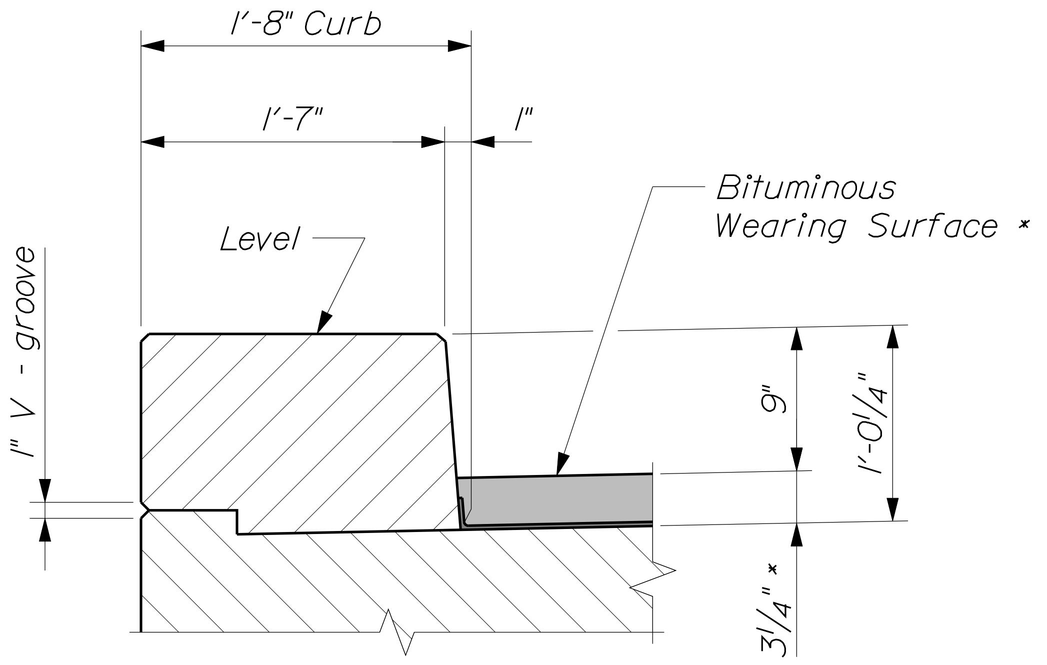
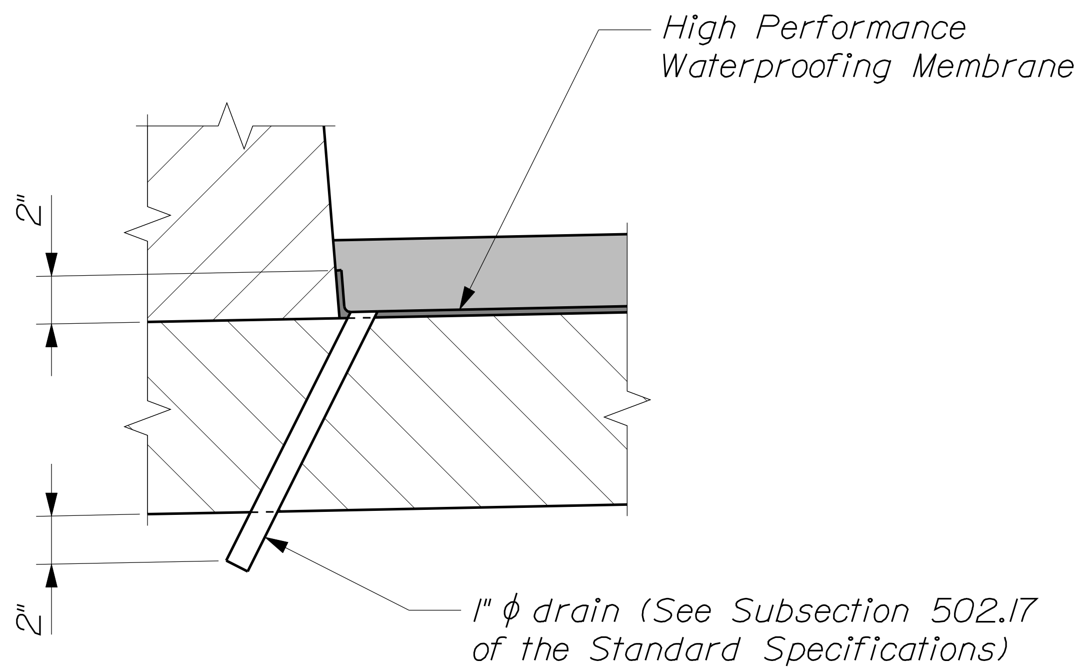
Development of MASH Computer Simulated Steel Bridge Rail and Transition Details - Appendices to Final Report

APPENDIX A: MAINE DOT STANDARD BRIDGE RAIL DRAWINGS



~ CURB WITH BITUMINOUS WEARING SURFACE ~

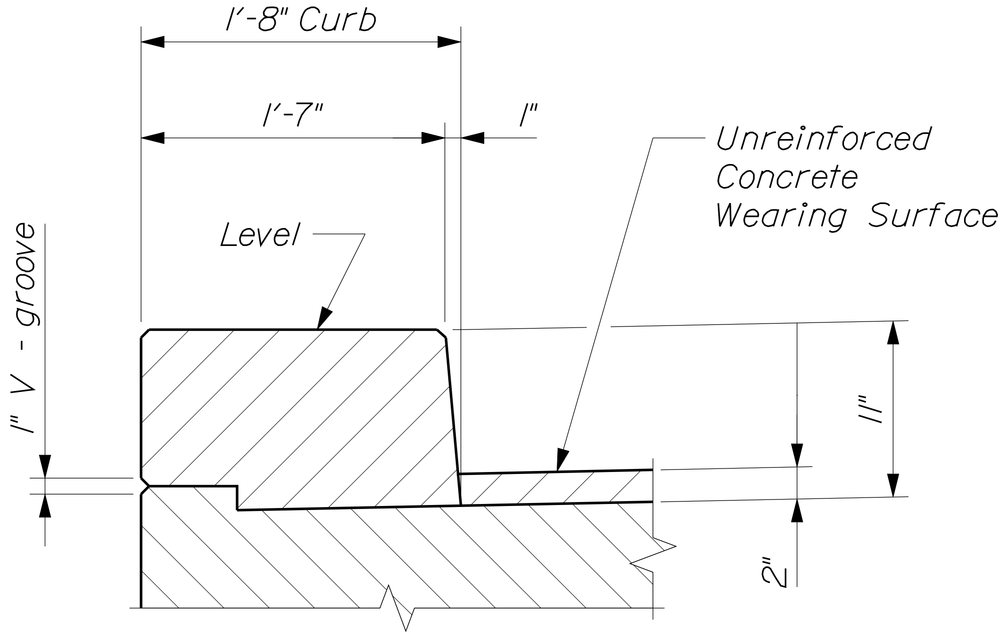
* 3" Hot Mix Asphalt + 1/4" (nom.) High Performance Waterproofing Membrane



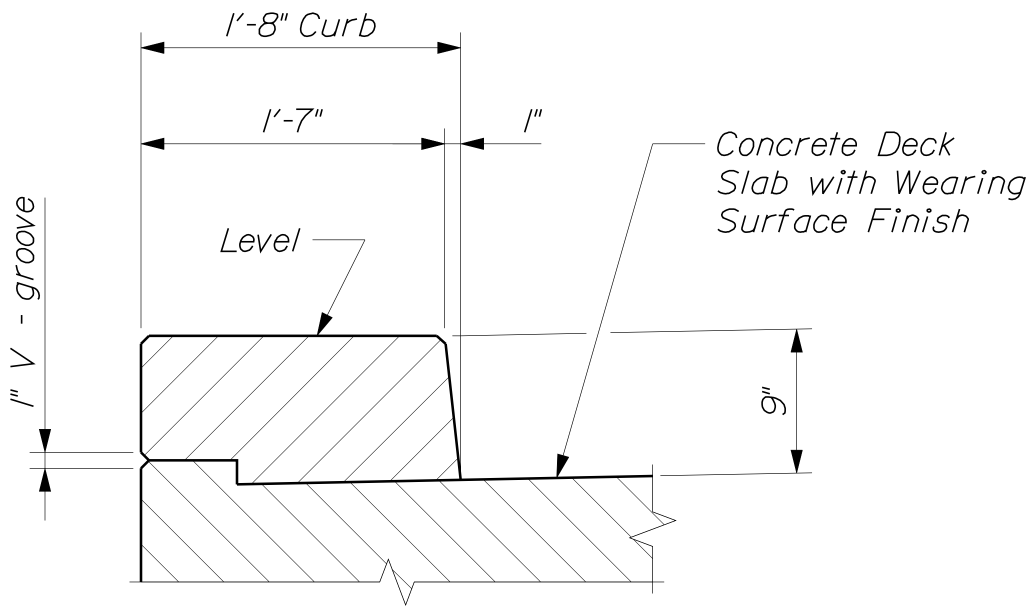
~ GUTTER DETAIL FOR BITUMINOUS W. S. ~

CONCRETE CURB

502(04)



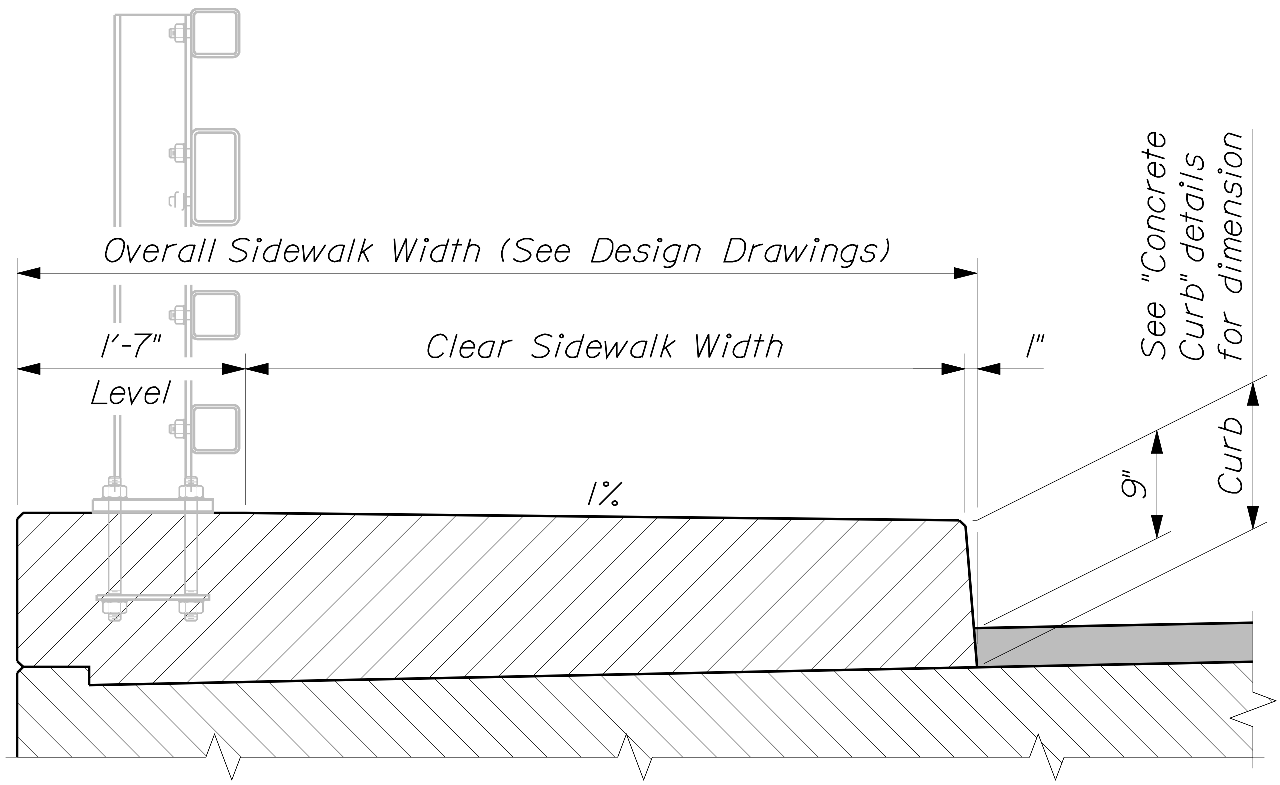
-- CURB WITH CONCRETE WEARING SURFACE --



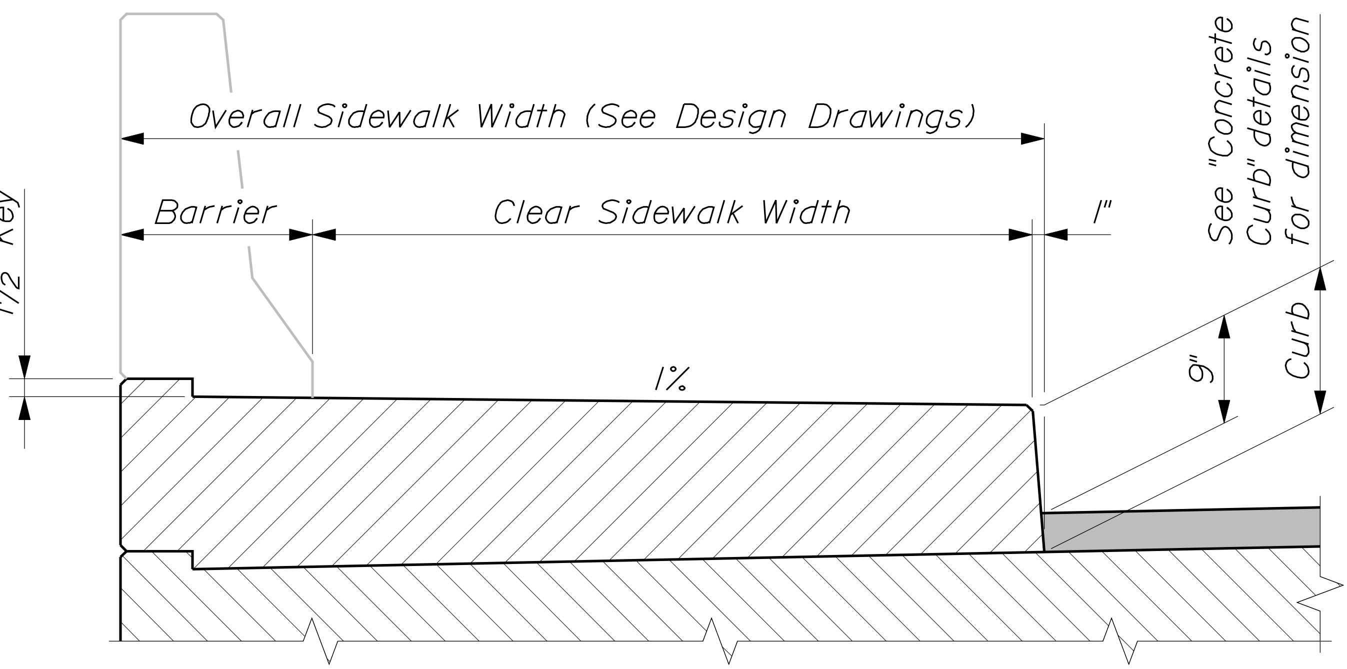
-- CURB WITH INTEGRAL WEARING SURFACE --

CONCRETE CURB

502(05)



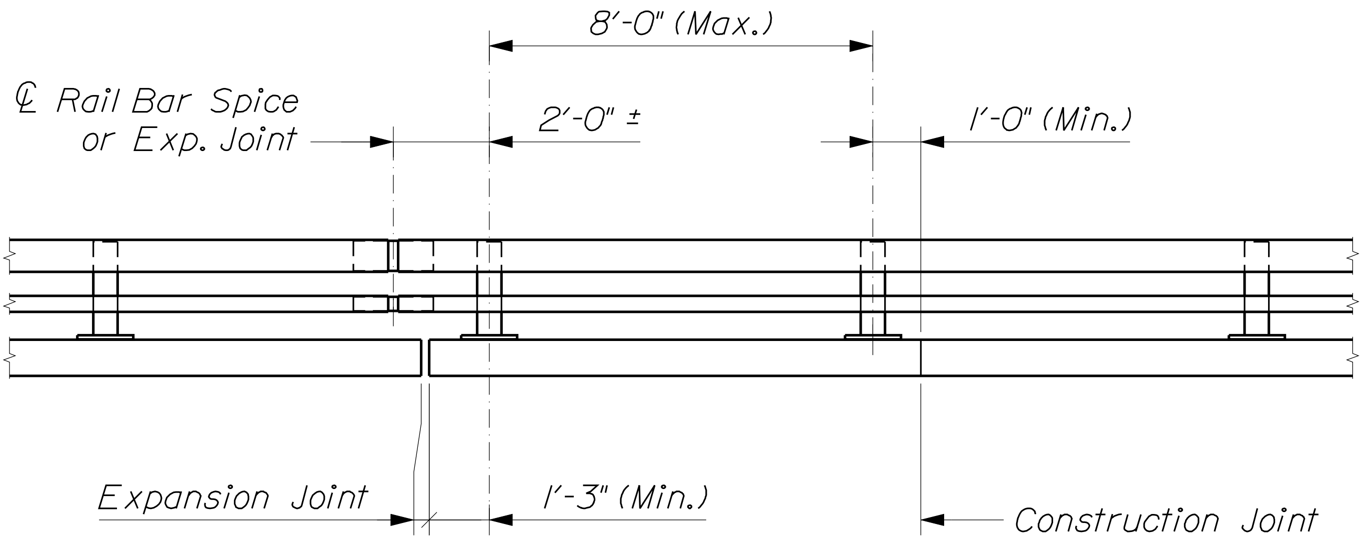
~ WITH STEEL BRIDGE RAILING ~



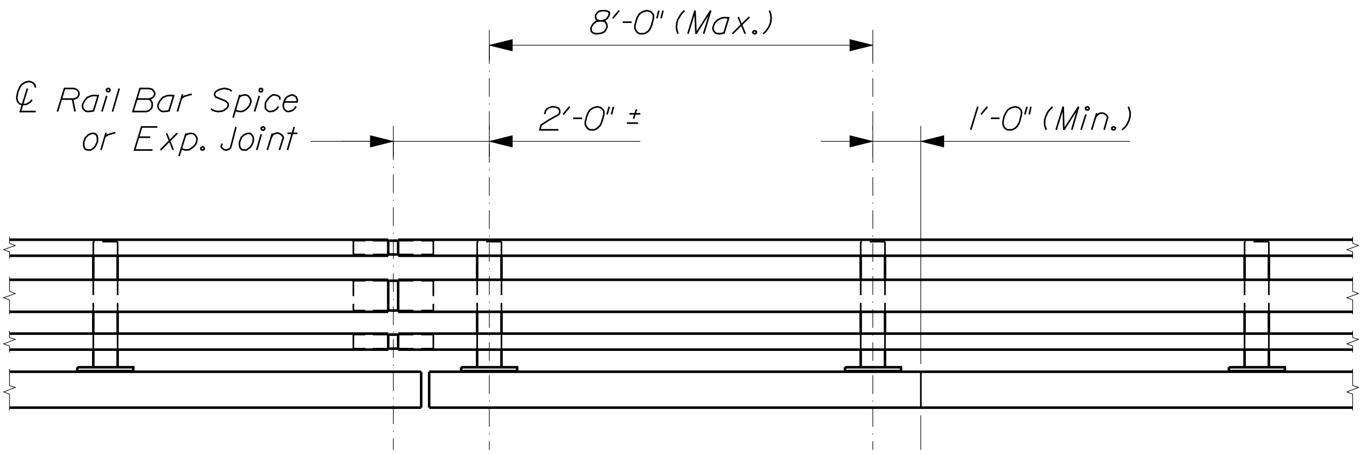
~ WITH PERMANENT CONCRETE BARRIER ~

CONCRETE SIDEWALK ON BRIDGES

502(06)

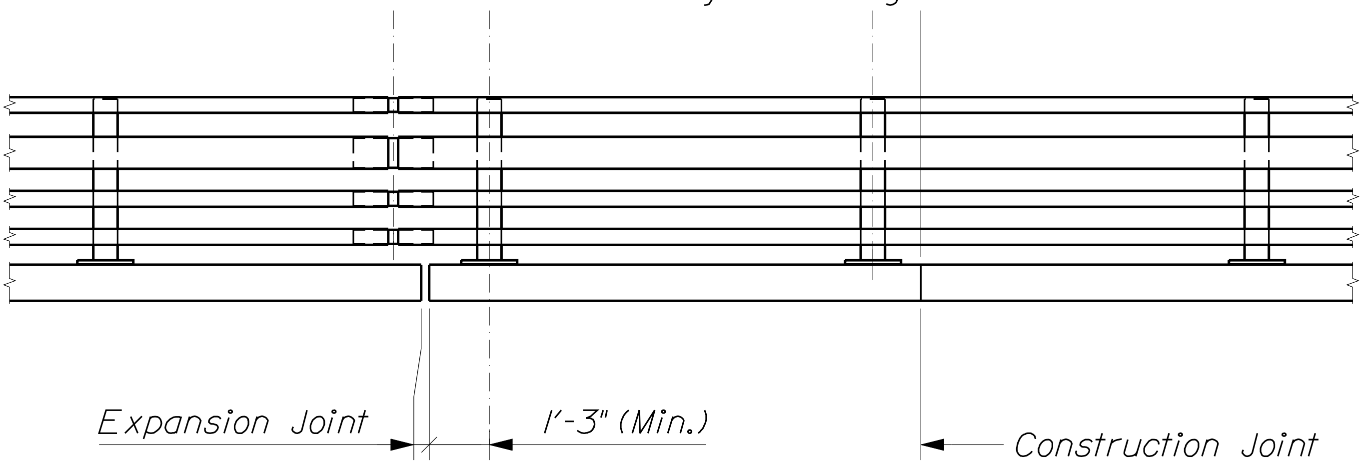


~ 2 - BAR TRAFFIC RAILING ~



~ 3 - BAR TRAFFIC / BICYCLE RAILING ~

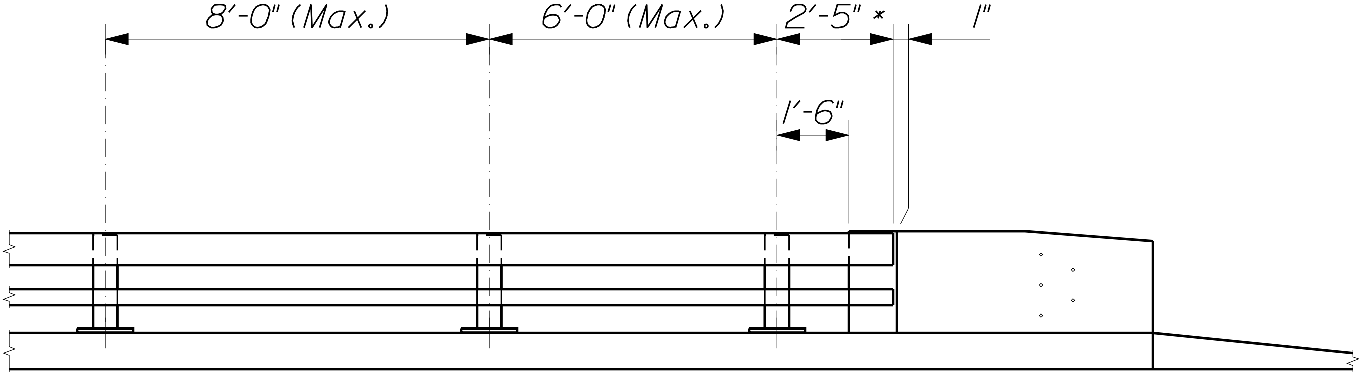
(4 - Bar Traffic / Bicycle Railing similar)



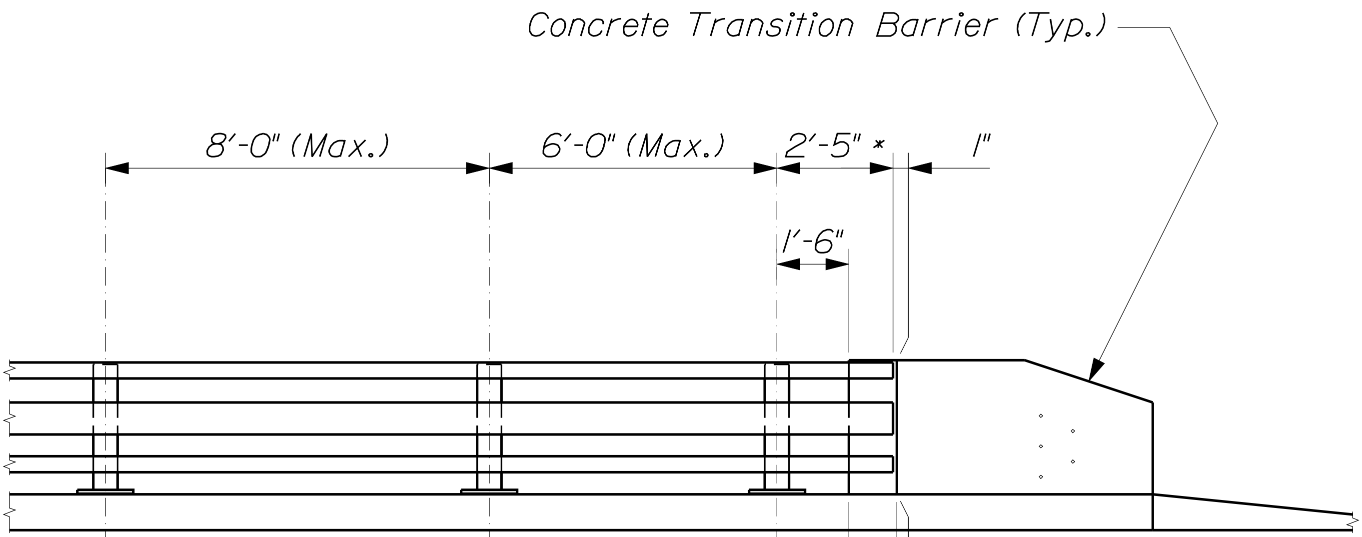
~ 4 - BAR TRAFFIC / PEDESTRIAN RAILING ~

STEEL BRIDGE RAILING

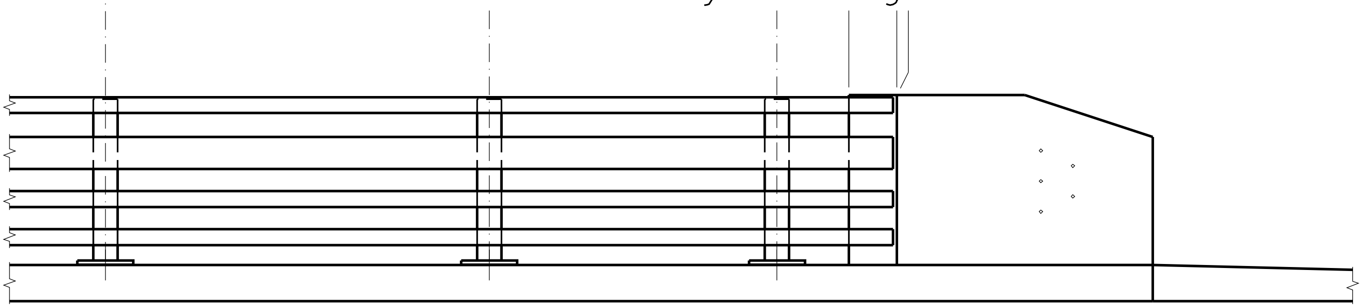
507(01)



~ 2 - BAR TRAFFIC RAILING ~



~ 3 - BAR TRAFFIC / BICYCLE RAILING ~
(4 - Bar Traffic / Bicycle Railing similar)

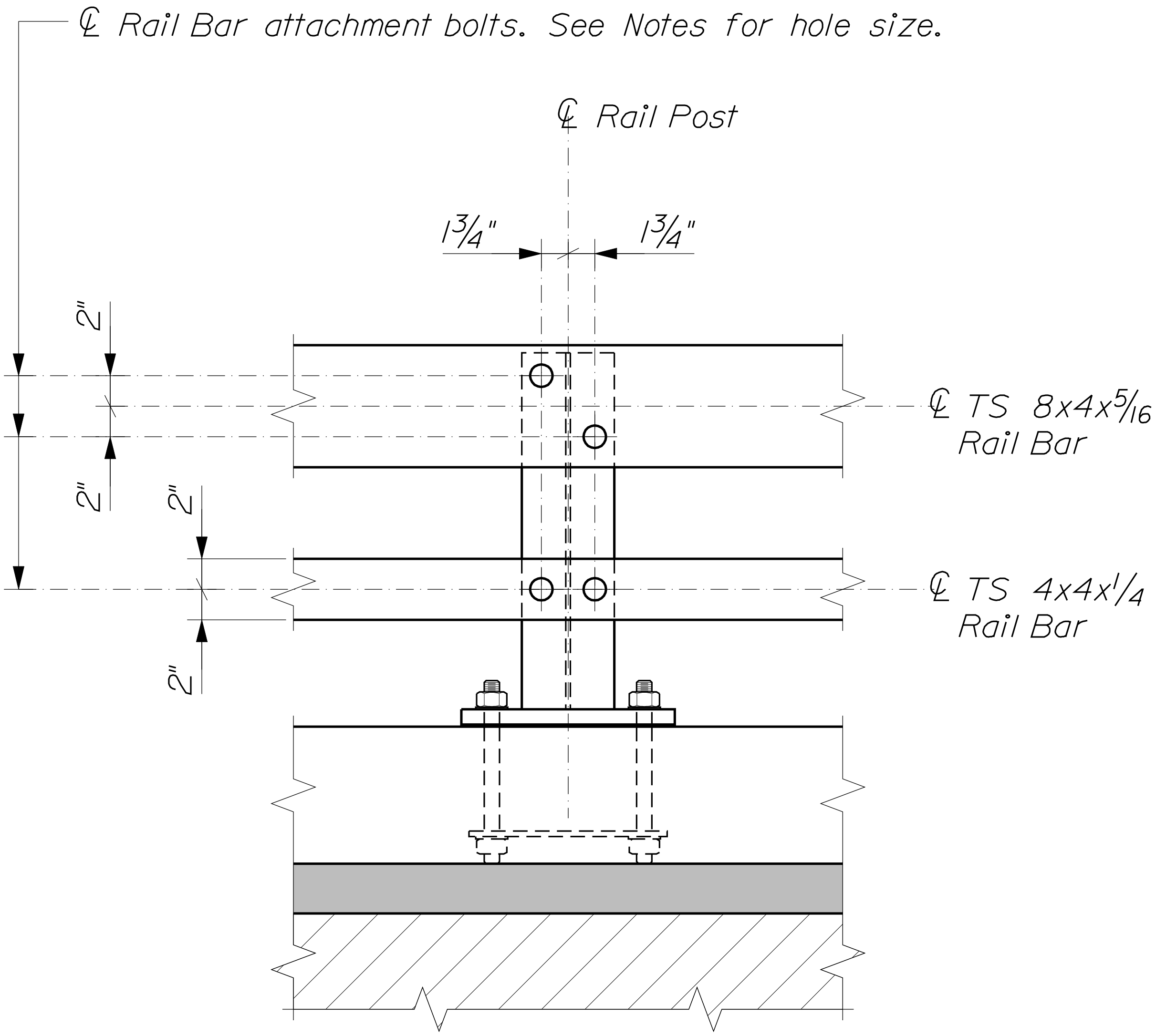


~ 4 - BAR TRAFFIC / PEDESTRIAN RAILING ~

* Including Rail Bar Cap (Typ.)

STEEL BRIDGE RAILING

507(02)



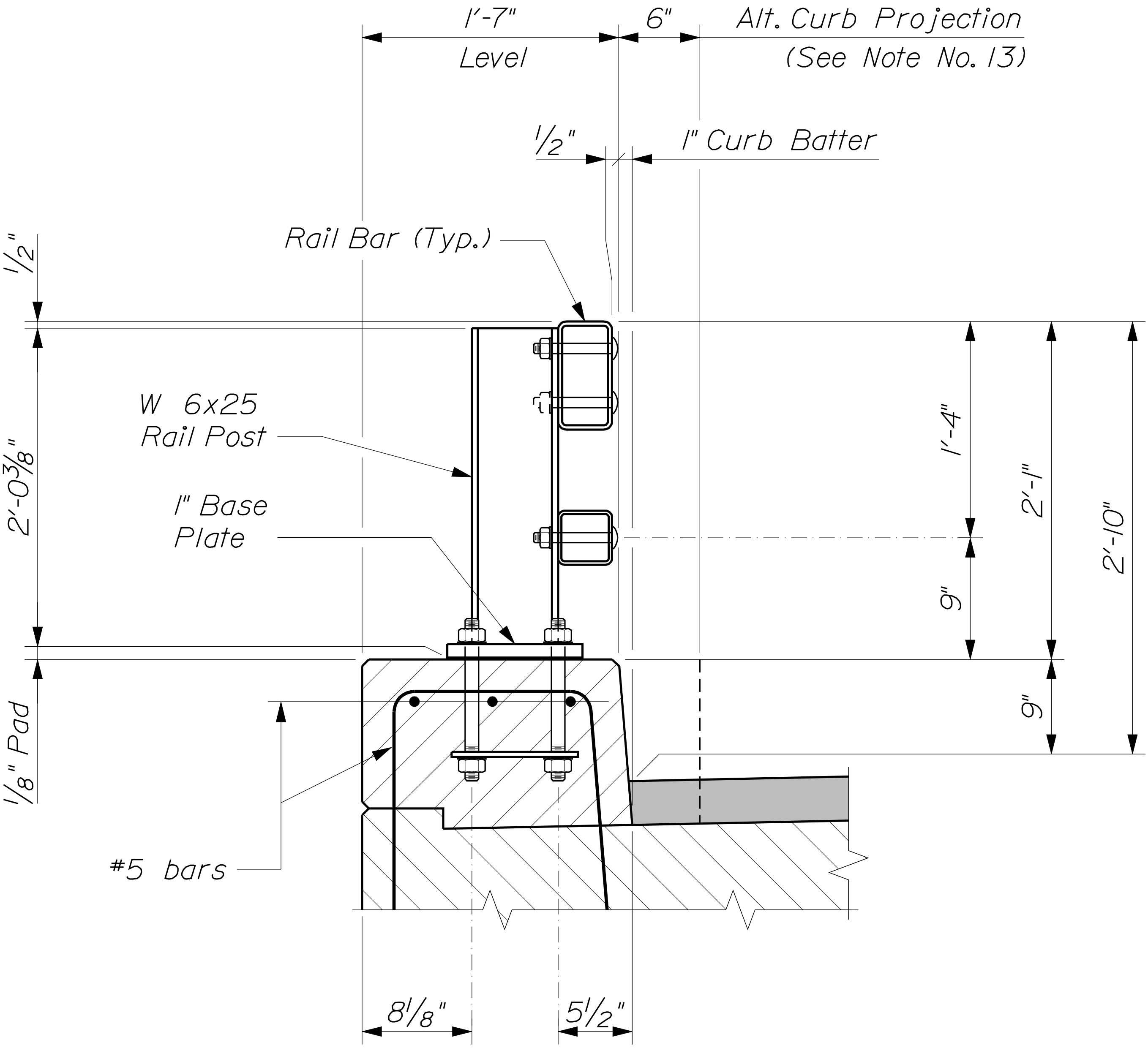
~ TYPICAL RAILING ELEVATION ~

2 - Bar Traffic Railing is shown.
Other railing configurations are similar.

STEEL BRIDGE RAILING

507(03)

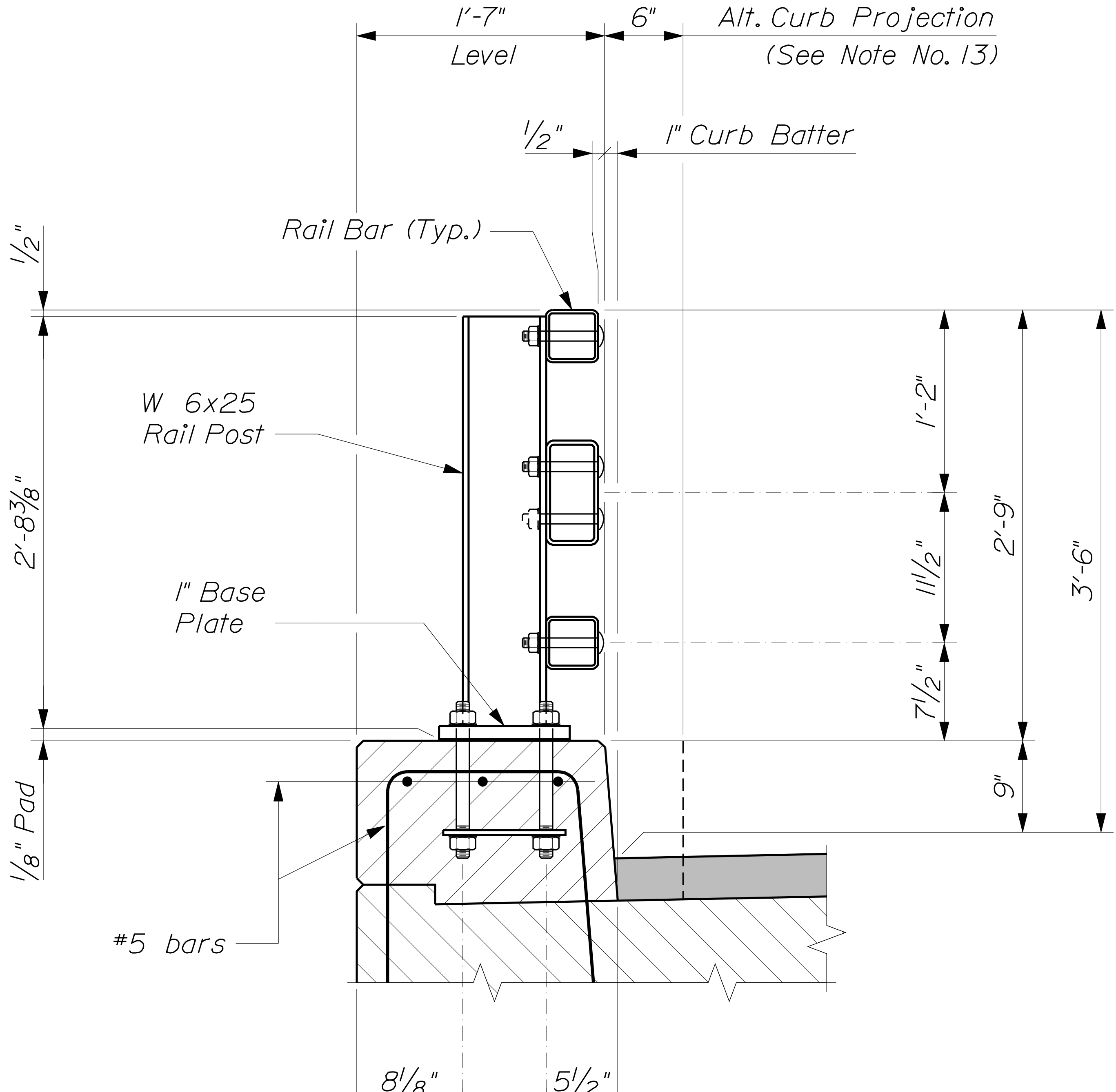
Rail Bars:
TS 8x4x5/16 (1)
TS 4x4x1/4 (1)



~ TYPICAL RAILING SECTION ~
(2 - Bar Traffic Railing)

STEEL BRIDGE RAILING
507(04)

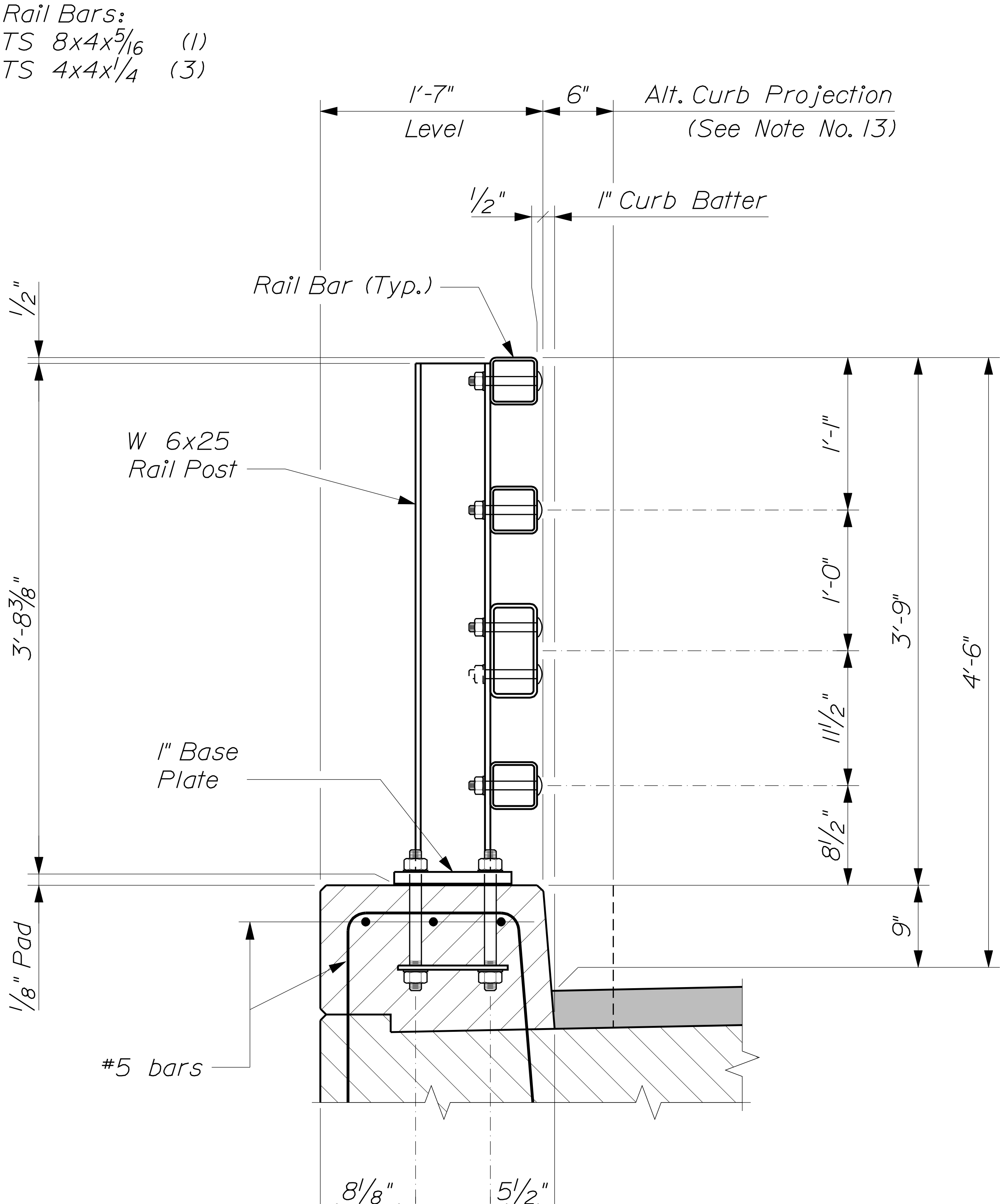
Rail Bars:
TS 8x4x5/16 (1)
TS 4x4x1/4 (2)



~ TYPICAL RAILING SECTION ~
(3 - Bar Traffic / Bicycle Railing)

STEEL BRIDGE RAILING

507(05)

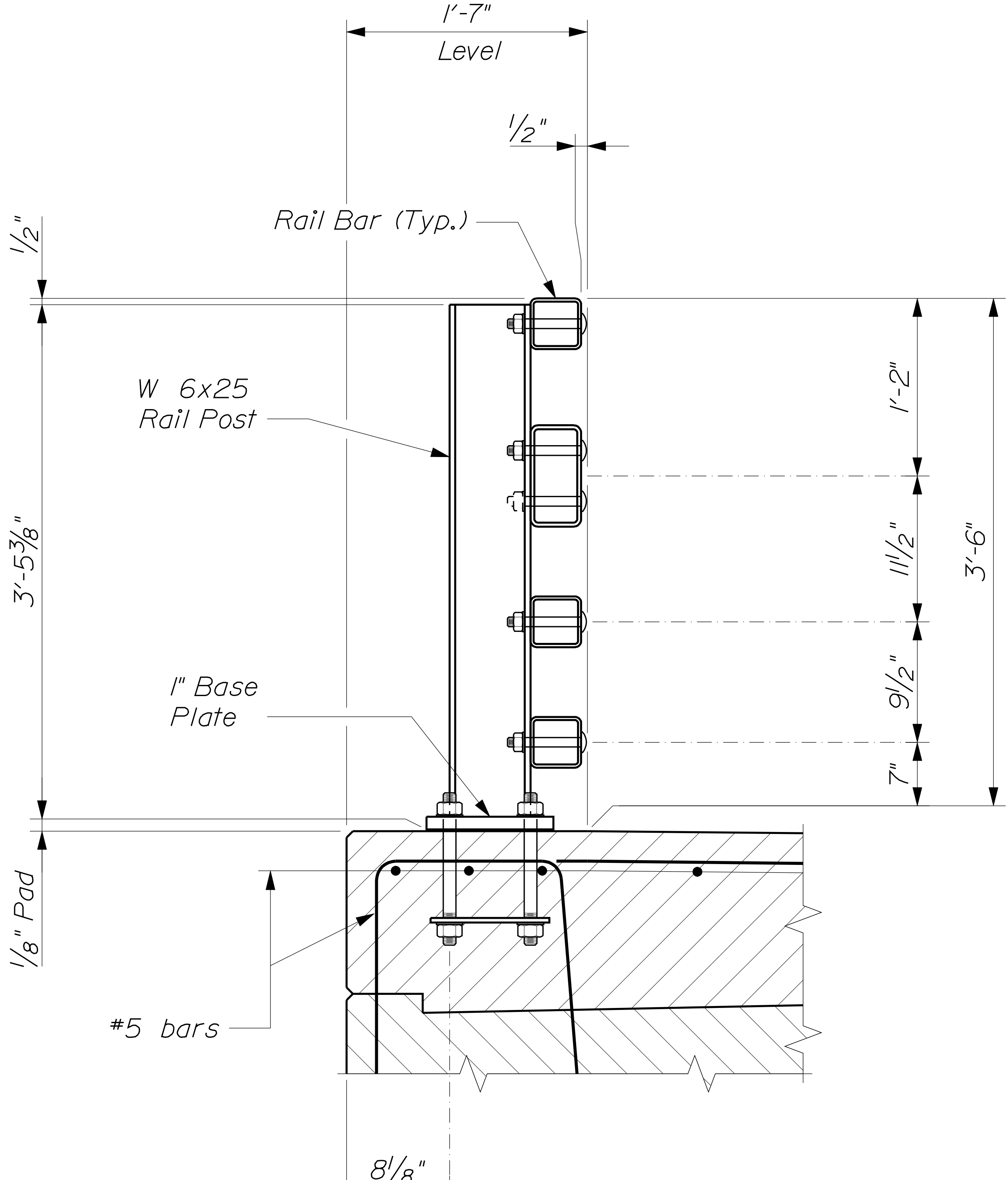


~ TYPICAL RAILING SECTION ~
(4 - Bar Traffic / Bicycle Railing)

STEEL BRIDGE RAILING

507(06)

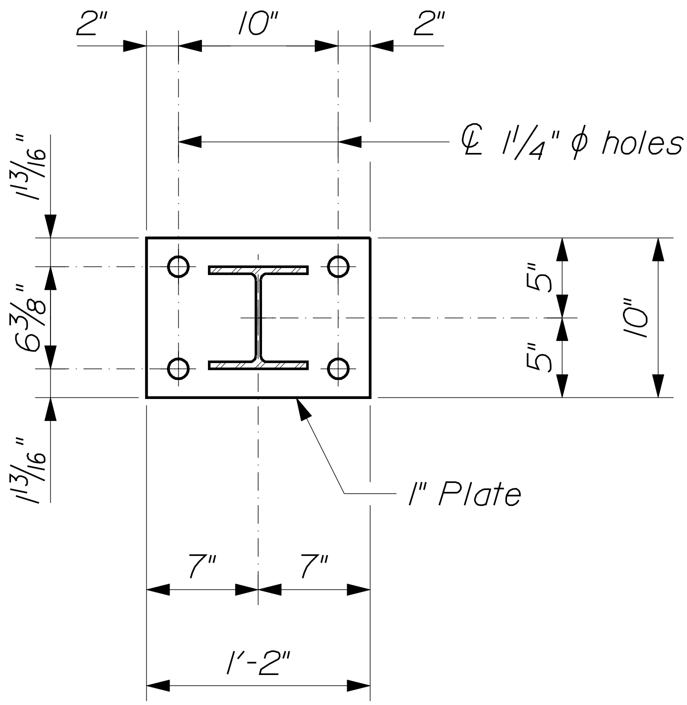
Rail Bars:
TS 8x4x5/16 (1)
TS 4x4x1/4 (3)



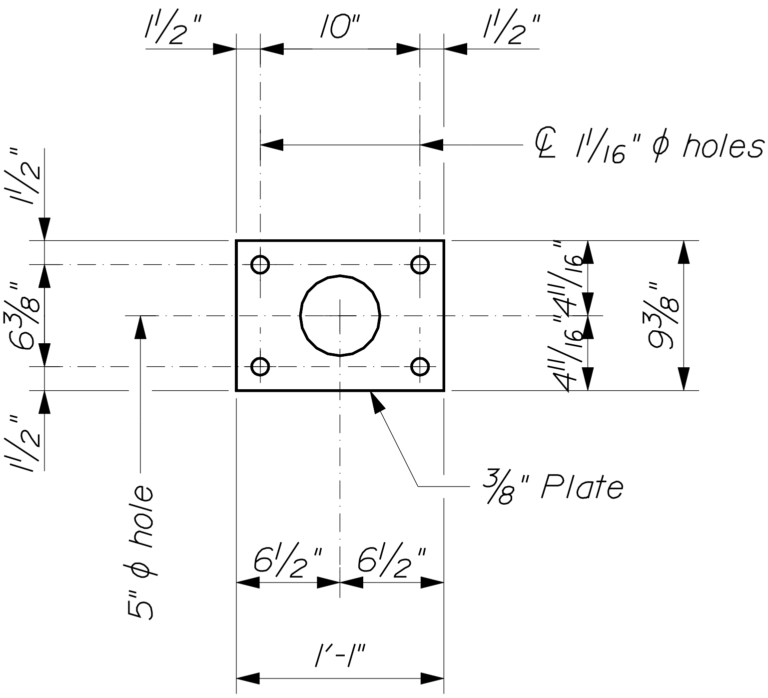
~ TYPICAL RAILING SECTION ~
(4 - Bar Traffic / Pedestrian Railing)

STEEL BRIDGE RAILING

507(07)



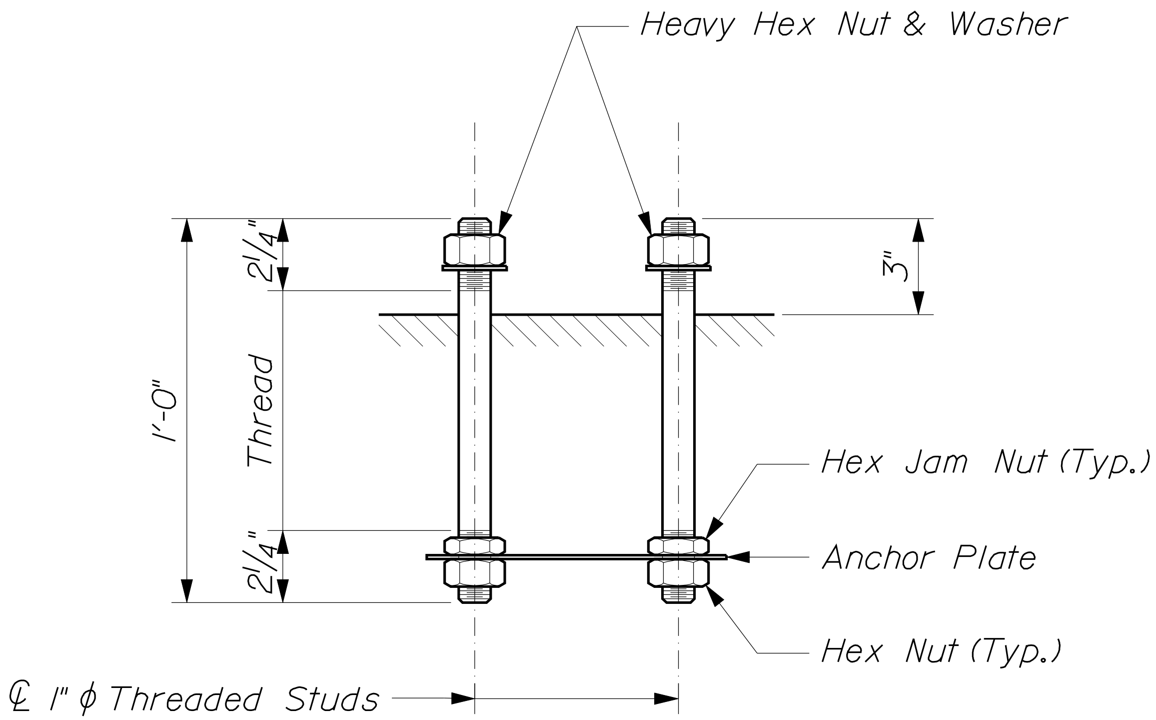
~ POST & BASE PLATE PLAN ~



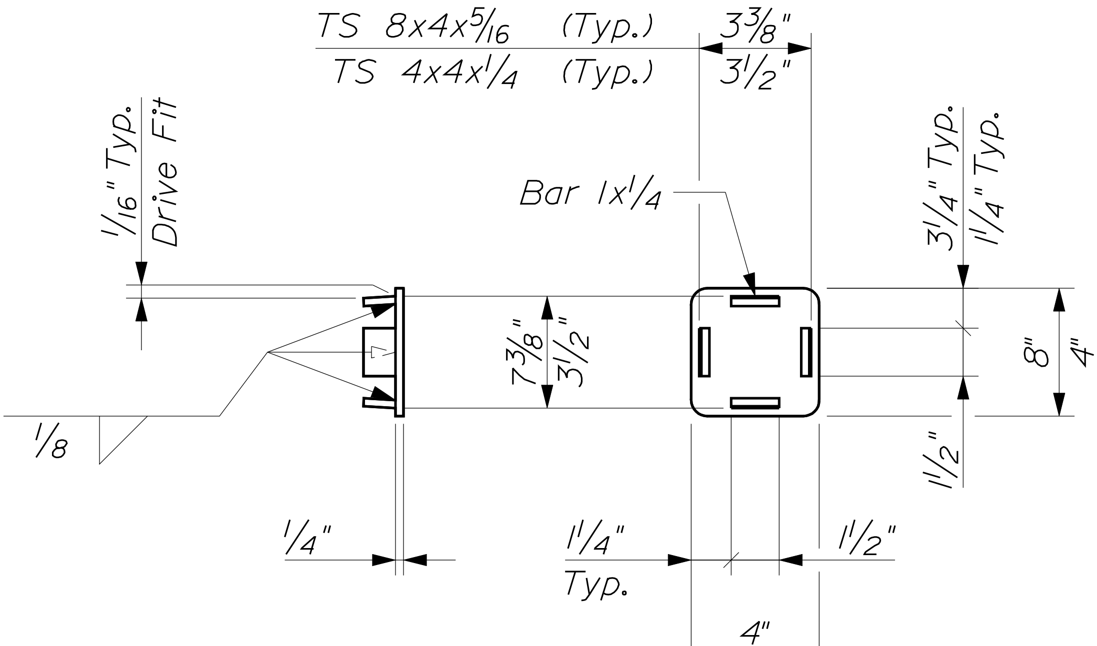
~ ANCHOR PLATE PLAN ~

STEEL BRIDGE RAILING

507(08)



~ RAIL POST ANCHORAGE ~

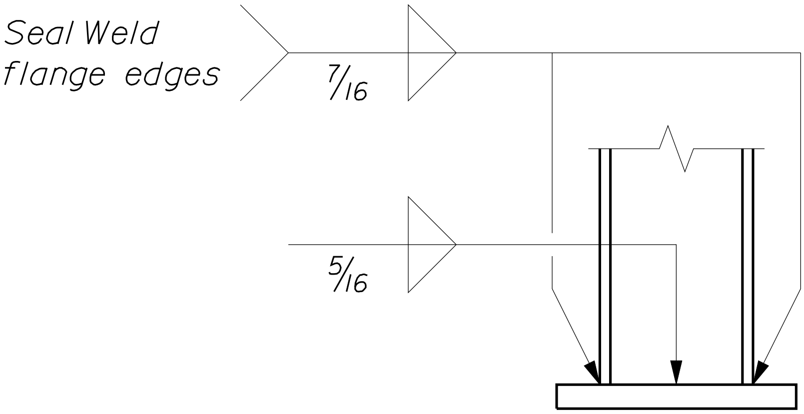


~ RAIL BAR CAP ~

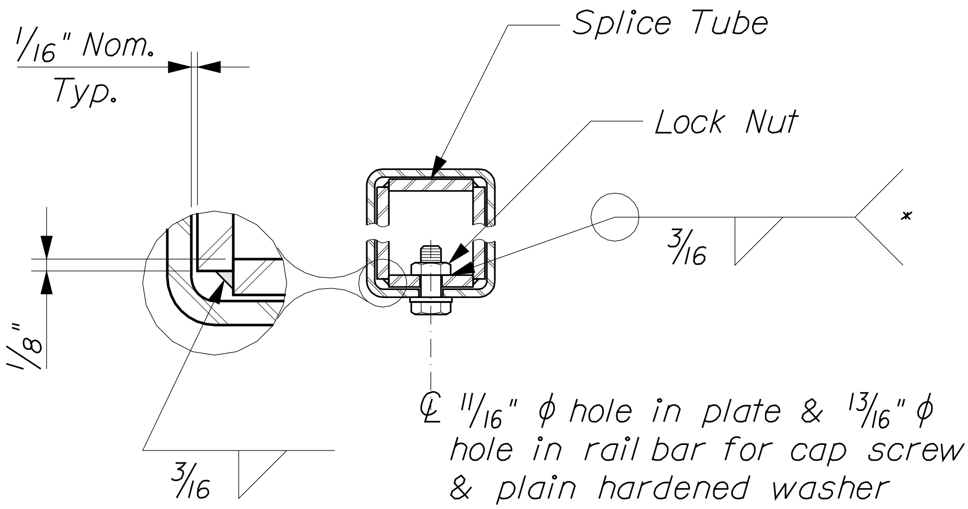
Note: Match corner radius of rail bar

STEEL BRIDGE RAILING

507(09)

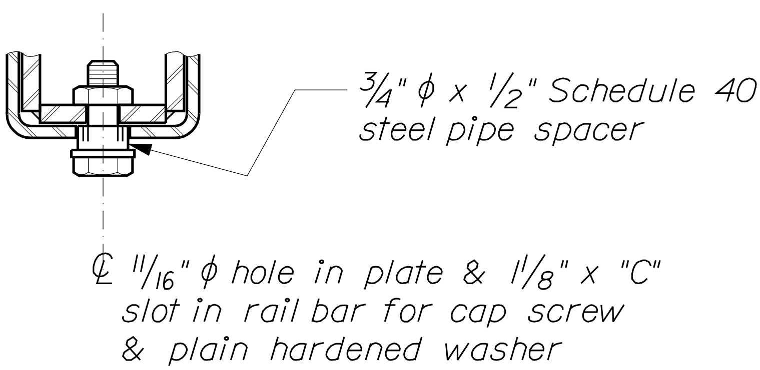


~ POST - TO - BASE WELD DETAIL ~



~ RAIL BAR SPLICE SECTION ~

* Weld nuts to plate before assembling splice tube

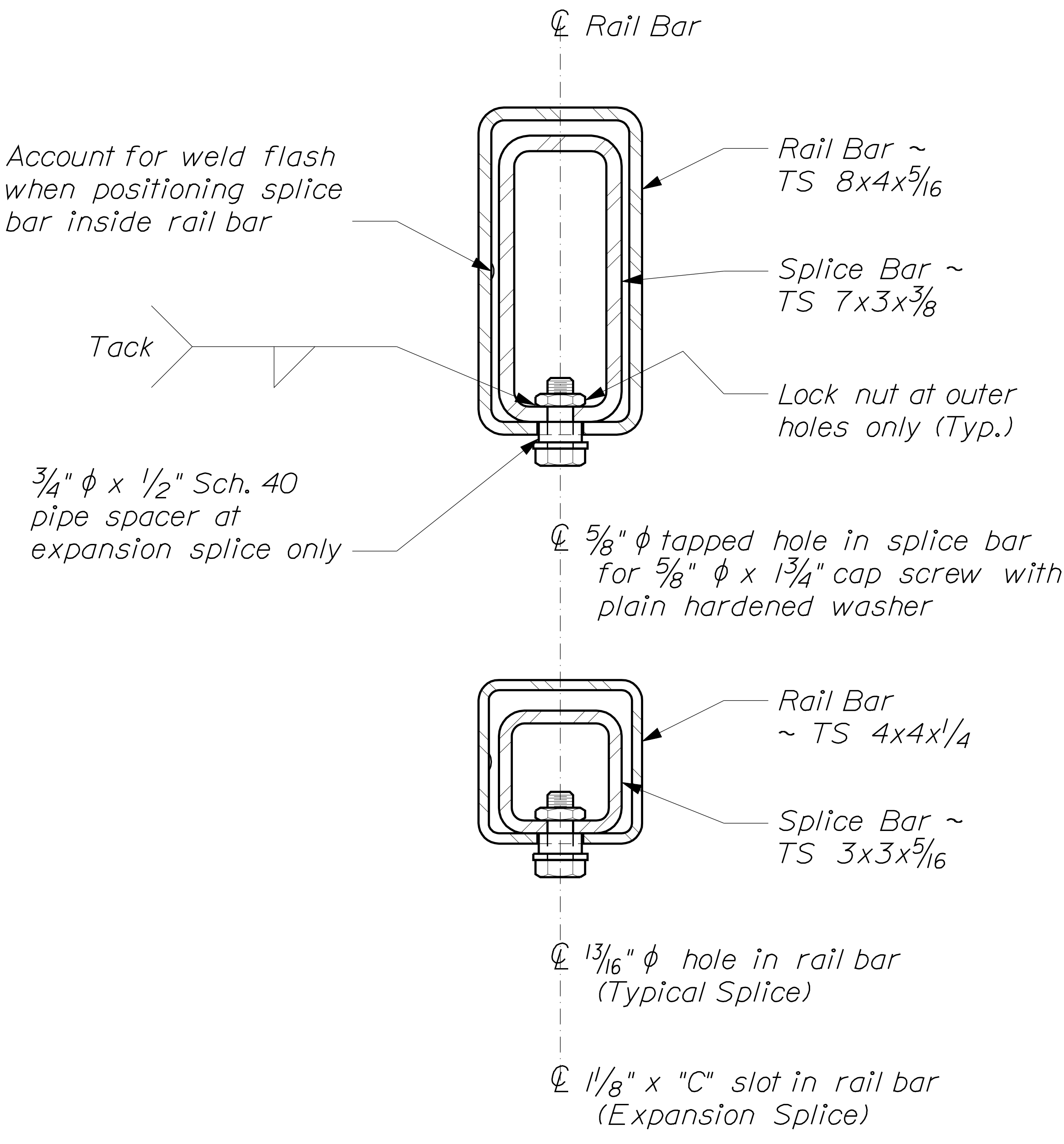


~ RAIL BAR EXPANSION JOINT SECTION ~

For details not shown, see "Rail Bar Splice Section"

STEEL BRIDGE RAILING

507(10)

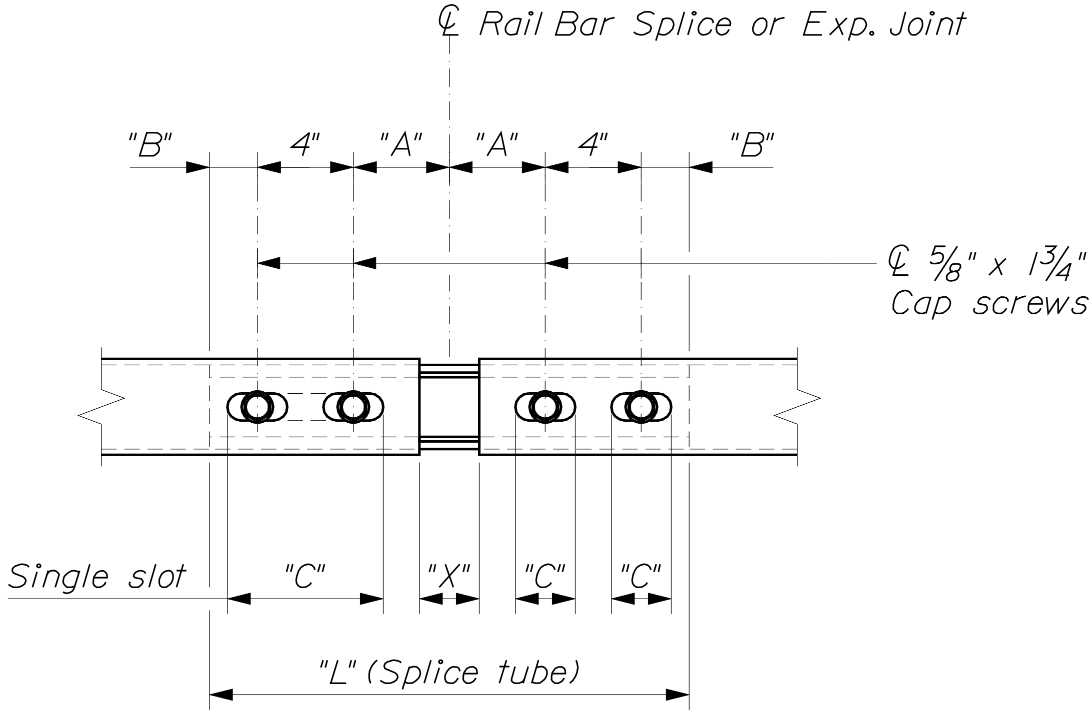


-- OPTIONAL RAIL BAR SPLICE SECTION --

(Details Typical for both rail bars)

STEEL BRIDGE RAILING

507(II)



~ RAIL BAR SPLICE & EXPANSION JOINT DETAIL ~
(Bottom View)

SPLICE TUBE DIMENSIONS		
	TS 8x4	TS 4x4
Top & Bot. Plates	$2\frac{1}{2} \times \frac{3}{8} \times$ "L"	$2\frac{5}{8} \times \frac{3}{8} \times$ "L"
Side Plates	$6\frac{3}{4} \times \frac{3}{8} \times$ "L"	$2\frac{7}{8} \times \frac{3}{8} \times$ "L"

SPLICE & EXPANSION JOINT TABLE					
"T"	"A"	"B"	"C"	"L"	"X"
Splice	4"	2"	--	1'-8"	$\frac{3}{4}$"
$\leq$ 4"	4"	2"	$2\frac{1}{2}$"	1'-8"	$2\frac{1}{2}$"
> 4" $\leq 6\frac{1}{2}$"	$5\frac{1}{2}$"	$2\frac{1}{2}$"	$3\frac{1}{2}$"	2'-0"	$3\frac{3}{4}$"
> $6\frac{1}{2}$" $\leq$ 9"	$6\frac{1}{2}$"	$3\frac{1}{2}$"	9" *	2'-4"	5"
> 9" $\leq$ 13"	$8\frac{1}{2}$"	$4\frac{1}{2}$"	11" *	2'-10"	7"

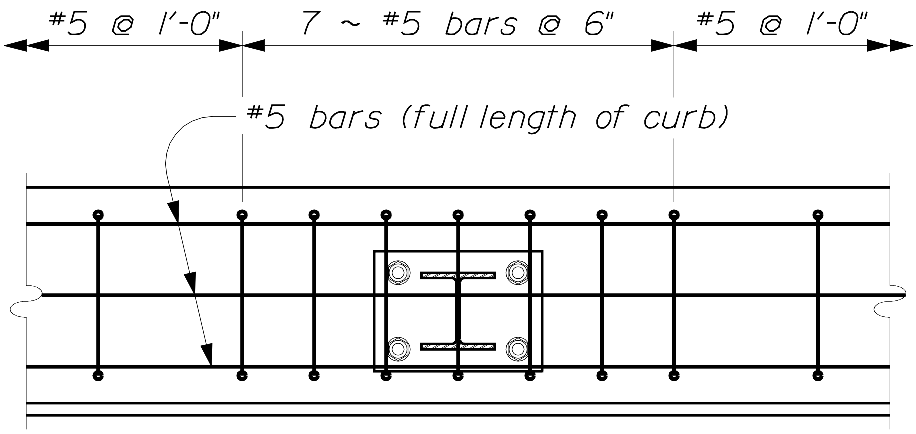
T = Total Movement * = Single Slot

MATERIALS:

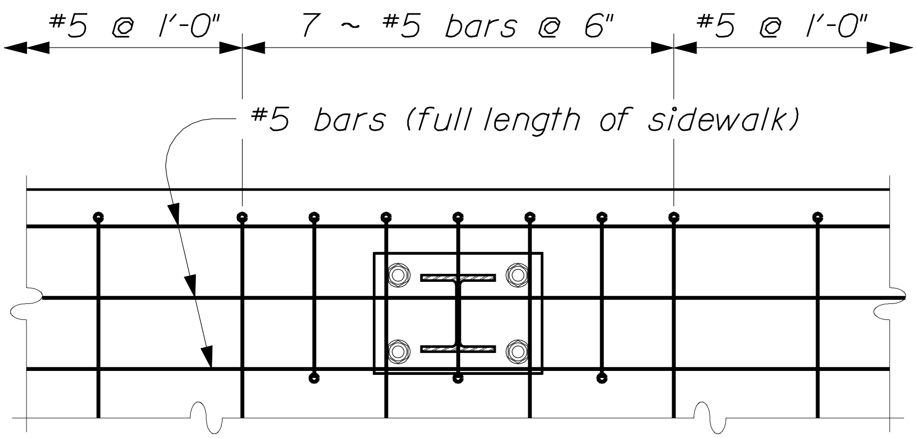
Rail bars .... ASTM A 500, Grade B
Rail posts, shapes & plates .... AASHTO M 270M/M 270, Grade 50
Anchor studs, washers & heavy hex nuts .... AASHTO M 314, Grade 105
All other bolts & nuts (unless noted) .... AASHTO A 307, Grade C

STEEL BRIDGE RAILING

507(12)



~ CURB REINFORCING PLAN ~



~ SIDEWALK REINFORCING PLAN ~

NOTES:

1. All work and materials shall conform to the provisions of Section 507 - Railings of the Standard Specifications.

2. Tubing shall meet the longitudinal CVN minimum requirements of 15 ft-lb at 0° F or proportional values of sub - size specimens. Testing shall be done in accordance with ASTM A 673. The H frequency shall be used and the material shall be as - rolled.

3. Twenty - five percent of the post - to - base welds in a production lot shall be tested by the Magnetic Particle Method. If rejectable discontinuities are found, another twenty - five percent of that production lot shall be tested. If rejectable discontinuities are found in the second twenty - five percent, all post - to - base welds in that lot shall be tested. Acceptance criteria shall be in accordance with the latest edition of the AWS D1.5 Bridge Welding Code.

STEEL BRIDGE RAILING

507(13)

NOTES (Continued):

4. All exposed cut or sheared edges shall be broken and free of burrs. The inside weld flash of tubing shall be removed at splices and expansion joints.

5. Rail posts shall be set normal to grade unless otherwise shown.

6. Lengths of rail bar shall be attached to a minimum of 2 rail posts and to at least 4 posts whenever possible.

7. Rail bar expansion joints shall be provided in any rail bay spanning a superstructure expansion joint. Expansion joint width shall be "X" at 45° F and will be adjusted in the field as directed by the Resident. Refer to detail and table on page 507(12) for dimension "X".

8. All parts shall be galvanized after fabrication in accordance with ASTM A 123, except that hardware shall meet the requirements of either ASTM A 153 or ASTM B 695, Class 50, Type I. Parts except hardware shall be blast - cleaned prior to galvanizing in accordance with SSPC - SP6.

9. Anchor bolts shall be set with a template. Nuts securing the post base plate shall be tightened to a snug fit and given an additional $1/8$ turn.

10. Rail bars shall be attached to posts using $3/4$" ϕ ~ ASTM A 307 bolts ($5/8$" ϕ ~ ASTM A 325 bolts may be substituted) inserted through the face of the rail bar. Bolts shall be round or dome head and may be rib neck, slotted, wrench head or tension control (TC or twist - off). Holes in posts shall be $1/16$" larger than the diameter of the bolt. Holes in rail bars shall be drilled to size as follows:

Slotted, wrench head or TC bolts: $1/16$" larger than bolt diameter
Rib neck bolts: Size appropriate to accomodate an interference fit

All bolts for fastening the rail bars to the posts shall be 6 inches in length and shall include a flat washer under the nut.

11. Holes in rail bars shall be field - drilled and shall be coated with an approved zinc - rich paint prior to erection.

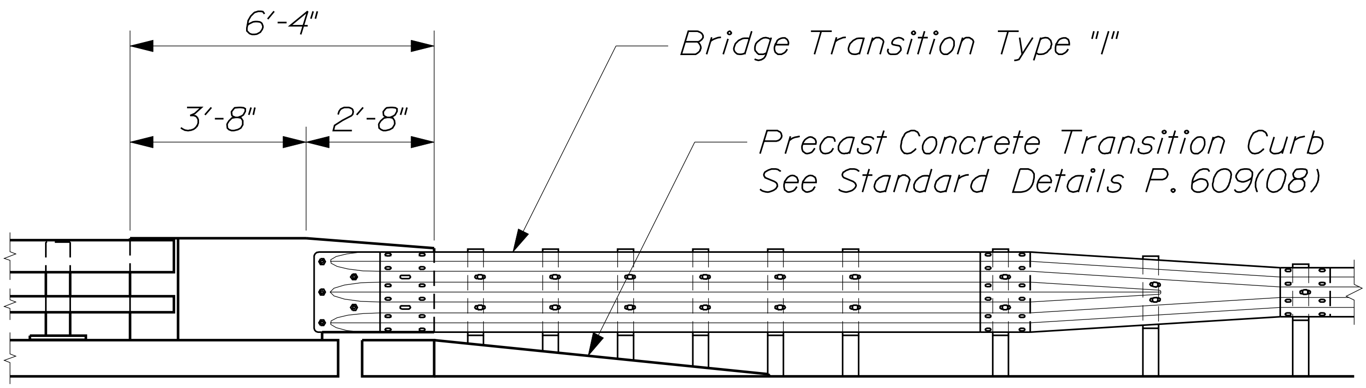
12. Bolts in expansion joints shall be tightened only to a point that will allow rail movement.

13. The alternate curb projection shown for the curb - mounted railings is intended for use with granite bridge curb.

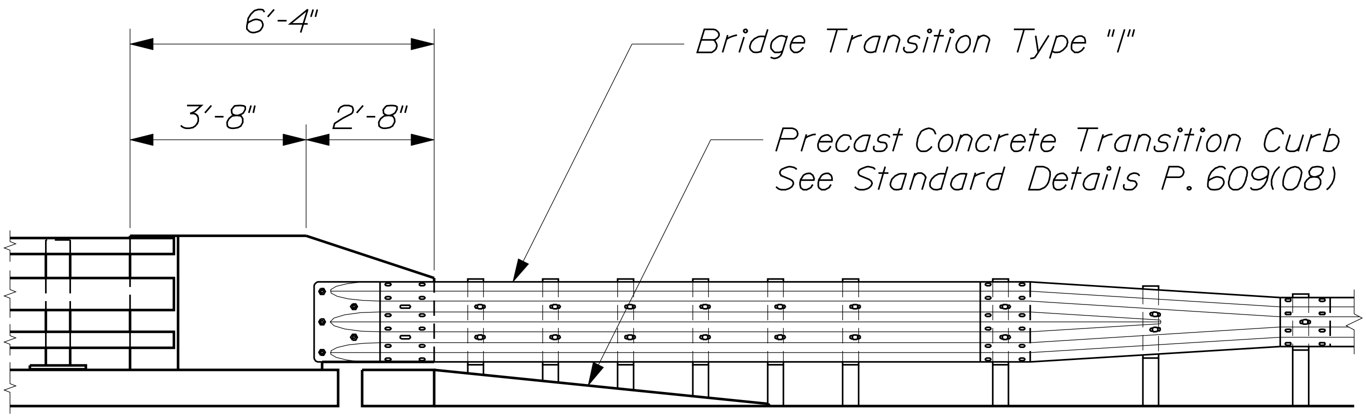
14. If there is a conflict between these Standard Details and the Design Drawings, the Contractor shall notify the Resident immediately.

STEEL BRIDGE RAILING

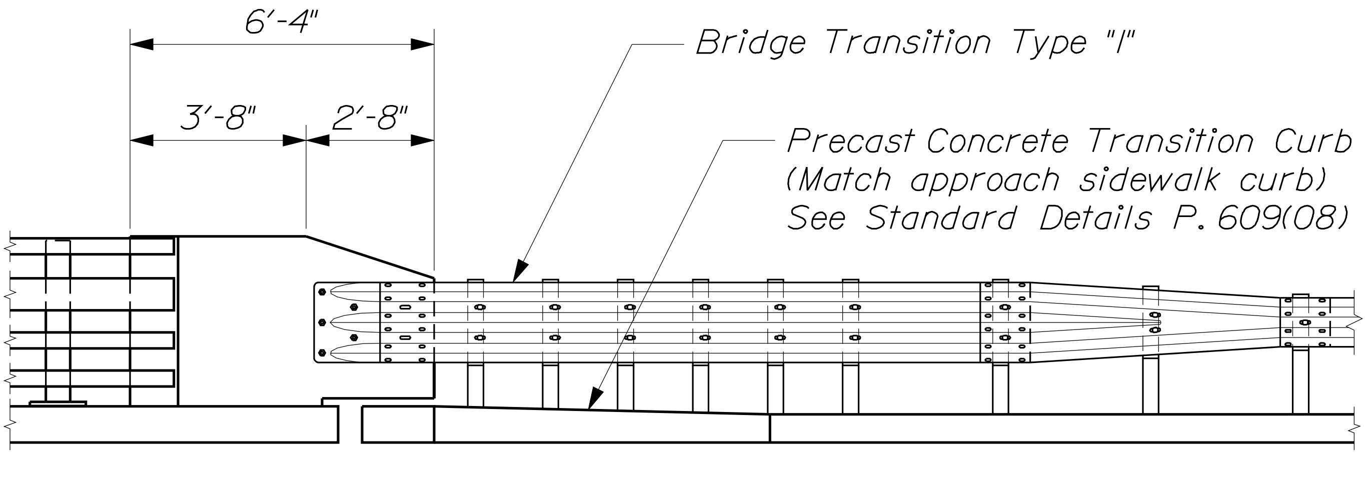
507(14)



~ CONCRETE TRANSITION BARRIER ~
(2 - Bar Traffic Railing)



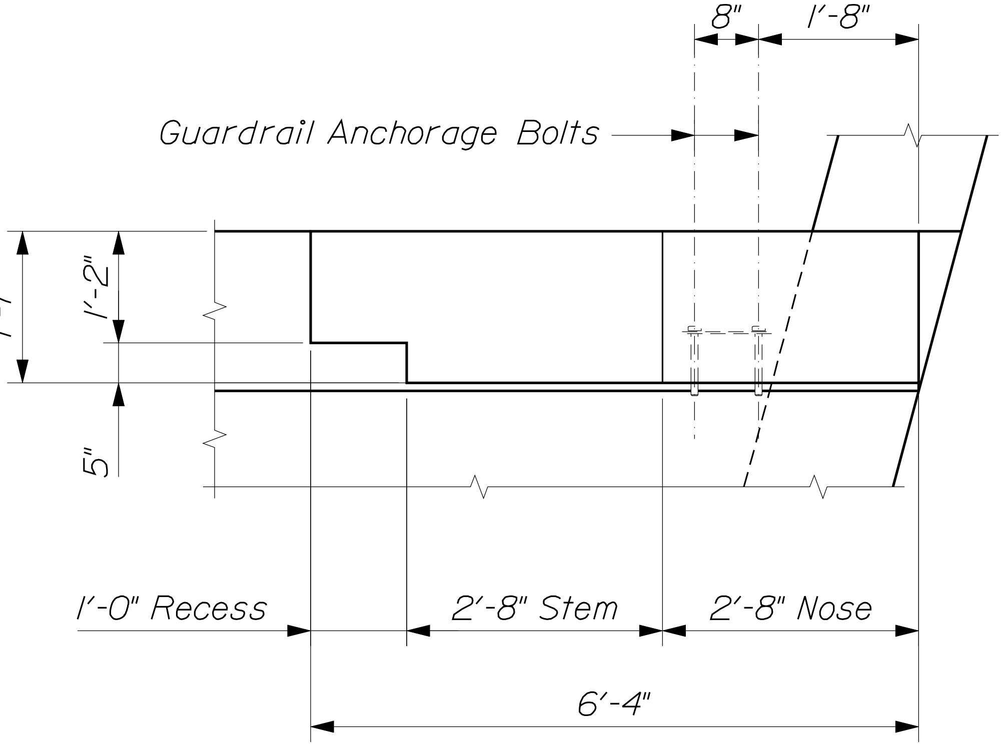
~ CONCRETE TRANSITION BARRIER ~
(3 - Bar Traffic / Bicycle Railing)
(4 - Bar Traffic / Bicycle Railing similar)



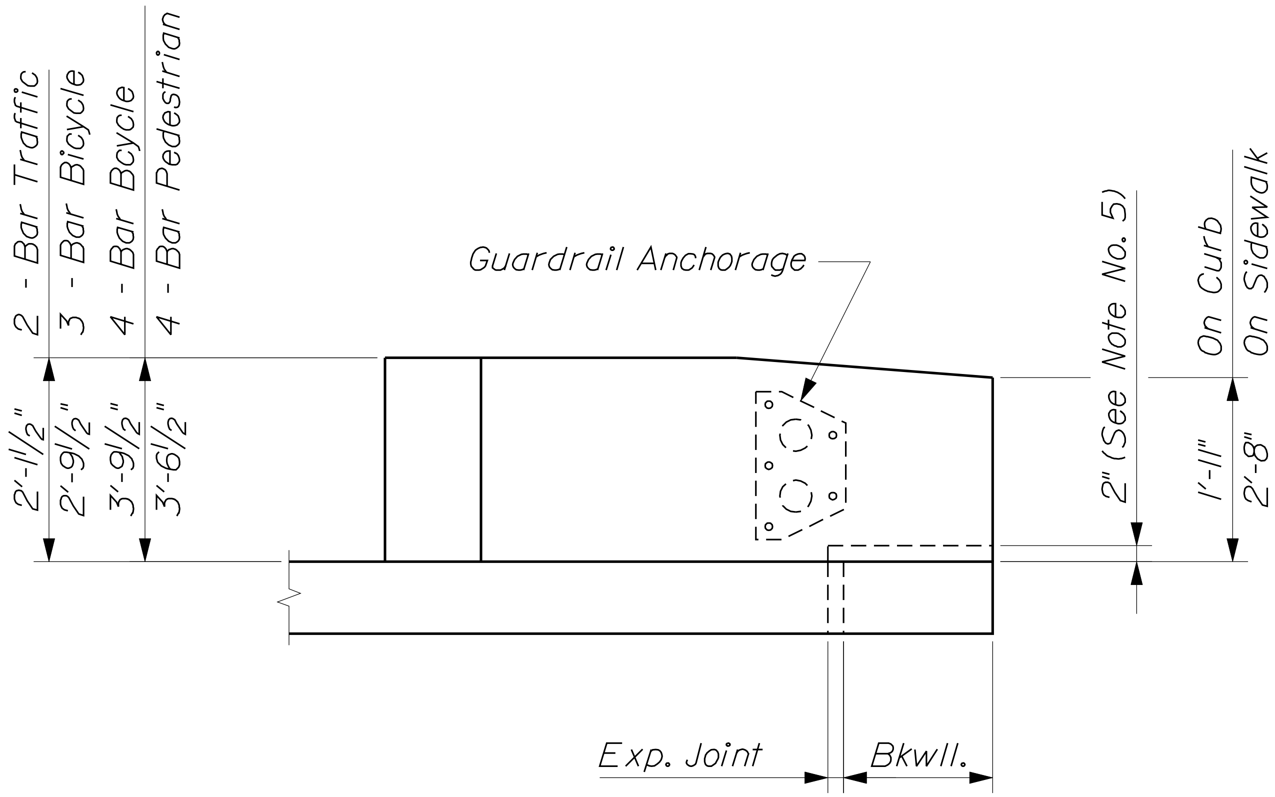
~ CONCRETE TRANSITION BARRIER ~
(4 - Bar Traffic / Pedestrian Railing)

CONCRETE TRANSITION BARRIER

526(22)



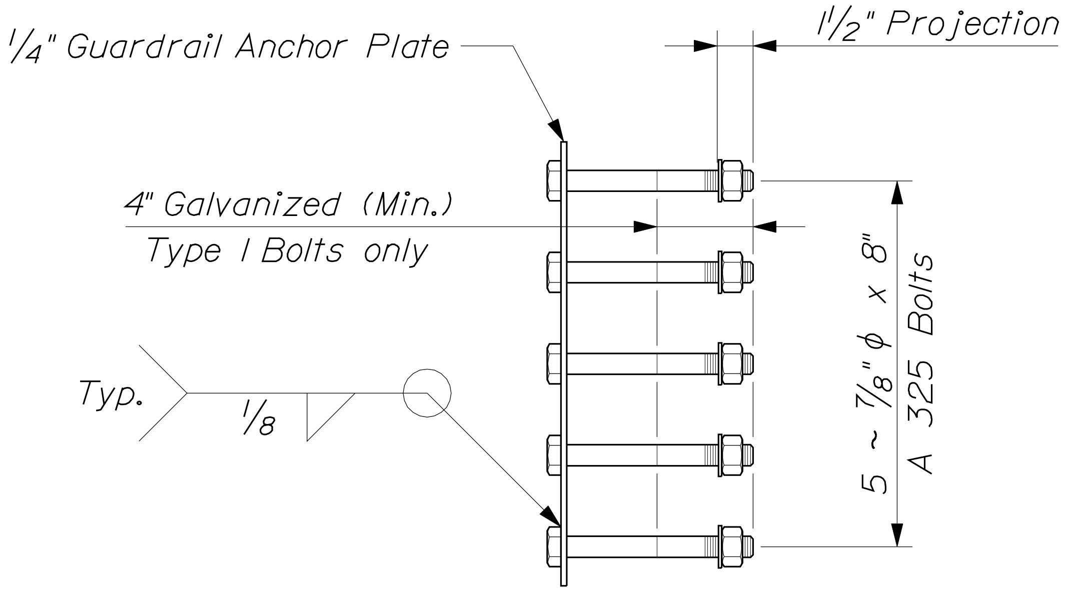
~ TRANSITION BARRIER PLAN ~



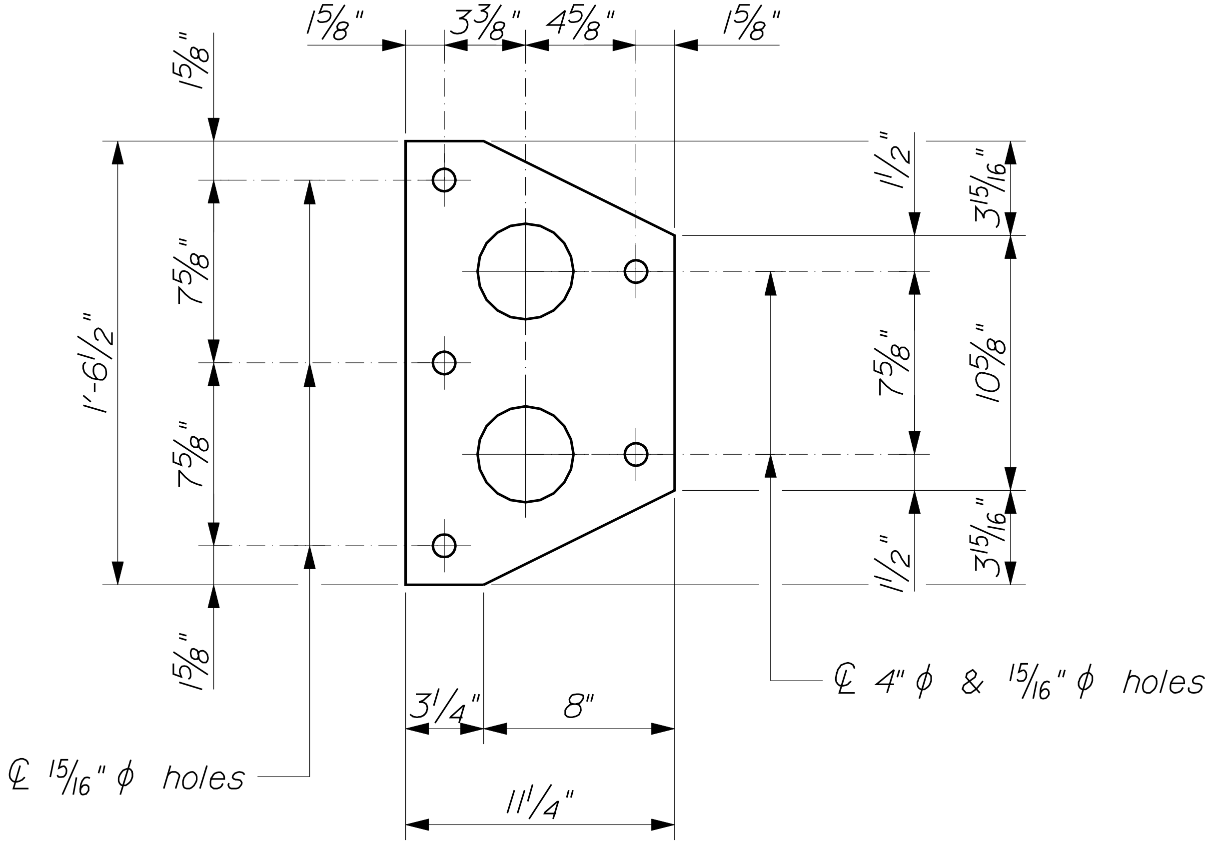
~ TRANSITION BARRIER ELEVATION ~

CONCRETE TRANSITION BARRIER

526(23)



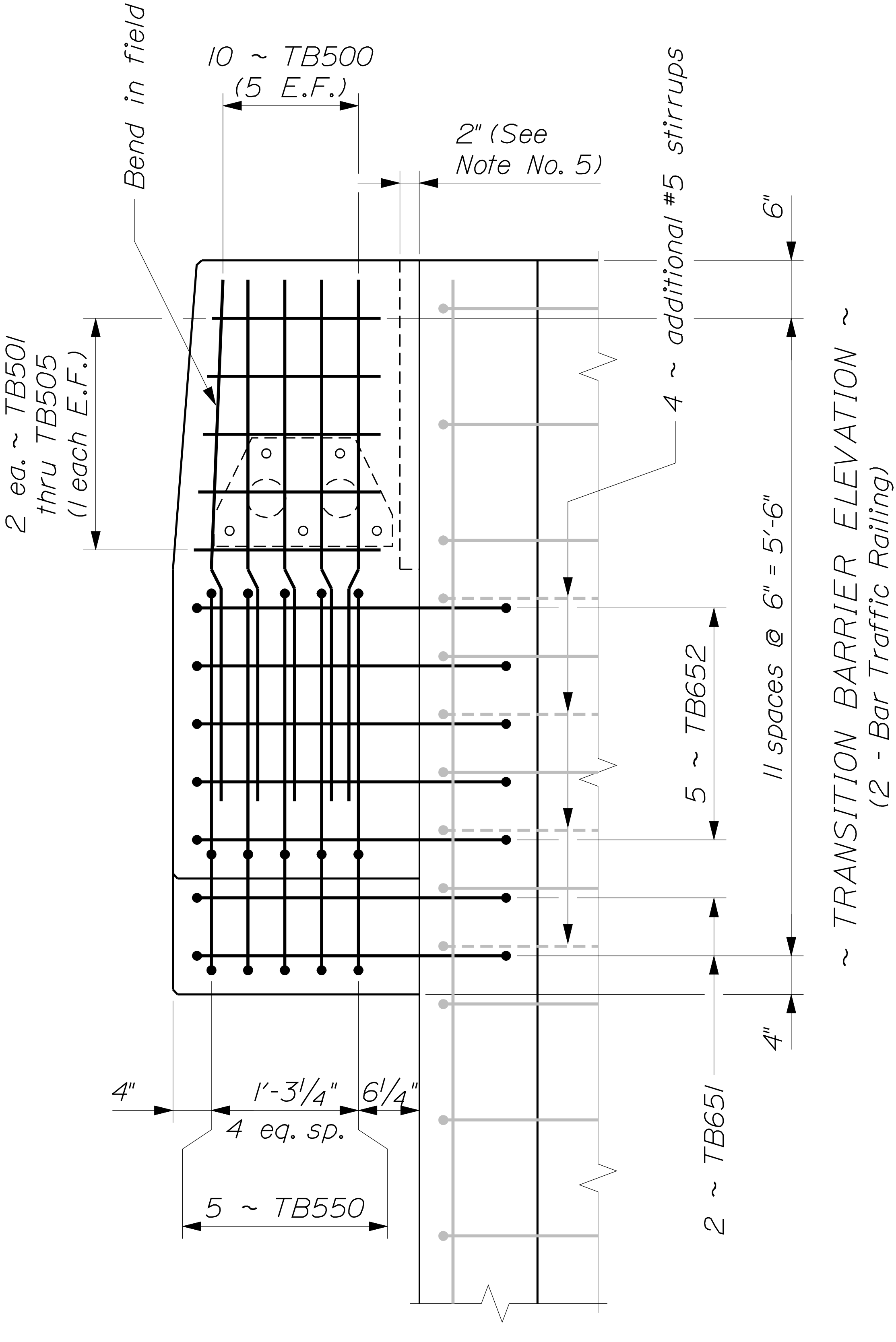
~ GUARDRAIL ANCHORAGE SECTION ~



~ GUARDRAIL ANCHOR PLATE ~

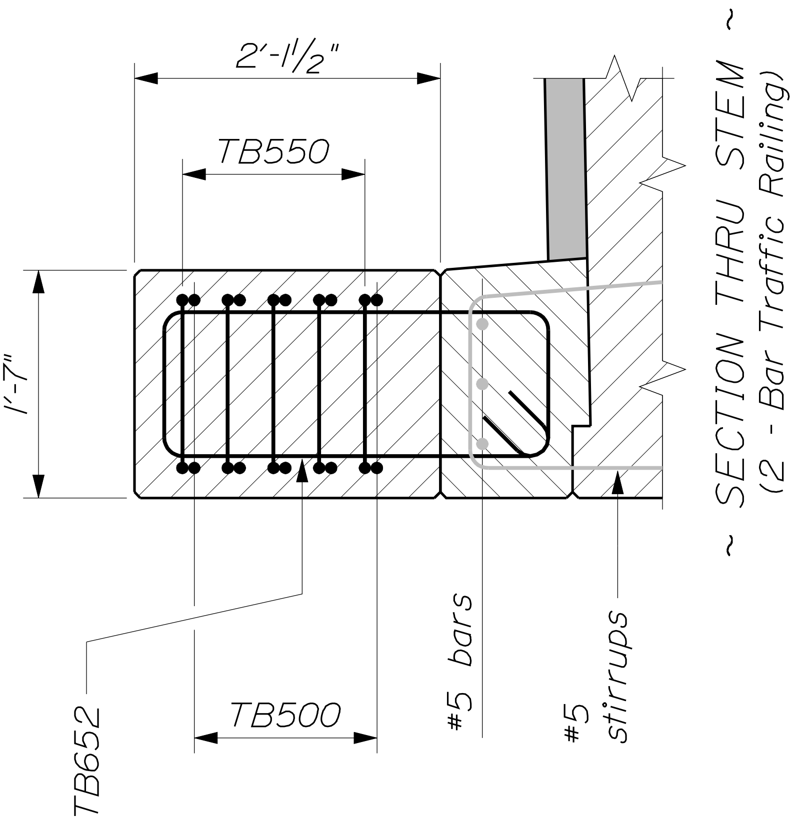
CONCRETE TRANSITION BARRIER

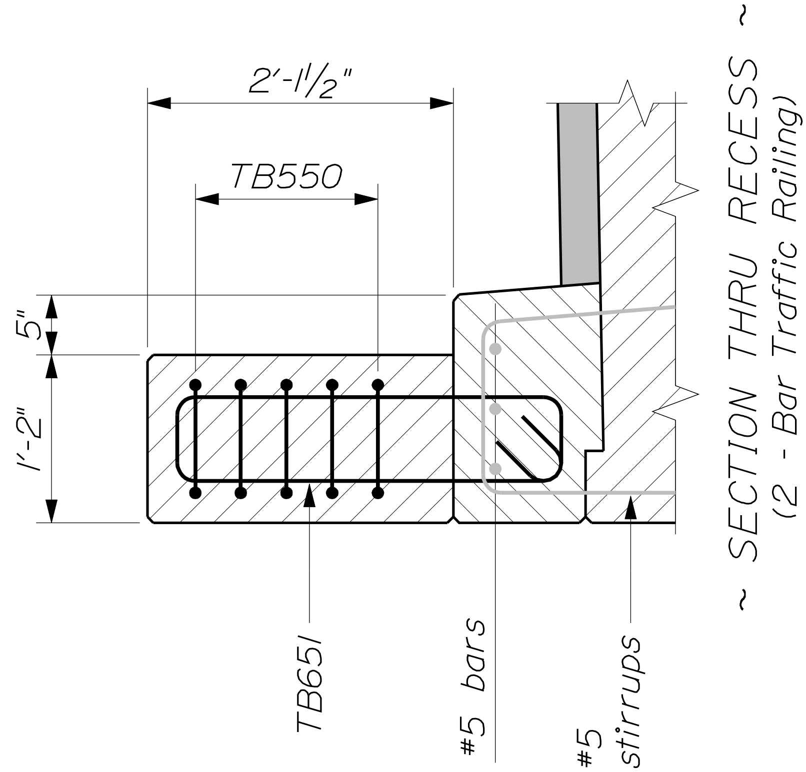
526(24)



CONCRETE TRANSITION BARRIER

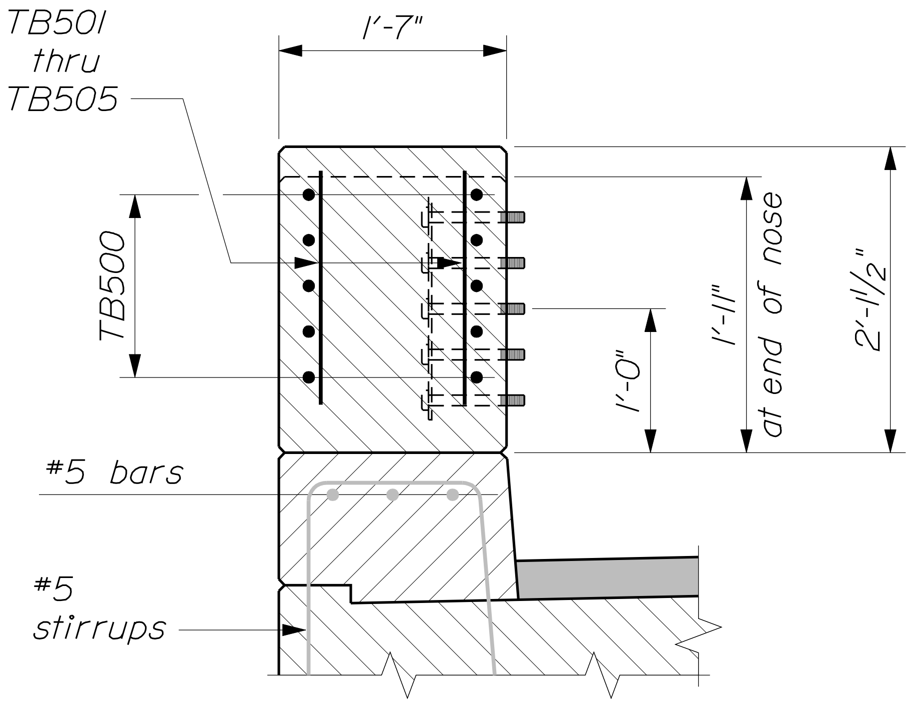
526(25)





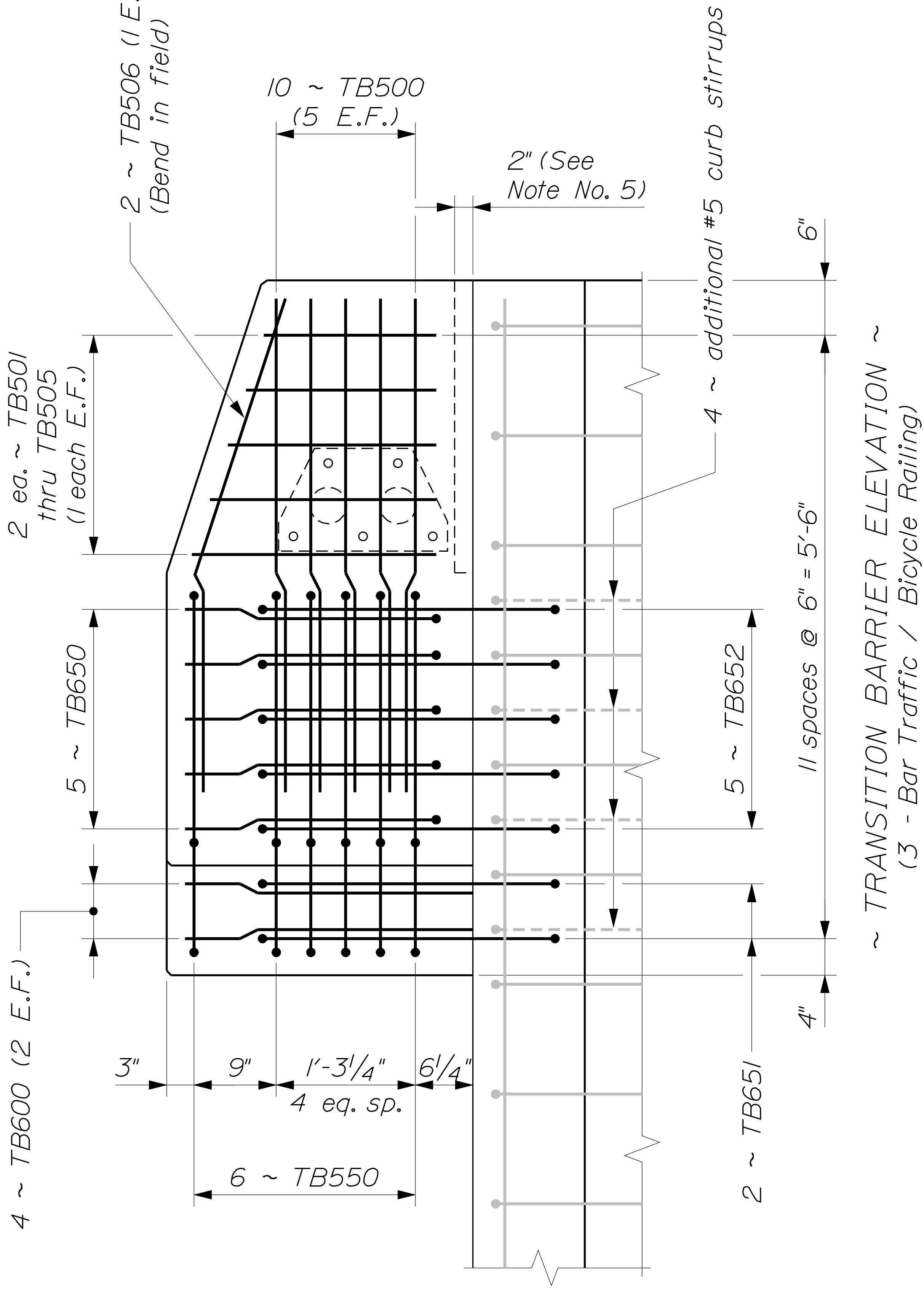
CONCRETE TRANSITION BARRIER

526(26)



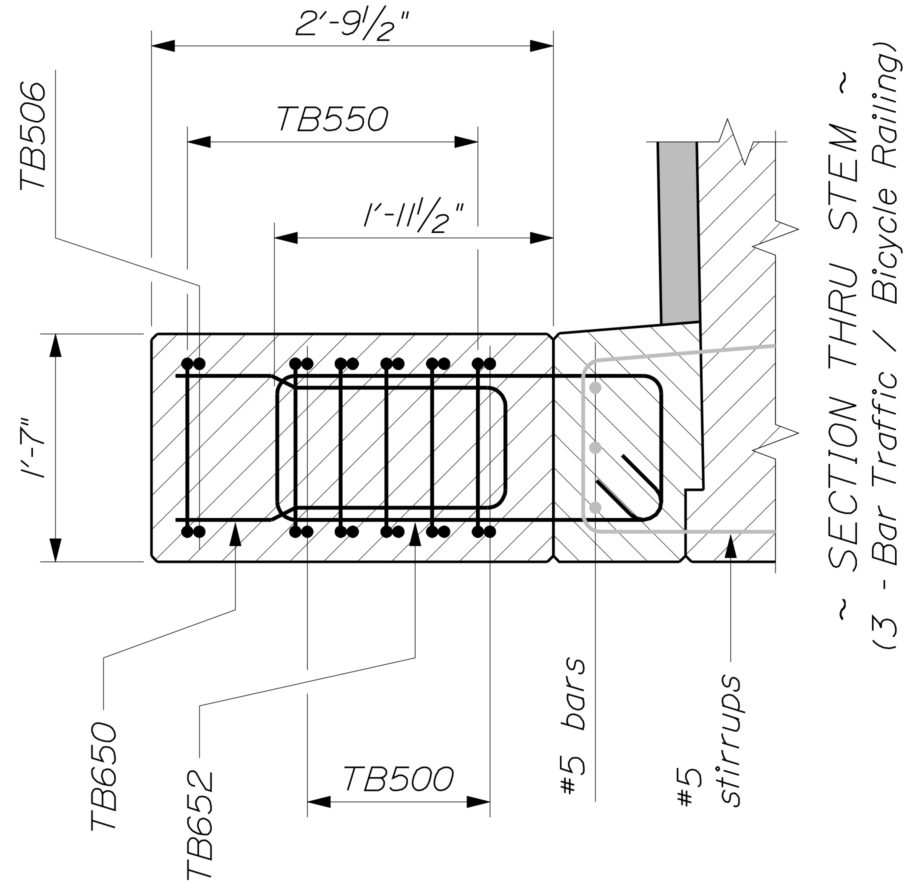
~ SECTION THRU NOSE ~
(2 - Bar Traffic Railing)

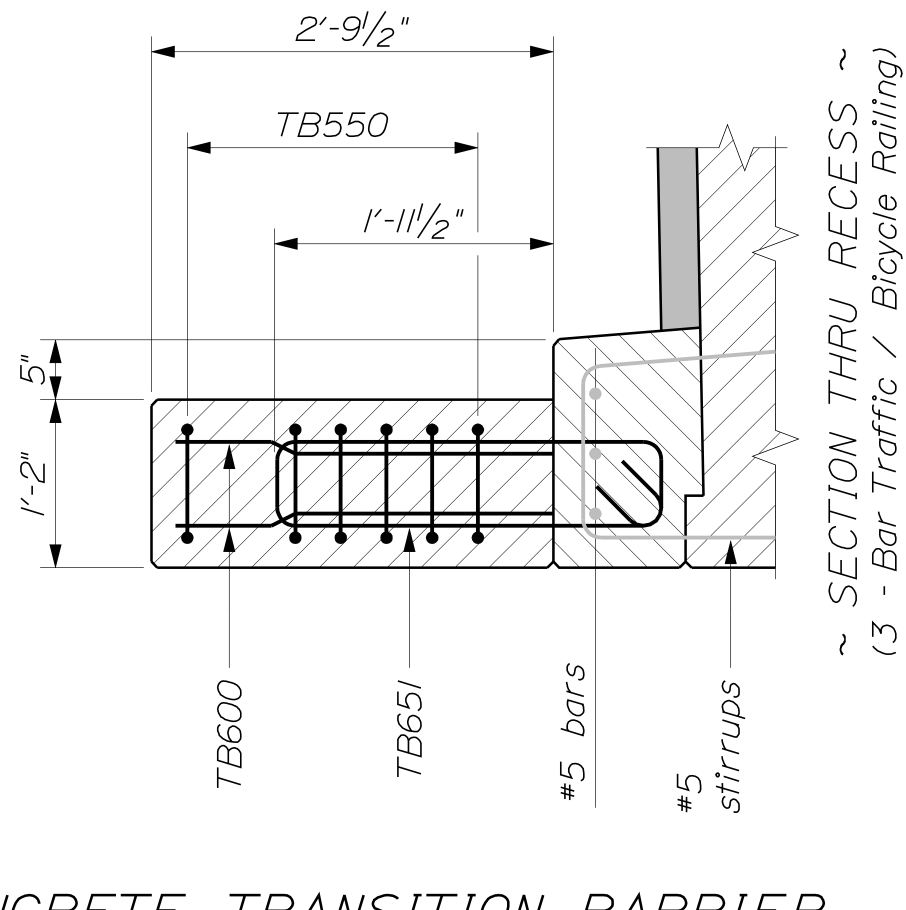
CONCRETE TRANSITION BARRIER
526(27)



CONCRETE TRANSITION BARRIER

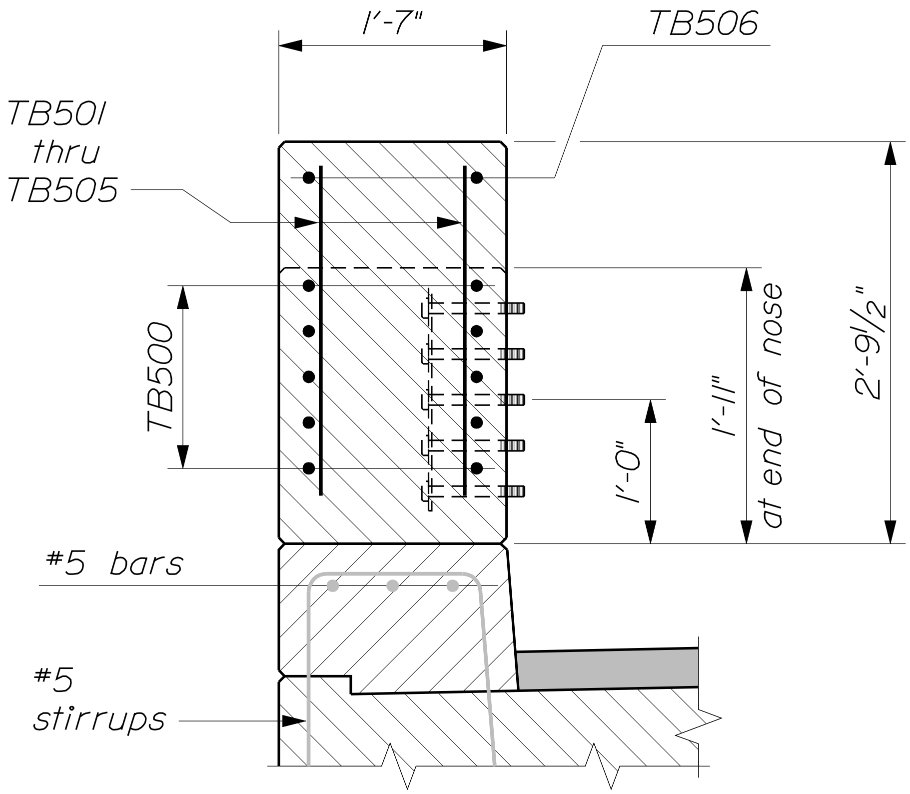
526(28)





CONCRETE TRANSITION BARRIER

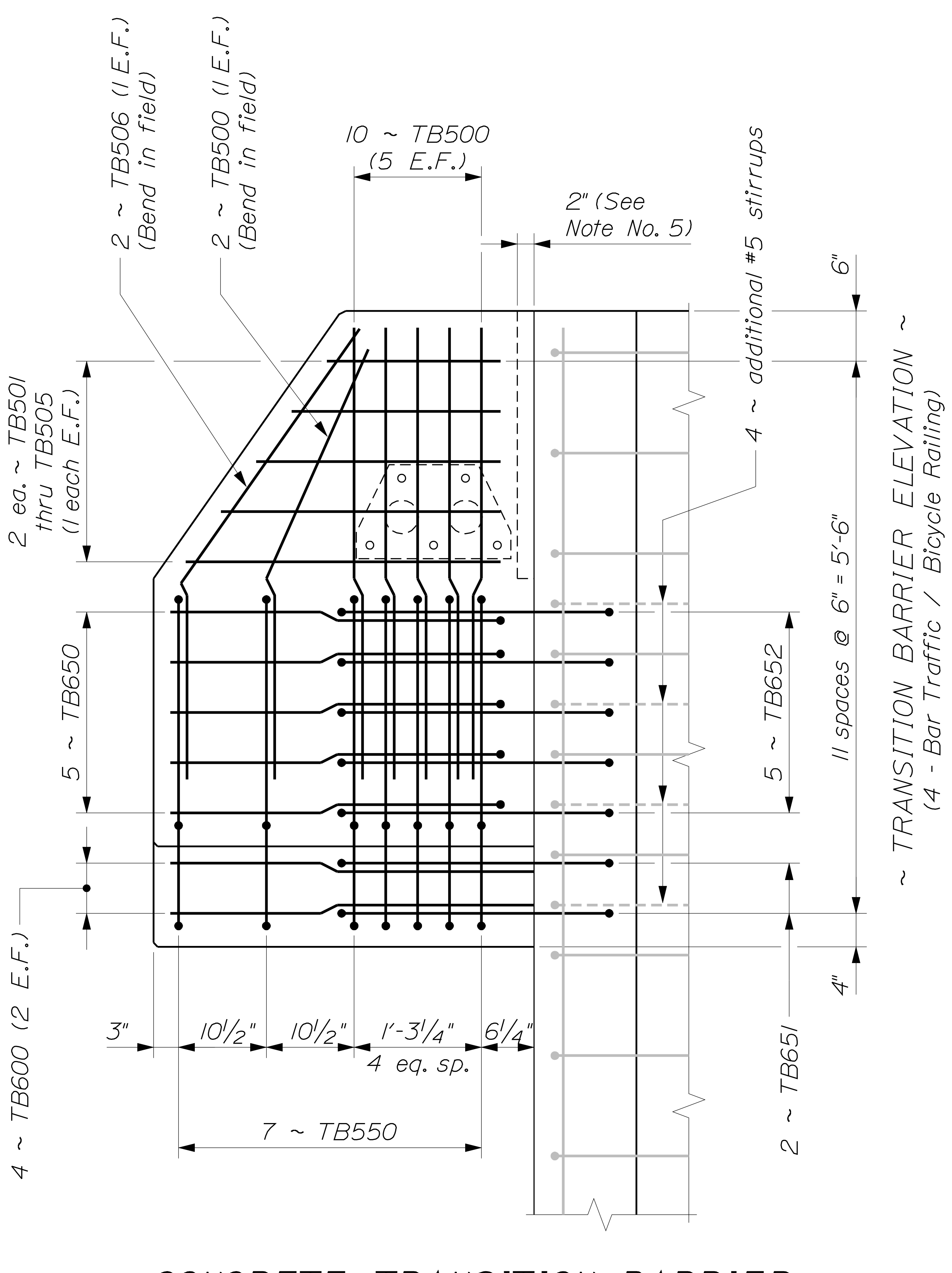
526(29)



~ SECTION THRU NOSE ~
(3 - Bar Traffic / Bicycle Railing)

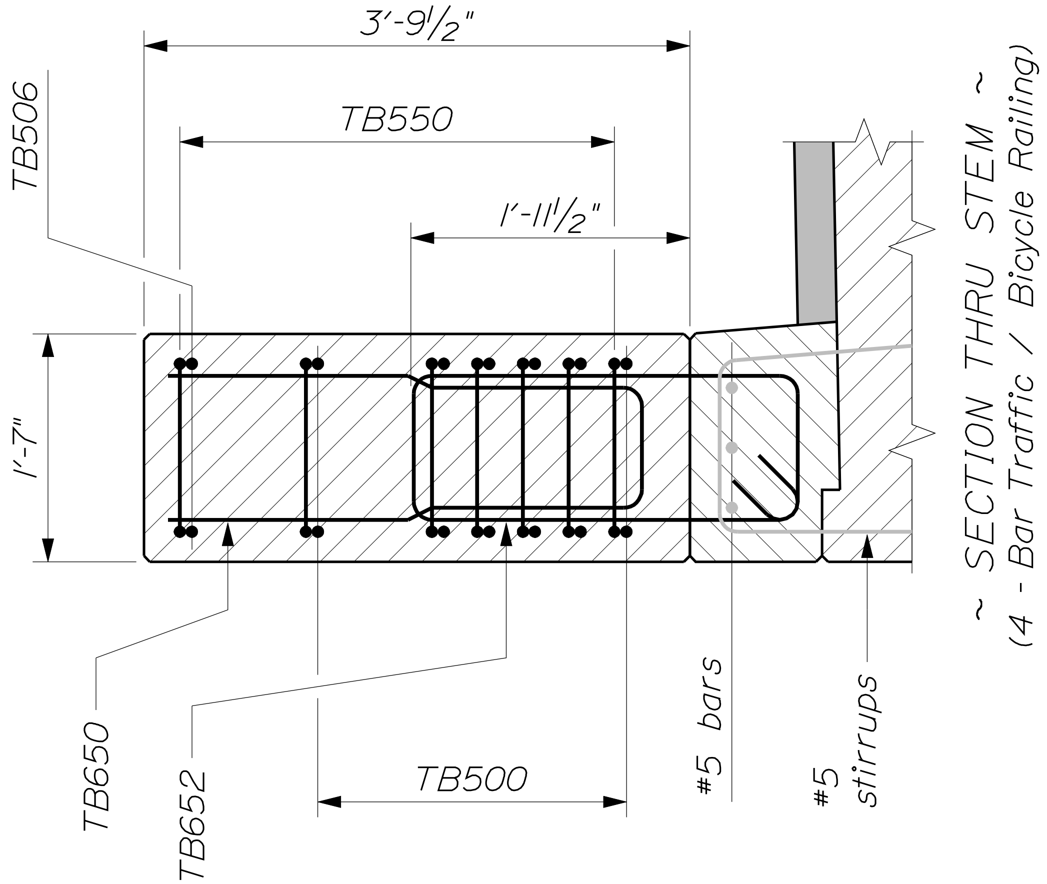
CONCRETE TRANSITION BARRIER

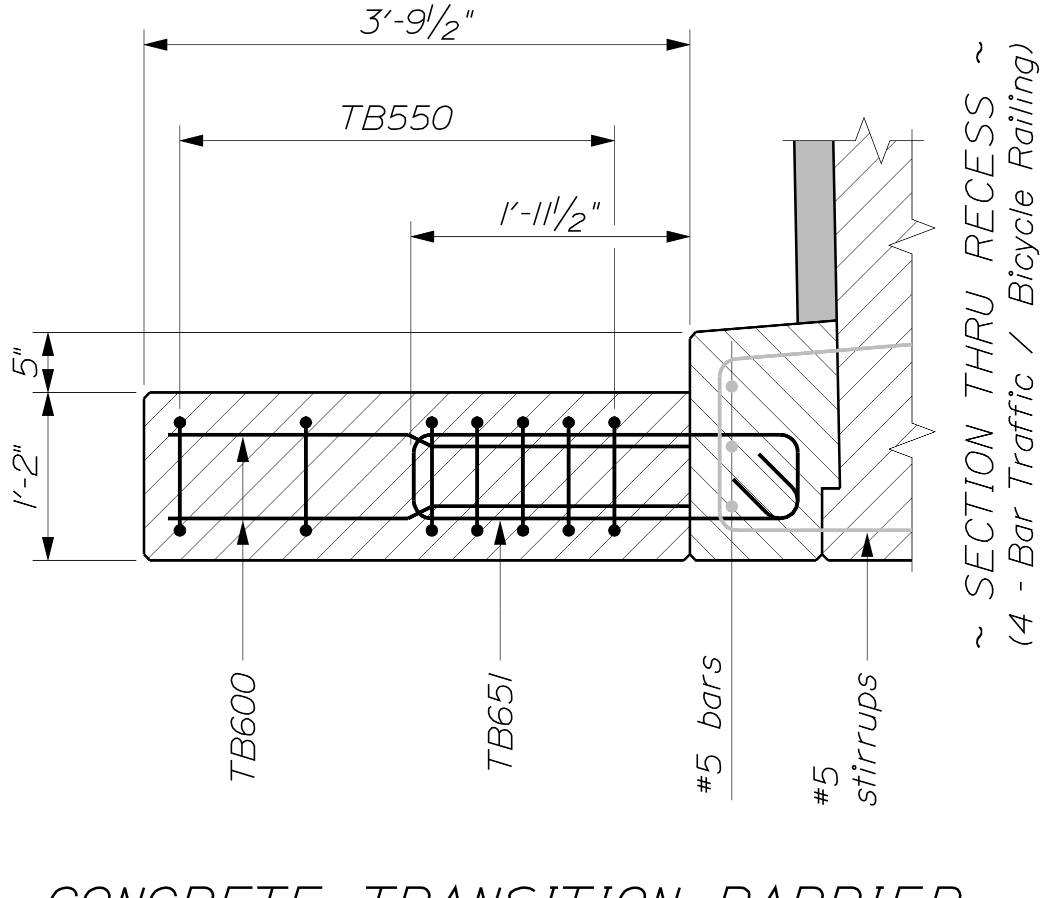
526(30)



CONCRETE TRANSITION BARRIER

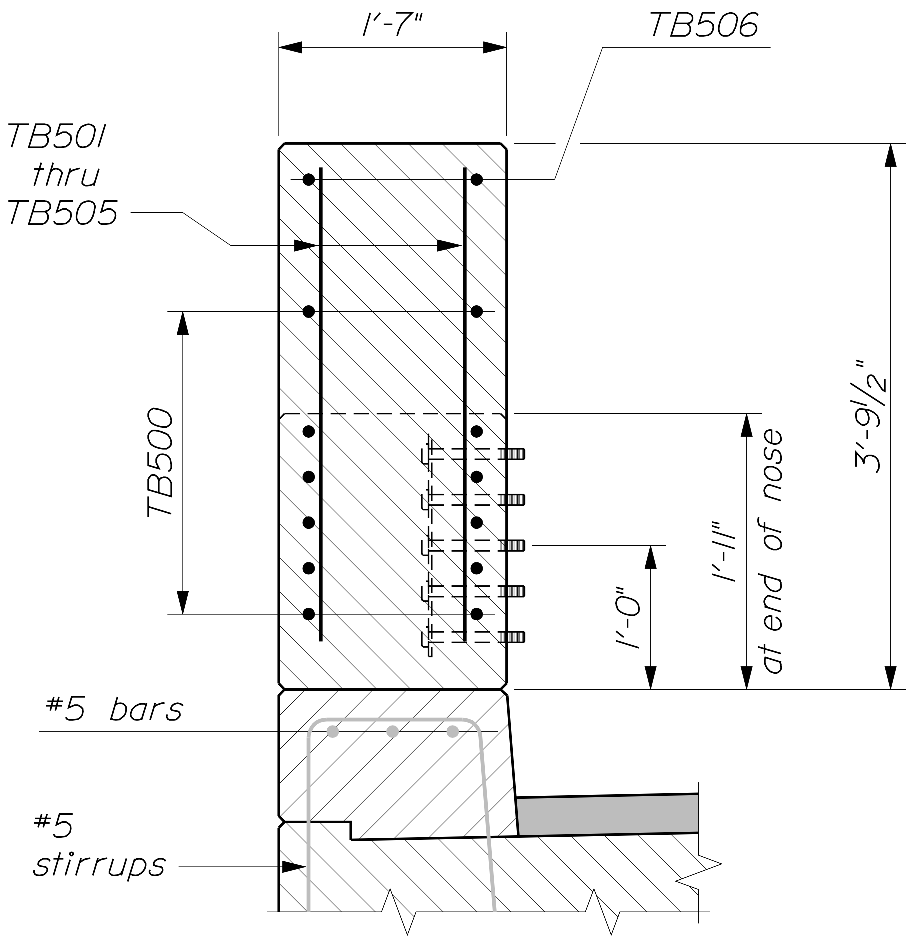
526(31)





CONCRETE TRANSITION BARRIER

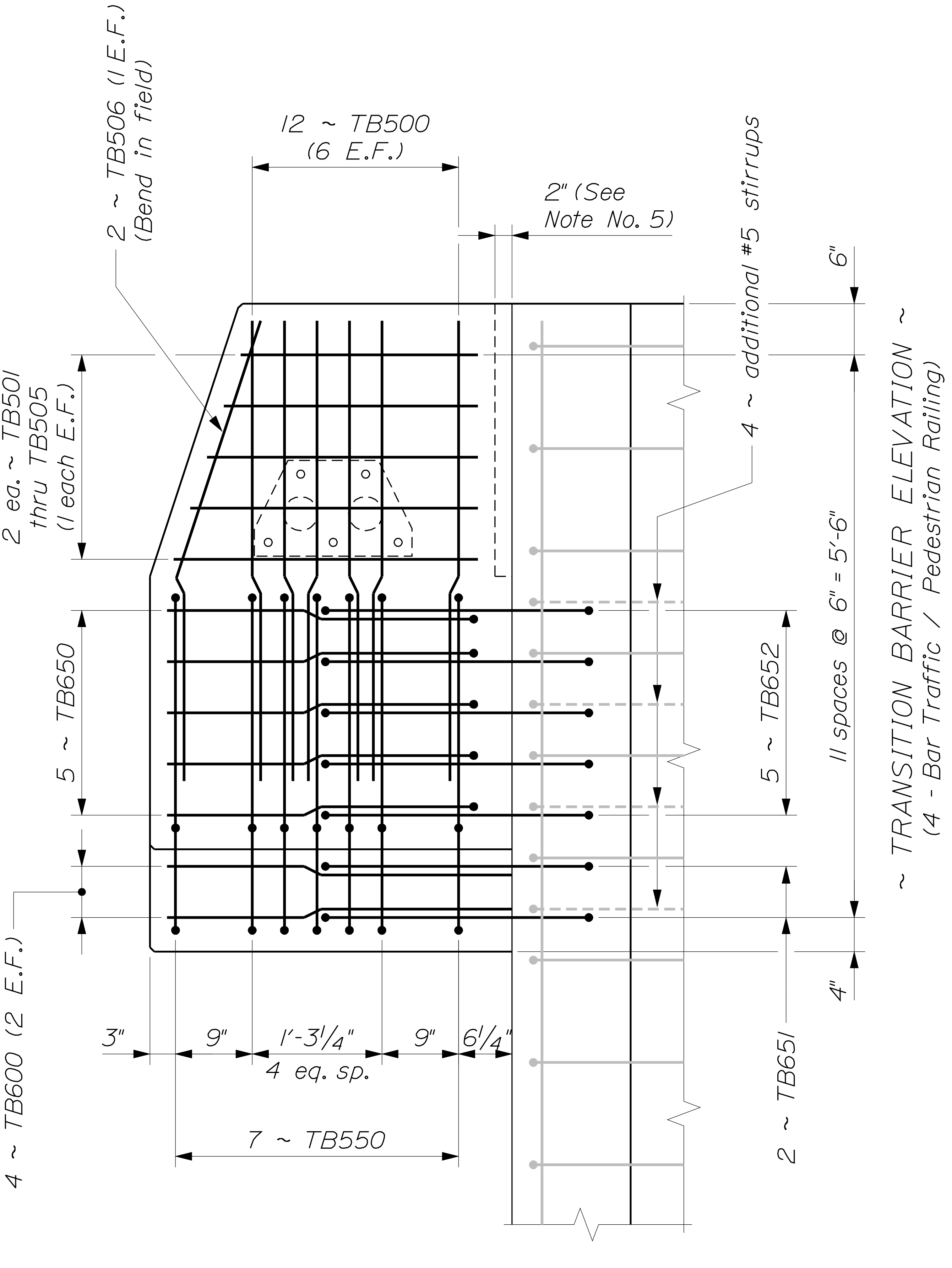
526(32)



~ SECTION THRU NOSE ~
(4 - Bar Traffic / Bicycle Railing)

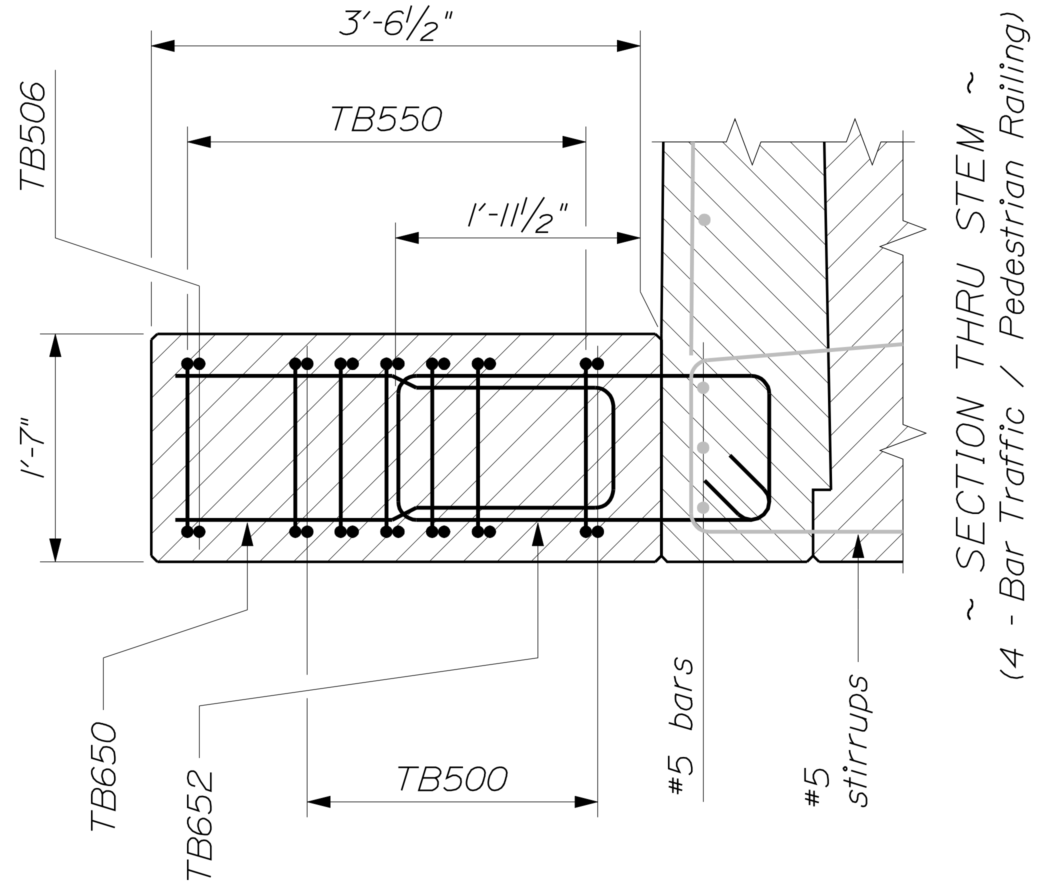
CONCRETE TRANSITION BARRIER

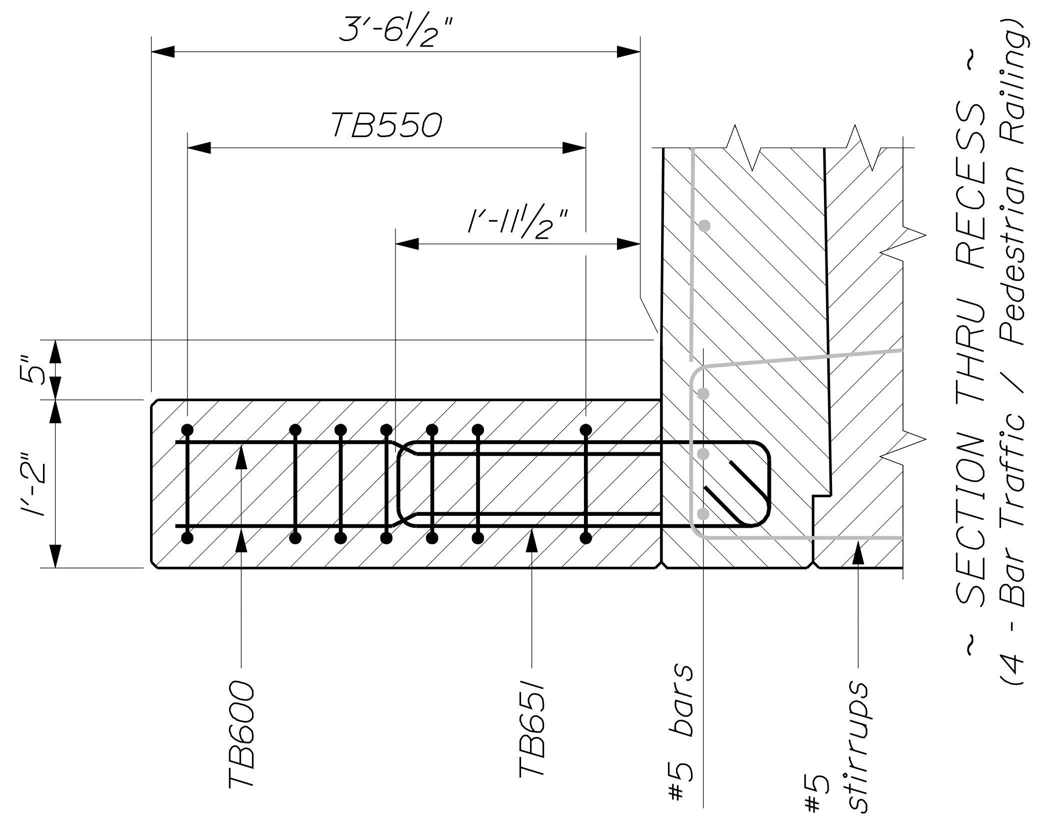
526(33)



CONCRETE TRANSITION BARRIER

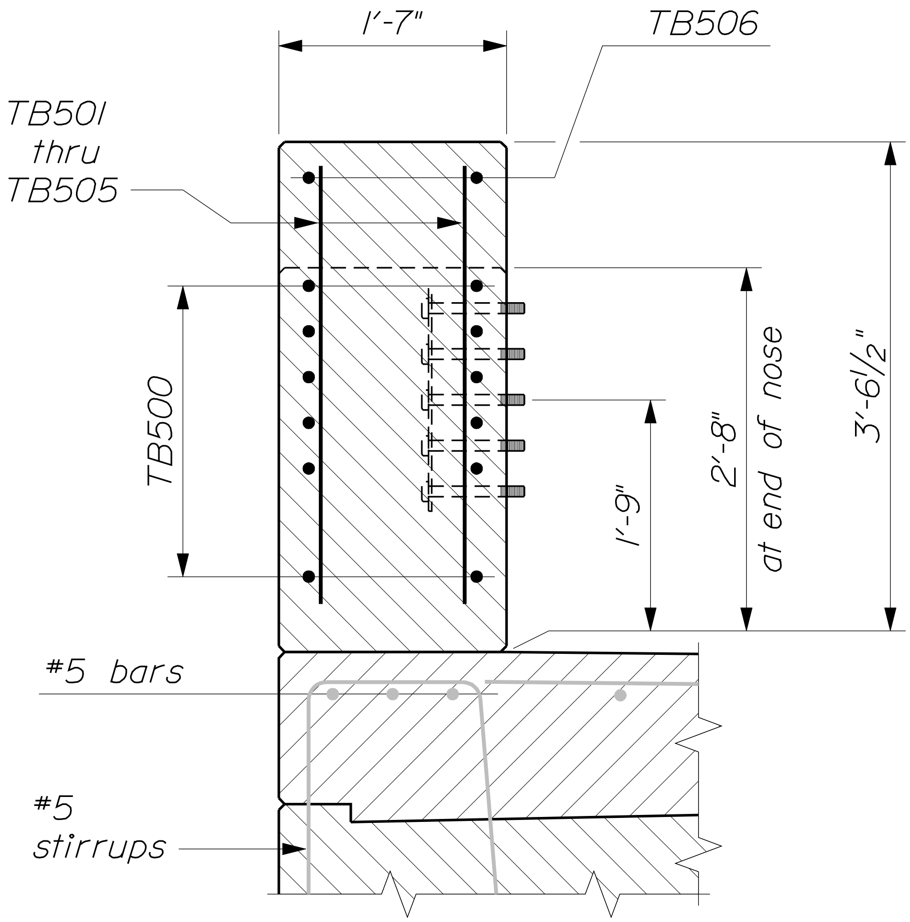
526(34)





CONCRETE TRANSITION BARRIER

526(35)



~ SECTION THRU NOSE ~
(4 - Bar Traffic / Pedestrian Railing)

CONCRETE TRANSITION BARRIER

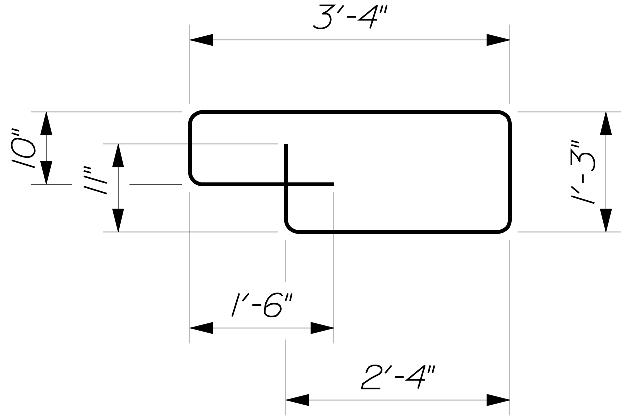
526(36)

REINFORCING STEEL SCHEDULE								
	2 - Bar Traffic		3 - Bar Bike		4 - Bar Bike		4 - Bar Ped.	
	Qty.	Length	Qty.	Length	Qty.	Length	Qty.	Length
TB500	10	4′-6″	10	4′-6″	12	4′-6″	12	4′-6″
TB501	2	1′-8″	2	2′-2″	2	3′-2″	2	2′-11″
TB502	2	1′-7″	2	2′-0″	2	2′-10″	2	2′-9″
TB503	2	1′-7″	2	1′-10″	2	2′-6″	2	2′-7″
TB504	2	1′-6″	2	1′-8″	2	2′-2″	2	2′-5″
TB505	2	1′-6″	2	1′-6″	2	1′-10″	2	2′-3″
TB506	--	--	2	4′-8″	2	5′-1″	2	4′-8″
TB550	5	10′-2″	6	10′-2″	7	10′-2″	7	10′-2″
TB600	--	--	4	2′-7″	4	3′-7″	4	3′-4″
TB650	--	--	5	5′-10″	5	7′-10″	5	7′-4″
TB651	2	7′-11″	2	7′-11″	2	7′-11″	2	7′-11″
TB652	5	8′-9″	5	8′-9″	5	8′-9″	5	8′-9″

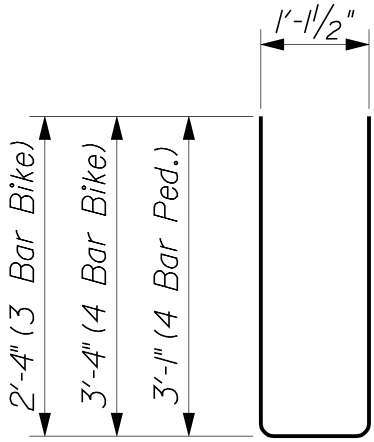
Notes:

The first digit following the letters of the mark indicate the size of the reinforcing bar. (TB500 = bar size #5.) All dimensions are out - to - out of bar.

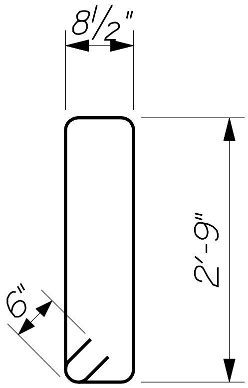
Quantities given are for one Transition Barrier.



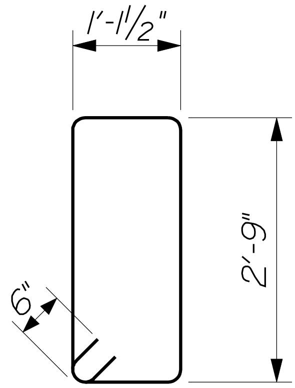
~ TB550 ~



~ TB650 ~



~ TB651 ~



~ TB652 ~

CONCRETE TRANSITION BARRIER

526(37)

NOTES:

1. All work and materials shall conform to the provisions of Standard Specifications Section 526 - Concrete Barrier.

2. The Contractor is responsible for ensuring that vertical reinforcing bars TB651 and TB652 are installed prior to placement of the curb or sidewalk concrete. Payment for these bars will be considered incicdental to Item No. 526.34, Permanent Concrete Transition Barrier.

3. Reinforcing steel shall have a minimum concrete cover of 2 inches.

4. Quantities of reinforcing bars shown are for one transition barrier only.

5. When the Concrete Transition Barrier is cantilevered over an expansion joint, the nose shall be blocked out as shown.

6. Payment for guardrail anchorage will be considered incidental to the transition barrier pay item. Class 8.8.3 bolts shall be used when corrosion - resistant steel guardrail is specified on the approach roadway

7. Precast Concrete Transition Curb shall meet the requirements of Standard Specifications Section 609 - Curb. The bridge end of the curb shall be saw cut in the field to fit flush against the backwall, as dictated by the bridge skew angle and the profile grade. Where curbing is specified on the adjacent highway, the transition shall be modified accordingly. Payment for transition curb will be considered incidental to the Concrete Transition Barrier pay item.

8. Concrete Transition Barrier is designed for attachment of Bridge Transition Type "I" unless otherwise indicated on the Design Drawings. Refer to Section 606 for details.

9. After installation of the guardrail is complete, upset the threads on the anchor bolts in three (3) places around each bolt, at the junction of the nut and the exposed thread, with a center punch or similar tool.

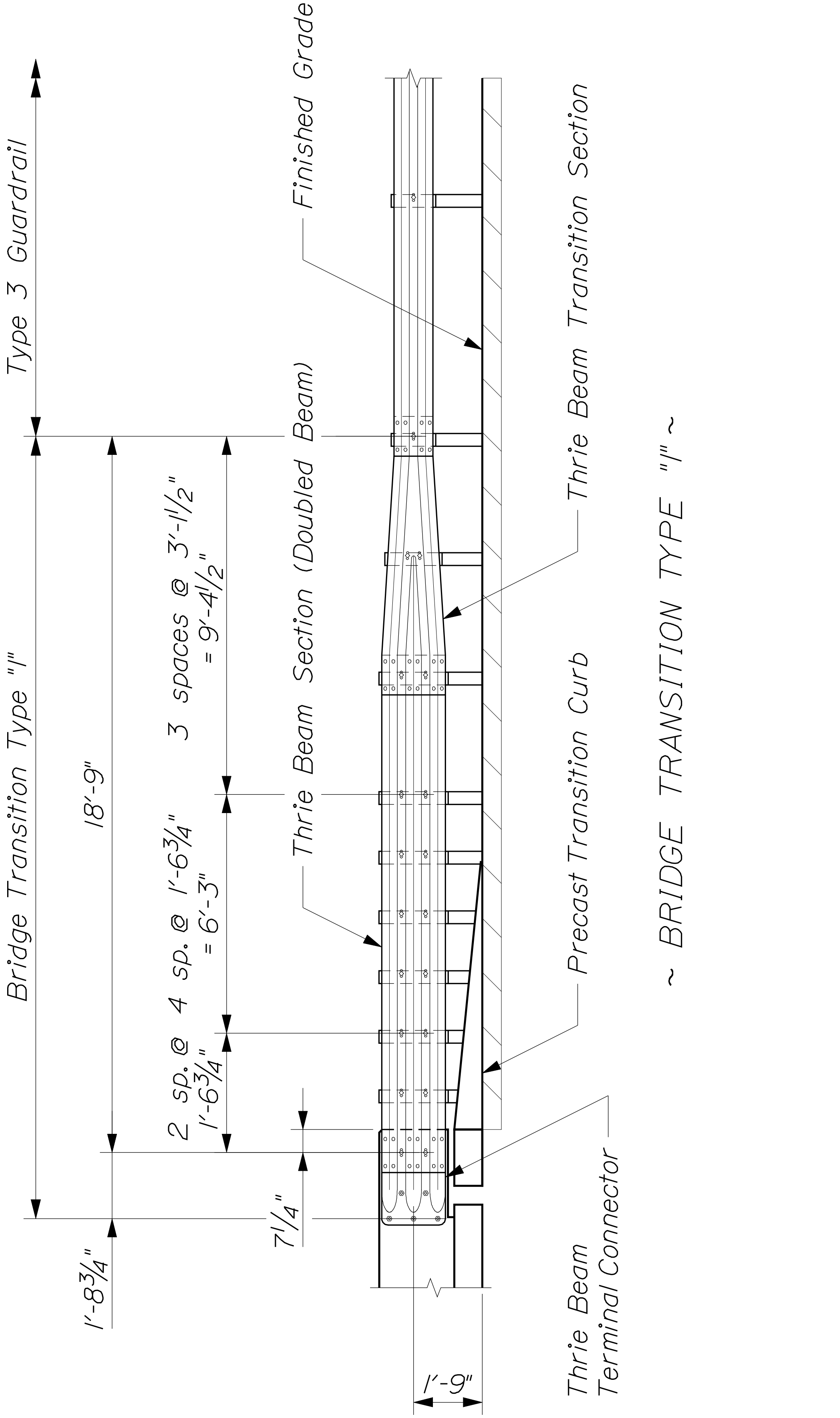
10. If there is a conflict between these Standard Details and the Design Drawings, the requirements of the Design Drawings shall be followed.

MATERIALS:

Concrete ____________________ Class "LP"
Reinforcing Steel ____________ AASHTO M 31M/M 31, Grade 60
Spacer Plate ________ AASHTO M 270M/M 270, Grade 36 (Galvanized)
Bolts ____________ AASHTO M 314, Grade 105 (Galvanized)

CONCRETE TRANSITION BARRIER

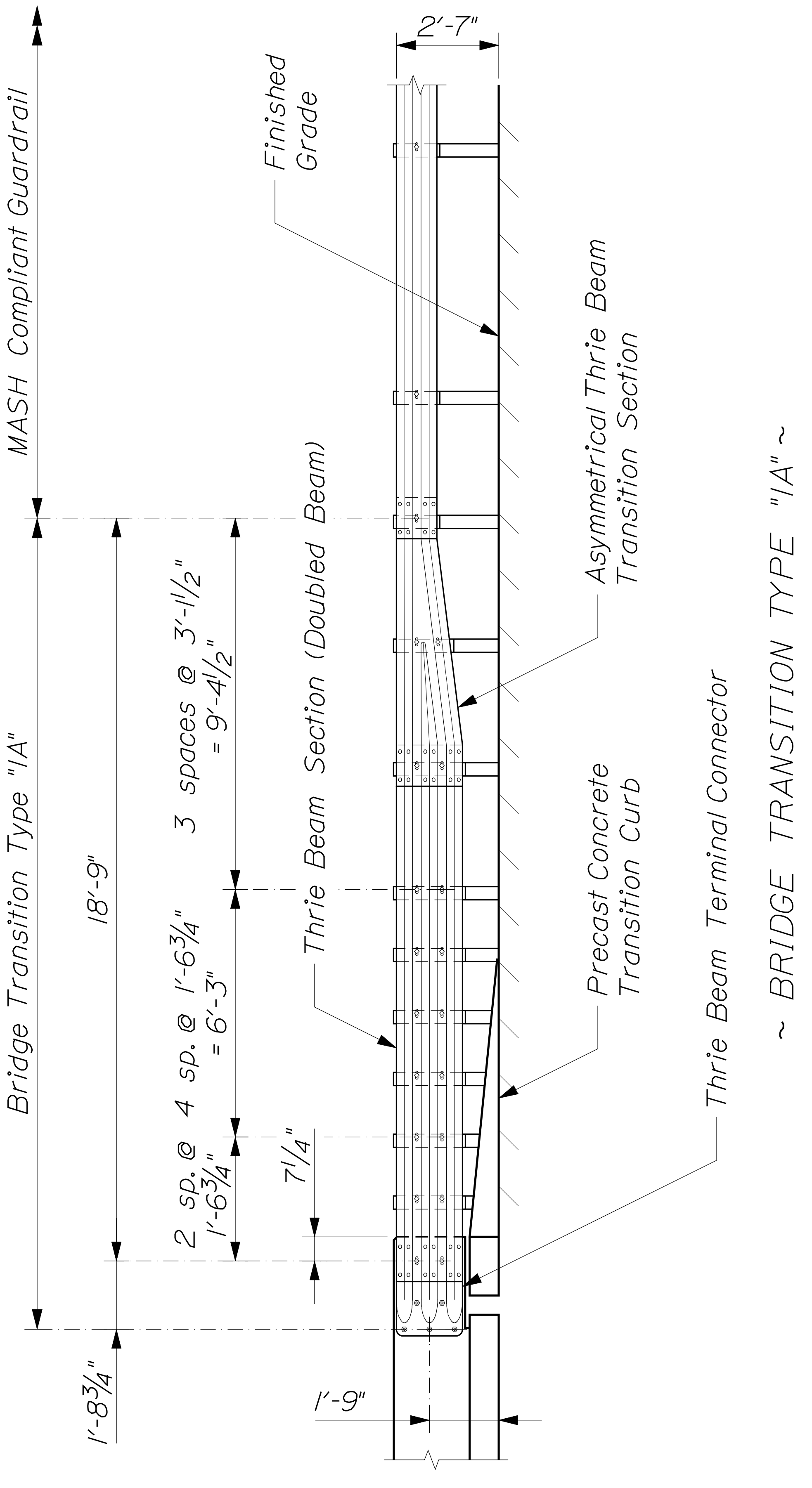
526(38)



NOTE: Part designations are shown in "A Guide to Standardized Highway Barrier Hardware" as prepared and approved by the AASHTO - AGC - ARTBA Joint Committee, Task Force 13 Report.

STANDARD BRIDGE TRANSITION - TYPE "I"

606(21)



NOTE: Part designations are shown in "A Guide to Standardized Highway Barrier Hardware" as prepared and approved by the AASHTO - AGC - ARTBA Joint Committee, Task Force 13 Report.

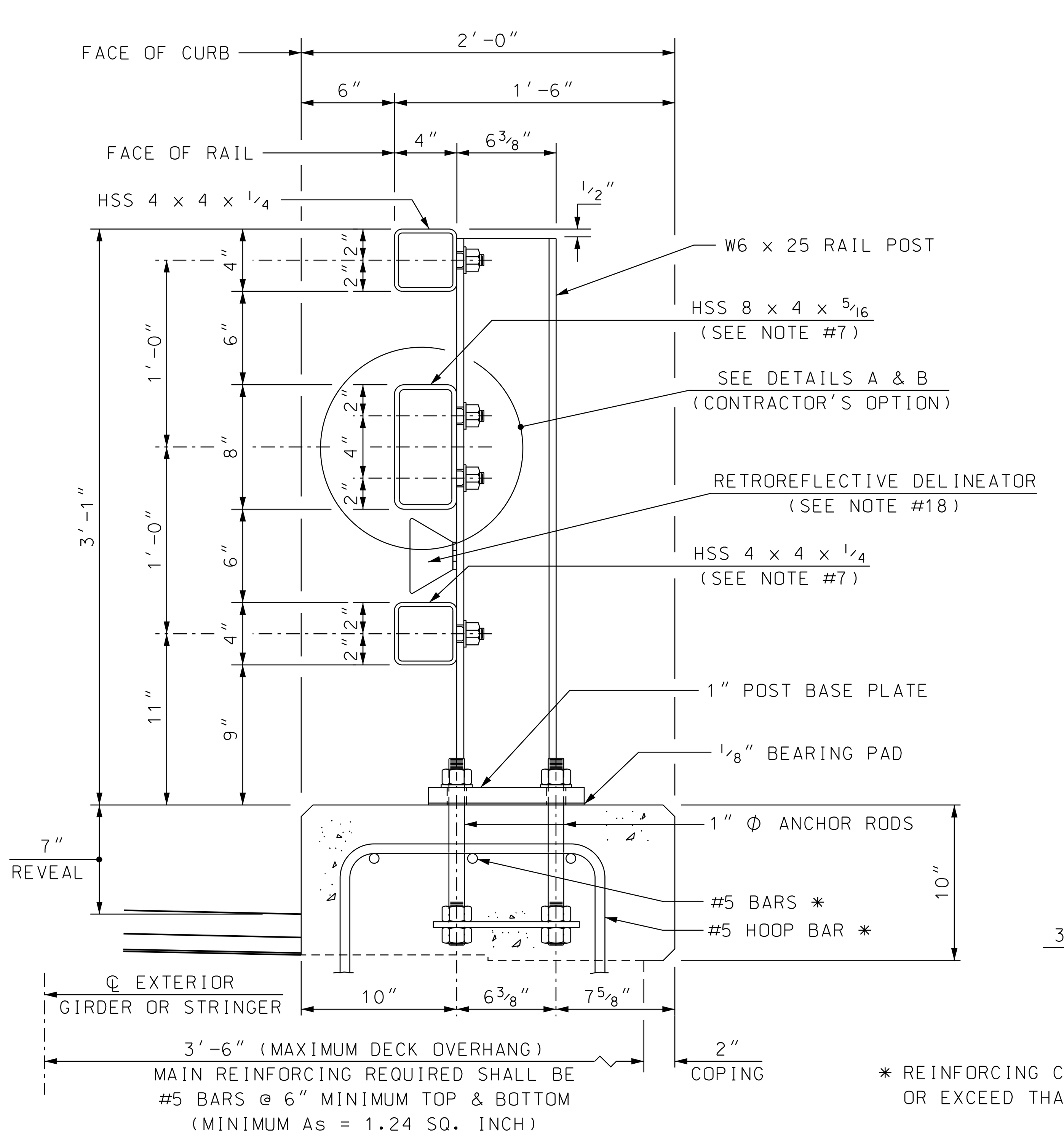
Suppl.
Std. Detail

BRIDGE TRANSITION - TYPE "1A"

606(21A)

Sept. 6, 2017

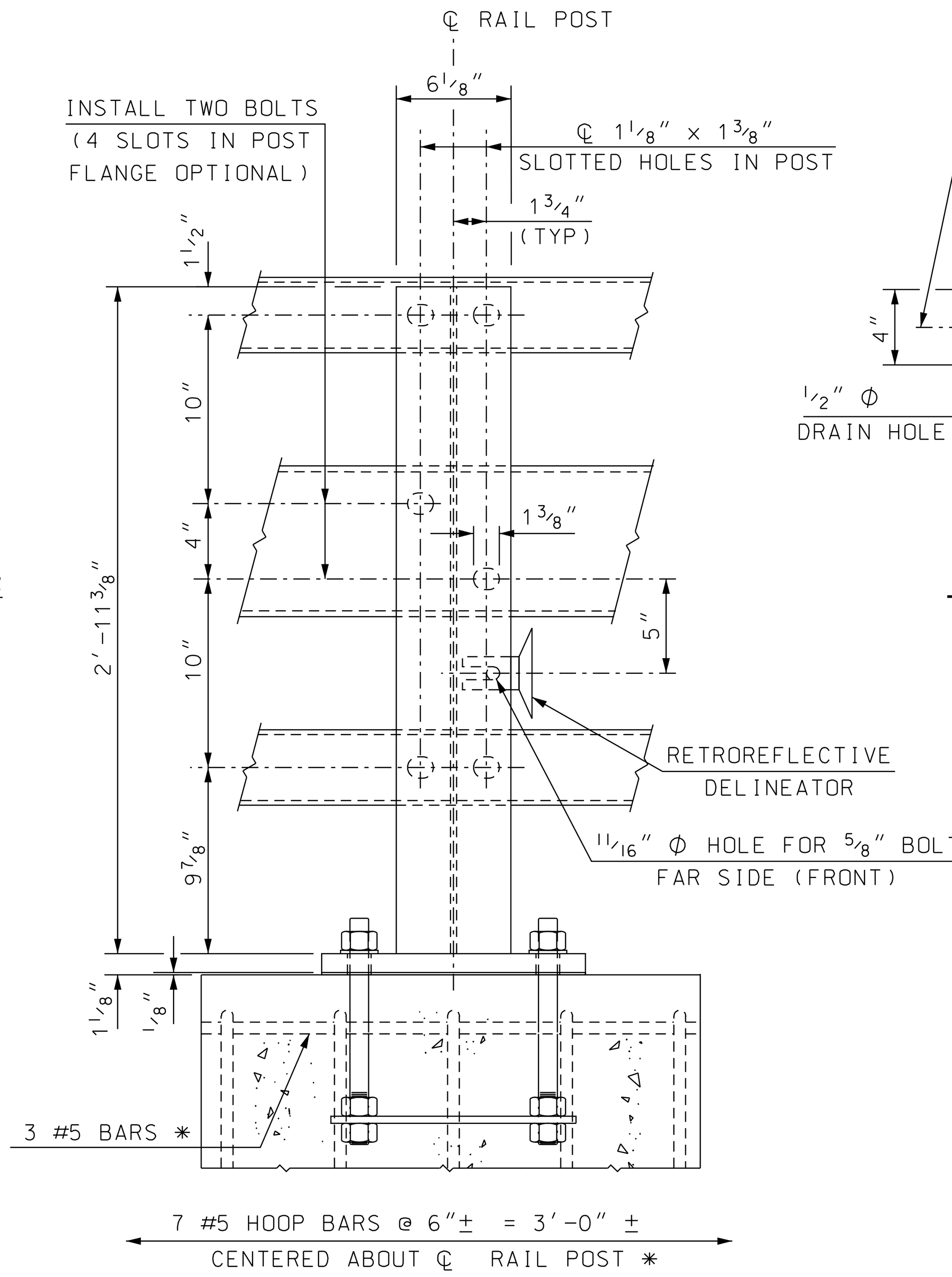
APPENDIX B: NEW HAMPSHIRE DOT STANDARD BRIDGE RAIL DRAWINGS



SECTION VIEW

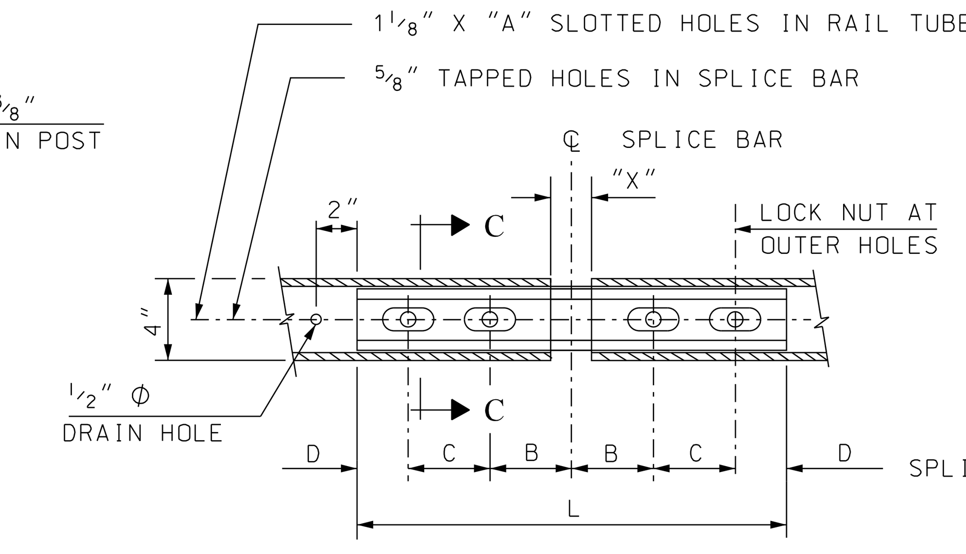
POST ASSEMBLY

SCALE: 1 1/2" = 1'-0"



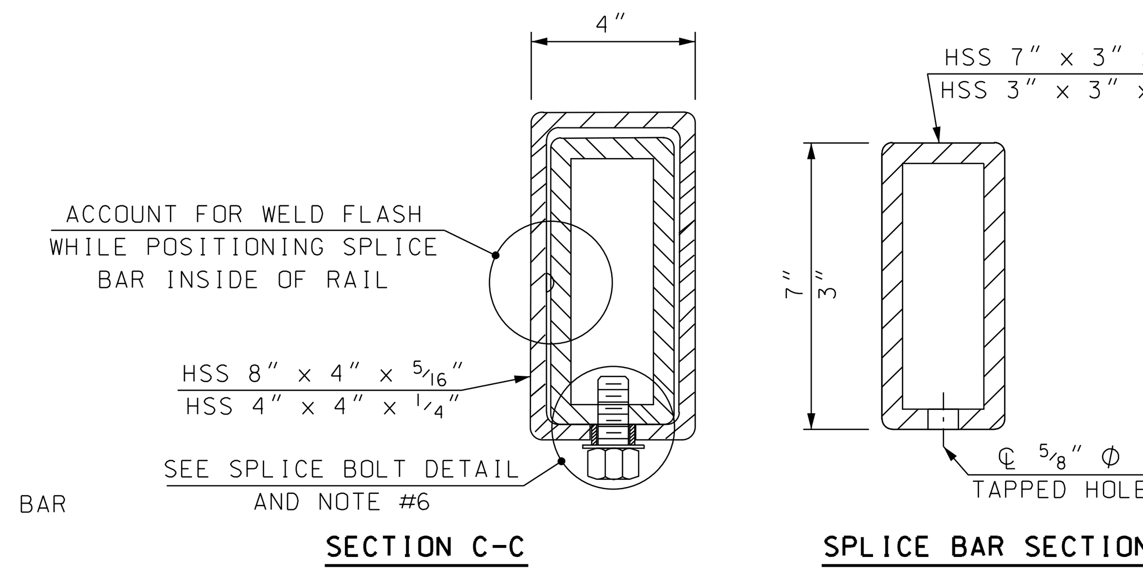
* REINFORCING CAPACITY SHALL MEET OR EXCEED THAT SHOWN

BACK ELEVATION VIEW



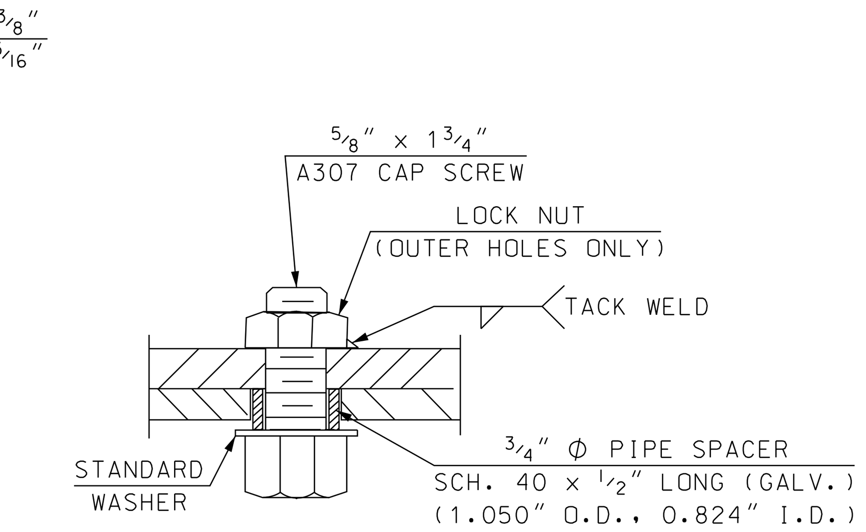
RAIL SPLICE (BOTTOM VIEW)

SCALE: 1 1/2" = 1'-0"



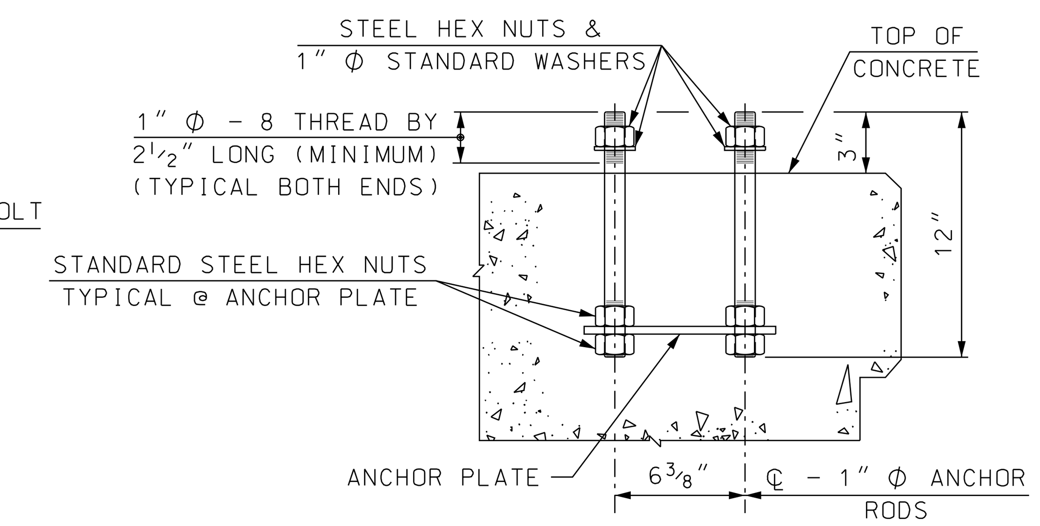
RAIL SPLICE DETAILS

SCALE: 3" = 1'-0"



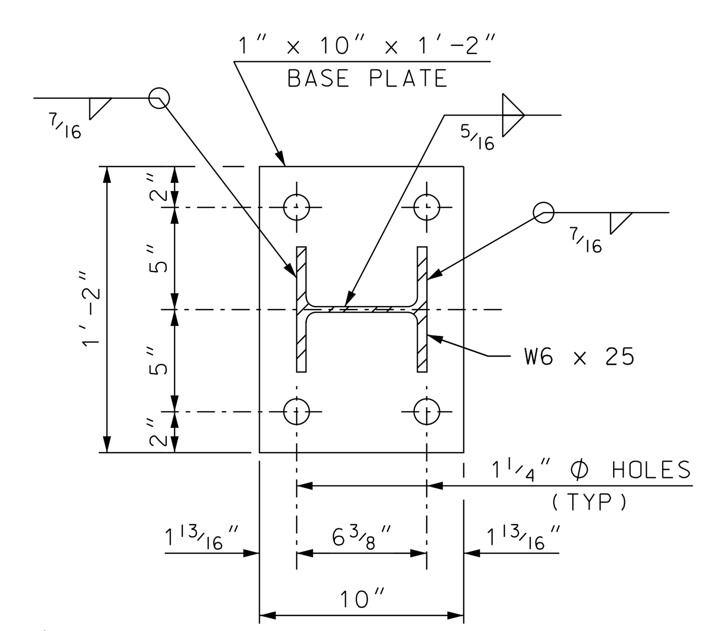
SPLICE BOLT DETAIL

SCALE: 6" = 1'-0"



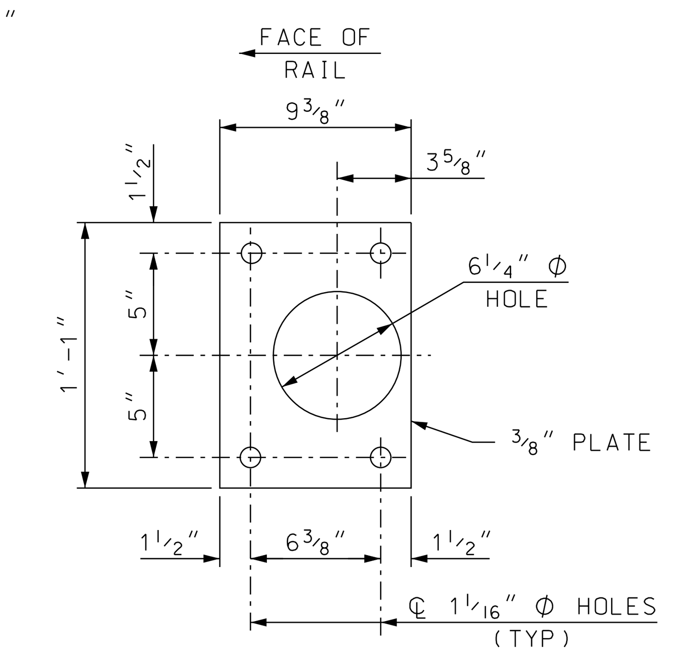
POST ANCHOR ASSEMBLY

SCALE: 1 1/2" = 1'-0"



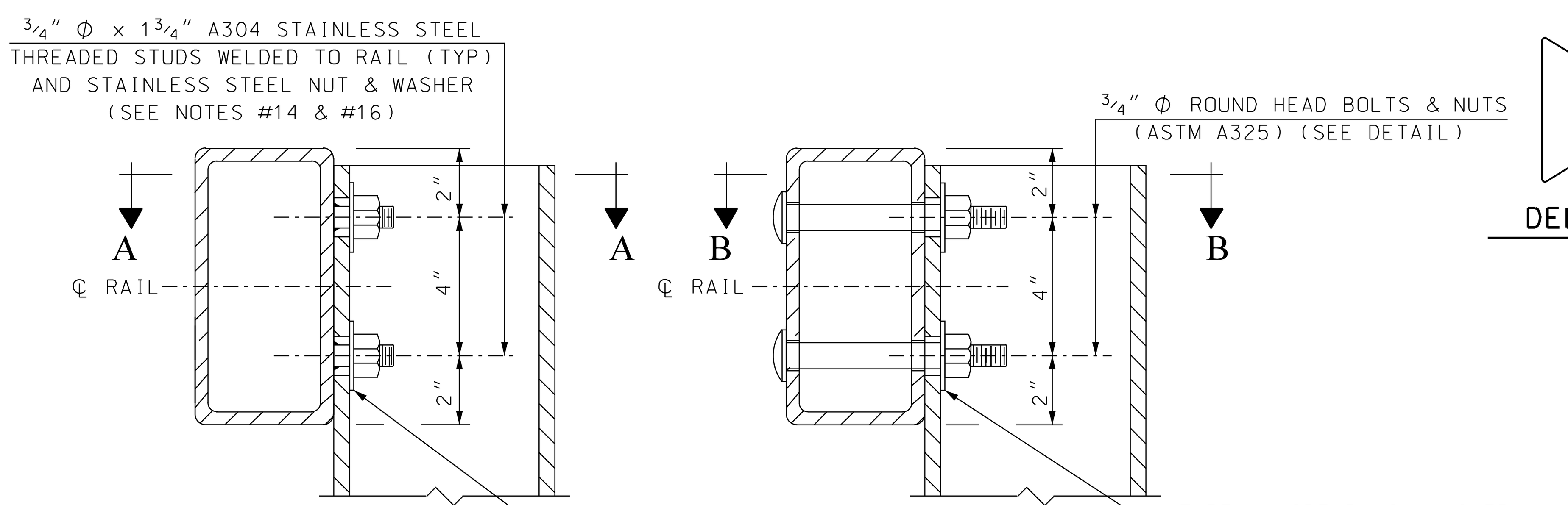
POST BASE PLATE

SCALE: 1 1/2" = 1'-0"



ANCHOR PLATE

SCALE: 1 1/2" = 1'-0"

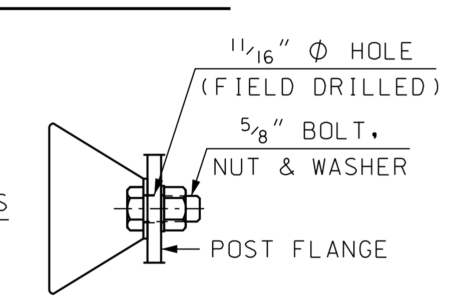


DETAIL A

SCALE: 3" = 1'-0"

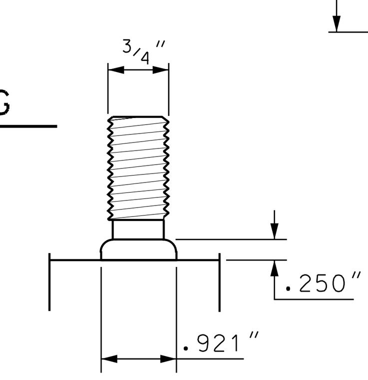
DETAIL B

SCALE: 3" = 1'-0"



DELINEATOR MOUNTING

NOT TO SCALE

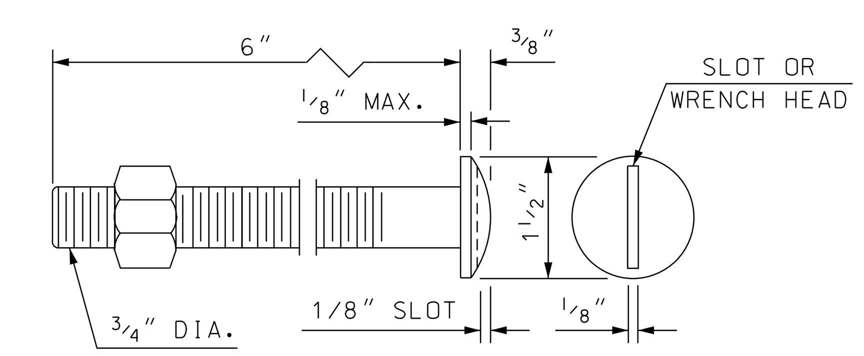


STUD WELD DETAIL

SCALE: 6" = 1'-0"

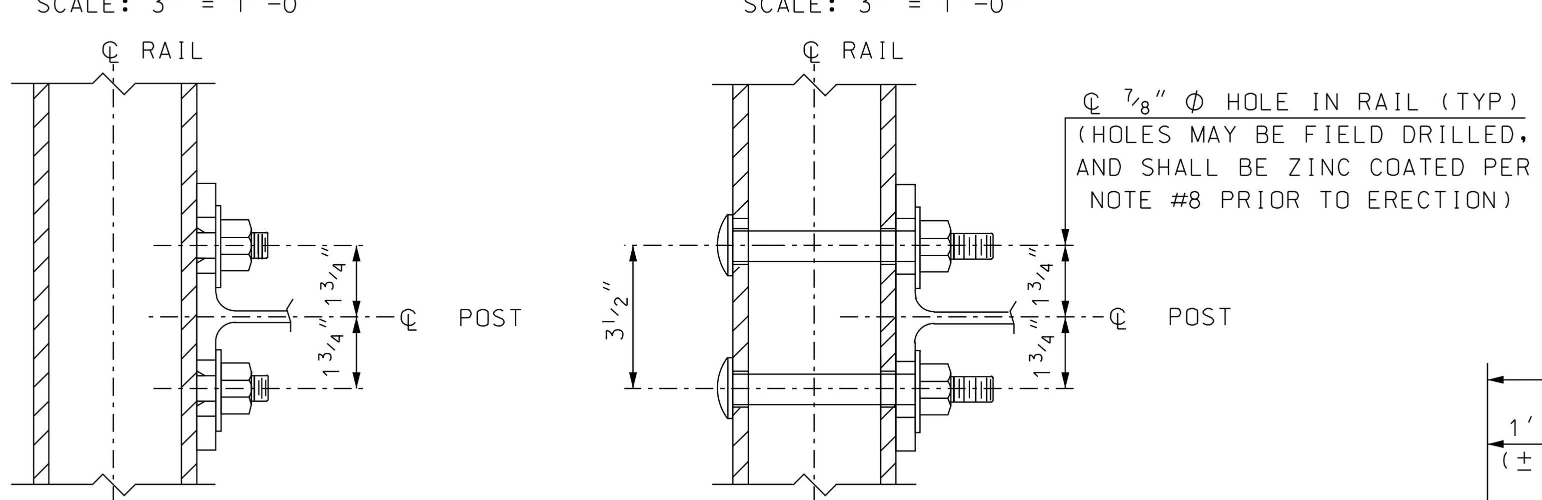
NO MODIFICATIONS PERMITTED TO THIS SHEET, EXCEPT AS NOTED BELOW:

1. POST SPACING @ RAIL ELEVATION
2. ITEM NUMBER AND DESCRIPTION IF SNOW SCREENING AND/OR PROTECTIVE SCREENING WILL BE USED
3. DESIGN OF DECK OVERHANG REINFORCING IS REQUIRED FOR DECK OVERHANG DISTANCE GREATER THAN 3'-6"



A325 ROUND HEAD BOLT DETAIL

SCALE: 6" = 1'-0"



SECTION A-A

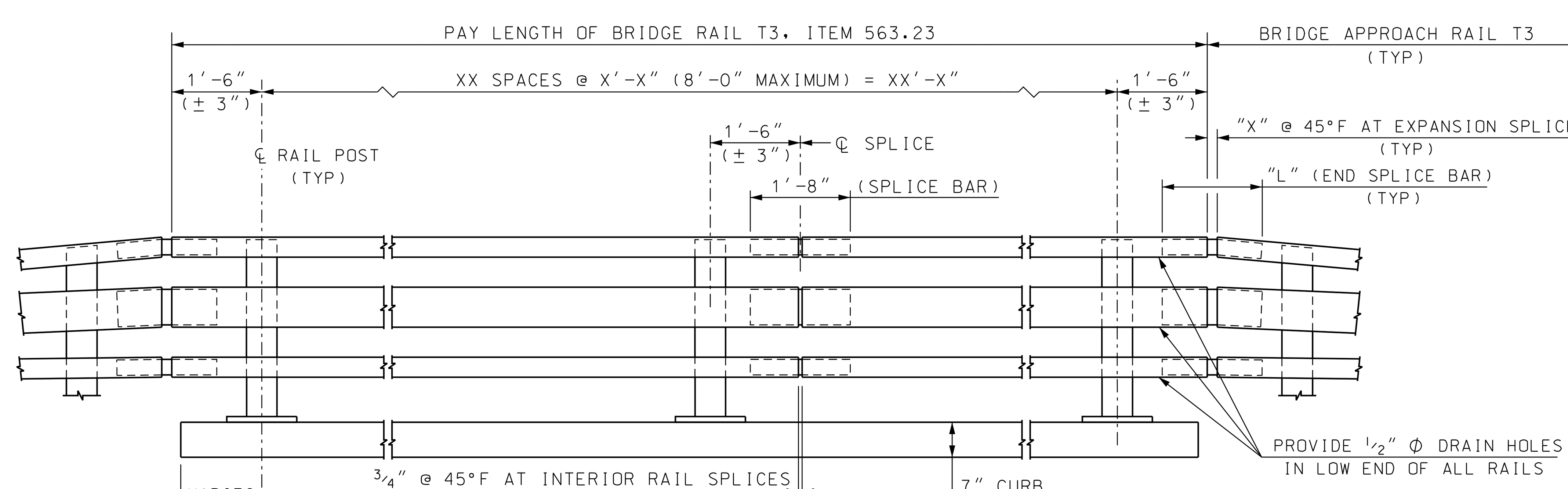
SCALE: 3" = 1'-0"

SECTION B-B

SCALE: 3" = 1'-0"

SPLICE BAR DIMENSION TABLE						
T	A	B	C	D	X	L
INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
** ≤ 3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
** 3 1/4" < T ≤ 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

T = TOTAL MOVEMENT OF BRIDGE
** = END SPLICE BAR



RAIL ELEVATION

SCALE: 1/2" = 1'-0"

RAIL NOTES

(1) ITEM 563.23, BRIDGE RAIL T3, SHALL INCLUDE POSTS, BASE PLATES, ANCHOR PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, ALL APPURTENANCES, AND GALVANIZING.

(2) BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 5% WHERE POSTS SHALL BE SET VERTICAL.

(3) ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.

(4) EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.

(5) BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.

(6) AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. ALL RAILS IN A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT END SPLICES PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON EACH SIDE.

(7) MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE (SEE SECTION 563.3.2.1).

(8) NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER GALVANIZING, EXCEPT AS ALLOWED IN DETAILS A AND B, AND FOR INSTALLATION OF DELINEATORS. DAMAGED AREAS OF GALVANIZING SHALL BE THOROUGHLY CLEANED, PRETREATED, AND PAINTED WITH TWO COATS OF ORGANIC ZINC-RICH GALVANIZING REPAIR PAINT, HAVING A MINIMUM 92% ZINC BY WEIGHT, TO A THICKNESS EQUAL TO THE ORIGINAL COATING, ACCORDING TO SECTION 550.2.9.1 AND ASTM A780.

(9) NUTS FOR 1" Φ THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.

(10) THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED, BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.

(11) THIS BRIDGE RAIL SYSTEM IS IN COMPLIANCE WITH T2 STEEL BRIDGE RAIL WHICH WAS SUCCESSFULLY CRASH TESTED FOR AASHTO PL2 IN 1994 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-4 PER FHWA LETTER HMHS-B50, MARCH 11, 1999.

MATERIAL NOTES

(12) STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V-NOTCH REQUIREMENTS OF 15 FT. LBS. AT 0°F. FOR ASTM A500, GRADE B, THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V-NOTCH IS NOT REQUIRED FOR SPLICE TUBES.

(13) RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.

(14) THREADED STUDS AND MATCHING NUTS FOR RAIL-TO-POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM A563 GRADE A RESPECTIVELY OR BETTER, EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22. ANCHOR RODS SHALL CONFORM TO ASTM A449.

(15) ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE GALVANIZED AFTER FABRICATION IN COMPLIANCE WITH AASHTO M232 (ASTM A153) AND AASHTO M111 (ASTM A123). THE GALVANIZING KETTLE SHALL HAVE 0.05 TO 0.09 PERCENT NICKEL. GALVANIZED SURFACES SHALL HAVE A UNIFORM APPEARANCE AND GALVANIZED MATERIAL SHALL BE PROPERLY STORED. IF PAINTING IS REQUIRED SEE SPECIAL PROVISIONS FOR 708.

(16) DETAIL A STUDS SHALL BE WELDED ON AFTER TUBES ARE GALVANIZED BY SPOT GRINDING OFF GALVANIZING, WELDING ON STUDS, THEN TOUCH UP GALVANIZING PER NOTE #8 ABOVE.

(17) PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

(18) RETROREFLECTIVE DELINEATORS, BOLTS, NUTS, WASHERS AND FIELD DRILLING OF POSTS, INCLUDING GALVANIZING TOUCH-UP, SHALL BE SUBSIDIARY TO ITEM 563.23. SEE STANDARD PLANS FOR ROAD AND BRIDGE CONSTRUCTION (DL-1) FOR ADDITIONAL DETAILS AND SPACING.

