/h) | 13 |
| Wind Direction (deg) | 198 |
| Temperature (°F) | 76 |
| Relative Humidity (%) | 84 |
| Vehicle Traveling (deg) | 195 |

Table 7.6. Weather Conditions 611801-04-1.

7.2.3. Test Vehicle

Figure 7.8 and Figure 7.9 show the 2017 Nissan Versa used for the crash test. Table 7.7 shows key vehicle measurements. Figure E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.



Figure 7.8. Impact Side of Test Vehicle before Test 611801-04-1.



Figure 7.9. Opposite Impact Side of Test Vehicle before Test 611801-04-1.

| Test Parameter | MASH | Allowed Tolerance | Measured |
|--|------|----------------------|----------|
| Dummy (if applicable) ^a (lb) | 165 | N/A | 165 |
| Test Inertial Weight (lb) | 2420 | ±55 | 2448 |
| Gross Static Weight ^a (lb) | 2585 | ±55 | 2613 |
| Wheelbase (inches) | 98 | ±5 | 102.4 |
| Front Overhang (inches) | 35 | ±4 | 32.5 |
| Overall Length (inches) | 169 | ±8 | 175.4 |
| Overall Width (inches) | 65 | ±3 | 66.7 |
| Hood Height (inches) | 28 | ±4 | 30.8 |
| Track Width ^b (inches) | 59 | ±2 | 58.4 |
| CG aft of Front Axle ^c (inches) | 39 | ±4 | 41.9 |
| CG above Ground ^{c,d} (inches) | N/A | N/A | N/A |

Table 7.7. Vehicle Measurements for Test 611801-04-1.

Note: N/A = not applicable; CG = center of gravity. ^a If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

^b Average of front and rear axles.

° For test inertial mass.

^d 2270P vehicle must meet minimum CG height requirement.

7.2.4. Test Description

Table 7.8 lists events that occurred during Test 611801-04-1. Figures E.4, E.5, and E.6 in Appendix E.2 present sequential photographs during the test.

| Time (s) | Events |
|----------|--|
| 0.0000 | Vehicle impacted installation |
| 0.0290 | Vehicle began to redirect |
| 0.0250 | Posts 25 and 26 began to lean toward field side |
| 0.0280 | Posts 27 and 28 began to lean toward field side |
| 0.0500 | Windshield began to fracture due to body flexing and torsion from the impact |
| 0.1800 | Vehicle was parallel with installation |
| 0.3240 | Vehicle exited the installation at 48 mi/h with a heading angle of 5.9 degrees and a trajectory angle of 4.5 degrees |

Table 7.8. Events during Test 611801-04-1.

7.2.5. Damage to Test Installation

The rails were scuffed at impact, and the traffic rail was deformed at post 27. The parapet was also scuffed. Table 7.9 provides the post soil gap and lean after the test. t/s: traffic side; f/s: field side

Table 7.10 describes the deflection and working width of the Box Beam to Concrete Barrier Transition. Figure 7.10 and Figure 7.11 show the damage to the Box Beam to Concrete Barrier Transition.

| Table 7.9. Post Soil Gap and Displacement of the Box Beam to Concrete Barrie |
|--|
| Transition for Test 611801-04-1. |

| Post # | Soil Gap | Post Lean from Vertical |
|--------|-------------------------|-------------------------|
| 23 | Soil Disturbed | 0.0° |
| 24 | ⅓-inch t/s & f/s | 0.3° |
| 25 | ⅓-inch t/s & ¼-inch f/s | 0.3° |
| 26 | ⅓-inch t/s & ¼-inch f/s | 0.4° |
| 27 | 1/4-inch f/s | 0.4° |
| 28 | ⅓-inch t/s | 0.3° |

t/s: traffic side; f/s: field side

| Table 7.10. Deflection and Working Width of the Box Beam to Concrete Barrier |
|--|
| Transition for Test 611801-04-1. |

| Test Parameter | Measured |
|---------------------------------------|--|
| Permanent Deflection/Location | 0.25 inches toward field side at post 27 |
| Dynamic Deflection | 1.3 inches toward field side, top of rail at post 26 |
| Working Width ^a and Height | 17.0 inches at a height of 32.0 inches, representing the top field side edge of the concrete barrier |

^a Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other

words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.



Figure 7.10. Box Beam to Concrete Barrier Transition at Impact Location after Test 611801-04-1.



Figure 7.11. Overall View of the Box Beam to Concrete Barrier Transition after Test 611801-04-1.

7.2.6. Damage to Test Vehicle

Figure 7.12 and Figure 7.13 show the damage sustained by the vehicle. Figure 7.14 and Figure 7.15 show the interior of the test vehicle. Table 7.11 and Table 7.12 provide details on the occupant compartment deformation and exterior vehicle damage. Figures E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.



Figure 7.12. Impact Side of Test Vehicle after Test 611801-04-1.



Figure 7.13. Door on the Impact Side of Test Vehicle after Test 611801-04-1.



Figure 7.14. Overall Interior of Test Vehicle after Test 611801-04-1.



Figure 7.15. Interior of Test Vehicle on Impact Side after Test 611801-04-1.

| Test Parameter | Specification | Measured |
|-------------------------------|----------------------------------|---|
| Roof | ≤4.0 inches | 0.0 inches |
| Windshield | ≤3.0 inches | Video shows cracking in the windshield due to the vehicle impacting the barrier, however, the majority of the windshield damage was from a secondary impact with an object not part of the test. This can be seen in the Real Time video. |
| A and B Pillars | ≤5.0 overall/≤3.0 inches lateral | 0.0 inches |
| Foot Well/Toe Pan | ≤9.0 inches | 1.0 inches |
| Floor Pan/Transmission Tunnel | ≤12.0 inches | 0.0 inches |
| Side Front Panel | ≤12.0 inches | 1.0 inches |
| Front Door (above Seat) | ≤9.0 inches | 3.0 inches |
| Front Door (below Seat) | ≤12.0 inches | 0.0 inches |

Table 7.11. Occupant Compartment Deformation 611801-04-1.

Table 7.12. Exterior Vehicle Damage 611801-04-1.

| Side Windows | The front side window on the impact side was shattered due to the flexing of the vehicle during impact, and not from contact with or penetration of the test article |
|--------------------------------------|---|
| Maximum Exterior Deformation | 10 inches in the front plate at the right front corner at bumper height. |
| VDS | 01RFQ5 |
| CDC | 01FREW3 |
| Fuel Tank Damage | None |
| Description of Damage to Vehicle: | The front bumper, hood, grill, right front strut and tower, right front tire and rim, right front quarter fender, right front door, right front floor pan, right rear door, right rear quarter fender, right rear rim, and right rear bumper were damaged. The right front door had a 5.25-inch gap at the top. From the video we can tell the windshield was cracked from the resultant vehicle body flexing due to the initial impact. After exiting the installation, the vehicle impacted a neighboring installation, which caused damage on the side opposite of impact with the target installation, and a rupture was also created in the windshield. The results of this secondary hit are not recorded in this report, with the exception of the vehicle damage photographs. |

7.2.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.13. Figure E.7 in Appendix E.3 shows the vehicle angular displacements, and Figures E.8 through E.10 in Appendix E.4 show acceleration versus time traces.

| Test Parameter | MASH ^a | Measured | Time |
|----------------------------|-------------------|-------------|---------------------------------|
| OIV, Longitudinal (ft/s) | ≤40.0 | 22.1 | 0.0798 seconds on right side of |
| | 30.0 | | interior |
| OIV, Lateral (ft/s) | ≤40.0 | 33.5 | 0.0798 seconds on right side of |
| | 30.0 | | interior |
| Ridedown, Longitudinal (g) | ≤20.49 | 3.6 | 0.0962 - 0.1062 seconds |
| | 15.0 | | |
| Ridedown, Lateral (g) | ≤20.49 | 7.2 | 0.1981 - 0.2081 seconds |
| | 15.0 | | |
| Theoretical Head Impact | N/A | 12.3 | 0.0786 seconds on right side of |
| Velocity (THIV) (m/s) | | | interior |
| Acceleration Severity | N/A | 2.7 | 0.0530 - 0.1030 seconds |
| Index (ASI) | | | |
| 50-ms Moving Avg. | | 10 - | |
| Accelerations (MA) | N/A | -12.7 | 0.0278 - 0.0778 seconds |
| | N 1/A | 40.0 | 0.0050 0.0750 / |
| 50-ms MA Lateral (g) | N/A | -19.8 | 0.0253 - 0.0753 seconds |
| 50-ms MA Vertical (g) | N/A | 4.3 | 0.0015 - 0.0515 seconds |
| Roll (deg) | ≤75 | 4.8 | 0.0468 seconds |
| Pitch (deg) | ≤75 | 4.7 | 0.2602 seconds |
| Yaw (deg) | N/A | 36.4 | 0.4401 seconds |

 Table 7.13. Occupant Risk Factors for Test 611801-04-1.

F. Values in italics are the preferred MASH values

7.2.8. Test Summary

Figure 7.16 summarizes the results of MASH Test 611801-04-1.

| | | | | | T / A | - | | | -1) |
|--|-------------------------|--|---------------------------------|------------------------------|--|--------------------------------|--|-----------------------|-------|
| | | | Test Agency | | lexas | A&M I rai | nsportation Institute (1) | 1) | |
| Test Standard/ | | | ndard/Test No. | MASH | 2016, Te | st 3-20 | | | |
| 4 | | TTI Project No. | | | 611801-04-1 | | | | |
| and the second | (Aller | | | | Test Date | 2023-0 | 3-23 | | |
| CARE AND AND | 1 stal | | TEST ART | ICLE | | | | | |
| | | | | Туре | Transition System | | | | |
| | | | | Name | Box Be | am to Co | oncrete Barrier Transitio | n | |
| | | Length | | | 165 ft 5 | inches | | | |
| 0.00 | 00 s | | Key Materials | | | 32-inch concret Steel tr | h-high concrete parapet and 60-inch wide ete deck. Steel box beam and rub rail. transition posts | | |
| | | | Soil Type and Condition | | | AASHT Concre | O M147- te | 17 Type 1 Grade D Cru | ushed |
| N. W. | ter) | N 10 | TEST VEH | IICLE | | 1 | | | |
| | No. | and the second | | Ty | pe/Designation | 1100C | | | |
| | | The second | Y | 'ear. M | ake and Model | 2017 N | issan Ve | rsa | |
| The second second | -27 | | | Ine | tial Weight (lb) | 2448 | | | |
| | and the second second | A real of the local distance of the local di | | | Dummy (lb) | 165 | | | |
| Contraction of the second | No. of Concession, Name | | | G | ross Static (lb) | 2613 | | | |
| 0.20 |)0 s | 100 million (100 million) | IMPACT C | | | 2010 | | | |
| 0.20 | | | | Impad | t Speed (mi/h) | 61.8 | | | |
| | | | | Impa | act Angle (deg) | 25.0 | | | |
| , , | | | | 59.7 in | 59.7 inches upstream from the end of the | | | | |
| the second second | | Impact Location co | | concret | e parape | t | | | |
| To late de | | Impact Severity (kip-ft) 55.8 | | | | | | | |
| | | EXIT CONDITIONS | | | | | | | |
| | | | Ex | it Speed (mi/h) | 48.0 | | | | |
| | | Trajectory/Heading Angle (deg) 4.5 / 5 | | | 4.5 / 5. | 9 | | | |
| Carlos and a second | | Exit Box Criteria Vehicle | | | Vehicle | did not d | cross the exit box. | | |
| | | Stopping Distance 118 ft | | 118 ft c | lownstrea | am | | | |
| 0.400 s | | | 510 | pping Distance | 7 ft to t | he traffic | side | | |
| | | | TEST ART | | DEFLECTIONS | | | | |
| | | - | Dynamic (inches) | | | 1.3 | | | |
| the second and | | - | Permanent (inches) | | 0.25 | | | | |
| | K | | Working Width / Height (inches) | | | 17.0/3 | 32.0 | | |
| | Nor . | Contraction of the | VEHICLE DAMAGE | | | | | | |
| 115 | 1 Martin | | VDS | | 01RFQ | 5 | | | |
| | | the total | CDC | | 01FRE | 01FREW3 | | | |
| Contraction of the second | and the second | and the second s | Max. Ext. Deformation (inches) | | 10 | 10 | | | |
| 0.600 s | | Max Oc | cupan | t Compartment Deformation | 3 inche | s in the s | ide panel | | |
| | | | 000 | UPAN | RISK VALUES | 5 | | | |
| Long. OIV (ft/s) | 22.1 | Long. Ride | down (g) | 3.6 | Max 50-ms Lo | ng. (g) | -12.7 | Max Roll (deg) | 4.8 |
| Lat. OIV (ft/s) | 33.5 | Lat. Rided | own (g) | 7.2 | Max 50-ms La | t. (g) | -19.8 | Max Pitch (deg) | 4.7 |
| THIV (m/s) | 12.3 | ASI | (0) | 2.7 | Max 50-ms Ve | ert. (g) | 4.3 | Max Yaw (deg) | 36.4 |
| 7' T T T T T T T T T T T T T | | | 2 | | 20 14 0 Section A.A Section B.B Section B.B Se | | | | |

Figure 7.16. Summary of Results for *MASH* Test 3-20 on Box Beam to Concrete Barrier Transition.

7.3. MASH TEST 3-21 (CRASH TEST 611801-04-2)

7.3.1. Test Designation and Actual Impact Conditions

See Table 7.14 for details of impact conditions for this test and Table 7.15 for the exit parameters. Figure 7.17 and Figure 7.18 depict the target impact setup.

Table 7.14. Impact Conditions for MASH TEST 3-21, Crash Test 611801-04-2.

| Test Parameter | Specification | Tolerance | Measured |
|--------------------------|--|-------------|---|
| Impact Speed (mi/h) | 62 | ±2.5 mi/h | 62.1 |
| Impact Angle (deg) | 25 | ±1.5° | 25.0 |
| Impact Severity (kip-ft) | 106 | ≥106 kip-ft | 116.3 |
| Impact Location | 84 inches upstream from the edge of the concrete parapet | ±12 inches | 83.8 inches upstream from the end of the concrete parapet |

| Table 7.15. Exit Parameters f | for MASH TEST 3-21, | Crash Test 611801-04-2. |
|-------------------------------|---------------------|-------------------------|
|-------------------------------|---------------------|-------------------------|

| Exit Parameter | Measured |
|--------------------------------|--|
| Speed (mi/h) | 52.1 |
| Trajectory angle (deg) | 4.1 |
| Heading angle (deg) | 8.1 |
| Brakes applied post impact (s) | 2.2 |
| Vehicle at rest position | 193 ft downstream of impact point17 ft to the traffic side60° right |
| Comments: | Vehicle remained upright and stable Vehicle crossed the exit box 57 feet downstream from loss of contact |

^a Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.



Figure 7.17. Box Beam to Concrete Barrier Transition/Test Vehicle Geometrics for Test 611801-04-2.



Figure 7.18. Box Beam to Concrete Barrier Transition/Test Vehicle Impact Location 611801-04-2.

7.3.2. Weather Conditions

Table 7.16 provides the weather conditions for 611801-04-2.

| Date of Test | 2023-03-30 AM |
|-------------------------|---------------|
| Wind Speed (mi/h) | 11 |
| Wind Direction (deg) | 156 |
| Temperature (°F) | 70 |
| Relative Humidity (%) | 90 |
| Vehicle Traveling (deg) | 195 |

 Table 7.16. Weather Conditions 611801-04-2.

7.3.3. Test Vehicle

Figure 7.19 and Figure 7.20 show the 2017 RAM 1500 used for the crash test. Table 7.17 shows key vehicle measurements. Figure F.1 in Appendix F.1 gives additional dimensions and information on the vehicle.



Figure 7.19. Impact Side of Test Vehicle before Test 611801-04-2.



Figure 7.20. Opposite Impact Side of Test Vehicle before Test 611801-04-2.

| Test Parameter | MASH | Allowed Tolerance | Measured |
|--|------|----------------------|----------|
| Dummy (if applicable) ^a (lb) | 165 | N/A | N/A |
| Test Inertial Weight (lb) | 5000 | ±110 | 5051 |
| Gross Static Weight ^a (lb) | 5000 | ±110 | 5051 |
| Wheelbase (inches) | 148 | ±12 | 140.5 |
| Front Overhang (inches) | 39 | ±3 | 40.0 |
| Overall Length (inches) | 237 | ±13 | 227.5 |
| Overall Width (inches) | 78 | ±2 | 78.5 |
| Hood Height (inches) | 43 | ±4 | 46.0 |
| Track Width ^b (inches) | 67 | ±1.5 | 68.25 |
| CG aft of Front Axle ^c (inches) | 63 | ±4 | 61.7 |
| CG above Ground ^{c,d} (inches) | 28 | ≥28 | 28.6 |

Table 7.17. Vehicle Measurements 611801-04-2.

Note: N/A = not applicable; CG = center of gravity. ^a If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

^b Average of front and rear axles.

° For test inertial mass.

^d 2270P vehicle must meet minimum CG height requirement.

7.3.4. Test Description

Table 7.18 lists events that occurred during Test 611801-04-2. Figures F.4, F.5, and F.6 in Appendix F.2 present sequential photographs during the test.

| Time (s) | Events |
|----------|--|
| 0.0000 | Vehicle impacted installation |
| 0.0320 | Vehicle began to redirect |
| 0.0170 | Posts 23 thru 27 began to lean toward field side |
| 0.0230 | Posts 28 began to lean toward field side |
| 0.1660 | Vehicle was parallel with installation |
| 0.2890 | Vehicle exited the installation at 52.1 mi/h with a heading angle of 8.2 degrees and a trajectory angle of 4.1 degrees |

Table 7.18. Events during Test 611801-04-2.

7.3.5. Damage to Test Installation

The box-beam and rub rail were scuffed and deformed at the impact location. Table 7.19 describes the post soil gap and lean after the test. Table 7.20 describes the deflection and working width of the Box Beam to Concrete Barrier Transition. Figure 7.21 and Figure 7.22 show the damage to the Box Beam to Concrete Barrier Transition.

 Table 7.19. Post Soil Gap and Displacement of the Box Beam to Concrete Barrier

 Transition for Test 611801-04-2.

| Post # | Soil Gap | Post Lean from Vertical |
|--------|--|-------------------------|
| 21 | Soil Disturbed | 0.0° |
| 22 | ¼-inch t/s & ⅓ f/s | 0.5° |
| 23 | ¼-inch t/s & ⅓ f/s | 1.0° |
| 24 | ³ ⁄ ₄ -inch t/s & ³ ⁄ ₈ - inch f/s | 1.0° |
| 25 | 1/2-inch t/s & 1/4-inch f/s | 1.1° |
| 26 | 5∕₅-inch t/s & ⅔-inch f/s | 1.3° |
| 27 | Soil Disturbed | 1.0° |
| 28 | Soil Disturbed | 1.0° |

t/s: traffic side; f/s: field side

Table 7.20. Deflection and Working Width of the Box Beam to Concrete BarrierTransition for Test 611801-04-2.

| Test Parameter | Measured |
|---------------------------------------|--|
| Permanent Deflection/Location | 1 inch toward field side, between posts 25 and 26 |
| Dynamic Deflection | 2.5 inches toward field side, at the top of the rail at post 26 |
| Working Width ^a and Height | 22.4 inches, at a height of 49.0 inches, corresponding to the vehicle side view mirror |

^a Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other

words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.



Figure 7.21. Box Beam to Concrete Barrier Transition at Impact Location after Test 611801-04-2.



Figure 7.22. Overall View of the Box Beam to Concrete Barrier Transition after Test 611801-04-2.

7.3.6. Damage to Test Vehicle

Figure 7.23 and Figure 7.24 show the damage sustained by the vehicle. Figure 7.25 and Figure 7.26 show the interior of the test vehicle. Table 7.21 and Table 7.22 provide details on the occupant compartment deformation and exterior vehicle damage. Figures F.2 and F.3 in Appendix F.1 provide exterior crush and occupant compartment measurements.



Figure 7.23. Impact Side of Test Vehicle after Test 611801-04-2.



Figure 7.24. Rear Impact Side of Test Vehicle after Test 611801-04-2.



Figure 7.25. Overall Interior of Test Vehicle after Test 611801-04-2.



Figure 7.26. Interior of Test Vehicle on Impact Side after Test 611801-04-2.

| Test Parameter | Specification | Measured |
|-------------------------------|----------------------------------|------------|
| Roof | ≤4.0 inches | 0.0 inches |
| Windshield | ≤3.0 inches | 0.0 inches |
| A and B Pillars | ≤5.0 overall/≤3.0 inches lateral | 0.0 inches |
| Foot Well/Toe Pan | ≤9.0 inches | 3.0 inches |
| Floor Pan/Transmission Tunnel | ≤12.0 inches | 0.0 inches |
| Side Front Panel | ≤12.0 inches | 0.0 inches |
| Front Door (above Seat) | ≤9.0 inches | 2.0 inches |
| Front Door (below Seat) | ≤12.0 inches | 0.0 inches |

 Table 7.21. Occupant Compartment Deformation 611801-04-2.

Table 7.22. Exterior Vehicle Damage 611801-04-2.

| Side Windows | The side windows remained intact |
|-----------------------------------|--|
| Maximum Exterior Deformation | 14 inches in the front plane at the right front corner at bumper height |
| VDS | 01RFQ4 |
| CDC | 01FREW3 |
| Fuel Tank Damage | None |
| Description of Damage to Vehicle: | The front bumper, hood, grill, right and left headlights, radiator and support, right front quarter fender, right front door, right front floor pan, right rear door, right cab corner, right rear quarter fender, right rear tire and rim, and rear bumper were damaged. The fright front door had a 7-inch gap at the top. |

7.3.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.23. Figure F.7 in Appendix F.3 shows the vehicle angular displacements, and Figures F.8 through F.10 in Appendix F.4 show acceleration versus time traces.

| Test Parameter | MASH ^a | Measured | Time | | | |
|----------------------------|-------------------|------------------------------|---------------------------------|--|--|--|
| OIV, Longitudinal (ft/s) | ≤40.0 | 16.4 | 0.0925 seconds on right side of | | | |
| | 30.0 | | interior | | | |
| OIV, Lateral (ft/s) | ≤40.0 | 31.8 | 0.0925 seconds on right side of | | | |
| | 30.0 | | interior | | | |
| Ridedown, Longitudinal (g) | ≤20.49 | 5.0 | 0.1613 – 0.1713 seconds | | | |
| | 15.0 | | | | | |
| Ridedown, Lateral (g) | ≤20.49 | 11.5 0.2142 – 0.2242 seconds | | | | |
| | 15.0 | | | | | |
| THIV (m/s) | N/A | 10.9 | 0.0909 seconds on right side of | | | |
| | | | interior | | | |
| ASI | N/A | 2.2 | 0.0643 – 0.1143 seconds | | | |
| 50-ms MA Longitudinal (g) | N/A | -8.7 | 0.0449 – 0.0949 seconds | | | |
| 50-ms MA Lateral (g) | N/A | -17.5 | 0.0423 – 0.0923 seconds | | | |
| 50-ms MA Vertical (g) | N/A | 3.6 | (0.1615 - 0.2115 seconds) | | | |
| Roll (deg) | ≤75 | 30.6 | 0.6239 seconds | | | |
| Pitch (deg) | ≤75 | 4.1 | 0.5445 seconds | | | |
| Yaw (deg) | N/A | 49.4 | 1.1732 seconds | | | |

 Table 7.23. Occupant Risk Factors for Test 611801-04-2.

