Development of MASH Computer Simulated Steel Bridge Rail and Transition Details

Task 5B
NETC 4-Bar w/ W8x28 Posts
Test 4-12

Project # : NETC 18-1
Federal Project No. : 2343018

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Roadsafe LLC

December 3, 2019

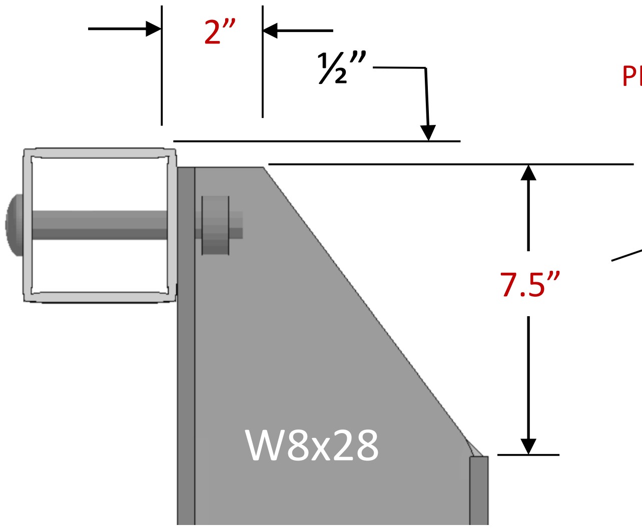
Roadsafe LLC

Task 5B – MASH Test 4-12 Evaluation of Modified NETC 4-Bar Bridge Rail

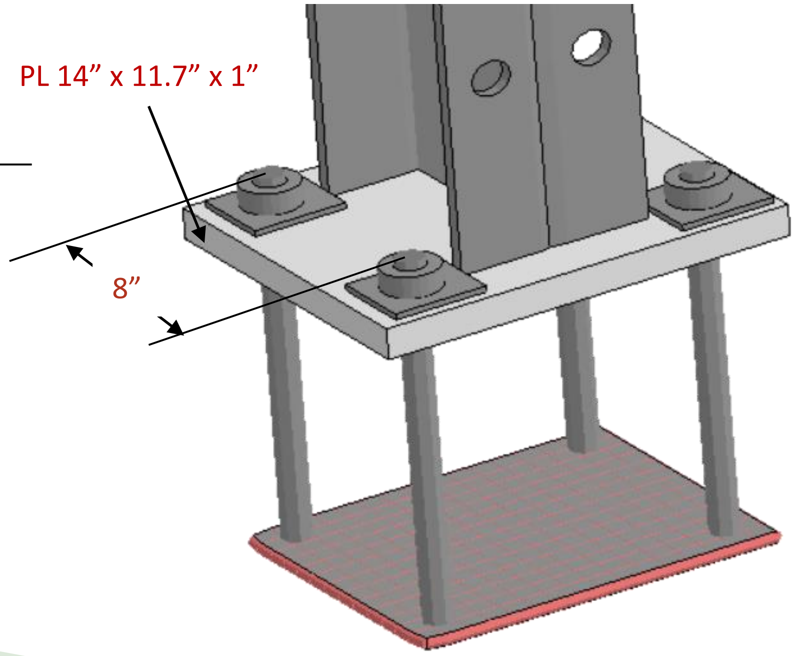
- The objective of this task was to use FEA simulations to determine if increasing the size of the bridge rail post to W8x28 would improve crash performance for MASH Test 4-12.
- The evaluation of the baseline 4-Bar bridge rail was performed in Task 5, where FEA simulations of Test 4-12 showed that this system resulted in the most severe damage to the post, base plate and curb.
- The W8x28, which is a readily available shape, has a plastic modulus that is approximately 40% higher than the W6x25 which will improve static strength calculations (e.g., LRFD ch 13).
- The length of the flange and web of the W8x28 are longer than that of the current post which will increase weld strength.
- The larger post requires that the base plate be extended 2” which should reduce the tensile forces on the front anchor bolts but will increase chance of pushout shear failure of concrete deck at the back of the post.