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN		BRIDGE NO.	STATE PROJECT
LOCATION			

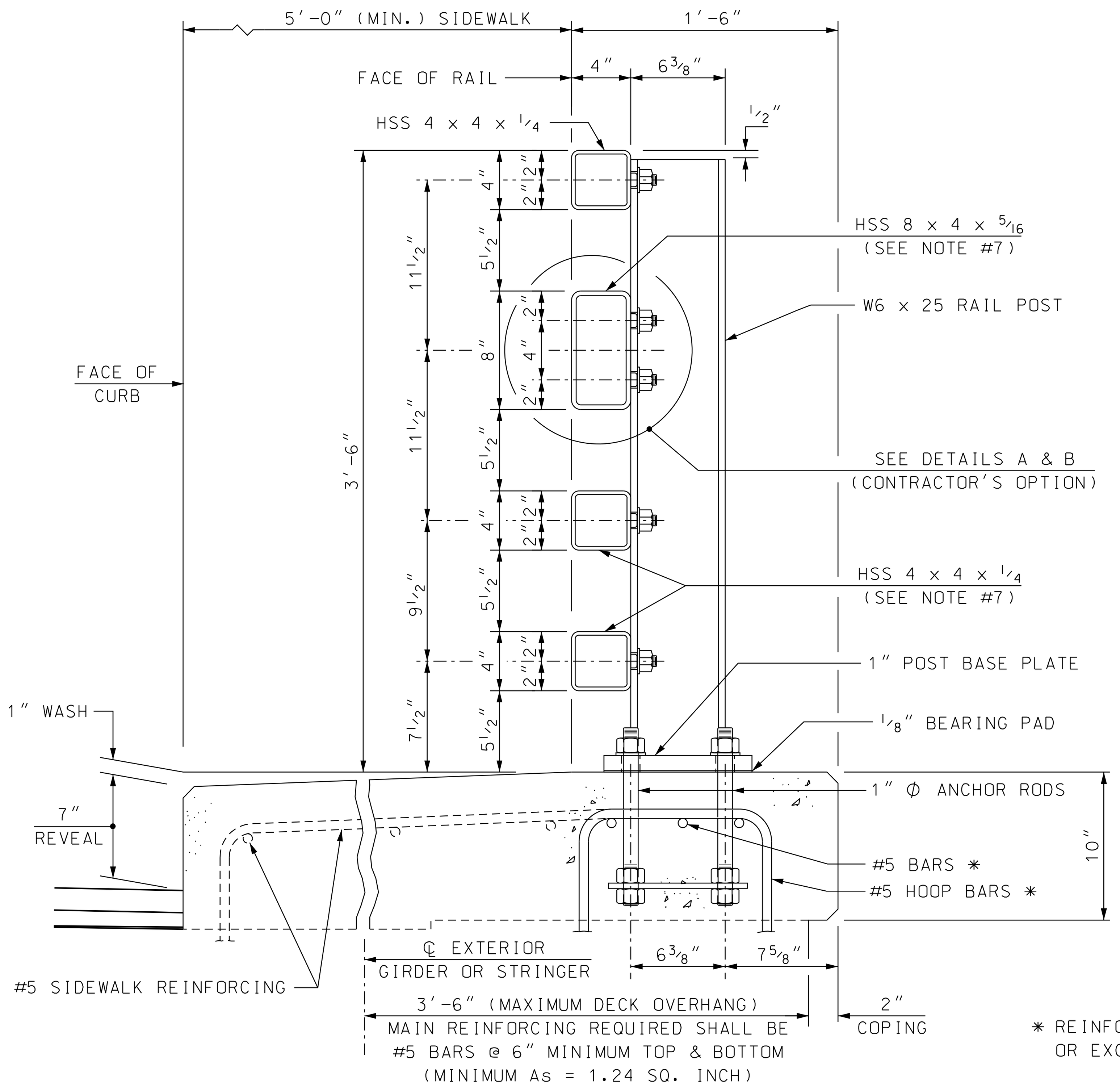
T3 STEEL BRIDGE RAIL

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
DESIGNED		NETC/JSZ	3/02	CHECKED	NHDOT	
DRAWN		PJP	10/05	CHECKED	JSZ	10/05
QUANTITIES				CHECKED		
ISSUE DATE		11/15/05		FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
REV. DATE		11/1/16				

BRIDGE SHEET OF

FILE NUMBER

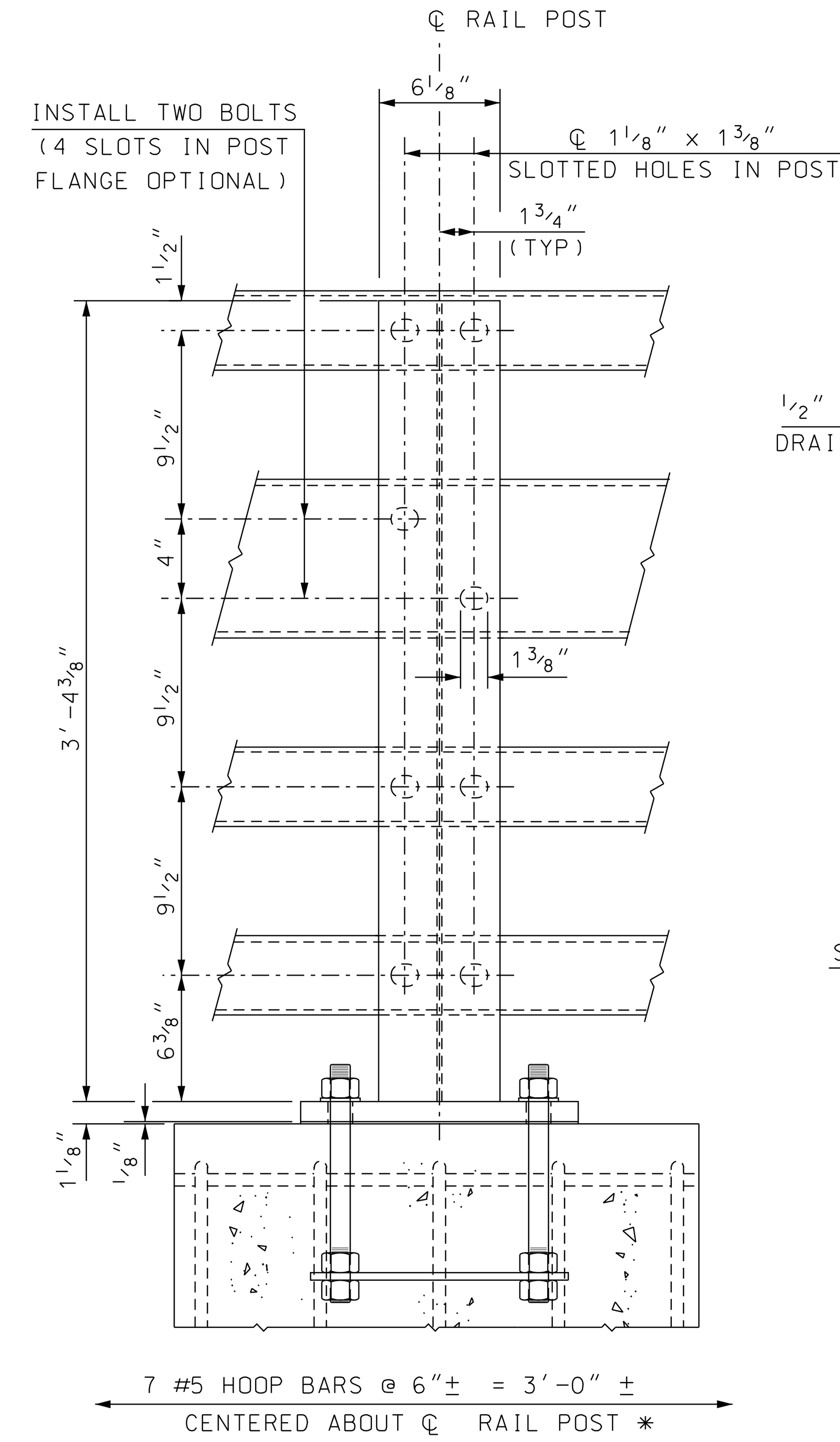
SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T3_BR-RAIL	AS NOTED



SECTION VIEW

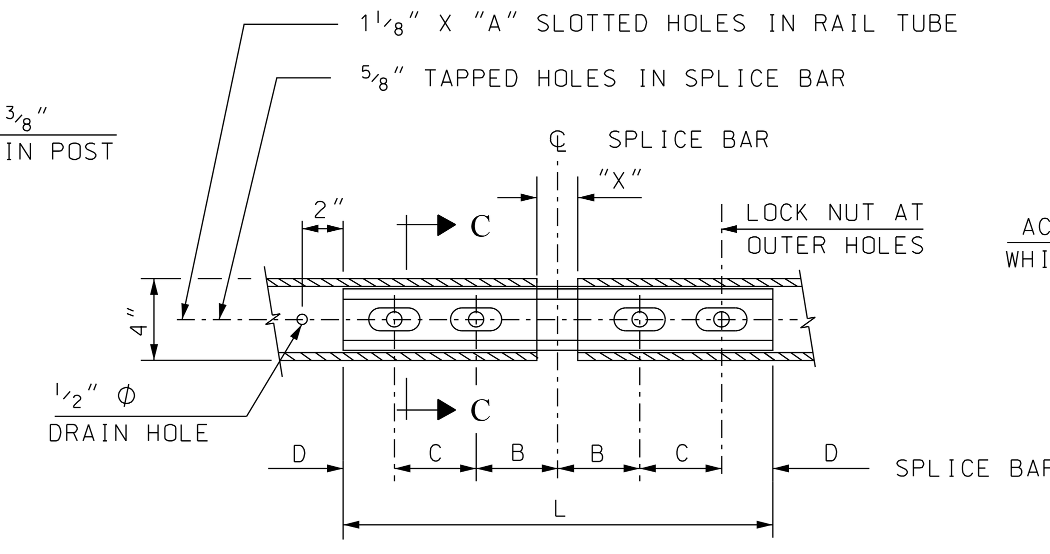
POST ASSEMBLY

SCALE: 1 1/2" = 1'-0"



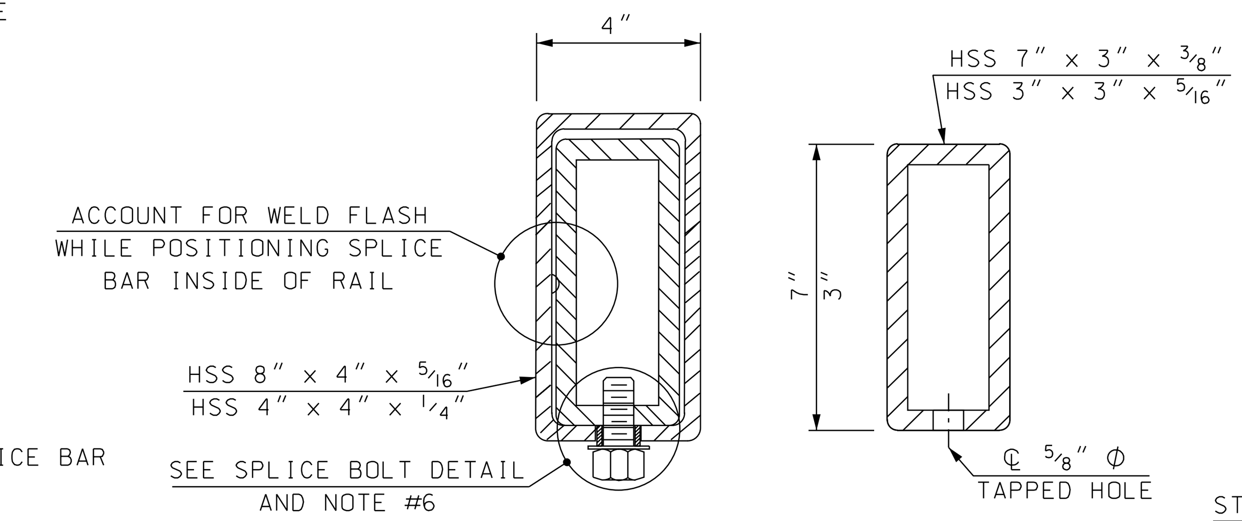
* REINFORCING CAPACITY SHALL MEET OR EXCEED THAT SHOWN

BACK ELEVATION VIEW



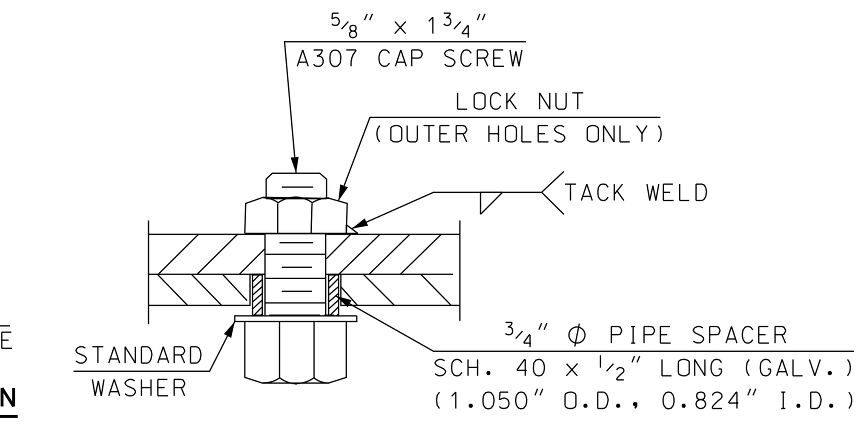
RAIL SPLICE (BOTTOM VIEW)

SCALE: 1 1/2" = 1'-0"



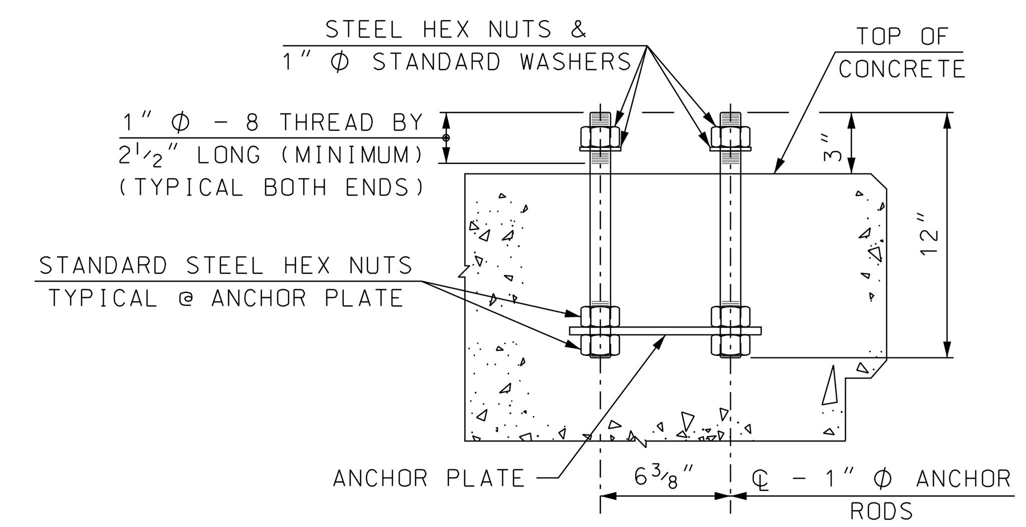
RAIL SPLICE DETAILS

SCALE: 3" = 1'-0"



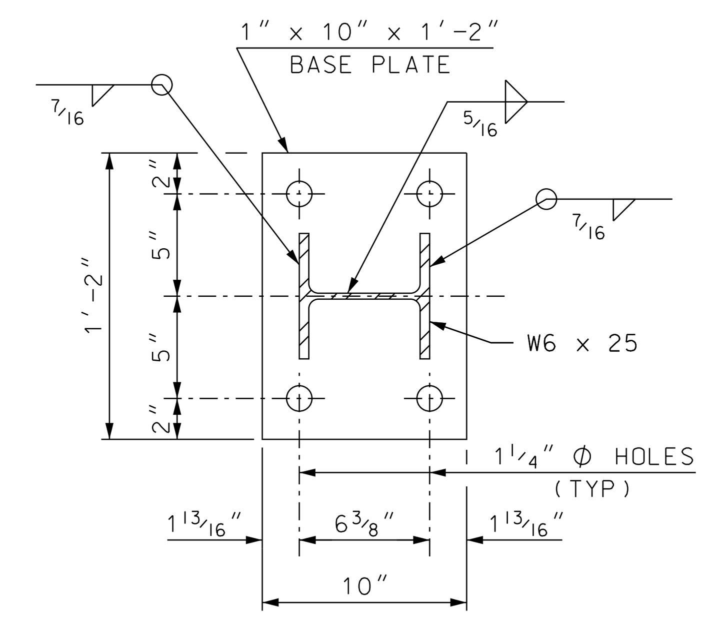
SPLICE BOLT DETAIL

SCALE: 6" = 1'-0"



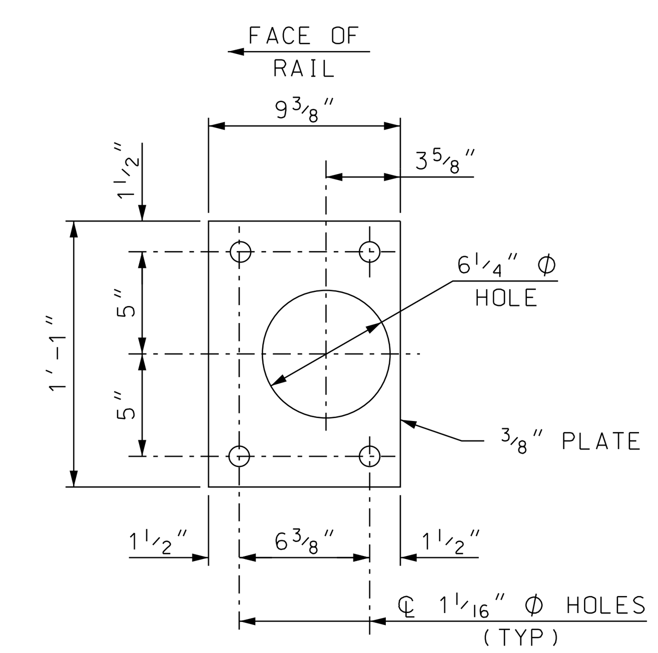
POST ANCHOR ASSEMBLY

SCALE: 1 1/2" = 1'-0"



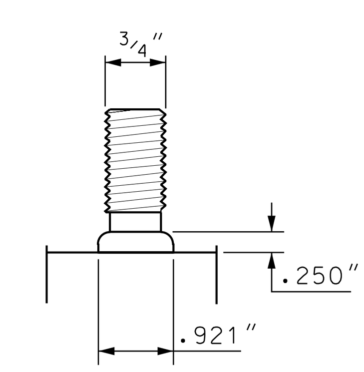
POST BASE PLATE

SCALE: 1 1/2" = 1'-0"



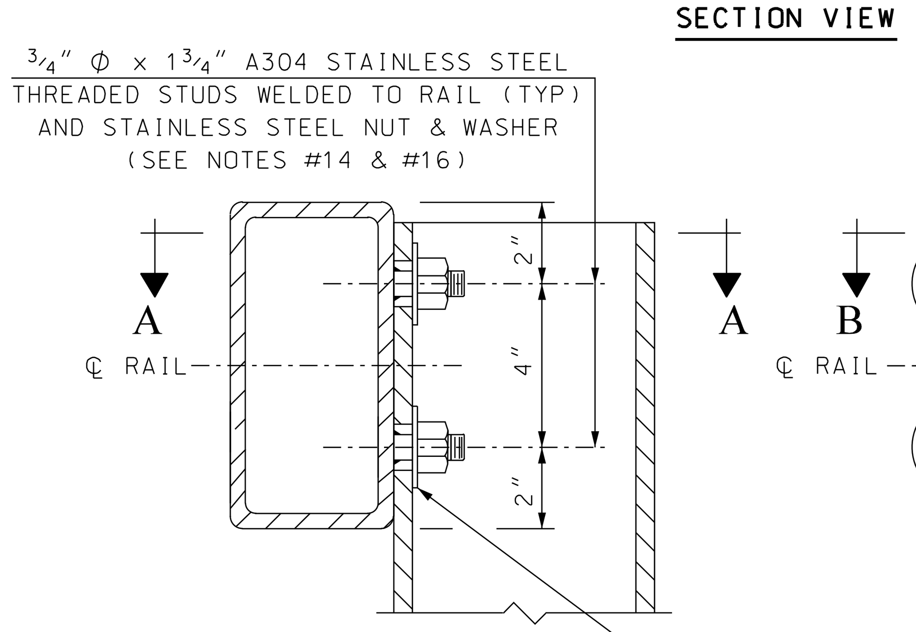
ANCHOR PLATE

SCALE: 1 1/2" = 1'-0"



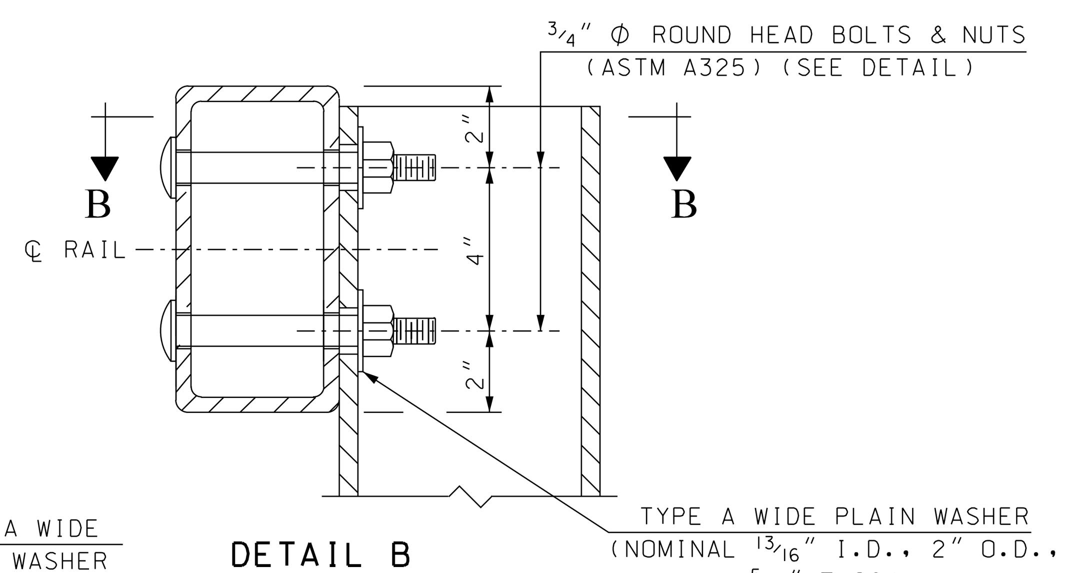
STUD WELD DETAIL

SCALE: 6" = 1'-0"



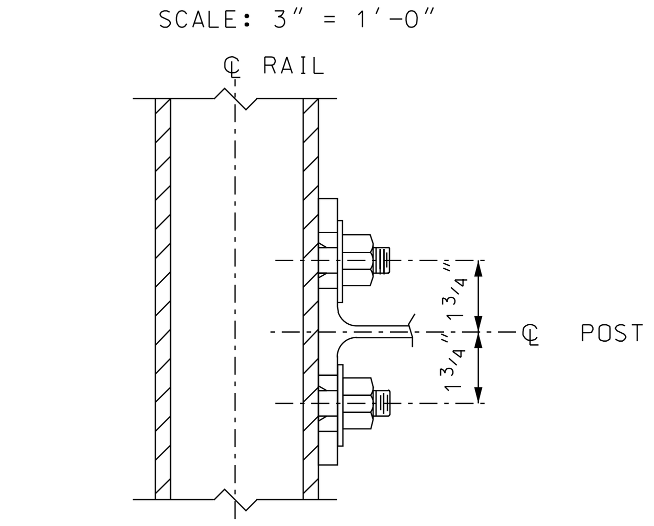
DETAIL A

SCALE: 3" = 1'-0"



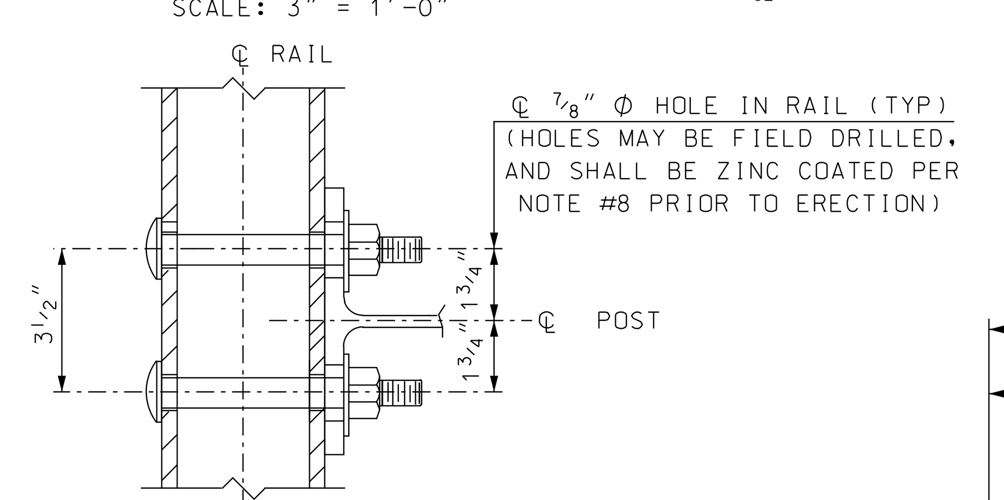
DETAIL B

SCALE: 3" = 1'-0"



SECTION A-A

SCALE: 3" = 1'-0"

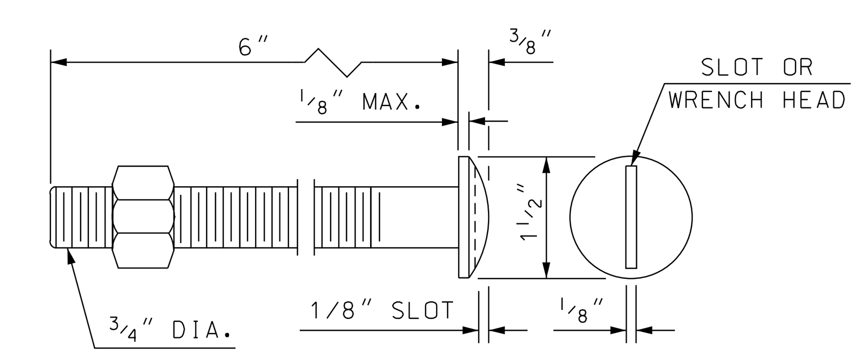


SECTION B-B

SCALE: 3" = 1'-0"

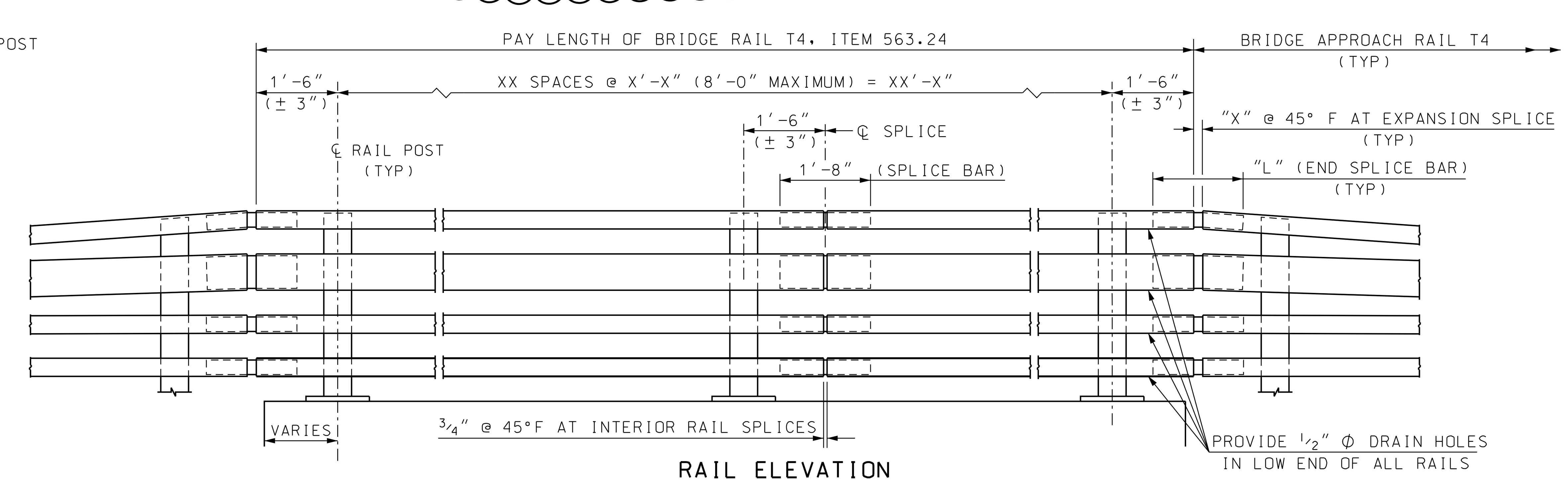
NO MODIFICATIONS PERMITTED TO THIS SHEET, EXCEPT AS NOTED BELOW:

1. POST SPACING @ RAIL ELEVATION
2. ITEM NUMBER AND DESCRIPTION IF SNOW SCREENING AND/OR PROTECTIVE SCREENING WILL BE USED
3. DESIGN OF DECK OVERHANG REINFORCING IS REQUIRED FOR DECK OVERHANG DISTANCE GREATER THAN 3'-6"



A325 ROUND HEAD BOLT DETAIL

SCALE: 6" = 1'-0"



RAIL ELEVATION

SCALE: 1/2" = 1'-0"

SPLICE BAR DIMENSION TABLE

	T	A	B	C	D	X	L
	INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
**	≤ 3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
**	3 1/4" < T ≤ 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

T = TOTAL MOVEMENT OF BRIDGE
** = END SPLICE BAR

RAIL NOTES

(1) ITEM 563.24, BRIDGE RAIL T4, SHALL INCLUDE POSTS, BASE PLATES, ANCHOR PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, ALL APPURTENANCES, AND GALVANIZING.

(2) BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 5% WHERE POSTS SHALL BE SET VERTICAL.

(3) ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.

(4) EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.

(5) BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.

(6) AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. ALL RAILS IN A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT END SPLICES PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON EACH SIDE.

(7) MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE (SEE SECTION 563.3.2.1).

(8) NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER GALVANIZING, EXCEPT AS ALLOWED IN DETAILS A AND B. DAMAGED AREAS OF GALVANIZING SHALL BE THOROUGHLY CLEANED, PRETREATED, AND PAINTED WITH TWO COATS OF ORGANIC ZINC-RICH GALVANIZING REPAIR PAINT, HAVING A MINIMUM 92% ZINC BY WEIGHT, TO A THICKNESS EQUAL TO THE ORIGINAL COATING, ACCORDING TO SECTION 550.2.9.1 AND ASTM A780.

(9) NUTS FOR 1" Φ THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.

(10) THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED, BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.

(11) THIS BRIDGE RAIL SYSTEM WAS SUCCESSFULLY CRASH TESTED FOR AASHTO PL2 IN 1994 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-4 PER FHWA LETTER HMHS-B50, MARCH 11, 1999.

MATERIAL NOTES

(12) STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V-NOTCH REQUIREMENTS OF 15 FT. LBS. AT 0°F. FOR ASTM A500, GRADE B, THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V-NOTCH IS NOT REQUIRED FOR SPLICE TUBES.

(13) RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.

(14) THREADED STUDS AND MATCHING NUTS FOR RAIL-TO-POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM A563 GRADE A RESPECTIVELY OR BETTER, EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22. ANCHOR RODS SHALL CONFORM TO ASTM A449.

(15) ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE GALVANIZED AFTER FABRICATION IN COMPLIANCE WITH AASHTO M232 (ASTM A153) AND AASHTO M111 (ASTM A123). THE GALVANIZING KETTLE SHALL HAVE 0.05 TO 0.09 PERCENT NICKEL. GALVANIZED SURFACES SHALL BE HANDLED AND GALVANIZED MATERIAL SHALL BE PROPERLY STORED. IF PAINTING IS REQUIRED SEE SPECIAL PROVISIONS FOR 708.

(16) DETAIL A STUDS SHALL BE WELDED ON AFTER TUBES ARE GALVANIZED BY SPOT GRINDING OFF GALVANIZING, WELDING ON STUDS, THEN TOUCH UP GALVANING PER NOTE #8 ABOVE.

(17) PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN	BRIDGE NO.	STATE PROJECT
LOCATION		

T4 STEEL BRIDGE RAIL

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
	DESIGNED	NETC/JSZ	3/02	CHECKED	NHDOT	
	DRAWN	PJP	10/05	CHECKED	JSZ	10/05
	QUANTITIES			CHECKED		
	ISSUE DATE	11/15/05		FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
	REV. DATE	11/1/16				

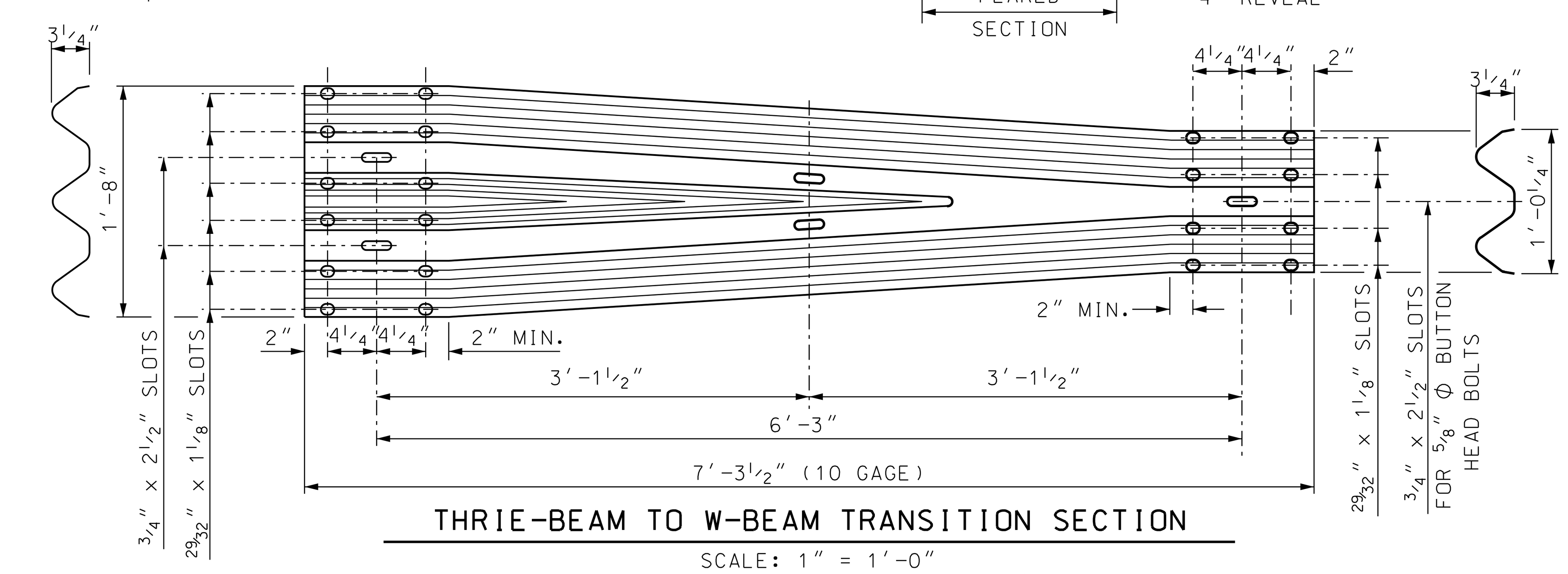
BRIDGE SHEET OF

FILE NUMBER

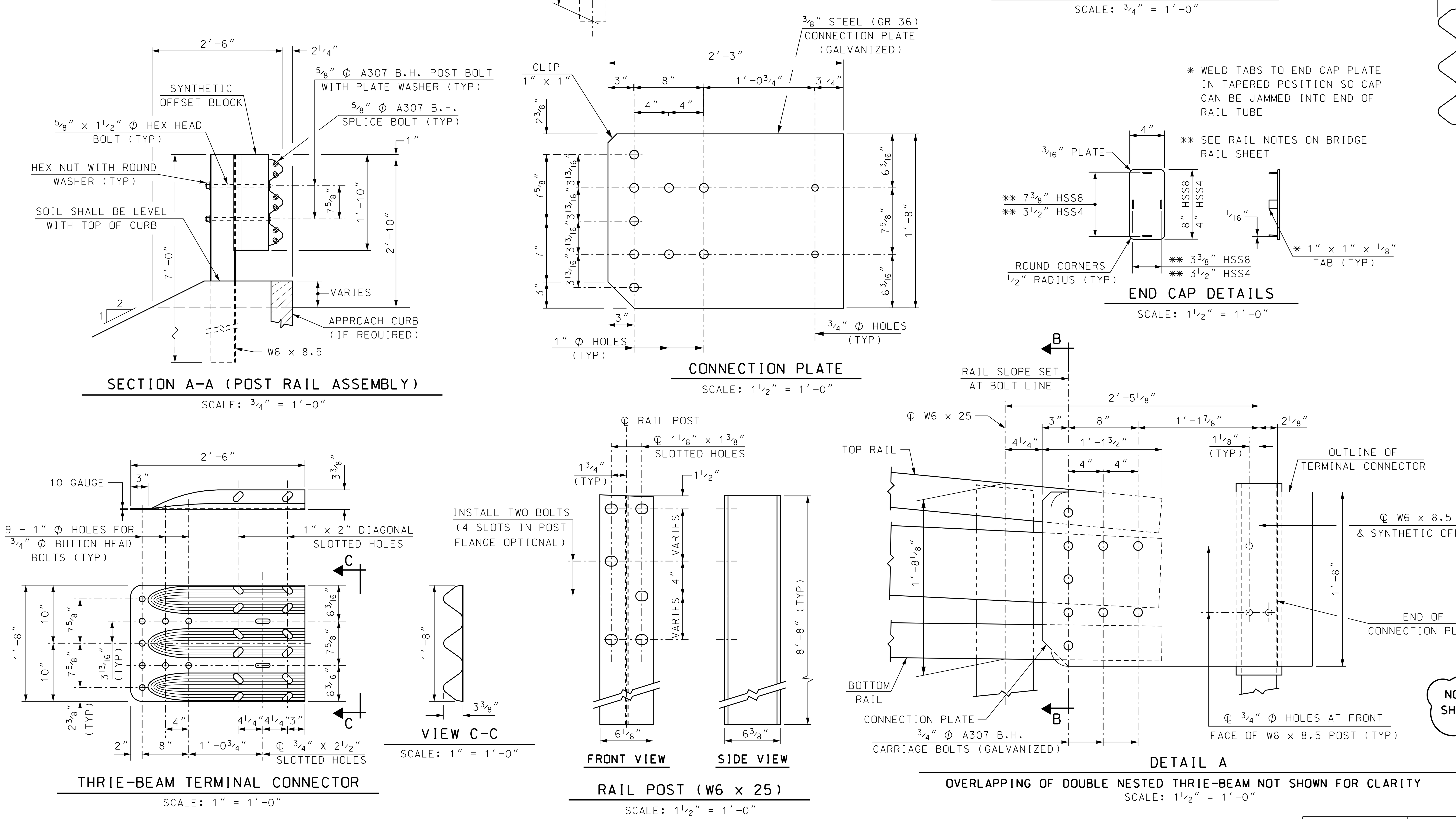
SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T4_BR-RAIL	AS NOTED

PLAN VIEW - APPROACH RAIL
SCALE: 3/4" = 1'-0"

ELEVATION - APPROACH RAIL
SCALE: 3/4" = 1'-0"



THRIE-BEAM TO W-BEAM TRANSITION SECTION
SCALE: 1" = 1'-0"



SECTION A-A (POST RAIL ASSEMBLY)
SCALE: 3/4" = 1'-0"

CONNECTION PLATE
SCALE: 1 1/2" = 1'-0"

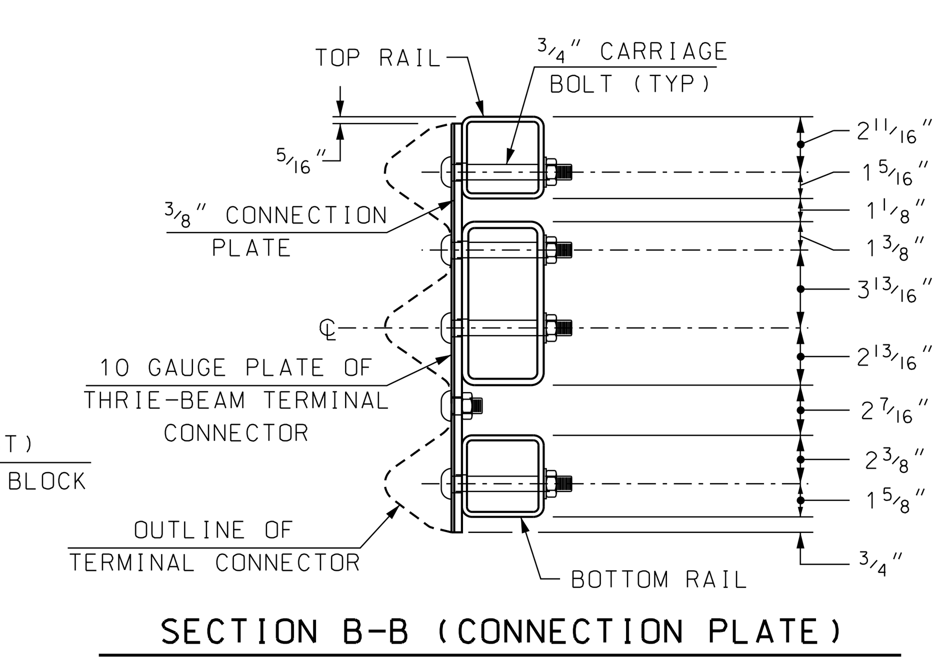
END CAP DETAILS
SCALE: 1 1/2" = 1'-0"

THRIE-BEAM TERMINAL CONNECTOR
SCALE: 1" = 1'-0"

VIEW C-C
SCALE: 1" = 1'-0"

RAIL POST (W6 x 25)
SCALE: 1 1/2" = 1'-0"

DETAIL A
OVERLAPPING OF DOUBLE NESTED THRIE-BEAM NOT SHOWN FOR CLARITY
SCALE: 1 1/2" = 1'-0"



SECTION B-B (CONNECTION PLATE)
SCALE: 1 1/2" = 1'-0"

NOTES:

(1) ALL BRIDGE APPROACH RAIL MATERIALS, DIMENSIONS, SIZES, AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED. SEE BRIDGE RAIL SHEET FOR NOTES AND ADDITIONAL INFORMATION.

(2) W6 x 25 POSTS SHALL BE THE SAME MATERIAL AS THE BRIDGE RAIL POSTS. W6 x 8.5 POSTS SHALL BE THE SAME AS W-BEAM GUARDRAIL POSTS.

(3) CARRIAGE BOLTS SHALL BE ASTM A307, AND NUTS SHALL BE ASTM A563 GRADE A OR BETTER (GALVANIZED).

(4) WELD BARS ADJUSTED FOR SLOPE & BEND. USE COMPLETE JOINT PENETRATION BUTT WELD (B-U2).

(5) THIS BRIDGE RAIL TRANSITION SYSTEM WAS SUCCESSFULLY CRASH TESTED IN APRIL 2005 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-3 PER FHWA LETTER HSSD/B-146.

(6) ALL COMPONENTS, EXCEPT TUBULAR RAIL, SHALL CONFORM TO SECTION 606 OF NHDOT SPECIFICATIONS.

NO MODIFICATIONS SHOULD BE MADE TO THIS SHEET

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN | BRIDGE NO. | STATE PROJECT
LOCATION

T3 STEEL BRIDGE APPROACH RAIL (STEEL POSTS)

	BY	DATE		BY	DATE
DESIGNED	NETC/JSZ	3/02	CHECKED	NHDOT	
DRAWN	PJP	10/05	CHECKED	JSZ	10/05
QUANTITIES			CHECKED		
ISSUE DATE	11/15/05				
REV. DATE	3/20/18				

REVISIONS AFTER PROPOSAL

BRIDGE SHEET OF | FILE NUMBER | FEDERAL PROJECT NO. | SHEET NO. | TOTAL SHEETS

SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T3SP_APPRAIL	AS NOTED

NOTES:

(1) ALL BRIDGE APPROACH RAIL MATERIALS, DIMENSIONS, SIZES, AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED. SEE BRIDGE RAIL SHEET FOR NOTES AND ADDITIONAL INFORMATION.

(2) W6 x 25 POSTS SHALL BE THE SAME MATERIAL AS THE BRIDGE RAIL POSTS. W6 x 8.5 POSTS SHALL BE THE SAME AS W-BEAM GUARDRAIL POSTS.

(3) CARRIAGE BOLTS SHALL BE ASTM A307, AND NUTS SHALL BE ASTM A563 GRADE A OR BETTER (GALVANIZED).

(4) WELD BARS ADJUSTED FOR SLOPE OR BEND. USE COMPLETE JOINT PENETRATION BUTT WELD (B-U2).

(5) THIS BRIDGE RAIL TRANSITION SYSTEM WAS SUCCESSFULLY CRASH TESTED IN APRIL 2005 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-3 PER FHWA LETTER HSSD/B-146.

(6) ALL COMPONENTS, EXCEPT TUBULAR RAIL, SHALL CONFORM TO SECTION 606 OF NHDOT SPECIFICATIONS.

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN	BRIDGE NO.	STATE PROJECT
LOCATION		

T4 STEEL BRIDGE APPROACH RAIL (STEEL POSTS)

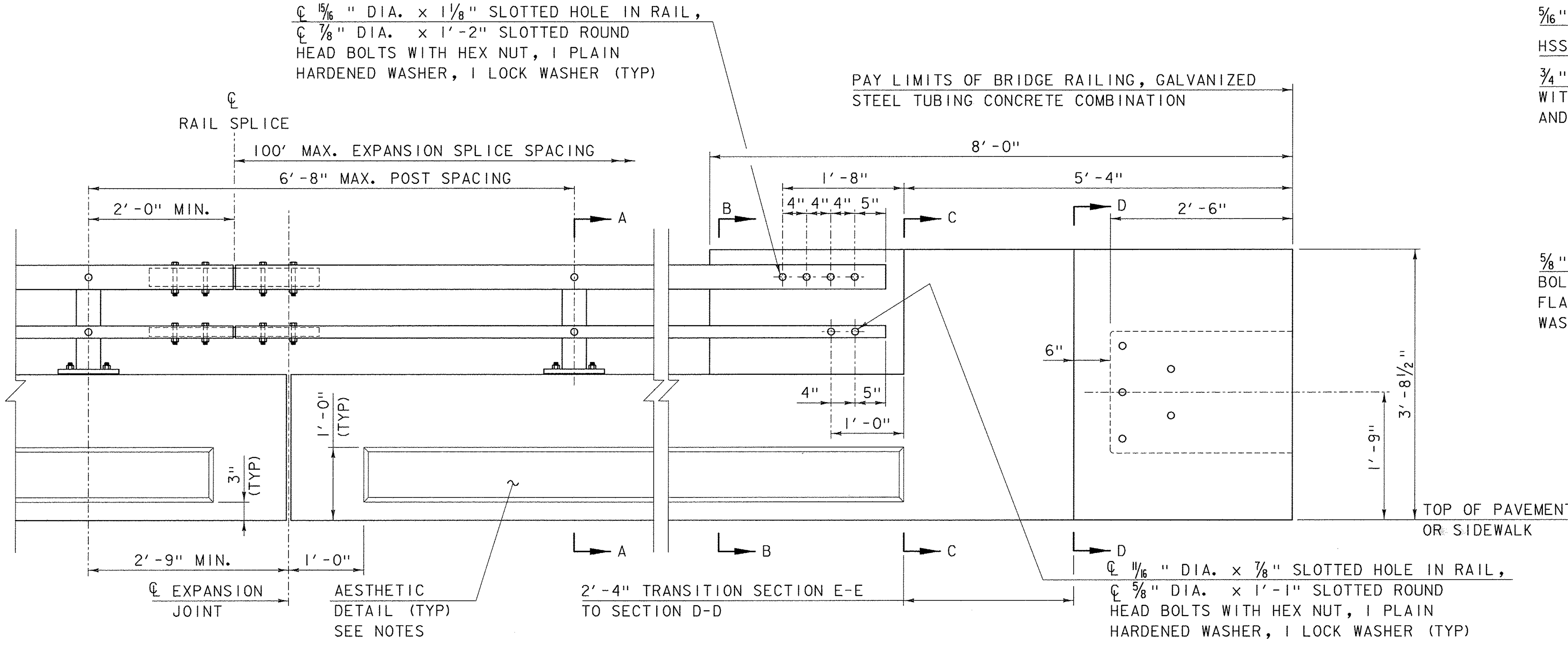
REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
DESIGNED	NETC/JSZ		3/02	CHECKED	NHDOT	
DRAWN	PJP		10/05	CHECKED	JSZ	10/05
QUANTITIES				CHECKED		
ISSUE DATE	11/15/05			FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
REV. DATE	3/20/18					

BRIDGE SHEET OF

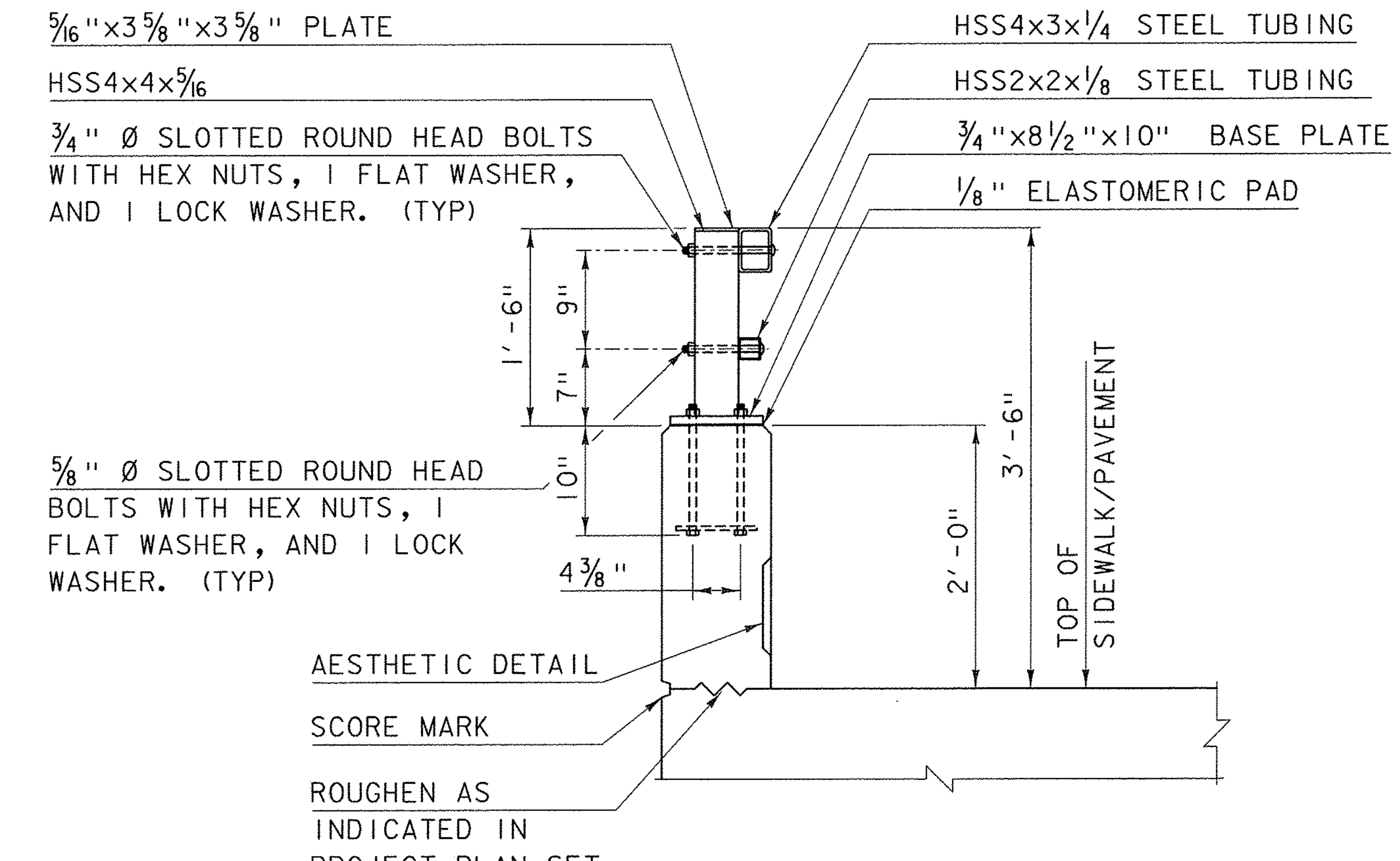
FILE NUMBER

SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T4SP_APPRAIL	AS NOTED

APPENDIX C: VERMONT DOT STANDARD BRIDGE RAIL DRAWINGS



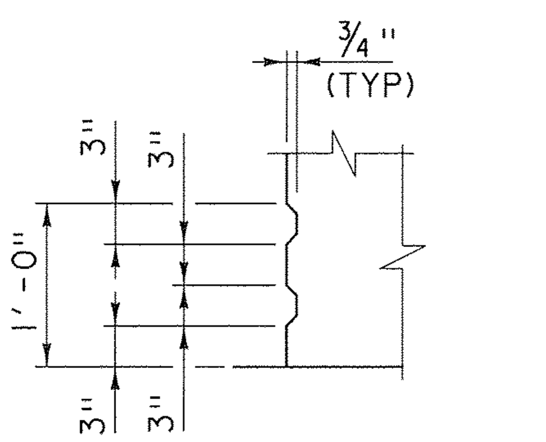
RAILING & END WALL APPROACH



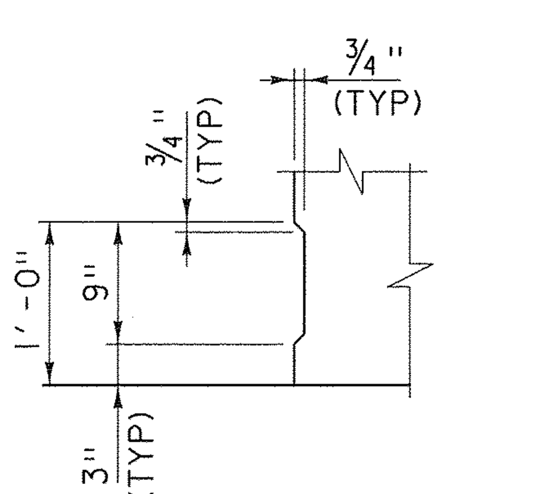
RAIL TYPICAL SECTION

NOTES:
1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE.
4. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO BRIDGE POSTS AND PREFERABLY TO AT LEAST 4 POSTS.
5. HOLES IN RAILS FOR TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
6. BOLTS SHALL BE TORQUED SNUG TIGHT (APPROXIMATELY 100 FT-LB).
7. RAIL TUBES SHALL BE ATTACHED USING 3/4" FULL DIAMETER BODY ASTM A 449 (TYPE 1) ROUND HEAD BOLTS INSERTED THROUGH THE FACE OF THE TUBE.
8. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT. PAYMENT FOR DELINEATORS SHALL BE INCIDENTAL TO OTHER ITEMS.
9. AESTHETIC TREATMENT TYPE SHALL BE APPLIED AS SPECIFIED IN THE CONTRACT PLANS. IF NONE IS SPECIFIED IT SHALL NOT BE USED. AESTHETIC TREATMENT DETAILED ON THIS SHEET MAY ALSO BE APPLIED ON THE FASCIA SIDE OF THE RAIL, IF SPECIFIED IN THE CONTRACT PLANS.
10. BRIDGE RAILING SHALL HAVE A RUBBED FINISH IN ACCORDANCE WITH SECTION 501.
11. THIS RAILING MEETS THE REQUIREMENTS FOR A NCHRP REPORT 350 TL-4 SERVICE LEVEL.

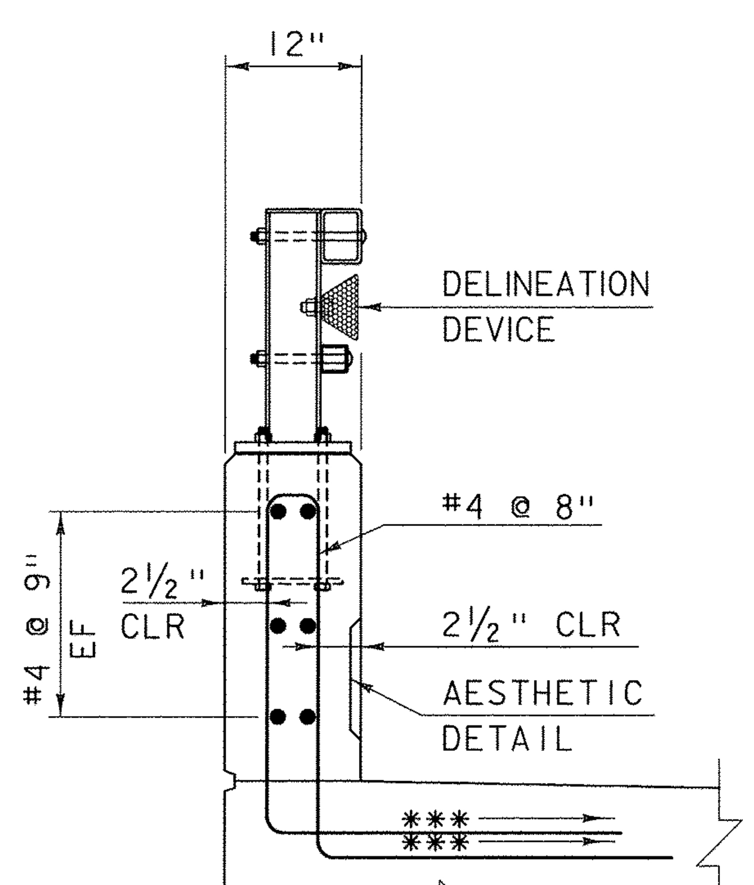
NOTE:
EF = EACH FACE
3" CLEAR, UNLESS OTHERWISE SPECIFIED ON THE PLANS.
2'-2" BAR LAP UNLESS OTHERWISE SPECIFIED ON THE PLANS.
*** MATCH SLOPE OF NEAREST TRANSVERSE STEEL



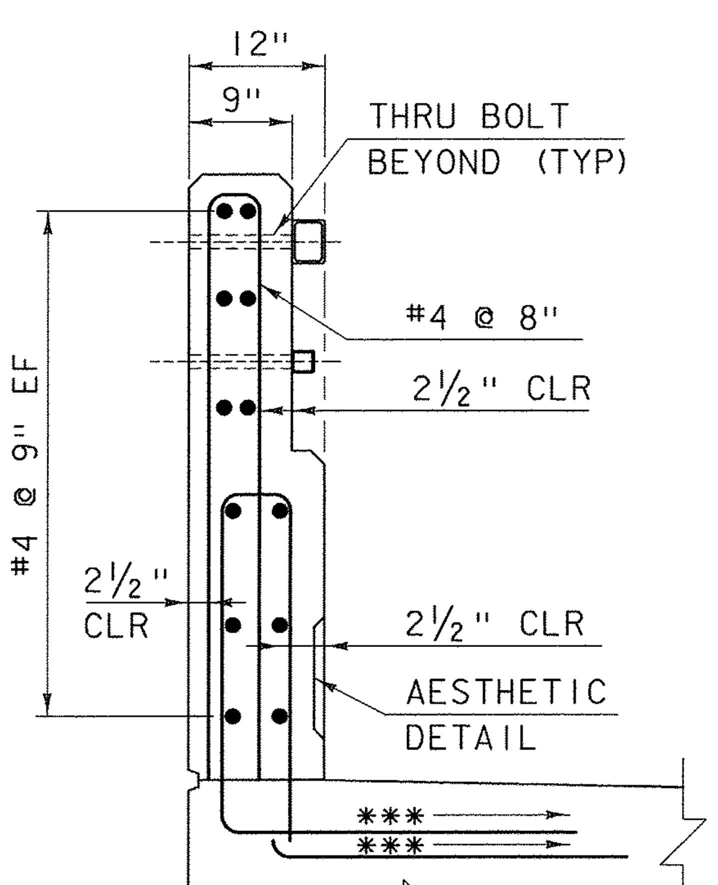
AESTHETIC DETAIL A



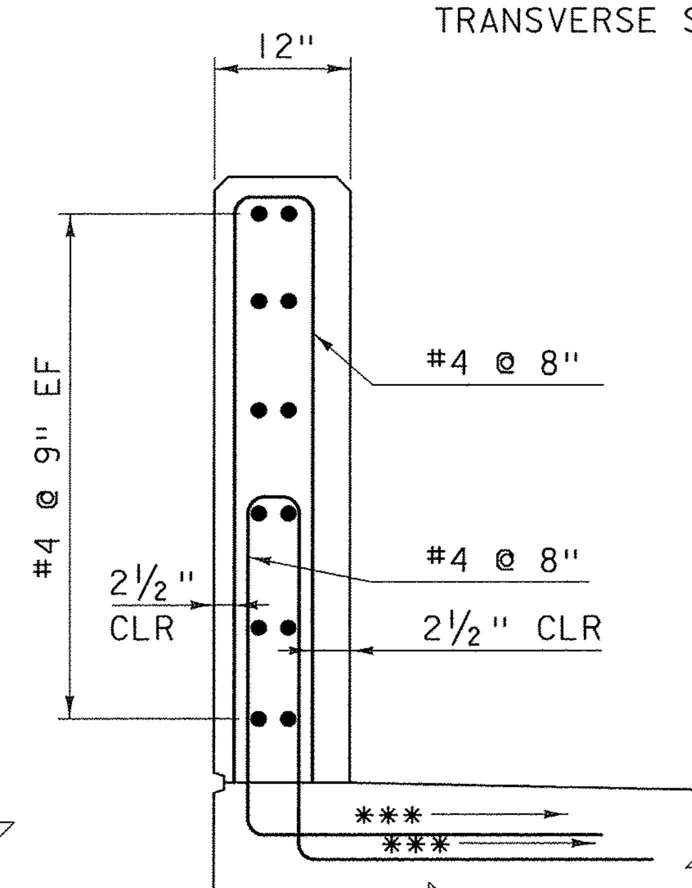
AESTHETIC DETAIL B



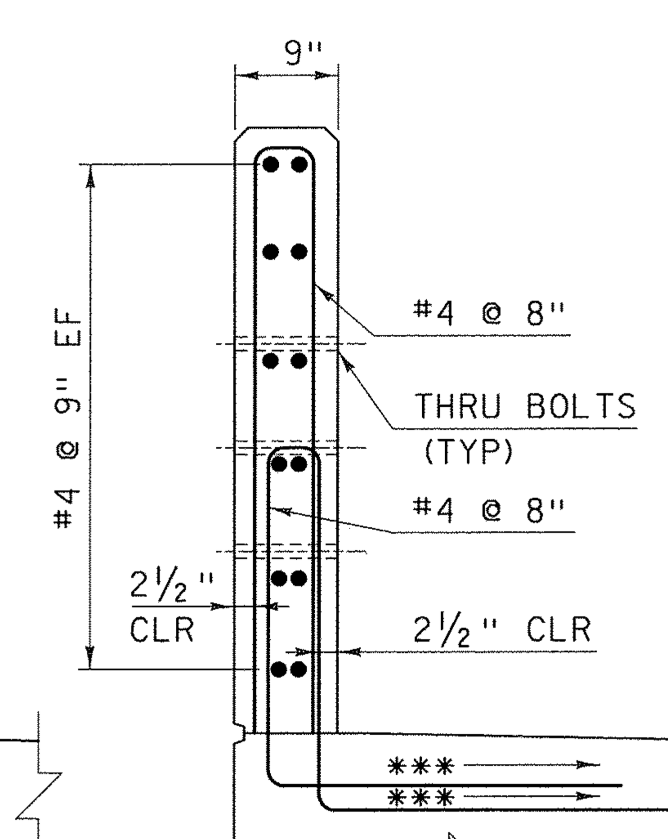
SECTION A-A



SECTION B-B



SECTION C-C



SECTION D-D

OTHER STDS. REQUIRED: G-1

REVISIONS AND CORRECTIONS

AUGUST 22, 2012 - ORIGINAL APPROVAL

APPROVED

Wm. Michael Hedges
STRUCTURES ENGINEER

Richard Tetreault
DIRECTOR OF PROGRAM DEVELOPMENT

Mark D. Richter
FEDERAL HIGHWAY ADMINISTRATION

BRIDGE RAILING, GALVANIZED STEEL TUBING / CONCRETE COMBINATION

VERMONT AGENCY OF TRANSPORTATION

STANDARD S-352A

OTHER STDS. REQUIRED: G-1

REVISIONS AND CORRECTIONS

AUGUST 22, 2012 - ORIGINAL APPROVAL

APPROVED

Wm. Michael Hedges
STRUCTURES ENGINEER

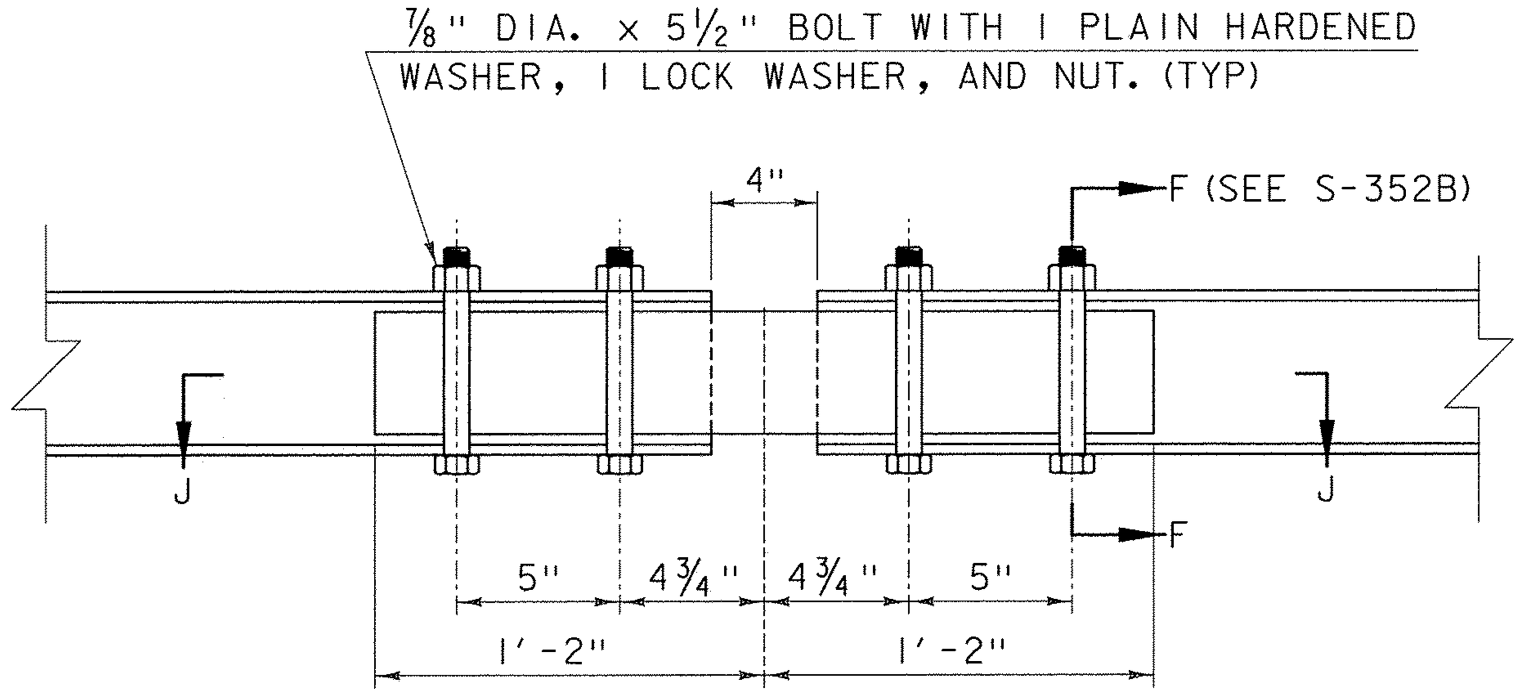
Richard Tetreault
DIRECTOR OF PROGRAM DEVELOPMENT

Mark D. Richter
FEDERAL HIGHWAY ADMINISTRATION

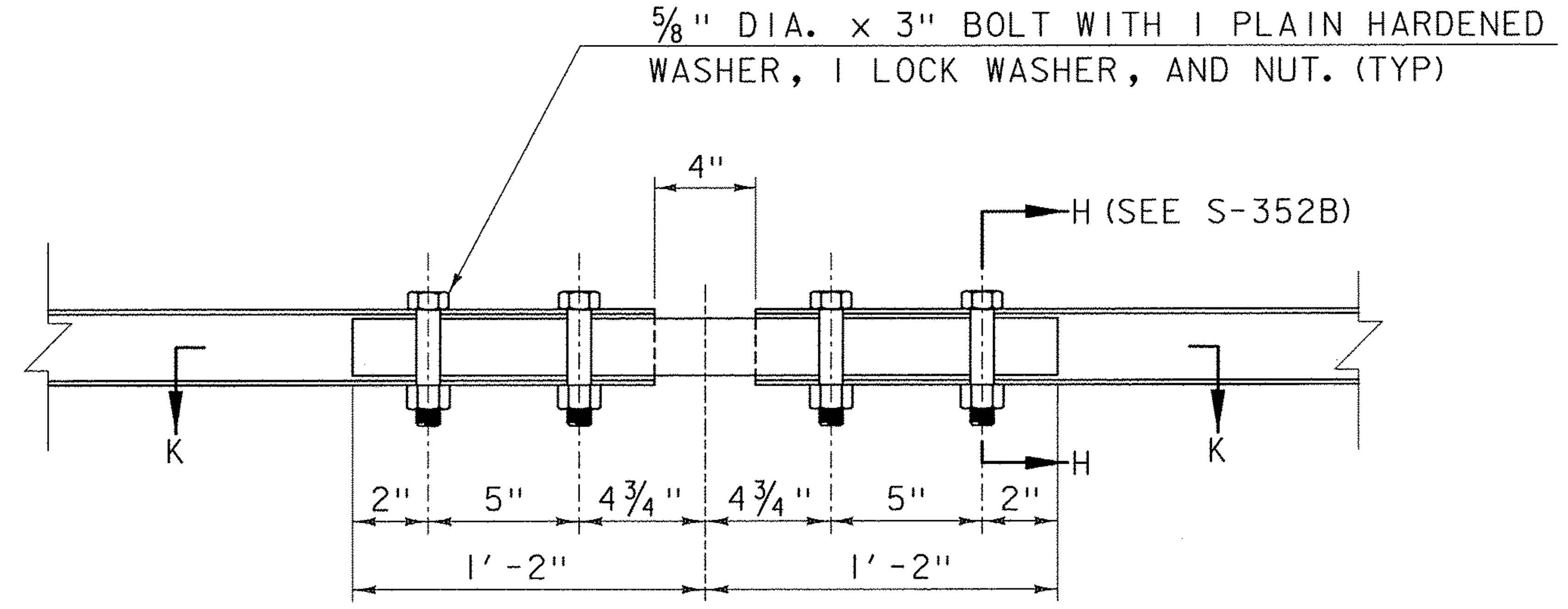
BRIDGE RAILING, GALVANIZED STEEL TUBING / CONCRETE COMBINATION

VERMONT AGENCY OF TRANSPORTATION

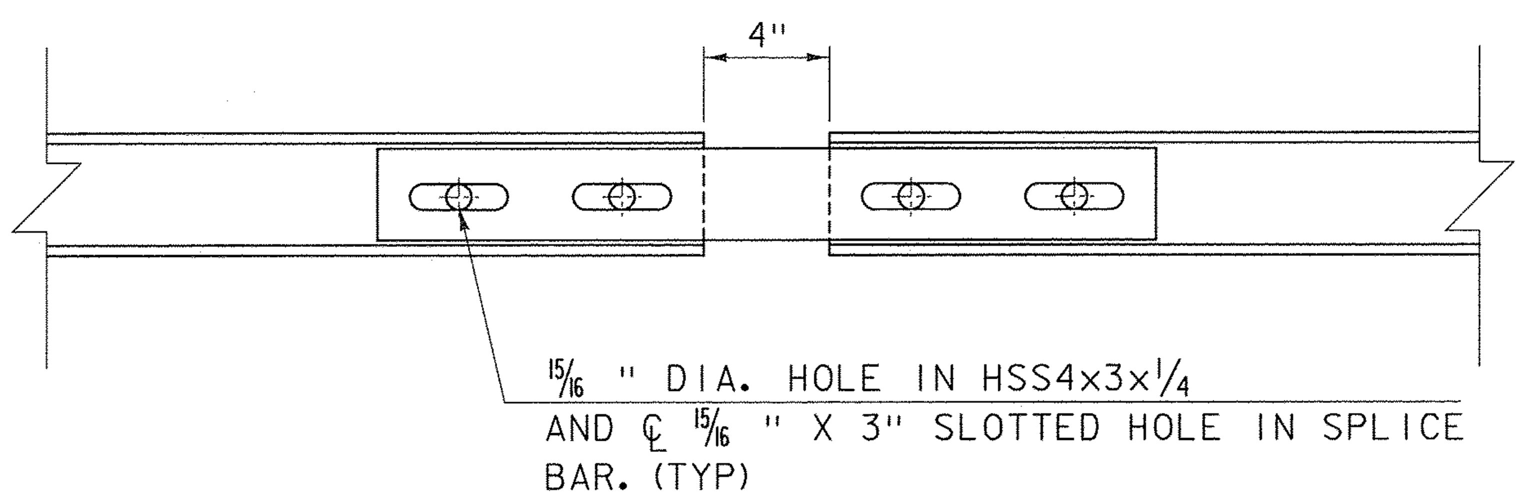
STANDARD S-352B



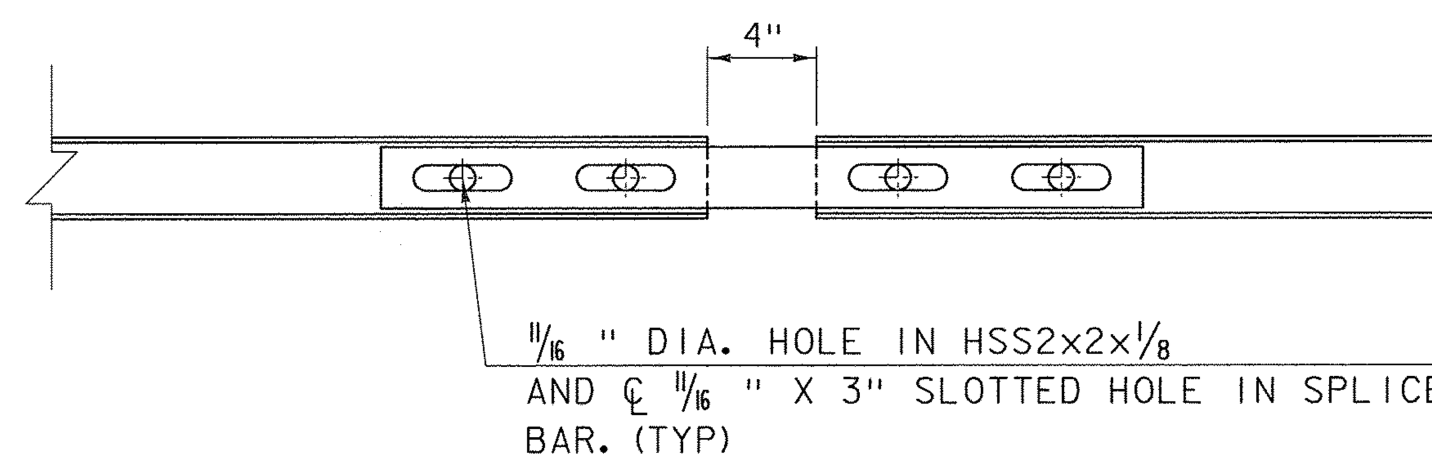
TOP RAIL EXPANSION SPLICE DETAIL



BOTTOM RAIL EXPANSION SPLICE DETAIL



SECTION J-J



SECTION K-K

OTHER STDS. REQUIRED: G-1

REVISIONS AND CORRECTIONS

AUGUST 22, 2012 - ORIGINAL APPROVAL

APPROVED

STRUCTURES ENGINEER

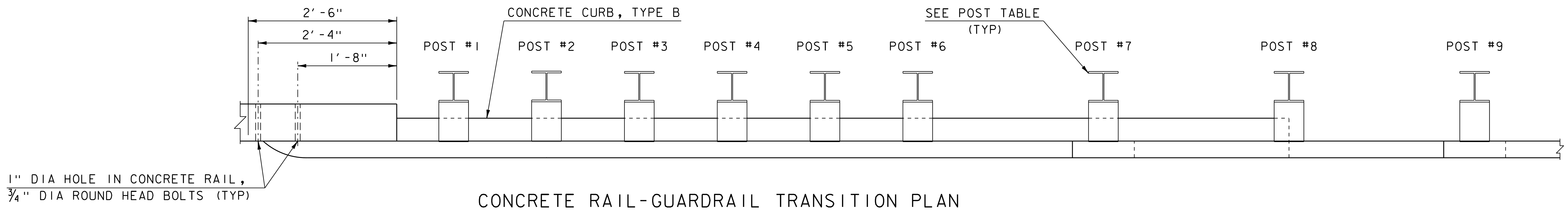
DIRECTOR OF PROGRAM DEVELOPMENT

FEDERAL HIGHWAY ADMINISTRATION

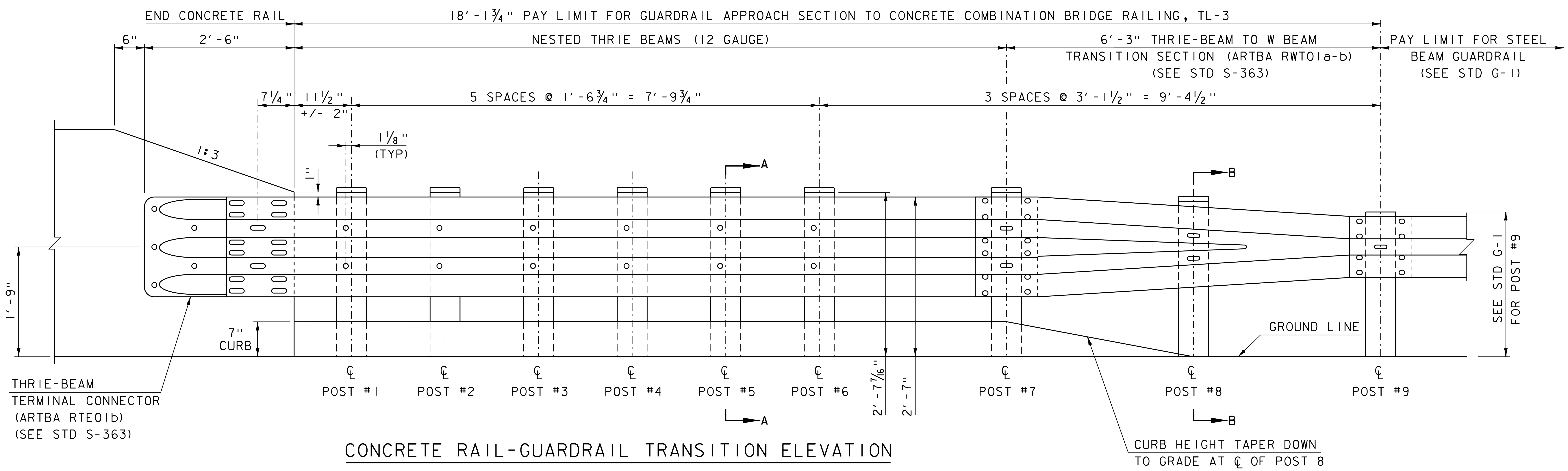
BRIDGE RAILING, GALVANIZED STEEL TUBING / CONCRETE COMBINATION

VERMONT AGENCY OF TRANSPORTATION

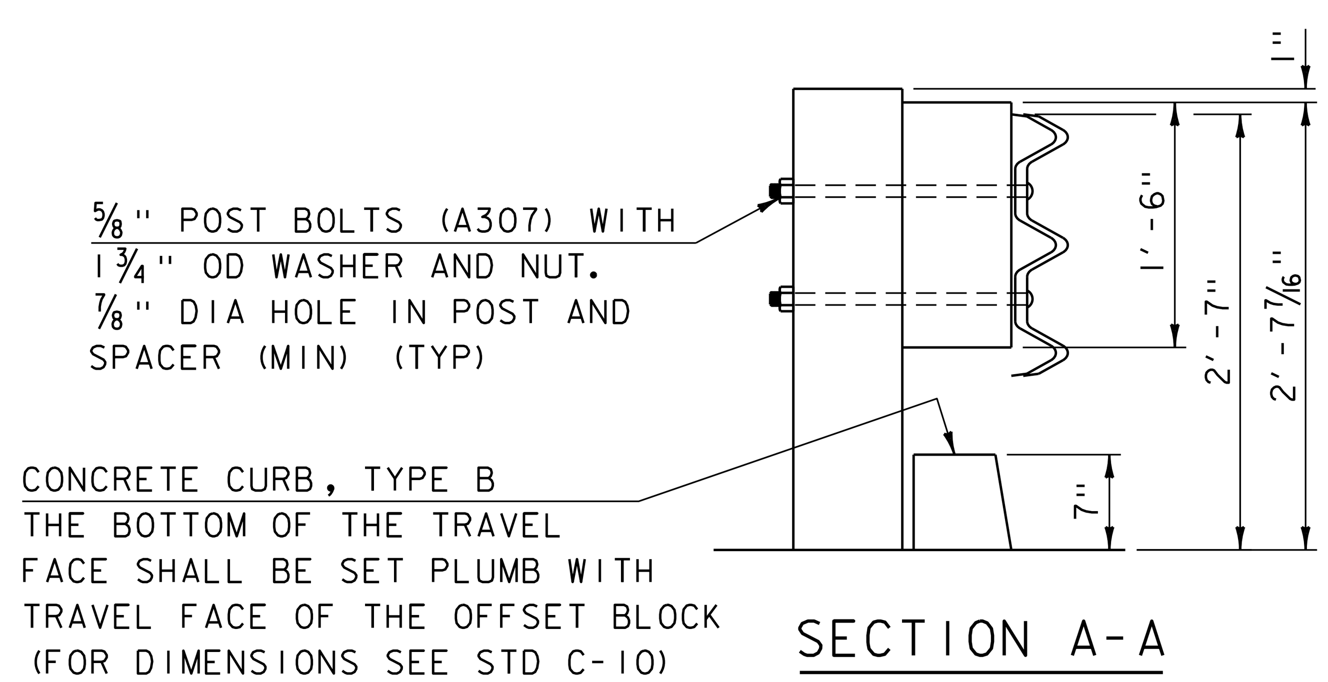
STANDARD S-352C



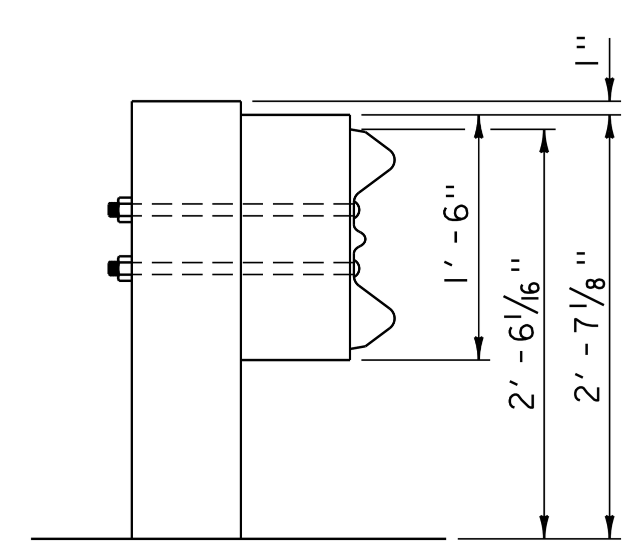
CONCRETE RAIL-GUARDRAIL TRANSITION PLAN



CONCRETE RAIL-GUARDRAIL TRANSITION ELEVATION



SECTION A-A



SECTION B-B

		WOOD	STEEL
SECTION		6"X8"	W6x9
OFFSET BLOCK		6"X8" WOOD	6"X8" RECESSED WOOD
POST LENGTH	POST# 1-6	7′-0"	7′-0"
	POST# 7&8	6′-0"	6′-0"
	POST# 9	SEE STD G-1	SEE STD G-1

POST TABLE

NOTES:

1. THRIE-BEAM TERMINAL CONNECTOR SHALL BE INCLUDED IN THE UNIT BID PRICE FOR GUARDRAIL APPROACH SECTION TO CONCRETE COMBINATION BRIDGE RAILING, TL-3.
2. UNLESS OTHERWISE DIRECTED BY THE ENGINEER, A COMPOSITE MATERIAL BLOCKOUT FROM THE APPROVED PRODUCTS LIST MAY BE SUBSTITUTED FOR A BLOCKOUT OF SIMILAR DIMENSIONS.
3. THIS RAILING MEETS THE REQUIREMENTS FOR A NCHRP REPORT 350 TL-3 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	AUGUST 22, 2012	ORIGINAL APPROVAL
1	FEBRUARY 2, 2017	REVISED POST DIMENSIONS AND CURB LAYOUT

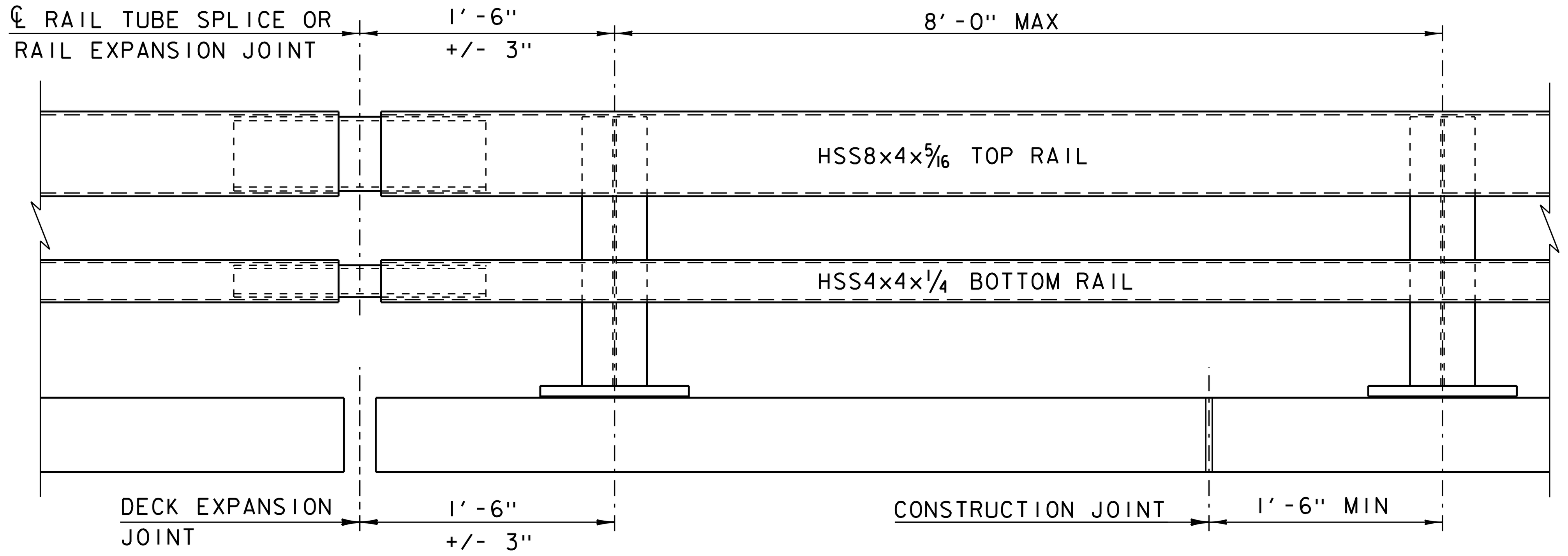
OTHER STANDARDS REQUIRED: C-10, G-1, S-363

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

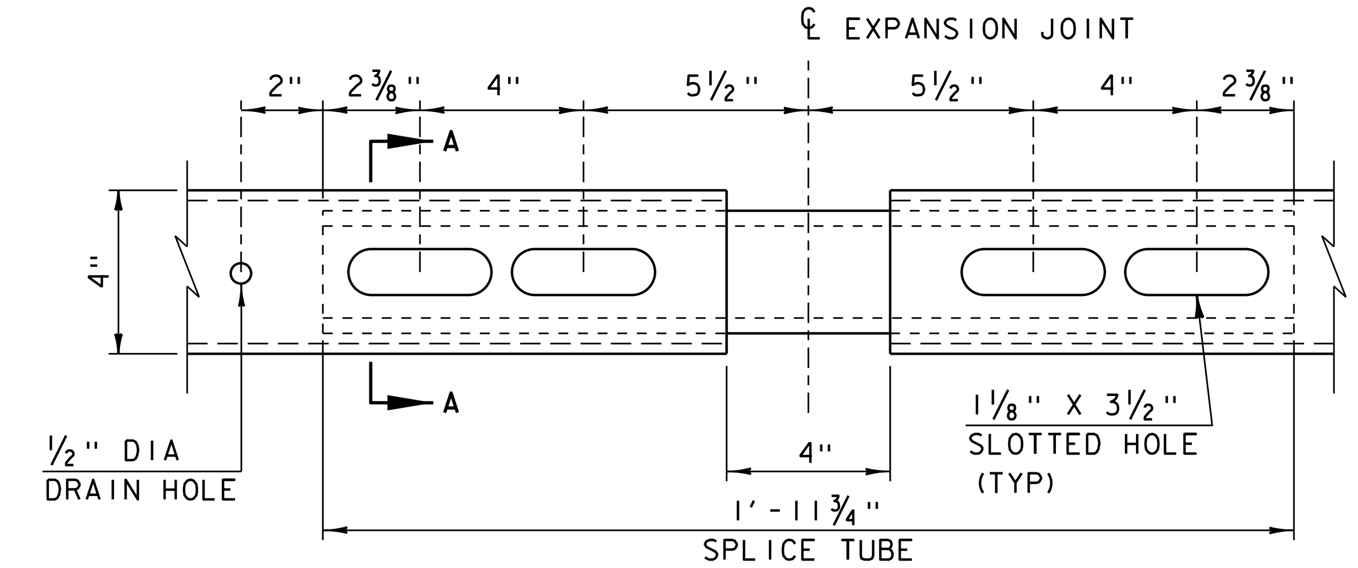
GUARDRAIL APPROACH SECTION TO CONCRETE COMBINATION BRIDGE RAILING, TL-3

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-352D

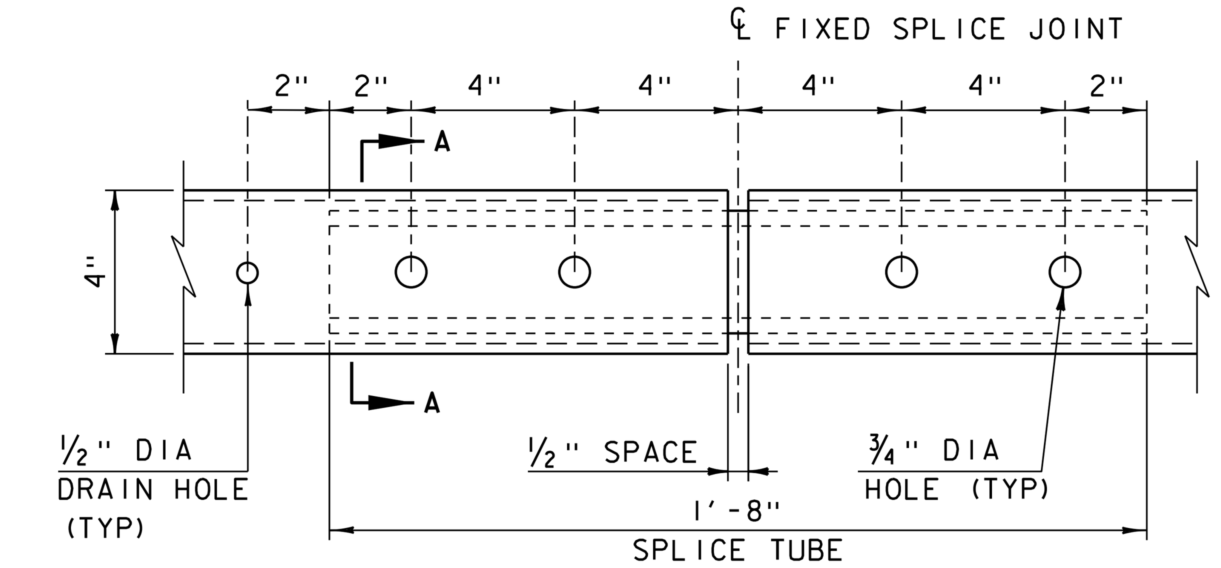


BRIDGE RAILING ELEVATION



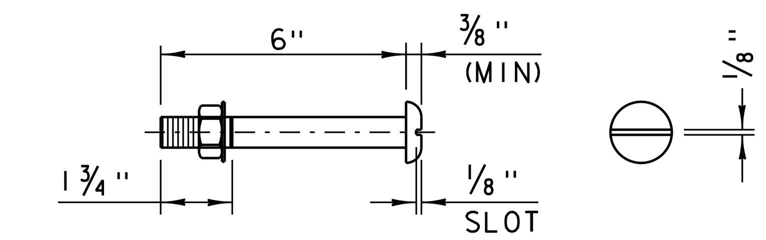
EXPANSION JOINT DETAIL

(BOTTOM VIEW)



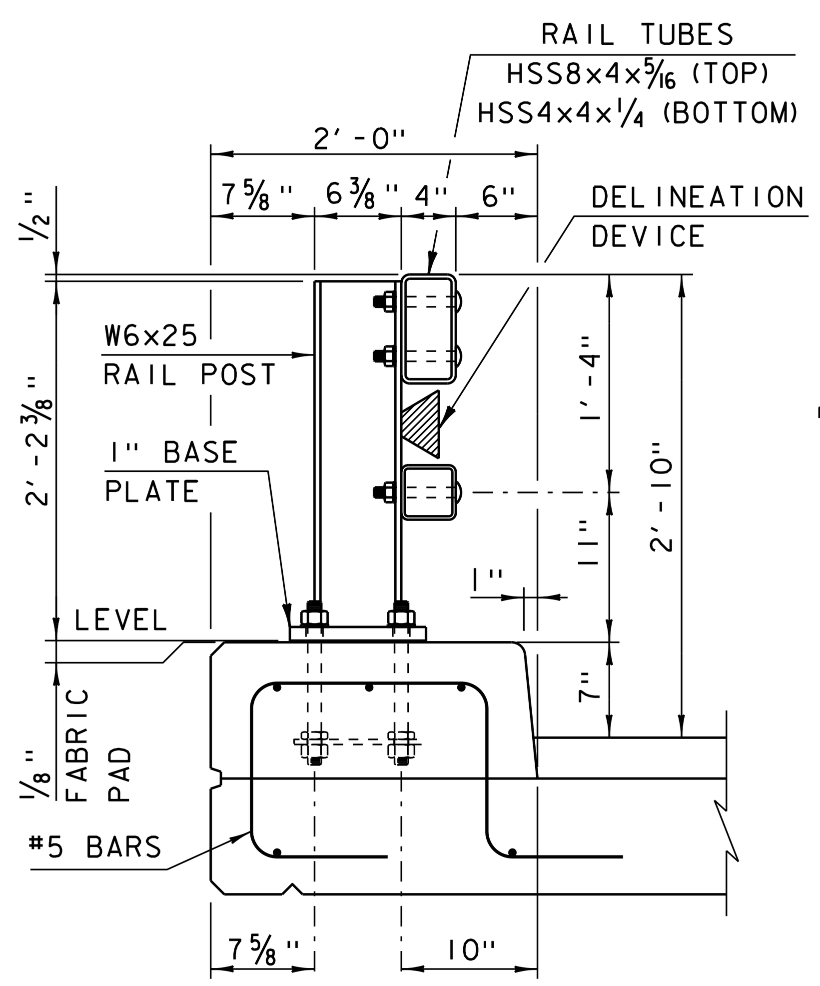
FIXED SPLICE JOINT DETAIL

(BOTTOM VIEW)

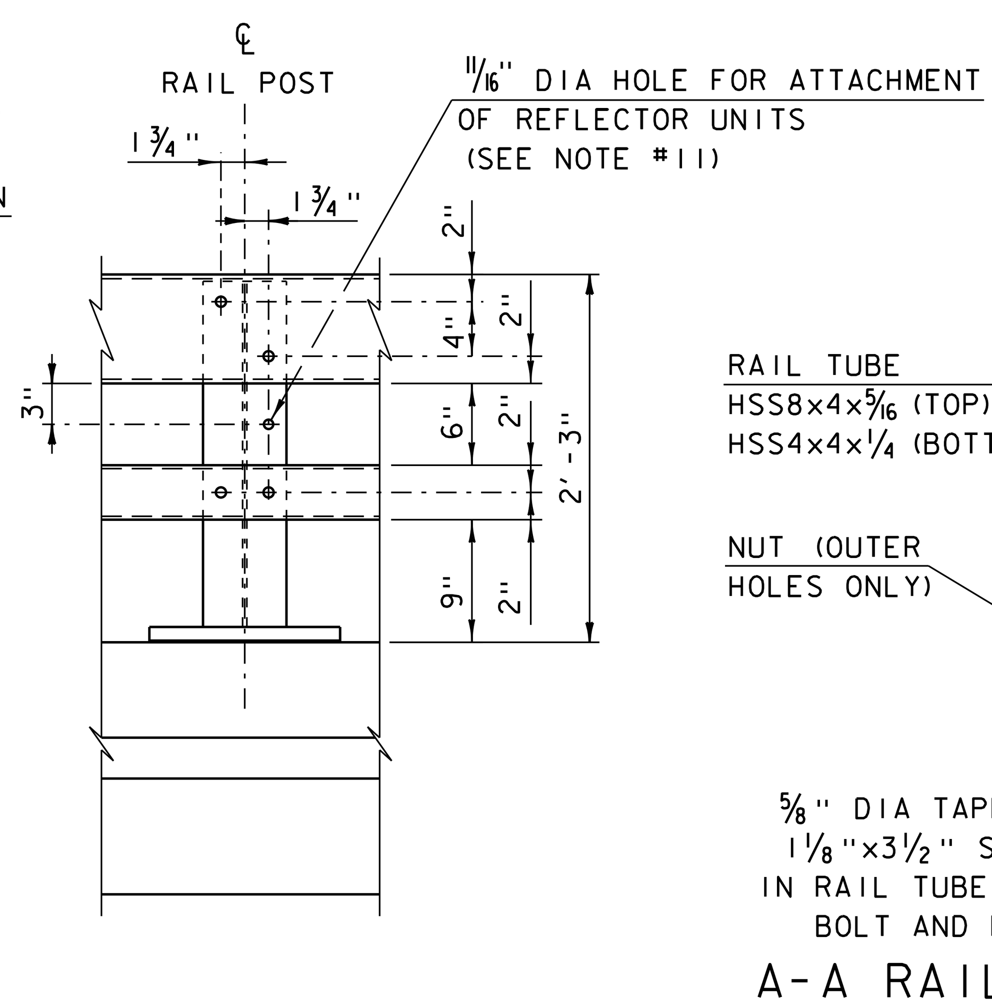


3/4" DIA A449 (TYPE I) ROUND HEAD BOLT

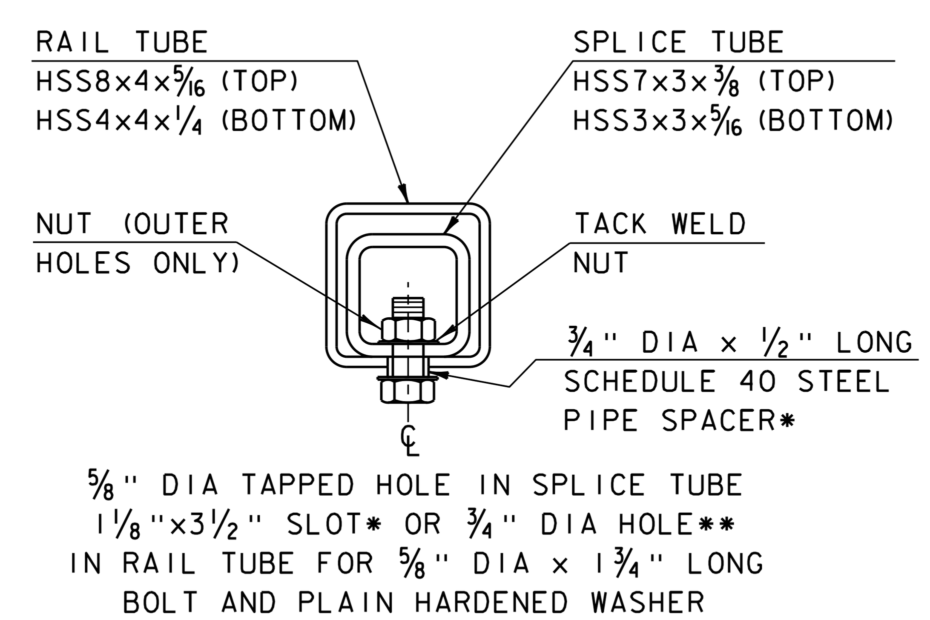
(WITH WASHER AND PREVAILING TORQUE TYPE LOCK NUT) (SEE NOTE #8)
ONLY FULL DIAMETER BODY BOLTS WILL BE ALLOWED.



TYPICAL SECTION

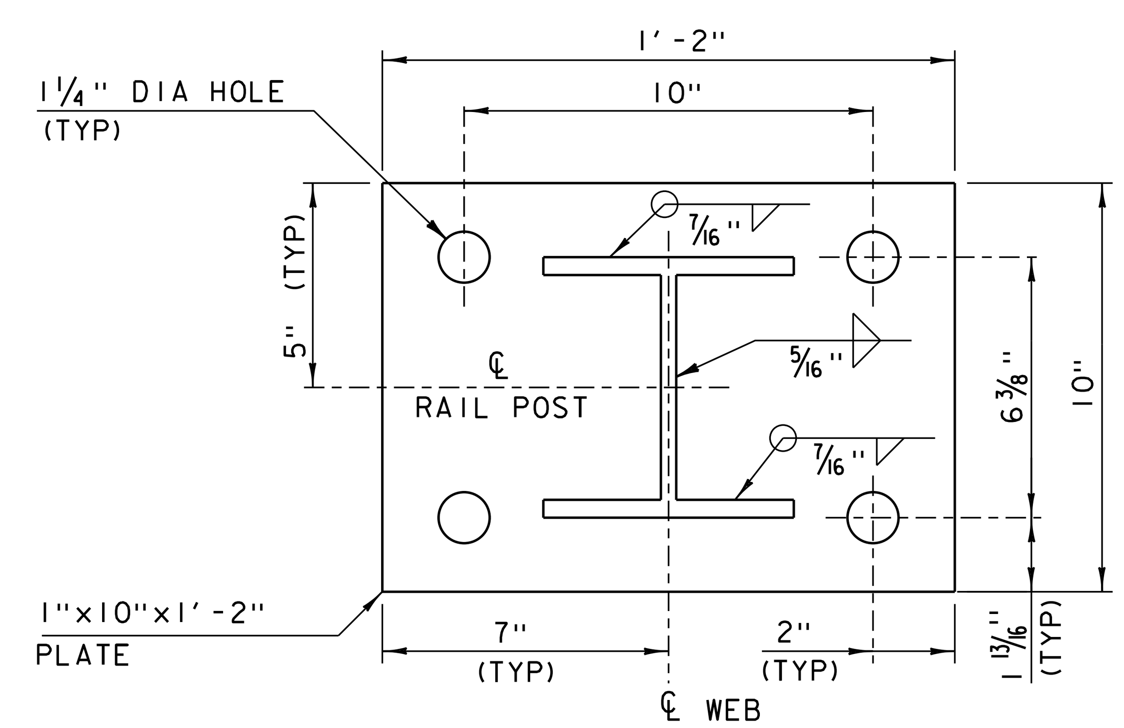


ELEVATION

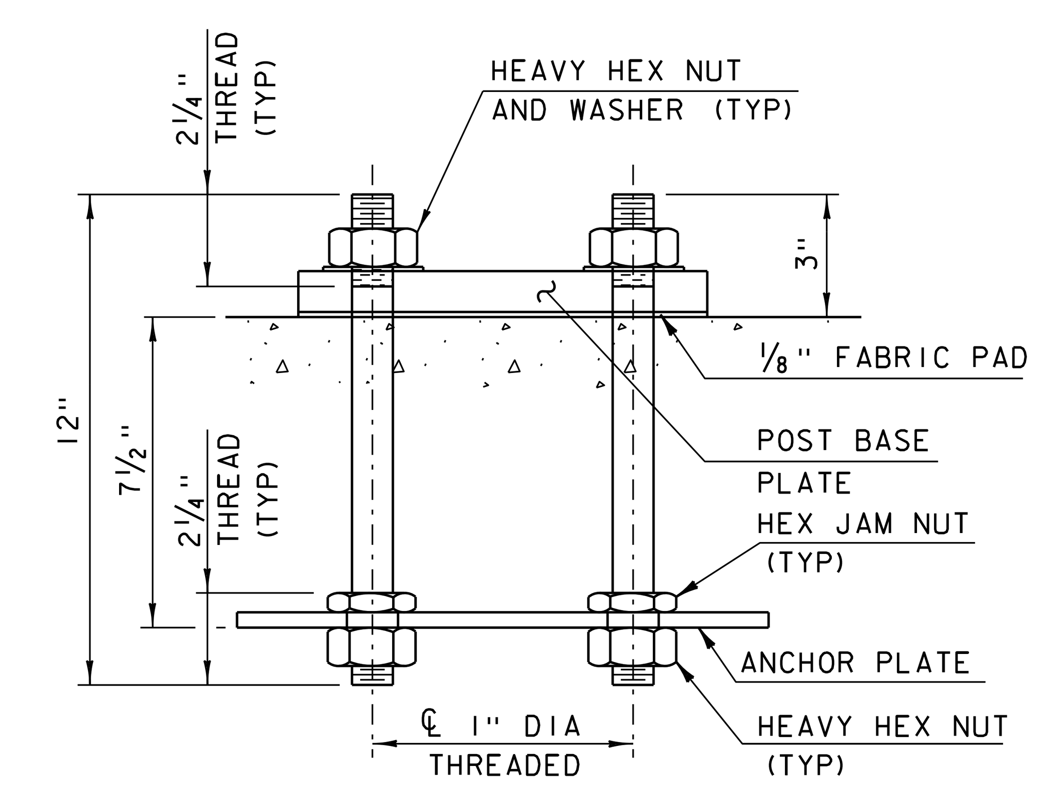


A-A RAIL TUBE SPLICE AND
RAIL EXPANSION JOINT SECTION

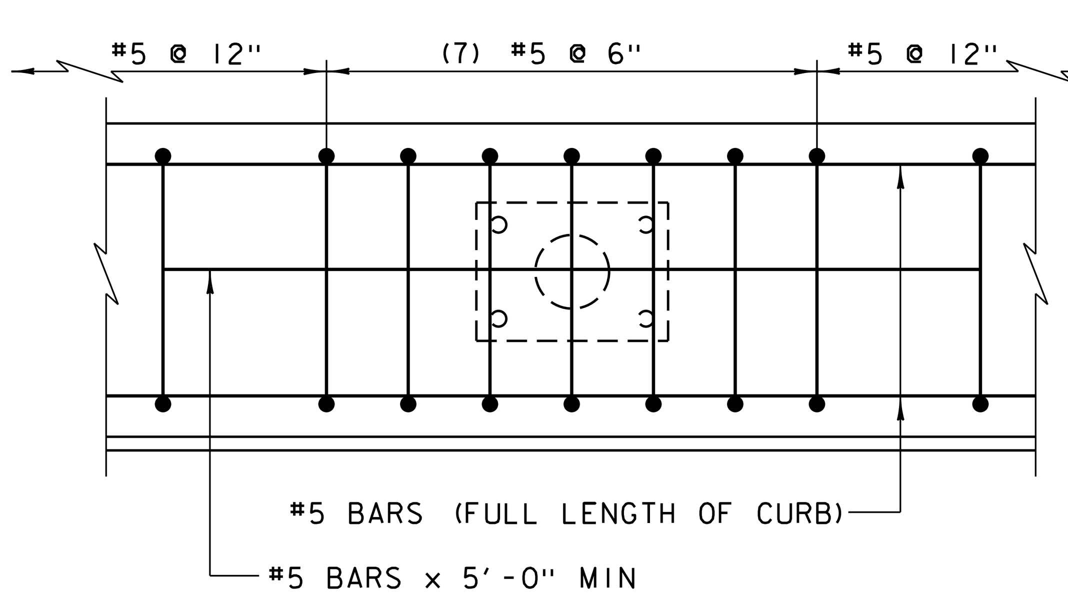
*EXPANSION JOINT **SPLICE



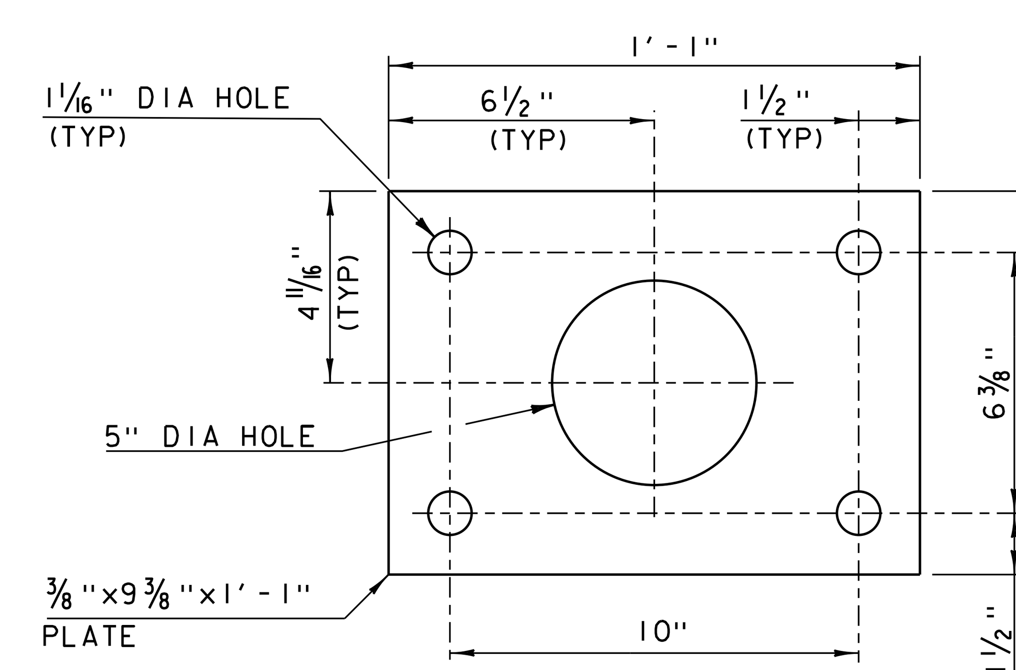
POST BASE PLATE



RAIL POST ANCHORAGE



CURB REINFORCING PLAN



ANCHOR PLATE

NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE.
4. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO BRIDGE RAIL POSTS AND PREFERABLY TO AT LEAST FOUR POSTS.
5. RAIL TUBE EXPANSION JOINTS SHALL BE PROVIDED IN ANY RAIL BAY SPANNING THE END OF AN INTEGRAL ABUTMENT BRIDGE AND AT ALL SUPERSTRUCTURE EXPANSION JOINTS. EXPANSION JOINT WIDTH SHALL BE 4" AT 68°F AND WILL BE ADJUSTED IN THE FIELD BY THE ENGINEER FOR OTHER TEMPERATURES.
6. HOLES IN RAILS FOR RAIL TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
7. RAIL POST ANCHORING NUTS SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL ONE-EIGHTH TURN.
8. RAIL TUBES SHALL BE ATTACHED USING 3/4" FULL DIAMETER BODY ASTM A 449 (TYPE I) ROUND HEAD BOLTS INSERTED THROUGH THE FACE OF THE TUBE. HOLES IN POSTS SHALL BE 1/16" LARGER THAN THE BOLT SIZE.
9. ANY BENDING OF RAIL SHALL BE DONE AT A FABRICATION PLANT ACCORDING TO A PROCEDURE PROVIDED BY THE FABRICATOR.
10. THE MINIMUM DISTANCE FROM THE POST TO AN EXPANSION JOINT SHALL BE DETERMINED BY THE MINIMUM EDGE DISTANCE OF 5" FROM ANY ANCHOR STUD TO THE END OF THE SLAB, OR TO THE EXPANSION JOINT RECESS POUR, IF ONE IS USED.
11. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT. PAYMENT SHALL BE INCIDENTAL TO OTHER ITEMS.
12. THIS RAILING MEETS THE REQUIREMENTS FOR A TL-4 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	DECEMBER 14, 2009	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: G-1

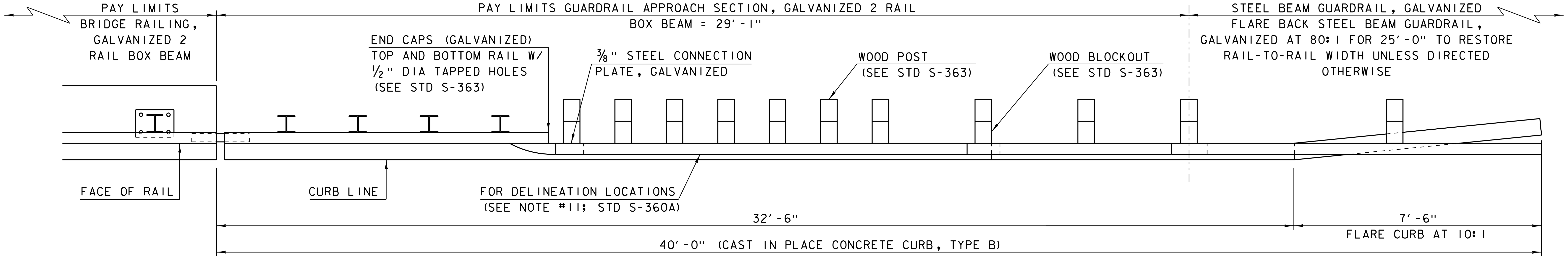
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

BRIDGE RAILING, GALVANIZED
2 RAIL BOX BEAM

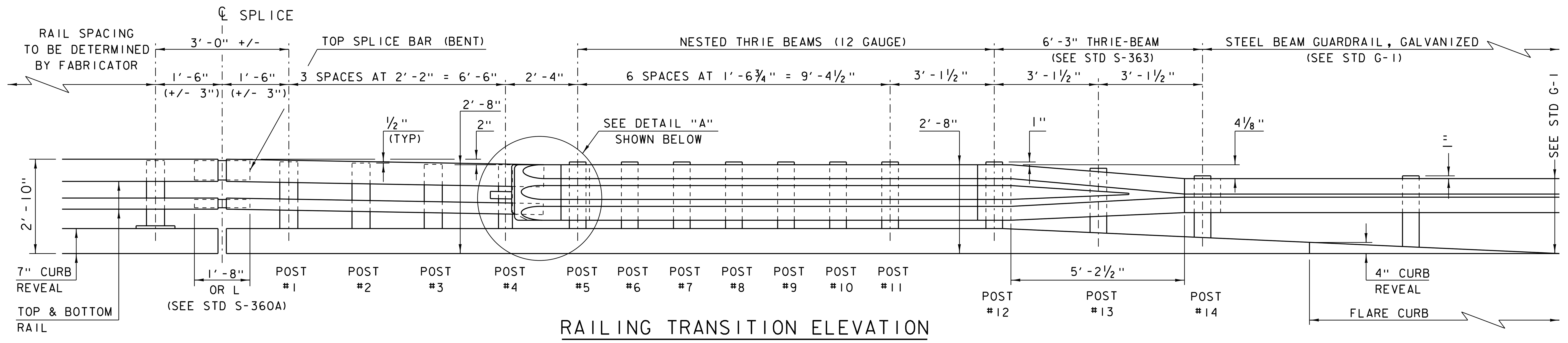
VTrans Working to Get You There
VERMONT AGENCY OF TRANSPORTATION

STANDARD

S-360A



RAILING TRANSITION PLAN

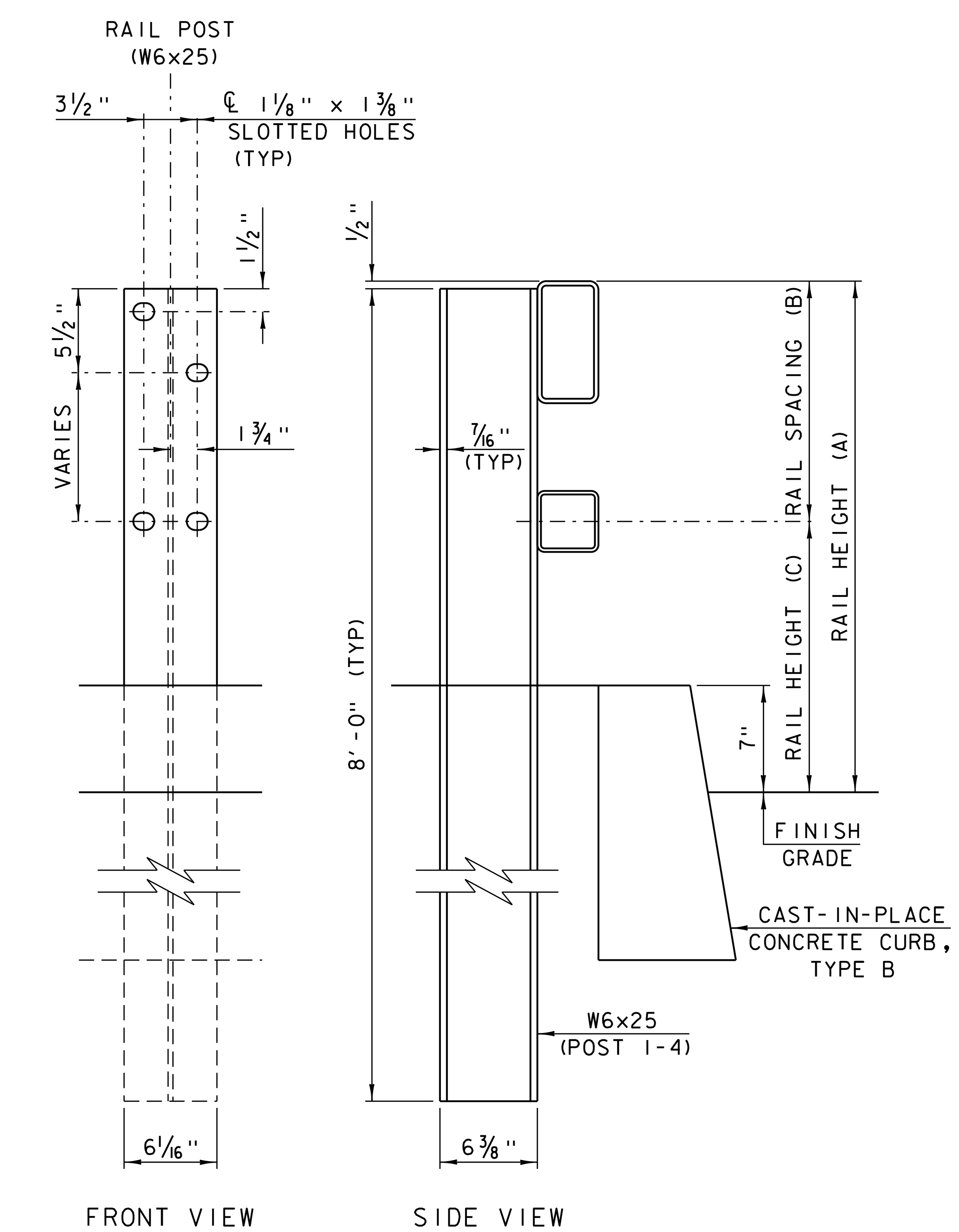


RAILING TRANSITION ELEVATION

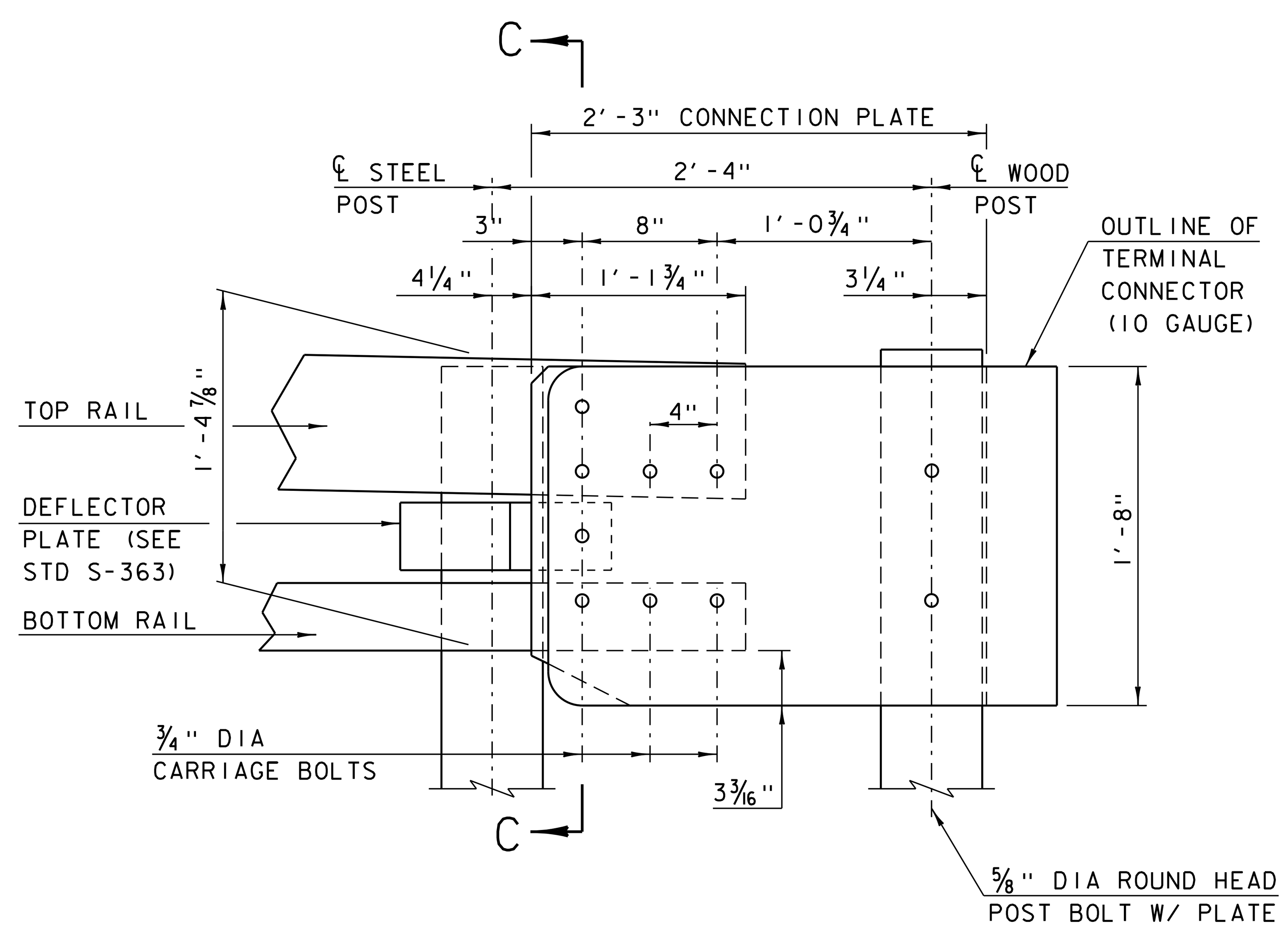
NOTES:

1. PAYMENT FOR GUARDRAIL APPROACH SECTION, GALVANIZED 2 RAIL BOX BEAM SHALL INCLUDE THE TERMINAL CONNECTOR, CONNECTION PLATE, DEFLECTOR PLATE, RAIL, POSTS, BLOCKS AND ATTACHMENT HARDWARE.
2. ALL APPROACH RAIL SPLICES SHALL BE LAPPED IN THE DIRECTION OF TRAFFIC FLOW.
3. TUBE AND STEEL POST MATERIALS, DIMENSION SIZES AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED.
4. APPROACH RAIL BOLTS SHALL BE ASTM A307 GRADE A AND NUTS SHALL BE AASHTO M291 (ASTM A563 GRADE A OR BETTER) (GALVANIZED). WASHERS SHALL BE ASTM F844.
5. PRIOR TO GALVANIZING, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".

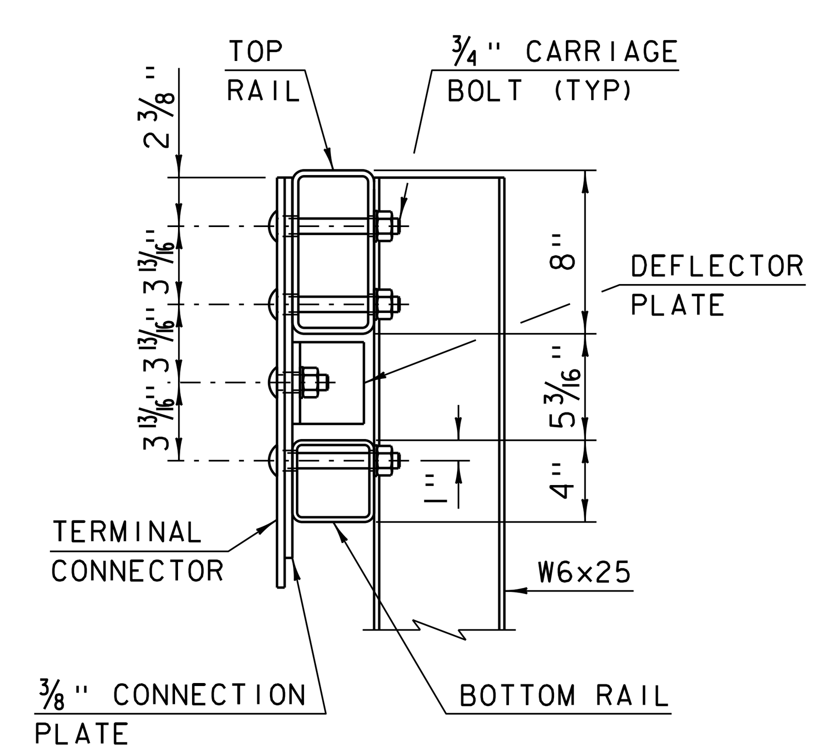
POST NUMBER	RAIL HEIGHT (A)	RAIL SPACING (B)	RAIL HEIGHT (C)
1	2'-9 1/2"	1'-3 3/4"	1'-5 3/4"
2	2'-9"	1'-3 1/2"	1'-5 1/2"
3	2'-8 1/2"	1'-3 3/16"	1'-5 5/16"
4	2'-8"	1'-2 7/8"	1'-5 1/8"



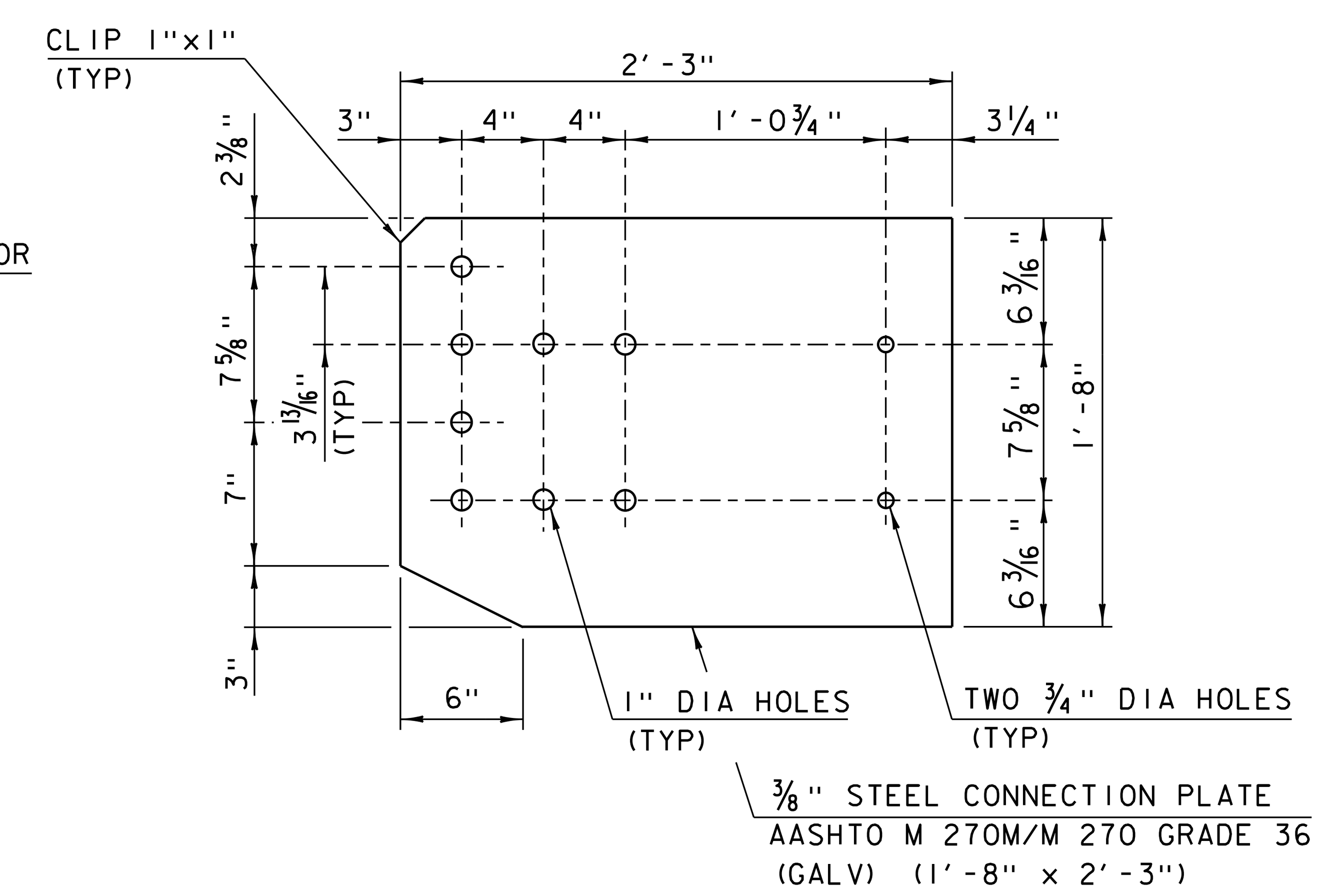
RAIL POST SECTION (POSTS 1-4)



DETAIL A



SECTION C-C (CONNECTION PLATE)



CONNECTION PLATE

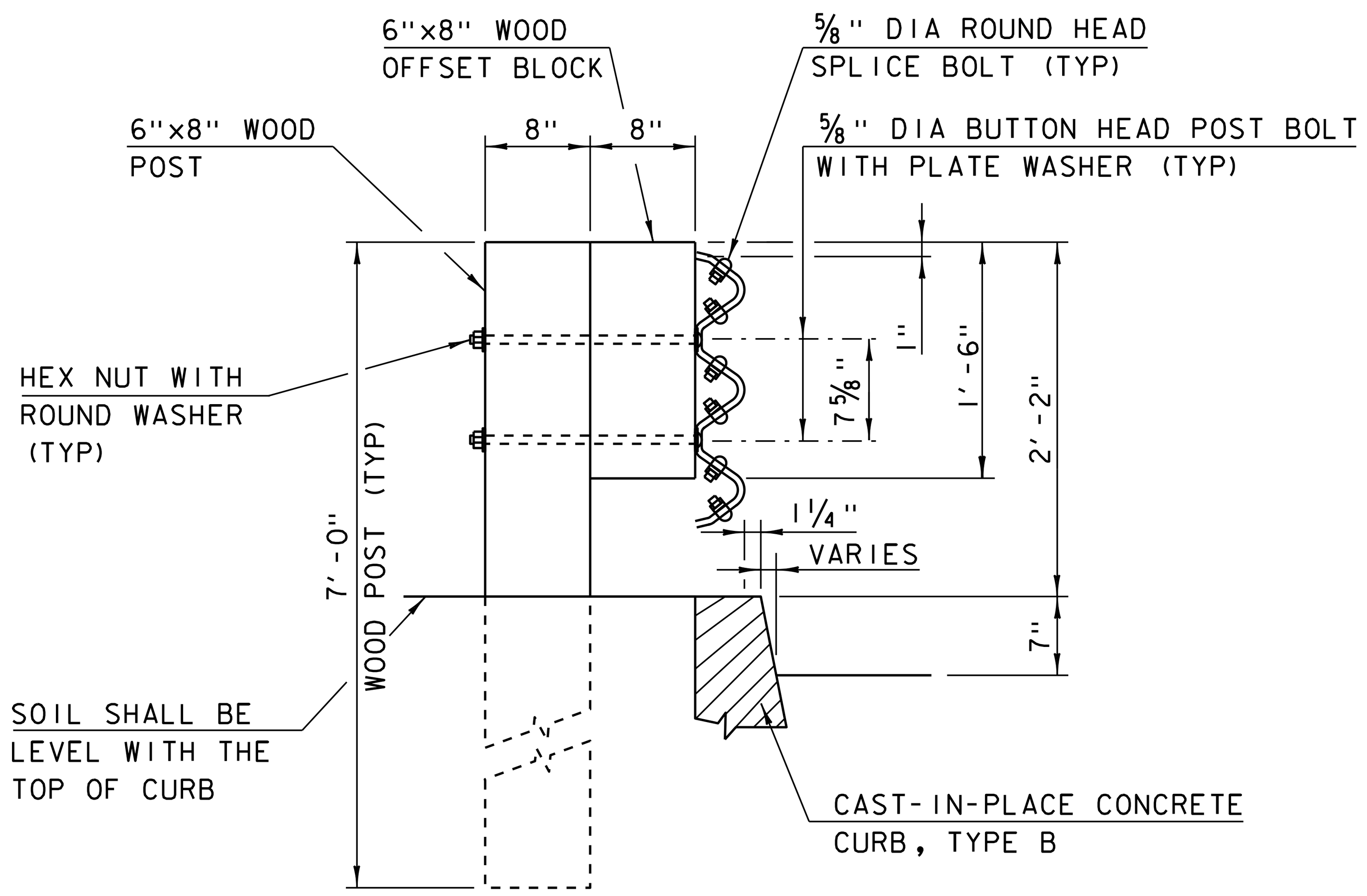
REV.	DATE	DESCRIPTION
0	DECEMBER 14, 2009	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	MARCH 10, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: C-10, G-1, S-360A, S-363
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 2 RAIL BOX BEAM

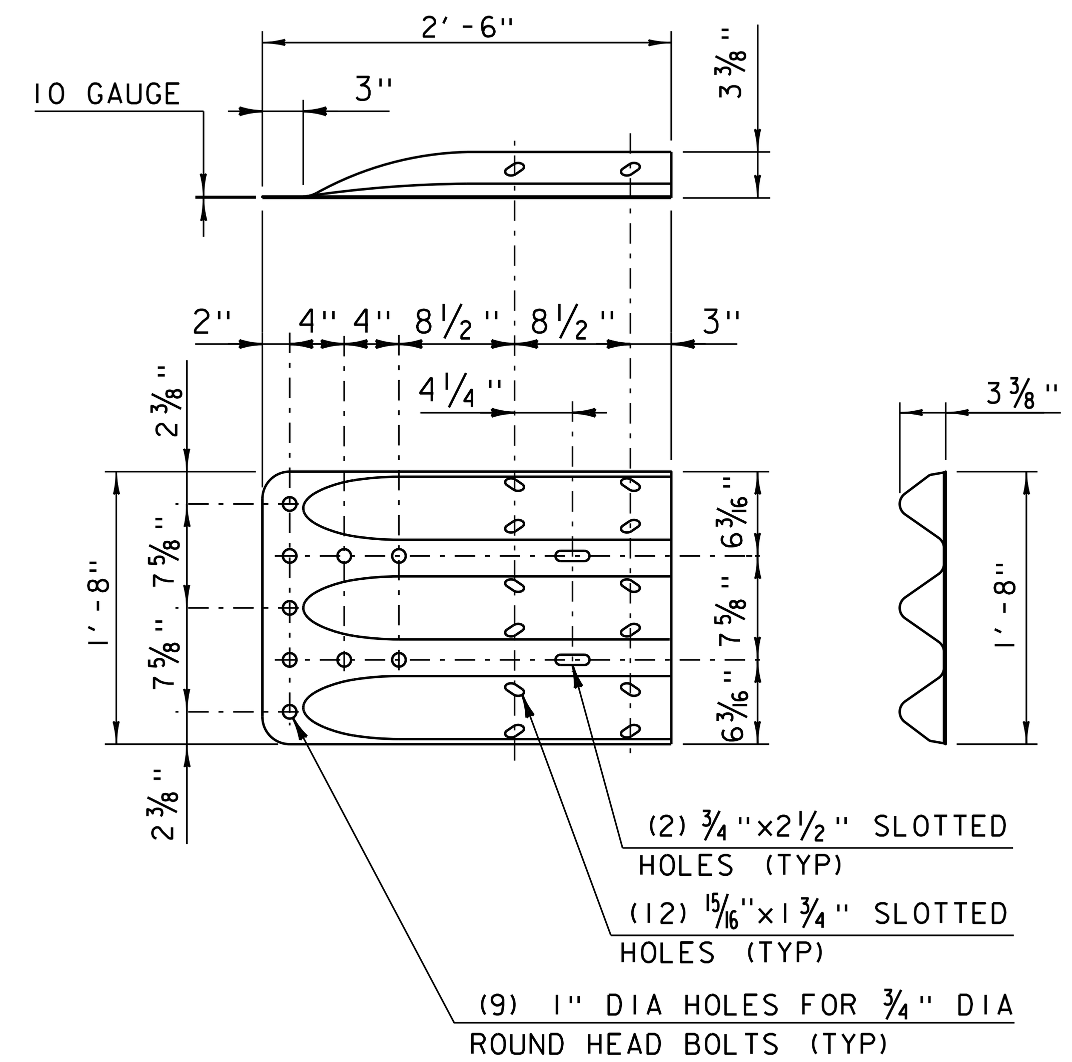
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-360B



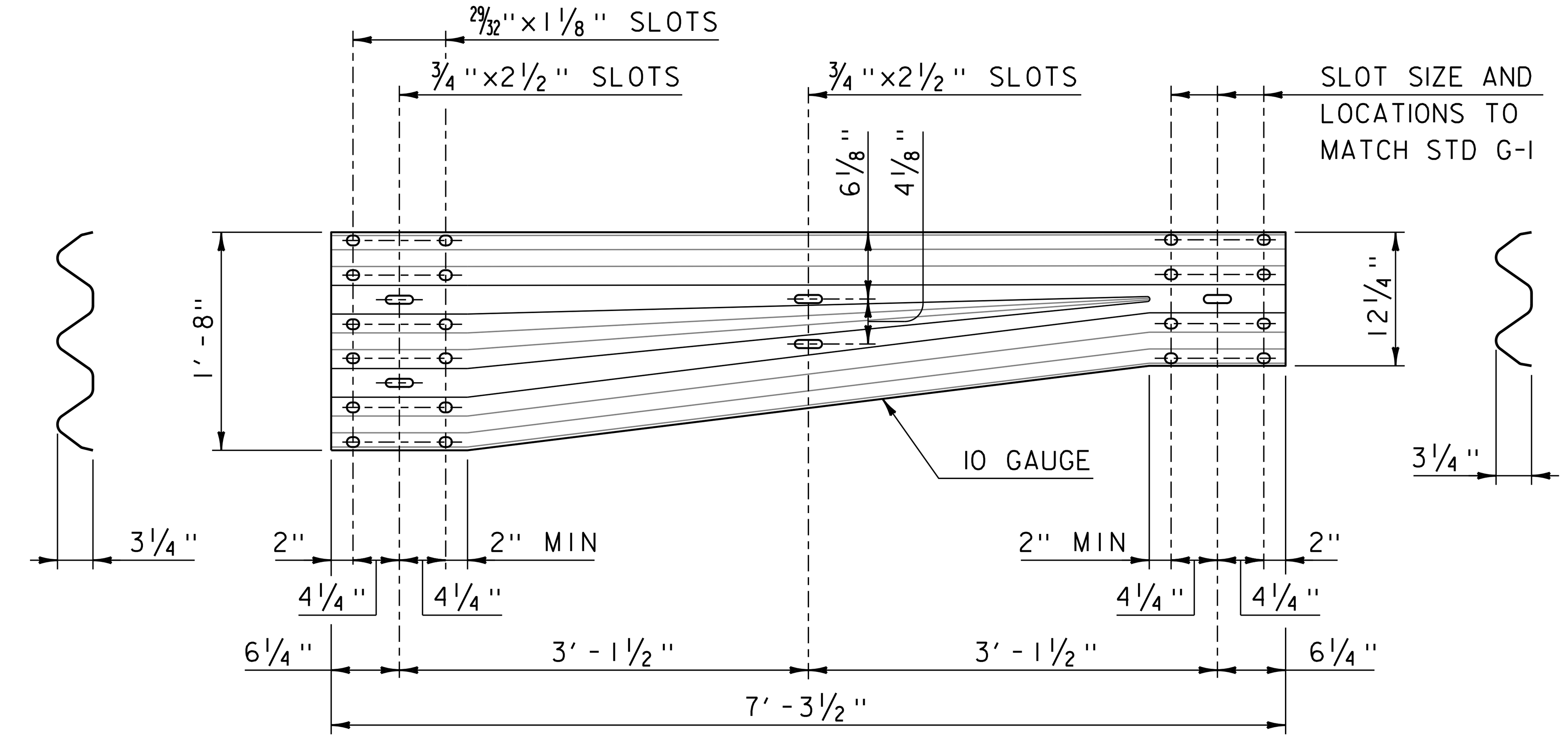
THRIE BEAM GUARDRAIL ASSEMBLY

(SEE STD S-360B)



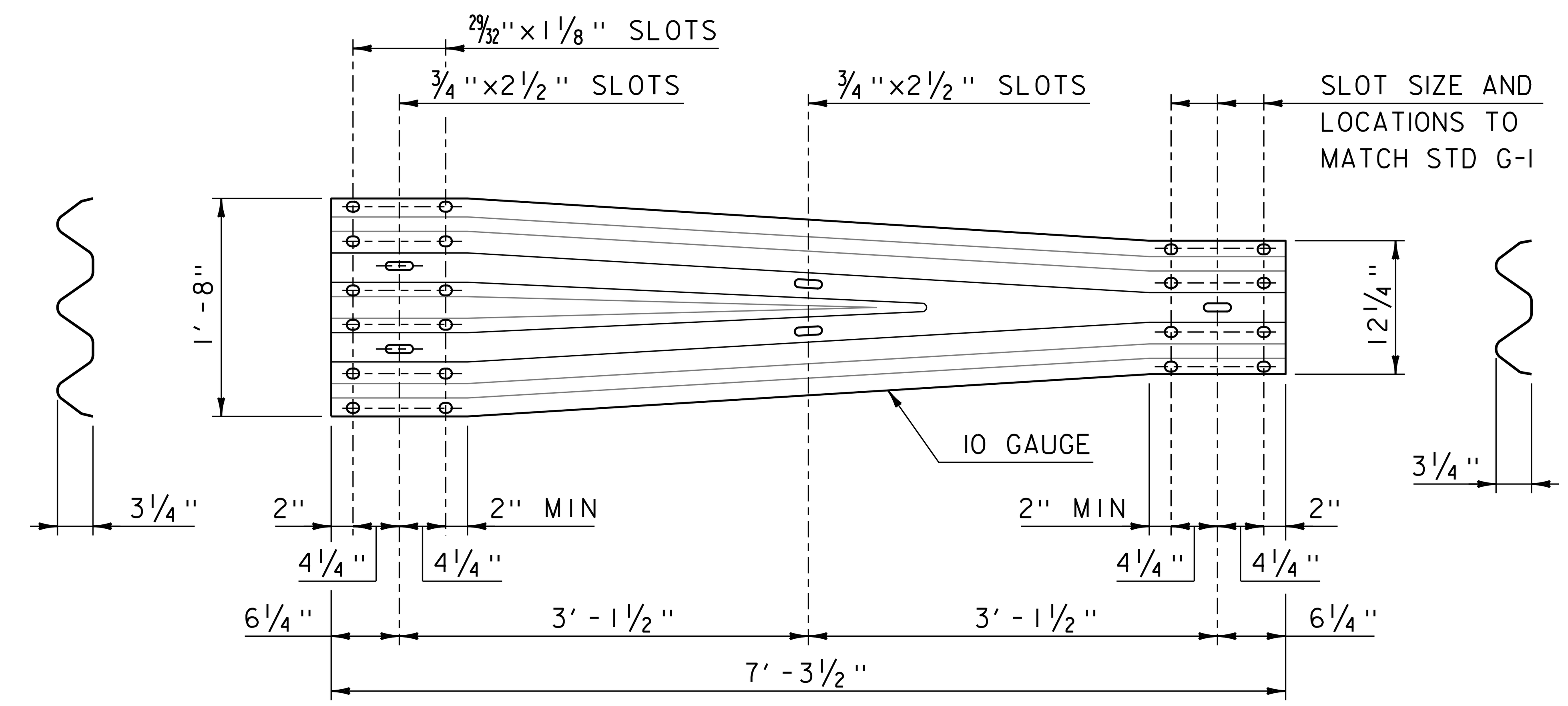
THRIE-BEAM TERMINAL CONNECTOR

(ARTBA RTE01b)



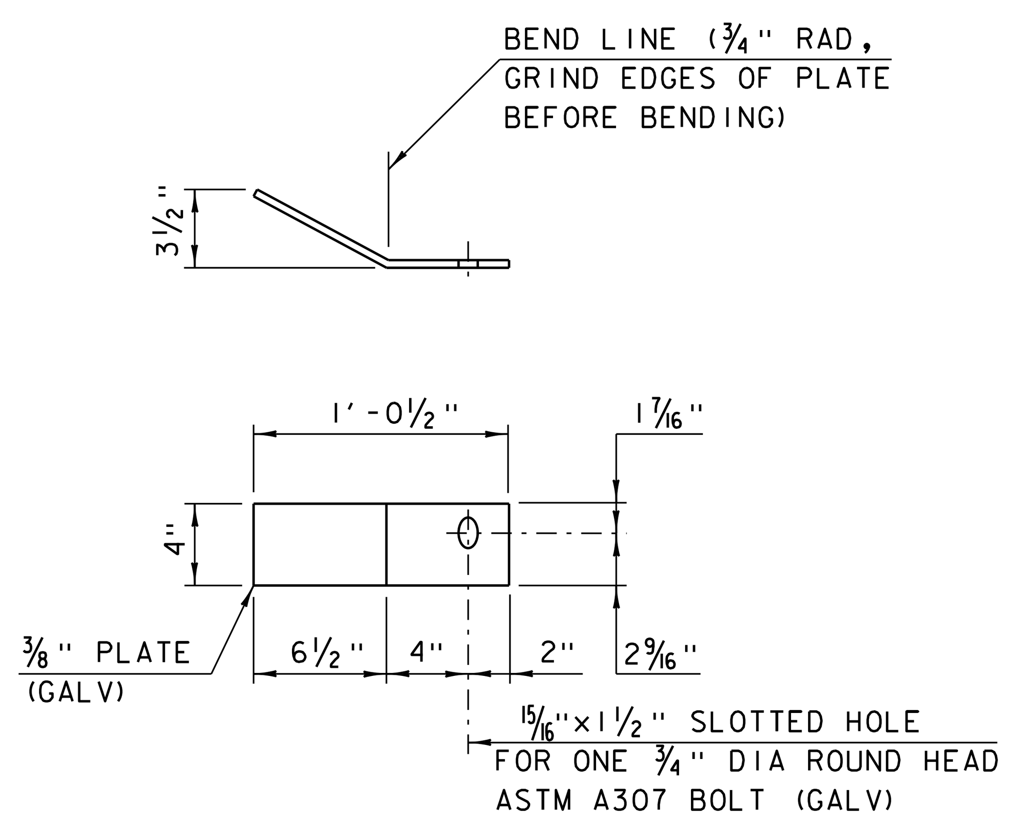
ASYMMETRICAL THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION

(ARTBA RWT02) (SEE NOTE #1)

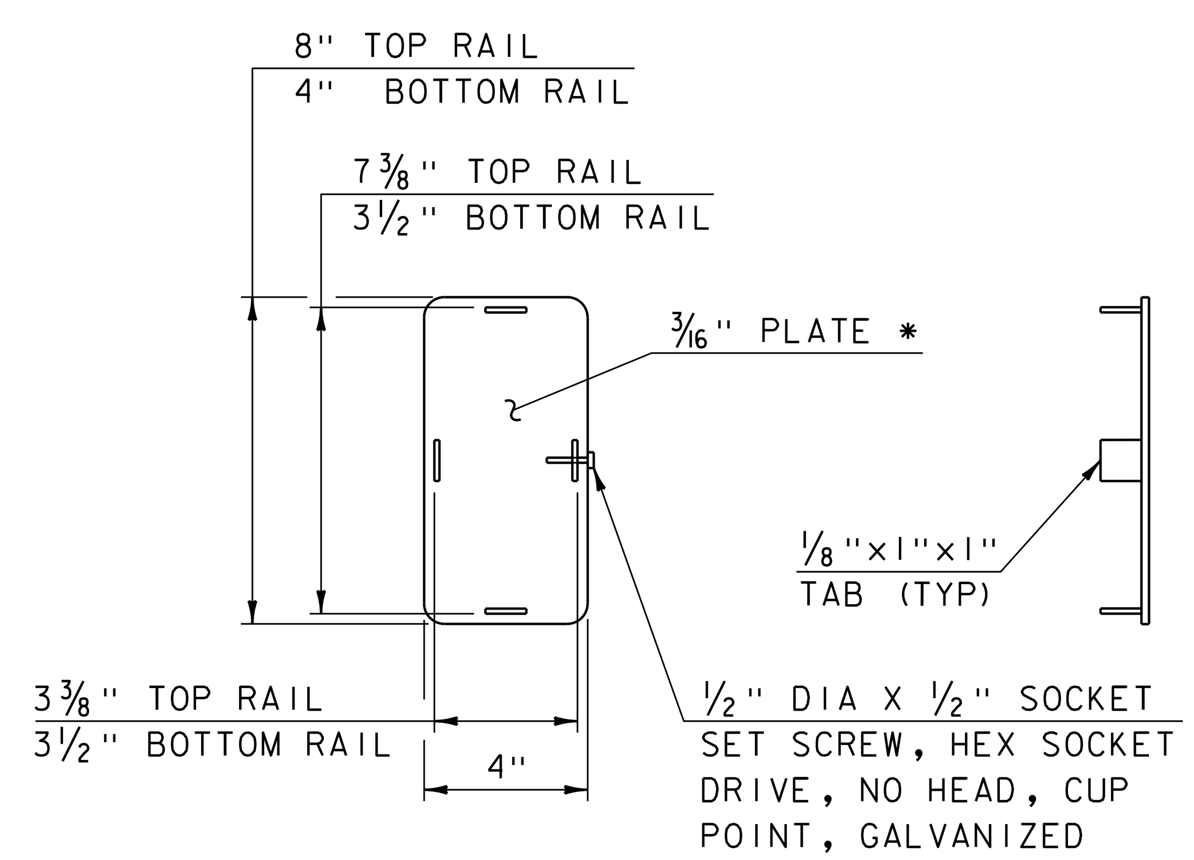


THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION

(ARTBA RWT01a-b)



DEFLECTOR PLATE DETAIL



END CAP DETAIL

* ROUND CORNERS 1/2" RADIUS (TYP)

NOTES:

1. THE ASYMMETRICAL THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION IS TO BE USED WITH THE G-1 STANDARD STEEL BEAM WHEN THE RAIL HEIGHT IS 32".

REV.	DATE	DESCRIPTION
0	DECEMBER 14, 2009	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

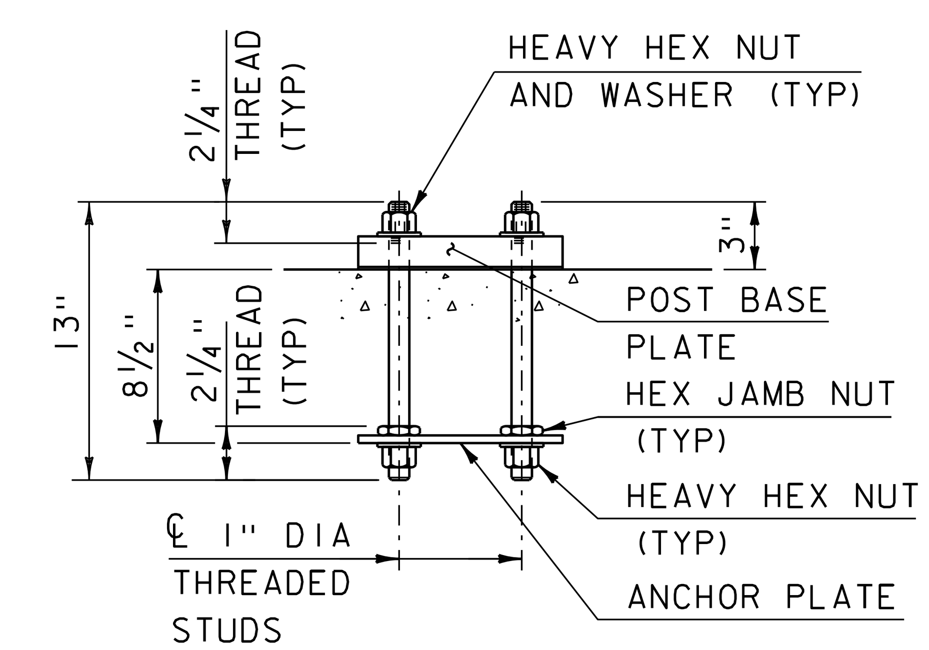
OTHER STANDARDS REQUIRED: C-10, G-1, S-360B

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

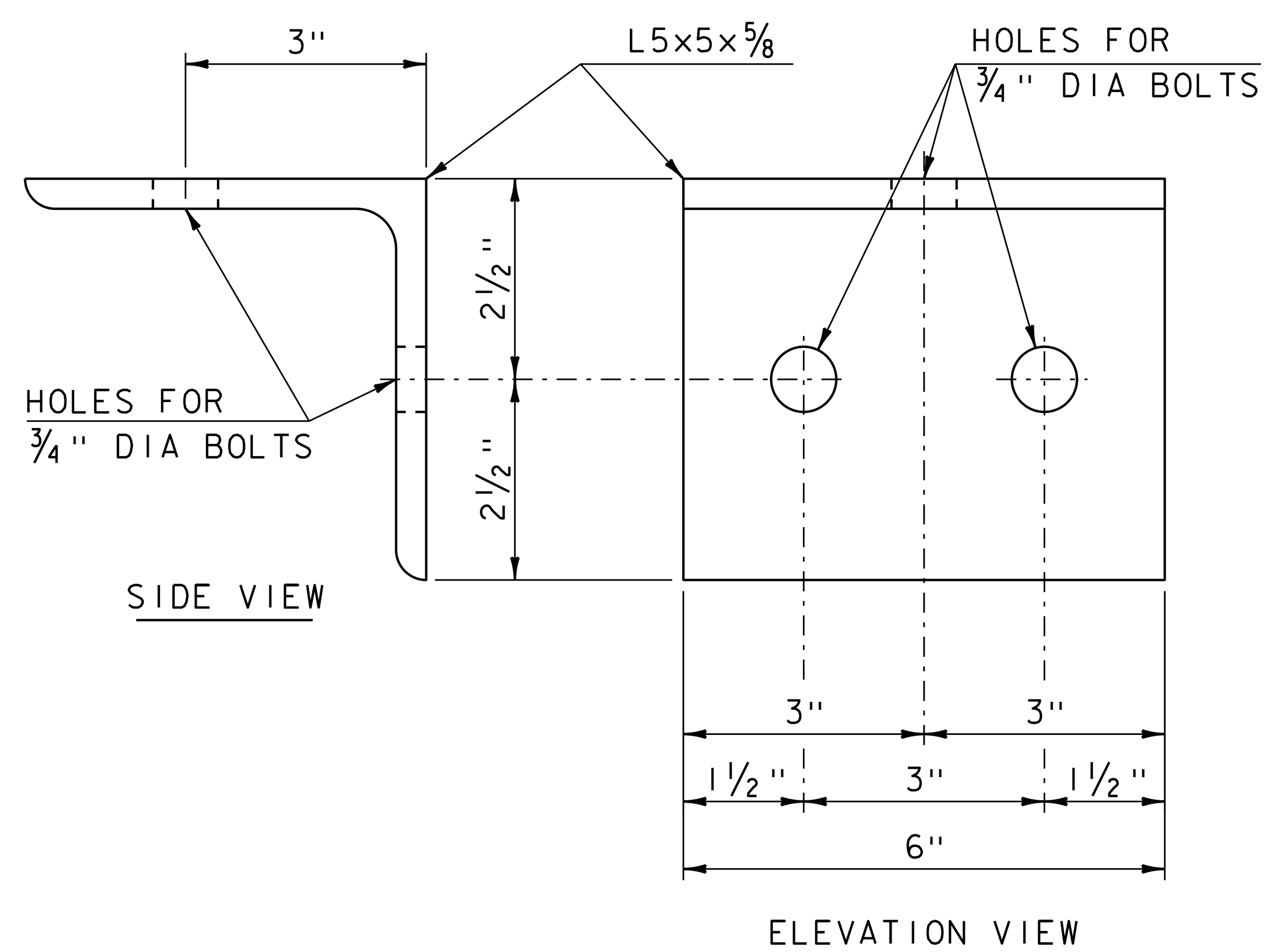
THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

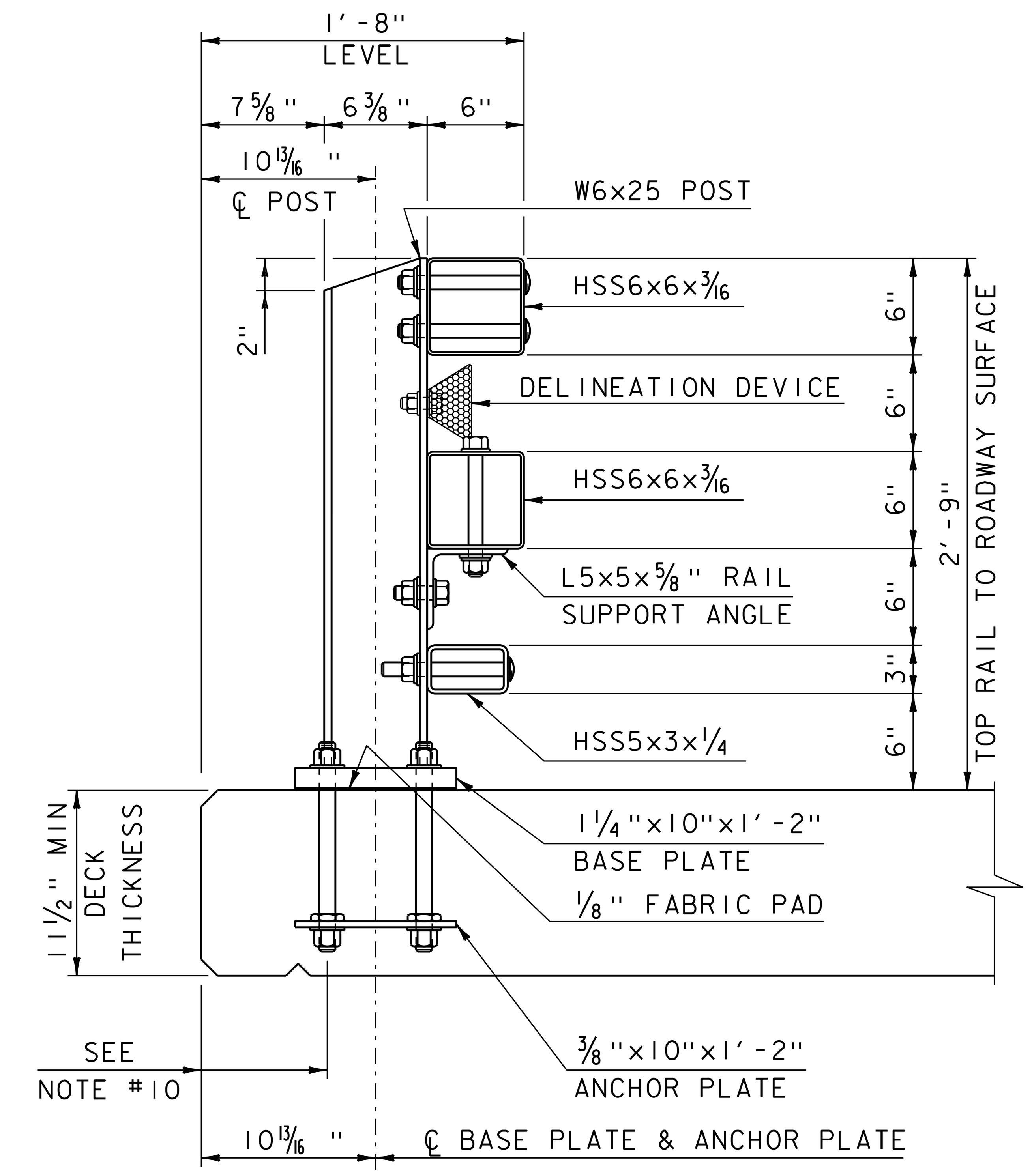
STANDARD S-363



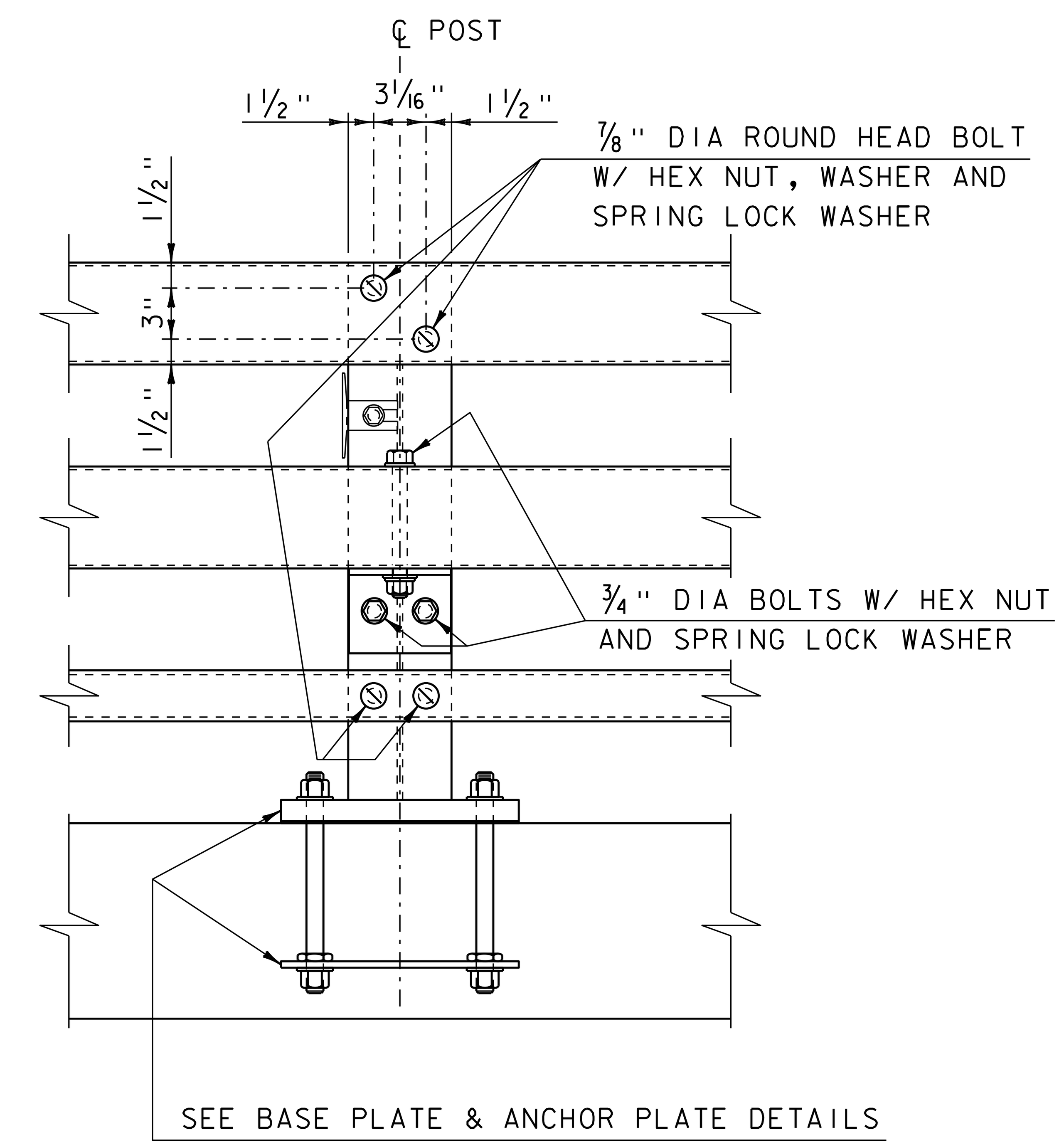
RAILING POST ANCHORAGE



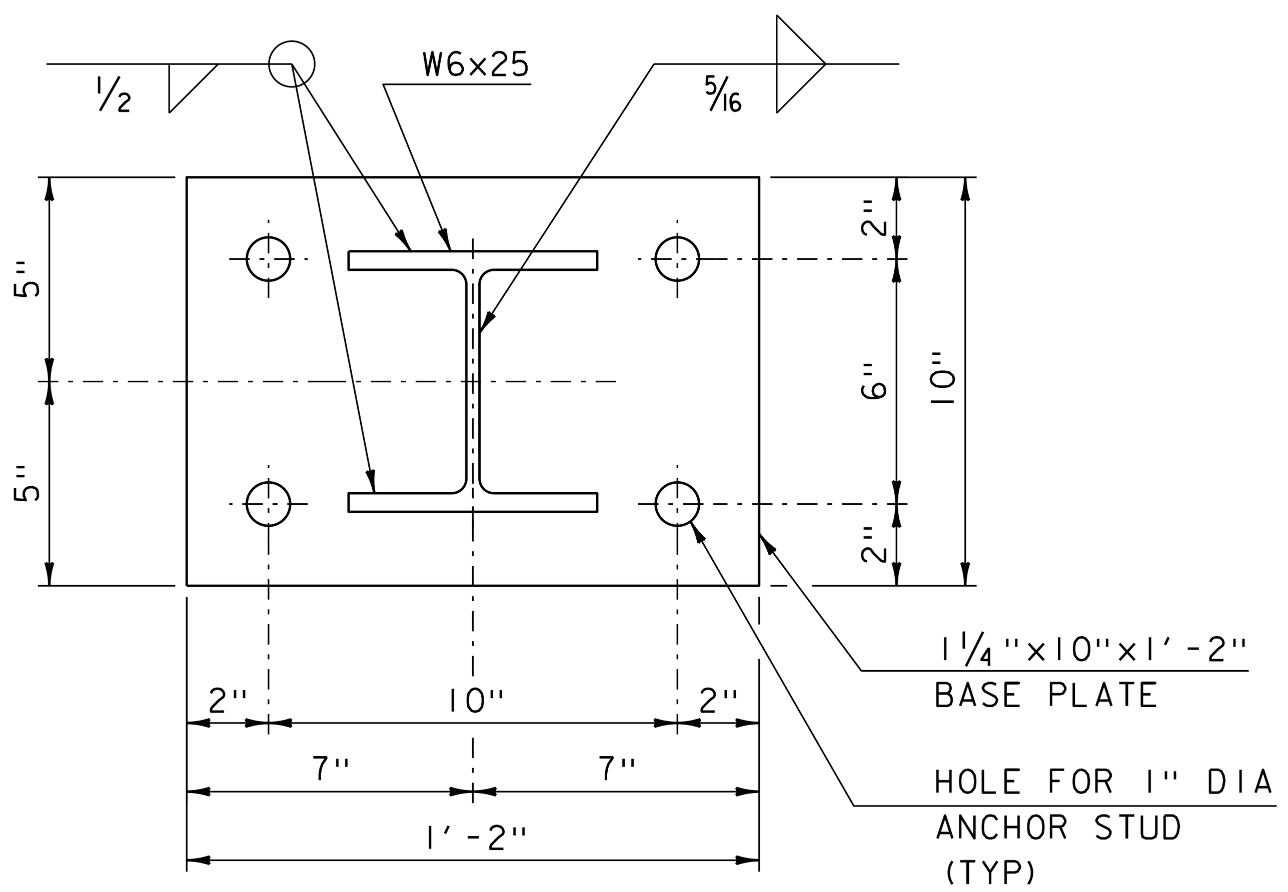
RAILING ANGLE DETAILS



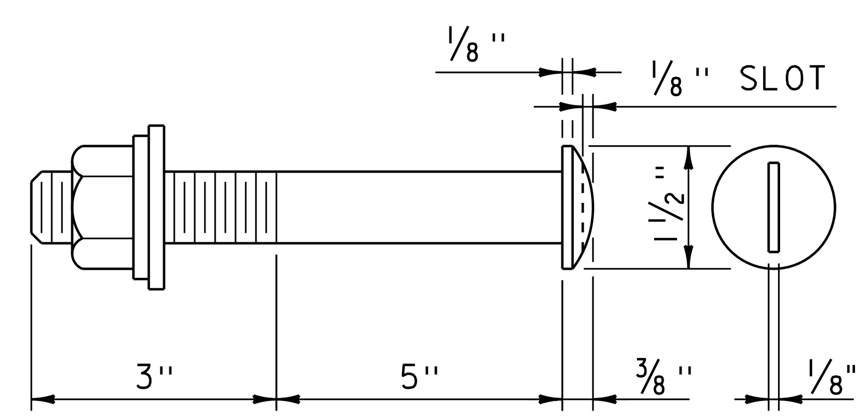
RAILING SECTION



RAILING ELEVATION

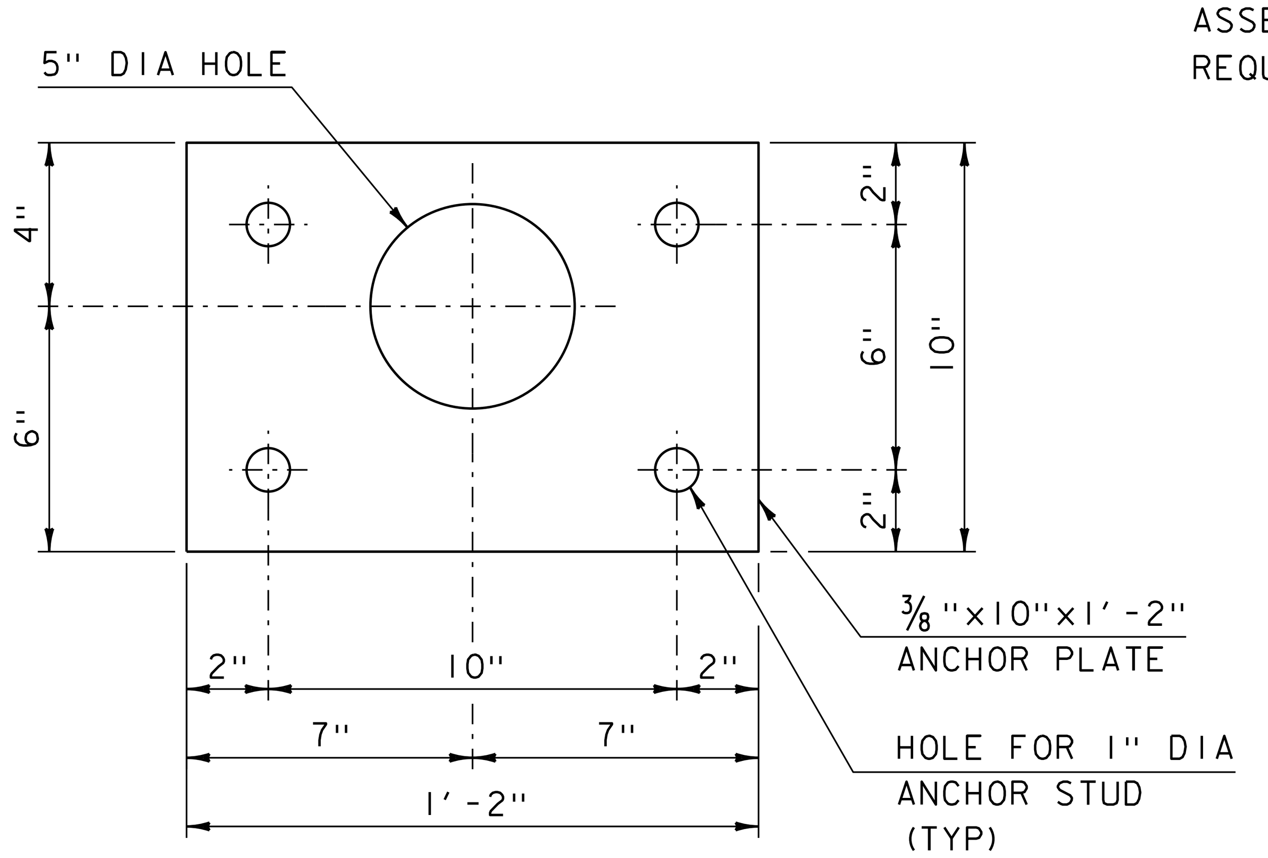


BASE PLATE DETAIL

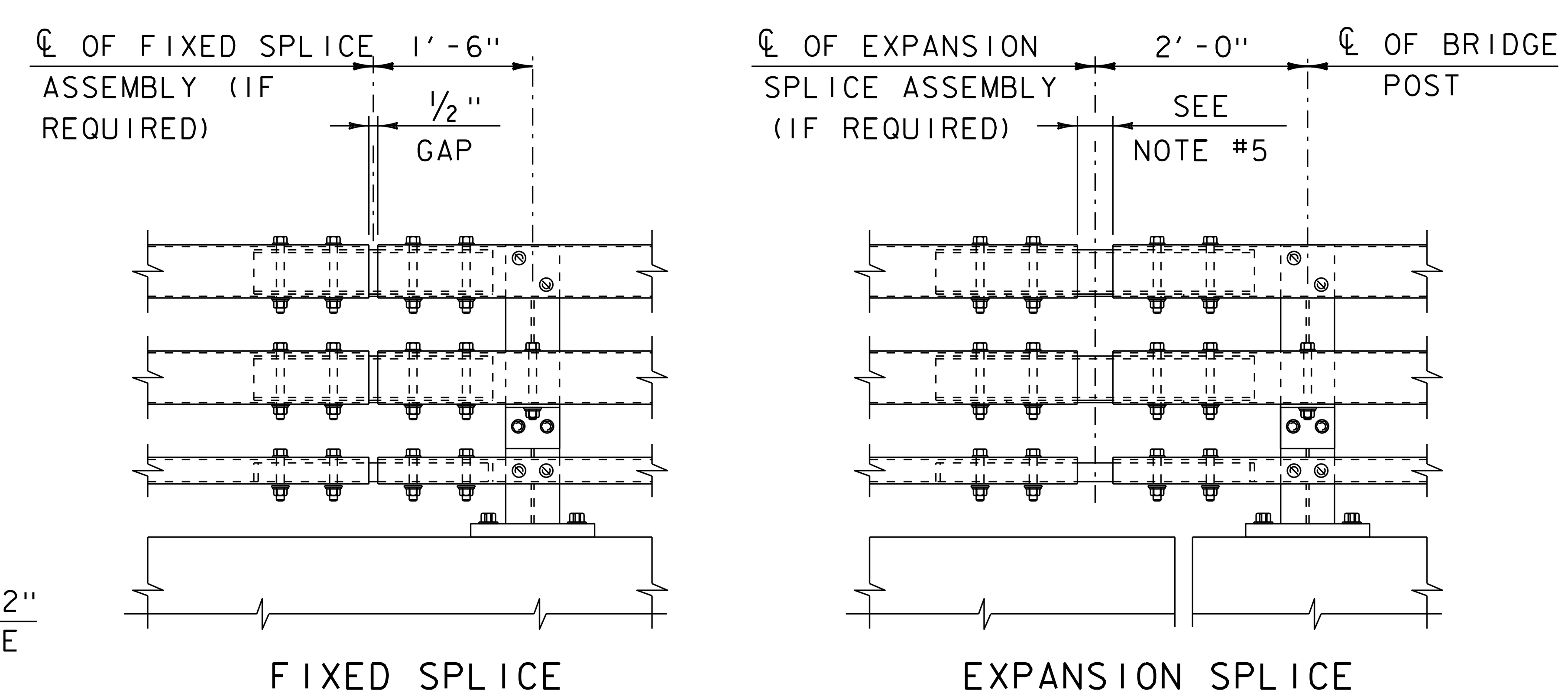


ROUND HEAD BOLT DETAIL

⅞" DIA ROUND HEAD BOLT (A449 TYPE 1), W/ HEX NUT, WASHER AND SPRING LOCK WASHER



ANCHOR PLATE DETAIL



RAILING SPLICE DETAIL ELEVATION

A RAILING EXPANSION SPLICE IS REQUIRED IN ANY POST SPACING THAT CONTAINS A SUPERSTRUCTURE EXPANSION JOINT

NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE. THE MAXIMUM CENTER TO CENTER SPACING OF BRIDGE RAIL POSTS IS 8'-3".
4. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO BRIDGE POSTS AND PREFERABLY TO AT LEAST 4 POSTS.
5. RAIL TUBE EXPANSION JOINTS SHALL BE PROVIDED IN ANY RAIL BAY SPANNING THE END OF AN INTEGRAL ABUTMENT BRIDGE AND AT ALL SUPERSTRUCTURE EXPANSION JOINTS. EXPANSION JOINT WIDTH SHALL BE 4" @ 68°F AND WILL BE ADJUSTED IN THE FIELD BY THE ENGINEER FOR OTHER TEMPERATURES.
6. HOLES IN RAILS FOR TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
7. BOLTS SHALL BE TORQUED SNUG TIGHT (APPROXIMATELY 100 FT-LB).
8. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT. PAYMENT SHALL BE INCIDENTAL TO OTHER ITEMS.
9. ANY BENDING OF RAIL SHALL BE DONE AT THE FABRICATION PLANT ACCORDING TO A PROCEDURE PROVIDED BY THE FABRICATOR.
10. THE MINIMUM DISTANCE FROM THE POST TO AN EXPANSION JOINT SHALL BE DETERMINED BY THE MINIMUM EDGE DISTANCE OF 5" FROM ANY ANCHOR STUD TO THE END OF THE SLAB OR TO THE EXPANSION JOINT RECESS POUR IF ONE IS USED.
11. THIS RAILING MEETS THE REQUIREMENTS FOR A TL-4 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 10, 2014	REVISED NOTE 2
3	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

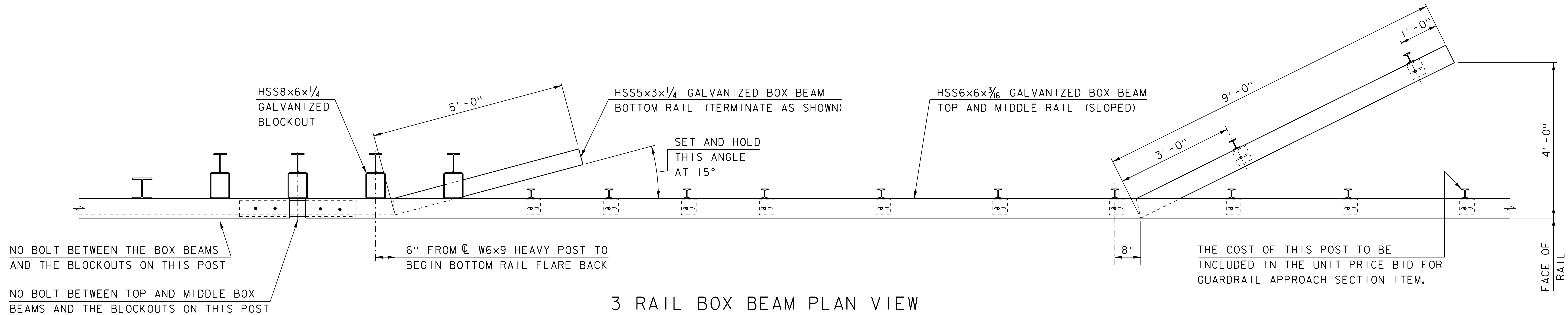
OTHER STANDARDS REQUIRED: G-1, S-364C

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

BRIDGE RAILING, GALVANIZED 3 RAIL BOX BEAM

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-364A



3 RAIL BOX BEAM PLAN VIEW

3 RAIL BOX BEAM ELEVATION

* LONG LEG HORIZONTAL

NOTES:

1. BOX BEAM TUBE AND STEEL POST MATERIALS, DIMENSION SIZES AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED.
2. S3x5.7 POSTS SHALL MEET THE REQUIREMENTS OF 728.01(c).

REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 10, 2014	CLARIFY TRANSITION POST REQUIREMENTS
3	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: G-1BM, S-364A

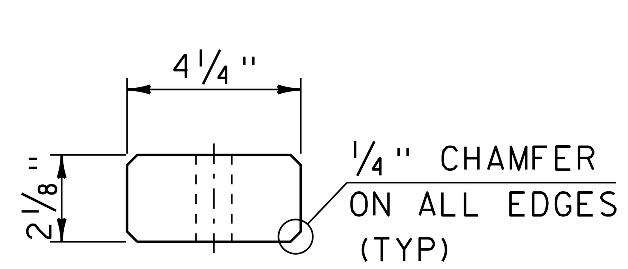
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD

S-364B



SECTION A-A

NOTES:

1. PROTRUSIONS CAUSED BY WELDING OR GALVANIZING ARE NOT PERMITTED ON THE ADJOINING SURFACES OF THE BOX BEAM RAILS, SPLICE TUBES AND FILL PLATES.

2. FOUR 3/4" DIAMETER FULLY THREADED BOLTS WITH TWO PLAIN HARDENED (F436) WASHERS AND A HEAVY HEX NUT ON EACH BOLT. NUT TO BE FINGER TIGHT AND THE FIRST THREAD BELOW THE NUT TO BE BURRED TO PREVENT DISLODGING. FOUR BOLTS AT EACH SPLICE.

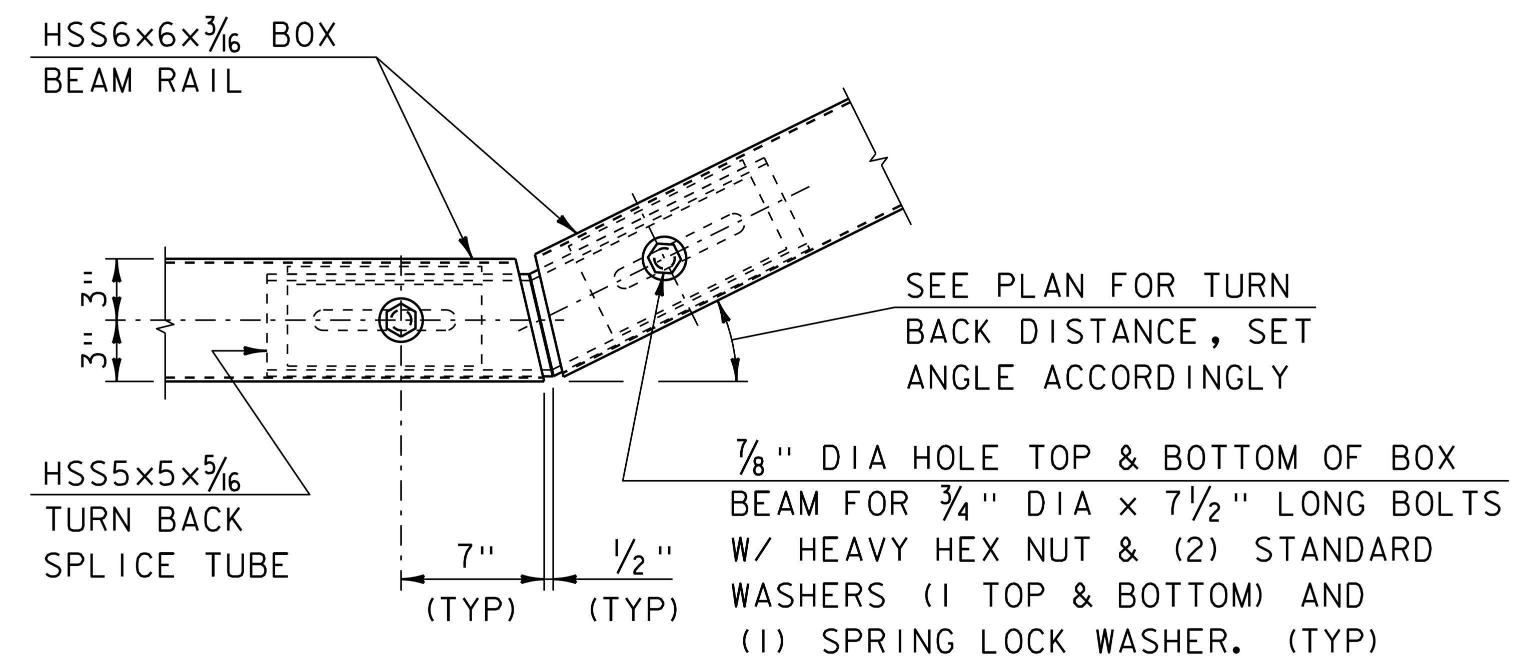
REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 10, 2014	CORRECTED SPLICE BAR DETAILS
3	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: NONE
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

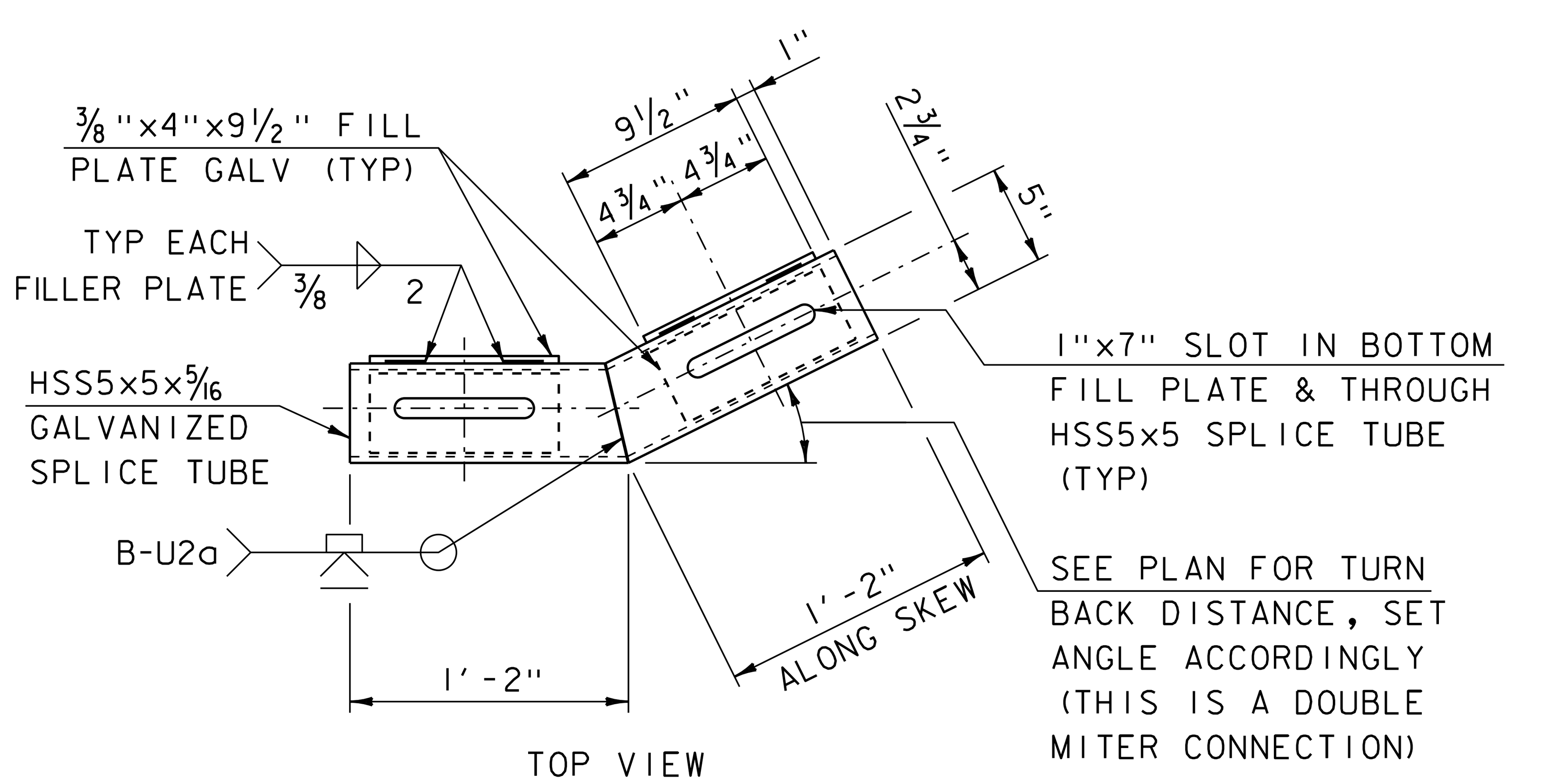
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-364C

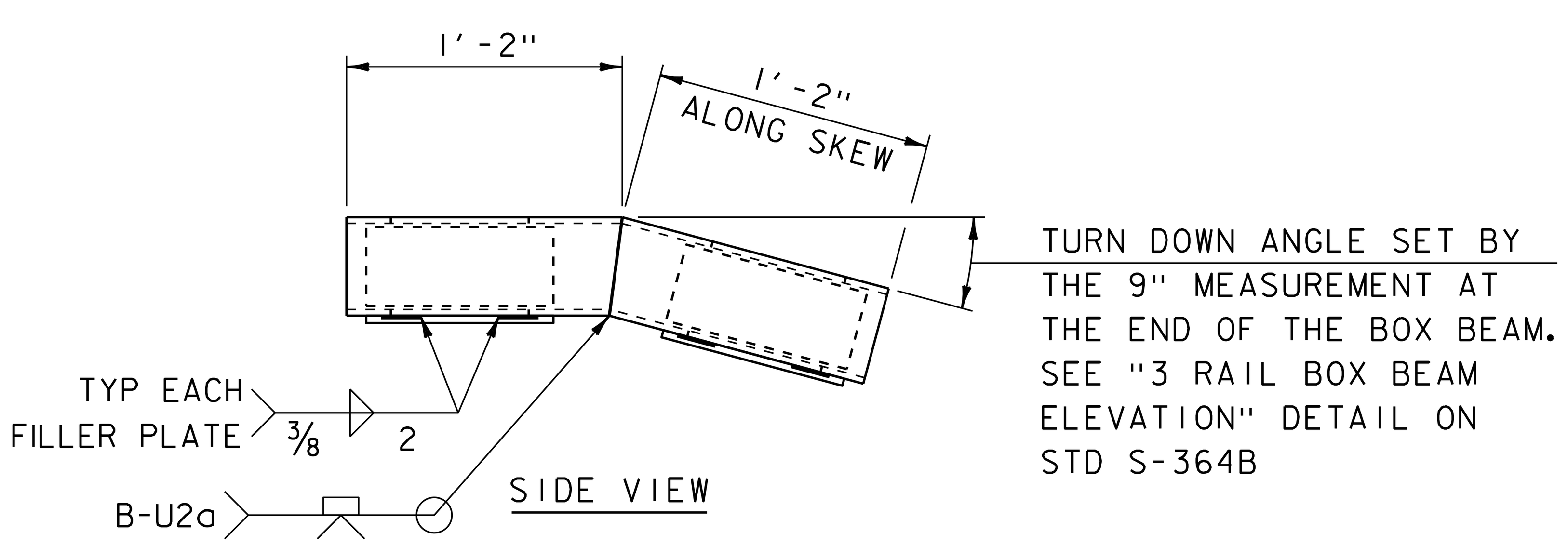


TOP VIEW

TURN BACK SPLICE TUBE ASSEMBLY



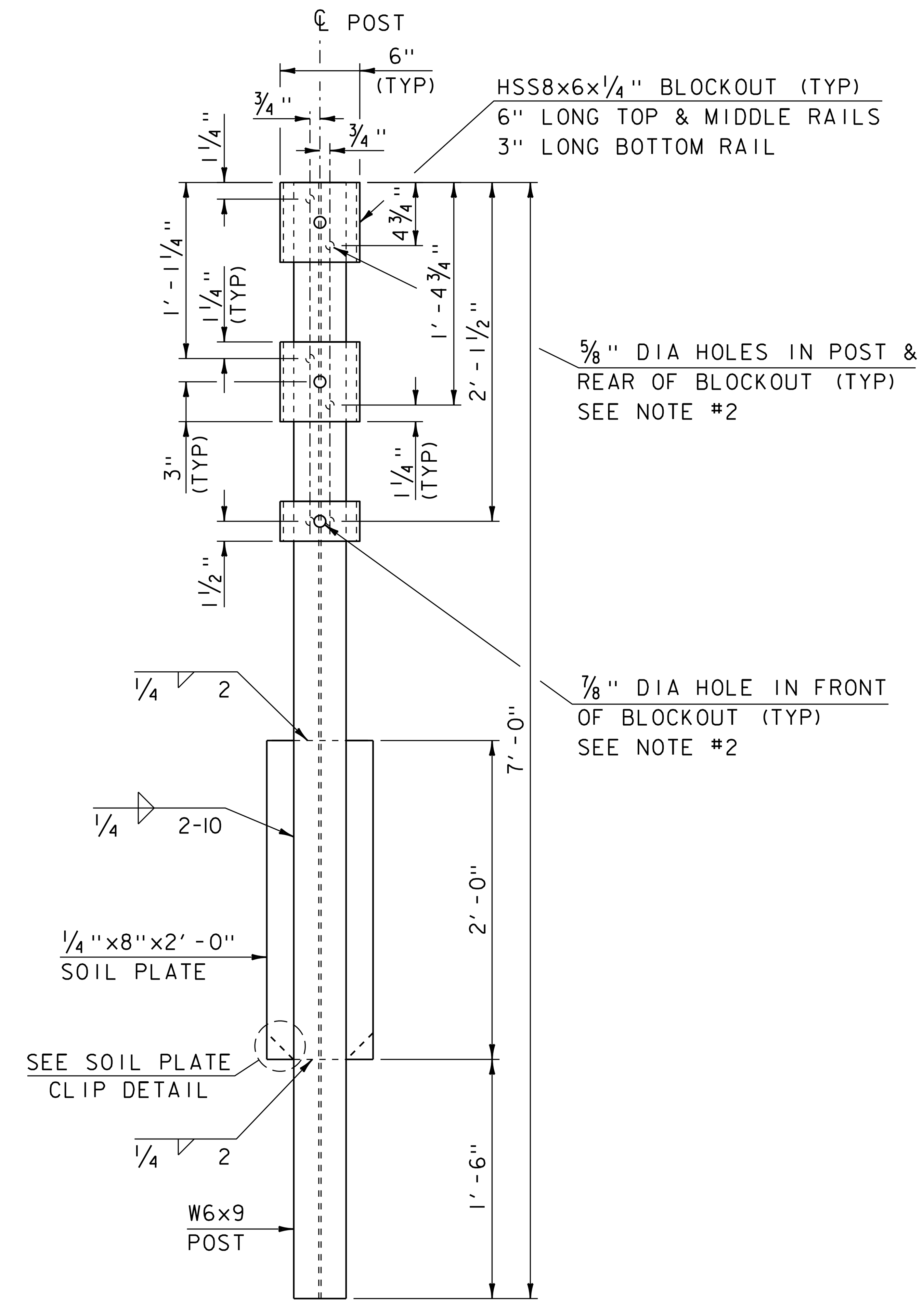
TOP VIEW



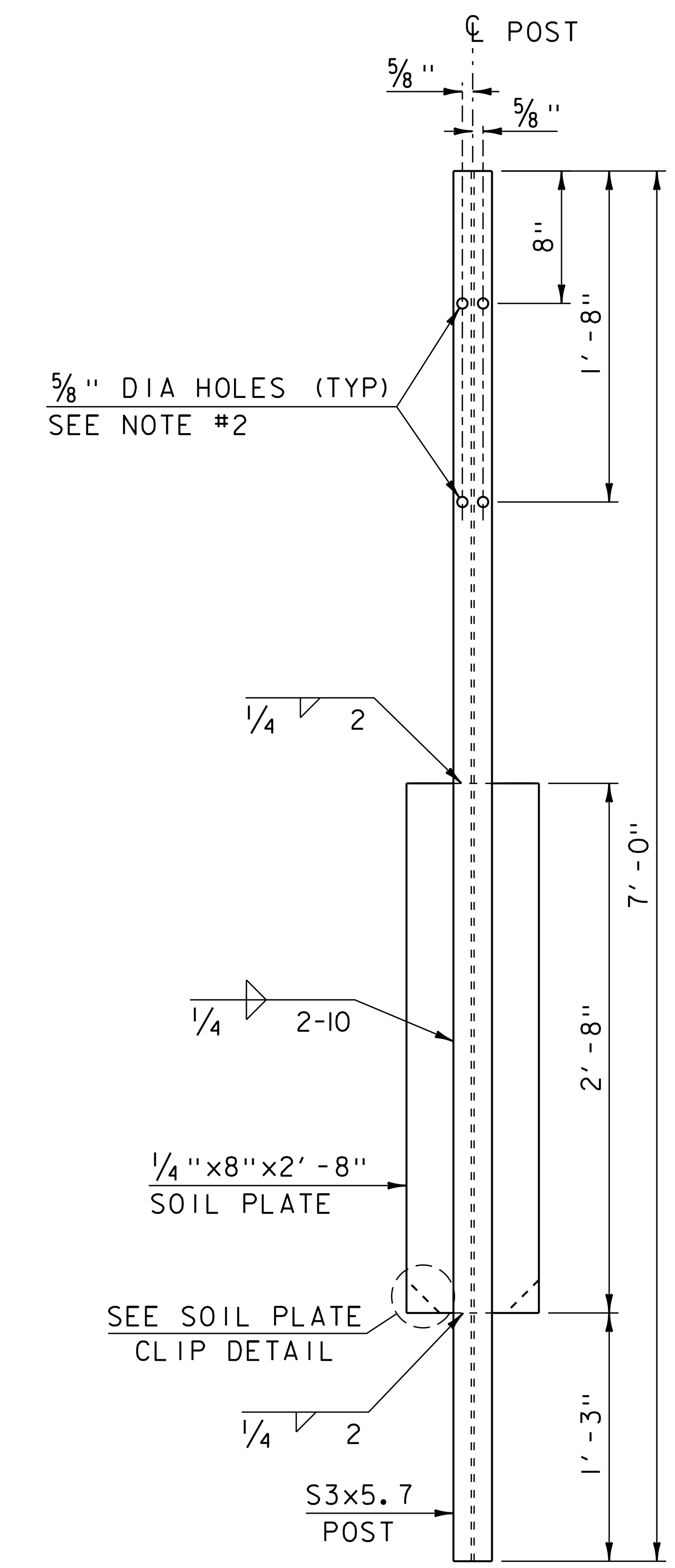
SIDE VIEW

TURN BACK SPLICE TUBE DETAIL

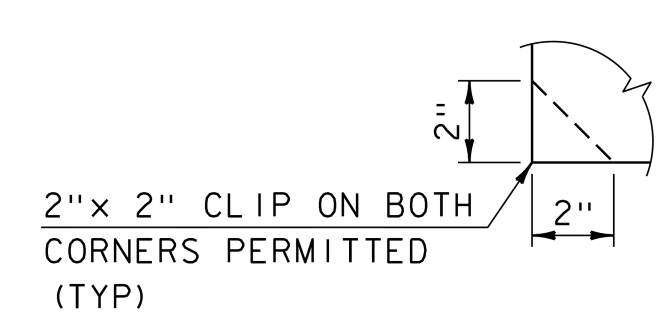
TURN BACK & TURN DOWN TUBE JOINT



HEAVY POST DETAIL



TRANSITION POST DETAIL



SOIL PLATE CLIP DETAIL

NOTES:

1. PROTRUSIONS CAUSED BY WELDING OR GALVANIZING ARE NOT PERMITTED ON THE ADJOINING SURFACES OF THE BOX BEAM RAILS, SPLICE TUBES AND FILL PLATES.

2. HOLES IN THE POST FOR MIDDLE AND BOTTOM RAILS MAY BE LOCATED AND DRILLED IN THE FIELD. IF SO, THE GALVANIZING SHALL BE REPAIRED IN ACCORDANCE WITH SPECIFICATION SECTION 525.

REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: S-364B

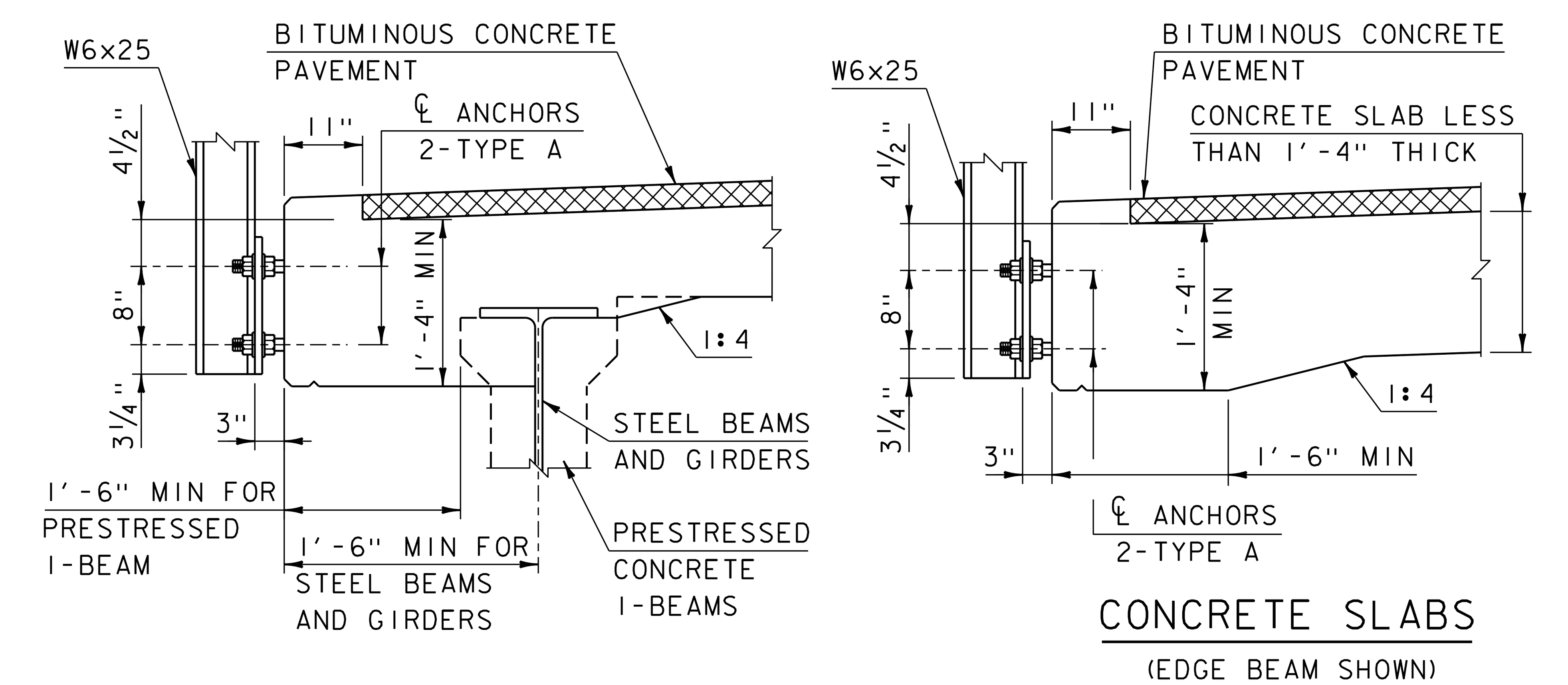
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD

S-364D



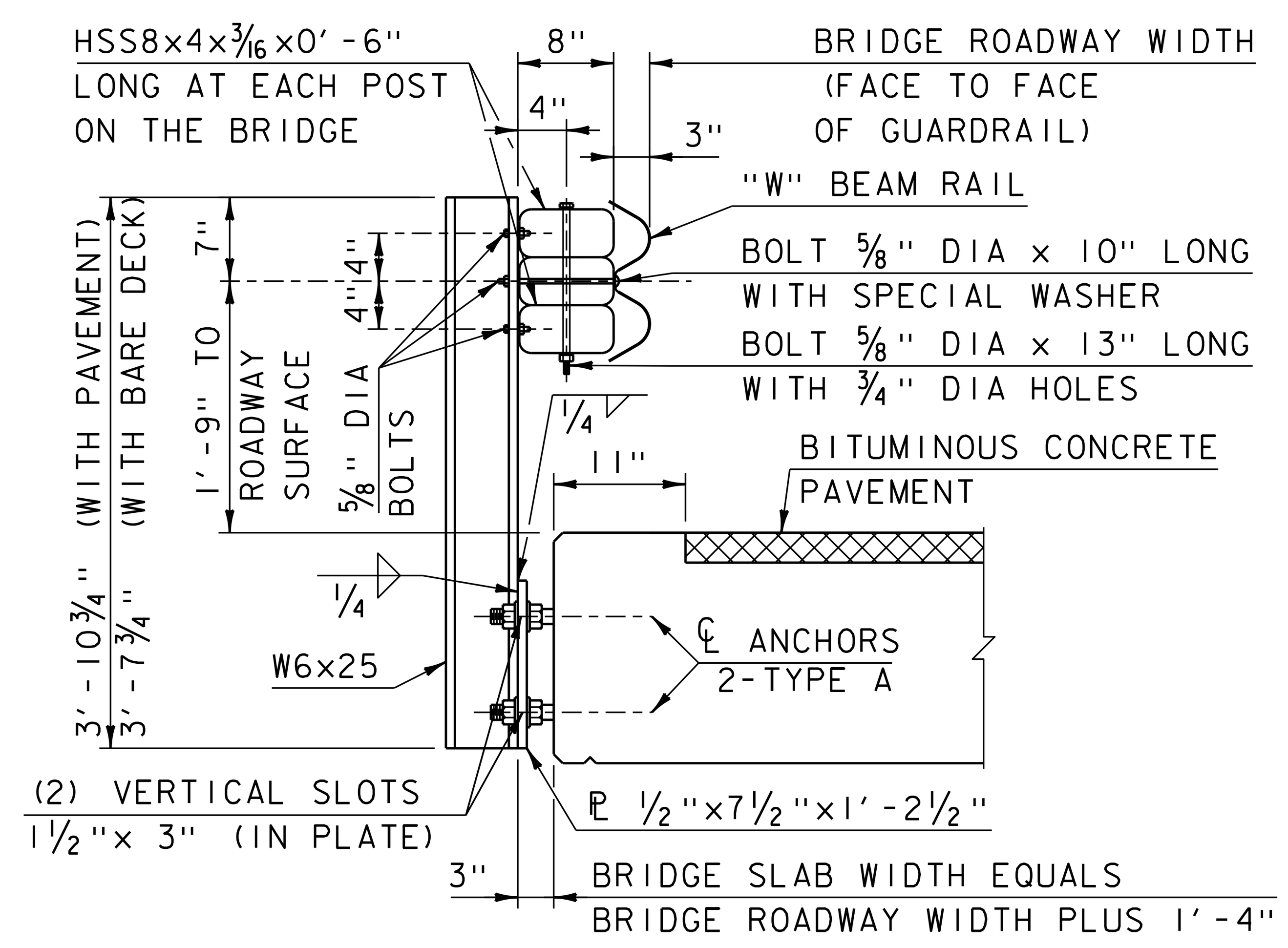
LONGITUDINAL BEAM BRIDGES

CONCRETE SLABS

(EDGE BEAM SHOWN)

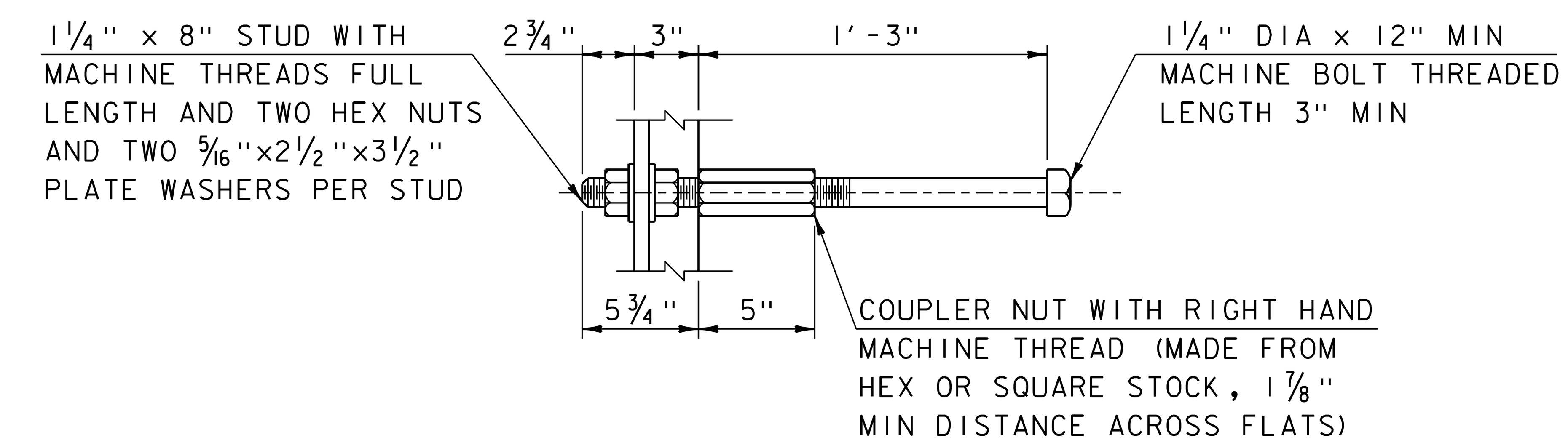
POST ANCHORAGE DETAILS

(NOT FOR USE WITH PRESTRESSED BOX BEAMS)

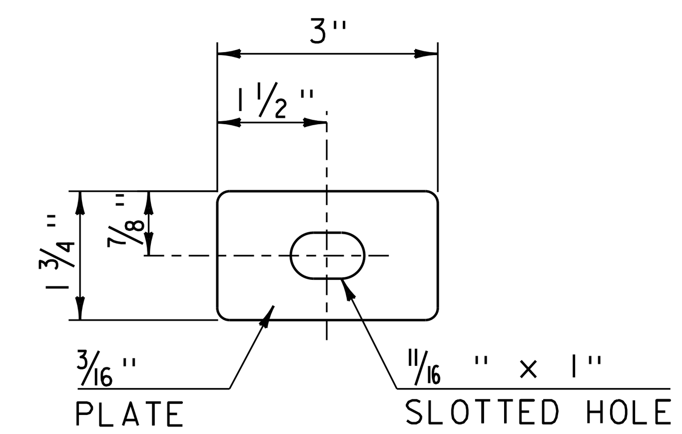


SECTION B-B

TYPE 1 POST

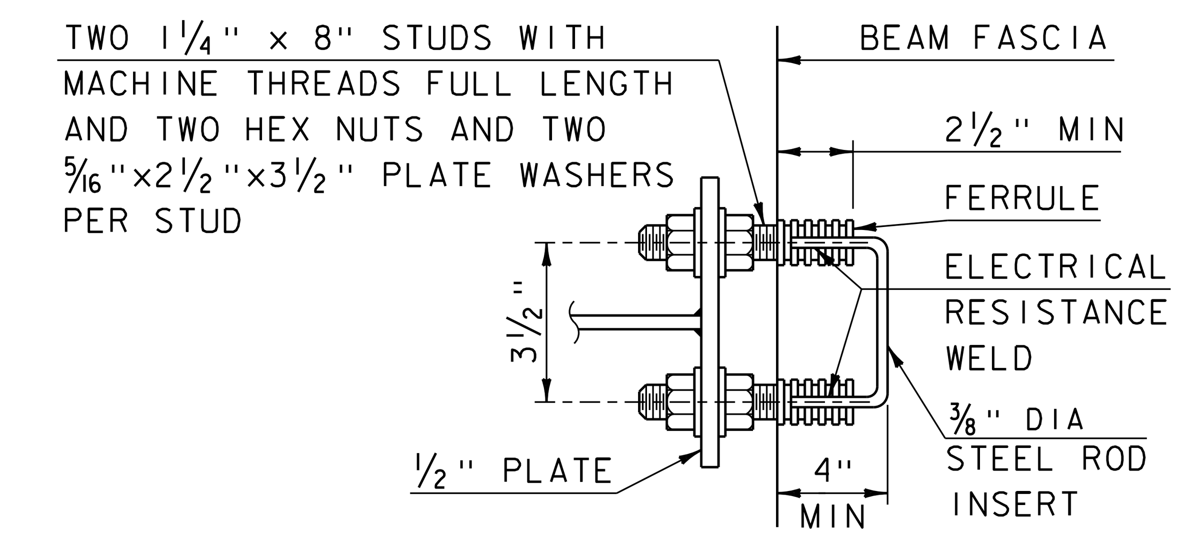


TYPE A ANCHOR DETAIL



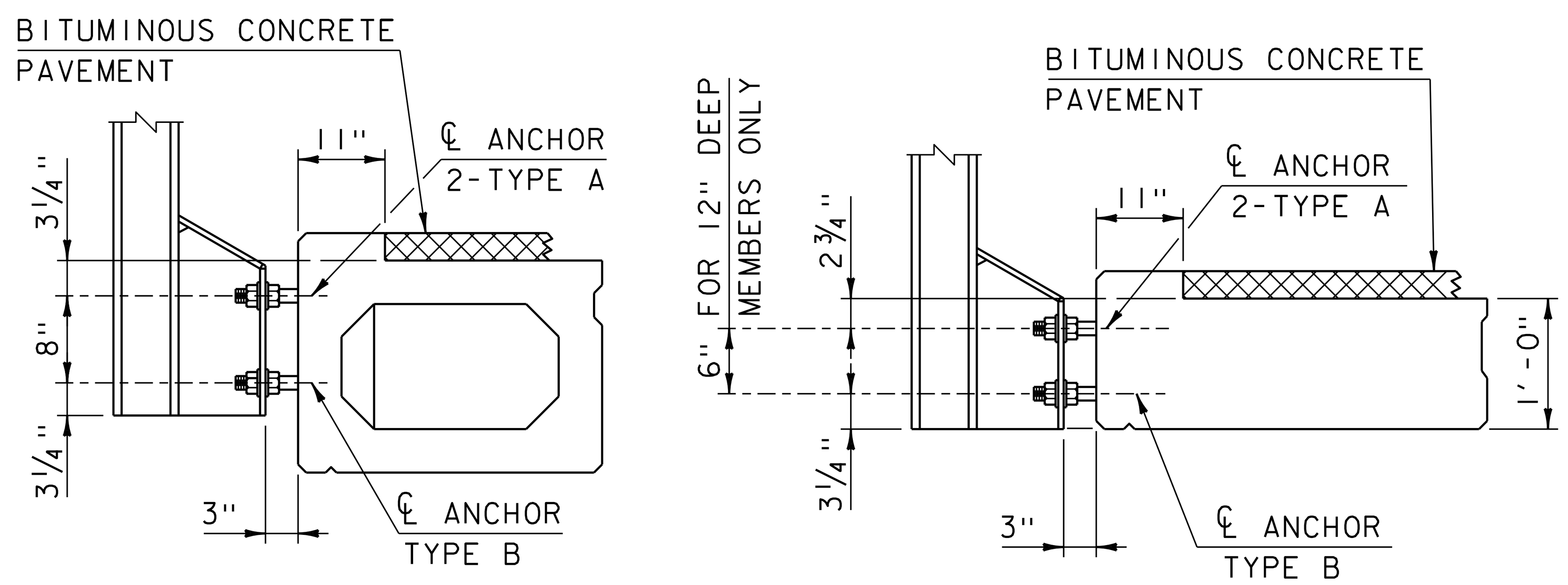
SPECIAL WASHER

PLACE WASHER BETWEEN BOLT HEAD AND FACE OF RAIL.