F. Values in italics are the preferred MASH values

7.3.8. Test Summary

Figure 7.27 summarizes the results of MASH Test 611801-04-2.

| | | | Test Agency Texa | | | | exas A&M Transportation Institute (TTI) | | | | | |
|--|---------|--|---|--------------------|--|-----------|---|---|------|--|--|--|
| E. | | andard/Test No. | MASH 2016, Test 3-21 | | | | | | | | | |
| | | | | TTI Project No. | 611801-04-2 | | | | | | | |
| | | | | Test Date | 2023-03-30 | | | | | | | |
| | | | TEST ARTICLE | | | | | | | | | |
| | | Туре | Transition System | | | | | | | | | |
| | | | | Name | Box Beam to Concrete Barrier Transition | | | | | | | |
| of Balling | Length | | | 165 ft 5 inches | | | | | | | | |
| 0.00 | | Key Materials | 32-inch-high concrete parapet and 60-inch wide concrete deck. Steel box beam and rub rail. Steel transition posts | | | | | | | | | |
| | | | | e and Condition | AASHTO M147-17 Type 1 Grade D Crushed Concrete | | | | | | | |
| | | | TEST VE | HICLE | | 1 | | | | | | |
| | | | Type/Designation 22 | | | | 2270P | | | | | |
| | | | Year, Make and Model | | | | 2017 RAM 1500 | | | | | |
| | | | | ertial Weight (lb) | 5051 | 5051 | | | | | | |
| A STREET | | and the second second | | Dummy (lb) | N/A | | | | | | | |
| State of the local division of the local div | | Concession of the local division of the loca | | | Gross Static (lb) | 5051 | 5051 | | | | | |
| 0.20 | 0 s | | IMPACT | CONDI | TIONS | | | | i i | | | |
| | | | | act Speed (mi/h) | 62.1 | | | | | | | |
| | | pact Angle (deg) | 25.0 | | | | | | | | | |
| | | | | Impact Location | 83.8 inches upstream from the end of the concrete parapet | | | | | | | |
| | | | Impact Severity (kip-ft) 116.3 | | | | | | | | | |
| | EXIT CO | NDITIO | NS | | | | | | | | | |
| | | | | xit Speed (mi/h) | 52.1 | | | | | | | |
| | | | Trajectory/Heading Angle (deg) | | | 4.1 / 8.1 | | | | | | |
| | | | Exit Box Criteria | | | | Vehicle crossed the exit box 57 feet downstream from loss of contact | | | | | |
| 0.400 s | | | Stopping Distance | | | | 193 ft downstream 17 ft to the traffic side | | | | | |
| | | | TEST ARTICLE DEFLECTIONS | | | | | | | | | |
| | | | | ynamic (inches) | 2.5 | | | | | | | |
| | | | | manent (inches) | 1 | | | | | | | |
| | | | Working Width / Height (inches) 2 | | | | 22.4 / 49.0 | | | | | |
| | | | VEHICLE | E DAMA | GE | ī | | | | | | |
| | | | | VDS | 01RFQ4 | | | | | | | |
| | | | | CDC | 01FREW3 | | | | | | | |
| A 1 1 1 | | | Max. Ext. Deformation (inches) | | | 14 | | | | | | |
| 0.600 s | | | Max Occupant Compartment Deformation | | | | 3 inches in the right toe pan | | | | | |
| | | | 000 | CUPAN | FRISK VALUES | | | | | | | |
| Long. OIV (ft/s) | 16.4 | Long. Ride | down (g) | 5.0 | Max 50-ms Long | g. (g) | -8.7 | Max Roll (deg) | 30.6 | | | |
| Lat. OIV (ft/s) | 31.8 | Lat. Rided | own (g) 11.5 | | Max 50-ms Lat. (g) | | -17.5 | Max Pitch (deg) | 4.1 | | | |
| THIV (m/s) | 10.9 | ASI | | 2.2 | 2.2 Max 50-ms Vert. | | 3.6 | Max Yaw (deg) | 49.4 | | | |
| 193' | | | | | | ₽ | | 28° 4 28° 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 | - | | | |
| Heading Angle | | | | | | | 30° T Section B-B Sect 1:20 Typ @ Pees 2 - 15 | | | | | |

Figure 7.27. Summary of Results for *MASH* Test 3-21 on Box Beam to Concrete Barrier Transition.
Chapter 8. SUMMARY AND CONCLUSIONS

8.1. ASSESSMENT OF TEST RESULTS AND CONCLUSIONS FOR THE CONCRETE PARAPET SHAPE TRANSITION

The crash tests reported in Chapter 6 were performed in accordance with *MASH*TL-3 on the Concrete Parapet Shape Transition.

Table 8.1 shows that the Concrete Parapet Shape Transition met the performance criteria for *MASH* TL-3 longitudinal barriers.

| Evaluation Criteria | Description | Test 611801-03-1 | Test 611801-03-2 |
|------------------------|---|---------------------|---------------------|
| А | Contain, Redirect, or Controlled Stop | S | S |
| D | No Penetration into Occupant Compartment | S | S |
| F | Roll and Pitch Limit | S | S |
| Н | OIV Threshold | S | S |
| Ι | Ridedown Threshold | S | S |
| Overall | Summary | Pass | Pass |

Table 8.1. Assessment Summary for MASH TL-3 Tests on the Concrete Parapet Shape Transition.

Note: S = Satisfactory; N/A = Not Applicable. ¹See Table 4.2 for details

8.2. ASSESSMENT OF TEST RESULTS AND CONCLUSIONS FOR THE BOX **BEAM TRANSITION TO CONCRETE PARAPET**

The crash tests reported in Chapter 7 were performed in accordance with MASHTL-3 on the Box Beam Transition to Concrete Parapet.

Table 8.1 shows that the Box Beam Transition to Concrete Parapet met the performance criteria for MASH TL-3 longitudinal barriers.

| Evaluation Criteria | Description | Test 611801-04-1 | Test 611801-04-2 |
|------------------------|---|---------------------|---------------------|
| A | Contain, Redirect, or Controlled Stop | S | S |
| D | No Penetration into Occupant Compartment | S | S |
| F | Roll and Pitch Limit | S | S |
| Н | OIV Threshold | S | S |
| I | Ridedown Threshold | S | S |
| Overall | Summary | Pass | Pass |

Table 8.2. Assessment Summary for MASHTL-3 Tests on the Box Beam Transition to Concrete Parapet.

Note: S = Satisfactory; N/A = Not Applicable. ¹See Table 4.2 for details

Chapter 9. IMPLEMENTATION

This research was a step in WYDOT's efforts to implement MASH to enhance roadside safety and reduce the severity of run-off-road crashes in Wyoming. Specifically, this project addressed the development of a stiffness transition from box beam guardrail to a vertical concrete parapet, and a shape transition of the vertical concrete parapet to a New Jersey profile concrete parapet.

Two different shape transitions were designed and evaluated through finite element impact simulations. These included a 32-inch-tall vertical concrete parapet to a 42-inch-tall single slope concrete parapet, and a 32-inch-tall vertical concrete parapet to a 32-inch-tall New Jersey concrete parapet. MASH criteria were satisfied for both transition systems. The shape transition from vertical to New Jersey profile was selected for full-scale crash testing based on being the more critical of the two shape transitions.

MASH Test 3-20 and Test 3-21 were successfully performed on the Concrete Parapet Shape Transition from vertical to New Jersey profile. The shape transition was accomplished over a length of 6 ft, providing a concrete transition parapet with an overall length of 9 ft including a 3-ft length of vertical parapet for connection of the box beam transition rails. Based on successful finite element simulation and the successful testing of the more critical shape transition from vertical to New Jersey profile, the shape transition from vertical to single slope profile is also considered MASH compliant.

MASH Test 3-20 and Test 3-21 were successfully performed on the downstream end of the box beam guardrail stiffness transition to vertical concrete parapet. It was initially planned for the design details of the upstream end of the transition to be similar to those of the MASH compliant box beam stiffness transition to C2P bridge rail that was developed under Phase I of this research (2). However, during the transition design process, the rubrail size in the box beam transition to vertical concrete parapet was changed from HSS6x2 to HSS4x3 to address stability concerns with the pickup truck observed in the impact simulations.

The other design details and rubrail termination methods used for the HSS4×3 rubrail were like those used in the successfully crash tested box beam transition with HSS6×2 rubrail (2). Additionally, MASH Test 3-20 and Test 3-21 impact simulations were performed on the upstream end of the box beam stiffness transition system with the HSS4x3 rubrail. Both simulations satisfied MASH criteria.

Based on the successful crash testing of a similar upstream transition, and successful MASH impact simulations on the upstream transition with HSS4x3 rubrail, the research team considers the upstream end of the box beam transition to vertical concrete parapet to be MASH compliant. Consequently, the box beam stiffness transition to vertical concrete parapet is considered MASH compliant.

The results of the research can be implemented through issuance of new or updated WYDOT standard plans. This will make the new MASH transition available for use in highway project plans and lettings. Specifically, the MASH box beam transition will supersede Standard Plan 606-6A—Transitions C&D to Concrete Barrier.

Detailed drawings developed for the Concrete Parapet Shape Transitions and box beam guardrail stiffness transition to vertical concrete parapet under this research project can serve as the basis for updating the relevant standard plans. Drawings for the box beam guardrail stiffness transition to vertical concrete parapet and concrete parapet shape transition from vertical to New Jersey profile are presented in Section A.2 in Appendix A. Drawings for the concrete parapet shape transition from vertical to single slope parapet are presented in Appendix G.

REFERENCES

- 1. AASHTO. *Manual for Assessing Roadside Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
- Bligh, R. P., Sheikh, N. M., Schulz, N. D., Kovar, J., Menges, W. L., Schroeder, W., Griffith, B. L., and Wegenast, S., *Development of Approach Guardrail Transition for Box Beam Guardrail System and MGS*, Report No. 611801-02, Wyoming Department of Transportation, Cheyenne, WY, May 2022.

APPENDIX A. DETAILS OF THE CONCRETE PARAPET SHAPE TRANSITION AND THE BOX BEAM TRANSITION TO CONCRETE PARAPET

A.1. DETAILS OF CONCRETE PARAPET SHAPE TRANSITION



Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing

66



Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing



Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing







Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing





Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing



106











2023-12-06



- 1-3/8"

19"

Ø 5/8" x 2 Traffic Side flange

Ø 5/8" x 2

Field Side flange

2.330

3.000

----.170

Roadside Safety and Physical Security Division -Proving Ground

Sheet 11 of 21 S3x5.7 Posts

2022-09-14

25"

۲

Section M-M Scale 1:5

11c. Galvanize all components after fabrication is complete.

Type R Post

Elevation View

See 11d

11d. All other details same as Type A Post.

Project #611801-03 Wyoming Box Beam Transition

Texas A&M Transportation

Scale 1:10

Institute

industry standard practices.

Drawn by GES

Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing

1/8

Type A Post

Elevation View

64"

Plate, 8" x 1/4" x 24"

ASTM A36



Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing









Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing





Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing





Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing



Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing



117

2023-12-06



118





A.2. DETAILS OF BOX BEAM TRANSITION TO CONCRETE PARAPET



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing





2023-03-22

Drawn by GES Scale 1:100 Sheet 3 of 21 Transition Detail Views

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



125



126

TR No. 611801-03 & -04

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing


S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing









S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing

TR No. 611801-03 & -04

130









S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing







APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

| Charr Charr Charr Charr Charr Charr Charr Contains Contains in With Charles Contains no weld repair contains no weld repair votatins no Mercuny cont anufactured in accordant anufactured in accordant a | Iue 71 1:1ksi 1:1ksi <th></th> <th>Characteristic Elongation Gage Lgth tes Yield to tensile ratio te Yield Strength tes Tensile Strength tes Elongation Gage Lgth tes Yield to tensile ratio tes Yield to tensile ratio tes</th> <th></th> <th>Value 0.15% 0.0.69% 0.0.17% 0.0.22% 0.14% 0.0.36% 0.14% 0.004% 0.004% 0.0003% 0.0012% 0.0003% 0.0003% 0.00012% 0.0003%</th> <th>Characteristic C Mn P S S Si Cu Cr Ni Cu Cr Ni Cu Cr Ni Ni Cu Cr Ni Ni Ni Sn B Ti Ni Cu Cr Sn B Ti Ni Ni Sn B Ti Ni Si Si Si Si Si Si Si Si Si Si Si Si Si</th> <th>HEAT: 1076655</th> | | Characteristic Elongation Gage Lgth tes Yield to tensile ratio te Yield Strength tes Tensile Strength tes Elongation Gage Lgth tes Yield to tensile ratio tes Yield to tensile ratio tes | | Value 0.15% 0.0.69% 0.0.17% 0.0.22% 0.14% 0.0.36% 0.14% 0.004% 0.004% 0.0003% 0.0012% 0.0003% 0.0003% 0.00012% 0.0003% | Characteristic C Mn P S S Si Cu Cr Ni Cu Cr Ni Cu Cr Ni Ni Cu Cr Ni Ni Ni Sn B Ti Ni Cu Cr Sn B Ti Ni Ni Sn B Ti Ni Si Si Si Si Si Si Si Si Si Si Si Si Si | HEAT: 1076655 |
|--|---|--|---|---|--|---|---|
| 55588 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 | sel Steel Distributors LP 10 W Little York Rd 1ston TX 17041-4917 3379500 6977335 | S Inte H 113 P Hou US T 713 0 713 | el Distributors LP Little York Rd TX -4917 00 | Intsel Stee 11310 W L Houston US 77041- 713937950 71369773 | | ANG 3 1/2 X 3 1/2x3/8 40 ANG 3 1/2 X 3 1/2x3/8 40 STM A36-19/A529-14 Gr 1 E: 11/13/2021 E: 11/11/2021 E: 11/11/2021 E: 11/11/2021 | Order WL SECTION: J GRADE: AS ROLL DATE MELT DATE Cert. No.: 8 |
| a hereby certify rate and confor Marcus W. P | ORT are accur. | oies call | CERTIFIED MILL TE For additional cop 800-637-3227 | A 2-3525 | EL ALABAM H STREET HAM AL 3521 | CMC STE 101 S 50T BIRMING | Y-102557-3 Page:1 |

| STANDARD "I" BEAM A 992 3 X 5.7# X 20' | | PO/REL W HEAT | /LY-22-273 : 2118669 | 80/ | | | C | BL WLY-570445-6 | 9/9/2022 | |
|---|-----------------------|---|--|--|--|------------------|----------------|--|----------|--|
| 018.2880m | .4x22 060' 00.00" | 14x22 045 00.00* 9360X32.9 013.7160m | 3X5.7 040,00.00 375X8.5 012.1920m | ascription 1 | APSHID : MO ARSHID : MO ASIME : SA-I ASIME : SA-I CSA : C40.2 | | Sold Io: | JCOR SIFEL - 155 Hagan Av 19er, SC 294 Lone: (843) | | |
| ed on 8' (20. 3',881;1',20; ((cr+Me+V)/5)',5', ((cr+Me+V)/5)',5', est hat the con est results an ce in complian d by the purch | 2119019 A992-11(15 | 1119065 R992-11(15 | 2118669 A992-11(15 | Heat# Grade(s) Cest/Heat JW | S: Tested in a Quality Man 270-345M270-50 36 13 2-11(15:/P36-1 21-44w/G40.21- 21-44w/G40.21- | EDUSION, IX | PO BOX 21119 | BERRELEY enue 50 336-6000 | | |
| .83 .22cm) gass f(Sit+1.45Sit+1.45Sit+1.45Sit+1.45Sit+1.45Sit+1.45 f(Sit+1.45Sit+1.45) f(S | -85 | .86 | .81 | Yield/ Tensile Ratio | -19 9/A529-1 50w/G40. | 77226 | ISTRIBUT | | | |
| 60200 (1799-1990-(1719-2199-(1719-2199-(1719-2199-(1719-2199-(1719-1719))))))))))))))))))))))))))))))) | 60400 | 57900 399 59400 410 | 53700 370 58000 400 | (PSI) (MPA) | e vith A #16 (4-3 9-50/A57 2150VM | | ORS | | | |
| 1,200 1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2,1,2 | 70900 2 | 69700 3 481 69000 2 476 | 65900 454 70800 488 | (psile (Mpa) | STM spec 0-21). 2502111, | | | 10 | | |
| 8.07 Weid Reg ications 6 accura 6 accura by the m pecifica | 7.22 | 11.03 15.40 54 Pc(s | 29.00 24.63 105 Pc(s | flong | cificati. /A7093618 | | Ship | ERIIFIED | | |
|) 95,04 ======== =========================== | | .07 .03 .03 .03 | .07 | *** | on A6/A61 3/A709503 | SIDE SIDE | IO: INTS | MILL TE | | |
| Qual the second | 83 | 0.004 1001 | .01 155 | Mn Mo | M-19 and 18 | 06728 ION, IX | EL STEEL | SI REPOR tructura nd hot r | | |
| Customer 1) d. (All 1) d. (All 1) depart 1) depart CE2 2 CE2 1) depart CE2 | .008 | .013 .0045 Customer | .016 .0046 Customer | | A370, Ie | 77041 | DIST E YORK | I section blied to tintent | | |
| PG: WIY | .019 | .022 .0002 | .021 .0002 | ж ж ж ж к с с с с с с с с с с с с с с с | sted in | | | 1014 1014 1014 1014 1014 1014 1014 1014 | | |
| 2730 2737 al tosti which is Sl)/6)+(| | .201 .001 .001 .004 | .002 | N A ST. | accordan | | | EAF MEL ed by Nu killed a | | |
| (Cr+Mo+V | .14 | .08 .028 .028 | .09 .015 BoI#: 15 | Cu | te with E | B.o.I. | Custon | any poir | | |
| -cb)/5)+((| .04 | 96845 96845 | 96846 | XXXXX XXXXXX CI | N10204-20 | #: 15 | Ner #.: 1 | AANUFACIUR Jrain prac ut during | | |
| 1274 1 the Quality 1 production 1 the Logical to 1 the 1 the | .23 | .2296 | .24 .2750 .1319 | CE1 | 04-3.1. | 96846 MOS; | 864 - 25 | 723/21 6:31; RED IN THE US CASE TICO. | | |
| | | | | | | R | | | | |

l

| STANDARD "I" BEAM A 992 3 X 5.7# X 20' | PO/REL WLY-22-2730/ HEAT: 2118669 | BL WLY-570445-6 9/9/2022 Order WLY-102557-6 Page:2 |
|---|---|---|
| <pre>impact ====================================</pre> | CSA : C40.21_44V/C40.21_504/ 3 Heat(5) for this MIR. | UCDR SIEL - BERKILEY 455 Hagen Avenue 455 Hagen Avenue uger, SC 29450 honei (843) 336-6000 honei (843) 336-6000 HOUSICK SIEL DISIRIBUTORS 90 BOX 21119 HOUSICK, IX 77226 PECIFICATIONS: Tested in accordance with PSIP ASME : SA-16 13 PSET 1620-1115-036 10-0510 10 50/0510 50 |
| <pre>h. 'No Weld Repair' was peformed, 'All mechanical resting is performed by the quality .29CuNNi)-(9.10NiNp)-33.39(CuNcu) testing lab, which is independent of the production departments:</pre> | | CERTIFIED MILL IEST REPORI 100% EAF MELTED AND MANUFACTURED IN THE USA and hot colled to a fully Mucor-Backeley are cast and hot colled to a fully Mucor-Backeley are cast. 11/23/21 6:31:40 Structural sections produced by Mucor-Backeley are cast. and hot colled to a fully Miled and file grain practice. Mercury not intentionally added at any point during manufacturing. Ship To: INTSEL STEEL DIST Customer H: 1864 - 25 ZIS 06728 Customer H: HOUSIDN, IN 77041 TM Specification R6/R6M-19 and R370. Tested in accordance with EN10204-2004-3.1. |
| | | |

| 14-22-2022 06:02 Load - 4062865 Brazos Industries LLC Cust. PO - | BL - 3916345 Heat - SM1278 Order - 21304494 | blr466 |
|---|---|--------|
| TUBULAR PRODUCTS | 6226 W. 74TH STREET https://www.nucortubular.com CHICAGO, IL 60638 https://www.nupportal.com Tel: 708-563-1950 Certificate Number: DCR 752830 | |
| Sold By: NUCOR TUBULAR PRODUCTS INC. DECATUR DIVISION 2000 INDEPENDENCE AVENUE N.W. DECATUR, AL 35601 Tel: 256 340-7420 Fax: 256 340-7415 | Purchase Order No: 7722972 Sales Order No: DCR 145113 - 16 Bill of Lading No: DCR 105846 - 5 Invoice No: Invoiced: | |
| Sold To: 1187 - KLOECKNER METALS - BUDA/HOUS 500 COLONIAL PARKWAY SUITE 500 ROSWELL, GA 30076 | Ship To: STON 1 - KLOECKNER METALS CORP HOUSTON 14200 ALMEDA ROAD 713-433-7211 HOUSTON, TX 77053 | |
| CERTIFICATE of ANALYSIS and Customer Part No: TUBING A500 GRADE B(C) 5" SQ X 1/4" X 48' | Certificate No: DCR 752830 Test Date: 3/14/2022 Total Pieces Total Weight Lbs 16 11,996 | |
| Bundle Tag Mill Heat Specs 622415 40N NM0839 YLD=6800 622452 40N SM1278 YLD=6410 Mill #: 40N Heat #: NM0939 Carbon Eq: 0.2 | Y/T Ratio Pieces Weight Lbs 00/TEN=77200/ELG=26 0.8808 12 8,997 00/TEN=77000/ELG=30 0.8325 4 2,999 | |
| C Mn P S Si 0.0600 0.9700 0.0080 0.0020 0.194 B Ti Ca | Al Cu Cr Mo V Ni Nb N 0 0.0180 0.1000 0.0600 0.0200 0.0050 0.0300 0.0240 0.0073 | |
| Output Output< | AI Cu Cr Mo V Ni Nb N | |
| B Ti Ca 0.0003 0.0010 0.0019 T/R FAX | 0 0.0270 0.1400 0.0600 0.0200 0.0020 0.0500 0.0070 0.0074 | |
| Certification: I certify that the above results are a true and co PRODUCTS INC. Sworn this day, 3/14/2022. THE SPECIFICATIONS LISTED BELOW BEP | prrect copy of records prepared and maintained by NUCOR TUBULAR | |
| CURRENT ISSUED DATES OF THESE STAN DOES NOT INDICATE THAT THE MATERIAL TO EACH OR ALL OF THE STANDARDS. WE MATERIAL ABOVE TO THE SPECIFICATION LINE DESCRIPTION. | ABOVE CONFORMS CERTIFY THE LISTED IN THE Are heaving | |
| CURRENT STANDARDS: A252-19 A500/A500/A-21 A513/A513M-20 ASTM A53/A53M-20 ASME SA-53/SA-53M-20 A847/A847M-14 A1085/A1085M-15 IN COMPLIANCE WITH EN 10204 SECTION 4 | Nora Oukajji Metallurgist/Quality Supervisor | |
| INSPECTION CERTIFICATE TYPE 3.1 | Page - 1 | |
| | | |

| | Bend Test 1 Passed | Tensile to Yield ratio test1 1.61 | Elongation Gage Lgth test 1 8IN | Elongation test 1 15% | Tensile Strength test 1 108.6ks | Yield Strength test 1 67.6ksi | | AI 0.002% | Sn 0.010% | Cb 0.000% | V 0.000% | Mo 0.054% | Ni 0.15% | Cr 0.09% | Cu 0.39% | Si 0.17% | S 0.049% | P 0.013% | Mn 0.80% | C 0.46% | Characteristic Value | Sert. No.: 83714603 / 111040A619 | VIELI DATE: 12/04/2021 | MELT DATE: 12/01/2021 | ROLL DATE: 19/11/20091 | GRADE: ASTM A615-20 Gr 420/60 | SECTION: REBAR 19MM (#6) 20'0" 420/60 | HEAT NO -3111040 | (und | SEGUIN TX 7815 |
|-------------------|---|---|---|--|---------------------------------|--|--------------------------|----------------|---------------------|-----------------------------|-----------------|--|----------|----------|----------|----------|----------|----------|----------|---------------|----------------------|----------------------------------|-----------------------------|-----------------------|------------------------|-------------------------------|---------------------------------------|------------------------------------|------------------|--|
| | | | | | <u>.</u> | | | | 0 | 0 | 0 | 0 | | | | | 0. | 0. | | | | - O | | C | | - (| 0 0 | 0 | | 5-7510 |
| | | | | | | | | | | | | | | | | | | | | Bend Test Dia | Characteristic | 79 774 5900 | 5 //845-/950 | onege station IX | Subsection TV | DRED State Hun 20 | INC COnstruction SVCS College Stati | MC Construction Suce College Stati | | 830-372-8 |
| | | | | | | | | | | | | | | | | | | | | imeter | Value | F O | | 7 | , - | - = | E U | 0 | ~ | 1771 |
| to www.P6 | or other re | known to | *Warning: | *Meets the | of the pla | *Manufactu | *Contains | *Contains | *EN10204: | *100% me | *Material ii | The Followi | | | | | | | | 3.750IN | C | 979 774 5900 | US //845-/950 | College Station 1 X | | 100ED State Hans 30 | CIVIC Construction SVcs College Sta | | O uality / | |
| 55Warnings.ca.gov | eproductive harm. For more information go |) the State of California to cause cancer, birth defe | This product can expose you to chemicals which. | e "Buy America" requirements of 23 CFR635.410, | ant quality manual | ured in accordance with the latest version | no Mercury contamination | no weld repair | :2004 3.1 compliant | elted and rolled in the USA | is fully killed | ing is true of the material represented by this MTR: | | | | | | | | | haracteristic Value | DLVRY PCS / HEAT: 1008 EA | DLVRY LBS / HEAT: 30282.000 | CUSI P/N: | CUSI PU#: 905997 | DUL#: /4003/10 | ati Delivery#: 83714603 | | Rolando A Davila | The state of the s |