Modified Model

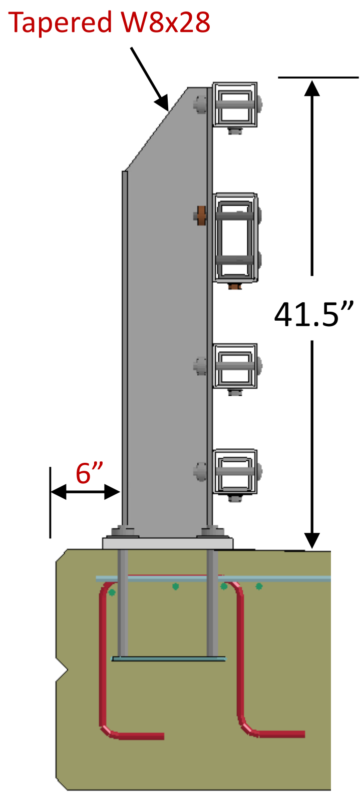
- The finite element model of the NETC 4-Bar system developed in Task 5 was used as baseline.
- The model was updated to include:
  - W8x28 posts tapered at the top
  - Base-plate and anchor-plate resized for post
  - Anchor-bolts repositioned for post.
- The resulting distance from anchor-bolt to back of curb = 6 inches



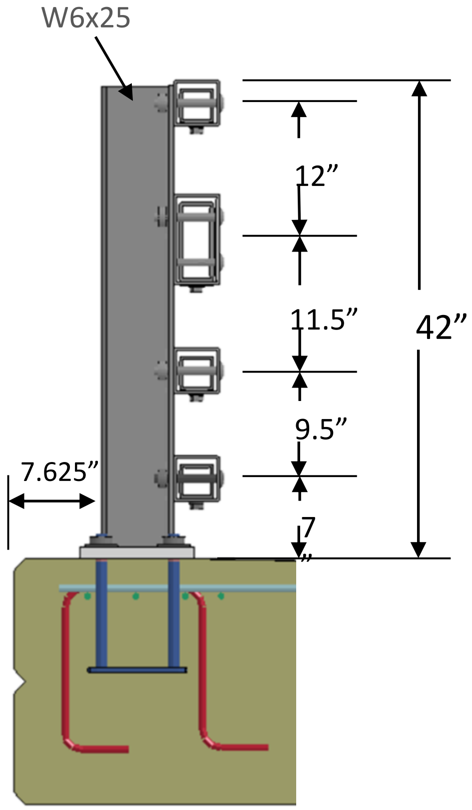