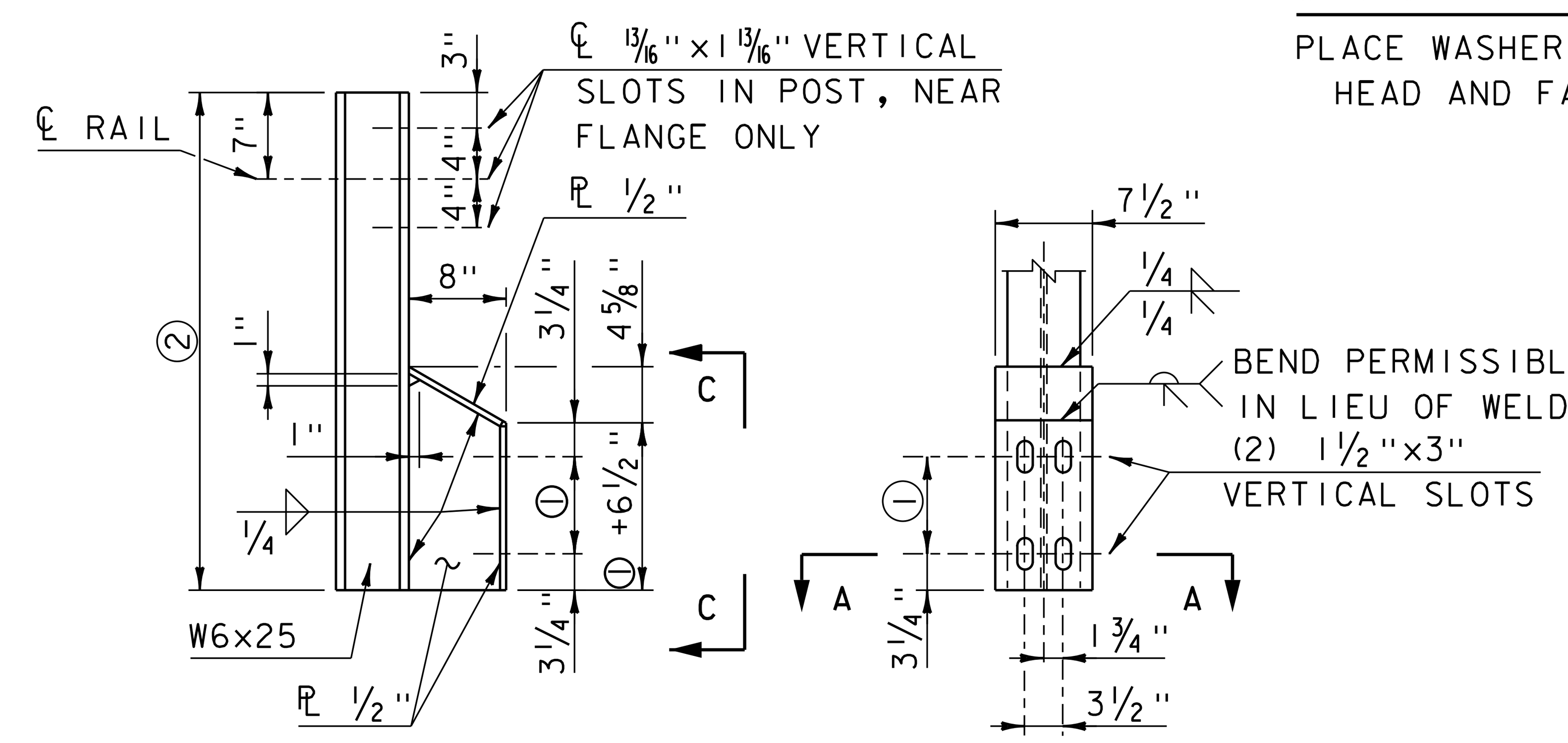


SECTION A-A

TYPE B ANCHOR DETAIL



POST ANCHORAGE DETAILS (PRECAST CONCRETE)



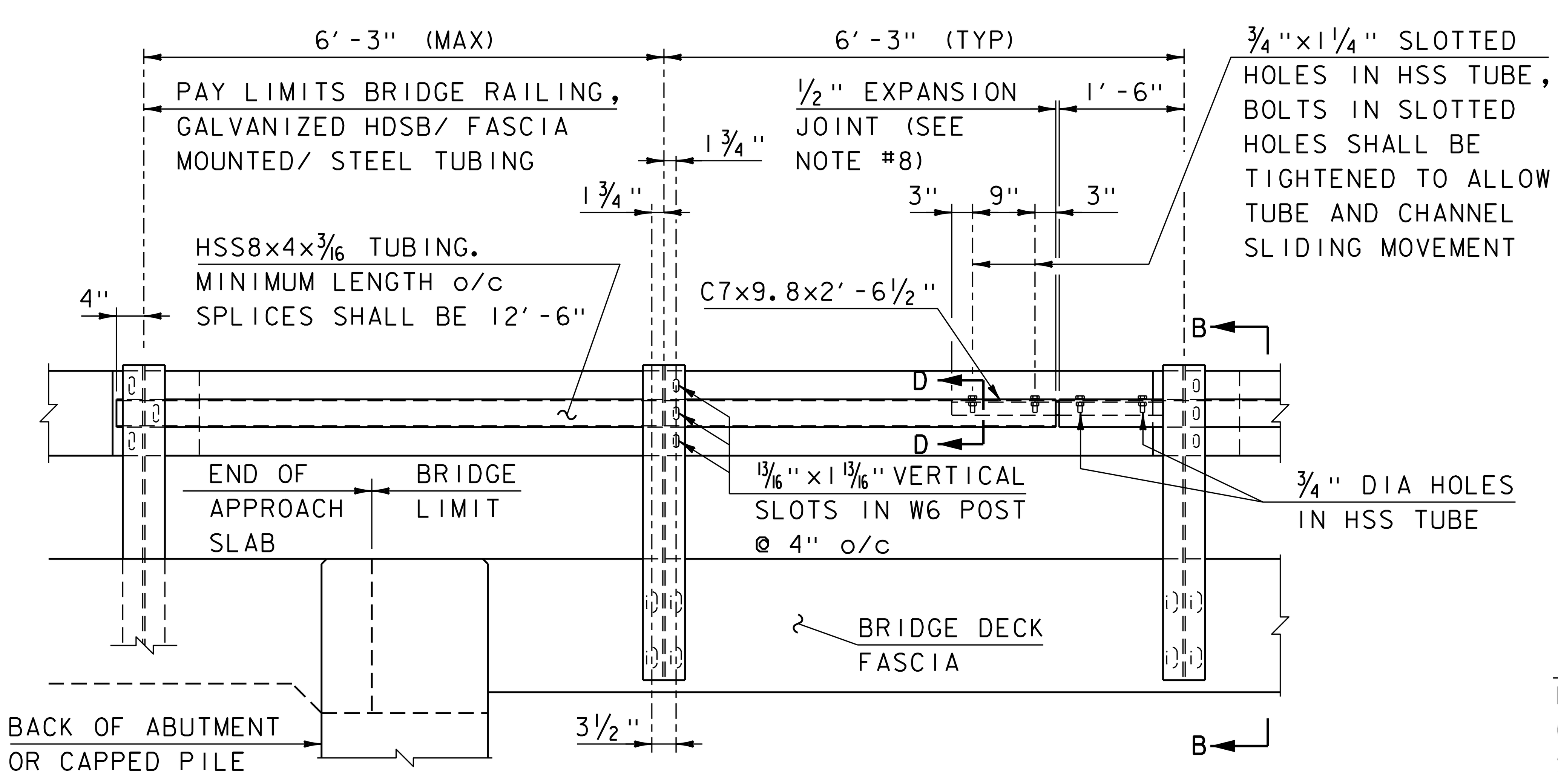
*SECTION B-B

TYPE 2 POST

*VIEW C-C

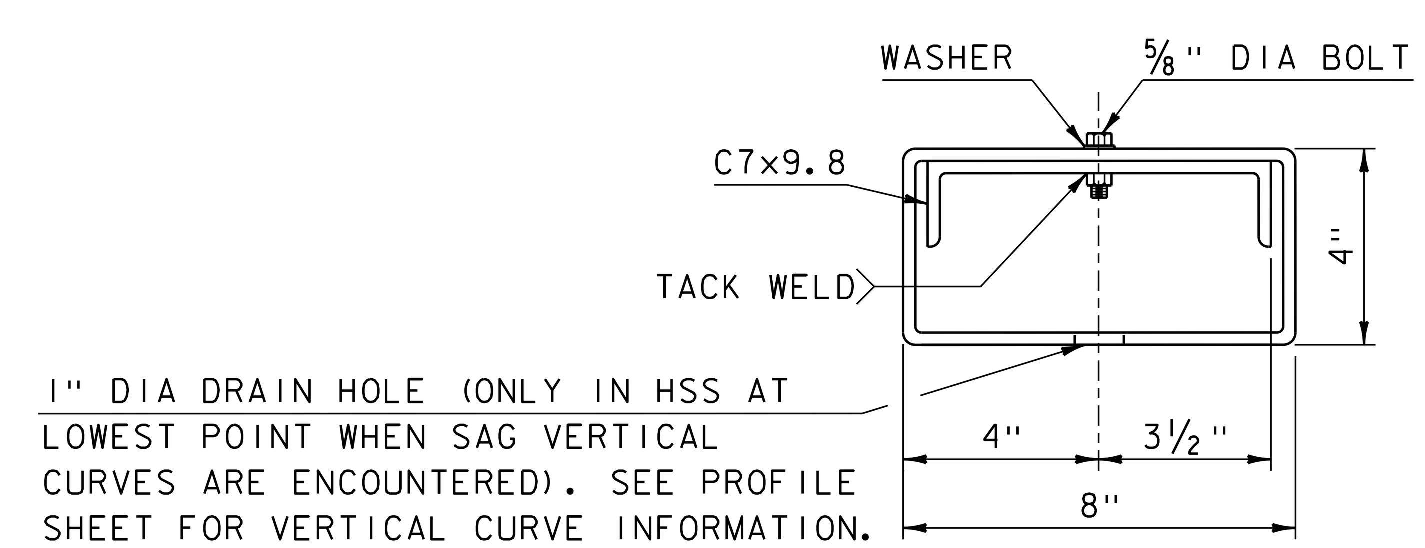
*FOR USE WITH PRESTRESSED CONCRETE BOX BEAMS:

DIMENSION ① IS 6" OR 8" DEPENDING ON BOX BEAM DEPTH. SEE PROJECT PLANS AND POST ANCHORAGE DETAILS. DIMENSION ② DETAILED BY FABRICATOR, SEE PROFILE AND CAMBER DETAILS. MINIMUM POST LENGTH IS 3'-6 1/2" AND MAXIMUM POST LENGTH IS 4'-1 1/4".



RAILING ELEVATION

(TYPE 1 POSTS SHOWN)



SECTION D-D

NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE.
4. SPLICES FOR THE STEEL BEAM GUARDRAIL SHALL LAP IN THE DIRECTION OF TRAFFIC.
5. A RAILING JOINT SPLICE SHALL BE PROVIDED IN ANY RAIL BAY SPANNING THE END OF AN INTEGRAL ABUTMENT BRIDGE AND AT ALL SUPERSTRUCTURE EXPANSION JOINTS.
6. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT.
7. THE 1/2" EXPANSION JOINT SHOWN IN THE RAILING ELEVATION IS DESIGNED FOR BRIDGE LENGTHS UP TO 80 FEET, ANY LONGER SPANS WILL HAVE TO BE MODIFIED TO ACCOUNT FOR THEIR MOVEMENT.
8. FOR RADII LESS THAN 950 FEET, HSS8x4 TUBES SHALL BE SHOP BENT TO FIT THE APPLICABLE CURVE.
9. THE MINIMUM DISTANCE FROM THE LAST POST TO THE END OF SLAB IS 1'-6".
10. FERRULES SHALL BE 12L14 COLD DRAWN CARBON STEEL.
11. HOLES IN RAIL FOR RAIL TUBE ATTACHMENT MAY BE FIELD DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
12. THIS RAILING MEETS THE REQUIREMENTS FOR A TL-2 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	MAY 24, 2012	ORIGINAL APPROVAL
1	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: G-1

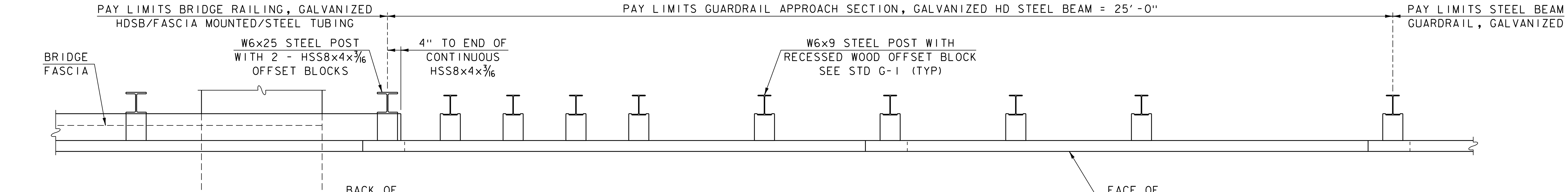
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

BRIDGE RAILING, GALVANIZED HDSB/FASCIA MOUNTED/STEEL TUBING

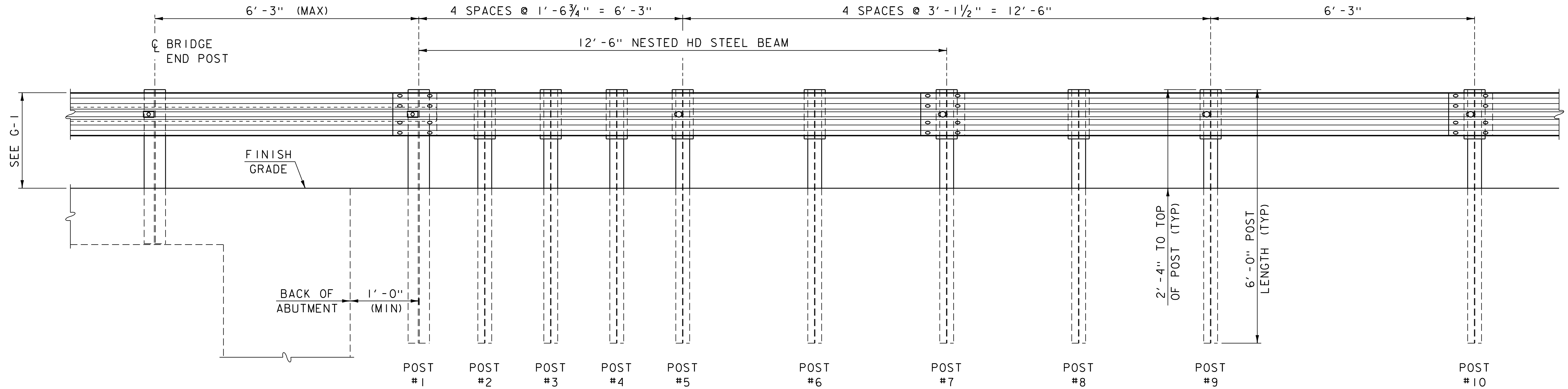
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD

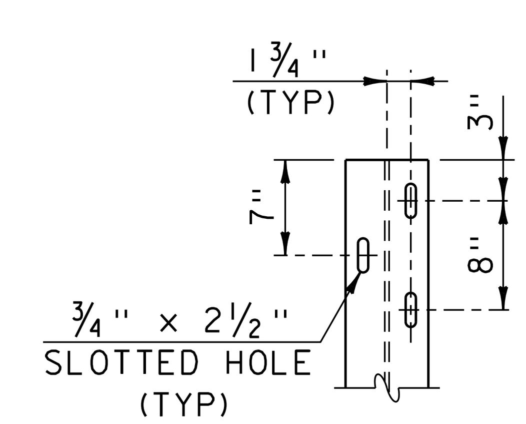
S-367A



RAILING PLAN



RAILING ELEVATION



POST #1 HOLE DETAIL

NOTES:

1. PAYMENT FOR POST #1, HSS8x4x3/16 OFFSET BLOCKS AND TUBULAR BACKUP RAIL EXTENDING TO POST #1 OFF THE BRIDGE SHALL BE MADE UNDER BRIDGE RAILING, GALVANIZED HDSB/FASCIA MOUNTED/STEEL TUBING.

2. BLOCKOUTS SHALL BE RECESSED WOOD ONLY. STEEL OR PLASTIC BLOCKOUTS ARE NOT PERMITTED.

3. GUARDRAIL IS NOT ATTACHED TO POST NUMBERS 2-4, 6 AND 8. THERE SHALL BE NO GAP BETWEEN THE POSTS THAT ARE NOT ATTACHED AND THE RAIL. OFFSET BLOCKS SHALL BE ATTACHED TO POST WITH STANDARD POST BOLT.

4. POSTS MAY BE SET IN DRILLED HOLES OR DRIVEN TO GRADE.

5. THIS RAILING MEETS THE REQUIREMENTS FOR A NCHRP REPORT 350 TL-3 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	MAY 24, 2012	ORIGINAL APPROVAL
1	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: G-1

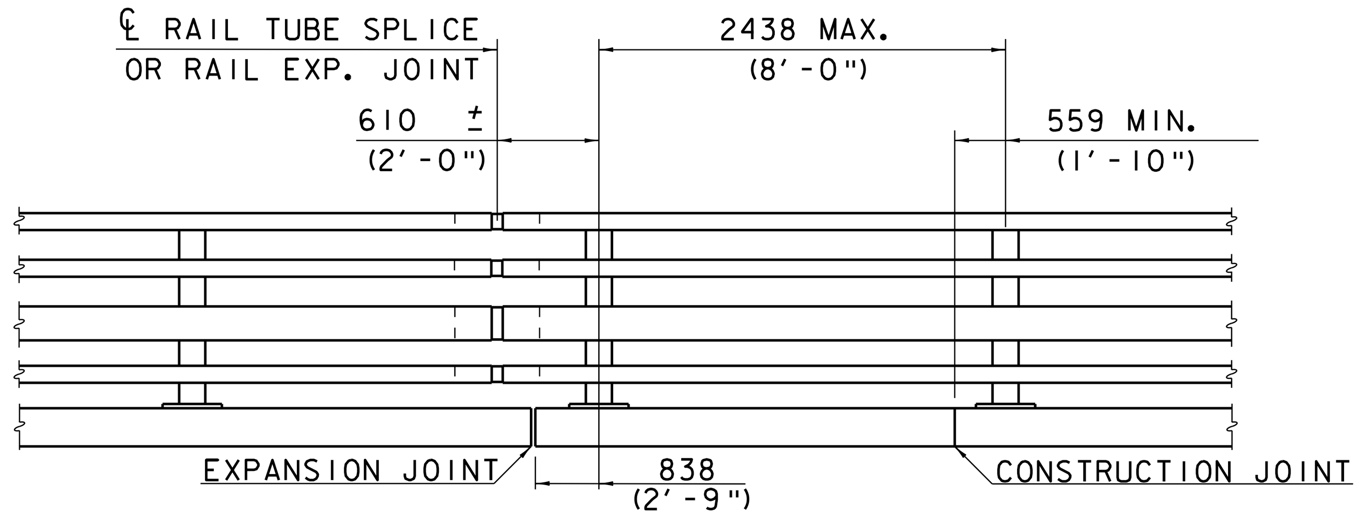
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED HD STEEL BEAM

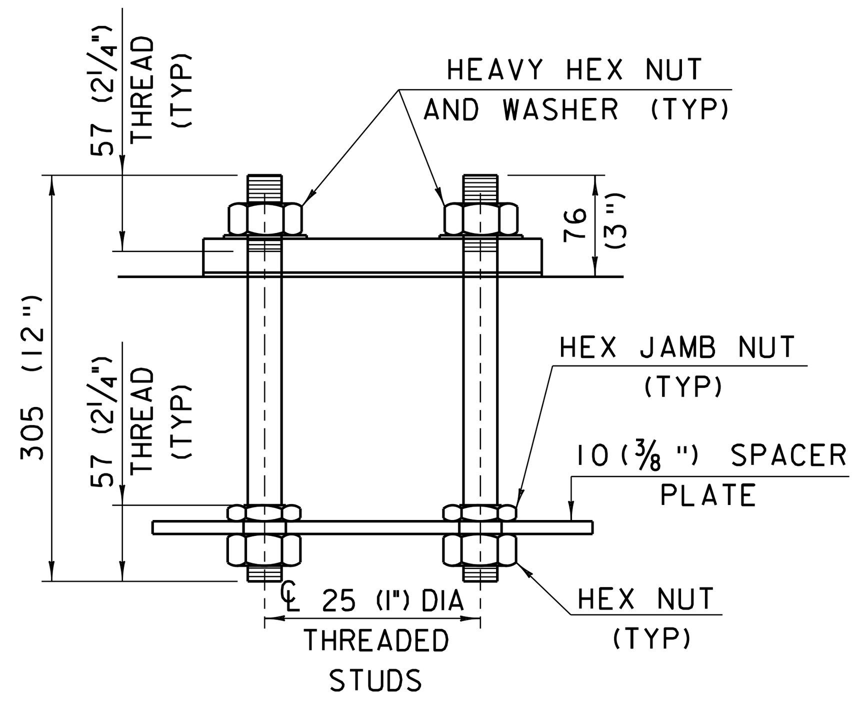
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD

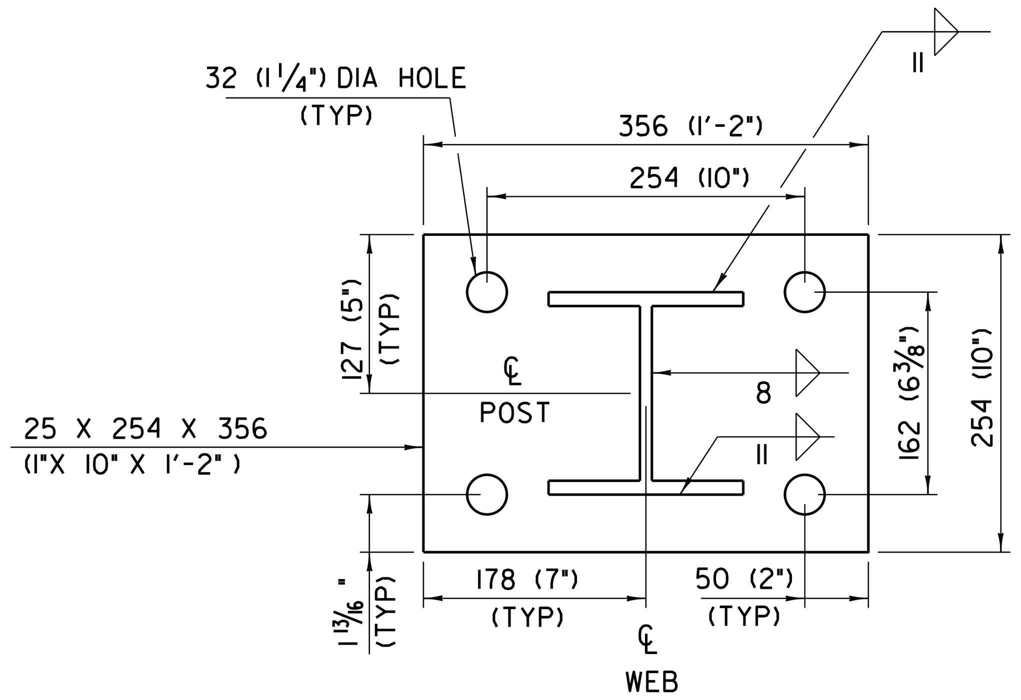
S-367B



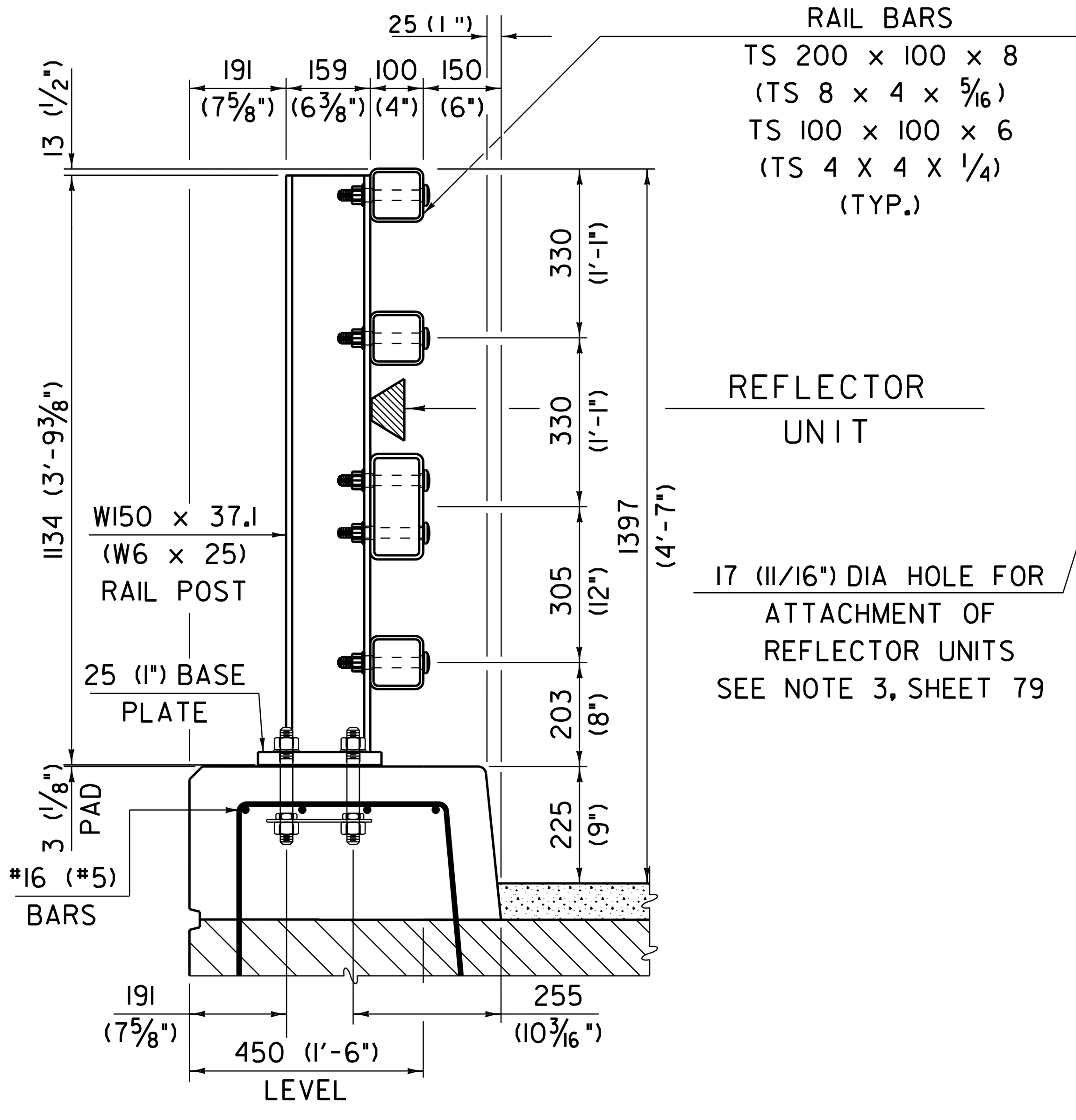
BRIDGE RAILING ELEVATION



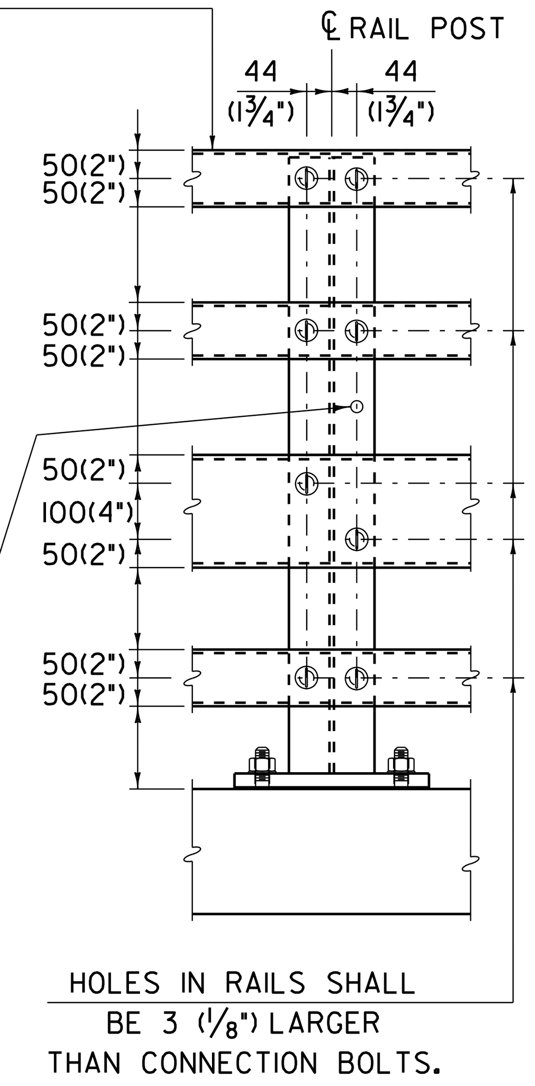
RAIL POST ANCHORAGE



POST AND BASE PLATE



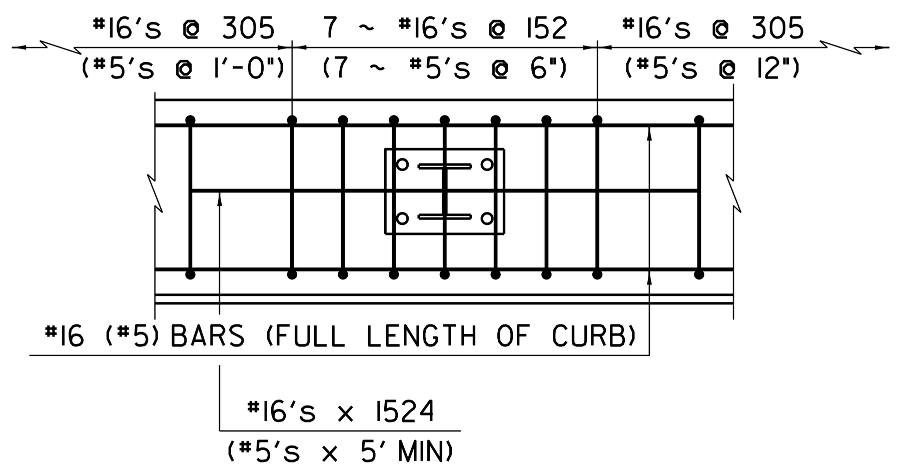
TYPICAL SECTION



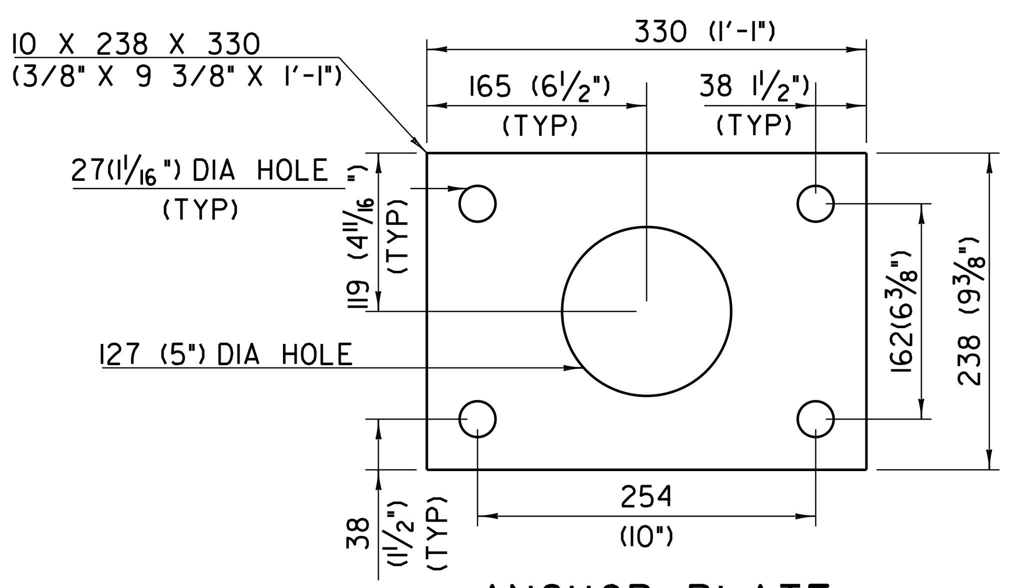
ELEVATION

NOTES

1. ALL WORK AND MATERIALS SHALL CONFORM TO THE PROVISIONS OF SECTION 525 - RAILINGS OF THE STANDARD SPECIFICATION FOR CONSTRUCTION.
2. TUBING AND POSTS SHALL MEET THE REQUIREMENTS OF SECTION 732.
3. ALL EXPOSED CUT OR SHEARED EDGES SHALL BE ROUNDED TO A 2 mm (1/16") RADIUS AND BE FREE OF BURRS.
4. RAIL POSTS SHALL BE SET NORMAL TO GRADE.
5. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO (2) RAIL POSTS AND PREFERABLY TO AT LEAST FOUR (4) POSTS.
6. RAIL TUBE EXPANSION JOINTS SHALL BE PROVIDED IN ANY RAIL BAY SPANNING A SUPERSTRUCTURE EXPANSION JOINT. EXPANSION JOINT WIDTH SHALL BE "X" AT 7°C (45°F) AND WILL BE ADJUSTED IN THE FIELD BY THE ENGINEER FOR OTHER TEMPERATURES.
7. RAIL POSTS ANCHORING NUTS SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL ONE-EIGHTH TURN.
8. RAIL TUBES SHALL BE ATTACHED USING 75 mm (3") FULL DIAMETER BODY AASHTO M164M (TYPE 1) ROUND HEAD BOLTS INSERTED THROUGH THE FACE OF THE TUBE. HOLES IN POSTS SHALL BE 2 mm (1/16") LARGER THAN THE BOLT SIZE.
9. HOLES IN RAILS FOR RAIL TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO ERECTION.
10. ANY BENDING OF RAIL SHALL BE DONE AT A FABRICATOR PLANT, ACCORDING TO A PROCEDURE PROVIDED BY THE FABRICATOR.
11. THE FABRICATOR SHALL SUBMIT FABRICATION DRAWINGS INCLUDING WELDING PROCEDURES TO THE STRUCTURES SECTION FOR APPROVAL IN ACCORDANCE WITH SECTION 105.



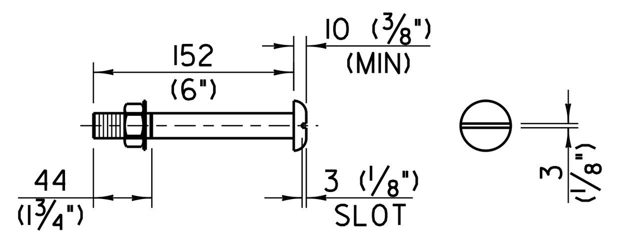
CURB REINFORCING PLAN



ANCHOR PLATE

MATERIALS

3 mm (⅛") PAD SHALL COMPLY WITH SUBSECTION 731.01 OR 731.02.

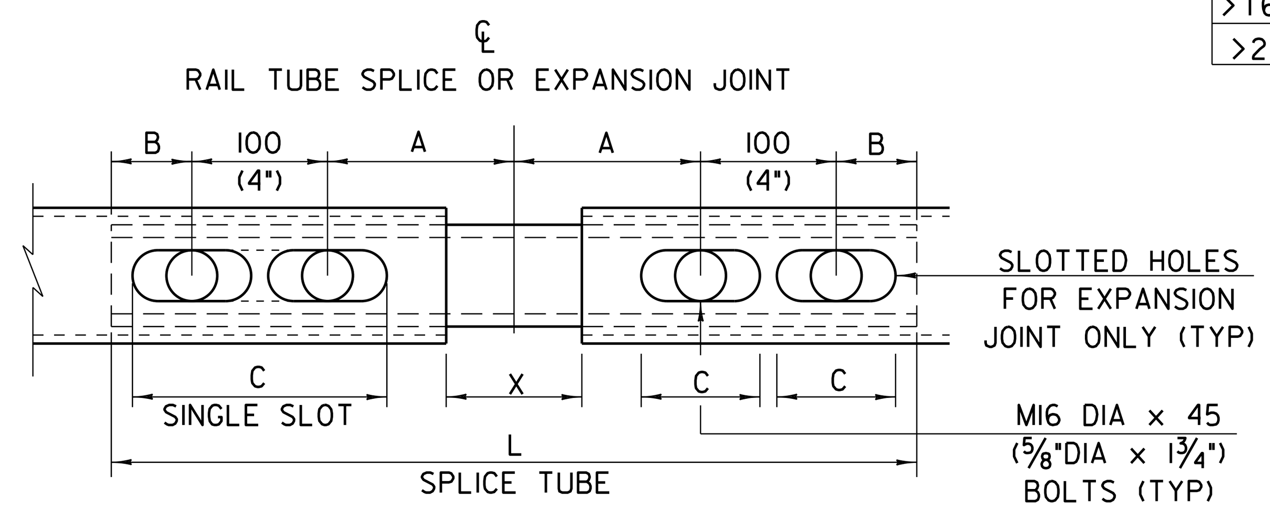


19 (¾") DIA M164 (TYPE 1) ROUND HEAD BOLT

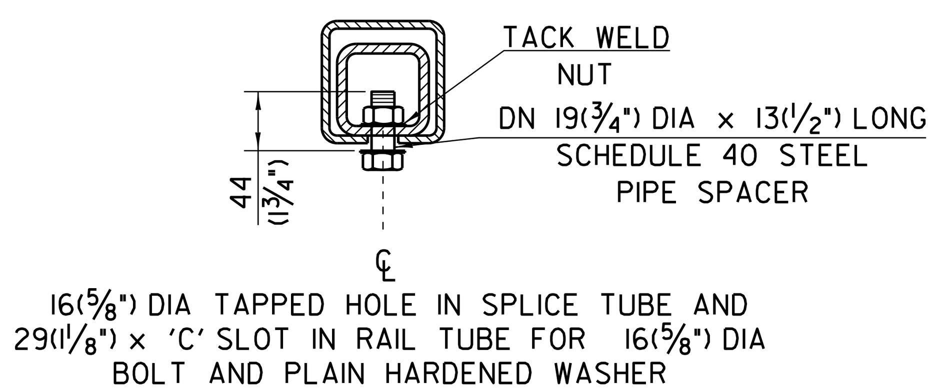
(WITH WASHER AND PREVAILING TORQUE TYPE LOCK NUT)
(SEE NOTE #8)
ONLY FULL DIAMETER BODY BOLTS WILL BE ALLOWED.

SPLICE TABLE					
T	A	B	C	L	X
N/A	100 (4")	50 (2")	--	508 (20")	19 (¾")
EXPANSION JOINT TABLE					
<100 (4")	100 (4")	50 (2")	64 (2½")	508 (20")	64 (2½")
>100 (4") <165 (6½")	140 (5½")	60 (2⅜")	89 (3½")	603 (23¾")	100 (4")
>165 (6½") <229 (9")	163 (6½")	86 (3⅜")	229 (9") *	705 (27¾")	127 (5")
>229 (9") <330 (13")	216 (8½")	111 (4⅜")	279 (11") *	857 (33¾")	179 (7")

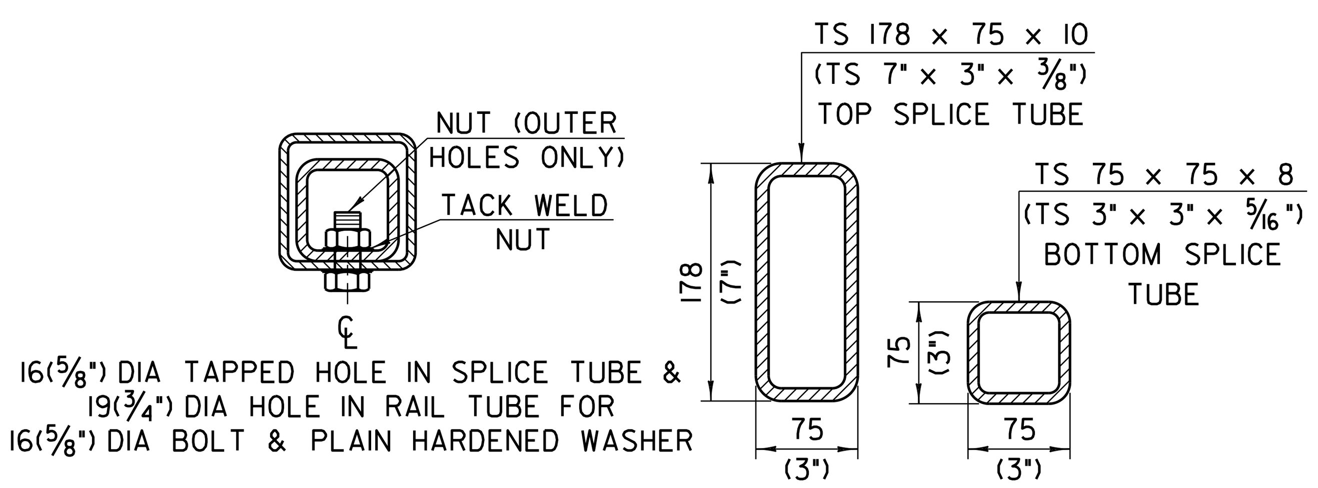
T = TOTAL MOVEMENT AT RAIL EXPANSION JOINT AS SHOWN ON THE CONTRACT PLANS. SEE NOTE 6.
* = SINGLE SLOT



RAIL TUBE SPLICE AND RAIL EXPANSION JOINT DETAIL
(BOTTOM VIEW)



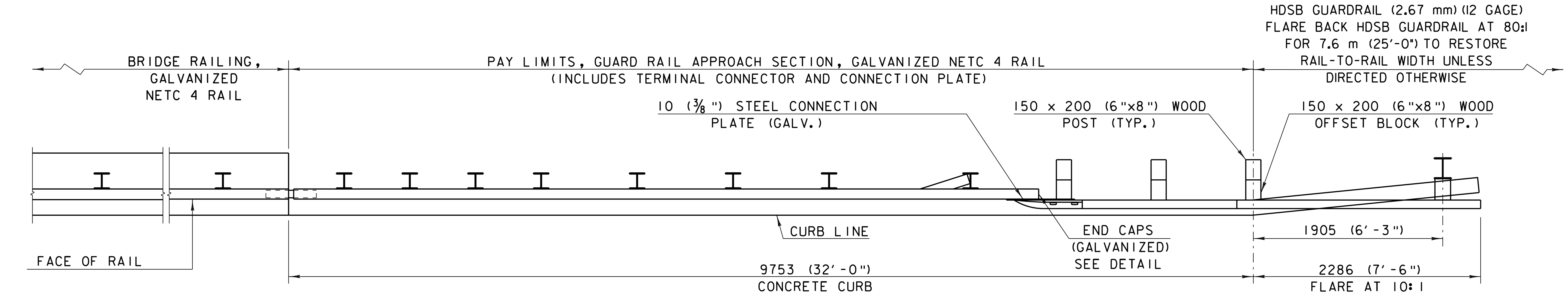
EXPANSION JOINT SECTION
FOR DETAILS NOT SHOWN,
SEE "RAIL TUBE SPLICE SECTION."



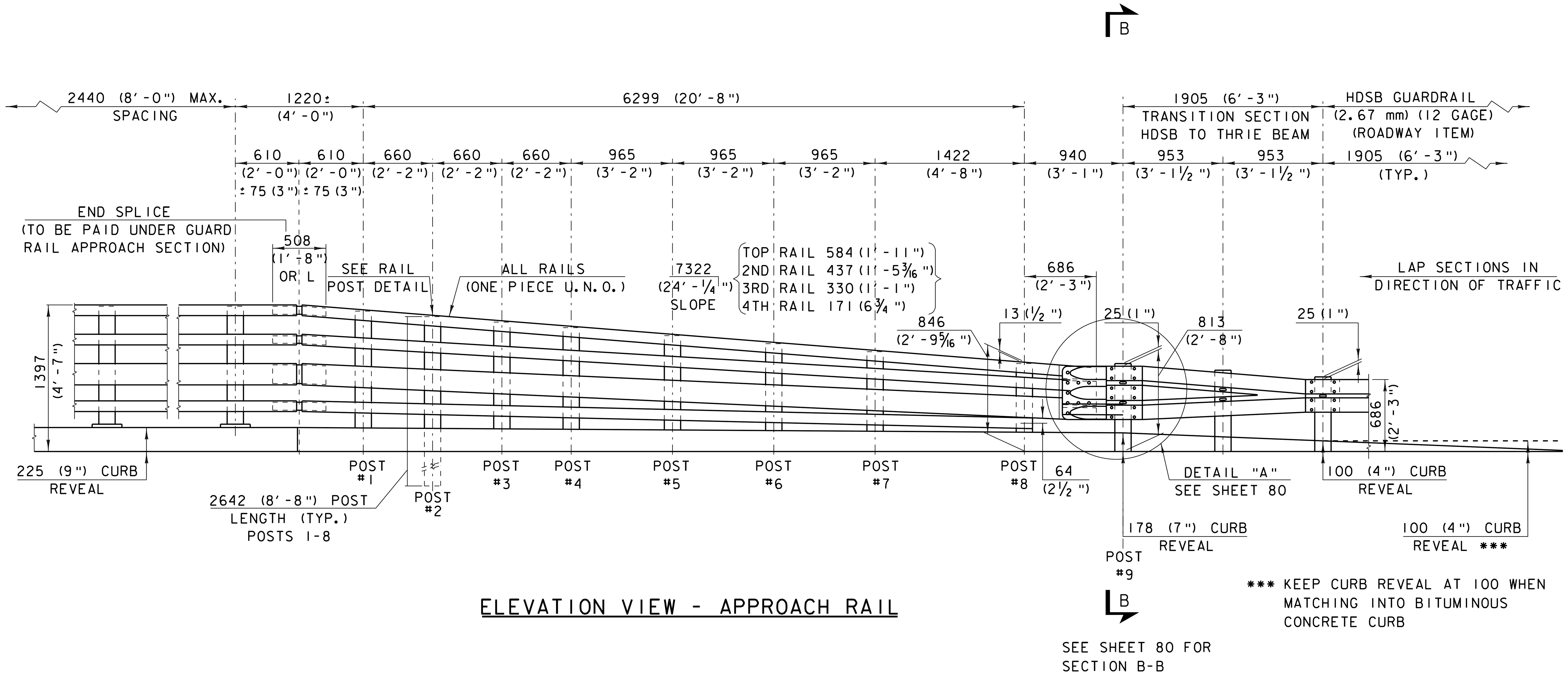
RAIL TUBE SPLICE SECTION

ALL DETAILS NOT TO SCALE

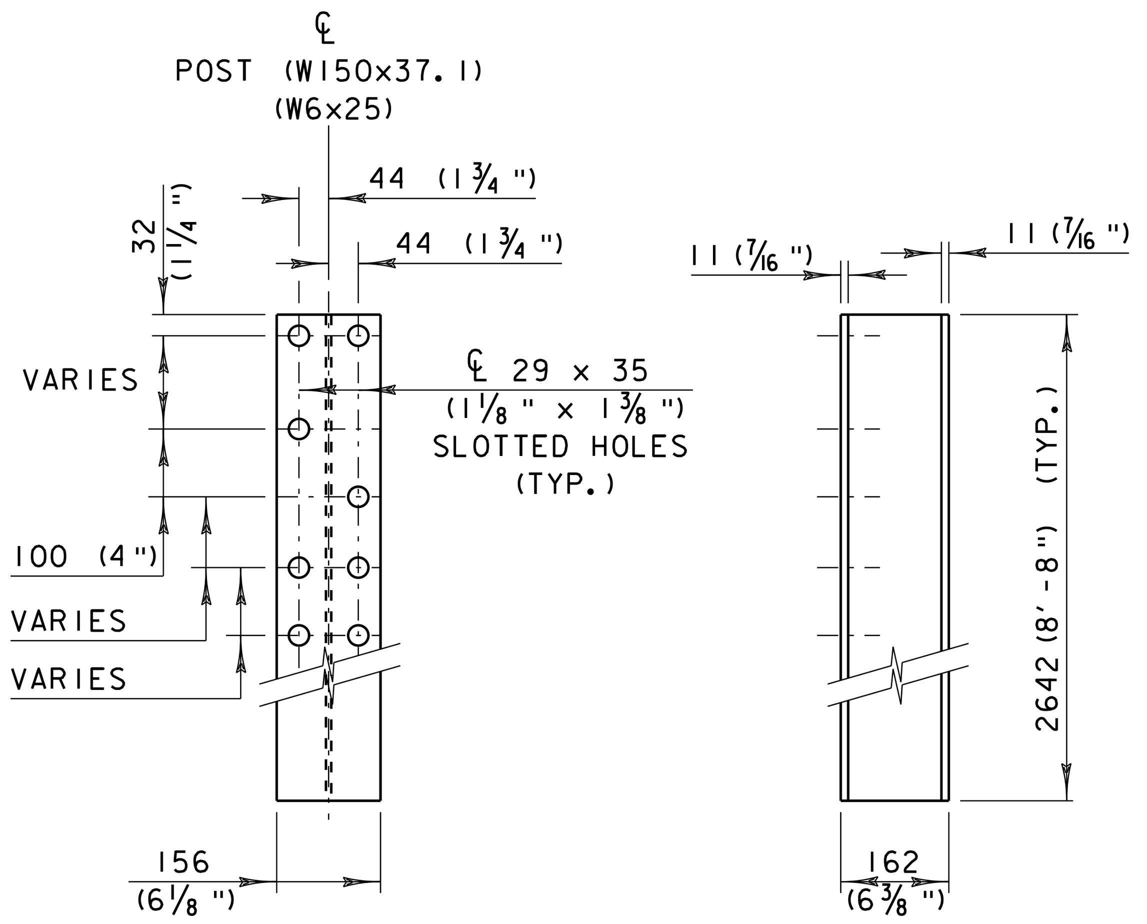
PROJECT: STOCKBRIDGE	PROJECT NO.: BRF 022-1(20)
DESIGN FILE NAME: 85e039\Structures\de039rail.dgn	
IPARM FILE NAME: de039rail2m.i	PLOT DATE: 08-APR-2010
DESIGNED BY: H. I. SALLS	DRAWN BY: H. I. SALLS
SQUAD LEADER: C. P. WILLIAMS	CHECKED BY: R. S. YOUNG
RAILING DETAIL 1	SHEET: 78 OF 139



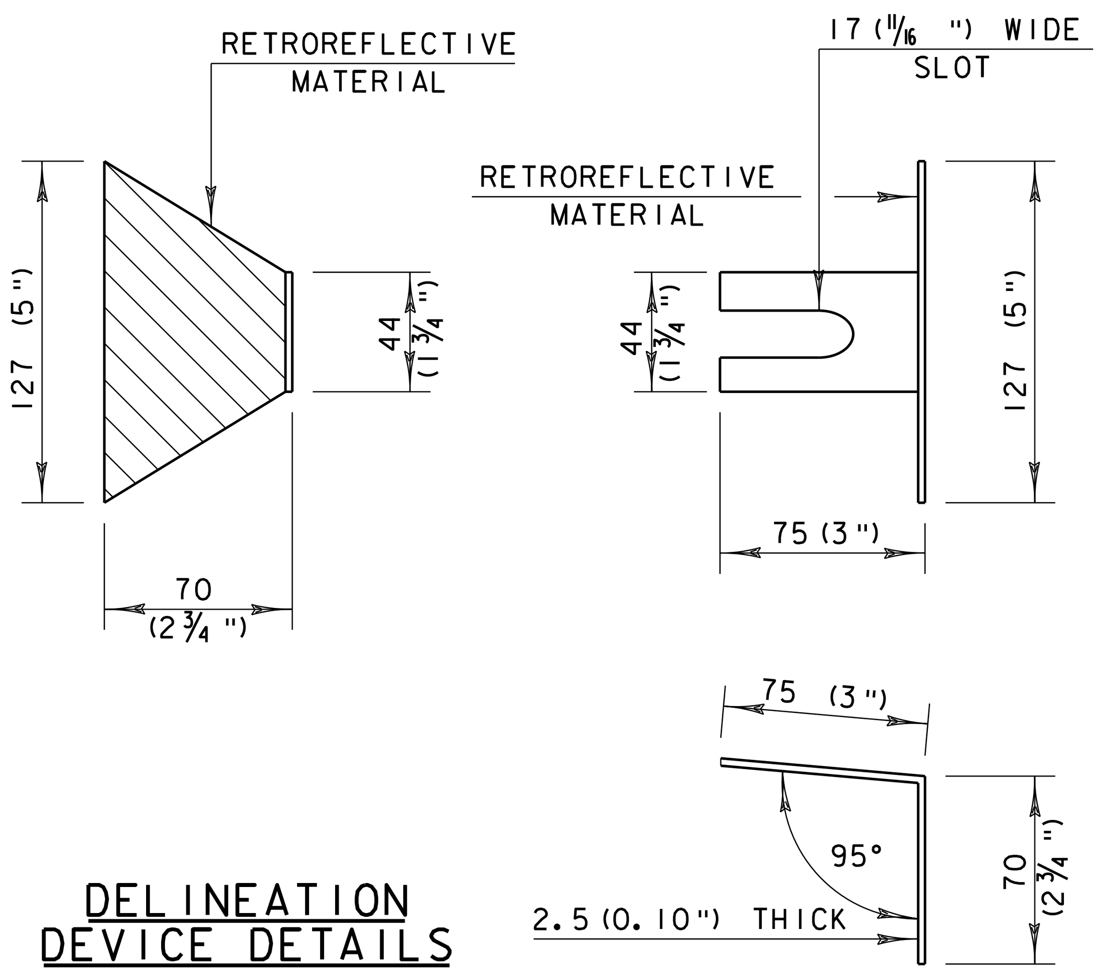
PLAN VIEW - APPROACH RAIL



ELEVATION VIEW - APPROACH RAIL



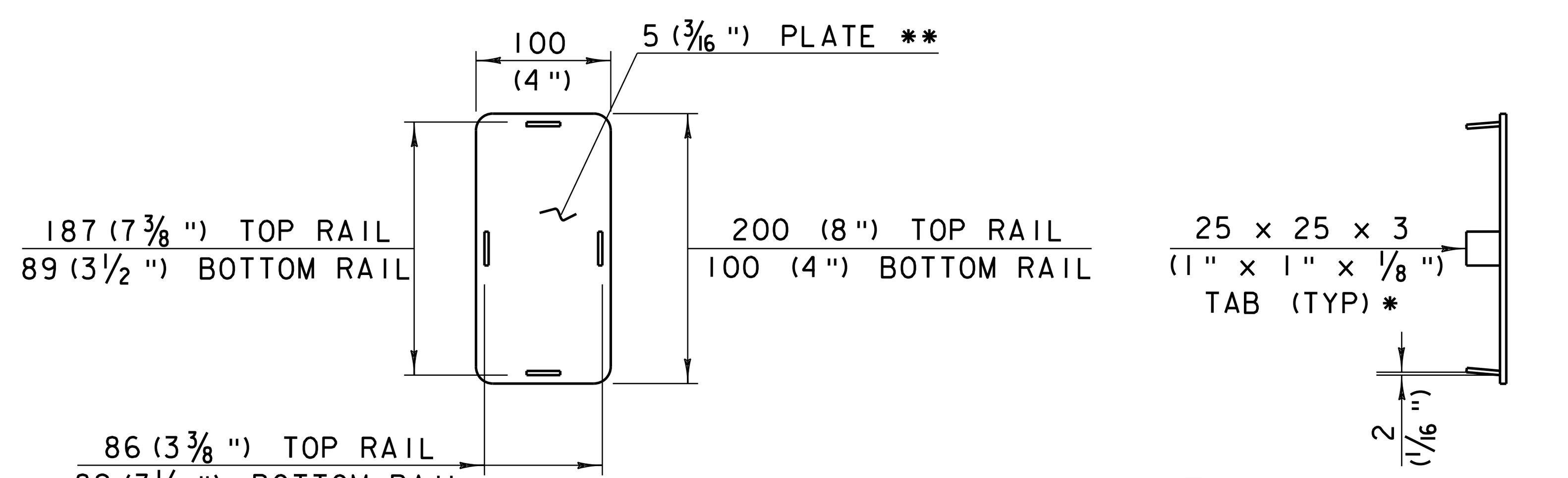
RAIL POST



DELINEATION DEVICE DETAILS

NOTES

1. REFER TO SHEET 78 FOR ADDITIONAL DETAILS, NOTES AND MATERIAL SPECIFICATIONS.
2. PAYMENT FOR GUARD RAIL APPROACH SECTION, GALVANIZED NETC 4 RAIL SHALL INCLUDE THE TERMINAL CONNECTOR, THE CONNECTION PLATE, RAIL, POSTS, BLOCKS AND ATTACHMENT HARDWARE.
3. RETROREFLECTIVE MATERIAL SHALL MEET REQUIREMENTS OF SUBSECTION 750.08 AND SHALL BE OF ENCAPSULATED LENS SILVER INSTALLED ON DRIVER'S RIGHT.
4. ALL APPROACH RAIL SPLICES SHALL BE LAPPED IN THE DIRECTION OF TRAFFIC FLOW.
5. ALL BRIDGE APPROACH RAIL MATERIALS, DIMENSION SIZES AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED.
6. APPROACH RAIL BOLTS SHALL BE ASTM A307 GRADE A AND NUTS SHALL BE AASHTO M291M (ASTM A563 GRADE A OR BETTER) (GALVANIZED). WASHERS SHALL BE ASTM F844.
7. WELD SPLICE BARS TO FIT BEND. USE COMPLETE PENETRATION WELD (B-U2).
8. THE CONCRETE CURB WILL BE PAID FOR AS ITEM 616.28, "CAST-IN-PLACE CONCRETE CURB, TYPE B."



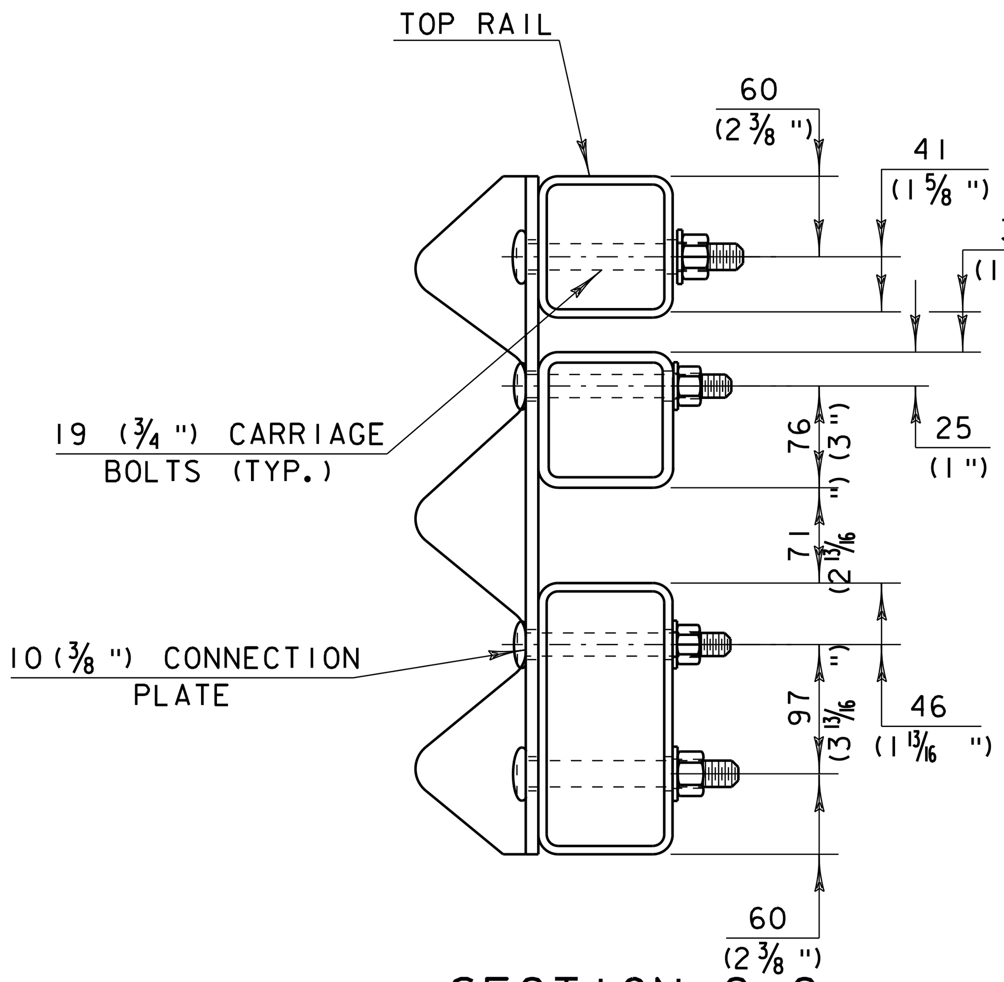
END CAP DETAIL

* WELD TABS TO END CAP PLATE IN TAPERED POSITION SO CAP CAN BE JAMMED INTO END OF RAIL TUBE.
** ROUND CORNERS 13 (1/2") RADIUS (TYP)

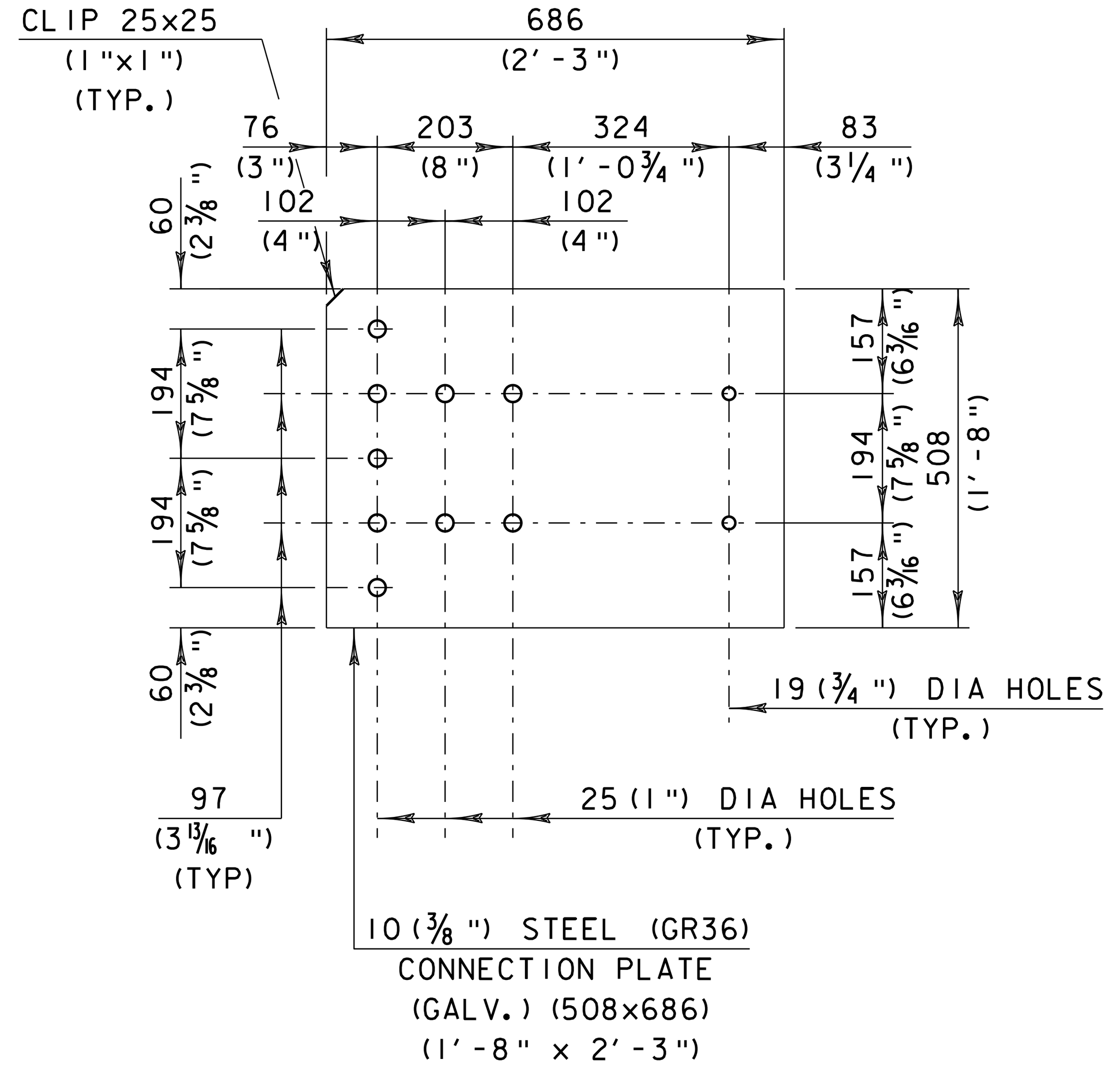
ALL DETAILS NOT TO SCALE

PROJECT: STOCKBRIDGE	PROJECT NO.: BRF 022-1(20)
DESIGN FILE NAME: 85e039\Structures\de039rail.dgn	
IPARM FILE NAME: de039raillm.i	PLOT DATE: 08-APR-2010
DESIGNED BY: H. I. SALLS	DRAWN BY: H. I. SALLS
SQUAD LEADER: C. P. WILLIAMS	CHECKED BY: R. S. YOUNG
RAILING DETAIL 2	SHEET: 79 OF 139

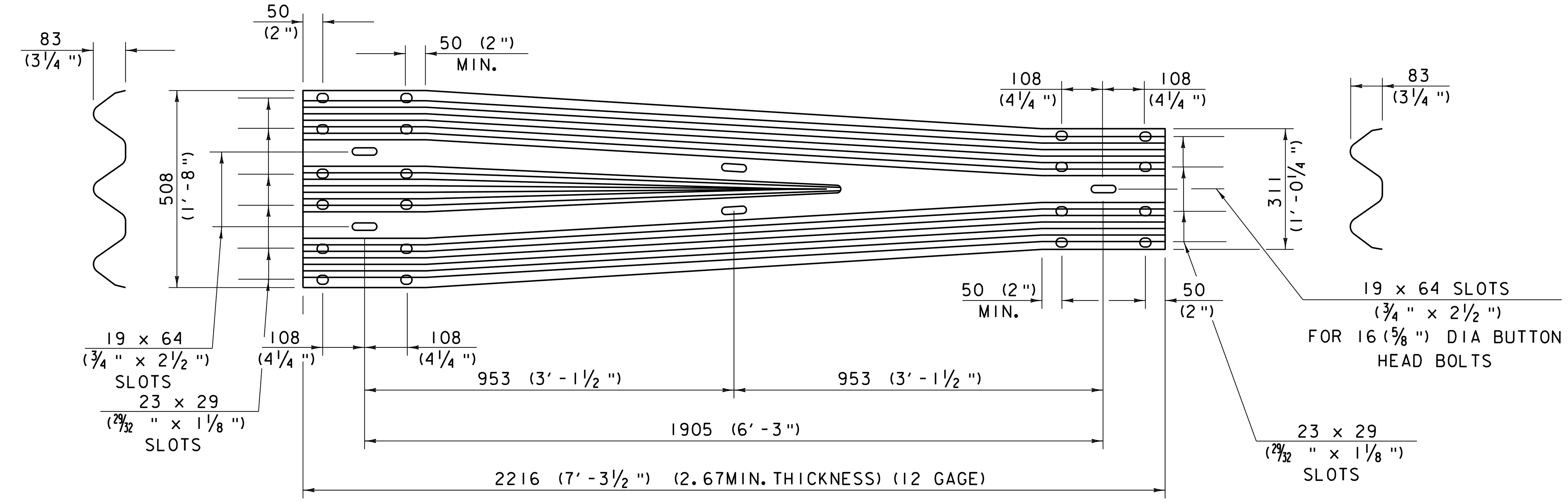
Metric



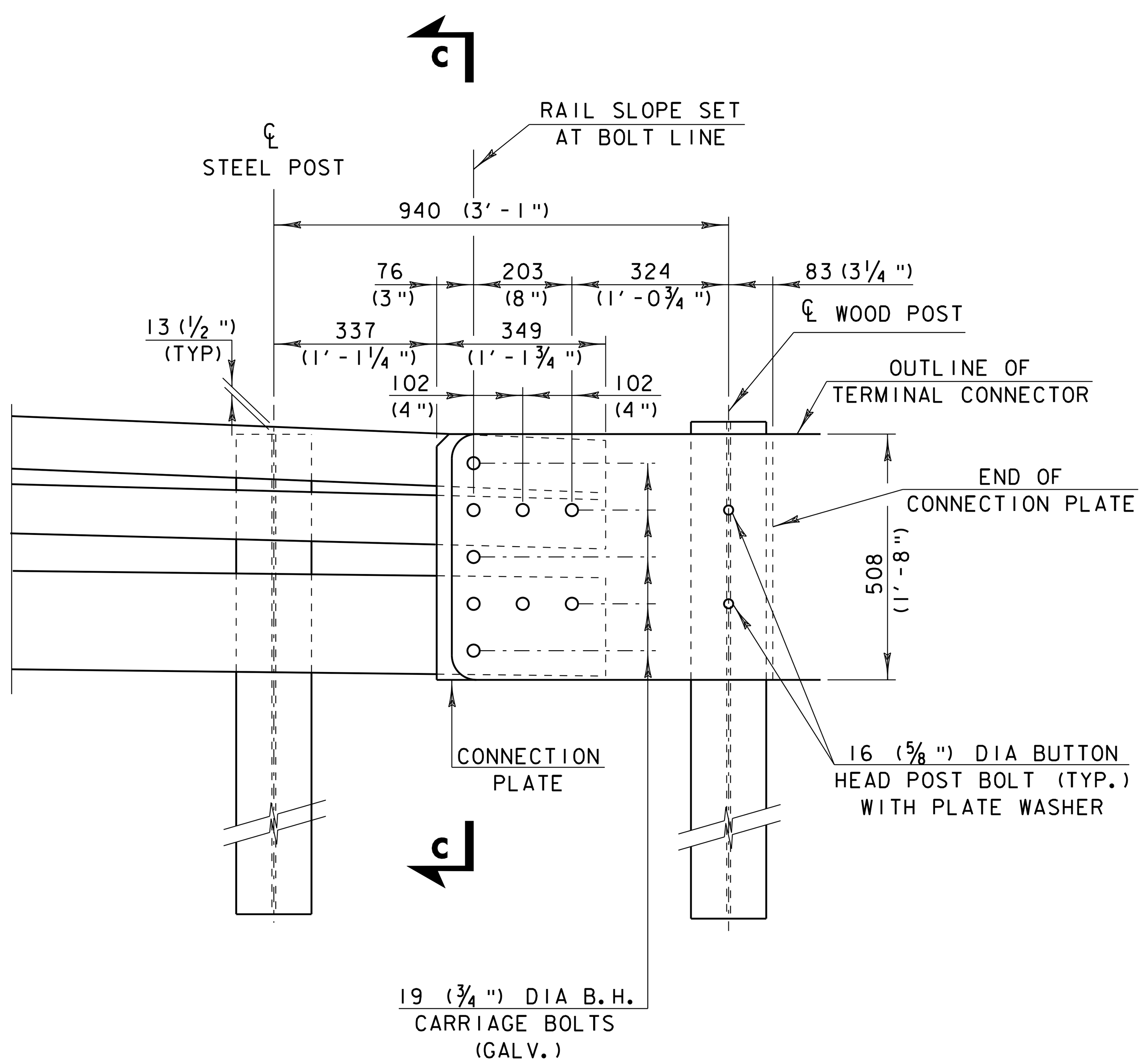
SECTION C-C
(CONNECTION PLATE)



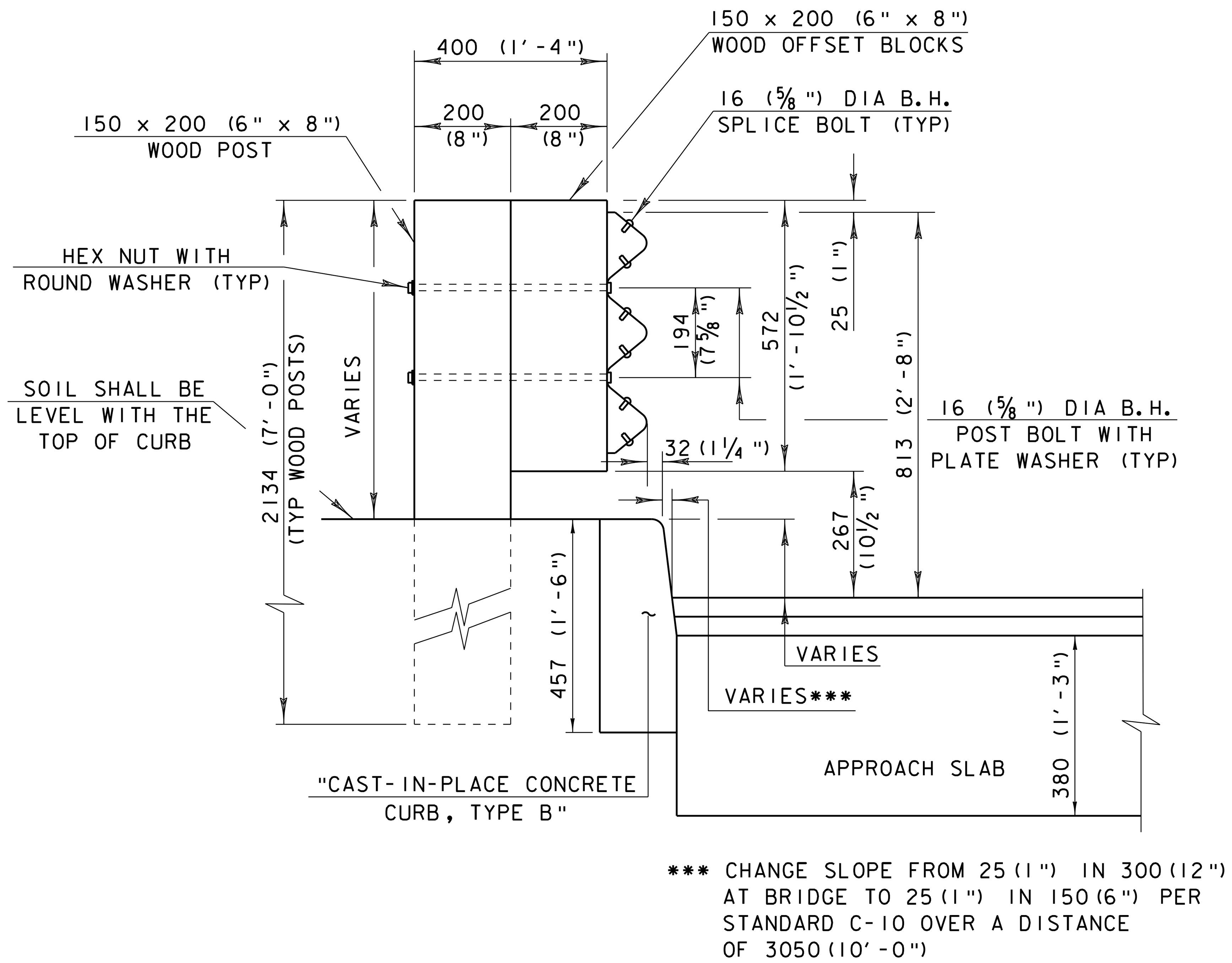
CONNECTION PLATE



THRIE-BEAM TO HDSB
TRANSITION SECTION
(HM-TF-13/RE-69)

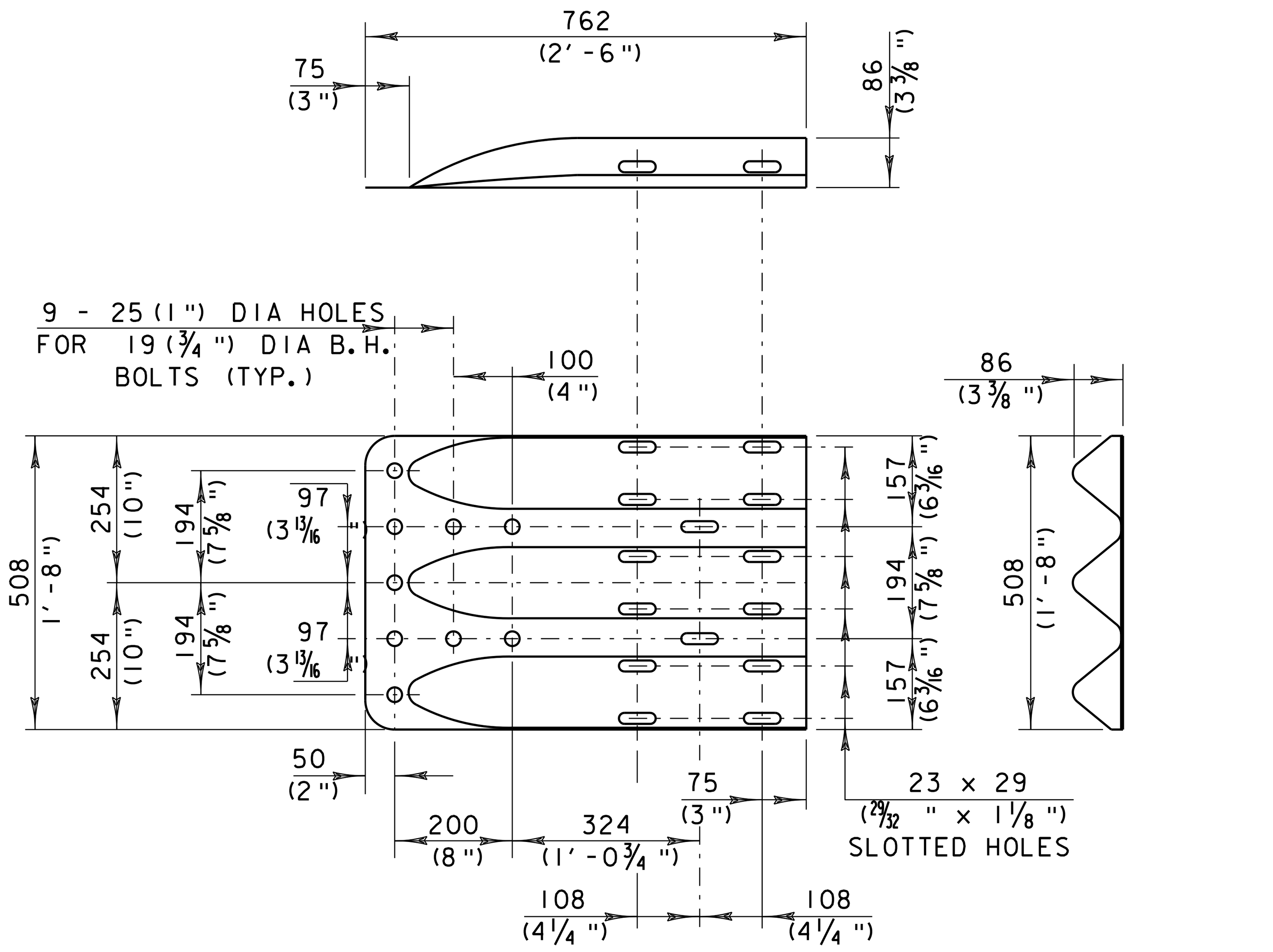


DETAIL A



*** CHANGE SLOPE FROM 25 (1") IN 300 (12") AT BRIDGE TO 25 (1") IN 150 (6") PER STANDARD C-10 OVER A DISTANCE OF 3050 (10'-0")

SECTION B-B (POST RAIL ASSEMBLY)

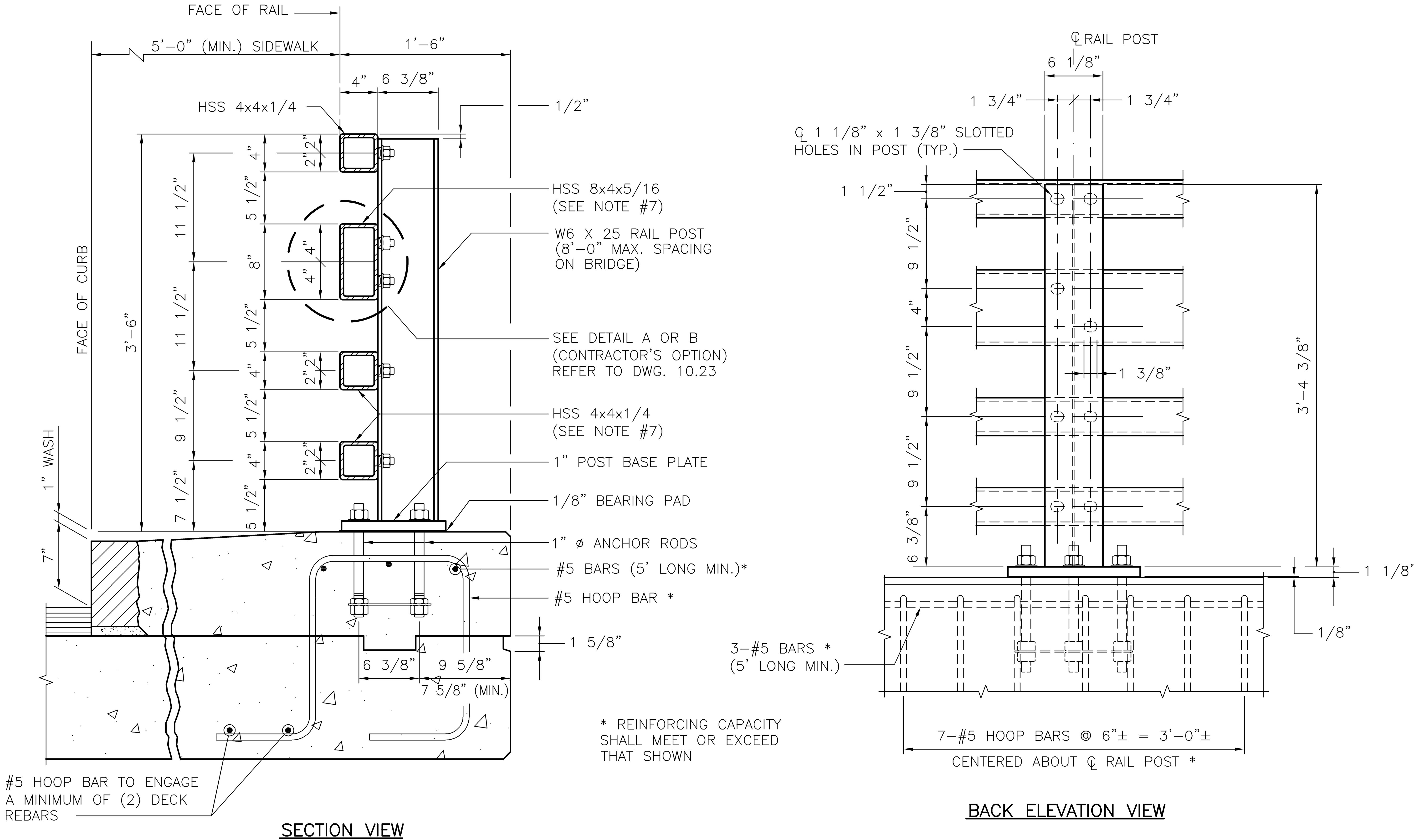


THRIE-BEAM TERMINAL CONNECTOR
(HM-TF-13/RE-67)

ALL DETAILS NOT TO SCALE

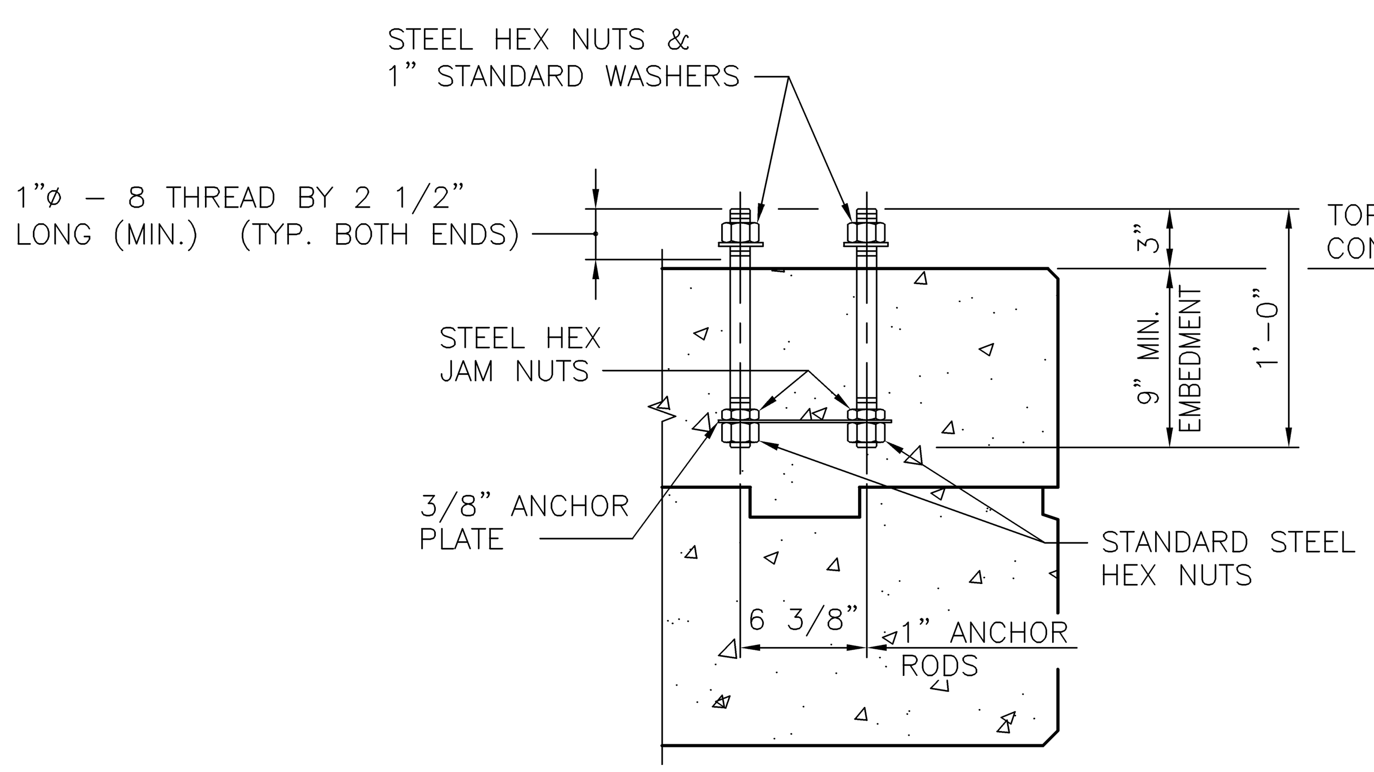
PROJECT: STOCKBRIDGE	PROJECT NO.: BRF 022-1 (20)
DESIGN FILE NAME: 85e039\Structures\de039rail.dgn	
IPARM FILE NAME: de039rail3m.i	PLOT DATE: 08-APR-2010
DESIGNED BY: H. I. SALLS	DRAWN BY: H. I. SALLS
SQUAD LEADER: C. P. WILLIAMS	CHECKED BY: R. S. YOUNG
RAILING DETAIL 3	SHEET: 80 OF 139

APPENDIX D: RHODE ISLAND DOT STANDARD BRIDGE RAIL DRAWINGS



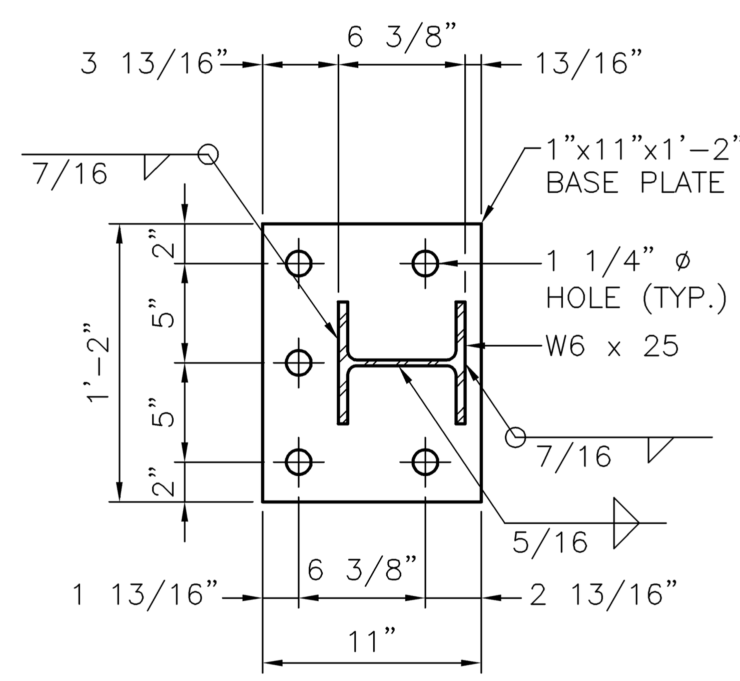
POST ASSEMBLY

SCALE:1 1/2"=1'–0"



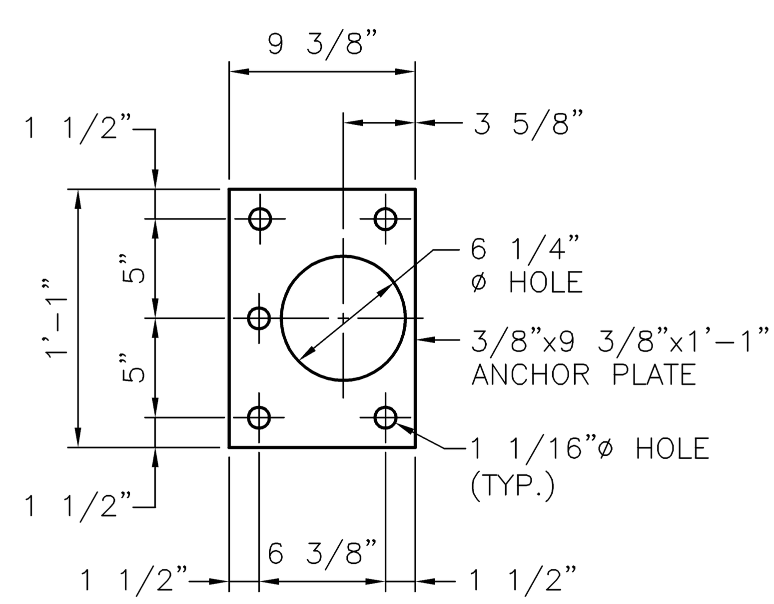
POST ANCHOR ASSEMBLY

SCALE:1 1/2"=1'–0"



POST BASE PLATE

SCALE:1 1/2"=1'–0"



ANCHOR PLATE

SCALE:1 1/2"=1'–0"

RAIL NOTES:

1. FOUR BAR (CRASH–TESTED) STEEL BRIDGE RAIL SHALL INCLUDE POSTS, BASE PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, RETRO REFLECTIVE DELINEATORS, ALL APPURTENANCES, METALIZING, AND PAINTING (IF SPECIFIED).
2. BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 1.5% WHERE POSTS SHALL BE SET VERTICAL.
3. ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.
4. EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.
5. BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.
6. AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. ALL 4 RAILS AT A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT END SPLICES AND AT INTERIOR EXPANSION SPLICES PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON BOTH SIDES.
7. MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE.
8. NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER METALIZING, (EXCEPT FOR DETAIL "A"). DAMAGED AREAS OF METALIZING SHALL BE REPAIRED IN STRICT CONFORMANCE WITH THE MATERIAL SUPPLIER'S RECOMMENDATIONS AND SHALL BE APPROVED BY THE ENGINEER.
9. NUTS FOR 1"ø THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.
10. THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.

MATERIAL NOTES:

11. STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V–NOTCH REQUIREMENTS OF 15 LBS. AT 0°F FOR ASTM A500, GRADE B. THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V–NOTCH IS NOT REQUIRED FOR SPLICE TUBES.
12. RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR. 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.
13. THREADED STUDS AND MATCHING NUTS FOR RAIL–TO–POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM 563 GRADE A RESPECTIVELY OR BETTER. ANCHOR RODS SHALL CONFORM TO ASTM A449 EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22.
14. ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE METALIZED AFTER FABRICATION IN CONFORMANCE WITH SECTION 827 "THERMAL SPRAYED ZINC COATING FOR NEW STRUCTURAL STEEL" OF THE RHODE ISLAND STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION. THE METALIZING SHALL HAVE A UNIFORM APPEARANCE, AND METALIZED MATERIAL SHALL BE PROPERLY STORED.
15. DETAIL "A" STUDS SHALL BE WELDED BEFORE TUBES ARE METALIZED.
16. PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

DESIGNER NOTE:
PROVIDE PAINT COLOR FOR RAILING SYSTEM.

THIS BRIDGE RAIL SYSTEM WAS SUCCESSFULLY CRASH TESTED FOR AASHTO TL4 IN 1997 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM.

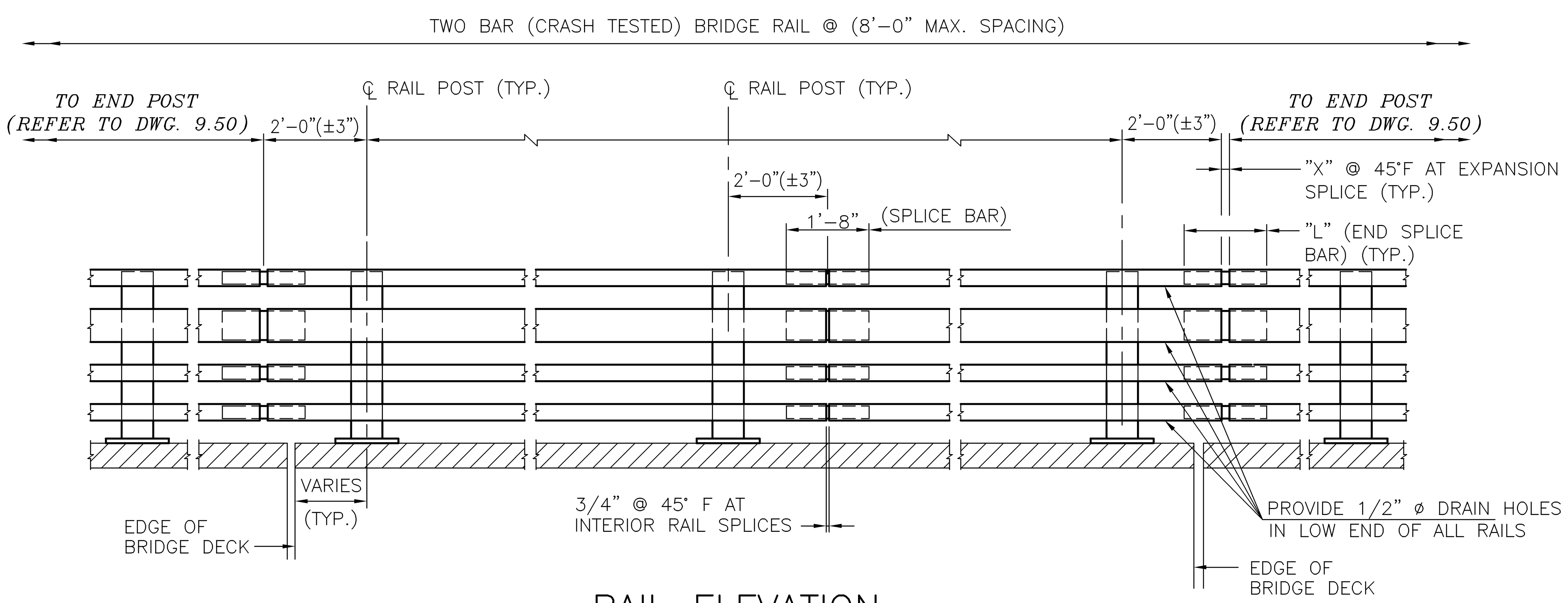
REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

BRIDGE STANDARDS

FOUR BAR STEEL BRIDGE RAIL (CRASH–TESTED TL–4) SHEET 1

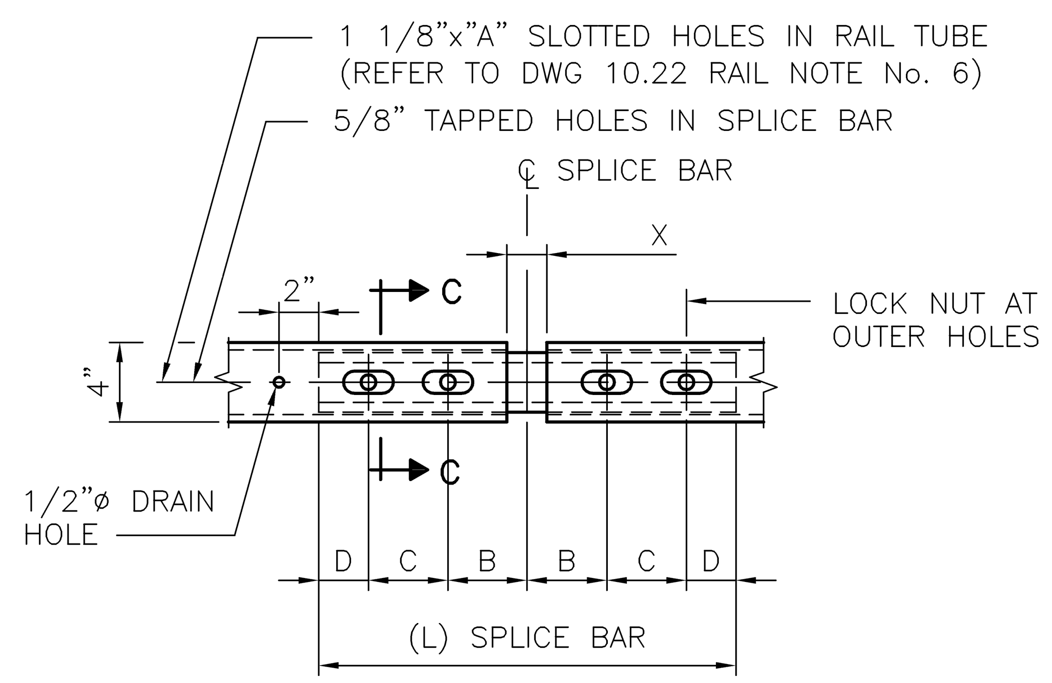
DRAWING NUMBER: 10.22



RAIL ELEVATION
SCALE:1/2"=1'-0"

SPLICE BAR DIMENSION TABLE							
	T	A	B	C	D	X	L
	INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
*	<3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
*	3 1/4" TO 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

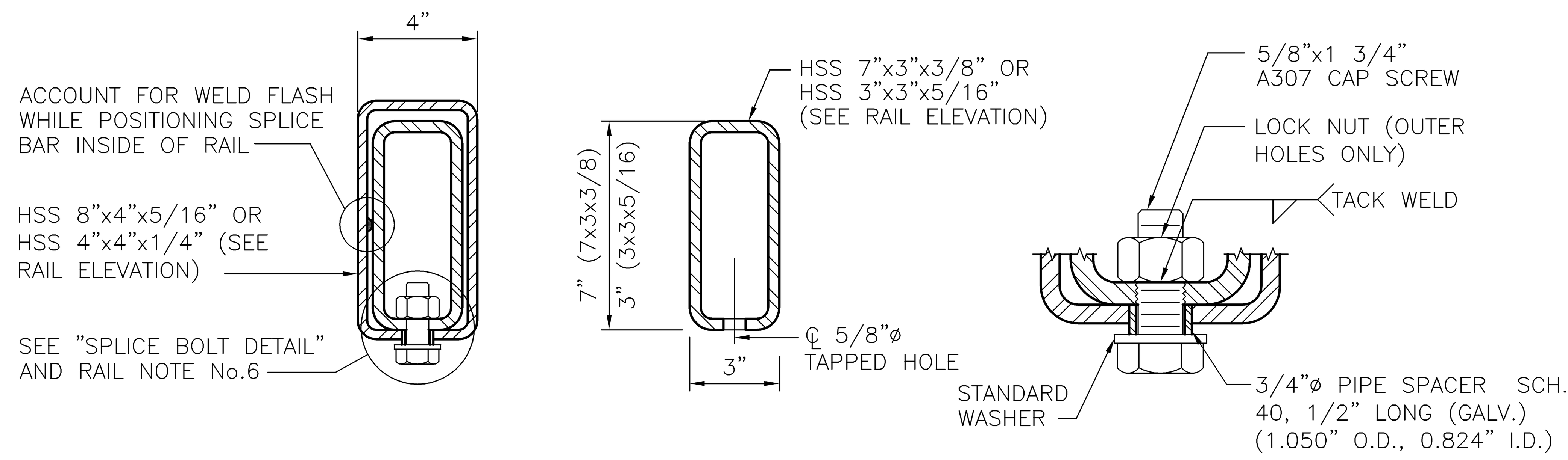
T = TOTAL MOVEMENT OF BRIDGE
* = END SPLICE BAR



SEE SPLICE BAR DIMENSION TABLE THIS SHEET

(BOTTOM VIEW)

RAIL SPLICE
SCALE: 1 1/2"=1'-0"

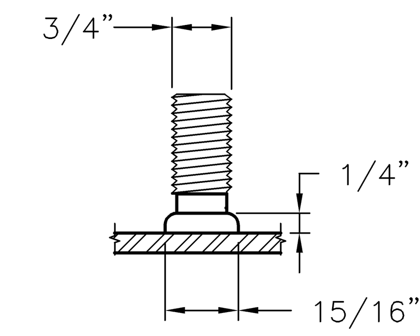


SECTION C-C

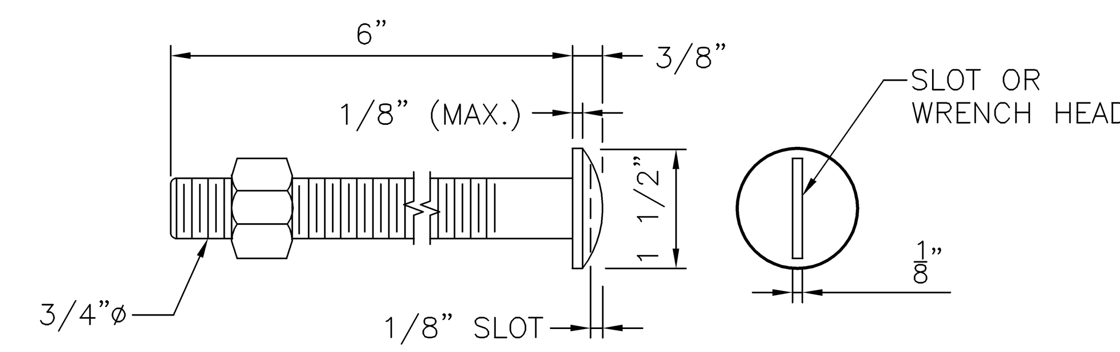
SPLICE BAR SECTION

SPLICE BOLT DETAIL

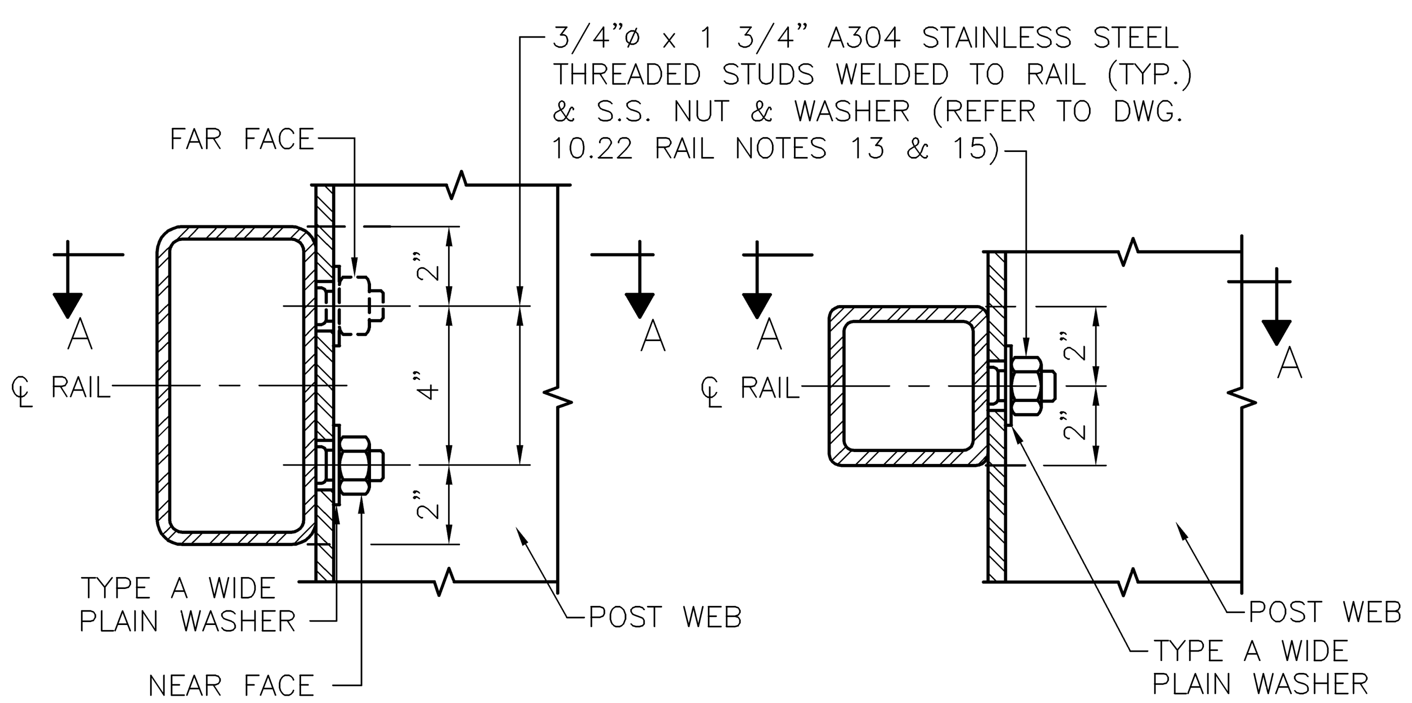
RAIL SPLICE DETAILS
SCALE: 3"=1'-0"



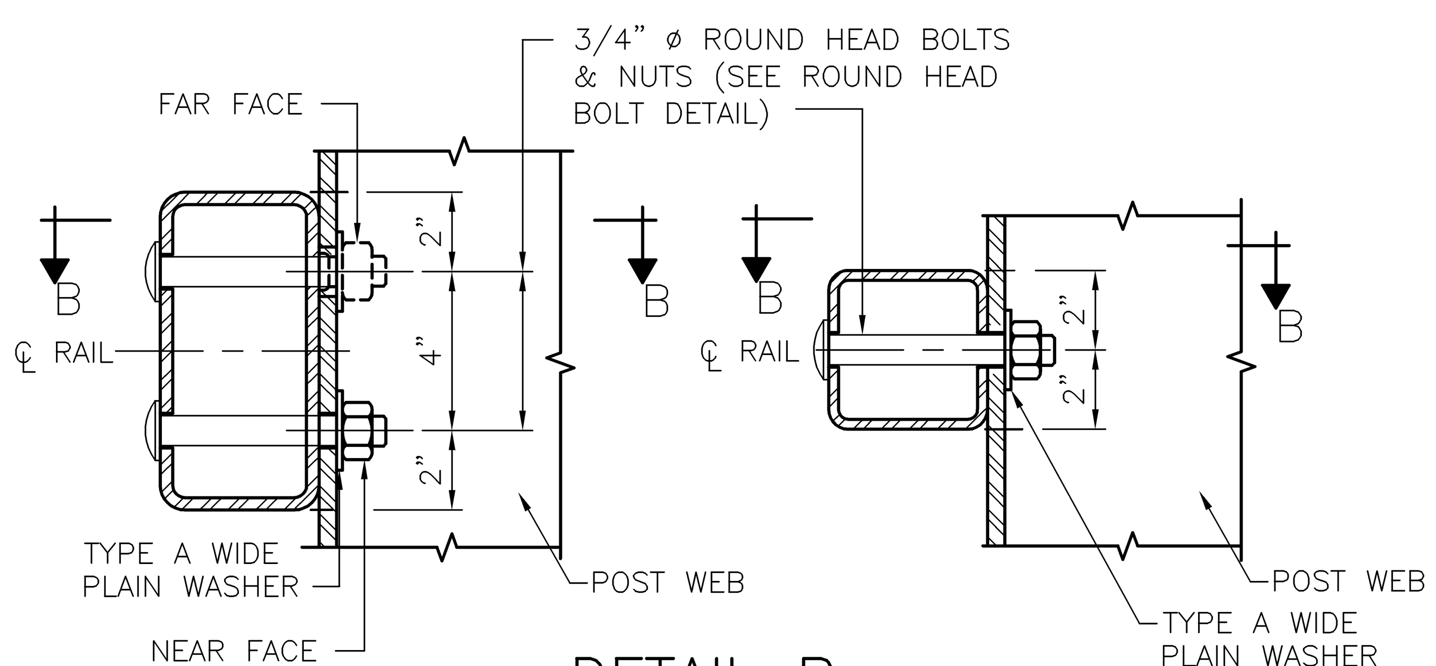
STUD WELD DETAIL
NOT TO SCALE



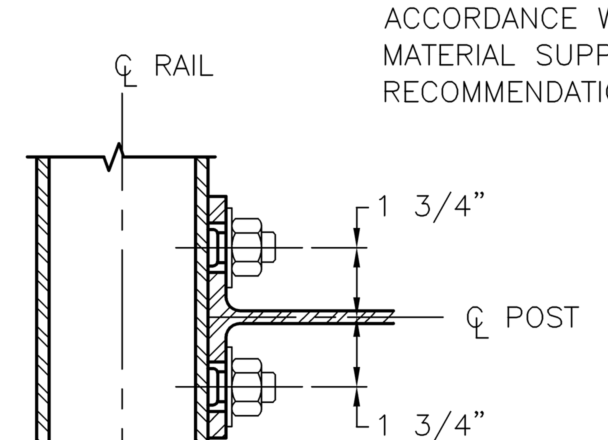
ROUND HEAD BOLT DETAIL
NOT TO SCALE



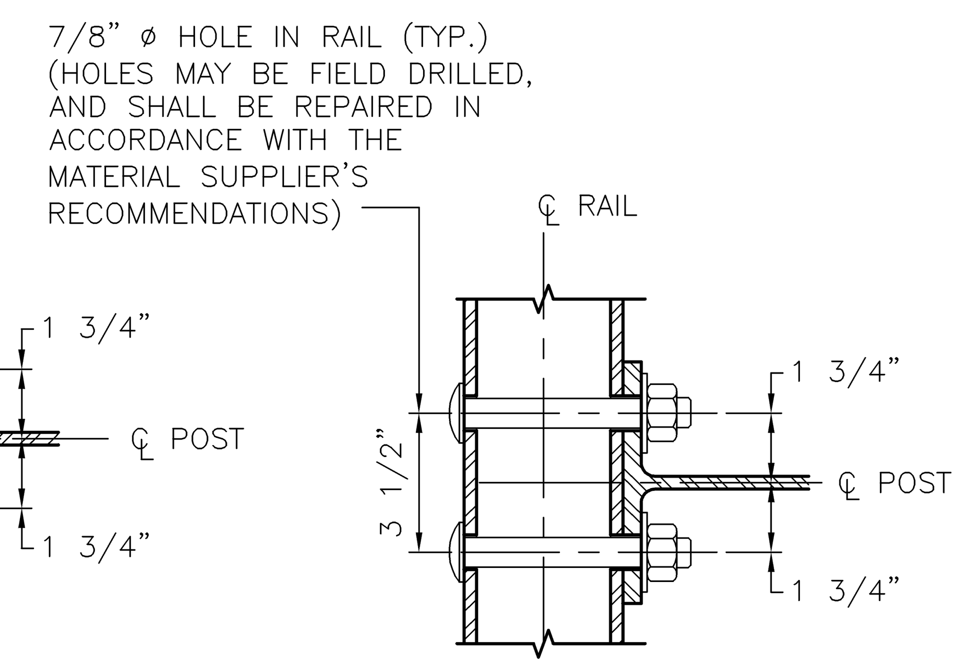
DETAIL A
SCALE: 3"=1'-0"



DETAIL B
SCALE: 3"=1'-0"



SECTION A-A
SCALE: 3"=1'-0"



SECTION B-B
SCALE: 3"=1'-0"

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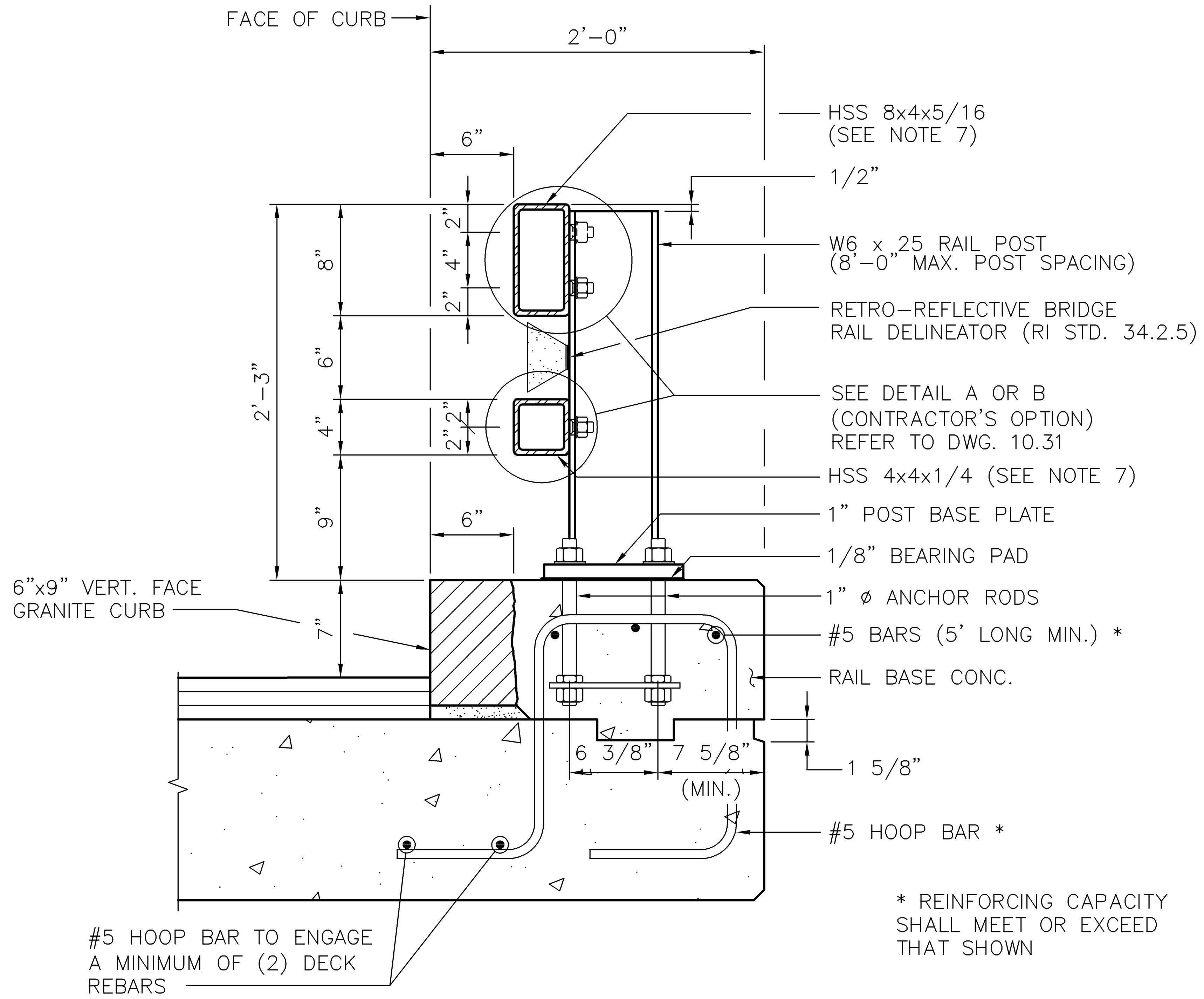
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

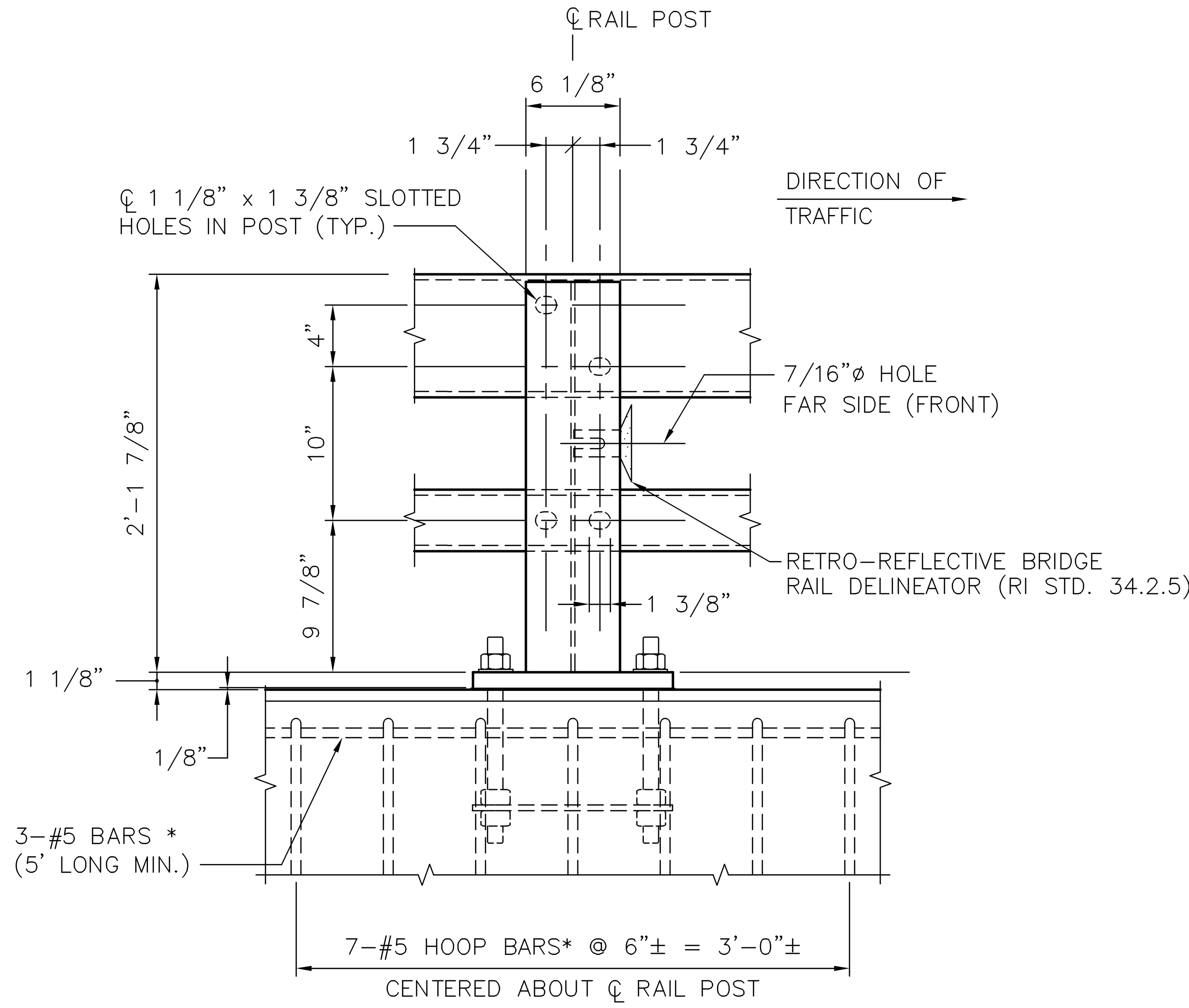
BRIDGE STANDARDS

FOUR BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4)
SHEET 2

DRAWING NUMBER: 10.23



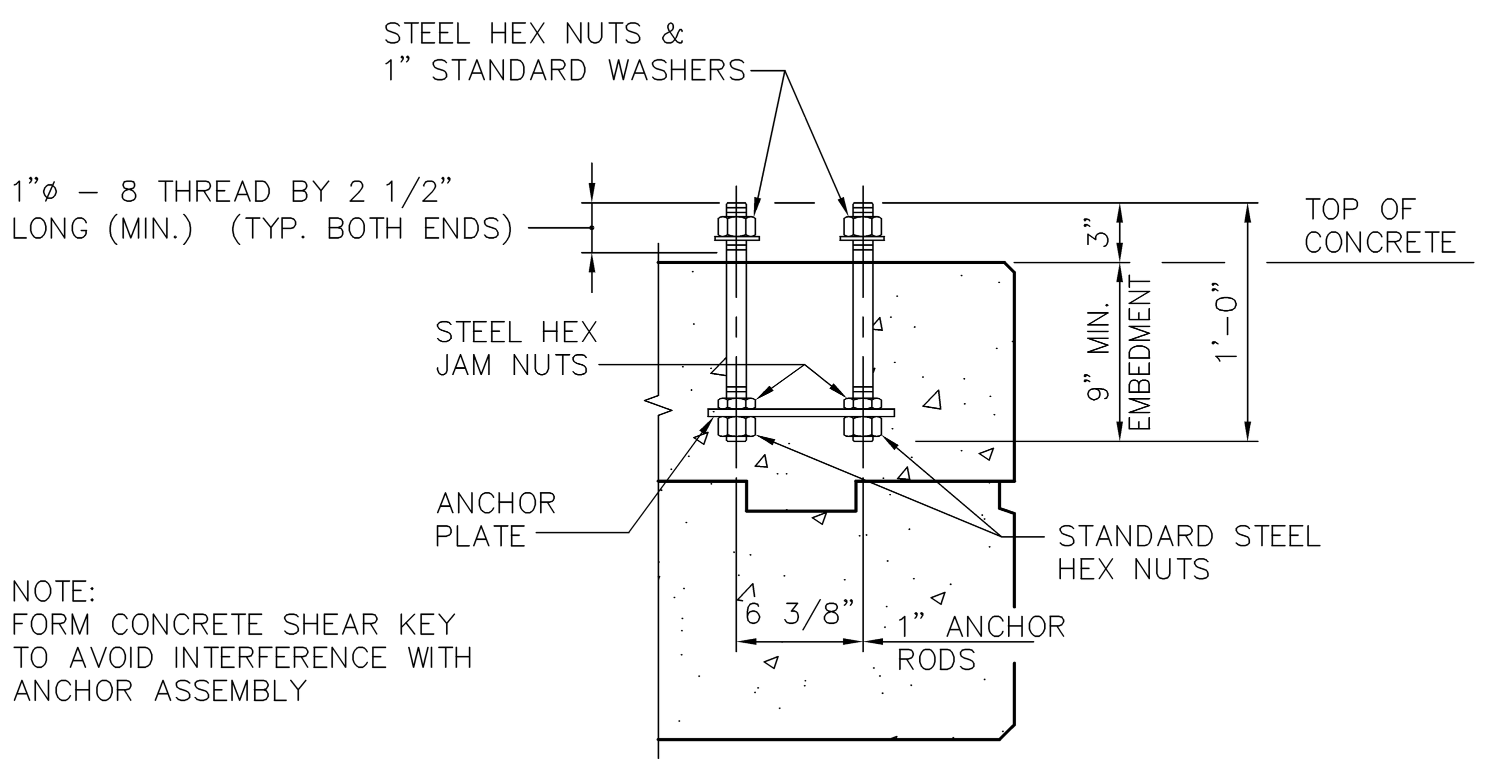
SECTION VIEW



BACK ELEVATION VIEW

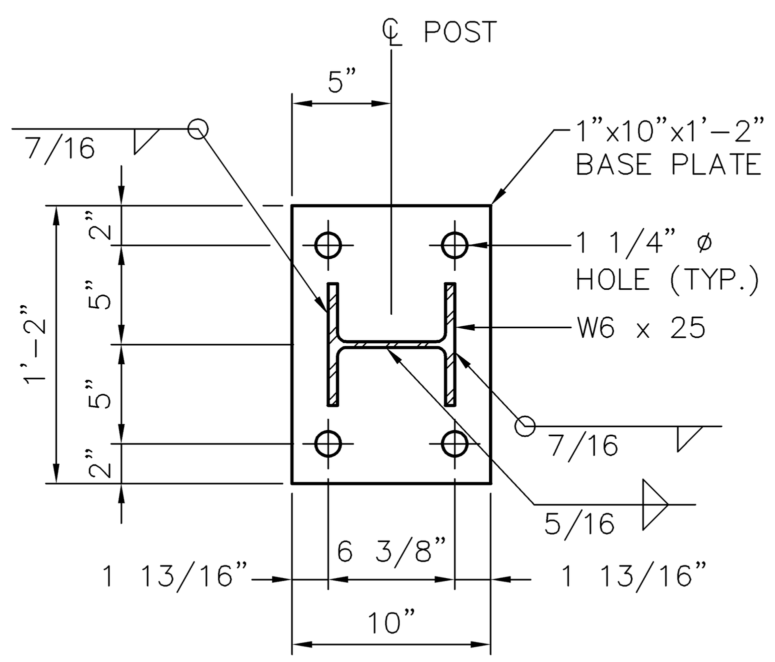
POST ASSEMBLY

SCALE:1 1/2"=1'-0"



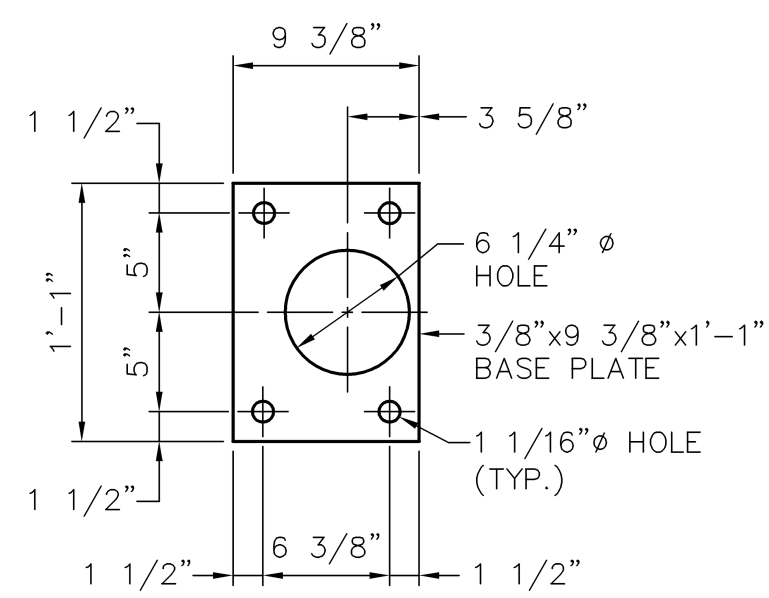
POST ANCHOR ASSEMBLY

SCALE:1 1/2"=1'-0"



POST BASE PLATE

SCALE:1 1/2"=1'-0"



ANCHOR PLATE

SCALE:1 1/2"=1'-0"

RAIL NOTES:

1. TWO BAR (CRASH-TESTED) STEEL BRIDGE RAIL, SHALL INCLUDE POSTS, BASE PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, RETRO REFLECTIVE DELINEATORS, ALL APPURTENANCES, METALIZING, AND PAINTING (IF SPECIFIED).
2. BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 1.5% WHERE POSTS SHALL BE SET VERTICAL.
3. ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.
4. EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.
5. BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.
6. AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. BOTH RAILS AT A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT INTERIOR EXPANSION JOINTS AND AT ALL END SPLICES, THE SLOTTED HOLES AND PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON EACH SIDE.
7. MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE.
8. NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER METALIZING, (EXCEPT FOR DETAIL "A"). DAMAGED AREAS OF METALIZING SHALL BE REPAIRED IN STRICT CONFORMANCE WITH THE MATERIAL SUPPLIER'S RECOMMENDATIONS AND SHALL BE APPROVED BY THE ENGINEER.
9. NUTS FOR 1"ø THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.
10. THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED, BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.
11. THE RAIL POST, BASE PLATE AND ANCHOR CAGE MUST BE INSTALLED PRECISELY TO THE LOCATION DIMENSIONED ON THESE PLANS. THE POSITION OF THE (3)-#5 LONGITUDINAL REBARS MAY BE ADJUSTED TO ACCOMMODATE THE ANCHOR CAGE, BUT MUST NOT BE CUT.

MATERIAL NOTES:

12. STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V-NOTCH REQUIREMENTS OF 15 LBS. AT 0'F FOR ASTM A500, GRADE B. THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V-NOTCH IS NOT REQUIRED FOR SPLICE TUBES.
13. RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR. 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.
14. THREADED STUDS AND MATCHING NUTS FOR RAIL-TO-POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM 563 GRADE A RESPECTIVELY OR BETTER. ANCHOR RODS SHALL CONFORM TO ASTM A449 EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22.
15. ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE METALIZED AFTER FABRICATION IN CONFORMANCE WITH SECTION 827 "THERMAL SPRAYED ZINC COATING FOR NEW STRUCTURAL STEEL" OF THE RHODE ISLAND STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION. THE METALIZING SHALL HAVE A UNIFORM APPEARANCE, AND METALIZED MATERIAL SHALL BE PROPERLY STORED.
16. DETAIL "A" STUDS SHALL BE WELDED BEFORE TUBES ARE METALIZED.
17. PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

DESIGNER NOTE:
PROVIDE PAINT COLOR FOR RAILING SYSTEM.

THIS BRIDGE RAIL SYSTEM WAS SUCCESSFULLY CRASH TESTED FOR AASHTO TL4 IN 1994 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM.

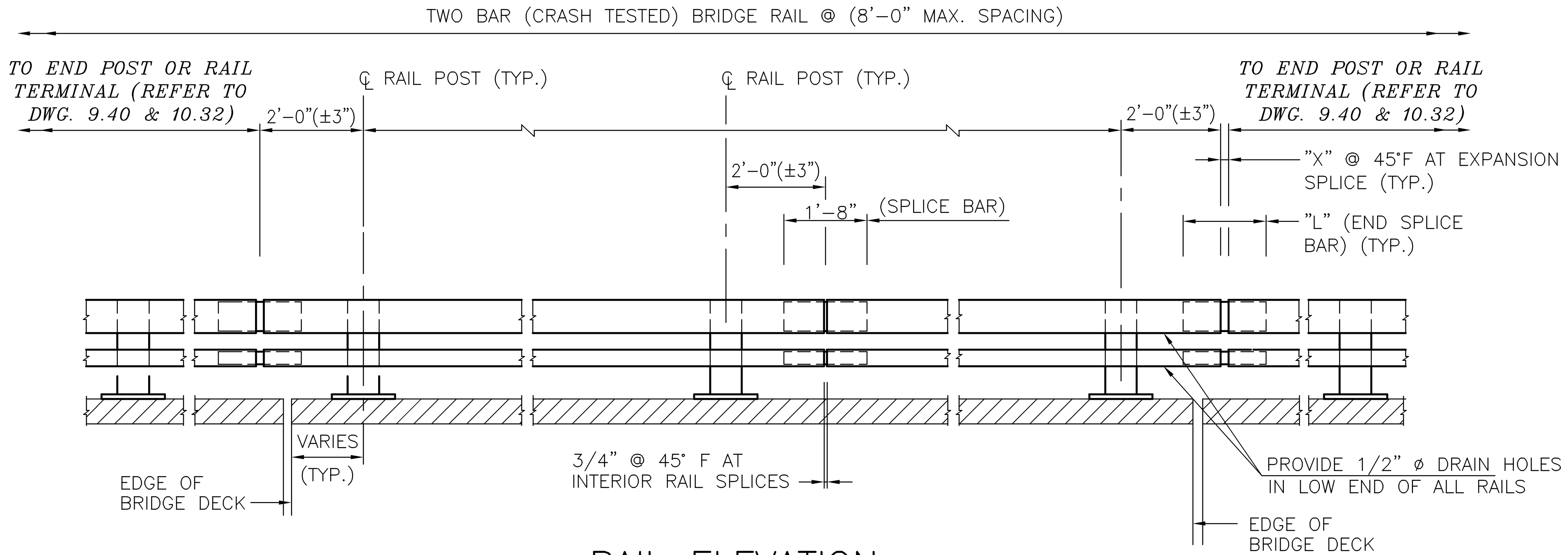
REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

BRIDGE STANDARDS

TWO BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4) SHEET 1

DRAWING NUMBER: 10.30

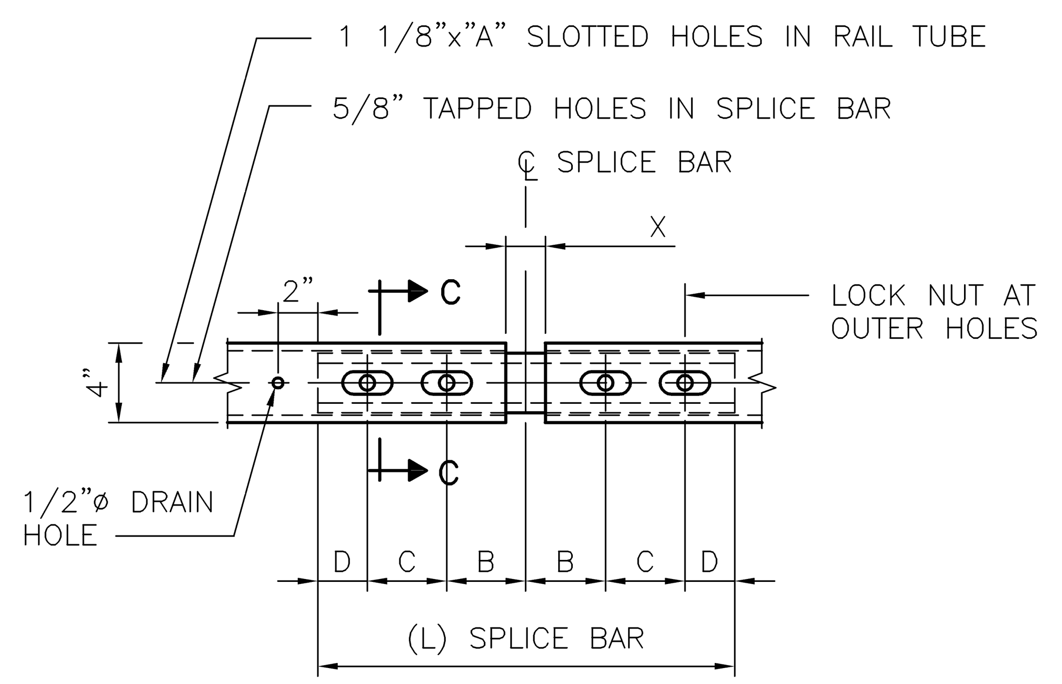


RAIL ELEVATION

SCALE:1/2"=1'-0"

SPLICE BAR DIMENSION TABLE							
	T	A	B	C	D	X	L
	INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
*	<3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
*	3 1/4" TO 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

T = TOTAL MOVEMENT OF BRIDGE
* = END SPLICE BAR

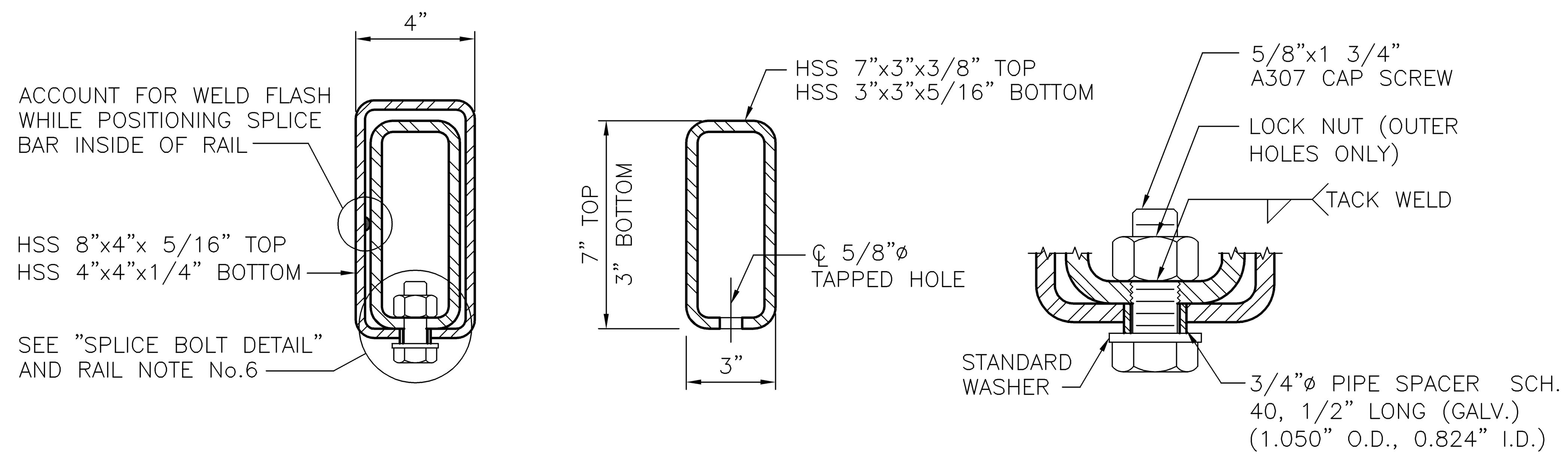


SEE SPLICE BAR DIMENSION TABLE THIS SHEET

(BOTTOM VIEW)

RAIL SPLICE

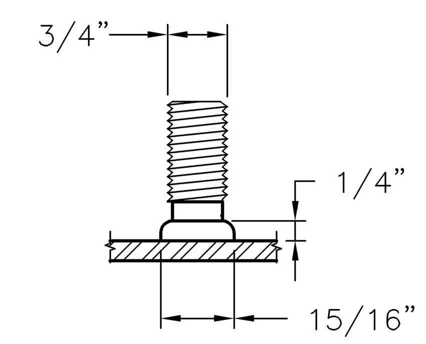
SCALE: 1 1/2"=1'-0"



SECTION C-C — SPLICE BAR SECTION — SPLICE BOLT DETAIL

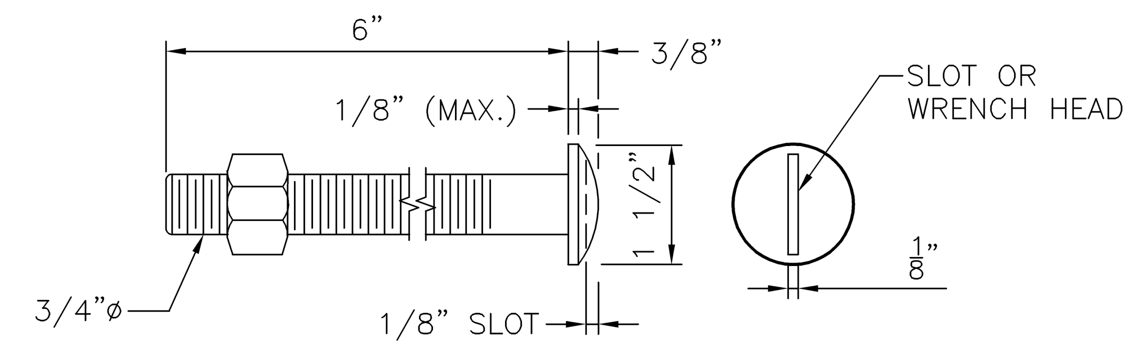
RAIL SPLICE DETAILS

SCALE: 3"=1'-0"



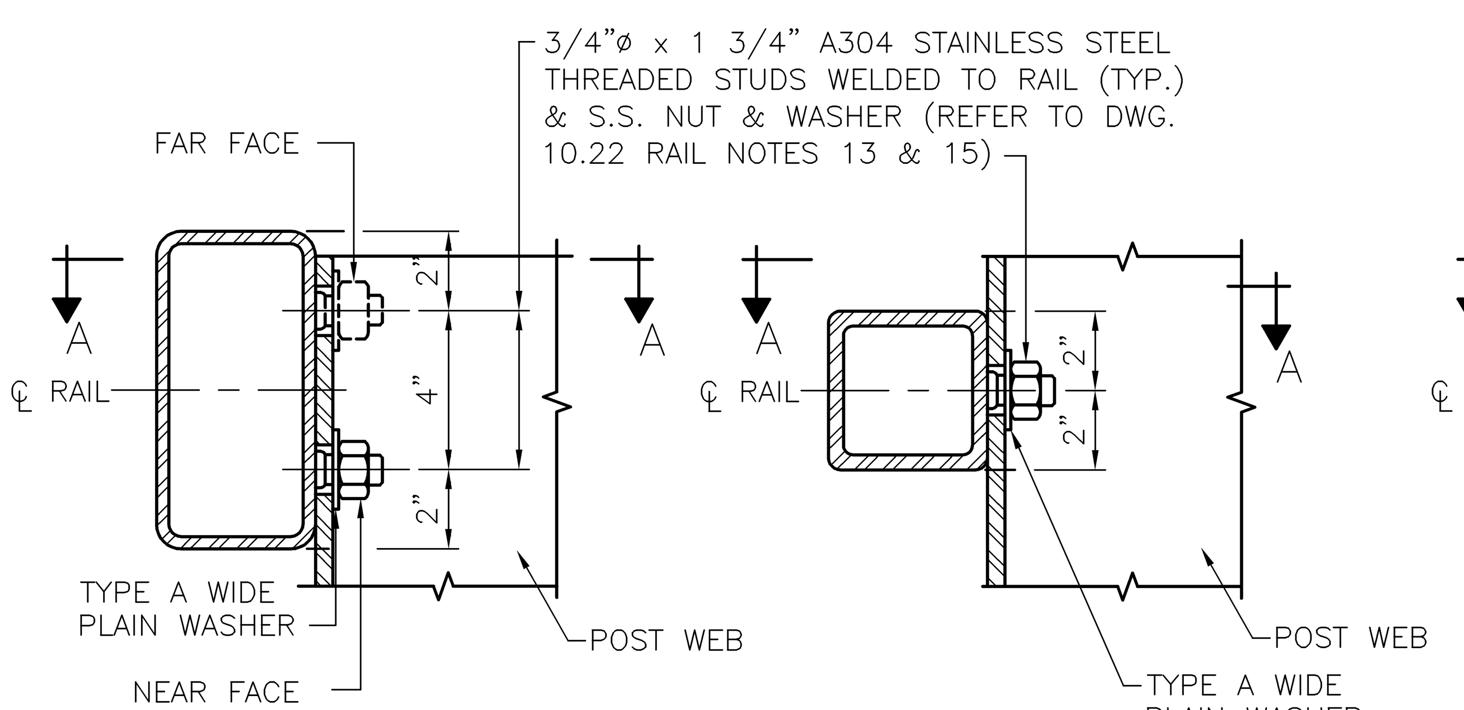
STUD WELD DETAIL

NOT TO SCALE



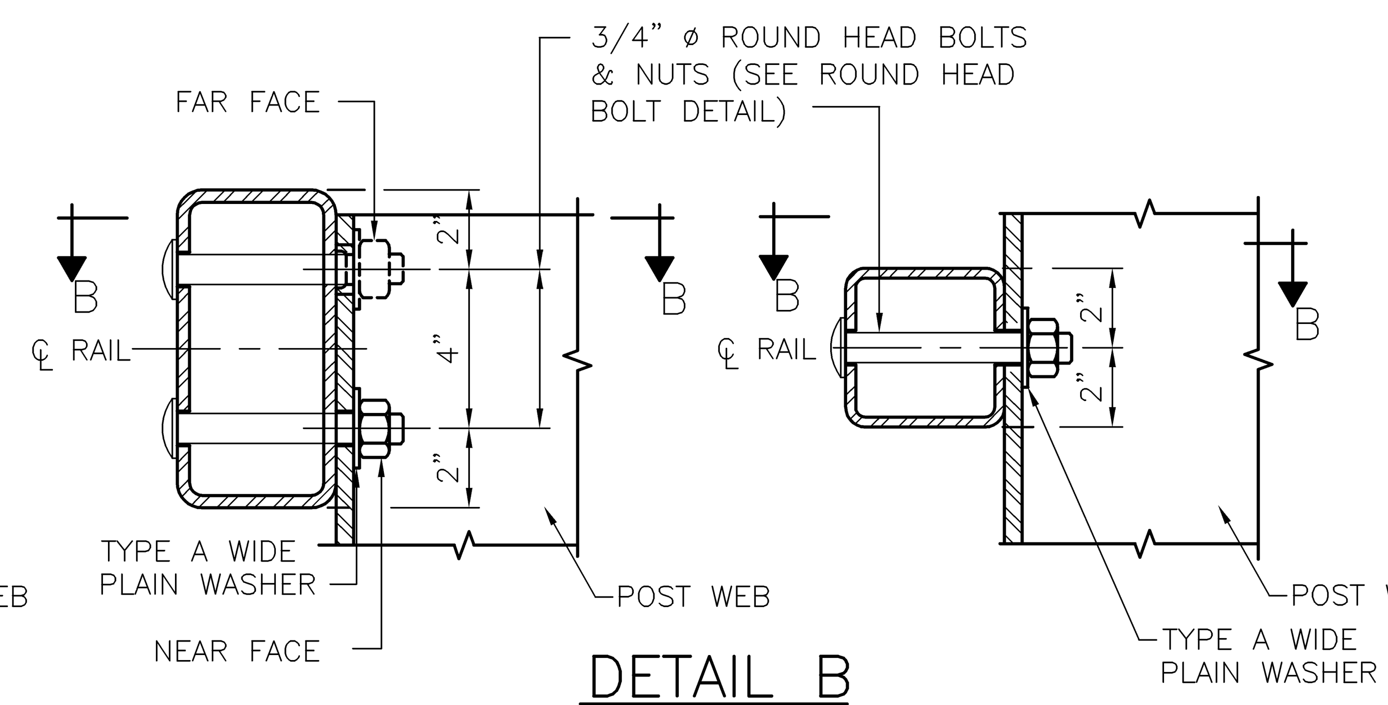
ROUND HEAD BOLT DETAIL

NOT TO SCALE



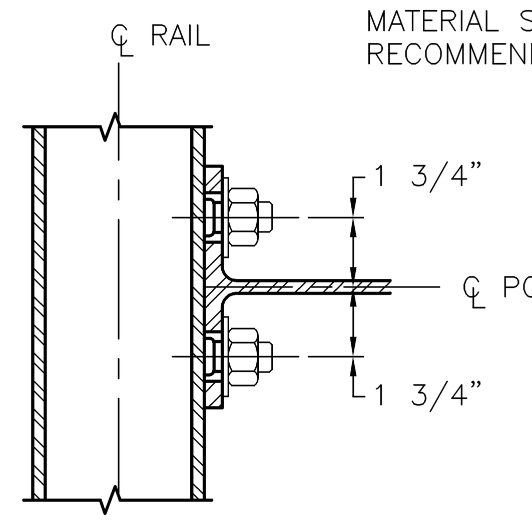
DETAIL A

SCALE: 3"=1'-0"



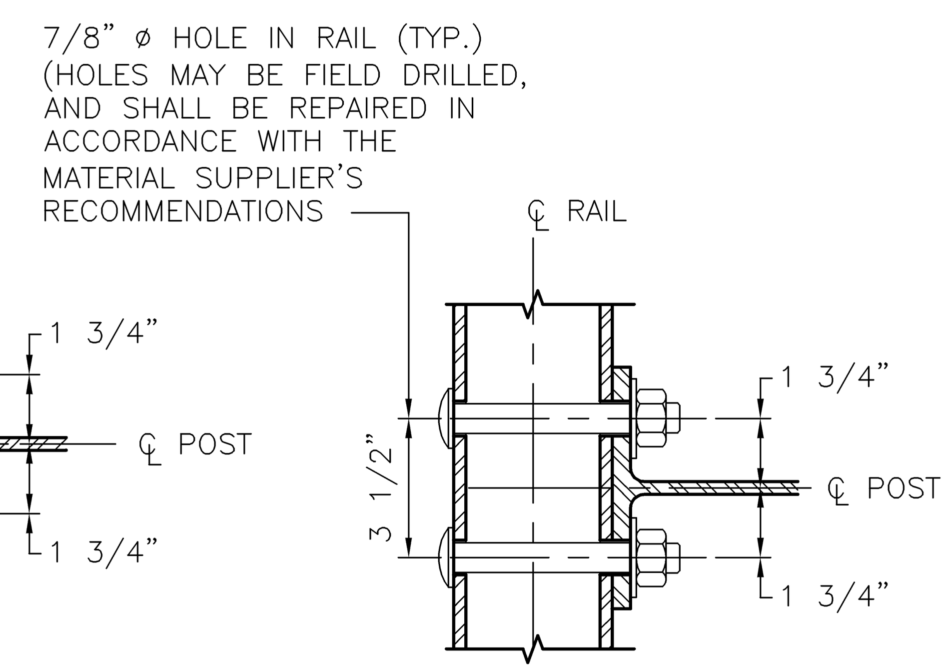
DETAIL B

SCALE: 3"=1'-0"



SECTION A-A

SCALE: 3"=1'-0"



SECTION B-B

SCALE: 3"=1'-0"

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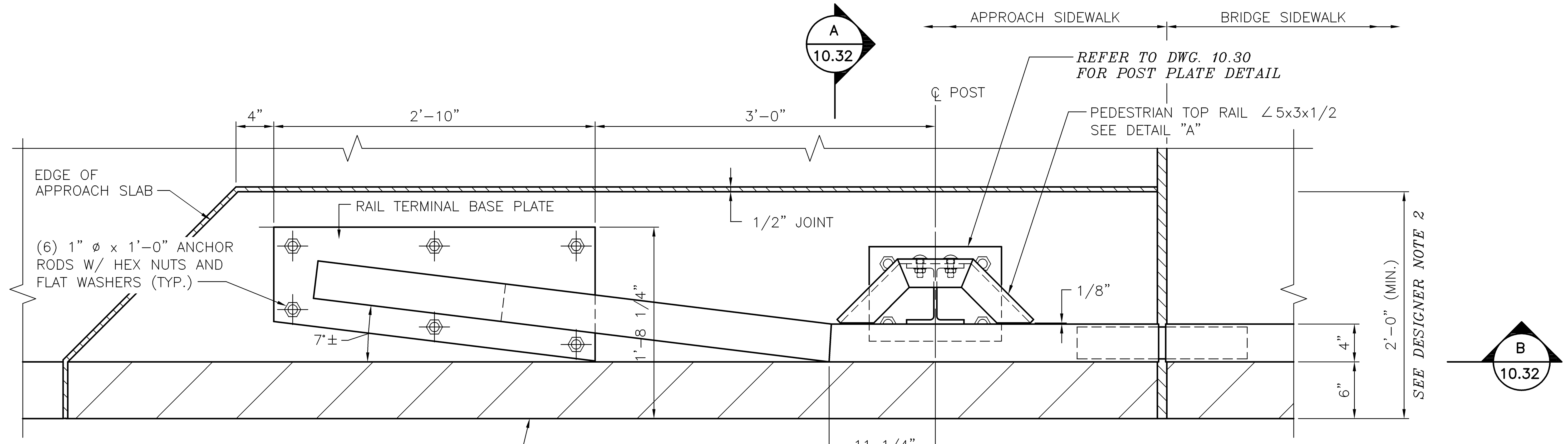
RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

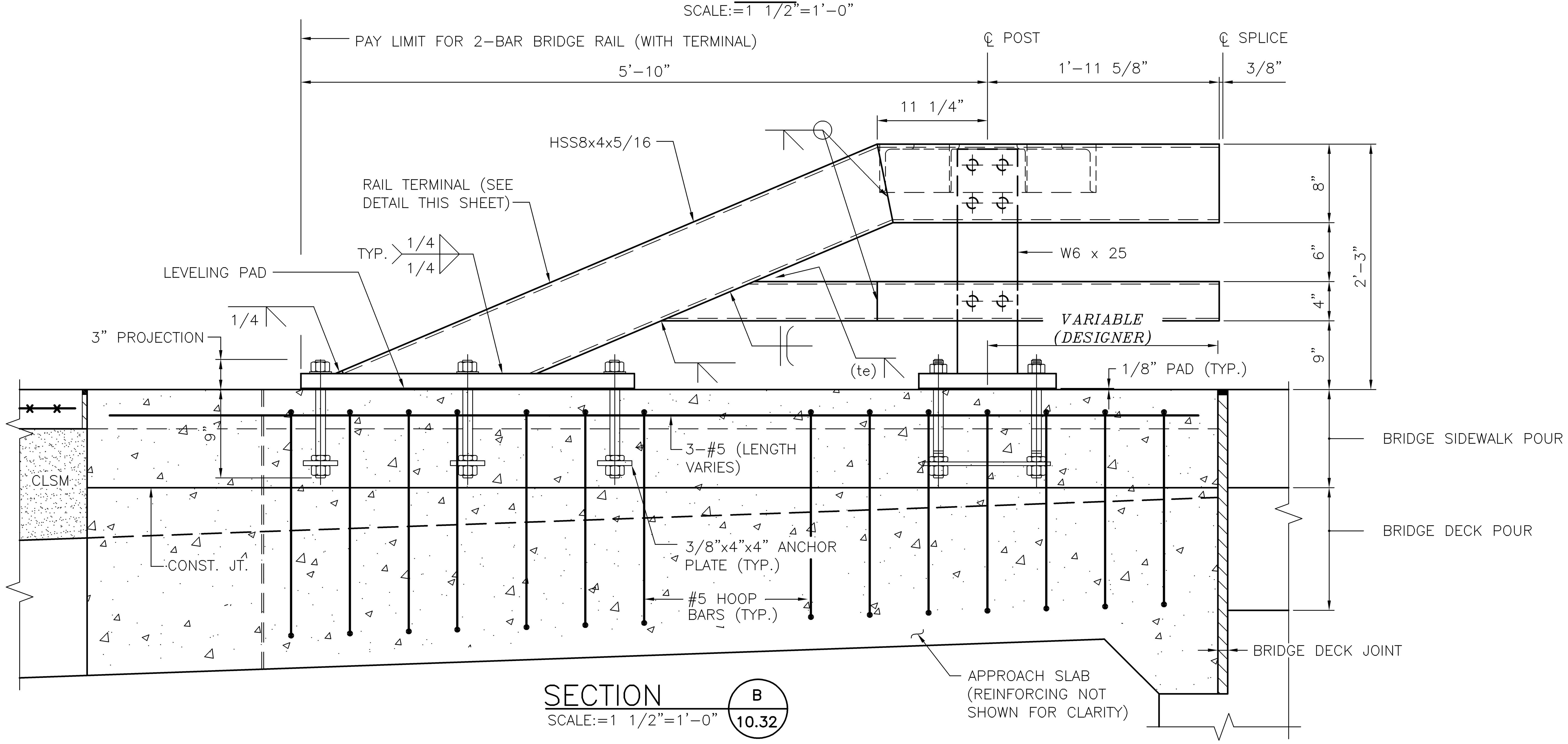
BRIDGE STANDARDS

TWO BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4) SHEET 2

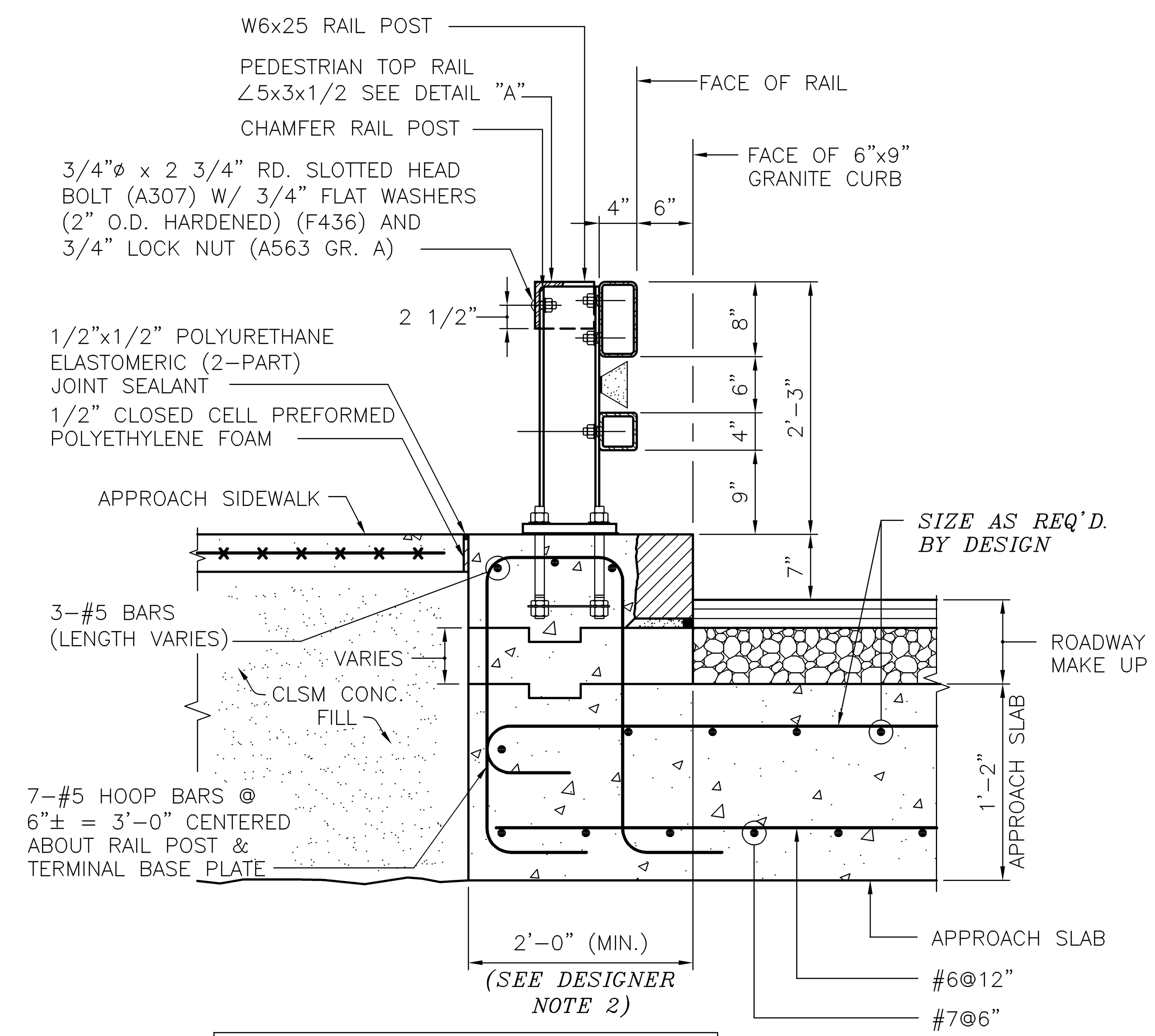
DRAWING NUMBER: 10.31



PLAN
SCALE:=1 1/2"=1'-0"



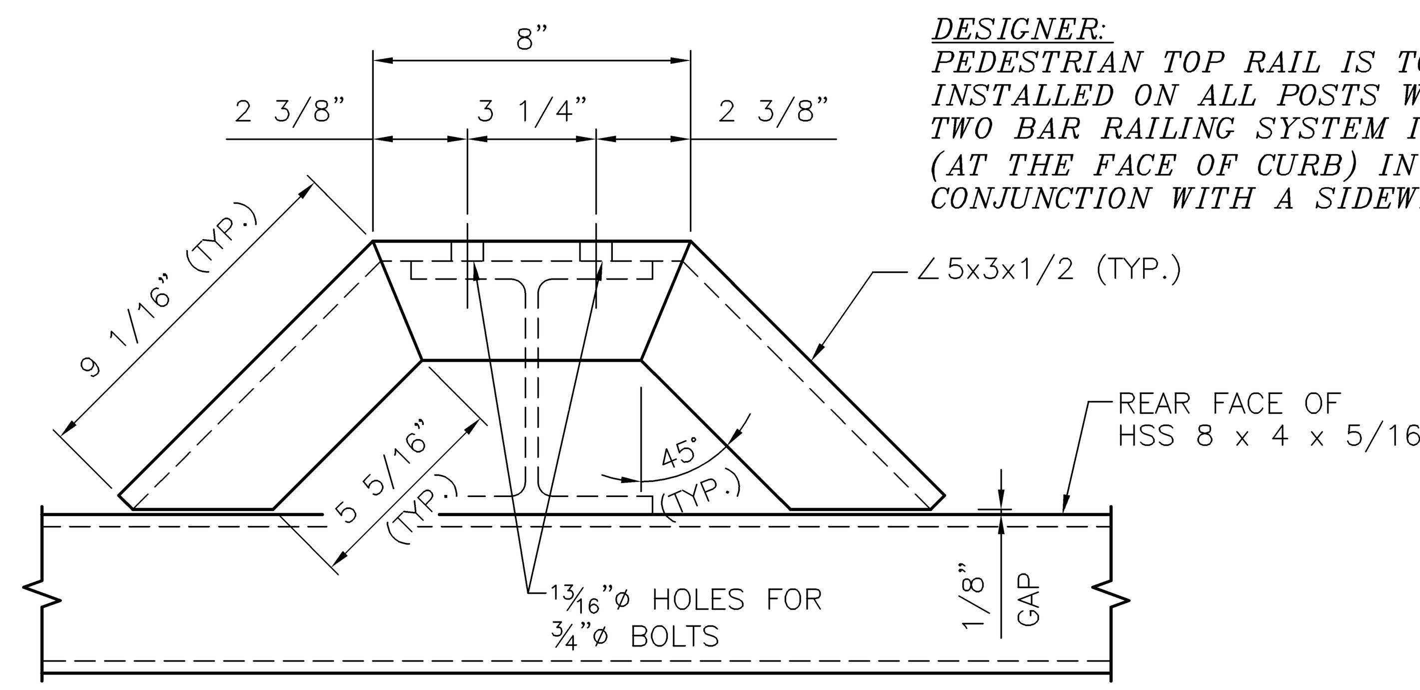
SECTION B 10.32
SCALE:=1 1/2"=1'-0"



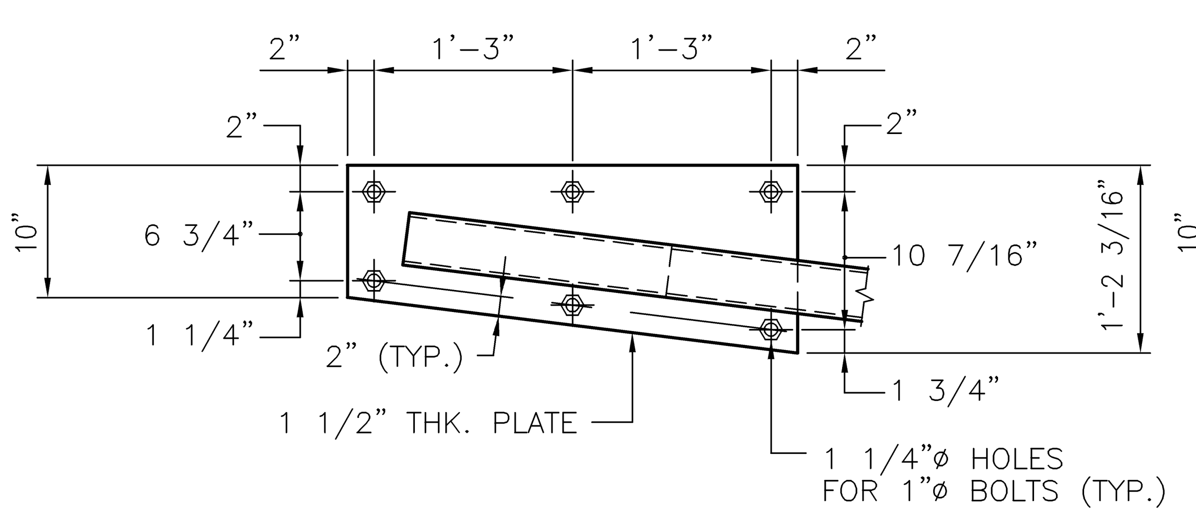
DESIGNER:
FOR RAIL AND POST DETAILS, REFER TO DRAWINGS No. 10.30 & 10.31

SECTION A 10.32
SCALE:=1"=1'-0"

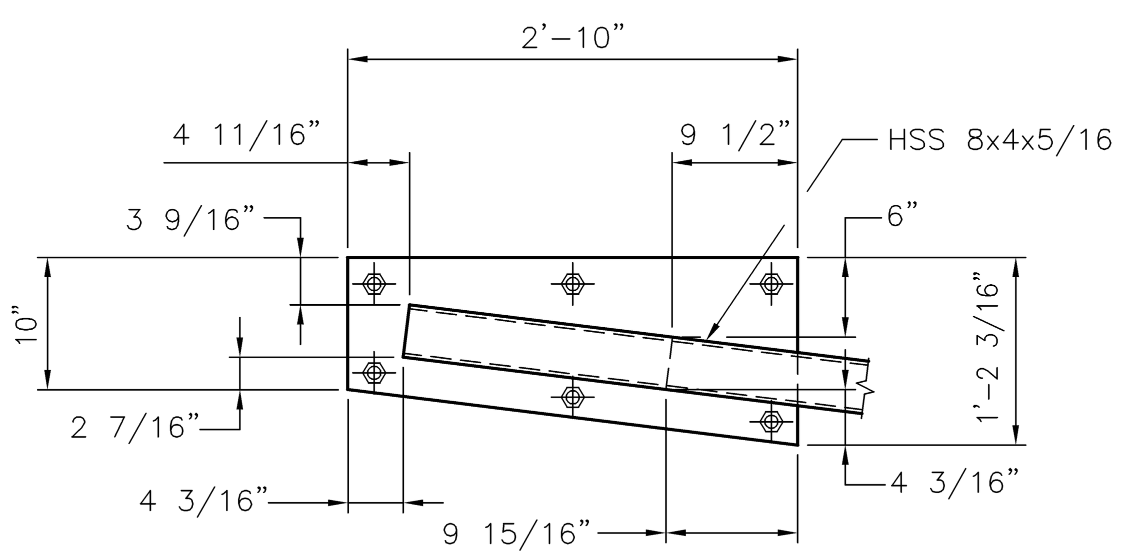
DESIGNER:
PEDESTRIAN TOP RAIL IS TO BE INSTALLED ON ALL POSTS WHEN TWO BAR RAILING SYSTEM IS USED (AT THE FACE OF CURB) IN CONJUNCTION WITH A SIDEWALK



DETAIL-A
SCALE:3"=1'-0"



ANCHOR HOLE LAYOUT



RAIL TERMINAL LAYOUT

RAIL TERMINAL BASE PLATE
SCALE: 1"=1'-0"

DESIGNER NOTES:

1. *THE DETAILS SHOWN ARE FOR TWO BAR RAIL TERMINALS (AT THE FACE OF CURB) ENDING OFF OF THE BRIDGE DECK. RAIL TERMINALS ENDING ON THE BRIDGE DECK WOULD BE SIMILAR.*
2. *THE RAIL TERMINAL FOUNDATION SHALL BE AS REQUIRED TO ACCOMMODATE THE APPLICABLE AASHTO LRFD RAIL IMPACT LOADING.*
3. *ALTERNATE RAIL TERMINAL FOUNDATIONS (SUCH AS FOUNDATIONS CANTILEVERED FROM THE REAR FACES OF THE ABUTMENT STEMS/BACKWALLS OR FOUNDATIONS SET ON INDIVIDUAL WALL STEMS AND FOOTINGS AND CAST INTEGRALLY WITH THE ABUTMENT STEMS AND FOOTINGS) MAY BE CONSIDERED.*

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No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

BRIDGE STANDARDS

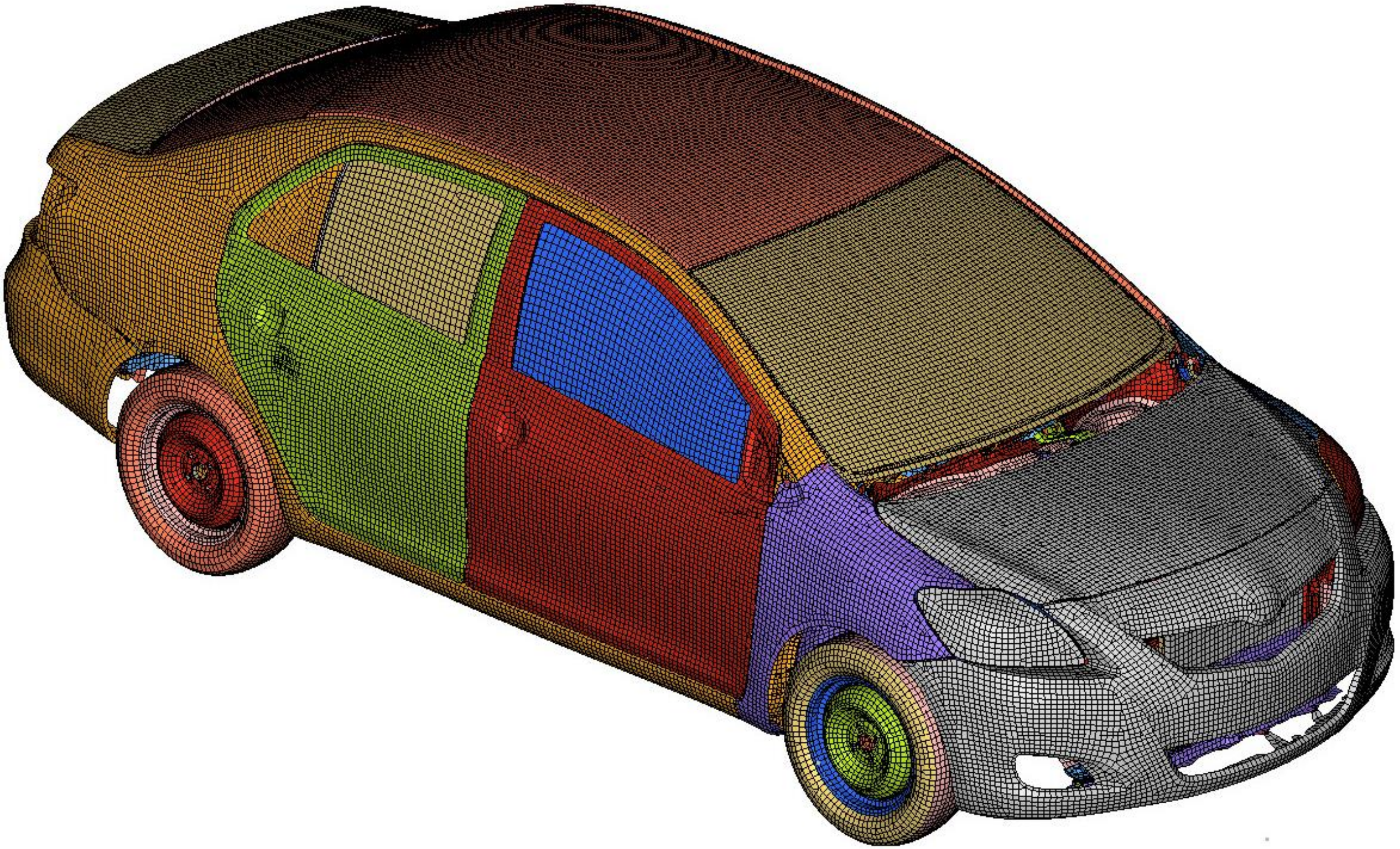
TWO BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4) SHEET 3

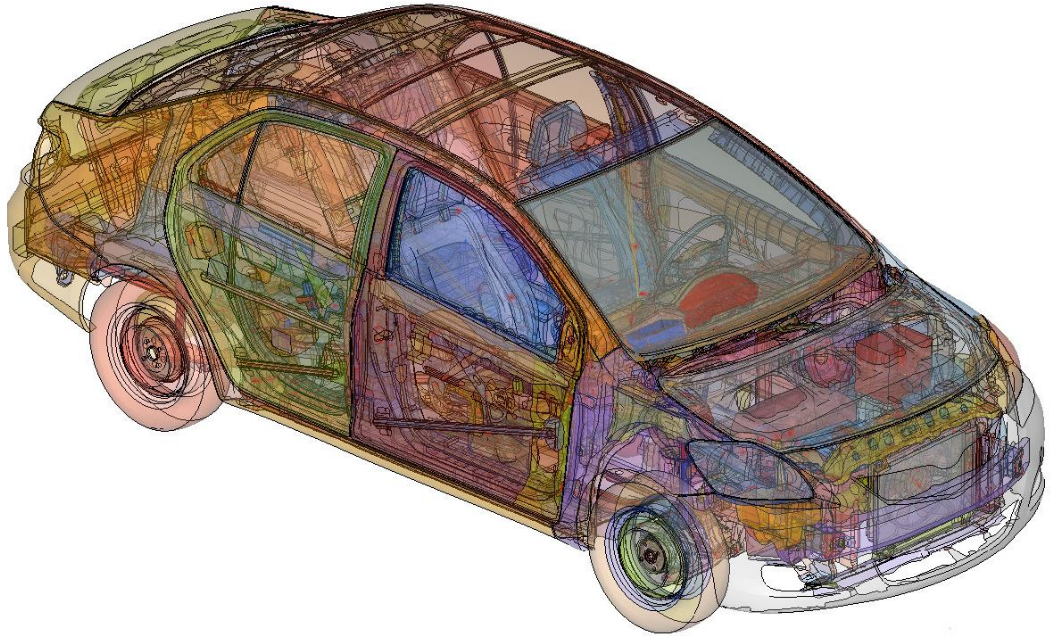
DRAWING NUMBER: 10.32

Appendix E

Validation Forms for Yaris (1100C) Vehicle Model

Model Information

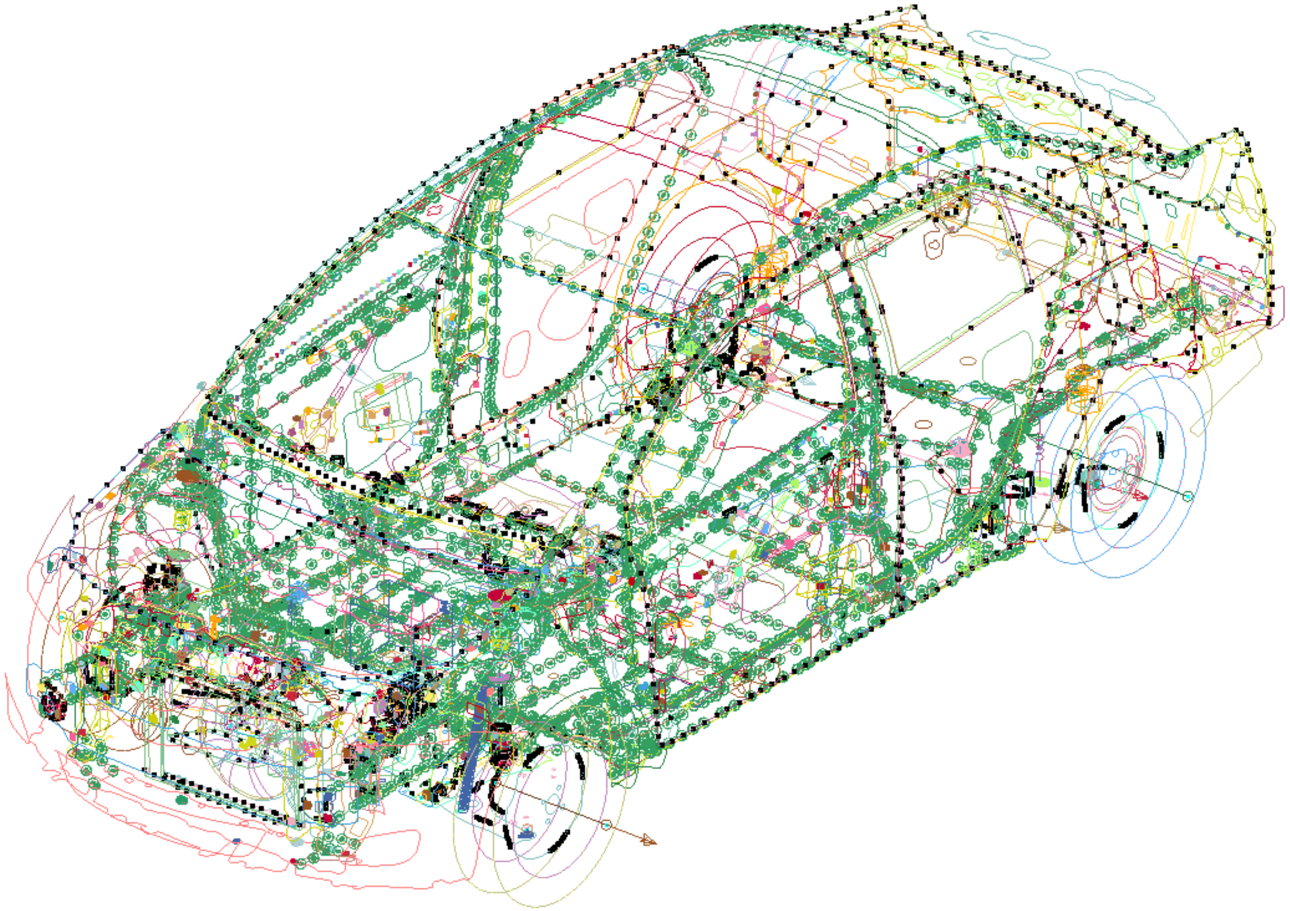




Number of parts	919
Number of nodes	393165
Number of solid elements	15234
Number of shell elements	358457
Number of beam elements	4685
Number of constrained joints	19

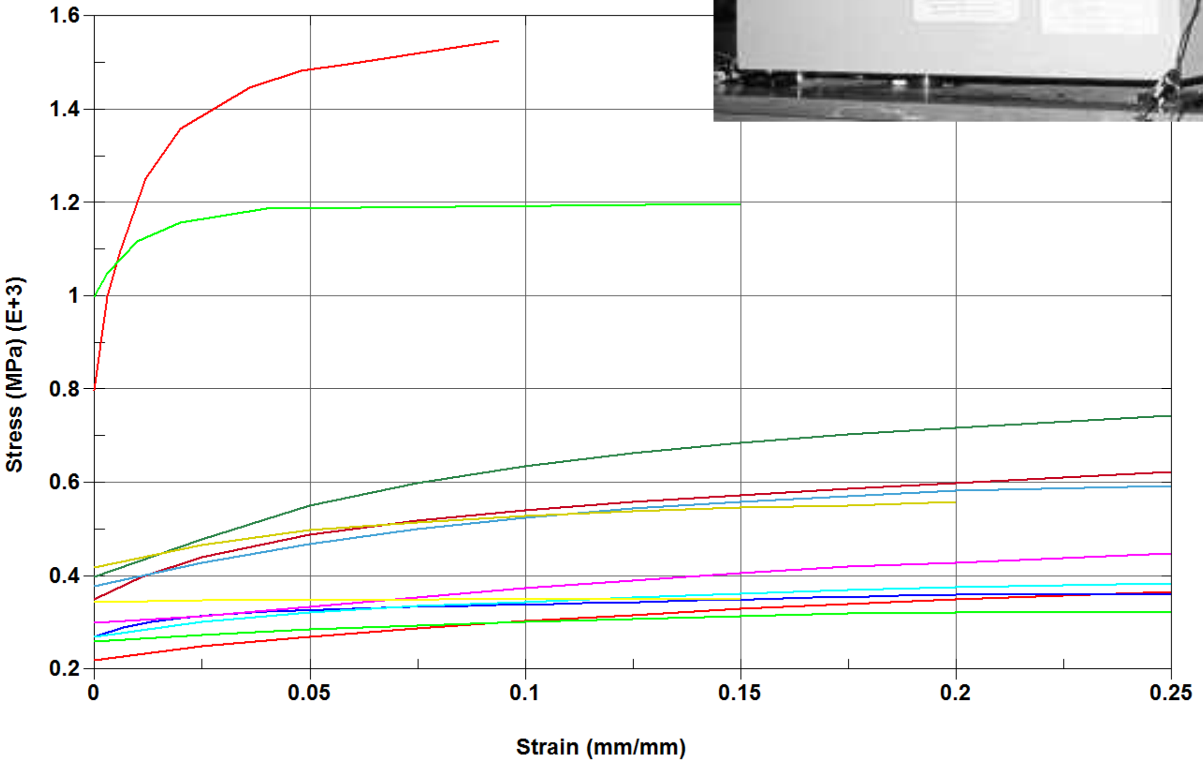
Connections

BEAM CONNECTIONS	4685
NODAL_RIGID_BODY	759
EXTRA_NODES_SET	20
JOINTS	44
RIGID_BODIES	2
SPOTWELD	2828



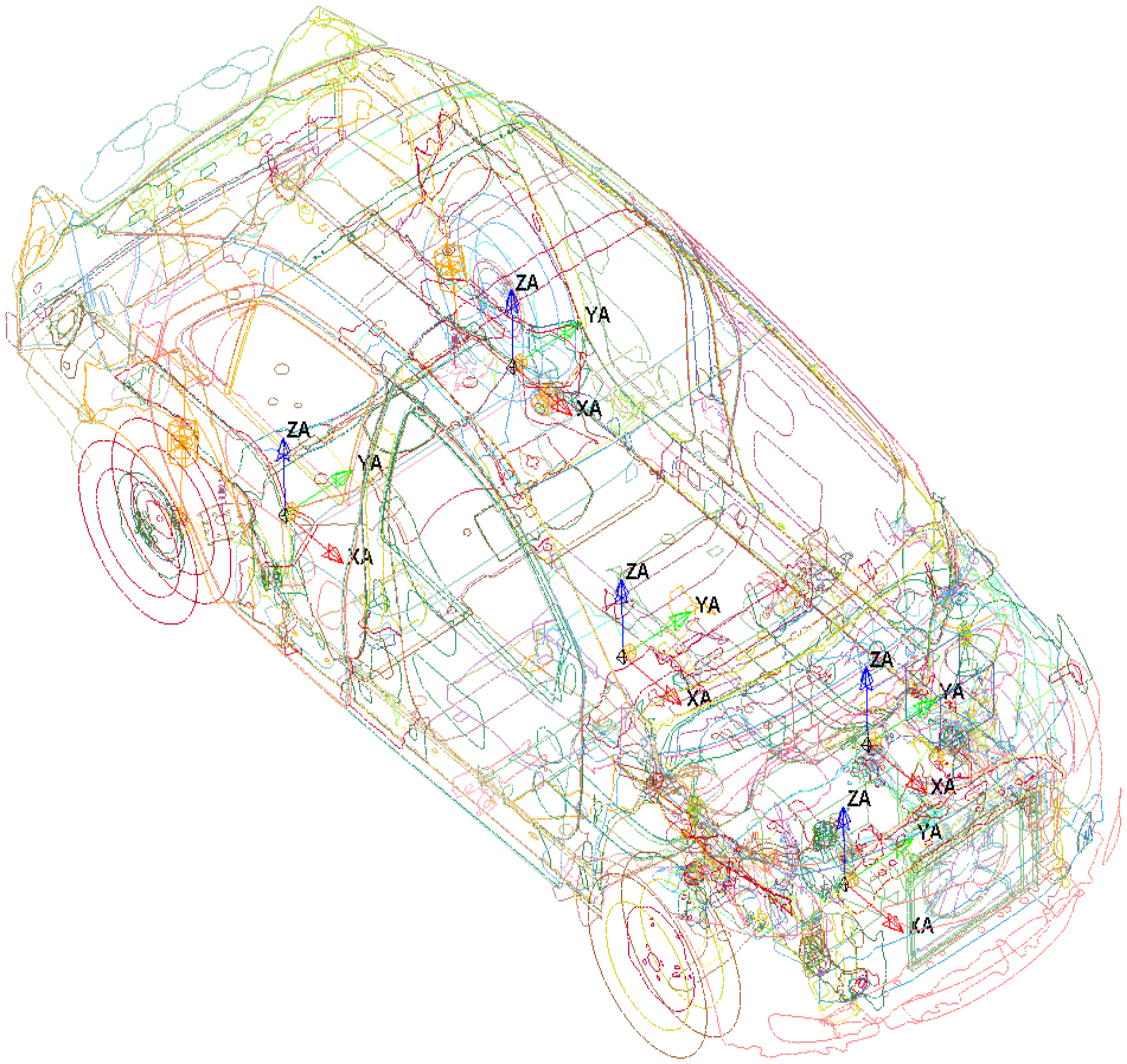
Material Testing

- Specimens were cut from actual components
- 160 tensile tests
- Data converted
- 12 different materials generated based on test data
- Parts grouped into

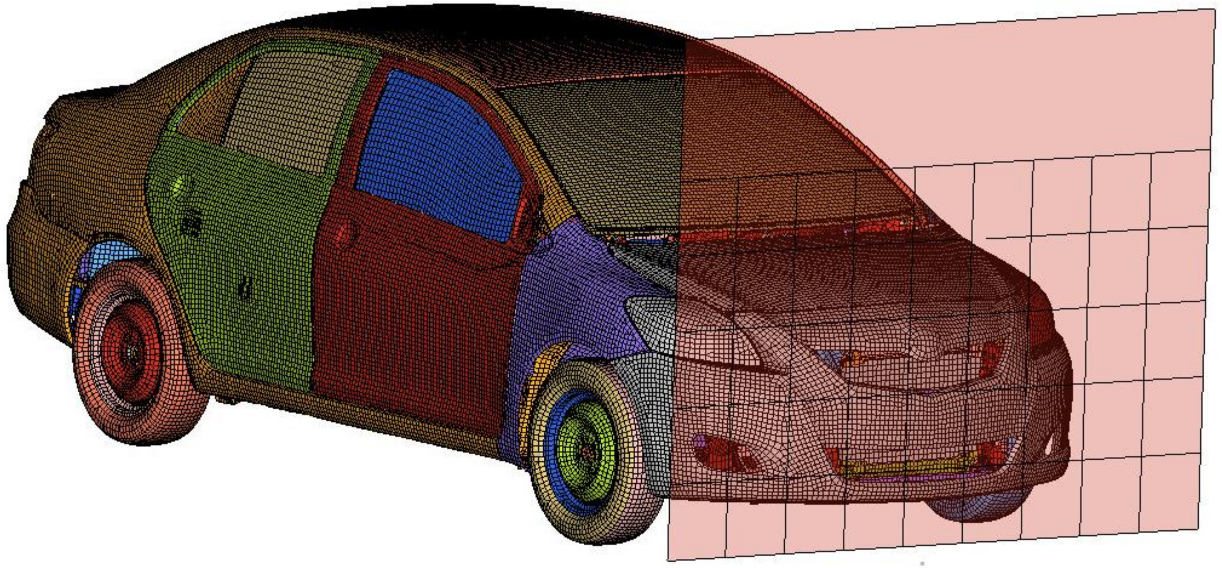


Accelerometers

- Left Rear Seat (Node 4000390)
- Right Rear Seat (Node 4000398)
- Engine Top (Node 4000414)
- Engine Bottom (Node 4000422)
- Vehicle C.G. (Node 4000406)



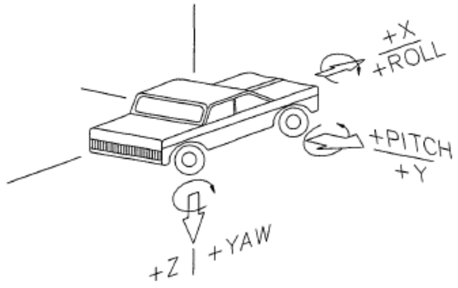
Simulation Benchmark



LS-DYNA	
Platform	Linux RHEL 5.4
Version	mpp s R6.1.2
Revision	85139
Precision	Single precision (I4R4)
Time to simulate 200 ms	1 hour 32 min.
Number of processors	16

Inertia Comparisons

	Actual Vehicle	*FE Model*
Weight, kg	1078	1101
Pitch inertia, kg-m^2	1498	1545
Yaw inertia, kg-m^2	1647	1718
Roll inertia, kg-m^2	388	396
Vehicle CG X, mm	1022	1025
Vehicle CG Y, mm	-8.3	-3.0
Vehicle CG Z, mm	558	557



Full-Scale Crash Tests

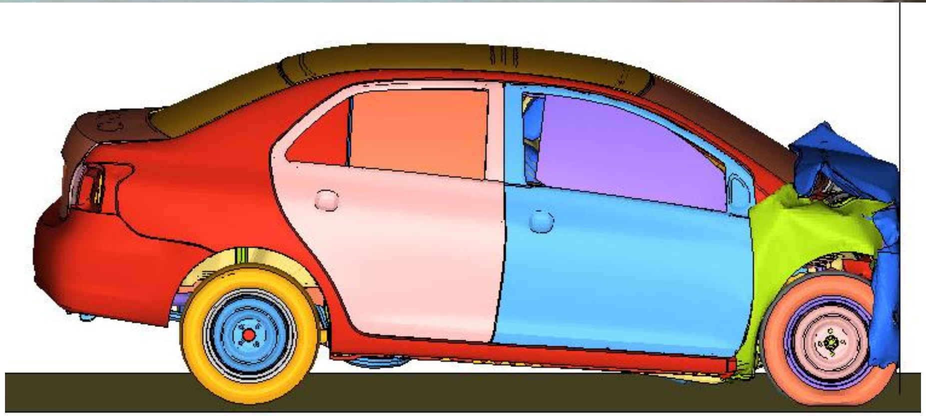
- Toyota Yaris (2006-2010)

Test Type	Test Number
Frontal Full Wall	NHTSA 5677 (56.3 km/hr), 6221 (56.2 km/hr), 6059 (39.8 km/hr), 6060 (39.8 km/hr), 6069 (39.8 km/hr)
Frontal Offset	IIHS CEF0610 (64.7 km/hr)
Side Impact NHTSA	NHTSA 5679 (62.1 km/hr), 6220 (62.3 km/hr), 6558 (61.9 km/h), 6585 (61.8 km/hr)
Side Impact IIHS	IIHS CES50638 (50.2 km/hr), CES0639 (50.0 km/hr)
Rigid Pole Test	NHTSA 7145 (7 deg, 56 km/hr)
Vehicle to Vehicle	NHTSA 7371 (15 deg, 112.7 km/hr, 50 % overlap), 7293 (7 deg, 112.7 km/hr, No frame overlap),
Roof Strength	IIHS SWR0920
Speed Bump	FOIL10002 (8 tests: varied speed bump configurations)
Sloped Terrain	FOIL 10003 (6 tests: 6H:1V slopes, 25 deg - 8, 16, and 24 km/hr)