Page 1 OF 1 01/12/2022 00:57:51

| HEAT NO.:3111523 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 172/6/2021 S CMC Construction Svcs College Stati L S CMC Construction Svcs College Stati H S CMC Construction Svcs College Stati H H MELT DATE: 12/21/2021 T 10650 State Hwy 30 T 10650 State Hwy 30 T 10650 State Hwy 30 F 10650 State Hwy 30 F 2000 F 2000 F 2000 979 774 5900 F 1070 % F F 1000 % F 1000 % F 1070 % F F 100000 % F 1000 % F 1000 % <td< th=""><th>known to the State of California to or other reproductive harm. For mo</th><th></th><th></th><th>anv 1.59 Passed</th><th>Tensile to Yield ratio test 1 Tensile to Yield ratio test1 Bend Test 1</th></td<> | known to the State of California to or other reproductive harm. For mo | | | anv 1.59 Passed | Tensile to Yield ratio test 1 Tensile to Yield ratio test1 Bend Test 1 |
|--|--|---|---------------------------------|---|--|
| HEAT NO.:3111523 GRADE: ASTM AG55.20 Gr 420/60 GRADE: 12/26/2021 S CMC Construction Svcs College Stati P S College Station TX P College Station TX | of the plant quality manual Meets the "Buy America" requirer Warning This product can expose | | | 107.1ksi 16% | Tensile Strength test 1 Elongation test 1 |
| HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20:0" 420/60 ROLL DATE: 12/26/2021 MELT DATE: 12/26/2021 Cert. No.: 83702613 / 111523A371 S I 0 CMC Construction Svcs College Stati P S College Station TX US 77845-7950 P S College Station TX US 77845-7950 P CMC Construction Svcs College Station TX P H 10650 State Hwy 30 P H College Station TX US 77845-7950 P H 10650 State Hwy 30 P College Station TX US 77845-7950 P P College Station TX US 77845-7950 P C | Contains no Mercury contaminatic Manufactured in accordance with | | | 67.5ksi | Yield Strength test 1 |
| HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 RoLL DATE: 12/21/2021 MELT DATE: 12/21/2021 Cert. No.: 83702613 / 111523A371 CMC Construction Svcs College Station D College Station TX S D D D D D D D D D D D D D D D D D D D | EN10204:2004 3.1 compliant Contains no weld repair | | | 0.016% 0.001% | Sn |
| HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20'0" 420/60 S O GRADE: ASTM A615-20 Gr 420/60 S College Station TX S College Station TX CMC Construction Svcs College Stati H H H H College Station TX H H H College Station TX H H H H College Station TX H H S S 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | Material is fully killed 100% melted and rolled in the US | | | 0.000% | СЬ |
| HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/26/2021 MELT DATE: 12/21/2021 Cert. No.: 83702613 / 111523A371 S CMC Construction Svcs College Stati 1 S CMC Construction Svcs College Stati 1 H MELT DATE: 12/21/2021 Cert. No.: 83702613 / 111523A371 T D College Station TX US 77845-7950 P College Station TX US 77845-79 | he Following is true of the material | | | 0.062% | Mo |
| HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/26/2021 MELT DATE: 12/21/2021 Cert. No.: 83702613 / 111523A371 S CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 T H H H H H H H H H D College Station Svcs College Station Svcs College Station TX H H H H D D D College Station TX H D D D College Station TX P | | | | 0.10% | |
| HEAT NO.:3111523 S CMC Construction Svcs College Stati S CMC Construction Svcs College Stati S CMC Construction Svcs College Stati H SECTION: REBAR 16MM (#5) 20'0" 420/60 L 10650 State Hwy 30 L 10737845-7950 L S 77845-7950 S 7794 5900 S 7794 5900 S 7794 5900 S 799 774 5900 S 799 | | | | 0.17% | <u>;</u> <u>v</u> |
| HEAT NO.:3111523 S CMC Construction Svcs College Stati H GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/26/2021 L 10650 State Hwy 30 L 107 7845-7950 L Value S 77845-7950 L Value S 77845-7950 US 77845-7950 US 77845-7950 0 979 774 5900 0 979 774 5900 0 979 774 5900 US 77845-7950 | | | | 0.011% | م ح |
| HEAT NO.:3111523 S CMC Construction Svcs College Stati S CMC Construction Svcs College Stati SECTION: REBAR 16MM (#5) 20'0" 420/60 0 1 10650 State Hwy 30 H H GRADE: ASTM A615-20 Gr 420/60 L 10650 State Hwy 30 I S College Station TX P College Station TX VS 77845-7950 US 77845-7950 T 979 774 5900 T 979 774 5900 T 979 774 5900 T 979 774 5900 Characteristic Value Ch < | | er 2.188IN | Bend Test Diamete | 0.44% | Min C |
| HEAT NO.:3111523 S CMC Construction Svcs College Stati S CMC Construction Svcs College Stati SECTION: REBAR 16MM (#5) 20'0" 420/60 0 0 H H GRADE: ASTM A615-20 Gr 420/60 L 10650 State Hwy 30 H H ROLL DATE: 12/26/2021 D College Station TX P College Station TX MELT DATE: 12/21/2021 T VS 77845-7950 T VS 77845-7950 Cert. No.: 83702613 / 111523A371 T 979 774 5900 T 979 774 5900 0 O VS 77845-7950 T 979 774 5900 0 0 | Characteristic Val | ue | Characteristic Val | Value | Characteristic |
| | lege Stati Delivery#: BOL#: 74E CUST PO# DLVRY LB DLVRY PC | CMC Construction Svcs Cc 1 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900 | Construction Svcs College Stati | 420/60 S CMC 420/60 L 1065 D Colleg US 77 1 T 979 7 | HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20'0" GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/26/2021 MELT DATE: 12/21/2021 Cert. No.: 83702613 / 111523A37 |
| | احم | Call Call | 830-372-8771 | X 78155-7510 | SEGUIN T |

Page 1 OF 1 12/29/2021 23:15:42

| mings.ca.gov | to www.P65Wa | | | | | |
|---|------------------------------------|-----------|--------------------------------|---------|------------|----------------------------------|
| uctive nami, For more information go | or other reprod | | | | 00000 | |
| the second to be a second to the second s | | | | | aread | Rond Test 1 E |
| State of California to cause cancer hirth | known to the | | | | .53 | Tensile to Yield ratio test1 |
| product can expose you to chemicals w | *Warning: This | | | | IN | Elongation Gage Lgth test 1 8 |
| y America" requirements of 23 CFR635. | *Meets the "Bu | | | | 4% | Elongation test 1 |
| rality manual | of the plant qu | | | | 09.8ksi | Tensile Strength test 1 |
| in accordance with the latest version | *Manufactured (| | | | 1.8ksi | Yield Strength test 7 |
| tercury contamination | *Contains no M | | | | | |
| eld repair | *Contains no w | | | | .002% | Al |
| 4 3.1 compliant | *EN10204:200- | | | | 1.017% | Sn |
| and rolled in the USA | * 100% melted | | | | 0.001% | CD |
| 'y killed | *Material is full | | | | 0.000% | 2 |
| : true of the material represented by this | The Following is | | | | 0000% | INIO |
| | | | | | 0.14% | Z |
| | | | | | 0.13% | Cr |
| | | | | | 0.30% | Cu |
| | | | | | 0.21% | Si |
| | | | | | 0.043% | S |
| | | | | | 0.010% | q |
| | | | | | 0.86% | Mn |
| | 1.750IN | leter | Bend Test Diam | | 0.45% | C |
| acteristic Value | Chara | Value | Characteristic V | | Value | Characteristic |
| DLVRY PCS / HEAT: 820 E | 79 774 5900 | 6 10 | 4 5900 | 979 77 | F O | Cert. No.: 83714604 / 1111173A13 |
| DI VRY I RS / HEAT: 10055 | S 77845-7950 | U | 45-7950 | US 778 | | MELT DATE: 12/08/2021 |
| CUST PO#: 905998 | 0650 State Hwy 30 | - 1 | Station TX | College | | ROLL DATE: 12/19/2021 |
| BOL#: 74563716 | | I | | 2000 | 420/60 0 | GRADE: ASTM A615.20 Cr 420/60 |
| Delivery#: 83714604 | MC Construction Svcs College Stati | s | onstruction Svcs College Stati | CMC C | s | SECTION DEDAD 12000 (44) 2000 |
| Rolando A Davila urance Manager | Quality Assu | | | | _ | |
| ID and | CONVU . | 71 | 830-372-87 | 10 | K 78155-75 | CMC SEGUIN T |
| mount to the reported grade spec | 2 | pies call | For additional cor | | ILL DRIVE | 「日本語語語」 「日本語語語語」 「日本語語語語』 |

Page 1 OF 1 01/12/2022 00:59:20

| 909 - 265 - 2458 | Chad Foltz |
|---|---|
| Tene Arari a TMD Donertintion su | |
| H | |
| I 10650 State Hwy 30 | CUICH SOFF. BULCONDO |
| P College Station my | |
| 115 779845-7455 | |
| T 379 774 4984 | |
| ò | |
| acterístic Value | Chatacceristic Value |
| Ge Lgill 1 (metri 200mm | |
| Send Test 1 Passed | |
| Fion Avg. Space 0,3271N | |
| mation Max. Gap 0.122IN | |
| | |
| | |
| | |
| | The Following is rue of the ensterial represented by this MTR: |
| | "Material is fully killed and is Hoy Rolled Steel |
| | TO A STRATE, CONST. AND INDUDUCIDADE IN THE USA |
| | "Contains no welf repair" |
| | "Cuntans in Merzury contamination |
| | "Adanutactured in accordance with the latest verson |
| | of the plant quality manual |
| | "Ments the "Suy America" requirements of 23 CFR635.410, 49 CFR 6 |
| | Warbary This product can expose you to chemicals which are |
| | Annum to the State of California to cause cancer, birth defects |
| | as other reprotactive hann. For more information go |
| 1 · · · · · · · · · · · · · · · · · · · | ege Stati S CMC Construction Sw H 1.65: State Hny 3: P College Station TX US 77845-755: C 979 T74 496;0 Send Test 1 Passed Son Avg. Spaci 0.1271W ion Avg. Heigh 0.0301W ation Max. Gop 0.1271W |

Page 1 of 1 12/02/2012 14:23:22

1

| gruuncuve narm. For more information go Sviarangs ca ppv | 296-MMM at | | | | | |
|---|----------------------------------|---------------|----------------------------------|----------|-------------|---------------------------------|
| arcoductive barns for more information of the second | st sther no | | | | 1.62 | Tensile to Vield ratio testi |
| the Sone of California to one and the state of the | | | | | NIC | Elongarion Gage Lyth test 1 |
| This printing was expand that in changed a first | Wanney 7 | | | | 14% | Elongation test 1 |
| "But America" remains of 22 CEORDE (1) - 4 PED 54 | "Meets the | | | | 753MPa | Tensile Strength 1 (metric) |
| and guadity shared | sta atthe sta | | | | 109.2ksi | Tensile Strength test 1 |
| d in annudance with the latest success | "Manufaouvre | | | | 463MPa | Vield Strength Test 1 (metri |
| e Moreury coatemination | Canans no | | | | 67.2ksi | Yield Strength test 1 |
| ia wold repair | •Contains no | | | | | |
| CC4 3 f compliant | 5×10204 20 | | | | 0.013% | Sn |
| hed, roked, and manufactured in the USA | -196%, met | | | | 0.002% | 43 |
| · July hilled and is Hat Rolled Stoel | *Material is | | | | 0.004% | ~ |
| ig is true of the material represented by this RATE: | The Following | | | | 0.022% | мо |
| | | | | | 0.078 | NT |
| | | | | | 0.12% | Cr |
| | | | | | 0.25% | 2 |
| | | 0.130IN | Rebar Deformation Max. Cap | | 0.18% | ذك |
| | | 0,037IN | Robar Deformation Avg. Heigh | | 0.0378 | دە د |
| | | 0.38113 | Rebar Defoundtion Avg. Spaci | | 0.011% | ę |
| | | 1020000C | Bend Test 1 | | 1.04% | Ma |
| | • | 200m | Elongation Gage Lgth 1 (metry | | 0.463 | Û |
| Characteristic Value | | Value | Characteristic | | Value | Characteristic |
| | | | | | | |
| TANAL CAR / NEWL / 98 EX | | | o | 0 | | |
| | | 979 774 5900 | 74 5900 T | 7 979 7 | | |
| DIWRY LES / HEAT: 15/24 DOD LA | 12 | US 77845-796 | 0667 5487 | | | |
| CUST P/N: | on TX | COLLege Stati | | 10 | | LT DATE: 11/09/2022 |
| CUST 20#: 935381 | or Am | Total State | as Station TV | | | DLL DATE: 11/09/2022 |
| BCL#: 75100412 | | 10680 01474 | Scate Hwy 32 | L 10650 | | ADE: ASTM A615 20 Gr 420/60 |
| ati Delivery#: 85247415 | The officer of the second second | | | 0 | 20/60 | SCTION: REBAR 16MM (#5) 20'0" 4 |
| | tion over outloo - Ar | CMC COnstruct | onstruction Svos College Stat. 5 | s chic c | | 2AT NO. : 5023781 |
| Chad Foltz Quality Assurance Manager | | | | | | |
| -det a D | | | | | | |
| CI I. I | | *100 | | | | CMC |
| 0 2 | | LASS CALL | | 234-4100 | wille FL 32 | Jäckson |
| nd conform to the reported grade specificati | the Constant and | | | | lebar Road | 16770 F |
| | | | | | | |

Page 1 OF 1 12/02/2022 21:45:53

.

| | CMC STEEL TEXAS | | CERTIFIED MILL TEST | We here! REPORT are accurate an | by certify that the test results presented here Id conform to the reported grade specification |
|---|--|-----------|--------------------------------------|------------------------------------|---|
| CMC | SEGUIN TX 78155-7 | 510 | For Additional copie 800-227-6489 | a ca | Rolando A Davila |
| | | | | Quality | r Assurance Manager |
| HEAT NO.:3119337 SECTION: REBAR 19MM | (#6) 20'0" 420/60 | | struction Svcs College Stati | S CMC Construction Svcs College St | tati Delivery#: 85233725 |
| GRADE: ASTM A615-20 | Gr 420/60 | L 10650 S | ate Hwy 30 | 1 10650 State Hwy 30 | BOL#: 75082383 CUST PO#: 934479 |
| MELT DATE: 11/01/202 | | US 7784 | tation TX | P College Station TX | CUST P/N: |
| Cert. No.: 85233725 / 1 | 19337A619 | F 979 774 | 5900 | 105 //845-/950 1 979 774 5900 | DLVRY LBS / HEAT: 17304.000 LB |
| | | 0 | | 0 | |
| Chara | cteristic Value | | Characteristic Va | lue c | Characteristic Value |
| | C 0.50% | | Bend Test Diamet | er 3.750/N | |
| | Mn 0.92% | | | | |
| | 5 0 044% | | | | |
| | Sí 0.24% | | | | |
| | Cu 0.34% | | | | |
| | Cr 0.08% | | | A-11.1 | |
| | Ni 0.13% | | | | |
| | Mo 0.046% | | | The Follow | ring is true of the material represented by this MTR: |
| | V 0,000% | | | *Material . | is fully killed and is Hot Rolled Steel |
| | Cb 0.007% | | | *100% m | elted, ralled, and manufactured in the USA |
| | 20 0.000 10 | | | *EN10204 | 1:2004 3. f compliant |
| **** | | | | Contains | no weld repair |
| Vield Strengt | h toost 1 73 51 | | | "Contains | No Mercury contamination |
| Tensile Strengt | hiert 1 110 Obal | | | "Manufact | tured in accordance with the latest version |
| | 1 103(1 1 10.3N) | | | of the pic | ant quality manual |
| | niest i 10% | | | *Meets the | e "Bity America" requirements of 22 CFR535,410, 49 CFR 661 |
| Electron Lage Lag | Test T din | | | "Winning: | This product can expass you to chemicale which yes |
| then pred to a series i | 10 test1 1.62 | | | a) umbes | a the Starn of California in waven cancer, bitth Antoess |
| Deba | LIEST I Passed | | | 1. Jelity JU | noradivetion ham Farman infamation In |
| | and and a day is a surround processing of the state of the | | | to www PE | 55Warnings.ca.gov |
| | | | | | |
| REMARKS : | | | | | |

Page 1 OF 1 11/18/2022 15:24:46

| PLATE A36 TEMPER LEVELED 1/4 X 60.0000" X 96.0000" | PO/REL HOU-22-2714/ HEAT: 221583 | BL HOU-934005-1 8/19/2022 Order HOU-30071-1 Page 1 |
|---|---|---|
| Plate | IEAT :21583 21583 21583 EAT 21583 21583 Fine Gr Country | USTOMER DORESS 121583 |
| A 36 Ton | COIL NO. 5441042 5441045 SLAB 7040 SLAB 7040 SLAB 7040 of origin: Steel | HOT ROLLED STI N2 0.0056 |
| LO# 37995 1/4 × 60 HR Hea# 221583 | SLAB 7030 7040 COIL NO. 5441045 COIL NO. 5441045 Heat melted and c | S DE MEXICO DEL IN COILS. |
| 1 4 t.o. | TEST THICKNESS(Inch) X 0.4925 (0.2400 SH SH 19.900 DELIVERY 1003092378 | MILL TEST CERT PROLONGACION JUA Mn P CHEM |
| a h | OF THE PRODUCT C.STRENGTH T. 16.240 (KSI) 66 77.260 (KSI) 78 IPPED PRODUCT TIPED PRODUCT 11PED PRODUCT 0.2400 CUSTOMER ORD PO2099/MAY22 END OF DATA | IFICATE AHMSA: REZ SIN NUMERO COLO ICAL COMPOSITION S SI CU |
| ISSUED : | STRENGTH & EL .403(KSI) 45(.832(KSI) 37(WIDTH(Inch) ORD 60.0000 000 A | QUALITY WITH THE NAALA LOMA MONCLO ante of issued 31.05.2022 Guarantee Cr. Ní |
| S100944 | 000. (*) (*) (*) (*) (*) (*) (*) (*) (*) (*) | PAGE PAGE PAGE 1 0.004 0.004 |
| | T.ELONG. 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 | H OF STEEL BS |
| | 0.210.44 | ALL COMPANY OF THE COMPANY. |
| | | |

| Authorized by The results report CE calculated up | Heat MI 21076142 Bit Material Note: Sales Or. Note | M500375810 | Bundle No | 21076142 | Heat No | Sales Order: | Sales Or. Note | 21104832 BI | Heat MI | M500381107 | 21104832 | Heat No | Sales Order: | Material: | Sold To Service Ste PO Box 960 HOUSTON USA | Atlas Tube 5039N Coi Blytheville 72315 Tel: Fax: |
|--|---|------------|------------|-------------|-----------|-------------------|----------------|--------------|---------------|-------------|-------------|---------|--------------|-----------------|---|---|
| Cuality Assisted on this no sing the AWS | GRIVER | | PC | 0.210 | C | 1689585 | | GRIVER | | 6 0d | 0.220 | c | 1683915 | 6.0x6.0x1 | el Warehous)7 TX 77213 | Arkansas unty Road 10 Arkansas US |
| Jurance: June port represent th D1.1 method. This D1.1 method. This D1.1 method. This D1.1 method. This | <u>Mill Location</u> Osceola,AR | 054608 Ps | S Yield | 0.770 0.009 | Mo | 0,00,00,01X1) | | Osceola,AR | Mill Location | 059205 P | 0.760 0.009 | Mn p | | 38x32'0"0(3x3). | e Co. L.P. | 115 VA |
| Reckered e actual attribute : document is in | | 075792 | Tensile | 0.001 | <i>in</i> | ŭ | | | | si 078372 | 0.002 | s | | | | |
| s of the mate compliance | Method EAF | Psi 38 % | Eln.2 | | | Ma | | EAF | Method | Psi 33% | 0.030 0 | IS IS | Pu | M | | |
| vith the require | Recycled Cont 76.00% | | .033 0.100 | Cu Cu | | terial No: | | 76.00% | Recycled Con | 2in | 0.025 0.040 | e Cu | rchase Orde | aterial No: | MATERIA | ADIVISION |
| ind indicate full ments of EN 10 | ant Post Co 95.00% | | 0.001 | G | : SSW1210 | 12004037 | | 95.00% | Itent Post C | | 0.002 | ß | r: SSW1210 | 60060188 | L TEST REF | N OF ZEKELM |
| compliance 204 type 3.1 | nsumer | ASTM | 0.018 | Mo | 29 |) UI | | onsumer | ASTM | Certit | 0.009 | Mo | 029 | w | PORT | an indus |
| with all ap | Pre-Consu 5.00 % | 1500-24 CD | 0.050 | N | | | | 5.00 % | A500-21 G | lication | 0.020 | N | | | | STRIES |
| plicable sp Metals | mer (Post j | ADE DOO | 0.050 | ç | | | | umer (Post | RADE B&C | 0.010 | 0.020 | ç | | | | |
| Servic | ndustriai) | | 0.004 | V | | Made ir Melted | | industrial) | | 0.000 | 0 003 | < | Melted | Made | | |
| e Center | <u>% Harvested</u> 75% | CE: | 0.001 0 | TI | | 1: and Poure | 1970 | % Harveste | | 0.001 CE | | 3 | and Poure | n | Shipped] Service St 8415 Clint HOUSTON USA | REF.B/L: Date: Custome |
| Bang tirement | Within 500 | 0.37 | 0.0001 0 | | | d in: | 500 | vertini | | 0.0001 | | 1 | ed in: | | [<u>e</u> eel Wareh on Drive √ TX 7702 | 81040 08/20/ r: 1746 |
| 50 S | Niles of Lo | | .0086 0 | ~ | Non | USA | | n Miles of L | | 0.0094 | N | | USA | 110 / | ouse Co., [9 | 2210 2021 |
| | 6 | | 00 | 2° | | | | 00 | | 0.0 | Co | | | | 1 | |

| Authorized by The results repo | Material Note Sales Or. Note | Bundle No M400189027 | 02285C | Heat No | Material: | 21089292 B Material Note Sales Or. Not | 0003484736 | Bundle No | 21089292 | Heat No | Material: Sales Order | Service Ste PO Box 96 HOUSTON USA | Atlas Tub 5039N Cc Blytheville 72315 Tel: Fax: |
|--|---------------------------------|-------------------------|-------------|--------------|--------------------|--|-------------|----------------|--------------|-----------|--------------------------|--|---|
| Auality Assorted on this to sing the Aws | œ · · | P | 0.210 | 16/1861 C | 3.0x2.0x2 | IGRIVER): le: | 1 | 0 | 0.200 | C | 14.0X14.(| eel Warehou 07 1 TX 77213 | e Arkansas ounty Road 1 9 Arkansas U |
| MERICA | | Co So | 0.840 | M | 50x40'0" | Oso | Mill | Cs | 0.740 | Mn |)x625x32 | se Co. L | 015 SA |
| Among the action of the second the second the second the second s | | Yield)61464 Psi | 0.010 | U | 0(6x3). | eola,AR | 051796 Psi | Yield | 0.011 | q | 2'0"0(1×1)R | ď. | |
| Ceckand itual attribute current is in | 10100 | Tensil | 0.008 | n | | | 07770; | Tensi | 0.002 | 'n | EC | | |
| compliar | 15 | | 0.011 | 2 | | EAF | 3 Psi | le | 0.030 | <u>e</u> | | | 898 |
| naterial furmi ice with the r Pag | 2 | In.2in | AU 0.046 | Purchase (| Material N | 20 <u>Kecycie</u> 76.00% | 3% | In.2in | 0 000 | Purchase | Material N | MAT | |
| shed and equiremen | | | 0.030 | Order: | | d Conten | | 0.000 | | Order: | <u>o</u> | ERIAL | TISION O |
| indicate fu | | 0.001 | Cb | SSW119 | 3002025 | 95.00 | | 0.001 | G | SSW11 | 140140 | TEST R | F ZEKEL |
| ll compliane 0204 type 3 | ASTA | Cert | Mo |)562 | 04000 | <u>Consumer</u> % | AST | 0.011 | Mo | 8116 | 625 | PORT | Tub |
| | A500-21 | flcation | N | | | Pre-Co 5.00 % | M A500-21 | 0.040 | Ni | | | | |
| applicable s | GRADE B&C | 0.060 | Cr | | | nsumer (Pos | GRADE B& | 0.050 | ç | | | | |
| S Servic | | 0.000 | ۷ | Meited | Made | t <u>Industrial</u>) | 0 | 0.002 | < | Matte | Made | | |
| and contra | | 0.001 | Ħ | and Pou | 2 | <u>% Harv</u> 75% | | 0.001 | TI | u ang Po | in: | Shippe Service 8415 C HOUS | REF.E Date: Custo |
| act require | 0 m 0.01 | 0.0000 | 80 | ared in: | | ested | CE: 0.35 | 0.0002 | W | ured in: | | B Steel W Ninton Dri TON TX | ML: 8 0.0 |
| ft IIfe | | 0.0050 | Z | USA | USA | <u>Nithin Miles (</u> 500 | | 0.0071 | Z | US | SN | arehouse Co ve 77029 | 1040210 8/20/2021 746 |
| | | 0.0000 | Ca | | | of Location | | 0.0031 | Ca | A | A | у., L.P. | |
| 49 FU#:3 FO#:55-5234 | I 671A :#OS | 0 | 355 3' F | AM- 160 | 1: B 12 이 문 문 1 | 2022 Tag 28* Tag | 870 7817 | 6_:6 | 976(2 :# |] Jeel | - L esnot | e, Steel Waret 01832* Qly: | ылас :rigm: Servic Ран: Тобоос |