Taper



Base-Plate and Anchor-Plate



Mod. Design

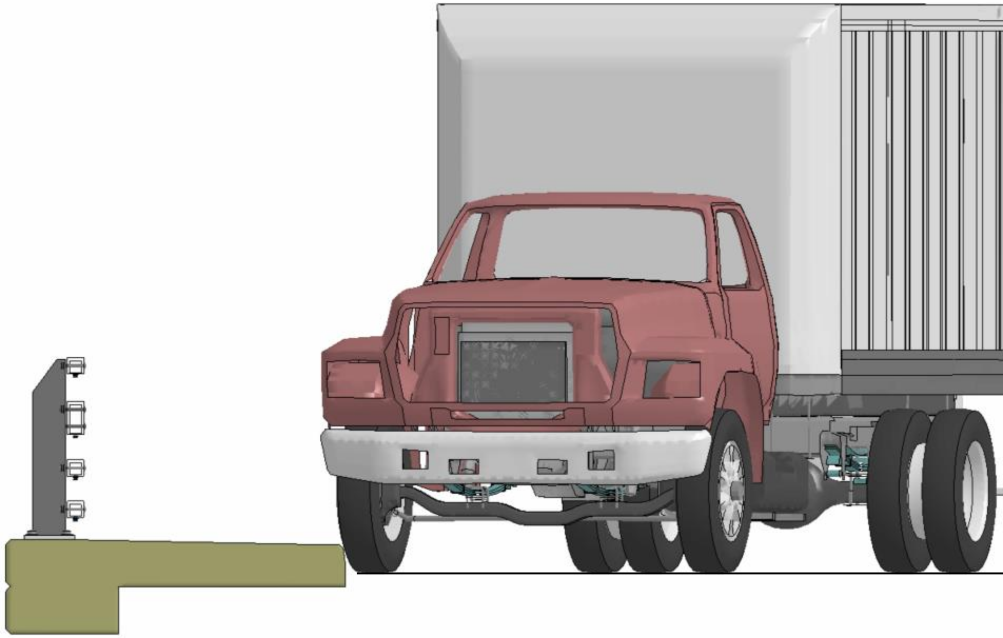


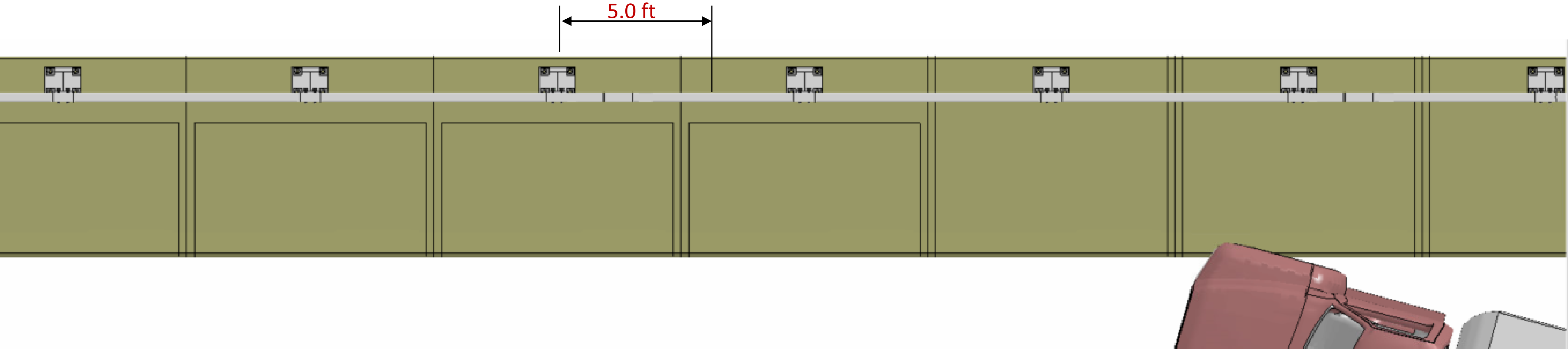
Original Design

Ford 800 Surrogate

MASH Test 4-12 Simulation

- **Impact Conditions**
  - Mass = 22,061 lb
  - Impact Speed = 56 mph (90 km/hr)
  - Impact Angle = 15 degrees
  - **Target Impact Point = 5.0 ft upstream of Post 7**
  - Actual Impact Point = 4.4 ft upstream of Post 7