Yaris – Frontal Full Wall – 56 km/hr

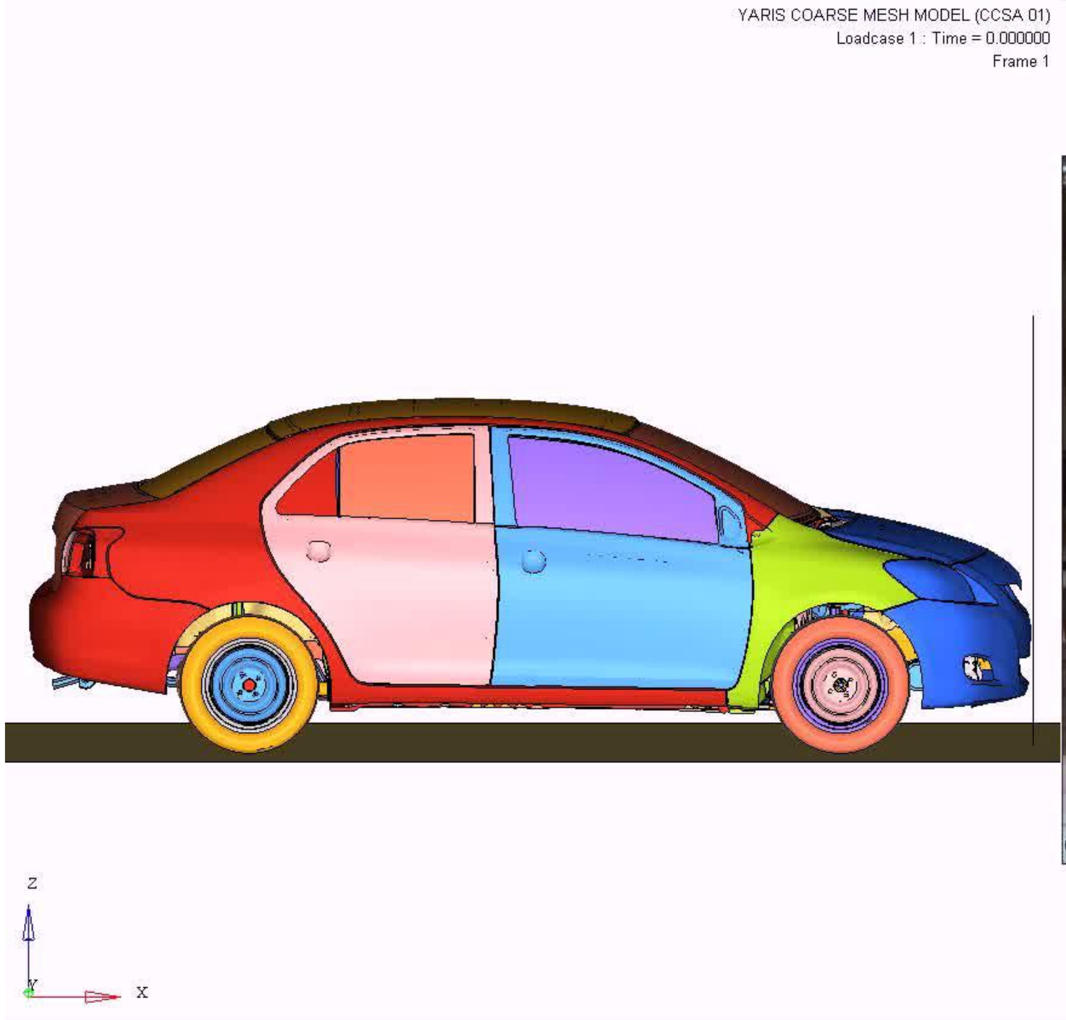
- Two Full-scale Crash Tests @ 56 km/hr:
    - NHTSA 5677 (56.3 km/hr) – 2007 Sedan
    - NHTSA 6221 (56.2 km/hr) – 2008 Hatch Back

Yaris – Frontal Full Wall – 56 km/hr

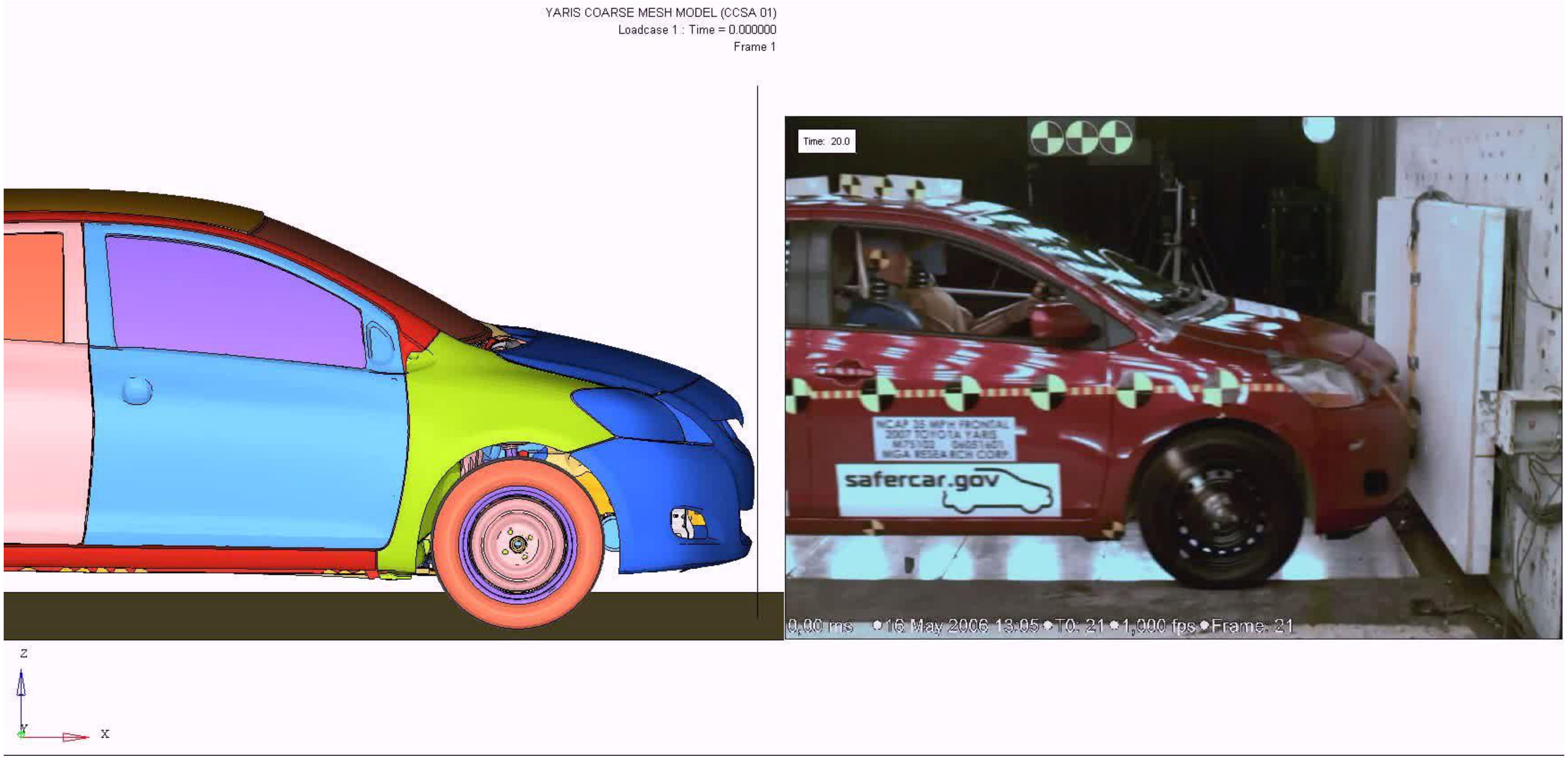


	FE Model	Test 5677	Test 6221
Weight (kg)	1263	1271	1245
Engine Type	1.5L V4	1.5L V4	1.5L V4
Tire size	P185/60R15	P185/60R15	P185/60R15
Attitude (mm) (As delivered)	F – 668	F – 673	F – 675
	R – 673	R – 680	R – 673
Wheelbase (mm)	2538	2551	2463
CG (mm) Rear of front wheel C/L	1035	999	976
Body Style	4 Door Sedan	4 Door Sedan	3 Door Liftback

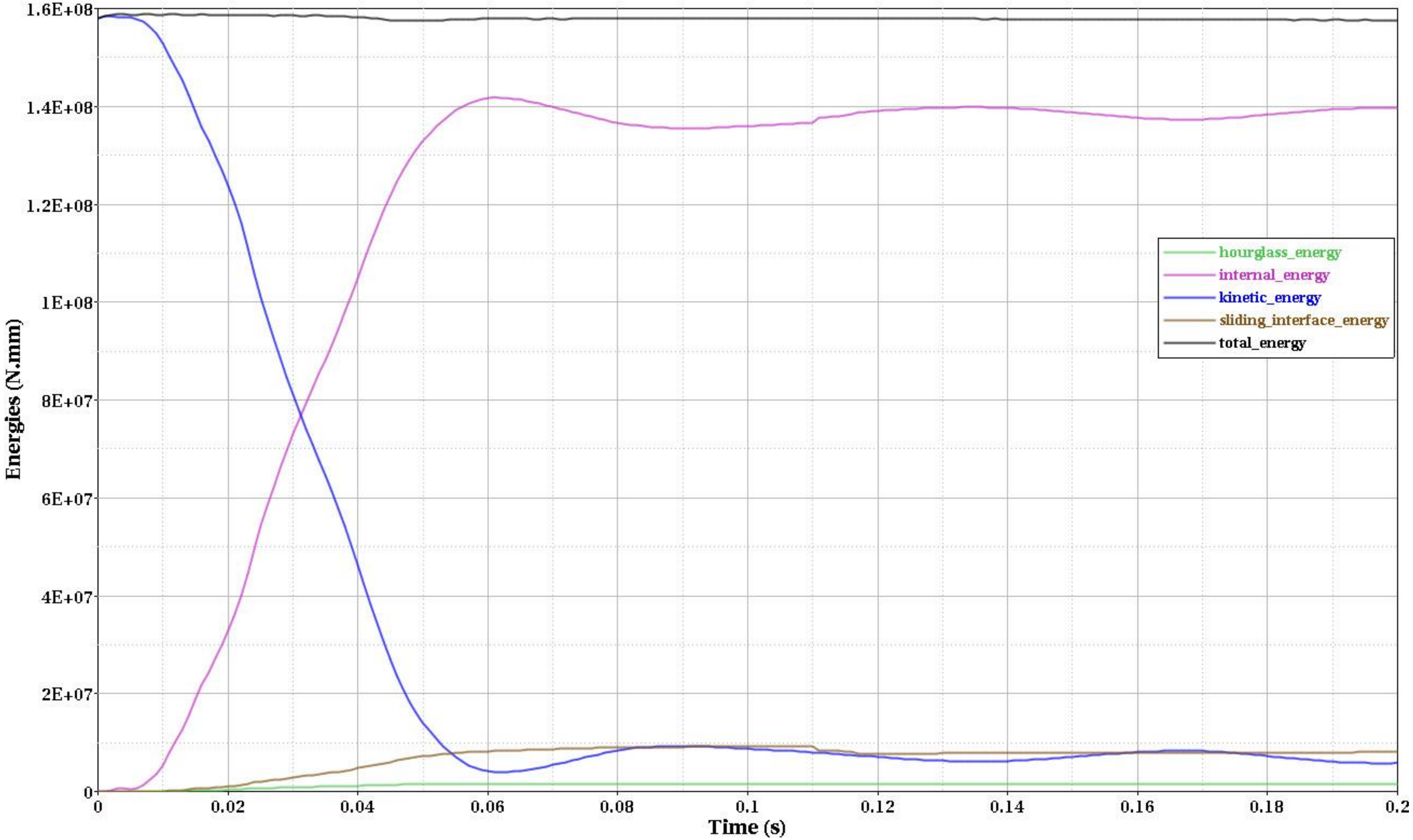
Yaris – Frontal Full Wall – 56 km/h - Video



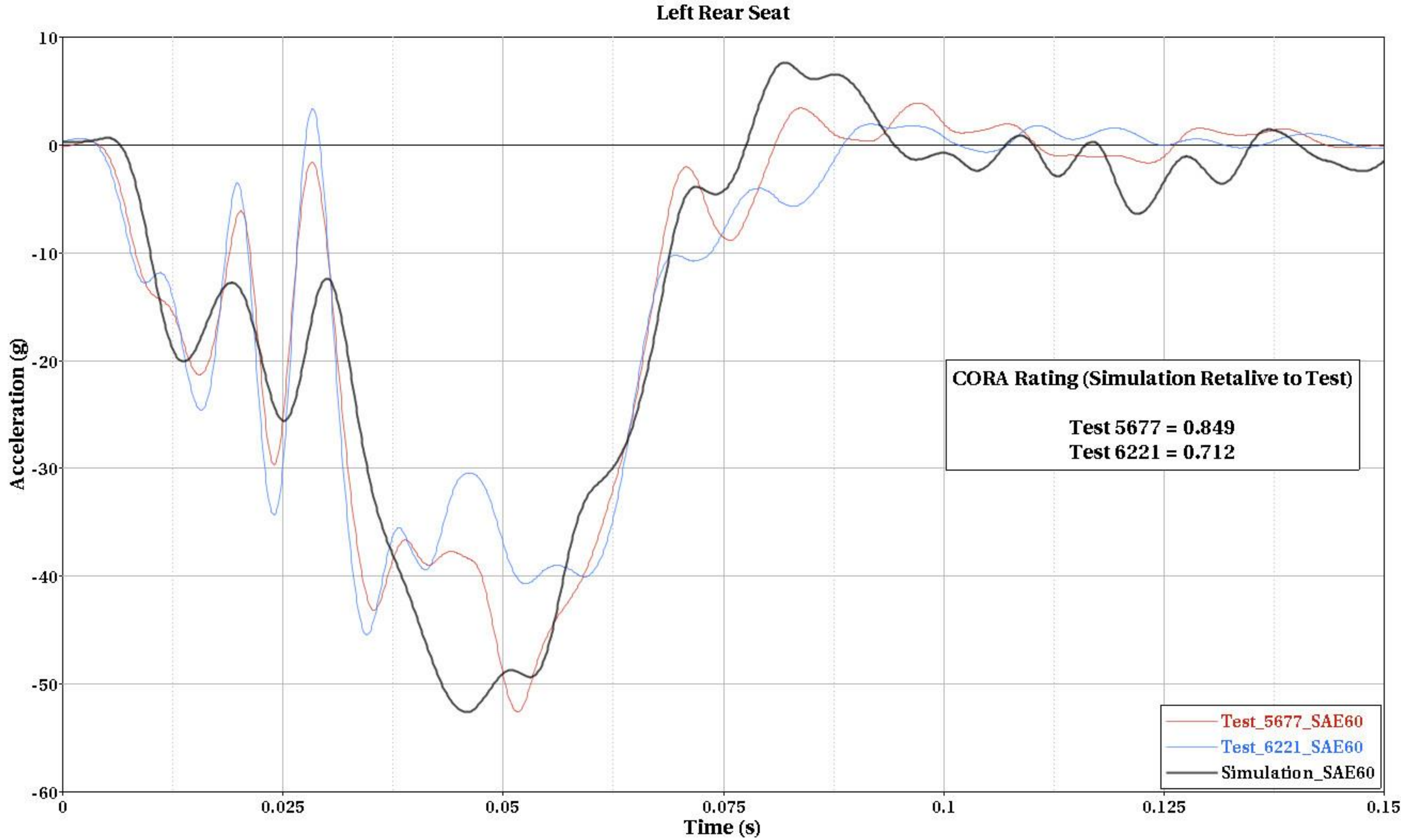
Yaris – Frontal Full Wall – 56 km/h - Video



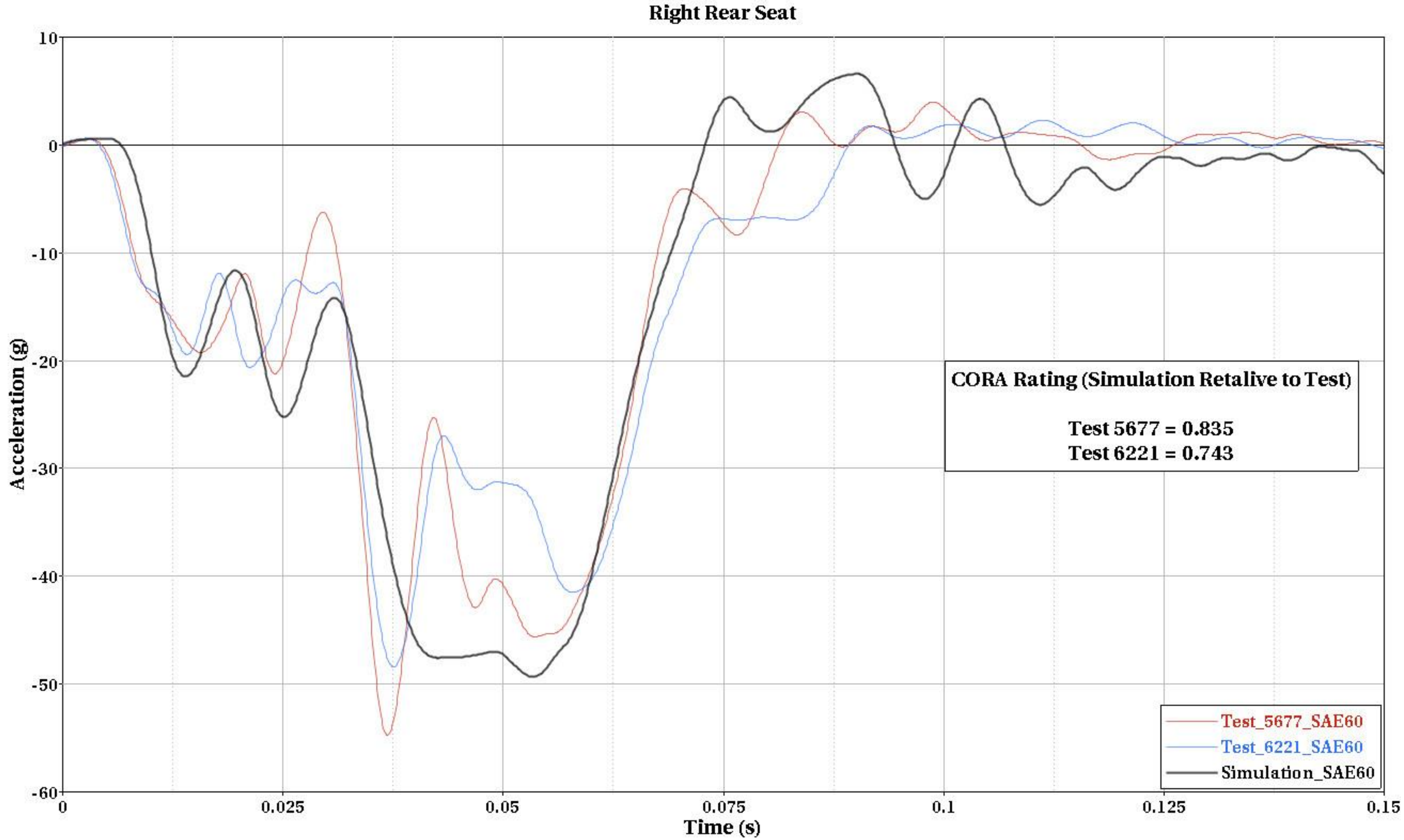
Yaris – Frontal Full Wall – 56 km/hr - Energy Summary



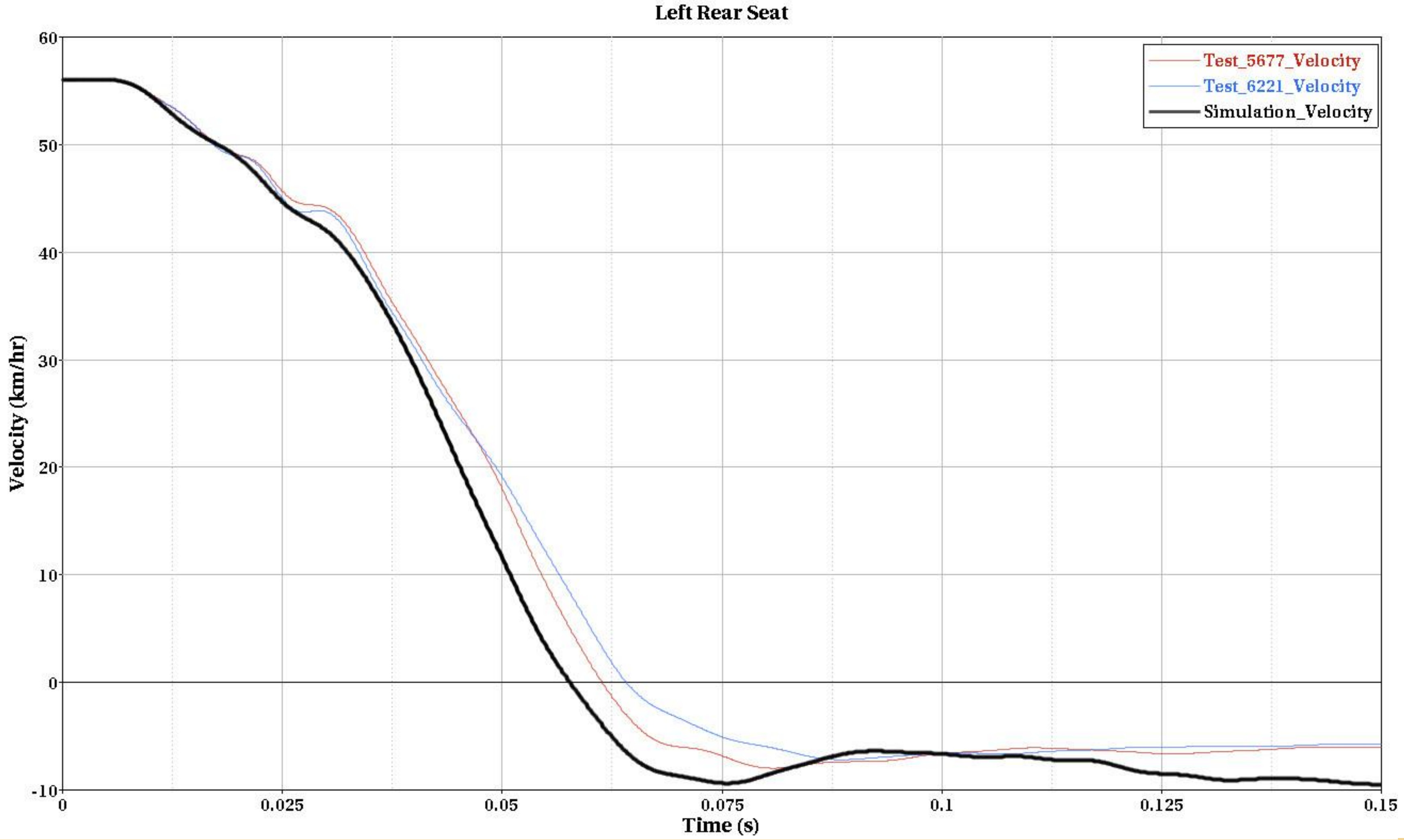
Yaris – Frontal Full Wall – 56 km/hr - Acceleration



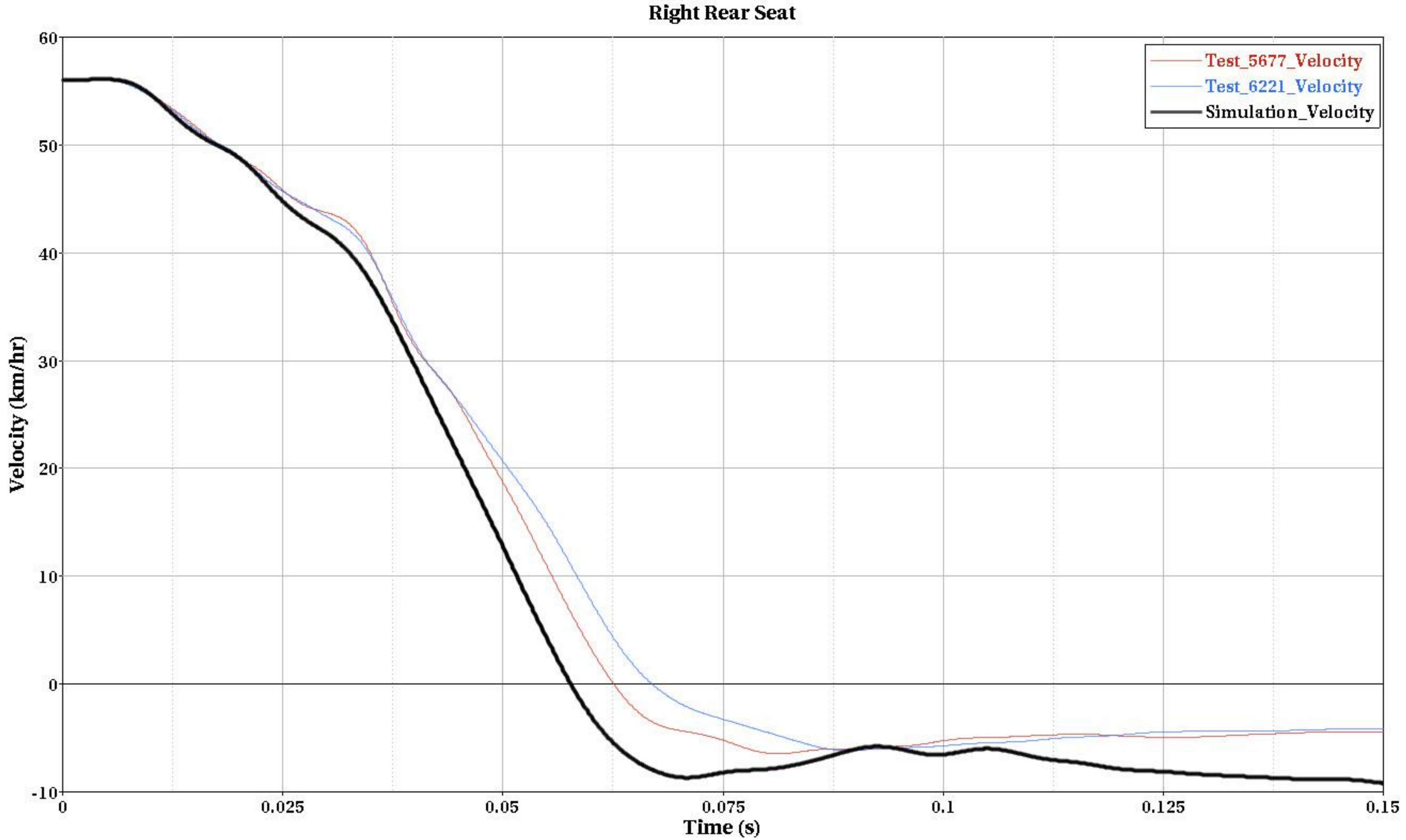
Yaris – Frontal Full Wall – 56 km/hr - Acceleration



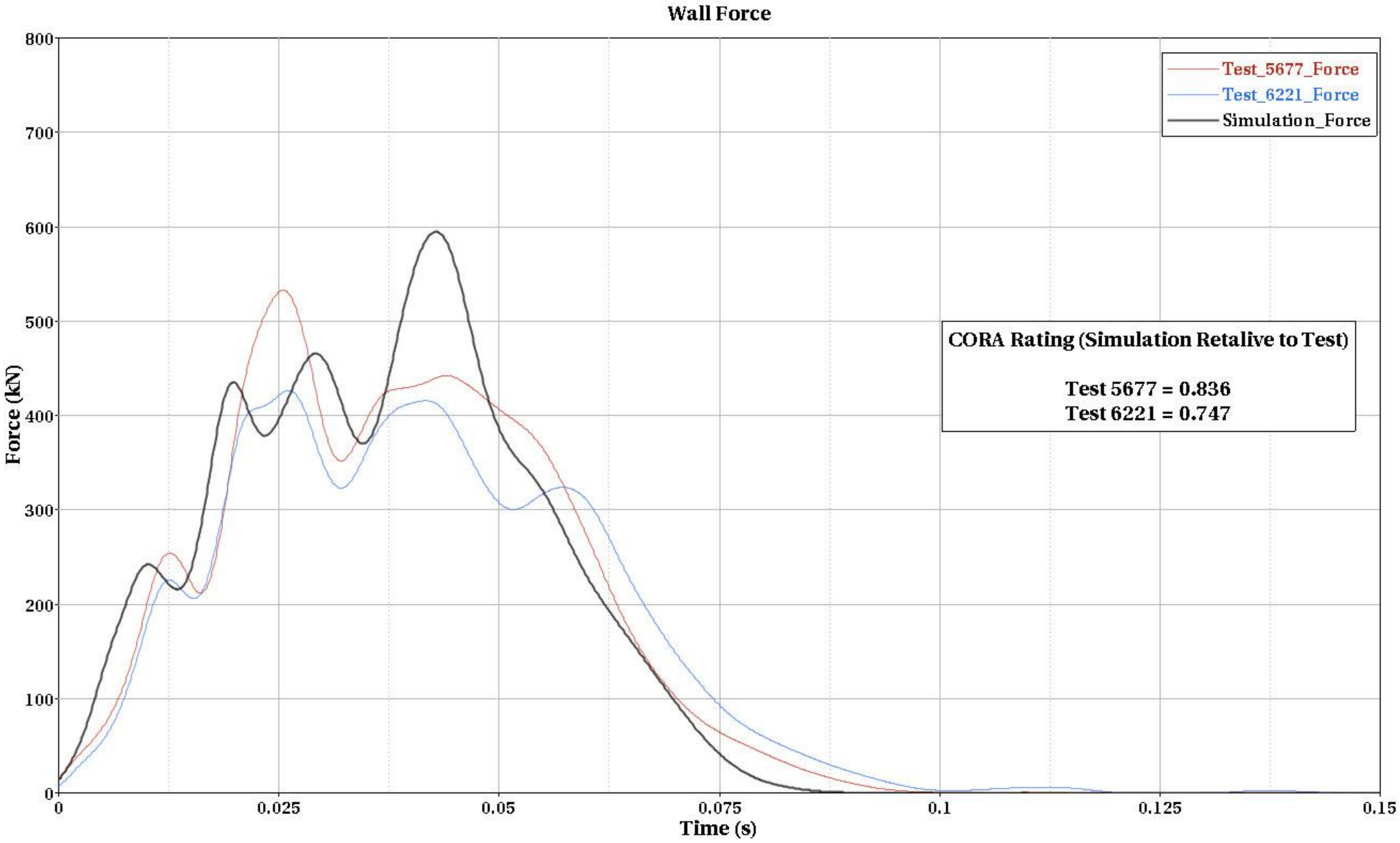
Yaris – Frontal Full Wall – 56 km/hr - Velocity



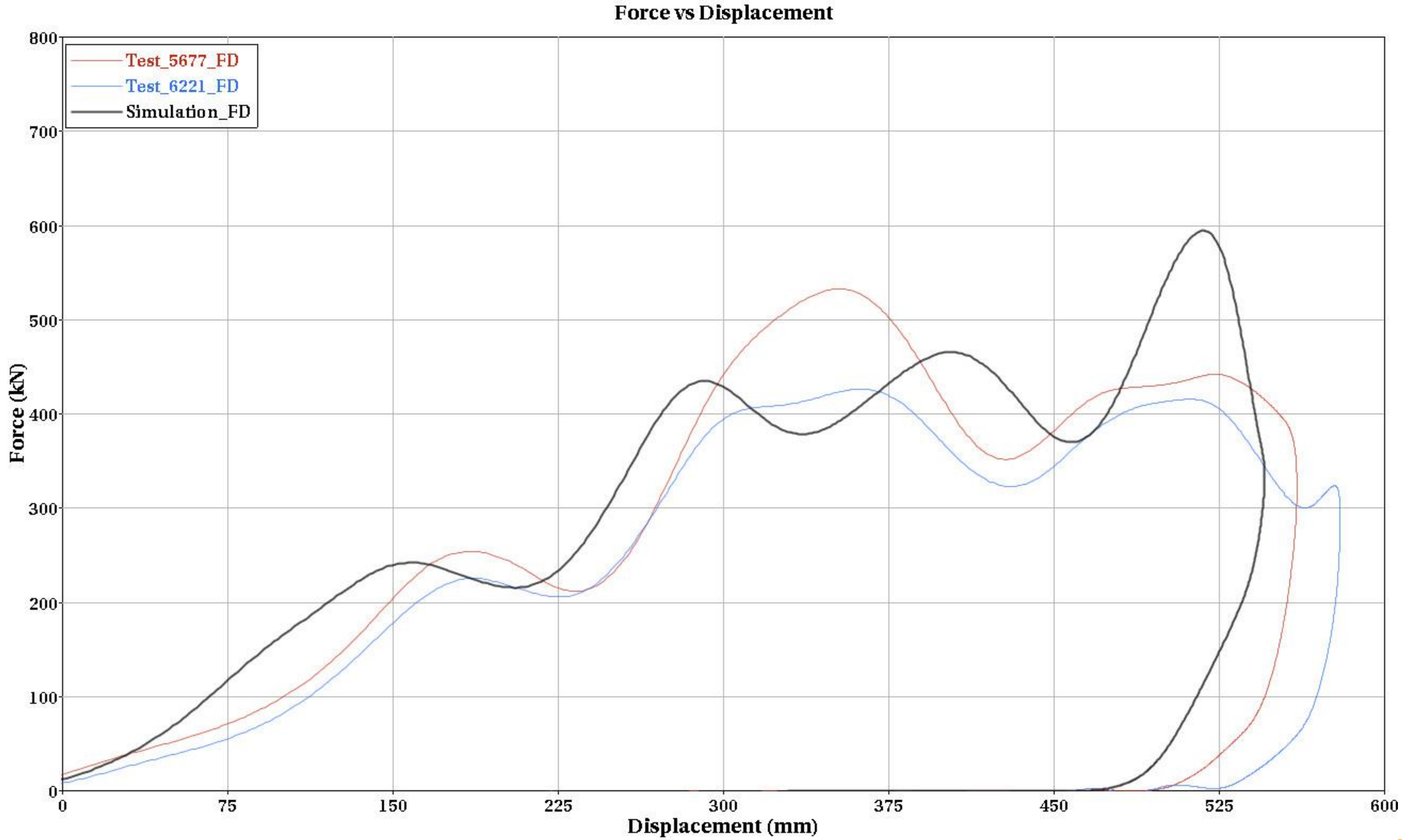
Yaris – Frontal Full Wall – 56 km/hr - Velocity



Yaris – Frontal Full Wall – 56 km/hr – Wall Force

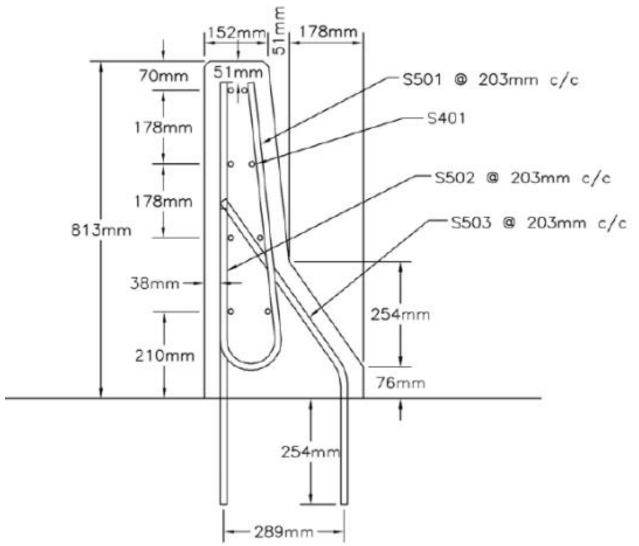


Yaris – Frontal Full Wall – 56 km/hr – Wall Force

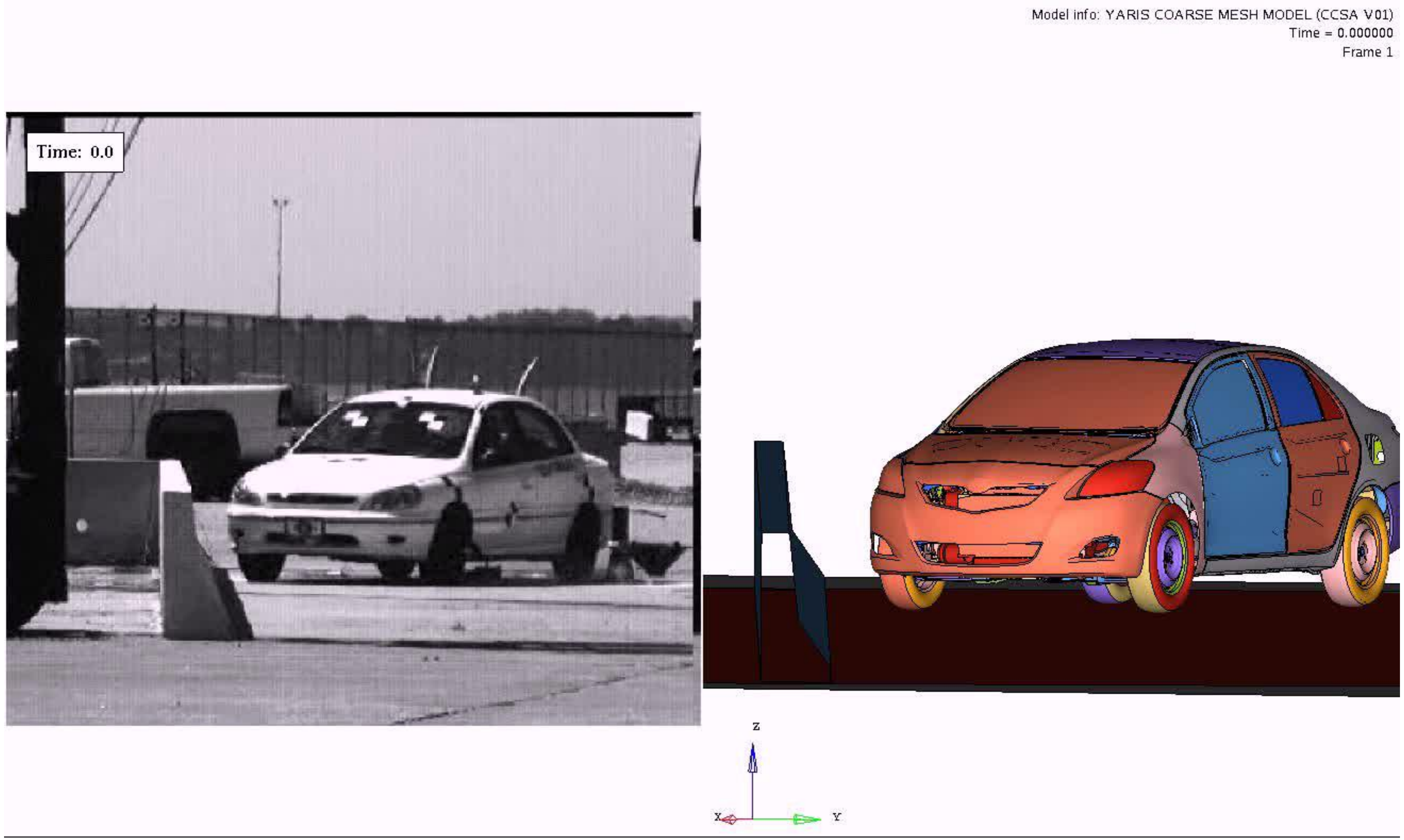


Yaris / NJ CMB

- MwRSF Test 2214NJ-1
- Impact Condition
  - 62.6 mi/hr
  - 26.1 deg
- Vehicle
  - 2002 Kia Rio

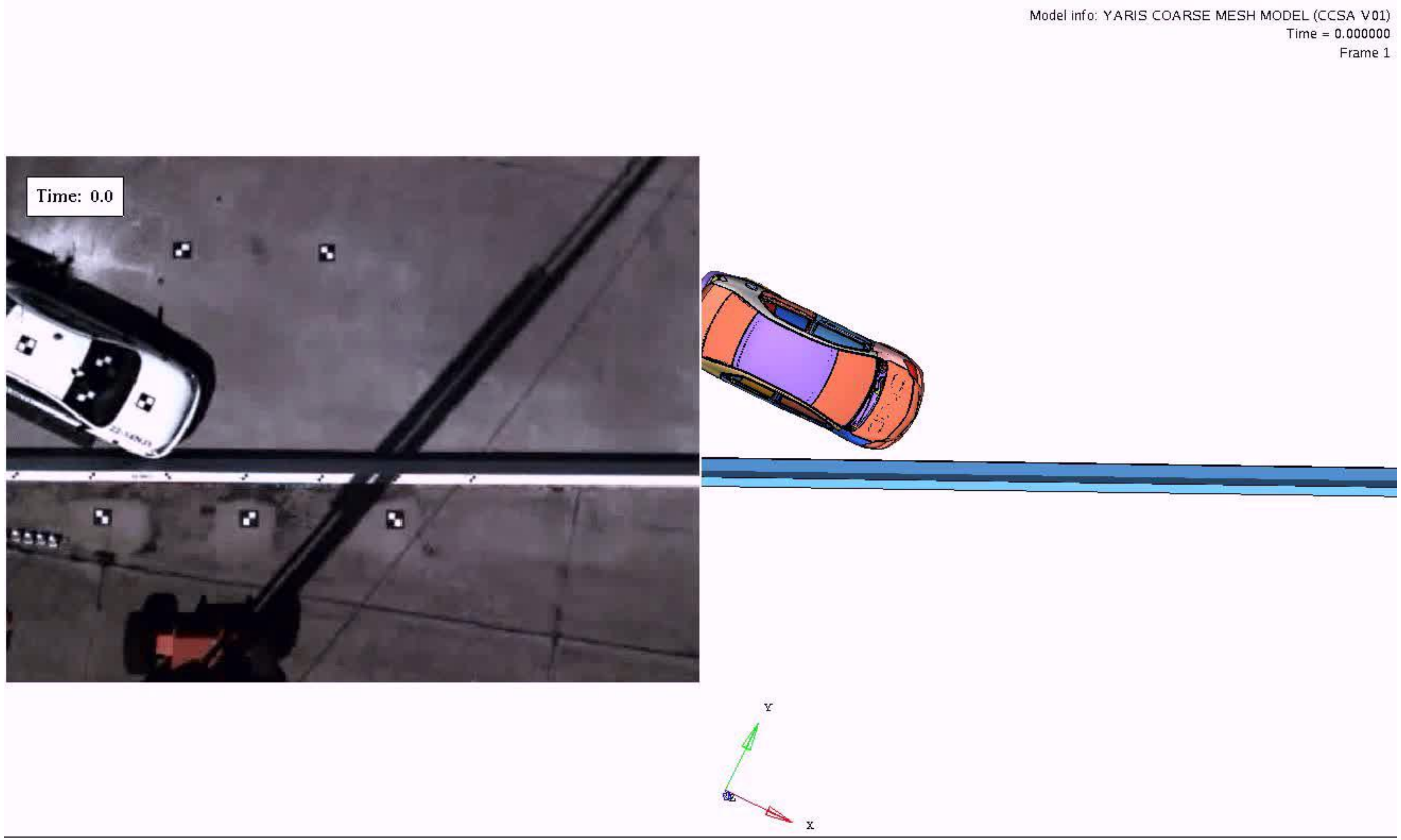


Yaris / NJ CMB - Video

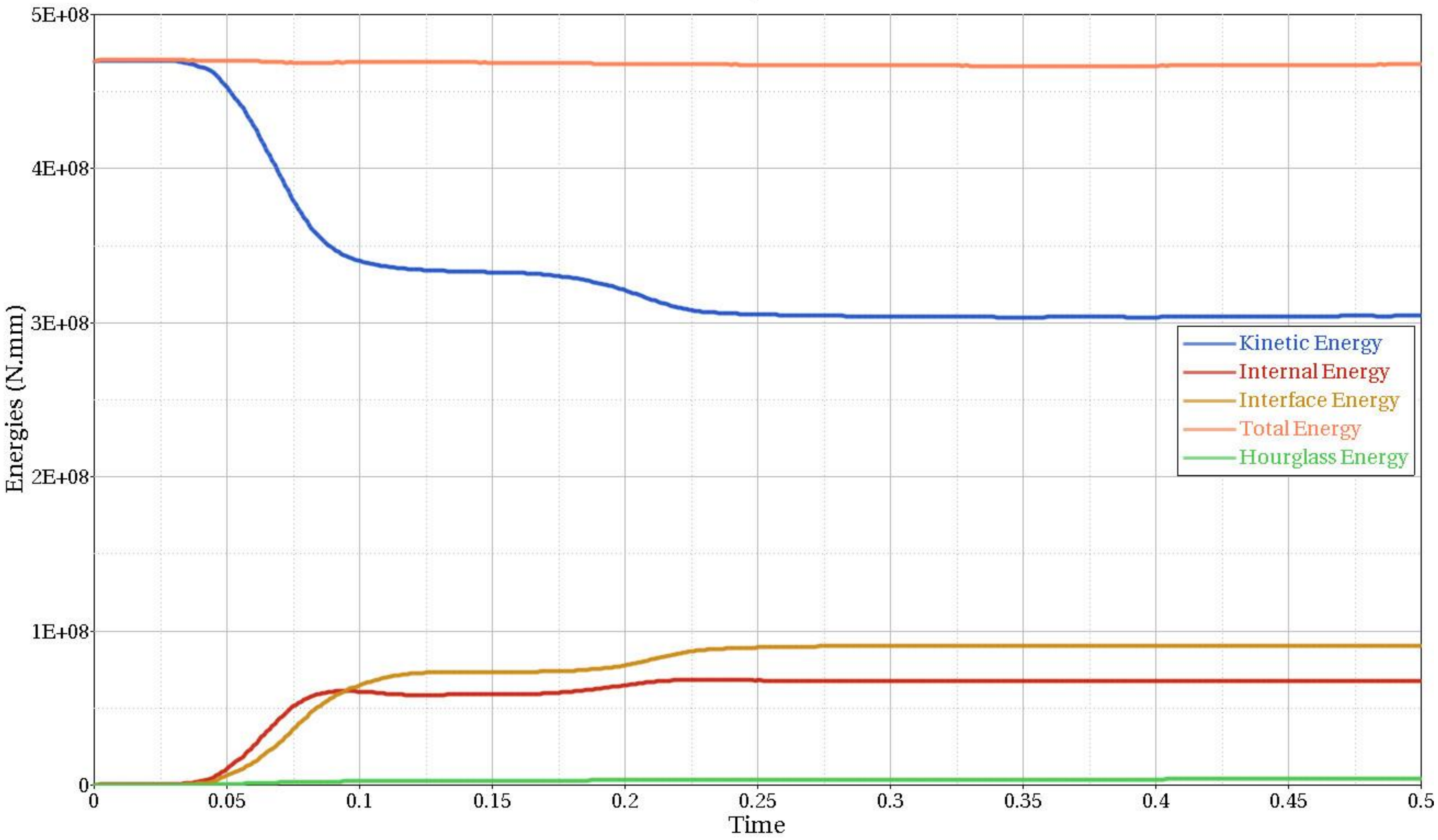


Yaris / NJ CMB - Video

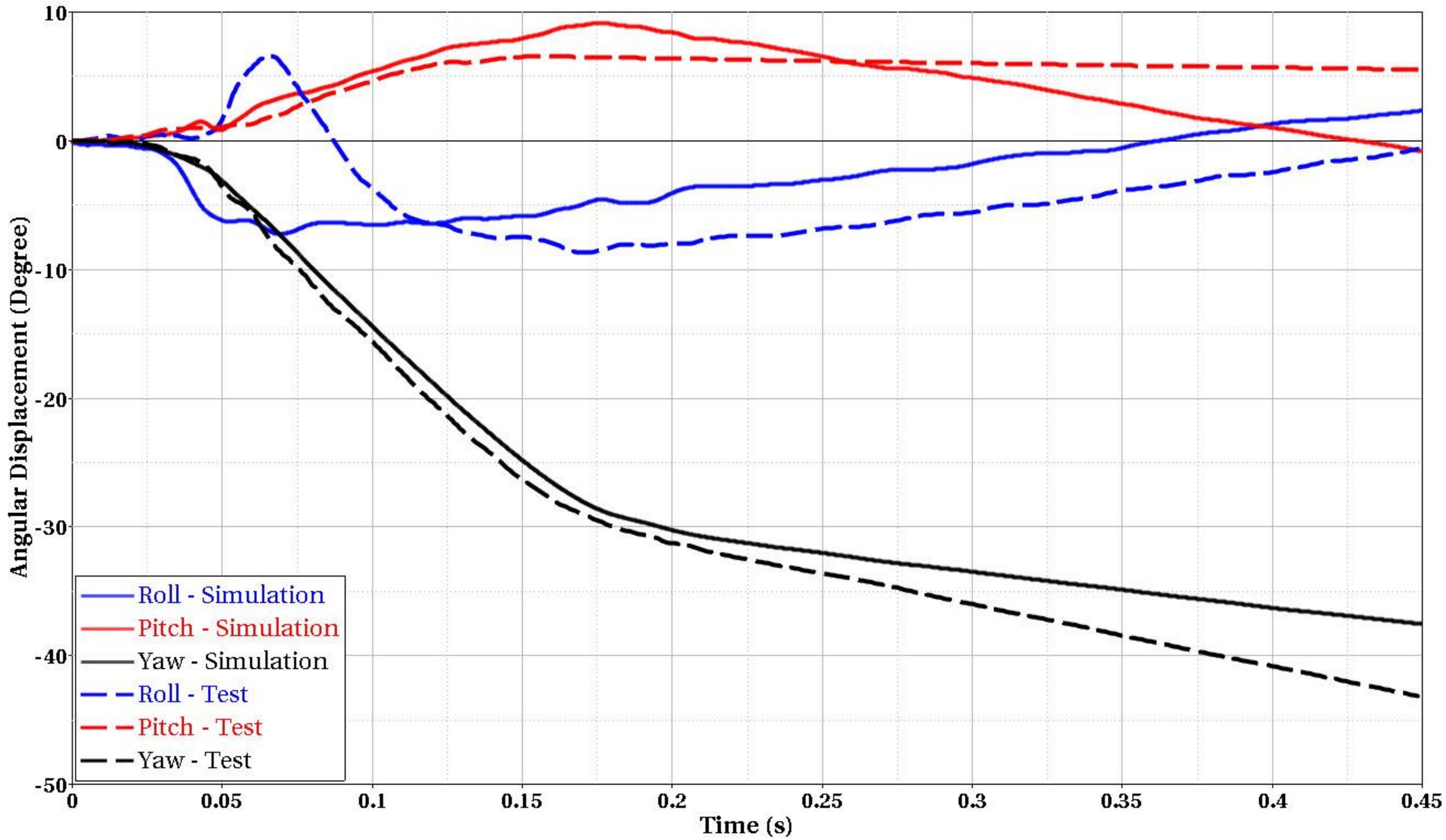
Yaris / NJ CMB - Video



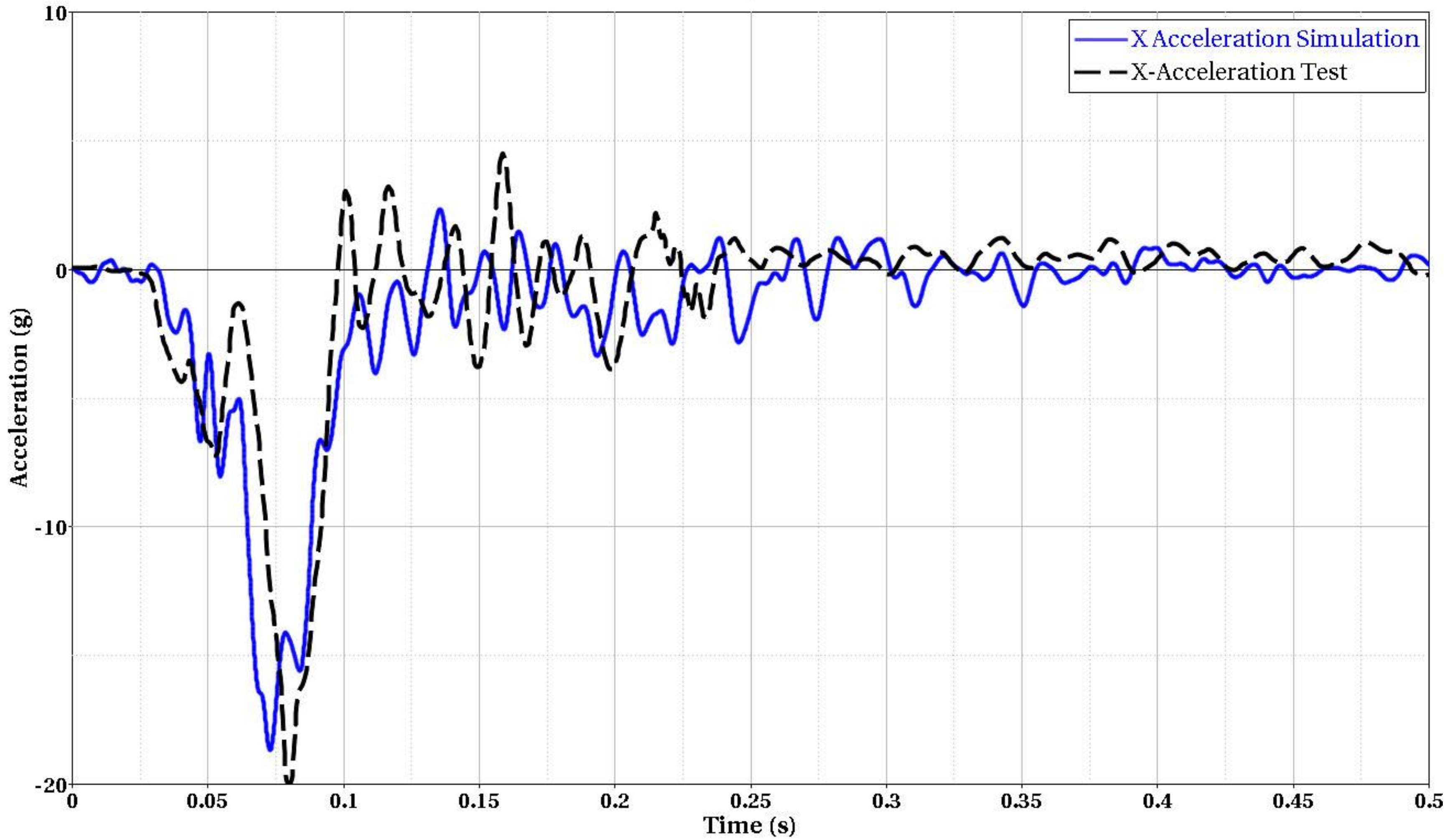
Yaris / NJ CMB - Energy Summary



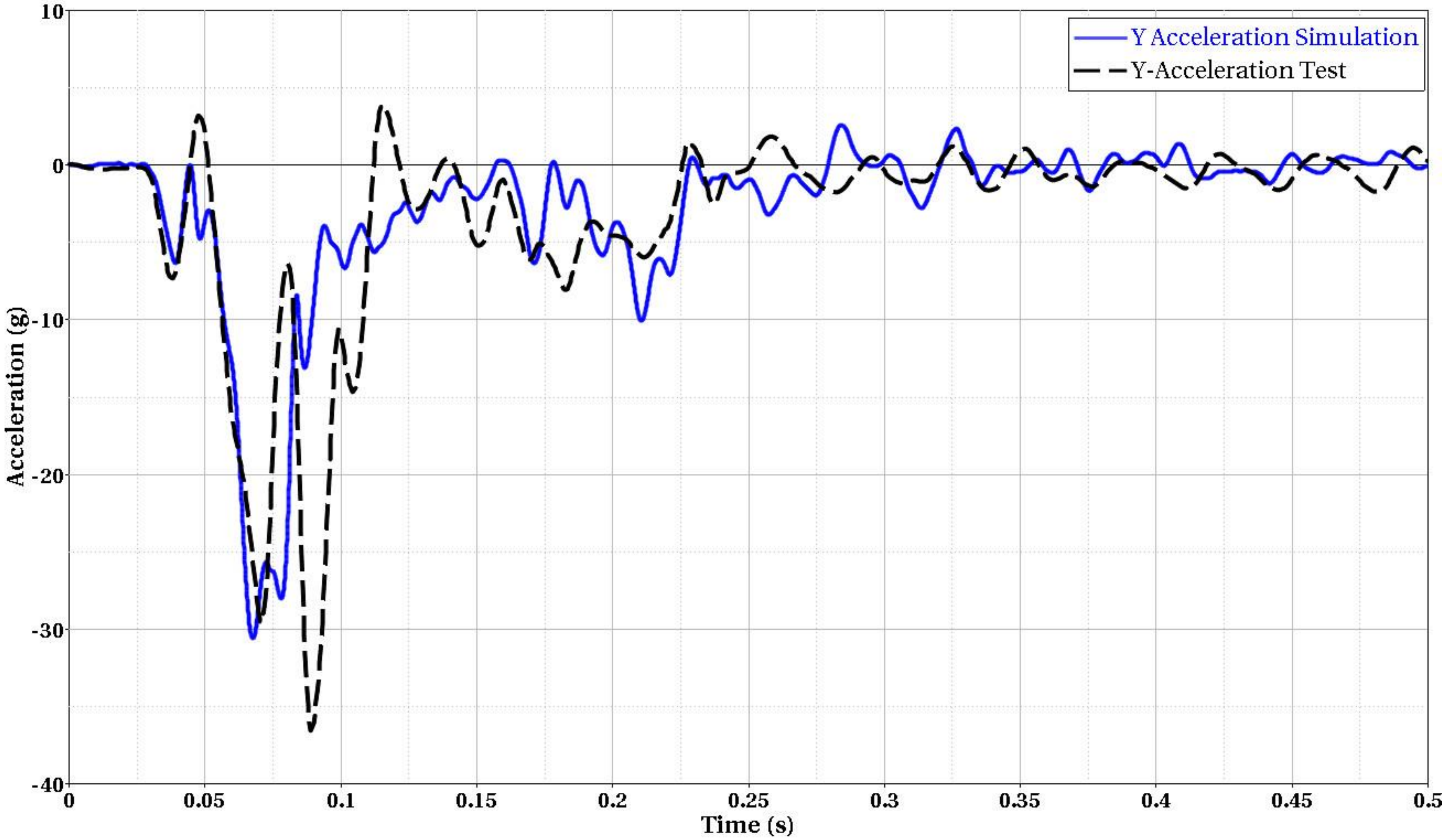
Yaris / NJ CMB - Roll, Pitch, and Yaw



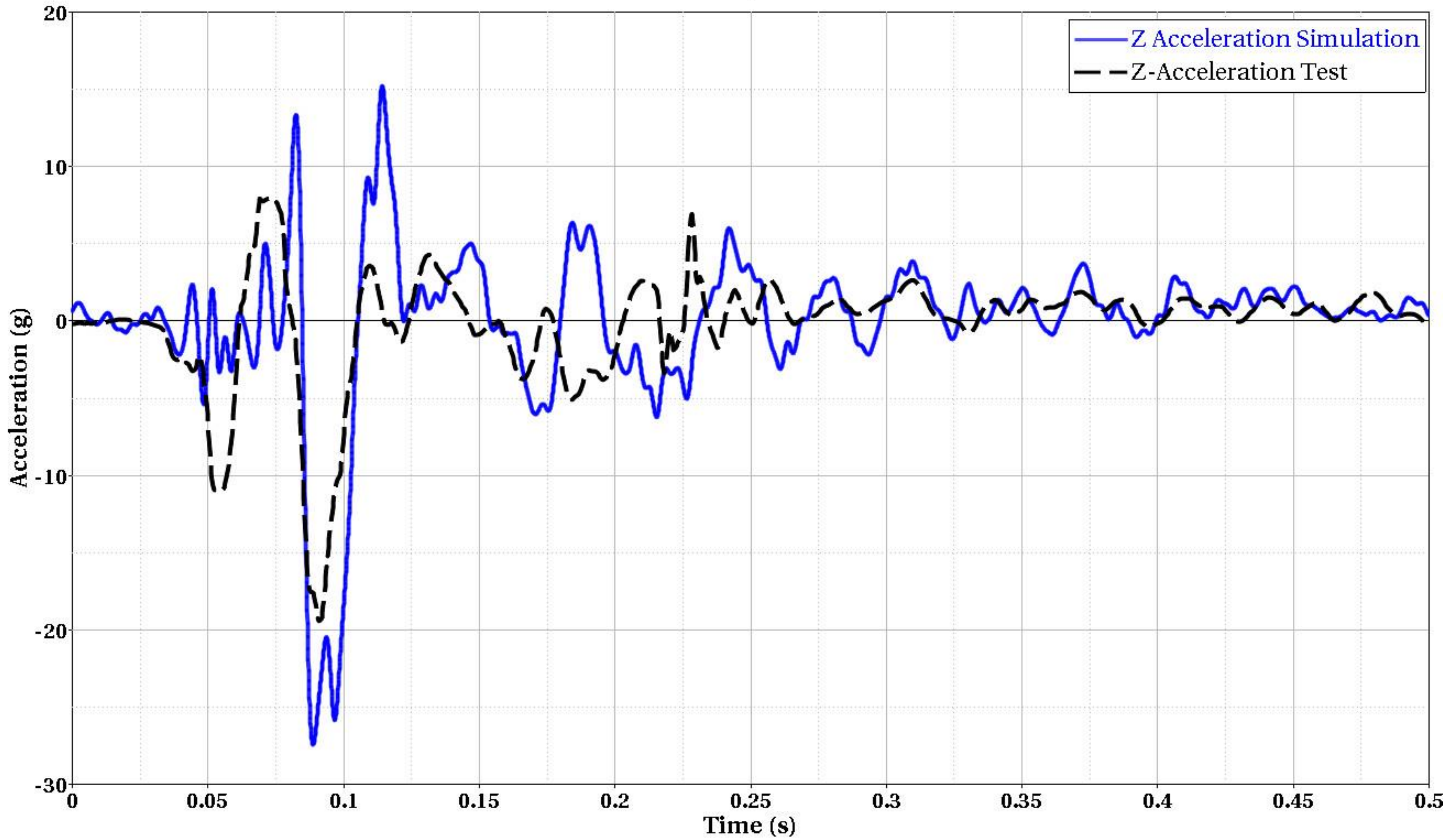
Yaris / NJ CMB – X - Acceleration



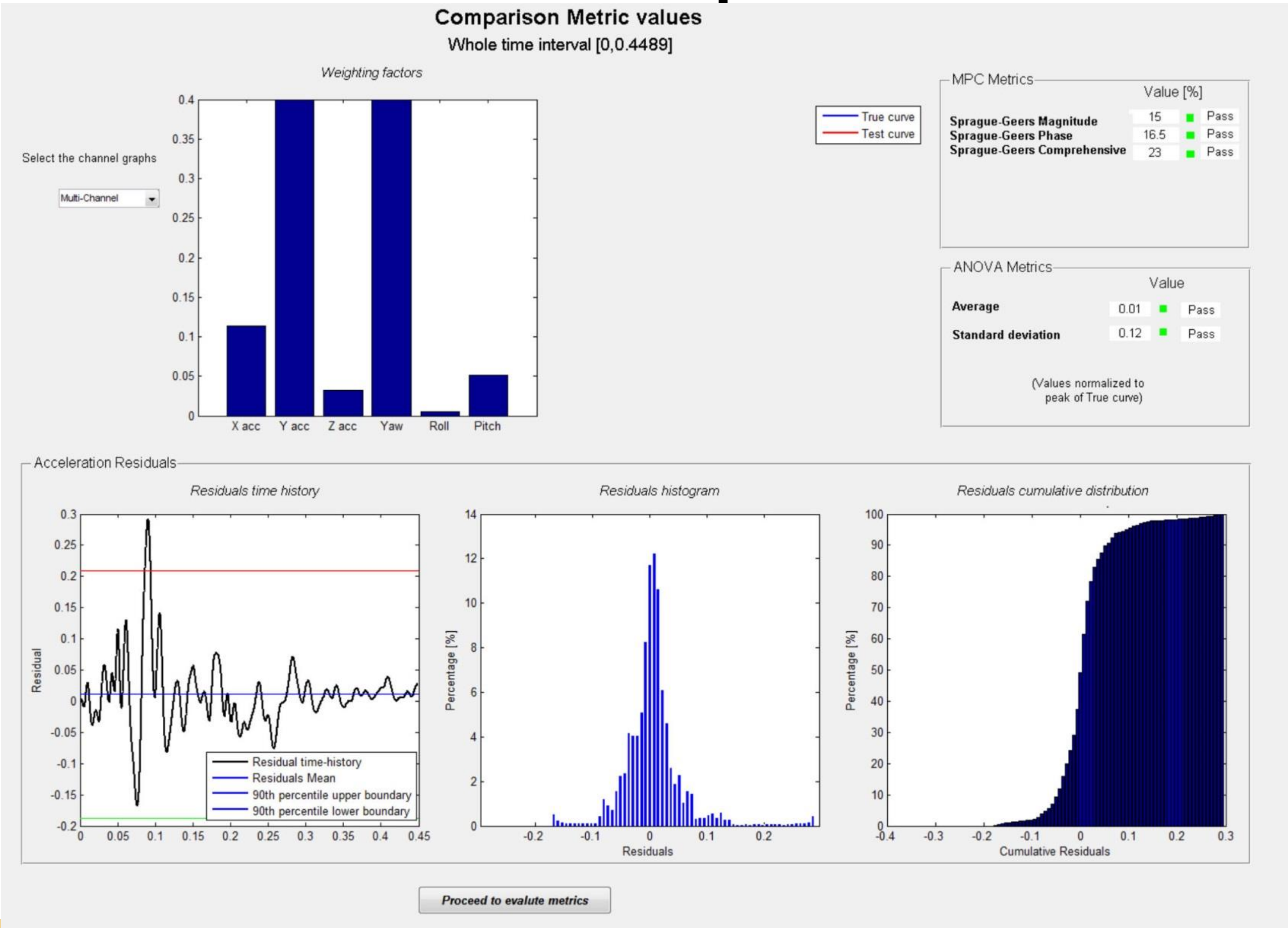
Yaris / NJ CMB – Y - Acceleration



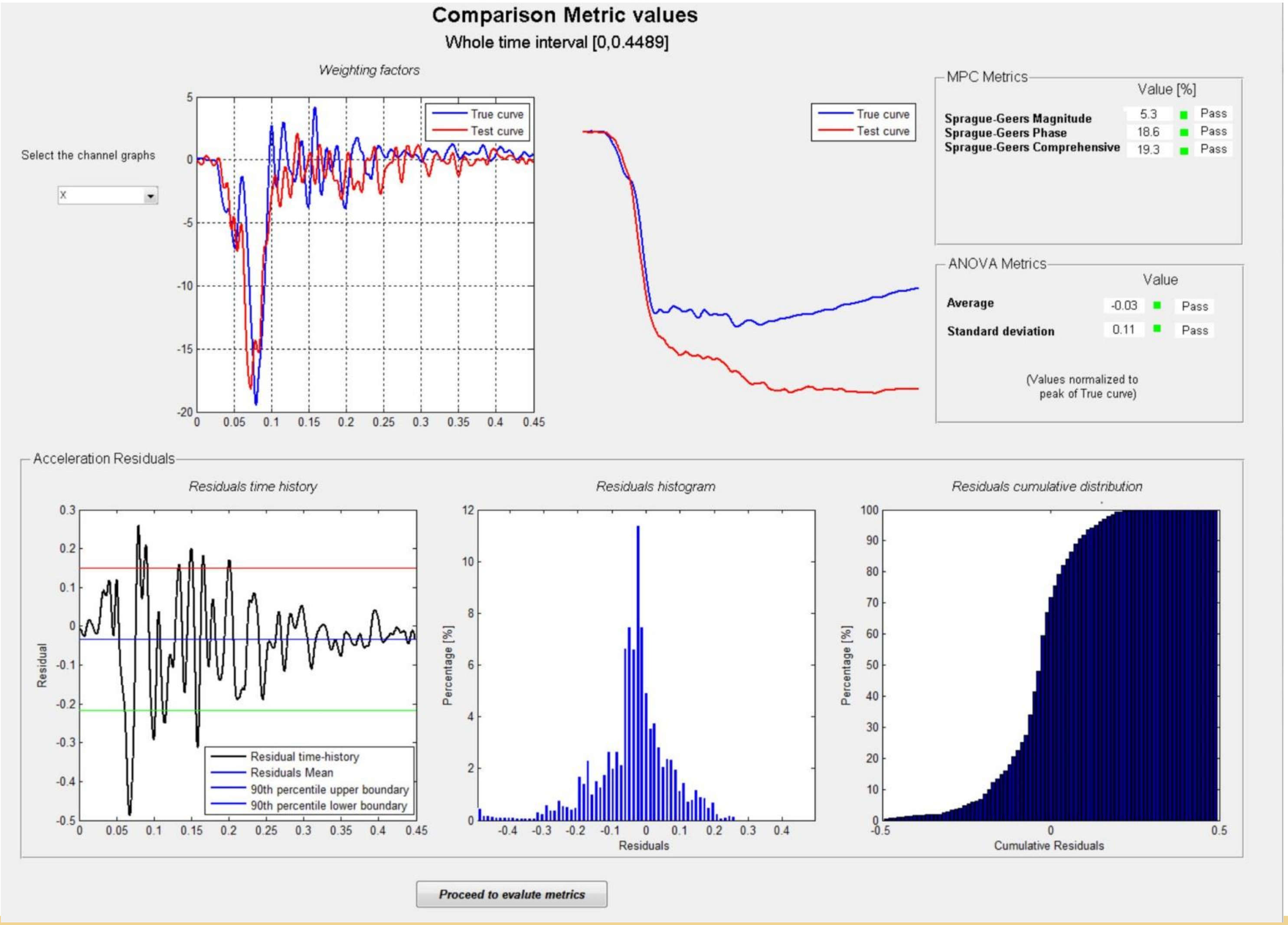
Yaris / NJ CMB – Z - Acceleration



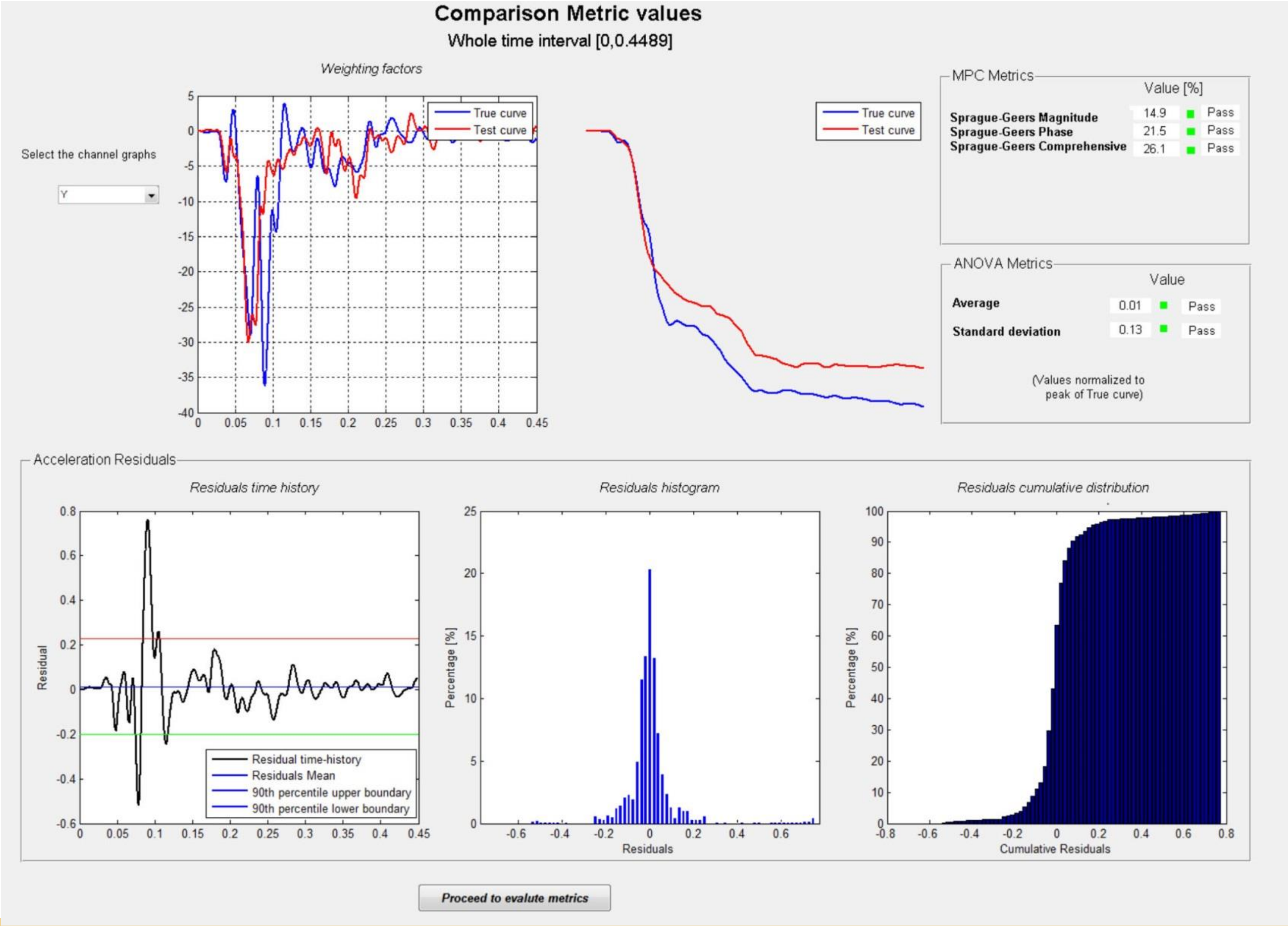
Yaris / NJ CMB – RSVVP Comparison Metrics



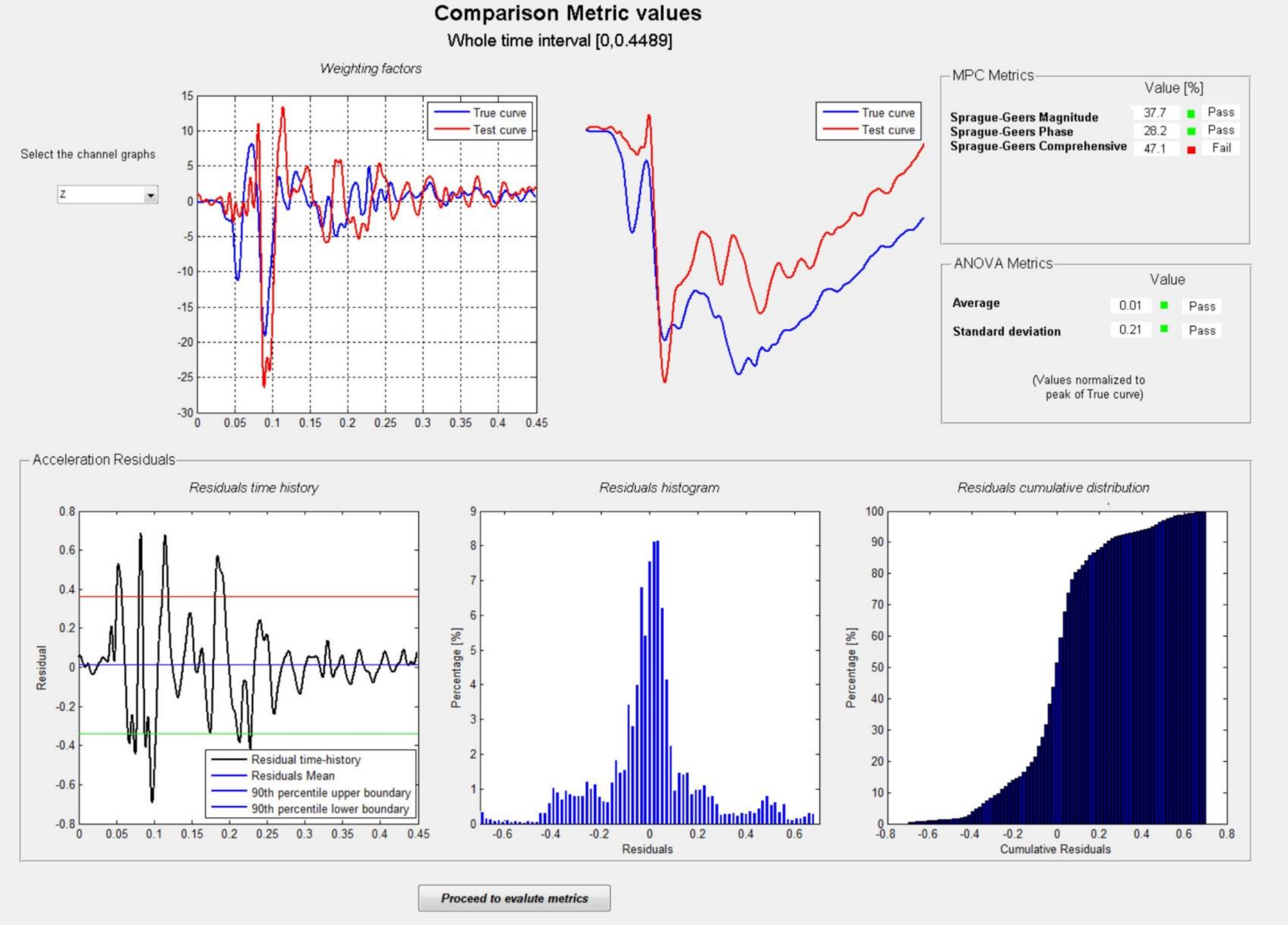
Yaris / NJ CMB – RSVVP Evaluation – X - Acceleration



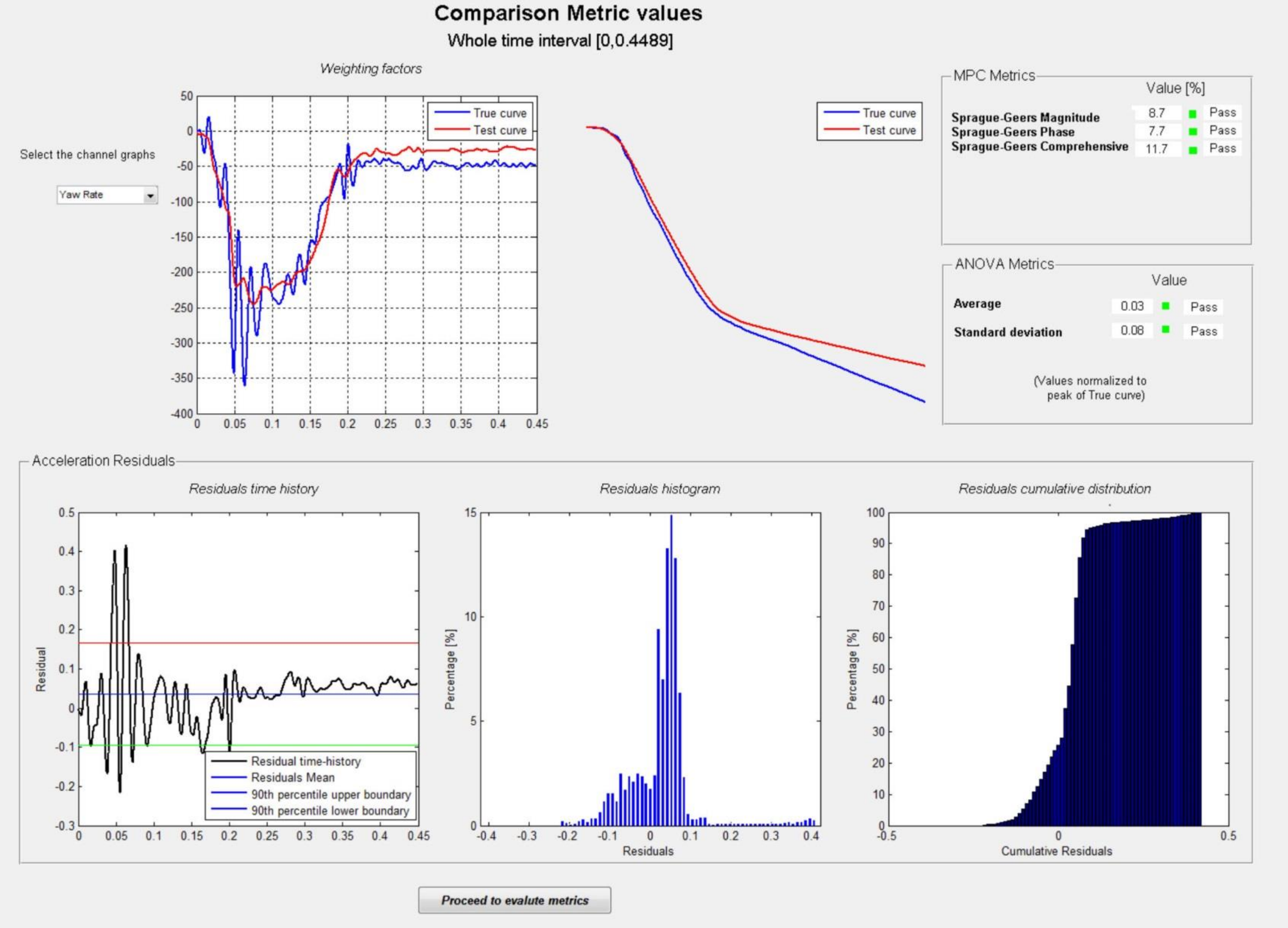
Yaris / NJ CMB – RSVVP Evaluation – Y - Acceleration



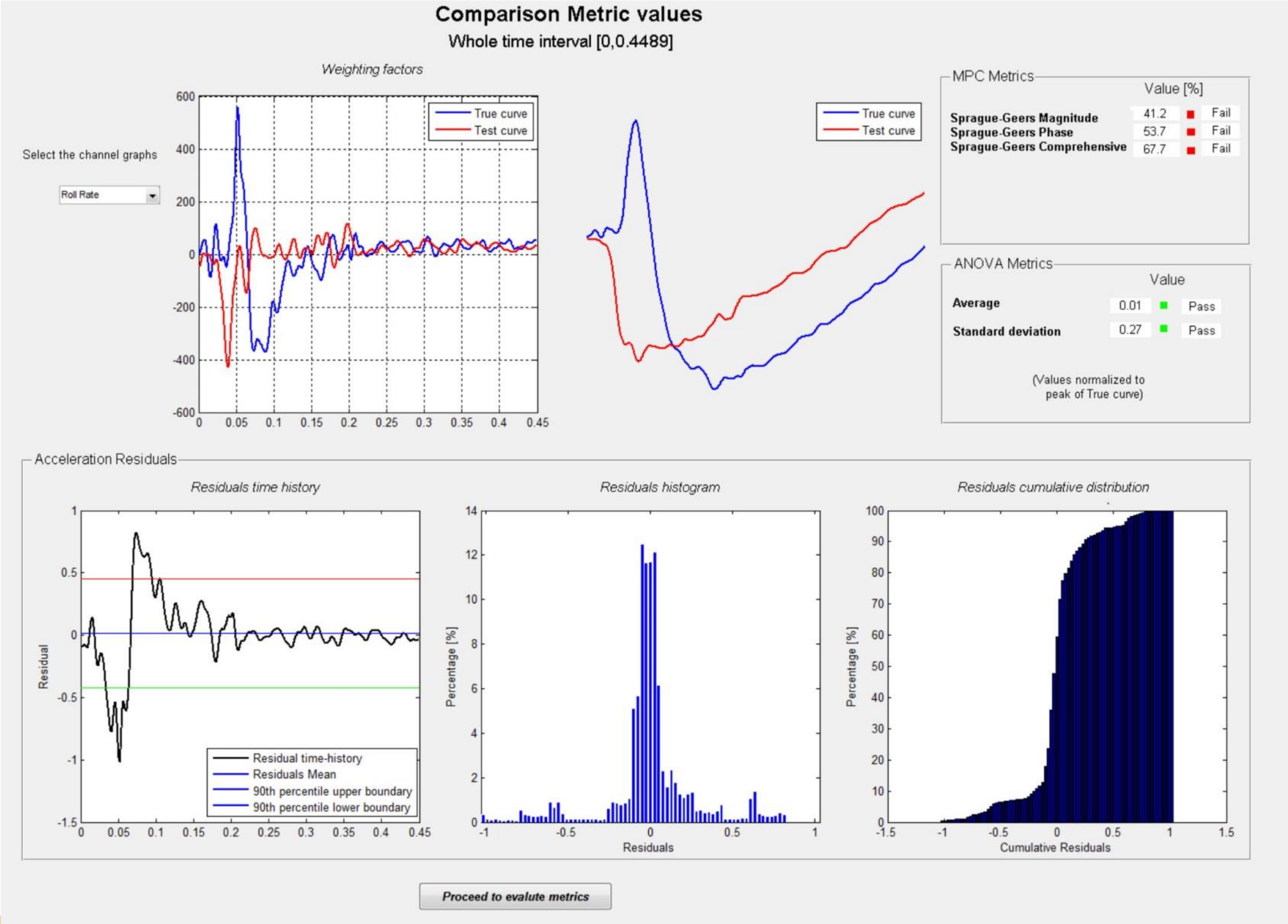
Yaris / NJ CMB – RSVVP Evaluation – Z - Acceleration



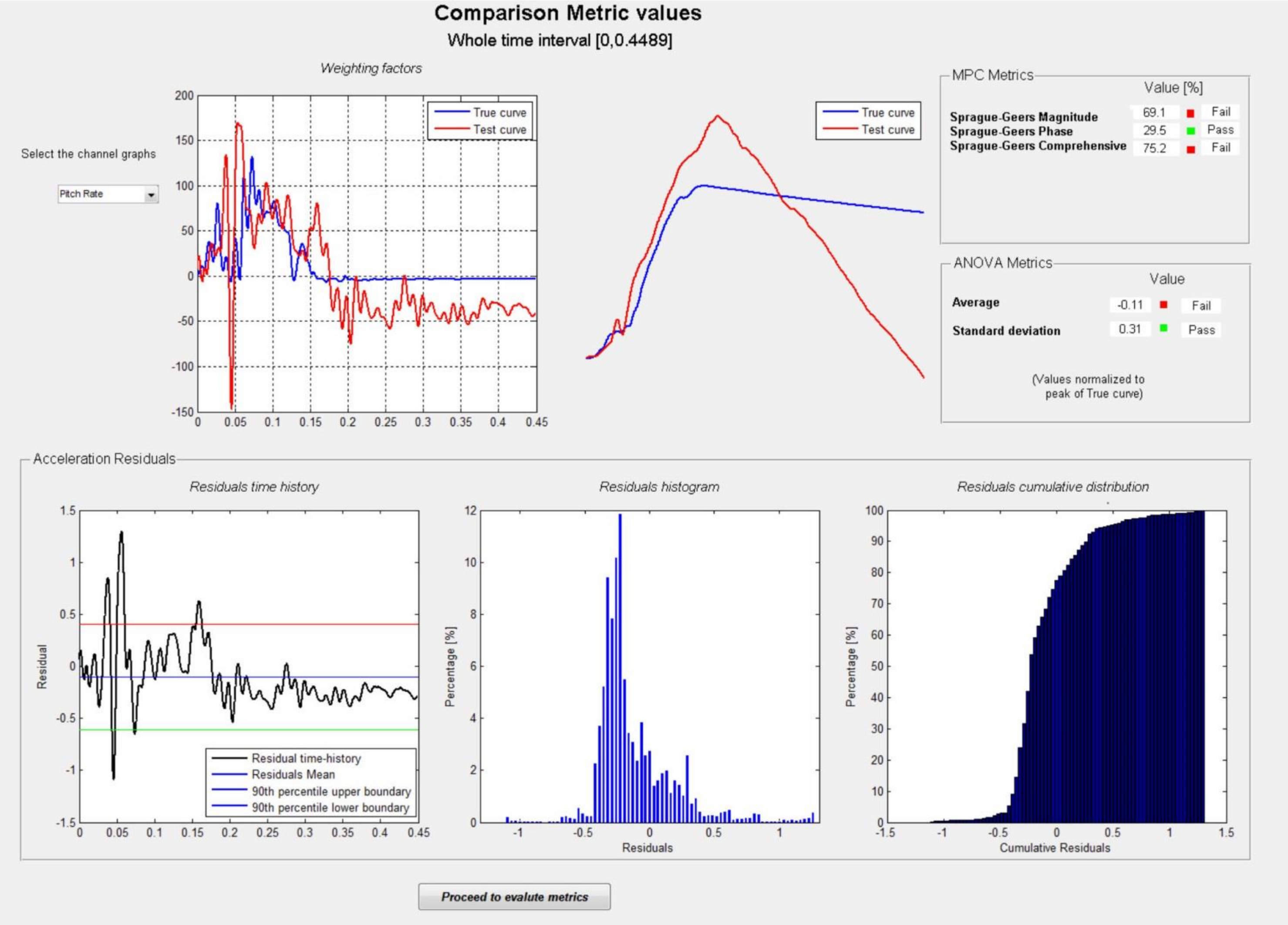
Yaris / NJ CMB – RSVVP Evaluation – Yaw Rate



Yaris / NJ CMB – RSVVP Evaluation – Roll Rate



Yaris / NJ CMB – RSVVP Evaluation – Pitch Rate



Summary

- Model verified in 56 km/hr and 40 km/hr full frontal impacts (NHTSA tests 5677, 6221, and 6069)
- Model verified in 64 km/hr frontal offset impact (IIHS test CEF0610)
- Model verified in NHTSA and IIHS side impacts (NHTSA tests 5679, 6220, 6558, 6585 and IIHS tests CES50638 CES0639)
- Model Validated in NJ shape concrete barrier impact (MwRSF Test 2214NJ-1, Kia Rio vehicle)

Appendix F

Validation Forms for Silverado (2270P) Vehicle Model

Validation Reports

- **Appendix F-1: NJ Concrete Barrier Impact with 2270P Vehicle**
- **Appendix F-2: G4(1S) Barrier Impact with 2270P Vehicle**
- **Appendix F-3: MGS Barrier Impact with 2270P Vehicle**

Each of the Reports Includes:

- **Table 1A – V&V Summary Table**
- **Table 1B – V&V Analysis Solution Verification Summary Table & RSVVP Results**
- **Figure 1 – Energy Balance Diagram**
- **Figure 2A – RSVVP Multi-Channel Comparison**
- **Figure 2B – RSVVP Longitudinal Acceleration Comparison**
- **Figure 2C – RSVVP Lateral Acceleration Comparison**
- **Figure 2D – RSVVP Vertical Acceleration Comparison**
- **Figure 2E – RSVVP Roll Angle Comparison**
- **Figure 2F – RSVVP Pitch Angle Comparison**
- **Figure 2G– RSVVP Yaw Angle Comparison**
- **Figure 3 – Comparison of Changes in Vehicle Velocities**
- **Figure 4 – Comparison of Changes in Vehicle Angles**
- **Table 1C – V&V PIRTs Summary Table**
- **Figure 5 – Full-Scale Test Summary**
- **Figure 6 – Sequential Comparisons (Front, rear, and top views)**
- **Table 1D – V&V Overall Summary Table**

Appendix F-1: New Jersey Concrete Barrier Impact with 2270P Vehicle

CCSA VALIDATION/VERIFICATION REPORT

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P Vehicle with New Jersey Safety Shape Barrier
Impact Description: 25 degree impact into barrier at 100 km/h (62 mph)
Governing Criteria: MASH TL-3
Report Date: February 2013

Table A – Information Sources:

General Information	Known Solution	Analysis Solution
Performing Organization	TTI	CCSA-GWU
Test/Run Number	RF476460-1-4	
Vehicle	2007 Chevrolet Silverado	CCSA - 2007 Silverado Model
Vehicle Mass (lb/kg)	5049 / 2290	5005 / 2270
Impact Speed (mph/kph)	62.6 / 100.75	62.6 / 100.75
Impact Angle (degrees)	25.2	25.2

Table B - Evaluation Parameters Summary:

Category	Subset	Values
Evaluation Method	MASH (V1, 2009)	
Hardware Type	Longitudinal	
Test Number	3-11	
Test Vehicle Required	2270P	
Criterion to be Applied	**Structural Adequacy**	**A -** Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.
	Occupant Risk	**D** - Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone.
		F - The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are
		H - The occupant impact velocity in the longitudinal direction should not exceed 40 ft/sec and the occupant ride-down acceleration in the longitudinal direction should not exceed 20 G"s.
		I - Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.
	Vehicle Trajectory	For redirective devices the vehicle shall exit within the prescribed box.

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections

Comparison Case: 2270P Vehicle with New Jersey Safety Shape Barrier

Table C – Analysis Solution Verification Summary

Verification Evaluation Criteria	Change (%)	Pass?
Total energy of the analysis solution (i.e., kinetic, potential, contact, etc.) must not vary more than 10 percent from the beginning of the run to the end of the run.	<1%	YES
Hourglass Energy of the analysis solution at the end of the run is less than 5 % of the total initial energy at the beginning of the run	<1%	YES
The part/material with the highest amount of hourglass energy at any time during the run is less than 5 % of the total initial energy at the beginning of the run.	<1%	YES
Mass added to the total model is less than 5 % the total model mass at the start of the run.	<1%	YES
The part/material with the most mass added had less than 10 % of its initial mass added.	<1%	YES
The moving parts/materials in the model have less than 5 % of mass added to the initial moving mass of the model.	<1%	YES
There are no shooting nodes in the solution?	NA	YES
There are no solid elements with negative volumes?	NA	YES

Table D - RSVVP Results

	Single Channel Time History Comparison Results	**Time interval [0 sec - 0.5 sec]**		
O	***Sprauge-Geer Metrics***	**M**	**P**	**Pass?**
	X acceleration	52.9	35.6	NO
	Y acceleration	3.2	16.2	YES
	Z acceleration	71.7	45.3	NO
	Yaw rate	13.4	9.5	YES
	Roll rate	16.8	24.4	YES
	Pitch rate	35.4	39.9	YES
P	***ANOVA Metrics***	**Mean**	**SD**	**Pass?**
	X acceleration/Peak	1.32	29.37	YES
	Y acceleration/Peak	0.84	12.15	YES
	Z acceleration/Peak	0.66	44.94	NO
	Yaw rate	0.2	14.87	YES
	Roll rate	0.21	17.28	YES
	Pitch rate	10.86	53.95	NO

Multi-Channel Weighting Factors		**Time interval [0 sec; 0.5 sec]**
Multi-Channel Weighting Method **Peaks Area I** **Area II Inertial**	**X Channel**	0.142263141
	Y Channel	0.312496147
	Z Channel	0.045240712
	Yaw Channel	0.19476326
	Roll Channel	0.200826808
	Pitch Channel	0.104409933

Sprauge-Geer Metrics	**M**	**P**	**Pass?**
All Channels (weighted)	21.4	23.1	YES
ANOVA Metrics	**Mean**	**SD**	**Pass?**
All Channels (weighted)	1.5	22	YES

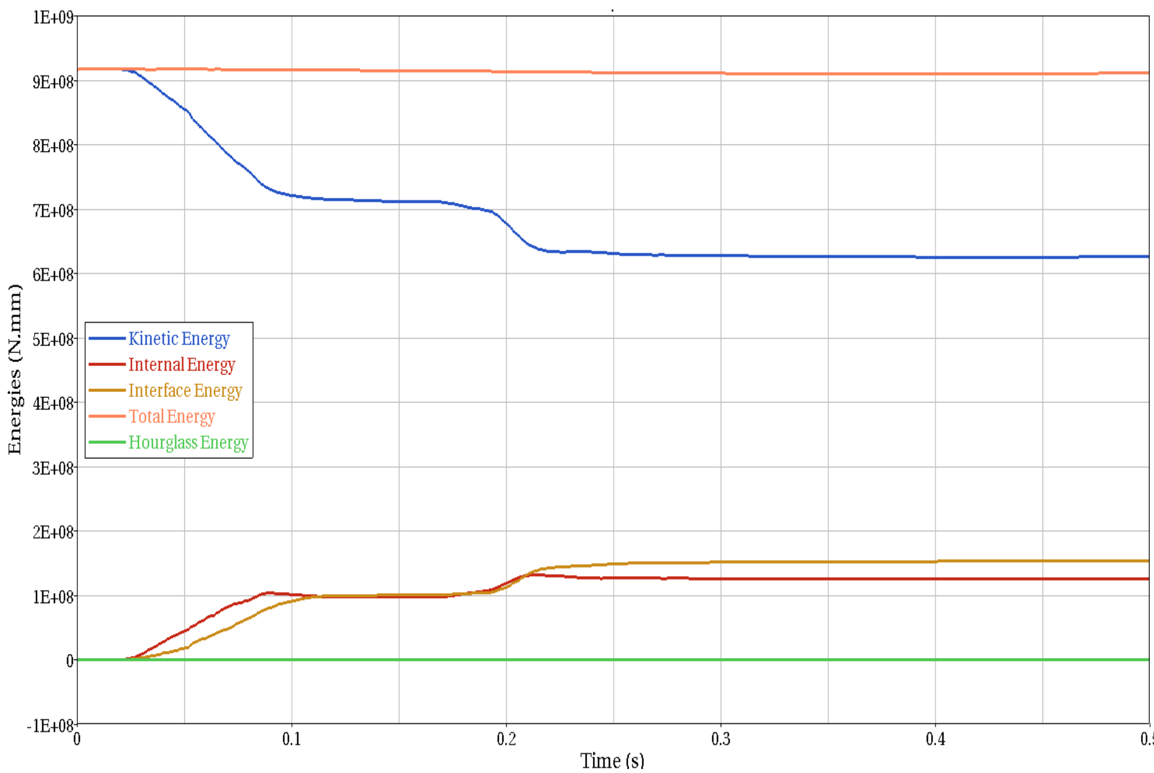


Figure 1: Simulations Energies

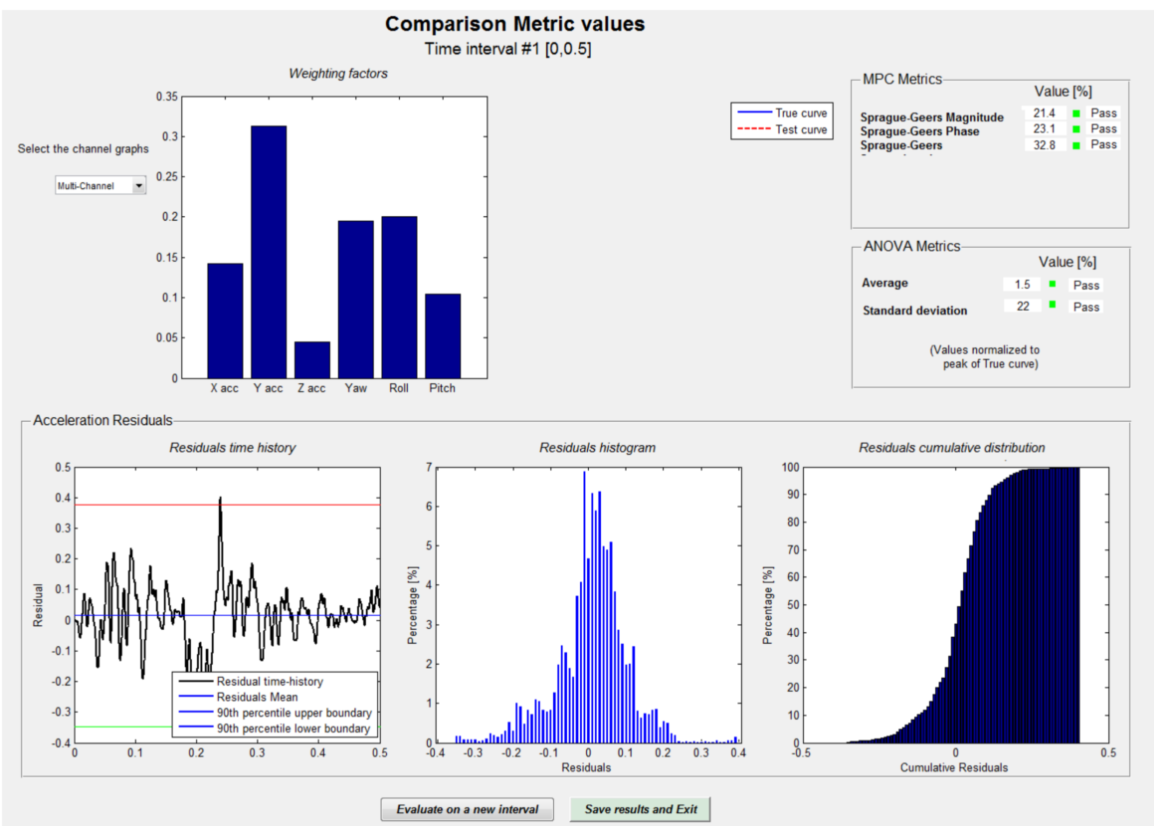


Figure 2a: RSVVP Results – All Channels

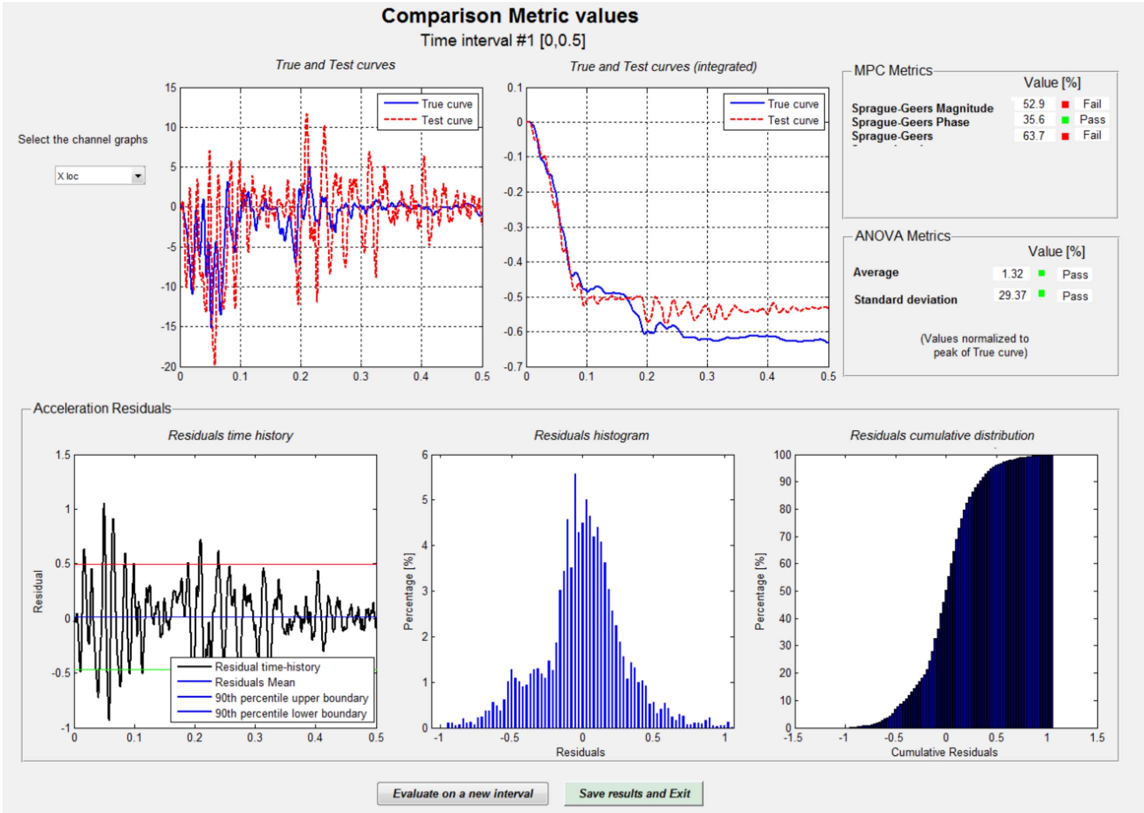


Figure 2b: RSVVP Results – Longitudinal Acceleration

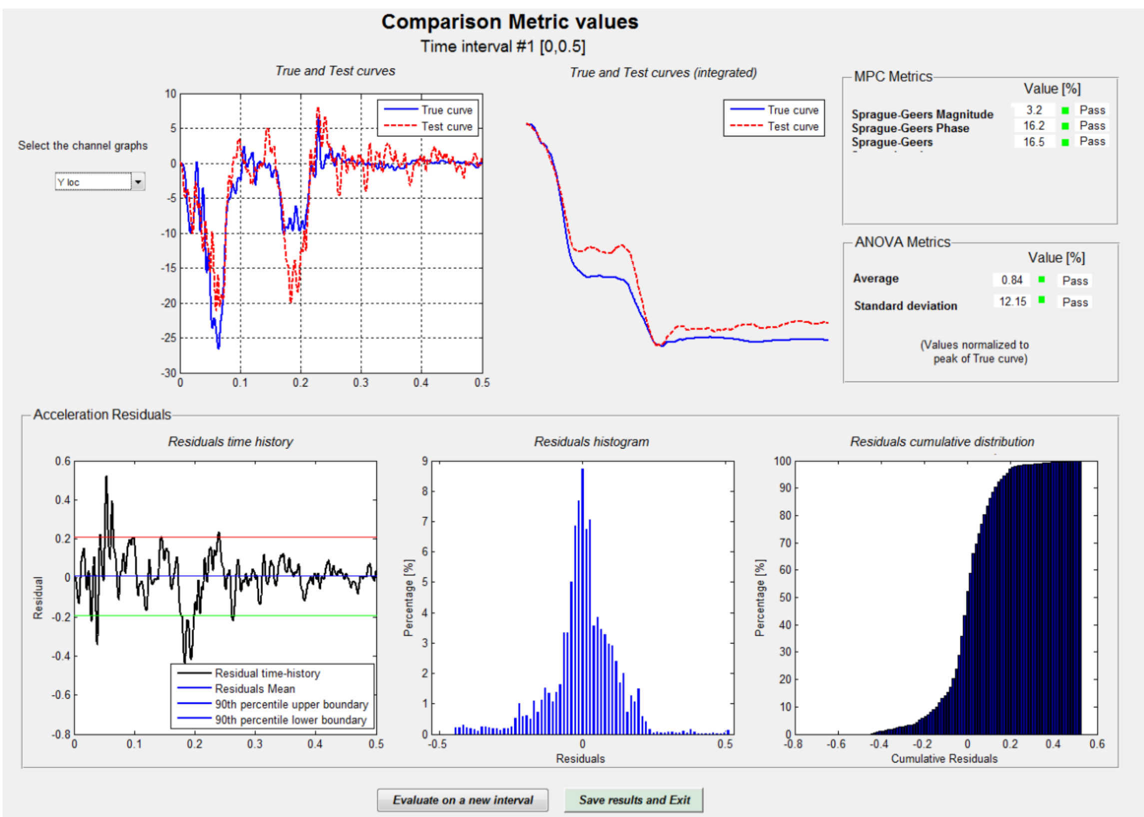


Figure 2c: RSVVP Results – Lateral Acceleration

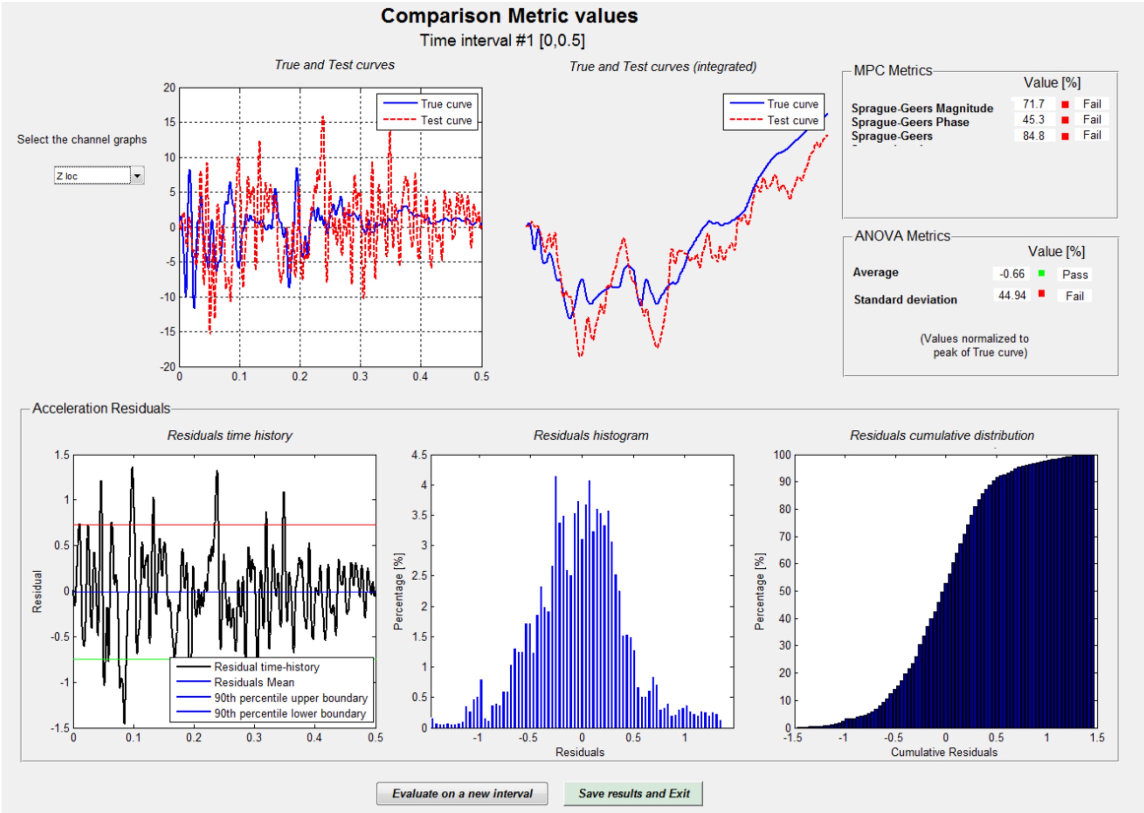


Figure 2d: RSVVP Results – Vertical Acceleration

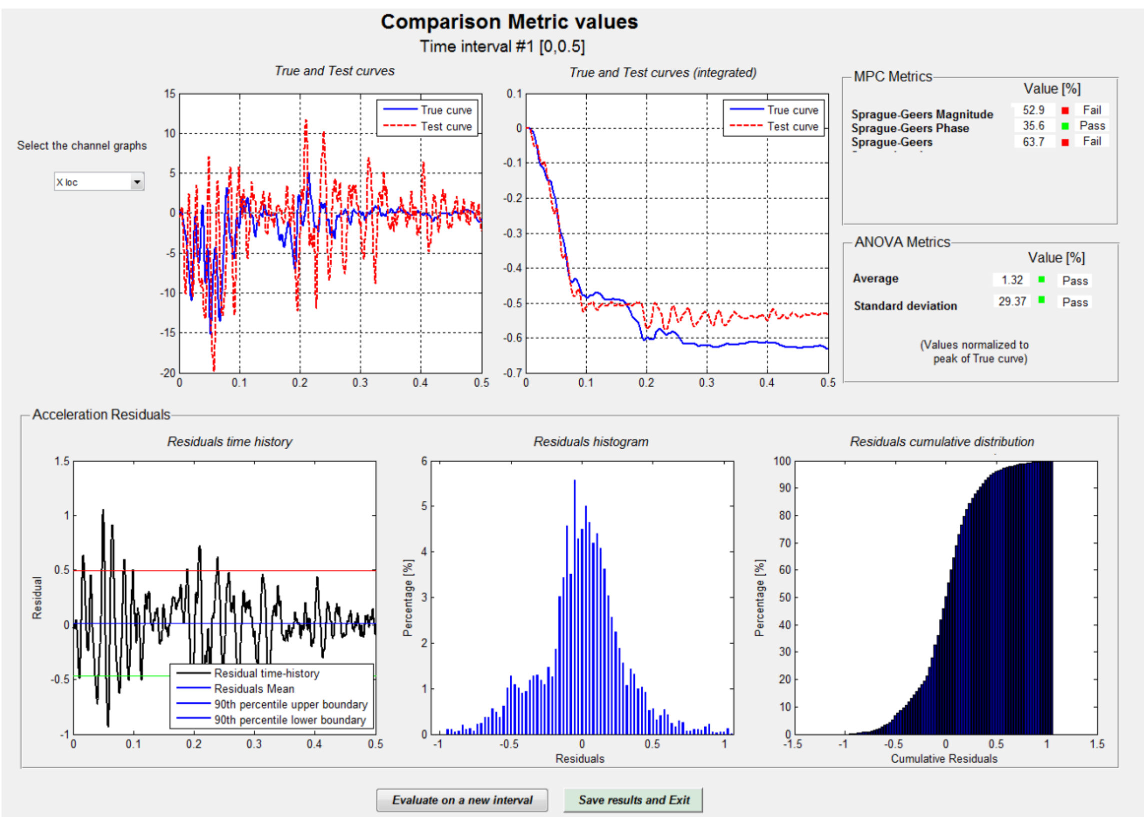


Figure 2e: RSVVP Results – Roll Angle

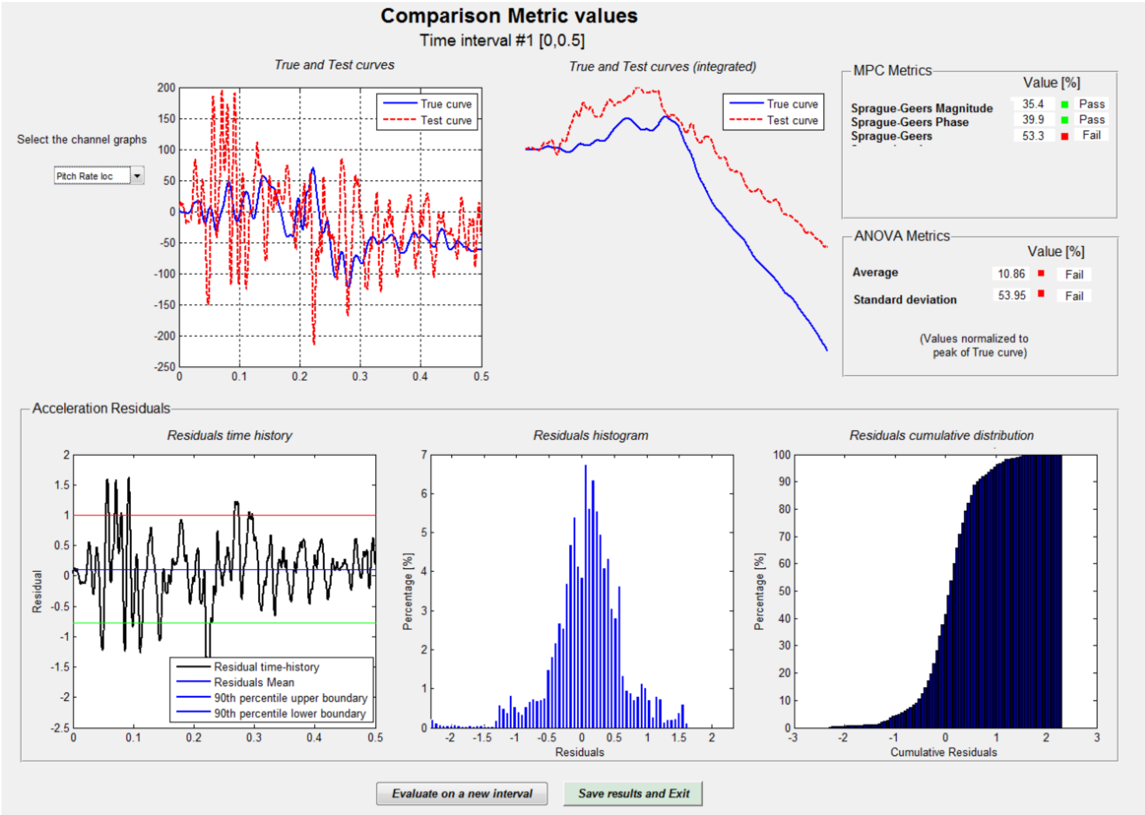


Figure 2f: RSVVP Results – Pitch Angle

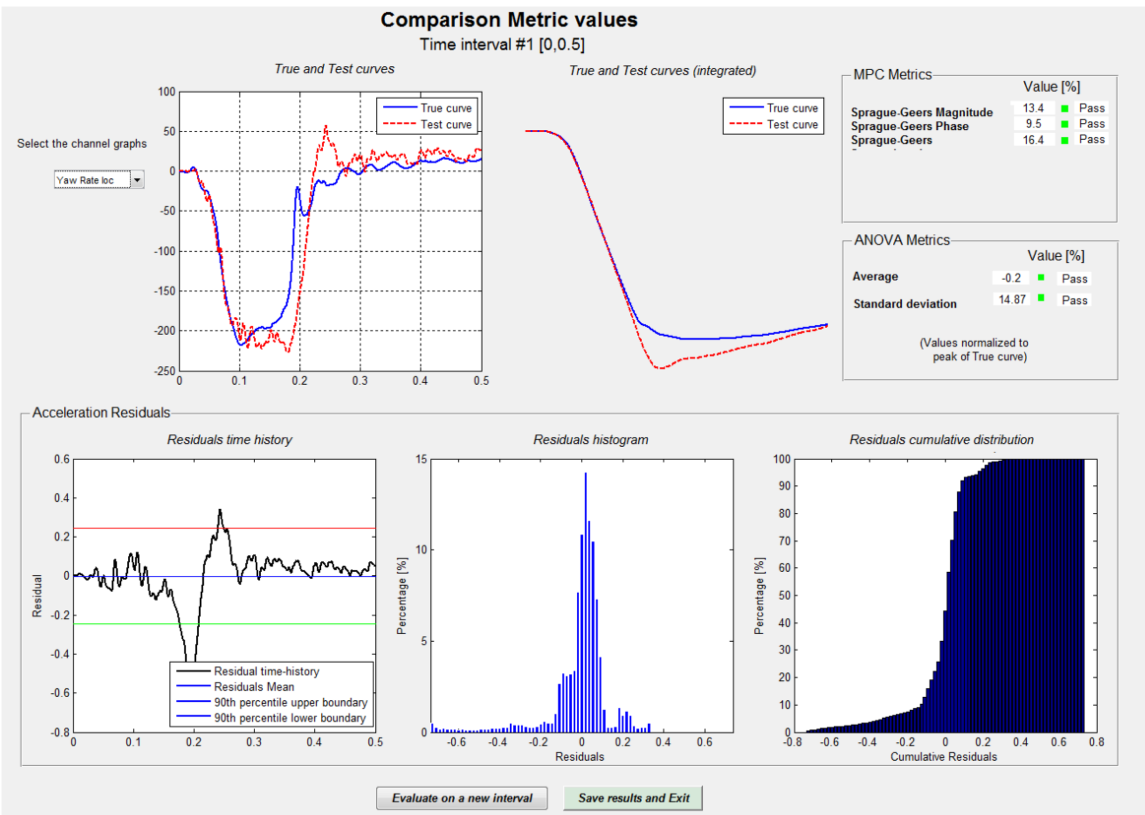


Figure 2g: RSVVP Results – Yaw Angle

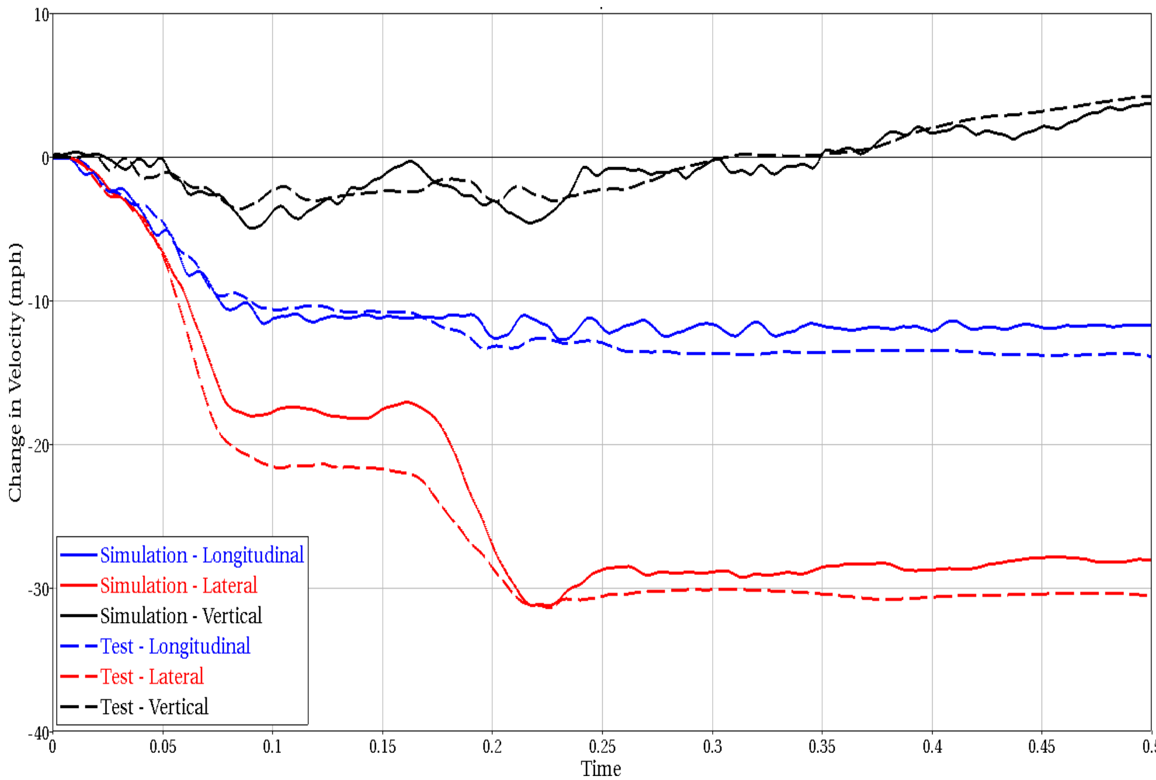


Figure 3: Change in Vehicle Velocities

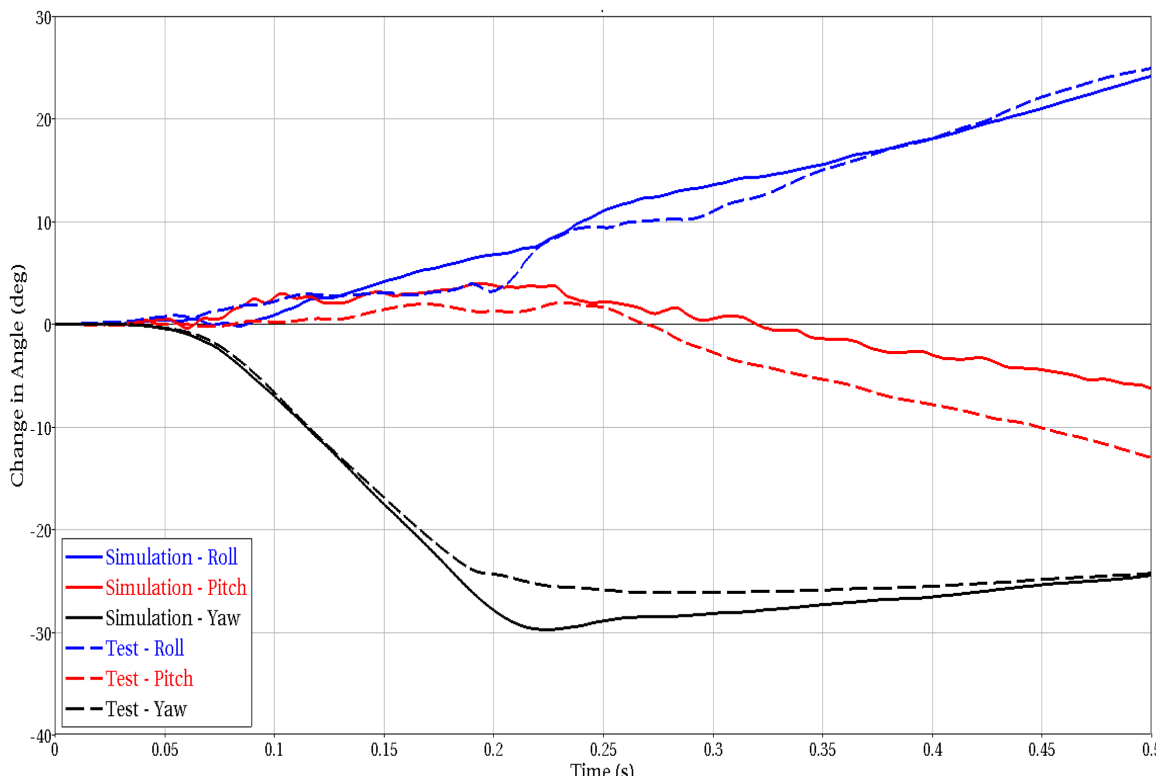
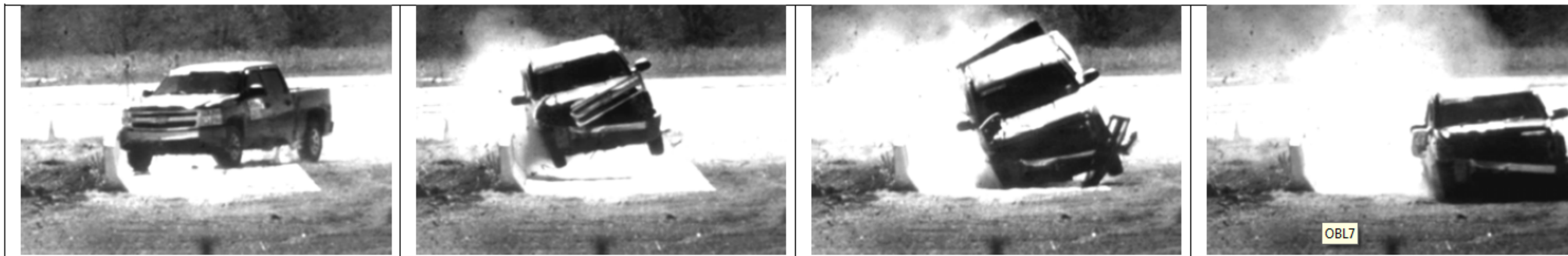


Figure 4: Change in Vehicle Angles

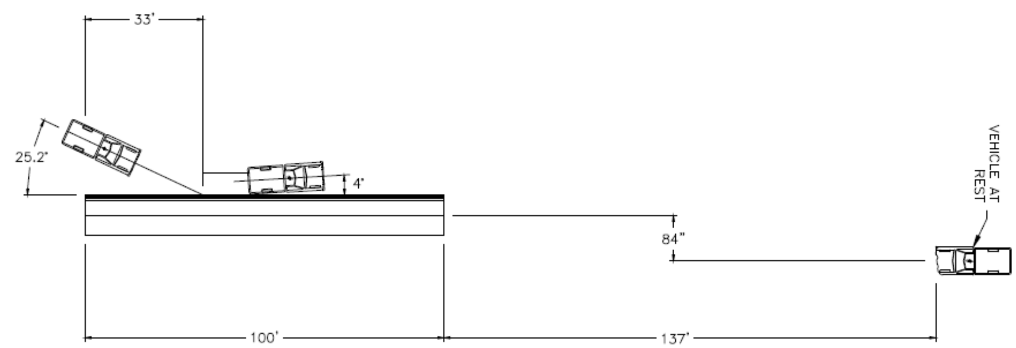
Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P Vehicle with New Jersey Safety Shape Barrier

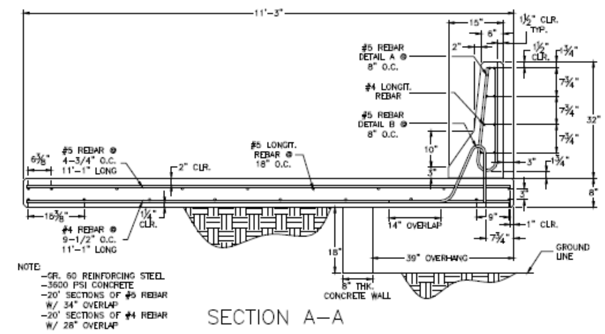
Table E - Roadside Safety Phenomena Importance Ranking Table (MASH Evaluation)

Evaluation Criteria				Known Result	Analysis Result	Relative Diff. (%)	Agree?
Structural Adequacy	A	A1	Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.	Yes	Yes		YES
		A2	The relative difference in the maximum dynamic deflection is less than 20 percent.	0.0 m	0.0 m	0%	YES
		A3	The relative difference in the time of vehicle-barrier contact is less than 20 percent.	0.238 s	0.214 s	10%	YES
		A4	The relative difference in the number of broken or significantly bent posts is less than 20 percent.	Yes	Yes		YES
		A5	Barrier did not fail (Answer Yes or No).	Yes	Yes		YES
		A6	There were no failures of connector elements (Answer Yes or No).	Yes	Yes		YES
		A7	There was no significant snagging between the vehicle wheels and barrier elements (Answer Yes or No).	Yes	Yes		YES
		A8	There was no significant snagging between vehicle body components and barrier elements (Answer Yes or No).	Yes	Yes		YES
Occupant Risk	D		Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone (Answer Yes or No).	Yes	Yes		YES
	F	F1	The vehicle should remain upright during and after the collision. The maximum pitch & roll angles are not to exceed 75 degrees.	Yes	Yes		YES
		F2	Maximum vehicle roll – relative difference is less than 20% or absolute difference is less than 5 degrees.	25 (.5s)	24 (.5s)	4% 1 deg	YES
		F3	Maximum vehicle pitch – relative difference is less than 20% or absolute difference is less than 5 deg.	12 (.5s)	7 (.5s)	41% 5 deg	YES
		F4	Maximum vehicle yaw – relative difference is less than 20% or absolute difference is less than 5 deg.	30 (.5s)	26 (.5s)	13% 4 deg	YES
	H	H1	Longitudinal & lateral occupant impact velocities (OIV) should fall below the preferred value of 30 ft/s (9.1 m/s), or at least below the maximum allowed value of 40 ft/s (12.2 m/s)	Yes	Yes		YES
		H2	Longitudinal OIV (m/s) - Relative difference is less than 20%t or absolute difference is less than 2 m/s	4.3	4.7	9% 0.4 m/s	YES
		H3	Lateral OIV (m/s - Relative difference is less than 20% or absolute difference is less than 2 m/s	9.2	7.9	14% 1.3 m/s	YES
	I	I1	Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.	Yes	Yes		YES
		I2	Longitudinal ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	5.6	7.6	35% 2 g	YES
		I3	Lateral ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	9.6	12.9	34% 3 g	YES
Vehicle Trajectory			The vehicle rebounded within the exit box. (Answer Yes or No)	Yes	Yes		YES



0.000 s	0.231 s	0.462 s	0.693 s





General Information	
Test Agency	Texas Transportation Institute
Test No.	RF476460-1-4
Date	2009-01-30
Test Article	
Type	Concrete Barrier
Name	32-inch New Jersey Safety Shape Barrier
Installation Length	100 ft-1 in
Material or Key Elements	Concrete
Soil Type and Condition	Concrete Deck, Dry
Test Vehicle	
Type/Designation	2270P
Make and Model	2007 Chevrolet Silverado Pickup
Mass	
Curb	5000 lb
Test Inertial	5049 lb
Gross Static	5049 lb

Impact Conditions	
Speed	62.6 mi/h
Angle	25.2 degrees
Exit Conditions	
Speed	52.6 mi/h
Angle	4.0 degrees
Occupant Risk Values	
Impact Velocity	
Longitudinal	14.1 ft/s
Lateral	30.2 ft/s
Ridedown Accelerations	
Longitudinal	-5.6 G
Lateral	-9.6 G
THIV	36.0 km/h
PHD	10.2 G
Max. 0.050-s Average	
Longitudinal	-6.8 G
Lateral	-15.7 G
Vertical	-3.2 G

Post-Impact Trajectory	
Stopping Distance	204 ft
Vehicle Stability	
Maximum Yaw Angle	-29 degrees
Maximum Pitch Angle	-16 degrees
Maximum Roll Angle	29 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	0
Permanent	0
Working Width	0
Vehicle Damage	
VDS	01RFQ5
CDC	01RFEW4
Max. Exterior Vehicle Crush (inches)	14.0 inches
Max. Occupant Compartment Deformation (inches)	2.0 inches

Figure 5: Full-Scale Test Summary

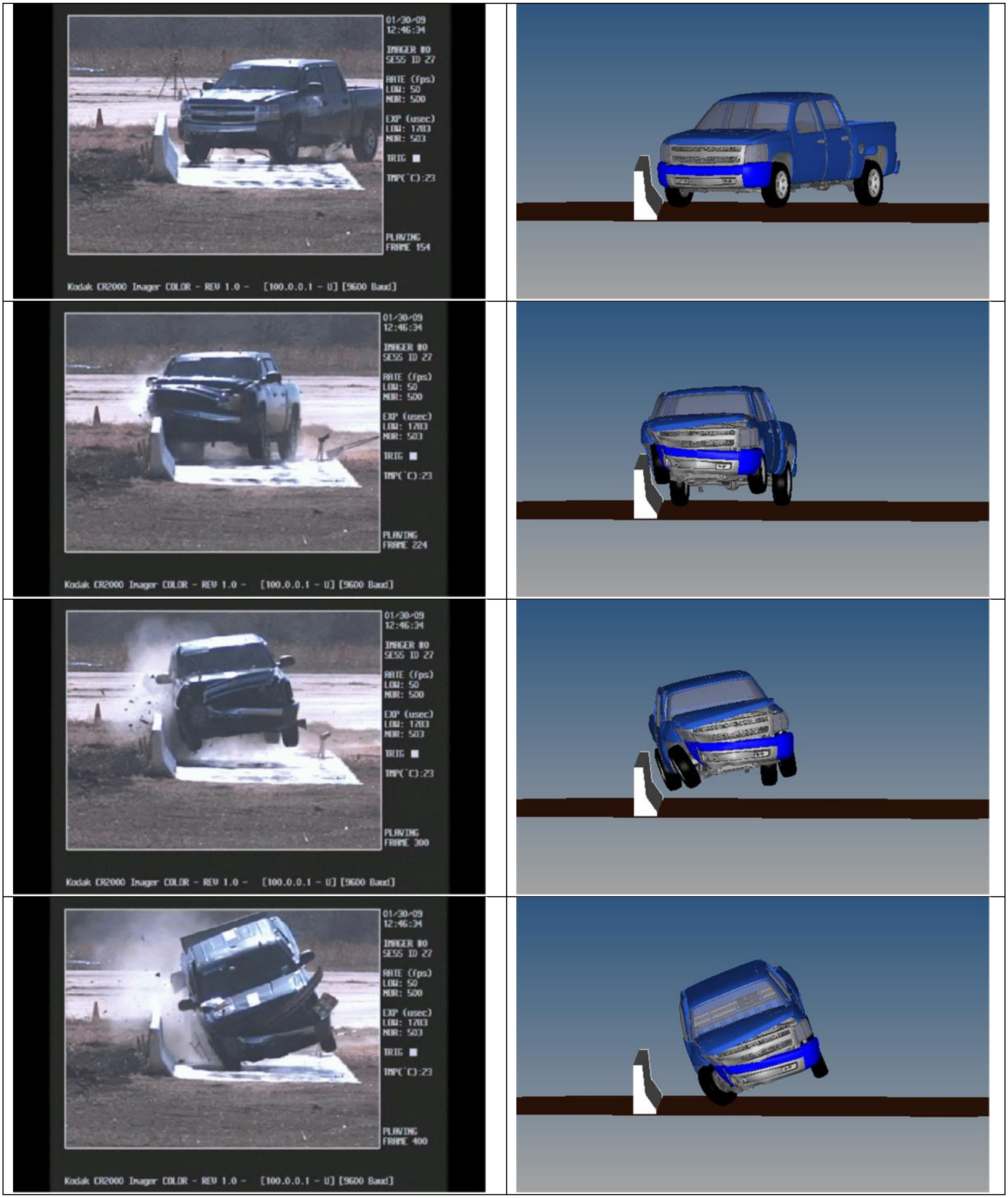


Figure 6a: Sequential Comparisons – Front View

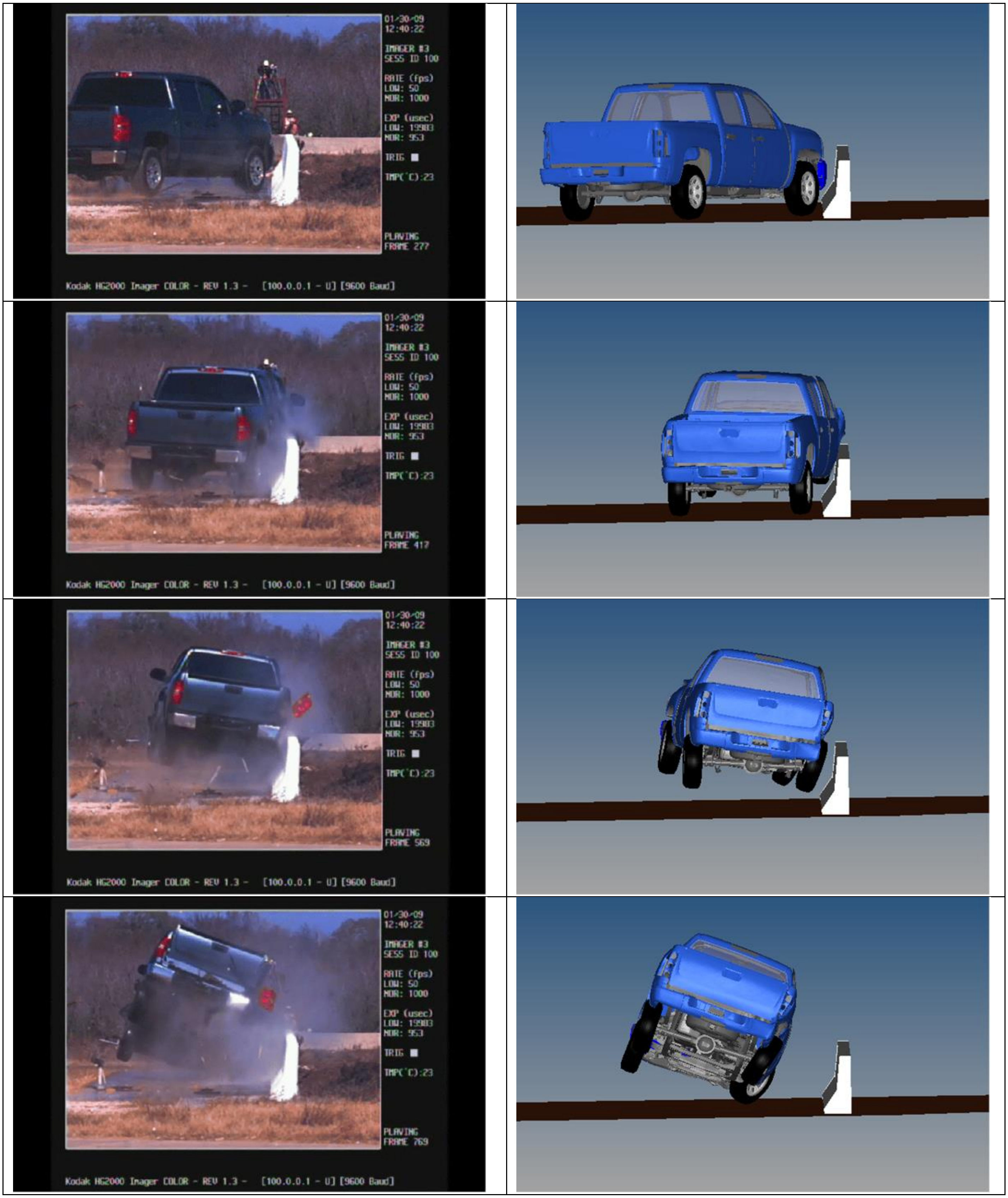


Figure 6b: Sequential Comparisons – Rear View

Figure 6c: Sequential Comparisons – Top View

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P Vehicle with New Jersey Safety Shape Barrier

Table F - Composite Verification and Validation Summary:

List the Report MASH08 Test Number		
Table C – Analysis Solution Verification s	Did all solution verification criteria in table pass?	YES
Table D - RSVVP Results	Do all the time history evaluation scores from the single channel factors result in a satisfactory comparison (i.e., the comparison passes the criterion)?	NO
	If all the values for Single Channel comparison did not pass, did the weighted procedure result in an acceptable	YES
Table E - Roadside Safety Phenomena Importance Ranking Table	Did all the critical criteria in the PIRT Table pass? Note: Tire deflation was observed in the test but not in the simulation. This due to the fact that tire deflation in not incorporated in the model. This is considered not to have a critical effect on the outcome of the test	YES
Overall	Are the results of Steps I through III all affirmative (i.e., YES)? If all three steps result in a "YES" answer, the comparison can be considered validated or verified. If one of the steps results in a negative response, the result cannot be considered validated or verified.	YES

NOTES:
(none)

Appendix F-2: G4(1S) Barrier Impact with 2270P Vehicle

CCSA VALIDATION/VERIFICATION REPORT

Project: **CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections**
Comparison Case: **2270P (Pickup Truck) with G41S Barrier**
Impact Description: **25.8 degree impact into barrier at 100.4 km/h (62.4 mph)**
Governing Criteria: **MASH TL-3**
Report Date: **March 2013**

Table A – Information Sources:

General Information	Known Solution	Analysis Solution
Performing Organization	MwRSF	CCSA-GWU
Test/Run Number	2214WB-2	RR130422b
Vehicle	Dodge Ram 1500 Quad Cab	Silverado C
Vehicle Mass (lb/kg)	5000 / 2268	4918 / 2231
Impact Speed (mph/kph)	62.4 / 100.4	62.4 / 100.4
Impact Angle (degrees)	25.8	25.8

Table B - Evaluation Parameters Summary:

Category	Subset	Values
Evaluation Method	MASH (V1, 2009)	
Hardware Type	Longitudinal	
Test Number	3-11	
Test Vehicle	2270C	
Criterion to be Applied	**Structural Adequacy**	**A -** Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.
	Occupant Risk	**D** - Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone.
		F - The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are
		H - The occupant impact velocity in the longitudinal direction should not exceed 40 ft/sec and the occupant ride-down acceleration in the longitudinal direction should not exceed 20 G"s.
		I - Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.
	Vehicle Trajectory	For redirective devices the vehicle shall exit within the prescribed box.

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P (Pickup Truck) with G41S Barrier

Table C – Analysis Solution Verification Summary

Verification Evaluation Criteria	Change (%)	Pass?
Total energy of the analysis solution (i.e., kinetic, potential, contact, etc.) must not vary more than 10 percent from the beginning of the run to the end of the run.	< 1%	YES
Hourglass Energy of the analysis solution at the end of the run is less than 5 % of the total initial energy at the beginning of the run	< 1%	YES
The part/material with the highest amount of hourglass energy at any time during the run is less than 5 % of the total initial energy at the beginning of the run.	< 1%	YES
Mass added to the total model is less than 5 % the total model mass at the start of the run.	< 1%	YES
The part/material with the most mass added had less than 10 % of its initial mass added.	< 1%	YES
The moving parts/materials in the model have less than 5 % of mass added to the initial moving mass of the model.	< 1%	YES
There are no shooting nodes in the solution?	NA	YES
There are no solid elements with negative volumes?	NA	YES

Table D - RSVVP Results

	Single Channel Time History Comparison Results	**Time interval [0 sec - 0.89**		
O	***Sprauge-Geer Metrics***	**M**	**P**	**Pass?**
	X acceleration	75	38.3	NO
	Y acceleration	29.9	32.6	YES
	Z acceleration	168.7	45.3	NO
	Yaw rate	14.1	12.7	YES
	Roll rate (test data not available)			
	Pitch rate (test data not available)			
P	***ANOVA Metrics***	**Mean**	**SD**	**Pass?**
	X acceleration/Peak	-1.79	41.87	NO
	Y acceleration/Peak	1.54	31.86	YES
	Z acceleration/Peak	0.16	73.73	NO
	Yaw rate	-.32	18.97	YES
	Roll rate (test data not available)			
	Pitch rate (test data not available)			

Multi-Channel Weighting Factors		**Time interval [0 sec; 0.89**
Multi-Channel Weighting Method	**X Channel**	0.22878683
Peaks Area I	**Y Channel**	0.225135792
Area II Inertial	**Z Channel**	0.046077378
	Yaw Channel	0.5
	Roll Channel	(test data not available)
	Pitch Channel	(test data not available)

Sprauge-Geer Metrics	**M**	**P**	**Pass?**
All Channels (weighted)	36.7	24.6	YES
ANOVA Metrics	**Mean**	**SD**	**Pass?**
All Channels (weighted)	-.02	29.6	YES

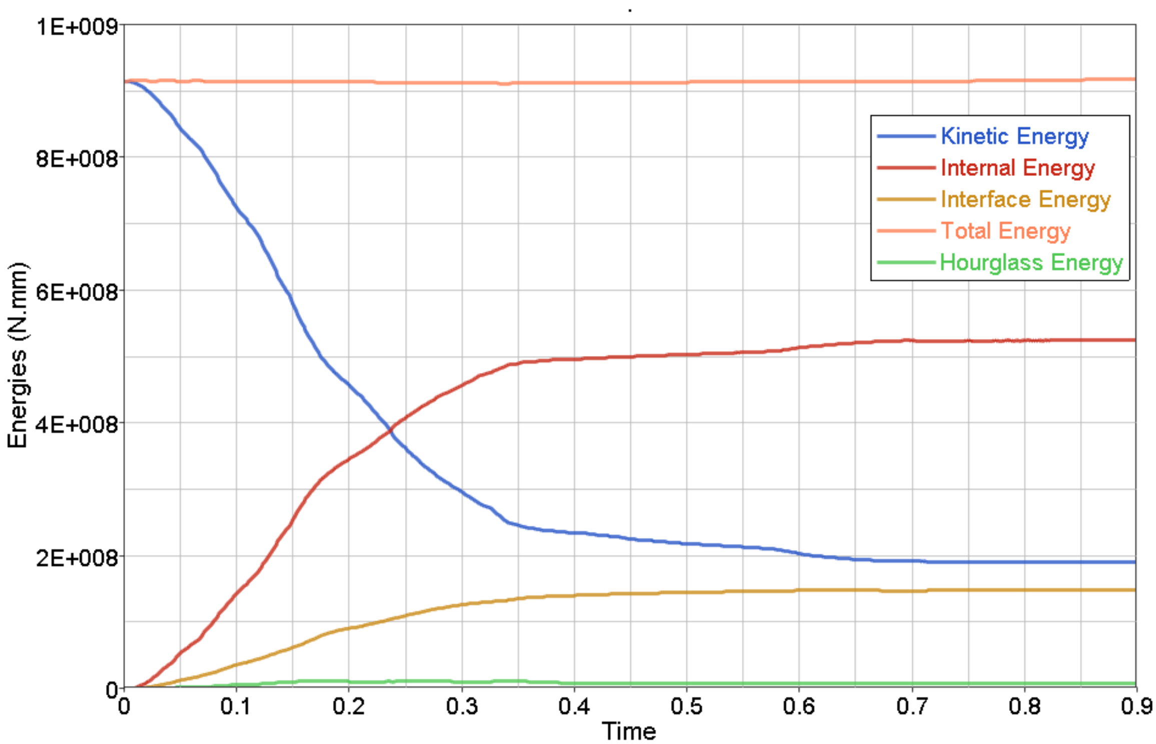


Figure 1: Simulations Energies

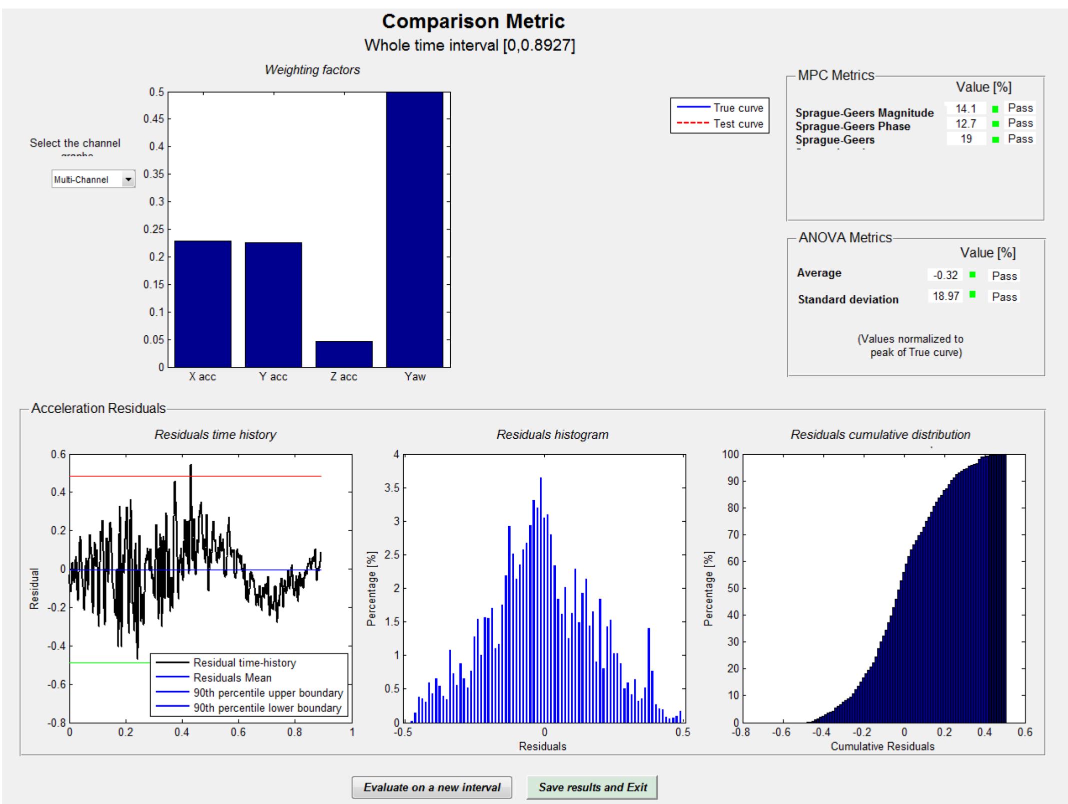


Figure 2a: RSVVP Results – All Channels

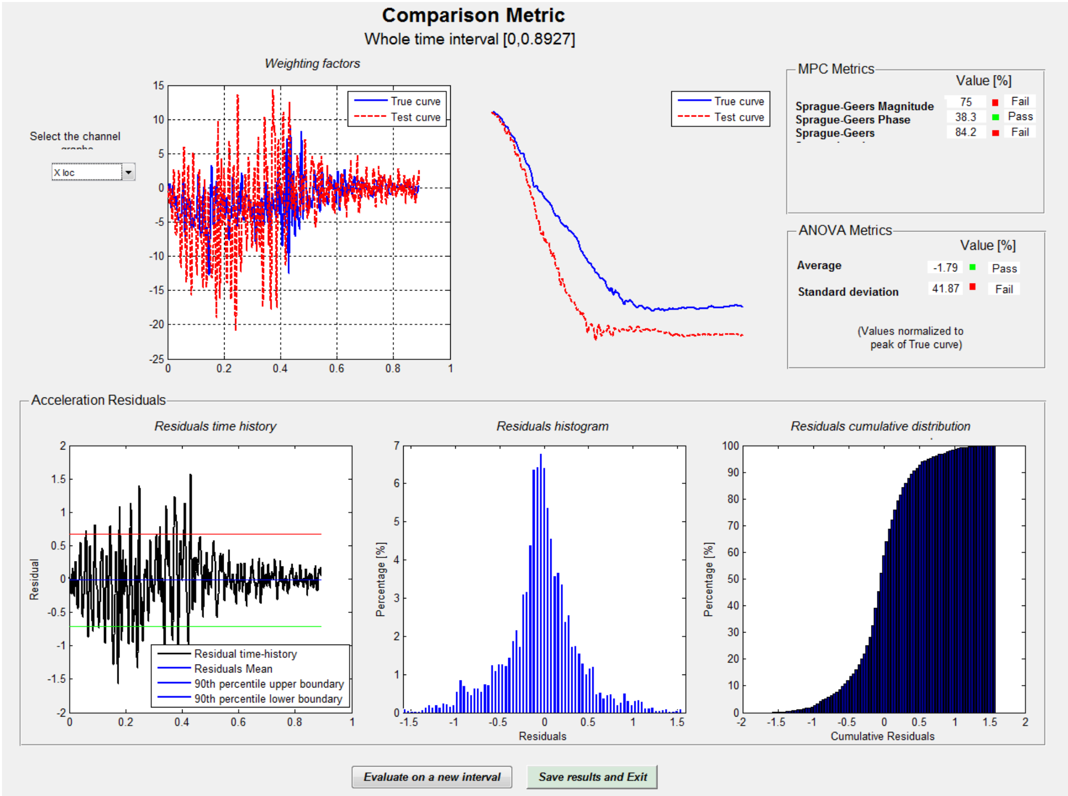


Figure 2b: RSVVP Results – Longitudinal Acceleration

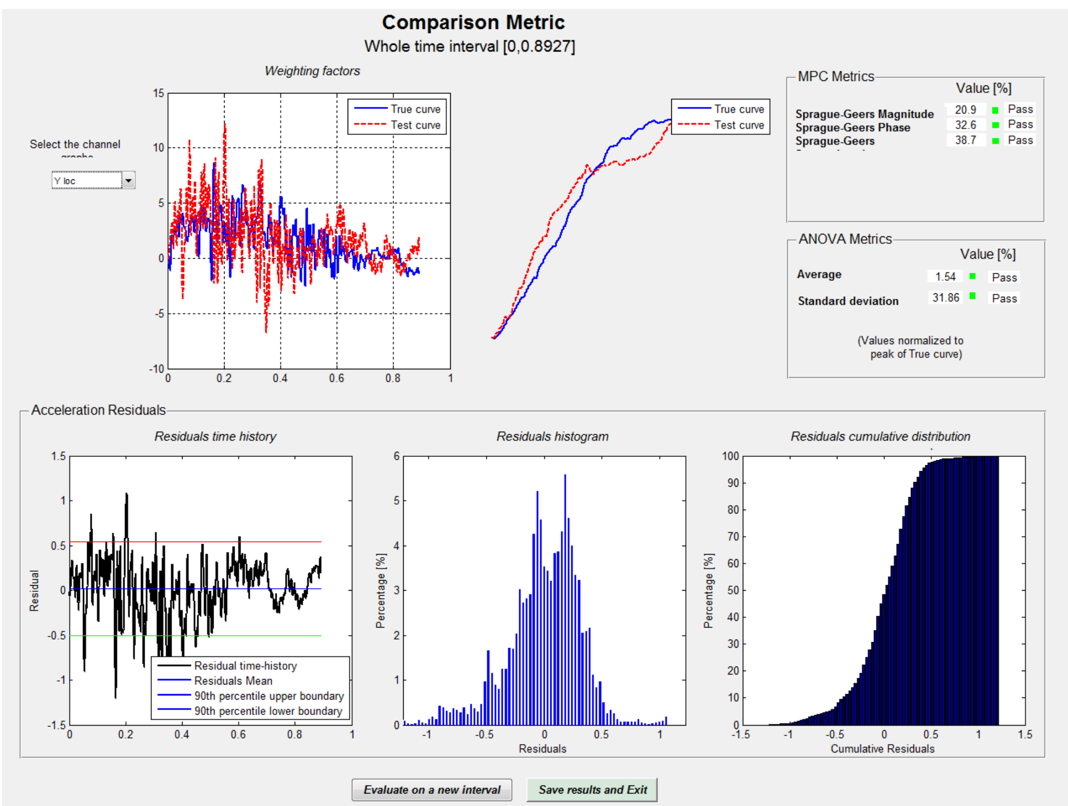


Figure 2c: RSVVP Results – Lateral Acceleration

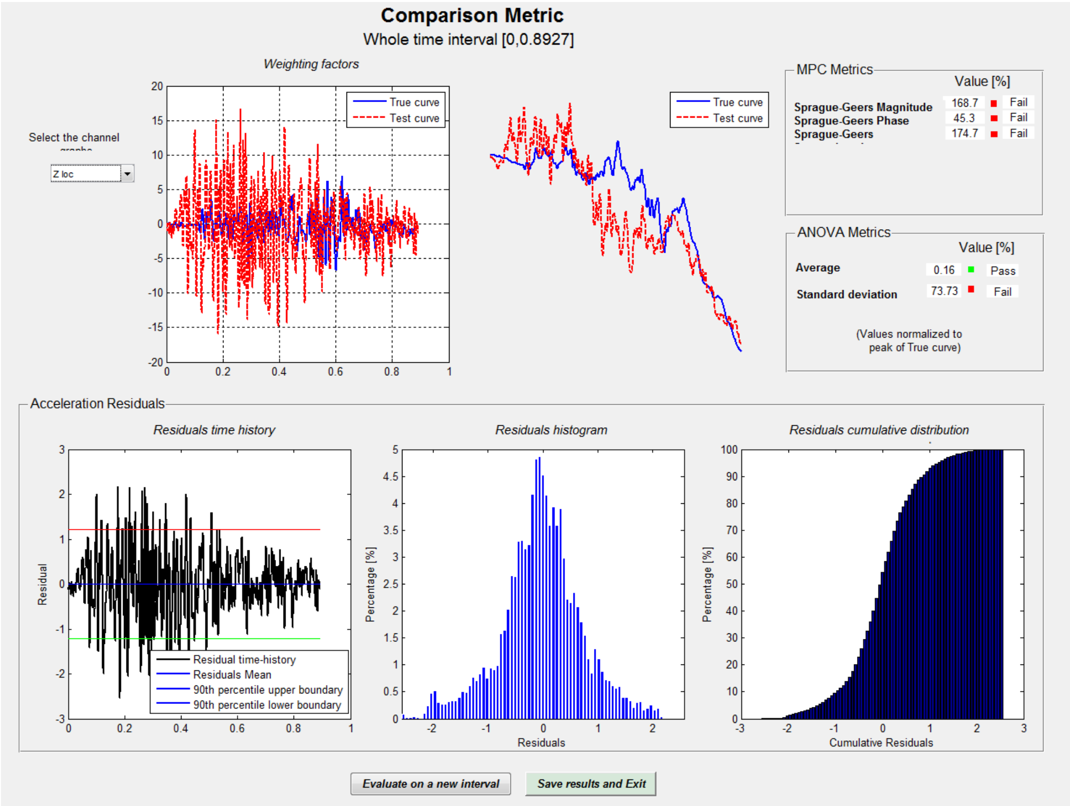


Figure 2d: RSVVP Results – Vertical Acceleration

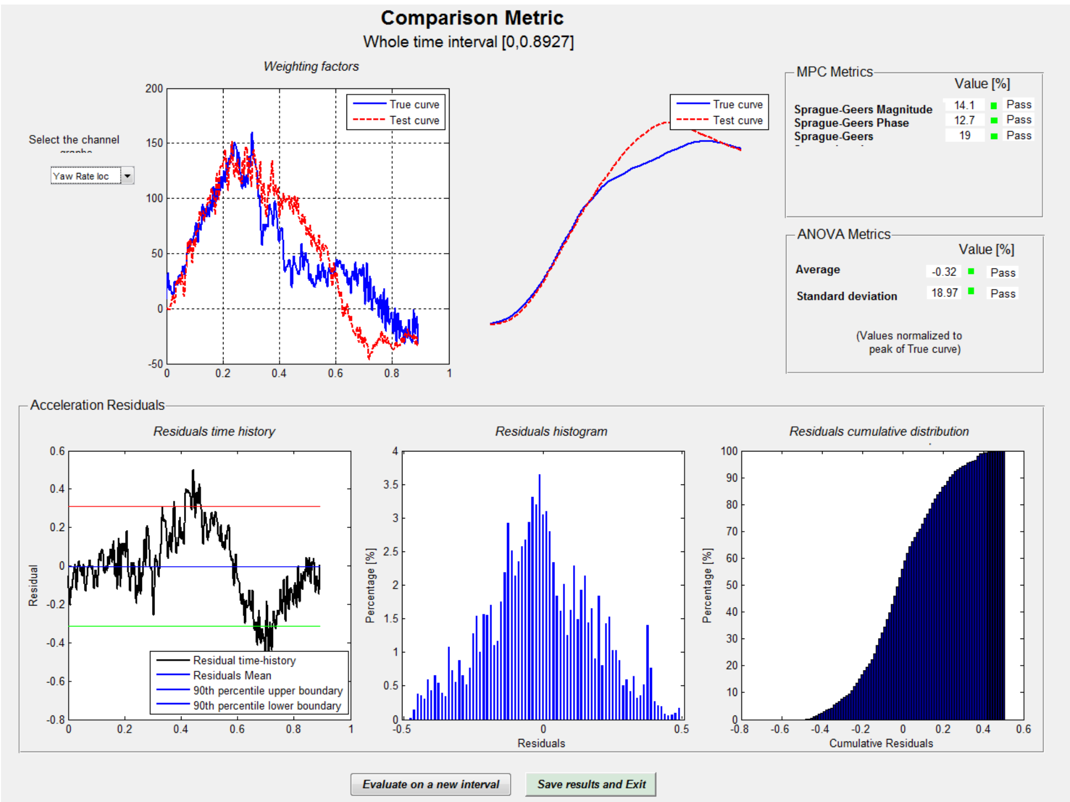


Figure 2e: RSVVP Results – Yaw Angle

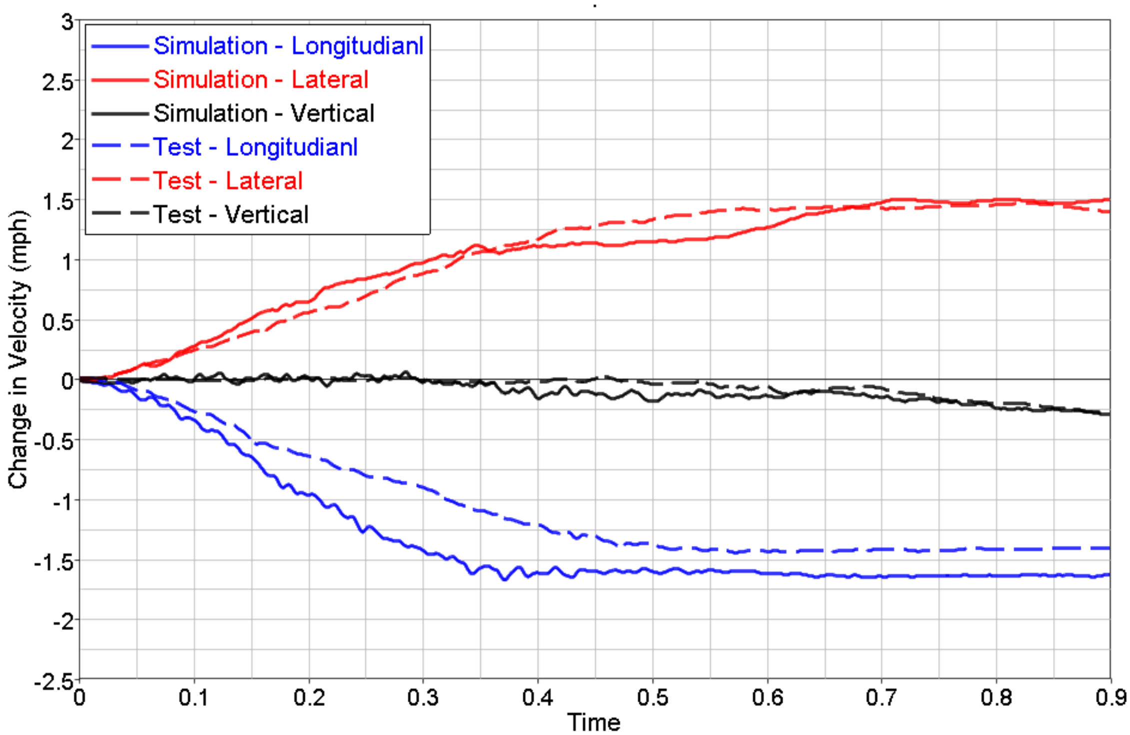


Figure 3: Change in Vehicle Velocities

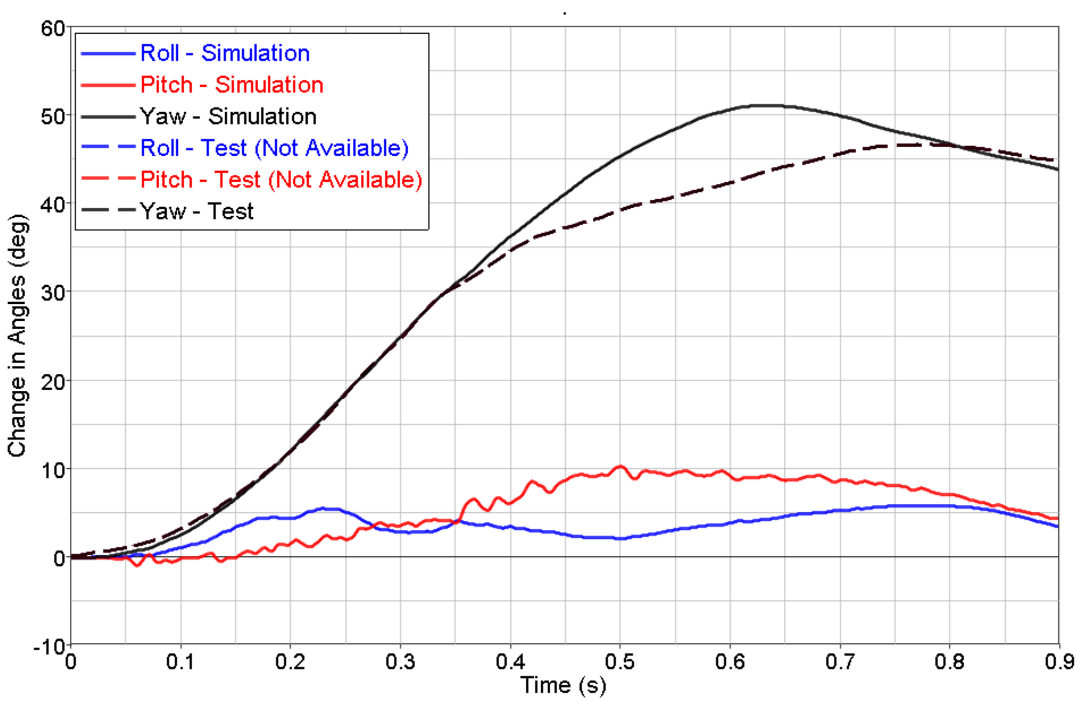


Figure 4: Change in Vehicle Angle

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P (Pickup Truck) with G41S Barrier

Table E - Roadside Safety Phenomena Importance Ranking Table (MASH Evaluation)

Evaluation Criteria				Known Result	Analysis Result	Relative Diff. (%)	Agree?
Structural Adequacy	A	A1	Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.	Yes	Yes		YES
		A2	The relative difference in the maximum dynamic deflection is less than 20 percent.	1.196 m	0.980 m	18.0 %	YES
		A3	The relative difference in the time of vehicle-barrier contact is less than 20 percent.	0.84 s	0.72 s	7.1 %	YES
		A4	The relative difference in the number of broken or significantly bent posts is less than 20 percent.	3	3		YES
		A5	Barrier did not fail (Answer Yes or No).	Yes	Yes		YES
		A6	There were no failures of connector elements (Answer Yes or No).	Yes	Yes		YES
		A7	There was no significant snagging between the vehicle wheels and barrier elements (Answer Yes or No).	Yes	Yes		YES
		A8	There was no significant snagging between vehicle body components and barrier elements (Answer Yes or No).	Yes	Yes		YES
Occupant Risk	D		Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone (Answer Yes or No).	Yes	Yes		YES
	F	F1	The vehicle should remain upright during and after the collision. The maximum pitch & roll angles are not to exceed 75 degrees.	Yes	Yes		YES
		F2	Maximum vehicle roll – relative difference is less than 20% or absolute difference is less than 5 degrees.	NA	NA	NA	
		F3	Maximum vehicle pitch – relative difference is less than 20% or absolute difference is less than 5 deg.	NA	NA	NA	
		F4	Maximum vehicle yaw – relative difference is less than 20% or absolute difference is less than 5 deg.	51 (.62s)	47 (.78s)	7.8% 4 deg	YES
	H	H1	Longitudinal & lateral occupant impact velocities (OIV) should fall below the preferred value of 30 ft/s (9.1 m/s), or at least below the maximum allowed value of 40 ft/s (12.2 m/s)	Yes	Yes		YES
		H2	Longitudinal OIV (m/s) - Relative difference is less than 20%t or absolute difference is less than 2 m/s	5.38	6.1	13.4% 0.72 m/s	YES
		H3	Lateral OIV (m/s) - Relative difference is less than 20% or absolute difference is less than 2 m/s	3.99	5.0	25.3% 1.01 m/s	YES
	I	I1	Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.	Yes	Yes		YES
		I2	Longitudinal ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	6.92	10.72	54.9% 3.8 g	YES
		I3	Lateral ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	6.61	9.86	49.2% 3.25 g	YES
Vehicle Trajectory			The vehicle rebounded within the exit box. (Answer Yes or No)	Yes	Yes		YES

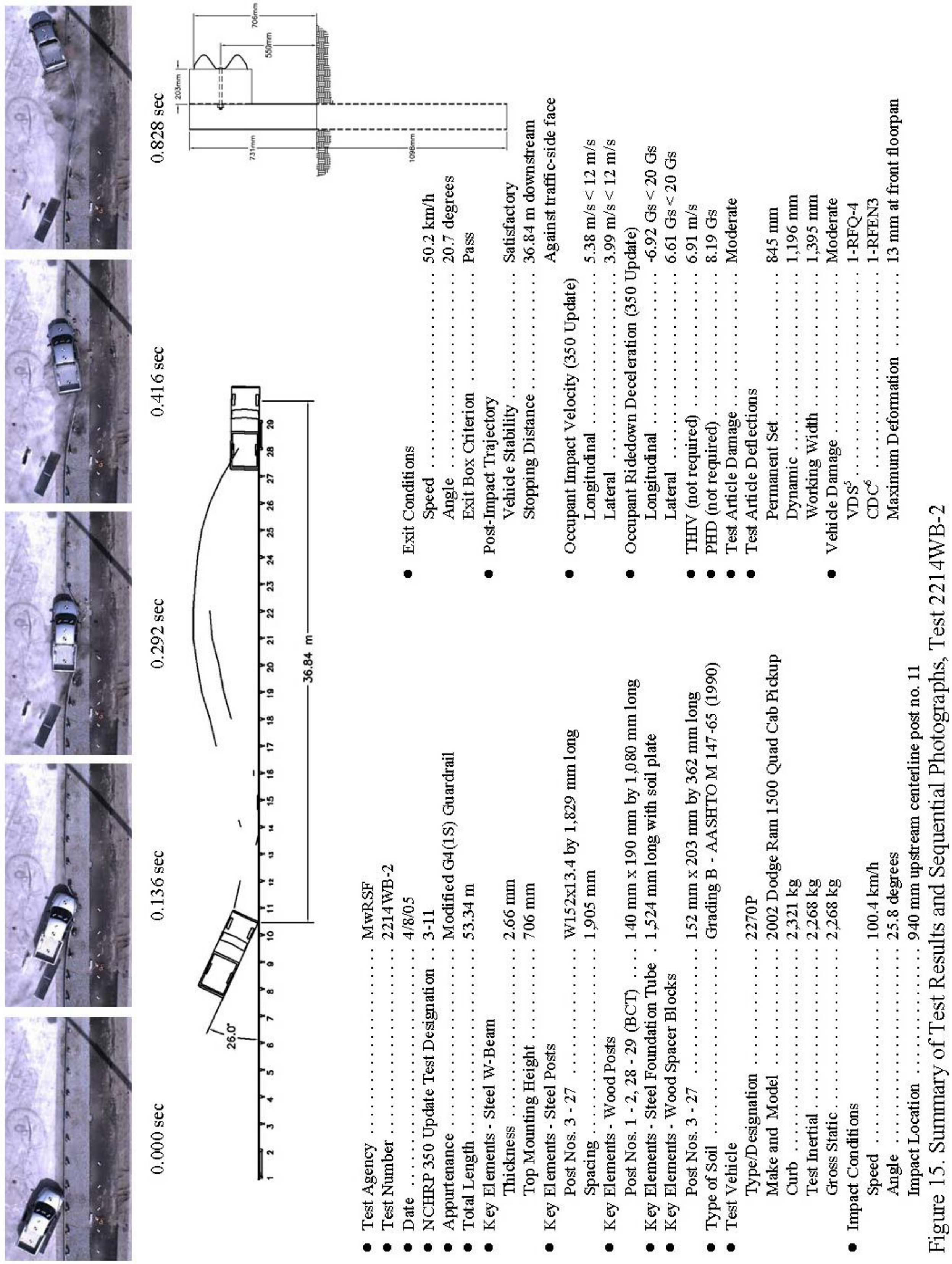


Figure 5: Full-Scale Test Summary

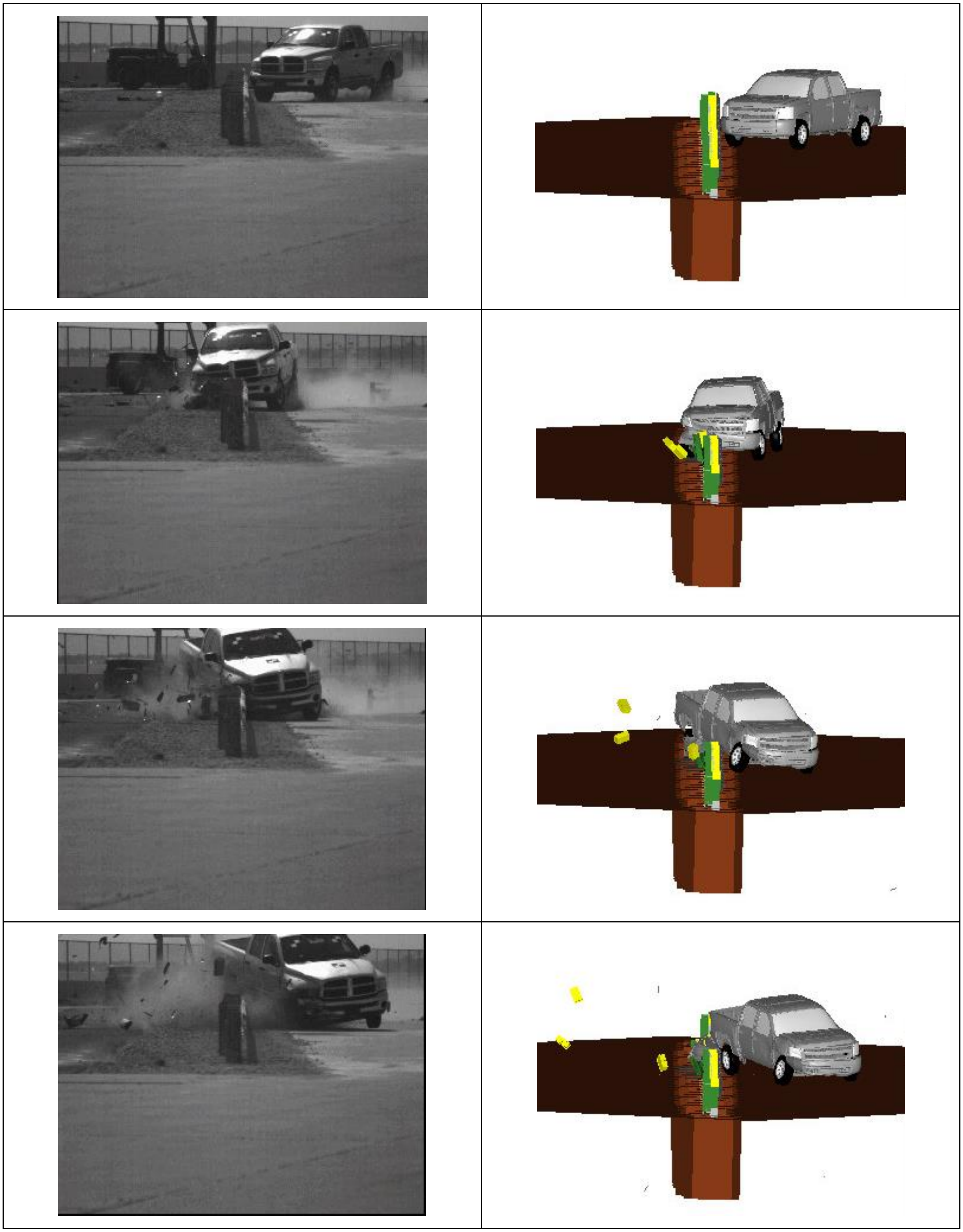


Figure 6a: Sequential Comparisons – Front View

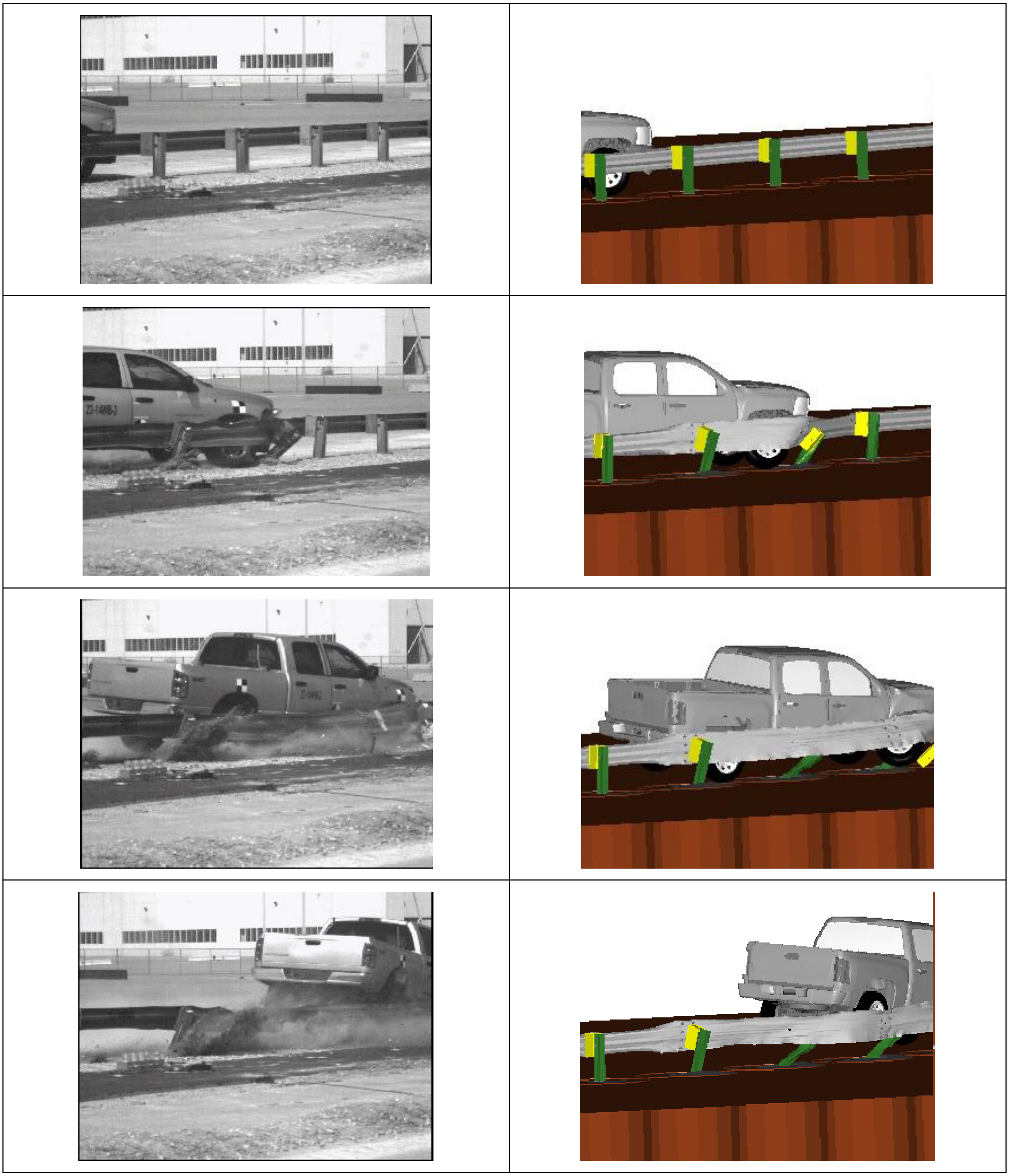


Figure 6b: Sequential Comparisons – Rear View

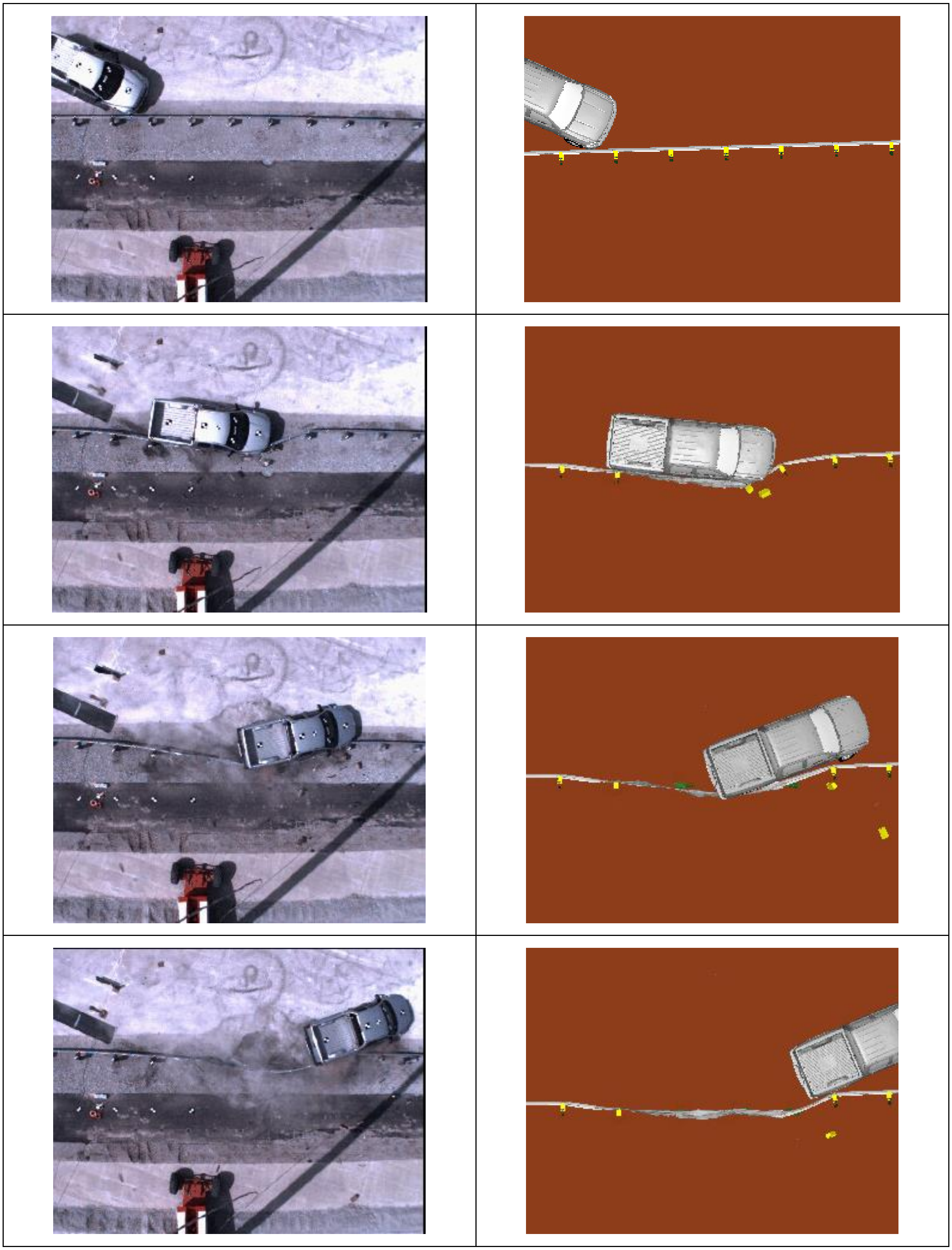


Figure 6c: Sequential Comparisons – Top View

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P (Pickup Truck) with G41S Barrier

Table F - Composite Verification and Validation Summary:

List the Report MASH08 Test Number		
Table C – Analysis Solution Verification s	Did all solution verification criteria in table pass?	YES
Table D - RSVVP Results	Do all the time history evaluation scores from the single channel factors result in a satisfactory comparison (i.e., the comparison passes the criterion)?	NO
	If all the values for Single Channel comparison did not pass, did the weighted procedure result in an acceptable	YES
Table E - Roadside Safety Phenomena Importance Ranking Table	Did all the critical criteria in the PIRT Table pass? Note: Tire deflation was observed in the test but not in the simulation. This due to the fact that tire deflation in not incorporated in the model. This is considered not to have a critical effect on the outcome of the test	YES
Overall	Are the results of Steps I through III all affirmative (i.e., YES)? If all three steps result in a "YES" answer, the comparison can be considered validated or verified. If one of the steps results in a negative response, the result cannot be considered	YES

NOTES:
(none)

Appendix F-3: MGS Barrier Impact with 2270P Vehicle

CCSA VALIDATION/VERIFICATION REPORT

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P (Pickup Truck) with MGS Barrier
Impact Description: 25.5 degree impact into barrier at 101.1 km/h (62.82 mph)
Governing Criteria: MASH TL-3
Report Date: March 2013

Table A – Information Sources:

General Information	Known Solution	Analysis Solution
Performing Organization	MwRSF	CCSA-GWU
Test/Run Number	TRP-03-171-06	s130411a
Vehicle	Dodge Ram 1500 Quad Cab	Silverado C
Vehicle Mass (lb/kg)	5000 / 2268	4918 / 2231
Impact Speed (mph/kph)	62.82 / 101.1	62.82 / 101.1
Impact Angle (degrees)	25.5	25.5

Table B - Evaluation Parameters Summary:

Category	Subset	Values
Evaluation Method	MASH (V1, 2009)	
Hardware Type	Longitudinal	
Test Number	3-11	
Test Vehicle	2270C	
Criterion to be Applied	**Structural Adequacy**	**A -** Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.
	Occupant Risk	**D** - Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone.
		F - The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are
		H - The occupant impact velocity in the longitudinal direction should not exceed 40 ft/sec and the occupant ride-down acceleration in the longitudinal direction should not exceed 20 G‟s.
		I - Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.
	Vehicle Trajectory	For redirective devices the vehicle shall exit within the prescribed box.