| Contract of the instantial furnitation and indicate full compliance with all applicable specification and contract requirements | Authorized by Quality Assurance: June 6 The results reported on this report represent the act CE calculated using the AWS Dr.1 method. This doc Stock Tube Instituted of the AWS AND | Heat MILL Mill Location 21076222 BIGRIVER Osceola,AR Material Note: Sales Or. Note: | Bundle No PCs Yield M400189027 3 044512 Dei | 21076222 0.210 0.860 0.011 | Material: 3.0x2.0x250x40'0"0(6x3). Sales Order: 1671861 | 21074851 BIGRIVER Osceola,AR Material Note: Sales Or. Note: | Bundle No PCs Yield M400189027 8 070547 Psi Heat MILL Mill Location | 21074851 0.210 0.820 0.040 | Sales Order: 1671861 | Sold To Service Steel Warehouse Co. L.P. PO Box 9607 HOUSTON TX 77213 USA Material: 3.0x2.0x250x40'0"0(6x3). | Attas Tube Arkansas 5039N County Road 1015 Blytheville Arkansas USA 72315 Tel: Fax: |
|---|--|--|--|---------------------------------------|--|---|---|----------------------------|----------------------------|---|--|
| Base Tuble REF.B/L: Babe: Brace Babe: Brace Babe | ual attributes of the material furnished and ument is in compliance with the requireme | 0620/91FSI 27 % <u>Method</u> <u>Recycled Conten</u> EAF 76.00% | Tensile Ein.2in | S SI AI Cu 0.002 0.030 0.029 0.070 | Material No: Purchase Order: | EAF 76.00% | 0.002 0.040 0.027 0.100 Tensile EIn.2in 081791 Psi 28 % | S SI AI Cu | Purchase Order: | MATERIAL | |
| REF.B/L: Customer: B104 Customer: B104 Customer: Ni Cr V Ti B 0.040 0.040 0.003 0.001 0.0002 Stop-21 GRADE B&C Made in: Metted and Poured in: Made in: TS% B Ni Cr V Ti B 0.040 0.003 0.001 0.0002 Stop-21 GRADE B&C Made in: Metted and Poured in: B Pre-Consumer (Post Industrial) % Harvested Stop-21 GRADE B&C With Stop 300 % Yee Consumer (Post Industrial) % Harvested Stop 300 % With Stop 300 % Yee Consumer (Post Industrial) % Harvested Stop 300 % Within Stop 300 % | Indicate full compliance ints of EN 10204 type 3.1 | ASTM A <u>Post Consumer</u> I 95.00% | 0.001 0.015 0 Certific | Cb Mo | 300202504000 SSW 119562 | 11 Post Consumer 95.00% | 0.001 0.012 Certifi ASTM | Cb Mo | 300202504000 SSW 119562 | TEST REPORT | as Tube |
| REF.B/L: 810.4 Date: 08/20 Customer: 1746 Shipped To Shipped To 8415 Circle Steel Warst 8415 Circle Steel Warst 8415 Circle NTX 7700 USA 0.001 0.0002 CE: 0.38 75% 500 0.001 CE: 0.38 0.001 CE: 0.38 0.001 CE: 0.38 500 CE: 0.38 500 CE: 0.38 500 CE: 0.38 500 CE: 0.38 500 CE: 0.38 | with all applicable specification | 500-21 GRADE B&C P re-Consumer (Post Industrial) 5.00 % | 0.040 0.050 0.004 ation | NI Cr V | Made Meltec | Pre-Consumer (Post Industrial 5.00 % | 0.040 0.040 0.003 <u>cation</u> A500-21 GRADE B&C | Ni Cr V | Made Melte | | RIES |
| 100136 Co., L.P 29 29 29 29 29 29 29 29 29 29 29 29 29 | and contract requirements. | % Harvested Within Miles of Loca 75% 500 | 0.001 0.0001 0.0070 0.00 | TI B N Ca | in: USA d and Poured in: USA | 1) <u>% Harvested</u> <u>Within Miles of Loc</u> 75% 500 | 0.001 0.0002 0.0061 0./ CE: 0.38 | TI B N | id and Poured in: USA | Shipped To Service Steel Warehouse Co., L.P 8415 Clinton Drive HOUSTON TX 77029 USA | REF.B/L: 81040210 Date: 08/20/2021 Customer: 1746 |

| Authorized by The results repor CE calculated us | 21076242 BIG Material Note: | Heat MIL | M400189018 | Bundle No | DINTED AD | oales Order: | Material: | Material Note: Sales Or. Note | Heat Mit | M400189018 | Bundle Me | Heat No | Sales Order: | Material: | Service Stee PO Box 960 HOUSTON 1 USA | Atlas Tube 5039N Cou Blytheville / 72315 Tel: Fax: |
|--|--------------------------------|------------|------------|-----------|-----------|--------------|--------------|----------------------------------|--------------|-----------------------|-----------|---------|--------------|-------------|---|---|
| Duality Assing the AWS | RIVER | | ° IC | 0.220 | C | 89957.91 | 3.0x2.0x25 | : SRIVER | | 9 PC | 0.210 | C | 1675568 | 3.0x2.0x2 | 7 7 17 17 77213 | Arkansas nty Road 10 Arkansas US |
| urance: poor represent | Osceola | Million | S Yiel | 0.840 0 | Mn | | 50x40'0*0(6; | Osceola | Mill Loc | <u>25</u> Yiel 059 | 0.860 | Mn | | 50x40'0"0(6 | e Co. L.P. | A 5 |
| have been haven been h | AR | ation | | 0.012 0. | s | | x3). | ı, AR | ation | 512 Psi | 0.011 0 | P | | x3). | | |
| Land Il attributes o ment is in coi | | UO LOCI PS | Tensile | .005 0.0 | S | | | | | Tensile 082079 Ps | 0.002 0.0 | Si Si | | | | |
| f the materia mpliance wit | EAF 76 | 70 % | Eln.2in | 30 0.03 | N | Purcl | Mate | EAF 70 | Method R | Eln.2lr | 0.030 | Z | Purc | Mate | | |
| al furnished a th the require Page: 4 o | .00% | | | 0.080 | Cu | hase Order: | rial No: | 5.00% | ecycled Cont | Ľ | 29 0.070 | Cu | hase Order | rial No: | MATERIA | A DIVISION |
| nd indicate fi ments of EN | ent Post (95.00% | | | 0.001 | ß | SSW11 | 3002020 | 95.00 | tent Post | | 0.001 | Cb | : SSW11 | 300202 | L TEST RI | DOF ZEKEL |
| uli complianc 10204 type 3. | <u>Consumer</u> % | ASTN | Certi | 0.016 | Мо | 9562 | 504000 | % | Consumer | Cert | 0.015 | Mo | 9562 | 504000 | EPORT | Tube |
| | Pre-Consu 5.00 % | A500-21 GF | fication | 0.040 | Ni | | | 5.00 % | Pre-Cons | ification | 0.040 | N | | | | STRIES |
| plicable spe | <u>imer (Post Ir</u> | ADE B&C | | 0.050 | Q | | | | umer (Poet) | | 0.050 | ç | | | | |
| cification ar | ndustrial) | | | 0.004 | < | metter a | Made in | | induced in D | 0.001 | 0.004 | < | Melted | Made in | | |
| d contract r | <u>∿ Harvested</u> ′5% | We line a | | 1001 | | nd Pourec | | <u>75%</u> 75% | | CE: | 0.001 | 1 | and Poure | | Shipped T Service Ste 8415 Clinte HOUSTON USA | REF.B/L: Date: Customer |
| Ren oquireinon oo | Within h | 0.00 | 1 20 | N NUC | 5 | 1 in: | | d Within 500 | | 0.38 | | , | d in: | | 9 9el Warehou on Drive TX 77029 | 810402 08/20/2 1746 |
| 6108 ² " | illes of Loca | | 0087 0.0 | Ga | • | USA | USA | Miles of Loc | | 1.0070 0.4 | 0 | | USA | 1100 | use Co., L.P | 021 |
| | 10 | | 023 | | | | | 300 | | 0027 | 1 200 | | | | | |

| Authorized by Q The results reporte CE calculated usin | <u>Bundle No</u> M400188549 Material Note: Sales Or. Note: | SL5150 | Heat No | Material: 4 Sales Order: 1 | M400189029 Material Note: Sales Or. Note: | Bundle No | NOVOR NO | Sales Order: | Material: | Service Steel PO Box 9607 HOUSTON TX USA | Atlas Tube A 5039N Count Blytheville Ar 72315 Tel: Fax: |
|--|---|--------------|-----------|-------------------------------|---|------------------|-------------|--------------|----------------------------|---|--|
| uality Assurance d on this report n g the AWS D1.1 m SCILULA NORTH AMERIC | 25 | 0.200 0.820 | | 1.0x2.0x125x40' 1690213 | 18 | 0.210 0.840 | C Mn | 1671861 | 3.0x2.0x250x40 | Warehouse Co. (77213 | rkansas yy Road 1015 kansas USA |
| e: June by present the acceleration of the sector of the s | <u>Yield</u> 073089 Psi | 0.006 | , | 0"0(5x5). | 061464 Psi | 0.010 | P | | 0"0(6x3). | Р | |
| Lual attributes c current is in co | <u>Tensile</u> 082130 Ps | 0.005 0.0 | , | | <u>Tensile</u> 081642 Ps | 0.008 0.0 | s S | | | r | |
| f the material fi | Eln.2in 28 % | AI | Purchas | Materia | <u>Eln.2In</u> 28 % | 0.046 | A | Purcha | Materia | M | |
| Page: 5 of 7 | 0.100 | Cu | se Order: | No: | | 0.030 | Cu | se Order: | I No: | ATERIAL T | DIVISION OF |
| ndicate full o ts of EN 102 | 0.002 | Cb. | SSW 12102 | 400201254 | | 0.007 | Cb | SSW1195 | 30020250 | EST REP | E ZEKELM |
| compliance (04 type 3.1 | Certific ASTM A | Mo | 29 | 1000 | Certifi ASTM / | 0.000 | Mo | 62 | 4000 | ORT | ube an indust |
| with all appl | 0.040 () <u>ation</u> 500-21 GRA | N | | | <u>cation</u> 4500-21 GR | 0.010 | N | | | | RIES |
| licable spe | 0.050 | Q | | | ADE B&C | 0.060 | Cr | | | | |
| Cification | 0.004 | V | | Made i Melted | | 0.000 | < | Meltec | Made | | |
| and contr | 0.001 | E | | n: and Poi | | 0.001 | 71 | and Po | in: | Service 8415 C HOUST USA | REF.B Date: Custo |
| act requirem | 0.0004 CE: 0.37 | ω | | ured in: | CE: 0.37 | 0 0000 | 0 | ured in: | | ed To Steel Wan Inton Drive INTX 77 | /L: 810 08/2 mer: 174 |
| ents. | 0.0062 | N | NON | USA | 0.0050 | N N | 5 | VSN | /SU | ehouse Co. 029 | 40210 20/2021 6 |
| | 0.0023 | Ca | | | 0.0000 | Ca | | | | | |
| 1872-22 #OP 8 #nJ 848827A #OS | 4,8, LP 1222 | -602 /M-> | 34 5 | ו 1:01 ; 1:01 ; | 104835* 9\13\2053 | 12 12 16:7 | heCl :#h | | | 901832* Qty: 101832* Qty: | Frem: Servic Part: T06006 |

| $\langle \rangle$ | Authorized b The results rep CE calculated | Sales Or. Not | 02748C U Material Note | Heat M | Bundle No M400185946 | 02748C | Heat No | Sales Order: | Materiai: | Material Note Sales Or. Not | Bundle No M400188550 | SL5150 | Heat No | Sales Order: | Material: | Sold To Service Ste PO Box 960 HOUSTON USA | Atlas Tube 5039N Cou Blytheville 72315 Tel: Fax: | |
|--|--|---------------|---------------------------|-------------|-------------------------|----------|--------------|--------------|-------------|--------------------------------|-------------------------|----------------|--------------|--------------|------------|---|---|--|
| Stee | y Quality A ported on th using the A | e: | SSTEEL | | | 0.210 | c | 1682826 | 6.0x4.0x | 6 | | 0.200 | c | 1690213 | 4.0x2.0x | el Warehou)7 TX 77213 | Arkansas unty Road 1 Arkansas L | |
| I Tul | lssurance: Is report rej WS D1.1 me | | GRA | Mill | 9 PCs | 0.840 | Mn | 0, | (250x40'0") | | PCs 25 | 0.820 | Mn | | 125x40'0" | ISE Co. L.F | 015 ISA | |
| e e | foresent the a | | NITE CITY,I | Location | Yield 068701 Psi | 0.018 | P | | 0(3x3). | | Yield 073089 Psi | 0.006 | P | | 0(5x5). | | | |
| | Richard actual attrib | | - | | 1ens 08362 | 0.008 | s | | | | Tens 08213 | 0.005 | s | | | | | |
| | utes of the in complia | | BOF | Metho | 20 Psi 3 | 0.013 | Si | | | | 30 Psi 2 | 0.026 | S | | | | | |
| P | material fur nce with the | | 36.90% | d Recycle | <u>In.2in</u> 4 % | 0.048 | A | Purchase | Material N | | <u>In.2in</u> 8 % | 0.034 | ð | Purchase | Material N | MAT | | |
| age: 6 of | nished and requireme | | | d Content | | 0.060 | Cu | Order: | lo: | | | 0.130 | Cu | Order: | ē | ERIAL TI | ISION OF | |
| 7 | indicate ful nts of EN 10 | | 19.80% | Post Co | | 0.007 | ĉ | SSW1210 | 60040250 | | | 0.002 | C) | SSW 1210 | 40020125 | EST REP | ZEKELMA | |
| | l complianc)204 type 3. | | | onsumer | Certif | 0.000 | Mo | 29 | 4000 | | Certif ASTM | 0.010 | Mo | 29 | 4000 | ORT | ube | |
| ക | e with all a | | 14.40% | Pre-Const | A500-21 GF | 0.020 | N | | | | A500-21 GI | 0.040 | Ni | | | | TRIES | |
| Metal | pplicable sp | | | Imer (Post | VADE B&C | 0.080 | C, | | | | RADE B&C | 0.050 | C, | | | | | |
| s Servi | oecification | | | Industrial) | | 0.000 | V | Melted | Made ir | | | 0.004 | ٧ | nanau | Made in | | | |
| te Cent | and contra | | 100% | % Harvest | CE | 0.001 | | and Pour | н I | | Q | 0.001 | T | and Pour | | Shipped 1 Service St 8415 Clint HOUSTON USA | REF.B/L: Date: Customei | |
| | ct requirem | | 500 | ed With | E 0.37 | 0.0000 | 03 | ed in: | | | : 0.37 | 0.0004 | 00 | ini pa | | Icel Wareh on Drive V TX 7702 | 81040 08/20/ r: 1746 | |
| tonica territoria territoria territoria | lerits. | | | in Wiles of | | 0.0040 | Z | USA | USA | | | 0.0062 | 2 | USA | USA | ouse Co., | 2210 2021 | |
| | | | | location | | 0.0000 | Ca | | | | | 0.0023 | C | | | P | | |
| 1872-25 | :#Od €:#U] | 649627A | <i>#</i> 09 | ~~~ | 55 (* 176 | AA 12 | 602 IAI-) | 719 718 | :68] :0] | 15* 022 | 0483 1/3/S | 544 9:0 | 916(; ;# | 169) 1 | ا esno | 1832* Qty: Steel Wareh | eoivie Service 080080T the ^o | |

| Authorized by Quality Assurance: The results reported on this report represent the arc calculated using the AWS D1.1 method. This do Stock Tube Institute OF NORTH AMERICA | Material Note: Sales Or. Note: | 21076402 BIGRIVER Osceola,AR | M500374036 5 056630 Psi | 21076402 0.220 0.770 0.017 | Heat No C Mn P | Sales Order: 1687379 | Material: 14.0x4.0x250x48'0"0(1x5). | Sold To Service Steel Warehouse Co. L.P. PO Box 9807 HOUSTON TX 77213 USA | Atlas Tube Arkansas 5039N County Road 1015 Blytheville Arkansas USA 72315 Tel: Fax: |
|--|-----------------------------------|--|--|----------------------------|----------------|----------------------|-------------------------------------|---|---|
| Lunent is in compliance with the requirement of the material furnish current is a compliance with the requirement is a com | | EAF 76.00% | <u>Tensile</u> <u>Eln.2in</u> 075109 Psi 33 % | 0.003 0.040 0.031 0.0 | S SI AI CI | Purchase Ore | Material No: | MATER | |
| ed and indicate full compliance wi ulrements of EN 10204 type 3.1 | | Content Post Consumer Pr 95.00% 5.0 | ASTM ASTM | 050 0.001 0.011 0.0 | u Cb Mo Ni | der: SSW121029 | 1400402504800 | IAL TEST REPORT | ON OF ZEKELMAN INDUSTRI |
| th all applicable specification and | | e-Consumer (Post Industrial) % | lion 0-21 GRADE B&C | 130 0.050 0.004 0.0 | Cr V TI | Weited and | Made in: | HO US | Constant Con |
| contract requirements. | | Marvested Within Miles of Lo | CE: 0.37 | 001 0.0002 0.0072 0. | N | d Poured in: USA | USA | <u>Ibped To</u> Nice Steel Warehouse Co., L.P TIS Clinton Drive USTON TX 77029 | F.B/L: 81040210 te: 08/20/2021 stomer: 1746 |
| 1672-22 #OS 6 #nJ 643657A #OS | To: RIK-MAR, LP Tag: B17091222 | ocation * 20 | 13/20 | 1.0025 | 3 ik 918 | 469 U | H I | ۲. 1835* OW: | Part. T060060 |

| VIAN, ISKW 30' SO TIN. | | Forza steel certifies that the products described in this document were manufactured in constitution of Forza steel certifies and inspections included in the quality plans of Forza Steel satisfactory results in all tests and inspections included in the quality plans of Forza Steel satisfactory results in all tests and inspections included in the quality plans of Forza Steel satisfactory results in all tests and inspections included in the quality plans of Forza Steel satisfactory for the | Forza Steel certifica que los productos descritos en este documento fueron fabricados en obteniendo resultados satisfactorios en todas sus pruebas e inspecciones incluidas en los pedido en referencia. | Lotes 5000-3-2,5000-2-53,5000-2-52,5000-2-55,5000-2-55A,500 | HSS OIF 5000 6x6 0.188 122305 ASTM AF00 0 | The de module. Orden Interna de | | CUSTOMER (Cliente) PURCHASE | FORZA STEEL Carretera Salinas Victor | Part: T06v0601830* Qty: 1 Heat#: 1223 |
|------------------------|--|--|--|---|--|---------------------------------|------------|-----------------------------|--|---------------------------------------|
| DAN | | pliance with the requirements of meet the requirements of the orc | Implimiento con los requerimient lanes de calidad de forza steel p | 9.15 30.02 | Metros Plee | E LENGTH INCHES (Longitud) | SSW121166 | RDER (Orden de Compra) | NTERIAL TEST REPORT - QUA CONSTANCIA DE INSPECTION C INSPECTION C (EN 10204 3.1 B-1 FORZA STEEL - PROD FORZA STEEL - PROD K.m. 2 s/n Salinas Victoria, Nuev | 95* Tag: B1/0 |
| | | the specification described, obtained in reference. | os de la especificación descrita, ara cumplir con los requerimien | 442.09 200.53 | Lbe Kg | MASS (Peso Unitario) | 5054309 | DELIVERY (Remi | INSPECTON INSPECTON CONSTANCY SO10474 3.18) UCTION FACILITY: UCTION FACILITY: | 91222 |
| | | aining | 2-34,5000-2-51,5 | 21.93 | Peso Lineal kg x metros | MASS PER METER | | sión) | ۹ +52 (51) 1958- | C#. 11 |
| | | OUALITY ASSUR | 2000-2-58,5000-2-60 Certily By | N/A N/A | Prueba Hidrostatica Requerimientos (psl) espectales | HYDROSTATIC TEST SPECIAL | 08/09/2021 | DATE (Fecha) | Padking List 3780 | 29049 LN#: 2 |
| | | 0 Olivo Hernández | (Autorizó) | 18 | S No. Piezze | TURE NUMPE | 06062021-1 | REFERENCE | Cod (Code); F Eititon (Felción): 1 Data of Rev (frecha Rev) ; Page (†idja); | 2. :#Od |
| NNAGER | ASSURANCE MA | QUALITY / | 10.00 | | | | | | | | | | | |
|--|---------------------|-------------------------|------------------|------------------|--|--|---------------------------------|------------------------------------|--------------------------------|--------------------------------|------------------------------------|-----------------------------------|---|-------------------------------|
| lernández | iuardo Olivo H | Ing. Edgar Ed | otaining | n described, ol | e specificatio. r in reference. | irements of the its of the order | e with the requirement | l in compliance Steel to meet t | manufactured ans of Forza (| cument were the quality pla | ibed in this do ins included in | and inspectio | tifies that the p sults in all tests | za steel cer isfactory rea |
| | r Millo | Poh | antos del | 1 los requerimik | ra cumplir cor | iorza steel par | ue calluad de l | on ivo pianes | | | | | rencia. | dido en refe |
| | rtify By (Autorizó) | Cer | <u>ه</u> | ficacion descrit | i de la especi | equerimientos | iento con los r | os en cumplin | eron fabricado | documento fu | critos en este a as sus prueba | productos desc ctorios en toda | rtifica que los p sultados satisfa | rza Steel ce teniendo res |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.010 | 0.001 | 00000 | | | | | | |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.010 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-3-4 | 122395 |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.010 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-3-3 | 122395 |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.015 | 0 001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-3-2 | 122395 |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.010 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-2-64 | 122395 |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-2-63 | 122395 |
| 35 | 72.50 | 60.15 | 100.0 | 0.002 | 0.020 | 0.015 | 100.0 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-2-62 | 122395 |
| 35 | 72.50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-2-61 | 122395 |
| 35 | 72.50 | 0U.15 | 0.001 | 0.002 | 0.000 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000-2-60 | 122395 |
| 35 | 72.50 | OU. ID | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 69-2-0005 | CRCZZI |
| 35 | /2.50 | 00.10 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 2000-2-58 | 122090 |
| 35 | 12.50 | 00.10 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.165 | 5000 0 50 | 122000 |
| 35 | 12.50 | 60 15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | Col. U | SUDU-Z-SSA | 100005 |
| 35 | 12.50 | 60 15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.105 | 5000 3 EEA | 100205 |
| 33 | 70 20 | 60 15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.100 | 5000-2-55 | 122205 |
| 30 | 79 50 | 60 15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.010 | 0.100 | 5000-2-02 | 122395 |
| 30 | 79 50 | 60 15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.010 | 0.100 | 5000-2-50 | 122395 |
| 35 | 79 50 | 60.15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.100 | 5000-2-50 | 122395 |
| and the second s | 11010101 | 60 15 | 0.001 | 0.002 | 0.020 | 0.015 | 0.001 | 0.005 | 0.012 | 0.520 | 0.015 | 0.100 | 5000-2-40 | 100005 |
| (%) (Elongation | (KSI) (Última | (KSI) (Límite elástico) | Mo | Ni | Cu | Ç | < | s | P | Mn | SI | 0 185 | 5000-2-49 | (Colada) 122395 |
| mecanicas) | Tensile Strength | | | | | | | Químico) | (Analisis | | | | | Heat |
| | Test (Prilabas n | Mechanica | | | | | | Analyses | Chemica | | | | | |
| ge (Hoja): 2/ | Pag | 958-3780 | 'el: +52 (51) 19 | o C.P. 65500 T | León , Méxic | rictoria, Nuevo | 2 s/n Salinas V | Victoria K.m. | etera Salinas | Carr | | | | |
| the second secon | | | | | | | | | |) | | | | |
| Edition Rev dición) :1 Rev ite of Rev cha Rev) : 20-01 | 1528 (E | Packing List | |)) TY: | INSPECCION INSTANCY IO10474 3.1B CTION FACILI | ISPECTION CO J204 3.1 B- ISI TEEL - PRODUC | CON IN (EN 10 FORZA ST | | | | | | HZ20 | |
| d (Code): FPD-PR | I Co | | EM | EMENT SYSTI | ITY MANAG | PORT - QUALI | IAL TEST REP | MATERI | | | | | | |
| | | | | | 91222 | B1/0 | lag | 22395 | al#: 12 | | wiy. | 1000 | | |
|)#: ? 273 | ¥:2 PC | 729549 Ln# | SO#: A | F | -MAR | To: | 022 | 9/13/2 | Date: | ouse | Wareh | Steel \ | 'ICe | |
| | | | | | | | | | | | | | | |