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P (Pickup Truck) with MGS Barr

Table C – Analysis Solution Verification Summary

Verification Evaluation Criteria	Change (%)	Pass?
Total energy of the analysis solution (i.e., kinetic, potential, contact, etc.) must not vary more than 10 percent from the beginning of the run to the end of the run.	1.07%	YES
Hourglass Energy of the analysis solution at the end of the run is less than 5 % of the total initial energy at the beginning of the run	< 1%	YES
The part/material with the highest amount of hourglass energy at any time during the run is less than 5 % of the total initial energy at the beginning of the run.	< 1%	YES
Mass added to the total model is less than 5 % the total model mass at the start of the run.	< 1%	YES
The part/material with the most mass added had less than 10 % of its initial mass added.	< 1%	YES
The moving parts/materials in the model have less than 5 % of mass added to the initial moving mass of the model.	< 1%	YES
There are no shooting nodes in the solution?	NA	YES
There are no solid elements with negative volumes?	NA	YES

Table D - RSVVP Results

Single Channel Time History Comparison Results			Time interval [0 sec - 0.67		
O	*Sprauge-Geer Metrics*		M	P	Pass?
	X acceleration		45	40	NO
	Y acceleration		13.2	27.6	YES
	Z acceleration		146.8	45.4	NO
	Yaw rate		13.4	11.7	NO
	Roll rate		9.6	52.7	NO
	Pitch rate		251.3	48	YES
P	*ANOVA Metrics*		Mean	SD	Pass?
	X acceleration/Peak		-1.92	39.08	NO
	Y acceleration/Peak		5.81	35.92	NO
	Z acceleration/Peak		1.09	65.76	NO
	Yaw rate		0.79	20.97	NO
	Roll rate		10.04	51.73	NO
	Pitch rate		1.45	119.09	YES
Multi-Channel Weighting Factors			Time interval [0 sec; 0.67		
Multi-Channel Weighting Method Peaks Area I Area II Inertial		**X Channel**	0.206777873		
		Y Channel	0.275396472		
		Z Channel	0.017825655		
		Yaw Channel	0.441018937		
		Roll Channel	0.032383125		
		Pitch Channel	0.026597937		
Sprauge-Geer Metrics			M	P	Pass?
	All Channels (weighted)		28.5	24.8	YES
ANOVA Metrics			Mean	SD	Pass?
	All Channels (weighted)		1.9	33.2	YES

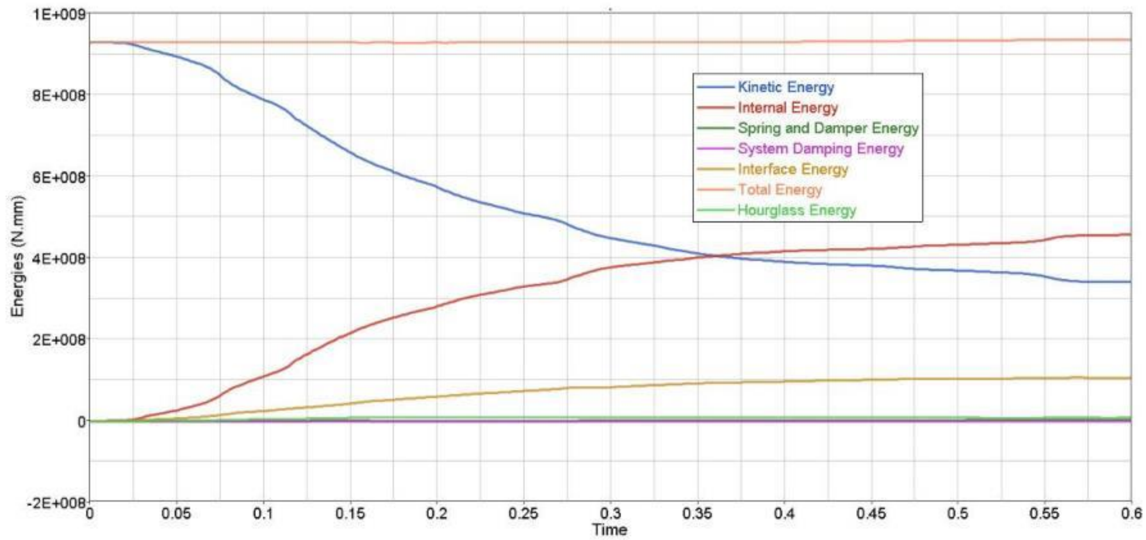


Figure 1: Simulations Energies

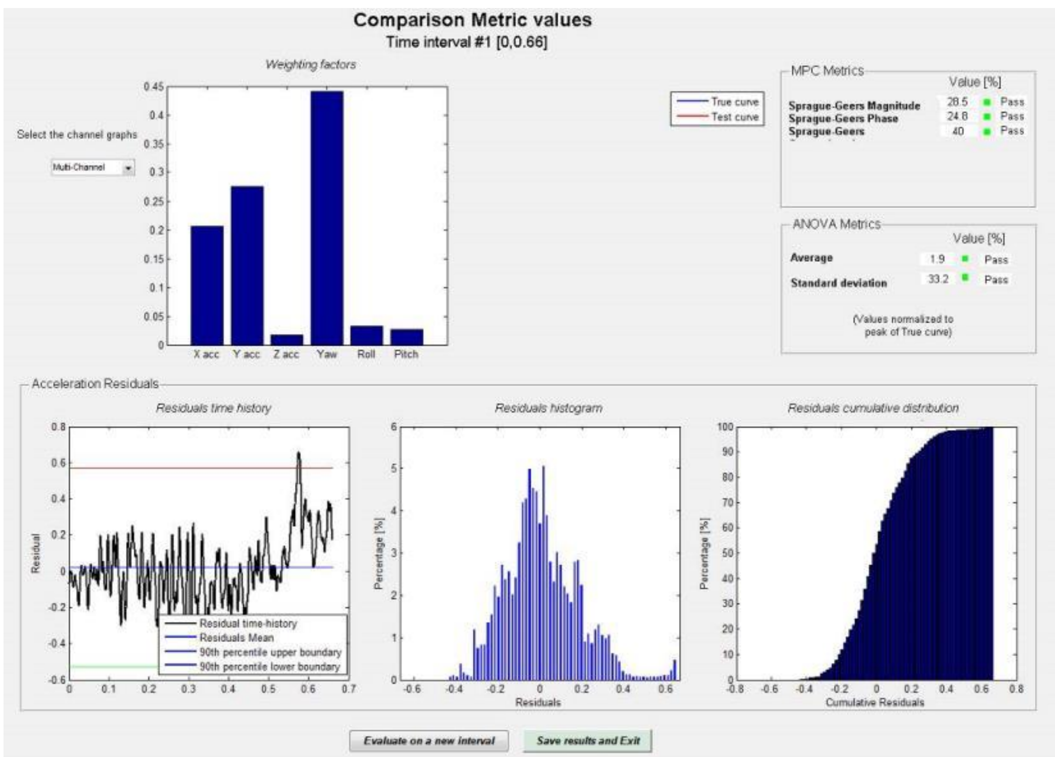


Figure 2a: RSVVP Results – All Channels

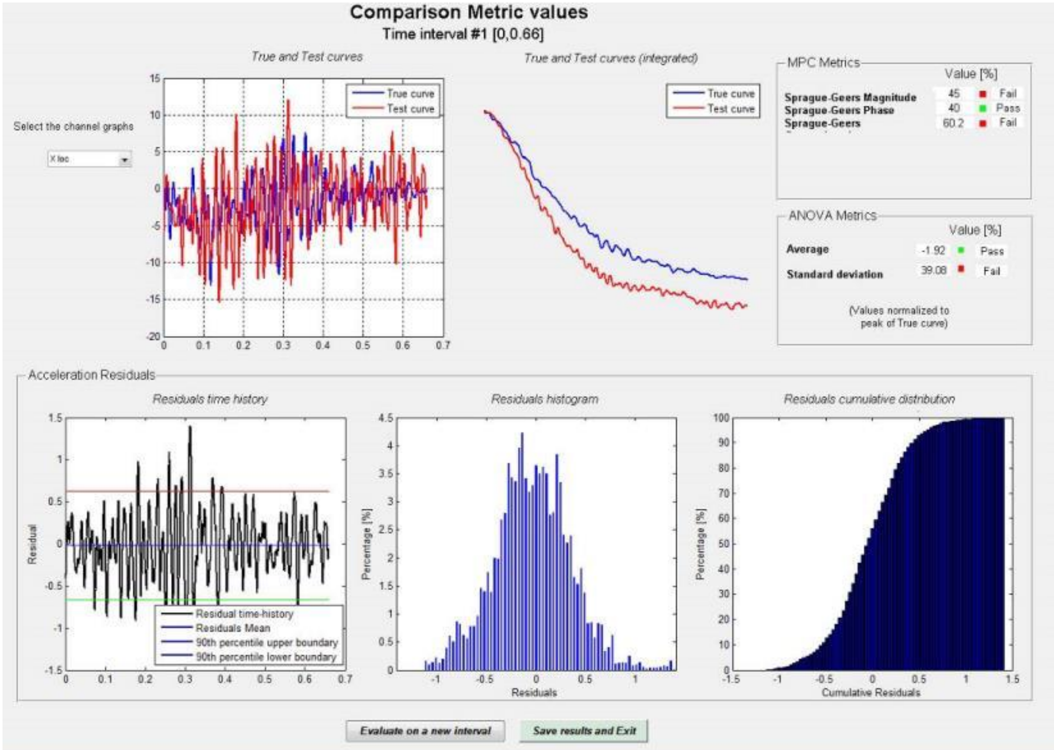


Figure 2b: RSVVP Results – Longitudinal Acceleration

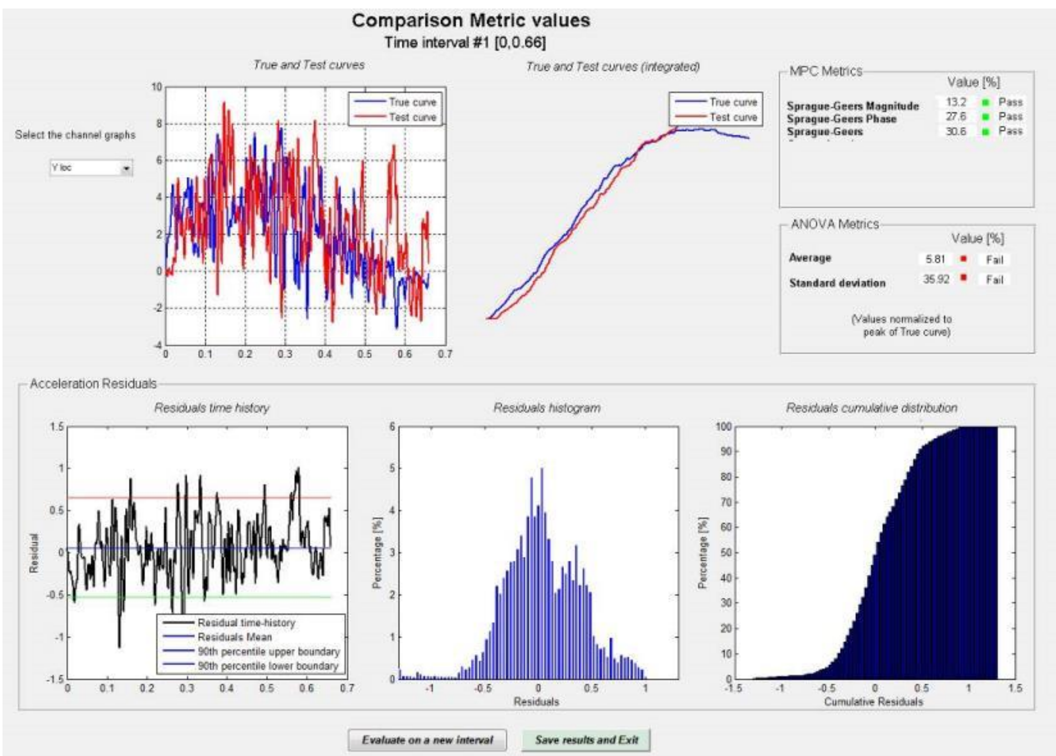


Figure 2c: RSVVP Results – Lateral Acceleration

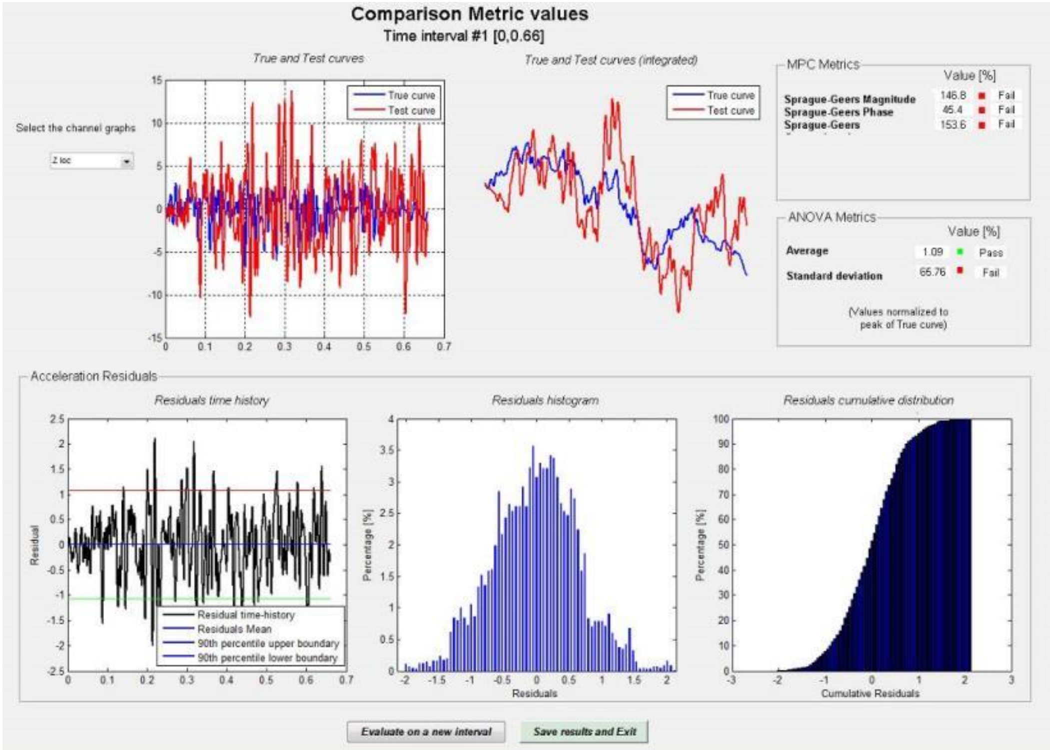


Figure 2d: RSVVP Results – Vertical Acceleration

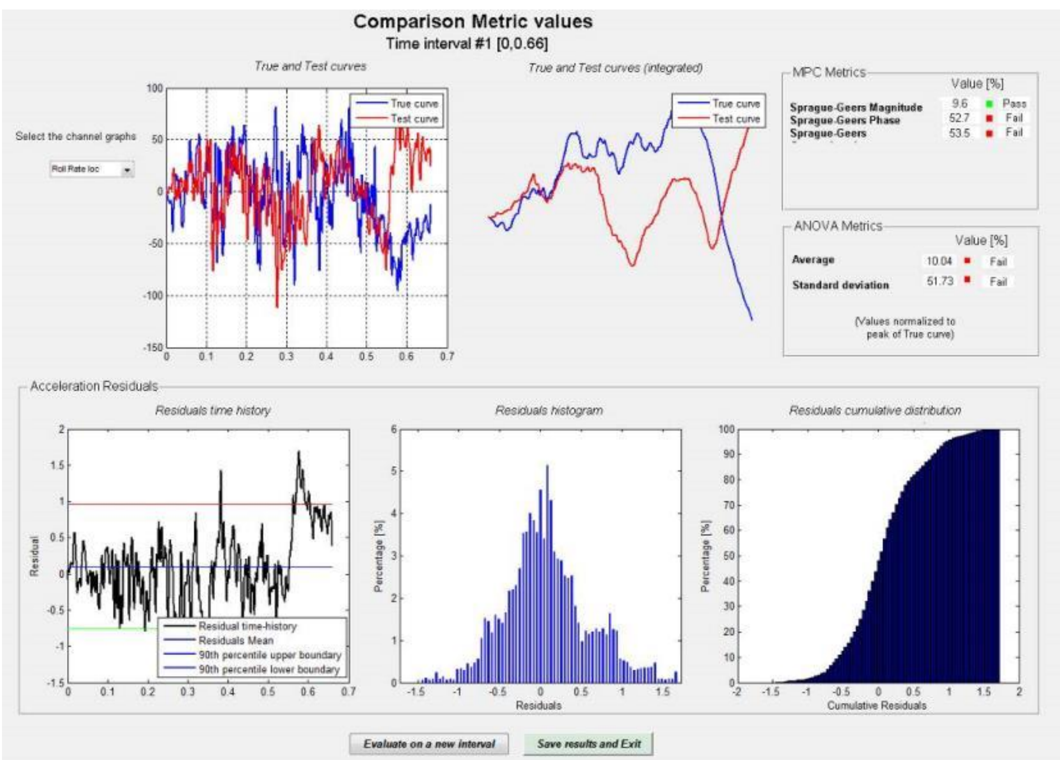


Figure 2e: RSVVP Results – Roll Angle

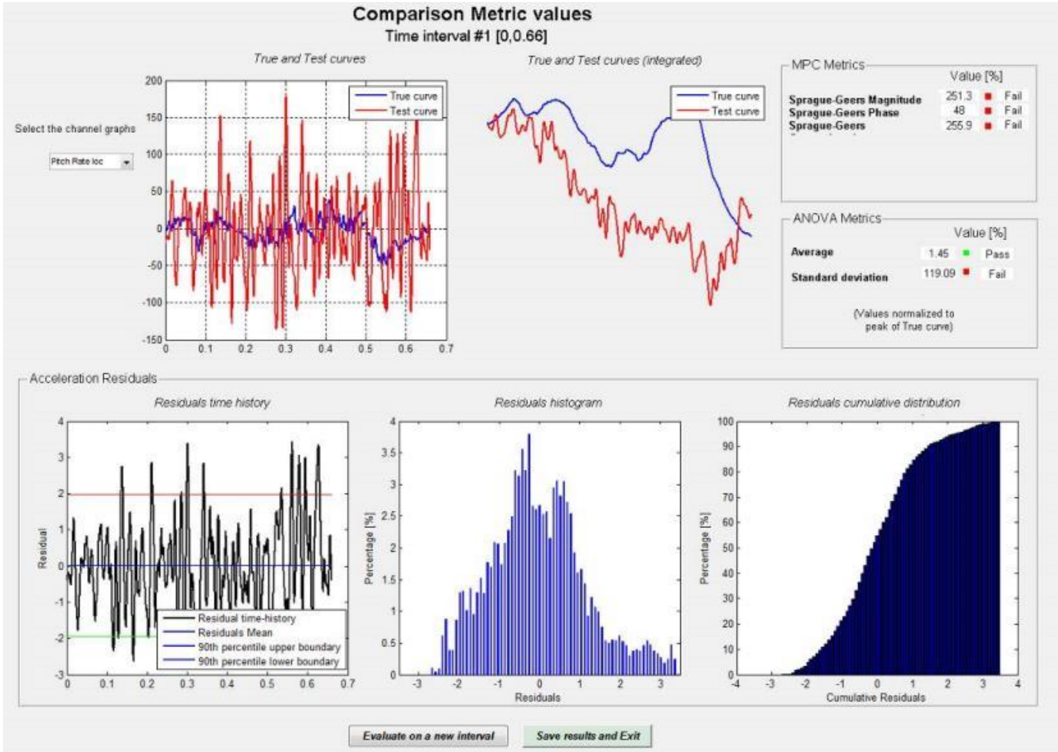


Figure 2f: RSVVP Results – Pitch Angle

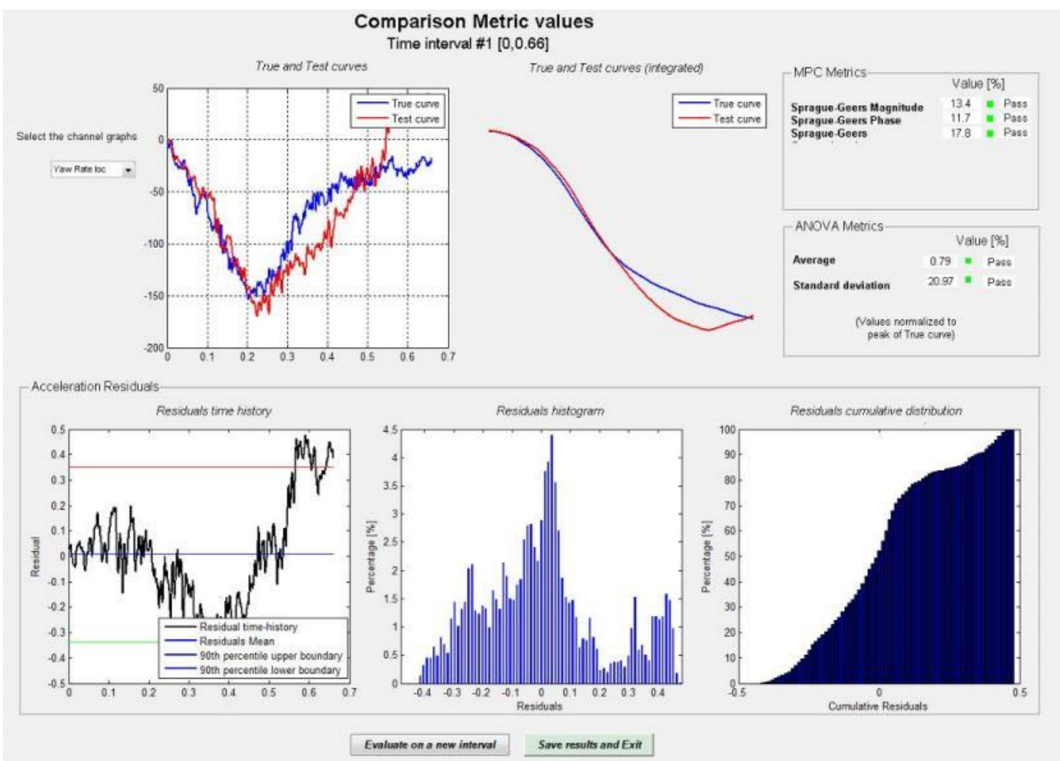


Figure 2g: RSVVP Results – Yaw Angle

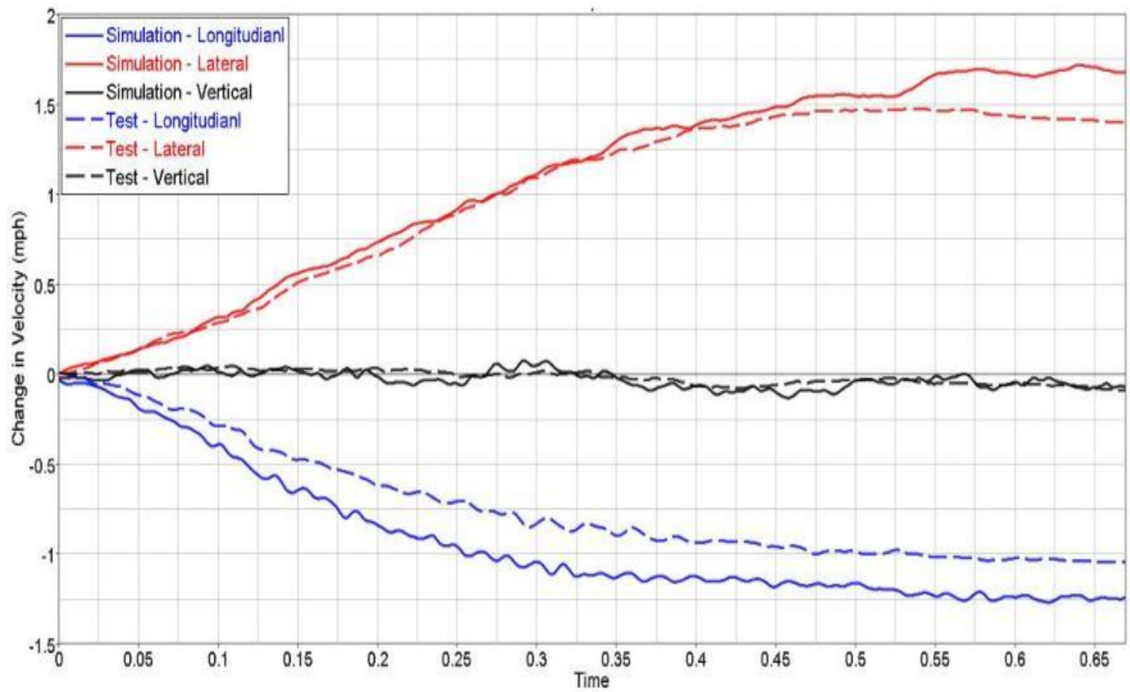


Figure 3: Change in Vehicle Velocities

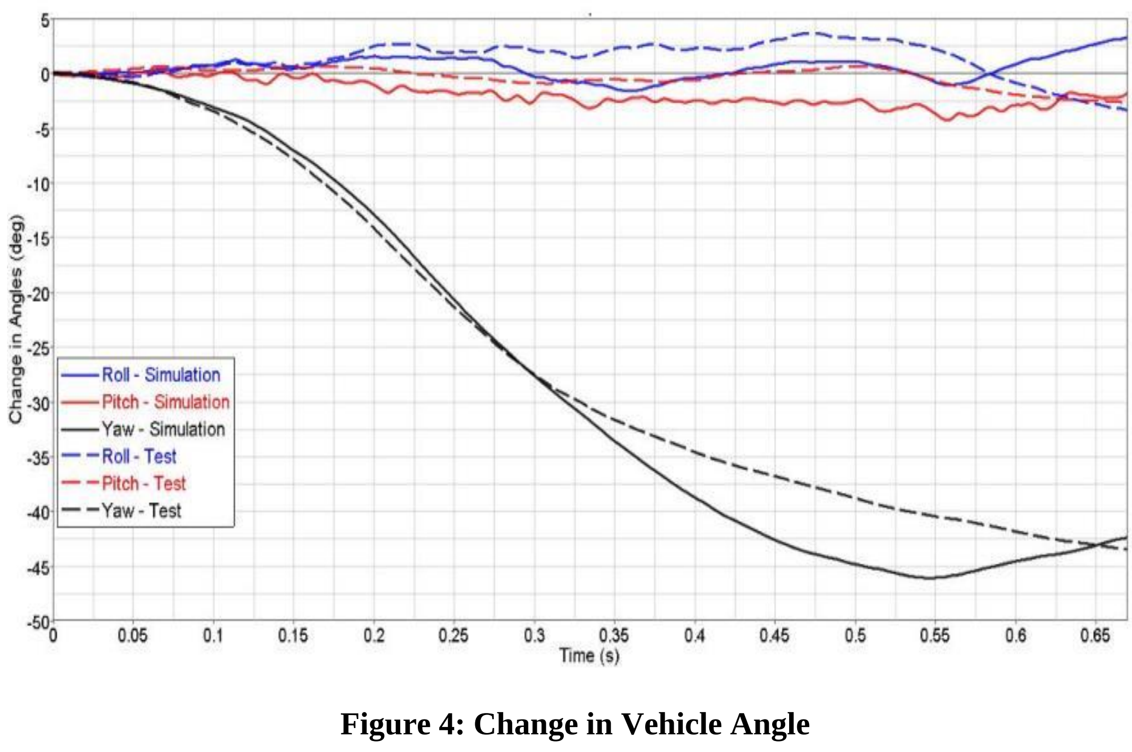
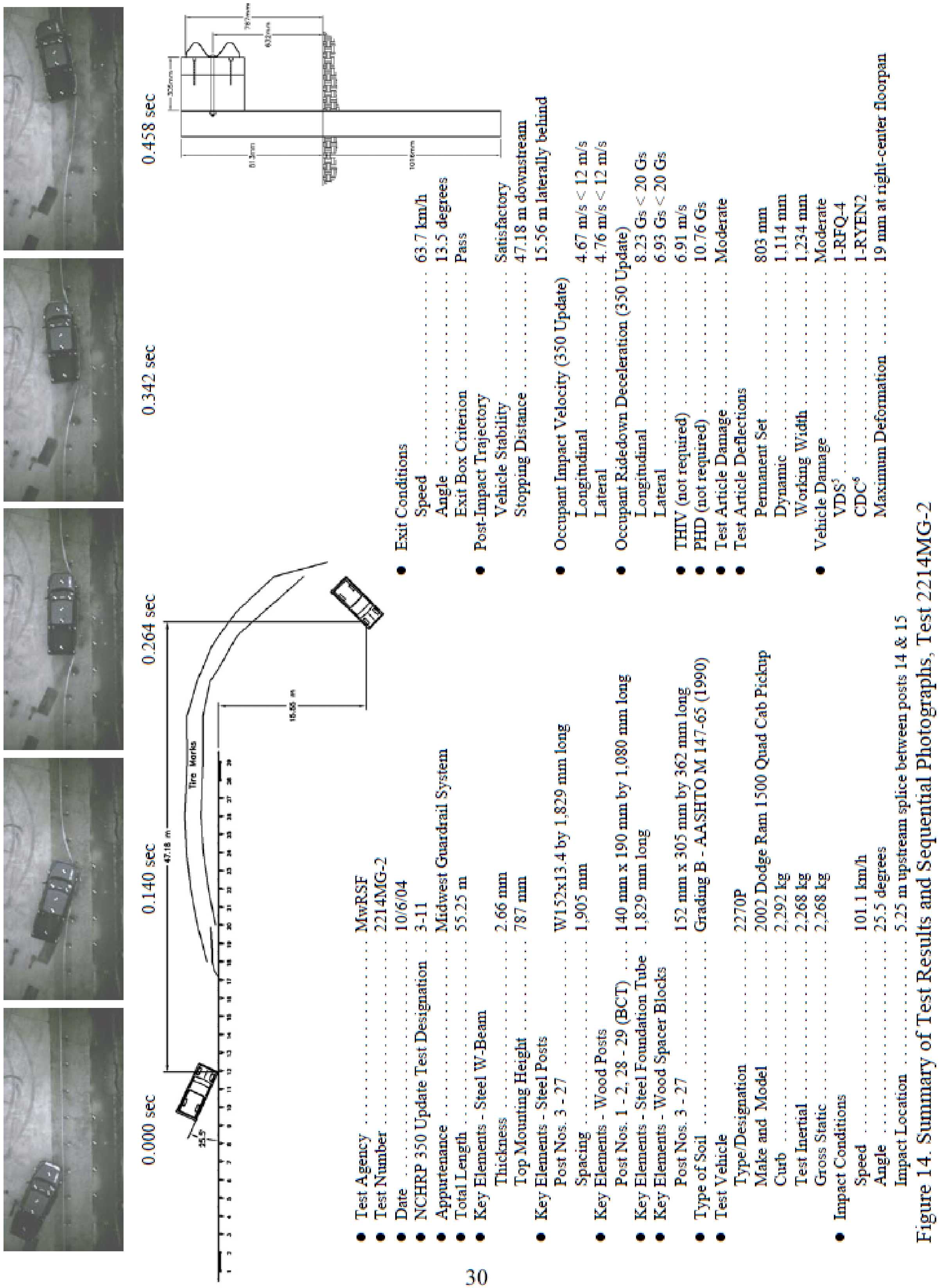


Figure 4: Change in Vehicle Angle

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 2270P (Pickup Truck) with MGS Barrier

Table E - Roadside Safety Phenomena Importance Ranking Table (MASH Evaluation)

Evaluation Criteria				Known Result	Analysis Result	Relative Diff. (%)	Agree?
Structural Adequacy	A	A1	Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.	Yes	Yes		YES
		A2	The relative difference in the maximum dynamic deflection is less than 20 percent.	1.11 m	1.03 m	7%	YES
		A3	The relative difference in the time of vehicle-barrier contact is less than 20 percent.	0.72 s	0.63 s	12%	
		A4	The relative difference in the number of broken or significantly bent posts is less than 20 percent.	3	3		YES
		A5	Barrier did not fail (Answer Yes or No).	Yes	Yes		YES
		A6	There were no failures of connector elements (Answer Yes or No).	Yes	Yes		YES
		A7	There was no significant snagging between the vehicle wheels and barrier elements (Answer Yes or No).	Yes	Yes		YES
		A8	There was no significant snagging between vehicle body components and barrier elements (Answer Yes or No).	Yes	Yes		YES
Occupant Risk	D		Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone (Answer Yes or No).	Yes	Yes		YES
	F	F1	The vehicle should remain upright during and after the collision. The maximum pitch & roll angles are not to exceed 75 degrees.	Yes	Yes		YES
		F2	Maximum vehicle roll – relative difference is less than 20% or absolute difference is less than 5 degrees.	3.58 (.68s)	3.49 (.68s)	3% 0.09 deg	YES
		F3	Maximum vehicle pitch – relative difference is less than 20% or absolute difference is less than 5 deg.	2.86 (.68s)	4.17 (.68s)	31.4% 1.31 deg	YES
		F4	Maximum vehicle yaw – relative difference is less than 20% or absolute difference is less than 5 deg.	43.74 (.68s)	46.01 (.68s)	4.9% 2.27 deg	YES
	H	H1	Longitudinal & lateral occupant impact velocities (OIV) should fall below the preferred value of 30 ft/s (9.1 m/s), or at least below the maximum allowed value of 40 ft/s (12.2 m/s)	Yes	Yes		YES
		H2	Longitudinal OIV (m/s) - Relative difference is less than 20%t or absolute difference is less than 2 m/s	4.67	5.59	16.4% 0.92 m/s	YES
		H3	Lateral OIV (m/s) - Relative difference is less than 20% or absolute difference is less than 2 m/s	4.76	5.09	6.5% 0.33 m/s	YES
	I	I1	Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.	Yes	Yes		YES
		I2	Longitudinal ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	8.23	12.10	31.9% 3.87 g	YES
		I3	Lateral ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	6.93	9.68	28.4% 2.75 g	YES
Vehicle Trajectory			The vehicle rebounded within the exit box. (Answer Yes or No)	Yes	Yes		YES



- Test Agency . . . . . MwRSF
- Test Number 2214MG-2
- Date 10/6/04
- NCHRP 350 Update Test Designation . . . 3-11
- Appurtenance . . . . . Midwest Guardrail System
- Total Length . . . . . 55.25 m
- Key Elements - Steel W-Beam
  - Thickness . . . . . 2.66 mm
  - Top Mounting Height . . . . . 787 mm
- Key Elements - Steel Posts
  - Post Nos. 3 - 27 . . . . . W152x13.4 by 1,829 mm long
  - Spacing . . . . . 1,905 mm
- Key Elements - Wood Posts
  - Post Nos. 1 - 2, 28 - 29 (BCT) . . . 140 mm x 190 mm by 1,080 mm long
- Key Elements - Steel Foundation Tube . . . 1,829 mm long
- Key Elements - Wood Spacer Blocks
  - Post Nos. 3 - 27 . . . . . 152 mm x 305 mm by 362 mm long
- Type of Soil . . . . . Grading B - AASHTO M 147-65 (1990)
- Test Vehicle
  - Type/Designation 2270P
  - Make and Model . . . . . 2002 Dodge Ram 1500 Quad Cab Pickup
  - Curb . . . . . 2,292 kg
  - Test Inertial . . . . . 2,268 kg
  - Gross Static . . . . . 2,268 kg
- Impact Conditions
  - Speed . . . . . 101.1 km/h
  - Angle . . . . . 25.5 degrees
  - Impact Location . . . . . 5.25 m upstream splice between posts 14 & 15
- Exit Conditions
  - Speed . . . . . 63.7 km/h
  - Angle . . . . . 13.5 degrees
  - Exit Box Criterion . . . . . Pass
- Post-Impact Trajectory
  - Vehicle Stability . . . . . Satisfactory
  - Stopping Distance . . . . . 47.18 m downstream
    15.56 m laterally behind
- Occupant Impact Velocity (350 Update)
  - Longitudinal . . . . . 4.67 m/s < 12 m/s
  - Lateral . . . . . 4.76 m/s < 12 m/s
- Occupant Ridedown Deceleration (350 Update)
  - Longitudinal . . . . . 8.23 Gs < 20 Gs
  - Lateral . . . . . 6.93 Gs < 20 Gs
- THIV (not required) . . . . . 6.91 m/s
- PHD (not required) . . . . . 10.76 Gs
- Test Article Damage . . . . . Moderate
- Test Article Deflections
  - Permanent Set . . . . . 803 mm
  - Dynamic . . . . . 1,114 mm
  - Working Width . . . . . 1,234 mm
- Vehicle Damage . . . . . Moderate
  - VDS[5] 1-RFQ-4
  - CDC[6] 1-RYEN2
  - Maximum Deformation . . . . . 19 mm at right-center floorpan

Figure 14. Summary of Test Results and Sequential Photographs, Test 2214MG-2

30

Figure 5: Full-Scale Test Summary

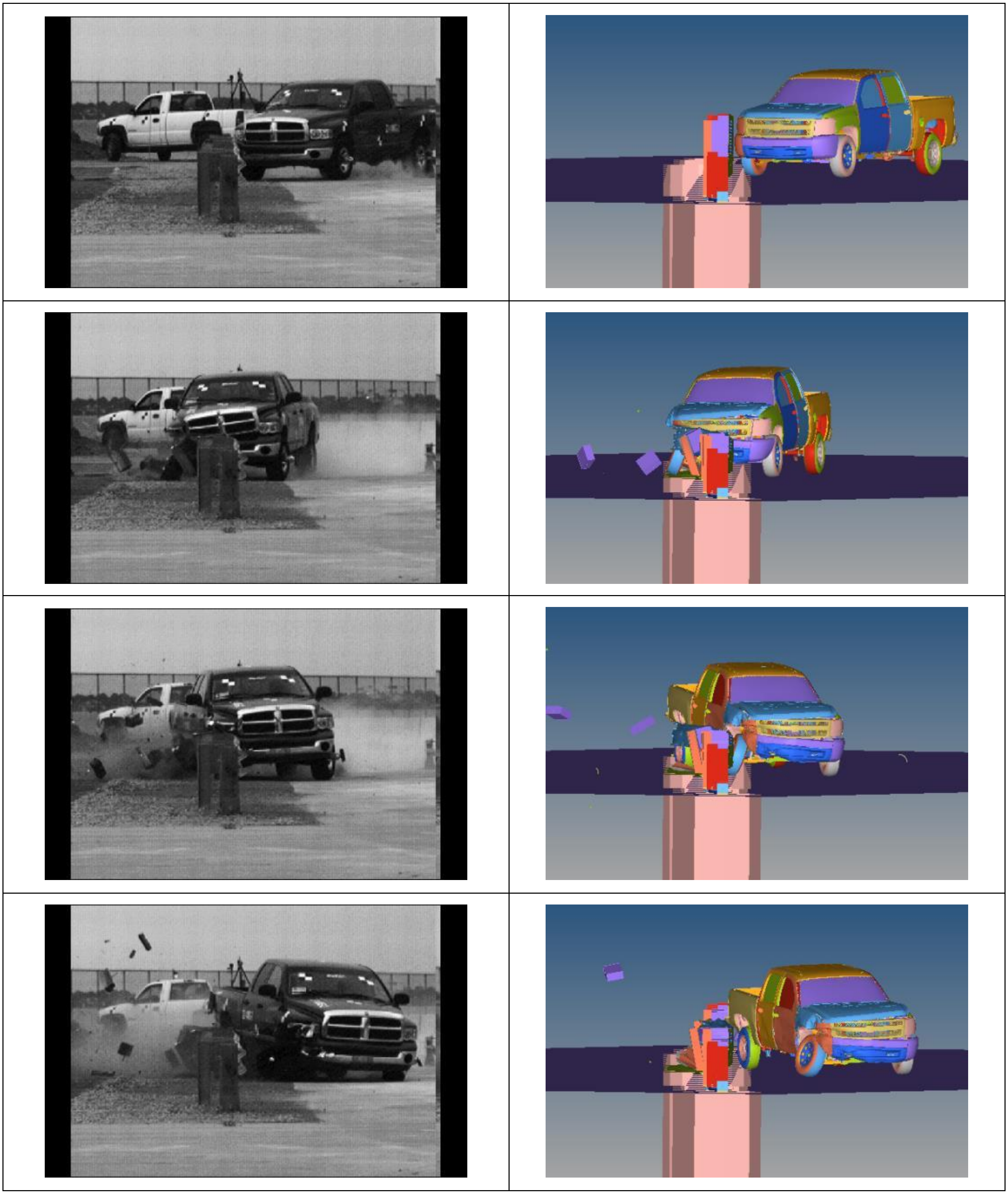


Figure 6a: Sequential Comparisons – Front View

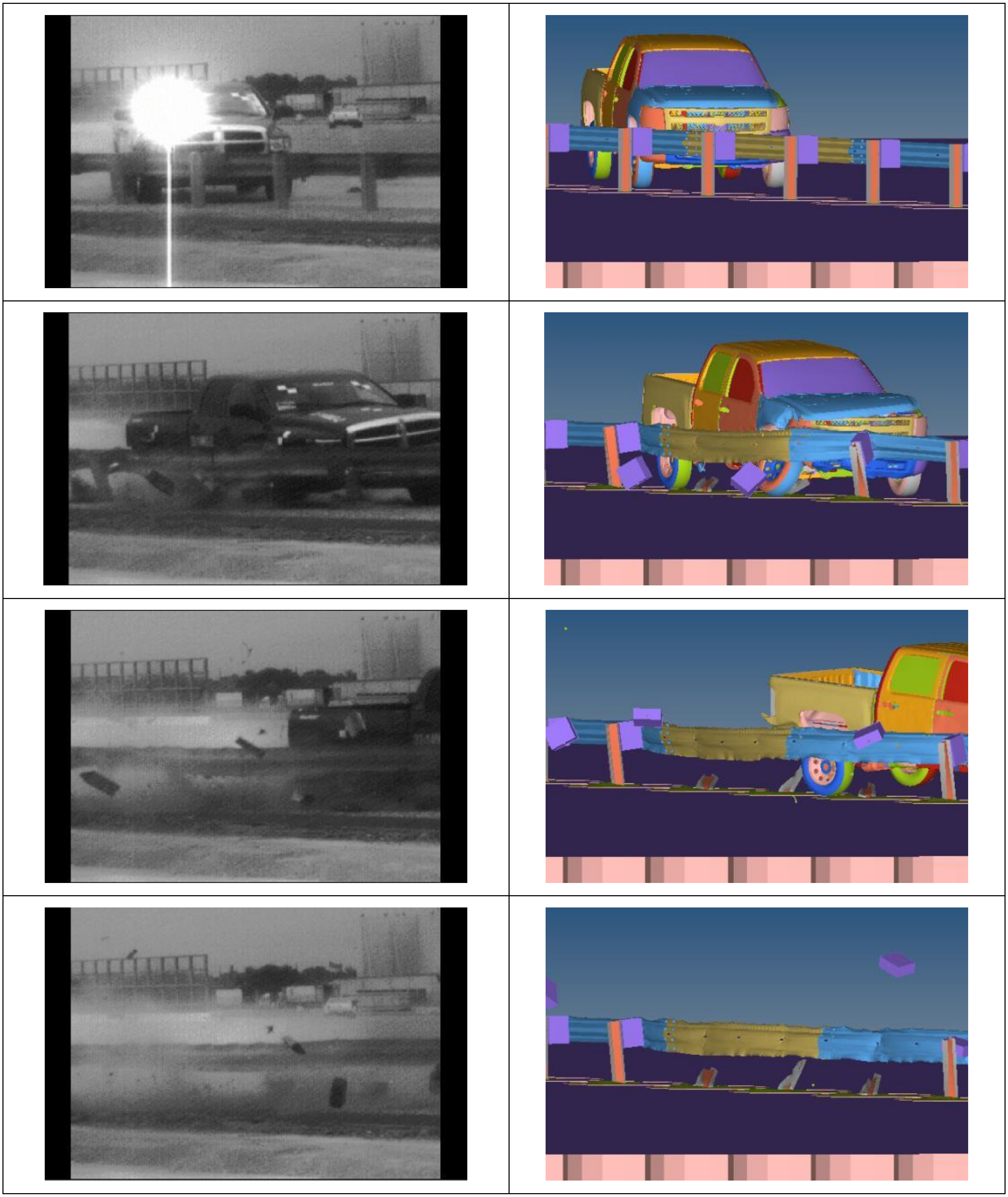


Figure 6b: Sequential Comparisons – Rear View

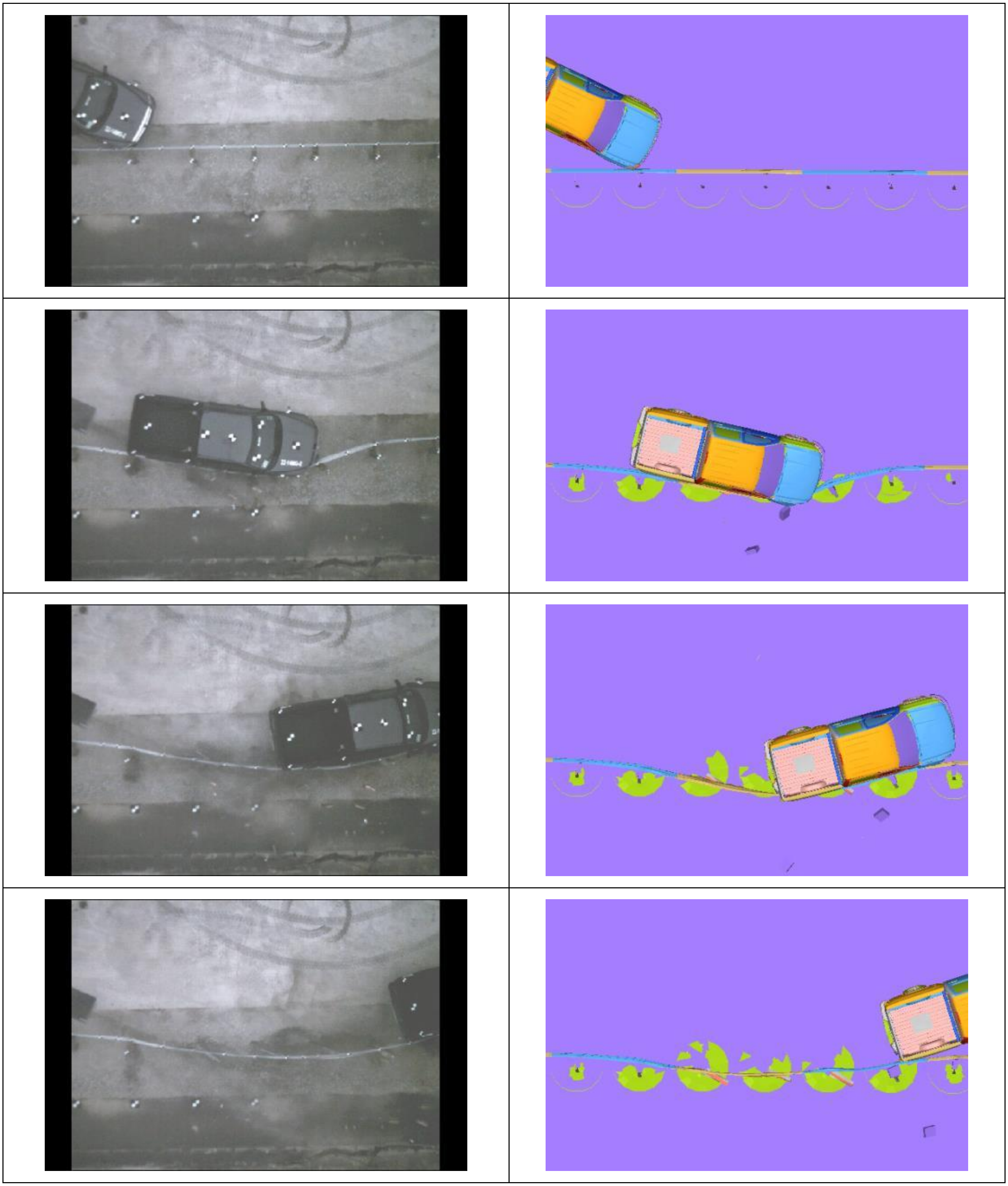


Figure 6c: Sequential Comparisons – Top View

CCSA VALIDATION/VERIFICATION REPORT

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections

Comparison Case: 2270P (Pickup Truck) with MGS Barrier

Table F - Composite Verification and Validation Summary:

List the Report MASH08 Test Number		
Table C – Analysis Solution Verification Summary	Did all solution verification criteria in table pass?	**YES**
Table D - RSVVP Results	Do all the time history evaluation scores from the single channel factors result in a satisfactory comparison (i.e., the comparison passes the criterion)?	**NO**
	If all the values for Single Channel comparison did not pass, did the weighted procedure result in an acceptable comparison.	**YES**
Table E - Roadside Safety Phenomena Importance Ranking Table	Did all the critical criteria in the PIRT Table pass? Note: Tire deflation was observed in the test but not in the simulation. This due to the fact that tire deflation in not incorporated in the model. This is considered not to have a critical effect on the outcome of the test	**YES**
Overall	Are the results of Steps I through III all affirmative (i.e., YES)? If all three steps result in a "YES" answer, the comparison can be considered validated or verified. If one of the steps results in a negative response, the result cannot be considered validated or verified.	**YES**

NOTES:
(none)

Appendix G

Validation Forms for NETC 4-Bar Bridge Rail Model

Comparison to Test NETC-3

NCHRP Report 350 Test 4-12

(Qualitative Validation Only)

FEA VALIDATION/VERIFICATION REPORT FORMS

Report 350 Test 4-12______________ (Report 350 or MASH08 or EN1317 Vehicle Type)

Impact of the

NETC 4-Bar Bridge Rail___________ (Roadside hardware type and name)

Report Date: _12/18/2018________

Type of Report (check one)

- ☐ Verification (known numerical solution compared to new numerical solution).
- ☒ Validation (physical test compared to a numerical solution).
- ☐ Extrapolation (validated numerical solution compared to modified numerical solution).

General Information	**Known Solution**	**Analysis Solution**
Performing Organization	SwRI	Roadsafe LLC
Analyst/Engineer	**C.E. Kimbal and J.B. Mayer**	Chuck Plaxico
Test/Run Number:	NETC-3	
Vehicle:	8000S – 1993 International 4600 LP SUT	F800 Version 181114
Reference:	Test 4-12	Test 4-12
Impact Conditions		
Vehicle Mass:	17,875-lb	17,911-lb
Speed:	49.8 mph	49.8 mph
Angle:	15 degrees	15 degrees
Impact Point:	24 inches upstream of Post 6	15 inches upstream of Post 7

Composite Validation/Verification Score

	List the Report 350/MASH08 or EN1317 Test Number: ____4-12______	Pass?
Part I	Did all solution verification criteria in Table C-1 pass?	Y
Part II	Do all the time history evaluation scores from Table C-2 result in a satisfactory comparison (i.e., the comparison passes the criterion)? If all the values in Table C-2 did not pass, did the weighted procedure shown in Table C-3 result in an acceptable comparison. If all the criteria in Table C-2 pass, enter "yes." If all the criteria in Table C-2 did not pass but Table C-3 resulted in a passing score, enter "yes."	N.A.
Part III	All the criteria in Table C-4 (Test-PIRT) passed? Not Required for Component Tests	Y
	Are the results of Steps I through III all affirmative (i.e., YES)? If all three steps result in a "YES" answer, the comparison can be considered validated or verified. If one of the steps results in a negative response, the result cannot be considered validated or verified.	Y

The analysis solution (check one):

- ☐ Is verified/validated against the known solution.
- ☒ Is NOT verified/validated against the known solution.

PART I: BASIC INFORMATION

1. What type of roadside hardware is being evaluated (check one)?
   - [x] Longitudinal barrier or transition
   - [ ] Terminal or crash cushion
   - [ ] Breakaway support or work zone traffic control device
   - [ ] Truck-mounted attenuator
   - [ ] Other hardware or component: ______________________________

2. What test guidelines were used to perform the full-scale crash test (check one)?
   - [x] NCHRP Report 350
   - [ ] MASH08
   - [ ] EN1317
   - [ ] Other: ______________________________

3. Indicate the test level and number being evaluated (fill in the blank): ______4-12____________

4. Indicate the vehicle type appropriate for the test level and number indicated in item 3 according to the testing guidelines indicated in item 2.

NCHRP Report 350/MASH08

[ ] 700C	[ ] 820C	[ ] 1100C	[ ] 2000P
[ ] 2270P	[ ] 8000S	[x] 10000S	[ ] 36000V
[ ] 36000T			

EN1317

[ ] Car (900 kg)	[ ] Car (1300 kg)	[ ] Car (1500 kg)
[ ] Rigid HGV (10 ton)	[ ] Rigid HGV (16 ton)	[ ] Rigid HGV (30 ton)
[ ] Bus (13 ton)	[ ] Articulated HGV (38 ton)	

[ ] Other:______________________

PART II: ANALYSIS SOLUTION VERIFICATION

Table G-1. Analysis Solution Verification Table.

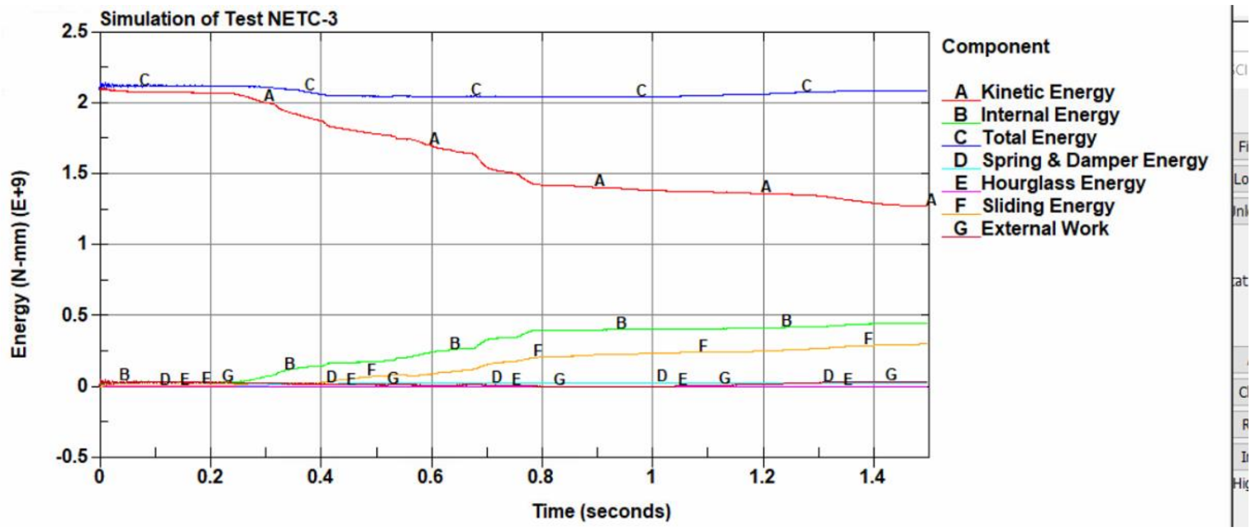
Verification Evaluation Criteria	Change (%)	Pass?
Total energy of the analysis solution (i.e., kinetic, potential, contact, etc.) must not vary more than 10 percent from the beginning of the run to the end of the run.	0	Y
Hourglass Energy of the analysis solution at the end of the run is less than *five percent* of the total *initial energy* at the *beginning* of the run.	0	Y
Hourglass Energy of the analysis solution at the end of the run is less than *ten percent* of the total *internal energy* at the *end* of the run.	0	Y
The part/material with the highest amount of hourglass energy at the end of the run is less than twenty percent of the total internal energy of the part/material at the end of the run.	19 (sidewalk)	Y
Mass added to the total model is less than five percent of the total model mass at the beginning of the run.	0	Y
The part/material with the most mass added had less than 10 percent of its initial mass added.	5.7	Y
The moving parts/materials in the model have less than five percent of mass added to the initial moving mass of the model.	5.7	Y
There are no shooting nodes in the solution?	Y	Y
There are no solid elements with negative volumes?	Y	Y
Exception Notes:		

☒ Analysis solution passes all the criteria in Table C-1 ☒ without exceptions.

☐ with exceptions as noted in Table C-1.

☐ Analysis solution does NOT pass all the criteria in Table C-1.

☐ Table C-1 is not applicable because ______________________________



Simulation of Test NETC-3
Component
A Kinetic Energy
B Internal Energy
C Total Energy
D Spring & Damper Energy
E Hourglass Energy
F Sliding Energy
G External Work
Energy (N-mm) (E+9)
Time (seconds)

PART III: HISTORY EVALUTION TABLES

Table G-2. Roadside Safety Validation Metrics Rating Table (single channel option).

<table>
<tr><td colspan="9">Evaluation Criteria</td><td colspan="3" rowspan="2">Time interval [seconds]</td></tr>
<tr><td rowspan="8">O</td><td colspan="8">Sprague-Geers Metrics
List all the data channels being compared. Calculate the M and P metrics using RSVVP and enter the results. Values less than or equal to 40 are acceptable.</td></tr>
<tr><td rowspan="2" colspan="2">Channel</td><td colspan="6">RSVVP Curve Preprocessing Options</td><td rowspan="2">M</td><td rowspan="2">P</td><td rowspan="2">Pass?</td></tr>
<tr><td>Filter Option</td><td>Sync. Option</td><td>Shift
True Curve</td><td>Shift
Test Curve</td><td>Drift
True Curve</td><td>Drift
Test Curve</td></tr>
<tr><td colspan="2">x-acceleration</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">y-acceleration</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">z-acceleration</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Yaw-rate</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Roll-rate</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Pitch-rate</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="7">P</td><td colspan="8">ANOVA Metrics
List all the data channels being compared. Calculate the ANOVA metrics using RSVVP and enter the results. Both of the following criteria must be met:
• The mean residual error must be less than five percent of the peak acceleration ($\bar{e} \leq 0.05 \cdot a_{Peak}$) and
• The standard deviation of the residuals must be less than 35 percent of the peak acceleration ($\sigma \leq 0.35 \cdot a_{Peak}$).</td><td>Mean Residual</td><td>Standard Deviation of Residuals</td><td>Pass?</td></tr>
<tr><td colspan="8">x-acceleration</td><td></td><td></td><td></td></tr>
<tr><td colspan="8">y-acceleration</td><td></td><td></td><td></td></tr>
<tr><td colspan="8">z-acceleration</td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Yaw-rate</td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Roll-rate</td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Pitch-rate</td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Exception Notes:</td></tr>
</table>

☐ Analysis solution passes all the criteria in Table C-2 ☐ without exceptions.

☐ with exceptions as noted in Table C-2.

☐ Analysis solution does NOT pass all the criteria in Table C-2.

☐ Table C-2 is not applicable because ____

☐ RSVVP Single-Channel Comparison Metric Values Screens for each channel are attached on the following pages.

Table G-3. Roadside Safety Validation Metrics Rating Table (multi-channel option).

Evaluation Criteria (time interval [0.0 – 1.0 seconds])					
Channels (Select which were used)					
☐ **X Acceleration**	☐ **Y Acceleration**	☐ **Z Acceleration**			
☐ **Roll rate**	☐ **Pitch rate**	☐ **Yaw rate**			
Multi-Channel Weights **- Area II method -**	**X Channel:** **Y Channel:** **Z Channel:** **Yaw Channel:** **Roll Channel:** **Pitch Channel:**				
O	***Sprague-Geer Metrics*** Values less or equal to 40 are acceptable.	**M**	**P**	**Pass?**	
P	***ANOVA Metrics*** Both of the following criteria must be met: • The mean residual error must be less than five percent of the peak acceleration ($\bar{e} \leq 0.05 \cdot a_{Peak}$) • The standard deviation of the residuals must be less than 35 percent of the peak acceleration ($\sigma \leq 0.35 \cdot a_{Peak}$)	**Mean Residual**	**Standard Deviation of Residuals**	Pass?	

☐ Analysis solution passes <u>all</u> the criteria in Table C-3 ☐ without exceptions

☐ with exceptions as noted in Table C-3.

☐ Analysis solution does NOT pass <u>all</u> the criteria in Table C-3.

☐ Table C-3 does not contain sufficient information for assessment.

☐ Table C-3 is not applicable because criteria were satisfied in Table C-2.

☒ RSVVP Multi-Channel Comparison Metric Values Screen is attached on the following page.

PART IV: PHENOMENAA IMPORTANCE RANKING TABLES

Table G-4. Evaluation Criteria Test Applicability Table.

<table>
<tr><th>Evaluation Factors</th><th colspan="2">Evaluation Criteria</th><th>Applicable Tests</th></tr>
<tr><td rowspan="2">Structural Adequacy</td><td>A</td><td>Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>10, 11, 12, 20, 21, 22, 35, 36, 37, 38</td></tr>
<tr><td>B</td><td>The test article should readily activate in a predictable manner by breaking away, fracturing or yielding.</td><td>60, 61, 70, 71, 80, 81</td></tr>
<tr><td></td><td>C</td><td>Acceptable test article performance may be by redirection, controlled penetration or controlled stopping of the vehicle.</td><td>30, 31, 32, 33, 34, 39, 40, 41, 42, 43, 44, 50, 51, 52, 53</td></tr>
<tr><td rowspan="7">Occupant Risk</td><td>D</td><td>Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone.</td><td>All</td></tr>
<tr><td>E</td><td>Detached elements, fragments or other debris from the test article, or vehicular damage should not block the driver’s vision or otherwise cause the driver to lose control of the vehicle. (Answer Yes or No)</td><td>70, 71</td></tr>
<tr><td>F</td><td>The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are acceptable.</td><td>All except those listed in criterion G</td></tr>
<tr><td>G</td><td>It is preferable, although not essential, that the vehicle remain upright during and after collision.</td><td>12, 22 (for test level 1 – 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44)</td></tr>
<tr><td rowspan="2">H</td><td>Occupant impact velocities should satisfy the following:
<table><tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>9</td><td>12</td></tr></table></td><td>10, 20, 30,31, 32, 33, 34, 36, 40, 41, 42, 43, 50, 51, 52, 53, 80, 81</td></tr>
<tr><td><table><tr><td>Longitudinal</td><td>3</td><td>5</td></tr></table></td><td>60, 61, 70, 71</td></tr>
<tr><td>I</td><td>Occupant ridedown accelerations should satisfy the following:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (g’s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15</td><td>20</td></tr></table></td><td>10, 20, 30,31, 32, 33, 34, 36, 40, 41, 42, 43, 50, 51, 52, 53, 60, 61, 70, 71, 80, 81</td></tr>
<tr><td rowspan="4">Vehicle Trajectory</td><td>K</td><td>After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td><td>All</td></tr>
<tr><td>L</td><td>The occupant impact velocity in the longitudinal direction should not exceed 40 ft/sec and the occupant ride-down acceleration in the longitudinal direction should not exceed 20 G’s.</td><td>11,21, 35, 37, 38, 39</td></tr>
<tr><td>M</td><td>The exit angle from the test article preferable should be less than 60 percent of test impact angle, measured at the time of vehicle loss of contact with test device.</td><td>10, 11, 12, 20, 21, 22, 35, 36, 37, 38, 39</td></tr>
<tr><td>N</td><td>Vehicle trajectory behind the test article is acceptable.</td><td>30, 31, 32, 33, 34, 39, 42, 43, 44, 60, 61, 70, 71, 80, 81</td></tr>
</table>

Table G-5(a). Roadside Safety Phenomena Importance Ranking Table (Structural Adequacy).

Evaluation Criteria				Known Result	Analysis Result	Difference Relative/ Absolute	Agree?
Structural Adequacy	A	1	Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable. (Answer Yes or No)	Y	Y		Y
		2	Maximum dynamic deflection: - Relative difference is less than 20 percent or - Absolute difference is less than 6 inches	1.0 in	1.08 in	8.0% 0.08 in	Y
		3	Maximum permanent deflection: - Relative difference is less than 20 percent or - Absolute difference is less than 6 inches	0.51 in	0.48 in	5.9% 0.03 in	Y
		4	Length of vehicle-barrier contact (at initial separation): - Relative difference is less than 20 percent or - Absolute difference is less than 6.6 ft	N.R. Posts 6-11	42 ft Posts 6-11		Y
		5	Number of broken or significantly bent posts is less than 20 percent.	0	0		Y
		6	Did the rail element rupture or tear (Answer Yes or No)	No	No		Y
		7	Concrete curb/deck failure	No	No		Y
		8	Was there significant snagging between the vehicle wheels and barrier elements (Answer Yes or No).	N	N		Y
		9	Was there significant snagging between vehicle body components and barrier elements (Answer Yes or No).	N*	N		Y

* *There was additional snagging between the bumper and the rail in the test that could not be captured in the FE model due to differences in bumper width.*

N.R. – Not Reported

Table G-5(b). Roadside Safety Phenomena Importance Ranking Table (Occupant Risk).

<table>
<tr><th colspan="4">Evaluation Criteria</th><th>Known Result</th><th>Analysis Result</th><th>Difference Relative/ Absolute</th><th>Agree?</th></tr>
<tr><td rowspan="15">Occupant Risk</td><td colspan="2">D</td><td>Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone. (Answer Yes or No)</td><td>N</td><td>N</td><td></td><td>Y</td></tr>
<tr><td rowspan="4">F</td><td>1</td><td>The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are acceptable. (Answer Yes or No)</td><td>Y</td><td>Y</td><td></td><td>Y</td></tr>
<tr><td>2</td><td>Maximum roll of the vehicle through 1.0 seconds:
- Relative difference is less than 20 percent or
- Absolute difference is less than 5 degrees.</td><td>*20.0 Deg</td><td>14.7 deg</td><td>26.5 %
5.3 deg</td><td>N</td></tr>
<tr><td>3</td><td>Maximum pitch of the vehicle through 1.0 seconds:
- Relative difference is less than 20 percent or
- Absolute difference is less than 5 degrees.</td><td>*5.0 deg</td><td>5.4 deg</td><td>8.0 %
0.4 deg</td><td>Y</td></tr>
<tr><td>4</td><td>Maximum yaw of the vehicle through 0.446 seconds:
- Relative difference is less than 20 percent or
- Absolute difference is less than 5 degrees.</td><td>14.8 deg</td><td>16.2 deg</td><td>9.7 %
1.4 deg</td><td>Y</td></tr>
<tr><td>G</td><td>1</td><td>Did the vehicle remain upright during and after collision</td><td>Y</td><td>Y</td><td></td><td>Y</td></tr>
<tr><td rowspan="9">L</td><td rowspan="4">1</td><td>Occupant impact velocities:
- Relative difference is less than 20 percent or
- Absolute difference is less than 6.6 ft/s.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>• Longitudinal OIV (ft/s)</td><td>5.4</td><td>5.9</td><td>9.1%
0.5 ft/s</td><td>Y</td></tr>
<tr><td>• Lateral OIV (ft/s)</td><td>-9.5</td><td>-12.1</td><td>28%
2.7 ft/s</td><td>Y</td></tr>
<tr><td>• THIV (ft/s)</td><td>N.R.</td><td>13.8</td><td></td><td></td></tr>
<tr><td rowspan="5">2</td><td>Occupant accelerations:
- Relative difference is less than 20 percent or
- Absolute difference is less than 4 g’s.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>• Longitudinal ORA</td><td>8.95</td><td>4.95</td><td>44.7 %
4 g</td><td>Y</td></tr>
<tr><td>• Lateral ORA</td><td>14.3</td><td>12.1</td><td>15.4 %
2.2 g</td><td>Y</td></tr>
<tr><td>• PHD</td><td>N.R.</td><td>12.8</td><td></td><td></td></tr>
<tr><td>• ASI</td><td>N.R.</td><td>0.42</td><td></td><td></td></tr>
</table>

N.R. – Not Reported

** Reported as “approximate”*

Table C-5(c). Roadside Safety Phenomena Importance Ranking Table (Vehicle Trajectory).

			Evaluation Criteria	**Known Result**	**Analysis Result**	**Difference Relative/ Absolute**	**Agree?**
Vehicle Trajectory	K	1	The exit angle from the test article preferable should be less than 60 percent of test impact angle, measured at the time of vehicle loss of contact with test device.	1.3%	8.0%		Y
		2	Exit angle at loss of contact: - Relative difference is less than 20 percent or - Absolute difference is less than 5 degrees.	4.1 deg	1.2 deg	2.9 deg	Y
	M	3	Exit velocity at loss of contact: - Relative difference is less than 20 percent or - Absolute difference is less than 6.2 mph.	35.8 mph	40.3 mph	12.8 % 4.6 mph	Y
		4	Front axle disconnected from suspension	Y	Y		Y

Note: Additional phenomena can be added to the tables in deemed appropriate by the analyst.

☐ Analysis solution passes all the criteria in Tables G-5(a) through G-5(c)

☐ without exceptions.

☒ with exceptions as noted in Tables G-5(a) through G-5(c).

☐ Does NOT pass all the criteria in Tables G-5(a) through 5(c).

☐ Tables G-5(a) through G-5(c) does not contain sufficient information for assessment.

☐ Tables G-5(a) through G-5(c) are not applicable because ___________________________________

☒ Synchronized side-by-side views of the known and analysis solutions are attached on the following pages.

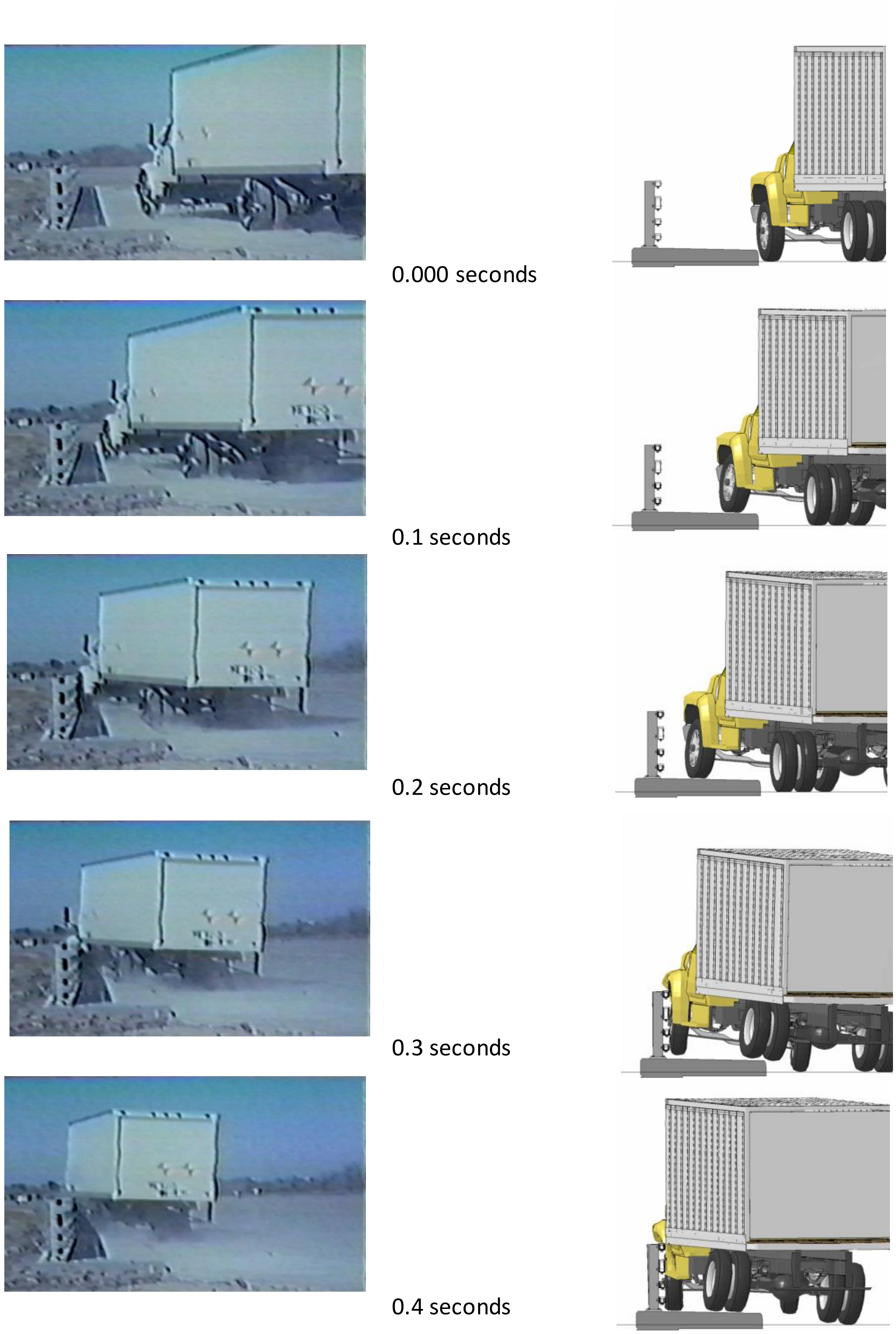


Figure 1. Sequential views from FEA and Test NETC-3 from a upstream view point.

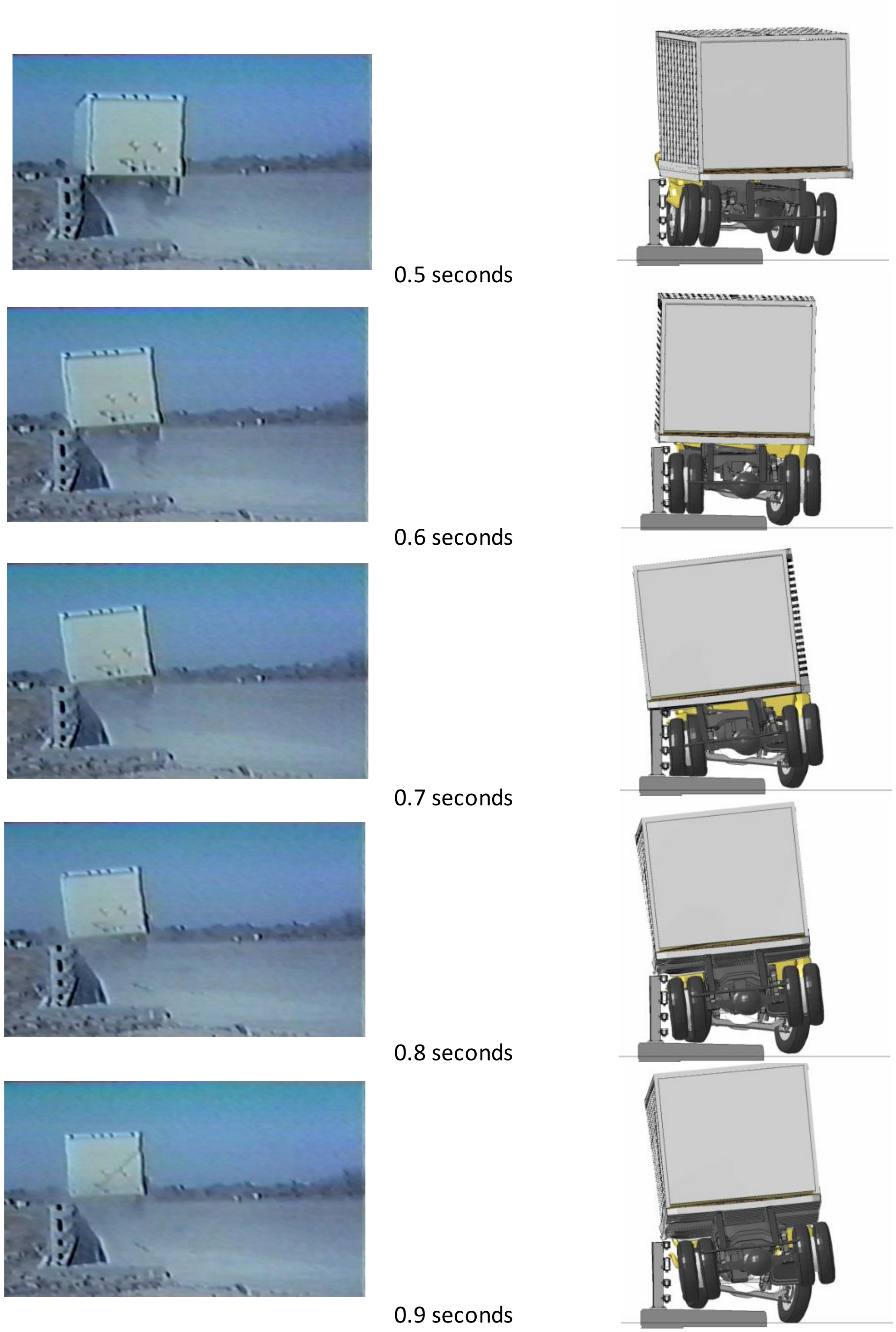


Figure 1. [Continued] Sequential views from FEA and Test NETC-3 from an upstream viewpoint.

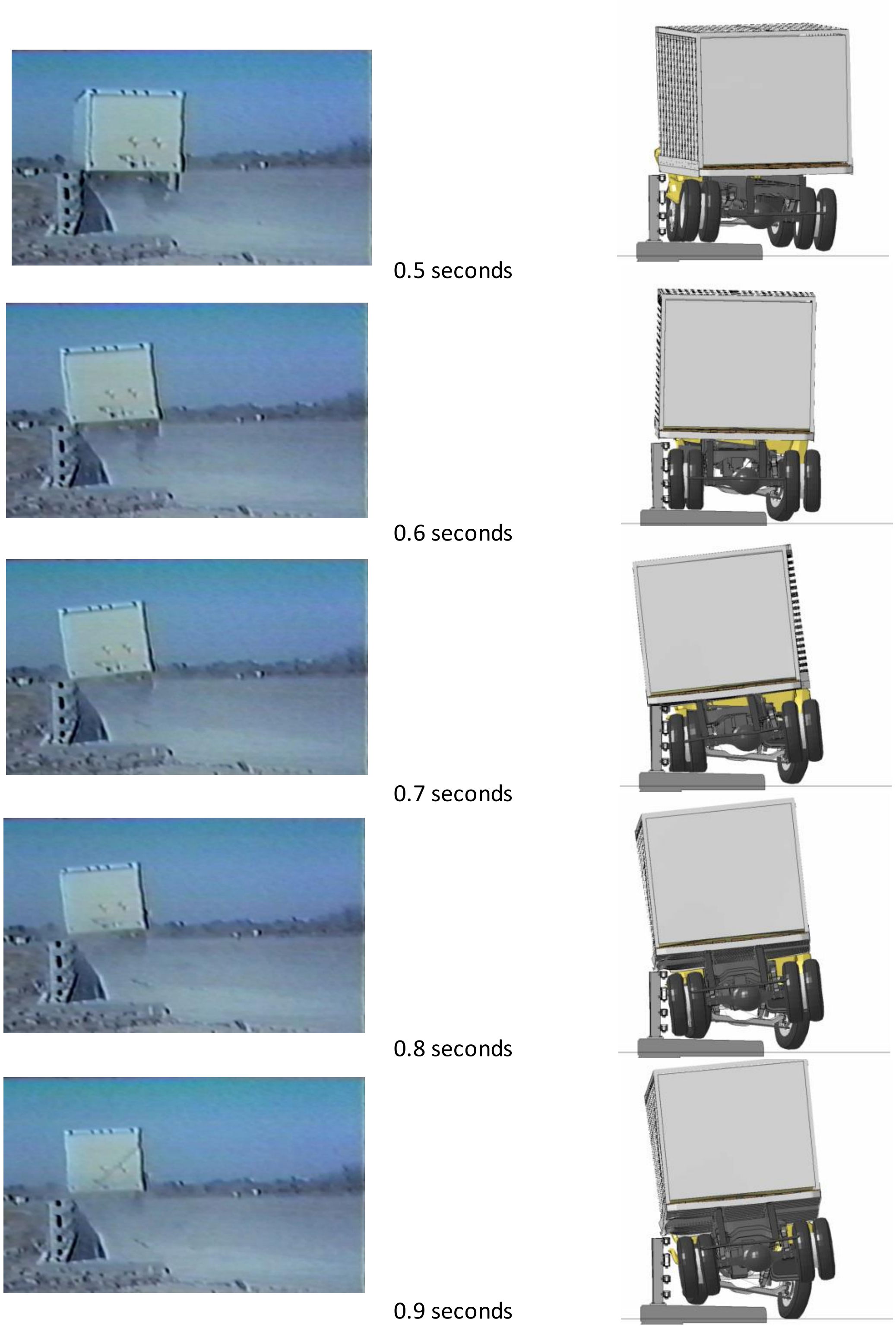


Figure 1. [Continued] Sequential views from FEA and Test NETC-3 from an upstream viewpoint.

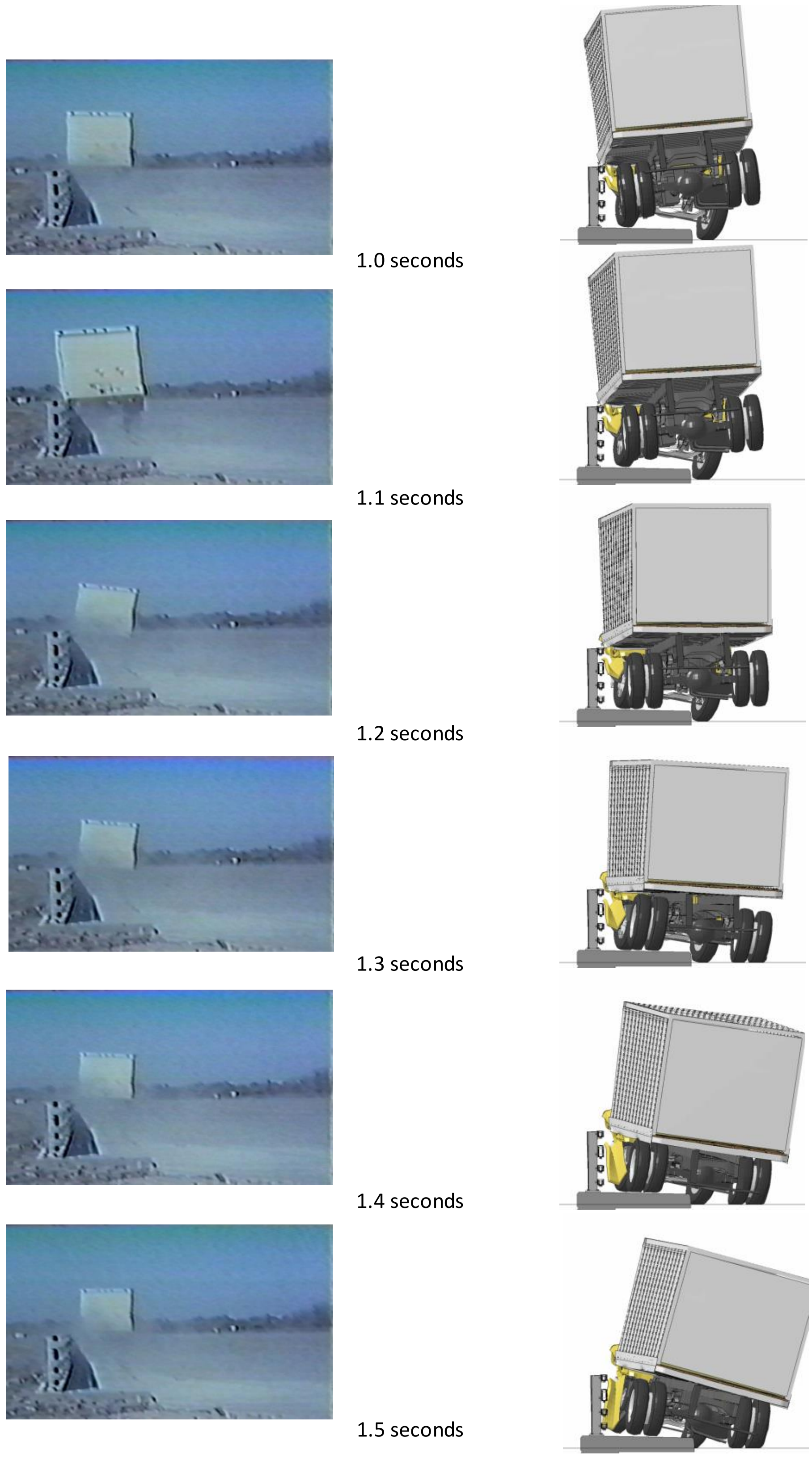


Figure 1. [Continued] Sequential views from FEA and Test NETC-3 from an upstream viewpoint.

Figure 2. Sequential views of Test NETC-3 and FE analysis from downstream viewpoint.

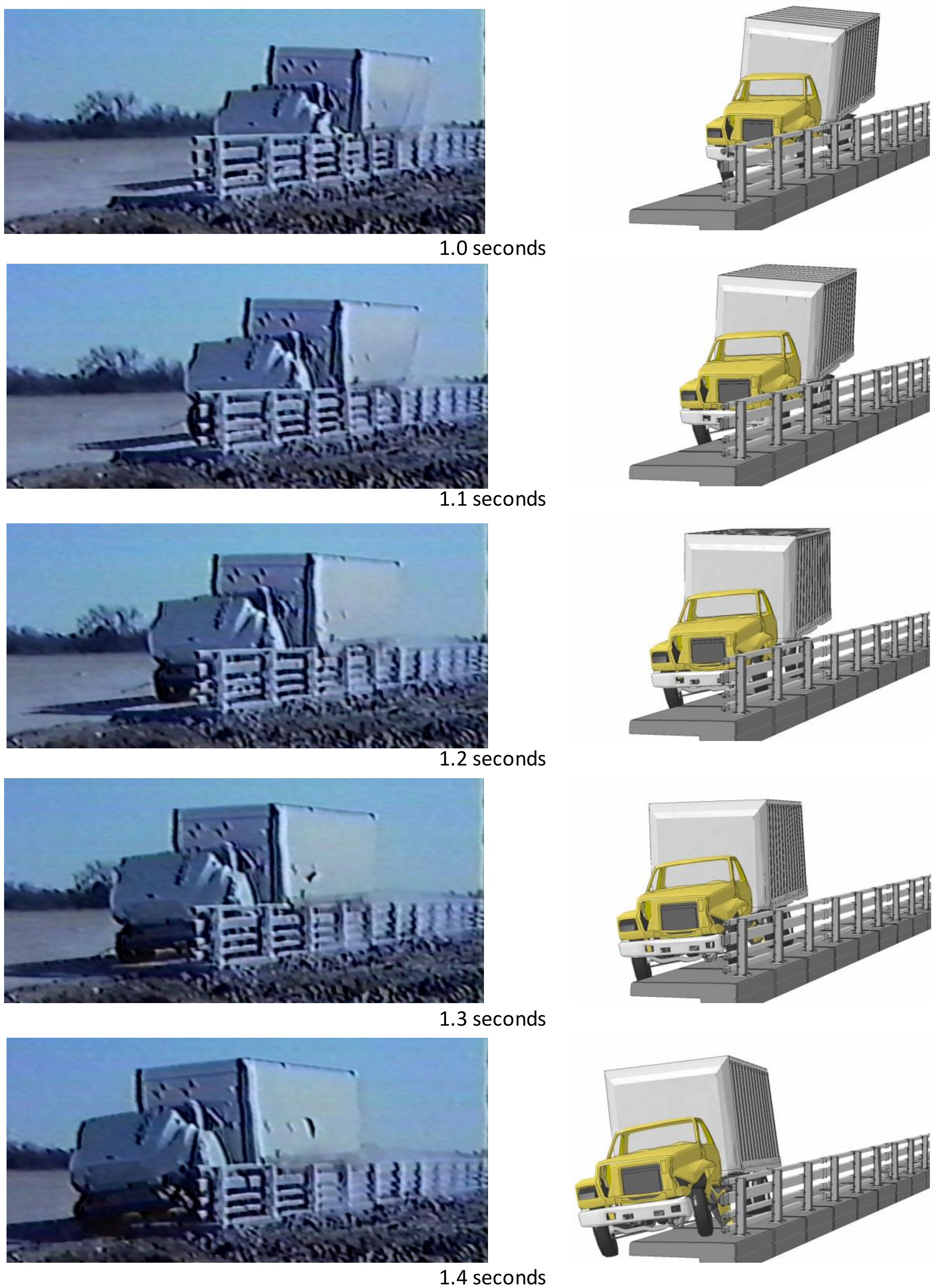


Figure 2. [CONTINUED] Sequential views of Test NETC-3 and FE analysis from downstream viewpoint.

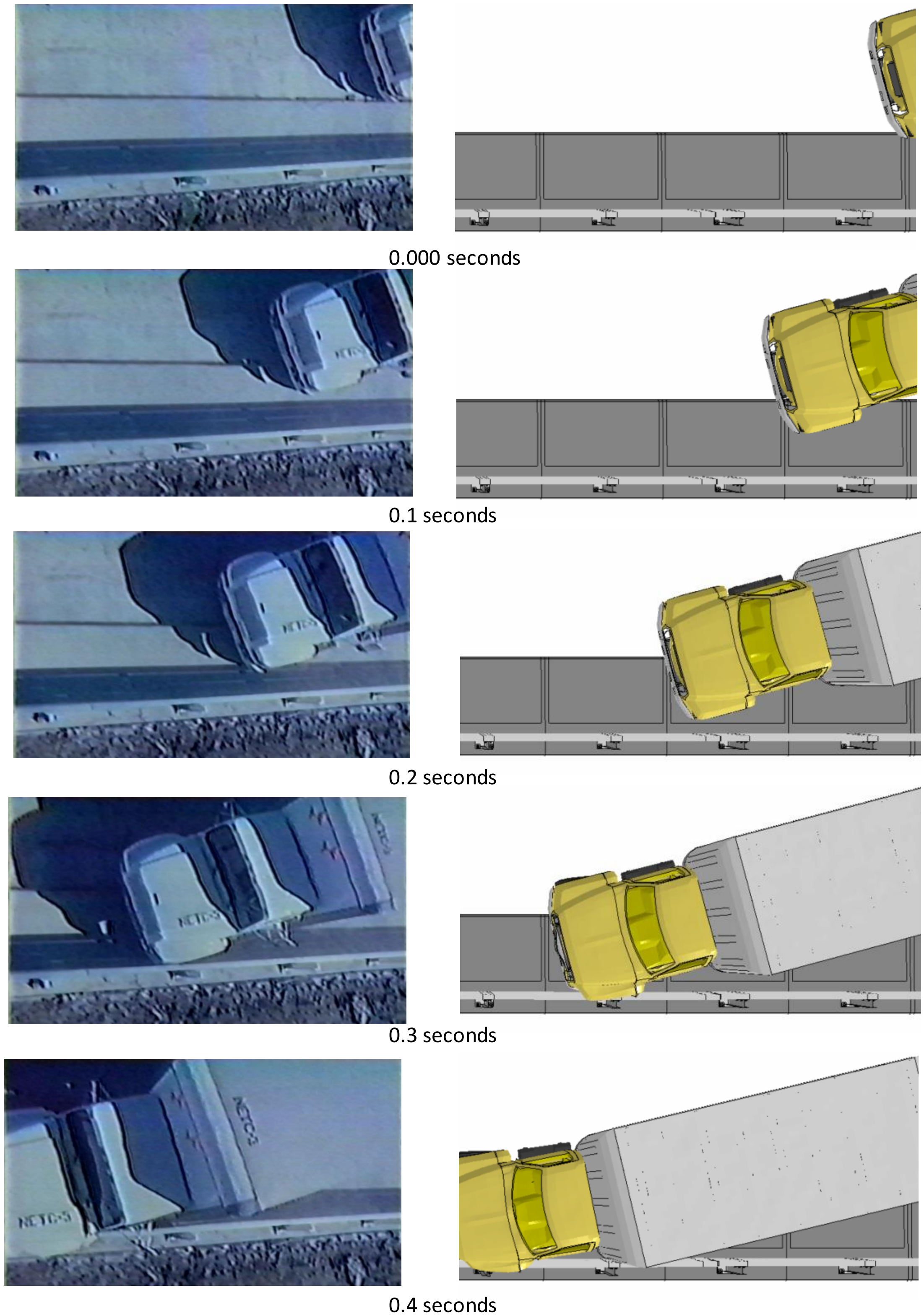
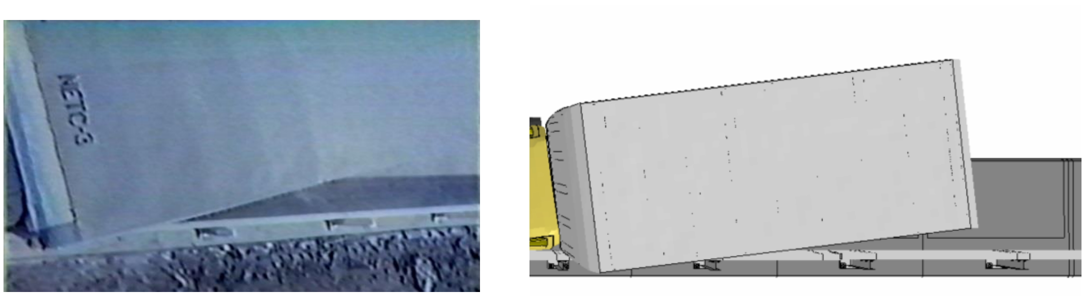
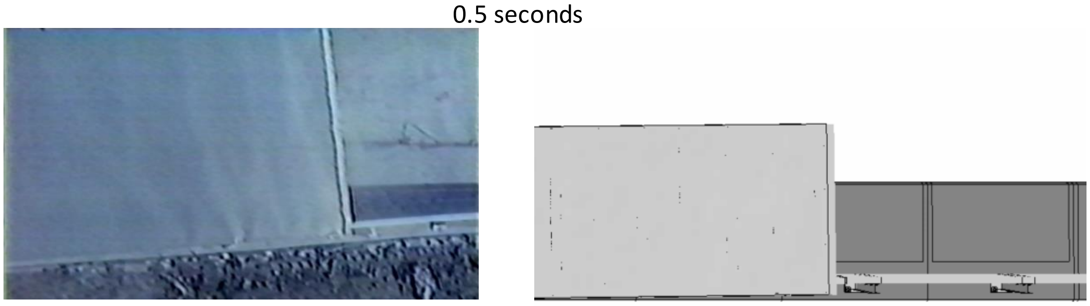


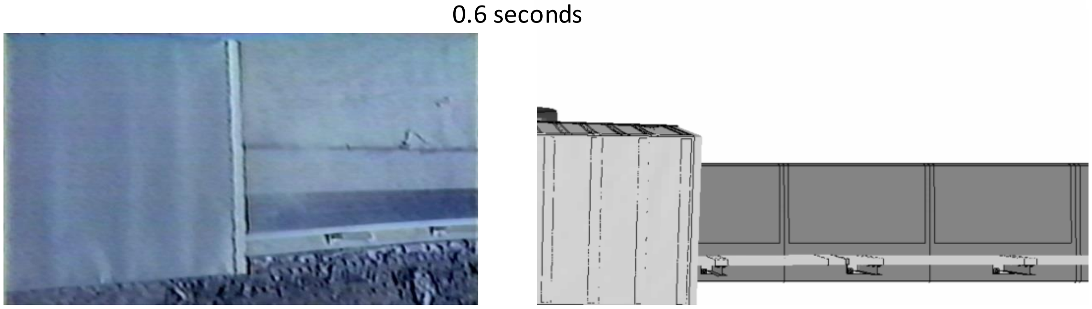
Figure 3. Sequential views of Test NETC-3 and FE analysis from overhead viewpoint.



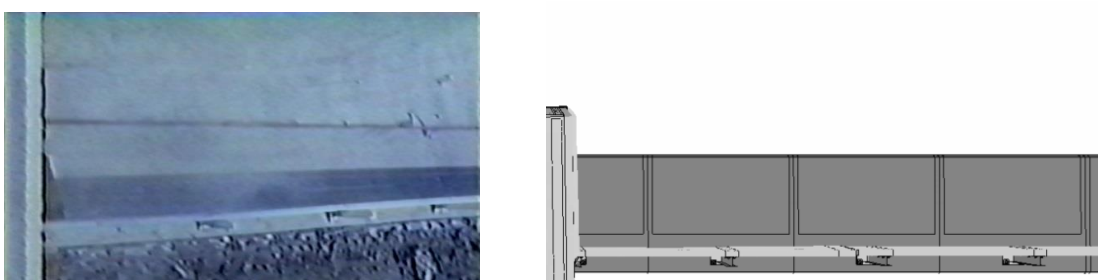
0.5 seconds



0.6 seconds



0.7 seconds



0.8 seconds

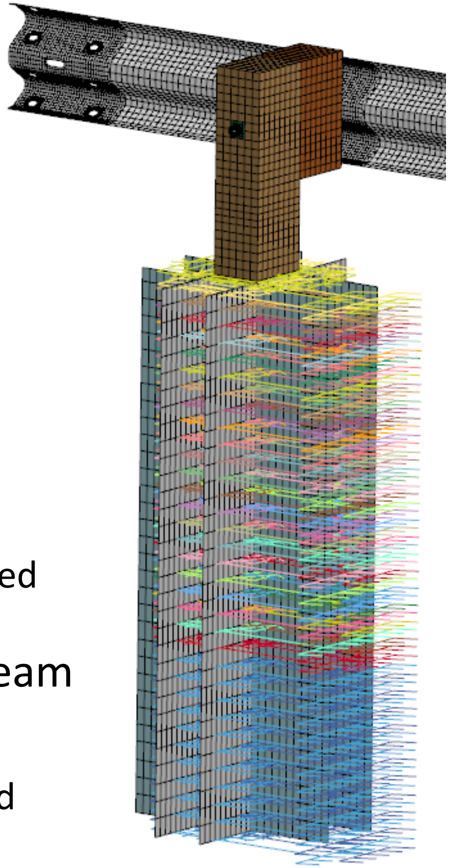
Figure 3. [CONTINUED] Sequential views of Test NETC-3 and FE analysis from overhead viewpoint.

Appendix H

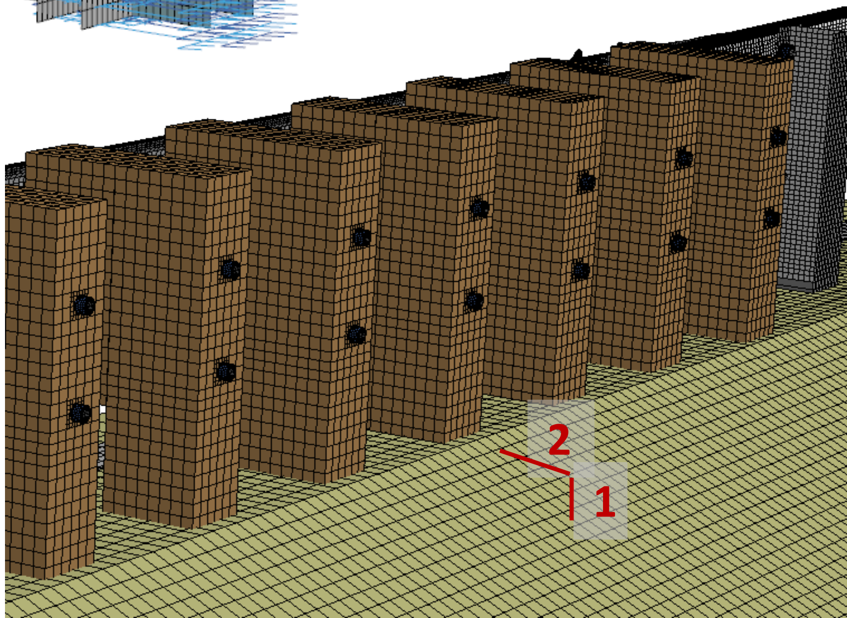
Soil Model Development and Calibration/Validation

Soil Model

- There are several approaches that may be used for modeling the soil in analyses of guardrail posts embedded in soil.
- Some common approaches include:
  - Posts embedded in a soil continuum of solid finite elements,
  - Posts embedded in a continuum of meshless finite elements, and
  - Subgrade reaction approach in which the post is supported by an array of uncoupled springs.
- Each of the methods mentioned above have been used by the research team with reasonable success.
  - Some advantages of the discrete element approach are that the soil model can undergo large deformations without effecting numerical accuracy and stability, and fewer calculations are required with discrete elements making the solution much more efficient.
  - The continuum method is reasonably accurate for low to moderate soil displacement but has the advantage of modeling soil interaction between neighboring posts.
- For the current study, two methods were used:
  - The discrete elements method (i.e., springs and dampers) was used to model the soil in the w-beam section (computational efficiency).
  - The soil continuum method (solid elements) was used in the impact region on the transition were the posts were closely spaced (i.e., thrie-beam and tube-rail sections).
  - The continuum soil model included a 2:1 slope starting just behind the thrie-beam posts.



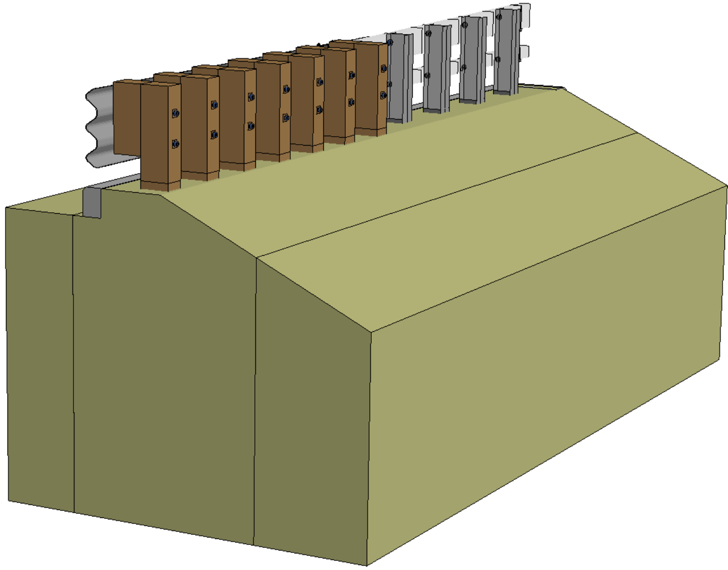
Soil Spring Model

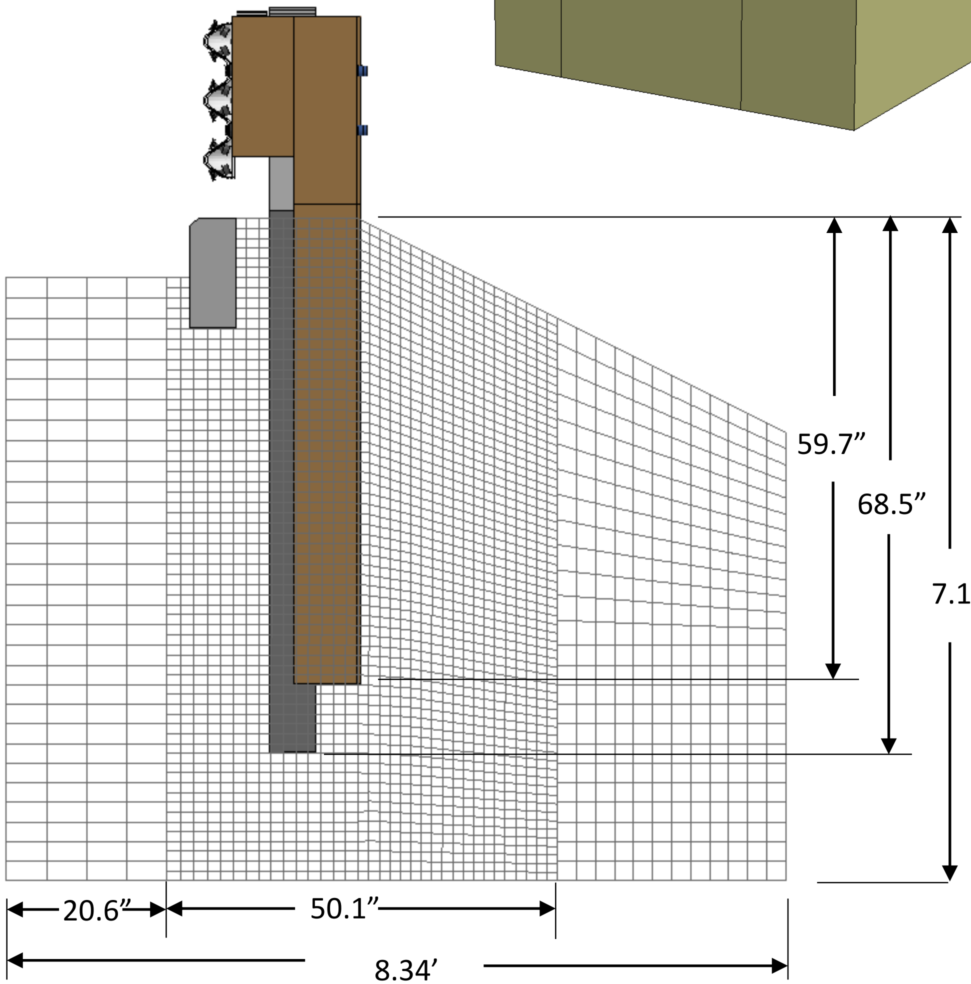


Soil Continuum Model

Soil Model

- Soil continuum model
  - Length = 21.7 feet
  - Lateral width = 8.34 feet
  - Vertical depth = 7.1 feet
- The material was modeled using the Drucker-Prager material model. This material model was calibrated based on comparison to full-scale tests (see following slides).
- The post was modeled with solid elements with single integration point.
  - The soil in the immediate post region was meshed with element side lengths of approximately 1.3 – 1.6 inches.
  - The soil at the father extents was meshed with element side lengths of 2.5 – 3 inches.
  - The refined-mesh region was “tied” to the elements of the coarse-mesh region using the *Contact_Tied option in LS-DYNA.



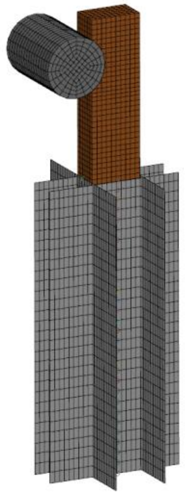


Soil Spring Model Validation

- The soil model was qualitatively validated based on comparison with impact tests on wood guardrail posts performed at the Midwest Roadside Safety Facility (MwRSF) [*Rosenbaugh11*]
- The properties of the spring elements were defined using a soil density of 126 pcf.
- A total of five (5) test cases were simulated which are listed in the Table to the left.
- In all cases, the impact point was at 24.9 inches above ground on the face of the post with loading in the strong bending direction for the post.
- The striker that was used in the tests was the MwRSF bogie with rigid nose.
  - The mass and impact speed of the striker varied slightly from test to test with a nominal mass and speed of 1,835-lb and 20 mph, respectively.
- A finite element model of the bogie vehicle was not available to the research team, so the striker was modeled as a simple rigid mass with a semi-rigid head.

Dynamic test cases used for model validation.

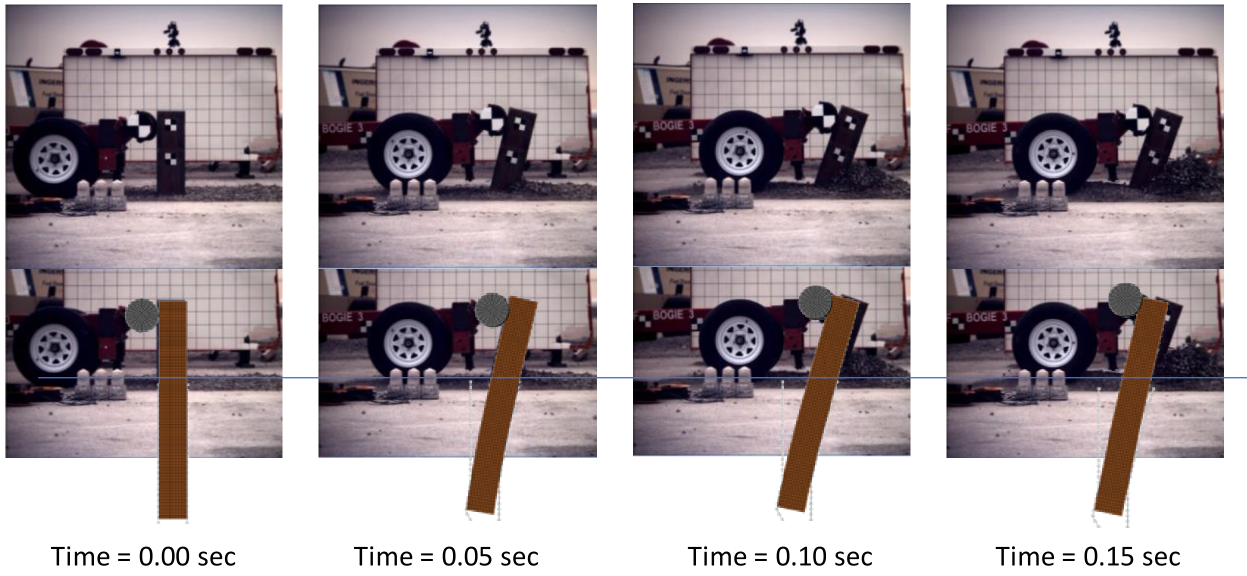
Test No.	Post Size (in. x in.)	Post Grade (as Modeled)	Soil density (as modeled) (pcf)	Embedment Depth (in.)	Impact Mass (lb)	Impact Speed (mph)
MGSATB-13	8 x 10	Grade 1	126	48	1,812.0	20.24
MGSATB-14	8 x 10	Grade 1	126	48	1,817.9	19.69
MGSATB-18	6 x 10	Grade 1	126	52	1,835.0	20.98
MGSATB-18	6 x 10	DS-65	126	52	1,835.0	20.98
MGSATB-19	6 x 10	Grade 1	126	52	1,835.0	19.73

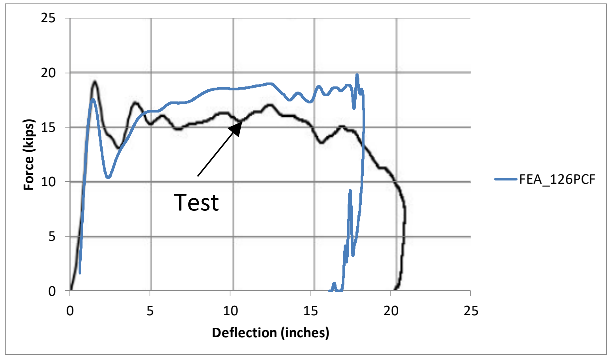


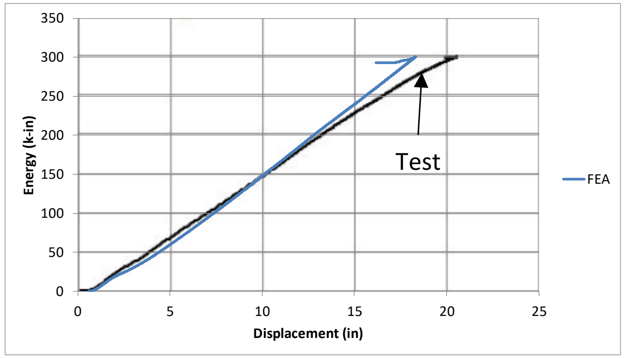
FEA Model

Soil Spring Model Validation

- The response of the soil-spring model matched well with the test results.
- The upper part of each figure shows sequential views of the test, followed by sequential views of the FEA overlaid onto the test images.
- Comparisons of FEA and test results regarding force versus displacement and energy versus displacement for each case are also provided.
- Test cases MGSATB-13 and MGSATB-14 were very similar (i.e., 8x10 post, similar impact mass and similar impact speed).
- The results from the FEA, accordingly, were very similar for both cases. The results, however, differed somewhat for the two test cases, with MGSATB-14 being approximately 4 kips stronger than case MGSATB-13.
- The FEA results tended to match better with the results of Test MGSATB-13 over the first 5 inches of deflection, and tended to match better with Test MGASTB-14 at higher deflections (see next slide).



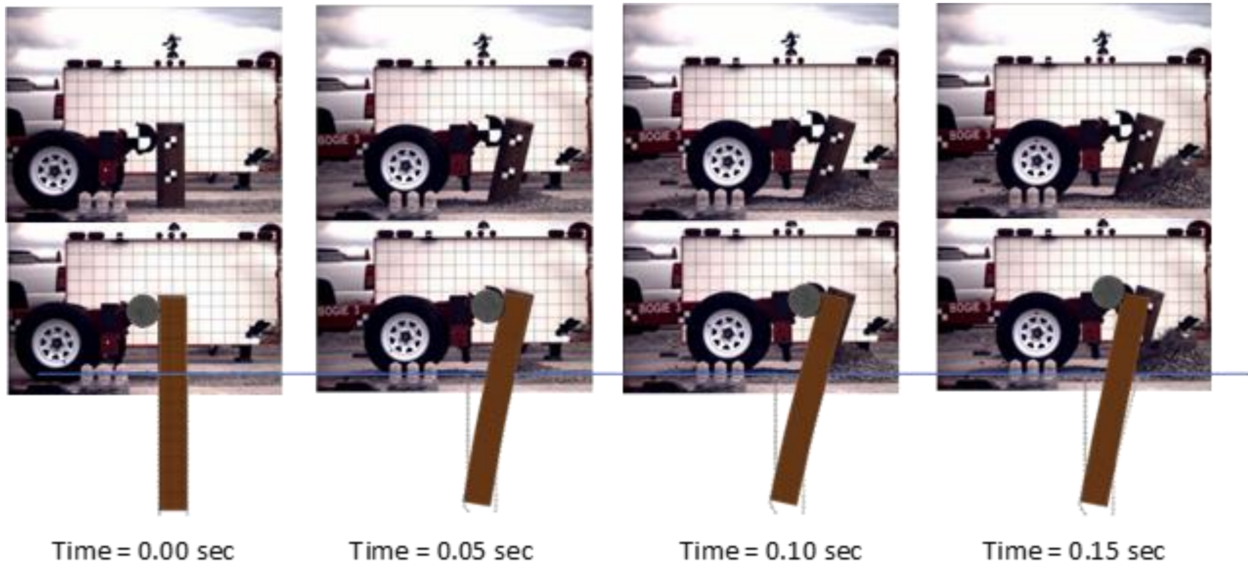


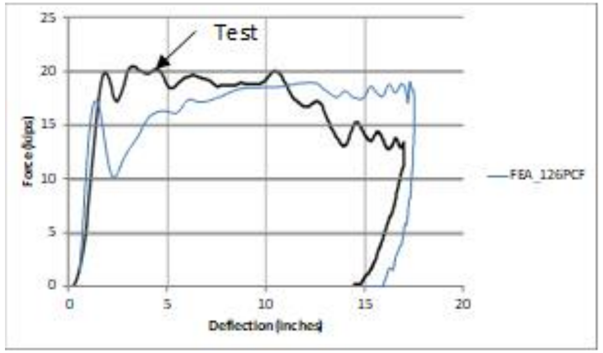


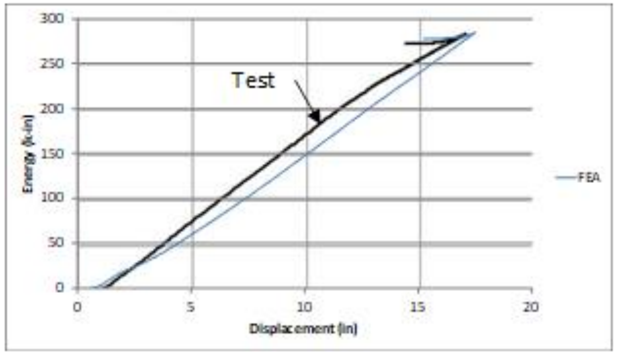
MGSATB-13 (Grade 1 Posts)

Soil Spring Model Validation

- The response of the soil-spring model matched well with the test results.
- The upper part of each figure shows sequential views of the test, followed by sequential views of the FEA overlaid onto the test images.
- Comparisons of FEA and test results regarding force versus displacement and energy versus displacement for each case are also provided.
- Test cases MGSATB-13 and MGSATB-14 were very similar (i.e., 8x10 post, similar impact mass and similar impact speed).
- The results from the FEA, accordingly, were very similar for both cases. The results, however, differed somewhat for the two test cases, with MGSATB-14 being approximately 4 kips stronger than case MGSATB-13.
- The FEA results tended to match better with the results of Test MGSATB-13 over the first 5 inches of deflection (see previous slide), and tended to match better with Test MGASTB-14 at higher deflections.



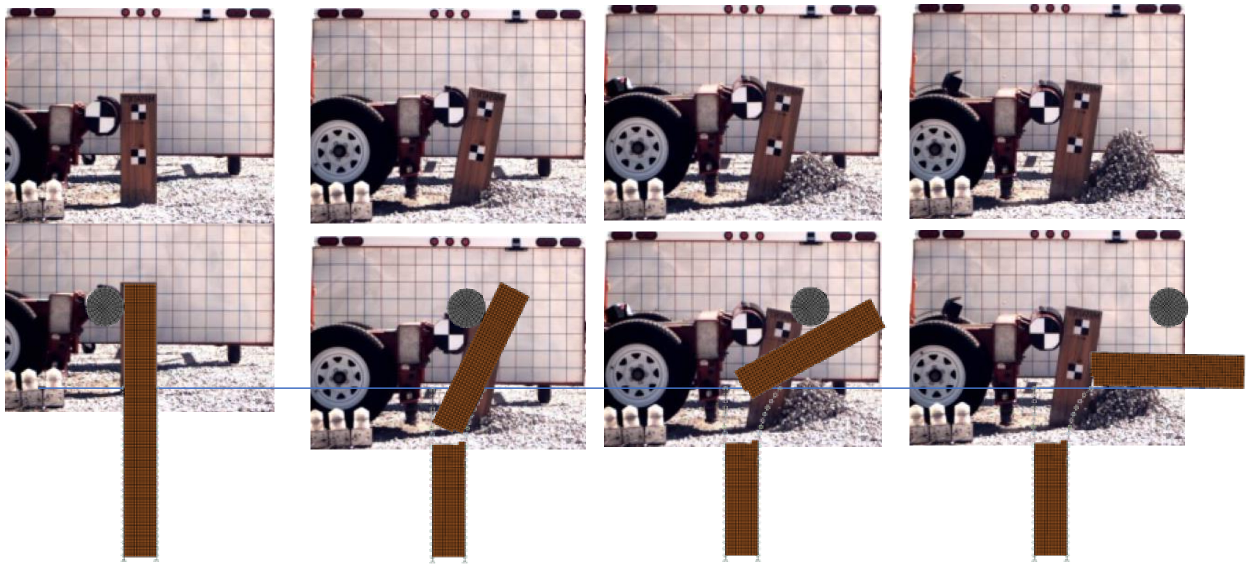


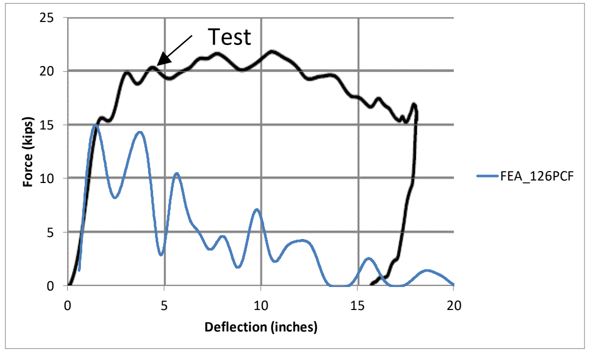


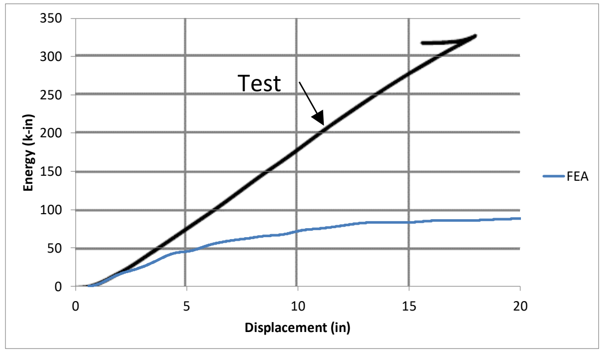
MGSATB-14 (Grade 1 Posts)

Soil Spring Model Validation

- Test cases MGSATB-18 and MGSATB-19 were also very similar (i.e., 6x10 post, identical impact mass, similar impact speed), but resulted in very different results.
- In the initial FEA simulation, using Grade 1 properties for the post, the post broke off at 16.4 inches below ground; whereas, the post did not break during the physical test for this case.



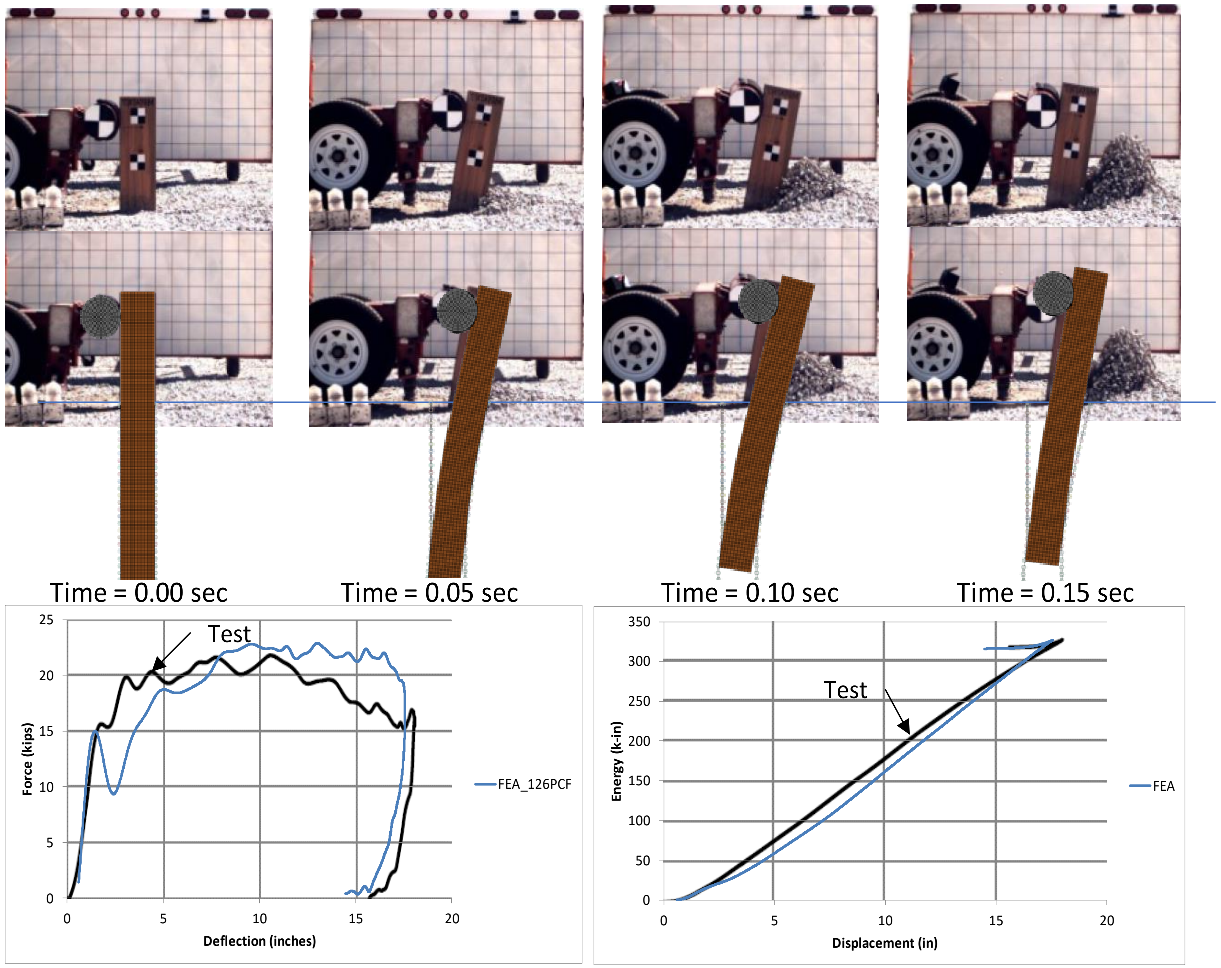




MGSATB-18 (Grade 1 Posts)

Soil Spring Model Validation

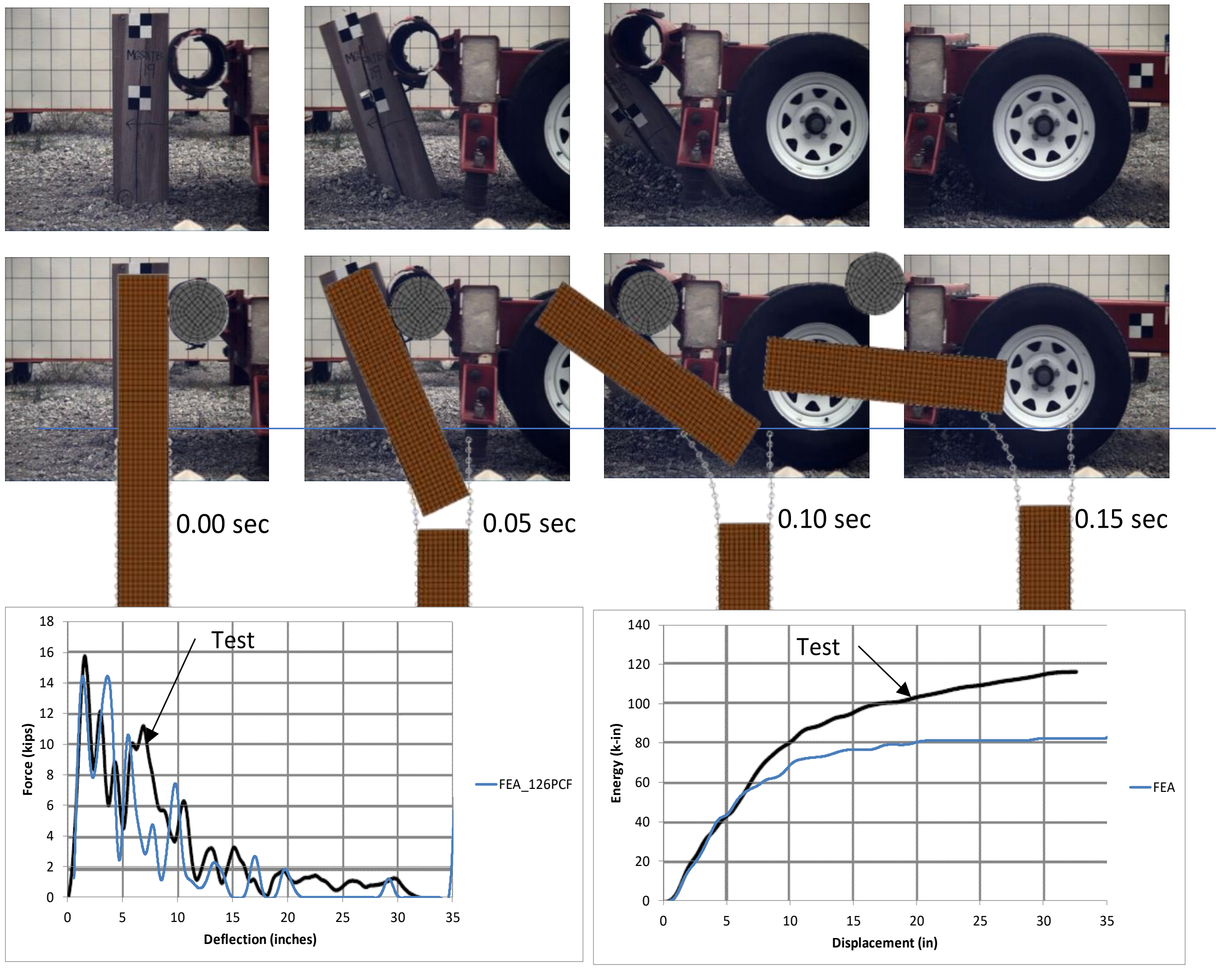
- The results of the model for Test MGSATB-18 (i.e., 6x10 post) matched well.
- DS-65 post (stronger than Grade 1) used in the analysis.



MGSATB-18 (DS-65 Posts)

Soil Spring Model Validation

- The results of the model for Test MGSATB-19 also matched reasonably well, with the post rupturing at 16.4 inches below grade.
- In the full-scale test, the post was split into three pieces with a break at 8 inches below grade.
- The overlay of the sequential views in Figure 35 show that the timing of the break and the overall speed of the striker throughout the event was similar for both FEA and test.



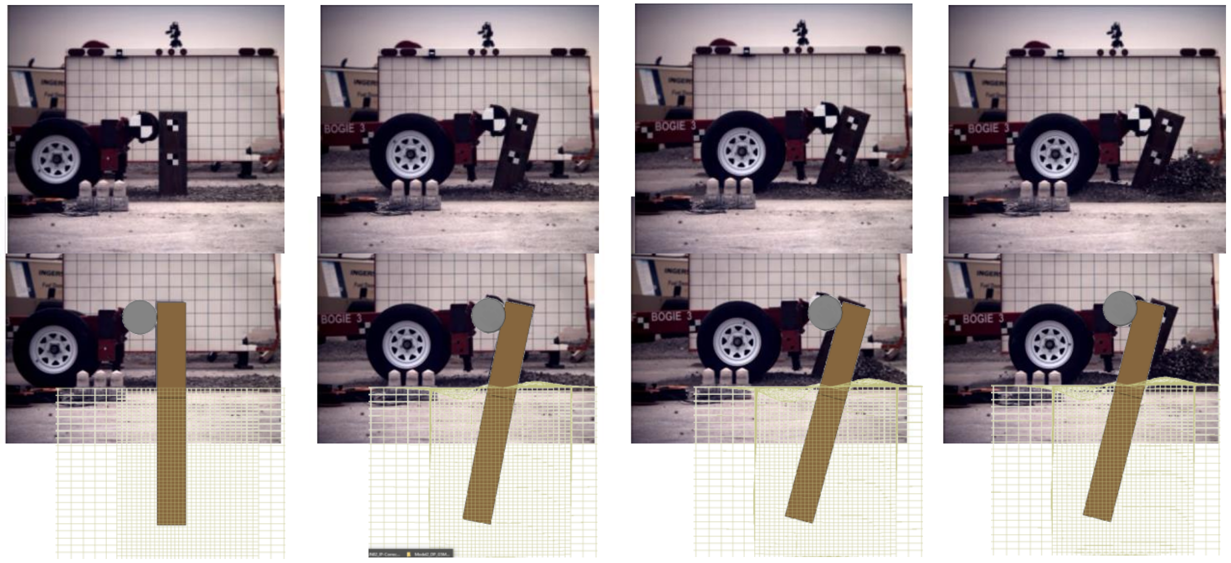
MGSATB-19 (Grade 1 Posts)

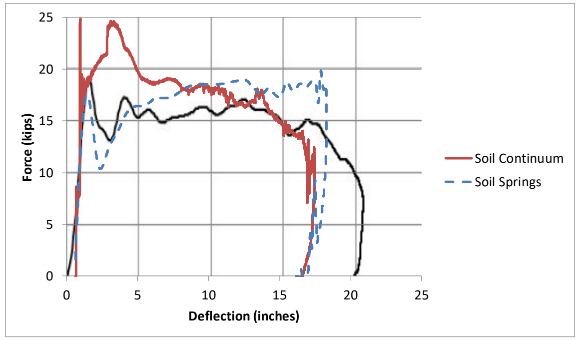
Soil Spring Model Limitations

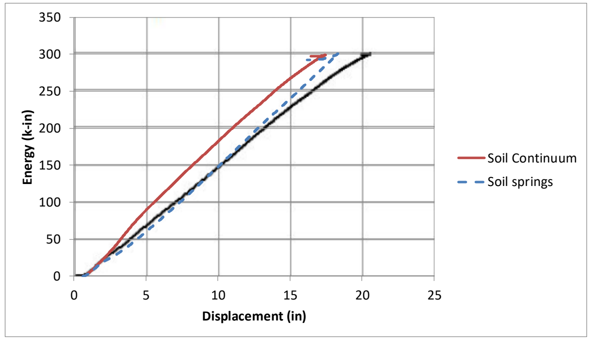
- The effects of dynamic loading of the soil (e.g., inertial spikes) are not accounted for in this model.
- The springs only provide lateral resistance for the posts.
- For the soil-plate model described here, the vertical resistance to pull-out comes from the vertical constraint on the plates.
- That is, the nodes of the soil-plates can move laterally but not vertically.
- It is assumed that this would become less of an issue as the vertical distance between springs is reduced (i.e., mesh refinement); however, accuracy in simulating large post rotation would likely be improved if the vertical response of the soil were included in the model.

Soil Continuum Model Validation

- Soil Continuum Model Compared with Tests MGSATB-13 and MGSATB-14
- Recall these test were very similar (i.e., 8x10 post, similar impact mass and similar impact speed).
- Sequential views of FEA vs. test is shown.
- The force-displacement and energy-displacement results are compared for the continuum model, soil spring model, and test.
- **Soil spring** model matches best for **MGSATB-13**.



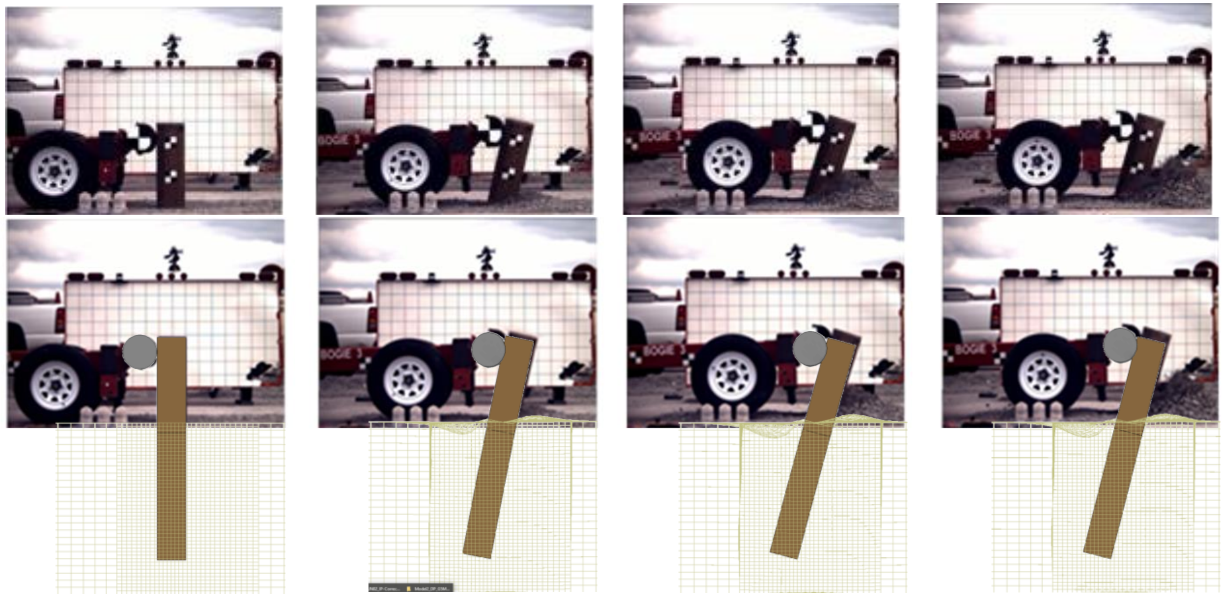


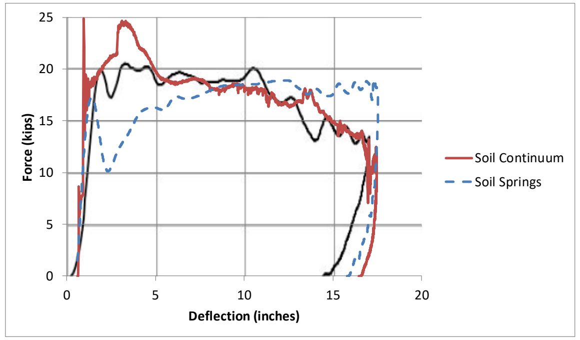


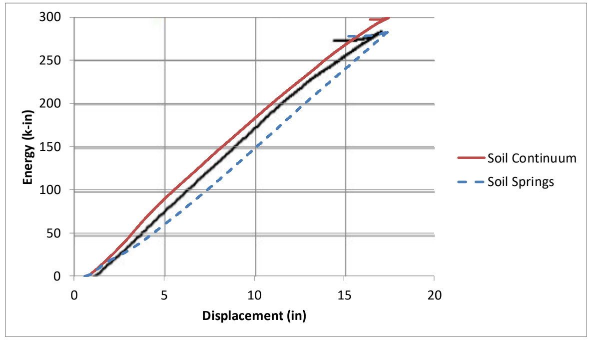
MGSATB-13 (Grade 1 Posts)

Soil Continuum Model Validation

- Soil Continuum Model Compared with Tests MGSATB-13 and MGSATB-14
- Recall these test were very similar (i.e., 8x10 post, similar impact mass and similar impact speed).
- Sequential views of FEA vs. test is shown.
- The force-displacement and energy-displacement results are compared for the continuum model, soil spring model, and test.
- **Continuum model** matches best for **MGSATB-14**.







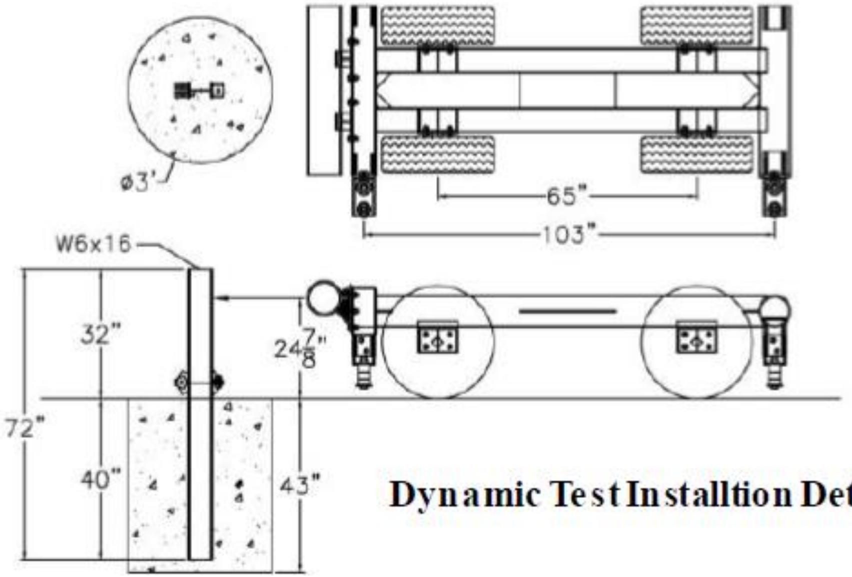
MGSATB-14 (Grade 1 Posts)

Soil Continuum Model Validation

- A secondary validation was performed for the continuum soil model based on a recent full-scale test of for the MGS stiffness transition with curb.[Winkelbaurer14]
- *"During the installation of a soil dependent system, additional* ***W6x16 posts are to be installed near the impact region utilizing the same installation procedures as used for the system*** *itself. Prior to full-scale testing, a dynamic impact test must be conducted to verify a* ***minimum dynamic soil resistance of 7.5 kips*** *at post deflections between 5 and 20 in., as measured at a height of 25 in."*
- The soil properties were the same as used in the previous comparison.
- Impact Conditions:
  - MwRSF bogie with rigid nose.
  - Mass = 1,843-lb
  - Impact Speed = 20 mph.
  - Impact Point = 24.9 inches above ground.

Dynamic Set up

Post-Test Photo of Post



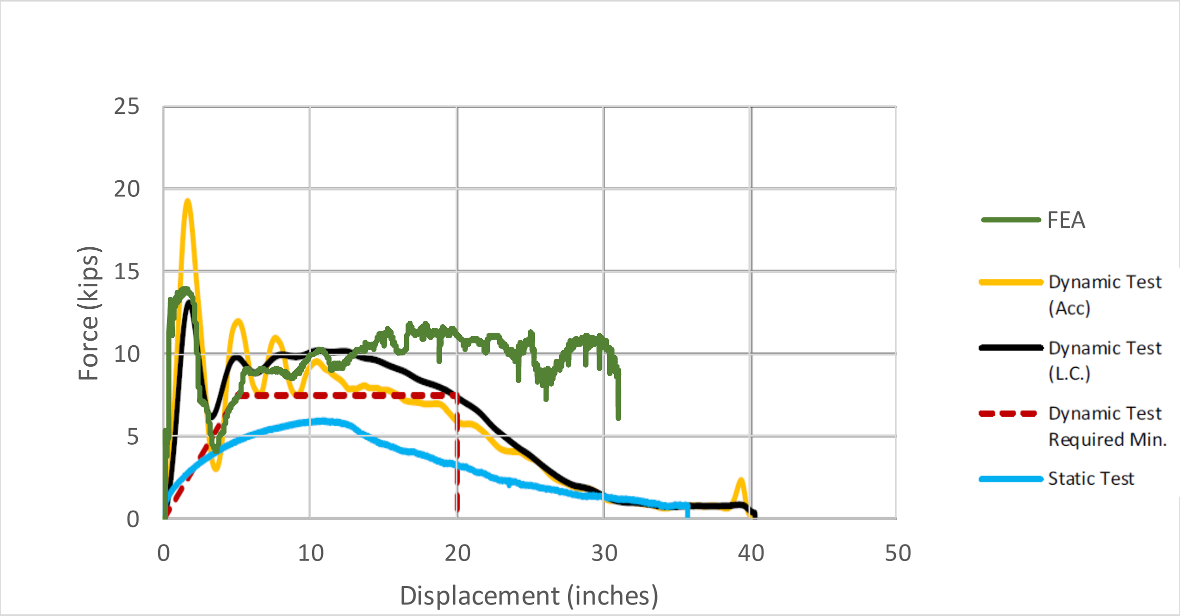
Dynamic Test Installtion Details

Soil Continuum Model Validation

- The results show that the continuum model matches well for the first 15 inches of displacement.
- But then shows stiffer response.
- *It should be noted that these tests correspond to calibration tests for the test-soil system.*
- *Actual stiffness on the day of testing varied for the three full-scale tests, with one case resulting in 67% stiffer soil conditions.*

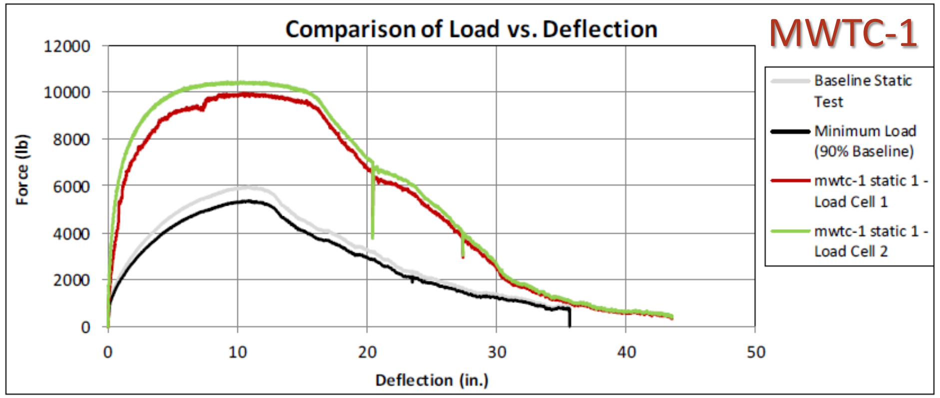
Dynamic Set up

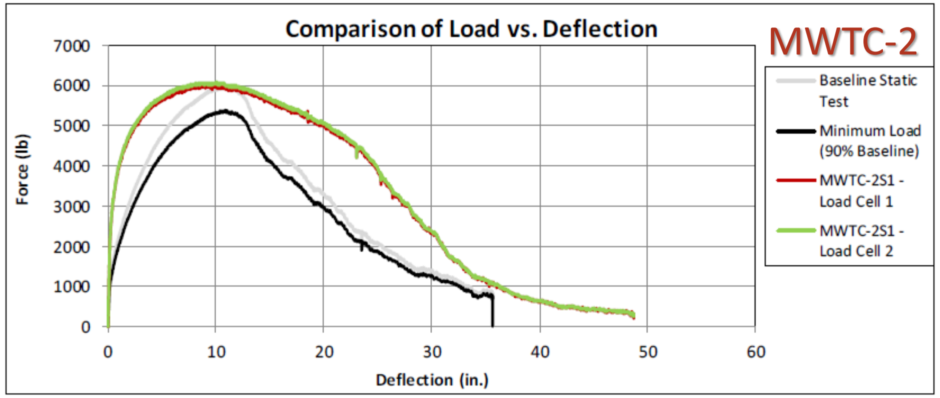
Post-Test Photo of Post

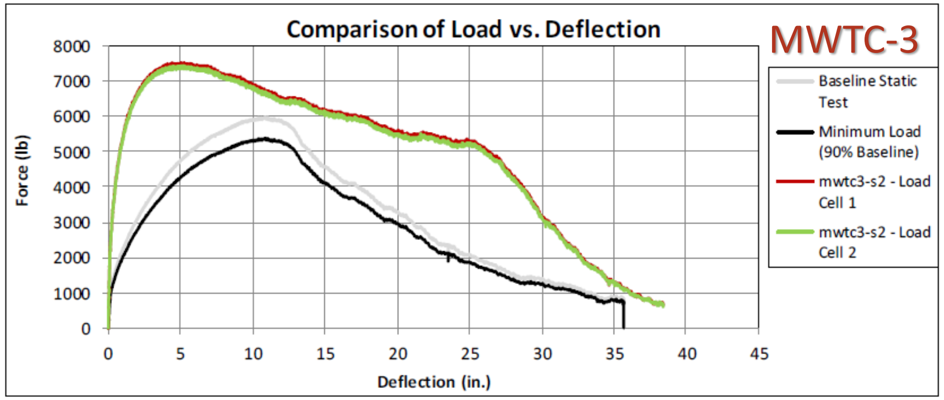


Baseline Soil Response Compared to Subsequent Test Soil Response

- MwRSF subsequently performed 3 full-scale tests on a transition design:
  - MWTC-1: MASH Test 4-20 (small car)
  - MWTC-2: MASH Test 4-20 (small car)
  - MWTC-3: MASH Test 4-21 (pickup)
- The preliminary static post-soil test for each of those test cases is shown here with comparison to baseline strength.
- The results show that the initial stiffness of the soil for the full-scale test cases was significantly higher than the baseline.
- The peak force for each cases was:
  - MWTC-1: 67% higher than baseline.
  - MWTC-2: Equal to baseline.
  - MWTC-3: 25% higher than baseline.

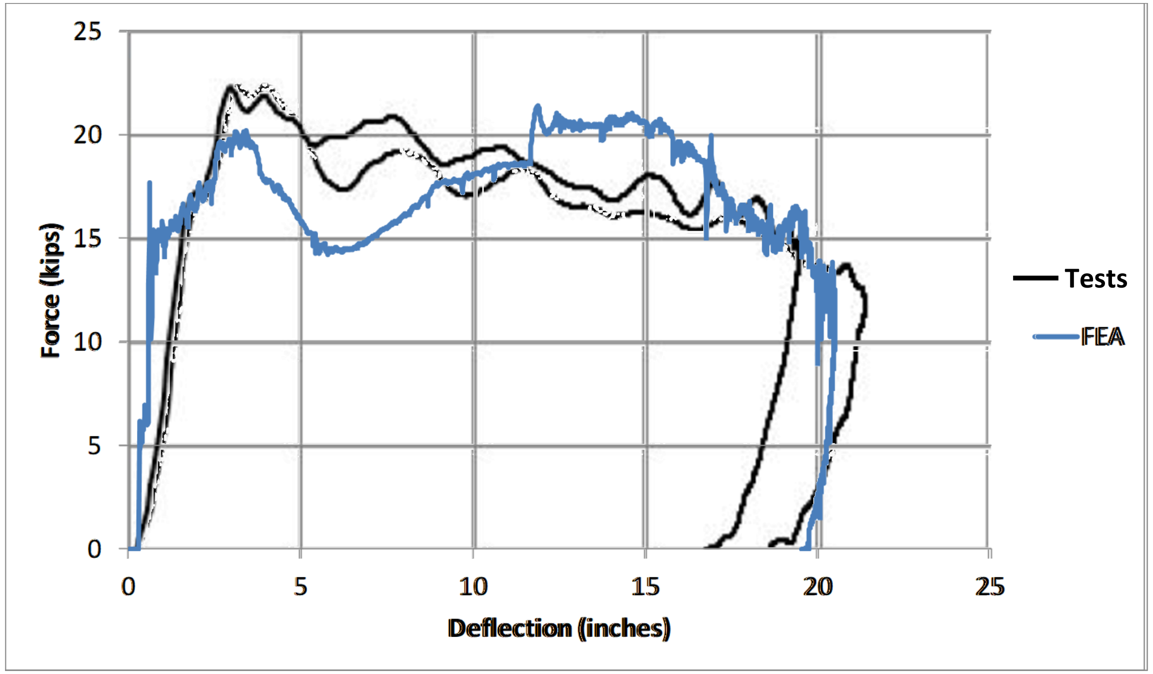




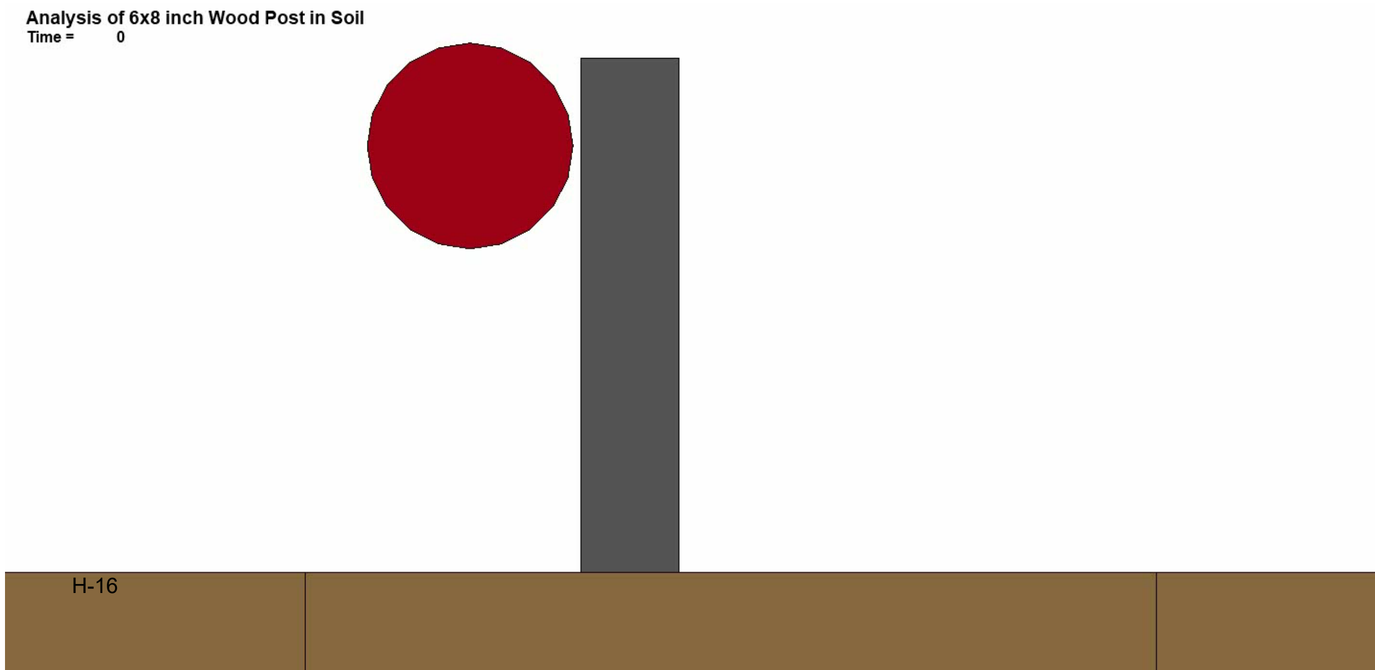


MGSATB-5 and MGSATB-6

Test No.	Post Size	Post Material	Soil Density (as modeled) (pcf)	Embedment Depth (inches)	Impact Mass (lb)	Impact Speed (mph)
MGSATB-1	W6x15	AASHTO M180	126	54	1810	19.22
MGSATB-2	W6x15	AASHTO M180	126	54	1810	19.71
MGSATB-5	W6x15	AASHTO M180	126	54	1816	21.9
MGSATB-6	W6x15	AASHTO M180	126	54	1816	21.7



Same test series as shown on Slide 22 but with steel posts



Appendix I

Validation Forms for 2-Bar Transition Model

Comparison to Test NETC-3

NCHRP Report 350 Test 4-12

(NCHRP Web Report 179 Forms)

FEA VALIDATION/VERIFICATION REPORT FORMS

Report 350 Test 3-21_____________ (Report 350 or MASH08 or EN1317 Vehicle Type)

Impact of the

NETC 2-Bar Transition___________ (Roadside hardware type and name)

Report Date: _2/25/2019_________

Type of Report (check one)

☐ Verification (known numerical solution compared to new numerical solution).

☒ Validation (physical test compared to a numerical solution).

☐ Extrapolation (validated numerical solution compared to modified numerical solution).

General Information	**Known Solution**	**Analysis Solution**
Performing Organization	Texas Transportaion Institute	Roadsafe LLC
Analyst/Engineer	**Dean Alberson**	Chuck Plaxico
Test/Run Number:	401181-1	
Vehicle:	2000 Chevrolet 2500	C2500D-V5b-R160309
Reference:	Test 3-21	Test 3-21
Impact Conditions		
Vehicle Mass:	4,706-lb	4,575-lb
Speed:	63.6 mph	63.6 mph
Angle:	24.9 degrees	24.9 degrees
Impact Point:	5.36 ft upstream of Critical Post	15 inches upstream of Post 7

Composite Validation/Verification Score

	List the Report 350/MASH08 or EN1317 Test Number: ____3-21______	Pass?
Part I	Did all solution verification criteria in Table C-1 pass?	Y
Part II	Do all the time history evaluation scores from Table C-2 result in a satisfactory comparison (i.e., the comparison passes the criterion)? If all the values in Table C-2 did not pass, did the weighted procedure shown in Table C-3 result in an acceptable comparison. If all the criteria in Table C-2 pass, enter "yes." If all the criteria in Table C-2 did not pass but Table C-3 resulted in a passing score, enter "yes."	Y
Part III	All the criteria in Table C-4 (Test-PIRT) passed? Not Required for Component Tests	Y
	Are the results of Steps I through III all affirmative (i.e., YES)? If all three steps result in a "YES" answer, the comparison can be considered validated or verified. If one of the steps results in a negative response, the result cannot be considered validated or verified.	Y

The analysis solution (check one):

☒ Is verified/validated against the known solution.

☐ Is NOT verified/validated against the known solution.

PART I: BASIC INFORMATION

1. What type of roadside hardware is being evaluated (check one)?
   - ☒ Longitudinal barrier or transition
   - ☐ Terminal or crash cushion
   - ☐ Breakaway support or work zone traffic control device
   - ☐ Truck-mounted attenuator
   - ☐ Other hardware or component: ______________________________

2. What test guidelines were used to perform the full-scale crash test (check one)?
   - ☒ NCHRP Report 350
   - ☐ MASH08
   - ☐ EN1317
   - ☐ Other: ______________________________

3. Indicate the test level and number being evaluated (fill in the blank): ______3-21____________

4. Indicate the vehicle type appropriate for the test level and number indicated in item 3 according to the testing guidelines indicated in item 2.

NCHRP Report 350/MASH08

☐ 700C	☐ 820C	☐ 1100C	☒ 2000P
☐ 2270P	☐ 8000S	☐ 10000S	☐ 36000V
☐ 36000T			

EN1317

☐ Car (900 kg)	☐ Car (1300 kg)	☐ Car (1500 kg)
☐ Rigid HGV (10 ton)	☐ Rigid HGV (16 ton)	☐ Rigid HGV (30 ton)
☐ Bus (13 ton)	☐ Articulated HGV (38 ton)	

☐ Other: ____________________

PART II: ANALYSIS SOLUTION VERIFICATION

Table I-1. Analysis Solution Verification Table.

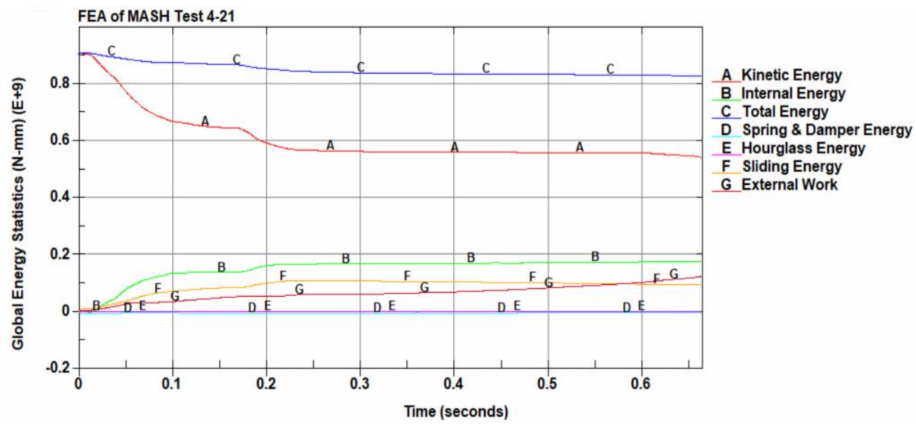
Verification Evaluation Criteria	Change (%)	Pass?
Total energy of the analysis solution (i.e., kinetic, potential, contact, etc.) must not vary more than 10 percent from the beginning of the run to the end of the run.	8.6%	Y
Hourglass Energy of the analysis solution at the end of the run is less than *five percent* of the total *initial energy* at the *beginning* of the run.	0%	Y
Hourglass Energy of the analysis solution at the end of the run is less than *ten percent* of the total *internal energy* at the *end* of the run.	0%	Y
The part/material with the highest amount of hourglass energy at the end of the run is less than twenty percent of the total internal energy of the part/material at the end of the run.	0%	Y
Mass added to the total model is less than five percent of the total model mass at the beginning of the run.	0%	Y
The part/material with the most mass added had less than 10 percent of its initial mass added.	0%	Y
The moving parts/materials in the model have less than five percent of mass added to the initial moving mass of the model.	0%	Y
There are no shooting nodes in the solution?	Y	Y
There are no solid elements with negative volumes?	Y	Y
Exception Notes:		

☒ Analysis solution passes <u>all</u> the criteria in Table C-1 ☒ without exceptions.

☐ with exceptions as noted in Table C-1.

☐ Analysis solution does NOT pass <u>all</u> the criteria in Table C-1.

☐ Table C-1 is not applicable because ______________________________



PART III: HISTORY EVALUTION TABLES

Table I-2. Roadside Safety Validation Metrics Rating Table (single channel option).

<table>
<tr><th colspan="10">Evaluation Criteria</th><th colspan="3" rowspan="2">Time interval
[seconds]</th></tr>
<tr><td rowspan="10">O</td><td colspan="9">Sprague-Geers Metrics
List all the data channels being compared. Calculate the M and P metrics using RSVVP and enter the results. Values less than or equal to 40 are acceptable.</td></tr>
<tr><td rowspan="3">Channel</td><td colspan="8">RSVVP Curve Preprocessing Options</td><td rowspan="3">M</td><td rowspan="3">P</td><td rowspan="3">Pass?</td></tr>
<tr><td rowspan="2">Filter Option</td><td colspan="3" rowspan="2">Sync. Option</td><td colspan="2">Shift</td><td colspan="2">Drift</td></tr>
<tr><td>True Curve</td><td>Test Curve</td><td>True Curve</td><td>Test Curve</td></tr>
<tr><td>x-acceleration</td><td>CFC 60</td><td colspan="3">none</td><td>none</td><td>none</td><td>none</td><td>none</td><td>11.1</td><td>33.6</td><td>Y</td></tr>
<tr><td>y-acceleration</td><td>CFC 60</td><td colspan="3">none</td><td>none</td><td>none</td><td>none</td><td>none</td><td>19.4</td><td>34.4</td><td>Y</td></tr>
<tr><td>z-acceleration</td><td>CFC 60</td><td colspan="3">none</td><td>none</td><td>none</td><td>none</td><td>none</td><td>17</td><td>53.8</td><td>N</td></tr>
<tr><td>Yaw-rate</td><td>CFC 60</td><td colspan="3">none</td><td>none</td><td>none</td><td>none</td><td>none</td><td>7.3</td><td>10.9</td><td>Y</td></tr>
<tr><td>Roll-rate</td><td>CFC 60</td><td colspan="3">none</td><td>none</td><td>none</td><td>none</td><td>none</td><td>4.0</td><td>41.4</td><td>≈Y</td></tr>
<tr><td>Pitch-rate</td><td>CFC 60</td><td colspan="3">none</td><td>none</td><td>none</td><td>none</td><td>none</td><td>20.4</td><td>23.3</td><td>Y</td></tr>
<tr><td rowspan="7">P</td><td colspan="9">ANOVA Metrics
List all the data channels being compared. Calculate the ANOVA metrics using RSVVP and enter the results. Both of the following criteria must be met:
• The mean residual error must be less than five percent of the peak acceleration ($\bar{e} \leq 0.05 \cdot a_{Peak}$) and
• The standard deviation of the residuals must be less than 35 percent of the peak acceleration ($\sigma \leq 0.35 \cdot a_{Peak}$).</td><td>Mean Residual</td><td>Standard Deviation of Residuals</td><td>Pass?</td></tr>
<tr><td colspan="9">x-acceleration</td><td>0.08</td><td>12.7</td><td>Y</td></tr>
<tr><td colspan="9">y-acceleration</td><td>1.5</td><td>13.6</td><td>Y</td></tr>
<tr><td colspan="9">z-acceleration</td><td>0.09</td><td>16.8</td><td>Y</td></tr>
<tr><td colspan="9">Yaw-rate</td><td>4.1</td><td>11.2</td><td>Y</td></tr>
<tr><td colspan="9">Roll-rate</td><td>3.74</td><td>52.8</td><td>N</td></tr>
<tr><td colspan="9">Pitch-rate</td><td>2.91</td><td>32.1</td><td>Y</td></tr>
<tr><td colspan="13">Exception Notes:</td></tr>
</table>

☐ Analysis solution passes <u>all</u> the criteria in Table I-2 ☐ without exceptions.

☐ with exceptions as noted in Table I-2.

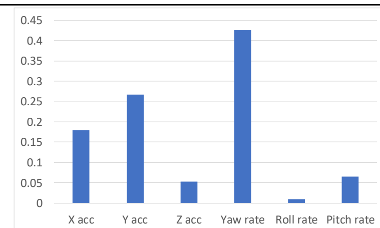
☒ Analysis solution does NOT pass <u>all</u> the criteria in Table I-2.

☐ Table I-2 is not applicable because ____

☐ RSVVP Single-Channel Comparison Metric Values Screens for each channel are attached on the following pages.

Table I-3. Roadside Safety Validation Metrics Rating Table (multi-channel option).

<table>
<tr><td colspan="6">Evaluation Criteria (time interval [0.0 – 1.0 seconds])</td></tr>
<tr><td colspan="6">Channels (Select which were used)</td></tr>
<tr><td colspan="2">☒ X Acceleration</td><td colspan="2">☒ Y Acceleration</td><td colspan="2">☒ Z Acceleration</td></tr>
<tr><td colspan="2">☒ Roll rate</td><td colspan="2">☒ Pitch rate</td><td colspan="2">☒ Yaw rate</td></tr>
<tr><td colspan="2">Multi-Channel Weights

- Area II method -</td><td colspan="2">X Channel: 0.180
Y Channel: 0.268
Z Channel: 0.053
Yaw Channel: 0.426
Roll Channel: 0.009
Pitch Channel: 0.065</td><td colspan="2">
</td></tr>
<tr><td rowspan="2">O</td><td rowspan="2">Sprague-Geer Metrics
Values less or equal to 40 are acceptable.</td><td>M</td><td>P</td><td colspan="2">Pass?</td></tr>
<tr><td>24.6</td><td>27.9</td><td colspan="2">Y</td></tr>
<tr><td rowspan="2">P</td><td rowspan="2">ANOVA Metrics
Both of the following criteria must be met:
The mean residual error must be less than five percent of the peak acceleration
($\bar{e} \leq 0.05 \cdot a_{Peak}$)
The standard deviation of the residuals must be less than 35 percent of the peak acceleration ($\sigma \leq 0.35 \cdot a_{Peak}$)</td><td>Mean Residual</td><td>Standard Deviation of Residuals</td><td colspan="2">Pass?</td></tr>
<tr><td>1.9</td><td>14.1</td><td colspan="2">Y</td></tr>
</table>

☒ Analysis solution passes <u>all</u> the criteria in Table I-3 ☐ without exceptions

☐ with exceptions as noted in Table I-3.

☐ Analysis solution does NOT pass <u>all</u> the criteria in Table I-3.

☐ Table I-3 does not contain sufficient information for assessment.

☐ Table I-3 is not applicable because criteria were satisfied in Table I-2.

☒ RSVVP Multi-Channel Comparison Metric Values Screen is attached on the following page.

PART IV: PHENOMENAA IMPORTANCE RANKING TABLES

Table I-4. Evaluation Criteria Test Applicability Table.

<table>
<tr><th>Evaluation Factors</th><th colspan="2">Evaluation Criteria</th><th>Applicable Tests</th></tr>
<tr><td rowspan="2">Structural Adequacy</td><td>A</td><td>Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>10, 11, 12, 20, 21, 22, 35, 36, 37, 38</td></tr>
<tr><td>B</td><td>The test article should readily activate in a predictable manner by breaking away, fracturing or yielding.</td><td>60, 61, 70, 71, 80, 81</td></tr>
<tr><td></td><td>C</td><td>Acceptable test article performance may be by redirection, controlled penetration or controlled stopping of the vehicle.</td><td>30, 31, 32, 33, 34, 39, 40, 41, 42, 43, 44, 50, 51, 52, 53</td></tr>
<tr><td rowspan="7">Occupant Risk</td><td>D</td><td>Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone.</td><td>All</td></tr>
<tr><td>E</td><td>Detached elements, fragments or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle. (Answer Yes or No)</td><td>70, 71</td></tr>
<tr><td>F</td><td>The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are acceptable.</td><td>All except those listed in criterion G</td></tr>
<tr><td>G</td><td>It is preferable, although not essential, that the vehicle remain upright during and after collision.</td><td>12, 22 (for test level 1 – 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44)</td></tr>
<tr><td rowspan="2">H</td><td>Occupant impact velocities should satisfy the following:<table><tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>9</td><td>12</td></tr></table></td><td>10, 20, 30,31, 32, 33, 34, 36, 40, 41, 42, 43, 50, 51, 52, 53, 80, 81</td></tr>
<tr><td><table><tr><td>Longitudinal</td><td>3</td><td>5</td></tr></table></td><td>60, 61, 70, 71</td></tr>
<tr><td>I</td><td>Occupant ridedown accelerations should satisfy the following:<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (g's)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15</td><td>20</td></tr></table></td><td>10, 20, 30,31, 32, 33, 34, 36, 40, 41, 42, 43, 50, 51, 52, 53, 60, 61, 70, 71, 80, 81</td></tr>
<tr><td rowspan="4">Vehicle Trajectory</td><td>K</td><td>After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.</td><td>All</td></tr>
<tr><td>L</td><td>The occupant impact velocity in the longitudinal direction should not exceed 40 ft/sec and the occupant ride-down acceleration in the longitudinal direction should not exceed 20 G's.</td><td>11,21, 35, 37, 38, 39</td></tr>
<tr><td>M</td><td>The exit angle from the test article preferable should be less than 60 percent of test impact angle, measured at the time of vehicle loss of contact with test device.</td><td>10, 11, 12, 20, 21, 22, 35, 36, 37, 38, 39</td></tr>
<tr><td>N</td><td>Vehicle trajectory behind the test article is acceptable.</td><td>30, 31, 32, 33, 34, 39, 42, 43, 44, 60, 61, 70, 71, 80, 81</td></tr>
</table>

Table I-5(a). Roadside Safety Phenomena Importance Ranking Table (Structural Adequacy).

Evaluation Criteria				Known Result	Analysis Result	Difference Relative/ Absolute	Agree?
Structural Adequacy	A	A1	Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable. (Answer Yes or No)	Y	Y		Y
		A2	Maximum dynamic deflection: - Relative difference is less than 20 percent or - Absolute difference is less than 6 inches	8.0 in	5.8 in (0.1 sec)	27.5% 2.2 in	Y
		A3	Maximum permanent deflection: - Relative difference is less than 20 percent or - Absolute difference is less than 6 inches	5.8 in	4.3 in	25.9% 1.5 in	Y
		A4	Length of vehicle-barrier contact (at initial separation): - Relative difference is less than 20 percent or - Absolute difference is less than 6.6 ft	14.4 ft	14.7 ft	1.5 % 0.22 ft	Y
		A5	Number of broken or significantly bent posts is less than 20 percent.	0	0		Y
		A6	Did the rail element rupture or tear (Answer Yes or No)	No	No		Y
		A7	Was there significant snagging between the vehicle wheels and barrier elements (Answer Yes or No).	N	N		Y
		A8	Was there significant snagging between vehicle body components and barrier elements (Answer Yes or No).	N	N		Y

Table I-5(b). Roadside Safety Phenomena Importance Ranking Table (Occupant Risk).

Evaluation Criteria				Known Result	Analysis Result	Difference Relative/ Absolute	Agree?
Occupant Risk	D		Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone. (Answer Yes or No)	N	N		Y
	F	F1	The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are acceptable. (Answer Yes or No)	Y	Y		Y
		F2	Maximum roll of the vehicle through 1.0 seconds: - Relative difference is less than 20 percent or - Absolute difference is less than 5 degrees.	-19.4 deg	-17 deg	12.4% 2.4 deg	Y
		F3	Maximum pitch of the vehicle through 1.0 seconds: - Relative difference is less than 20 percent or - Absolute difference is less than 5 degrees.	-13.7 deg	-16.5 deg	20.0 % 2.8 deg	Y
		F4	Maximum yaw of the vehicle through 1.0 seconds: - Relative difference is less than 20 percent or - Absolute difference is less than 5 degrees.	55.6 deg	48.2 deg	13.3 % 7.4 deg	Y
		5	Did the vehicle remain upright during and after collision	Y	Y		Y
	L	L1	Occupant impact velocities: - Relative difference is less than 20 percent or - Absolute difference is less than 6.6 ft/s.				
			• Longitudinal OIV (ft/s)	17.1	19.7	15.2% 2.6 ft/s	Y
			• Lateral OIV (ft/s)	-24.6	-24.9	1.2% 0.3 ft/s	Y
			• THIV (ft/s)	29.9	31.5	5.4% 1.6 ft/s	Y
		L2	Occupant accelerations: - Relative difference is less than 20 percent or - Absolute difference is less than 4 g's.				
			• Longitudinal ORA	-8.3	-8.3	0% 0 g	Y
			• Lateral ORA	10.0	7.5	25 % 2.5 g	Y
			• PHD	11.9	9.1	23.5 % 2.8 g	Y
			• ASI	1.74	1.48	14.9 % 0.26	Y

Table I-5(c). Roadside Safety Phenomena Importance Ranking Table (Vehicle Trajectory).

<table>
<tr><th colspan="4">Evaluation Criteria</th><th>Known Result</th><th>Analysis Result</th><th>Difference Relative/ Absolute</th><th>Agree?</th></tr>
<tr><td rowspan="3">Vehicle Trajectory</td><td rowspan="3">K
M</td><td>M1</td><td>The exit angle from the test article preferable should be less than 60 percent of test impact angle, measured at the time of vehicle loss of contact with test device.</td><td>*33%</td><td>36%</td><td></td><td>Y</td></tr>
<tr><td>M2</td><td>Exit angle at loss of contact:
- Relative difference is less than 20 percent or
- Absolute difference is less than 5 degrees.</td><td>*8.21 deg (0.375 sec)</td><td>8.95 deg (0.375 sec)</td><td>9.0%
0.74 deg</td><td>Y</td></tr>
<tr><td>M3</td><td>Exit velocity at loss of contact:
- Relative difference is less than 20 percent or
- Absolute difference is less than 6.2 mph.</td><td>*47.0 mph</td><td>44.6 mph</td><td>5.1 %
2.4 mph</td><td>Y</td></tr>
</table>

**Reported as 11.7 degrees. Test data showed the 8.21 degrees at 0.375 seconds in TRAP report.*

*** Reported as 52.9 mph. Test data showed 47 mph at 0.375 seconds in TRAP report.*

☒ Analysis solution passes <u>all</u> the criteria in Tables G-5(a) through I-5(c)

☒ without exceptions.

☐ with exceptions as noted in Tables G-5(a) through I-5(c).

☐ Does NOT pass <u>all</u> the criteria in Tables I-5(a) through 5(c).

☐ Tables I-5(a) through I-5(c) does not contain sufficient information for assessment.

☐ Tables I-5(a) through I-5(c) are not applicable because ___________________________________

☒ Synchronized side-by-side views of the known and analysis solutions are attached on the following pages.

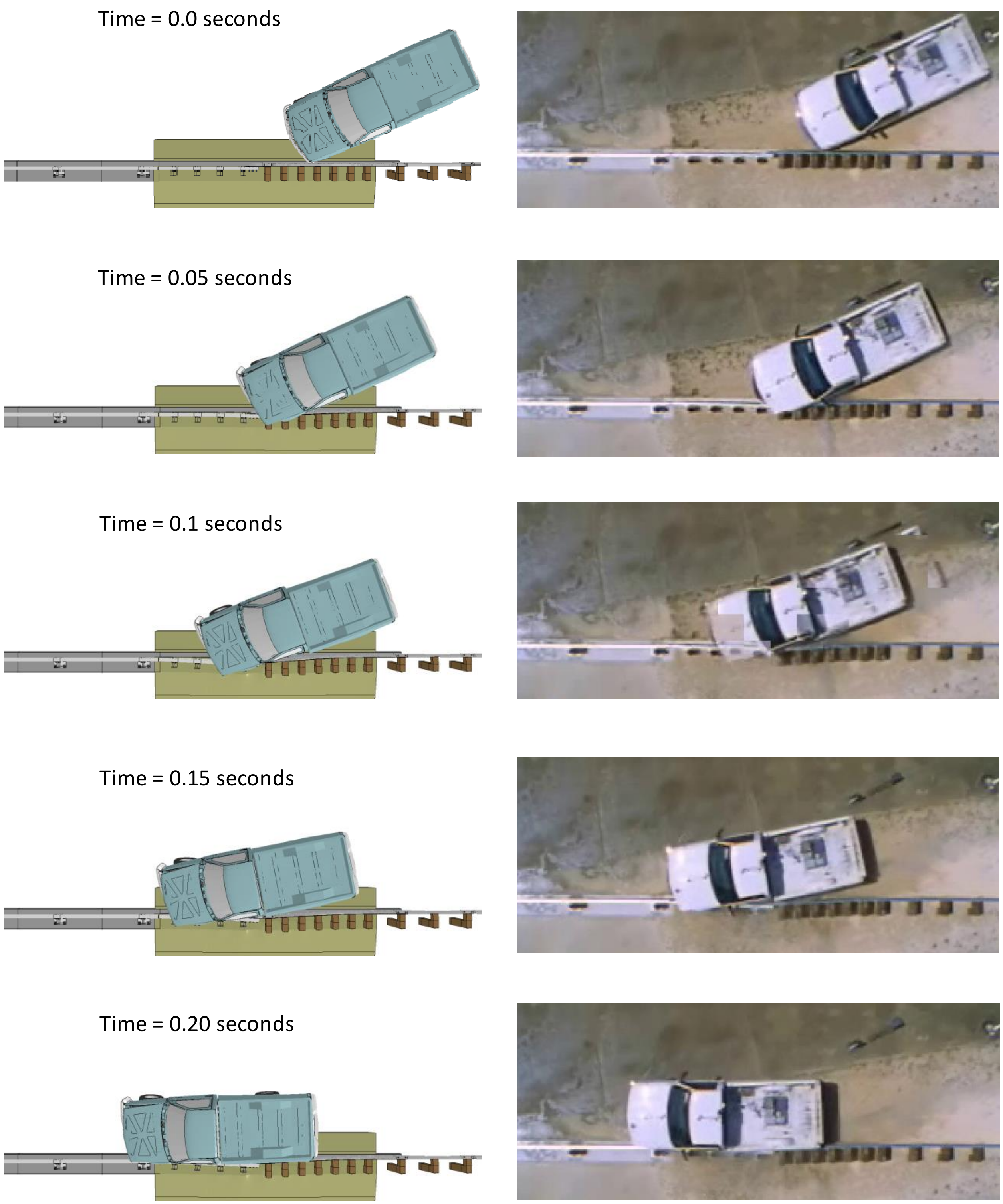


Figure 1. Sequential views from FEA and Test 401181-1 from an overhead viewpoint.

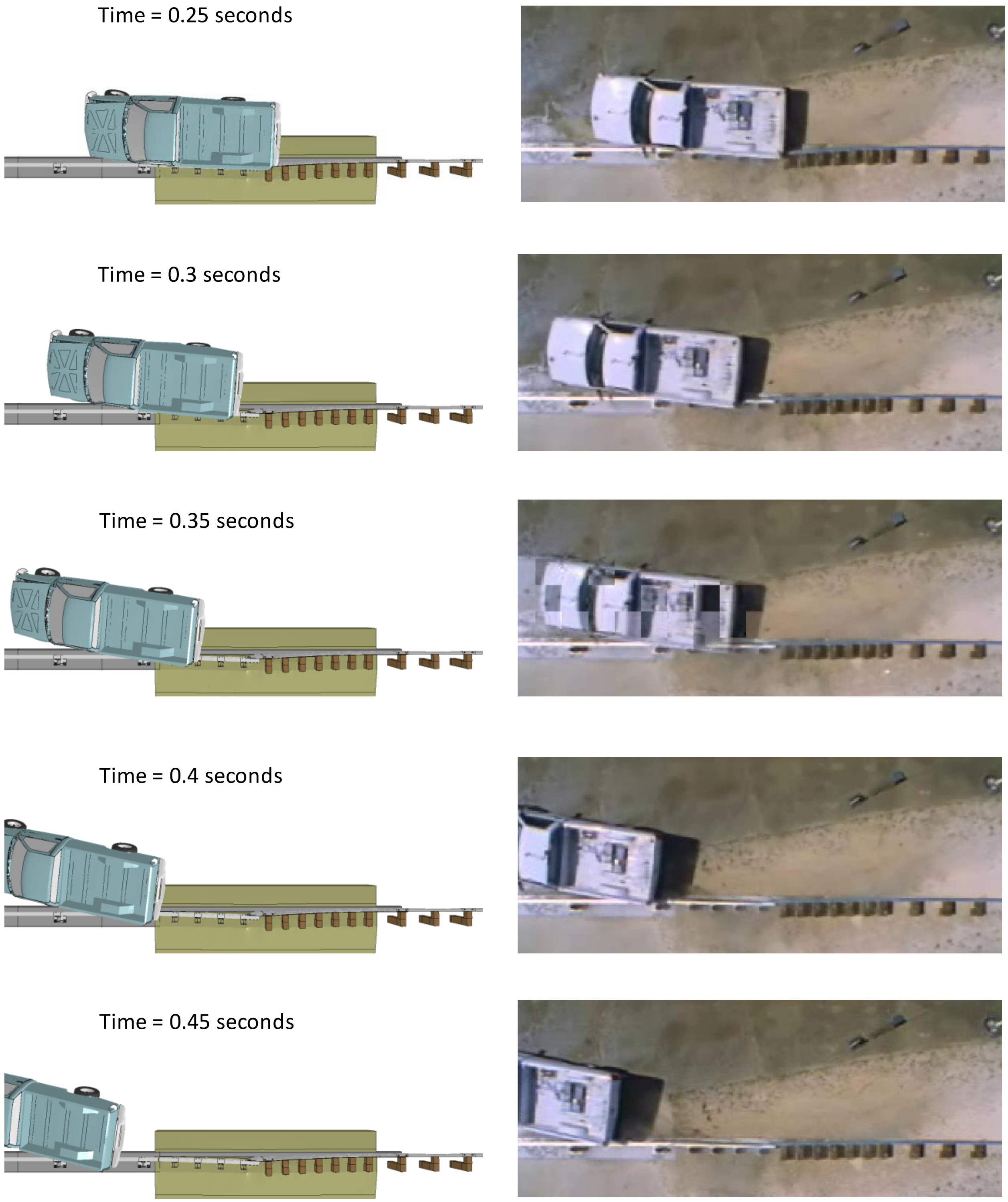


Figure 1. [Continued] Sequential views from FEA and Test 401181-1 from an overhead viewpoint.

Time = 0.5 seconds

Time = 0.55 seconds

Figure 1. [Continued] Sequential views from FEA and Test 401181-1 from an overhead viewpoint.

Figure 2. Sequential views from FEA and Test 401181-1 from a downstream viewpoint.

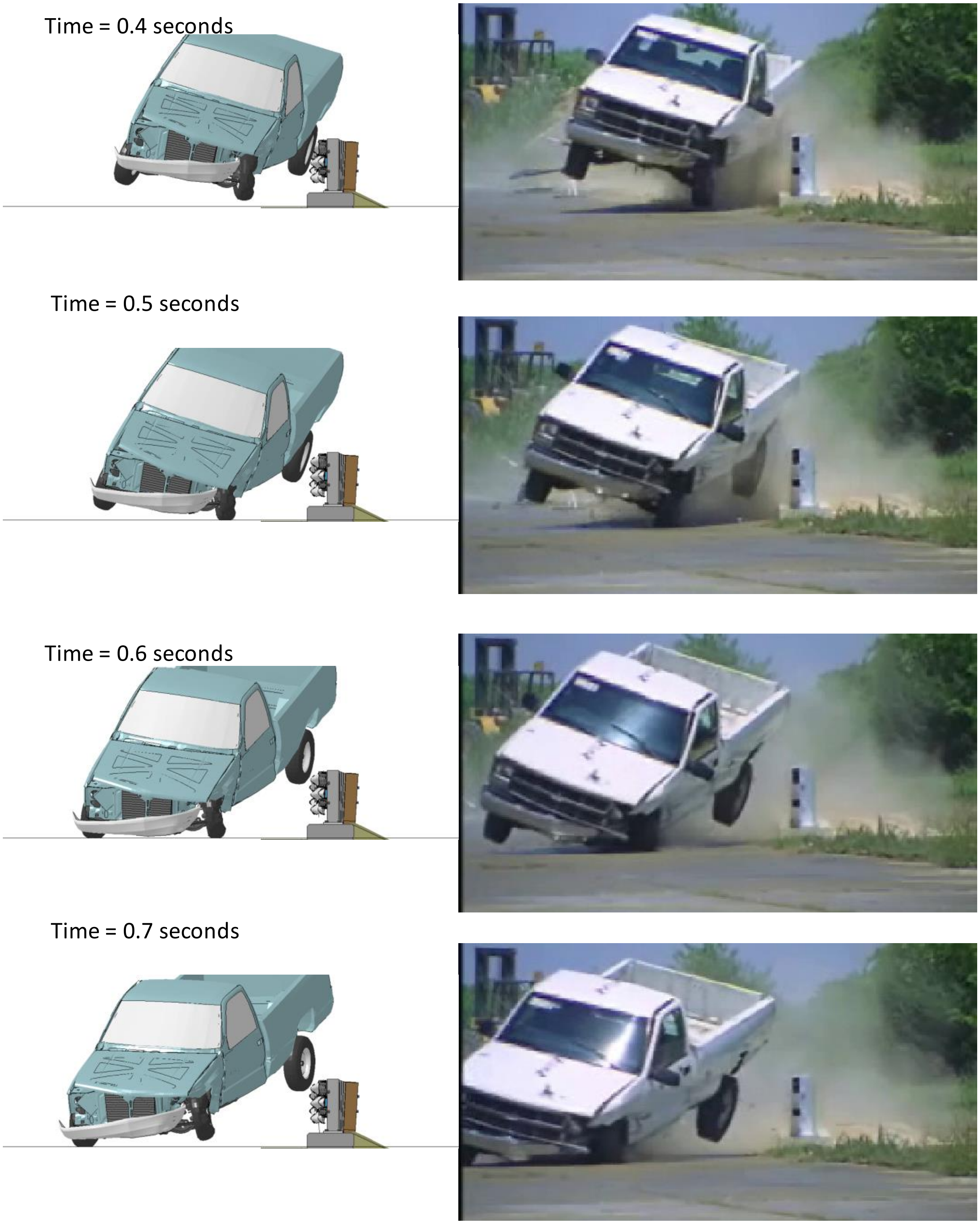


Figure 2. [CONTINUED] Sequential views from FEA and Test 401181-1 from a downstream viewpoint.

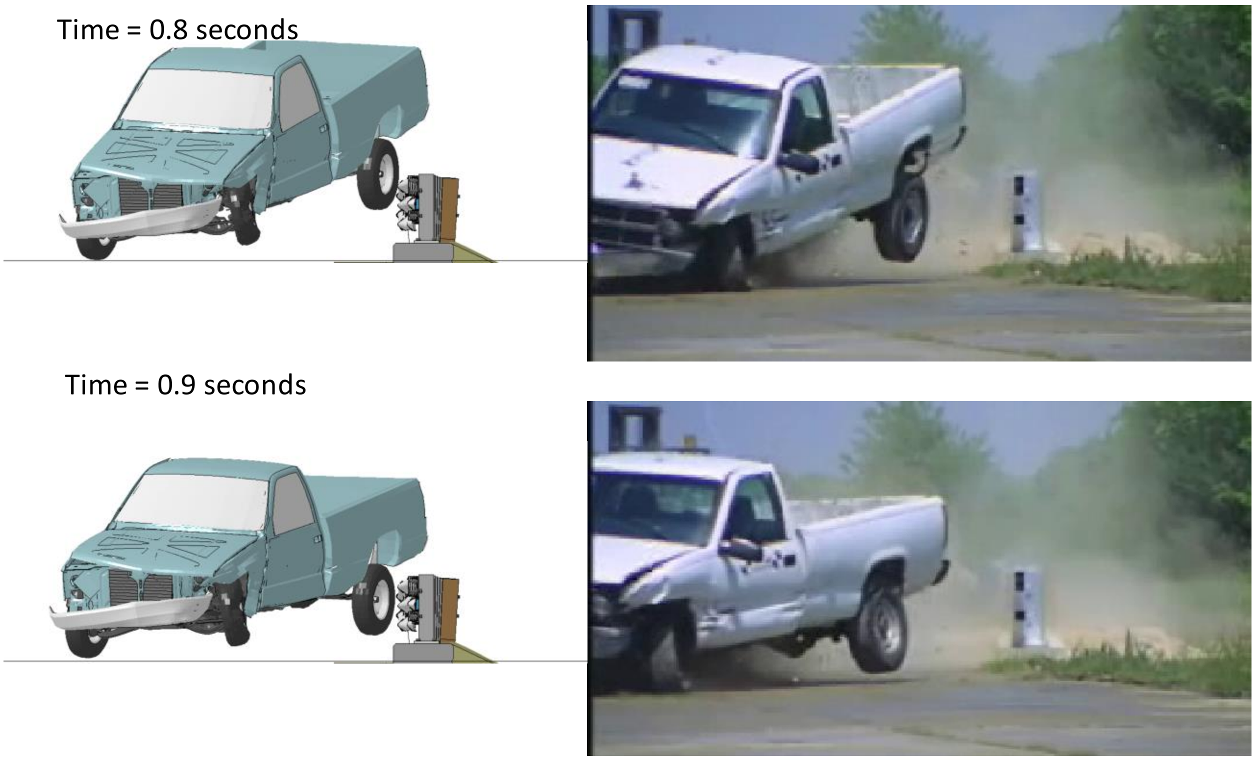


Figure 2. [CONTINUED] Sequential views from FEA and Test 401181-1 from a downstream viewpoint.

Appendix J

Sequential Views for Test 4-10 on

Curb-Mounted NETC 3-Bar Bridge Rail

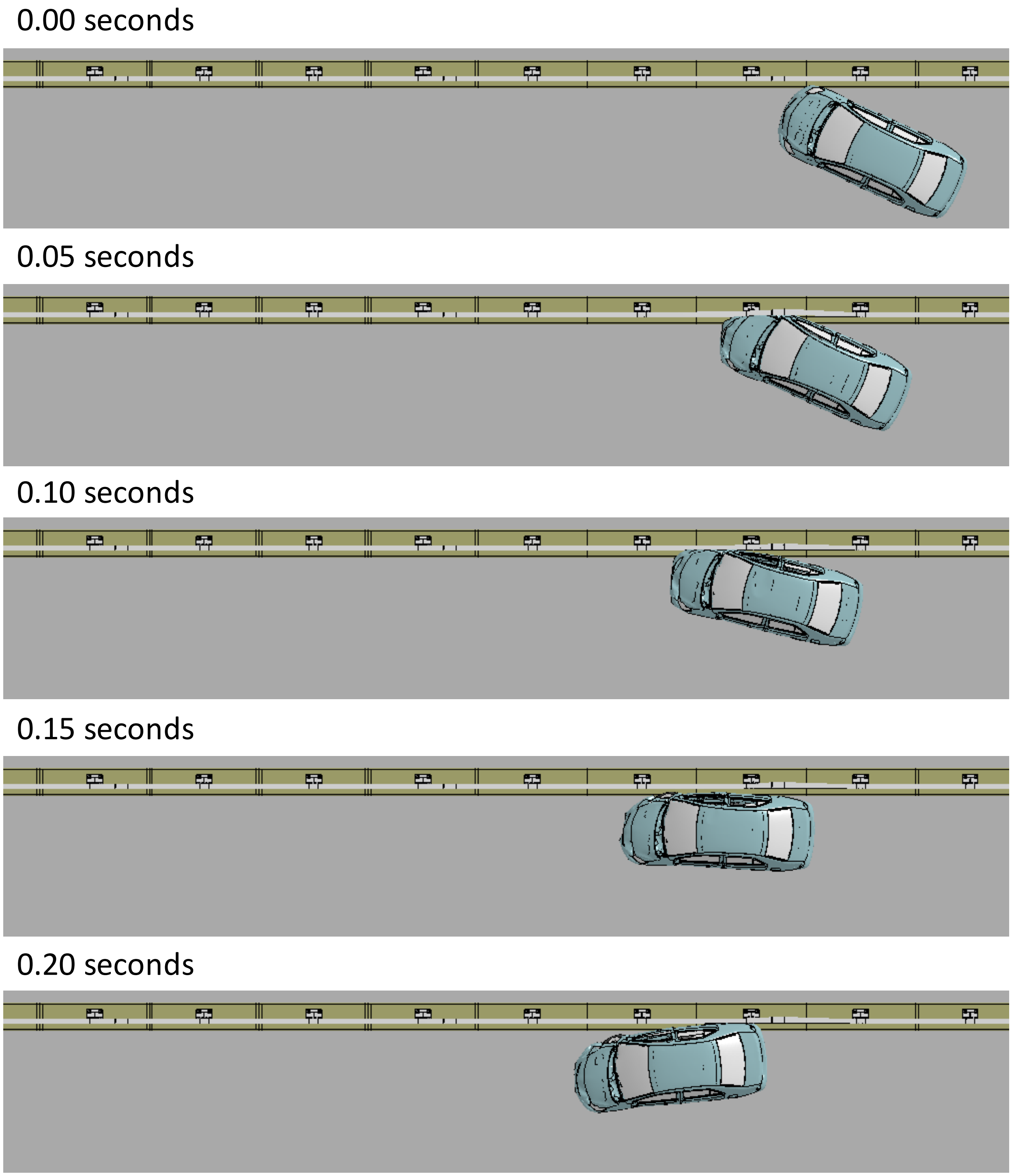


Figure J-1. Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from an overhead viewpoint.

0.25 seconds

0.30 seconds

0.35 seconds

0.40 seconds

0.45 seconds

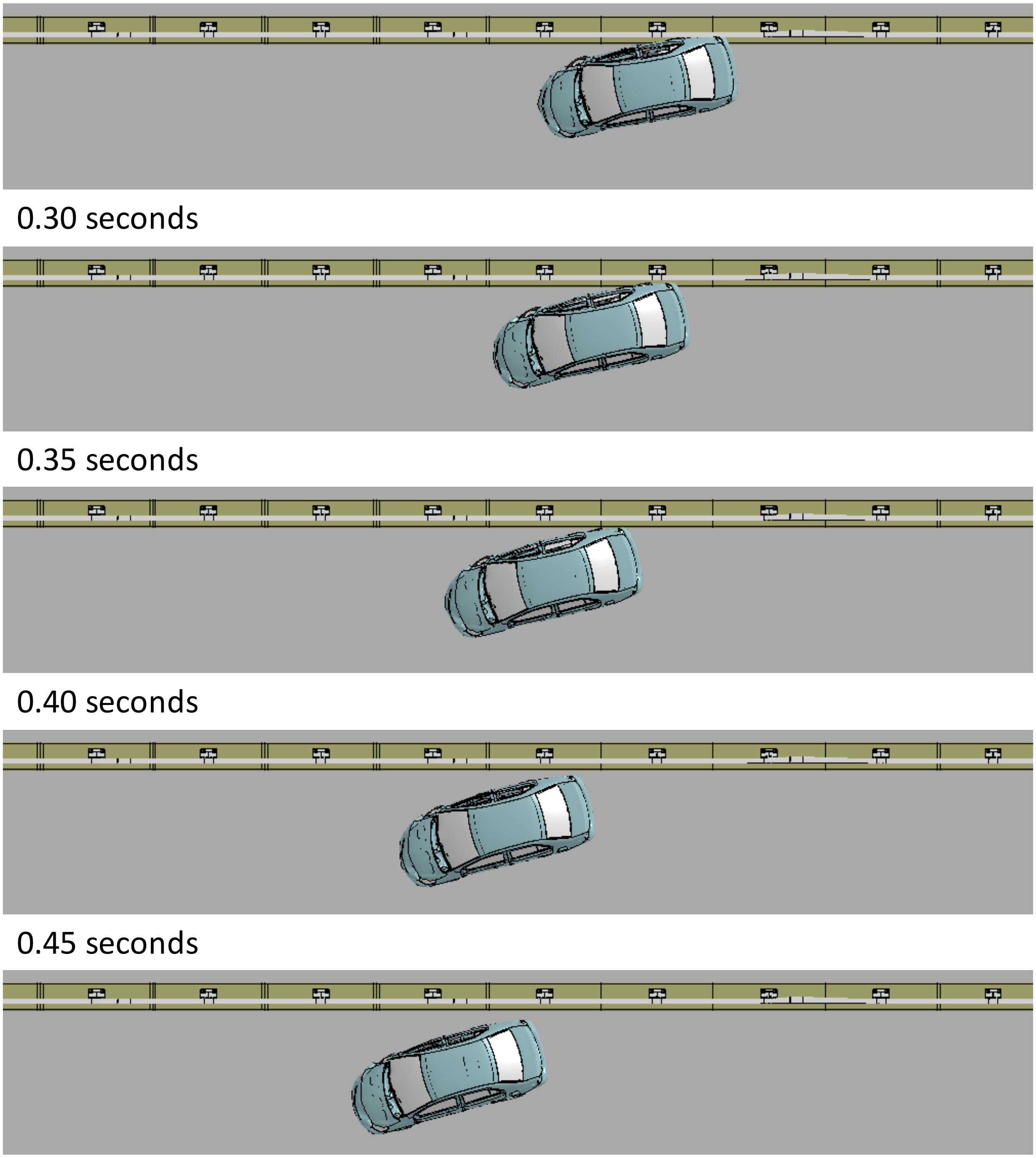
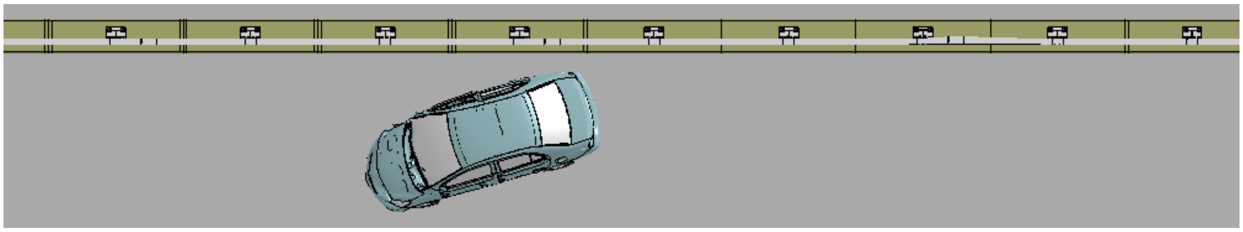


Figure J-1. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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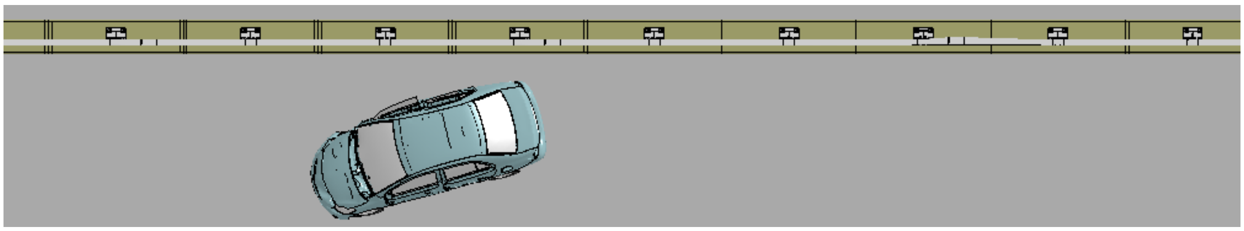

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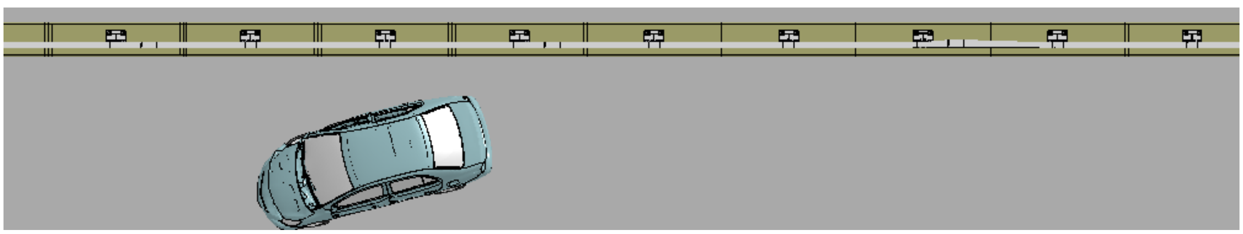

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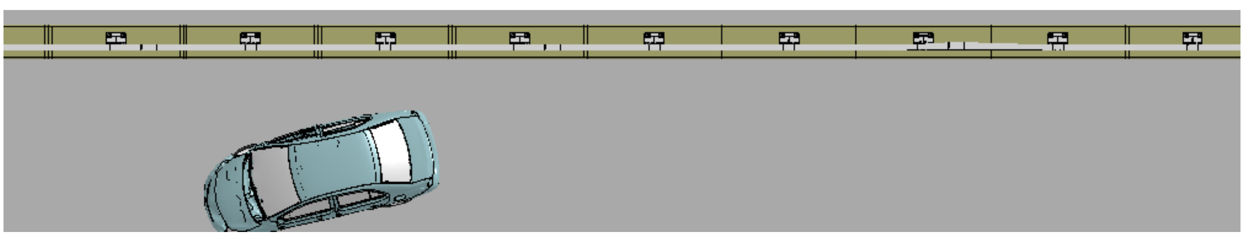


0.70 seconds

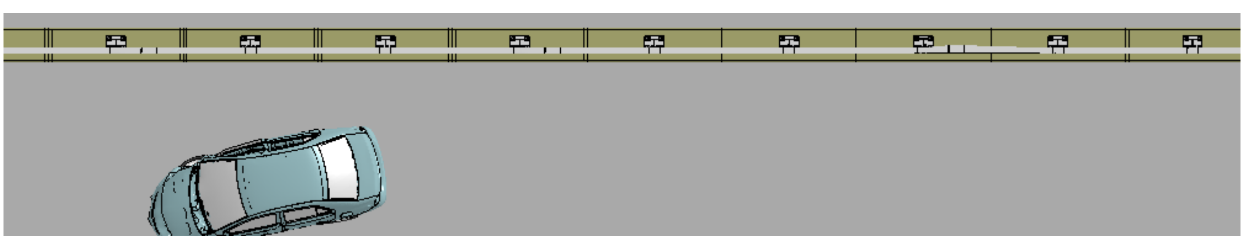
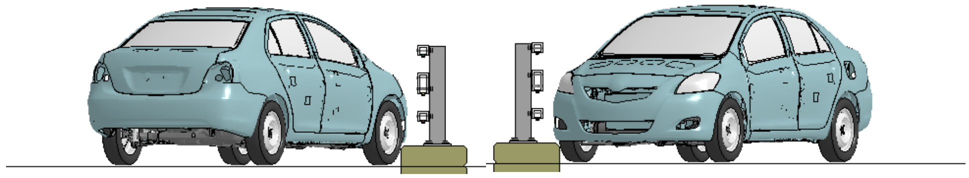
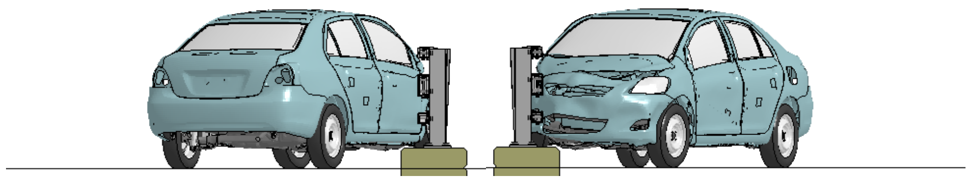


Figure J-1. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from an overhead viewpoint.

0.00 seconds



0.05 seconds



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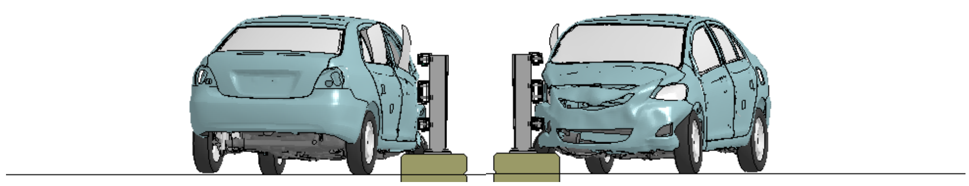

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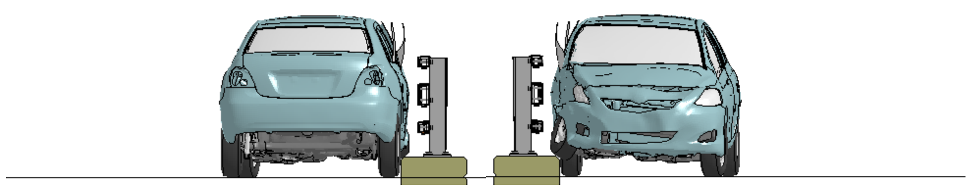

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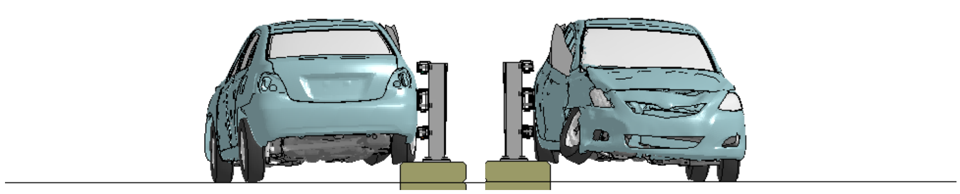
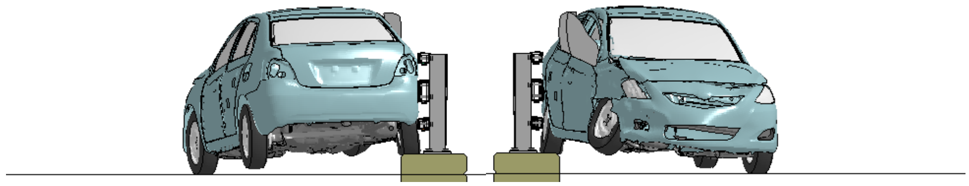


Figure J-2. Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from upstream and downstream viewpoints.

0.25 seconds



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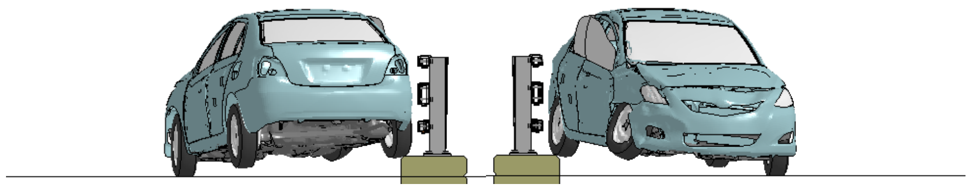

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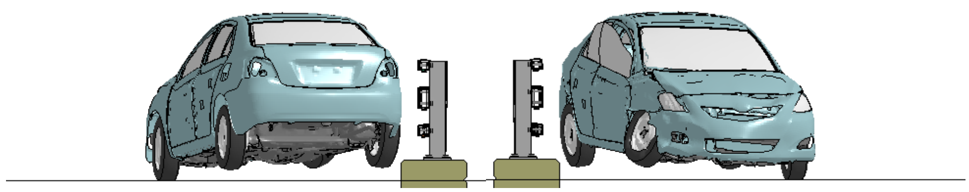

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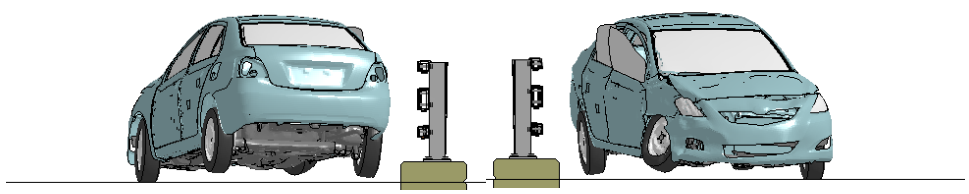

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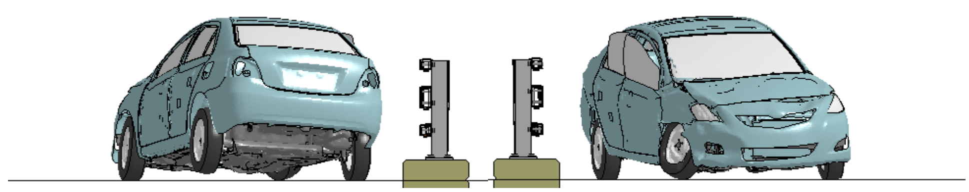


Figure J-2. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from upstream and downstream viewpoints.