| The or the or the second secon | $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | SIZE THICKNESS LENGHT HEAT N.OF C SI Mm P S Cr AI N Nb V CRDER NO SERIAL NUMBER Mail 0,27 1,4 0,045 0,045 0 <th>QUALITY GRADE B/C DESCRIPTION OF GOODS PRIME NEWLY PRODUCED COLD FORMED, WELDED, STEEL SQUARE AND RECTANGULAR TUBING. QUALITY DURABILITY No performance determined CHEMICAL ANALYSIS (%) TS CEN / EN 10261</th> <th>OZDEMİR BORU PROFİL SAN VE TICAŞ QUALITY ASSURANCE AND CONTROL DEPARTMENT BÖLÜCEK MAH. 2 NOLU SANAYİ CADDESİ NO: 128</th> <th>OZDEMIR BORU PROFIL SANAYI VE TIÇAF ORHANLAR MAH. YALI ÇAD THE FIRST FAÇILITY 1: BÖLÜÇEK MAH. 2 NOLU THE SECOND FAÇILITY 2: HAMZAFAKIHLI MAH. YASAR TETKER BULV/ KDZ EREGLI - TURKEY</th> <th>rom: Srice Steel Warehouse Date: 9/13/2022 To: F^{.,}{-N art: T06v0601828* Qty: 2 Heat#: <u>2111574*</u> Tag: C0z090</th> | QUALITY GRADE B/C DESCRIPTION OF GOODS PRIME NEWLY PRODUCED COLD FORMED, WELDED, STEEL SQUARE AND RECTANGULAR TUBING. QUALITY DURABILITY No performance determined CHEMICAL ANALYSIS (%) TS CEN / EN 10261 | OZDEMİR BORU PROFİL SAN VE TICAŞ QUALITY ASSURANCE AND CONTROL DEPARTMENT BÖLÜCEK MAH. 2 NOLU SANAYİ CADDESİ NO: 128 | OZDEMIR BORU PROFIL SANAYI VE TIÇAF ORHANLAR MAH. YALI ÇAD THE FIRST FAÇILITY 1: BÖLÜÇEK MAH. 2 NOLU THE SECOND FAÇILITY 2: HAMZAFAKIHLI MAH. YASAR TETKER BULV/ KDZ EREGLI - TURKEY | rom: Srice Steel Warehouse Date: 9/13/2022 To: F ^{.,} {-N art: T06v0601828* Qty: 2 Heat # : <u>2111574*</u> Tag: C0z090 |
|--|--|--|--|--|--|--|
| | 0.347 55825 76125 32.00 21 Z1 Z1 Z1 Z1 Z1 Z1 21 Z1 Z1 Z1 Z1 0.339 6435 88665 32.00 32. | IT NI Mod Cu CEV PSI PSI PSI L Formula State PSI L Formula State PSI L Formula State Tempo (*C]: + 20° Tempo (*C]: + 20° 1 2 3 Av 1 2 3 Av 1 2 3 Av | ASTM ASOO GRADE B/C | Date : 23.02.2022 SEBA INTERNATIONAL INC | RET ANONIM SIRKETI . NO: 15 SANAYI CADDESI NO: 128 JRI NO: 2 KDZ EREĞLİ ORGANİZE SANAYİ BÖLGESİ Y | MAR, LP SO#: A729549 Ln#: 1 PO#: 22 731 0922 |

| $\begin{array}{c c c c c c c c c c c c c c c c c c c $ |
|--|
|--|

| the second second second second second second second second second second second second second second second s | 8 x 8 | 8×8 | 8×8 | 8 x 8 | 8 x 8 | 8 x 8 | 8×8 | 8 x 8 | 8 x 8 | 8 x 8 | 8 x 8 | 8×8 | 8×8 | 8 x 8 | | 2 X X X | 0X0 | 0 1 0 | 0X0 | C A C | 2020 | 2020 | 2020 | 2000 | | 0X0 | ax b | 6x6 | 6x6 | 6×6 | 6 x 6 | 6x6 | 6 x 6 | 6×6 | 6×6 | 6 x 6 | 6×6 | 6x6 | 6 X 6 | 6 X 6 | 6x6 | 6 x 6 | | | | |
|--|---------|---------|---------|---------|---------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------|--------|----------|---------|---------|---------|--------|--------|-----------|---|---|---|--|
| | 0.375 | 0.313 | 0.313 | 0,313 | 0,313 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0 100 | 0,100 | 0,188 | 0,100 | 0,500 | 0,300 | 0,000 | 0,000 | 0,000 | 0,000 | 0,3/5 | 0,3/5 | 0,375 | 0,375 | 0,375 | 0,375 | 0,375 | 0,375 | 0,313 | 0.313 | 0.313 | 0.313 | 0.250 | 0.250 | 0 250 | 0.250 | 0,250 | 0,250 | | | | |
| 00 | 30 | 40 | 32 | 30 | 28 | 48 | 40 | 36 | 34 | 32 | 00 | 30 | 28 | 20 | 40 | 40 | 30 | 87 | 48 | 48 | 40 | 200 | 07 | 28 | 48 | 40 | 36 | 34 | 32 | 30 | 28 | 20 | 40 | 30 | 28 | 24 | 48 | 40 | 40 | 30 | 32 | 30 | 1 | (| | |
| CTTTTTT | 2111616 | 2111611 | 2111611 | 2111611 | 2111611 | 0007111C | 2111609 | 2111610 | 2111610 | 2111610 | 2111610 | 2111610 | 2111610 | 2111610 | 2TTTPOF | 2111606 | 2111606 | 2111606 | 2111592 | 2111592 | 2111594 | 2111596 | 2111596 | 2111596 | 2111586 | 2111588 | 2111591 | 2111591 | 2111591 | 2111591 | 2111591 | 2111591 | 211158/ | 211150 | 211158 | 211158/ | 2111570 | 2111576 | 2111570 | 211150 | 211158 | 211158 | 1 | | / | |
| 1 1 1 14 | 7.4 | 7~1 | - Jul | 311 | 74 | TATT - | 1/1/1 | JAC I | 3VE | 3v6 | 220 | 340 | Ave | 4X4 | 9x6 | 1x4 | 1x9 | 1x9 | 2 5x2 | 2 3x02 | + 1x6 | 5x4 | 1x2 | 2x4 | 12x4 | 3 18x4 | 1 3x4 | 1 3x4 | 1 4x4 | 5x6 | 1x6 | 4x9 | 1 9×4 | 740 | 1 1.0 | 300 | 1Euc | 0X77 6 | 0X7 7 | 3.6 | 546 | 2 3x9 | | | | |
| 1 0,100 | 0,10/ | 0,10/ | 101,0 | 1010 | 0,159 | 0,100 | 0,104 | 0,104 | 0,104 | 0,104 | 0,104 | 0,104 | 0,104 | 0,163 | 0,163 | 0,163 | 0,163 | 0,163 | 0,168 | 0,168 | 0,162 | 0,158 | 0,158 | 0,158 | 0,162 | 0,170 | 0,170 | 0,170 | 0,170 | 0.170 | 0 170 | 0,170 | 0,161 | U, TP | 0,10 | CT'D | 0,16, | 0,16, | 0,16 | 0,10 | 0,10 | 1016 | | | | |
| 10,232 | 0,180 | 0,186 | 0,186 | 0,100 | 0,228 | 0,221 | 0,234 | 0,234 | 0,234 | 0,234 | 0,234 | 0,234 | 0,234 | 0,236 | 0,236 | 0,236 | 0,236 | 0,236 | 0,249 | 0,249 | 0,177 | 0,196 | 0,196 | 0,196 | 0,240 | 0,199 | 0,236 | 0,236 | 0.236 | 0.236 | 0,220 | 0120 | 0,203 | 0,20 | 0,20 | 0,228 | 0,205 | 0,209 | 0,209 | 0,205 | 0,202 | 2000 | | | | |
| 11,215 | 1,209 | 1,209 | 1,209 | 507'T | 1,083 | 1,135 | 1,096 | 1,096 | 1,096 | 1,096 | 1,096 | 1,096 | 1,096 | 1,106 | 1,106 | 1,106 | 1,106 | 1,106 | 1,190 | 1,190 | 1,221 | 1,242 | 1,242 | 1,242 | 1,221 | 1,226 | 1,216 | 1.216 | 1.216 | 1 316 | 1 7/2 0 | 1,240 | 1,240 | 1,240 | 1,240 | 1,083 | 1,106 | 1,106 | 1,106 | 1,106 | DUT'T | 1 1 1 100 | | | | |
| 0,019 | 0,015 | 0,015 | 0,015 | 0,015 | 0,009 | 0,017 | 0,013 | 0,013 | 0,013 | 0,013 | 0,013 | 0,013 | 0,013 | 0,012 | 0,012 | 0,012 | 0.012 | 0,012 | 0,015 | 0,015 | 0,015 | 0,015 | 0,015 | 0,015 | 0,019 | 0.012 | 0,011 | 0.011 | 0011 | 110,011 | TTO'O | 0,016 | 0,016 | 0,016 | 0,016 | 0,009 | 0,012 | 0,012 | 0,012 | 0,012 | 0,012 | | | | | |
| 0,006 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 600,0 | 0,009 | 0,009 | 0009 | 0.009 | 0.004 | 0.004 | 0,006 | 0,003 | 0,003 | 0,003 | 0,007 | 0.004 | 0.007 | 0,007 | 0,007 | 10,00/ | 1000 | 0,003 | 0,003 | 0,003 | 0,003 | 0,004 | 0,008 | 0,008 | 0,008 | 0,008 | 800,0 | | | | | |
| 0,044 | 0,038 | 0,038 | 0,038 | 0,038 | 0,035 | 0,034 | 0,043 | 0,043 | 0,043 | 0,043 | 0,043 | 0,043 | 0,043 | 0,037 | 0.037 | 0.037 | 100,0 | 0.037 | 0.034 | 0.034 | 0.033 | 0.040 | 0.040 | 0.040 | 0.047 | 0 044 | 0.035 | 0,000 | 0,035 | 0,035 | 0,035 | 0,041 | 0,041 | 0,041 | 0,041 | 0,035 | 0,038 | 0,038 | 850'0 | 0,038 | 0,038 | | | | | |
| | | | | | | | | | | | | | | | | | + | | | + | | | + | + | + | + | | + | | | | | | | | | | | - | | | | | | | |
| - | | | | | | _ | | _ | | | - | | | | | | | | | + | | | | | | + | + | | | | | | | | | _ | _ | | | - | _ | | | | | |
| 0.3 | 0,3 | 0,3 | 0.3 | 0,3 | 0,3 | 0.3 | 0.3 | 0.3 | 0,3 | 0,3 | 0.3 | 0.3 | 0,3 | 0.3 | 0,0 | 0,0 | 0,3 | 2,0 | 0,3 | 0,0 | | 0,0 | c10 | | 0,0 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | E U | 0.3 | | | | | |
| 69 635 | 69 635 | 69 635 | 69 635 | 69 635 | 40 572 | 54 693 | 48 603 | 48 603 | 48 603 | 48 603 | 48 603 | 48 603 | 48 603 | 47 558 | A7 500 | 4/ 558 | 4/ 558 | 100 00 | TQ QQ | 08 /55 | | | | 0/ 024 | 14 594 | 13 64 | 73 642 | 73 642 | 73 642 | 73 642 | 73 642 | 70 677 | 70 67 | 70 67 | 70 67 | 40 57 | 51 52 | 51 57 | 51 57 | 51 53 | 51 52 | | | | | |
| 10 82 | 10 80 | 10 80 | 10 80 | 10 80 | 75 76 | 10 20 | 20 79 | 20 79 | 20 79 | 20 79 | 70 70 | 20 79 | 20 79 | 37 26 | 0/ C7 | 10 27 | 25 76 | 35 82 | 35 82 | 86 08 | 00 00 | | | 11 56 | 50 74 | 35 84 | 35 84 | 35 84 | 35 84 | 35 84 | 35 84 | 15 83 | 15 83 | 15 02 | 15 93 | 75 76 | 00 76 | 75 | 20 20 | 100 7C | 00 76 | | | | | |
| 565 | 765 | 765 | 765 | 765 | 705 | 510 | 460 | ARO | 460 | 460 | 100 | 460 | 460 | 175 | 571 | 125 | 125 | 212 | 215 | 000 | 3/5 | 3/5 | 3/5 | 202 | 240 | 535 | 535 | 535 | 535 | 535 | 535 | 230 | 230 | 720 | 220 | 705 | 137 | 132 | 135 | 130 | 175 | | | | | |
| 00,00 | 2000 | 00 C2 | 22,00 | 100 00 | 32 00 1 | 20,00 | 20,00 | 19,00 | 00,00 | 20,00 | 30 00 | 20,00 | 02/00 | 00/20 | 52,00 | 32,00 | 32,00 | 36,00 | 36,00 | 36,00 | 30,00 | 30,00 | 30,00 | 32,00 | 32,00 | 30,00 | 30,00 | 30,00 | 30,00 | 30,00 | 30.00 | 34.00 | 34 00 | 24,00 | 24,00 | 22 00 02 | 24,00 | 24,00 | 04,00 | 54,00 | 34 00 | | | | | |
| - | + | + | + | - | + | - | | | - | + | - | - | - | | | | | | | | | | | | | | | | | - | - | + | + | | + | + | | - | + | | | | | | | |
| | | - | | + | | | | | | - | - | | | | | | | | | | | | | | | | | | - | | | + | | | - | | | | | | | | | | | |
| | T | | - | | | | | | + | - | | | | | | | | - | | | | | | | | | | | | | | | 1 | | | | | | | | hand | | | | | |
| T | T | 1 | T | T | 1 | I | T | | 1 | | 1 | | | 1 | | | | | | | | | | | | | 1 | | 1 | 1 | | | 1 | | | | T | | | | | | | | | |

| - | | | 4 | - | | | | | 4 | _ | _ | | | | | 1 | C' | | 1 | 4 | | | | | | | | - | X | | | | | | | | | | | | |
|---------|--------|--------|-------|--------|-------|-------|-------|-------|--------|-------|--------|--------|--------|--------|--------|-------|--------|--------|-------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-------|---------|---------|---------|-------|--------|---------|---------|--------|--------|---|--|
| 4 x 3 | 4 x 3 | 6 x 2 | -6x2 | 6x2 | 6x2 | 6 x 2 | 4 x 2 | 4 x 2 | <4x2 | 4 x 2 | 4 x 2 | 4 x 2 | 4×2 | 4 x 2 | 3 x 2 | 3 x 2 | -3×2 | 2 X X | 2×c | 2XC | 77 X 77 | DI X DT | 10 × 10 | 10 x 10 | 10 x 10 | 10 x 10 | 10 × 10 | 10 × 10 | 10 × 10 | 10×10 | 10 × 10 | 10 x 10 | 10 × 10 | 8×8 | 8×8 | 8X8 | 8×8 | 8×8 | 8×8 | | |
| 0,188 | 0,188 | 0,188 | 0,188 | 0,188 | 0,188 | 0,188 | 0.250 | 0,250 | 0.250 | 0.250 | 0.188 | 0.188 | 0.188 | 0.188 | 0.250 | 0.250 | 0.250 | 0,100 | 0,188 | U, LAN | 0,250 | 0,500 | 0,375 | 0,375 | 0,375 | 0,375 | 0.375 | 0.375 | CTC/D | 0,313 | 0,313 | 0,250 | 0,250 | 0,500 | 0,500 | 0,375 | 0,375 | 0,375 | 0,375 | ~ | |
| 24 | 20 | 48 | 40 | 40 | 24 | 20 | 40 | 24 | 20 | 20 | 40 | 28 | 24 | 00 | 40 | 24 | 22 | 340 | 20 | 20 | 40 | 40 | 40 | 36 | 34 | 32 | 30 | 28 | 40 | 36 | 30 | 48 | 40 | 40 | 20 | 48 | 40 | 34 | 32 | - | |
| 21115 | 21115 | 21115 | 21115 | 21115 | 21115 | 2111 | 21119 | 21110 | 21110 | 21115 | 21110 | 21119 | 21110 | 21110 | 21110 | 21110 | 21110 | CTTT7 | 21115 | 21115 | 21116 | 21116 | 21116 | 21116 | 21116 | 21116 | 21116 | 21116 | 21112 | 21116 | 21116 | 21116 | 21116 | 21116 | TTT7 | 21116 | 21116 | 21116 | 21116 | | |
| 524 6x2 | 524 1x | 561 7x | 62 3x | 62 1x | 62 2x | 62 1x | 22 Ex | XL 27 | 222 44 | 2) 1v | 371 54 | 21 JV | 271 20 | -71 JA | N01 00 | 10 34 | XT DTC | X7 BUG | 08 1x | 08 3x | 541 8x | 532 15 | 30 23 | 531 4x | 31 3x | 31 5x | 31 54 | 11 676 | XT 670 | 29 3x | 529 3x | 526 19 | 27 20 | 18 10 | TT FTG | 12 20 | 513 40: | 516 3x | 516 4x | | |
| 20 | 20 | 00 | 12 | 9 | 24 | 24 | 5 | 12 | 24 | 512 | 51 | 24 | 24 | 74 | 100 | | 4 | 20 | ω | 35 | 2 | ×2 | x2 | 2 | 2 | | 5 7 | 24 | 9 | 2 | 4 | ×2 | XA | 24 | ×4 | ×2 | x2 | 4 | 4 | | |
| 0,161 | 0,161 | 0.168 | 0.164 | 0.164 | 0 164 | 0164 | 0150 | 0150 | 0,100 | 0,170 | 0,170 | 0,173 | C/1/0 | 0,102 | 0,167 | 101,0 | 0,16/ | 0,169 | 0,169 | 0,169 | 0,169 | 0,162 | 0,164 | 0,162 | 0,162 | 0 162 | 201/0 | SQT 0 | 0,168 | 0,168 | 0,168 | 0,164 | 0151 | 0163 | 0,158 | 0,164 | 0,158 | 0,166 | 0.166 | | |
| 0,224 | 0,224 | 0.217 | 0.234 | 0 234 | 10734 | 0,224 | 417/0 | 0,214 | 0,214 | 0,228 | 022/0 | 0,228 | 877'0 | 502,0 | C/225 | 0,225 | 0,225 | 0,007 | 0,007 | 0,007 | 0,229 | 0,212 | 0,230 | 0.240 | 0.240 | 0 240 | 0,240 | 0,201 | 0,201 | 0,201 | 0,201 | 0.205 | 0,111 | 0,196 | 0,196 | 0,209 | 0,237 | 0,232 | 0 737 | | |
| 1.119 | 1,119 | 1010 | 1100 | 1 100 | 1100 | 1100 | 1000 | 1,099 | EGOT | 1,104 | 1,104 | 1,104 | 1,104 | 1,120 | 1,135 | 1,135 | 1,135 | 0,881 | 0,881 | 0,881 | 1,086 | 1,212 | 1,195 | 1 221 | 1.221 | 1221 | 1/2/1 | 1,208 | 1,208 | 1,208 | 1,208 | 1.096 | 1110 | 1,242 | 1,242 | 1,193 | 1,208 | 1.215 | 1 715 | | |
| 0.014 | 0.014 | 0010 | 0012 | 0,010 | 0,013 | 0,010 | 010/0 | 0,010 | 0,010 | 0,011 | 10,011 | 10,011 | 0,011 | 0,013 | 0,013 | 0,013 | 0,013 | 0,010 | 0,010 | 0,010 | 0,014 | 0,010 | 0,019 | 0010 | 0 019 | 0,019 | 0,019 | 0,015 | 0,015 | 0,015 | 0,015 | 0012 | 0,015 | 0,015 | 0,015 | 0,014 | 0.017 | 0.019 | 10010 | | |
| 0.004 | 0.004 | 0.004 | | 200,00 | 0,002 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,004 | 0,012 | 0,012 | 0,012 | 0,007 | 0,005 | 0,003 | 0,007 | 0,00/ | 0,00/ | 0,007 | 0,003 | 0,003 | 0,003 | 0.003 | 0,005 | 0,005 | 0,003 | 0,003 | 0,003 | 0.005 | 0,006 | 10000 | | |
| | | | | | 0 | 0, | 0, | 0. | 0. | 0 | 0 | 0 | 0 | 0, | 0, | 0, | 0, | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0, | 0, | 0, | 0 | 0,0 | | 0, | 0, | 0 | 0 | 0 | | - | | |
| 045 | 033 | | 150 | 150 | 150 | 038 | 038 | 038 | 038 | 042 | 042 | 042 | 042 | 038 | 041 | 041 | 041 | 030 | 030 | 030 | 032 | 035 | 850 | 140 | 04/ | 047 | 047 | 040 | 040 | 040 | 040 | 041 | 033 | 040 | 040 | 037 | 040 | 044 | | | |
| + | | T | | | F | F | | | | | | | | | | | | | _ | _ | - | + | + | | | | | | | | + | | | | | | - | + | - | | |
| + | + | + | + | + | + | + | | | | | | | | | | | | _ | + | + | + | + | + | + | + | - | | | | + | + | + | | | | + | + | + | - | | |
| | 0 | 0, | 0, | 0, | 0, | 0, | 0, | 0. | 0. | 0, | 0, | 0, | 0, | 0, | 0, | 0, | 0 | 0 | 0 | | 0 | | | 0 | 0 | 0, | 0, | 0 | 0 | 0 | | 0, | 0. | 0, | 0 | 0,0 | | 0,0 | - | | |
| 249 0 | 339 6 | 348 6 | 348 6 | 348 6 | 348 6 | 341 5 | 341 5 | 341 5 | 341 5 | 359 6 | 359 6 | 359 6 | 359 6 | 358 6 | 358 5 | 358 5 | 358 5 | 329 6 | 329 6 | 200 0 | 350 50 | 200 000 | 300 0 | 366 6 | 366 6 | 366 6 | 366 6 | 369 6 | 369 6 | 9 695 | 34/ 6 | 338 5 | 368 7 | 365 6 | 365 6 | 263 292 | 202 0 | 369 6 | | | |
| TATA | 1335 | 1770 | 1770 | 1770 | 1770 | 6840 | 6840 | 6840 | 6840 | 4235 | 4235 | 4235 | 4235 | 2568 | 8870 | 8870 | 8870 | 3133 | 3133 | 2122 | 1000 | 2800 | 2495 | 2495 | 2495 | 2495 | 2495 | 8730 | 8730 | 8730 | 0030 | 2656 | 5980 | 5105 | 5105 | 0305 | 1755 | 3510 | | | |
| 81490 | 81635 | 80475 | 80475 | 80475 | 80475 | 77140 | 77140 | 77140 | 77140 | 83665 | 83665 | 83665 | 83665 | 83897 | 78155 | 78155 | 78155 | 74791 | 74791 | 74701 | CCUTO | CTCC/ | 77865 | 77865 | 77865 | 77865 | 77865 | 83665 | 83665 | 20050 | 80620 | 79170 | 00986 | 83375 | 83375 | 20170 | 83665 | 83665 | | | |
| 32,0 | 30,0 | 34,0 | 34,0 | 34,0 | 34,0 | 32,0 | 32,0 | 32,0 | 32,0 | 32,0 | 32,0 | 32.0 | 32.0 | 28.0 | 30,0 | 30.0 | 30.0 | 29.0 | 0,67 | 20,00 | 34,0 | 30,0 | 32,0 | 32,0 | 32,0 | 32.0 | 32.0 | 32,0 | 0.75 | 0,75 | 30,0 | 28,0 | 36,0 | 30,0 | 20.0 | 0,75 | 34,0 | 34,0 | | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | | | | 0 | 0 | | | |
| | | | | _ | | | | | | | - | - | - | | | | | | | - | + | - | | | - | | | - | Ŧ | - | - | | - | - | - | | | | | | |
| | | | | | _ | - | - | | _ | | - | | | | | | - | | | - | - | | | _ | | - | _ | 1 | T | T | | | | - | - | | | | | | |
| | | | - | | | | | _ | 1 | | - | | - | - | - | - | - | 1 | T | 1 | | | | | | | - | - | | | | | - | | | - | | | | | |
| - | | - | | | 1 | T | 1 | 1 | 1 | T | Ť | T | 1 | 1 | 1 | Ť | t | T | T | t | t | 1 | 1 | | - | 1 | 1 | t | t | + | 1 | 1 | 1 | + | T | 1 | | | | | |

From: Service.Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 1 PO#: 22-2731 Part: T0600601828* Qty: 2 Heat#: 2111574* Tag: C02090922