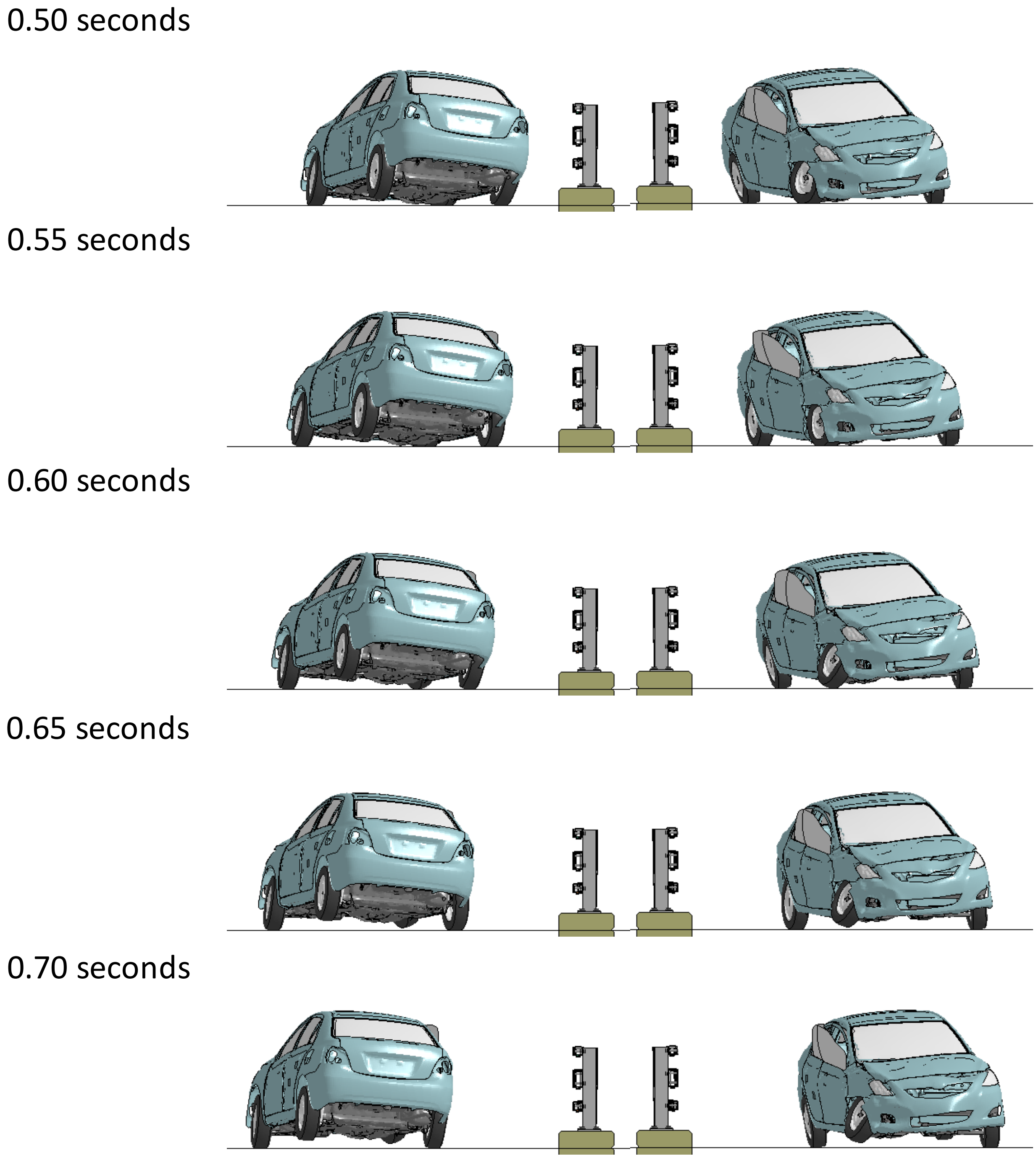
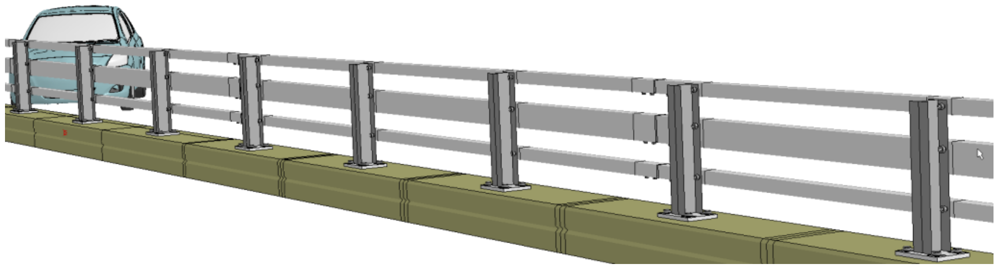


Figure J-2. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from upstream and downstream viewpoints.

0.00 seconds



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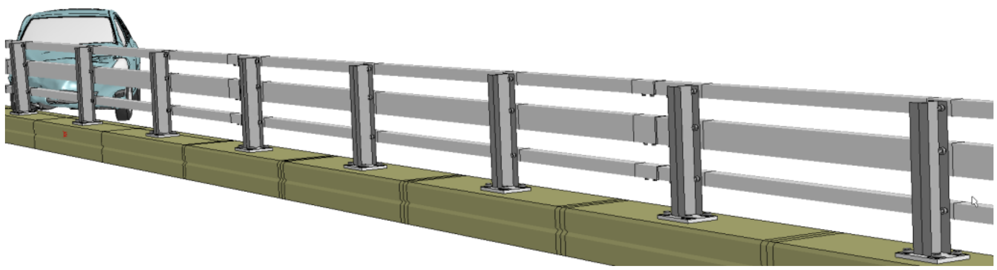

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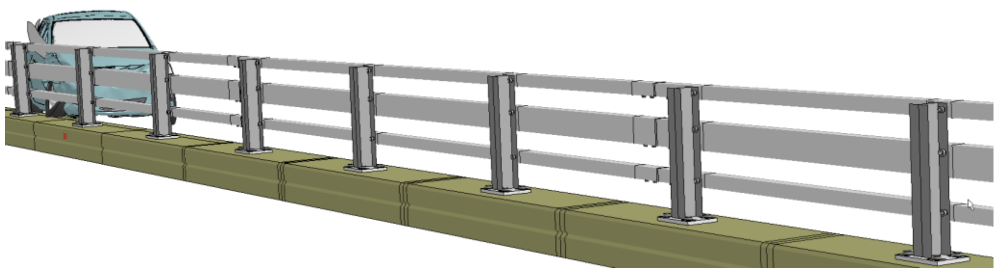

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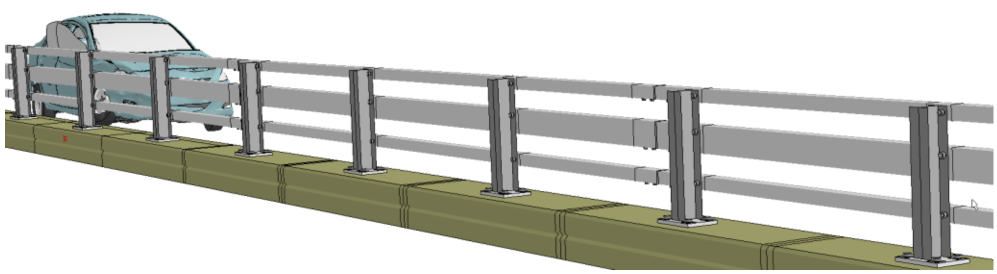
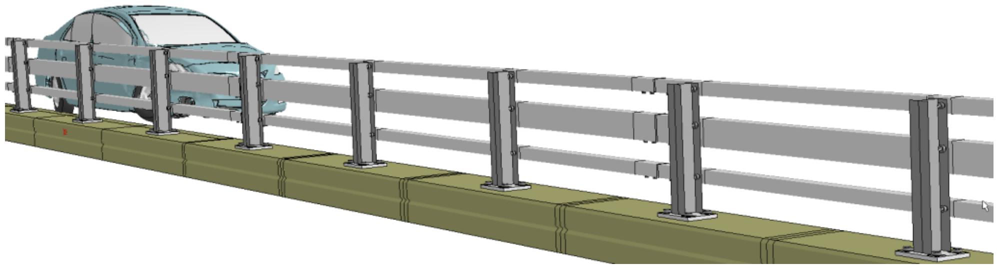


Figure J-3. Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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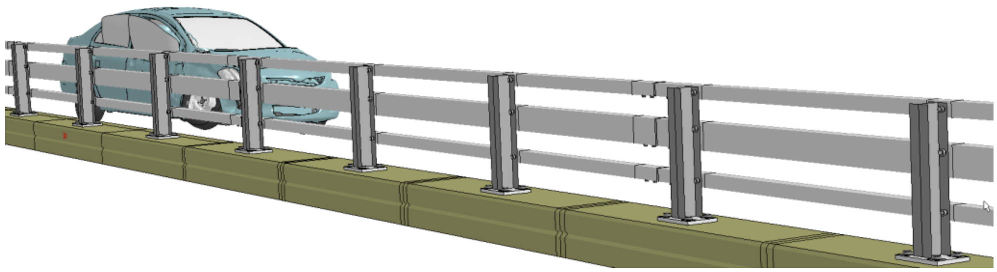

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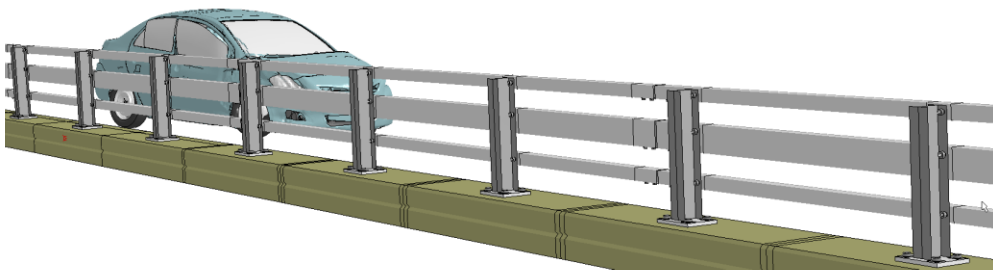

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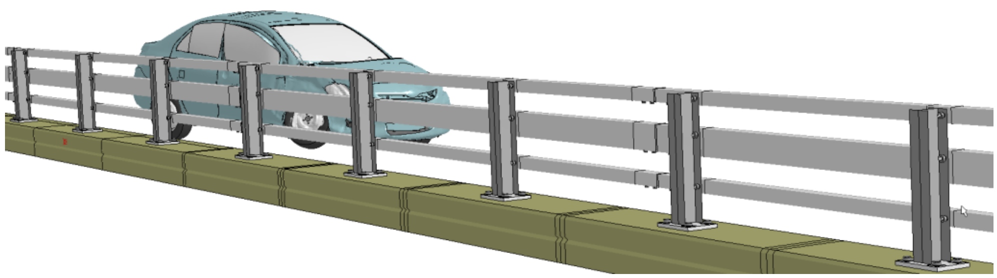
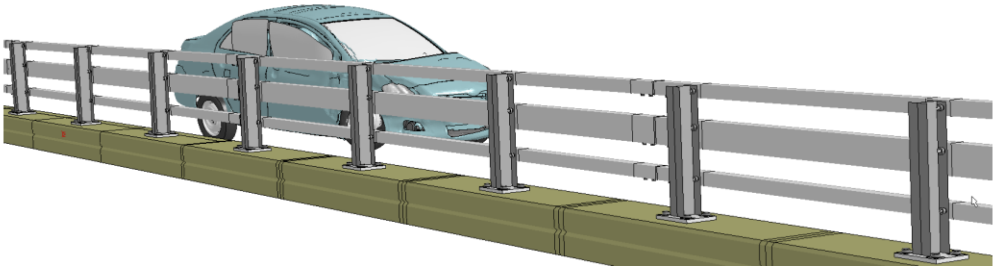


Figure J-3. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from from an oblique viewpoint.

0.40 seconds



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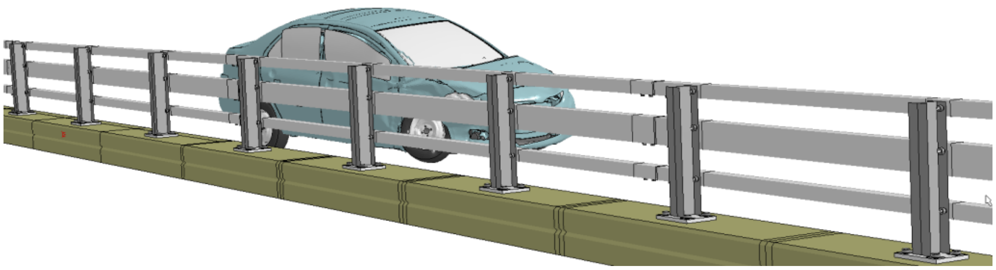

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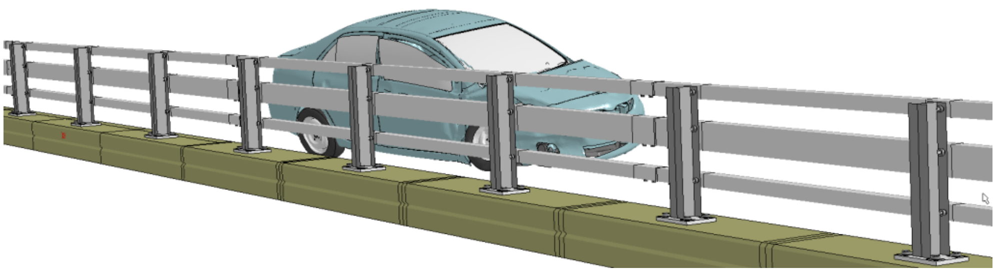

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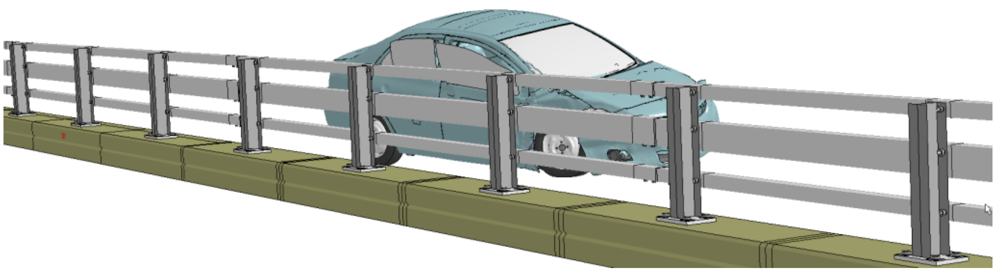


Figure J-3. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 3-Bar bridge rail from an oblique viewpoint.

Appendix K

Sequential Views for Test 4-11 on

Curb-Mounted NETC 3-Bar Bridge Rail

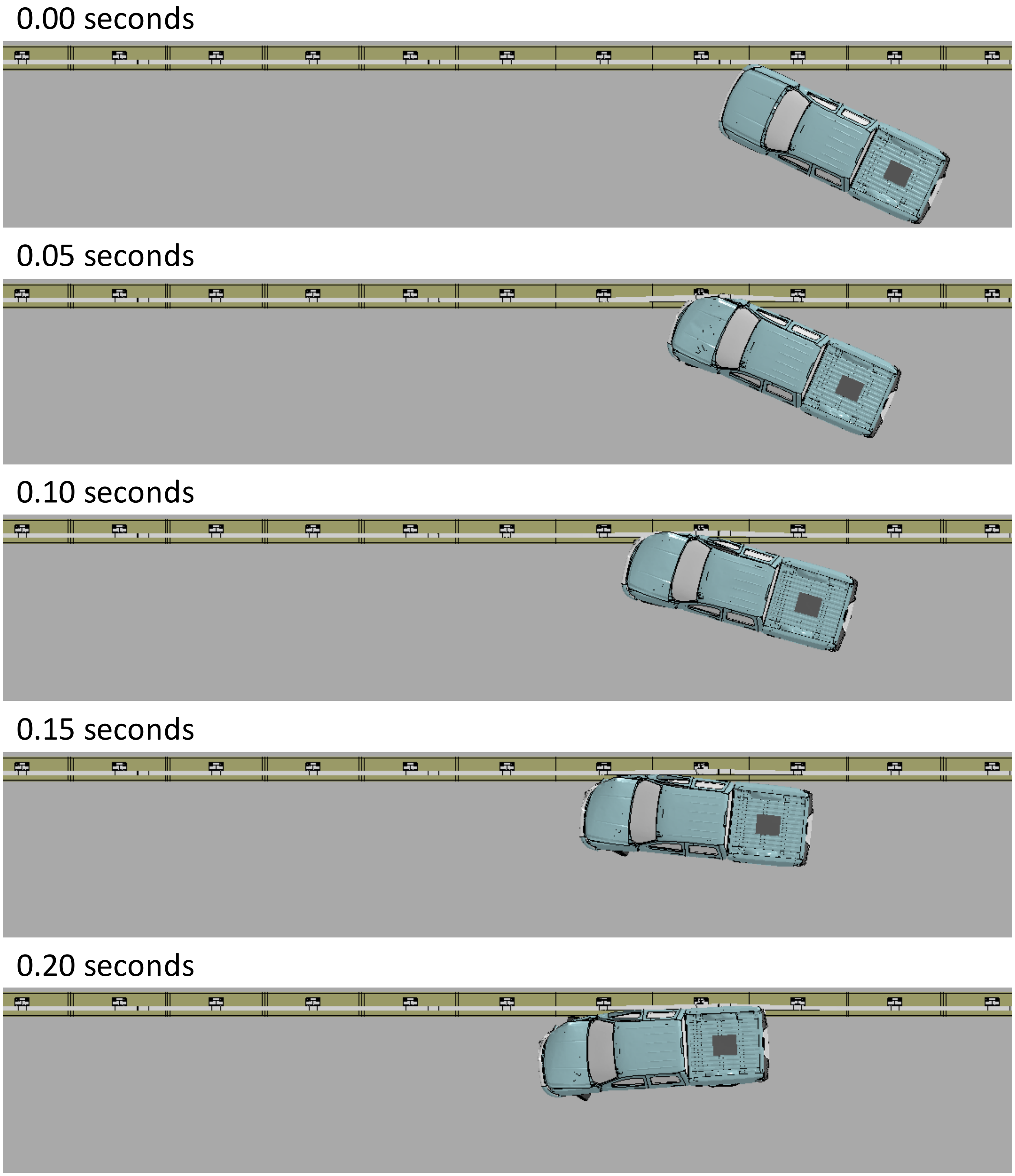
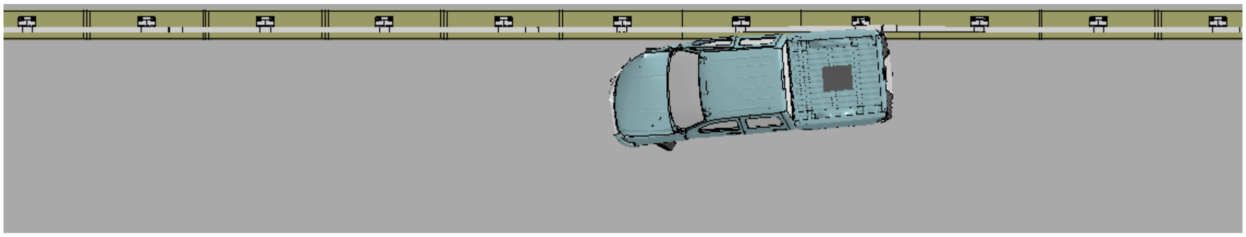
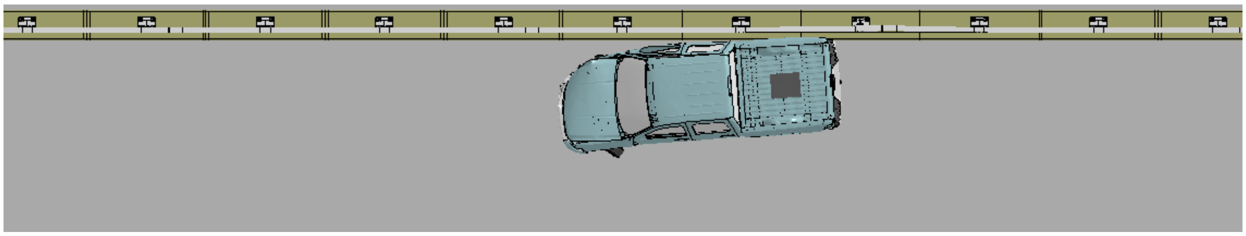


Figure K-1. Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from an overhead viewpoint.

0.25 seconds



0.30 seconds



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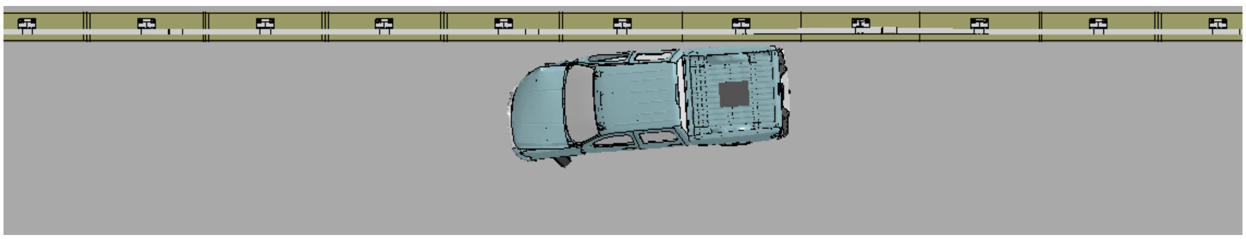

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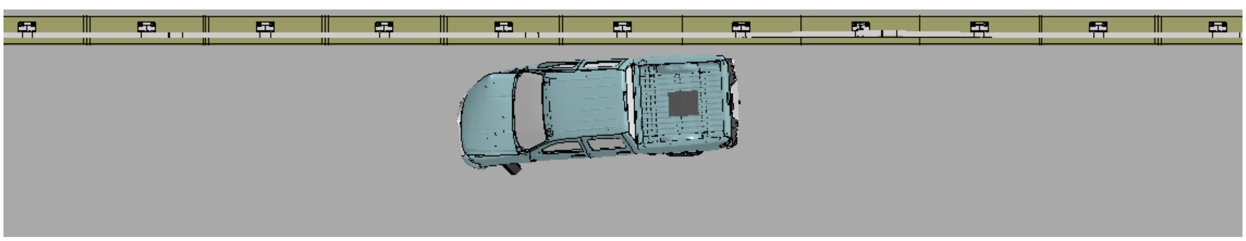

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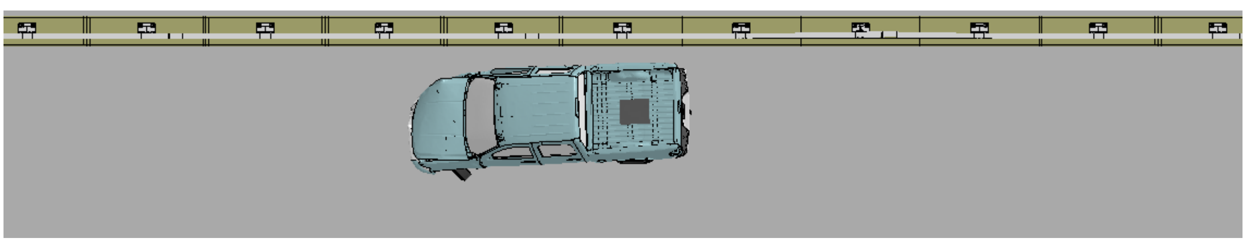
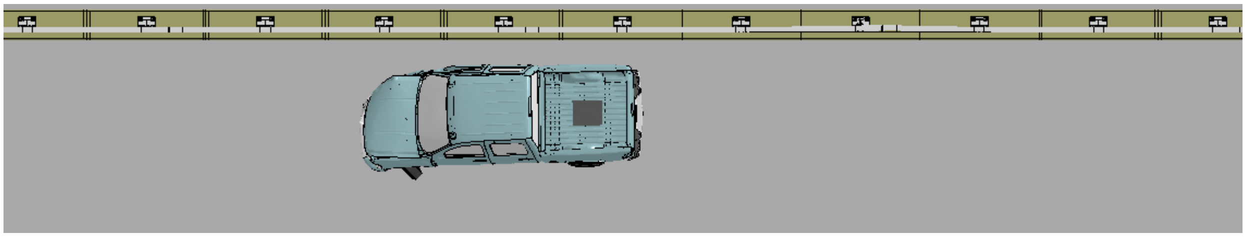


Figure K-1. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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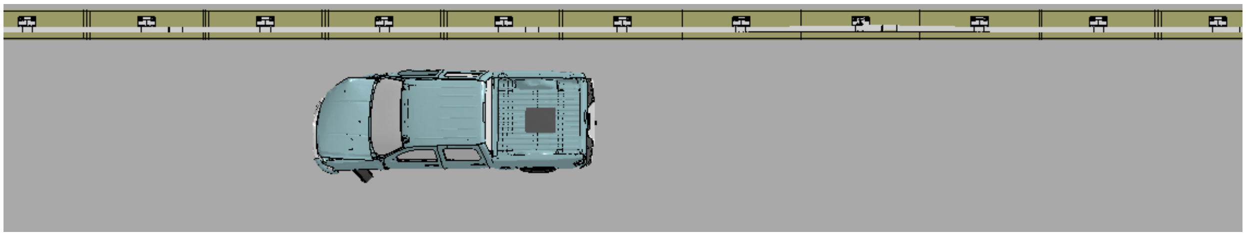

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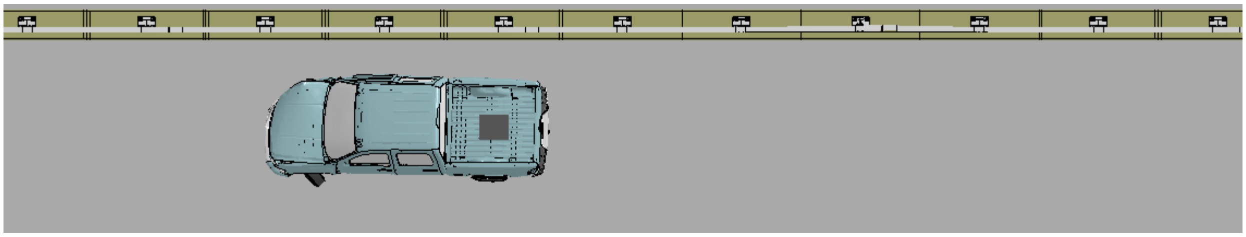

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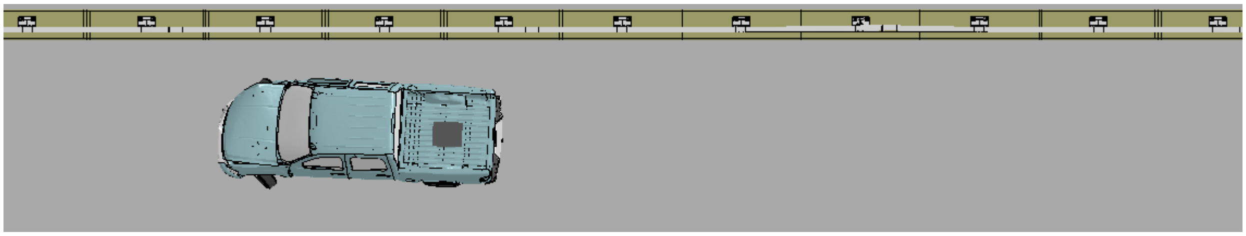

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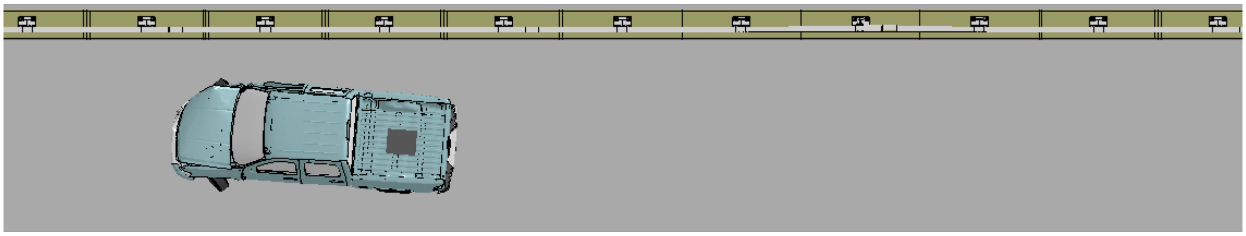

Figure K-1. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from an overhead viewpoint.

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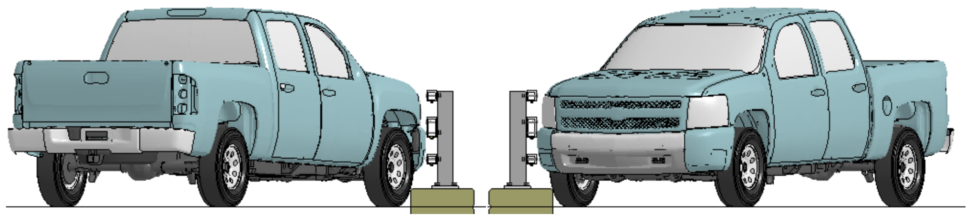

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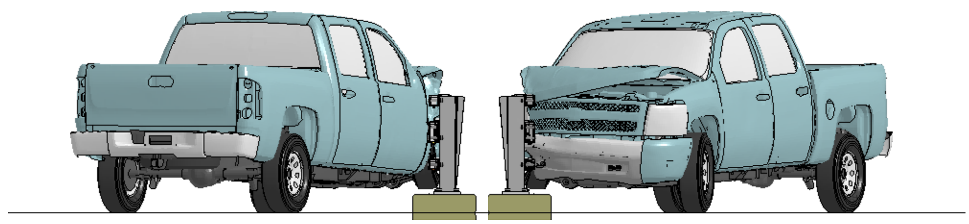

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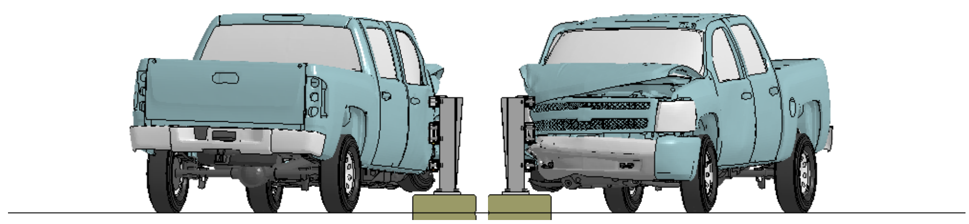

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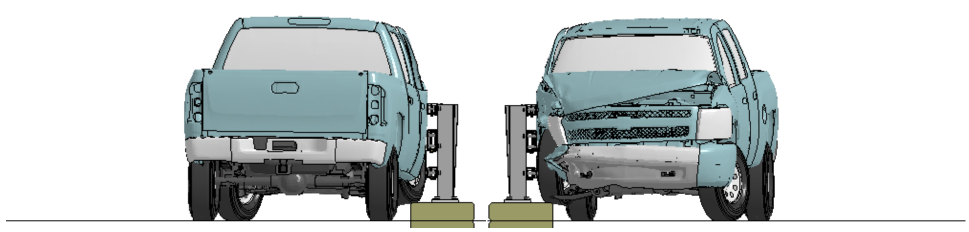

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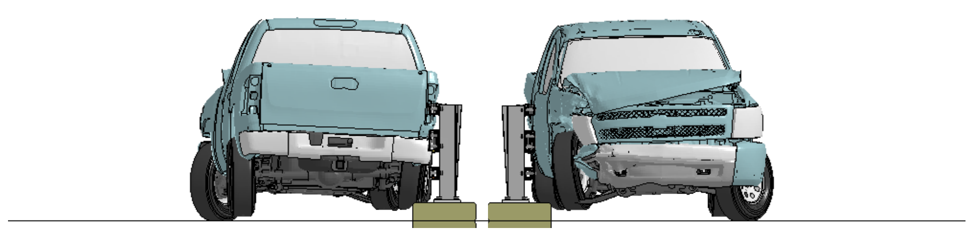

Figure K-2. Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from upstream and downstream viewpoints.

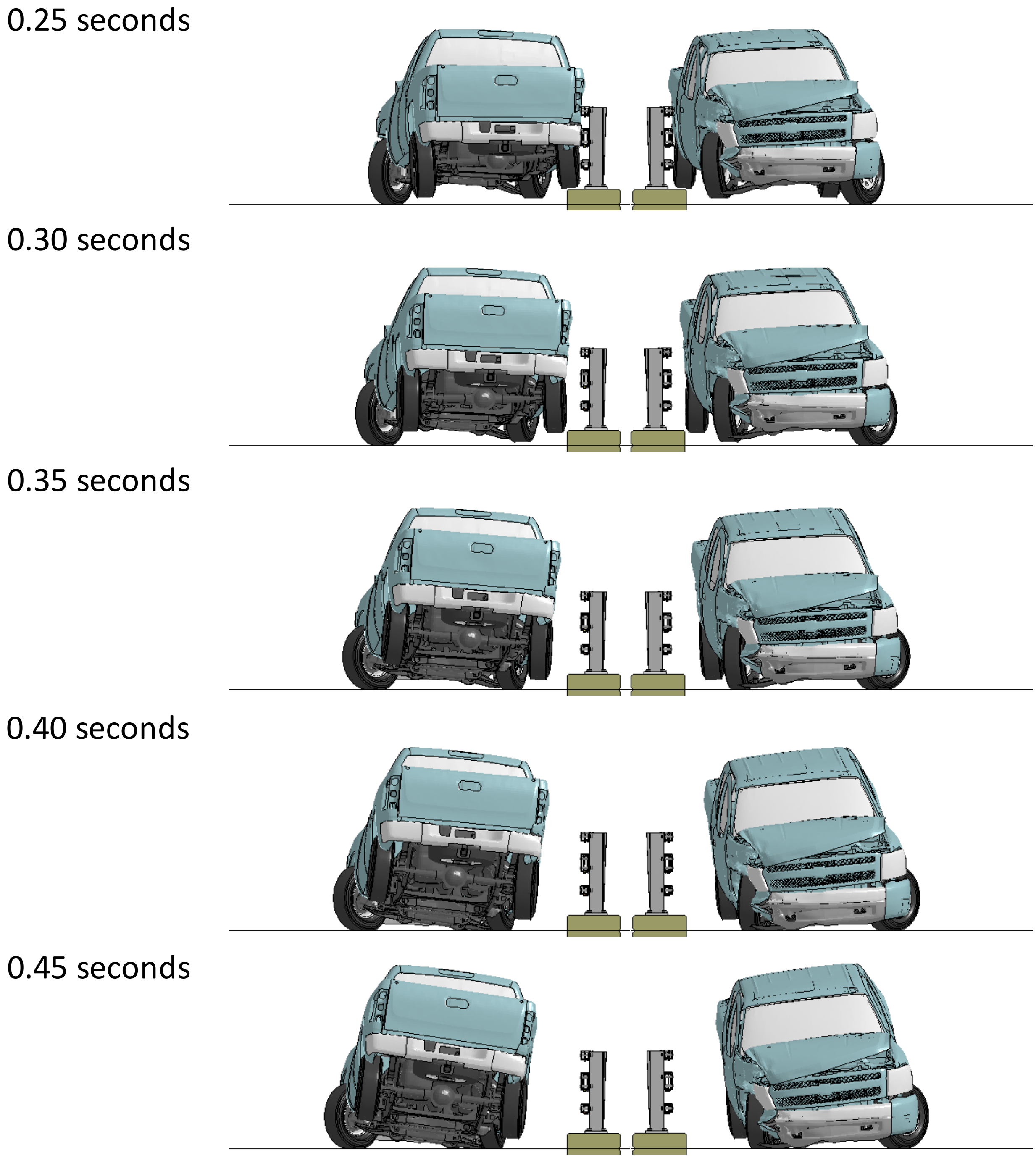

Figure K-2. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from upstream and downstream viewpoints.

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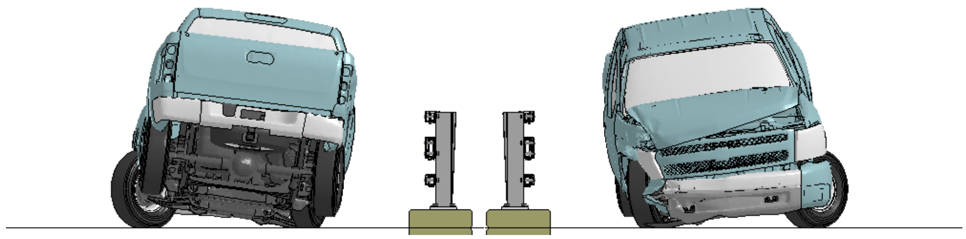

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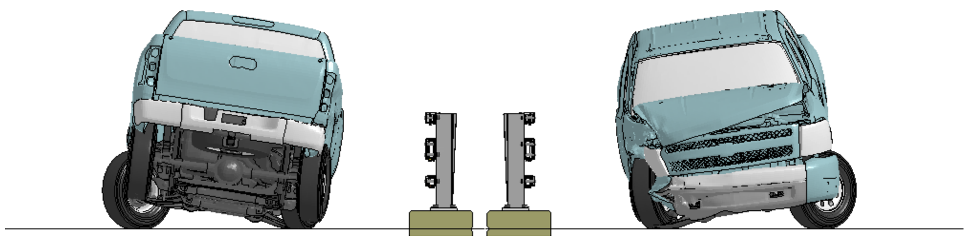

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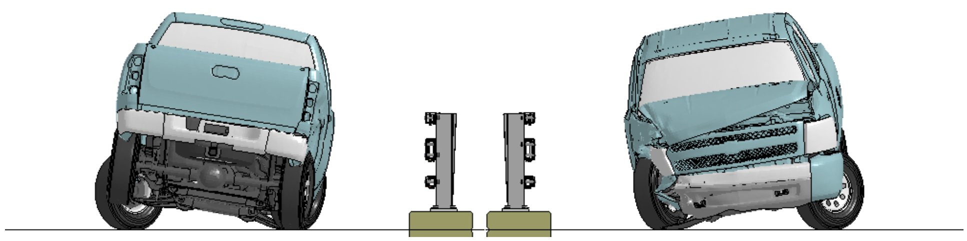

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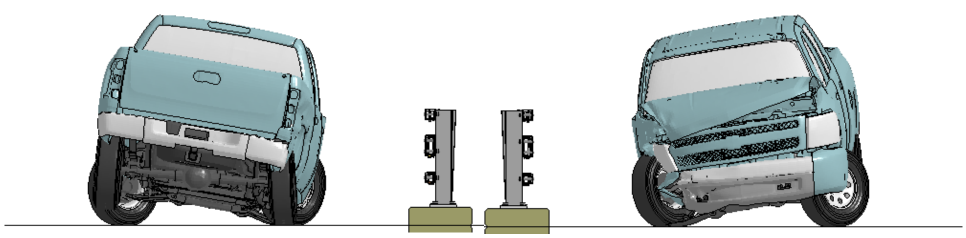

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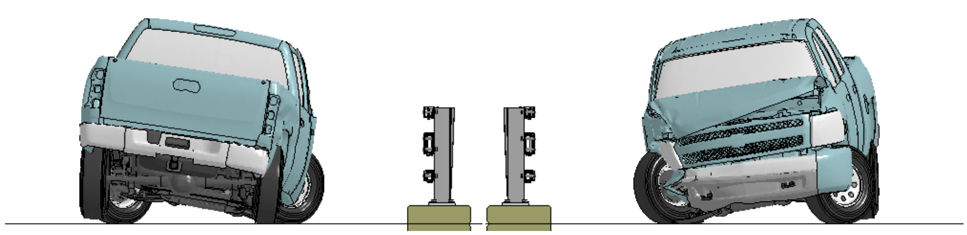
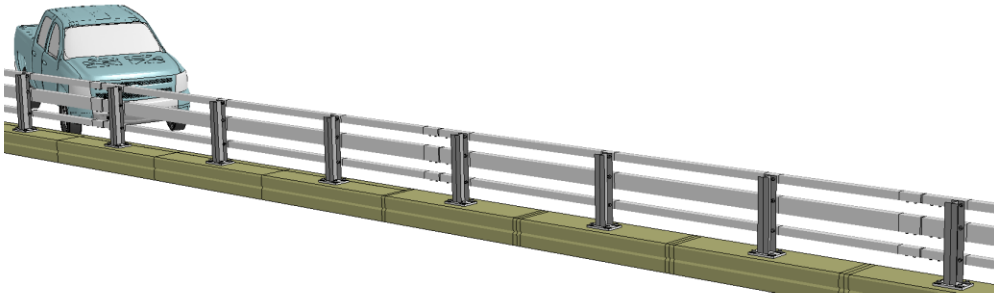


Figure K-2. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from upstream and downstream viewpoints.

0.00 seconds



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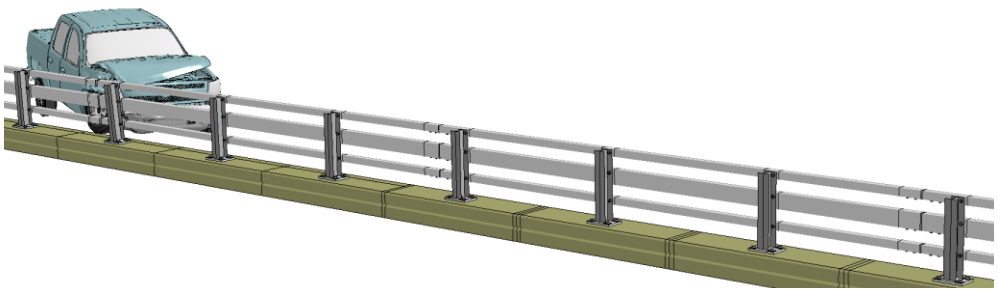

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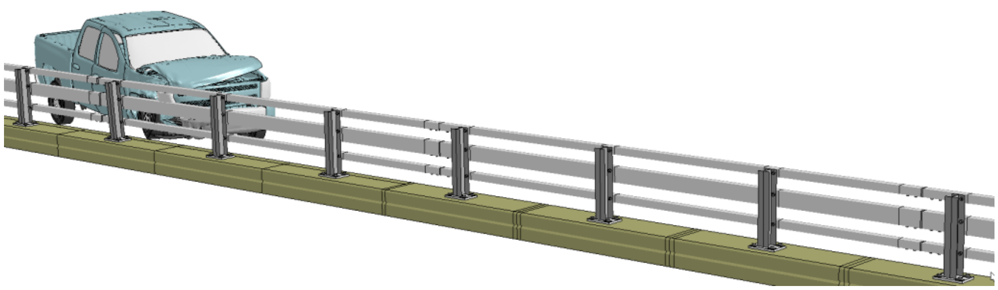

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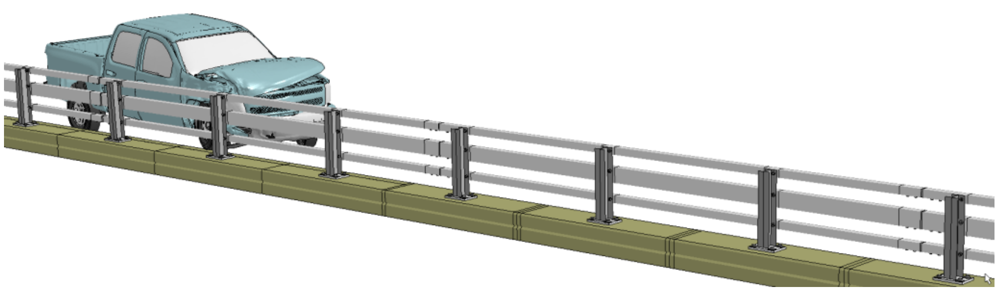
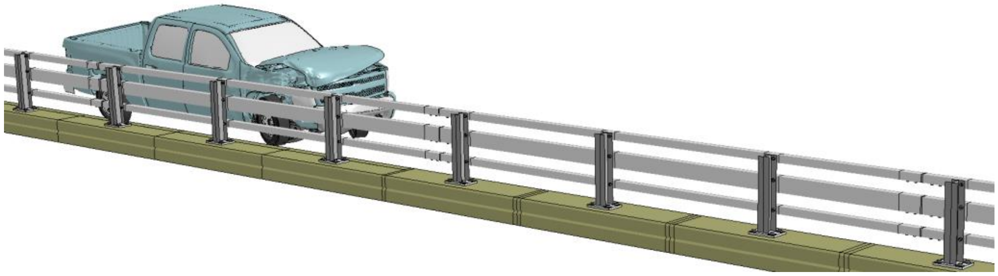


Figure K-3. Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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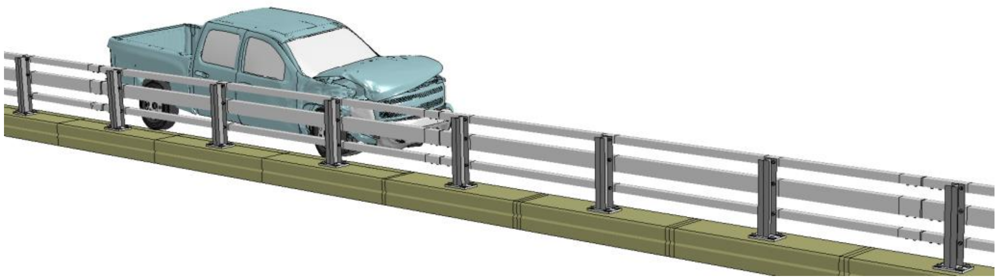

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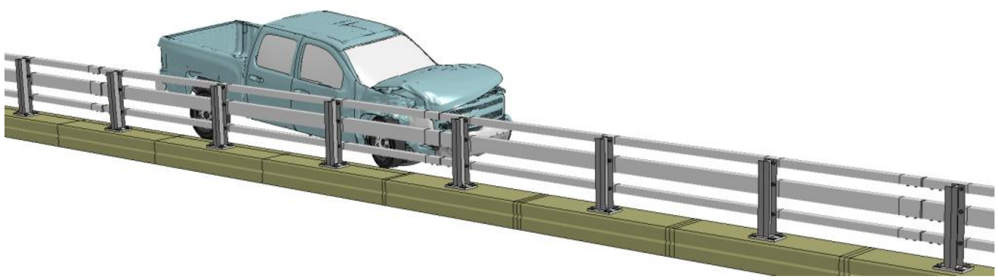

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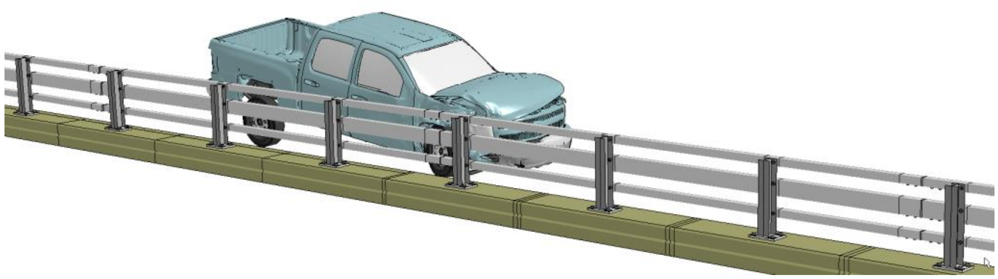
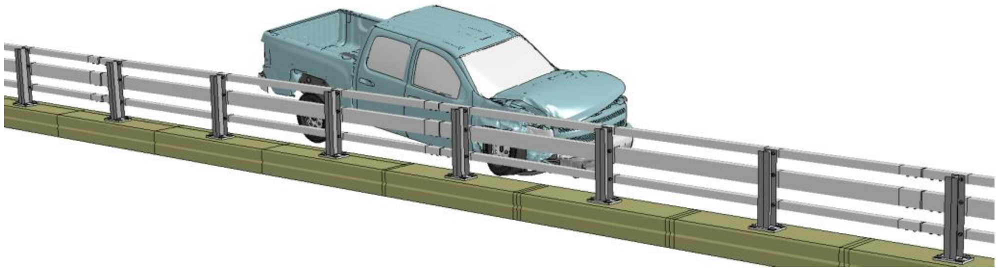


Figure K-3. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from from an oblique viewpoint.

0.40 seconds



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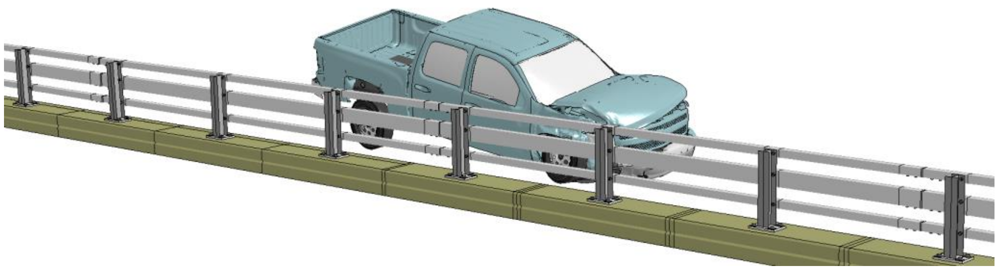

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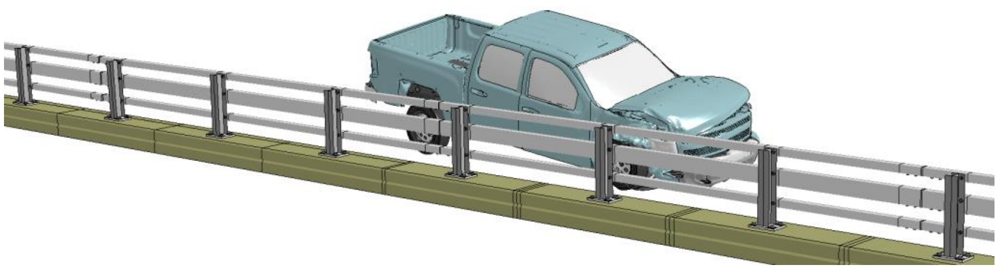

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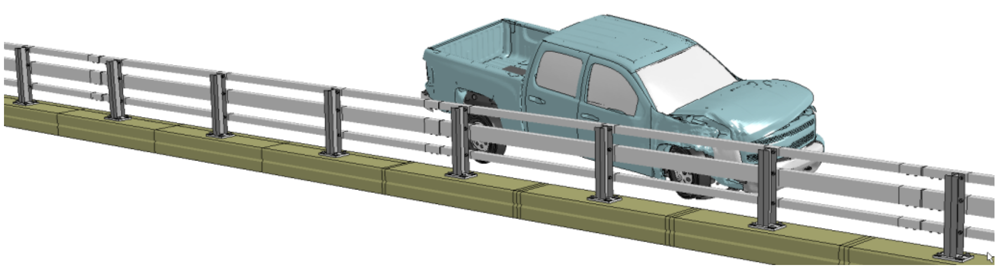


Figure K-3. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 3-Bar bridge rail from an oblique viewpoint.

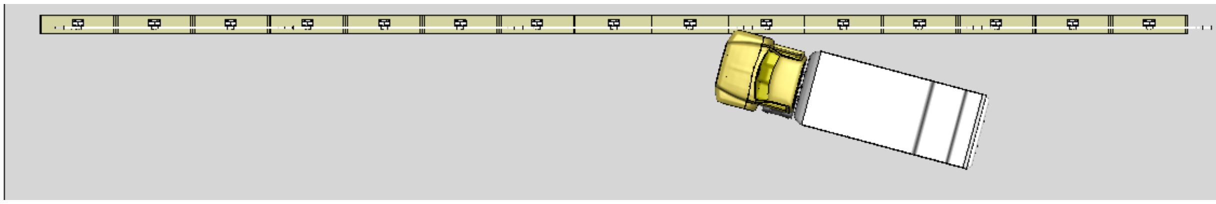
Appendix L

Sequential Views for Test 4-12 on

Curb-Mounted NETC 3-Bar Bridge Rail

(Case 1 – 47.5” Truck Bed)

0.00 seconds



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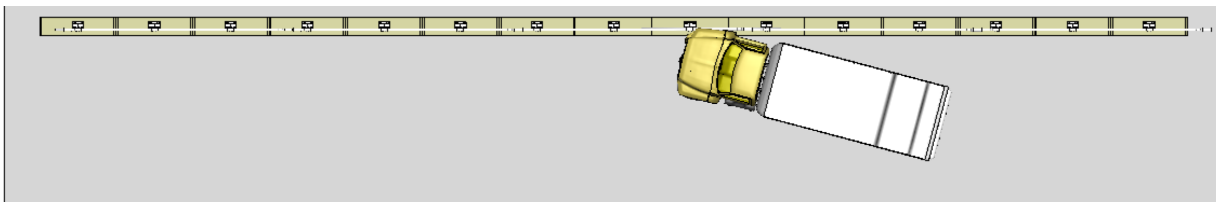

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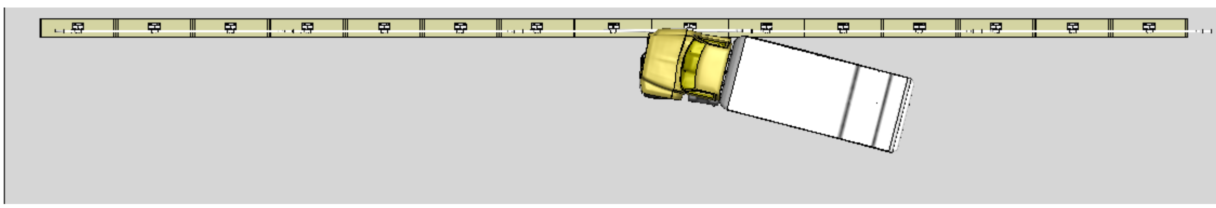

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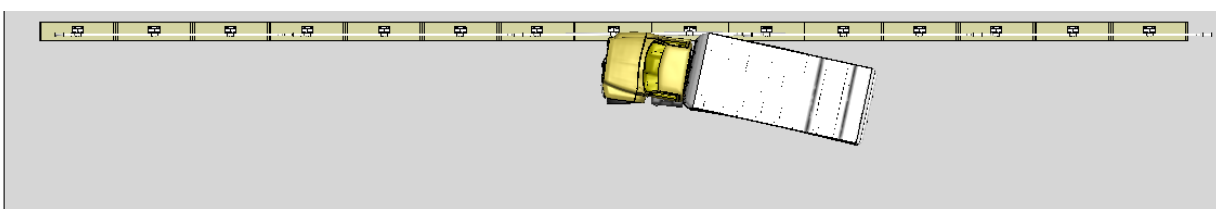

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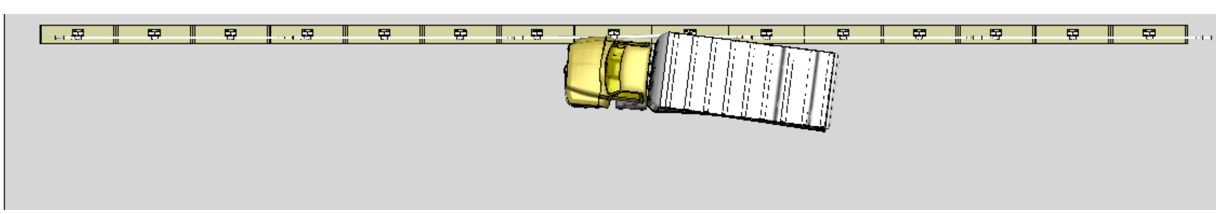
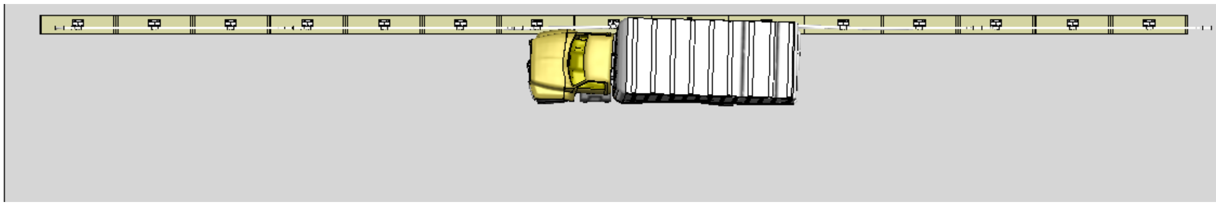


Figure L-1. Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 1.

0.25 seconds



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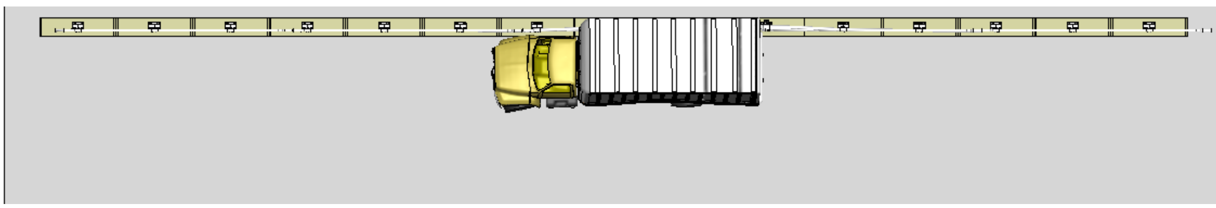

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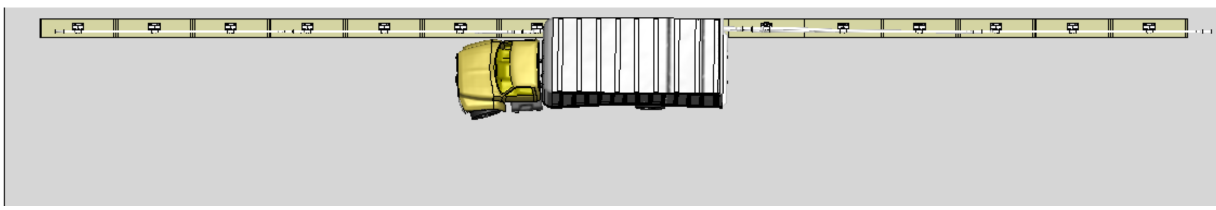

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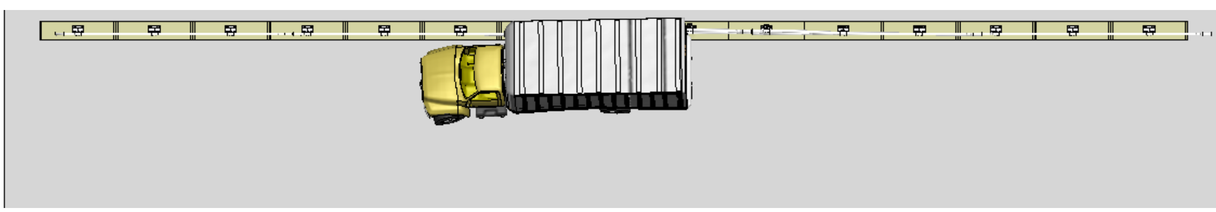

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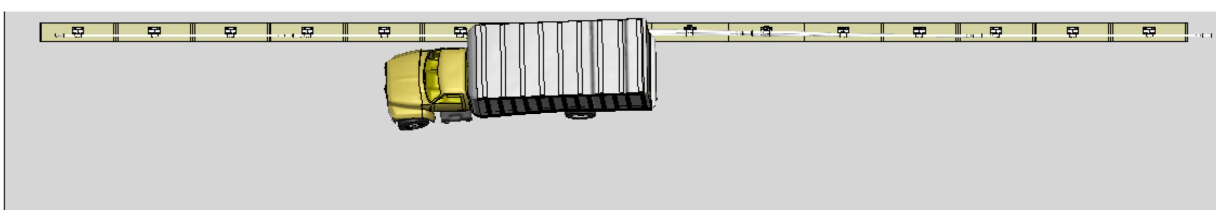

Figure L-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 1.

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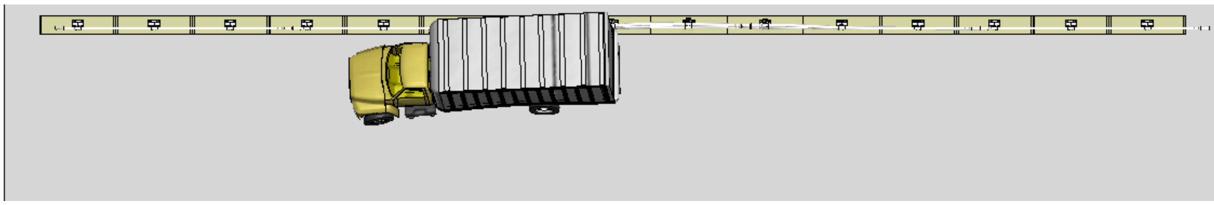

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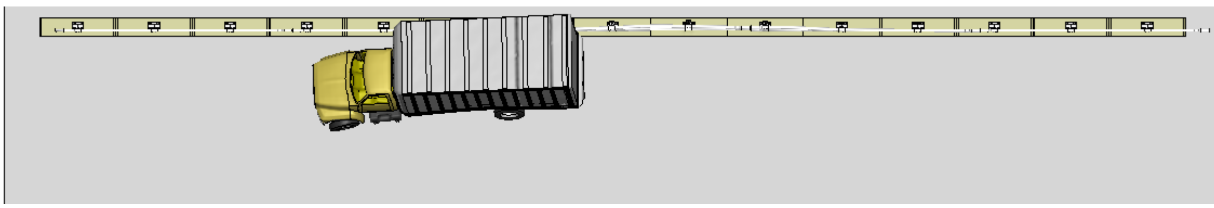

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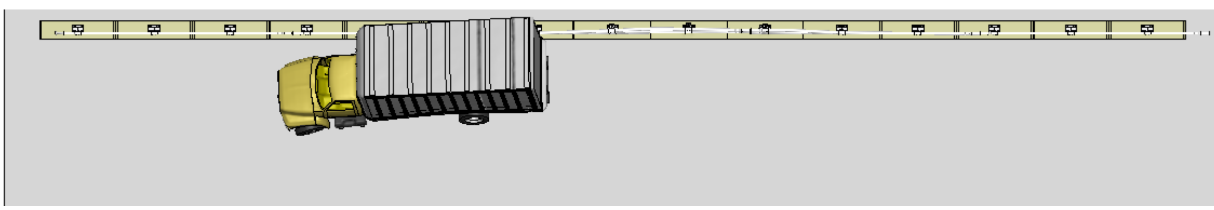

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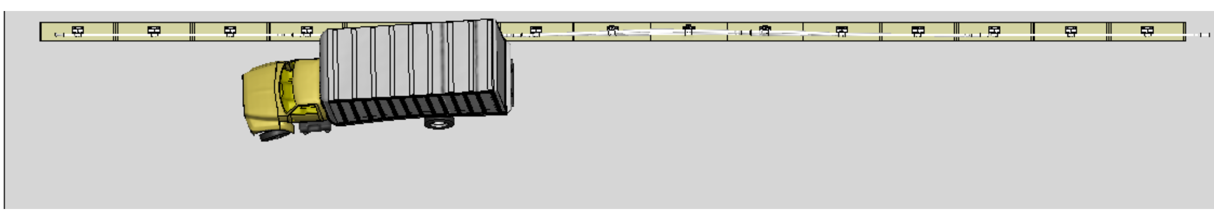

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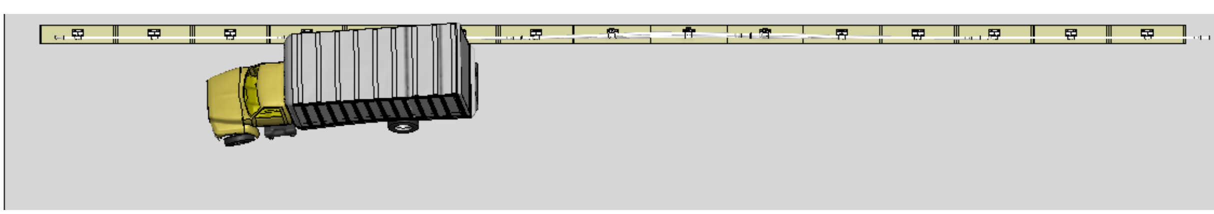

Figure L-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 1.

0.75 seconds

0.80 seconds

0.85 seconds

0.90 seconds

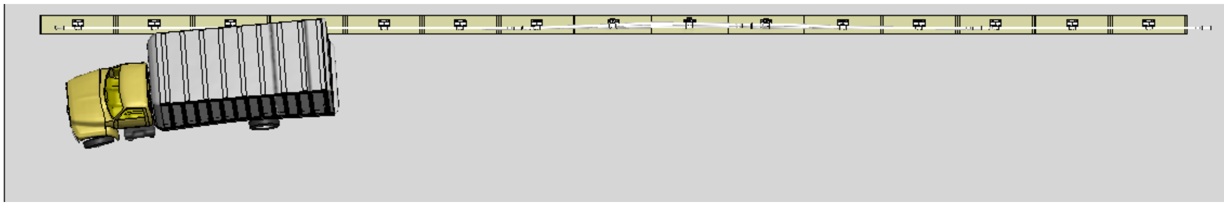

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Figure L-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 1.

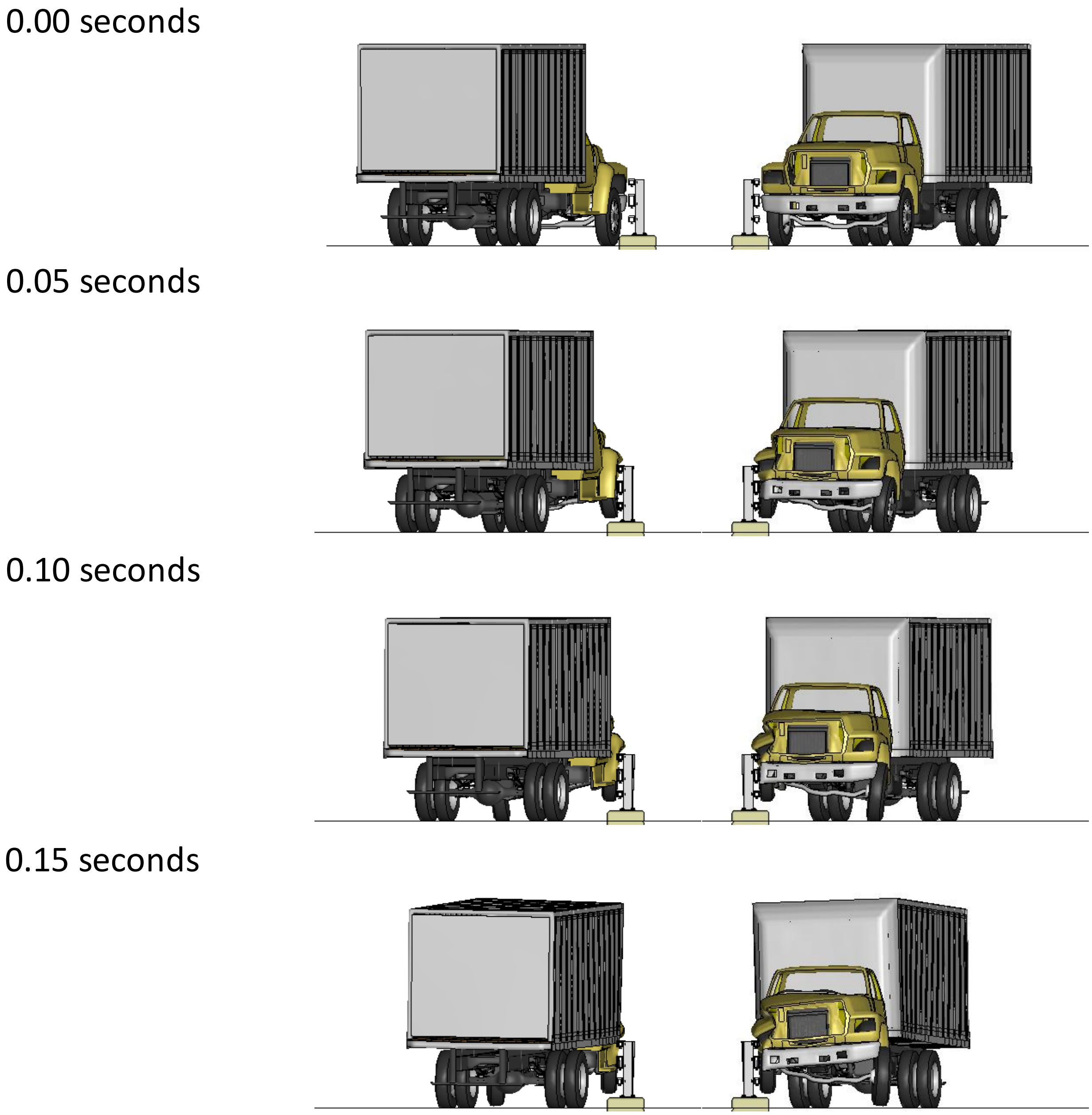

Figure K-2. Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 1.

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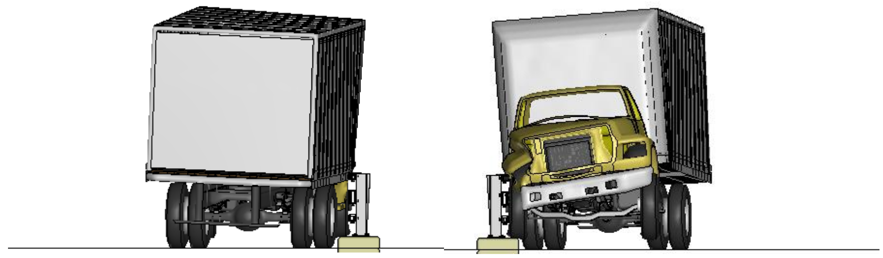

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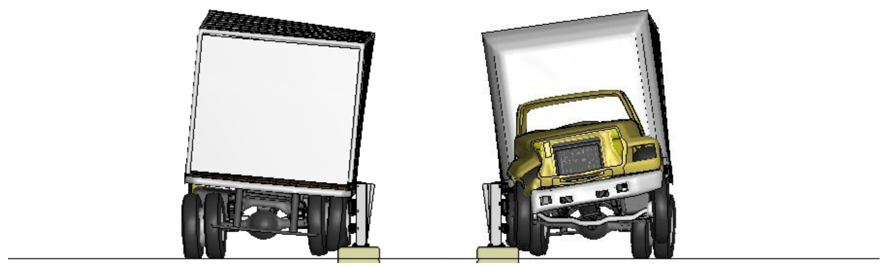

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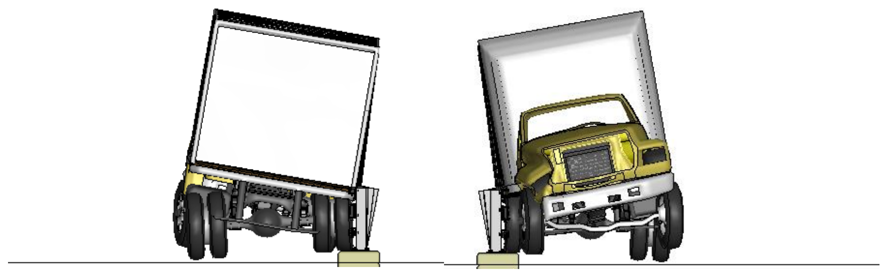

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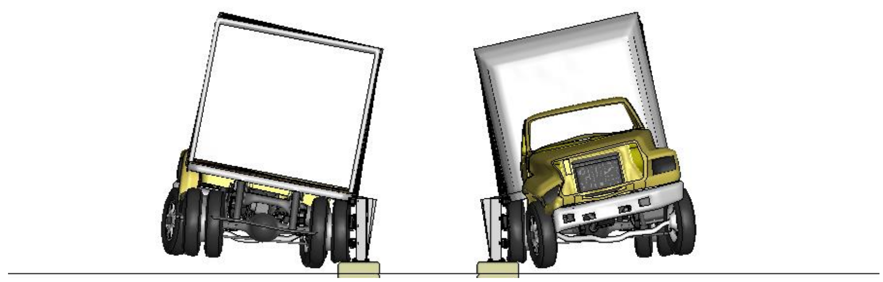

Figure K-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 1.

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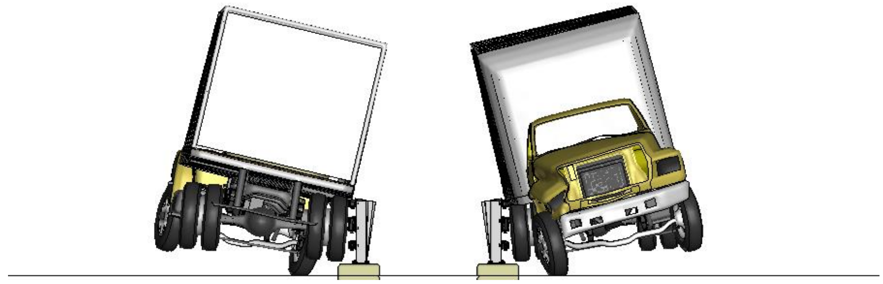

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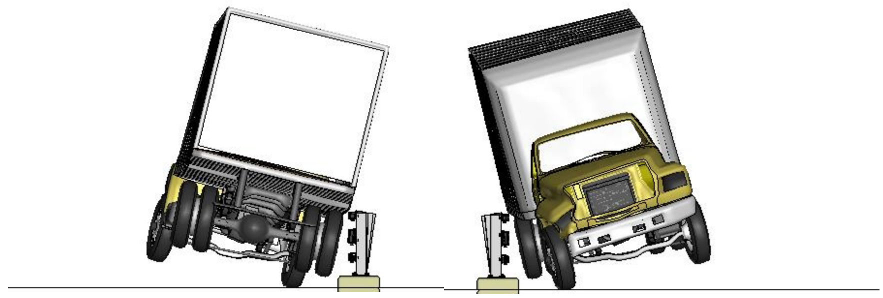

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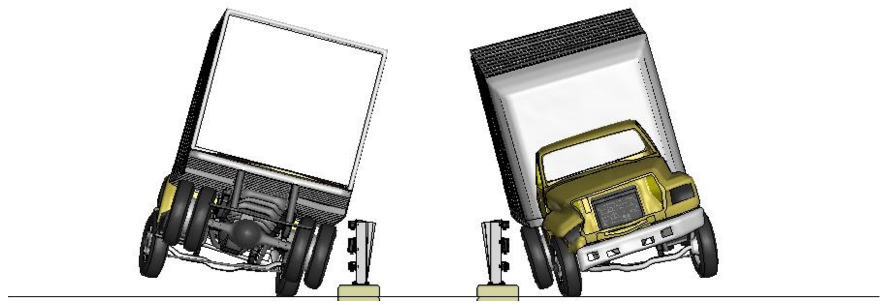

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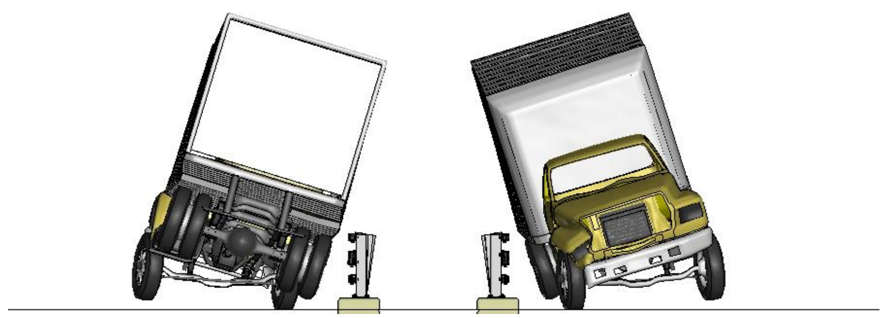

Figure K-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 1.

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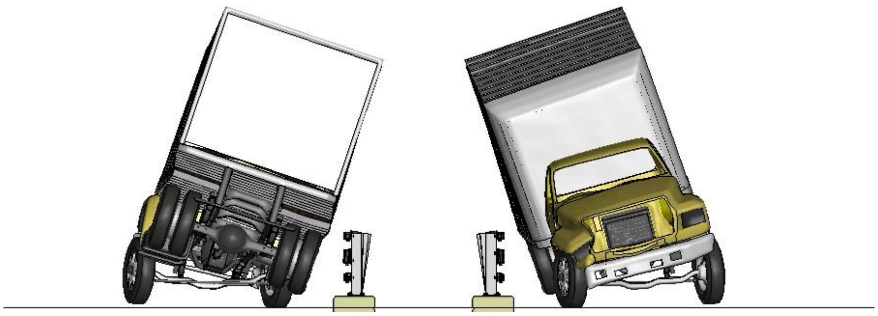

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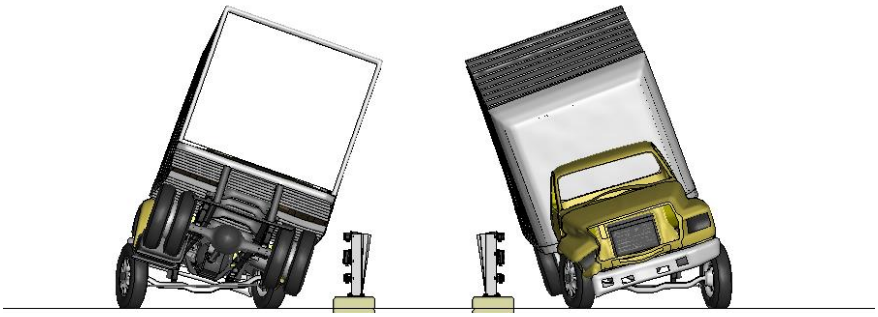

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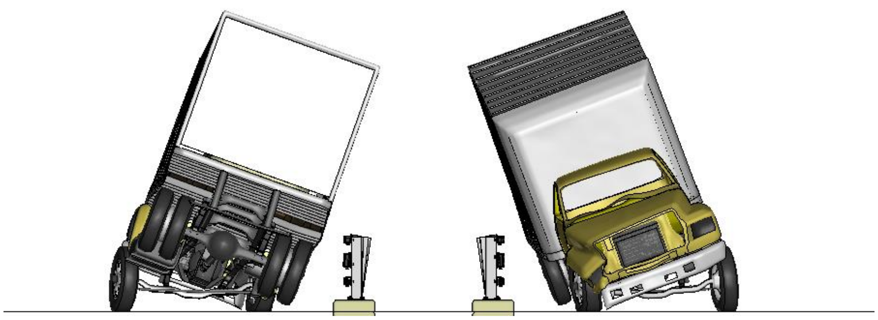

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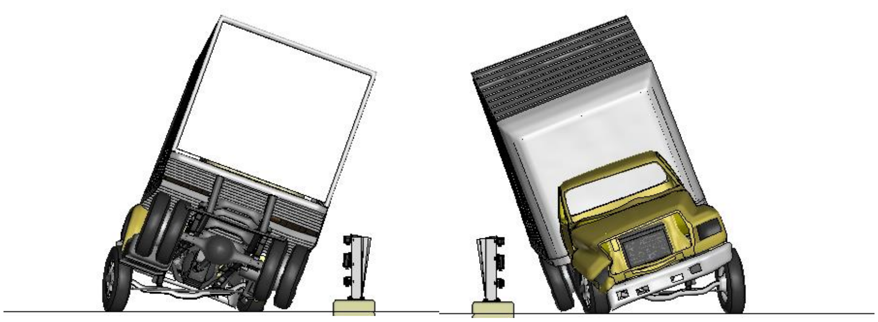

Figure K-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 1.

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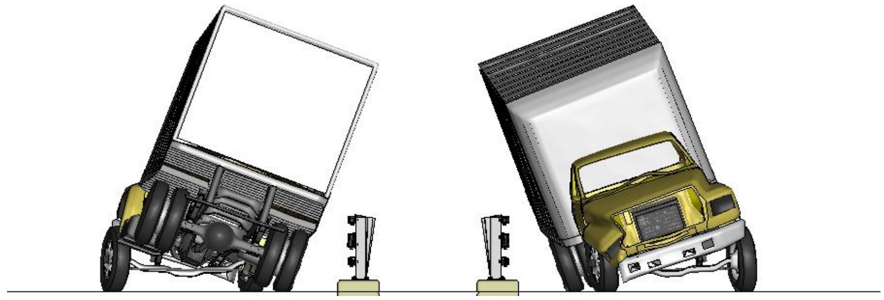

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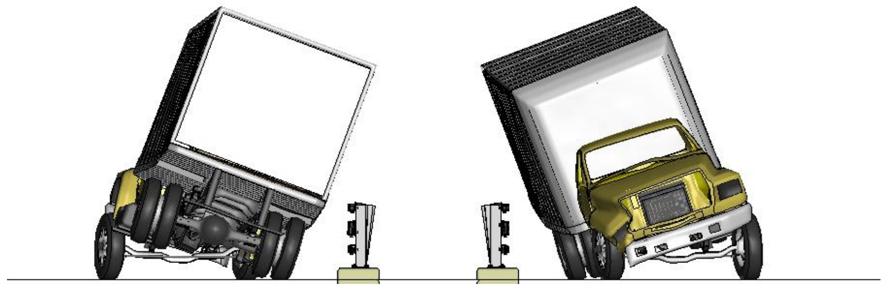

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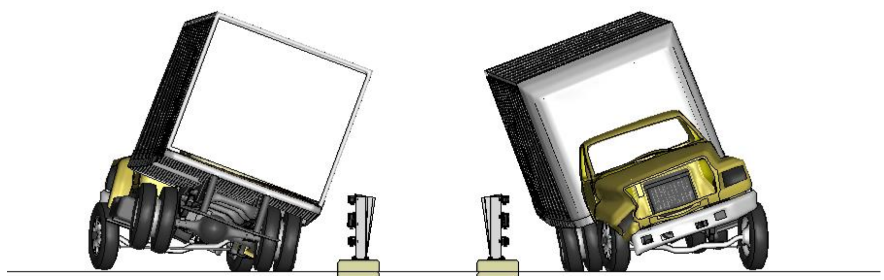

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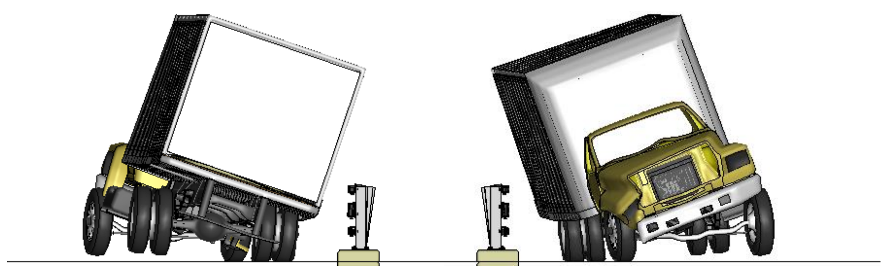

Figure K-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 1.

0.00 seconds

0.05 seconds

0.10 seconds

0.15 seconds

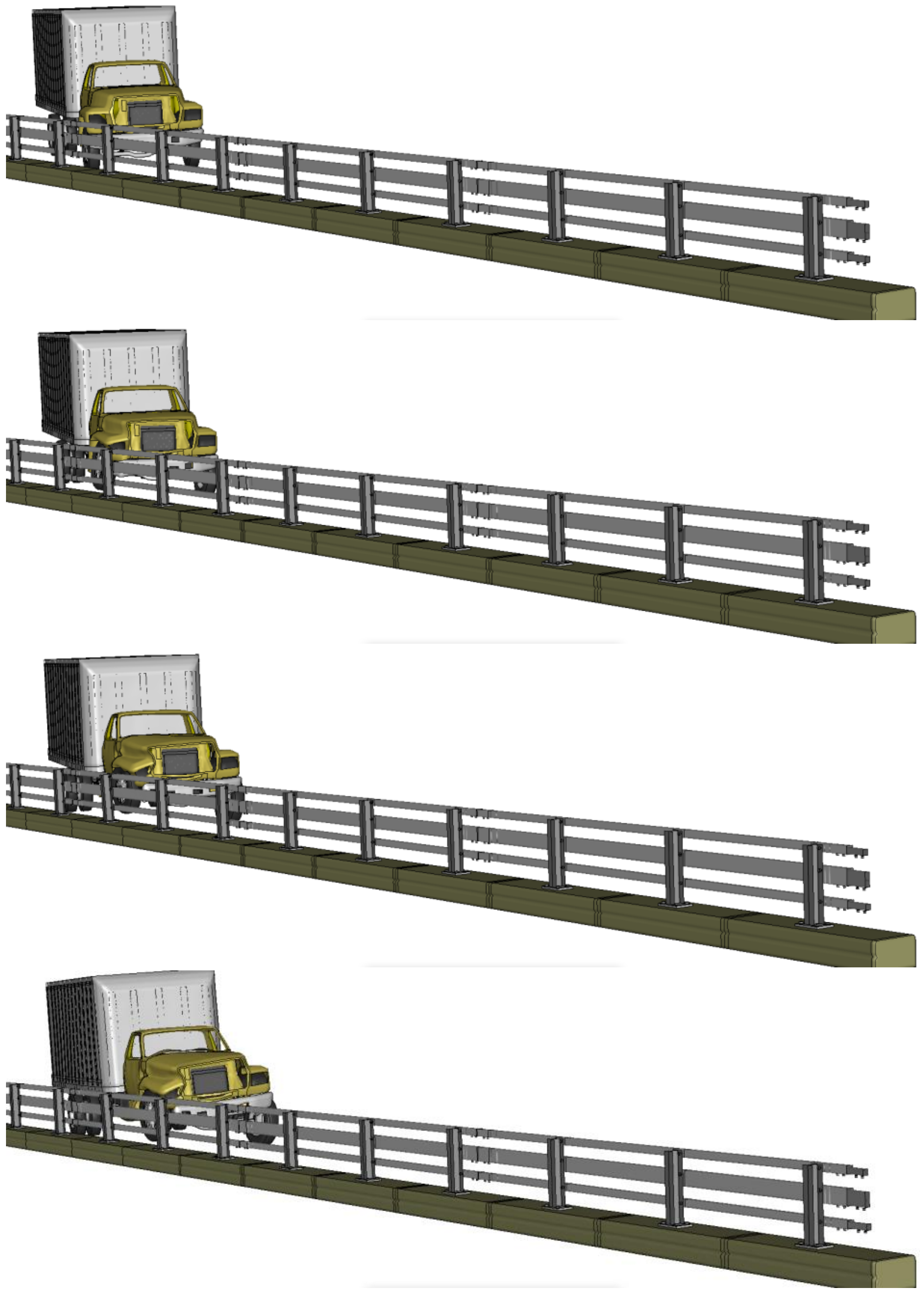

Figure K-3. Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 1.

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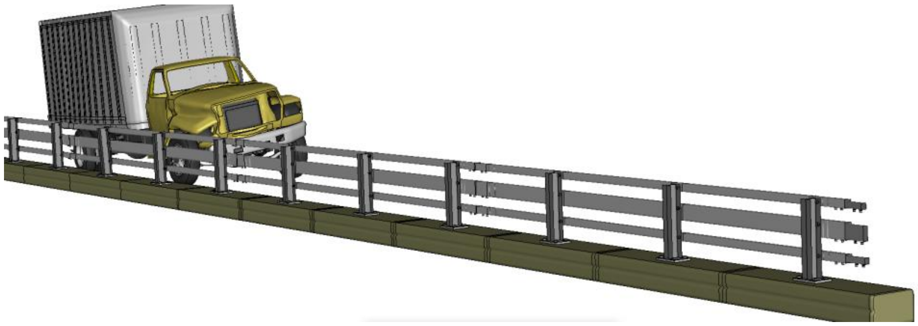

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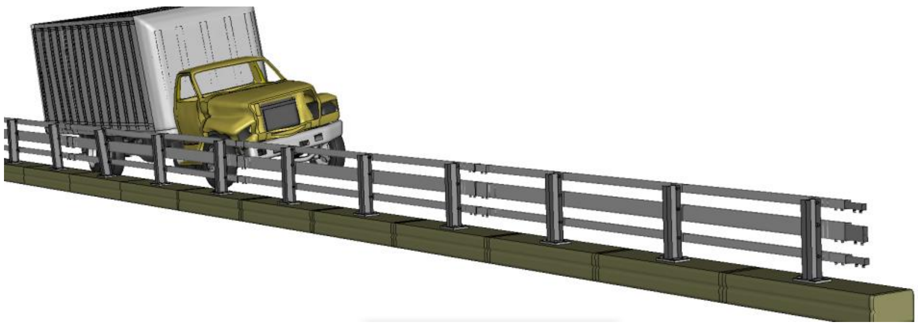

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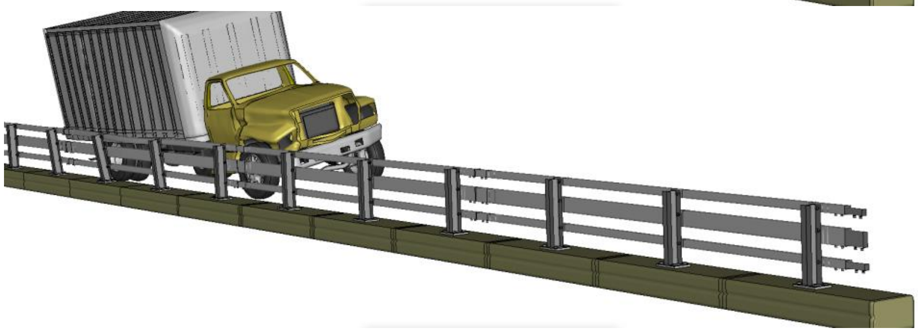

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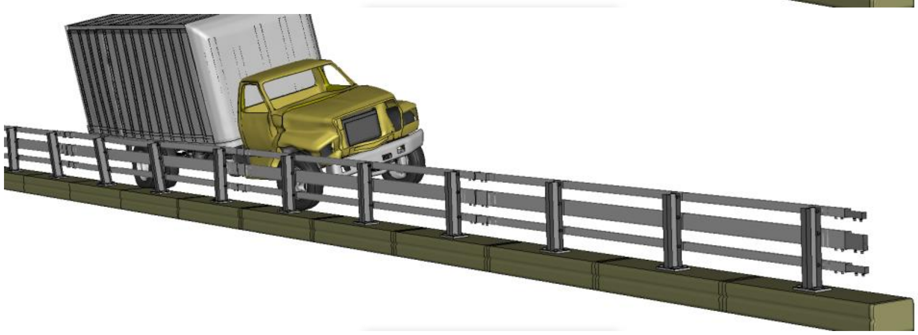
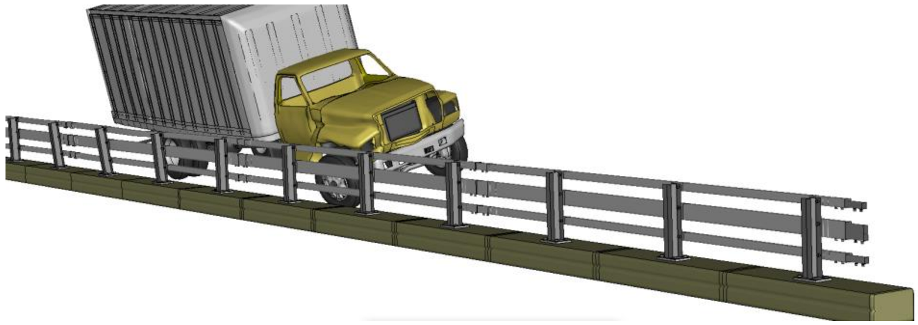


Figure K-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 1.

0.40 seconds



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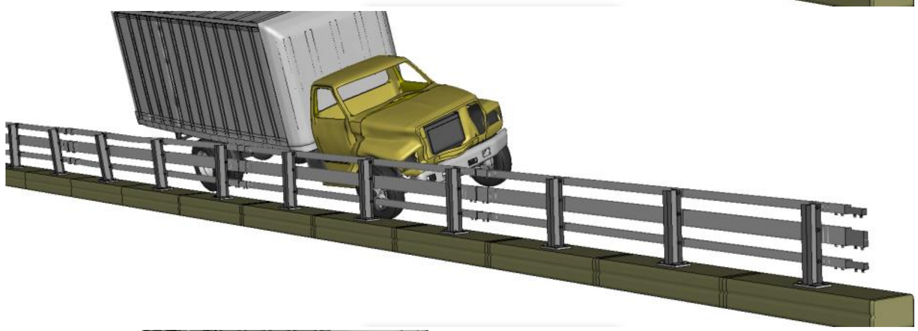

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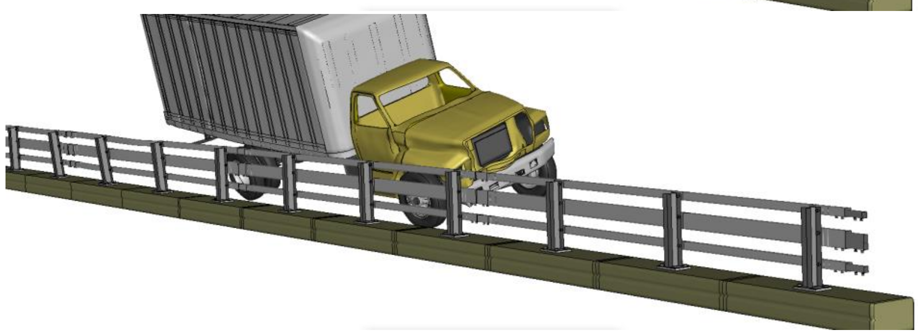

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Figure K-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 1.

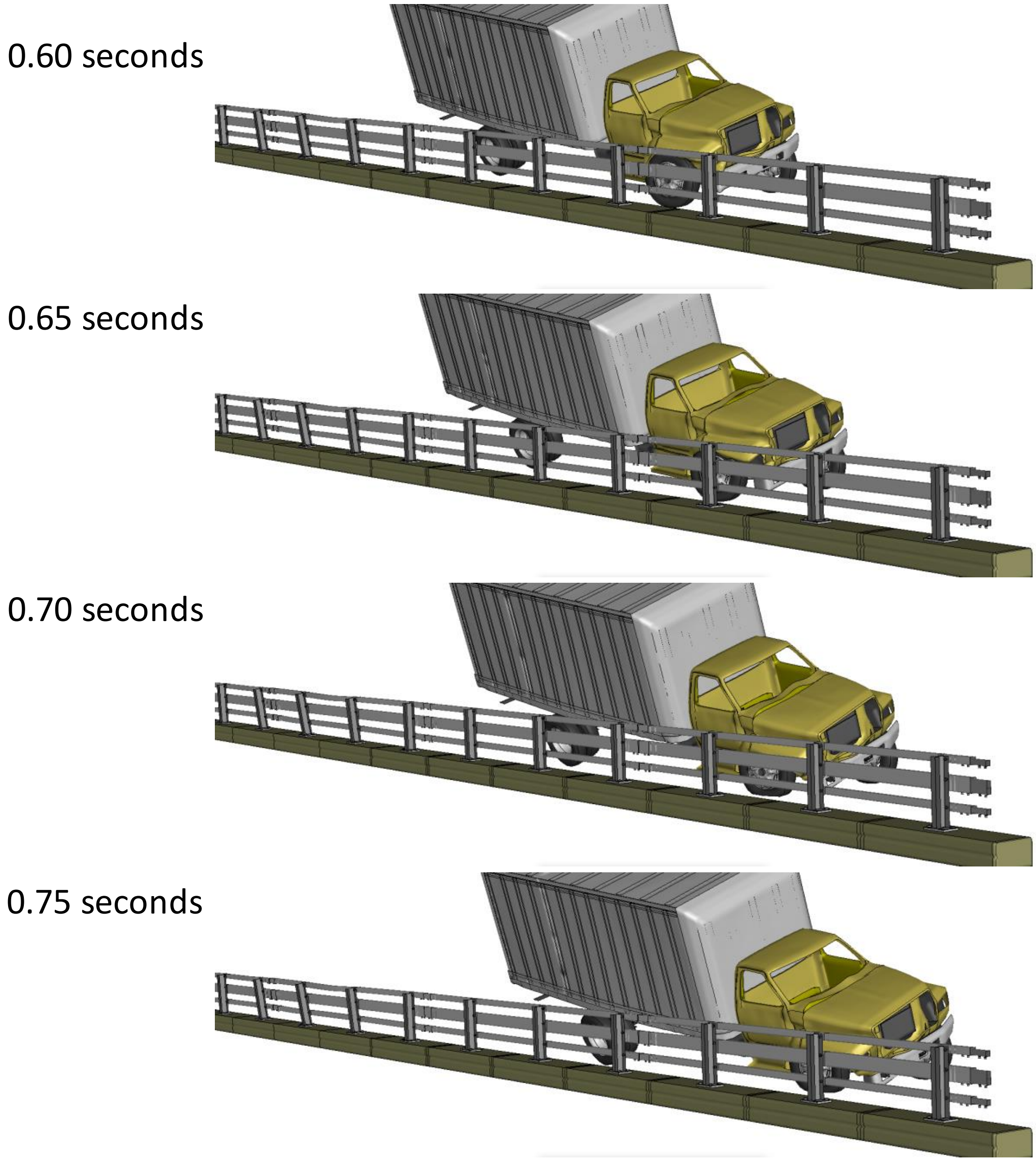


Figure K-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 1.

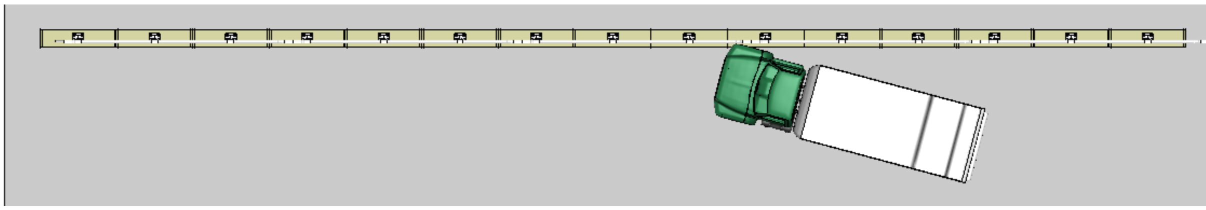
Appendix M

Sequential Views for Test 4-12 on

Curb-Mounted NETC 3-Bar Bridge Rail

(Case 2 – 50” Truck Bed)

0.00 seconds



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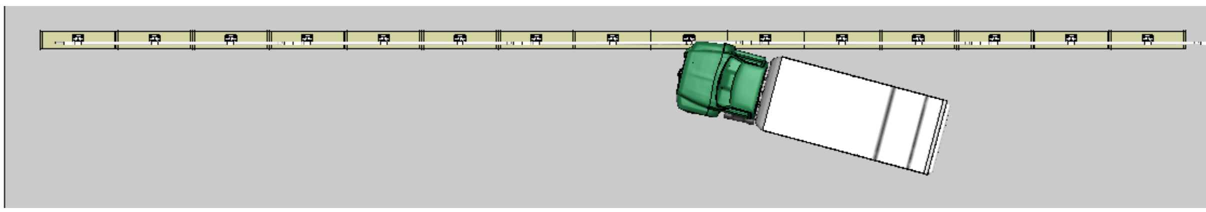

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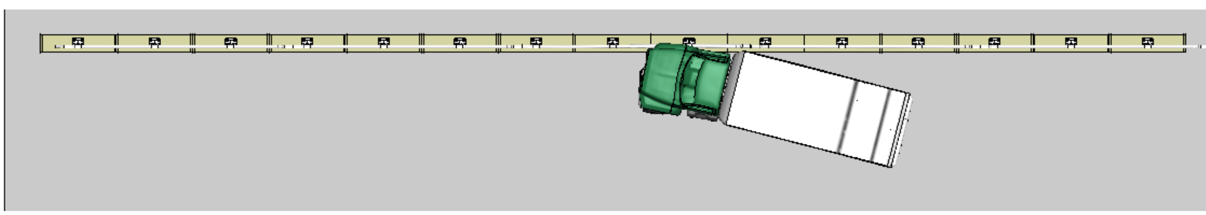

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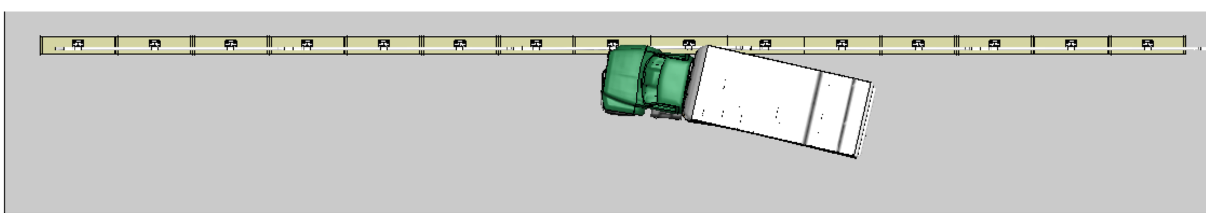

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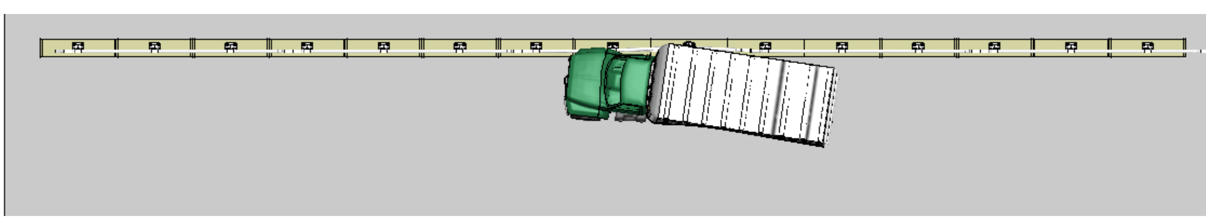
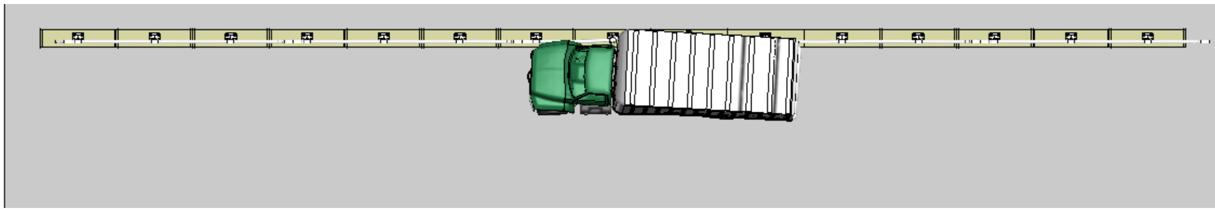


Figure M-1. Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 2.

0.25 seconds



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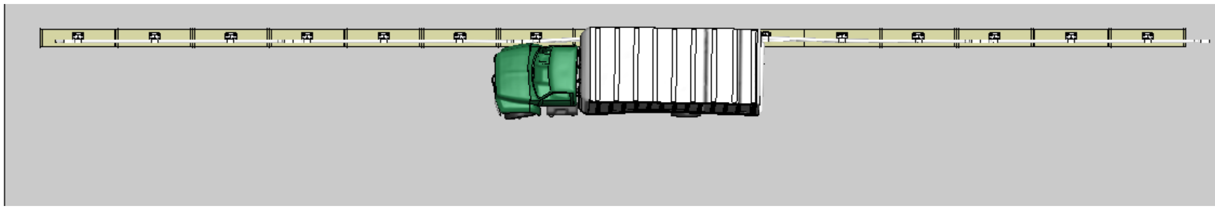

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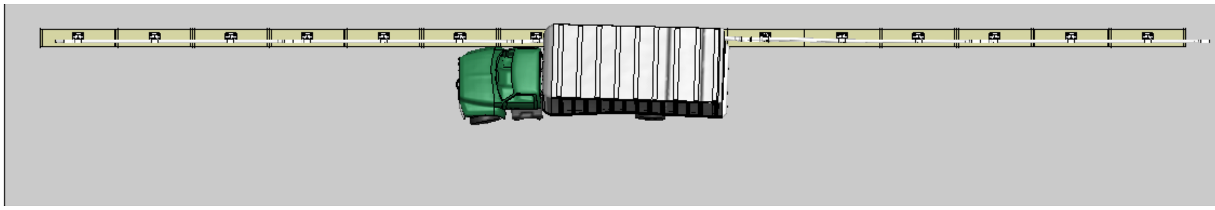

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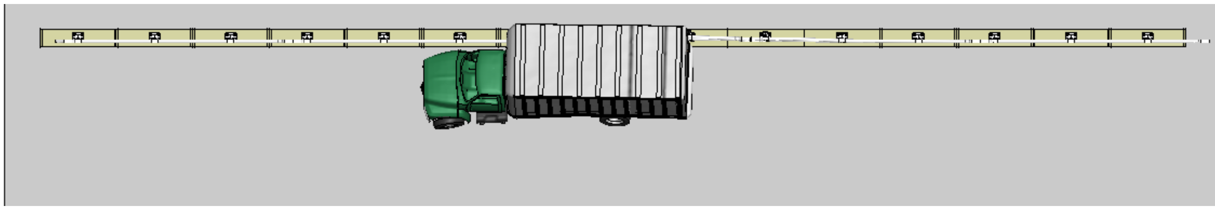

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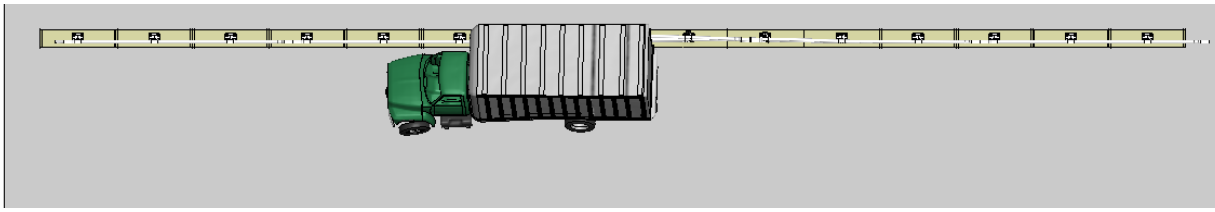

Figure M-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 2.

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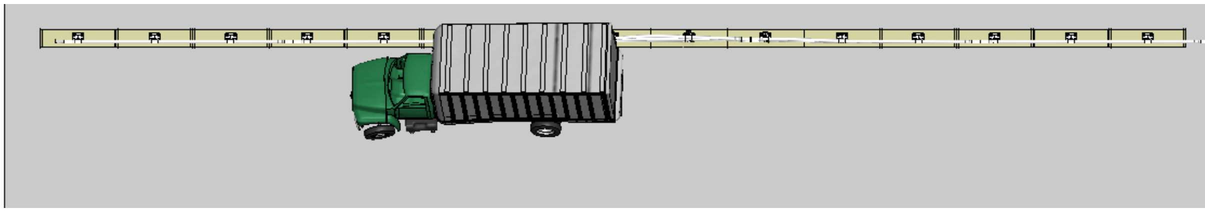

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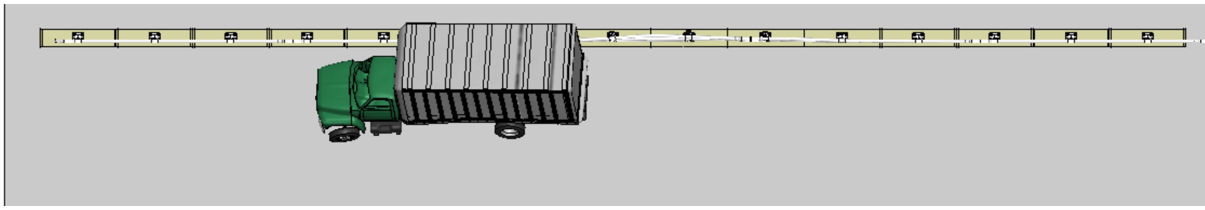

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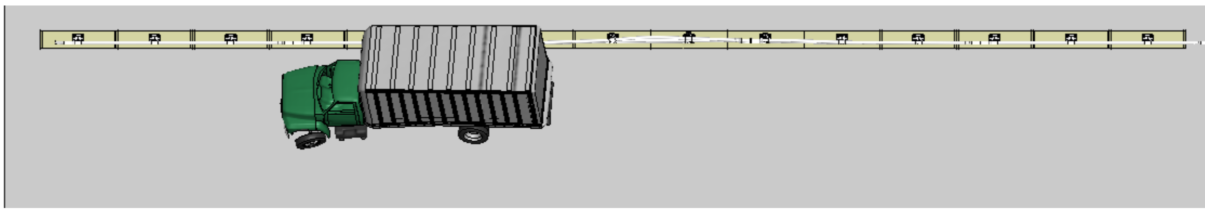

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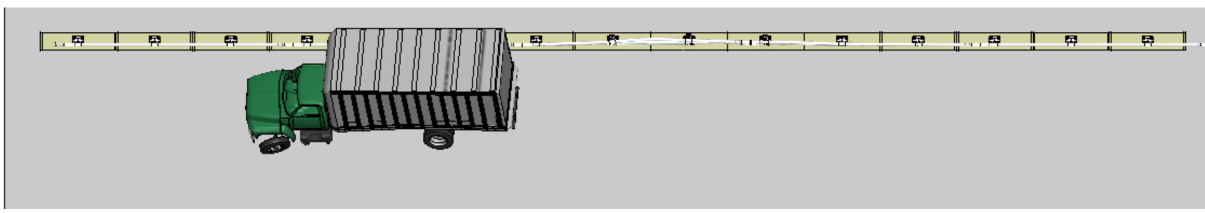

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Figure M-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint - Case 2.

0.75 seconds

0.80 seconds

0.85 seconds

0.90 seconds

0.95 seconds

Figure M-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an overhead viewpoint – Case 2.

0.00 seconds

0.05 seconds

0.10 seconds

0.15 seconds

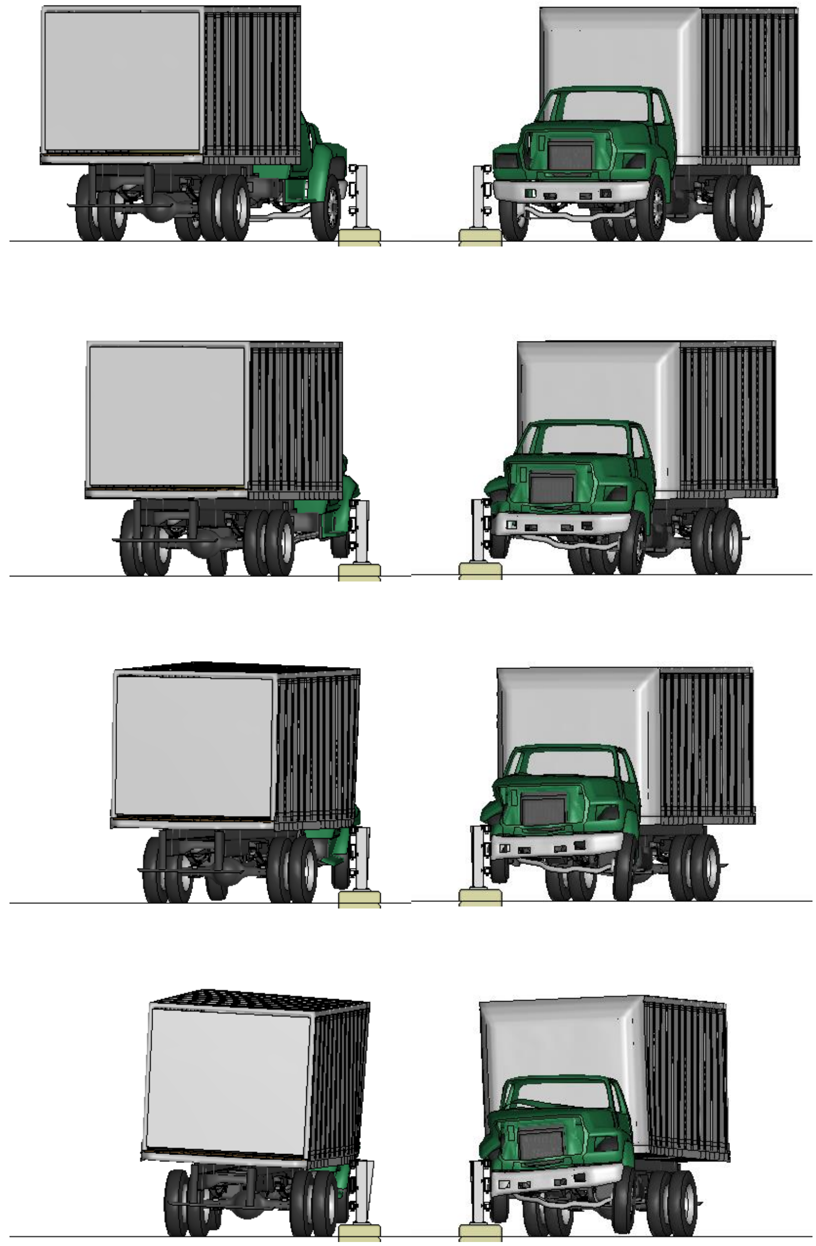
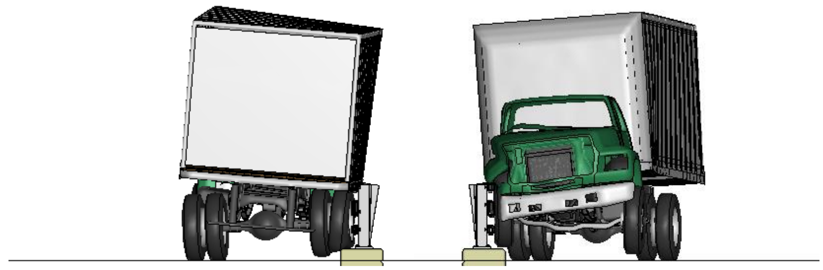


Figure M-2. Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 2.

0.20 seconds



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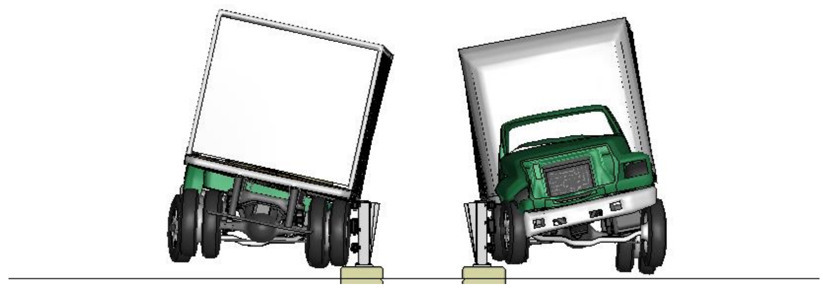

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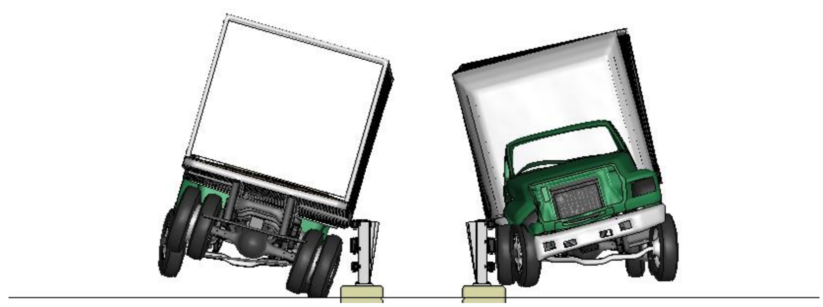

Figure M-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 2.

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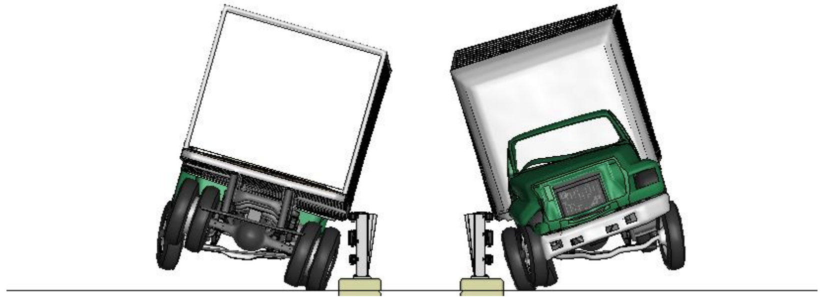

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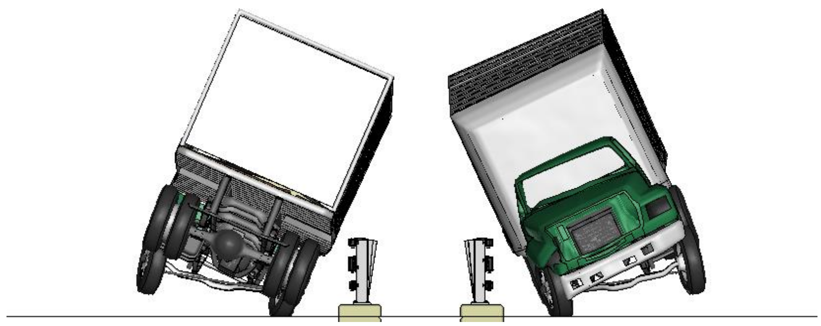

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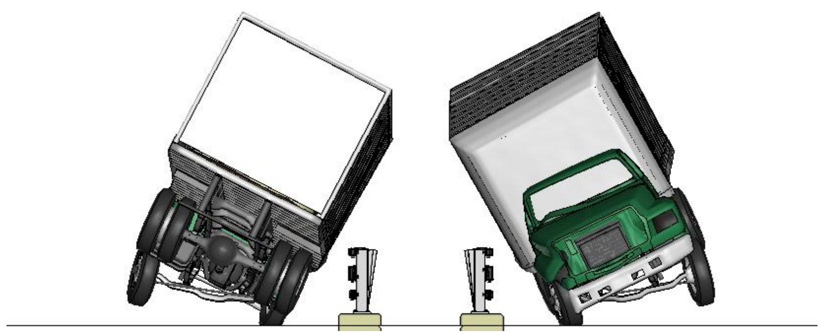
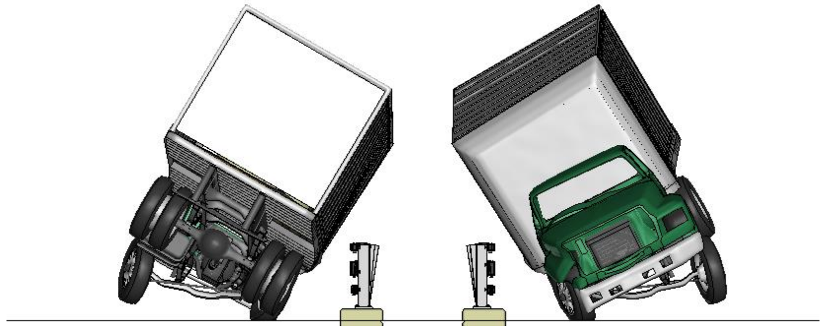


Figure M-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 2.

0.60 seconds



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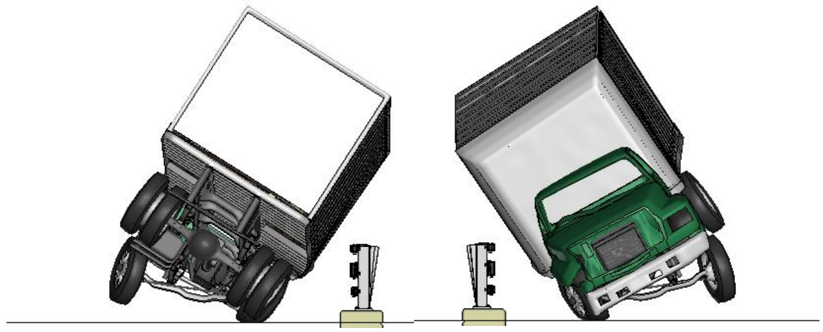

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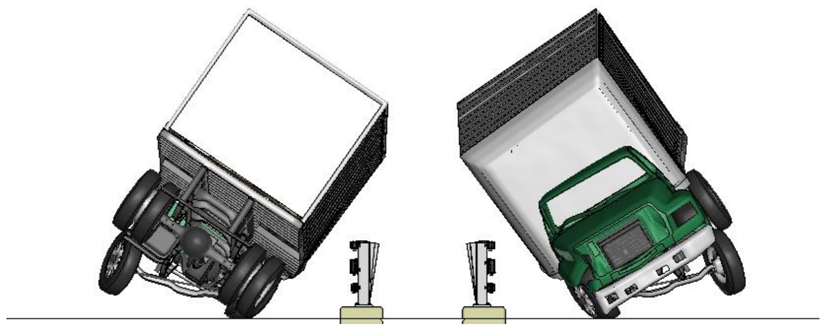

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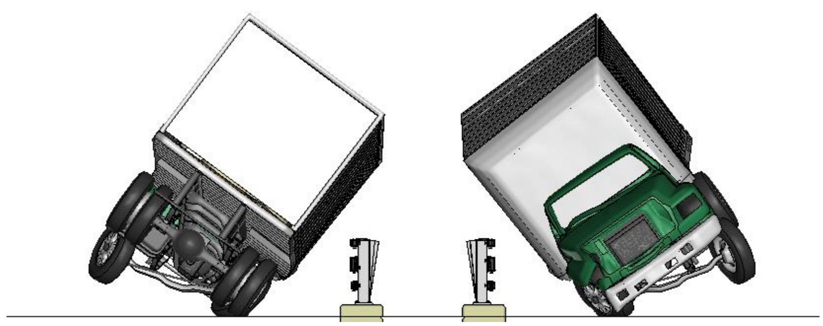

Figure M-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 2.

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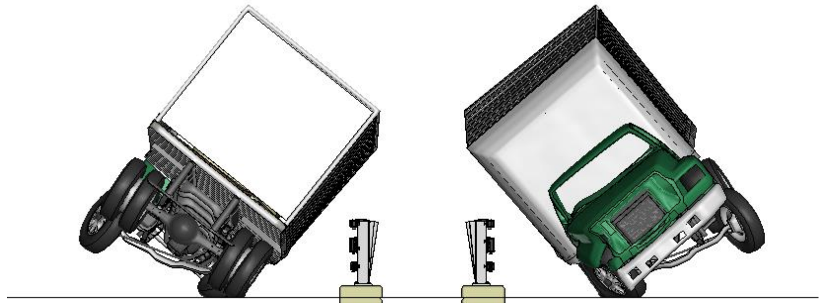

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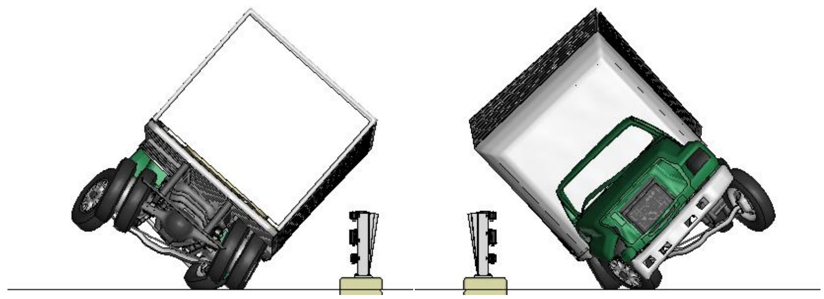

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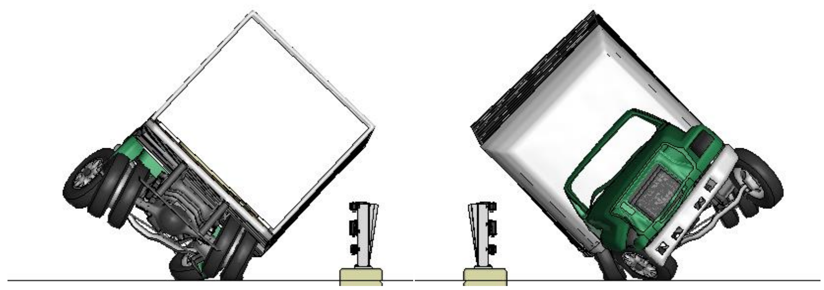

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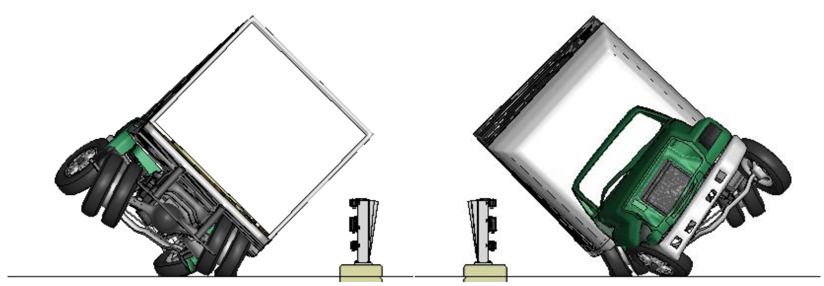

Figure M-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from upstream and downstream viewpoints – Case 2.

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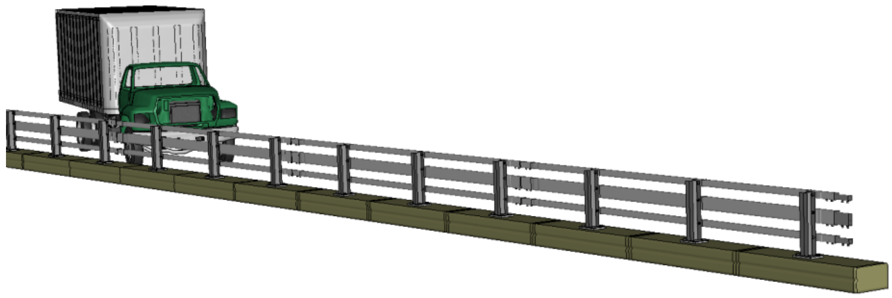

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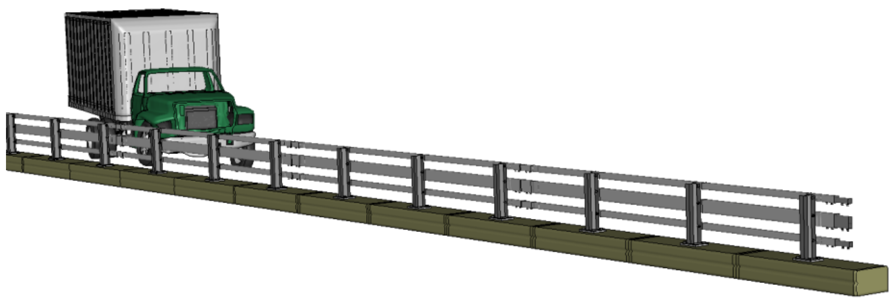

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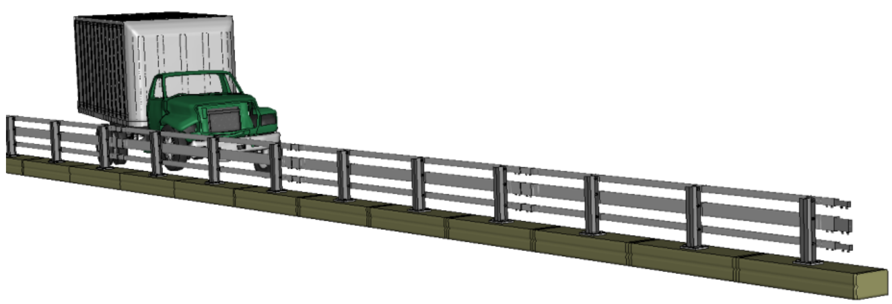

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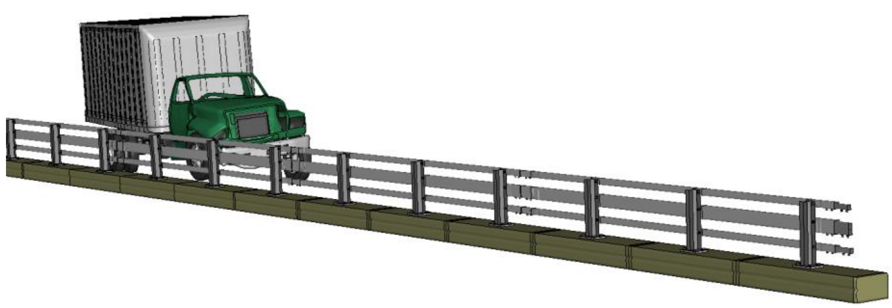

Figure M-3. Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 2.

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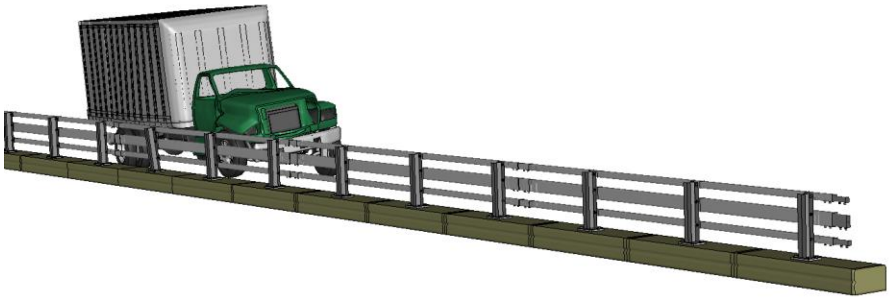

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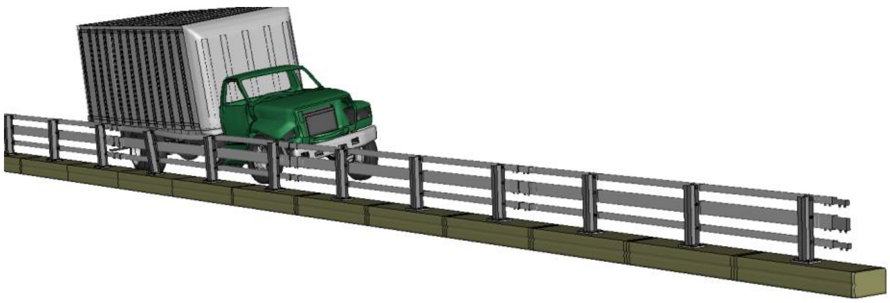

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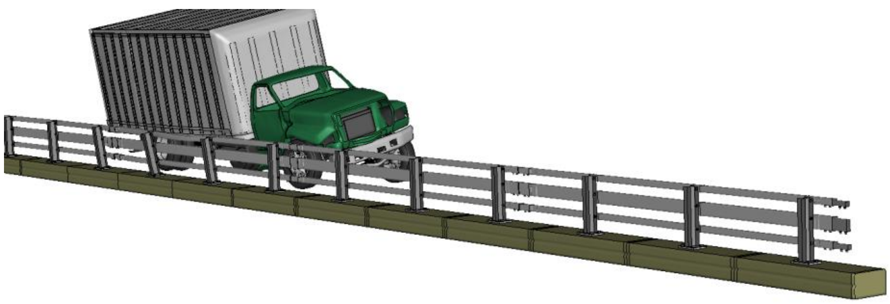

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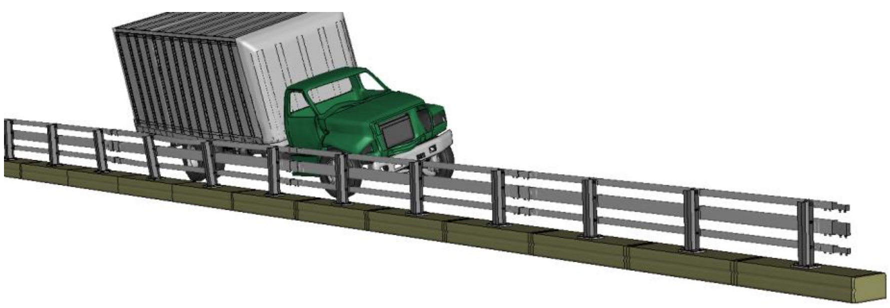

Figure M-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 2.

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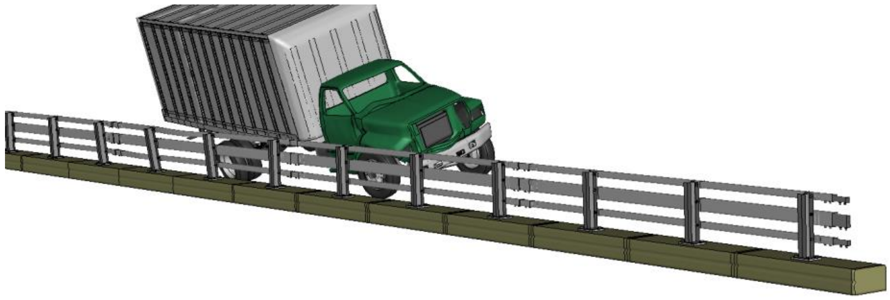

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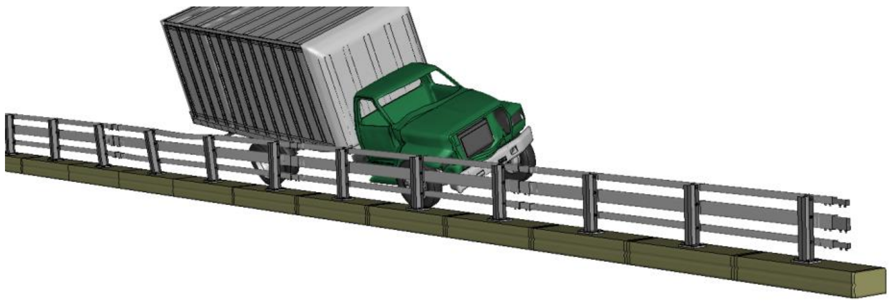

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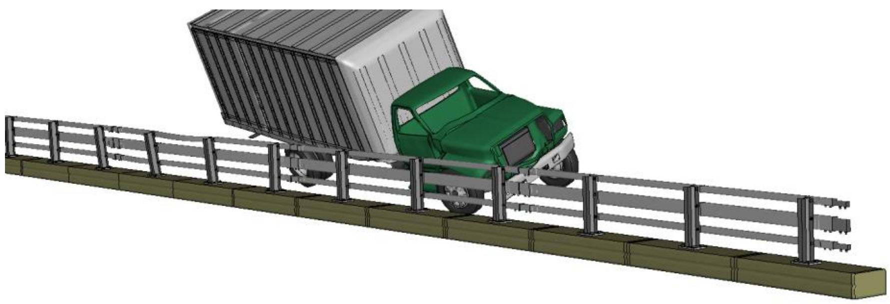

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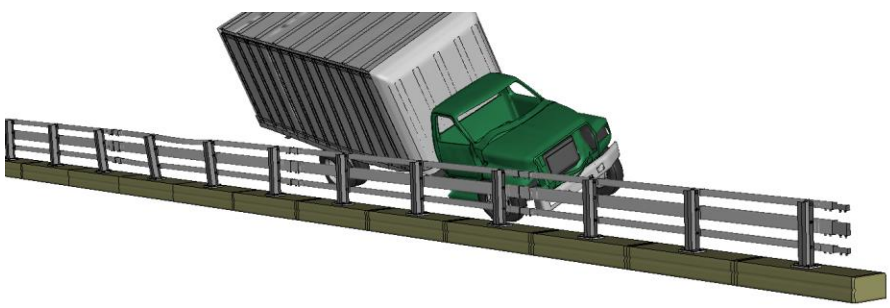

Figure M-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 2.

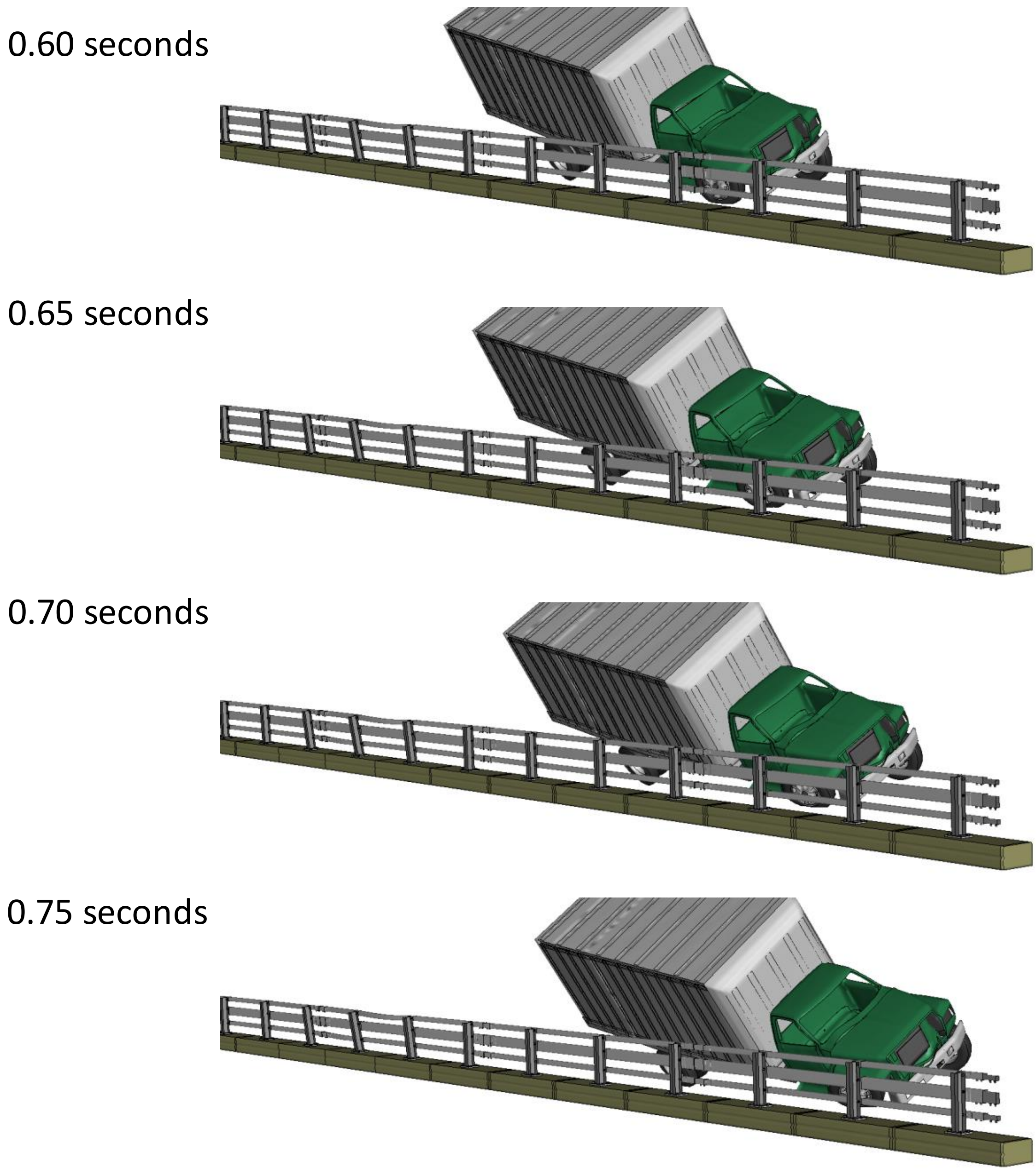

Figure M-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 3-Bar bridge rail from an oblique viewpoint – Case 2.

Appendix N

Sequential Views for Test 4-20 on

AGT 3-Bar Transition

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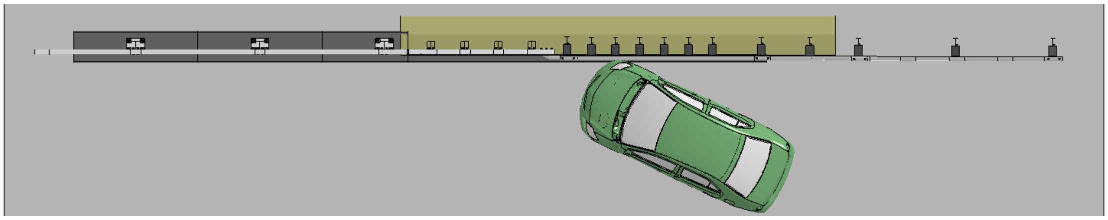

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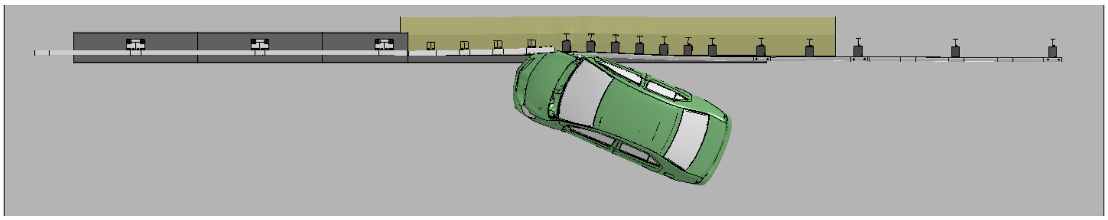

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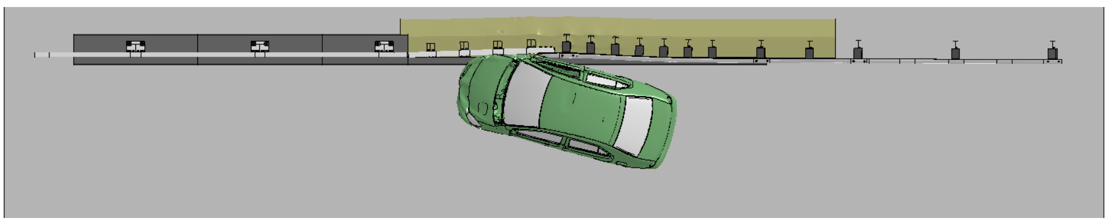

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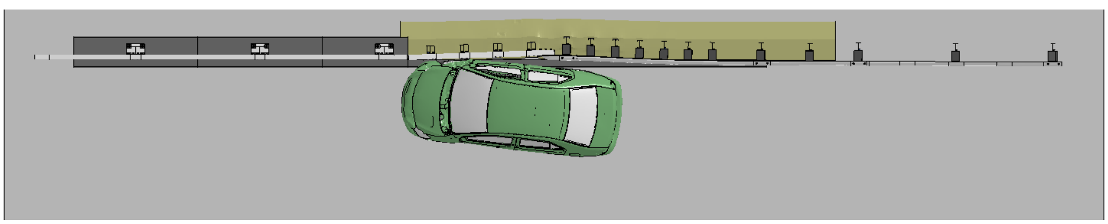

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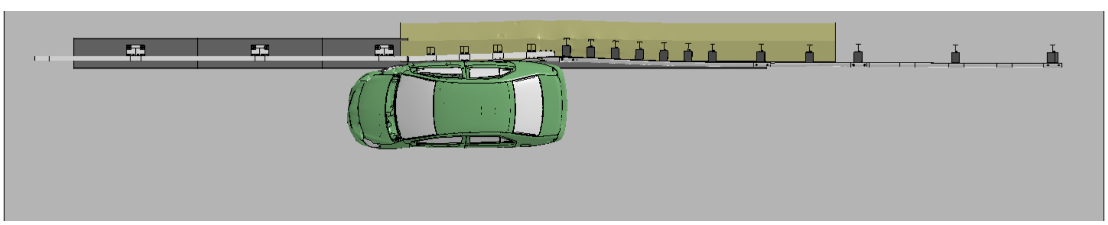
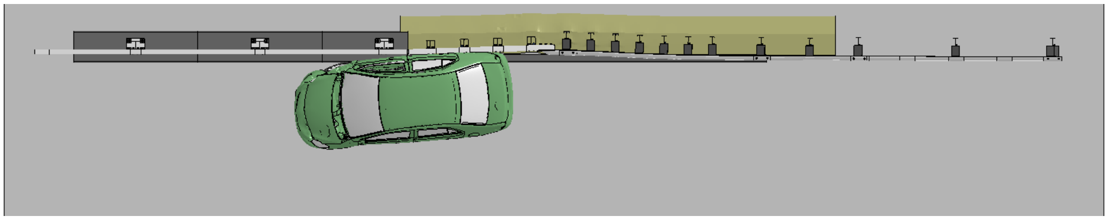


Figure N-1. Sequential views from analysis of MASH Test 4-20 for AGT 3-Bar transition from an overhead viewpoint.

0.25 seconds



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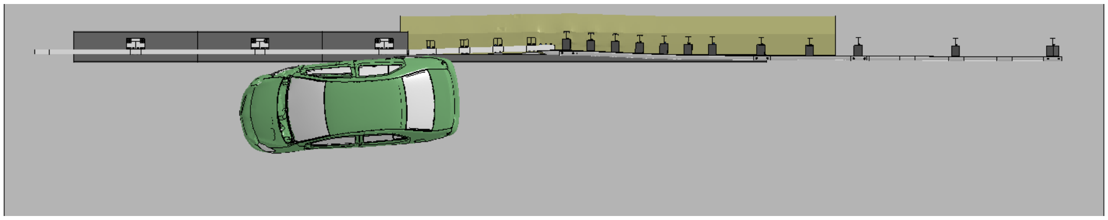

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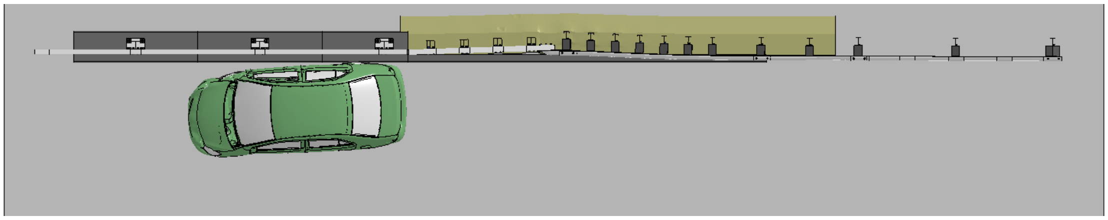

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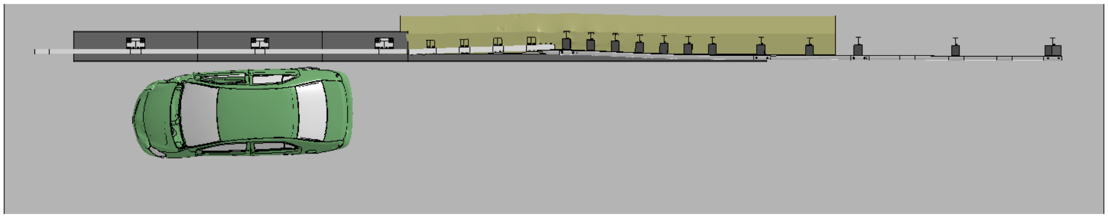

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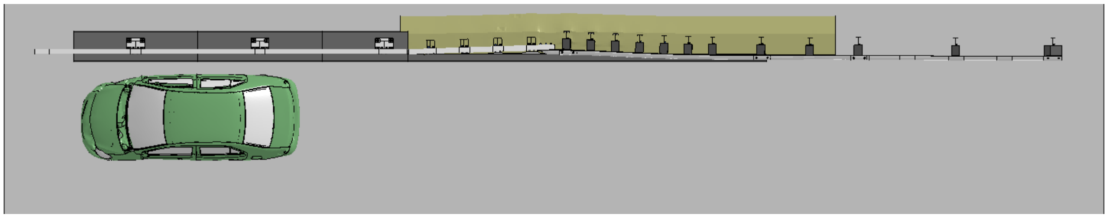


Figure N-1. [Continued] Sequential views from analysis of MASH Test 4-20 for AGT 3-Bar transition from an overhead viewpoint.

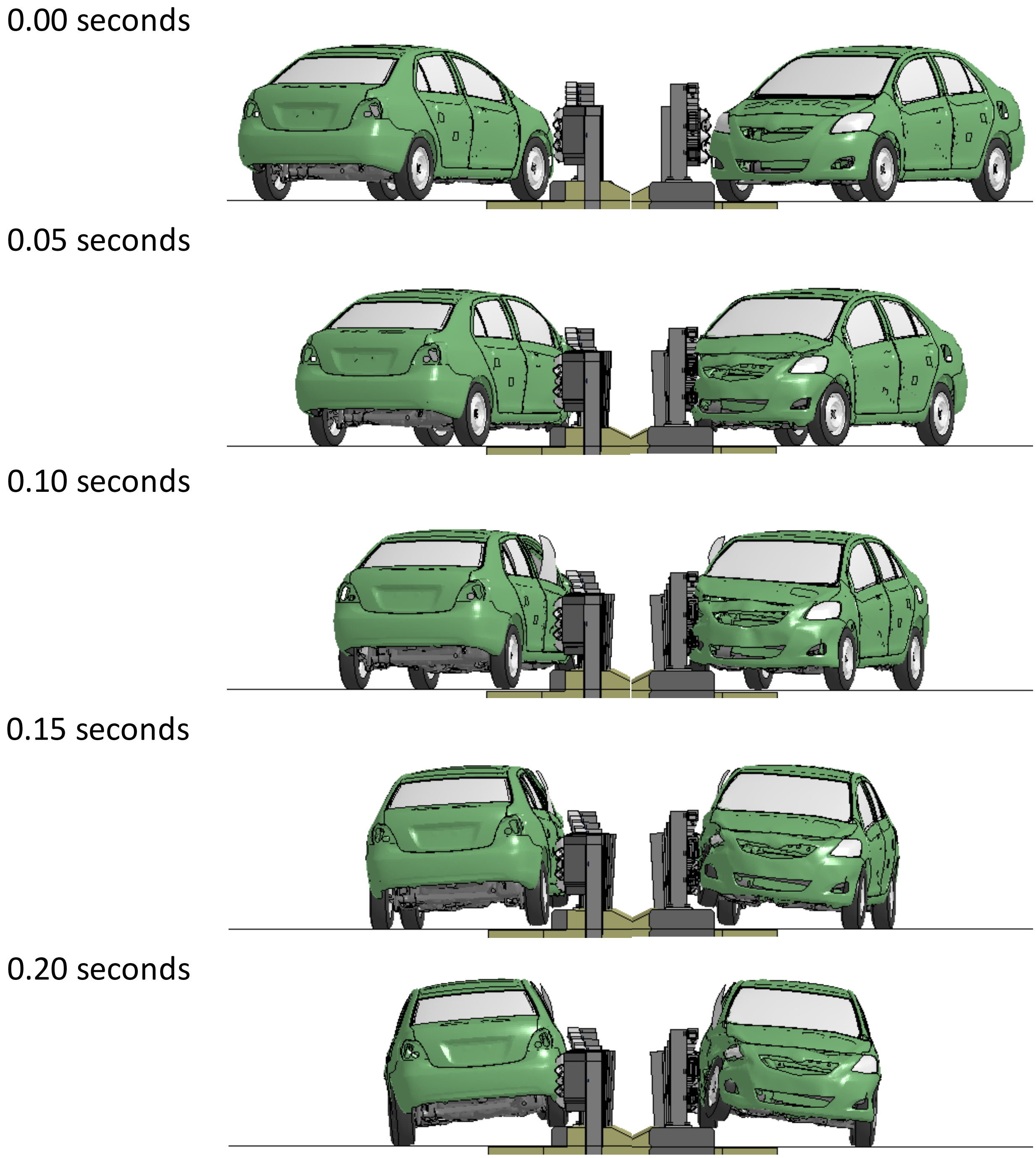
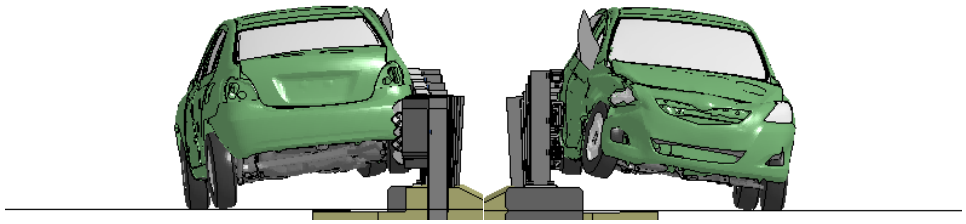


Figure N-2. Sequential views from analysis of MASH Test 4-20 for AGT 3-Bar transition from upstream and downstream viewpoints.

0.25 seconds



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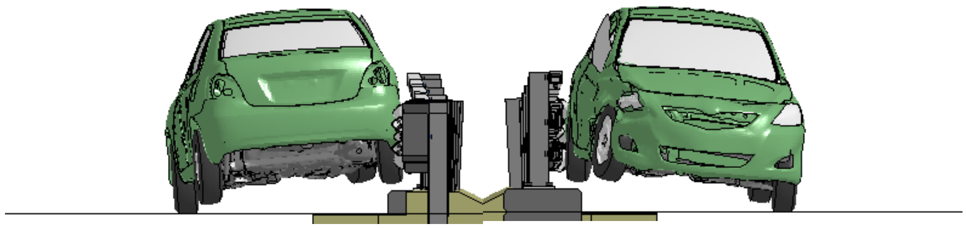

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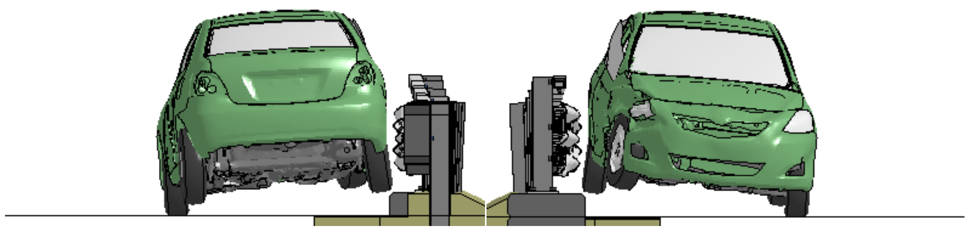

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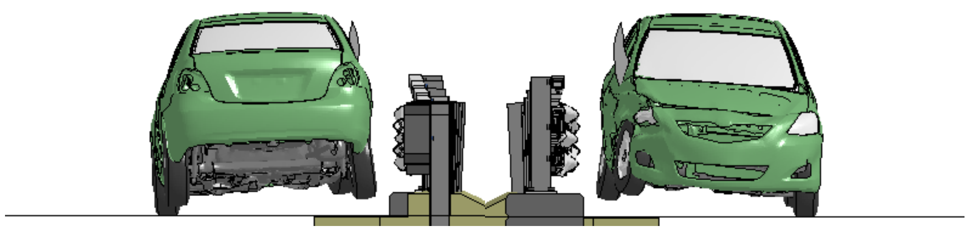

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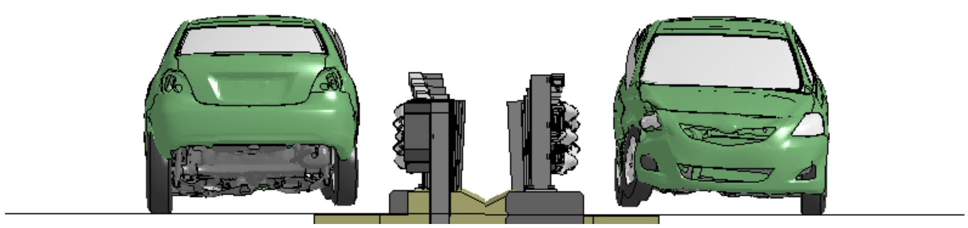
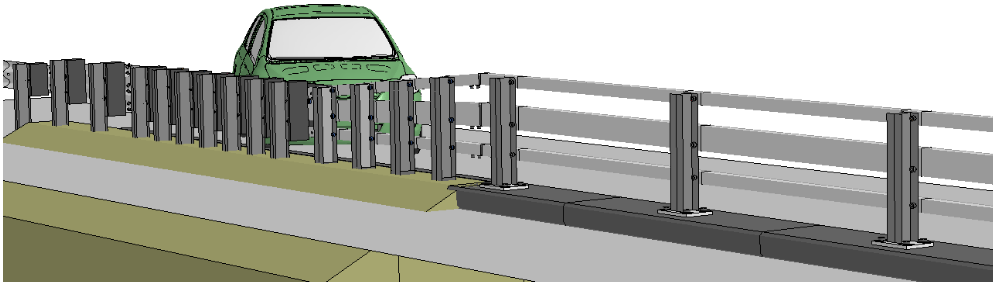


Figure N-2. [Continued] Sequential views from analysis of MASH Test 4-20 for AGT 3-Bar transition from upstream and downstream viewpoints.

0.00 seconds



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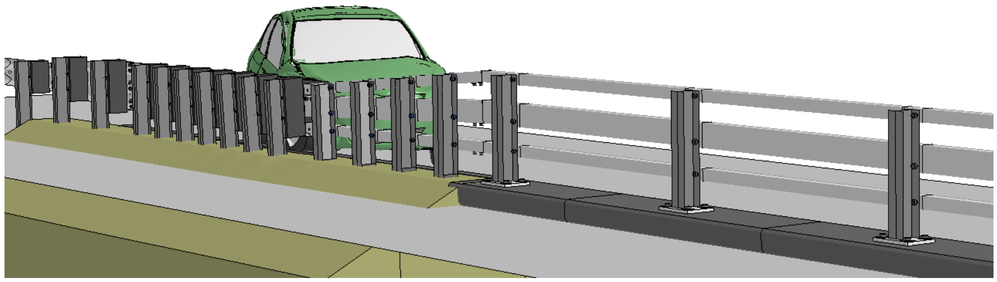

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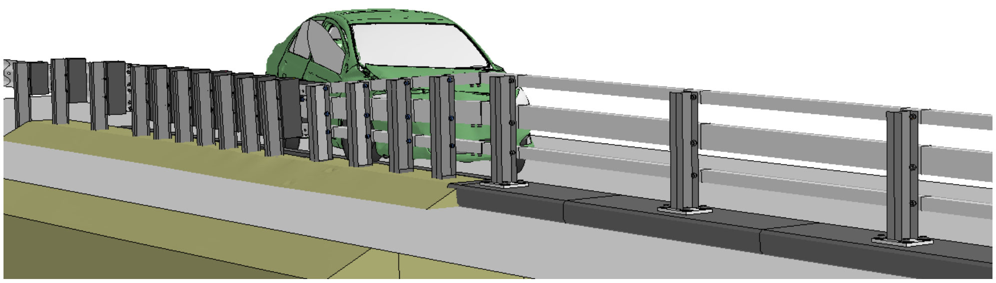

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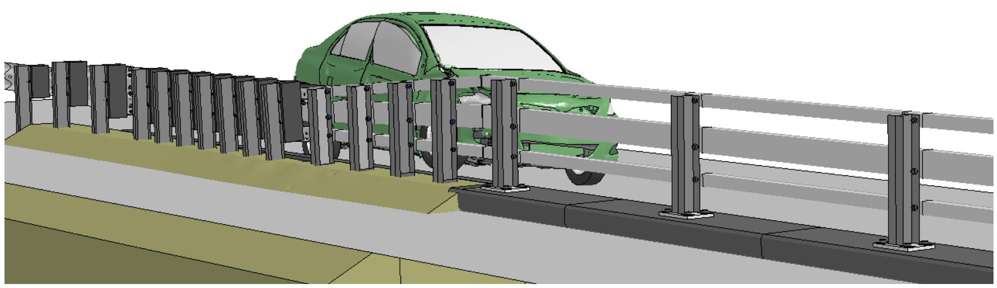
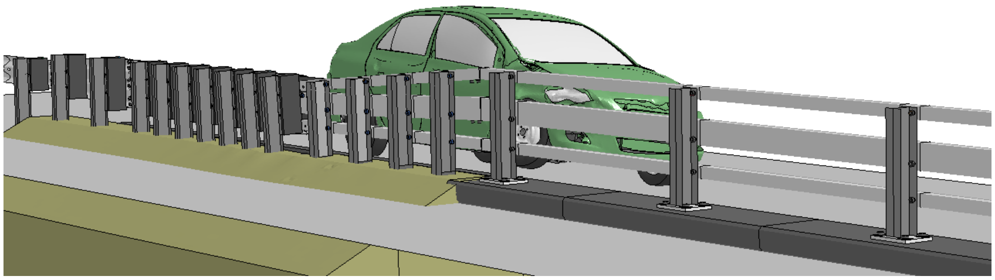


Figure N-3. Sequential views from analysis of MASH Test 4-20 for AGT 3-Bar transition from an oblique viewpoint.

0.20 seconds



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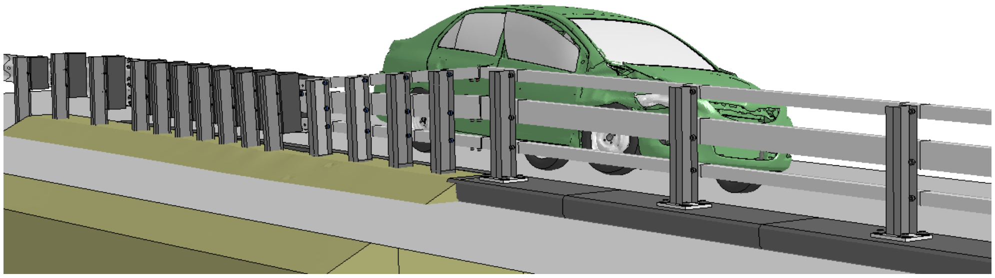

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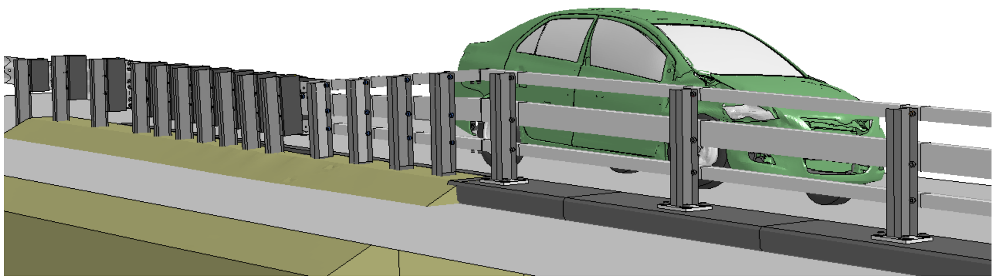

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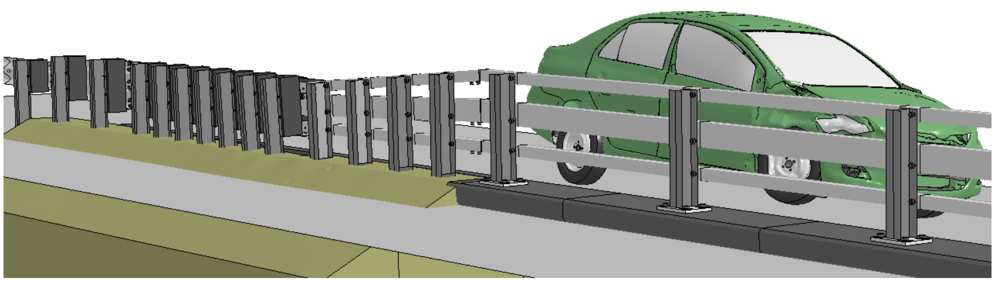


Figure N-3. [Continued] Sequential views from analysis of MASH Test 4-20 for AGT 3-Bar transition from an oblique viewpoint.

Appendix O

Sequential Views for Test 4-21 on

AGT 3-Bar Transition

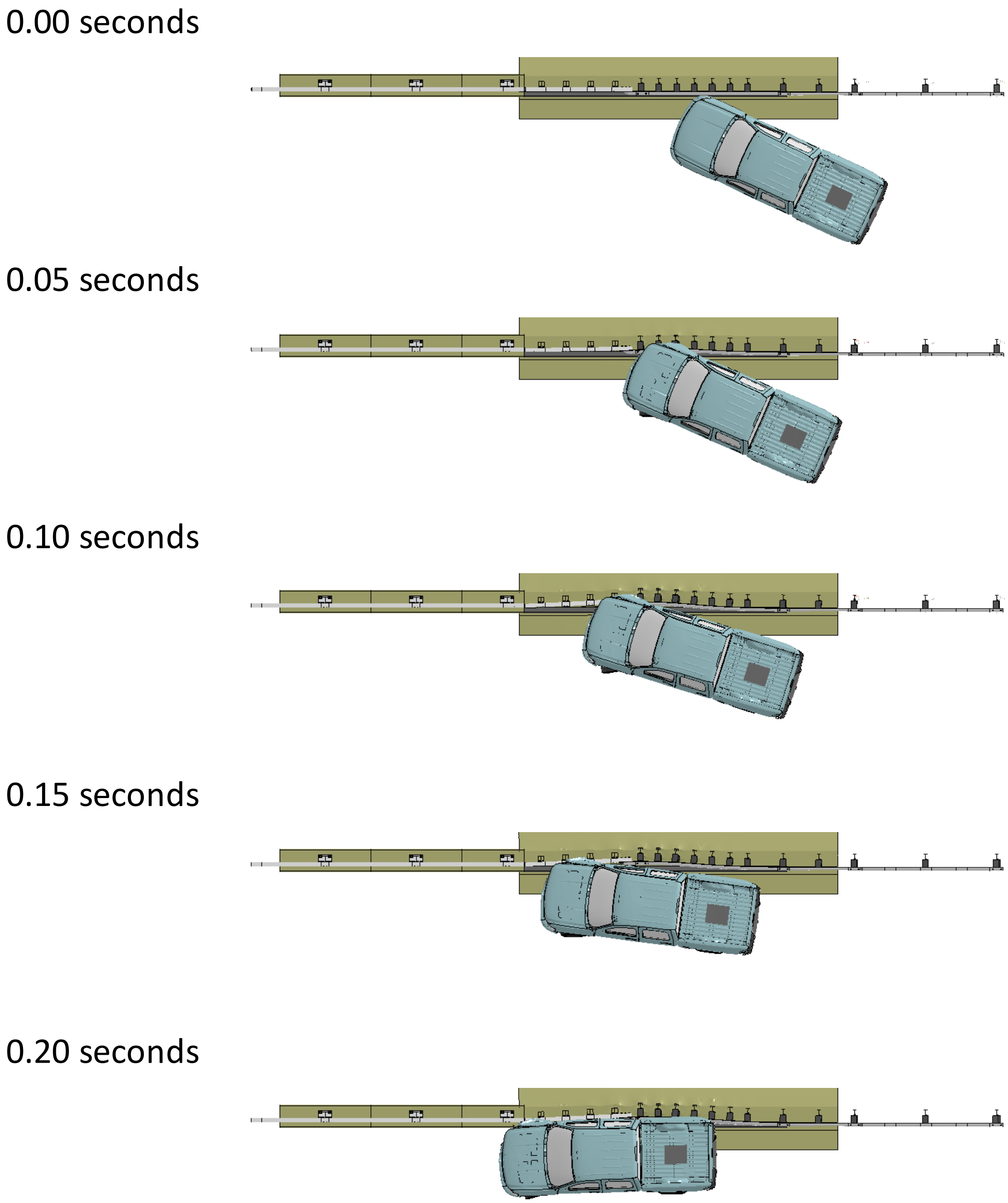
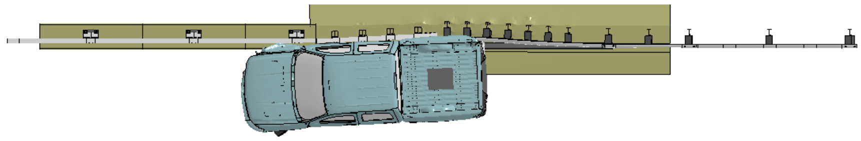


Figure O-1. Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from an overhead viewpoint.

0.25 seconds



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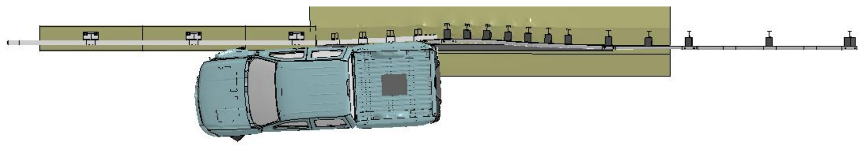

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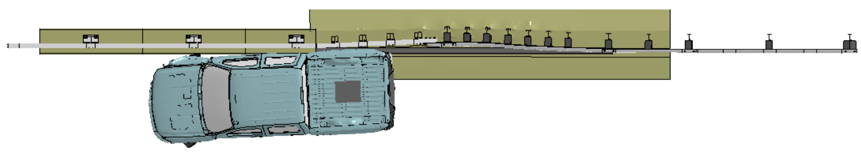

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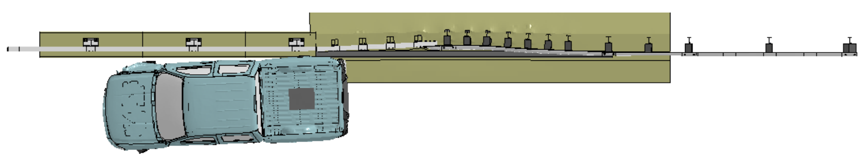

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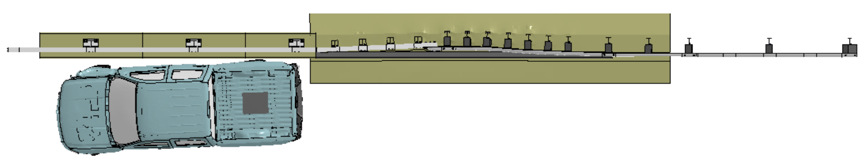
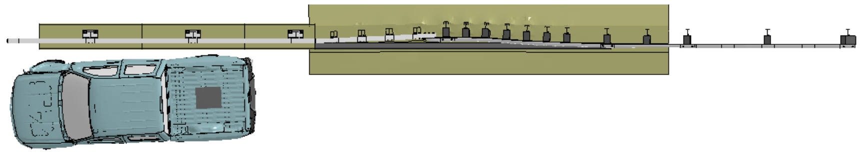


Figure O-1. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from an overhead viewpoint.

0.50 seconds



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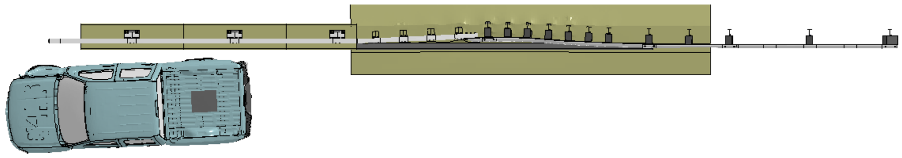

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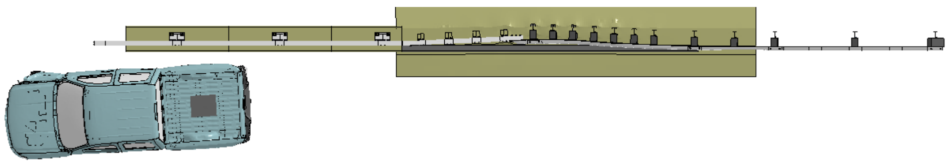

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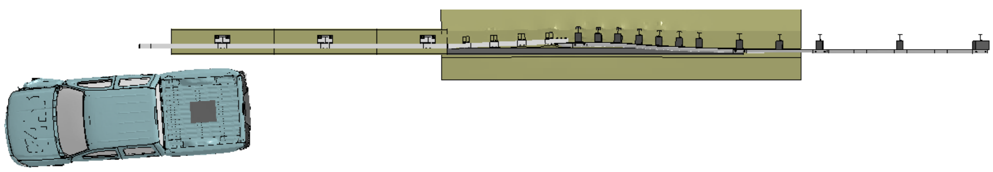

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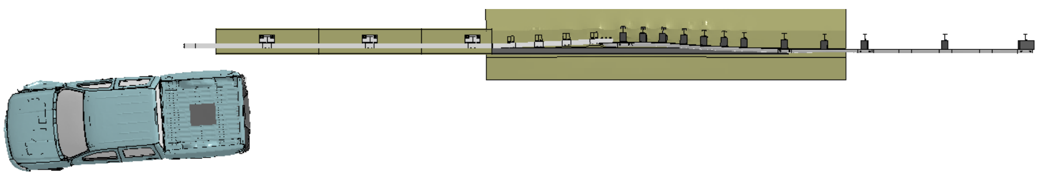


Figure O-1. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from an overhead viewpoint.

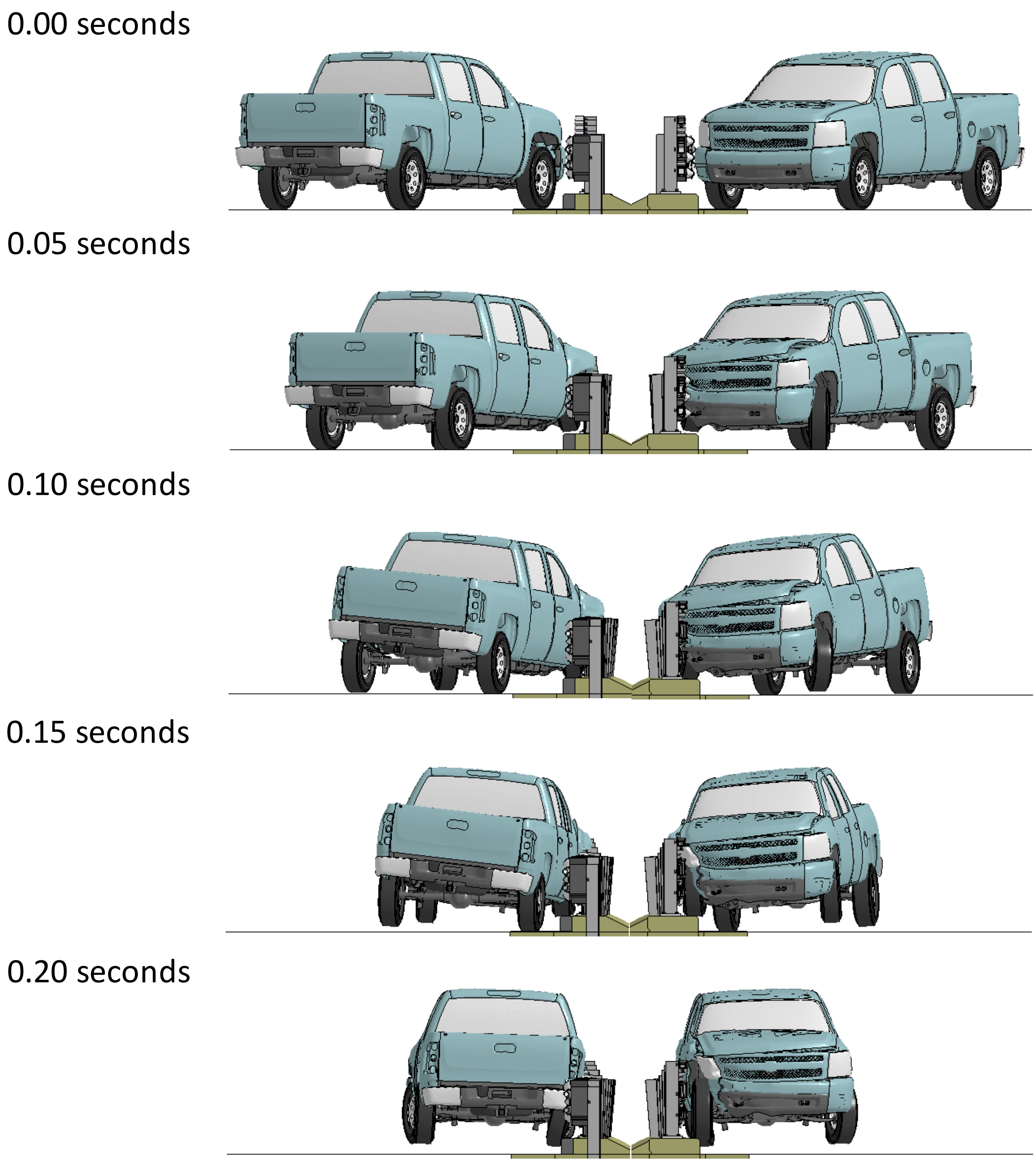
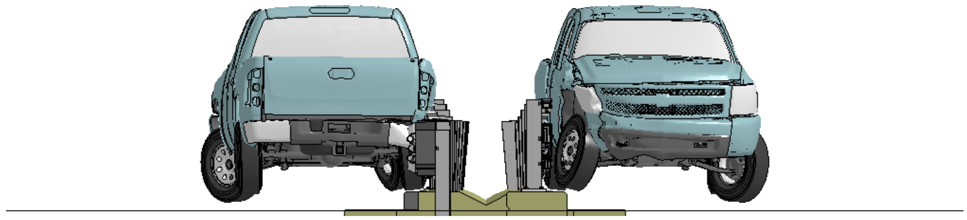


Figure O-2. Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from upstream and downstream viewpoints.

0.25 seconds



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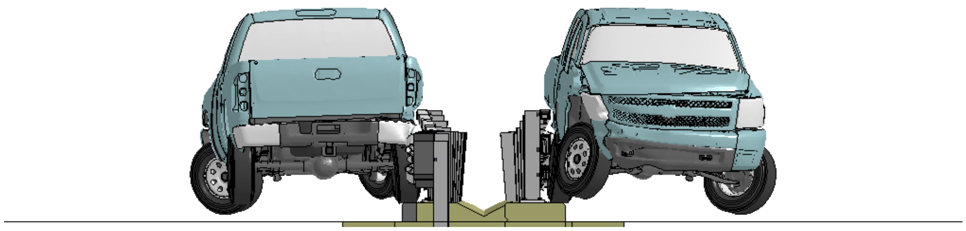

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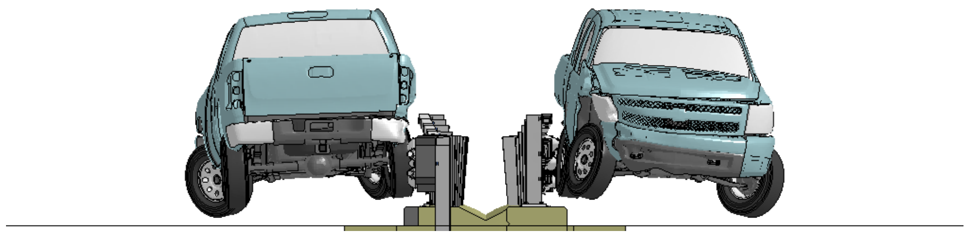

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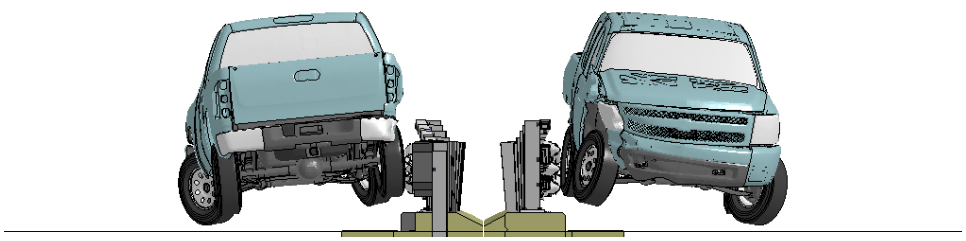

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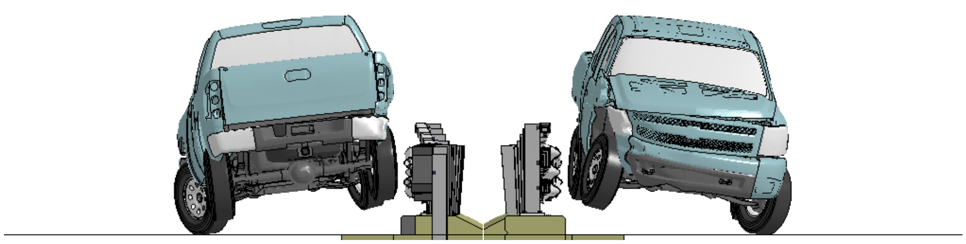

Figure O-2. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from upstream and downstream viewpoints.

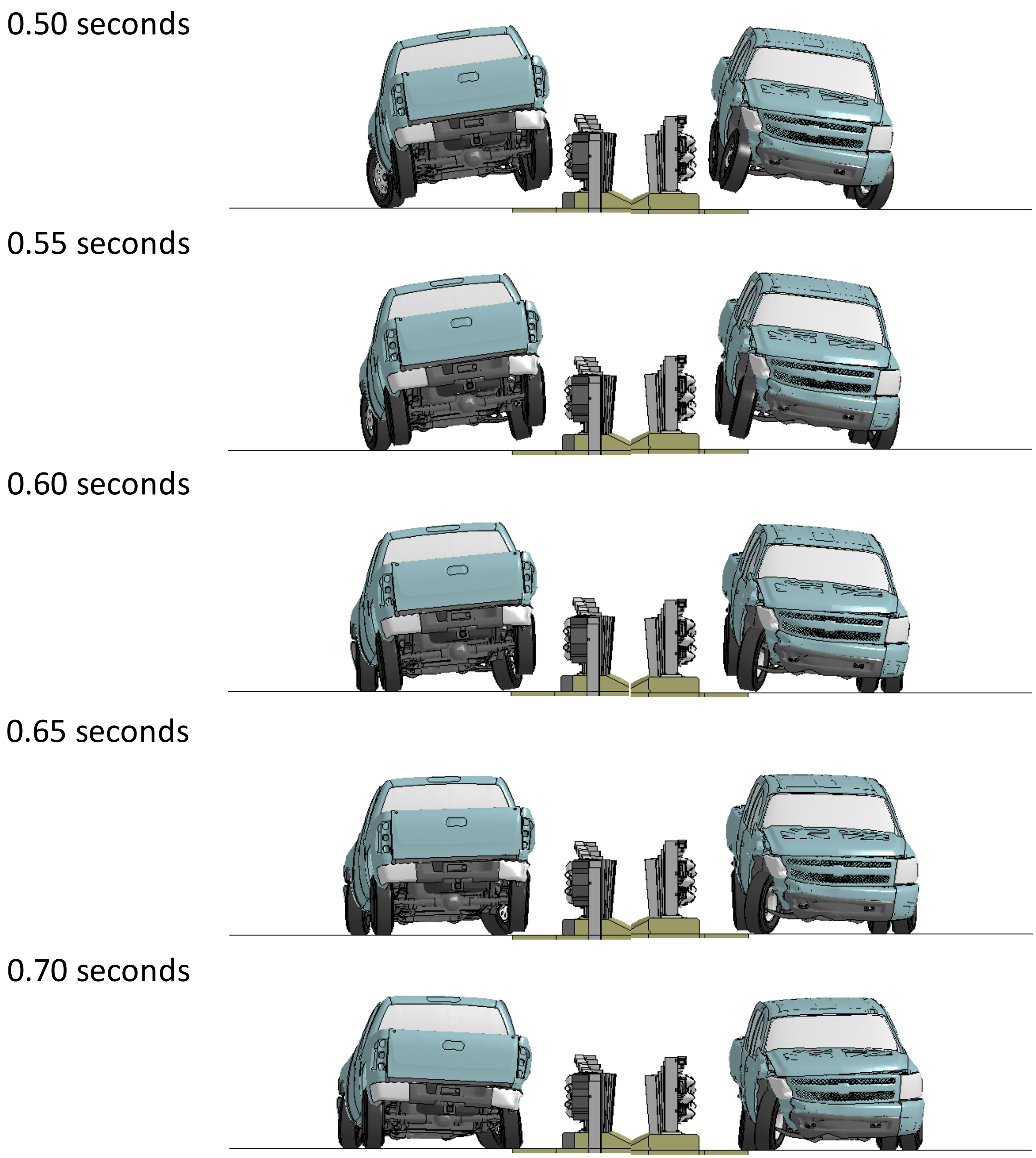

Figure O-2. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from upstream and downstream viewpoints.

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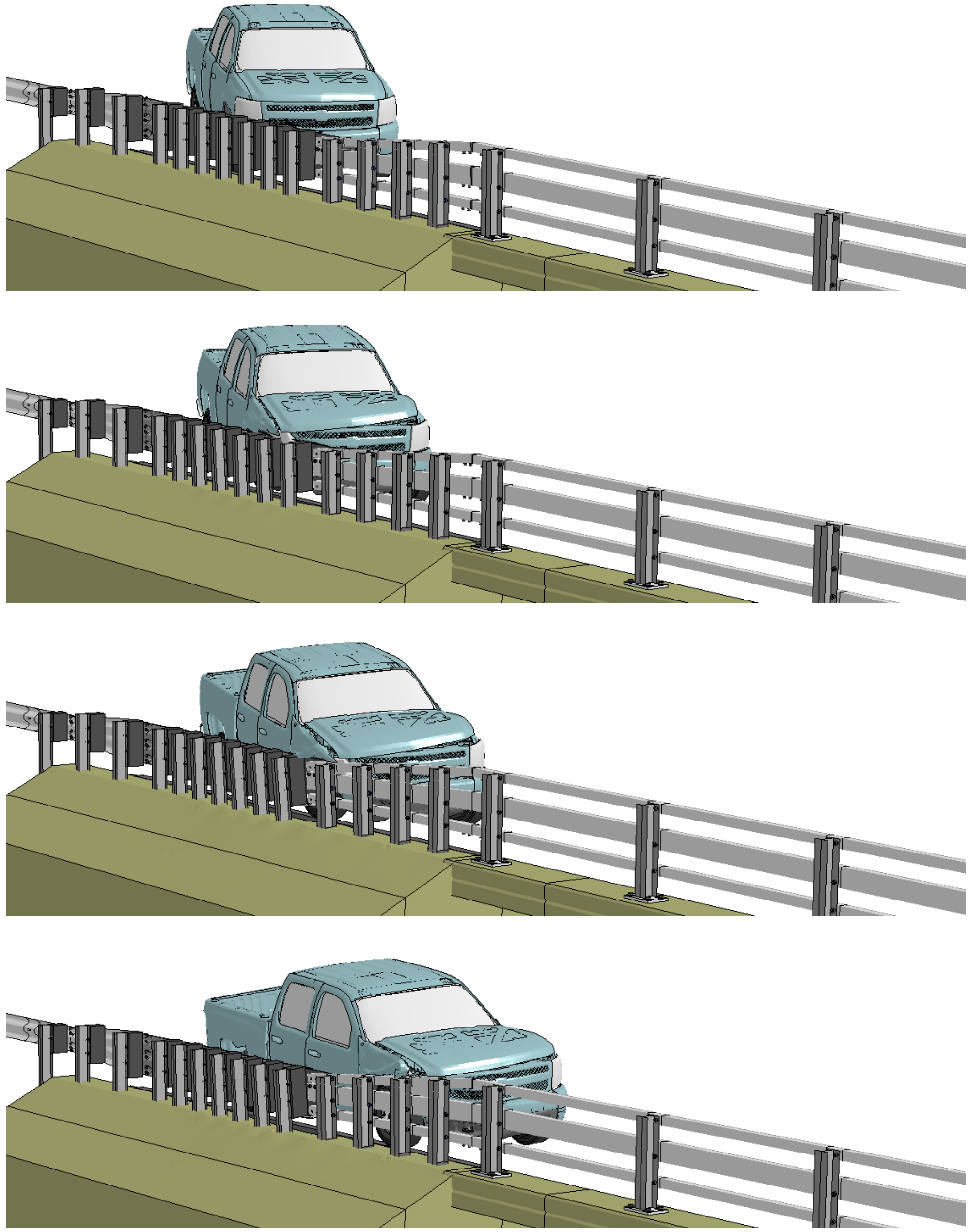

Figure O-3. Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from an oblique viewpoint.

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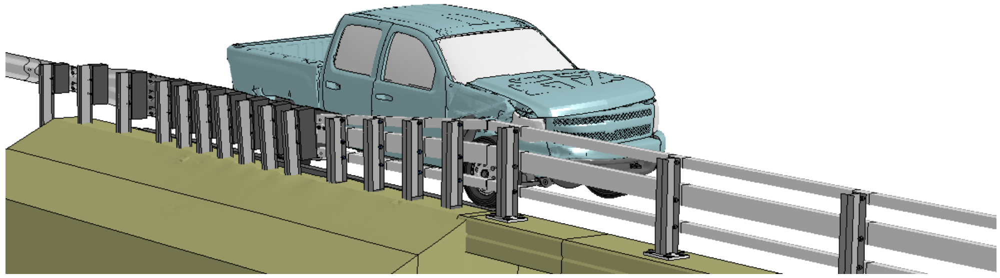

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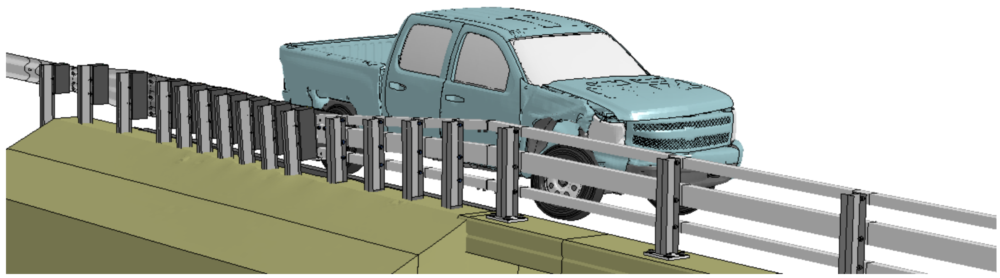

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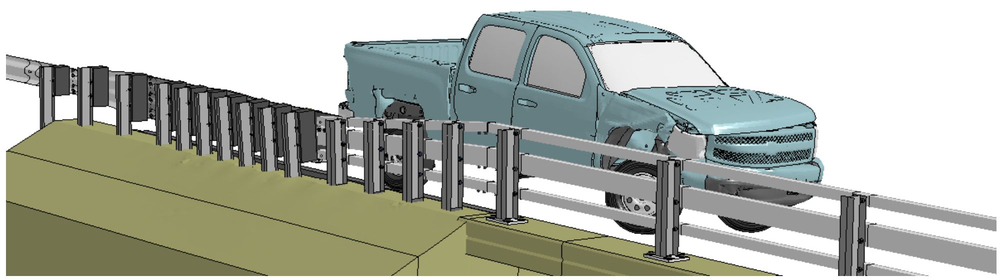

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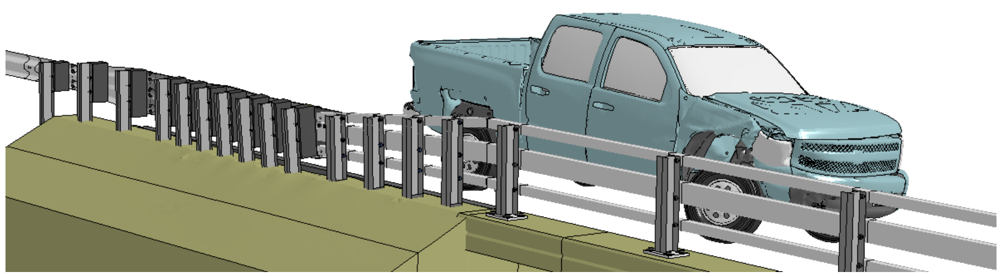

Figure O-3. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from from an oblique viewpoint.

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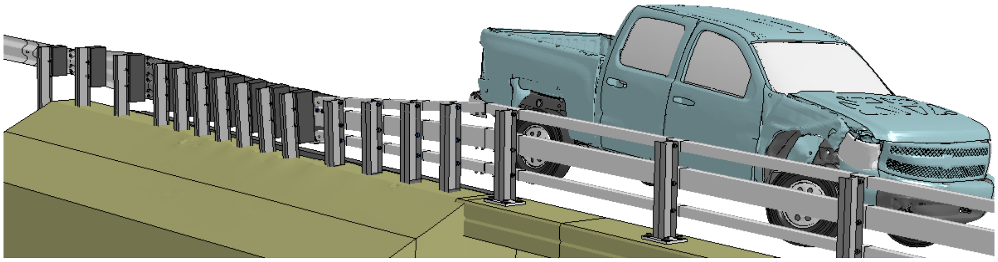

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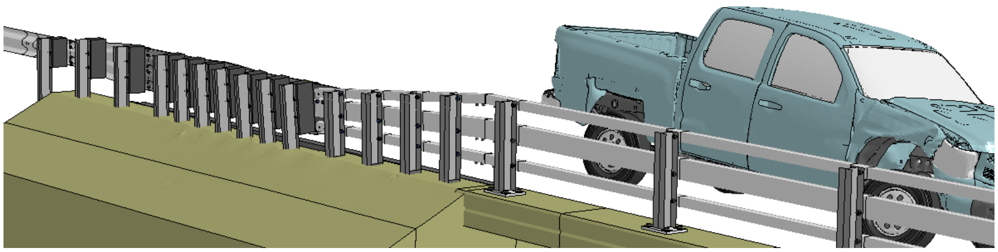

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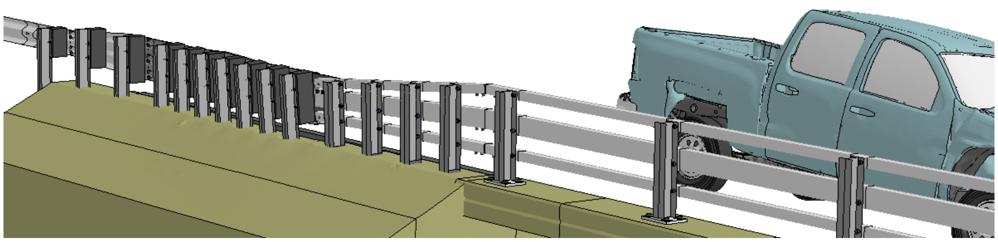

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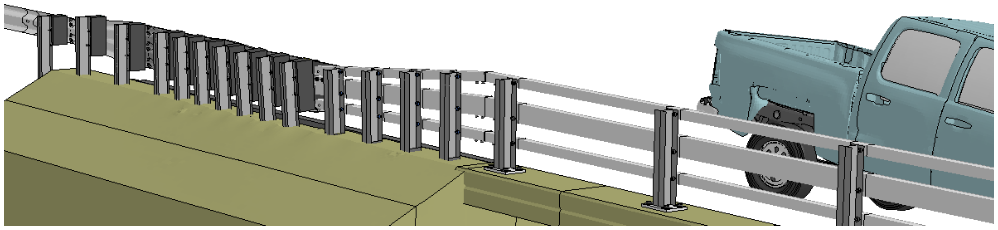

Figure O-3. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 3-Bar transition from an oblique viewpoint.

Appendix P

Sequential Views for Test 4-22 on

AGT 3-Bar Transition

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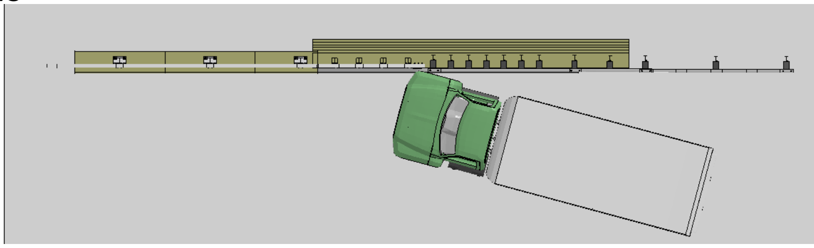

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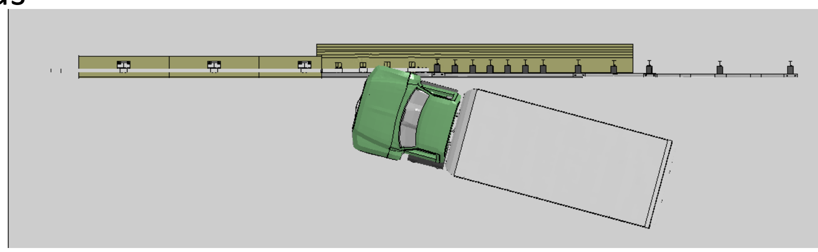

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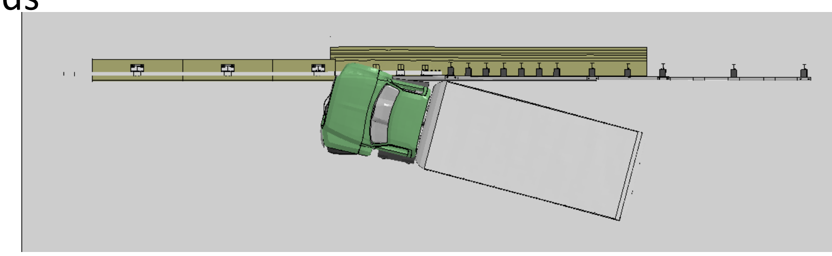

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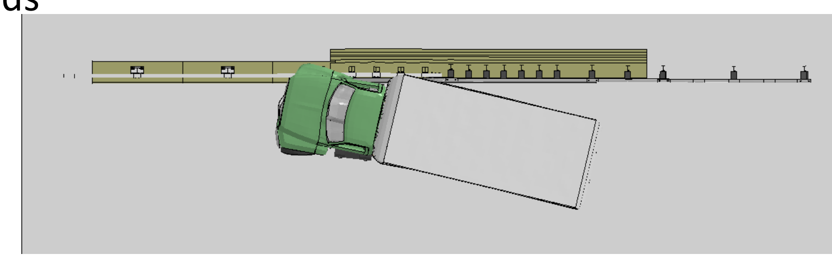

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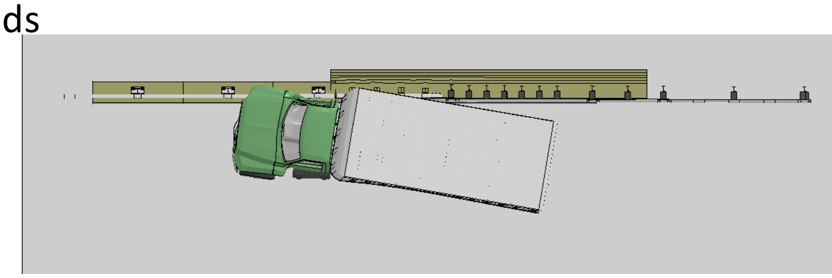
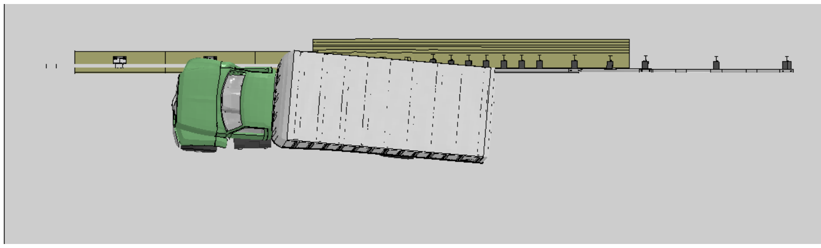


Figure P-1. Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from an overhead viewpoint.