1

1

| 12/0 HOT/0 AUC ANAL A | 10 x 4 0.250 40 2111620 3Y6 0.164 0.20 | 10x4 0.250 30 2111620 1X8 0.164 0.20 | 10 x 4 0.250 30 2111620 1Y1 0.164 0.20 | 10 x 4 0,250 24 2111620 1X10 0 164 0 16 | 8 x 4 0,375 40 2111601 1X3 0165 0 73 | 8 x 4 0,375 40 2111601 4X4 0165 0 75 | 8 x 4 0,375 24 2111600 1X1 0 167 0 16 | 8 x 4 0,250 40 2111600 14X6 0.167 0.18 | 8 x 4 0,250 24 2111600 2X12 0.167 0.18 | 6 x 4 0,375 24 2111573 1X2 0.168 0.70 | A-6 x 4 0,250 40 2111570 6x6 0.169 0.20 | 6 x 4 0,250 40 2111570 1x2 0.169 0.20 | 6 x 4 0,250 30 2111571 1x12 0.170 0.70 | 6 x 4 0,250 24 2111571 2x12 0.170 0.20 | 6 x 4 0,250 20 2111571 4x12 0.170 0.20 | X 6 x 4 0,188 40 2111569 4x9 0.161 0.70 | 6 x 4 0,188 40 2111569 1x4 0.161 0.20 | 6 x 4 0,188 30 2111569 2x12 0161 0.20 | 6 x 4 0,188 28 2111569 1x12 0,161 0.30 | 6x4 0,188 24 2111569 1x1 0,161 0,20 | 6 x 4 0 188 34 2111569 2X12 0,161 0,20 | 0,168 0,182 00 01115 00 245 0,168 0,20 | 6 x 3 0 313 A0 2111568 6x6 0,168 0,20 | 6 v 0,230 40 2111567 8x6 0,174 0,11 | 6 × 2 0,250 24 2111567 2×12 0,174 0,14 | 6 X 3 0,188 40 2111566 3x12 0,161 0,20 | 6 x 3 0,188 30 2111566 1x15 0,161 0,20 | 6 x 3 0,188 28 2111566 1x15 0.161 0.70 | 6 x 3 0,188 24 2111566 1x18 0.161 0.20 | 6 x 3 0,188 20 2111566 1x18 0.161 0.20 | X 5 X 3 0.250 40 2111551 4X5 0.164 0.2 | 5 x 3 0 250 24 2111551 2x12 0,164 0,2 | 5 x 3 0,188 40 2111550 3x12 0,168 0,2 | 5 x 3 0,188 40 2111550 1x4 0,168 0,2 | 5 x 3 0,188 24 2111550 2x20 0,168 0.2 | 5x3 0,188 20 2111550 2x24 0.168 0.2 | A 4 x 3 0,250 40 2111529 6x12 0167 0 3 | 4 x 3 0,250 40 2111529 1x1 0167 0.2 | 4 x 3 0,250 24 2111579 3x70 0,167 0,2 | 4 x 3 0,250 20 2111529 3x20 0167 0.2 | 4x3 0.188 40 2111524 4x12 0.444 10- | (| |
|----------------------------------|--|--------------------------------------|--|---|--------------------------------------|--------------------------------------|---------------------------------------|--|--|---------------------------------------|---|---------------------------------------|--|--|--|---|---------------------------------------|--|--|-------------------------------------|--|--|---------------------------------------|-------------------------------------|--|--|--|--|--|--|--|---------------------------------------|---------------------------------------|--------------------------------------|---------------------------------------|-------------------------------------|--|-------------------------------------|---------------------------------------|--------------------------------------|-------------------------------------|---|--|
| 0,0 300,0 210,0 360,1 cu | 1,096 0,012 0,006 0,0 | 0,0 1,096 0,012 0,006 0,0 | U2 1,096 0,012 0,006 0,0 | | 0,0 200,0 500,0 500,7 55 | 22 1 106 001 / 1,008 0,0 | | | | | | | | | | | | | | 08 1,087 0,013 0,004 0,0 | 08 1,087 0,013 0,004 0,0 | 01 1,208 0,015 0,003 0,0 | 01 1,208 0,015 0,003 0,0 | 81 1,106 0,014 0,004 0.0 | 81 1,106 0,014 0,004 0.0 | 08 1,087 0.013 0.004 0.0 | | | 08 1 087 0 013 0 004 0,0 | 1/ 1,102 0,015 0,004 0,0 | 17 1,102 0,015 0,004 0,0 | 17 1,102 0,015 0,004 0,0 | 17 1,010 0,010 0,004 0.0 | 17 1.010 0.010 0.004 0.0 | 17 1 010 0 010 0 004 0,0 | | | 1,103 0,013 0,004 0,0 | 02 1,103 0,013 0,004 0,0 | 24 1,119 0,014 0,004 0,0 | | | |
| 42 0,347 | 42 0,347 | 42 0,347 | 42 0,347 | 35 0,371 | 35 0,371 | 29 0,360 | 29 0,360 | 29 0,360 | 40 0,373 | 0,350 | 0,350 | 0,362 | 0,362 | 0,362 | 0,344 | 0,344 | 0,344 | 38 0,344 | 38 0,344 | 38 0,344 | 38 0.344 | 40 0.369 | 40 0.369 | | 32 0.344 | 30 0,344 | 38 0,344 | 0,344 | 0,344 | 142 0,348 | 42 0,348 | 42 0 3/9 | 33 0,336 | 0,336 | 0,336 | 0,353 | 49 0,353 | 149 0,353 | 149 0,353 | 145 0,349 | | | |
| 60030 80620 30,00 | 60030 80620 30 nn | 60030 80620 30 nn | 60030 80620 30.00 | 61712 82897 36.00 | 61712 82897 36,00 | 63800 83230 30,00 | 63800 83230 30.00 | 63800 83230 30,00 | 65105 84535 34,00 | 59450 83375 30,00 | 59450 83375 30,00 | 58725 80185 32,00 | 58725 80185 32,00 | 58725 80185 32,00 | 60755 79170 34,00 | 60755 79170 34,00 | 60755 79170 34,00 | 60755 79170 34.00 | 60755 79170 34.00 | 60755 79170 34.00 | 60755 70170 32,00 | 68730 22655 22,00 | 68730 83655 34,00 | 56260 78155 34,00 | 60755 79170 34,00 | 60755 79170 34,00 | 60755 79170 34,00 | 60755 79170 34,00 | 60755 79170 34,00 | 57130 80185 34.00 | 57130 80185 34,00 | E7130 00105 30,00 | 61335 81635 30,00 | 61335 81635 30,00 | 61335 .81635 30,00 | 63655 83810 34.00 | 63655 83810 34.00 | 63655 83810 34 nn | 63655 83810 34 00 | 56550 80475 30 nn | | | |
| | | | | | | | | | | | | | | | | | | Construction of the second sec | | | | | | | | | | | | | | | | | | | | | | | | | |

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 1 PO#: 22-2731 Part: T0600601828* Qty: 2 Heat#: 2111574* Tag: C02090922

| | MANUF | ine tubes used in the production of the above materials were m WE CONFIRM HEREWITH THAT THE DELIVERED MATERIAL COMI | L: Longitudinally (Direction of the test pieces) | 21 20 40 2111040 6X2 0,178 0,174 | 12 x 8 0,250 40 2111638 4X4 0,167 0,202 | 12 x 8 0,250 40 2111638 1X2 0.167 0.202 | 12 x 8 0.250 30 2111638 2X4 0.167 0.202 | 10 x 8 0 250 20 2111637 12X2 0,168 0,249 | 12 x 6 0,500 40 2111637 1X1 0,168 0,249 | 12 x 6 0,375 40 2111636 9X2 0,164 0,230 | 12 x 6 0,375 30 2111636 1X4 0,164 0,230 | 12 x 6 0 375 30 3114536 2X4 0,164 0,230 | 12 × 6 0,250 40 2111635 1X2 0,174 0,181 | 12 x 6 0,250 40 2111635 7X4 0,174 0,181 | 10 x 6 0,500 40 2111623 8X2 0.168 0.249 | 10 x 6 0,375 40 2111622 10x4 0,159 0,228 | 10 x 6 0 750 A0 2111605 6X2 0,168 0,249 | 2 2 2 0,575 40 2111604 10X4 0,158 0,237 | 8x6 0,375 40 2111604 1X3 0,158 0,237 | X8x6 0,313 40 2111603 1X3 0.161 0.203 | 8 x 6 0,313 40 2111603 12X4 0 161 0 202 | 7 x 5 0,188 40 2111597 7x6 0,170 0,170 | X10 x 4 0.250 40 2111620 1X1 0.164 0.205 12 x 4 0.375 40 2111624 11x3 0.164 0.205 | | Ø. | A |
|--|---|--|--|----------------------------------|---|---|---|--|---|---|---|---|---|---|---|--|---|---|--------------------------------------|---------------------------------------|---|--|---|--|----|---|
| | ACTURER : OZDEMIR BORU PROFIL SANAYI VE | telted and poured in Turkiye from Erdemir Iron PLIES WITH TERMS OF THE ORDER | | 1,228 0,011 0,006 0,035 | 1,103 0,013 0,004 0,049 | 1,103 0,013 0,004 0,049 | 1,103 0,013 0,004 0,049 | 1,190 0,015 0,004 0.034 | 1,190 0,015 0.004 0.034 | 1 105 0,019 0,003 0,038 | 1,195 0,019 0,003 0,038 | 1,195 0,019 0,003 0,038 | 1,106 0,014 0,004 0,032 | 1.106 0.014 0.004 0.032 | 1 190 0.015 0.006 0.044 | 1,083 0,009 0,004 0,035 | 1,190 0,015 0,004 0,034 | 1,208 0.017 0.005 0.040 | 1,208 0.017 0.005 0.000 | 1 240 0,016 0,003 0,041 | 1,1/3 0,013 0,008 0,028 | 1,222 0,015 0,004 0,046 | 1,096 0,012 0,006 0,042 | | | |
| ÖZDEMİ SANAYI Odmanta Maş Taktorzy 322 gö Fox: 19372 Maşfou Ku | TICARET ANONIM SIRKETI | and Steel Industry Trade and Co.Inc. Auth | 00'755 contre acesta | 0.383 64960 83665 32.00 | 0,353 63655 83810 34,00 | 0,353 63655 83810 34,00 | 0.353 63655 82215 36.00 | 0,366 61335 82215 36,00 | 0,365 58290 79315 36,00 | 0,365 58290 79315 36.00 | 0,365 58290 79315 36,00 | 0.365 50260 78155 34,00 | 0,360 56260 78155 34,00 | 0,366 61335 82215 36,00 | 0,369 63510 83665 34.00 | 0.340 57275 76705 37.00 | 0.366 61326 02346 32,00 | 0,361 60465 77285 32,00 | 0,368 67715 83230 34,00 | 0,368 67715 83230 34.00 | 0.366 64235 83665 74 00 | 0.371 59450 78560 37.00 | 0.347 60030 80650 30.00 | | | |
| R BORU PROFIL New Control Con | | orised Representative Sezal ORHAN | | | | | | | | | | | | | | | | | | | | | | | | |

| | exas A&M ransportation stitute | QF 7.3-01 Sam | Concrete pling | Doc. No. QF 7 .3-01 | Revision Date: 2020-0 7- 29 |
|---|--------------------------------------|--|---|-------------------------------|---------------------------------------|
| Quality | y Form | Revised by: B.L. Griffi Approved by: D. L. Ku | th hn | Revision: 7 | Page: 1 of 1 |
| Project No: | 611801-03 | Casting Date: | 6/13/2022 | Mix Design (psi): | 4000 |
| Name of Technician Taking Sample | Terr | acon | Name of Technician Breaking Sample | Terr | acon |
| Signature of Technician Taking Sample | Terr | acon | Signature of Technician Breaking Sample | Terr | acon |
| Load No. | Truck No. | Ticket No. | Locat | ion (from concrete | e map) |
| T1 | Raymond G. 125 | 127217 | | 100% of deck | |
| Load No. | Break Date | Cylinder Age | Total Load (lbs) | Break (psi) | Average |
| | | -, | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| | Redit-max Concette Compa Redit-max Concette Compa REMIT PAYMEN P.O. BOX138 KURTEN, TX 77 | ца _{му} NT TO: ⁷⁸⁶² 5222 S Вгу | Sandy Point RD. van, Tx 77807 | 17534 SH 6 College Station | South TX 77845 | BISS Circle Lake Di inehurst, TX 77362 | BCS DISPAT PINEHURST DISPAT OFFI | 127217 CH - 979-316-2906 CH - 936-232-5815 CE - 979-985-3636 |
|---|---|---|--|--|---|---|--|--|
| | | | | | 2818,RT H E "T",RT H AY STRAIGH | WY 21,LT 5: WY 47,LT II TALL THE WA | ILVER HILL NTORELLIS NY DÓWN TO | ,RT AT ENTRANCE, THE GATE |
| 1 | TIME | FORMULA | LOAD SIZE | YARD ORDERED | | DRIVER/TRUCK | | PLANT TRANSACTION# |
| | 9:55 B | CSN40500 | 4.00 | 4.00 P | | ROYMONI |) G 125 | 62704 |
| | DATE | | LOAD# | YARDS DEL. | BATCH# | WATER TRIM | SLUMP | TICKET NUMBER |
| | 6/13/22 | PROJECT | ing and add to about | 6 00 | | conte la amiaza v | | |
| | OUANITITY | CODE | DESCRIPTION | 4.00 | | | LINIT PRICE | EXTENDED PRICE |
| | 4.00 yd 1.00 ea 1.00 ea | I BCSN4050 SOVE ENVIRONM FUEL | | MUN, 4 Envir Fuel (| 200,BLND,5 onmental S Charge | " undry Ch annen Thank või | | husiness |
| | LEFT PLANT | ARRIVED JOB | START UNLOADING | SLUMP | CONCRETE TEMP | | a state | DADINES 5 |
| | 161D | In 2M | ~ | | | AIRTEMP | Prev. AM | r en en en en en en en en en en en en en |
| | 10,10 | 10,00 | | ON SITE | TERTING | | Ticket Tota | al contract of the |
| | FINISH UNLOADING | LEFTJOB | ARRIVED AT PLANT | TERI | RACON | | and and the date | |
| | | diensaliena ave | | TESTING LAB: GES CME | SNER OTHER | A THUR DING | ADDITIONAL CHARC | GE 1 |
| | | TE | STED | AIR | CYLINDERS | | ADDITIONAL CHARC | GE 2 |
| | | YES | NO | | N. THE MAN | | GRAND TOTAL | |
| | IRRITATI Contains Portland Comer CONTACT MAY CAUSE Contact with Skin. In Case Water. If Irritation Persists CONORETE is a PERISHA PUROMASER UPON LEAV OTAL CONTROL CONTROL VIENT CONTROL CONTROL VIENT CONTROL VIENT CONTROL VIENT CONTROL VIENT CONTROL AND CONTROL AND CONTROL VIENT CONTROL CONTROL VIENT CONTROL C | WARNING NG TO THE SKIN A HURNS. Avoid Contact V BURNS. Avoid Contact V BURNS. Avoid Contact V Burns Avoid Contact V Burns and Statematic V of Contact with Skin or Ey Get Medical Attention KEI BLE COMMODITY and BECOM Nas the PLANT, ANY OFAAN Insteas to pay all costs, including s owed. Loss of the Cash Discounted will 90 min. will be \$100.00hr. | ND EYES Ind Gloves. PROLONGED With Eyes and Prolonged res, Rinse Thoroughly With BYES THE PROPERTY of the BEEP CHILDREN AWAY. WES THE PROPERTY of the EXECUTION of 0 reasonable attorney's fees. If at the rate of 19% par- ality. No Claim Allowed Unless be Collected on all Returned | PROPERTY DA TO BE SIGNED IF DELVERNT Deer Customer - The driver size and weight of this truck is the premises and/or adjace material in this load where yr and this supplier from any re may nocur (b) the driverse material and that you al most of the driverse of the driver this material and that you al must from the weight of has be undersigned agrees to inde driver of this truck and this au the premises and ico have an significant of the driverse and significant of the driver | MAGE RELEASE TO BE MADE INSIDE CUBB LINE; of this truck, in presenting this may possibly cause damage to int property if the places the cu denire if. It is our wink to cup the second second places and space to the place the space to help him remove hields so that he will not liter the minity and hold harmless the point of RELEASE the all damage be and of all damage to help him remove hields so that he will not liter the minity and hold harmless the point of active which may be sen out of delivery of this order | Excessive Wate H ₂ 0 Ac GAL X. WEIGHMASTER NOTICE: MY SIGNATURE E VARNING NOTICE AND SUP CAUSED WHEN DELIVERING LOAD RECEIVED BY X | r is Detrimental to Concr Ided by Request/Authoria harge for credit c HELOW INDICATES THAT I PUER WILL NOT BE RESPO INSIDE CURB LINE. | ards HAVE READ THE HEALTH NSIBLE FOR ANY DAMAGE |
| | | | | | | | | 07047 |
| | | | | | | | | 127217 |

 Report Number
 A1171057.0230

 Service Date:
 06/13/22

 Report Date:
 09/15/22

 Task:
 PO# 611801-3

Client

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

Material Information

Specified Strength: 4,000 psi @ 28 days

| Mix ID: | BCSN40500 | | |
|-------------|-----------|-------------|-------|
| Supplier: | Texcrete | | |
| Batch Time: | 0955 | Plant: | 63704 |
| Truck No.: | 125 | Ticket No.: | 61872 |
| | | | |

Result

Bryan, TX Project Number: A1171057 Sample Information Sample Date: Sampled By:

Water Added Before (gal): 0 Water Added After (gal): 0

Weather Conditions:

Accumulative Yards:

Placement Method:

Sample Location:

Placement Location:

Project

Riverside Campus

Riverside Campus

06/13/22 Sample Time: 1035 Steven Savala Clear

erracon

College Station, TX 77845-5765

979-846-3767 Reg No: F-3272

6198 Imperial Loop

10 Batch Size (cy): 10 Chute

0 Main runway, SW side of runway on the side of the runway Main runway, SW side of runway on the side of the runway

Field Test Data Test

| Slump (in): | 5 1/2 |
|-------------------------|-------|
| Air Content (%): | 1.5 |
| Concrete Temp. (F): | 92 |
| Ambient Temp. (F): | 91 |
| Plastic Unit Wt. (pcf): | |
| Yield (Cu. Yds.): | |

Laboratory Test Data

| Set No. | Spec ID | Cyl. Cond. | Avg Diam. (in) | Area (sq in) | Date Received | Date Tested | Age at Test (days) | Max Load (lbs) | Comp Strength (psi) | Frac Type | Tested By |
|------------|------------|---------------|-------------------|-----------------|------------------|----------------|--------------------------|----------------------|---------------------------|--------------|--------------|
| 1 | А | Good | 6.00 | 28.27 | | 09/14/22 | 93 F | 127,900 | 4,520 | 5 | SCG |
| 1 | В | Good | 6.00 | 28.27 | | 09/14/22 | 93 F | 132,230 | 4,680 | 3 | SCG |
| 1 | С | Good | 6.00 | 28.27 | | 09/14/22 | 93 F | 85,230 | 3,010 | 3 | SCG |
| 1 | D | | | | | | Hold | | | | |
| Initial C | ure: Out | tside | | Final | Cure: Field (| Cured | Sa | ample Descri | iption: 6-inch d | iameter cyl | inders |

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

Note: Reported air content does not include Aggregate Correction Factor (ACF).

Specification

NA

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.: Steven Savala Reported To: Bill at TTI Contractor: MBC Management Report Distribution:

(1) Texas Transportation Institute, Bill Griffith

Reviewed By:

Start/Stop: **

lexander 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.

CR0001, 3-31-22, Rev.7

| | exas A&M ansportation stitute | QF 7.3-01 Samj | Concrete pling | Doc. No. QF 7.3- 01 | Revision Date: 2020-0 7- 29 |
|---|-------------------------------------|--|---|-------------------------------|---------------------------------------|
| Quality | y Form | Revised by: B.L. Griffi Approved by: D. L. Ku | th hn | Revision: 7 | Page: 1 of 1 |
| Project No: | 611801-03 | Casting Date: | 6/29/2022 | Mix Design (psi): | 4000 |
| Name of Technician Taking Sample | Terr | acon | Name of Technician Breaking Sample | Terr | acon |
| Signature of Technician Taking Sample | Terr | acon | Signature of Technician Breaking Sample | Terr | acon |
| Load No. | Truck No. | Ticket No. | Locat | ion (from concrete | e map) |
| T1 | ChesterMoori 3 | 126474 | | 100% Parapet | |
| | | | | | |
| Load No. | Break Date | Cylinder Age | Total Load (lbs) | Break (psi) | Average |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| REMIT PAYM P.O. BOX138 KURTEN, TX | ENT TO: 77862 5222 Bi A&M TRANSP WE A BRYAN | Sandy Point RD. ryan, Tx 77807 | EXCO 17534 SH College Station IN 41 RD | 6 South n, TX 77845 2818 RT F TO RELLIS H ST, RT JOB ON RT | 18935 Circle Lake D Pinehurst, TX 77362 IWY 21 U TUI LFT AT STOR FLIGHT LN I TTI OFFICI | BCS DISPAT PINEHURST DISPAT Ir. OFF 2 RN JUST PA PSIGN RT A RD, RT FLI 5 BUILDING | 126474 CH - 979-316-2906 CH - 936-232-5815 ICE - 979-985-3636 ST 47 RT VE A, RT GHT LINE |
|--|--|--|--|---|---|---|--|
| TIME | FORMULA | LOAD SIZE | YARD ORDERED | | | | |
| 8:40 | BCSN40500 | 3.00 | 3.00 P | 0# | CHESTER | MODDITZ | PLANT TRANSACTION# |
| DATE | Part of the | LOAD# | YARDS DEL. | BATCH# | WATER TRIM | SILIMP | TICKET NUMBER |
| 6729722 | TTIRELL | 3.00 | 3.00 | | | 5.000018 | COO07 |
| QUANTITY | CODE | DESCRIPTION | | | Sector Inclusion | UNIT PRICE | EXTENDED PRICE |
| 1.00 e 1.00 e | ENVIRON A FUEL | | Envir Fuel (| | | | business |
| LEFT PLANT | ARRIVED JOB | START UNLOADING | SLUMP | CONCRETE TEMP. | AIR TEMP | Tax | |
| and | 904 | a sal Maran | alton decemen | | and another trade they | | 1 |
| FINISH UNLOADING | LEFT JOB | ARRIVED AT PLANT | ON SITE | TESTING | | | |
| | 1 elunora e di | | TESTING LAB: GES: CME | SNER OTHER | THE TRUE DUTY | ADDITIONAL CHARGI | E 1 |
| | | STED | AIR | CYLINDERS | | ADDITIONAL CHARGE | E 2 |
| | L YES | NO NO | | | a destimited of | GRAND TOTAL | |
| IRRITAT Contains Portland Cerm CONTACT MAY CAUSI Contact with Skin. In Ca Water. If Irritation Persist OCONCRETE is a Persity. PURCHASER UPON LEA ORIGINAL INSTRUCTIONS procured in collecting any use All accent of the Addit within S Made at Time Material is A \$25.00 Service Charge and Checks. Demoge Charge at | WARNING ING TO THE SKINA AI NIT, Wear Rubber Boots an E BURNS. Avoid Contact Vi e of Contact with Skin or Eye S. Get Medical Attention.KEE BIEL COMMODITY and BECOM WIST be TELEPHONED to the of MIST be TELEPHONED to the WIST be TELEPHONED to the Stowed. | ND EYES d Gloves. PROLONGED Vith Eyes and Prolonged as. Rinse Thoroughly With PCHILDREN AWAY. IES THE PROPERTY of the ES or CANCELLATION of FICE BEFORE LOADING reasonable attorney's fees. At the rate of 18% per thy. No Colian Allowed Unless be Collected on all Returned | PROPERTY LOAD TO BE SINCH F GUILTENT Per Customer - The driver of HELEASE buy to you sign the premises and/or adjacer material in this load where you driver is requesting that you and this supplement from any te public groups and that you adjace the supplement of the sup- tion of the truck and this sup- claimed by supplement of the sup- sidence of the truck and this sup- claimed by supplement of the sup- science of the truck and this sup- claimed by supplement of the sup- science of the truck and the sup- ter of the truck and the sup- science o | MAGE RELEASE Of EMADE INSIDE CURB LINE; Of this truck in presenting this atture is of the coinnon that the Way DoseNay datases damage to the coinnon that the approximation of the coinnon that and the coinnon that the coinnon and the coinnon that the and coinnon that the coinnon and the coinnon that the and coinnon that the coinnon that the coinnon that the and coinnon that the coinnon the coinnon that the coinnon the coinnon that the coinnon the coinnon that the coinnon that the coinnon that the coinnon the coinnon that the coinnon that the coinnon that the coinnon that the coinnon that the coinnon the coinnon that the coinnont the coinnont the coinnon that the coinnon that the | Excessive Water H ₂ O Ado GAL X WEIGHMASTER Surcha WARNING NOTICE AND SUPP CAUSED WIEN DELUXERING LOAD RECEIVED BY X | Is Detrimental to Concret led by Request/Authorize arge for credit ca LOW INDICATES THAT I IN LIER WILL NOT BE RESPON USIDE CURB LINE. | e Performance. d By: rds NE READ THE HEALTH HELE FOR ANY DAMAGE |
| | | | | | | 1 | 26474 |

 Report Number:
 A1171057.0232

 Service Date:
 06/29/22

 Report Date:
 09/15/22

 Task:
 PO# 611801-3

Client

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

Material Information

Specified Strength: 4,000 psi @ 28 days

 Mix ID:
 Bcsn40500

 Supplier:
 Texcrete

 Batch Time:
 0840
 Plant:
 2

 Truck No.:
 13
 Ticket No.:
 64754

Field Test Data

| Test | Result | Specification |
|-------------------------|--------|---------------|
| Slump (in): | 6 1/4 | |
| Air Content (%): | 2.4 | |
| Concrete Temp. (F): | 87 | |
| Ambient Temp. (F): | 81 | |
| Plastic Unit Wt. (pcf): | 145.2 | |
| Yield (Cu. Yds.): | | |

College Station, TX 77845-5765 979-846-3767 Reg No: F-3272 Project Riverside Campus Riverside Campus

Project Number: A1171057

Bryan, TX

Sample Information 06/29/22 Sample Time: 0920 Sample Date: Sampled By: Brian Maass Weather Conditions: Clear light wind Accumulative Yards: 10-10 Batch Size (cy): 10 Placement Method: Direct Discharge Water Added Before (gal): 5 Water Added After (gal): 0 Upper half middle Sample Location: **Placement Location:** West barrier

6198 Imperial Loop

Terracon

Laboratory Test Data

| Set No. | Spec ID | Cyl. Cond. | Avg Diam. (in) | Area (sq in) | Date Received | Date Tested | Age at Test (days) | Max Load (lbs) | Comp Strength (psi) | Frac Type | Tested By |
|------------|------------|-------------------|-------------------|-----------------|------------------|----------------|--------------------------|----------------------|---------------------------|--------------|--------------|
| 1 | А | Good | 6.00 | 28.27 | | 09/14/22 | 77 F | 116,030 | 4,100 | 3 | SCG |
| 1 | В | Good | 6.00 | 28.27 | | 09/14/22 | 77 F | 131,370 | 4,650 | 3 | SCG |
| 1 | С | Good | 6.00 | 28.27 | | 09/14/22 | 77 F | 122,860 | 4,350 | 5 | SCG |
| 1 | D | | | | | | Hold | | | | |
| Initial C | ure: Out | tside Plastic Lie | ds | Final | Cure: Field (| Cured | S | ample Descri | ption: 6-inch d | iameter cyl | inders |

Comments: F = Field Cured

Note: Reported air content does not include Aggregate Correction Factor (ACF).