0.25 seconds



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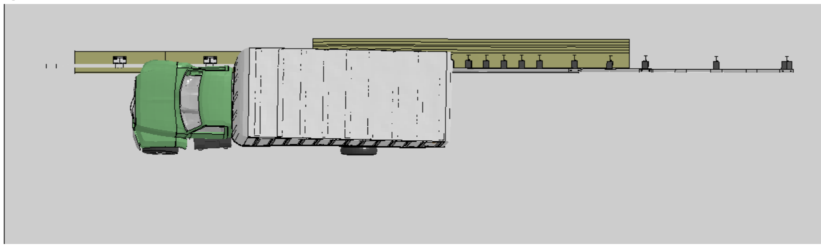

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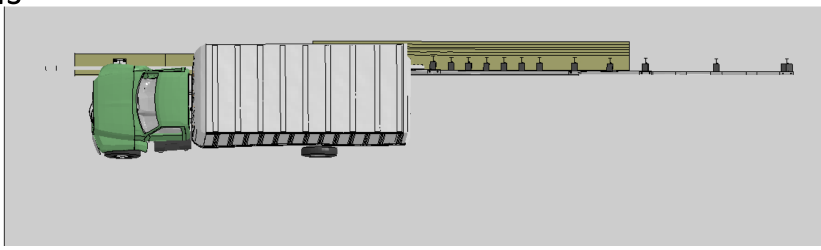

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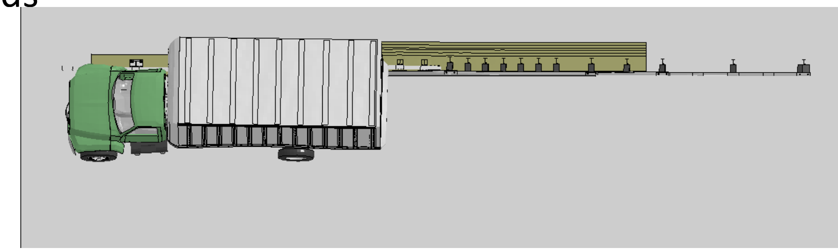

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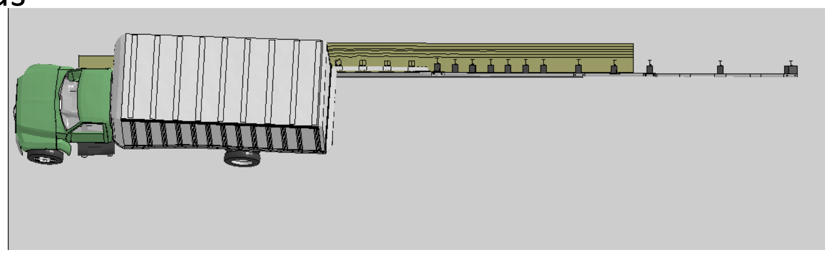

Figure P-1. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from an overhead viewpoint.

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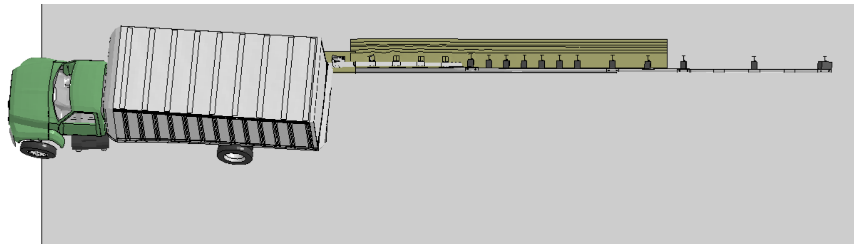

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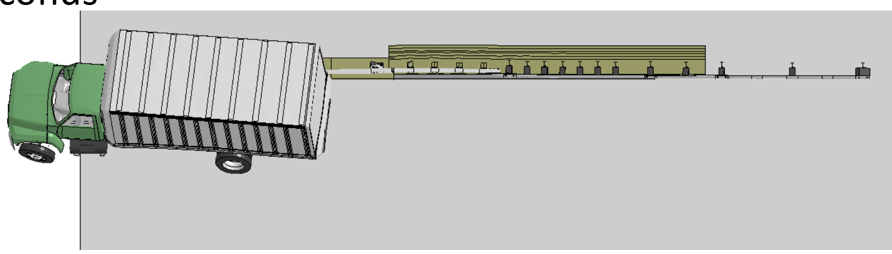

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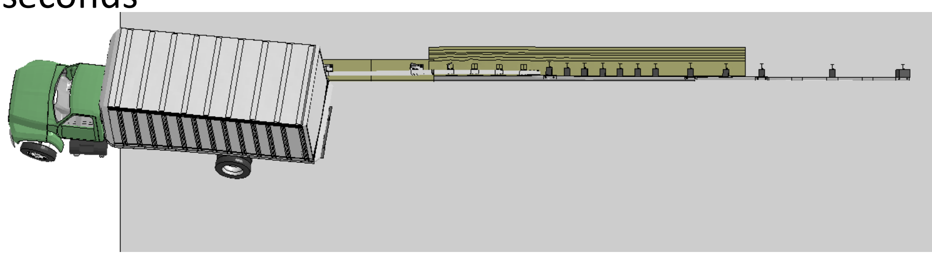

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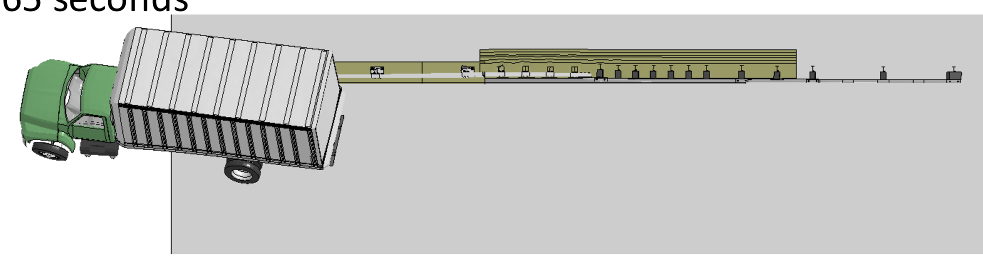

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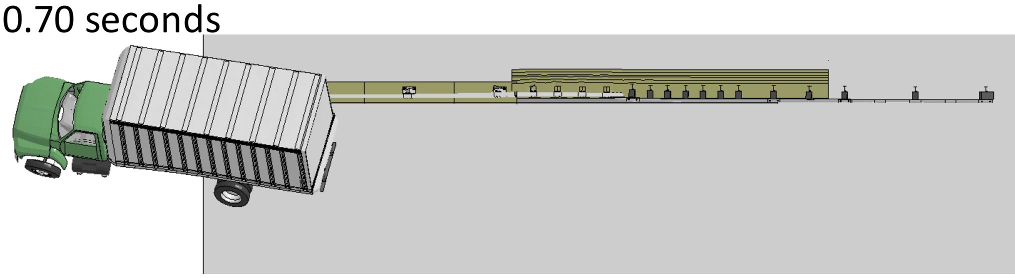

Figure P-1. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from an overhead viewpoint.

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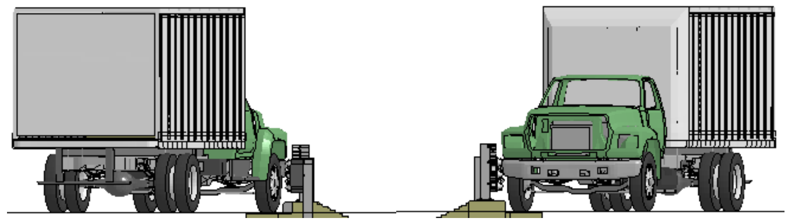

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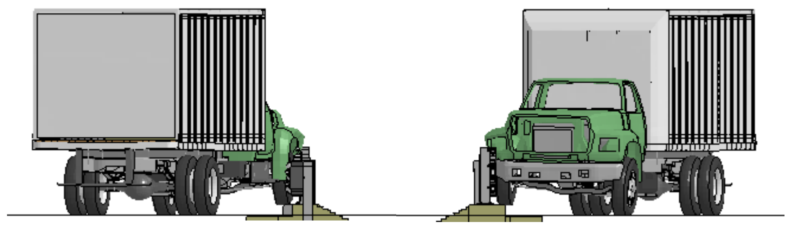

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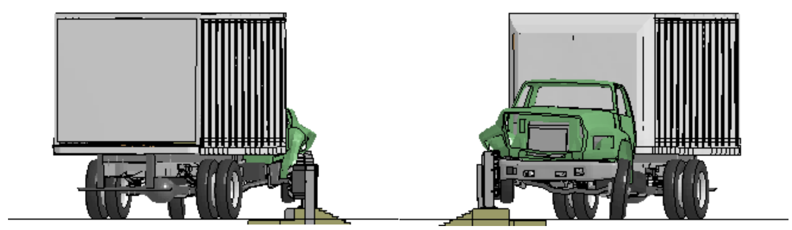

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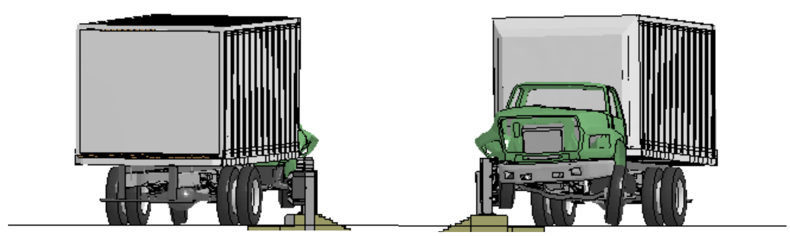

Figure P-2. Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from upstream and downstream viewpoints.

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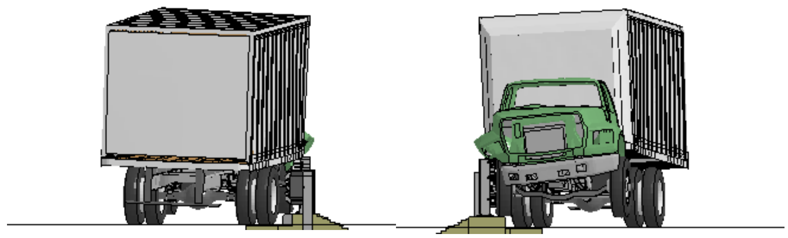

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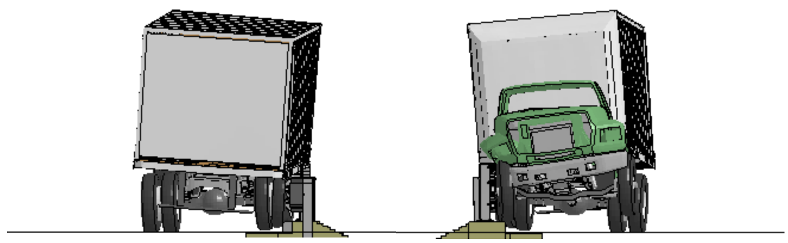

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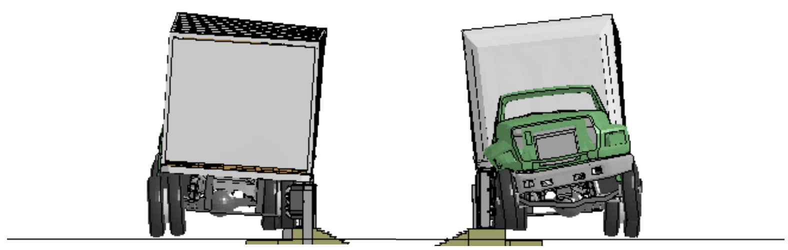

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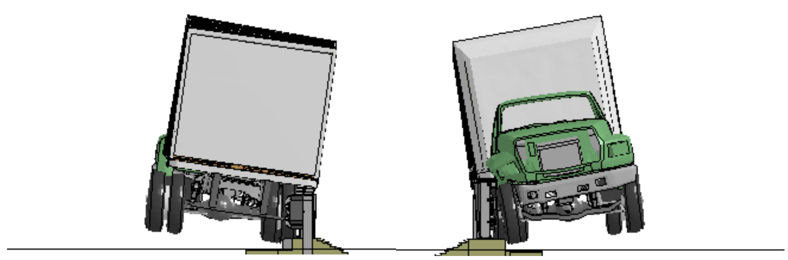

Figure P-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from upstream and downstream viewpoints.

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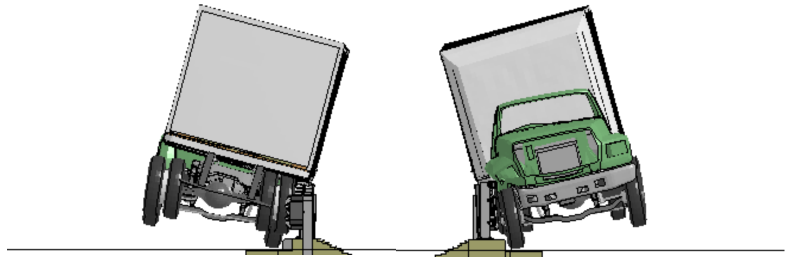

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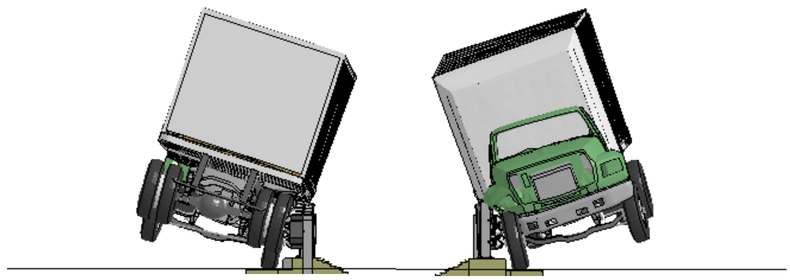

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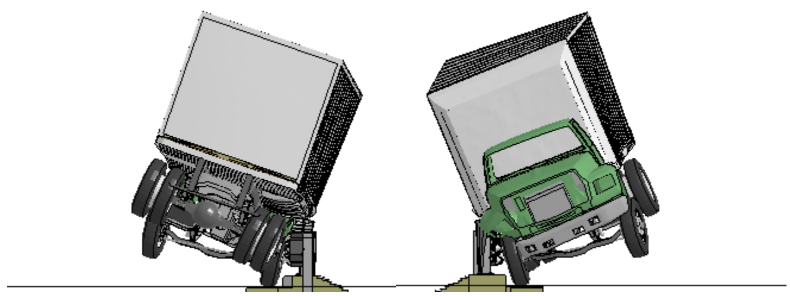

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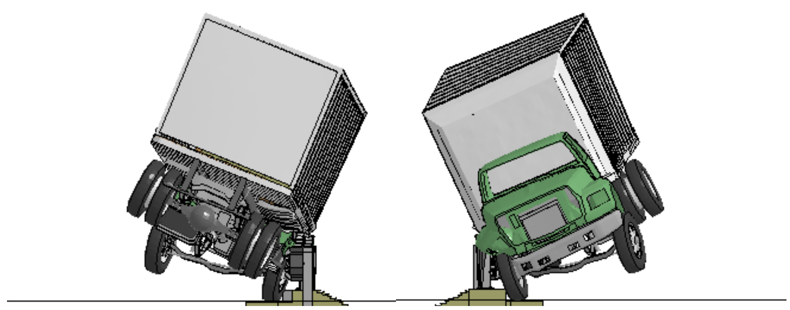

Figure P-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from upstream and downstream viewpoints.

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0.70 seconds

0.75 seconds

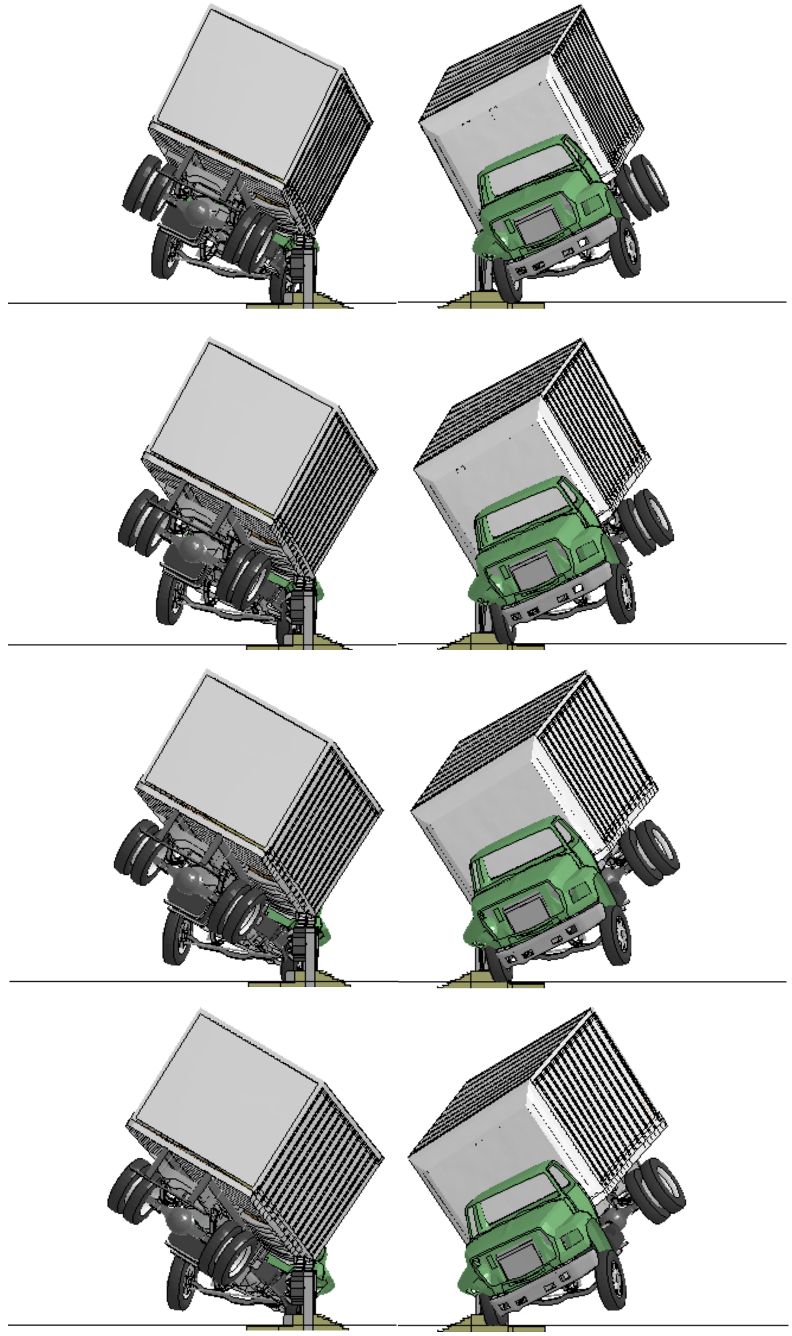

Figure P-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from upstream and downstream viewpoints.

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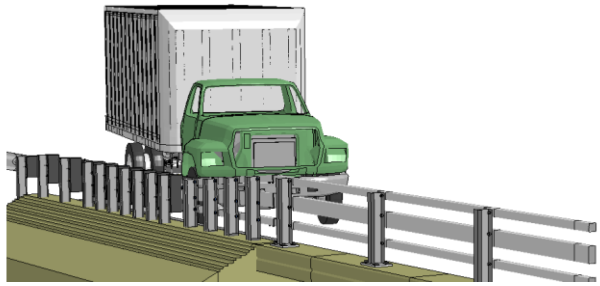

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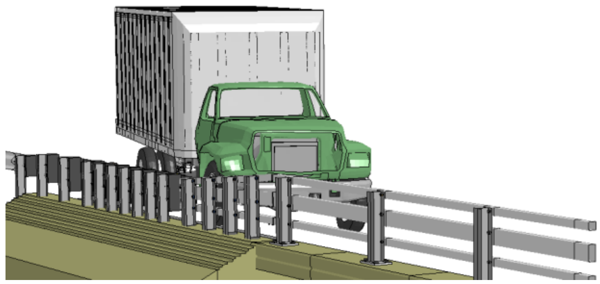

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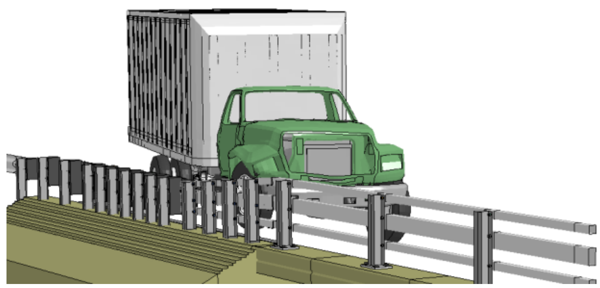

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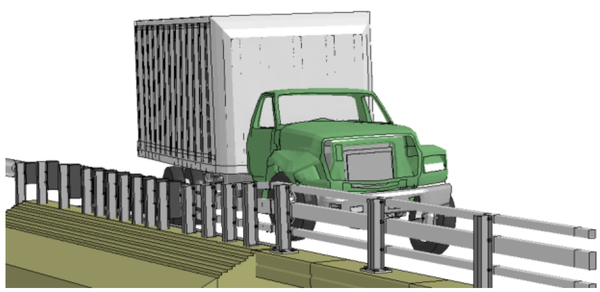
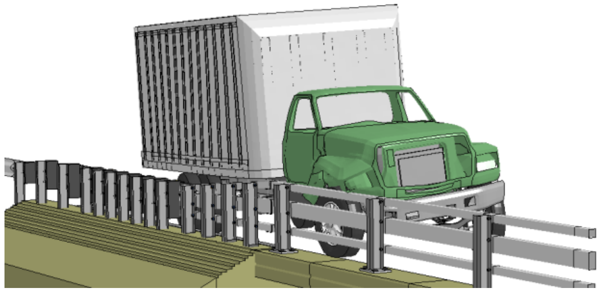


Figure P-3. Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from an oblique viewpoint.

0.20 seconds



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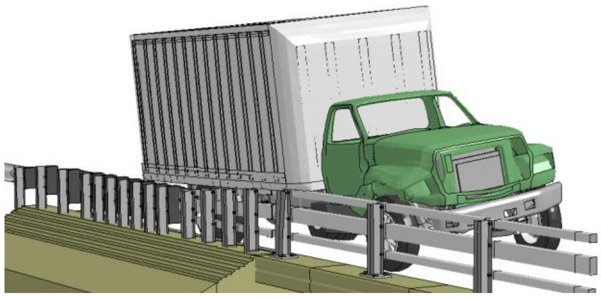

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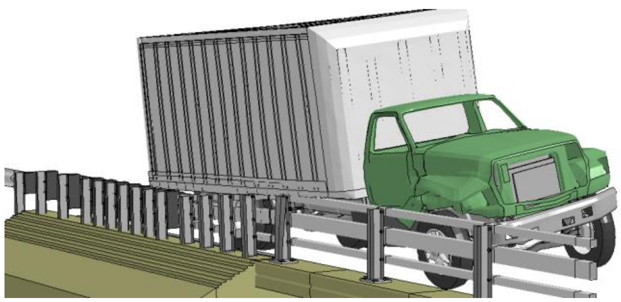

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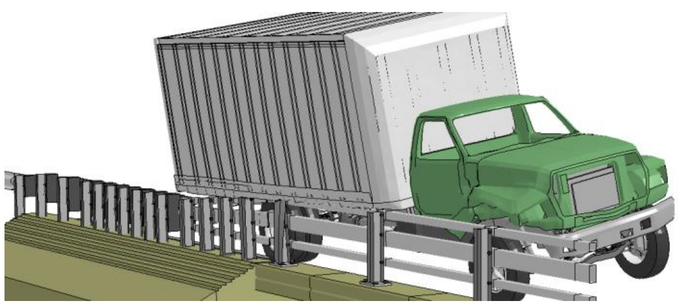
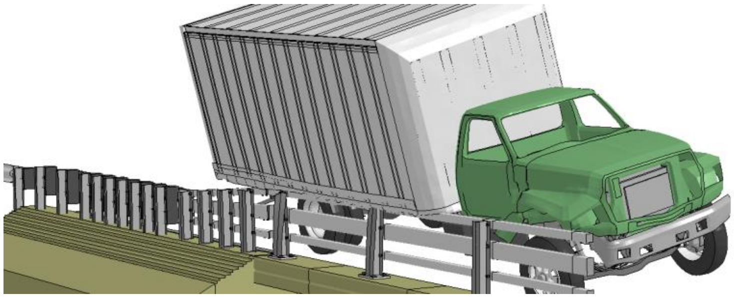


Figure P-3. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from an oblique viewpoint.

0.40 seconds



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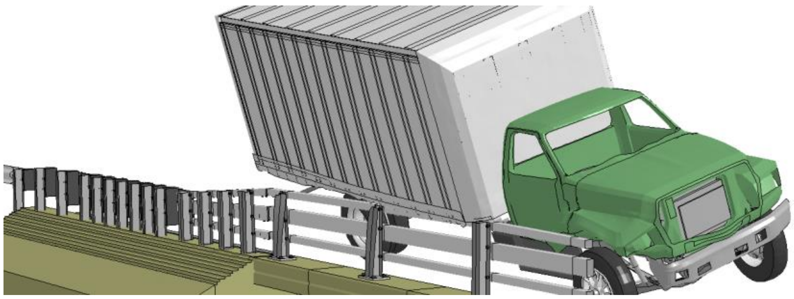

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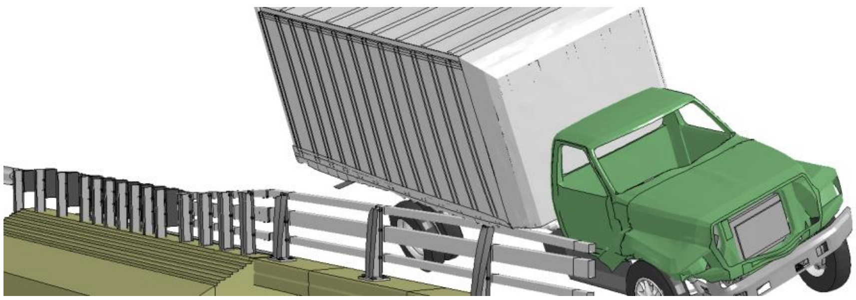

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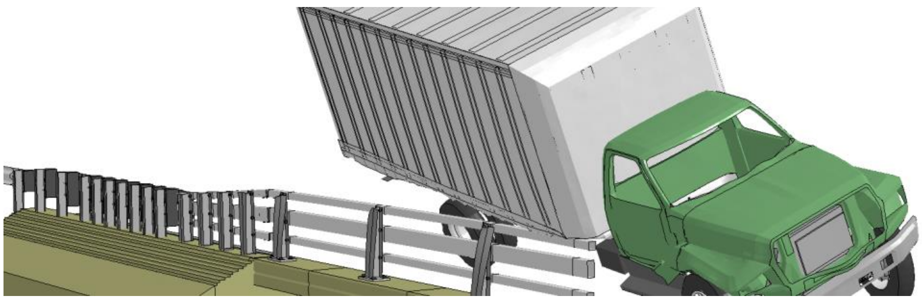


Figure P-3. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 3-Bar transition from an oblique viewpoint.

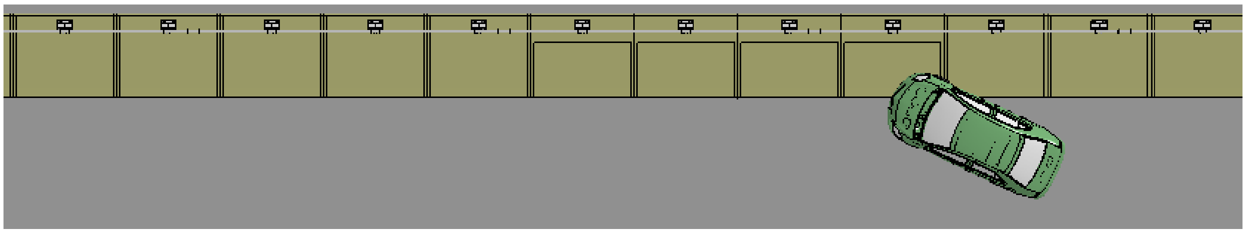
Appendix Q

Sequential Views for Test 4-10 on

Sidewalk-Mounted NETC 4-Bar Bridge Rail

0.00 seconds

0.05 seconds



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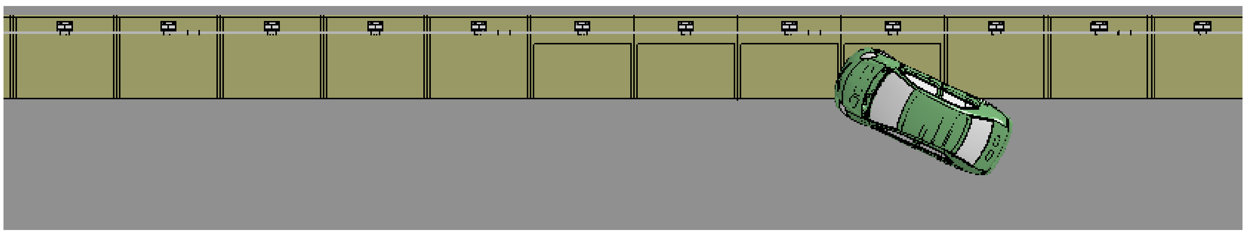

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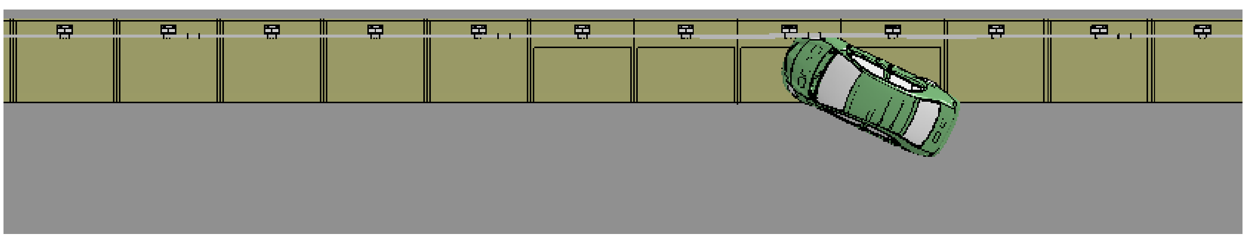

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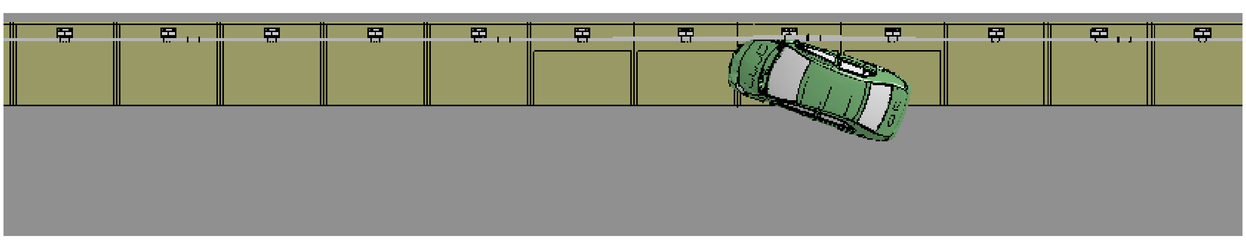
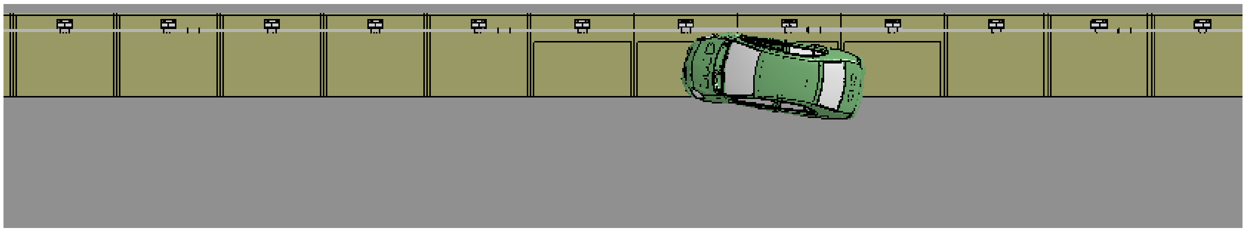


Figure Q-1. Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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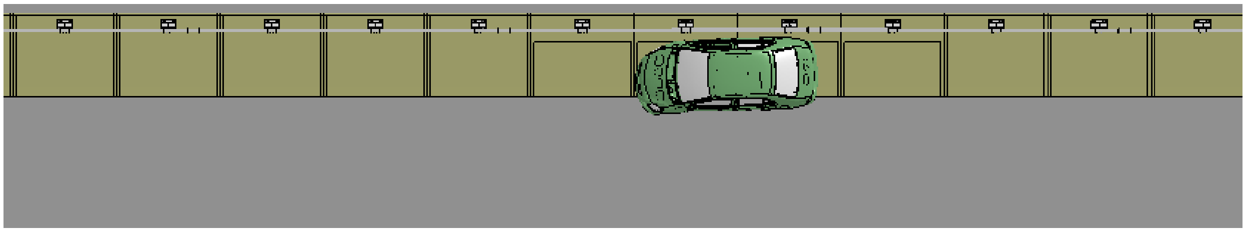

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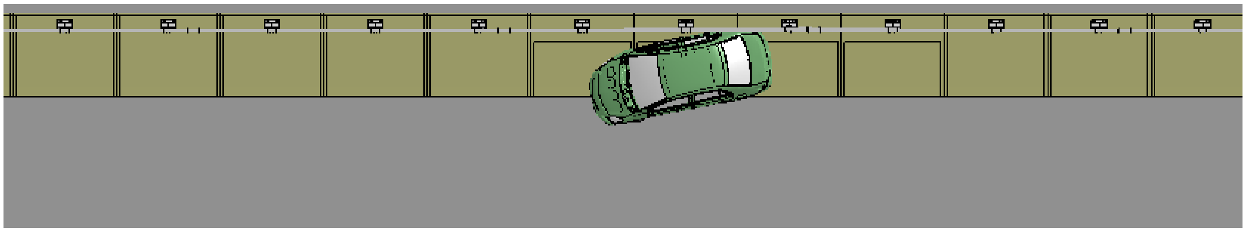

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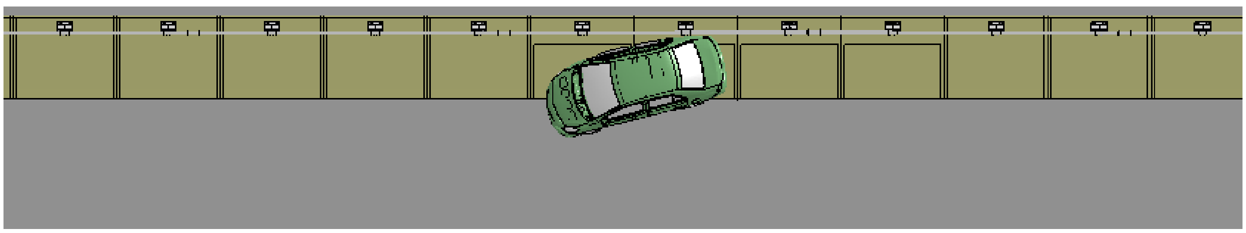

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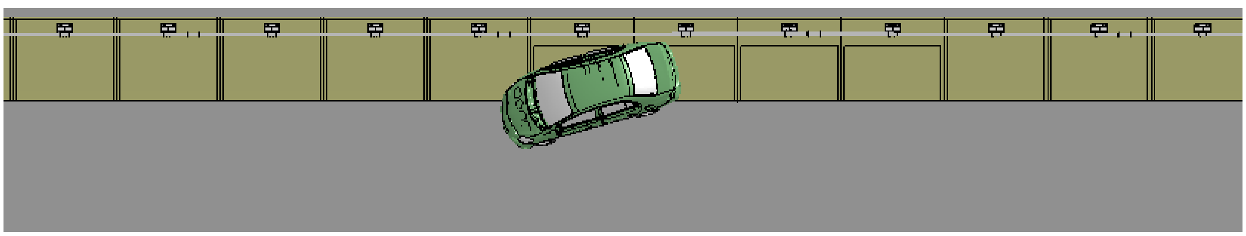
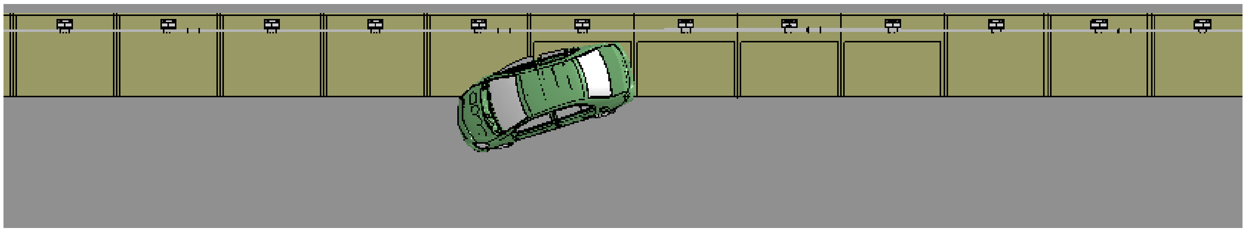


Figure Q-1. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from an overhead viewpoint.



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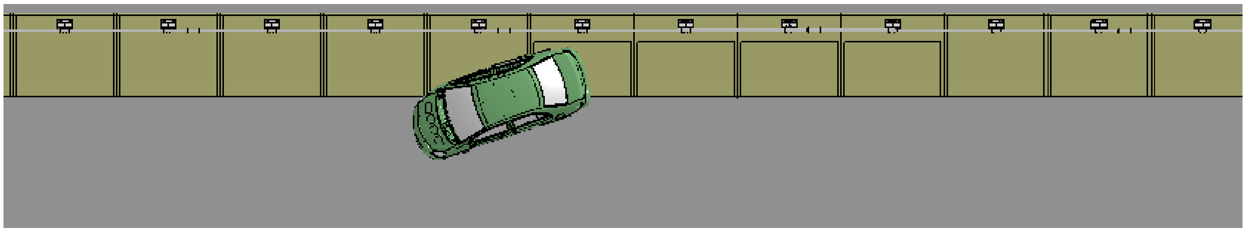

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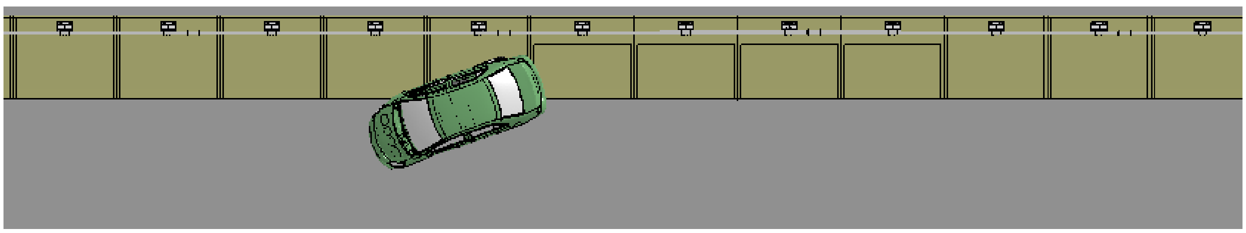

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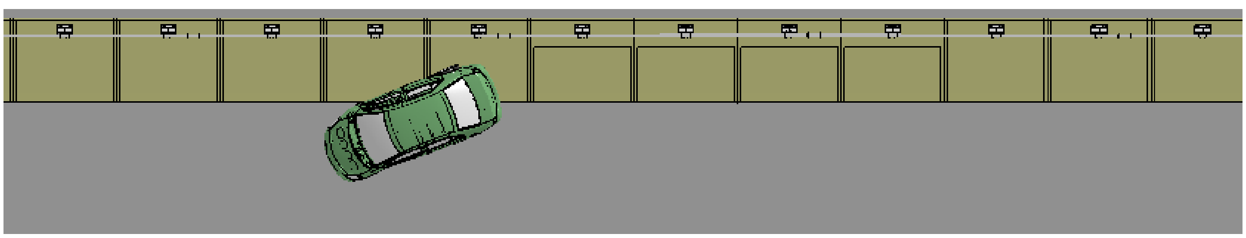

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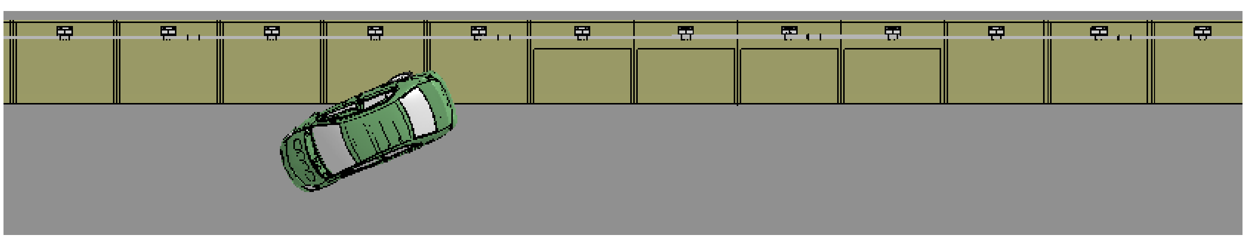


Figure Q-1. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from an overhead viewpoint.

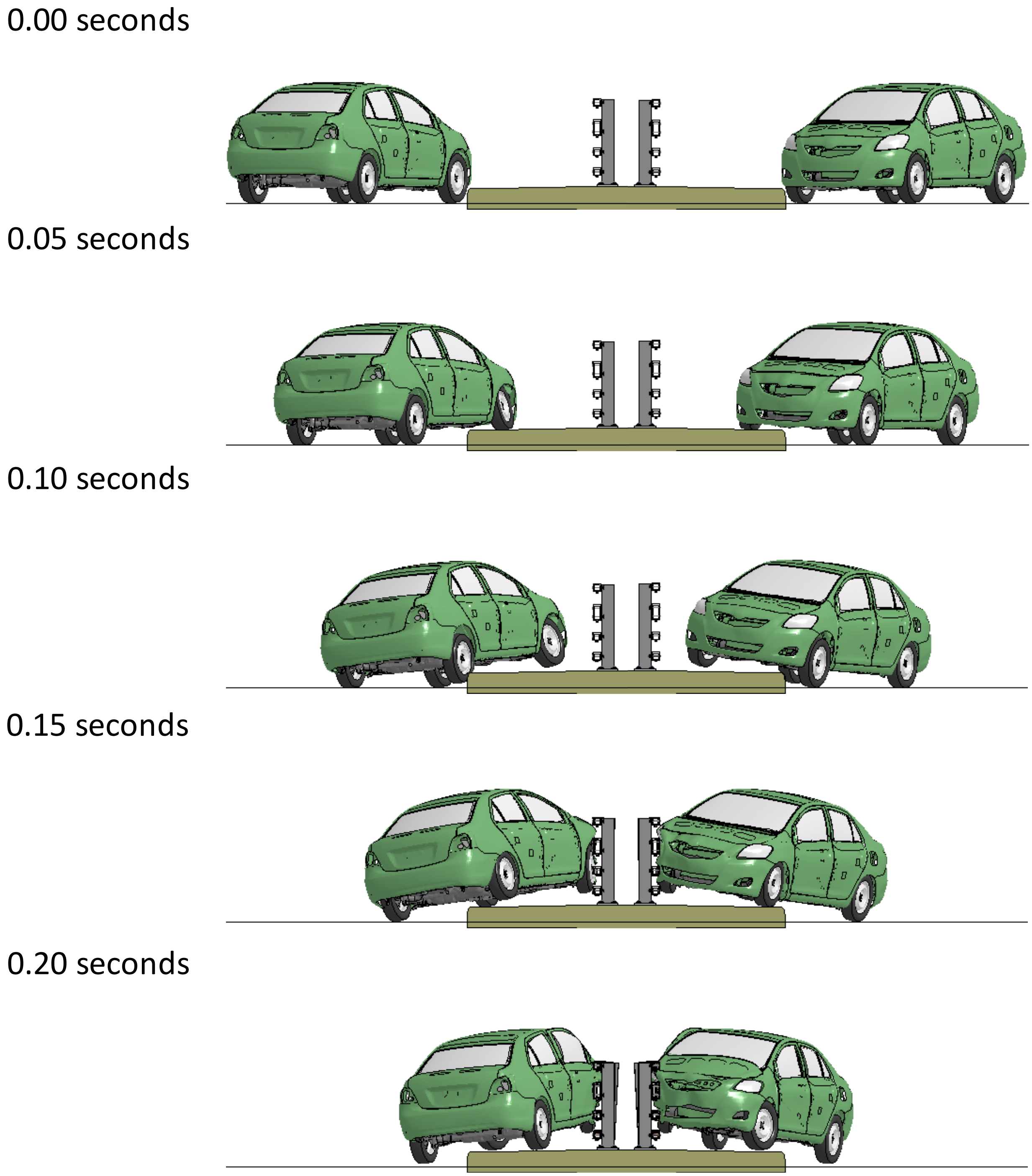
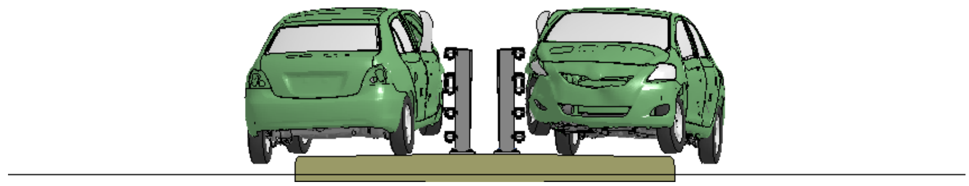


Figure Q-2. Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

0.25 seconds



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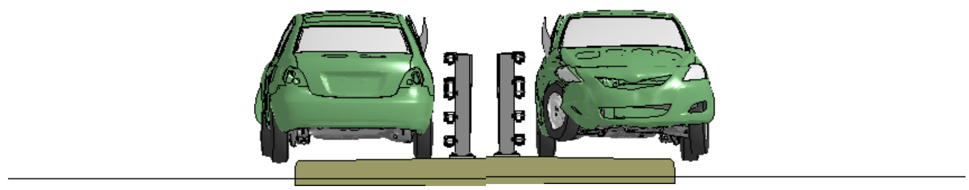

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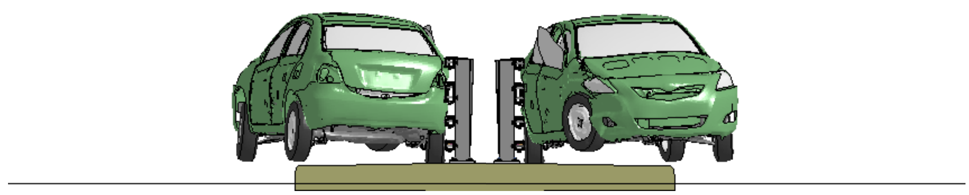

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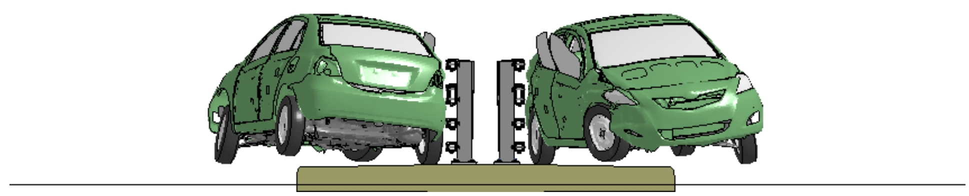

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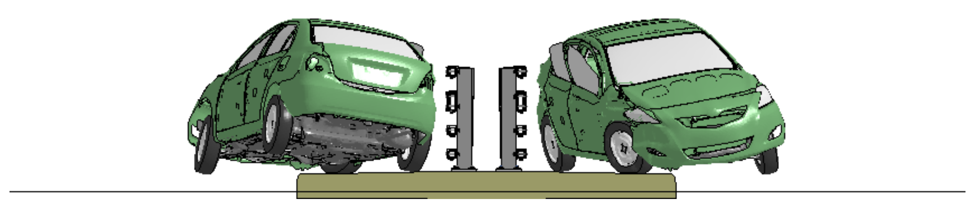
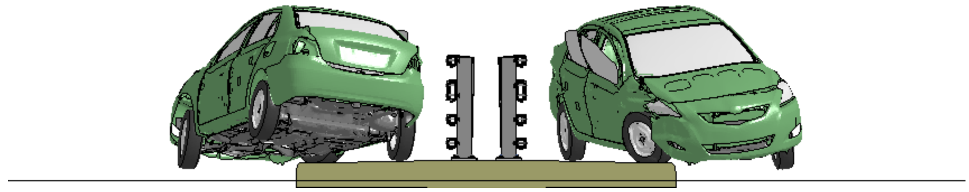


Figure Q-2. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

0.50 seconds



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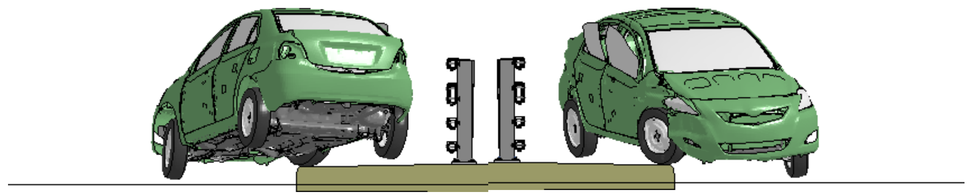

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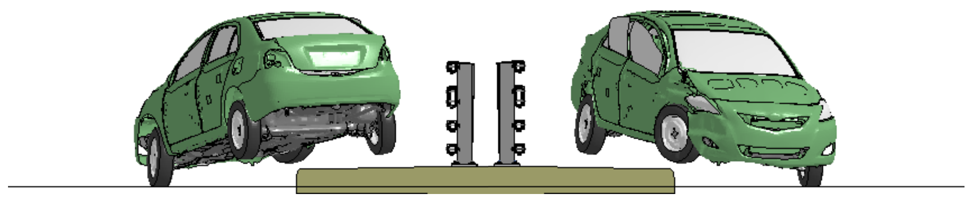

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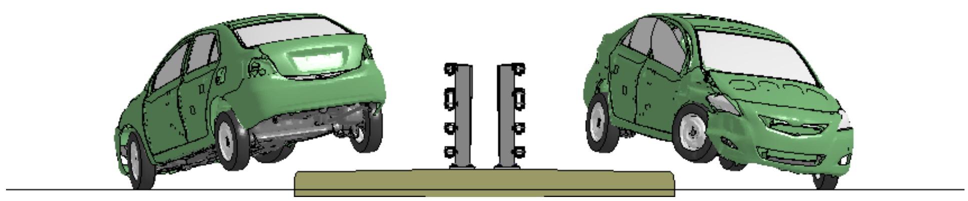

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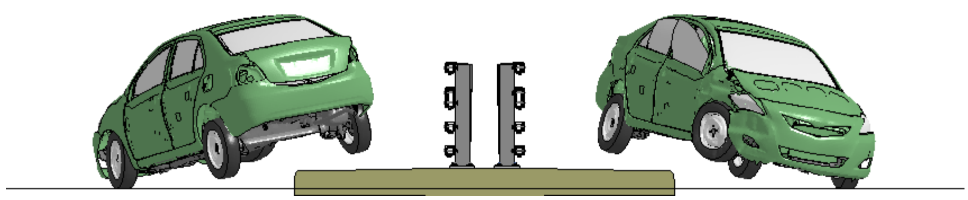


Figure Q-2. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

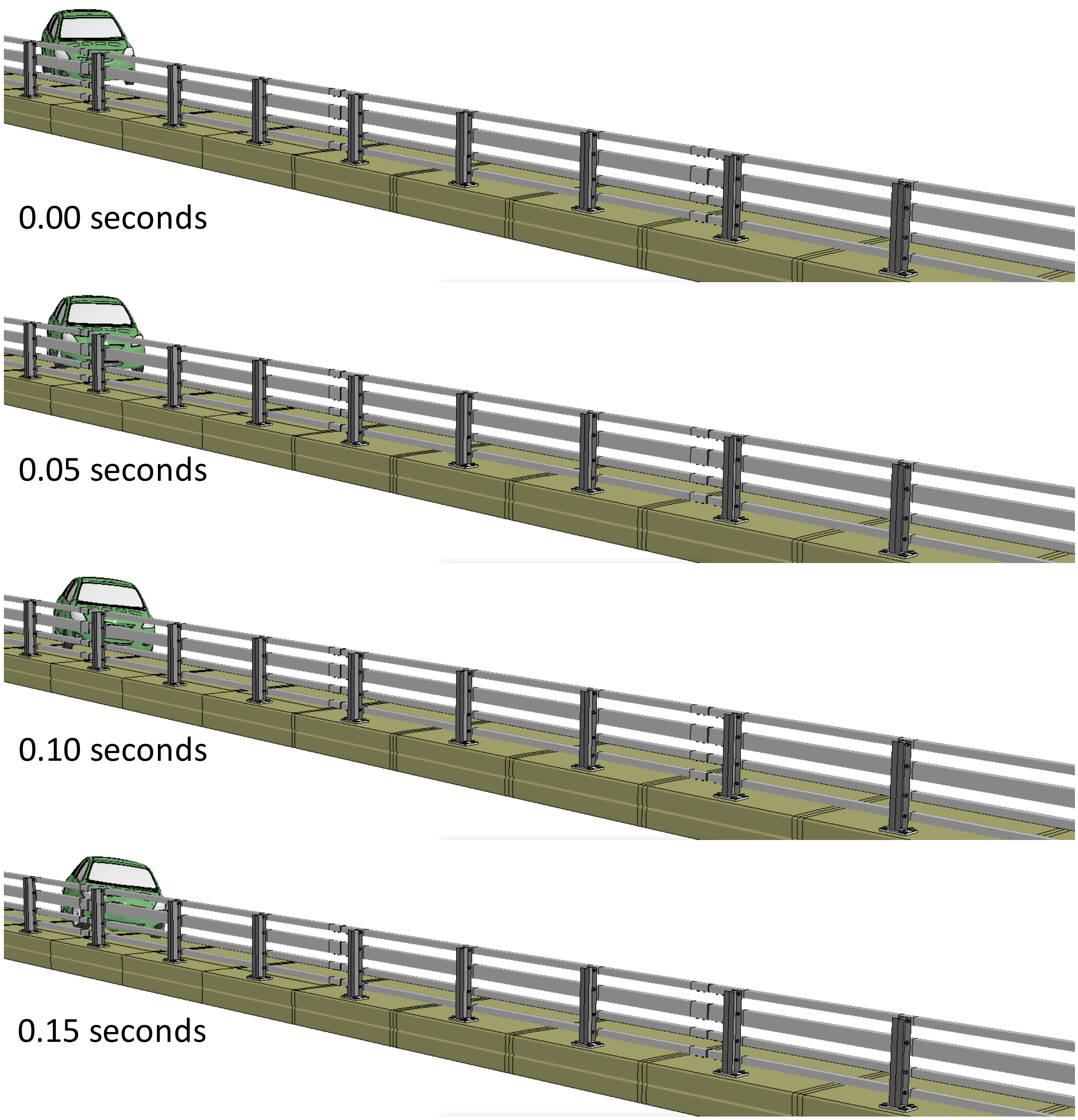


Figure Q-3. Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from an oblique viewpoint.

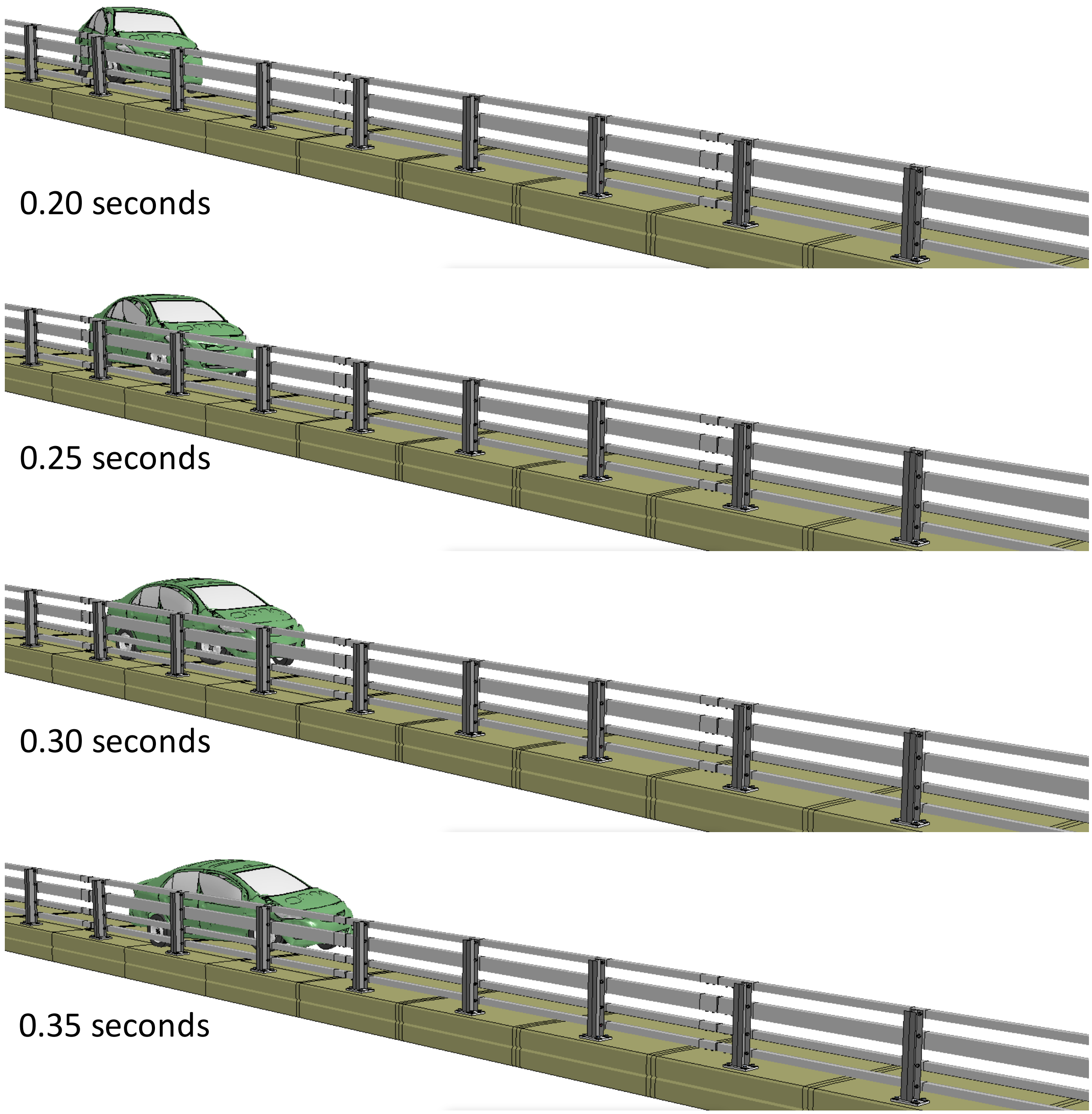


Figure Q-3. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from from an oblique viewpoint.

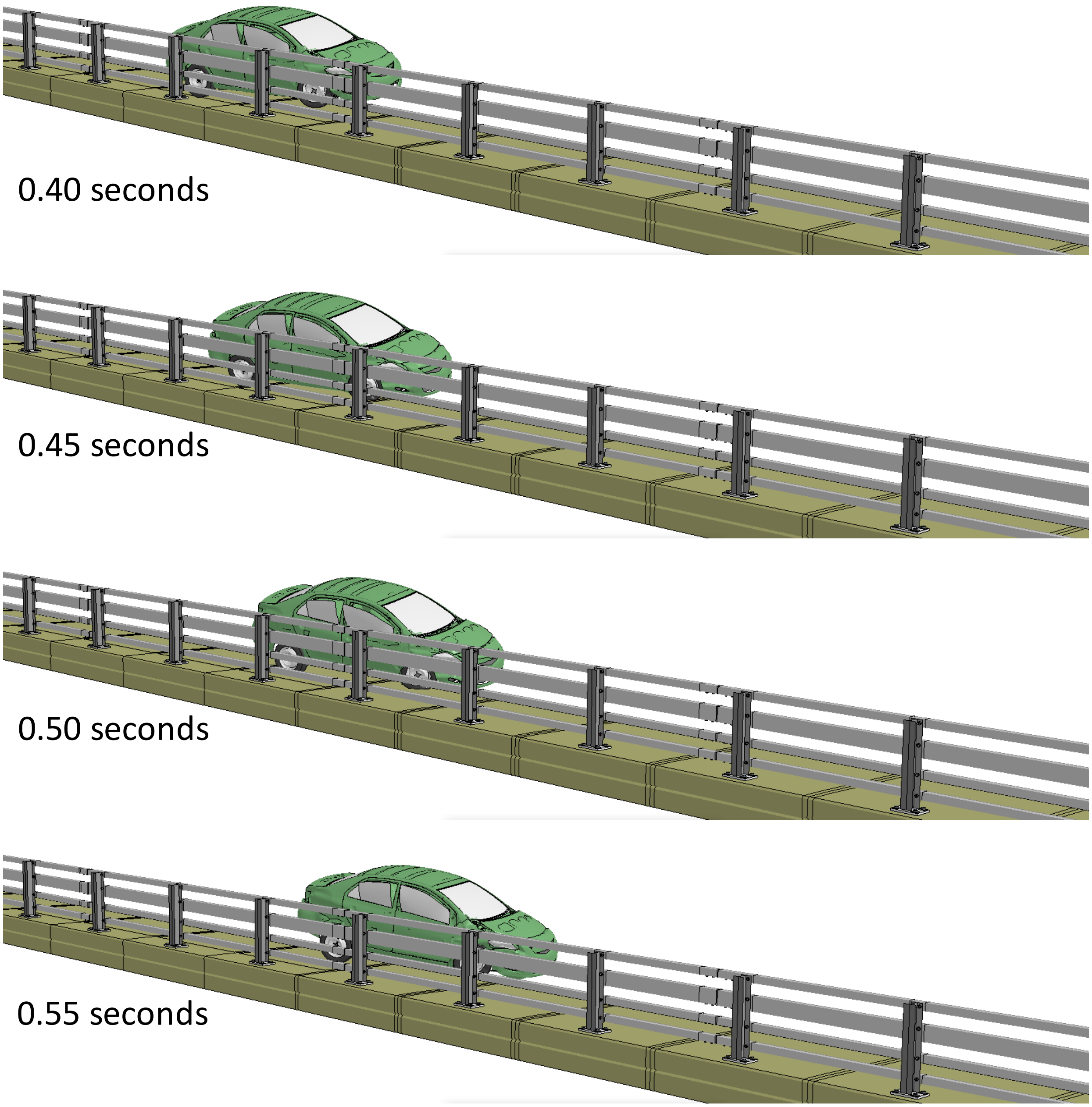


Figure Q-3. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from an oblique viewpoint.

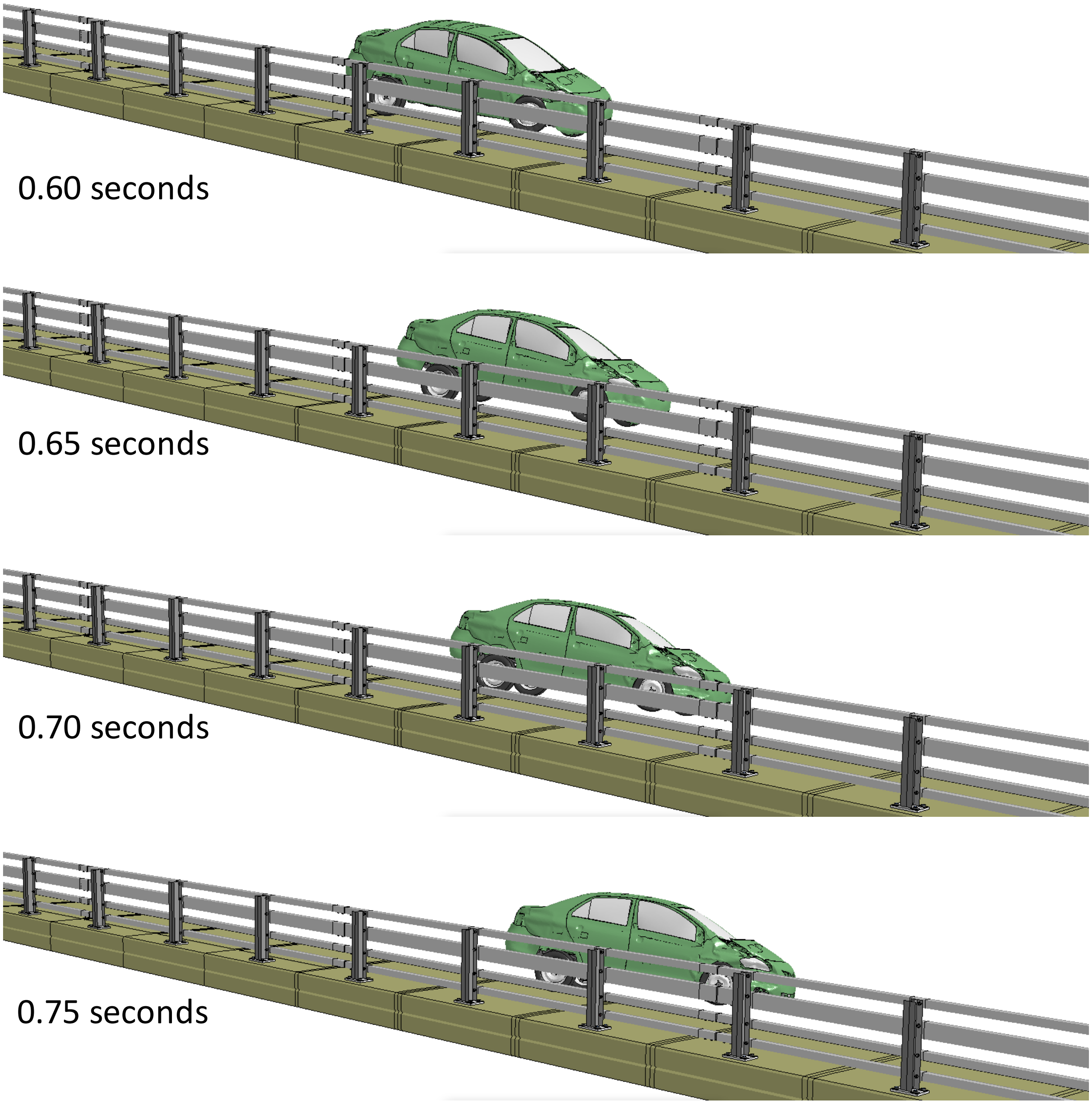


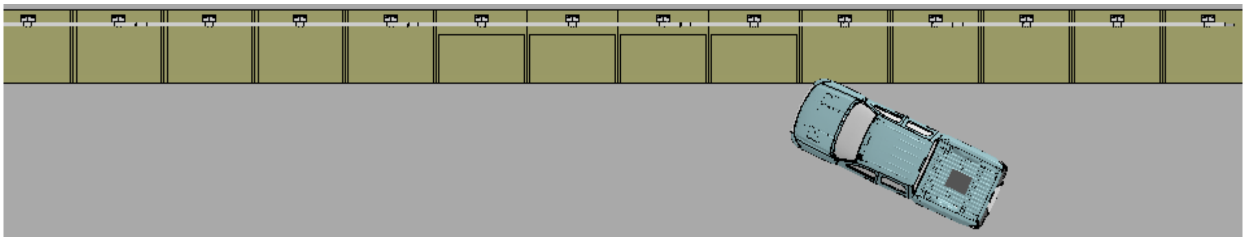
Figure Q-3. [Continued] Sequential views from analysis of MASH Test 4-10 for NETC 4-Bar bridge rail from an oblique viewpoint.

Appendix R

Sequential Views for Test 4-11 on

Sidewalk-Mounted NETC 4-Bar Bridge Rail

0.00 seconds



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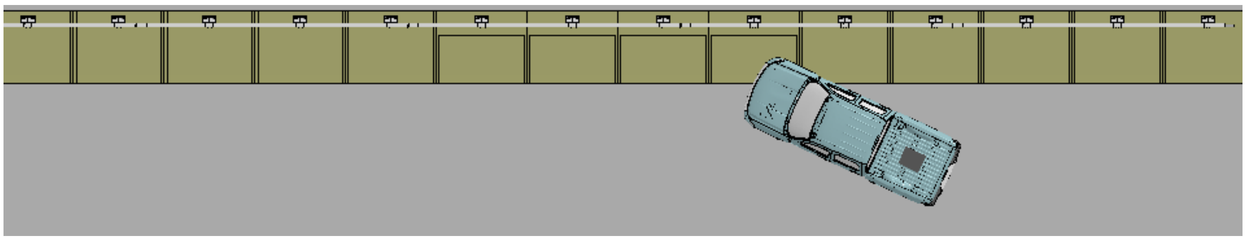

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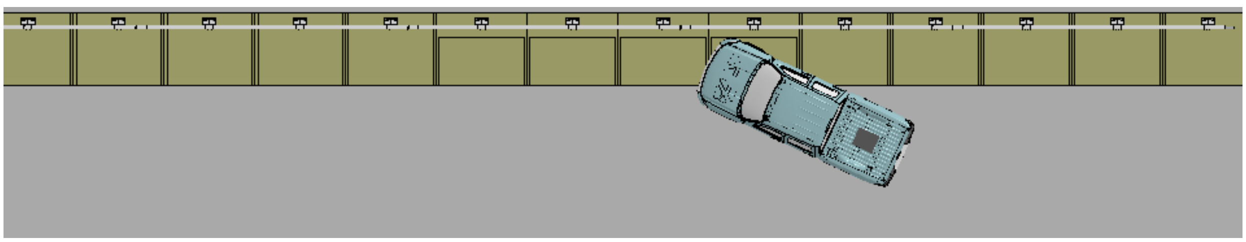

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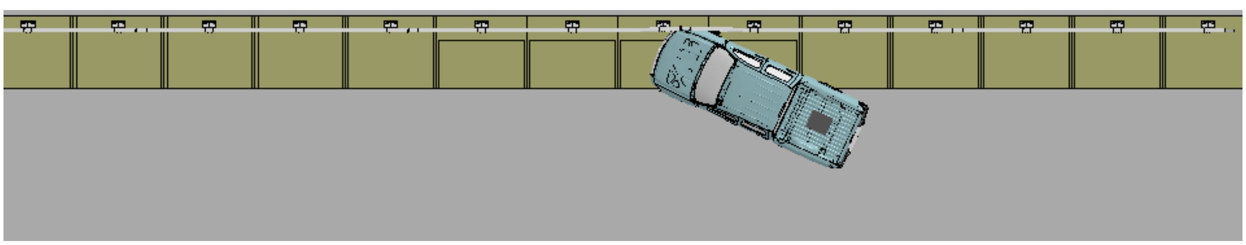

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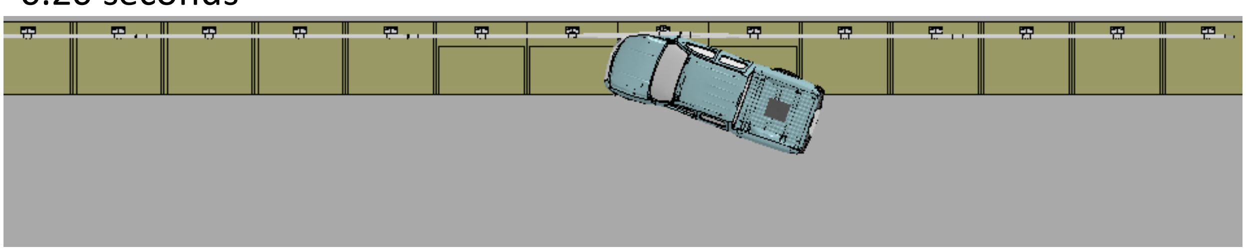
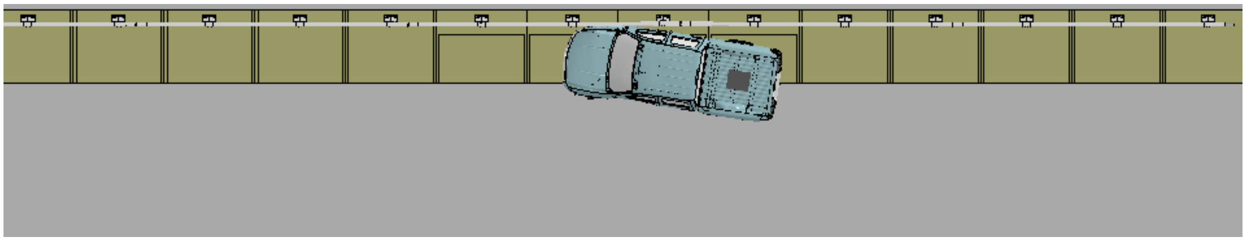


Figure R-1. Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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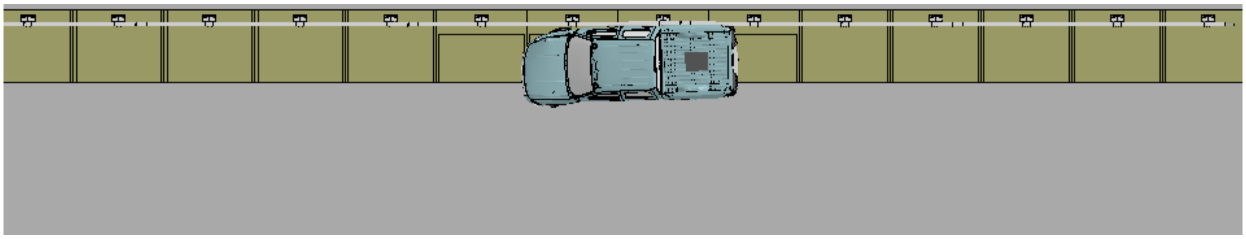

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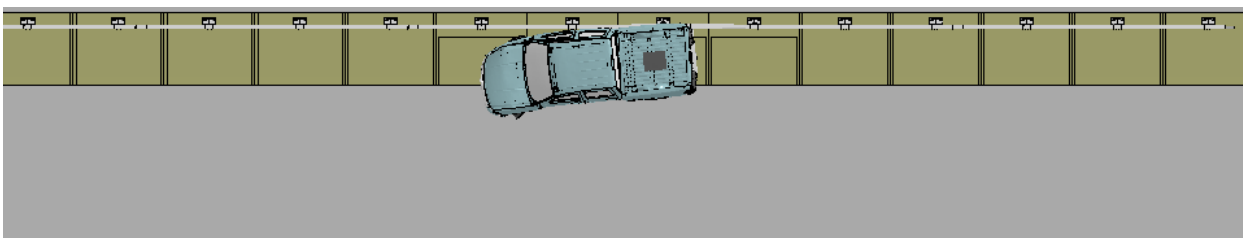

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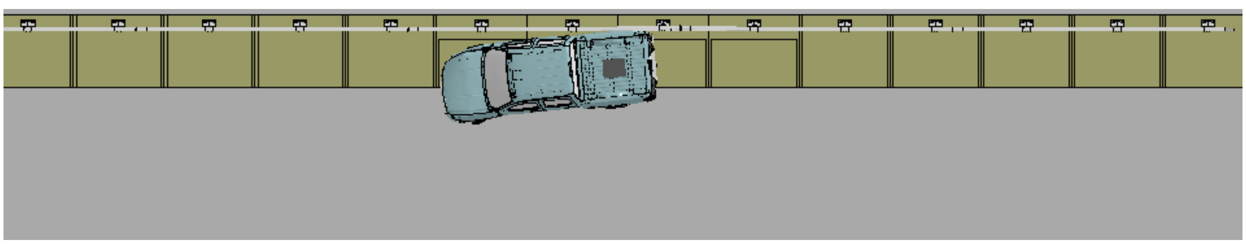

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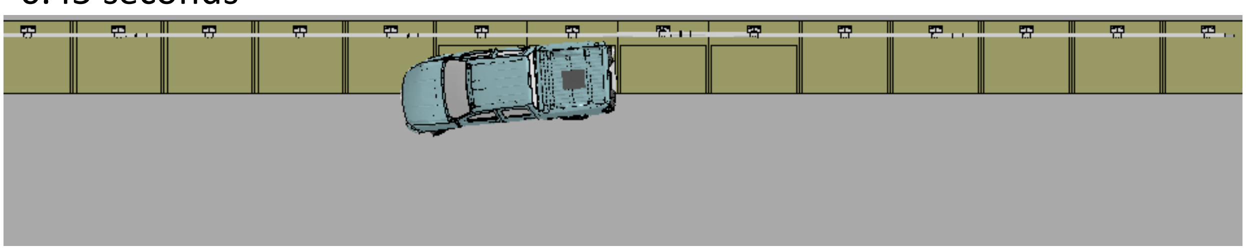
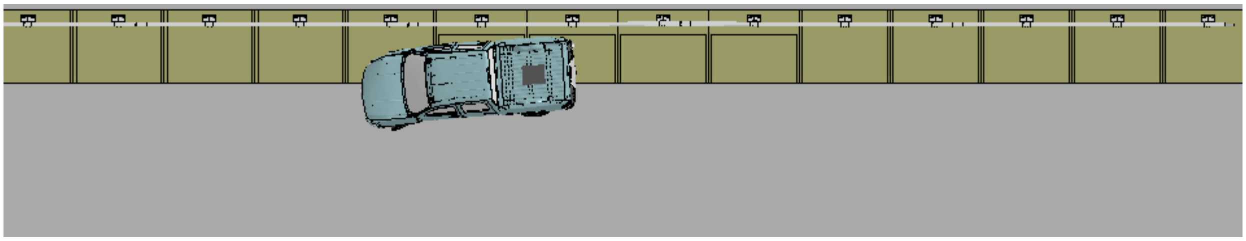


Figure R-1. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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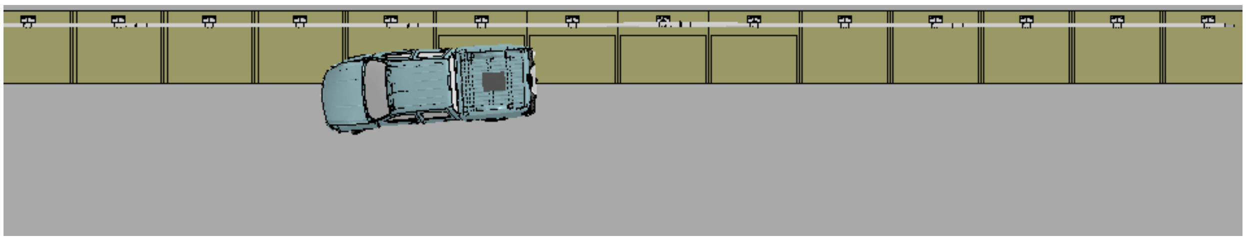


0.60 seconds

0.65 seconds

0.70 seconds

Figure R-1. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from an overhead viewpoint.

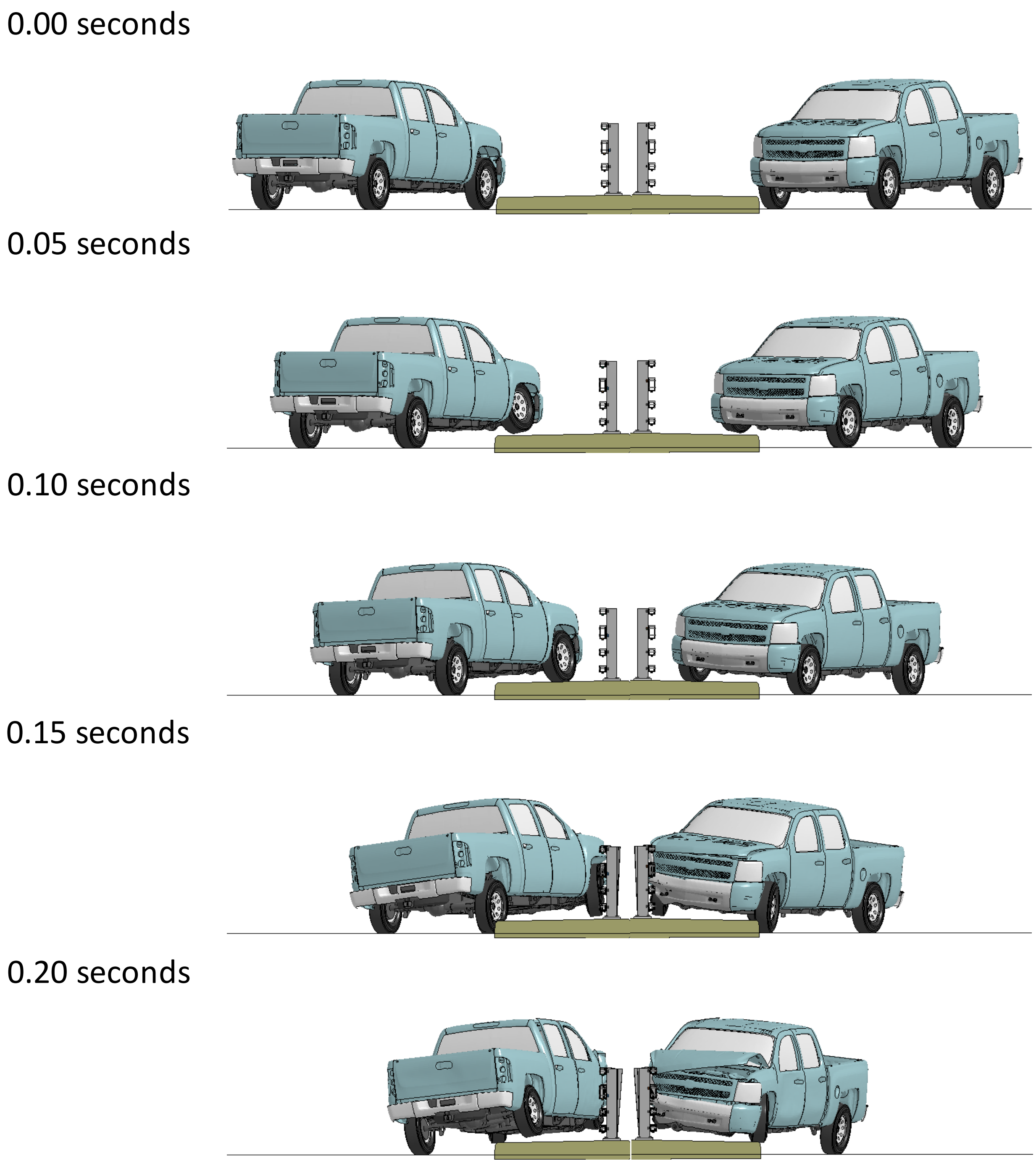


Figure R-2. Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

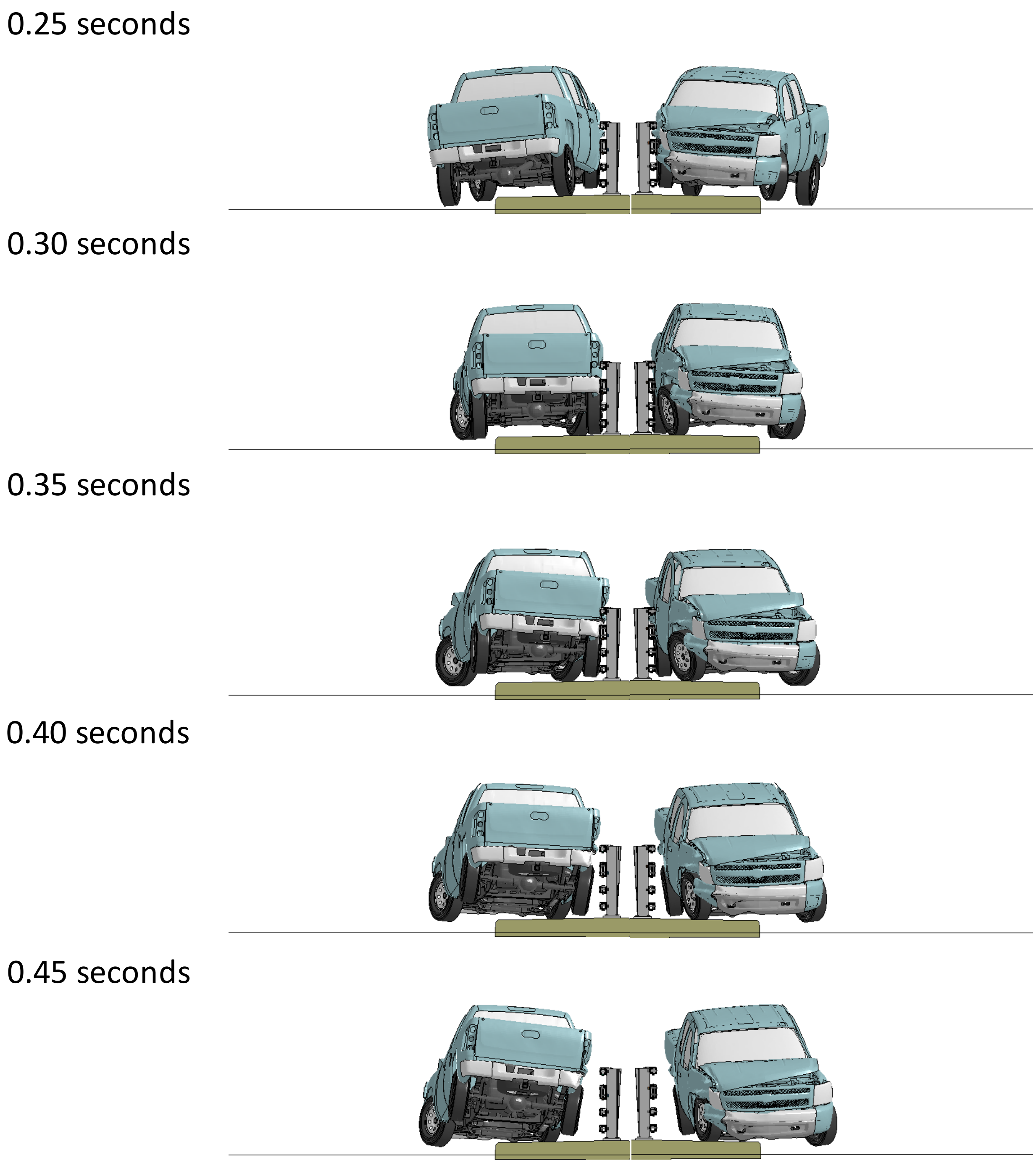
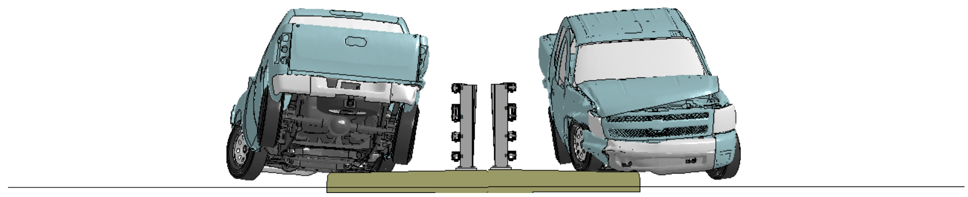


Figure R-2. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

0.50 seconds



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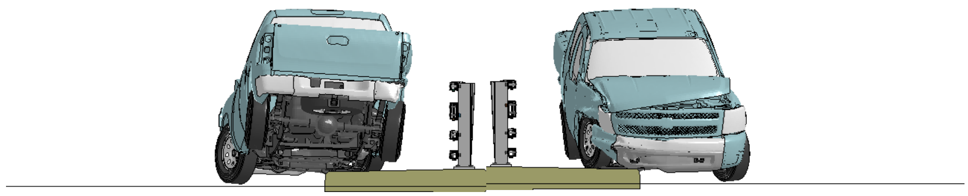

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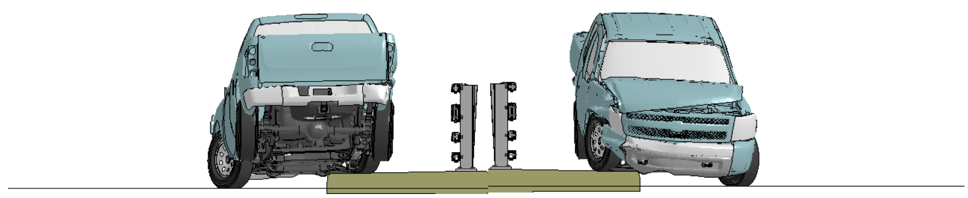

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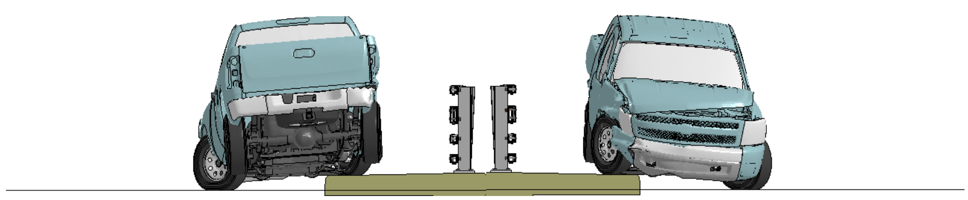

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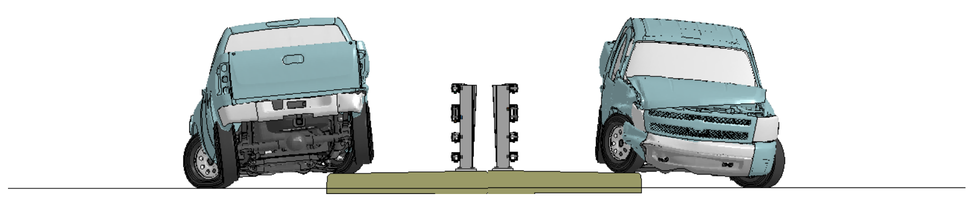
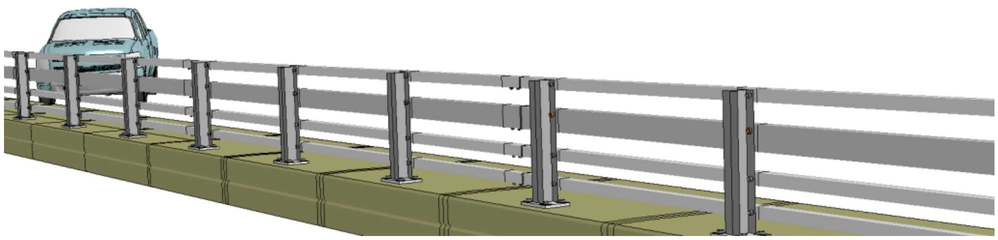


Figure R-2. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

0.00 seconds



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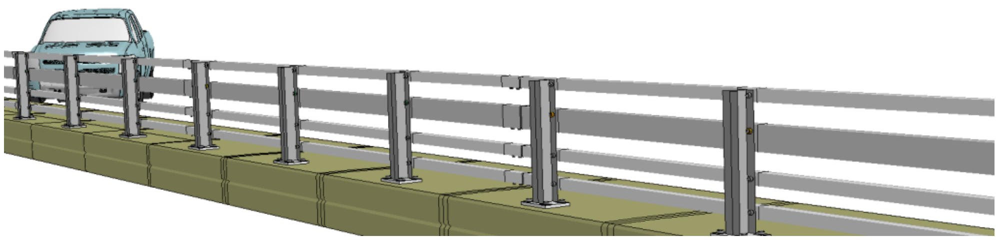

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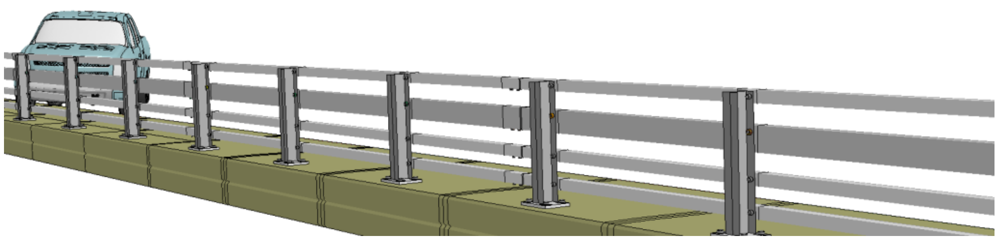

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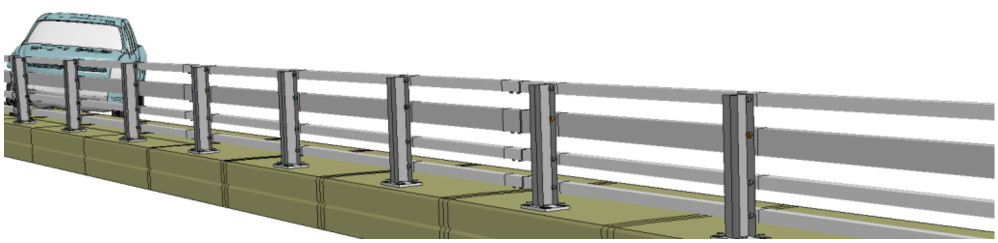
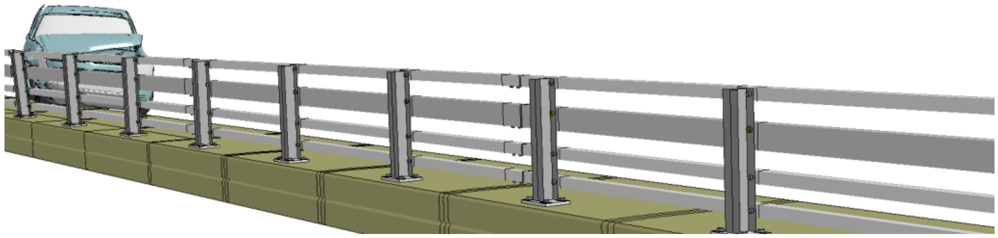


Figure R-3. Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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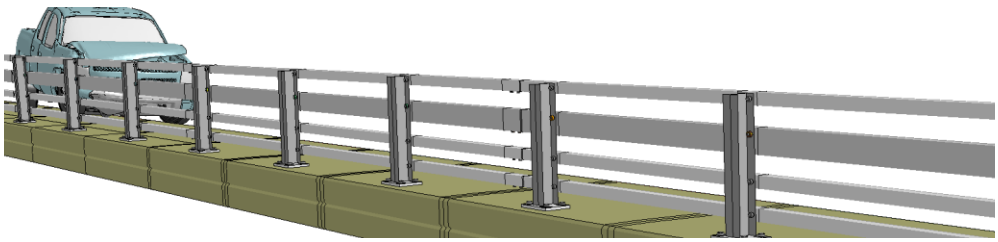

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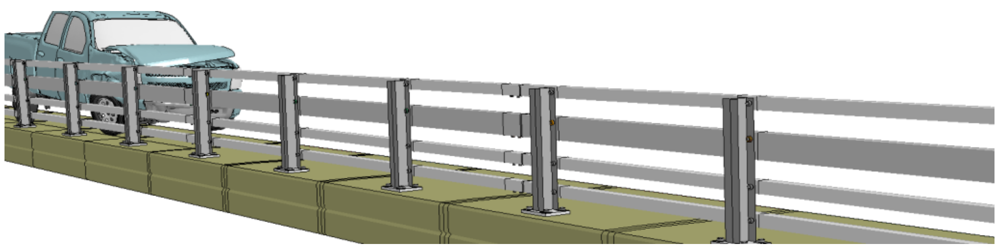

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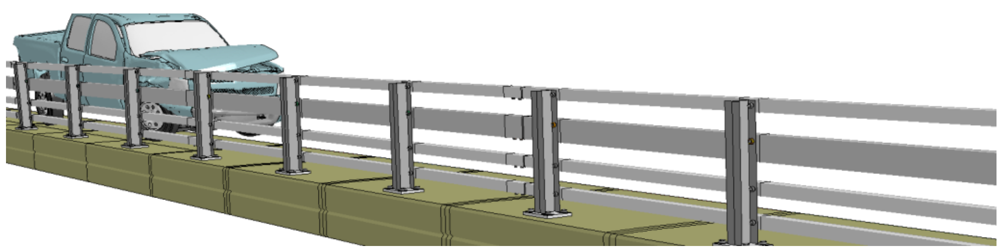
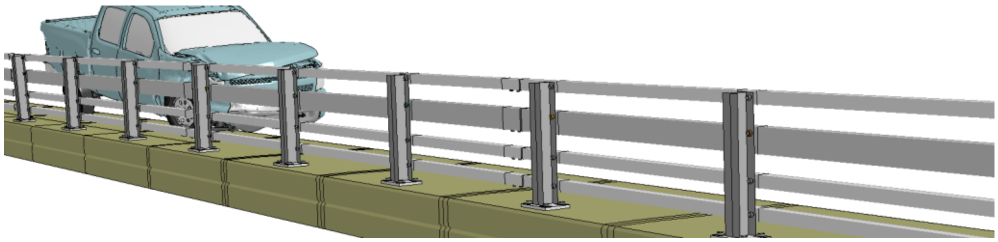


Figure R-3. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from from an oblique viewpoint.

0.40 seconds



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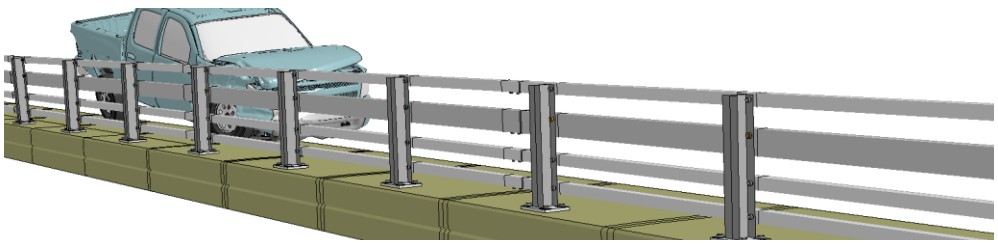

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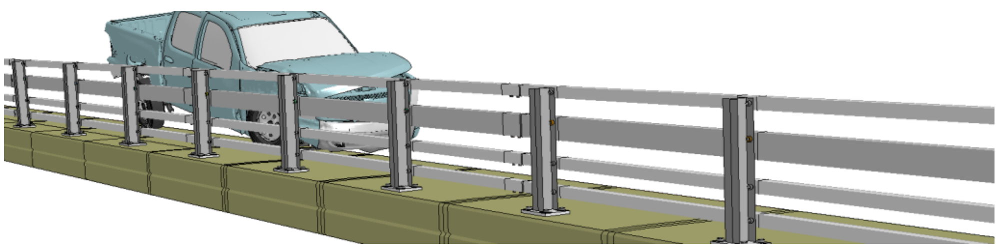

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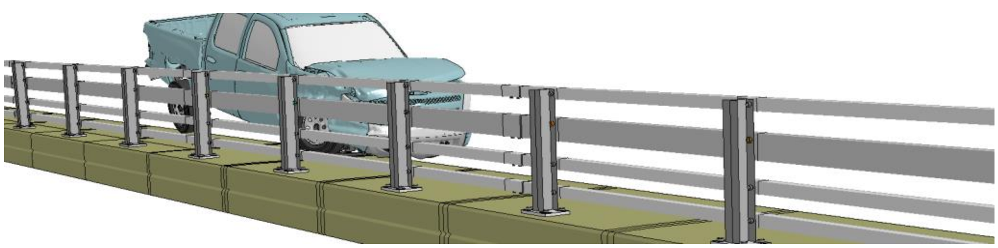
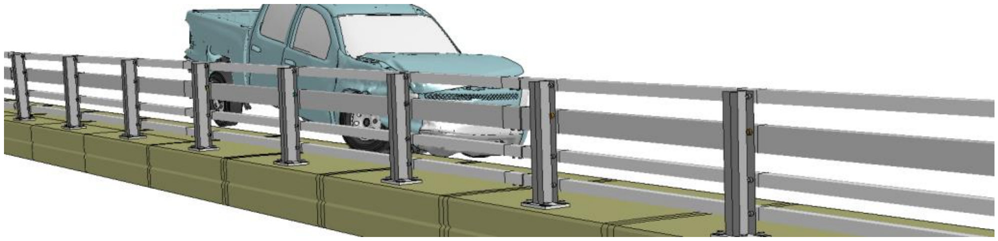


Figure R-3. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from an oblique viewpoint.

0.60 seconds



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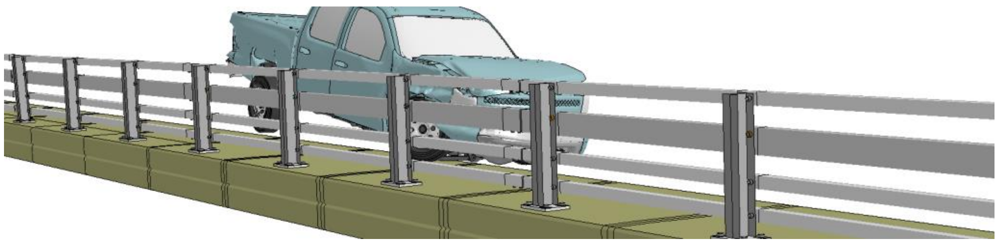

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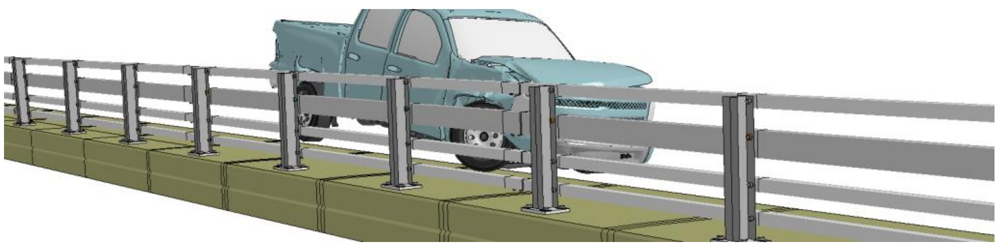

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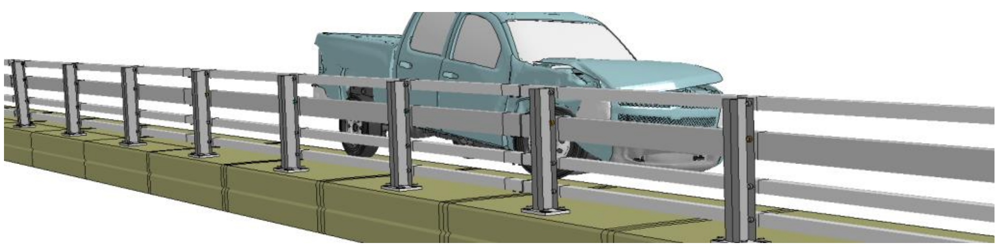


Figure R-3. [Continued] Sequential views from analysis of MASH Test 4-11 for NETC 4-Bar bridge rail from an oblique viewpoint.

Appendix S

Sequential Views for Test 4-12 on

Sidewalk-Mounted NETC 4-Bar Bridge Rail

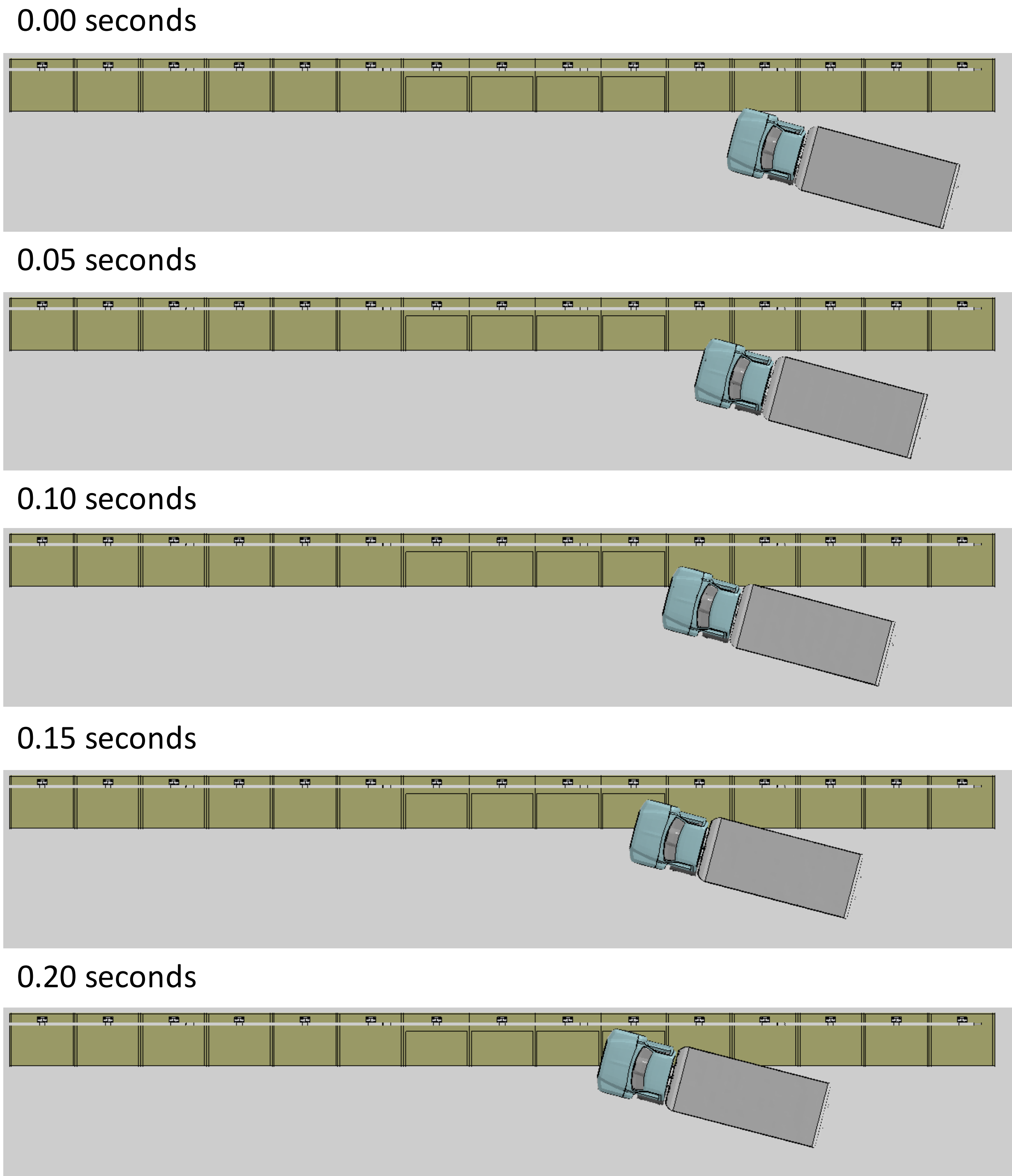
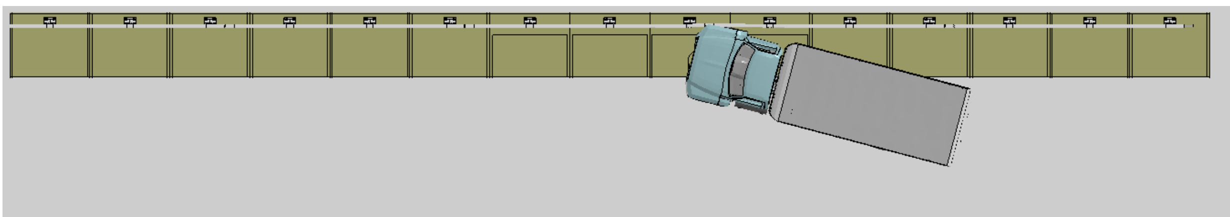


Figure S-1. Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an overhead viewpoint.

0.25 seconds

0.30 seconds



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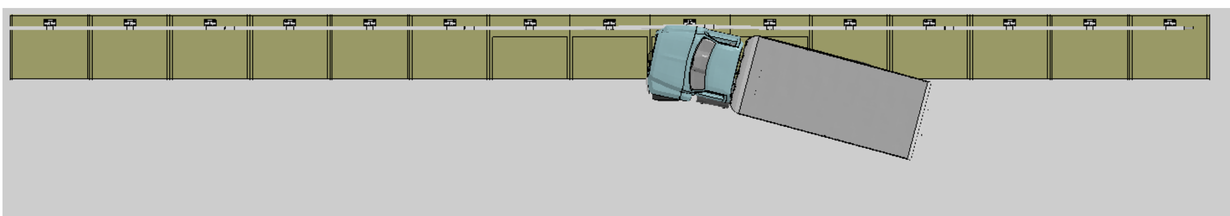

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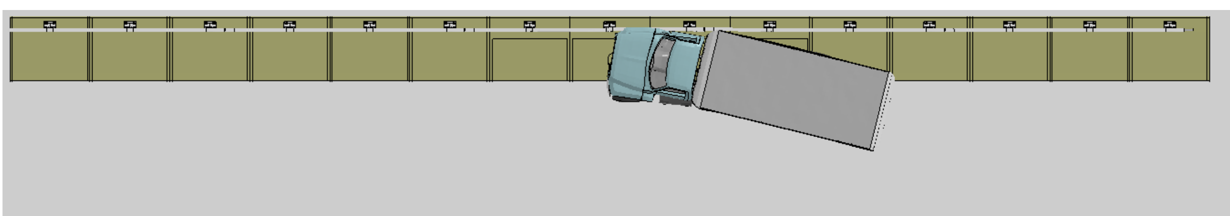

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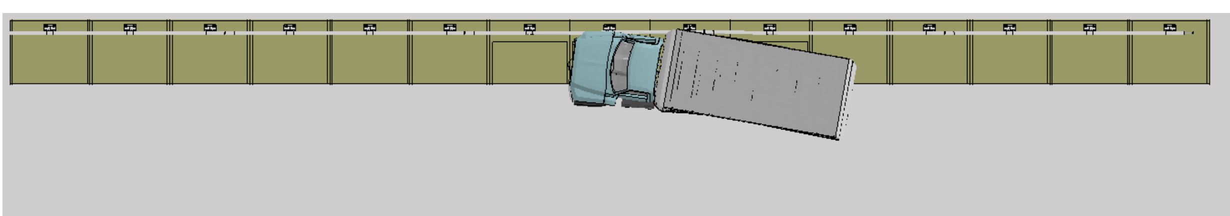
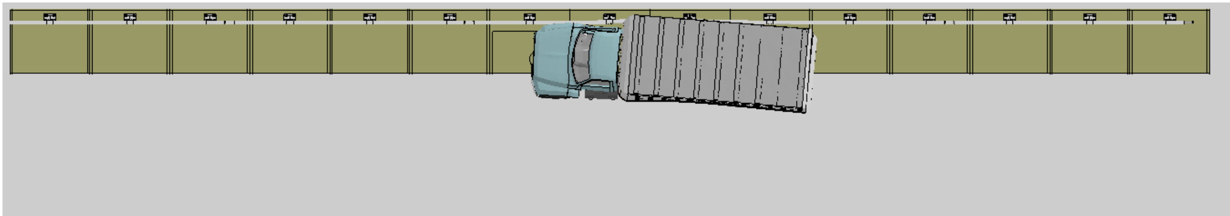


Figure S-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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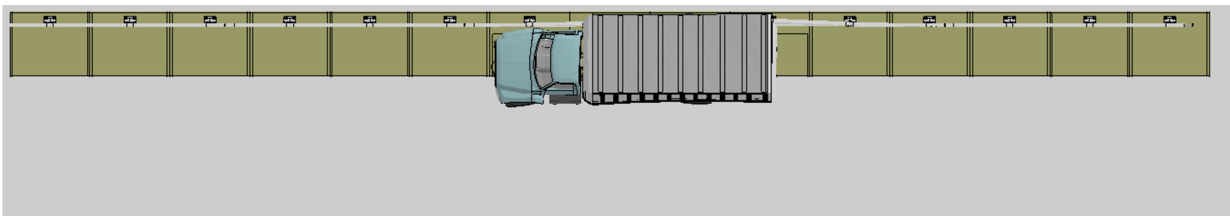

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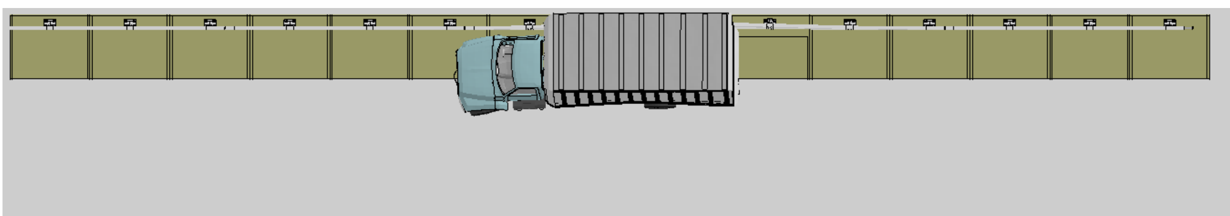

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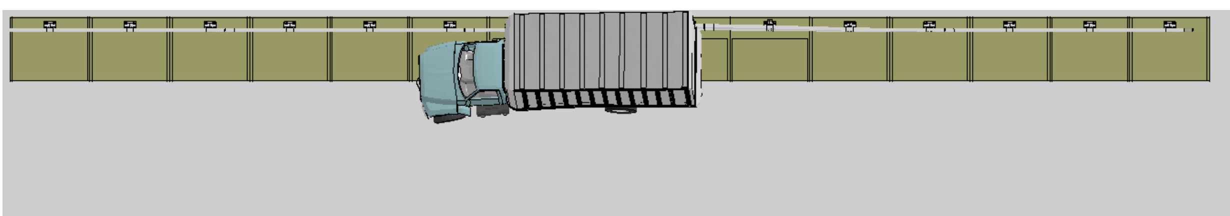

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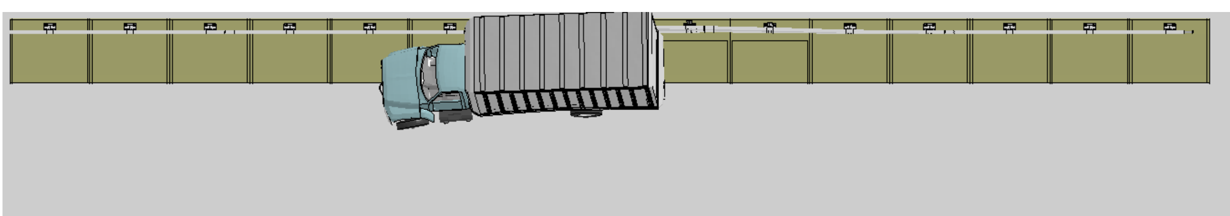
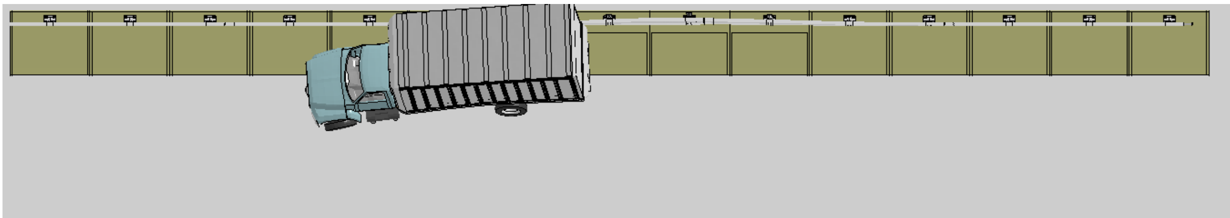


Figure S-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an overhead viewpoint.

0.75 seconds



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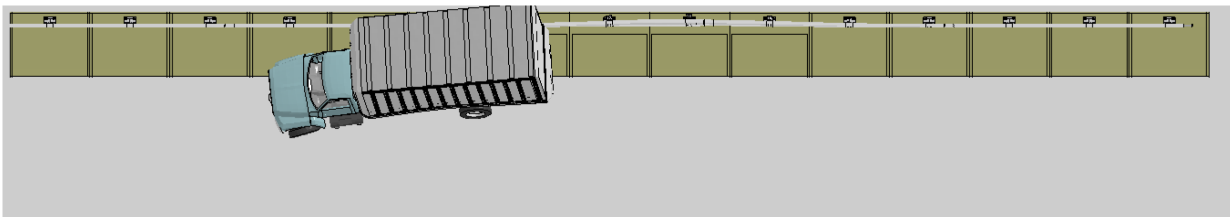

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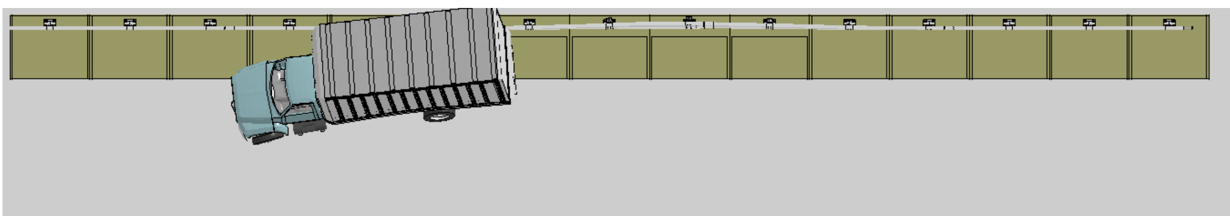

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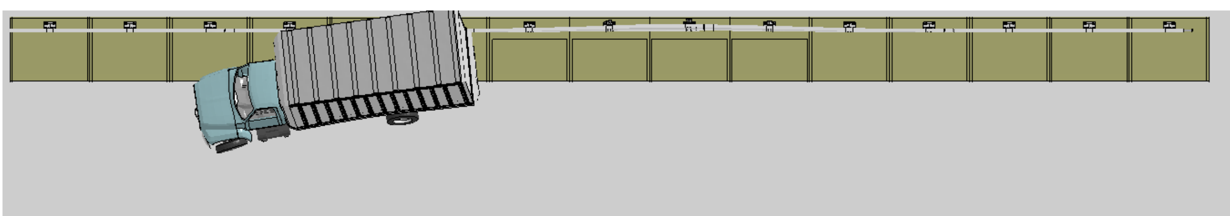

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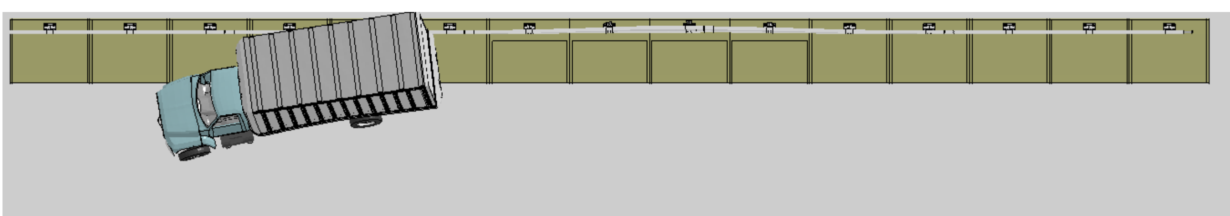


Figure S-1. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an overhead viewpoint.

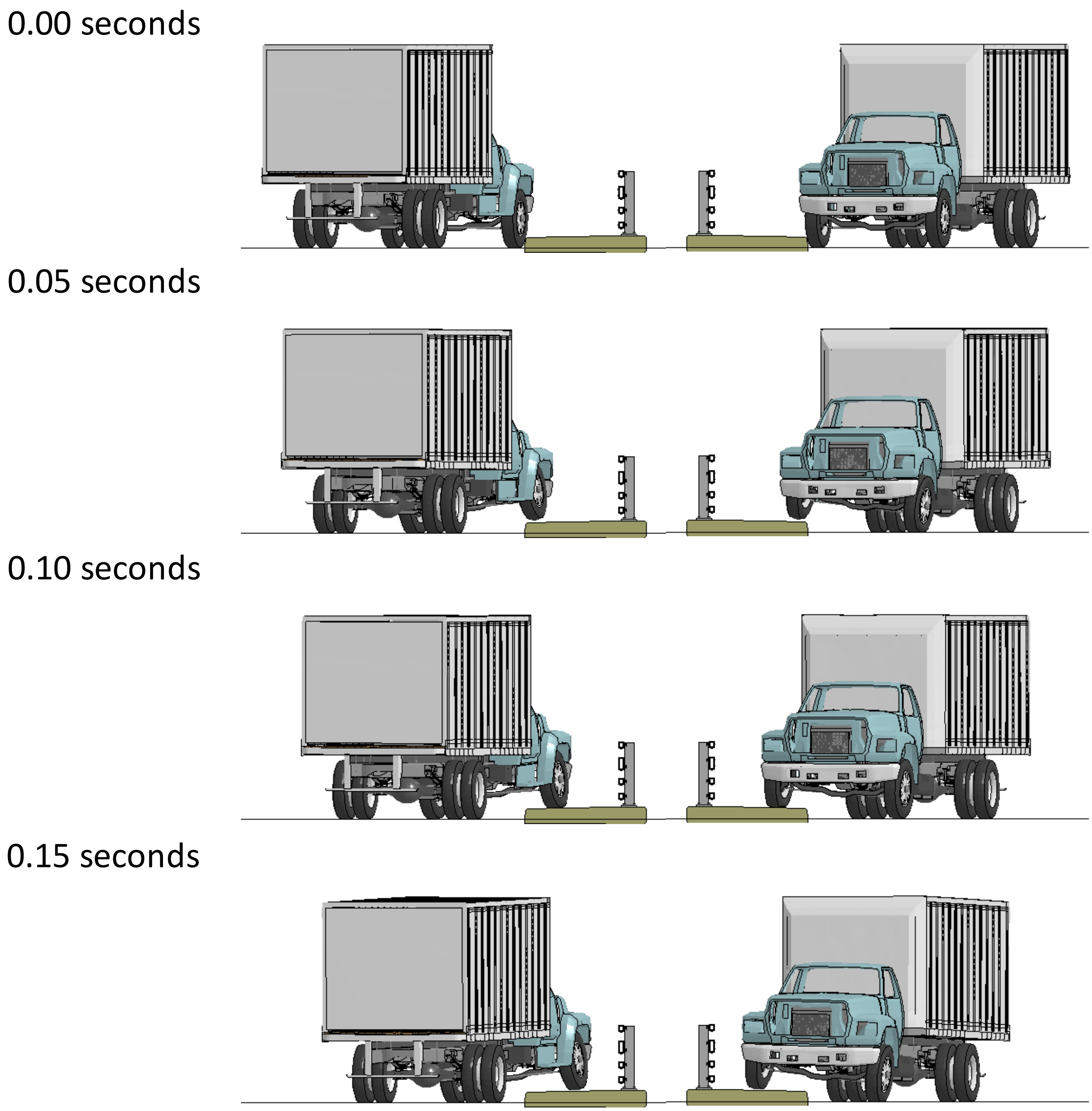
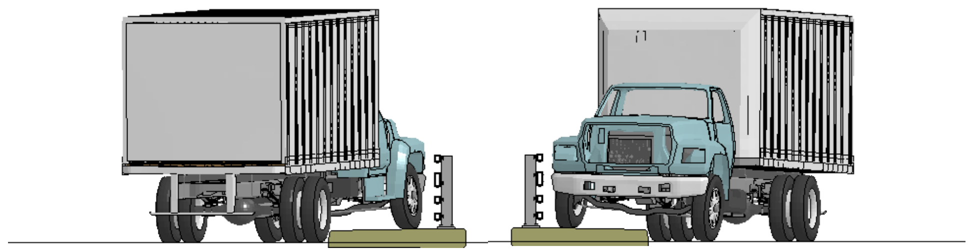


Figure S-2. Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

0.20 seconds



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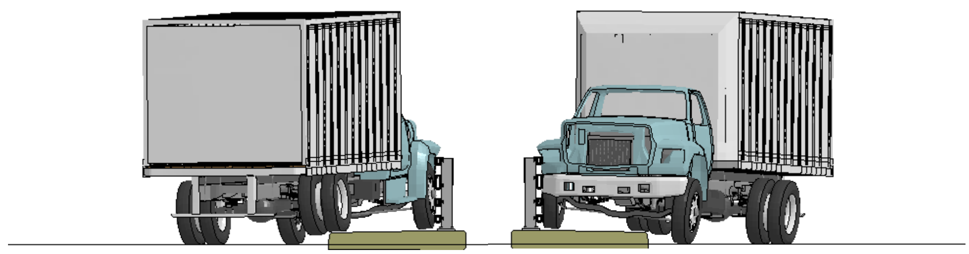

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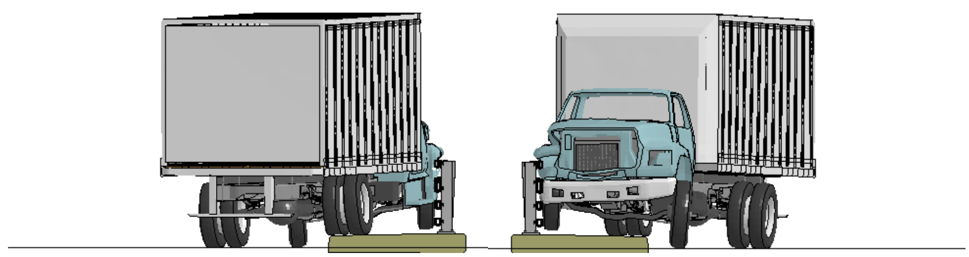

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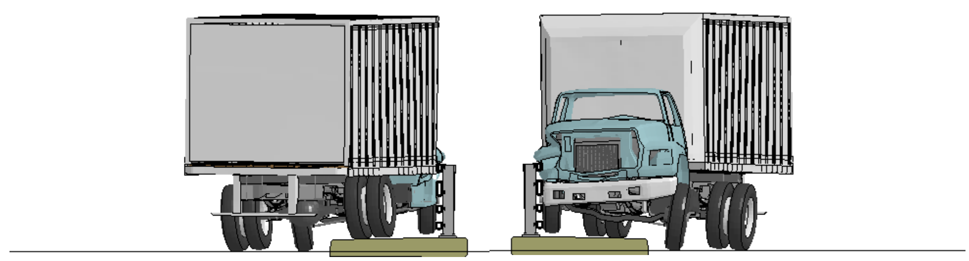

Figure S-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

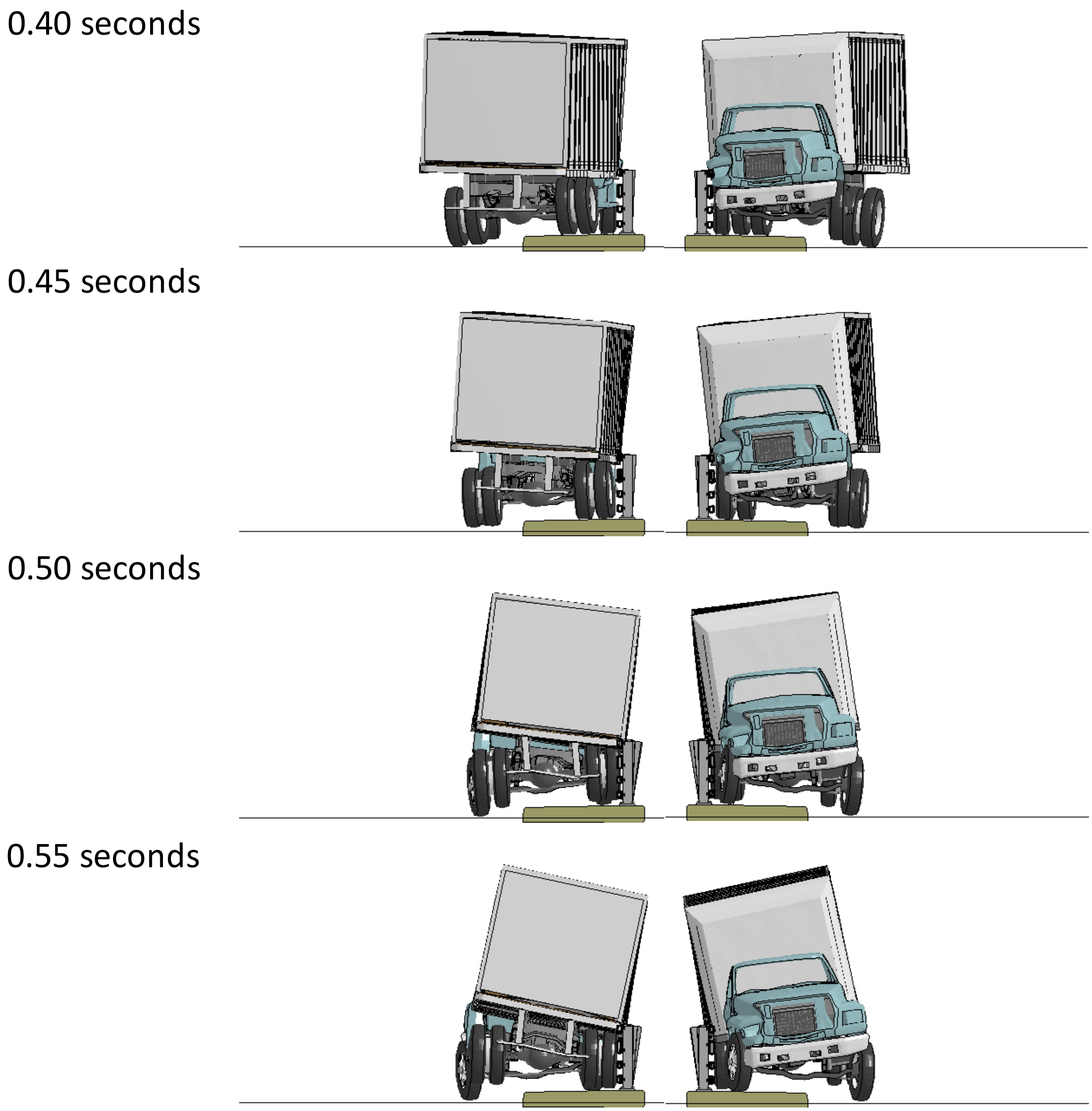

Figure S-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

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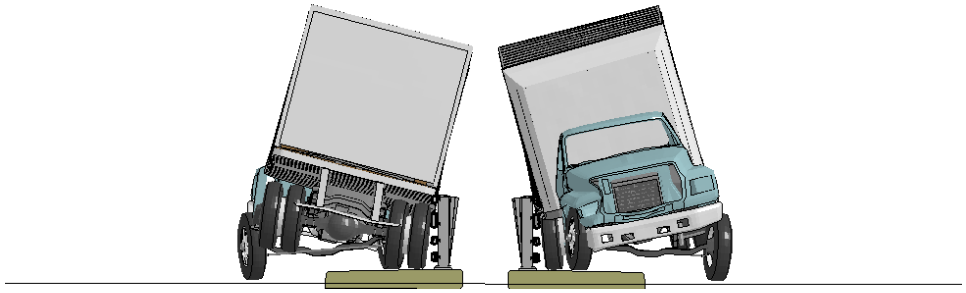

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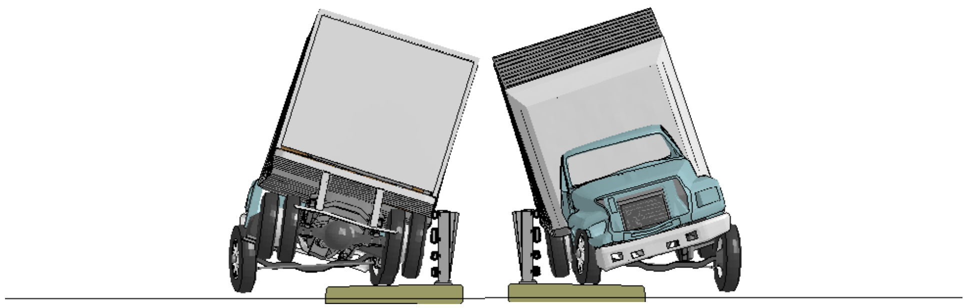

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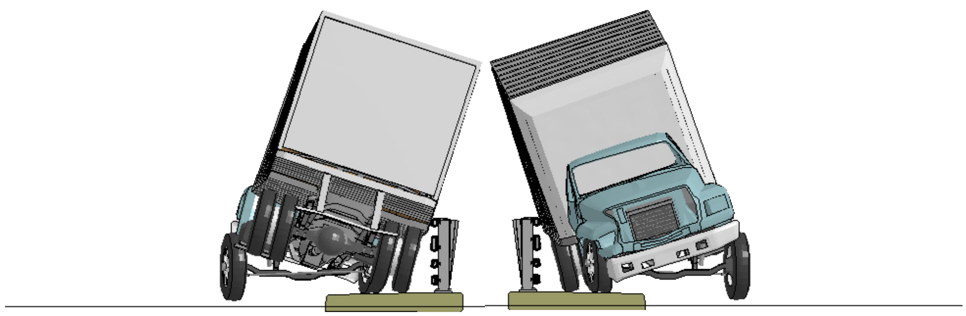

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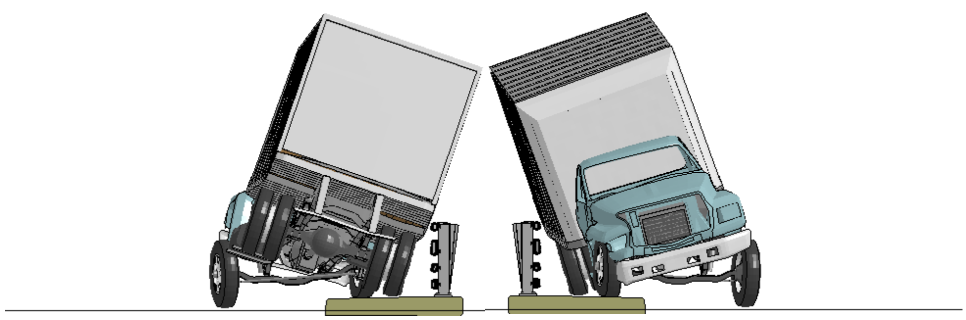

Figure S-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

0.80 seconds

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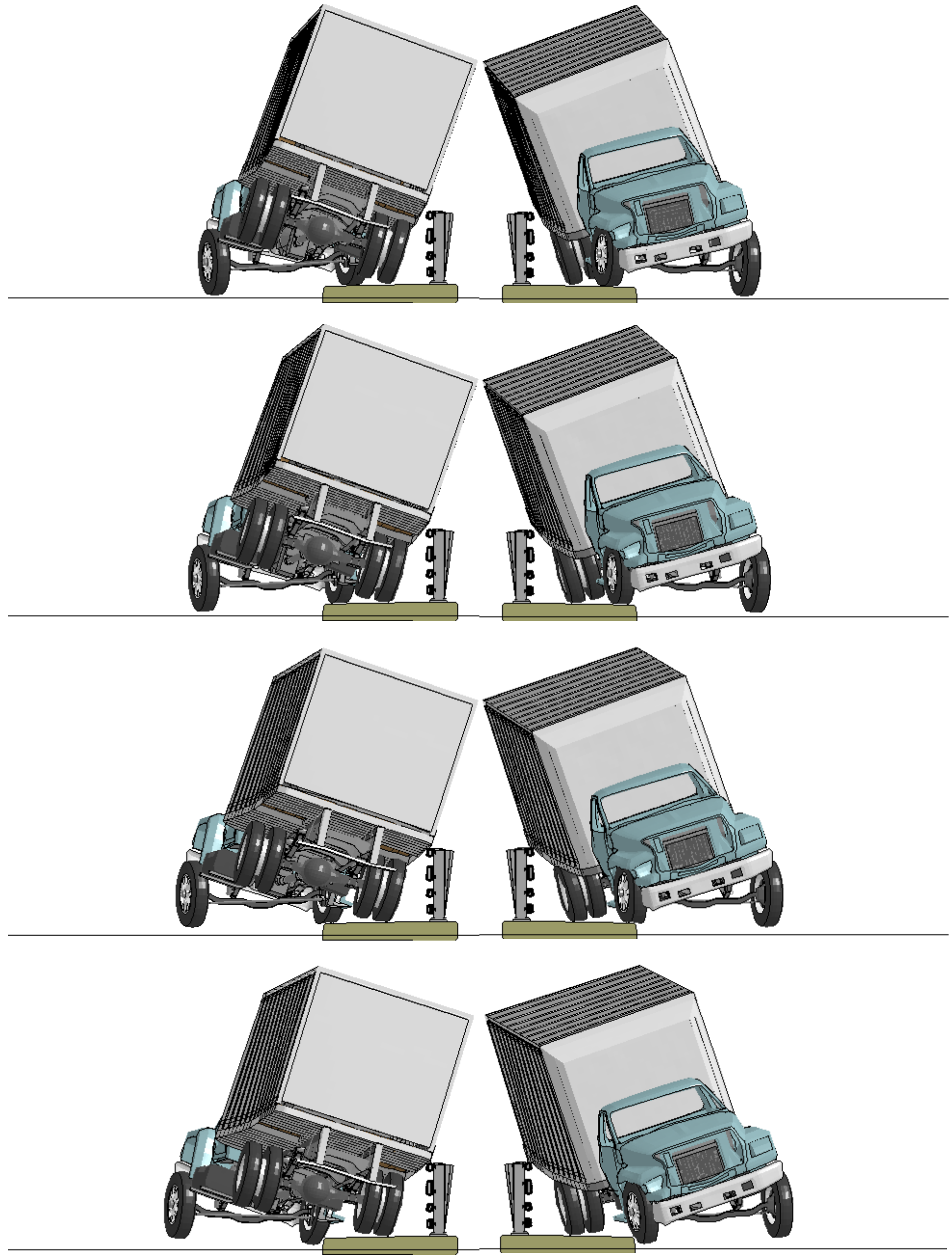

Figure S-2. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from upstream and downstream viewpoints.

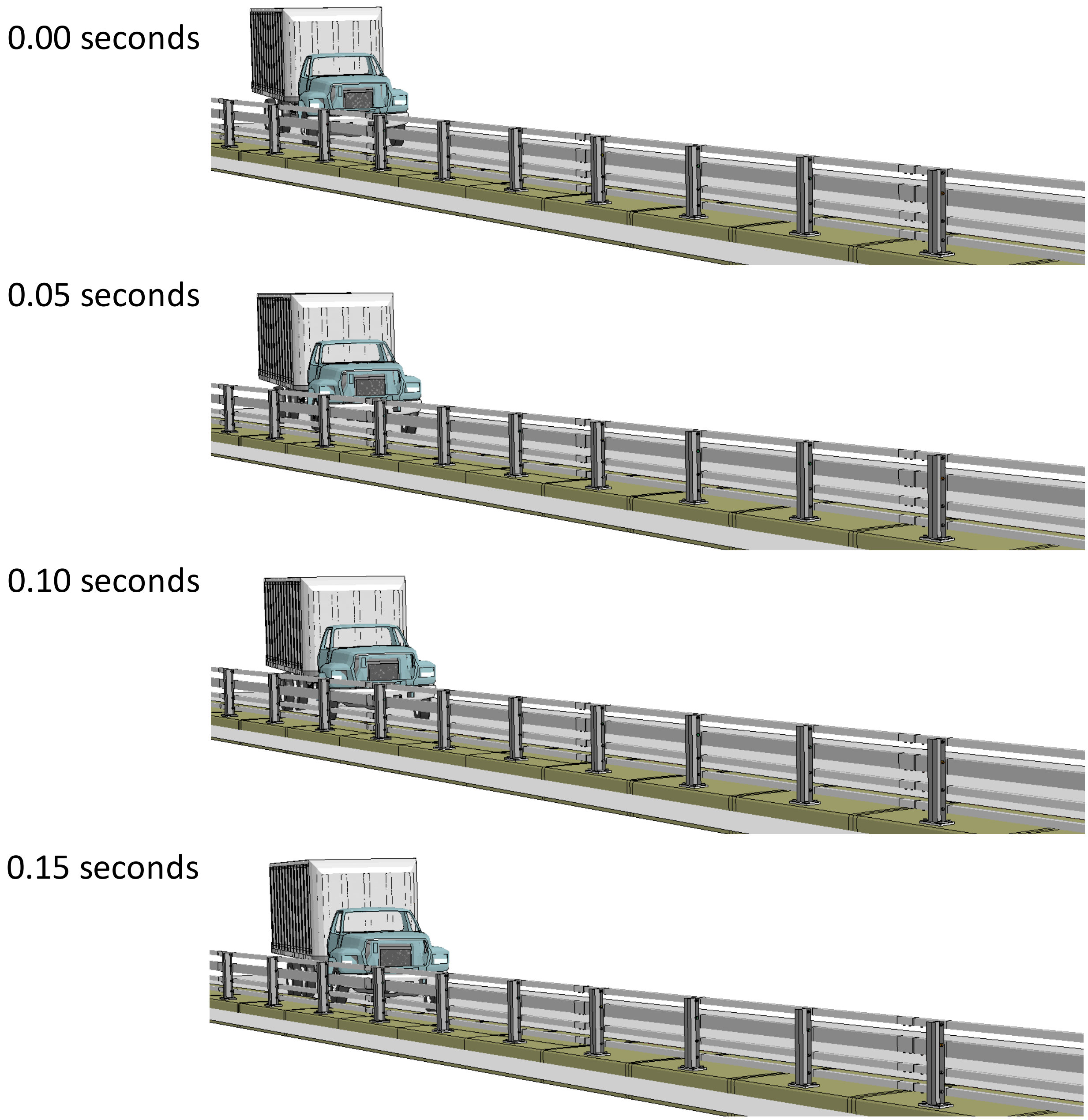

Figure S-3. Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an oblique viewpoint.

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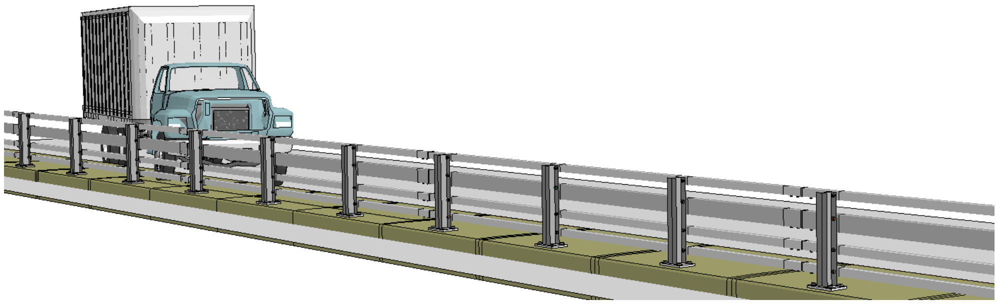

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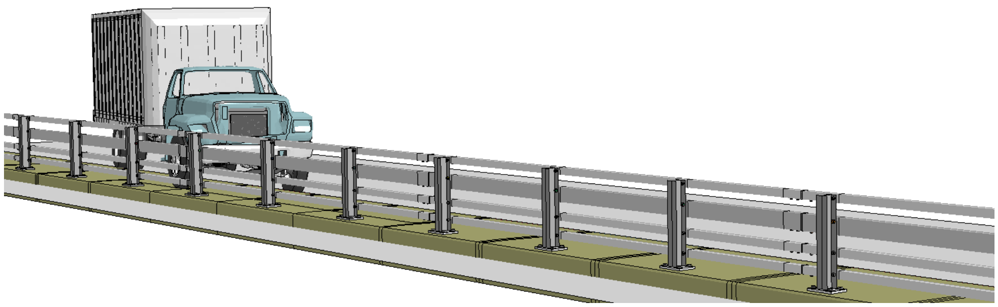

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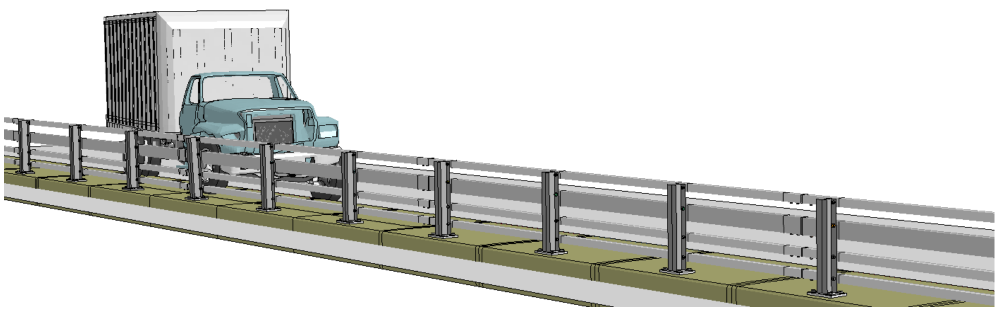

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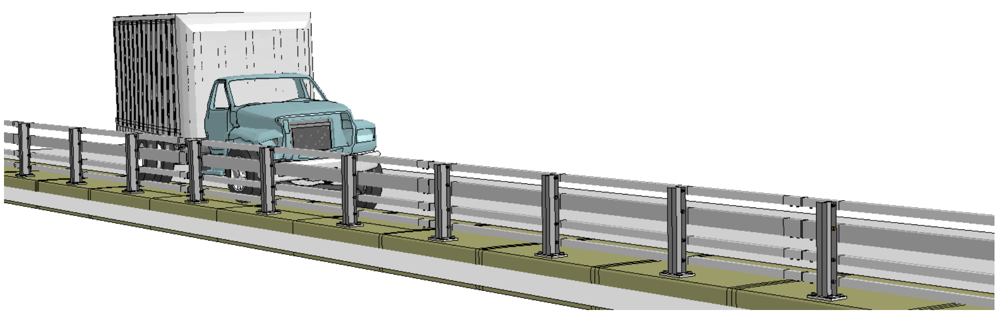

Figure S-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an oblique viewpoint.

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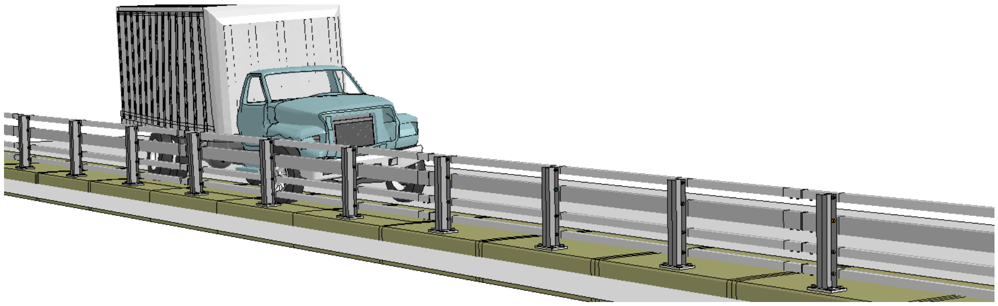

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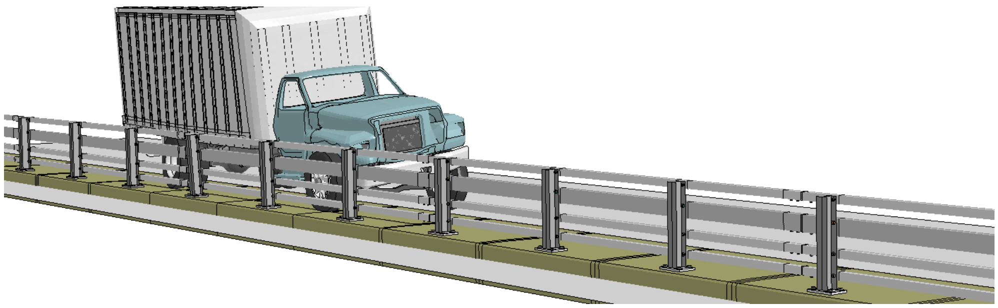

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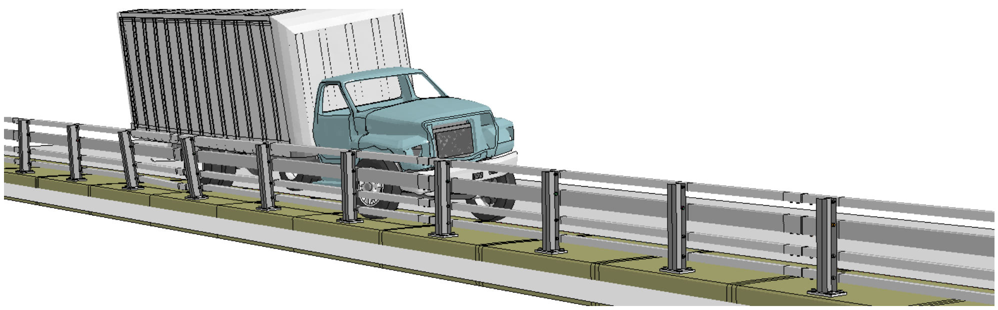

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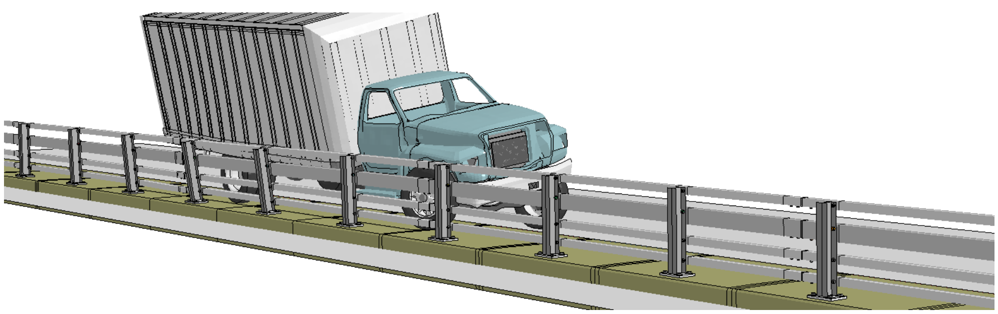

Figure S-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an oblique viewpoint.

0.60 seconds

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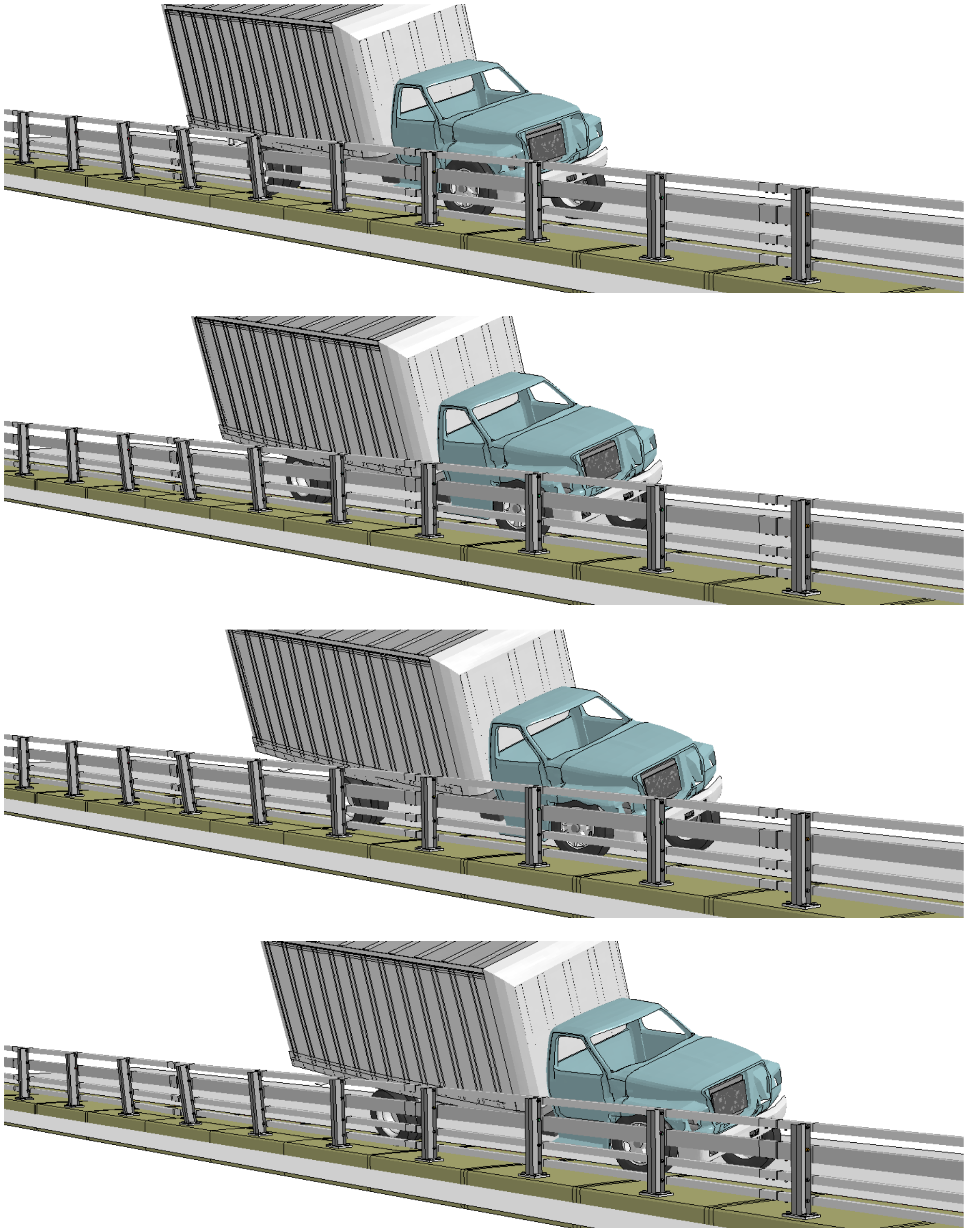

Figure S-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an oblique viewpoint.

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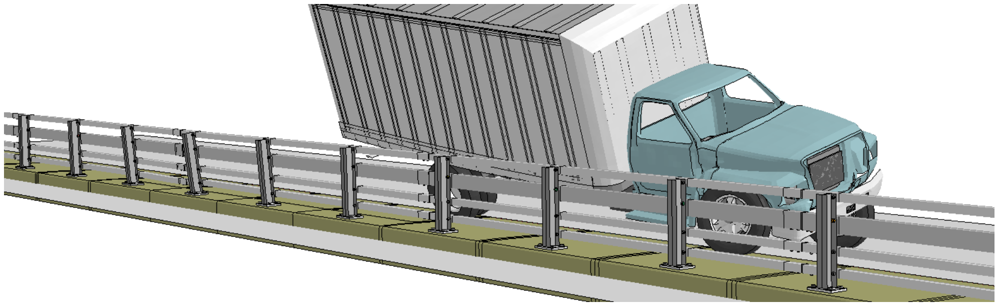

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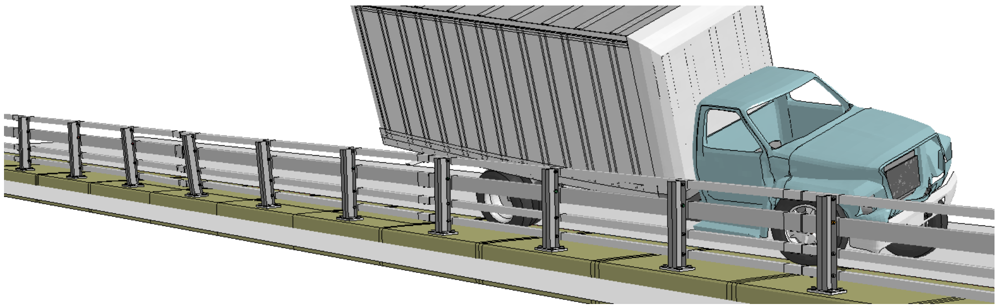

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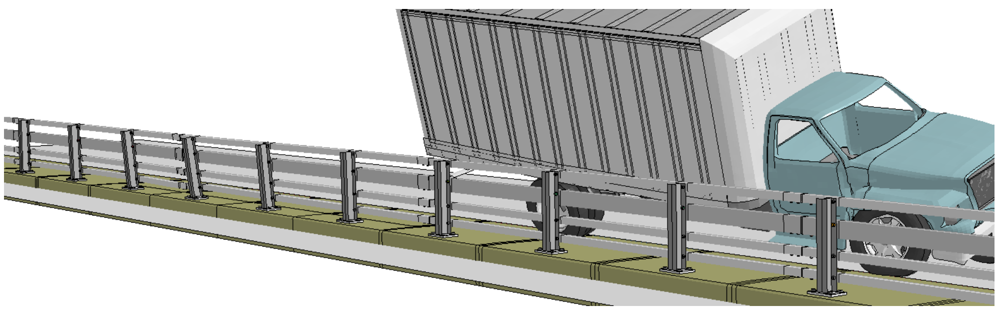

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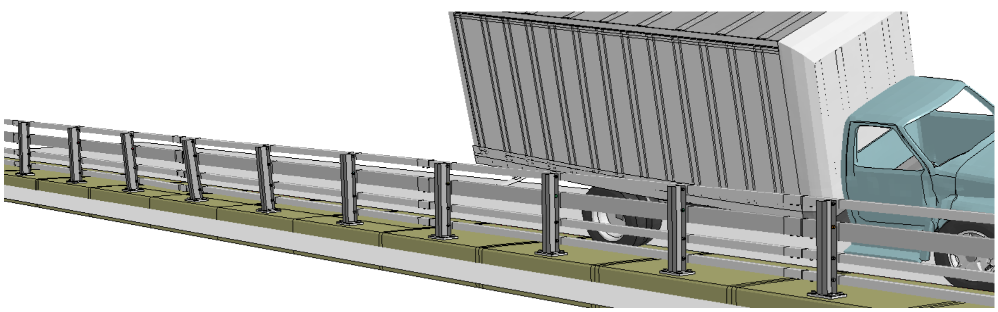

Figure S-3. [Continued] Sequential views from analysis of MASH Test 4-12 for NETC 4-Bar bridge rail from an oblique viewpoint.

Appendix T

Sequential Views for Test 4-20 on

Sidewalk-Mounted AGT 4-Bar Bridge Rail

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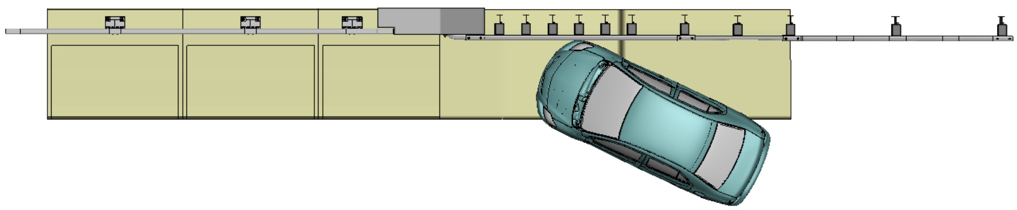

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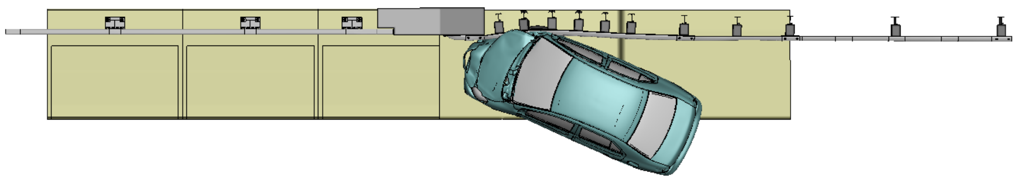

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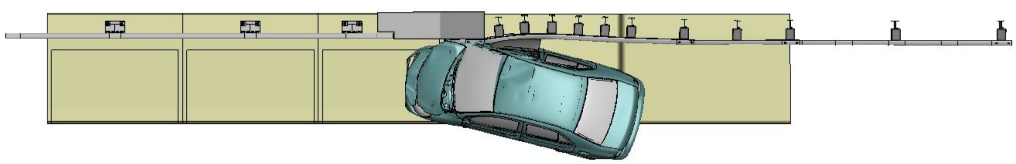

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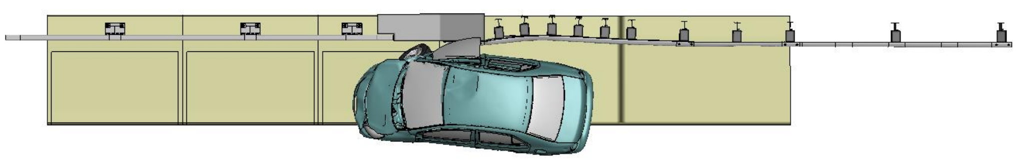

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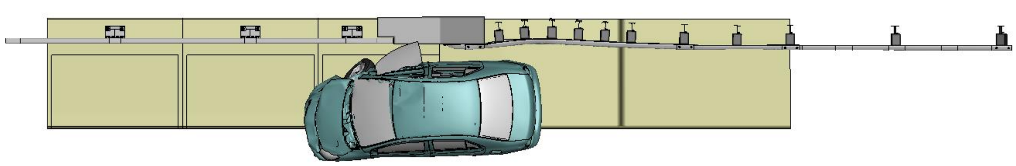
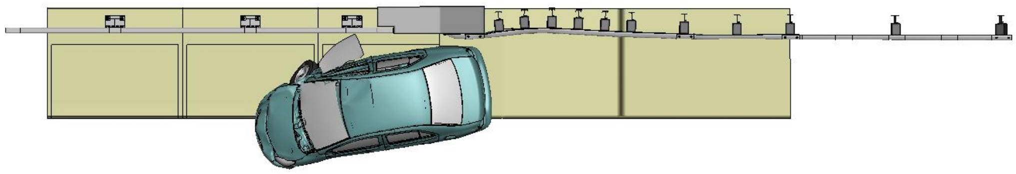


Figure T-1. Sequential views from analysis of MASH Test 4-20 for AGT 4-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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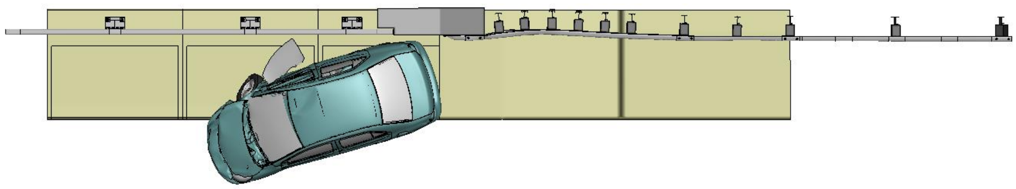

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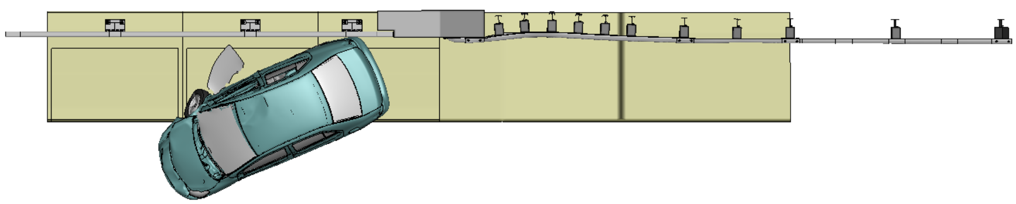

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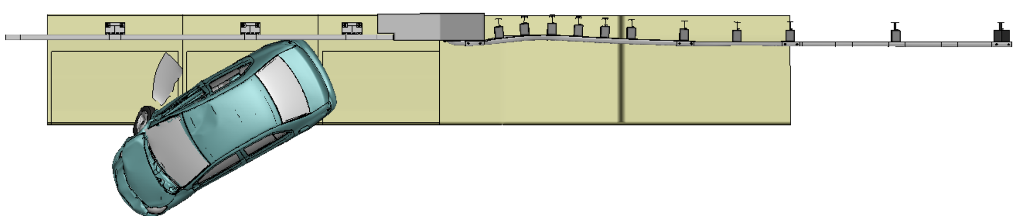

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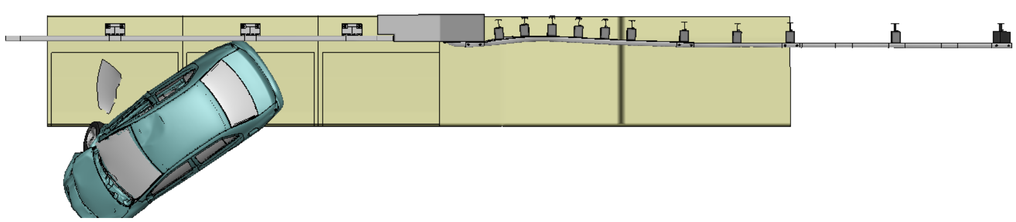

Figure T-1. [Continued] Sequential views from analysis of MASH Test 4-20 for AGT 4-Bar bridge rail from an overhead viewpoint.

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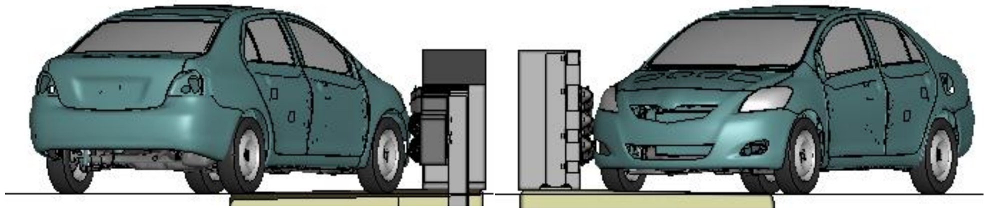

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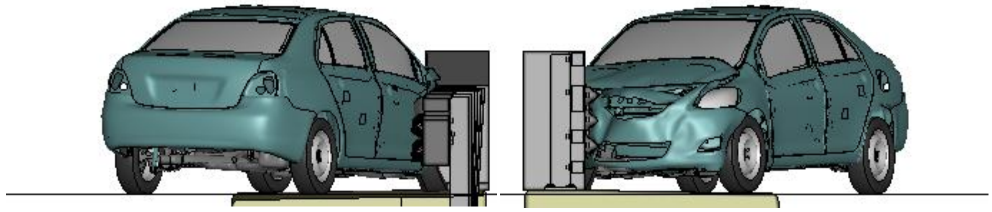

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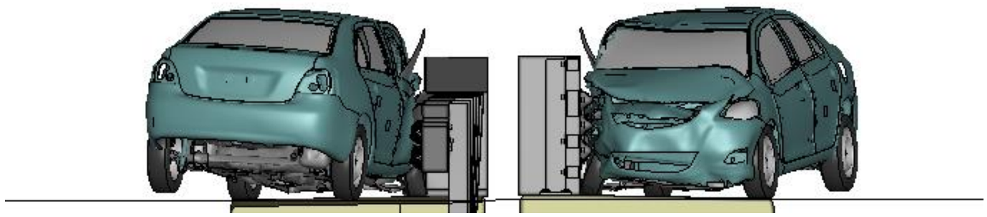

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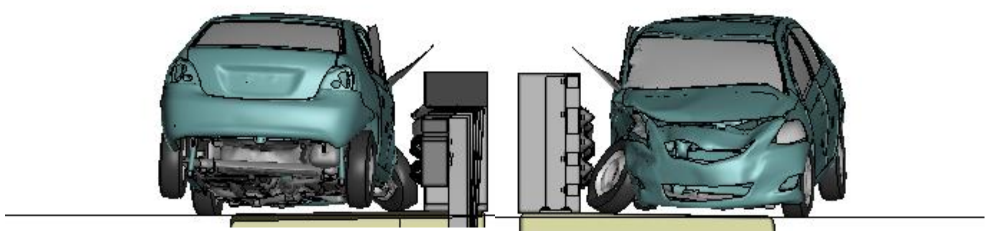
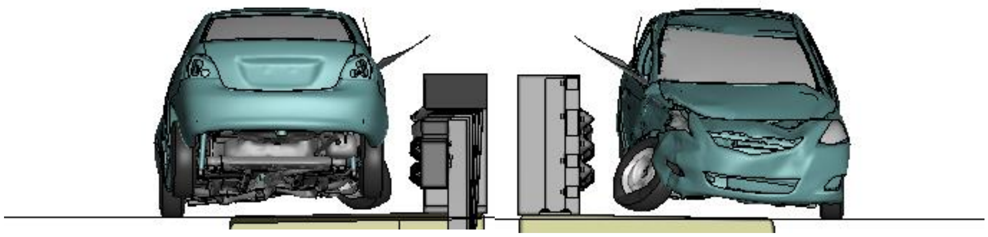


Figure T-2. Sequential views from analysis of MASH Test 4-20 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

0.20 seconds



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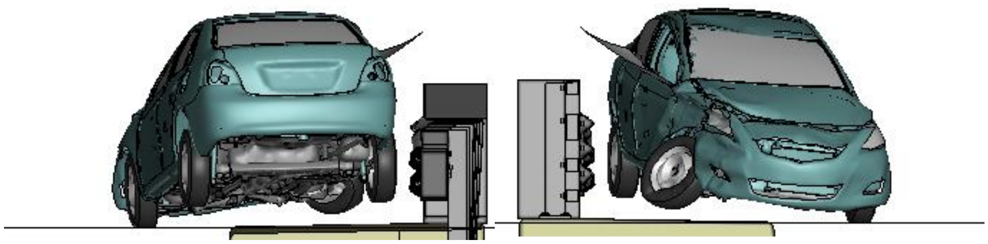

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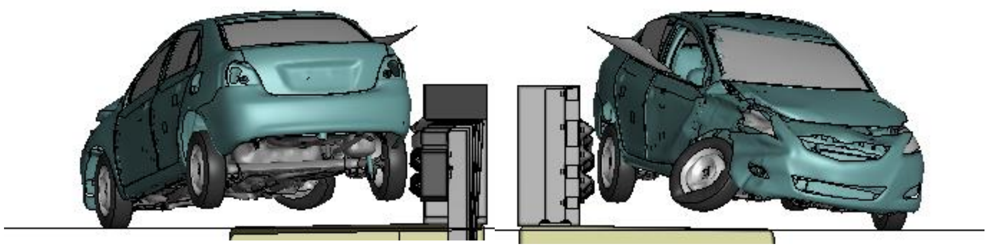

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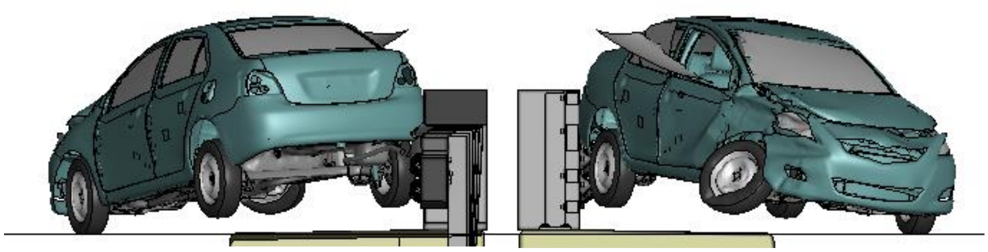

Figure T-2. [Continued] Sequential views from analysis of MASH Test 4-20 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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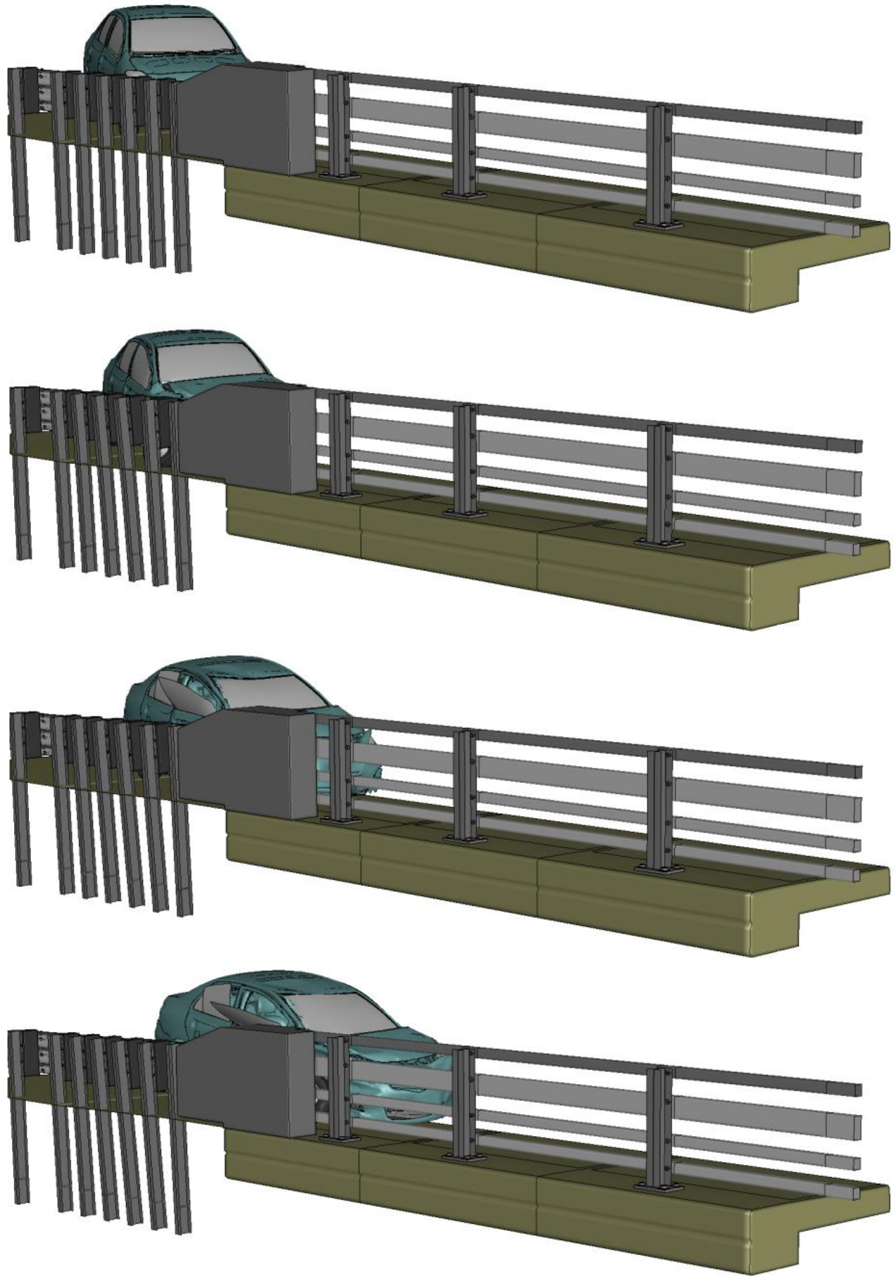
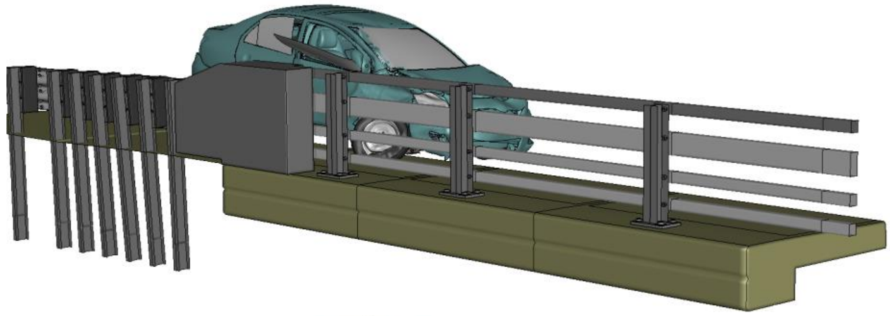


Figure T-3. Sequential views from analysis of MASH Test 4-20 for AGT 4-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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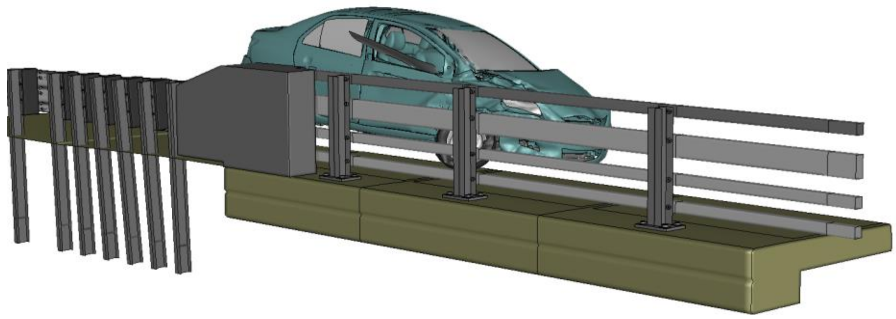

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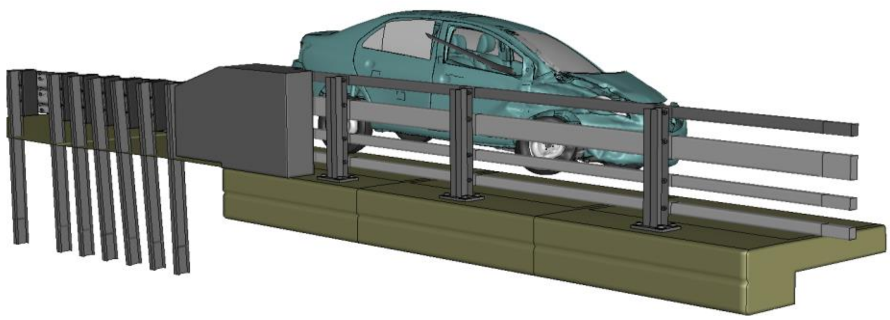

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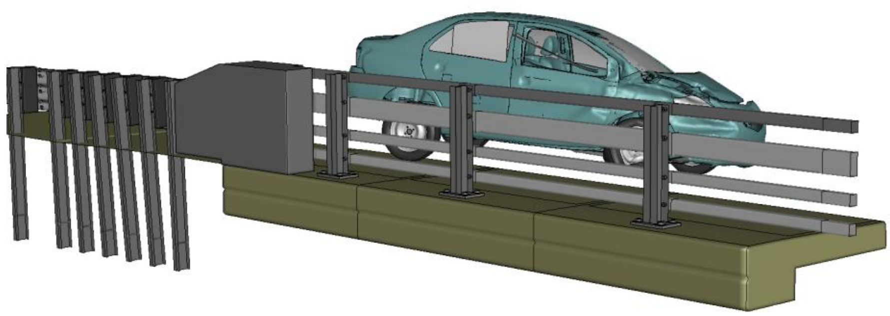

Figure T-3. [Continued] Sequential views from analysis of MASH Test 4-20 for AGT 4-Bar bridge rail from an oblique viewpoint.

Appendix U

Sequential Views for Test 4-21 on

Sidewalk-Mounted AGT 4-Bar Bridge Rail

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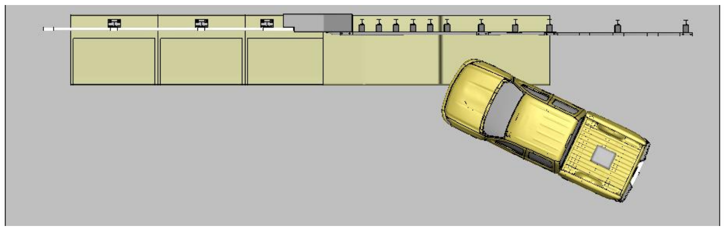
0.05 seconds



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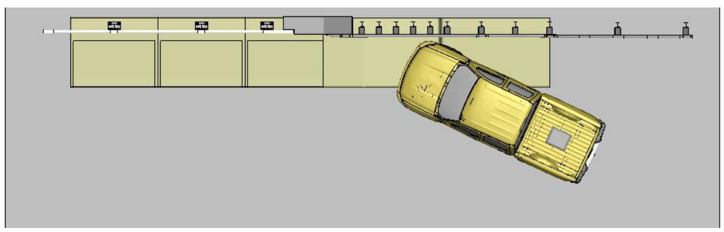

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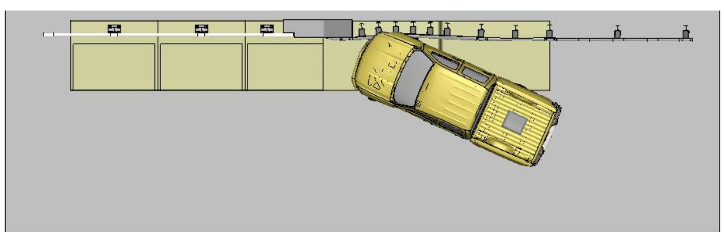

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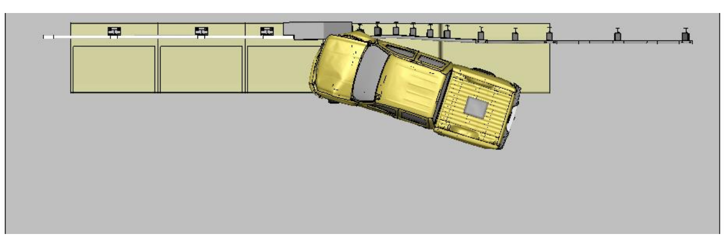
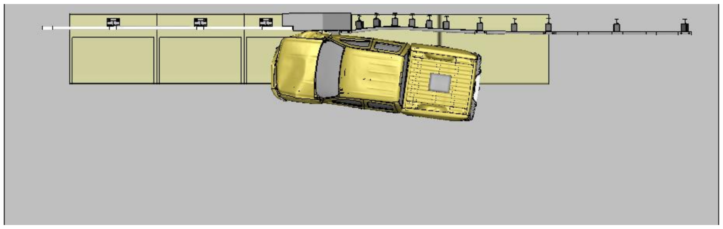


Figure U-1. Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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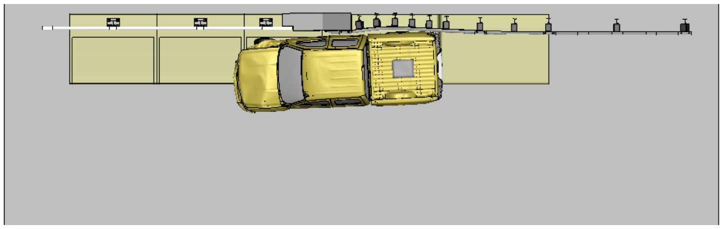

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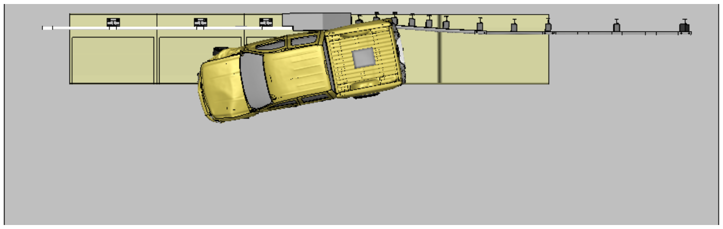

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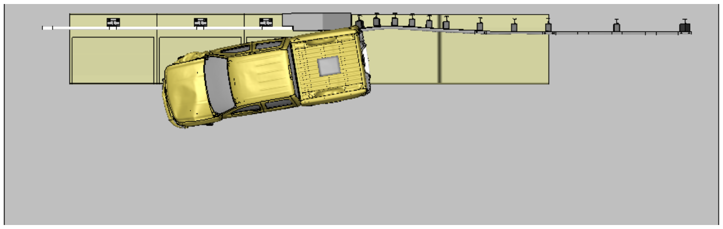

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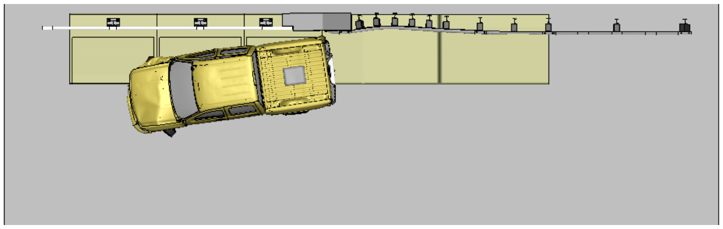
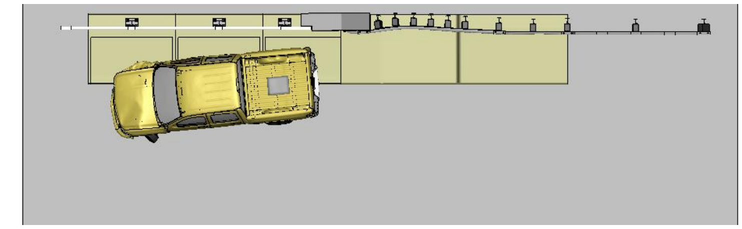


Figure U-1. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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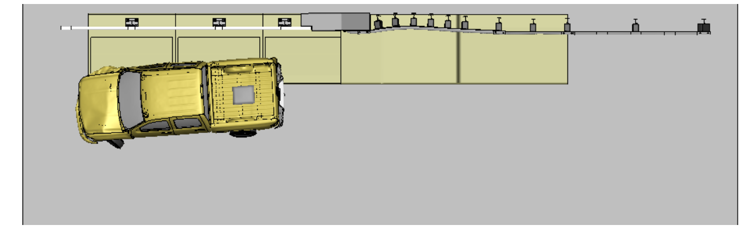

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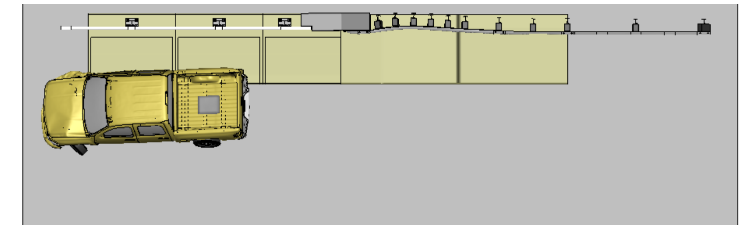

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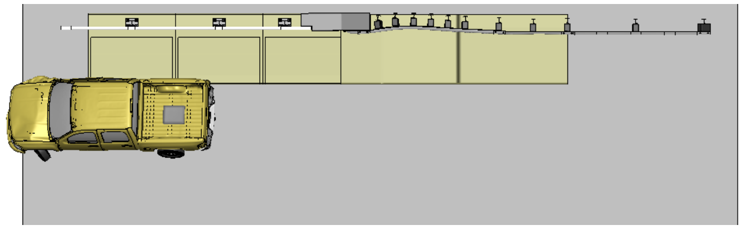

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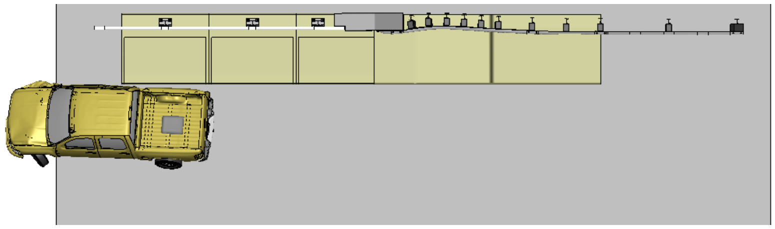

Figure U-1. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an overhead viewpoint.

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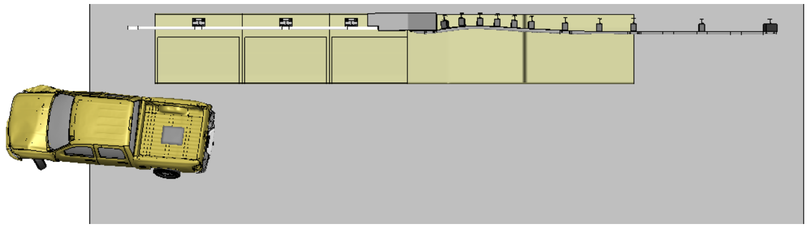

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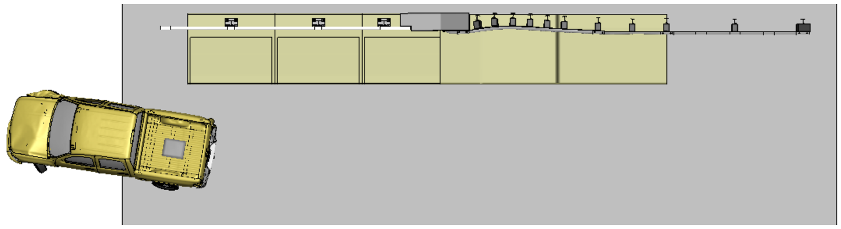

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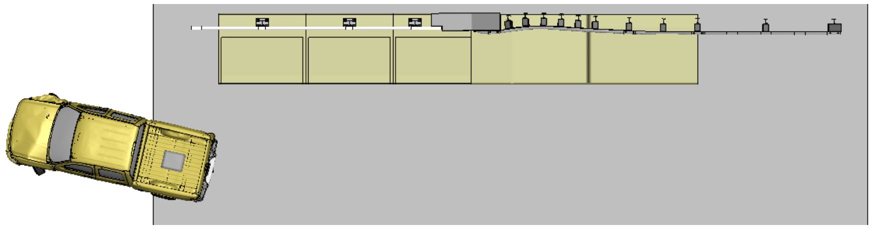

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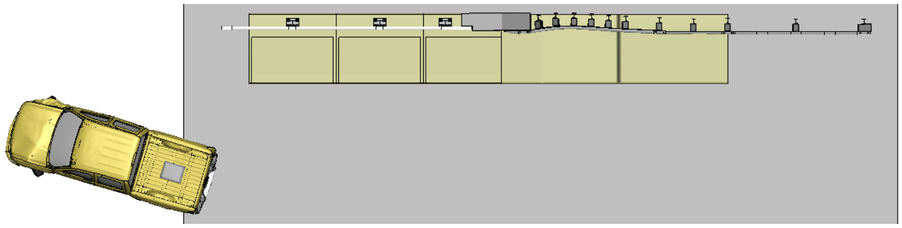

Figure U-1. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an overhead viewpoint.

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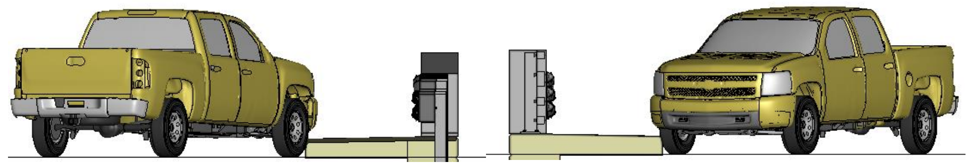

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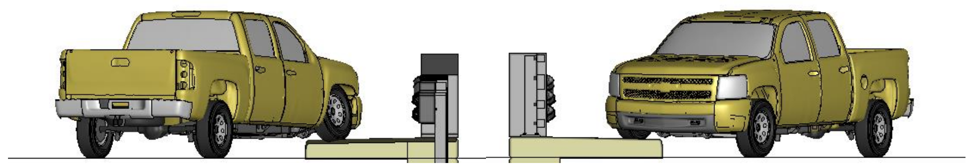

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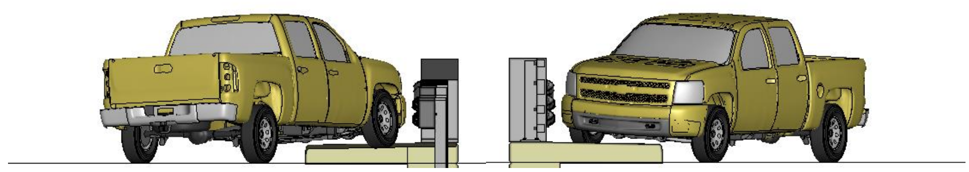

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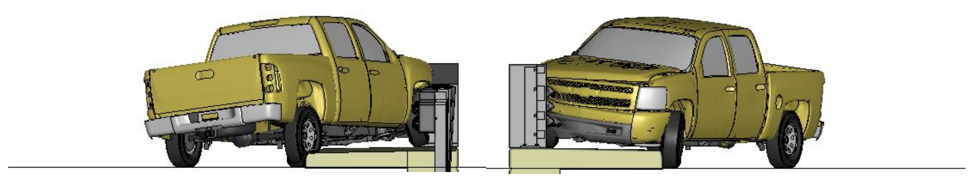

Figure U-2. Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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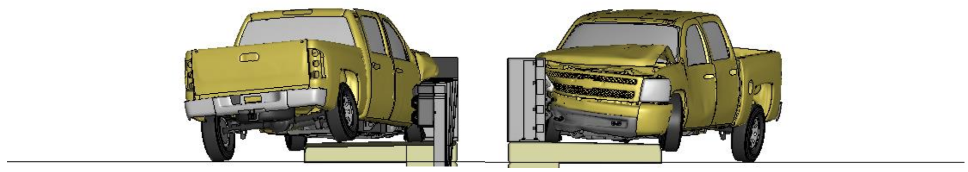

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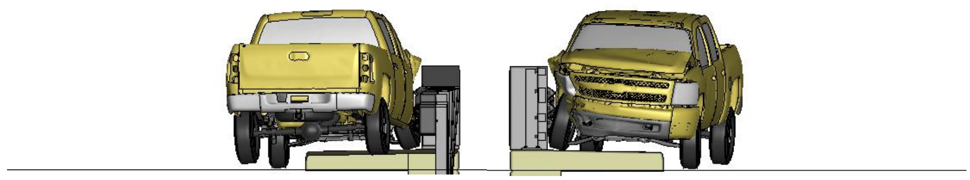

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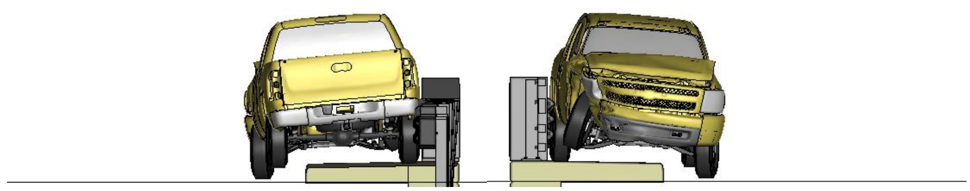

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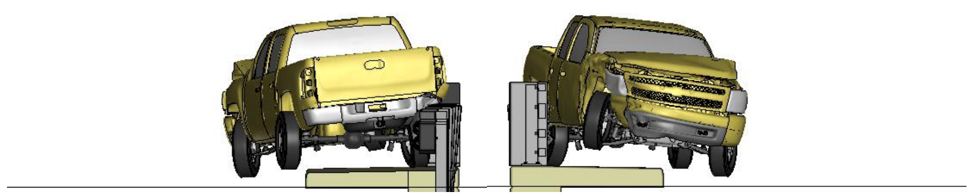

Figure U-2. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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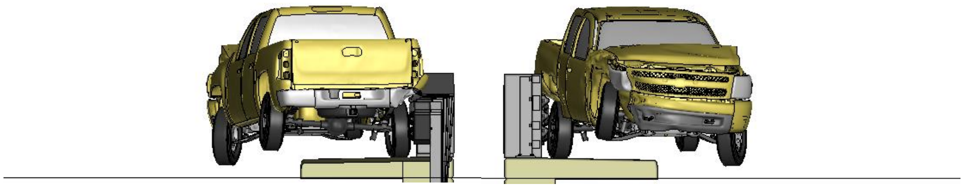

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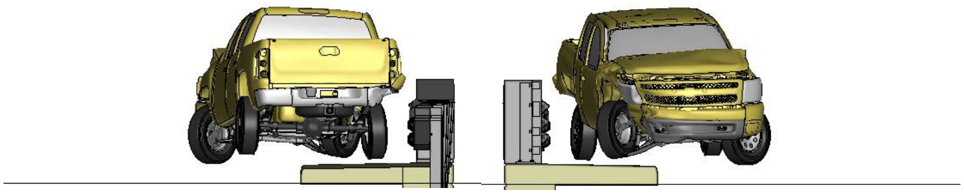

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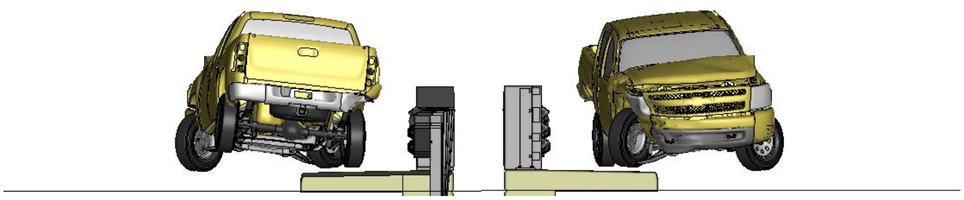

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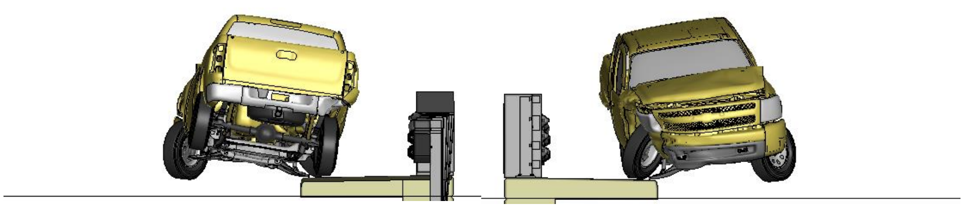

Figure U-2. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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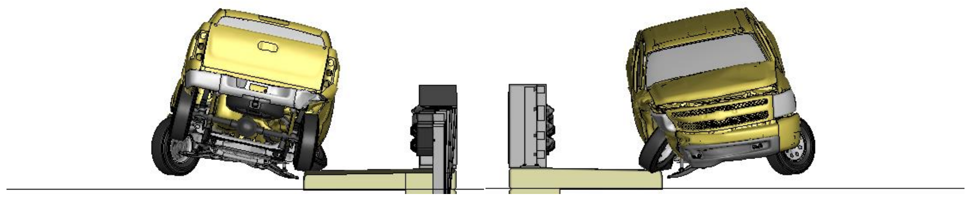

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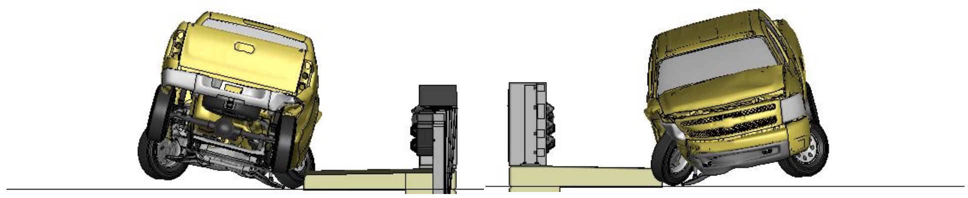

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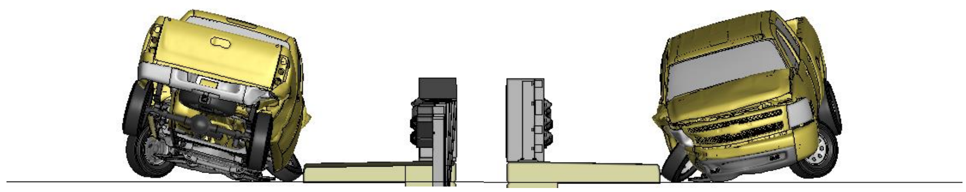

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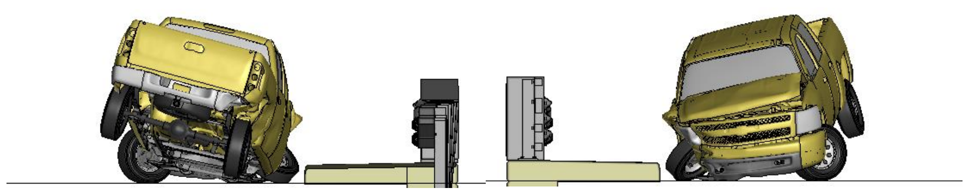

Figure U-2. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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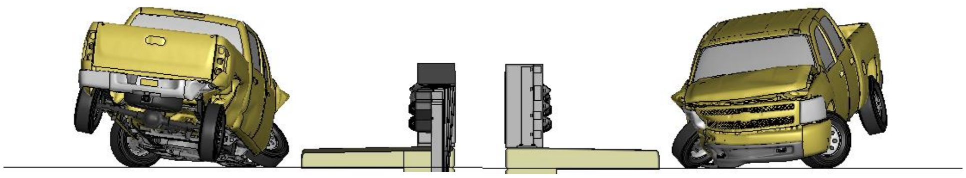

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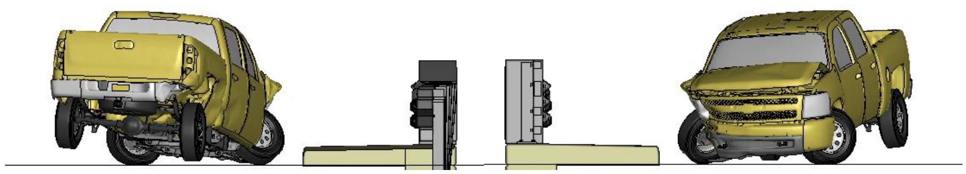

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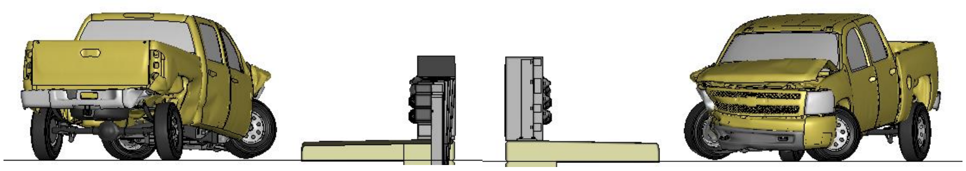
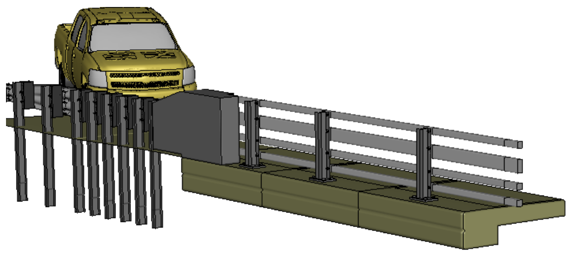


Figure U-2. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

0.00 seconds



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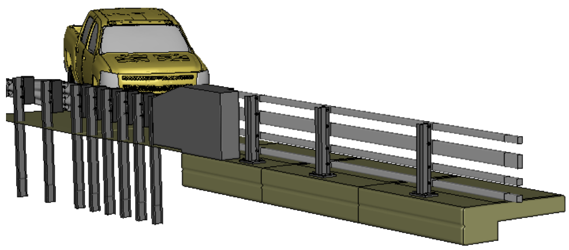

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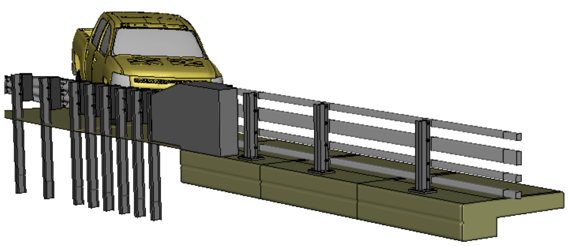

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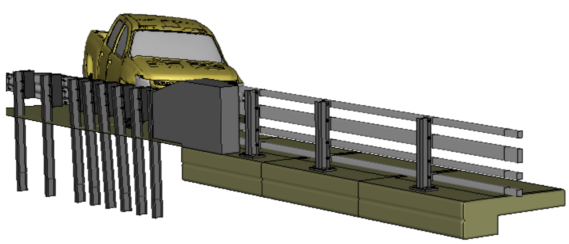
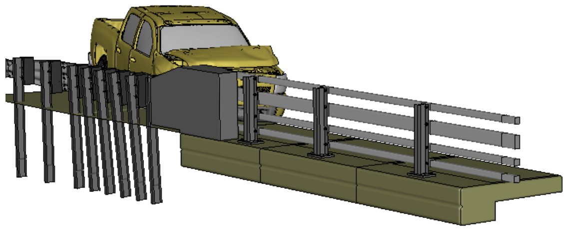


Figure U-3. Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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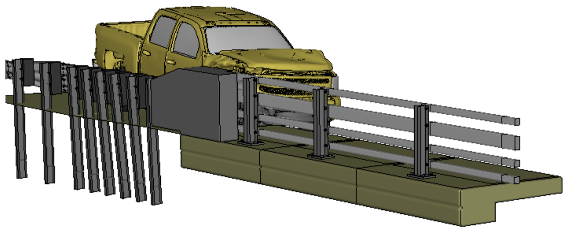

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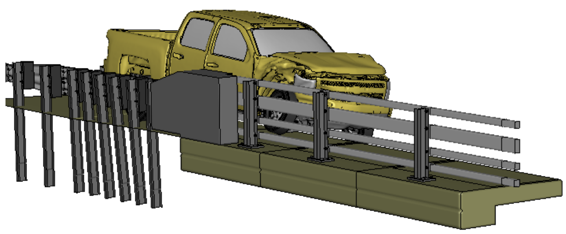

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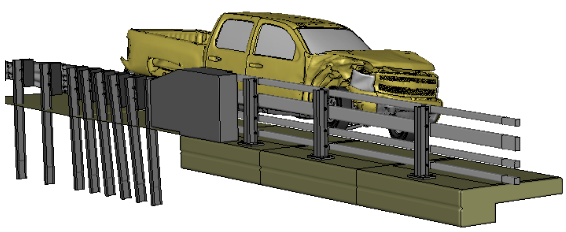

Figure U-3. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an oblique viewpoint.