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.: Brian Maass Reported To: Contractor: MBC Management Report Distribution:

(1) Texas Transportation Institute, Bill Griffith

Start/Stop: 0815-1000

Reviewed By: lexander 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.

CR0001, 3-31-22, Rev.7

| | exas A&M ransportation stitute | QF 7.3-01 Sam | Concrete pling | Doc. No. QF 7 .3-01 | Revision Date: 2020-0 7- 29 | |
|---|--------------------------------------|--|---|-------------------------------|---------------------------------------|--|
| Quality | y Form | Revised by: B.L. Griffi Approved by: D. L. Ku | th lhn | Revision: 7 | Page: 1 of 1 | |
| Project No: | 611801-03 | Casting Date: | 2/6/2023 | Mix Design (psi): | 4000 | |
| Name of Technician Taking Sample | Terr | acon | Name of Technician Breaking Sample | Terr | acon | |
| Signature of Technician Taking Sample | Terr | acon | Signature of Technician Breaking Sample | Terr | acon | |
| Load No. | Truck No. | Ticket No. | Locat | ion (from concrete | e map) | |
| T1 | Jeremy Gonzal5 | 72867 | | 100% of Deck | | |
| Load No | Break Date | Cylinder Age | Total Load (lbs) | Break (nsi) | Average | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

| | TEXCRE Roli-mis Concrete (| ТЕ С | | www.sa | unders-usa con | | | 147097 |
|----------------------------|---|--|---|--|--|---|---|---|
| | REMIT PAYM P.O. BOX138 KURTEN, TX | 7786 5222 Br | Sandy Point RD. yan, Tx 77807 | 17534 SH College Static | 6 South 1 n, TX 77845 F | 8935 Circle Lake D Pinehurst, TX 77362 | . open | 979-316-290 936-232-581 - 979-985-363 |
| | TEXAS RELLIS | A&M TRANSP CAMPUS, BR | DRTATIO YAN TX | R' TI S' | T 2818,RT H He "T",RT H Tay straigh | WY 21,LT S WY 47,LT I ITALL THE W | ILVER HILL NTORELLIS AY DOWN TO | , RT AT ENTRANCE, THE GATE |
| | TIME | FORMULA | LOAD SIZE | YARD ORDERED | The sector of | DBIVEBATELICK | in the second | |
| | 12:31 | BCSN40500 | 3.00 | 3.00 | 0# | TEDEMV | CONTOL 5 | PLANT TRANSACT |
| | DATE | PROJECT | LOAD# | YARDS DEL. | BATCH# | WATER TRIM | SLUMP | TICKET NUMBE |
| | 2/6/23 | TTIRELL | 3.00 | 3.00 | basen lin cost | 1 to 200 10 200 | 5 00 in | 70067 |
| F | QUANTITY | CODE | DESCRIPTION | MALEY SUR | CRIMERENCIO. | | UNIT PRICE | EXTENDED PR |
| - | 3.00 y | d BCSN4050 | 00 | MUN, 4 | 000, BLND. 5 | 11 | | |
| | LEFT PLANT | ARRIVED JOB 12:53 LEFT JOB | START UNLOADING | SLUMP ON SITE | CONCRETE TEMP. | | for your Tax Prev. AMT Ticket Total | business |
| | 1 | augocod miss | | TESTING LAB: GES | RACON SNER | | | |
| H | | TES | STED | AIR | CYLINDERS | RHING DUST P | ADDITIONAL CHARGE | |
| | 61 | YES | NO | | bag OPA va | daamulana pabu | GRAND TOTAL | |
| Con CON Con Wate | IRRITATIN ntains Portland Cemen NTACT MAY CAUSE tact with Skin. In Case er. If Irritation Persists. | WARNING IG TO THE SKIN AN t, Wear Rubber Boots and BURNS. Avoid Contact Wir of Contact with Skin or Eyes Get Medical Attention.KEEF | D EYES Gloves. PROLONGED th Eyes and Prolonged S, Rinse Thoroughly With CHILDREN AWAY. | PROPERTY DAI (TO BE SIGNED IF DELIVERY T Dear Customer - The driver of RELEASE to you for your sign size and weight of this truck me the premises and/or adjacer material in this load where yo help you in everyway that we of driver is requesting that you sign and this everyway that you sign. | MAGE RELEASE D BE MADE INSIDE CURB LINE) of this truck in presenting this ature is control to the coprion that the tary poor the coprion that the tary poor the coprion that the tary poor the coprion the coprise to desire it. It is places the u desire it. It is places the and, but in order to do this the no this RELEASE relieving the target of the target of the coprise the coprised of the target of the target of the coprised of the target of target of the target of the target of the target of the target of target of the target of targ | Excessive Water i H ₂ 0 Add GAL X WEIGHMASTER | s Detrimental to Concrete ed by Request/Authorized | Performance. J By: |
| CON PUF ORI start | NCRETE is a PERISHAB RCHASER UPON LEAVIN GINAL INSTRUCTIONS M ts. The undersigned promi | LE COMMODITY and BECOME IG the PLANT. ANY CHANGE UST be TELEPHONED to the Of ses to pay all costs, including re | S THE PROPERTY of the S or CANCELLATION of FFICE BEFORE LOADING assonable attorney's fees. | may occur to the premises buildings, sidewalks, driveways this material and that you als mud from the wheels of his veh | and or adjacent property, , curbs, etc. by the delivery of 0 agree to help him remove icle so that he will not liter the | Surcha | rae for gradit any | |
| All a | ccounts not paid within 30 c Not Responsible For R | owed. days of delivery will bear interest a leactive Aggregate or Color Quality | t the rate of 18% per v. No Claim Allowed Unless | undersigned agrees to indem driver of this truck and this sup the premises and /or adjace claimed by anyone to have arise | idditional consideration; the nify and hold harmless the blier for any and all damage to nt property which may be | NOTICE: MY SIGNATURE BEL | OW INDICATES THAT I HAN | E READ THE HEALTH |
| A \$2 Che | te at Time Material is Delivi 25.00 Service Charge and L cks. Demerge charge after s | ored. oss of the Cash Discounted will be 0 min. will be \$100.00/hr. | Collected on all Returned | SIGNED: V Try and to have an at | L | OAD RECEIVED BY | IDE CURB LINE. | BLE FOR ANY DAMAGE |
| - | ad a set of the | | | | > | 04 9 11 | | |
| | | | | | | | | |
| | | | | | | | 1, | 17007 |
| | | | | | | | - | 1031 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Report Number: A1171057.0265 Service Date: 02/06/23 Report Date: 03/23/23 Task: PO# 611801



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

Client Texas Transportation Institute Attn: Bill Griffith TTI Business Office 3135 TAMU College Station, TX 77843-3135

Material Information

Specified Strength: 4,000 psi @ 28 davs

Bcsb40500 Mix ID: Supplier: Texcrete Batch Time: 1343 Plant: Truck No.: Ticket No.: 72767

Field Test Data

| Test | Result |
|-------------------------|--------|
| Slump (in): | 4 |
| Air Content (%): | 2.0 |
| Concrete Temp. (F): | 70 |
| Ambient Temp. (F): | 72 |
| Plastic Unit Wt. (pcf): | |
| Yield (Cu. Yds.): | |

Sample Information 02/06/23 Sample Time: Sample Date: Sampled By: Blake Youngblood Weather Conditions: Sunny, windy Accumulative Yards: 3 Batch Size (cy): 3 Placement Method: Chute Water Added Before (gal): 0 Water Added After (gal): 0 Sample Location: Slab Placement Location: Slab Sample Description:

1300

6-inch diameter cylinders

Laboratory Test Data

| | | | | | | | Age at | Max | Comp | | |
|-----|------|-------|-----------|---------|----------|----------|--------|---------|----------|------|--------|
| Set | Spec | Cyl. | Avg Diam. | Area | Date | Date | Test | Load | Strength | Frac | Tested |
| NO. | ID | Cona. | (in) | (sq in) | Received | rested | (uays) | (IDS) | (psi) | туре | Бу |
| 1 | Α | Good | 6.00 | 28.27 | | 03/22/23 | 44 F | 170,360 | 6,030 | 2 | AWD |
| 1 | В | Good | 6.00 | 28.27 | | 03/22/23 | 44 F | 159,900 | 5,660 | 3 | AWD |
| 1 | С | Good | 6.00 | 28.27 | | 03/22/23 | 44 F | 149,230 | 5,280 | 3 | AWD |
| 1 | D | | | | | | Hold | | | | |

Project

Bryan, TX

Riverside Campus

Riverside Campus

Project Number: A1171057

Initial Cure: Covered with Blanket Final Cure: Field Cured

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

Note: Reported air content does not include Aggregate Correction Factor (ACF).

Specification

Samples Made By: Terracon

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.: Blake Youngblood

Reported To:

Services:

Contractor: MDC

Report Distribution:

(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Reviewed By:

Start/Stop: 1245-1400

lexander 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.

CR0001, 3-31-22, Rev.7

| | exas A&M ansportation stitute | QF 7.3-01 Sam | Concrete pling | Doc. No. QF 7.3- 01 | Revision Date: 2020-0 7- 29 |
|---|-------------------------------------|--|---|-------------------------------|---------------------------------------|
| Quality | y Form | Revised by: B.L. Griffith Approved by: D. L. Kuhn | | Revision: 7 | Page: 1 of 1 |
| Project No: | 611801-03 | Casting Date: 2/17/2023 | | Mix Design (psi): | 4000 |
| Name of Technician Taking Sample | Terr | acon | Name of Technician Breaking Sample | Terr | acon |
| Signature of Technician Taking Sample | Terr | acon | Signature of Technician Breaking Sample | Terr | acon |
| Load No. | Truck No. | Ticket No. | Locat | ion (from concrete | e map) |
| T1 | Jessie R. 152 | 73473 | | 100% of Parapet | |
| | Break Date | Culinder Age | Total Load (lbs) | Break (nsi) | Average |
| Load No. | bleak bate | Cynnael Age | 10tal 20au (153) | Dieak (psi) | Avelage |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |



Report Number: A1171057.0267 Service Date: 02/17/23 Report Date: 03/23/23 Task: PO# 611801

Client

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

Material Information

Field Test Data

Specified Strength: 4,000 psi @ 28 davs

| Mix ID: | BCSN40500 | | |
|-------------|-----------|-------------|--------|
| Supplier: | Texcrete | | |
| Batch Time: | 1125 | Plant: | 75270 |
| Truck No.: | 152 | Ticket No.: | 147685 |
| | | | |

Sample Information 02/17/23 Sample Time: Sample Date: Sampled By: Steven Savala Weather Conditions: Clear Accumulative Yards: 3 Batch Size (cy): 3 Placement Method: Chute Water Added Before (gal): 6 Water Added After (gal): 0 Sample Location: Placement Location:

Test Result Slump (in): 5 1/4 1.3 Air Content (%): Concrete Temp. (F): 74 Ambient Temp. (F): 51 Plastic Unit Wt. (pcf): Yield (Cu. Yds.):

Concrete stopper on runway Runway Sample Description: 6-inch diameter cylinders

erracon

1205

College Station, TX 77845-5765

979-846-3767 Reg No: F-3272

6198 Imperial Loop

Laboratory Test Data

| Set No. | Spec ID | Cyl. Cond. | Avg Diam. (in) | Area (sq in) | Date Received | Date Tested | Age at Test (days) | Max Load (lbs) | Comp Strength (psi) | Frac Type | Tested By |
|------------|------------|---------------|-------------------|-----------------|------------------|----------------|--------------------------|----------------------|---------------------------|--------------|--------------|
| 1 | А | Good | 6.00 | 28.27 | | 03/22/23 | 33 F | 150,070 | 5,310 | 3 | AWD |
| 1 | В | Good | 6.00 | 28.27 | | 03/22/23 | 33 F | 139,670 | 4,940 | 5 | AWD |
| 1 | С | Good | 6.00 | 28.27 | | 03/22/23 | 33 F | 141,270 | 5,000 | 5 | AWD |
| 1 | D | | | | | | Hold | | | | |
| Initial C | ure: Out | tside | | Final | Cure: Field (| Cured | | | | | |

Project

Bryan, TX

Riverside Campus

Riverside Campus

Project Number: A1171057

Initial Cure: Outside

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

Note: Reported air content does not include Aggregate Correction Factor (ACF).

Specification

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.: Steven Savala Will with TTIReported To: Contractor: ΠI **Report Distribution:**

(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Start/Stop: 1000-1300

Reviewed By: lexander 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.

CR0001, 3-31-22, Rev.7



| Texas A&M Transportation Institute | LF-SST1 Crushed Concrete Soil Strength Performance Test Record | Doc. No. LF-SST2 | Revision Date: 2021-04-05 |
|---|--|---------------------|---------------------------------|
| Laboratory Form | Revised by: B.L.Griffith Approved by: D. L. Kuhn | Revision: 0 | Page: 1 of 1 |
| The information contained in this document is confidential to | TTI Proving Ground. | | |

Crushed Concrete Soil Strength Performance Test **MASH**, Appendix B

Project Number: 611801-04-1

Date of Crash Test: 2023-03-23

 Post No.
 1
 of
 1
 Fill Moisture:
 n/a %
 Native Moisture:
 n/a %

Temperature: <u>72</u> ° F Humidity: <u>95%</u>

File Name: Soil Strength_33.ASC

| Displacement (in.) | *Pull Force (Lbf) | Minimum Force (Lbf) | Pass / Fail |
|--------------------|-------------------|---------------------|-------------|
| 5 | 10,242 | 4420 | Р |
| 10 | 10,060 | 4981 | Р |
| 15 | 10,152 | 5282 | Р |

*Do not exceed 10,000 lbf

| Test Post | 25 | ft | South | 🛛 North | of terminal post |
|-----------|----|----|----------|---------|------------------|
| Location: | | ft | 🗆 East 🛛 | □ West | of terminal post |

Performed by: e-brackin & m-robinson Date: 2023-03-23

Printed copies are not controlled documents. LF-SST2 Crushed Concrete Soil Strength Performance

ISO/IEC 17025:2017

| Texas A&M Transportation Institute | LF-SST1 Crushed Concrete Soil Strength Performance Test Record | Doc. No. LF-SST2 | Revision Date: 2021-04-05 |
|---|--|---------------------|---------------------------------|
| Laboratory Form | Revised by: B.L.Griffith Approved by: D. L. Kuhn | Revision: 0 | Page: 1 of 1 |
| The information contained in this document is confidential to | TTI Proving Ground. | | |

Crushed Concrete Soil Strength Performance Test **MASH**, Appendix B

Project Number: 611801-04-2

Date of Crash Test: 2023-03-30

Post No. 1 of 1 Fill Moisture: <u>n/a %</u> Native Moisture: <u>n/a %</u>

Temperature: <u>65</u> ° <u>F</u> Humidity: <u>92%</u>

File Name: Soil Strength_35.ASC

| Displacement (in.) | *Pull Force (Lbf) | Minimum Force (Lbf) | Pass / Fail |
|--------------------|-------------------|---------------------|-------------|
| 5 | 8545 | 4420 | Р |
| 10 | 9515 | 4981 | Р |
| 15 | 10,181 | 5282 | Р |

*Do not exceed 10,000 lbf

| Test Post | 15 | ft | South North of terminal post |
|-----------|----|----|------------------------------|
| Location: | | ft | East UWest of terminal post |

Performed by: e-brackin & m-robinson Date: 2023-03-30

Printed copies are not controlled documents. LF-SST2 Crushed Concrete Soil Strength Performance

ISO/IEC 17025:2017

APPENDIX C. MASH TEST 3-20 (CRASH TEST NO. 611801-03-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

| Date: | 2022-09-15 | Test No.: | 611801-03-1 | VIN No.: | 3N1CN7P4GL840091 |
|--------------|----------------------|---|--|--|--|
| Year: | 2016 | 6 Make: | Nissan | Model: | Versa |
| Tire Inf | lation Pressu | re: <u>36 PSI</u> | Odometer: <u>85337</u> | | Tire Size: <u>P185/65R15</u> |
| Descrit | pe any damag | ge to the vehicle pri | or to test: <u>None</u> | | |
| • Den | otes accelero | meter location. | | | |
| NOTES | S: <u>None</u> | | — A M — — — | _ | •• |
| | | | | | |
| Engine | Type: <u>4 C</u> | YL | | | |
| Transn | nission Type: | | Q | | |
| | | | | | |
| <u>None</u> | | | | | |
| | v Data: | | | | |
| Type: | <u>- 501</u> | th Percentile Male | _ ^{_]} | <h <₩</h | |
| Seat I | Position: | | _ ! | €E € | |
| Geom | etry: inche | s | 4 | | C |
| A 66.7 | 70 70 | F 32.50 | K 12.50 | P 4.50 | U 15.50 |
| B 59.6 | 60 | G | L 26.00 | Q 24.00 | 0 V 21.25 |
| C 175 | .40 | H 41.17 | M 58.30 | R 16.2 | 5 W |
| D 40.5 | 50 | l 7.00 | N 58.50 | S 7.50 | X 79.75 |
| E <u>102</u> | .40 | J <u>22.50</u> | O <u>30.50</u> | T <u>64.5</u> 0 | 0 |
| Whe | eel Center Ht | Front 11.50 | Wheel Center H | It Rear 11.50 | о w-н <u>-41.17</u> |
| RA | ANGE LIMIT: A = 65 ± | ±3 inches; C = 169 ±8 inches; E (M+N)/2 = 59 ± | = 98 ±5 inches; F = 35 ±4 inches; 2 inches; W-H < 2 inches or use MAS | H = 39 ±4 inches; O 6H Paragraph A4.3.2 | (Top of Radiator Support) = 28 ±4 inches |
| GVWR | Ratings: | Mass: Ib | <u>Curb</u> | <u>Test I</u> | nertial Gross Static |
| Front | 1750 | Mfront | 1420 | 1457 | 1542 |
| Back | 1687 | M _{rear} | 938 | 980 | 1060 |
| Total | 3389 | MTotal | 2358 | 2437 | 2602 |
| | | | Allowable TIM = 2 | 2420 lb ±55 lb Allow | able GSM = 2585 lb ± 55 lb |
| IVIASS [| Jistribution: | F [.] 712 | RF: 745 | | RR^{\cdot} 480 |
| u, | | LI. <u>112</u> | 1NL. <u>743</u> | LIN. <u>300</u> | × 400 |
| | Fig | ure C.1. Vehic | le Properties for | Test No. | 611801-03-1. |

| Date: | 2020-09-15 | Test No.: | 611801-03-1 | VIN No.: | 3N1CN7AP4GL840091 |
|-------|------------|-----------|-------------|----------|-------------------|
| Year: | 2016 | Make: | Nissan | Model: | Versa |

VEHICLE CRUSH MEASUREMENT SHEET¹

| 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) | X1+X2 _ | | | | | |
| < 4 inches | 2 | | | | | |
| ≥ 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.

| e | Direct Damage | | | | | | | | | | |
|------------------|-----------------------------|-------------------|-----------------|--------------|-------|------------------|-------|----|----|-------|-----|
| Impact Number | Plane* of C-Measurements | Width*** (CDC) | Max*** Crush | Field L** | C_1 | 1 C ₂ | C_3 | C4 | C5 | C_6 | ±D |
| 1 | AT FT BUMPER | 14 | 7 | 36 | | | | | | | -10 |
| 2 | APOVE FT BUMPER | 14 | 8 | 48 | | | | | | | 60 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | Measurements recorded | | | | | | | | | | |
| | 🖌 inches or 🗌 mm | | | | | | | | | | |
| | | | | | | | | | | | |

¹Table 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 C.2. Exterior Crush Measurements for Test No. 611801-03-1.

| Date: | 2020-09-15 | Test No.: | 611801-03-1 | | VIN No.: | 3N1CN7AP4 | GL840091 |
|--------------------|------------|------------------|-------------|---------|---------------------|-------------------|---------------|
| Year: | 2016 | Make: | Nissan | | Model: V | ersa | |
| (| H- | | | C DE | DCCUPAN FORMATIO | COMPART | MENT EMENT |
| | F | | | | Before | After (inches) | Differ. |
| | G | | | A1 | 67.50 | 67.50 | 0.00 |
| 1L | | | | A2 | 67.25 | 67.25 | 0.00 |
| \bigtriangledown | | | | A3 | 67.75 | 67.75 | 0.00 |
| | | | | B1 | 40.50 | 40.50 | 0.00 |
| | | | | B2 | 39.00 | 39.00 | 0.00 |
| | B1, B2 | , B3, B4, B5, B6 | | B3 | 40.50 | 40.50 | 0.00 |
| | | | | B4 | 36.25 | 36.25 | 0.00 |
| | A1, A | 2, &A 3 | | B5 | 36.00 | 36.00 | 0.00 |
| \exists | | 3 8 03 . | | B6 | 36.25 | 36.25 | 0.00 |
| \Box | | | | C1 | 26.00 | 26.00 | 0.00 |
| ~ | | | | C2 | 0.00 | 0.00 | 0.00 |
| | | | | C3 | 26.00 | 24.00 | -2.00 |
| | | | | D1 | 9.50 | 9.50 | 0.00 |
| | | | | D2 | 0.00 | 0.00 | 0.00 |
| | | | | D3 | 9.50 | 9.50 | 0.00 |
| | | B2 D2 | | E1 | 51.50 | 46.50 | -5.00 |
| | | | | E2 | 51.00 | 54.50 | 3.50 |
| | | | | F | 51.00 | 51.00 | 0.00 |
| | | | | G | 51.00 | 51.00 | 0.00 |
| | | | | Н | 37.50 | 37.50 | 0.00 |
| | | | | 1 | 37.50 | 37.50 | 0.00 |

*Lateral area across the cab from

driver's side kick panel to passenger's side kick panel.

Figure C.3. Occupant Compartment Measurements for Test No. 611801-03-1.

Т

J*

51.00

-5.00

46.00

C.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure C.4. Sequential Photographs for Test No. 611801-03-1 (Overhead Views).



(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure C.5. Sequential Photographs for Test No. 611801-03-1 (Frontal Views).



(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure C.6. Sequential Photographs for Test No. 611801-03-1 (Rear Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Roll, Pitch and Yaw Angles

Figure C.7. Vehicle Angular Displacements for Test No. 611801-03-1.

C.4. VEHICLE ACCELERATIONS



Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-03-1 (Accelerometer Located at Center of Gravity).



Figure C.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-03-1 (Accelerometer Located at Center of Gravity).



Figure C.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-03-1 (Accelerometer Located at Center of Gravity).

APPENDIX D. MASH TEST 3-21 (CRASH TEST NO. 611801-03-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

| Date: 2 | 2022-09-28 | Test No. | : 61180 | 1-03-2 | VIN No. | : <u>1C6R</u> F | R6GT4GS | 133477 |
|-------------------------------|--------------------|-------------------------|------------------------------|-------------------------|---------------------|--------------------------|-----------------------|-------------|
| Year: | 2016 | Make | :RA | M | Model | : | 1500 | |
| Tire Size: | 265/70 F | R 17 | | Tire I | nflation Pre | essure: | 35 p | si |
| Tread Type: | Highway | | | | Odd | ometer: <u>111</u> | 002 | |
| Note any dar | mage to the | e vehicle prior to | o test: <u>Nor</u> | e | | | | |
| Denotes a | iccelerome | ter location. | |] | ◀───X ─ ◀── ₩ ─► | - | | |
| NOTES: N | one | | 1 + | | 77 | | | |
| | | | | | | | | |
| Engine Type Engine CID: | e: V-8 5.7 lite | er | | EL C | | | | WHEEL WHEEL |
| Transmission | n Type: or | 🗖 Manual | | | | ТЕ | ST INERTIAL C. M. | |
| |) _ RV | | C | | | | | • |
| Optional Equ None | uipment: | | | | | | $\overline{\bigcirc}$ | |
| Dummy Data Type: | a: | | J-J- | | | | (P)- | |
| Mass: Seat Positio | on: | | _ | - F | €H►- € | └─ G E | → D - | • |
| Geometry: | inches | | | Ť | M FRONT | | ▼ M REAR | |
| A78 | 50 | F40.00 | _ к | 20.00 | Р | 3.00 | U | 26.75 |
| В74 | .00 | G28.50 | <u> </u> | 30.00 | Q | 30.50 | _ V | 30.25 |
| C227 | .50 | H61.29 | <u> </u> | 68.50 | R | 18.00 | _ W_ | 61.25 |
| D 44 | .00 | I <u>11.75</u> | N | 68.00 | S | 13.00 | _ X _ | 79.00 |
| E <u>140</u> | 0.50 | J27.00 | | 46.00 | _ Т_ | 77.00 | | |
| Wheel Ce Height F | ront | 14.75 c | Wheel We Clearance (Front |) | 6.00 | Bottom Fra Height - F | ame ront | 12.50 |
| Wheel Ce Height F | nter Rear | 14.75 | Wheel We Clearance (Rear | | 9.25 | Bottom Fra Height - F | ame Pear | 22.50 |
| RANGE LIMIT: A= | =78 ±2 inches; C= | 237 ±13 inches; E=148 ± | :12 inches; F=39 ±3 i | / nches; G = > 28 ir | nches; H = 63 ±4 | inches; O=43 ±4 inch | nes; (M+N)/2=67 | ±1.5 inches |
| GVWR Ratir | ngs: | Mass: It | o <u>Cu</u> | rb | Test | Inertial | Gros | s Static |
| Front | 3700 | Mfront | | 2960 | | 2825 | | |
| Back | 3900 | M _{rear} | | 2075 | | 2186 | | |
| Total | 6700 | М _{Тоtal} | | 5035 | | 5011 | | 5011 |
| Mass Distril | bution: | | | (Allowable | Range for TIM and | d GSM = 5000 lb ±11 | 10 lb) | |
| lb | | LF: <u>1425</u> | | 1400 | LR: | 1110 | RR: | 1076 |

Figure C.1. Vehicle Properties for Test No. 611801-03-2.

| Date: | 2022-09-28 | Test No.: | 611801-03-2 | VIN No.: | 1C6RR6GT4GS133477 |
|-------|------------|-----------|-------------|----------|-------------------|
| Year: | 2016 | Make: | RAM | Model: | 1500 |

VEHICLE CRUSH MEASUREMENT SHEET¹

| 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) | X1+X2 _ | | | | | | |
| < 4 inches | 2 = | | | | | | |
| \geq 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.

| | | Direct Damage | | | | | | | | | |
|------------------------------|-----------------------------|-------------------|-----------------|--------------|----|----------------|----|-------|-------|-------|-----|
| Specific Impact Number | Plane* of C-Measurements | Width*** (CDC) | Max*** Crush | Field L** | C1 | C ₂ | C3 | C_4 | C_5 | C_6 | ±D |
| 1 | AT FT BUMPER | 24 | 12 | 36 | | | | | | | -18 |
| 2 | SAME | 24 | 12 | 72 | | | | | | | 64 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | Measurements recorded | | | | | | | | | | |
| | √ inches or ☐ mm | | | | | | | | | | |
| | | | | | | | | | | | |

¹Table 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 D.2. Exterior Crush Measurements for Test No. 611801-03-2.

| Date: | 2022-09-28 | _ Test No.: | 611801-03-2 | _ VIN No.: | 1C6RR6GT4GS133477 | | | | |
|-----------|---------------|-------------|-------------|---|-------------------|---------|--|--|--|
| Year: | 2016 | _ Make: | RAM | Model: | 150 | 0 | | | |
| | The | - + -) / + | т. D | OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT | | | | | |
| | F | | 1 | Before | After (inches) | Differ. | | | |
| | | E2 E3 E | A1 | 65.00 | 65.00 | 0.00 | | | |
| K | | | A2 | 63.00 | 63.00 | 0.00 | | | |
| | | | Аз | 65.50 | 65.50 | 0.00 | | | |
| | | | B1 | 45.00 | 45.00 | 0.00 | | | |
| | | | B2 | 38.00 | 38.00 | 0.00 | | | |
| | | | B3 | 45.00 | 45.00 | 0.00 | | | |
| B1-3 B4-6 | B4 | 39.50 | 39.50 | 0.00 | | | | | |
| | -6 B5 | 43.00 | 43.00 | 0.00 | | | | | |
| 6 | | -3 | В6 | 39.50 | 39.50 | 0.00 | | | |
| | | | C1 | 26.00 | 26.00 | 0.00 | | | |
| | \mathcal{I} | | C2 | 0.00 | 0.00 | 0.00 | | | |
| | ~ | | C3 | 26.00 | 22.50 | -3.50 | | | |
| | | | D1 | 11.00 | 11.00 | 0.00 | | | |
| | | | D2 | 0.00 | 0.00 | 0.00 | | | |
| | | | D3 | 11.50 | 11.50 | 0.00 | | | |
| B1,4 B3,6 | E1 | 58.50 | 57.00 | -1.50 | | | | | |
| | E2 | 63.50 | 65.00 | 1.50 | | | | | |
| | | 1-4 | E3 | 63.50 | 63.50 | 0.00 | | | |
| | | | E4 | 63.50 | 63.50 | 0.00 | | | |
| | | | F | 59.00 | 59.00 | 0.00 | | | |

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

| Figure D 3 | Occupant | Compartment | Magguraments | for Test No | 611801-03-2 |
|-------------|----------|-------------|--------------------|--------------|--------------|
| Figure D.J. | Occupant | Compartment | ivicasui citicitis | IOI TESLINO. | 011001-03-2. |

G Н

I

J*

59.00

37.50

37.50

24.00

59.00

37.50

37.50

21.50

0.00

0.00

0.00

-2.50

D.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s

(b) 0.100 s



€ 0.200 s

(d) 0.300 s



€ 0.400 s

(f) 0.500 s






(a) 0.000 s

(b) 0.100 s



€ 0.200 s

(d) 0.300 s



€ 0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure D.5. Sequential Photographs for Test No. 611801-03-2 (Frontal Views).



(a) 0.000 s

(b) 0.100 s



€ 0.200 s

(d) 0.300 s



€0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure D.6. Sequential Photographs for Test No. 611801-03-2 (Rear Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Roll, Pitch and Yaw Angles

Figure D.7. Vehicle Angular Displacements for Test No. 611801-03-2.

D.4. VEHICLE ACCELERATIONS



Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-03-2 (Accelerometer Located at Center of Gravity).



Figure D.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-03-2 (Accelerometer Located at Center of Gravity).



Figure D.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-03-2 (Accelerometer Located at Center of Gravity).

APPENDIX E. MASH TEST 3-20 (CRASH TEST NO. 611801-04-1)

E.1. VEHICLE PROPERTIES AND INFORMATION

| Date: | 2023-03-27 | Test No.∶ | <u>611801-04-1</u> | | VIN No.: | <u>3N1CN7AF</u> | 24HL801342 |
|------------------|----------------------------------|---------------------------------------|---|---|-----------------------------------|---------------------|------------------------|
| Year: | 2017 | Make: | Nissan | | Model: | Versa | |
| Tire Infl | lation Pressure: <u>36 I</u> | PSI | _ Odometer: | 234630 | | Tire Size: | P185/65R15 |
| Describ | be any damage to the | e vehicle pric | or to test: <u>No</u> | one | | | |
| • Deno | otes accelerometer lo | ocation. | † | | | ==== | |
| NOTES | S: <u>None</u> | | - д м —— | | | •• | |
| | | | - | | | | |
| Engine Engine | Type: <u>4 CYL</u> CID: 1.6 L | | _ <u>* · · · · · · · · · · · · · · · · · · </u> | | | | |
| | nission Type: Auto or П | Manual | _ | ← Q → | - 0 | | |
| Optiona | FWD I RWD | 4WD | P | | | | |
| None | | | - • • • • • | | 1 | | |
| | D / | | | | | | |
| Dummy Type: | / Data: 50th Percer | ntile Male | ا تـ _ا | ⋖ ─F─ ⊳ ⋖─ | —н— - в | | ∟к |
| Mass: | 165 lb | | _ | | —— | | D -> |
| Seat F | Position: <u>IMPACT SI</u> | DE | - | - | | -X | |
| Geome | etry: inches | | , | 4 | | C | |
| A <u>66.7</u> | 0 F <u>32.</u> | 50 | K <u>12.50</u> | | P <u>4.50</u> | | U <u>15.50</u> |
| B <u>59.6</u> | <u> </u> | | L <u>26.00</u> | | Q <u>24.0</u> | D | V <u>21.25</u> |
| C <u>175.</u> | 40 H <u>41.8</u> | 37 | M <u>58.30</u> | | R <u>16.2</u> | 5 | W <u>41.75</u> |
| D <u>40.5</u> | 0l <u>7.00</u> |) | N <u>58.50</u> | | S <u>7.50</u> | | X <u>79.75</u> |
| E <u>102.</u> | 40 J <u>22.</u> | 50 | O <u>30.50</u> | | T <u>64.5</u> | 0 | |
| Whe | el Center Ht Front <u>1</u> | 1.50 | Wheel (| Center Ht F | Rear <u>11.50</u> |) | W-H <u>-0.12</u> |
| RA | NGE LIMIT: A = 65 ±3 inches; C | = 169 ±8 inches; E (M+N)/2 = 59 ±2 | = 98 ±5 inches: F = 35 inches: W-H < 2 inche | 5 ±4 inches; H = 3 es or use MASH Pa | 9 ±4 inches; O aragraph A4.3.2 | (Top of Radiator Su | upport) = 28 ±4 inches |
| GVWR | Ratings: | Mass: Ib | <u>Curb</u> | | <u>Test I</u> | <u>nertial</u> | Gross Static |
| Front | 1750 | M _{front} | 1421 | | 1447 | | 1532 |
| Back | 1687 | M _{rear} | 988 | | 1001 | | 1081 |
| Total | 3389 | M _{Total} | 2409 | | 2448 | | 2613 |
| | N - 4-11 41 - | | Allo | wable TIM = 2420 | lb ±55 lb Allow | able GSM = 2585 I | b ± 55 lb |
| IVIass E | Jistribution: ∣ ⊑ | 821 | RF: 626 | | I R [.] 447 | , | RR: 554 |
| | | | | | <u></u> | | |

Figure E.1. Vehicle Properties for Test No. 611801-04-1.

| Date: | | _ Test No.: | 611801-04- | 1 | VIN No.: | 3N1CN7AP4HL801342 |
|-------|-------------------|-----------------|-------------|-------------|--------------|-------------------|
| Year: | 2017 | Make: | Nissan | | Model: | Versa |
| | V | EHICLE C | RUSH ME. | ASUREM | ENT SHE | ET ¹ |
| | | (| Complete Wh | en Applicab | le | |
| | End Dar | nage | | | Si | de Damage |
| | Undeformed | end width | | - | Bowing: B1 | X1 |
| | Corne | r shift: A1 | | | B2 | X2 |
| | | A2 | | | | |
| | End shift at fram | e (CDC) | | Bow | ving constan | t |
| | (check on | e) | | | X1+X2 | |
| | | <4 inches | | | 2 | |
| | | \geq 4 inches | | | | |

Note: Measure C₁ to C₆ from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

| | | Direct Damage | | | | | | | | | |
|------------------------------|-----------------------------|-------------------|-----------------|--------------|----|----------------|----|-------|----|-------|----|
| Specific Impact Number | Plane* of C-Measurements | Width*** (CDC) | Max*** Crush | Field L** | C1 | C ₂ | C3 | C_4 | C5 | C_6 | ±D |
| 1 | AT FT BUMPER | 12 | 8 | 56 | | | | | | | 28 |
| 2 | ABOVE FT BUMPER | 12 | 10 | 48 | | | | | | | 56 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | Measurements recorded | | | | | | | | | | |
| | 🖌 inches or 🗌 mm | | | | | | | | | | |
| | | | | | | | | | | | |

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

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

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

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

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

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

Figure E.2. Exterior Crush Measurements for Test No. 611801-04-1.

| Date: | | Test No.: | 611801-04-1 | <u>۱</u> | /IN No.: | 3N1CN7AP4 | HL801342 |
|-------|--------------|---------------------|-------------|-----------|--------------------|-----------------------|---------------|
| Year: | 2017 | Make: | Nissan | ٩ | Model: Ver | sa | |
| | H- | | 2 | O(DEF | CCUPANT ORMATIO | COMPARTI N MEASURI | MENT EMENT |
| | F | | | | Before | After (inches) | Differ. |
| | G | | | A1 | 67.50 | 67.50 | 0.00 |
| 11 | | 7 | | A2 | 67.25 | 67.25 | 0.00 |
| Q | | | | A3 | 67.75 | 67.75 | 0.00 |
| | | | | B1 | 40.50 | 40.50 | 0.00 |
| | | | | B2 | 39.00 | 39.00 | 0.00 |
| | B1, B2, E | 33, B4, B5, B6 | | B3 | 40.50 | 40.50 | 0.00 |
| | | | | B4 | 36.25 | 36.25 | 0.00 |
| | | | | B5 | 36.00 | 36.00 | 0.00 |
| | D1, D2, & D3 | | | B6 | 36.25 | 36.25 | 0.00 |
| | | FT ((| | C1 | 26.00 | 26.00 | 0.00 |
| | | | | C2 | 0.00 | 0.00 | 0.00 |
| | | | | C3 | 26.00 | 25.00 | -1.00 |
| | | | | D1 | 9.50 | 9.50 | 0.00 |
| | | | | D2 | 0.00 | 0.00 | 0.00 |
| | | 1 | | D3 | 9.50 | 9.50 | 0.00 |
| | | 2 02 | | E1 | 51.50 | 48.50 | -3.00 |
| | | $F2 \rightarrow F2$ | | E2 | 51.00 | 52.00 | 1.00 |
| | | | | F | 51.00 | 51.00 | 0.00 |
| | | | | G | 51.00 | 51.00 | 0.00 |
| | | | | Н | 37.50 | 37.50 | 0.00 |

*Lateral area across the cab from

driver's side kick panel to passenger's side kick panel.

Figure E.3. Occupant Compartment Measurements for Test No. 611801-04-1.

| J* 37.50

51.00

37.50

50.00

0.00

-1.00

E.2. **SEQUENTIAL PHOTOGRAPHS**





(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(h) 0.700 s (g) 0.600 s Figure E.4. Sequential Photographs for Test No. 611801-04-1 (Overhead Views).



(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure E.5. Sequential Photographs for Test No. 611801-04-1 (Frontal Views).





(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s

(h) 0.700 s

Figure E.6. Sequential Photographs for Test No. 611801-04-1 (Rear Views).

E.3. VEHICLE ANGULAR DISPLACEMENTS



Roll, Pitch and Yaw Angles

Figure E.7. Vehicle Angular Displacements for Test No. 611801-04-1.

E.4. VEHICLE ACCELERATIONS



X Acceleration at CG





Y Acceleration at CG

Figure E.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-04-1 (Accelerometer Located at Center of Gravity).



Figure E.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-04-1 (Accelerometer Located at Center of Gravity).

APPENDIX F. MASH TEST 3-21 (CRASH TEST NO. 611801-04-2)

F.1. VEHICLE PROPERTIES AND INFORMATION

| Date: | 2023-03-30 |) | Test No. | :61180 | 01-04-2 | VIN No.: | 1C6RR | 6GTXHS | 512761 |
|-------------------|--------------------|----------|--------------------|----------------------------|---------------------|----------------------|-----------------------------|--------------------------------|------------------|
| Year: | 2017 | | Make | :R | АМ | Model | | 1500 | |
| Tire Size: | 265/70 F | २ १७ | | | Tire I | nflation Pre | essure: | 35 p | osi |
| Tread Type | e: Highway | / | | | | Odd | meter: <u>1541</u> | 98 | |
| Note any d | amage to th | e veh | icle prior to | o test: No | ne | | | | |
| • Denotes | accelerome | ter lo | cation | | | | | | |
| | Vono | | oution. | 4 | | | | | |
| NOTES: 1 | NUTIE | | | - 1 | | 7// T | | | |
| Engine Typ | be: <u>V-8</u> | | | | EEL CK | +- | | | |
| Engine CIL |): <u>5.7 lit</u> | er | | - + + | -6- | - | | _j | TRACK |
| Transmissi | on Type: | | Manual | | | | TEST | Í INERTIAL C. M. | |
| | | WD | | C | R - P | | | | 4 |
| Optional Ec | quipment: | | | | | | | | 7 |
| None | | | | _ 1 _ | | T. | | 3 | ЦВ |
| Dummy Da | ta: | | | Ţ J-Ţ I | |))~ \ + | ₩ ₩ ₩ ₩ | P | T _K L |
| Type: Mass: | | | | | - F | ∟u ש—-H_ | | | |
| Seat Posi | tion: | | | _ | - | • | - E | → -> | • |
| Geometry | inches | | | | Ψ. | M FRONT | | $\mathbb{V}_{\text{rear}}^{M}$ | |
| A 7 | 8.50 | F | 40.00 | к | 20.00 | Р | — с — <u>3</u> .00 | U | 26.75 |
| в 7 | 4.00 | G _ | 28.62 | _ L _ | 30.00 | | 30.50 | v | 30.25 |
| C 22 | 27.50 | н _ | 61.66 | M | 68.50 | R | 18.00 | W | 61.50 |
| D4 | 14.00 | Ι | 11.75 | N | 68.00 | s | 13.00 | X _ | 79.00 |
| E14 | 10.50 | J _ | 27.00 | _ | 46.00 | _ Т_ | 77.00 | | |
| Wheel C Height | Center Front | 1 | 4.75 c | Wheel We learance (Fror | ell it) | 6.00 | Bottom Fran Height - Fro | ne ont | 12.50 |
| Wheel C Height | Center Rear | 1 | 4.75 (| Wheel We Clearance (Rea | ell (r) | 9.25 | Bottom Fran Height - Re | ne Par | 22.50 |
| RANGE LIMIT: . | A=78 ±2 inches; C: | =237 ±13 | inches; E=148 ± | 12 inches; F=39 ±3 | inches; G = > 28 ir | nches; H = 63 ±4 i | nches; O=43 ±4 inche | es; (M+N)/2=67 | ±1.5 inches |
| GVWR Rat | ings: | | Mass: Ib | D <u>Ci</u> | <u>urb</u> | Test | Inertial | Gros | s Static |
| Front | 3700 | | Mfront | | 2920 | | 2834 | | 2834 |
| Back | 3900 | | M _{rear} | | 2145 | | 2217 | | 2217 |
| Total | 6700 | | M _{Total} | | 5065 | | 5051 | | 5051 |
| Mass Dist | ribution: | | | | (Allowable | rcange for i nvi and | 1 1 1 ± al 000 = 1468 | נטרי | |
| lb | _ | LF: | 1401 | | 1433 | LR: | 1135 | RR: | 1082 |

Figure F.1. Vehicle Properties for Test No. 611801-04-2.

| Date: | 2023-03-30 | Test No.: | 611801-04-2 | VIN No.: | 1C6RR6GTXHS512761 | | |
|-------|------------|-----------|-------------|----------|-------------------|--|--|
| Year: | 2017 | Make: | RAM | Model: | 1500 | | |

VEHICLE CRUSH MEASUREMENT SHEET¹

| 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) | X1+X2 _ |
| < 4 inches | 2 |
| \geq 4 inches | |

Note: Measure C1 to C6 from Driver to Passenger Side in Front or Rear Impacts - Rear to Front in Side Impacts.

| | | Direct Damage | | | | | | | | | |
|------------------------------|-----------------------------|------------------|-----------------|--------------|-------|-------|-------|-------|-------|-------|-----|
| Specific Impact Number | Plane* of C-Measurements | Width** (CDC) | Max*** Crush | Field L** | C_1 | C_2 | C_3 | C_4 | C_5 | C_6 | ±D |
| 1 | AT FT BUMPER | 12 | 10 | 36 | | | | | | | +18 |
| 2 | ABOVE FT BUMPER | 12 | 14 | 64 | | | | | | | 74 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | Measurements recorded | | | | | | | | | | |
| | √ inches or ☐ mm | | | | | | | | | | |
| | | | | | | | | | | | |

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

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

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

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

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

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

Figure F.2. Exterior Crush Measurements for Test No. 611801-04-2.

| Date: | 2023-03-30 | _ Test No.: _ | 611801-04-2 | VIN No.: | 1C6RR6GTX | HS512761 |
|-----------|---------------|----------------------|--|-----------------------|----------------------|---------------|
| Year: | 2017 | _ Make: | RAM | _ Model: | 150 | 0 |
| | 717 | + -) / + | TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT | OCCUPANT EFORMATIO | COMPARTI N MEASUR | MENT EMENT |
| | F | | | Before | After (inches) | Differ. |
| | J E1 | E2 E3 E | A1 | 65.00 | 65.00 | 0.00 |
| K | | | A2 | 63.00 | 63.00 | 0.00 |
| | | н | ⊉⊑ АЗ | 65.50 | 65.50 | 0.00 |
| | | | B1 | 45.00 | 45.00 | 0.00 |
| | | | B2 | 38.00 | 38.00 | 0.00 |
| | | | ВЗ | 45.00 | 45.00 | 0.00 |
| | | | B4 | . 39.50 | 39.50 | 0.00 |
| | | B1-3 B4- | -6 B5 | 43.00 | 43.00 | 0.00 |
| 6 | DI | -3 | B6 | 39.50 | 39.50 | 0.00 |
| \square | | | C1 | 26.00 | 26.00 | 0.00 |
| | | | C2 | 0.00 | 0.00 | 0.00 |
| | <u> </u> | | C3 | 26.00 | 23.00 | -3.00 |
| | | | D1 | 11.00 | 11.00 | 0.00 |
| | | | D2 | 0.00 | 0.00 | 0.00 |
| | | | D3 | 11.50 | 11.50 | 0.00 |
| | | | E1 | 58.50 | 56.50 | -2.00 |
| | B1,4 | <u> B3,6</u> | E2 | 63.50 | 64.50 | 1.00 |
| | − E | 1-4 | E3 | 63.50 | 63.50 | 0.00 |
| | | | E4 | 63.50 | 63.50 | 0.00 |
| | | | F | 59.00 | 59.00 | 0.00 |
| | | | G | 59.00 | 59.00 | 0.00 |
| | | | Н | 37.50 | 37.50 | 0.00 |

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

Figure F.3. Occupant Compartment Measurements for Test No. 611801-04-2.

L

J*

37.50

25.00

37.50

25.00

0.00

0.00

F.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s







(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s (h) 0.700 s Figure F.5. Sequential Photographs for Test No. 611801-04-2 (Frontal Views).



(a) 0.000 s

(b) 0.100 s



(c) 0.200 s

(d) 0.300 s



(e) 0.400 s

(f) 0.500 s



(g) 0.600 s

(h) 0.700 s

Figure F.6. Sequential Photographs for Test No. 611801-04-2 (Rear Views).

F.3. VEHICLE ANGULAR DISPLACEMENTS



Roll, Pitch and Yaw Angles

Figure F.7. Vehicle Angular Displacements for Test No. 611801-04-2.

F.4. VEHICLE ACCELERATIONS



Figure F.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-04-2 (Accelerometer Located at Center of Gravity).



Y Acceleration at CG

Figure F.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-04-2 (Accelerometer Located at Center of Gravity).



Figure F.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-04-2 (Accelerometer Located at Center of Gravity)

APPENDIX G. DETAILS OF THE CONCRETE SINGLE SLOPE PARAPET TRANSITION



S:Vaccreditation-17025-2017/EIR-000 Project Files/611801-04, Wyoming DoT - Bligh & Sheikh\Drafting for transition to SS/2023-10-23/Vertical Wall to SS Drawing



S:Vaccreditation-17025-2017/EIR-000 Project Files/611801-04, Wyoming DoT - Bligh & Sheikh\Drafting for transition to SS/2023-10-23/Vertical Wall to SS Drawing





228



S:Vaccreditation-17025-2017/EIR-000 Project Files/611801-04, Wyoming DoT - Bligh & Sheikh\Drafting for transition to SS/2023-10-23/Vertical Wall to SS Drawing



230

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting for transition to SS\2023-10-23\Vertical Wall to SS Drawing



S: Accreditation-17025-2017 EIR-000 Project Files 611801-04, Wyoming DoT - Bligh & Sheikh\Drafting for transition to SS\2023-10-23 \Vertical Wall to SS Drawing