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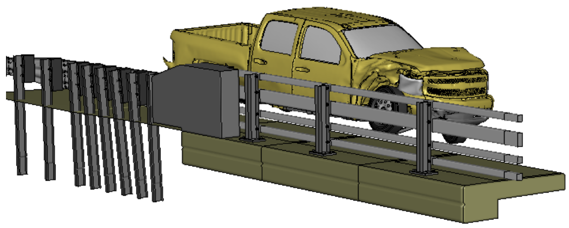

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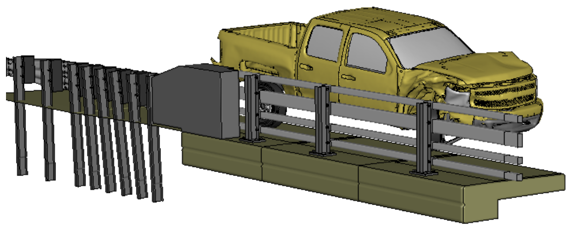

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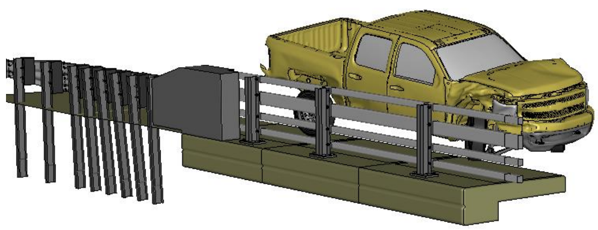

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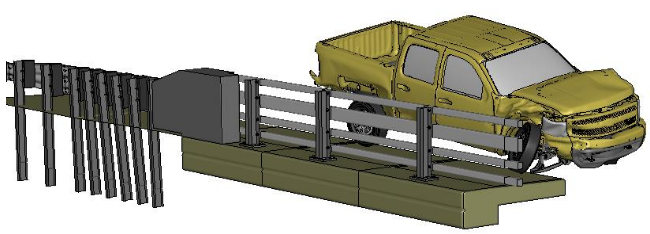

Figure U-3. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an oblique viewpoint.

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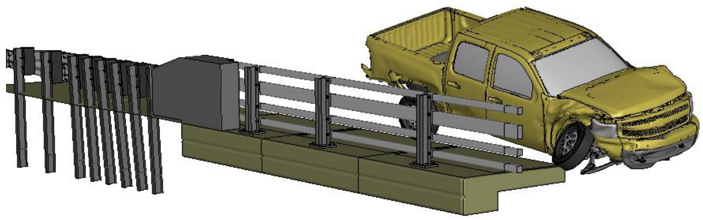

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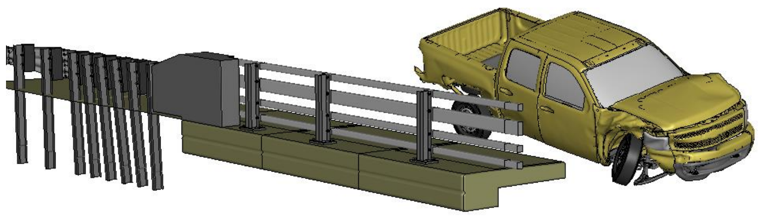

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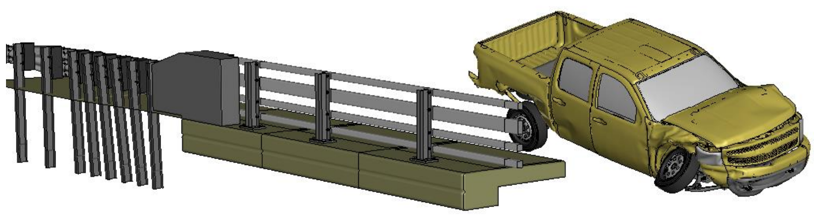

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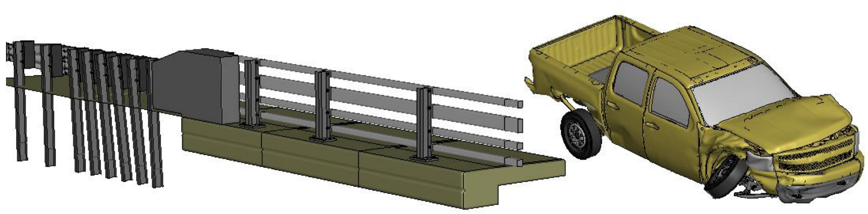


Figure U-3. [Continued] Sequential views from analysis of MASH Test 4-21 for AGT 4-Bar bridge rail from an oblique viewpoint.

Appendix V

Sequential Views for Test 4-22 on

Sidewalk-Mounted AGT 4-Bar Bridge Rail

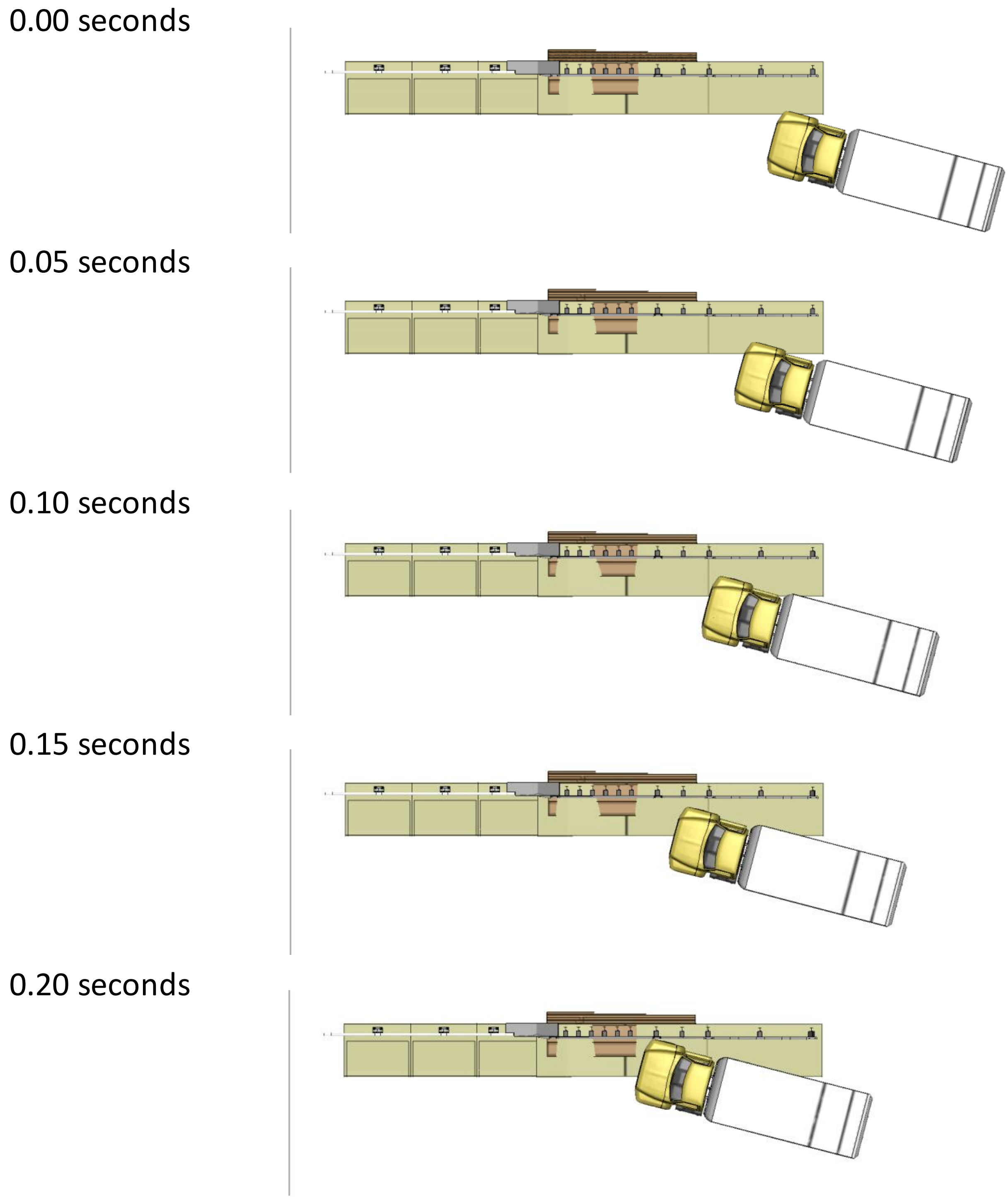
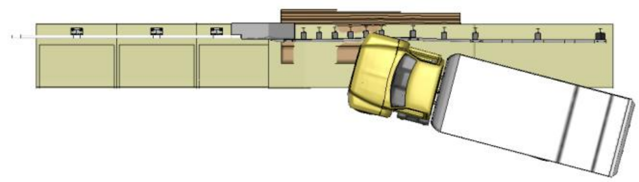


Figure V-1. Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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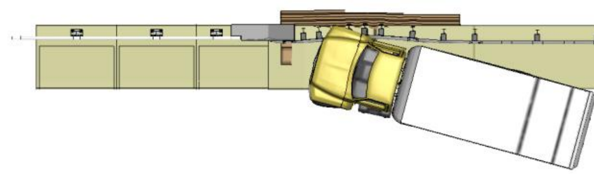

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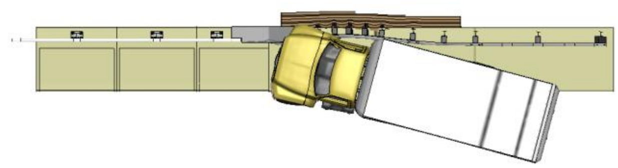

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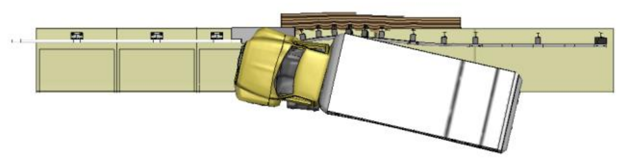

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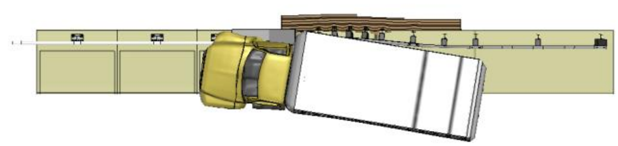
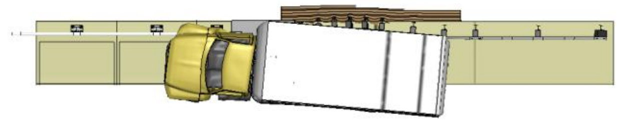


Figure V-1. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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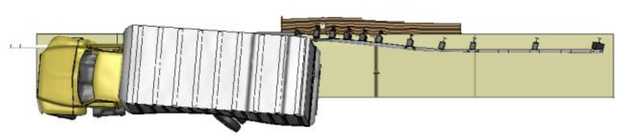

Figure V-1. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an overhead viewpoint.

0.75 seconds

0.80 seconds

0.85 seconds

0.90 seconds

0.95 seconds

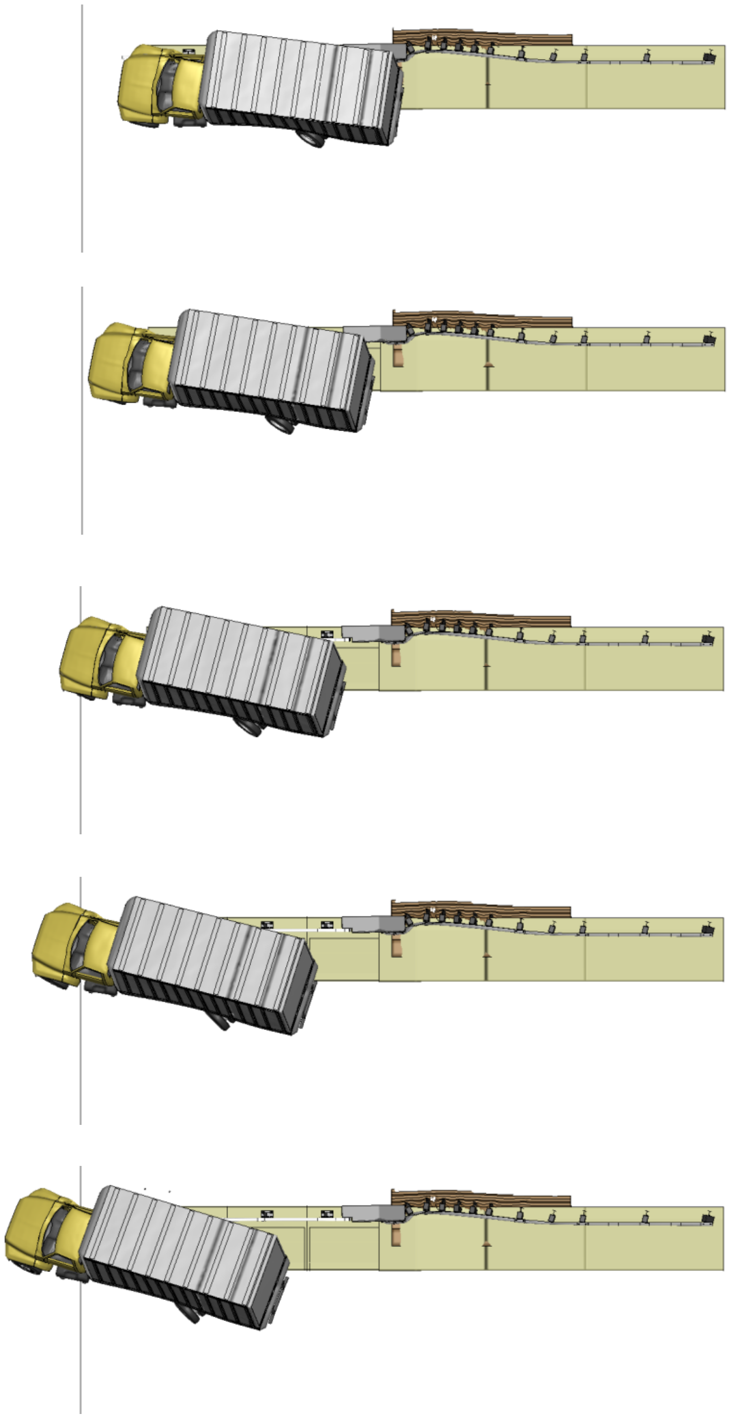

Figure V-1. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an overhead viewpoint.

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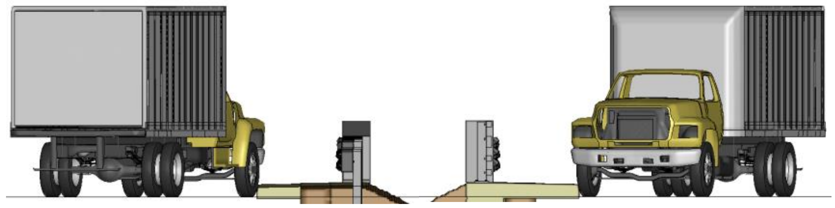

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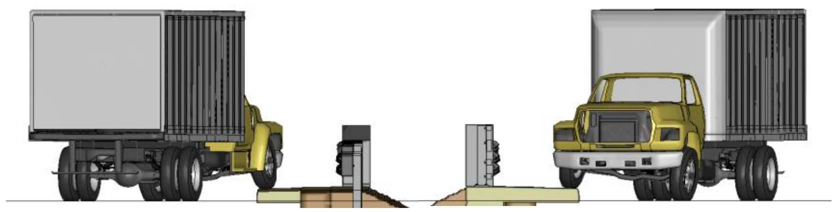

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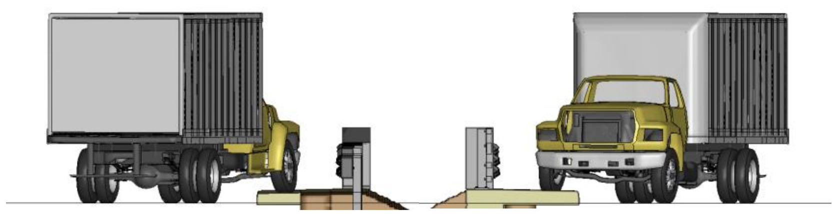

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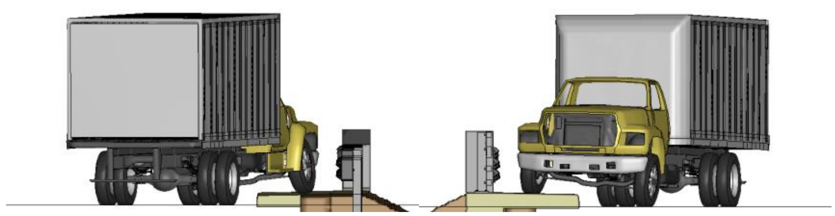

Figure V-2. Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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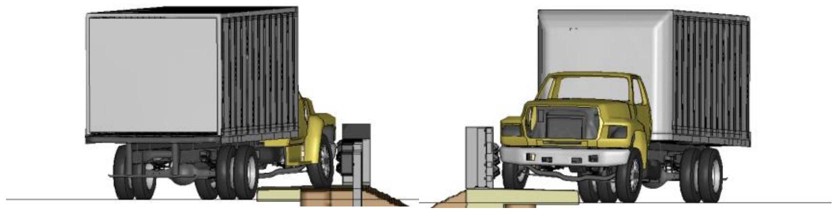

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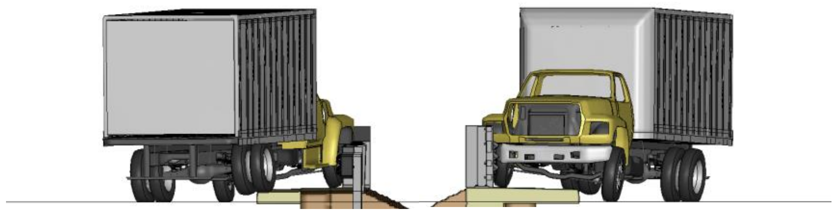

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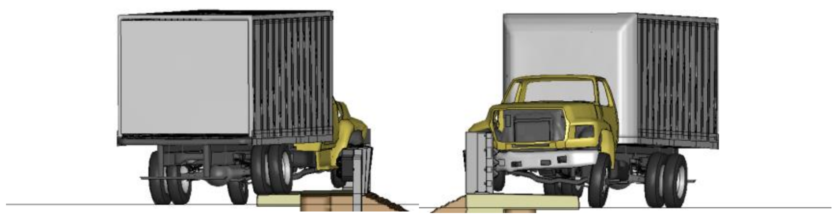

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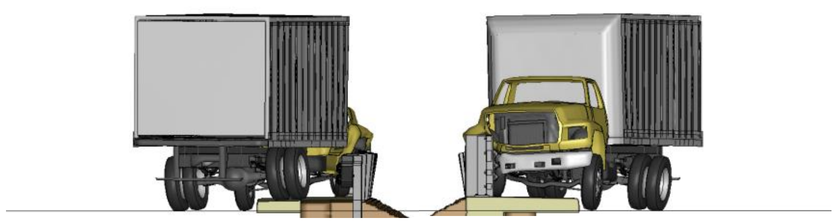

Figure V-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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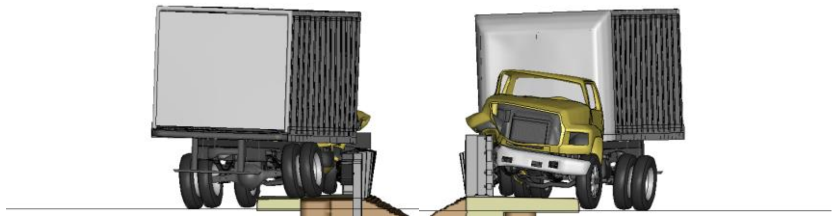

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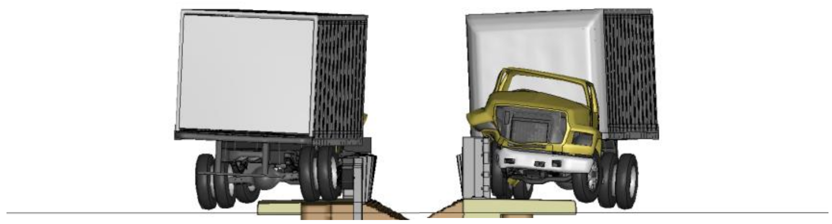

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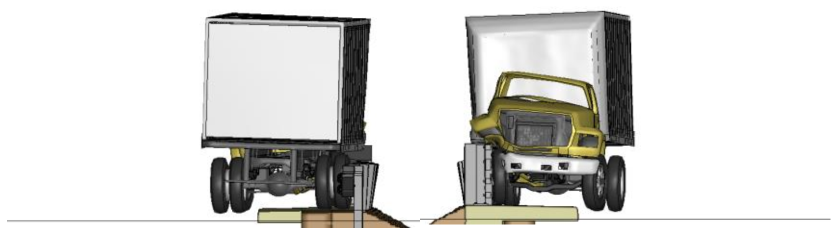

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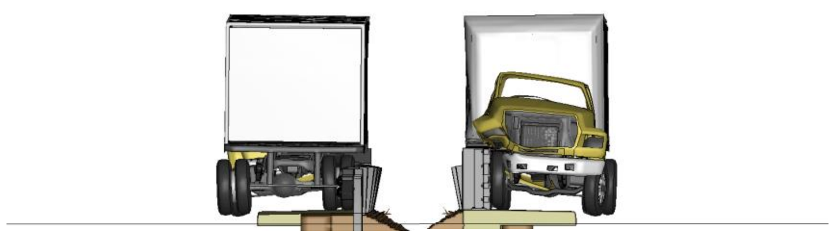

Figure V-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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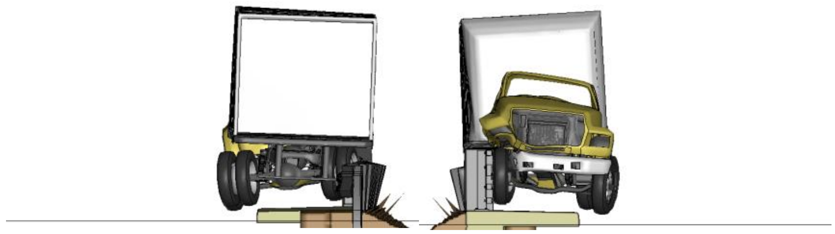

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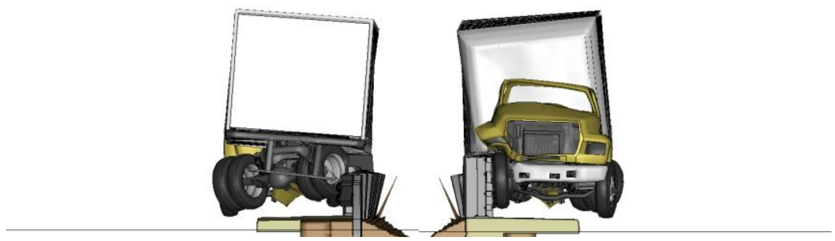

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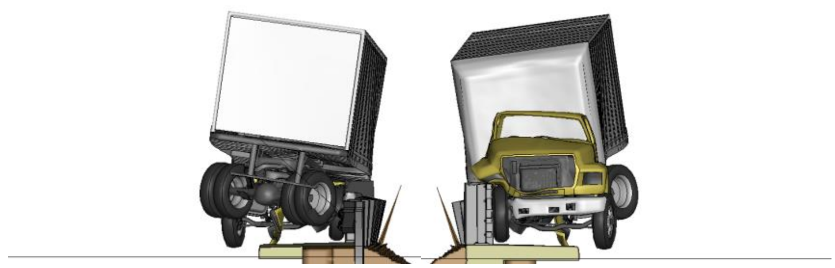

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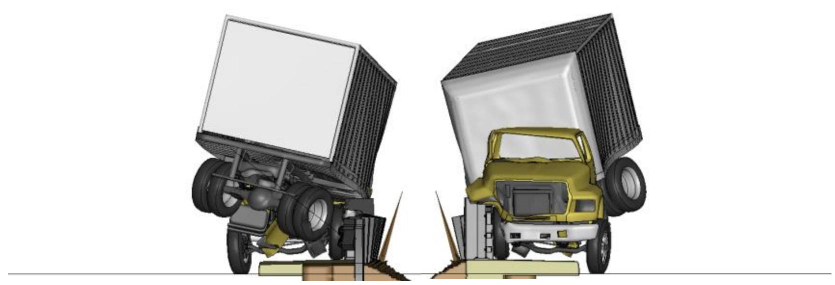

Figure V-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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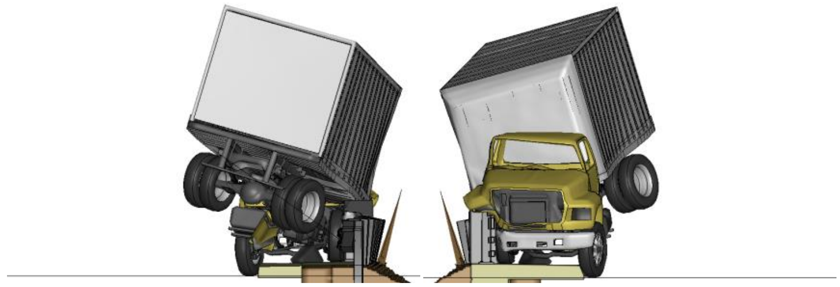

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Figure V-2. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from upstream and downstream viewpoints.

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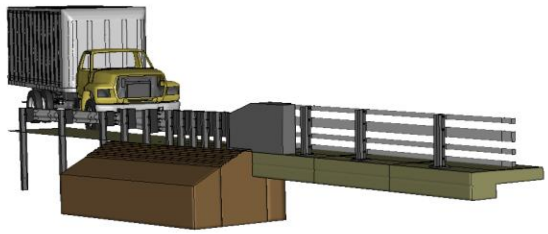

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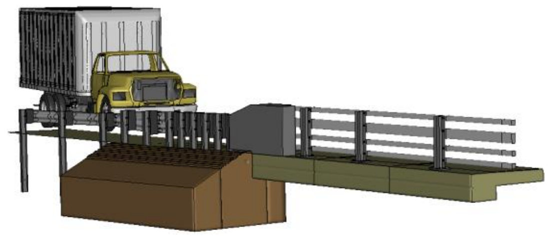

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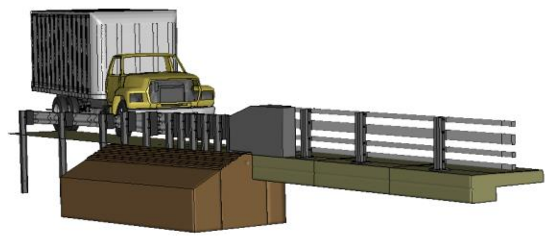

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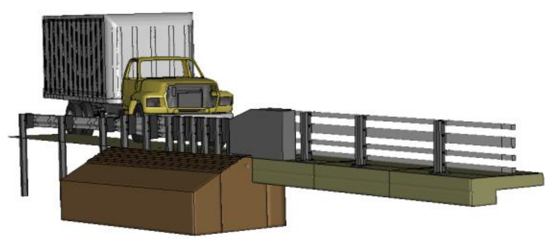
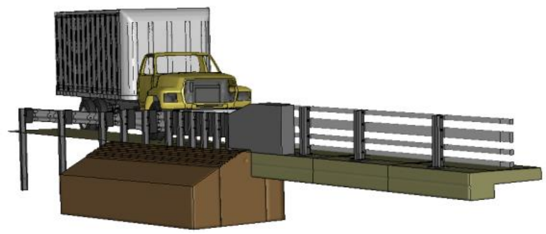


Figure V-3. Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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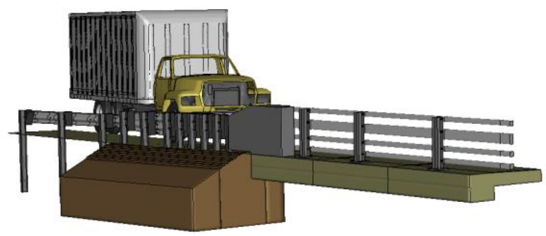

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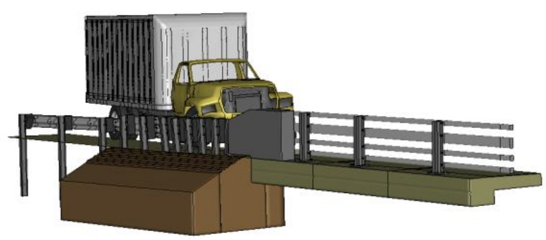

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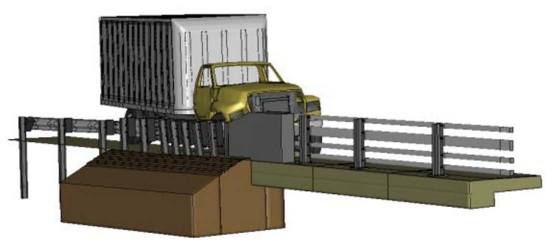

Figure V-3. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an oblique viewpoint.

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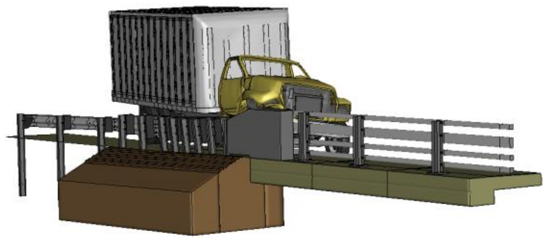

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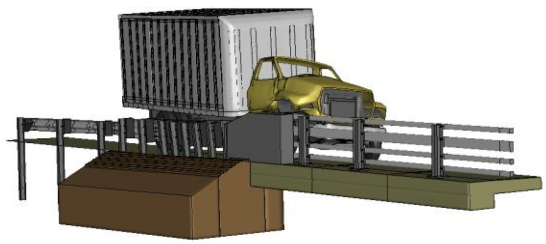

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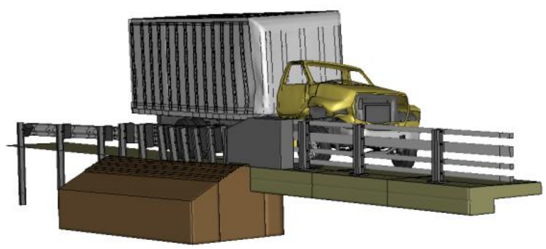

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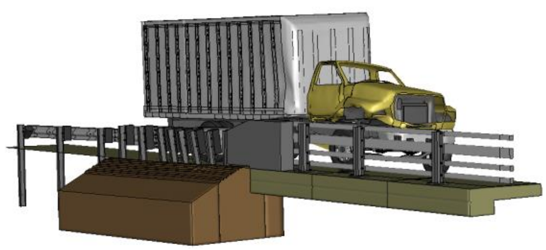

Figure V-3. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an oblique viewpoint.

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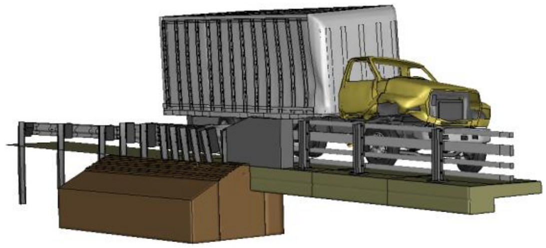

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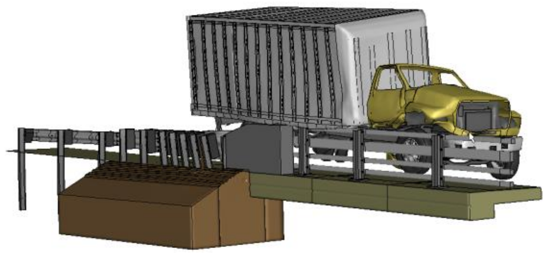

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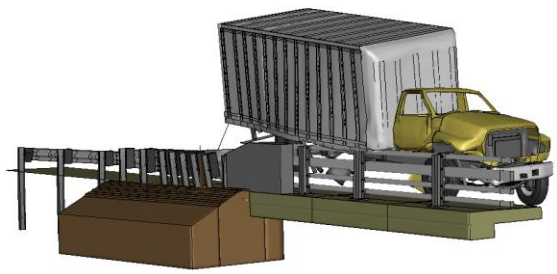

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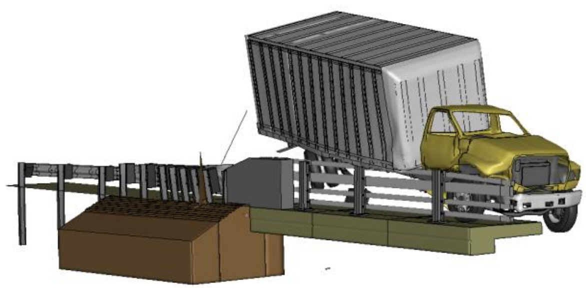
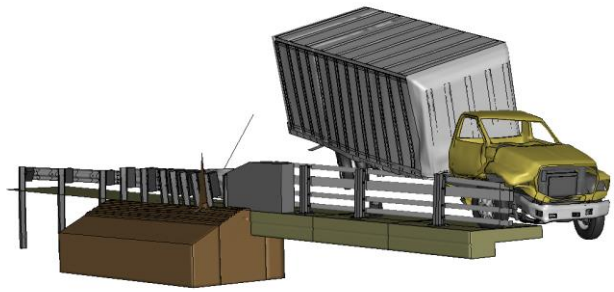


Figure V-3. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an oblique viewpoint.

0.80 seconds



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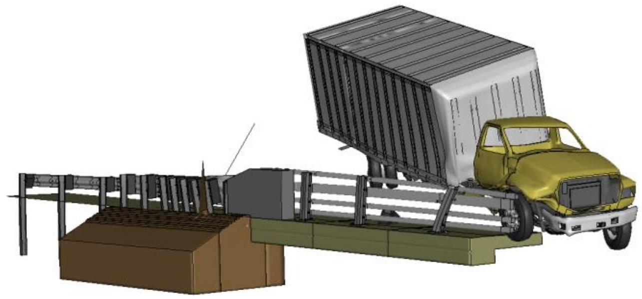

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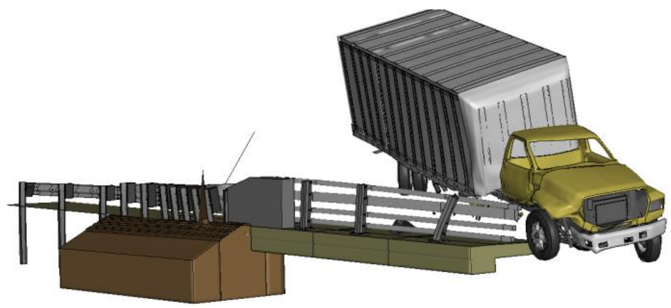

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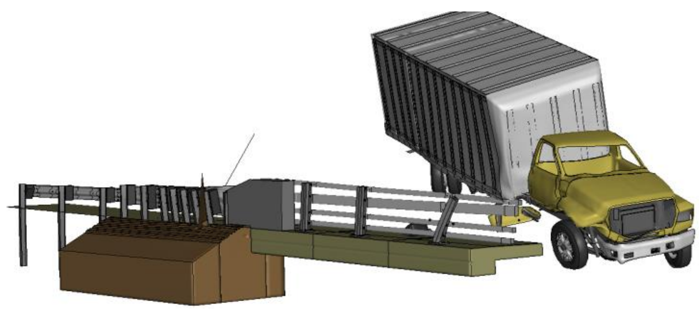
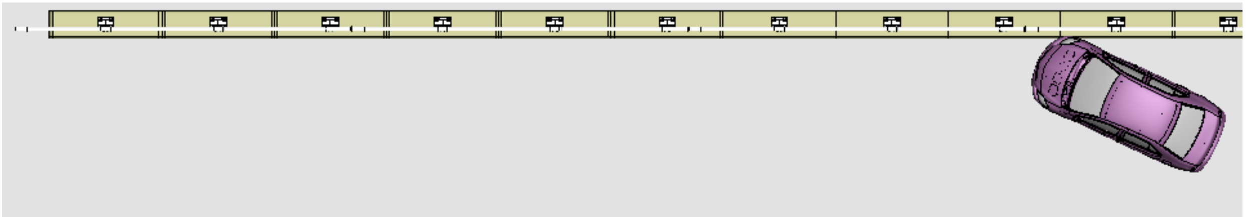


Figure V-3. [Continued] Sequential views from analysis of MASH Test 4-22 for AGT 4-Bar bridge rail from an oblique viewpoint.

Appendix W

Sequential Views for Test 3-10 on

Curb-Mounted NETC 2-Bar Bridge Rail



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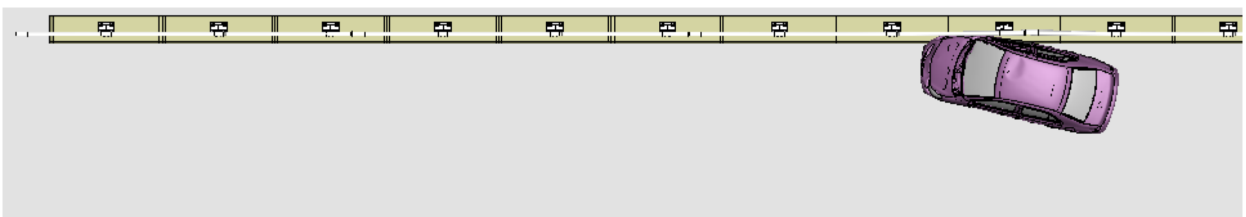

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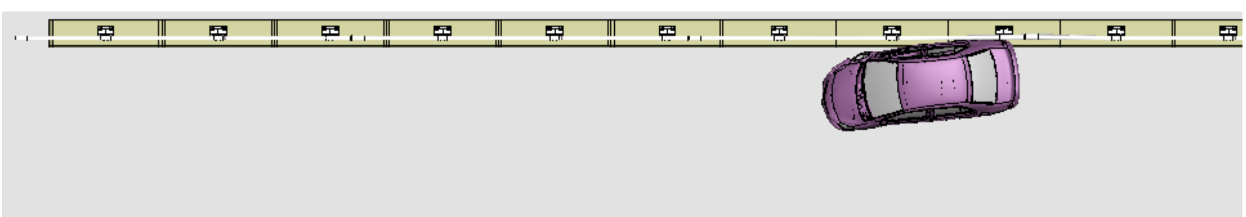
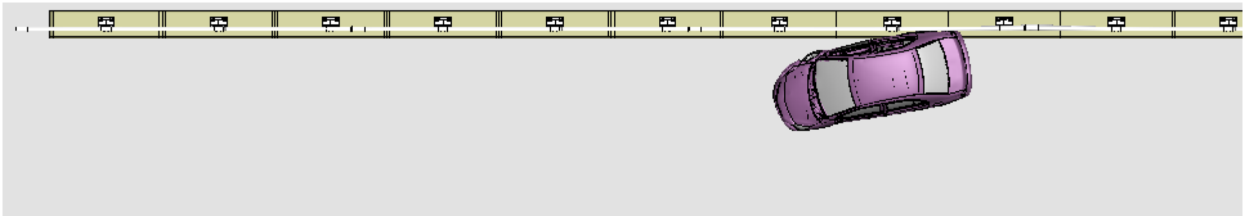


Figure W-1. Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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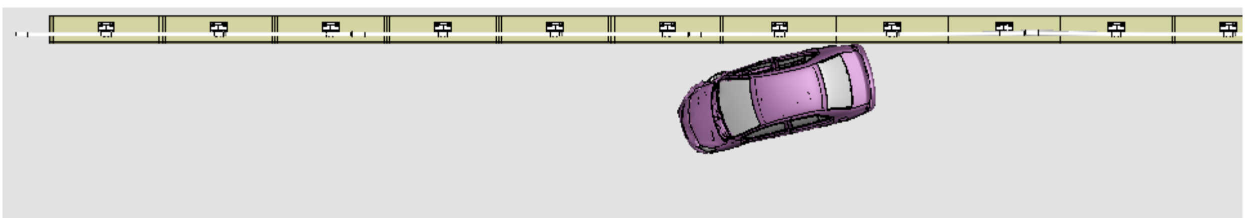

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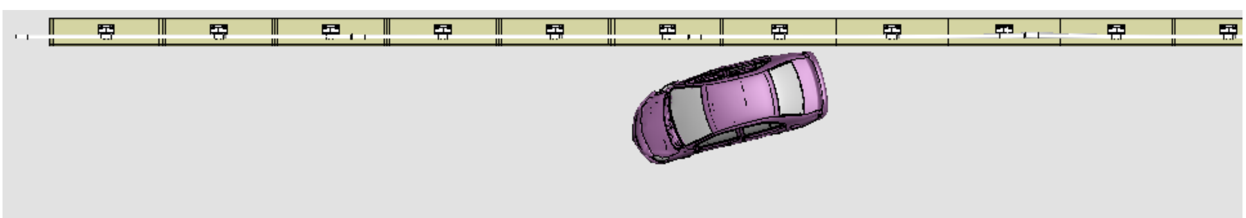

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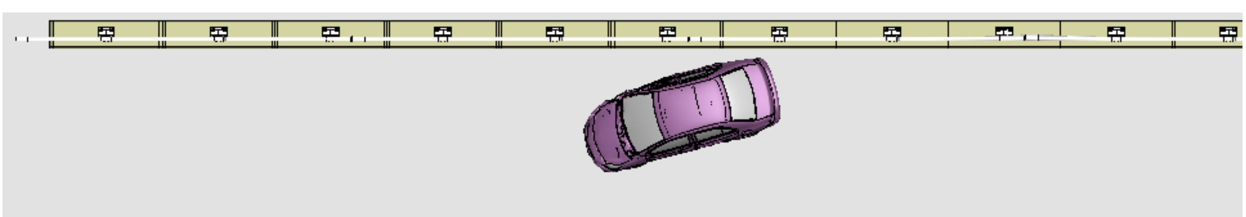

Figure W-1. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an overhead viewpoint.

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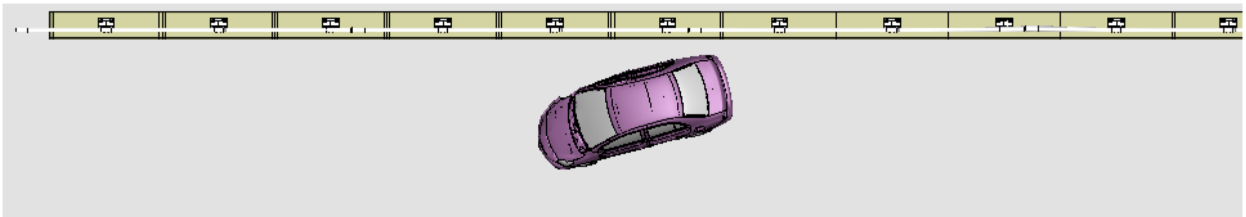

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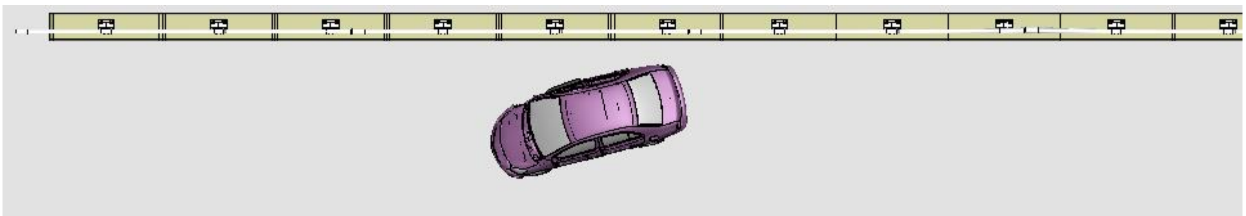

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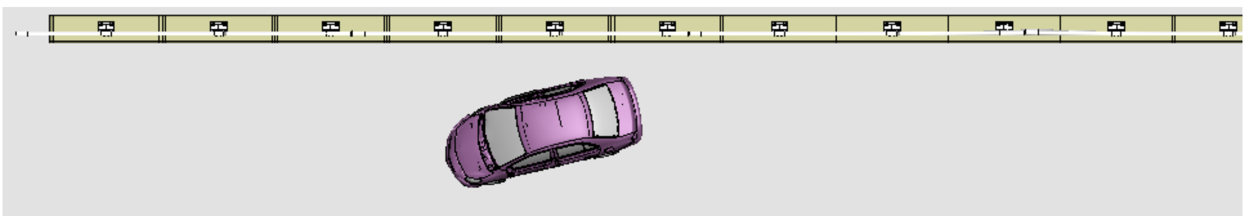

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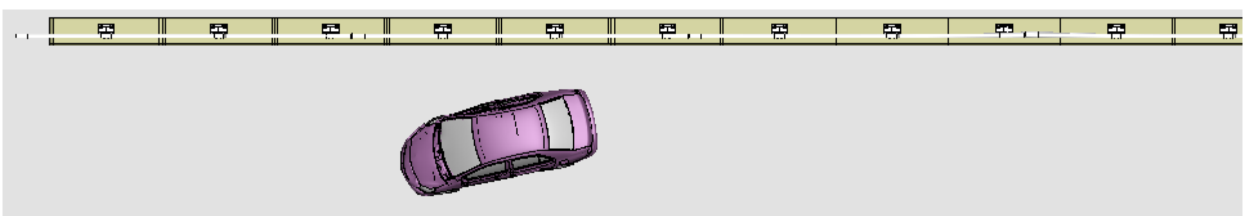

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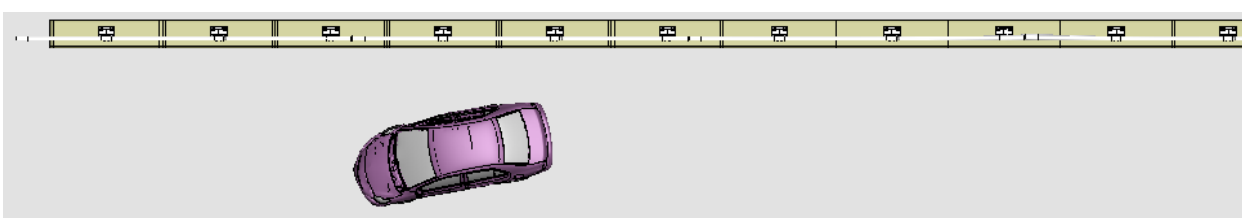

Figure W-1. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an overhead viewpoint.

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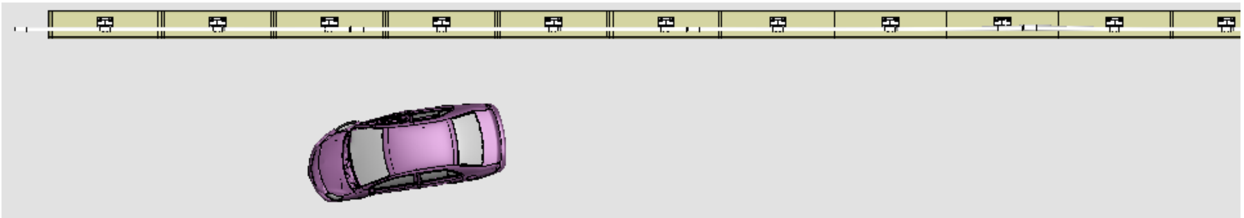

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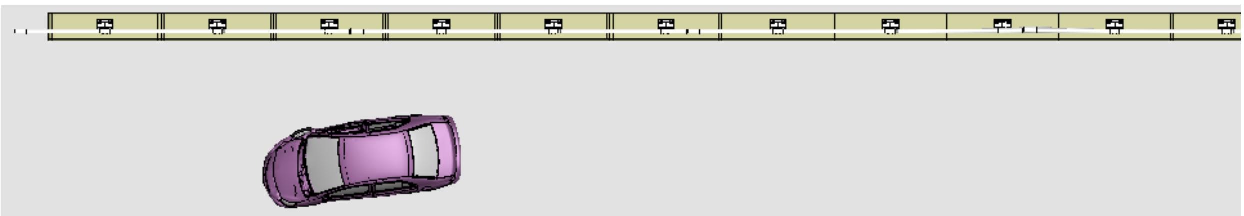

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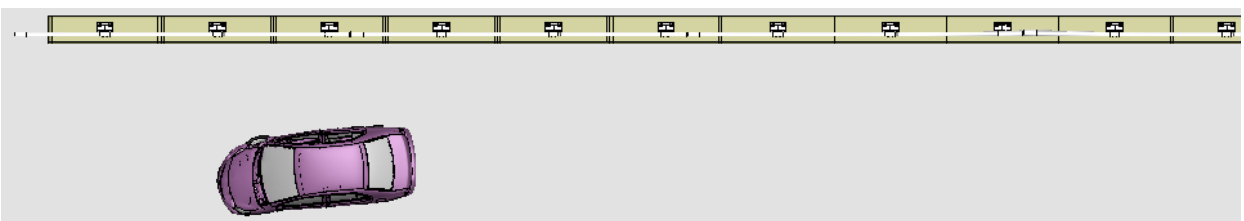

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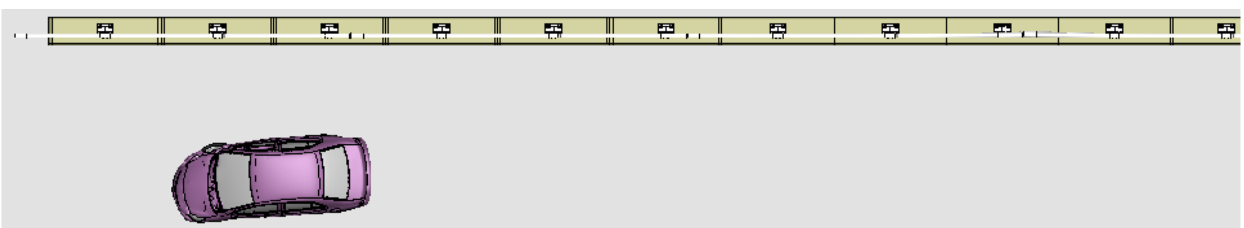

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Figure W-1. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an overhead viewpoint.

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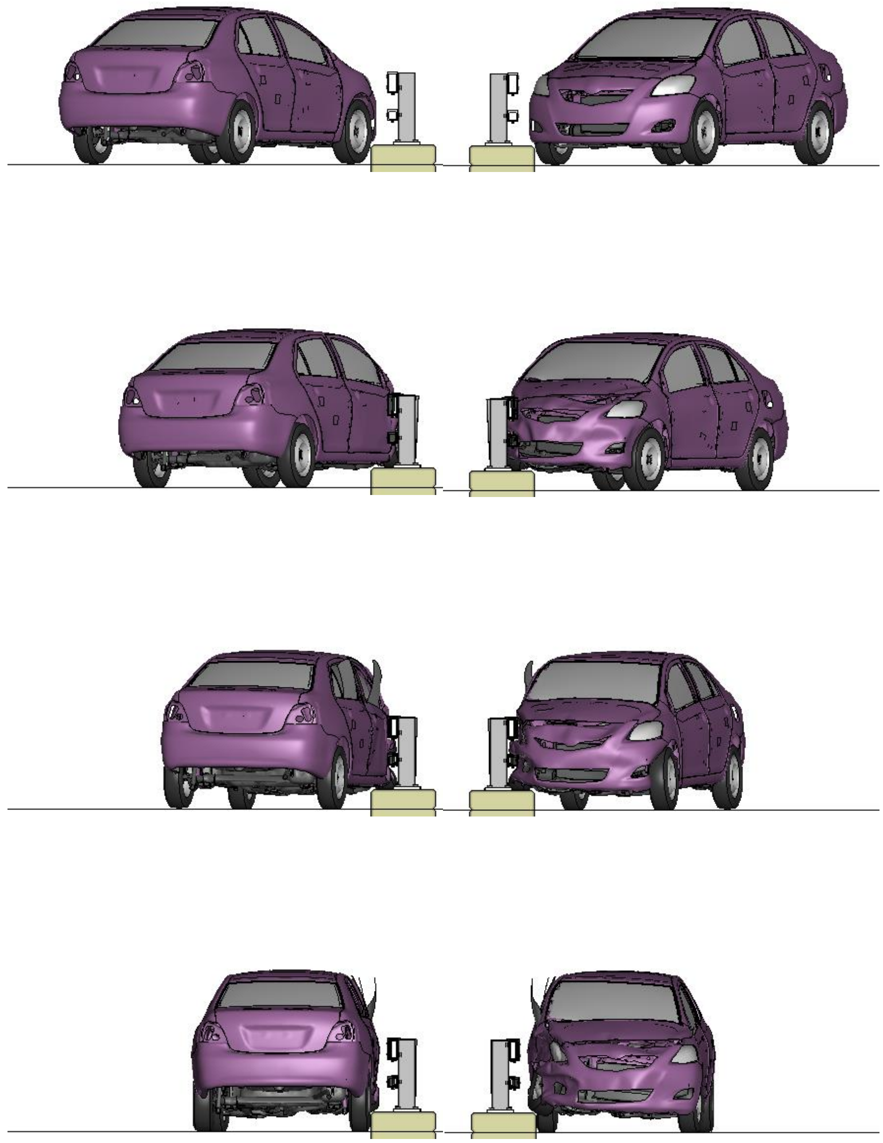

Figure W-2. Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

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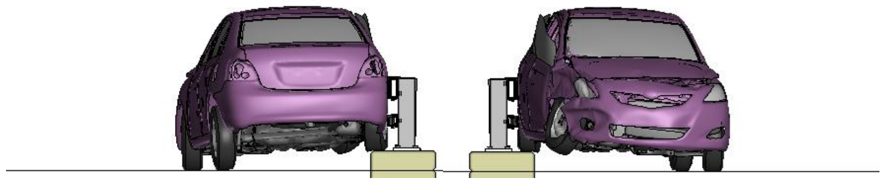

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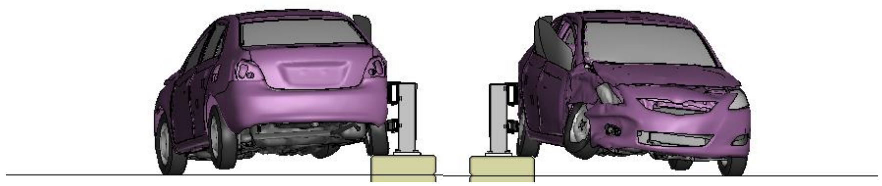

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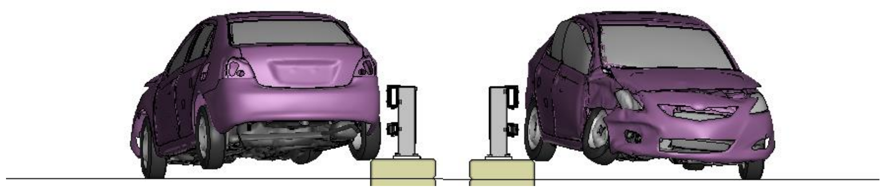

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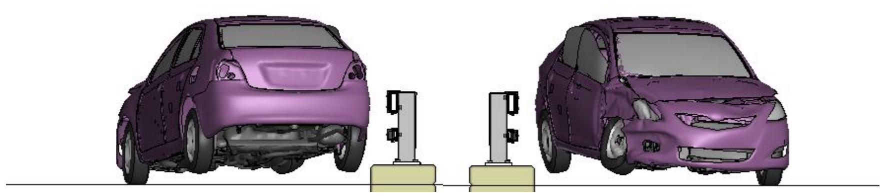

Figure W-2. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

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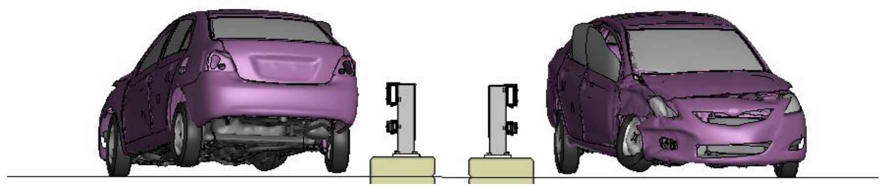

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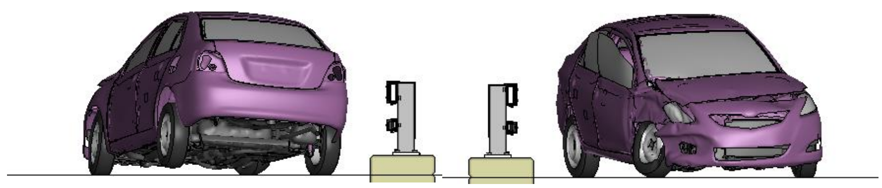

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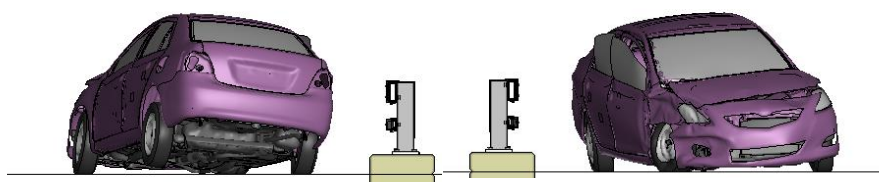

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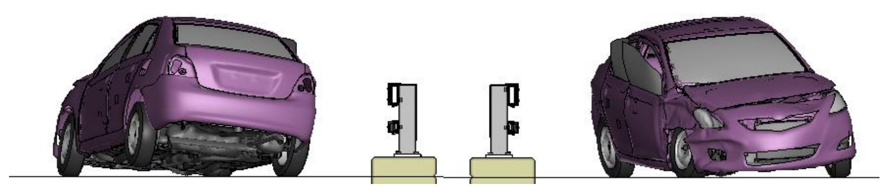


Figure W-2. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

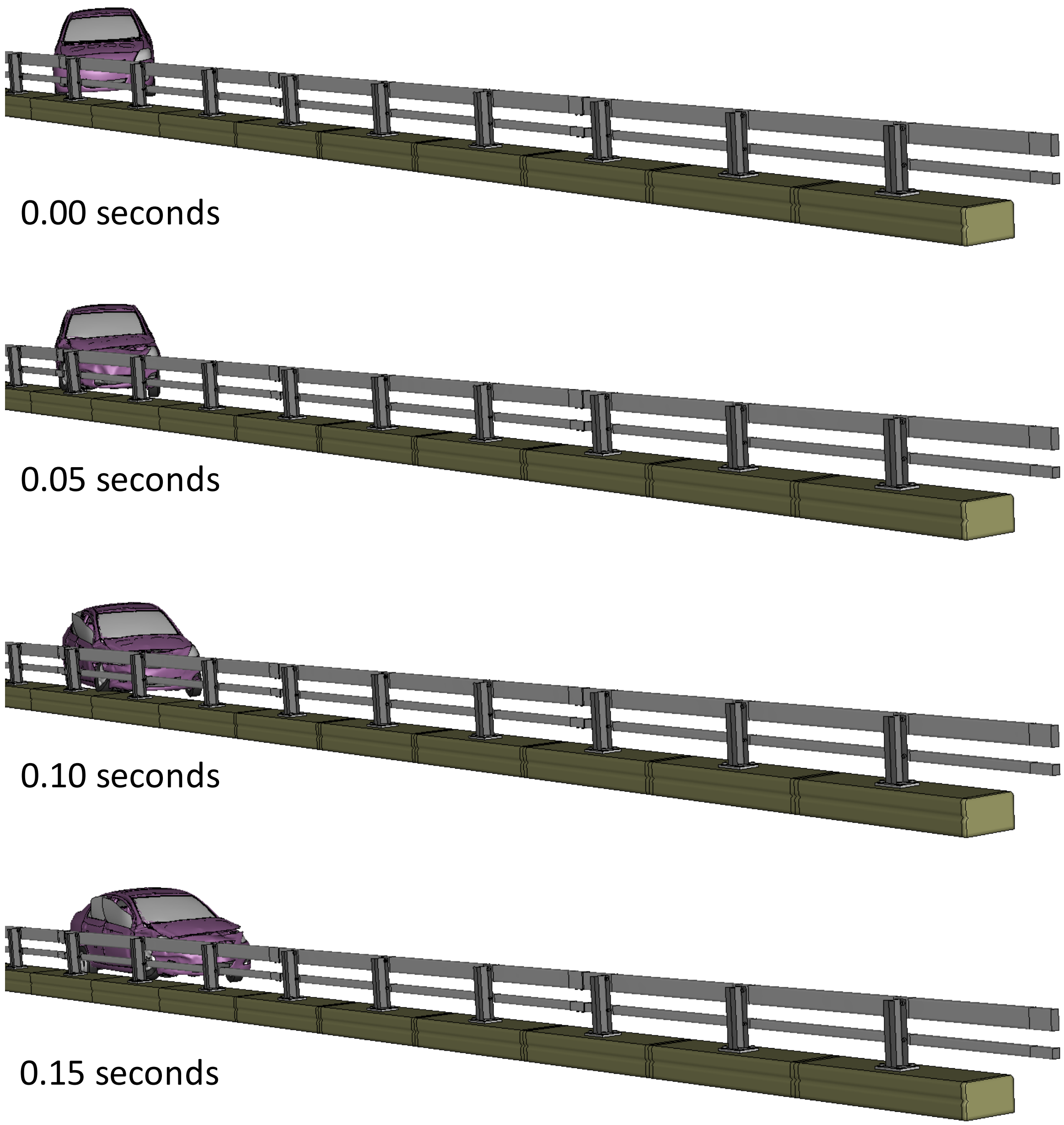
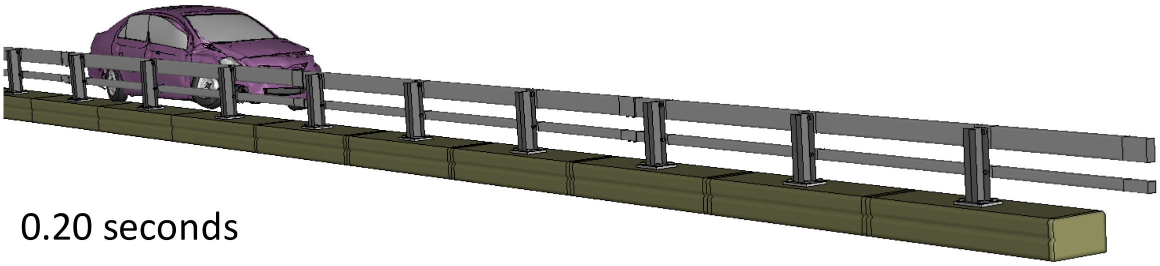


Figure W-3. Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an oblique viewpoint.



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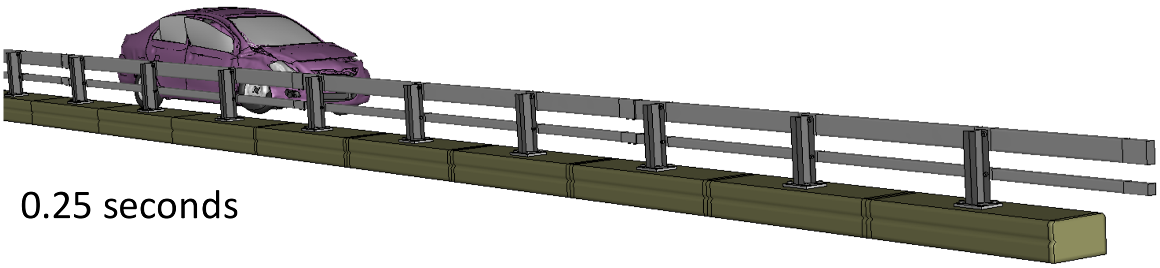

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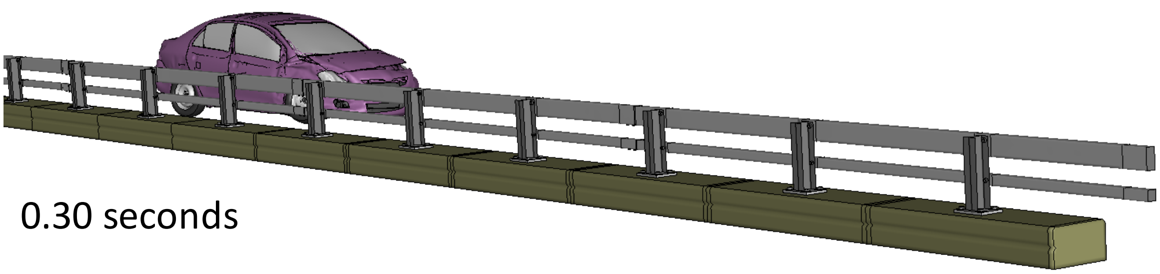

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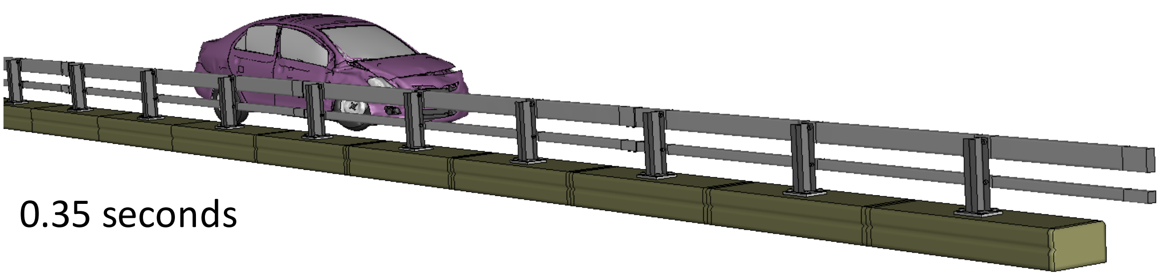

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Figure W-3. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an oblique viewpoint.

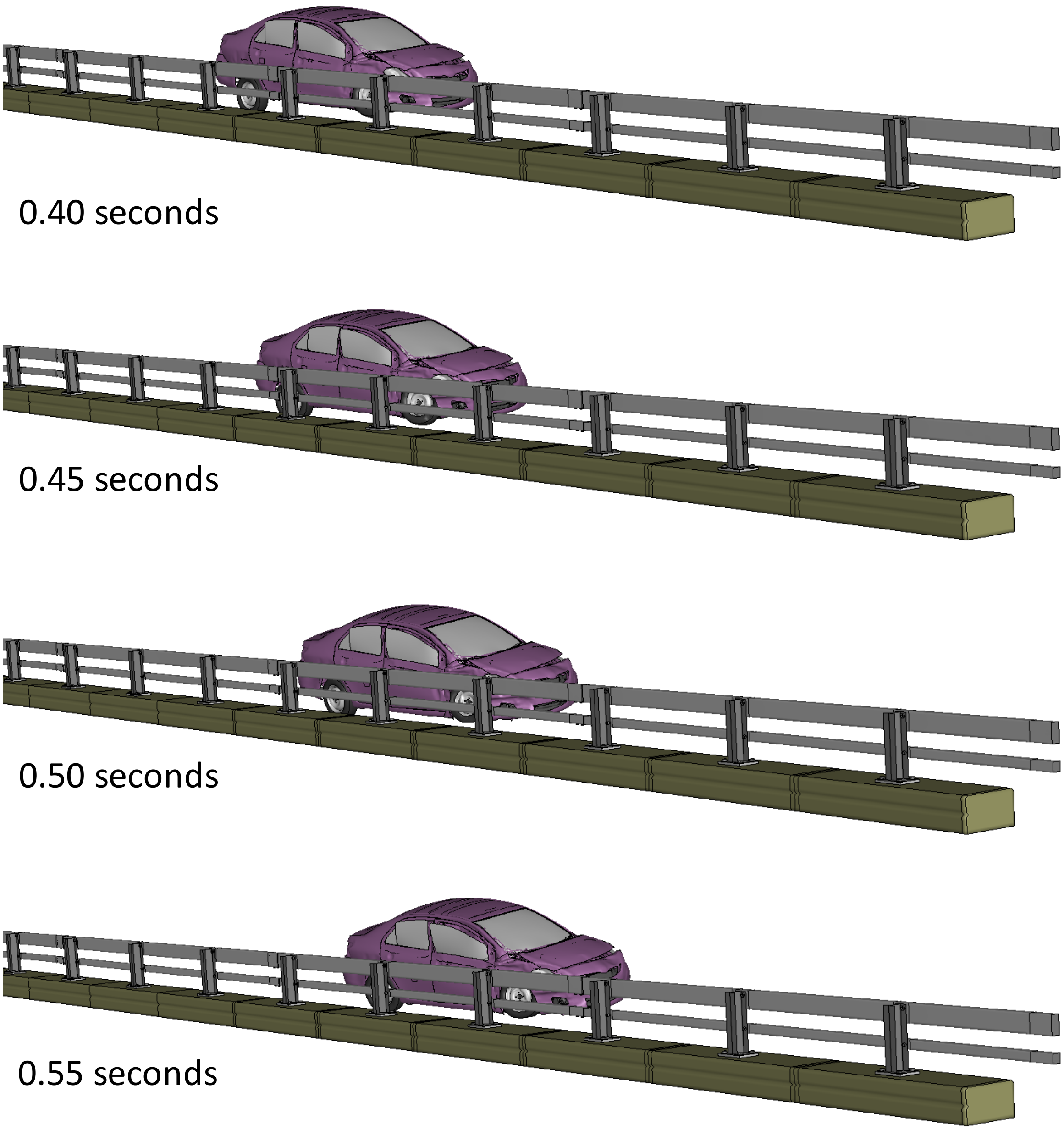


Figure W-3. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an oblique viewpoint.

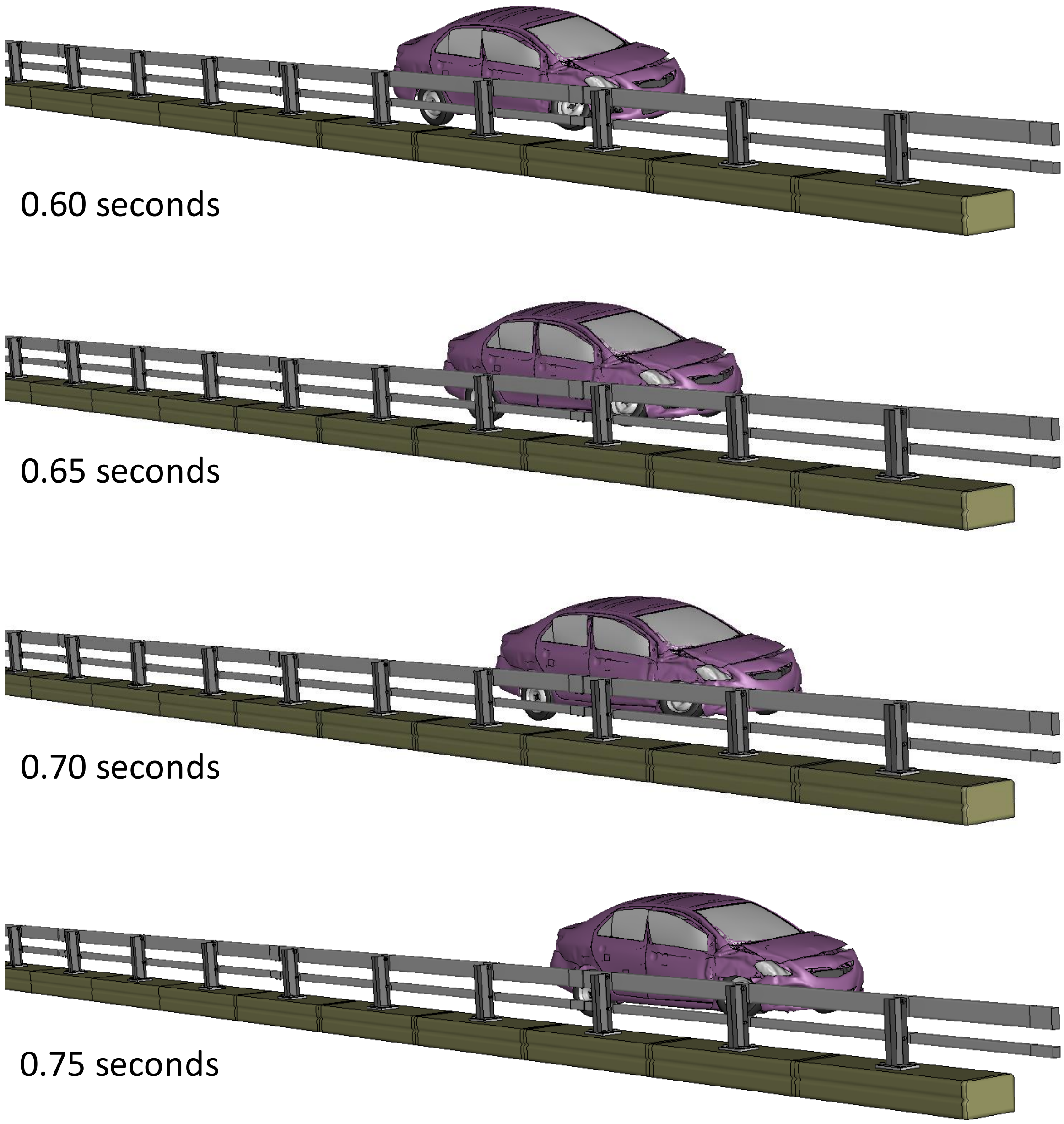


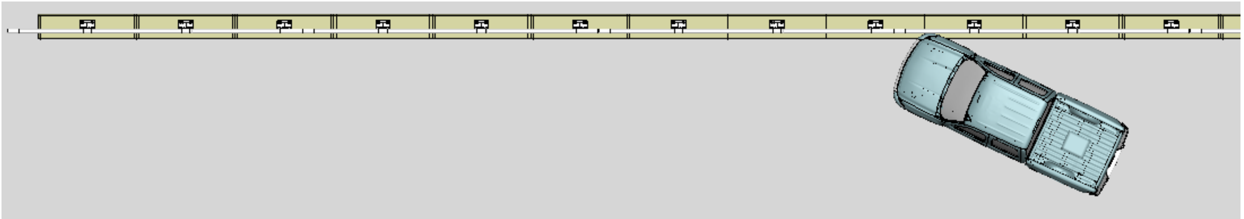
Figure W-3. [Continued] Sequential views from analysis of MASH Test 3-10 for NETC 2-Bar bridge rail from an oblique viewpoint.

Appendix X

Sequential Views for Test 3-11 on

Curb-Mounted NETC 2-Bar Bridge Rail

0.00 seconds



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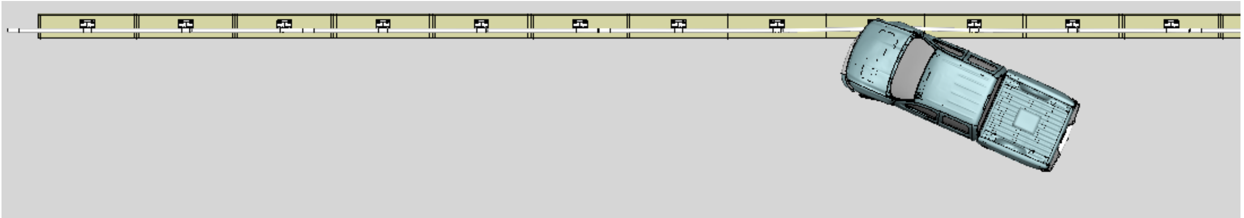

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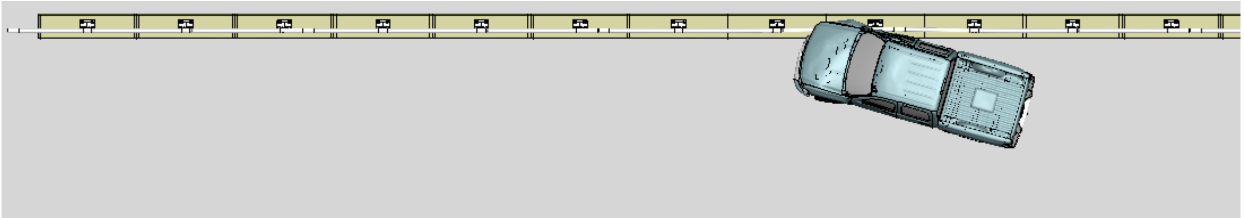

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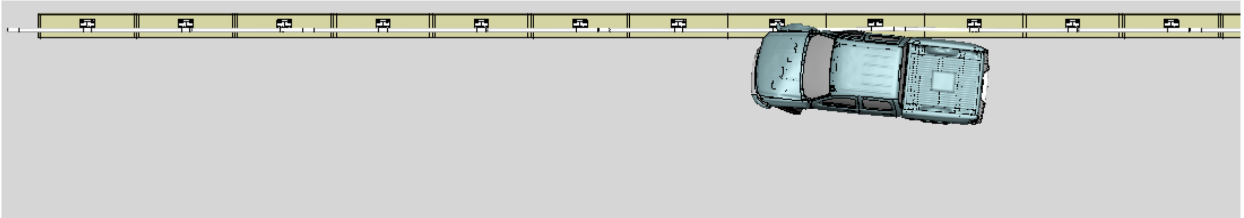

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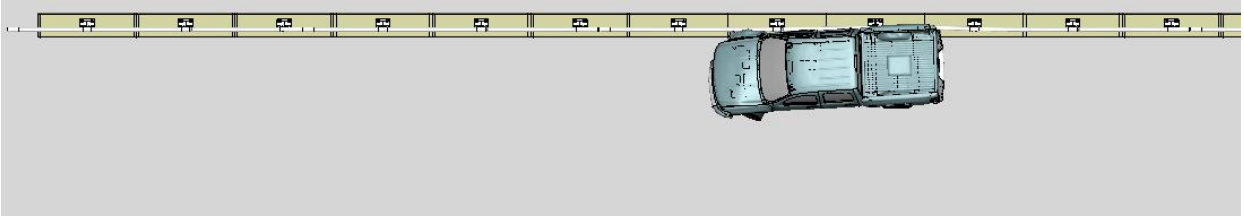
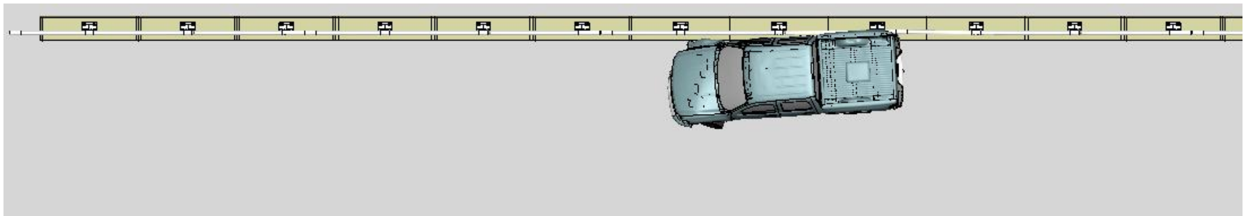


Figure X-1. Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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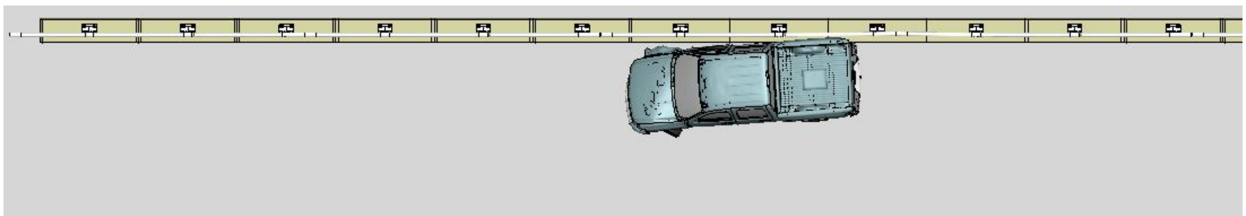

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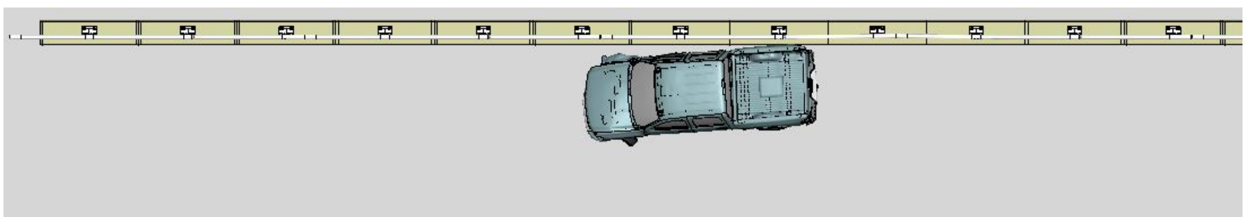

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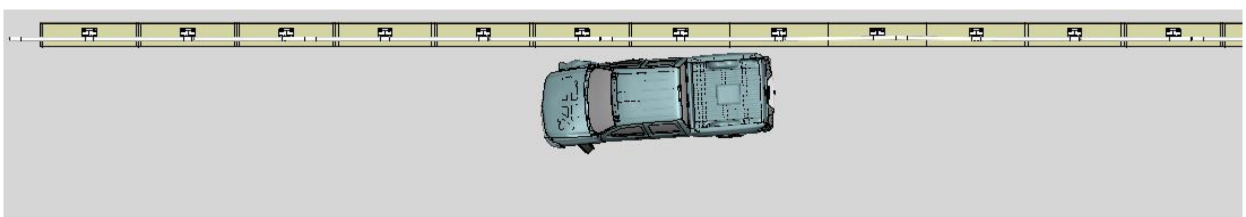

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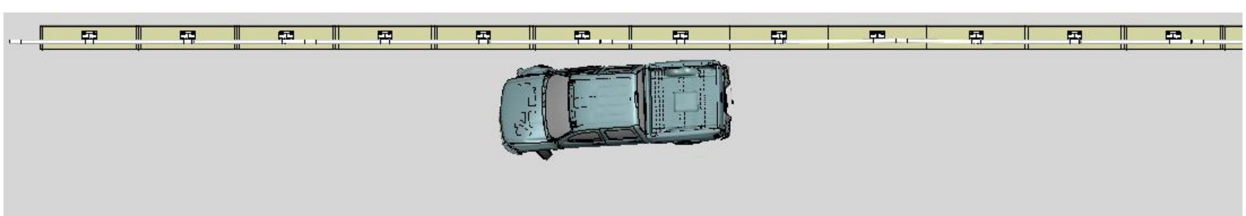
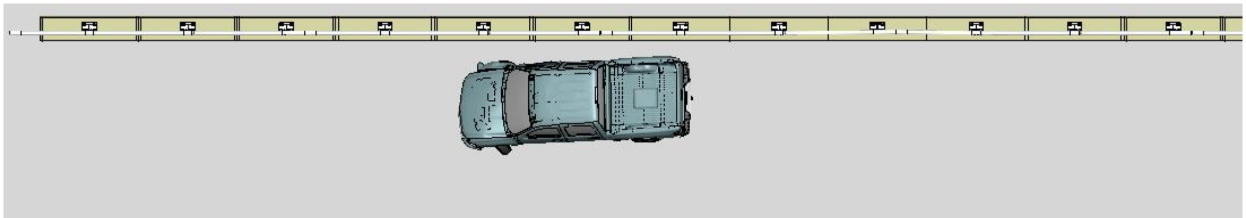


Figure X-1. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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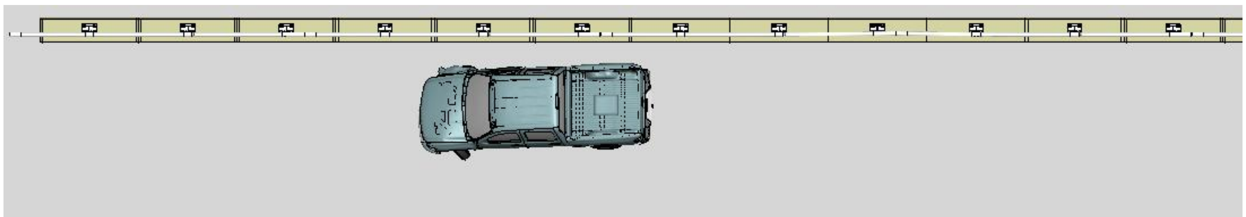

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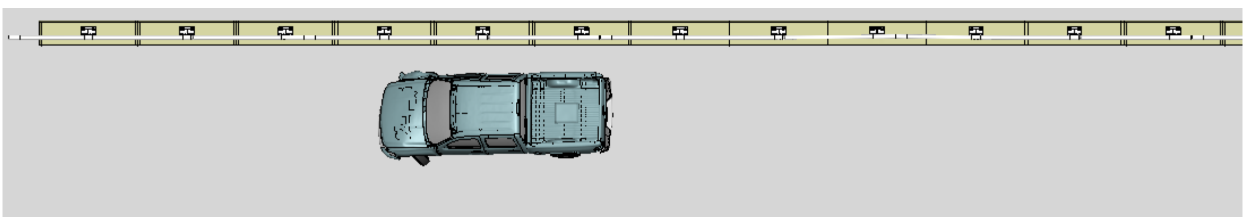

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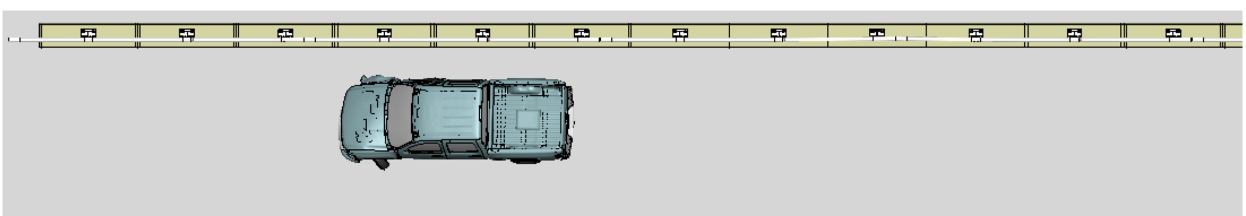

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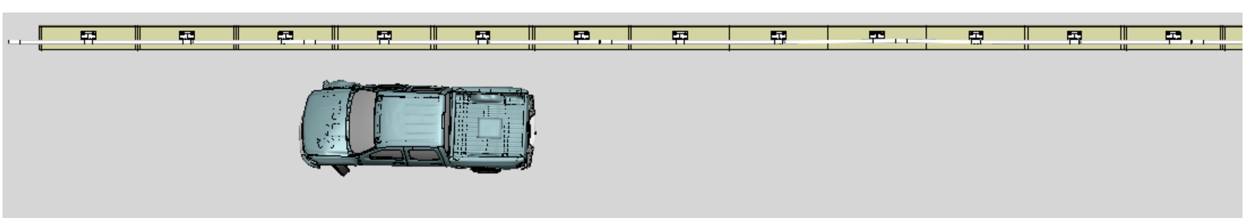
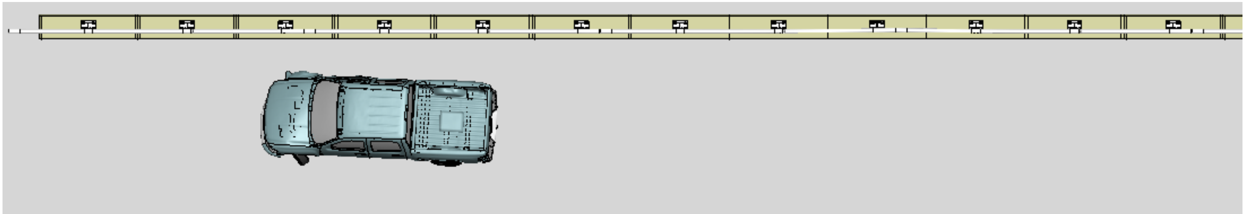


Figure X-1. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an overhead viewpoint.

0.75 seconds



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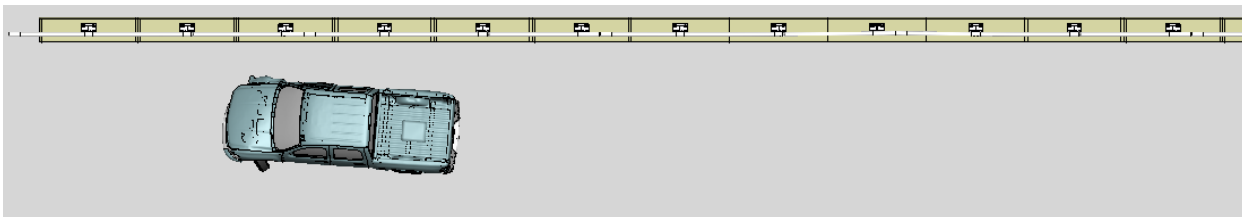

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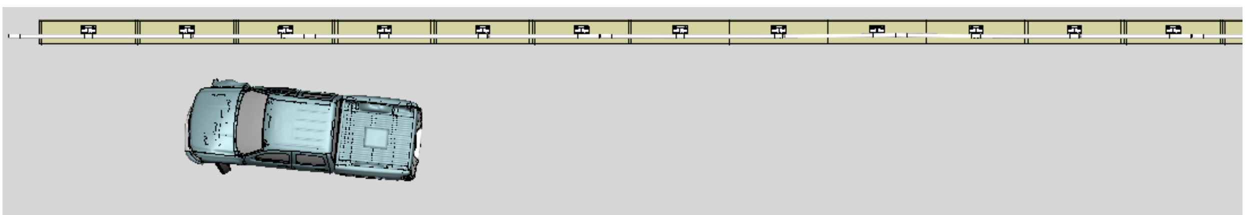

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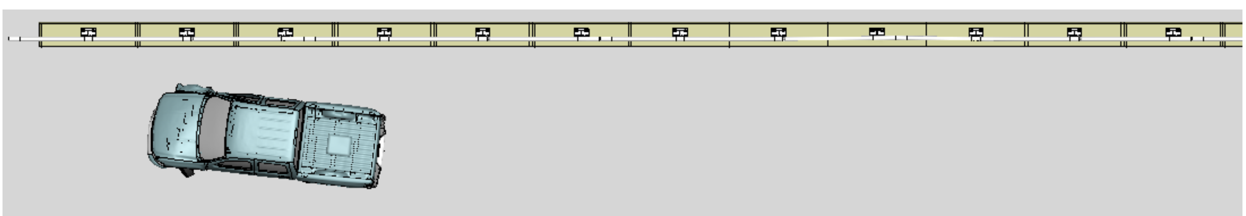


Figure X-1. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an overhead viewpoint.

0.00 seconds

0.05 seconds

0.10 seconds

0.15 seconds

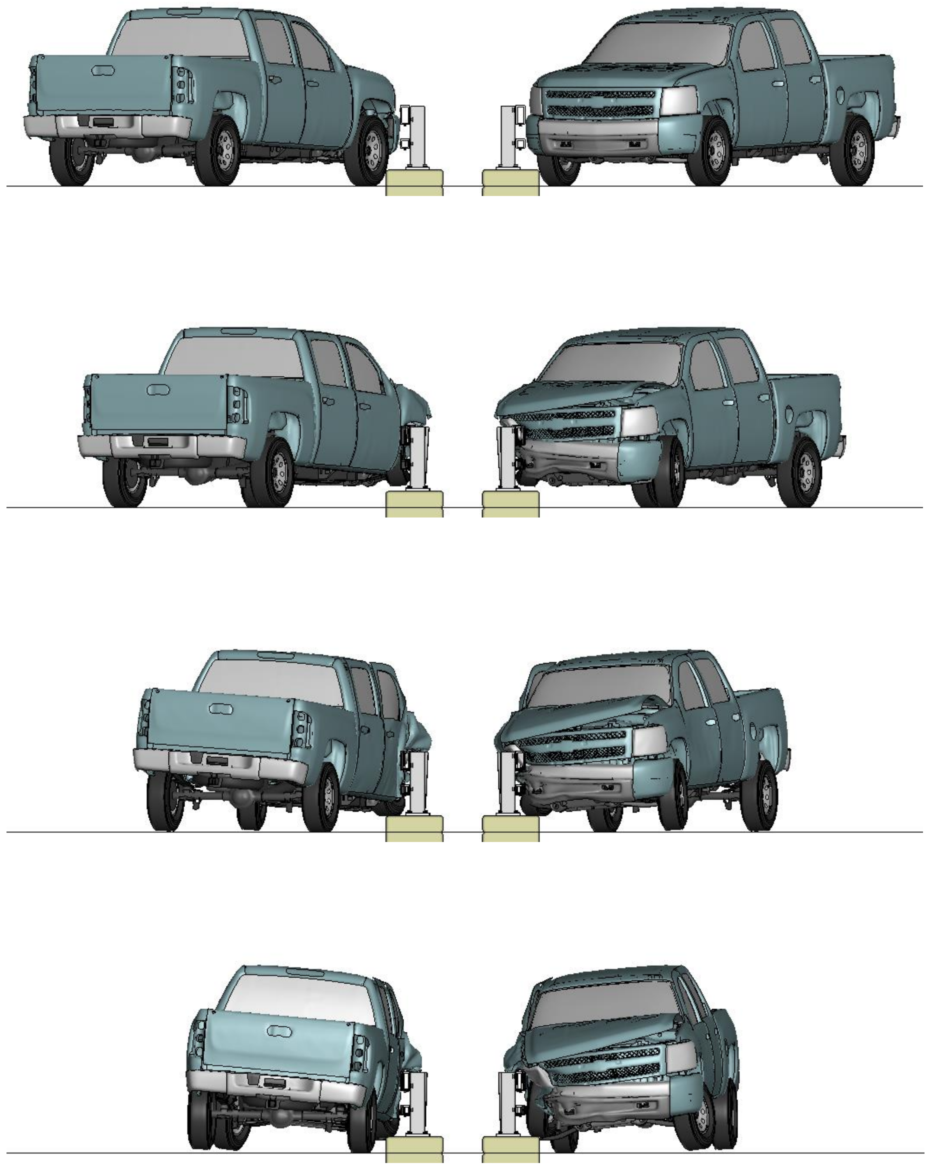
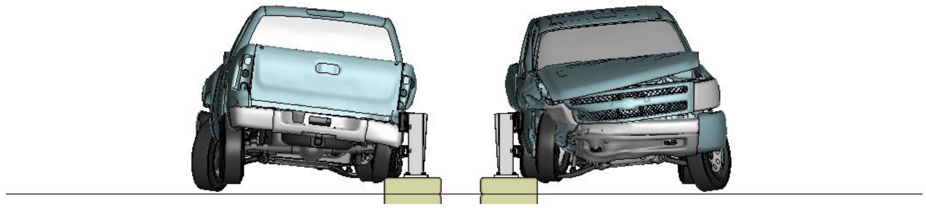


Figure X-2. Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

0.20 seconds



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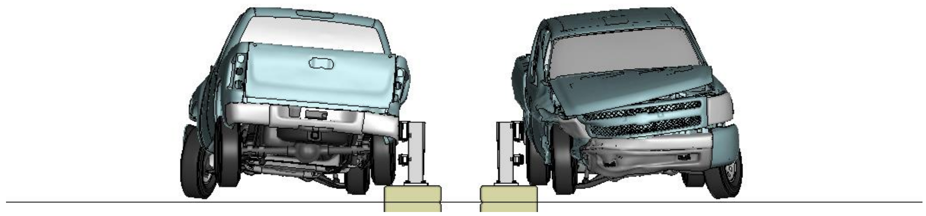

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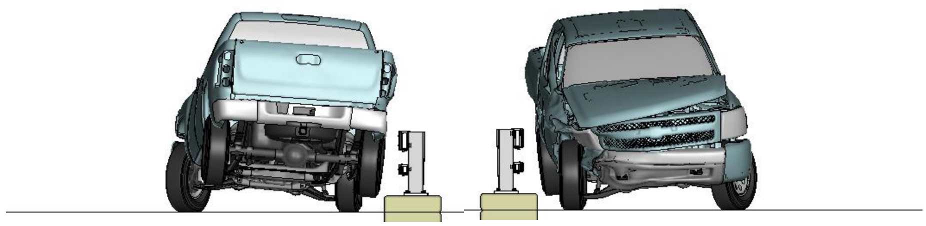

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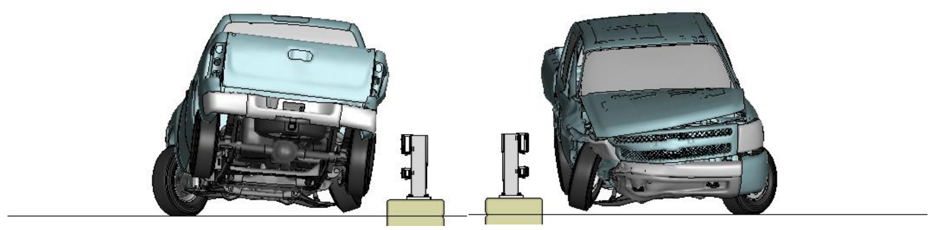
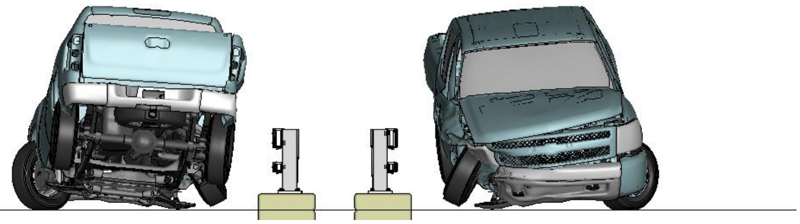


Figure X-2. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

0.40 seconds



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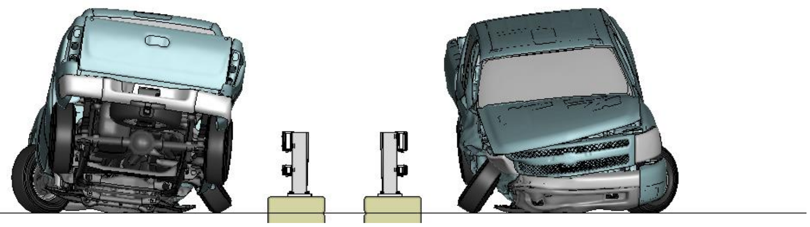

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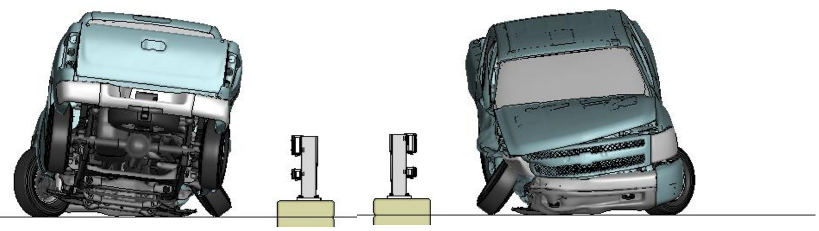

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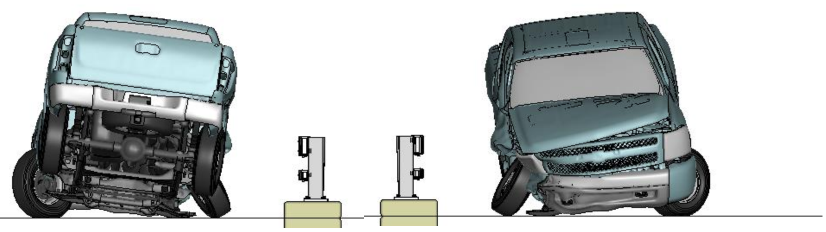
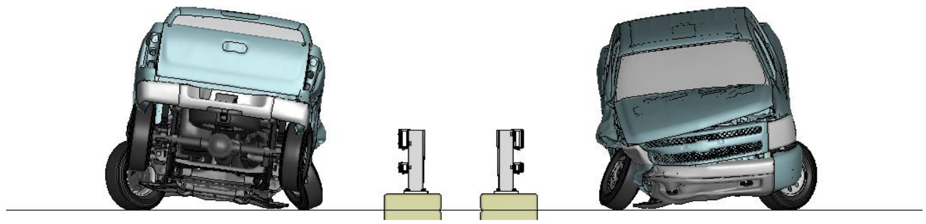


Figure X-2. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

0.60 seconds



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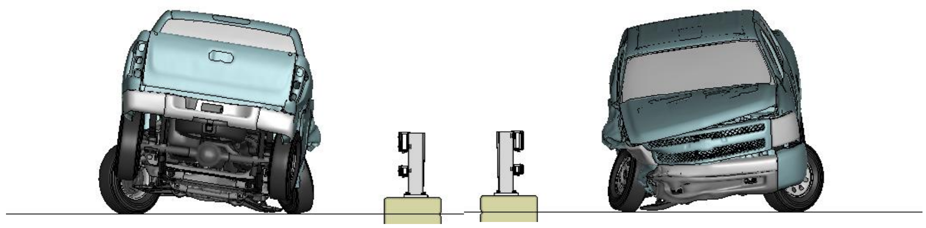

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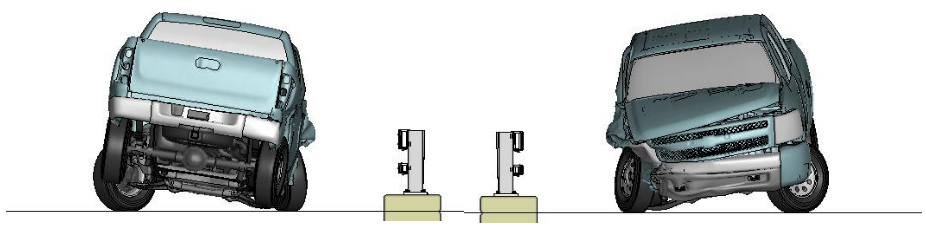

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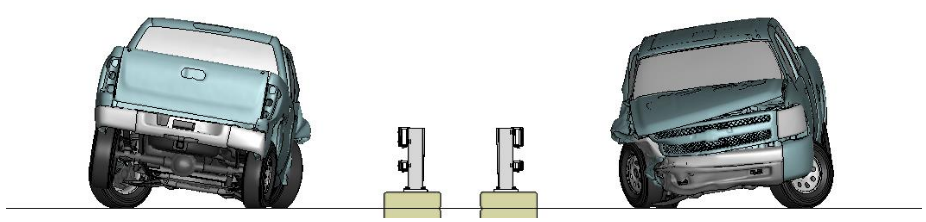
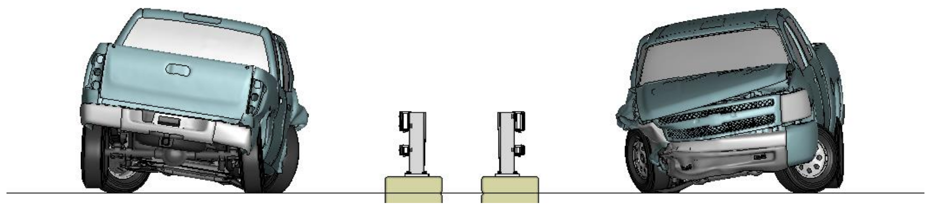


Figure X-2. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

0.80 seconds



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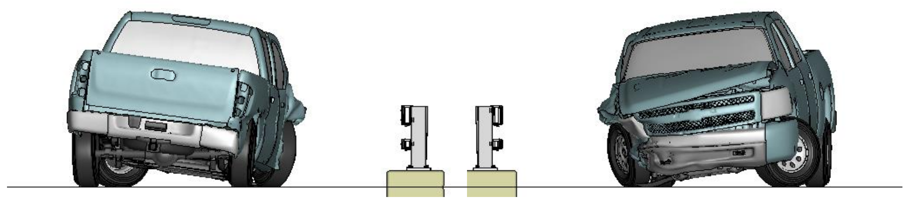

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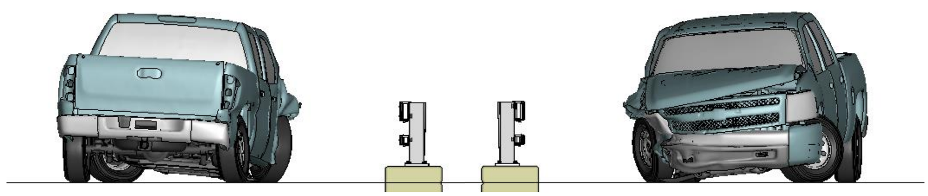


Figure X-2. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from upstream and downstream viewpoints.

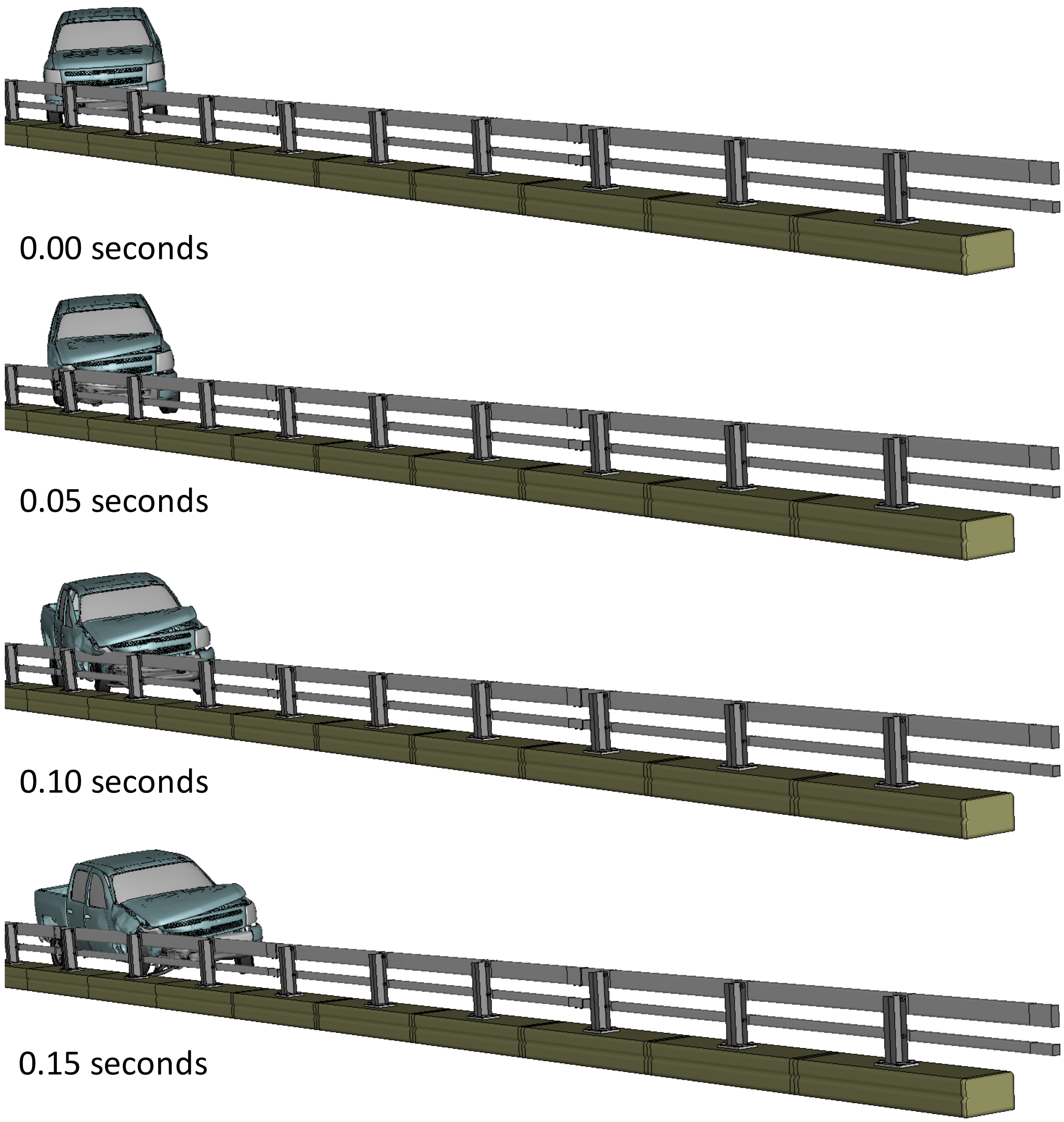


Figure X-3. Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an oblique viewpoint.

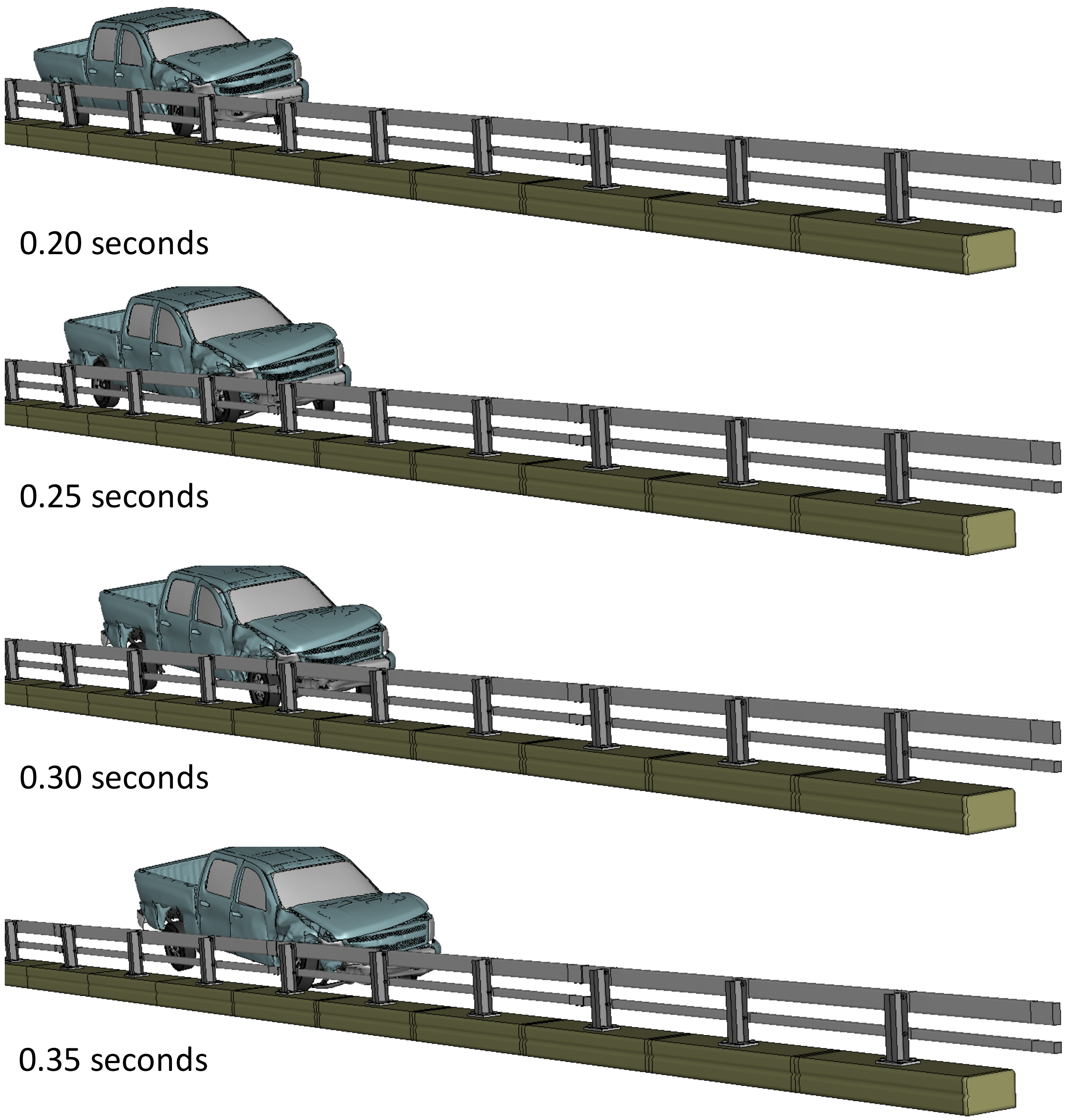


Figure X-3. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an oblique viewpoint.

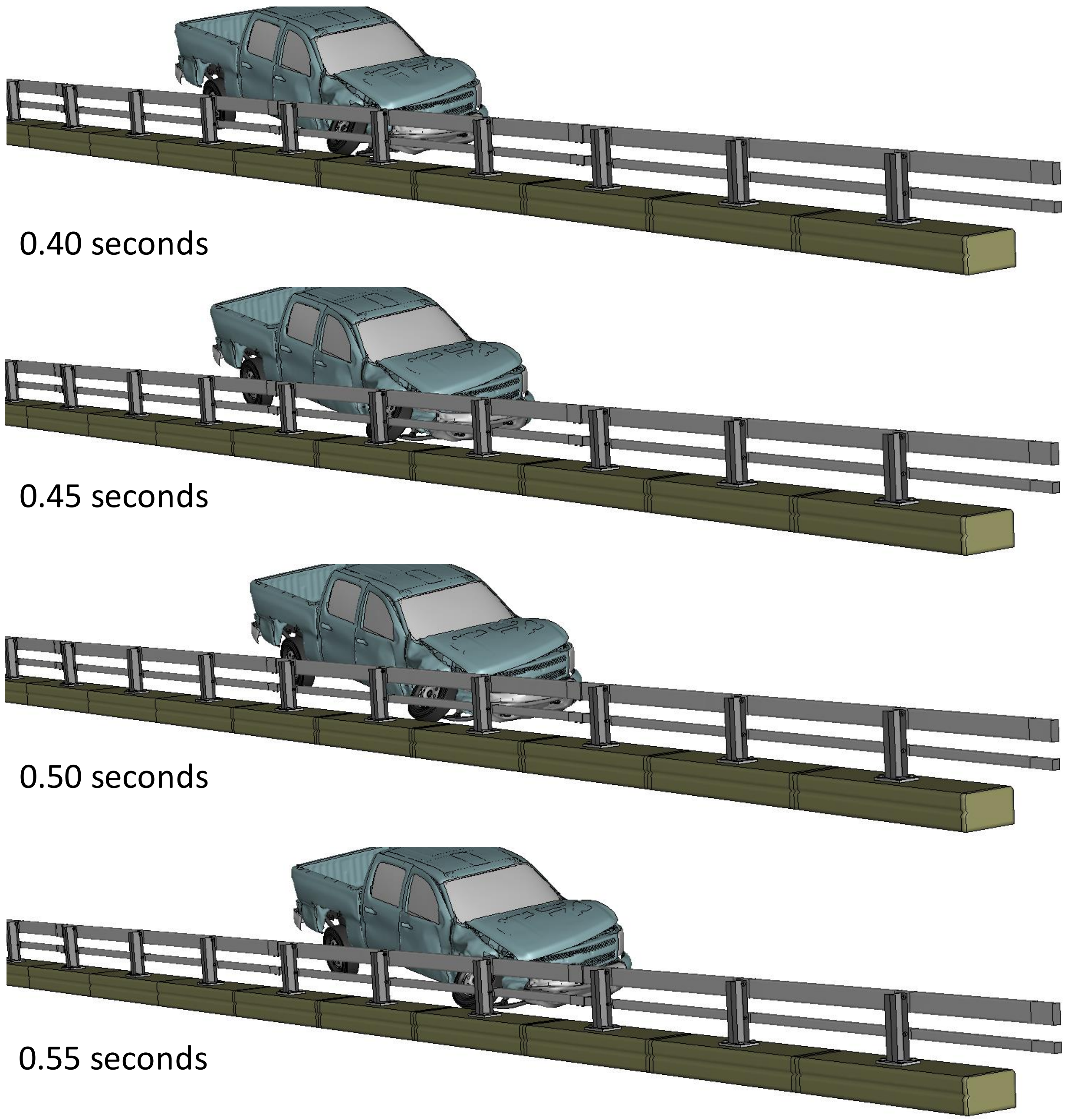


Figure X-3. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an oblique viewpoint.

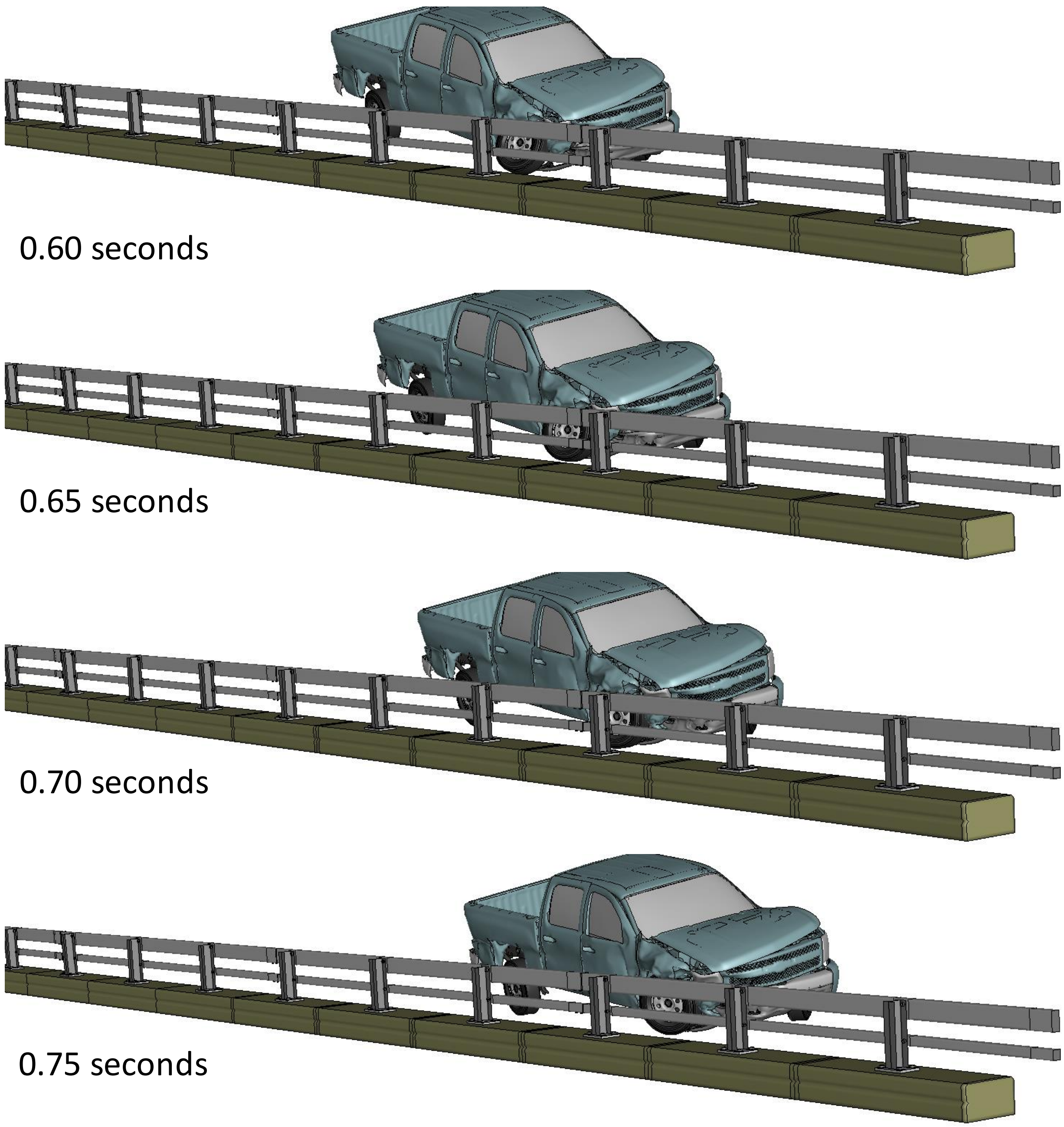


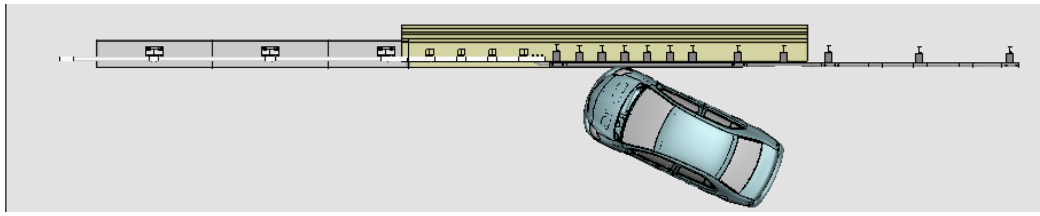
Figure X-3. [Continued] Sequential views from analysis of MASH Test 3-11 for NETC 2-Bar bridge rail from an oblique viewpoint.

Appendix Y

Sequential Views for Test 3-20 on

Curb-Mounted AGT 2-Bar Bridge Rail

0.00 seconds



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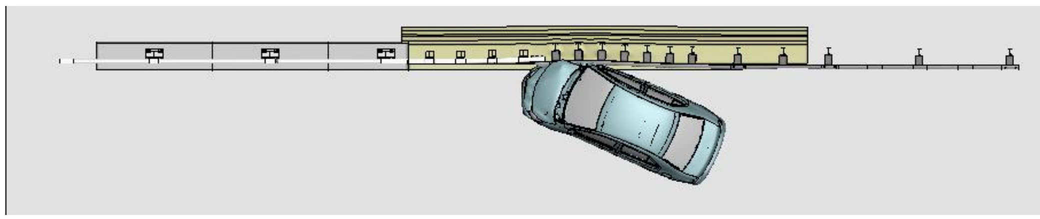

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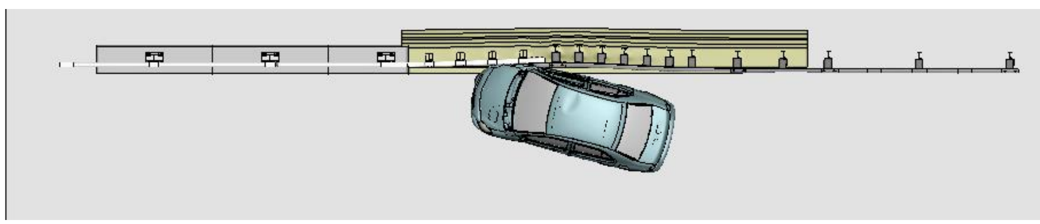

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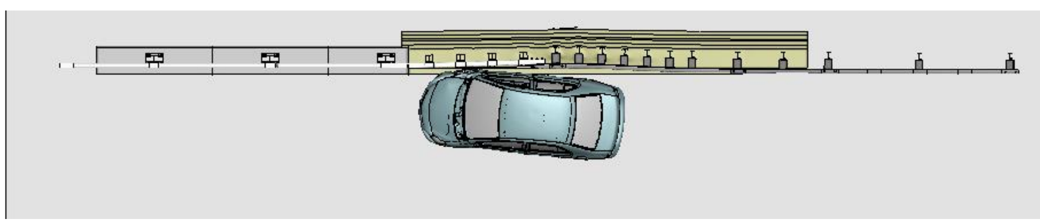

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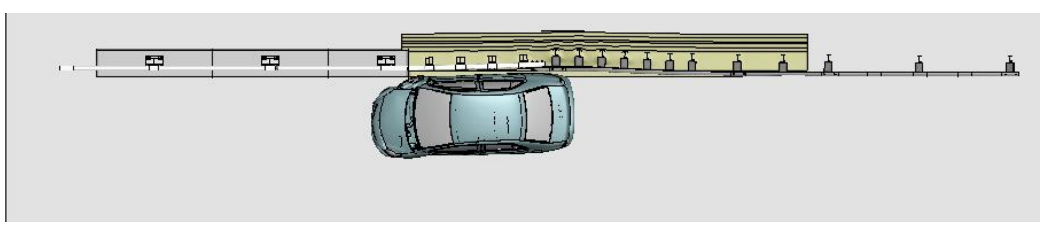
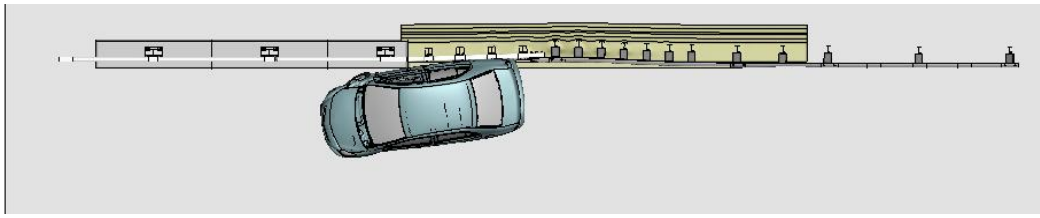


Figure Y-1. Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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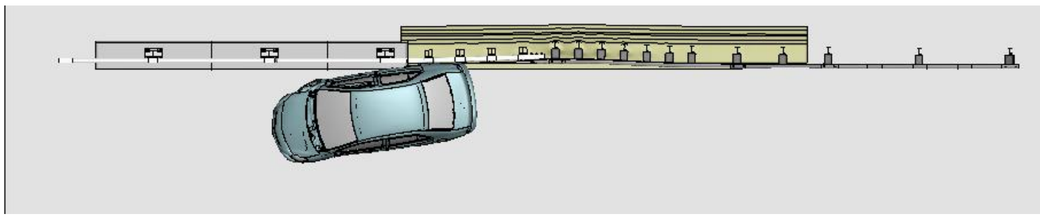

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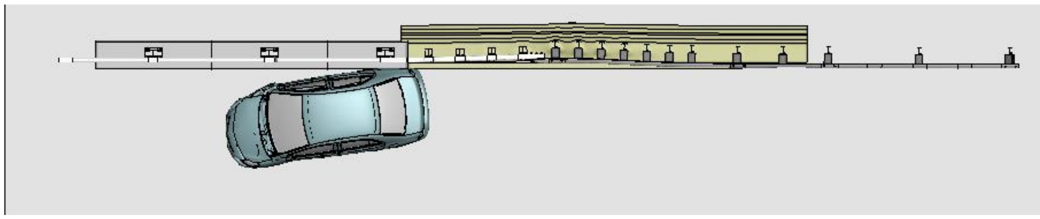

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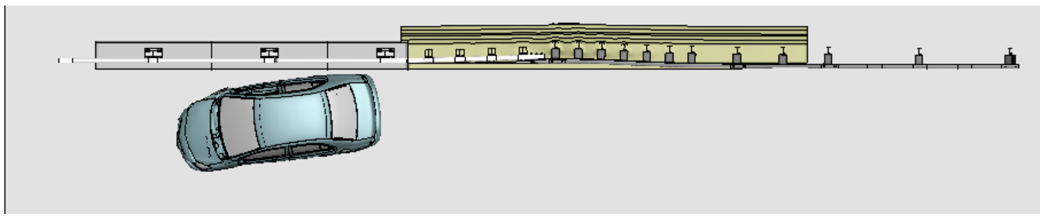

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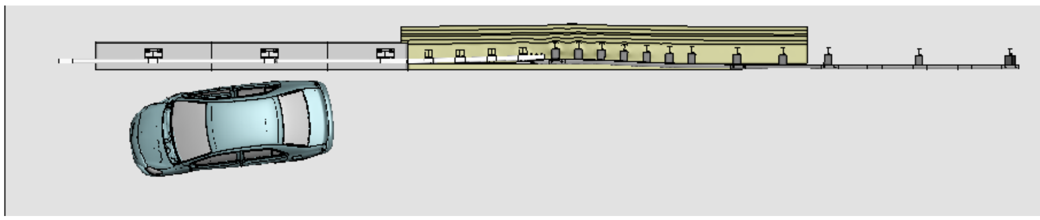
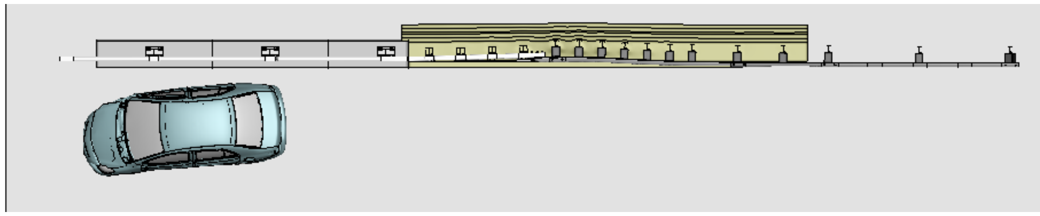


Figure Y-1. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an overhead viewpoint.

0.50 seconds



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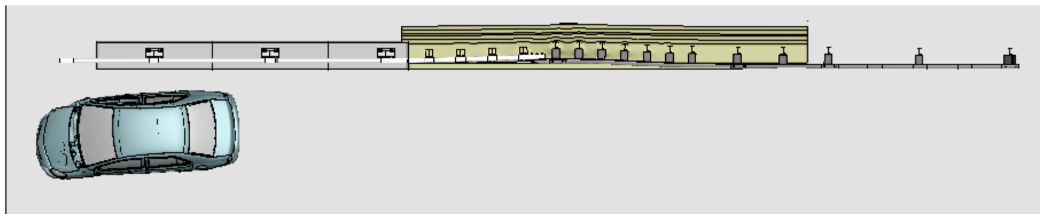

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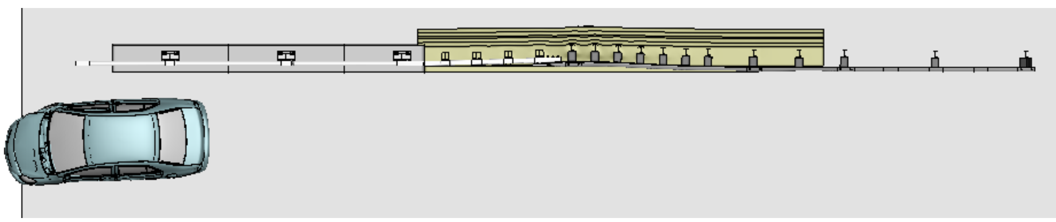

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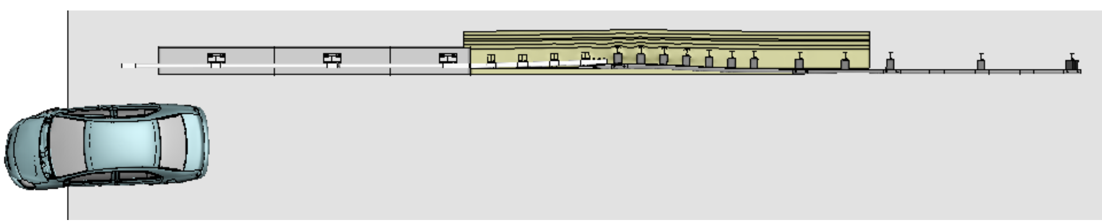

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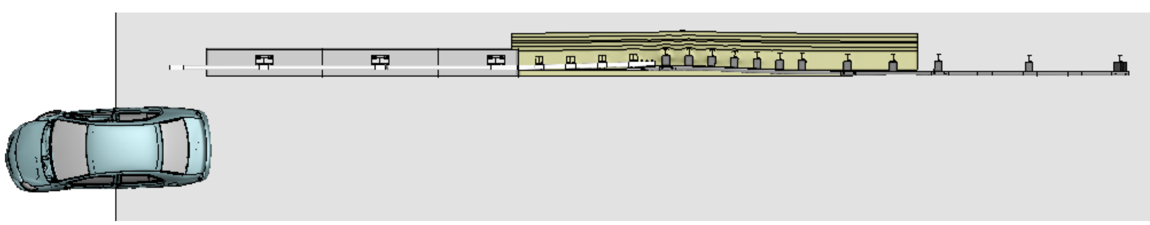
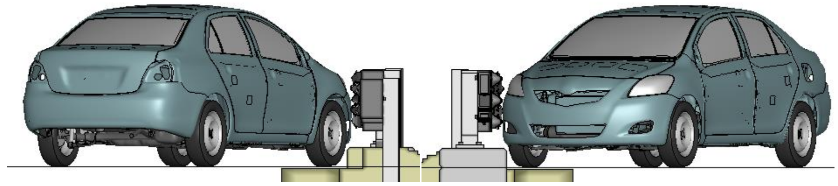


Figure Y-1. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an overhead viewpoint.

0.00 seconds



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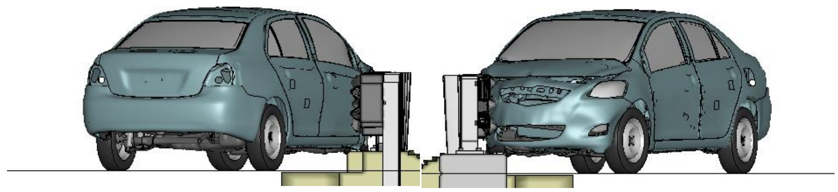

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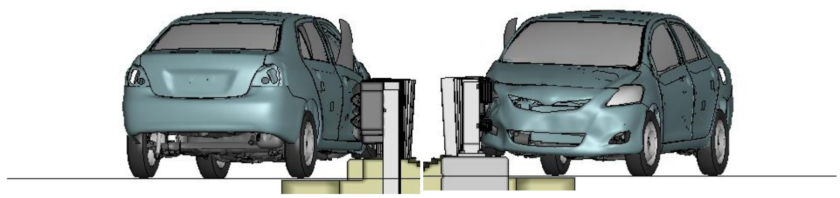

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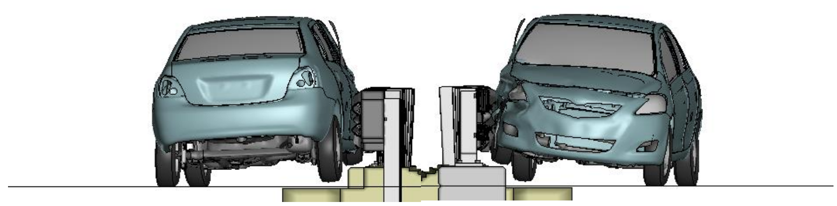
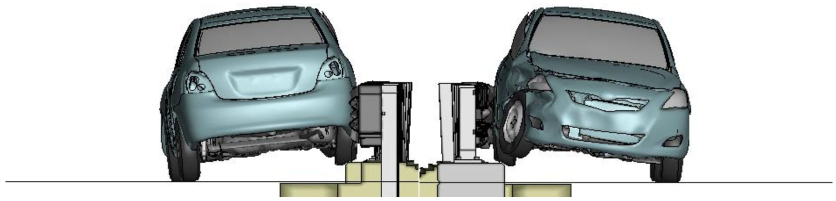


Figure Y-2. Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

0.20 seconds



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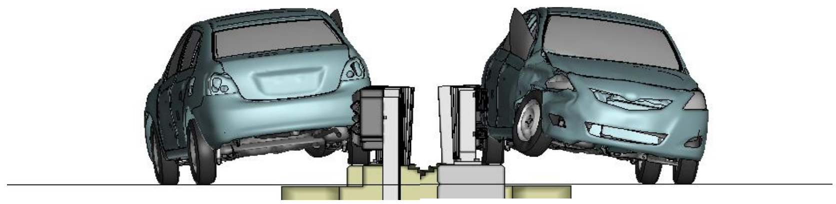

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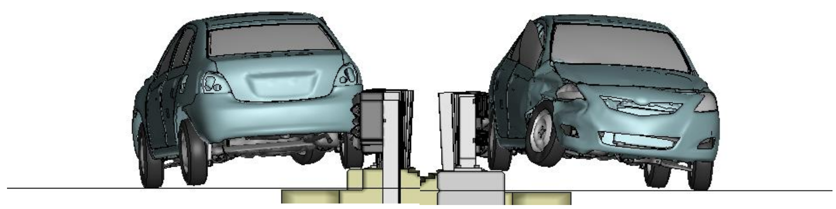

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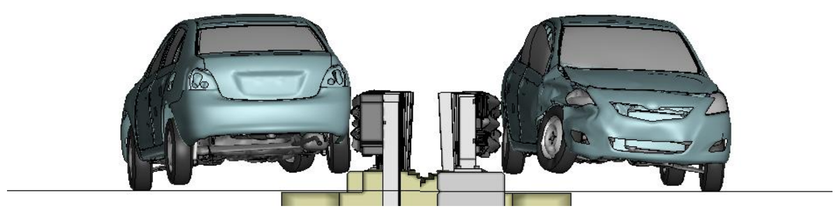
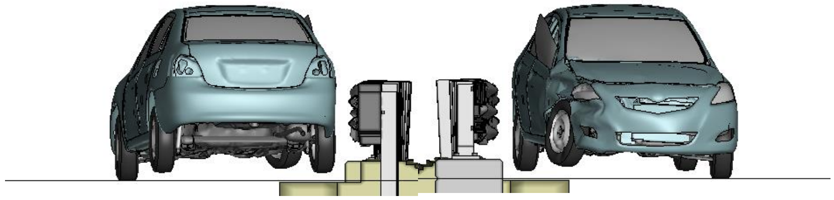


Figure Y-2. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

0.40 seconds



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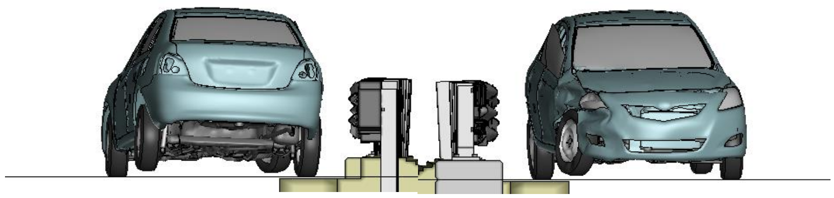

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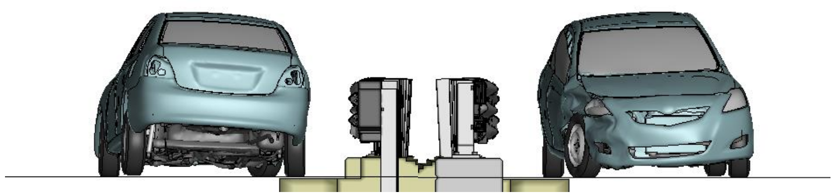

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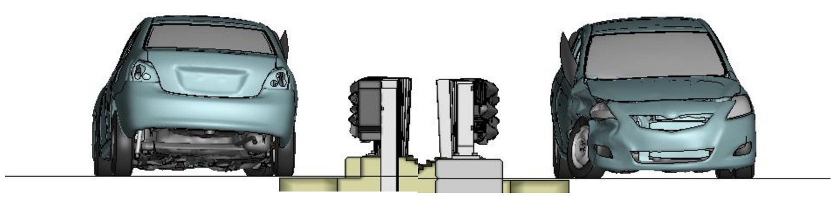

Figure Y-2. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

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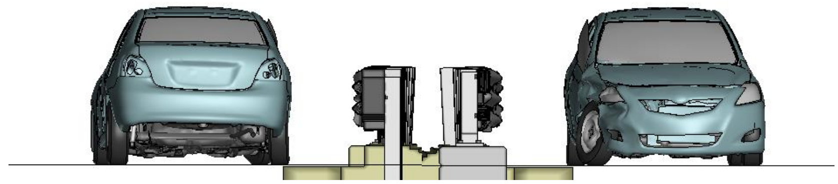

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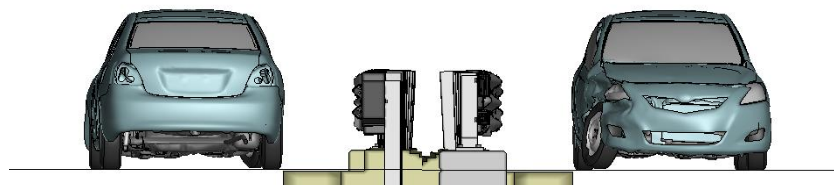

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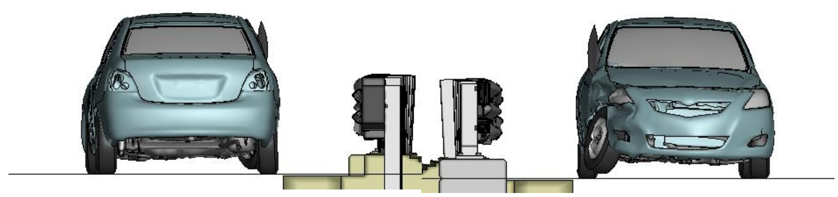

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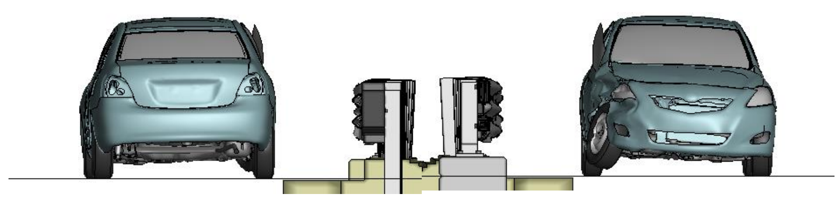


Figure Y-2. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

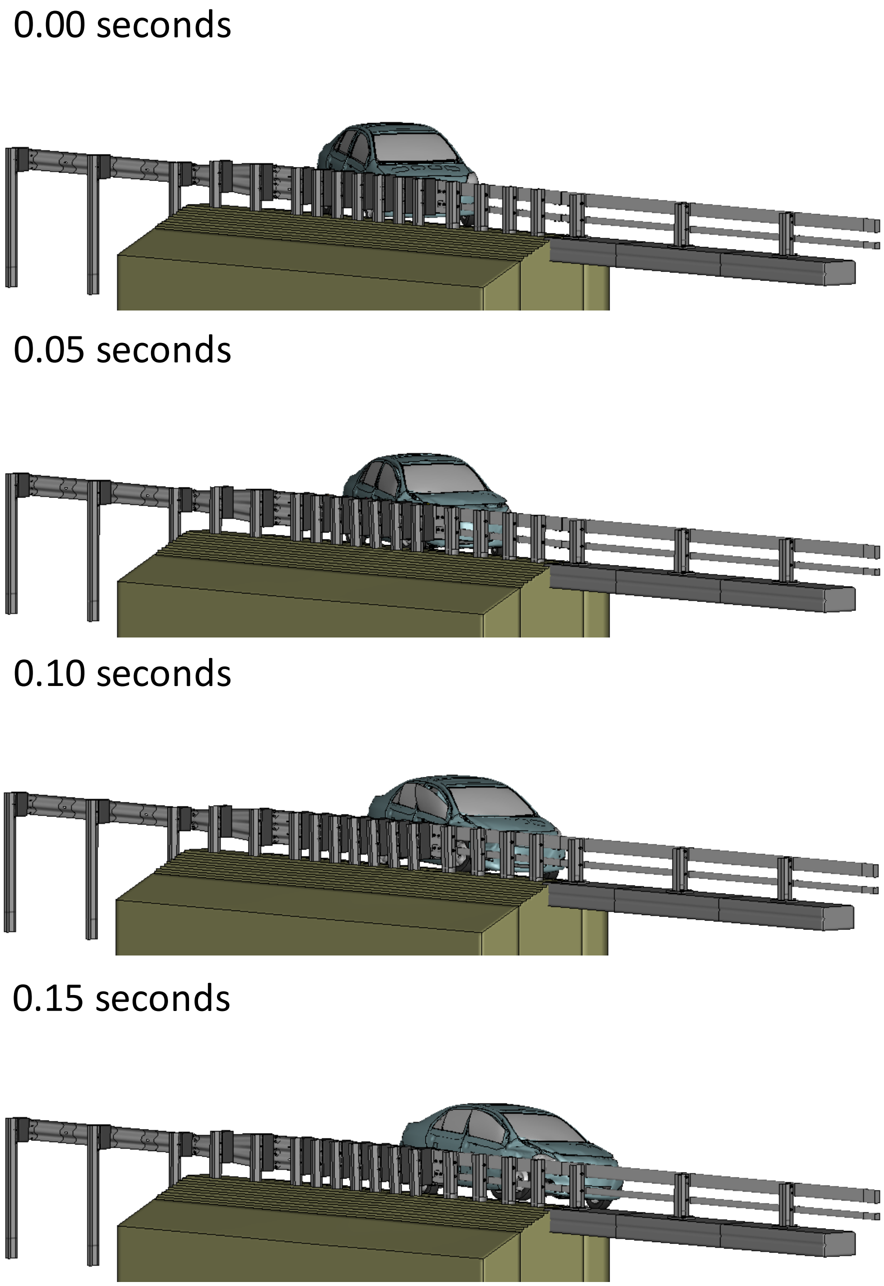
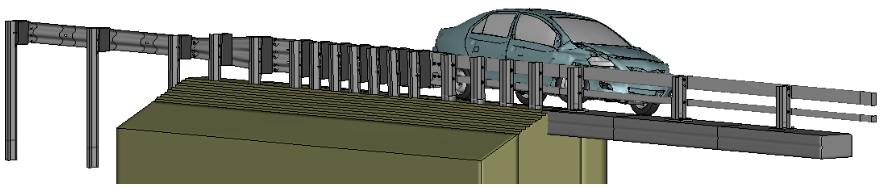


Figure Y-3. Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an oblique viewpoint.

0.20 seconds



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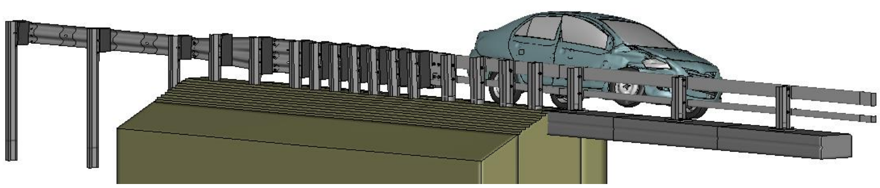

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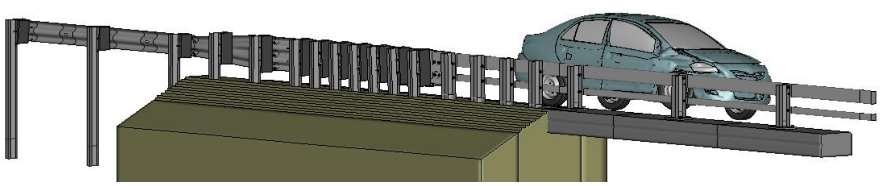

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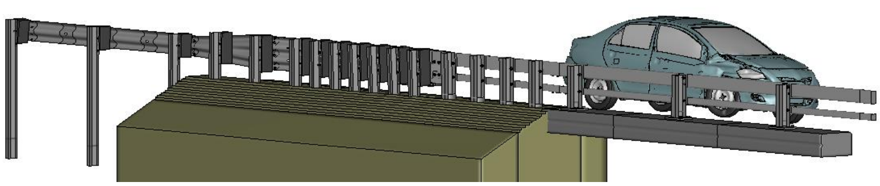
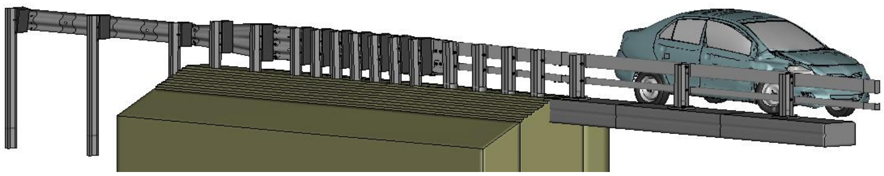


Figure Y-3. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an oblique viewpoint.

0.40 seconds



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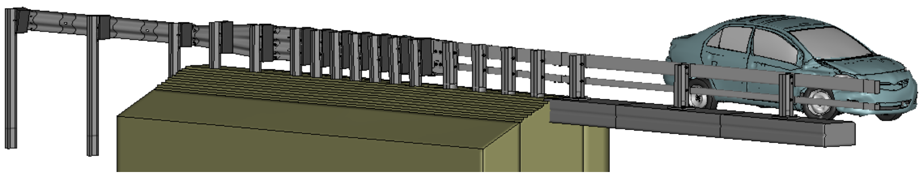

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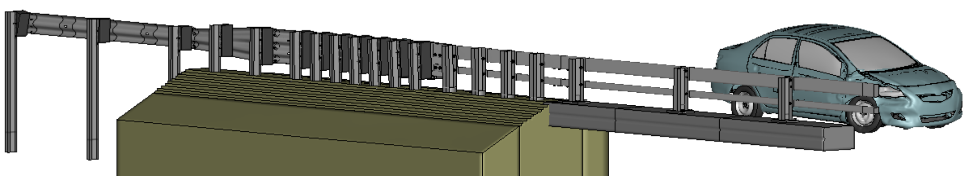

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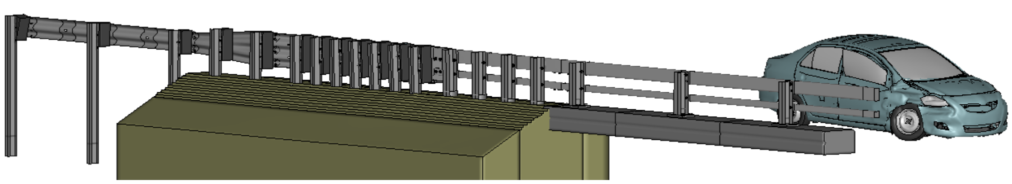
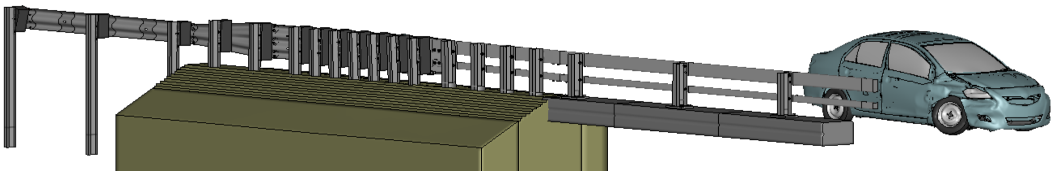


Figure Y-3. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an oblique viewpoint.

0.60 seconds



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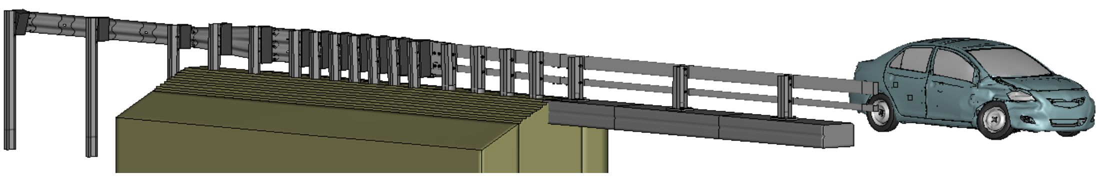

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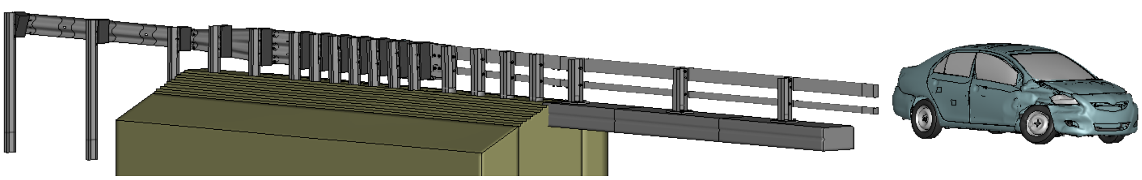

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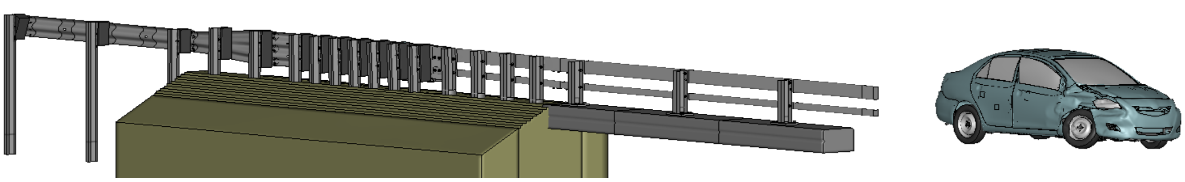


Figure Y-3. [Continued] Sequential views from analysis of MASH Test 3-20 for AGT 2-Bar bridge rail from an oblique viewpoint.

Appendix Z

Sequential Views for Test 3-21 on

Curb-Mounted AGT 2-Bar Bridge Rail

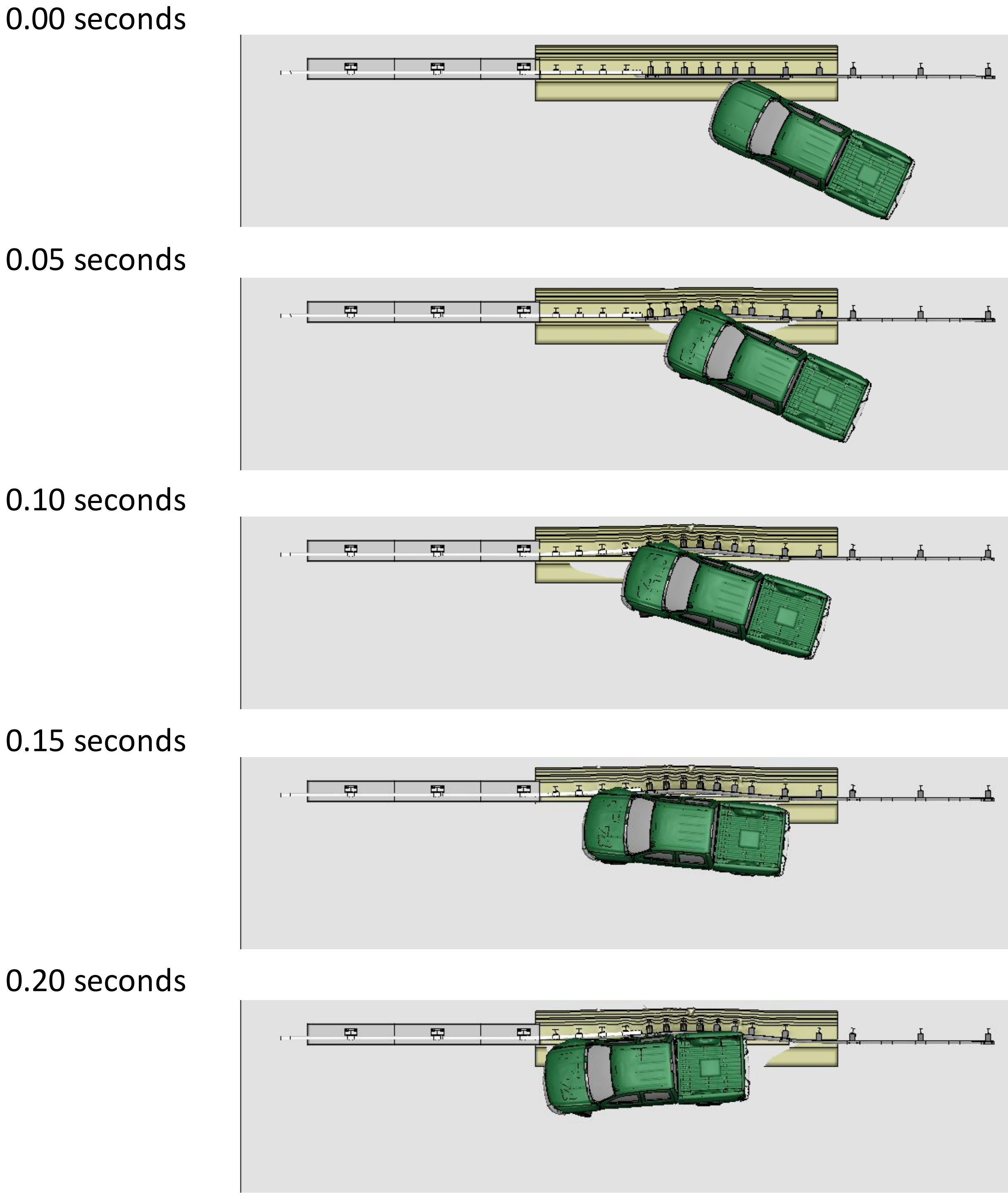
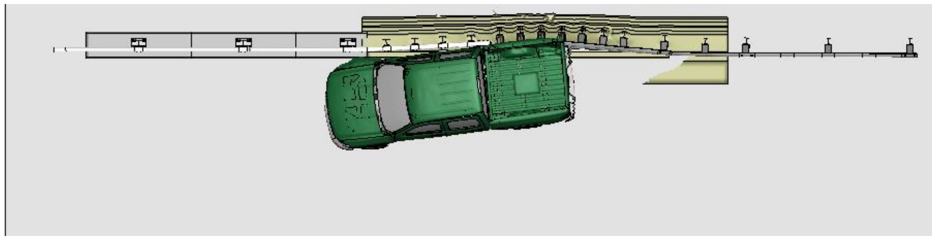


Figure Z-1. Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an overhead viewpoint.

0.25 seconds



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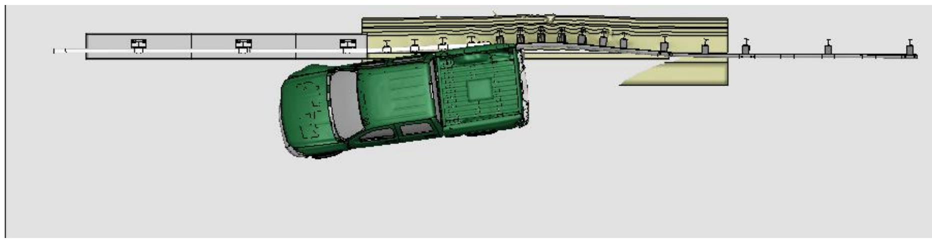

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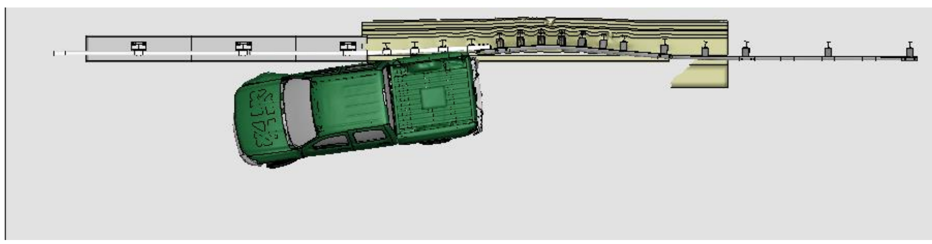

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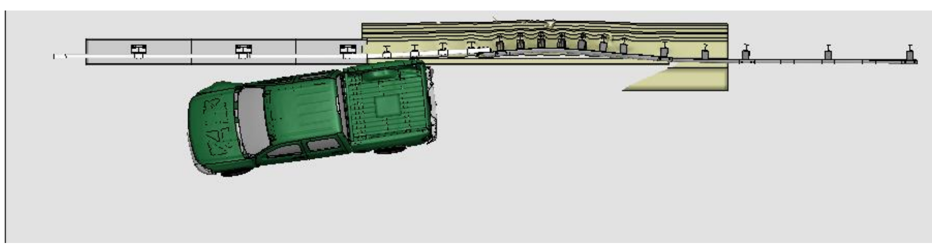

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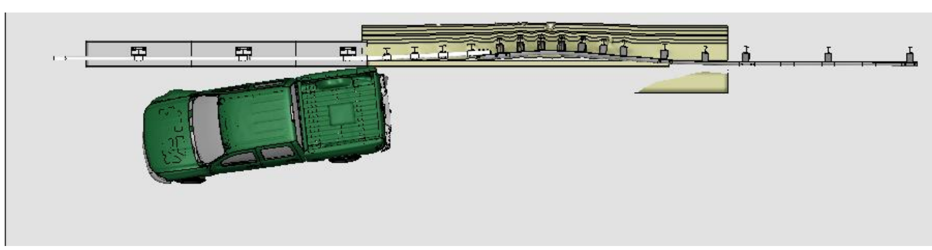

Figure Z-1. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an overhead viewpoint.

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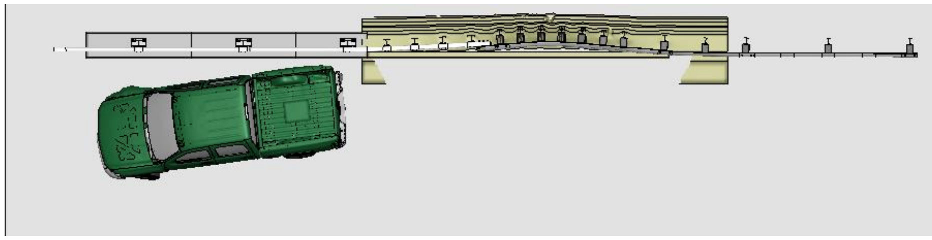

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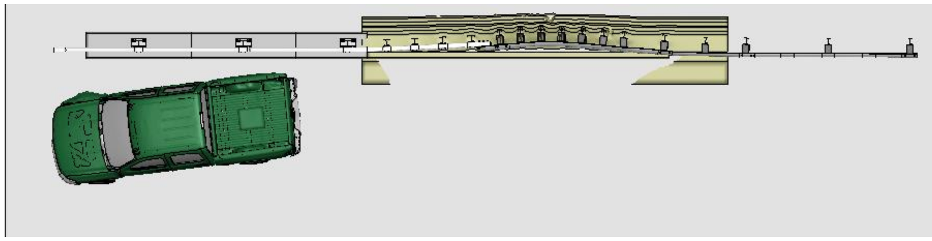

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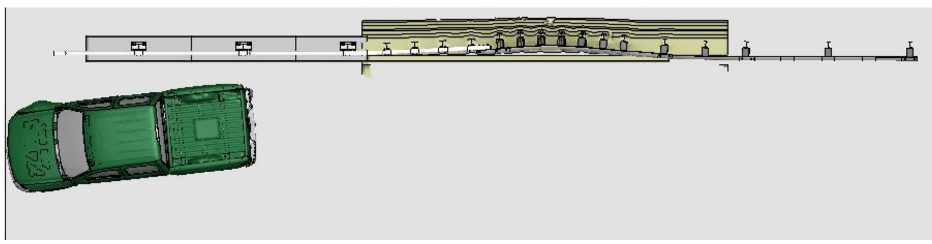

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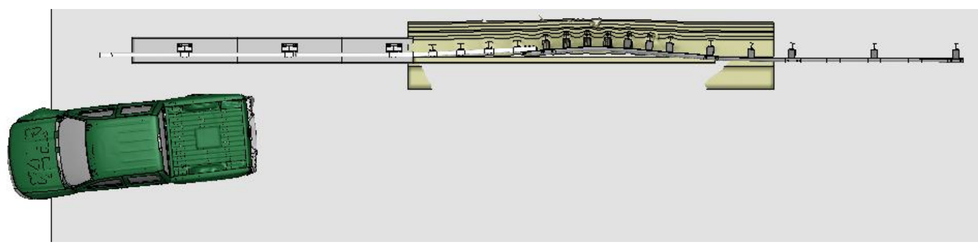

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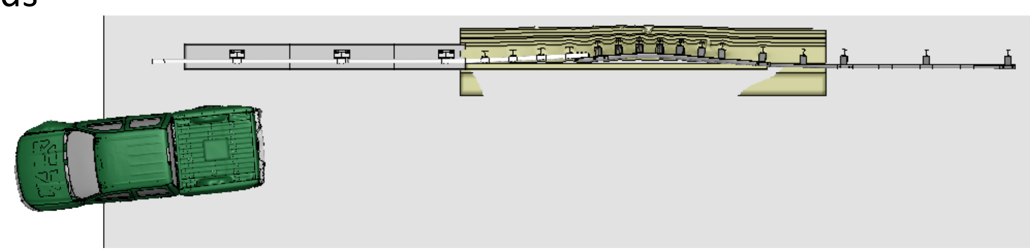

Figure Z-1. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an overhead viewpoint.

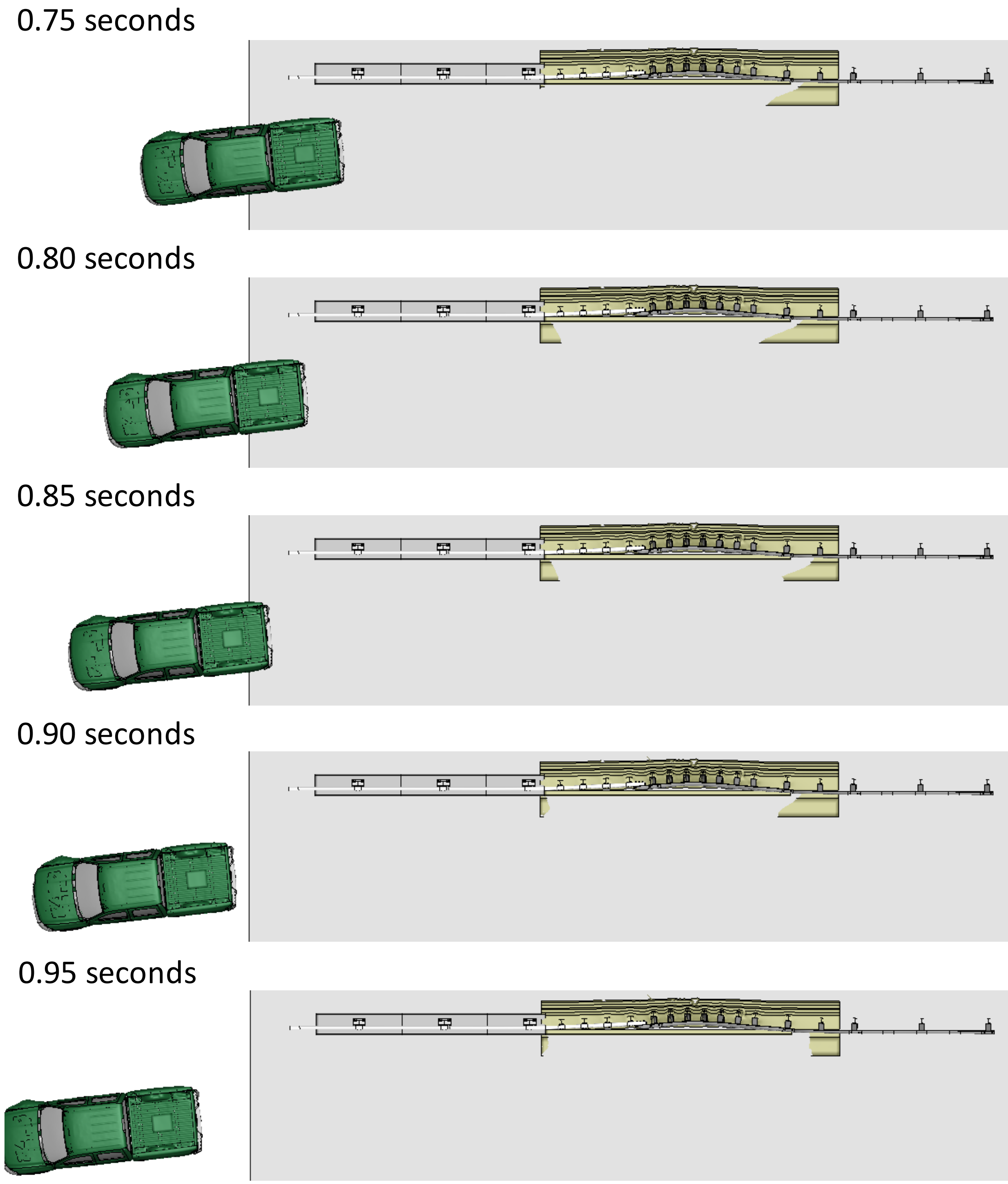

Figure Z-1. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an overhead viewpoint.

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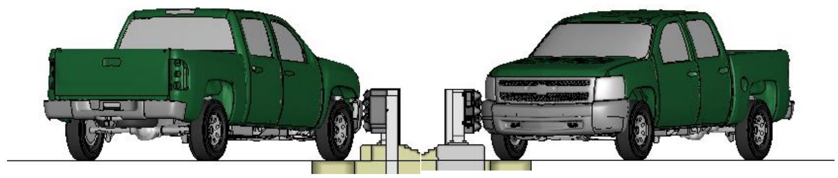

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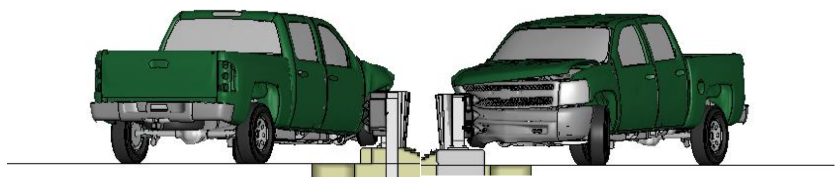

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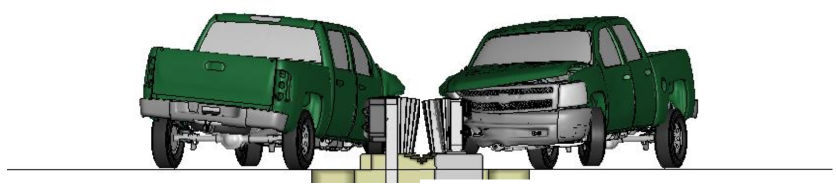

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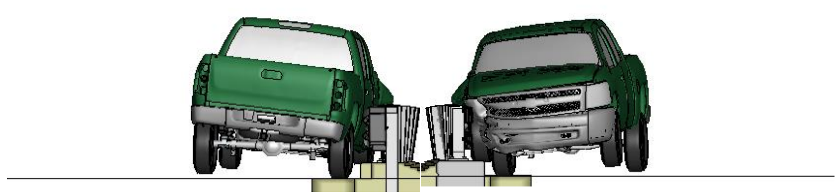

Figure Z-2. Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

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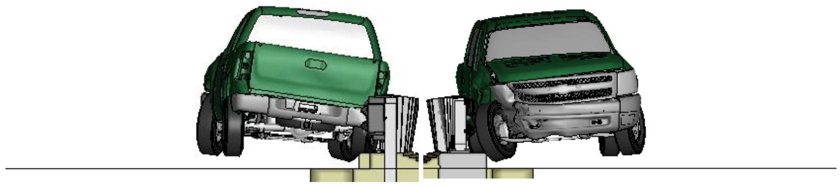

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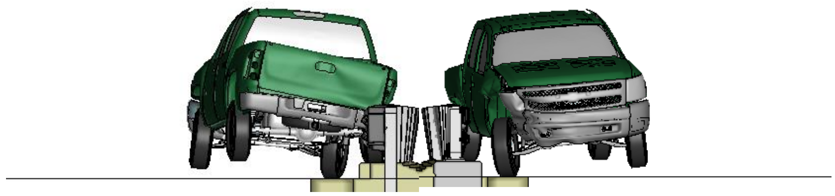

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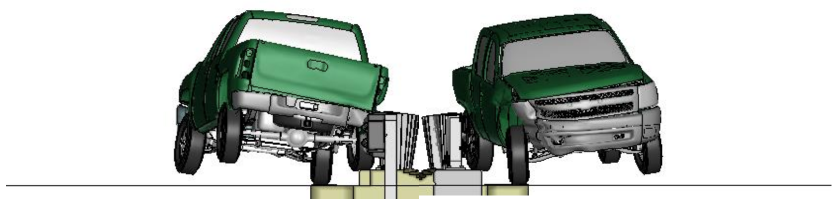

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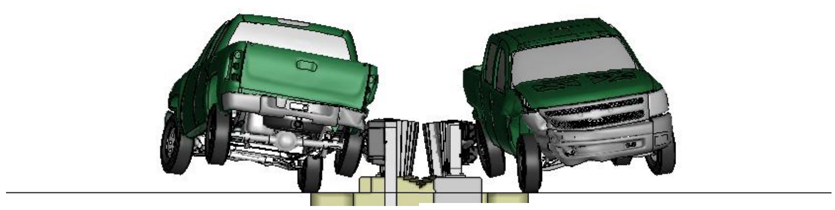

Figure Z-2. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

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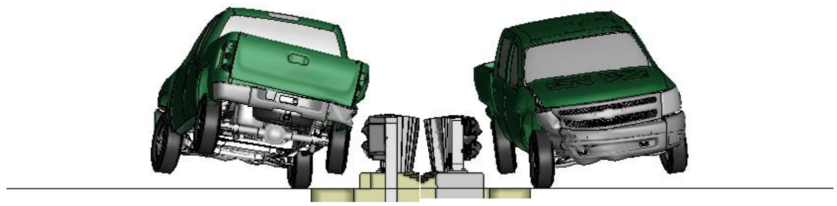

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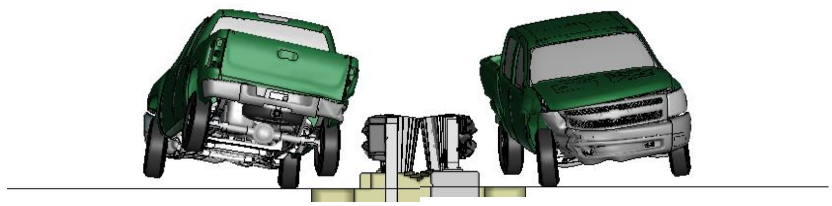

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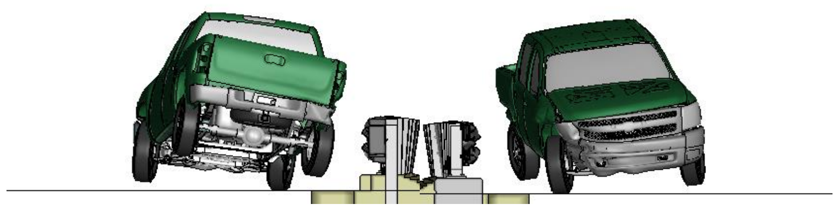

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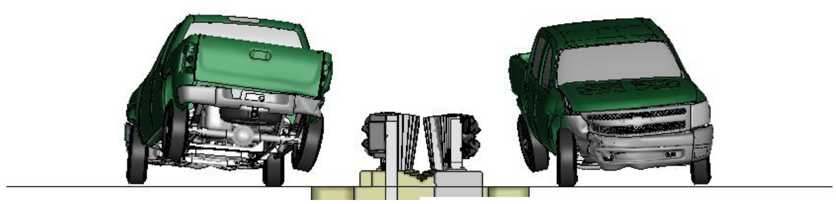

Figure Z-2. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

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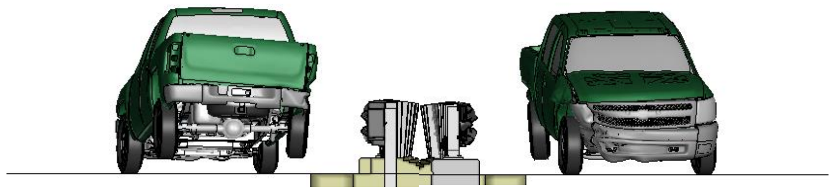

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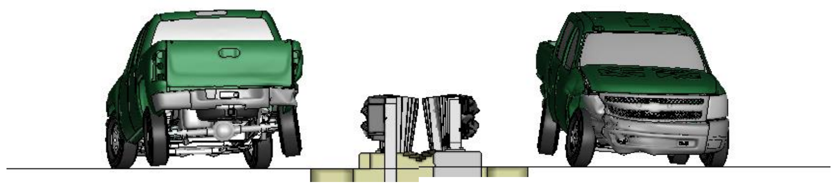

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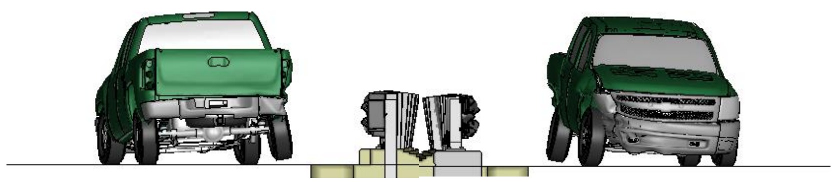

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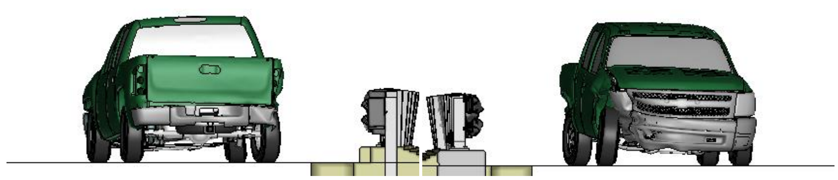

Figure Z-2. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

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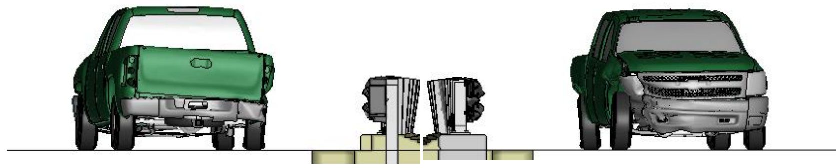

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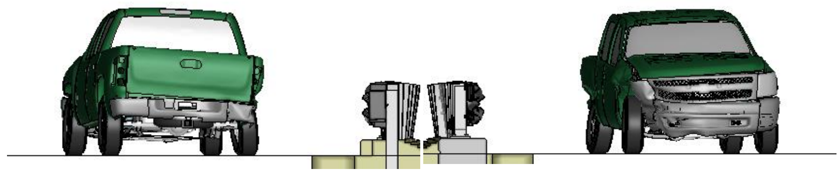

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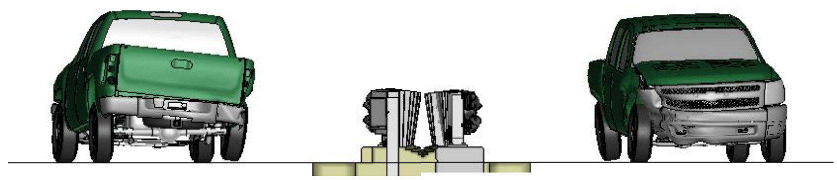

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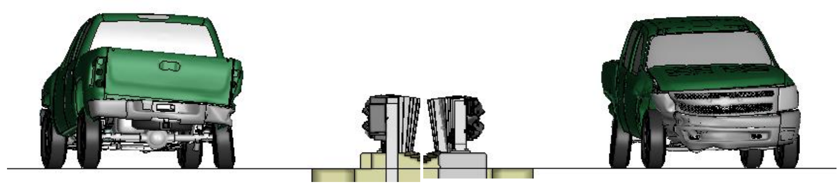

Figure Z-2. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from upstream and downstream viewpoints.

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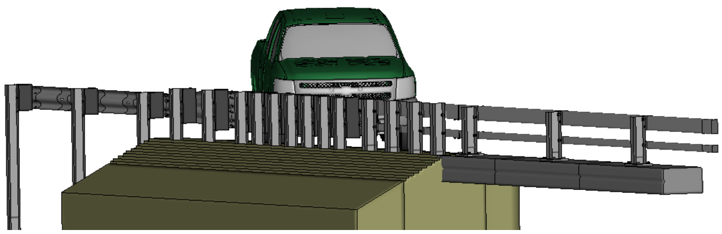

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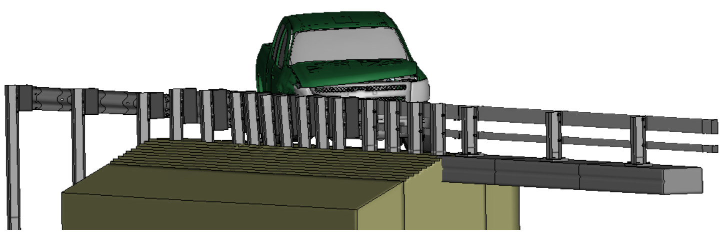

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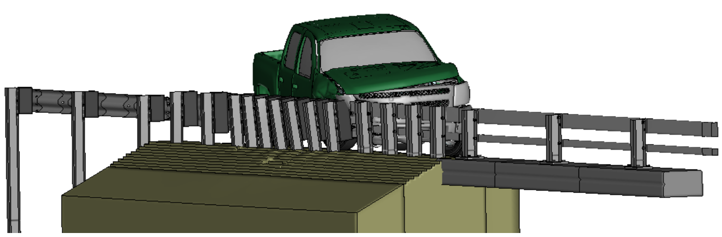

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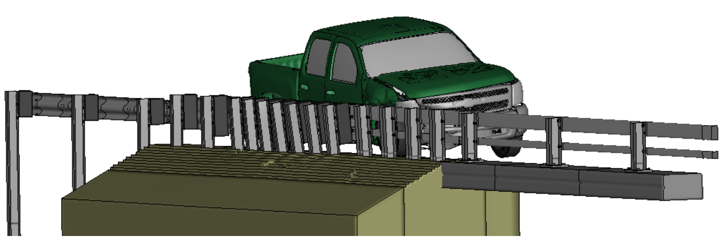

Figure Z-3. Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an oblique viewpoint.

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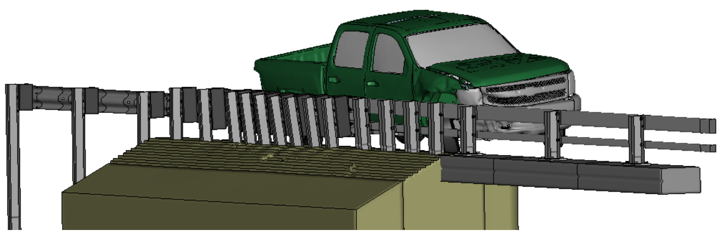

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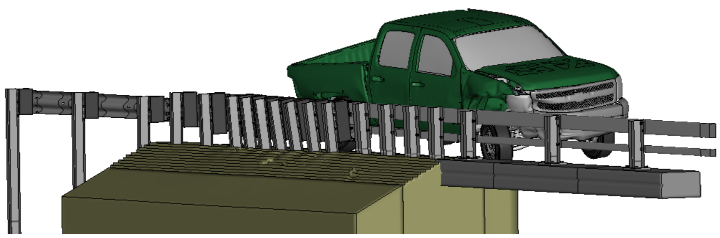

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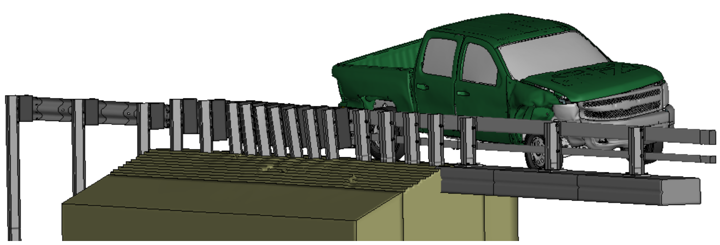

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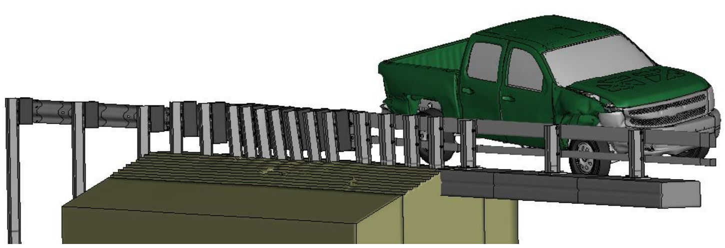

Figure Z-3. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an oblique viewpoint.

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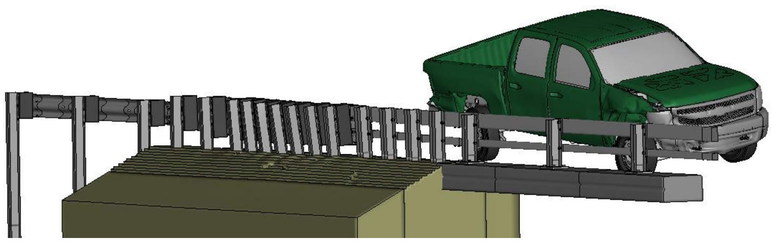

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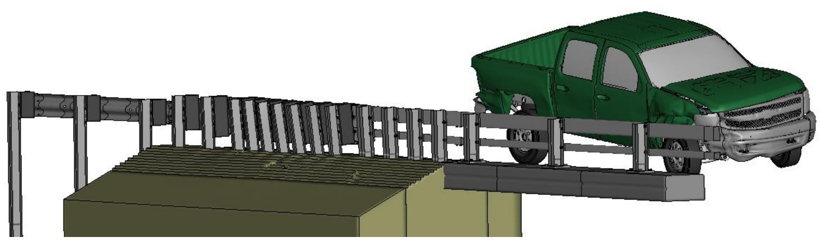

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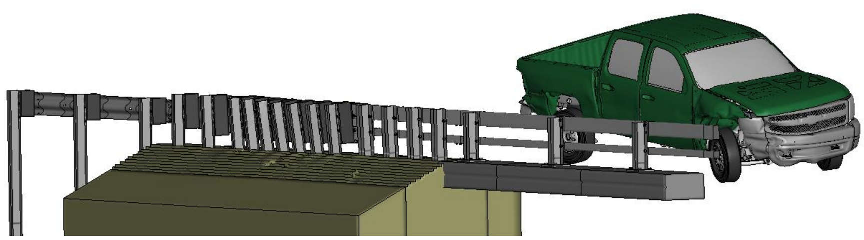

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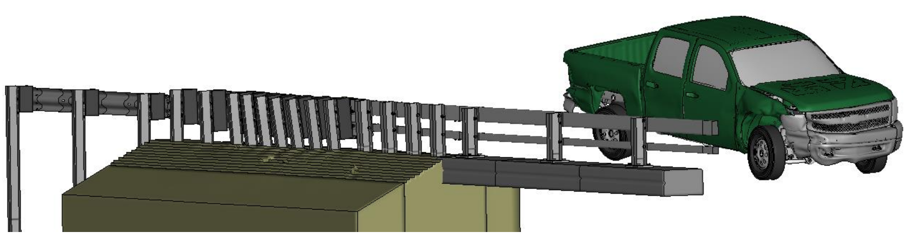

Figure Z-3. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an oblique viewpoint.

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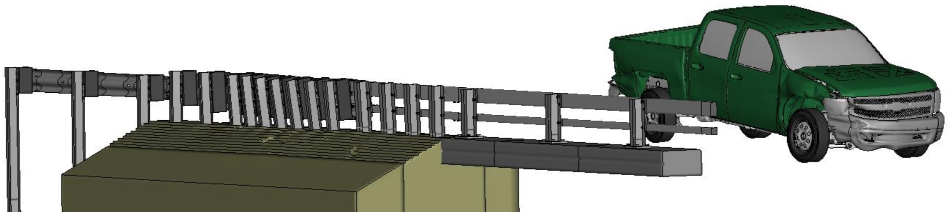

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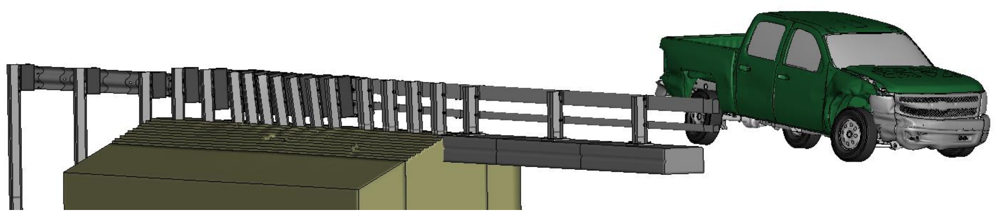

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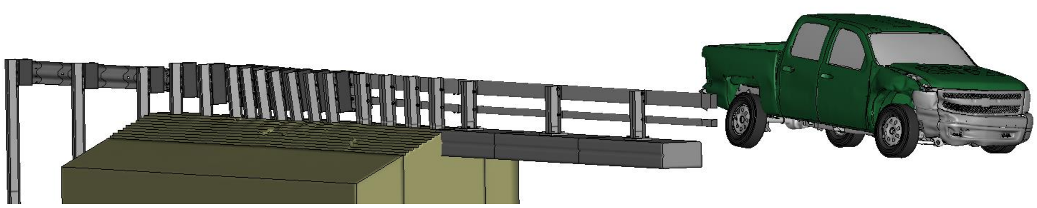

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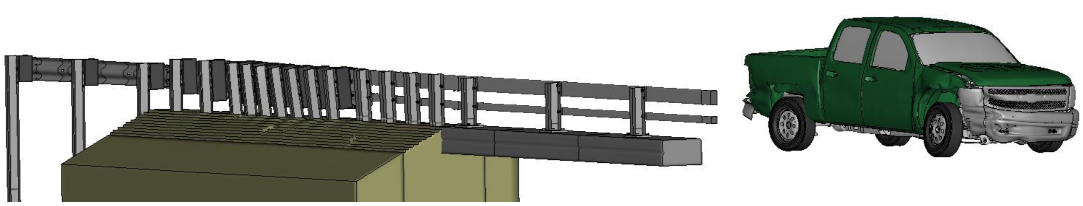

Figure Z-3. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an oblique viewpoint.

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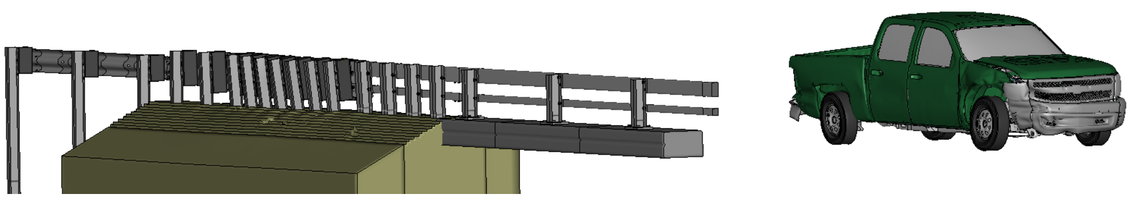

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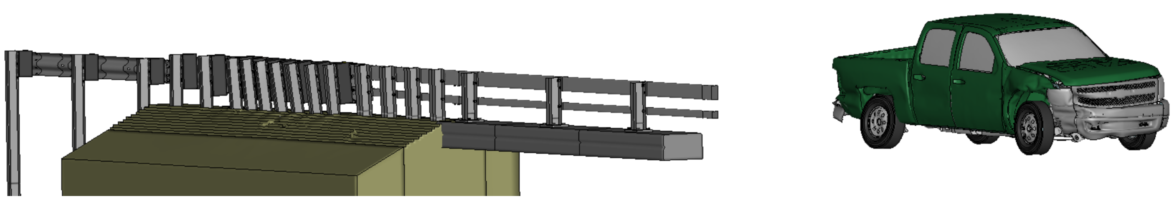
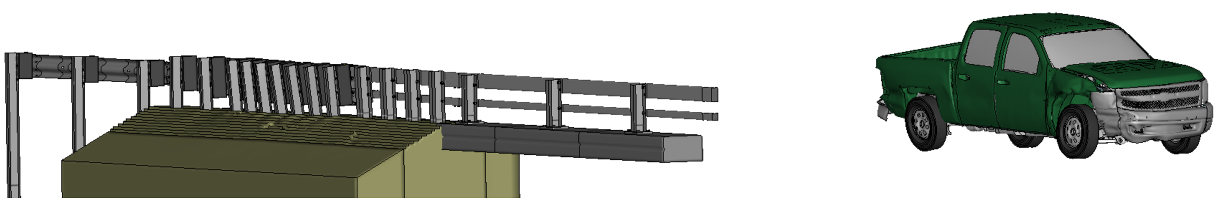


0.90 seconds



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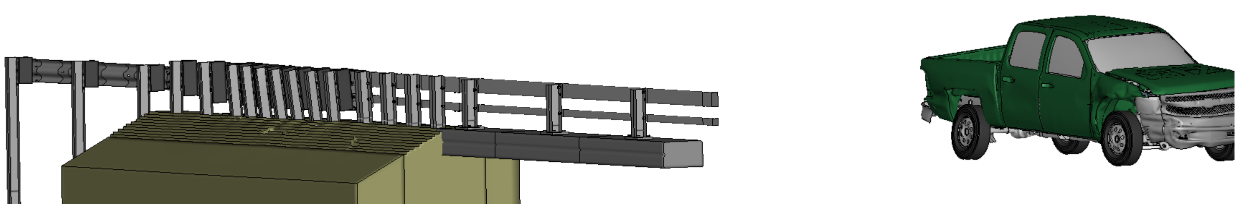

Figure Z-3. [Continued] Sequential views from analysis of MASH Test 3-21 for AGT 2-Bar bridge rail from an oblique viewpoint.