MASH Test 4-12 Simulation

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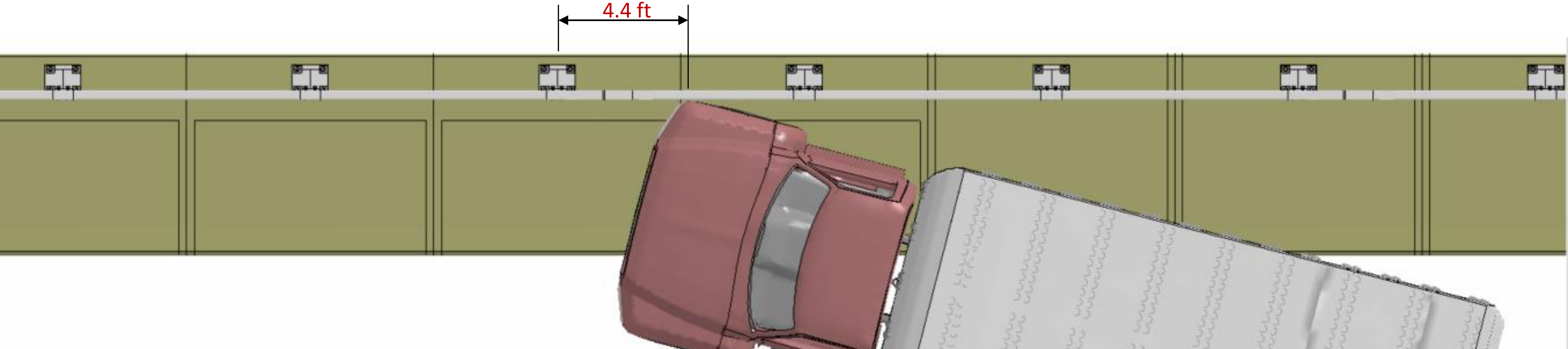
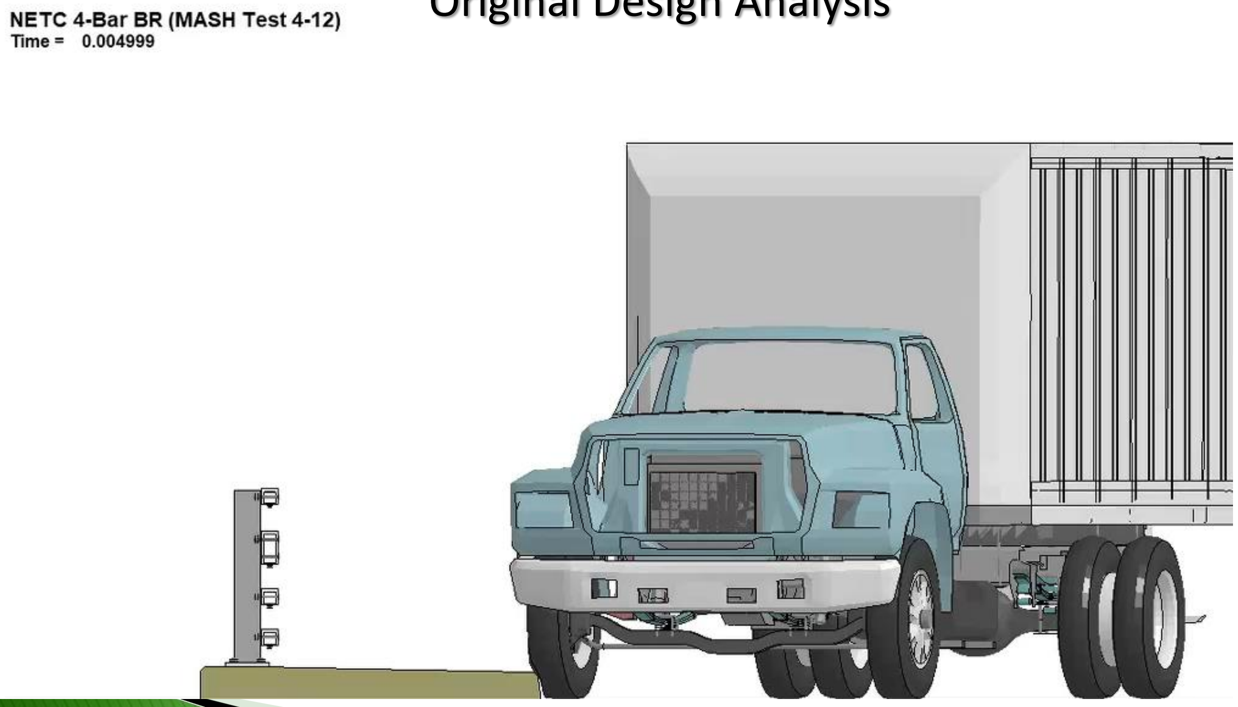
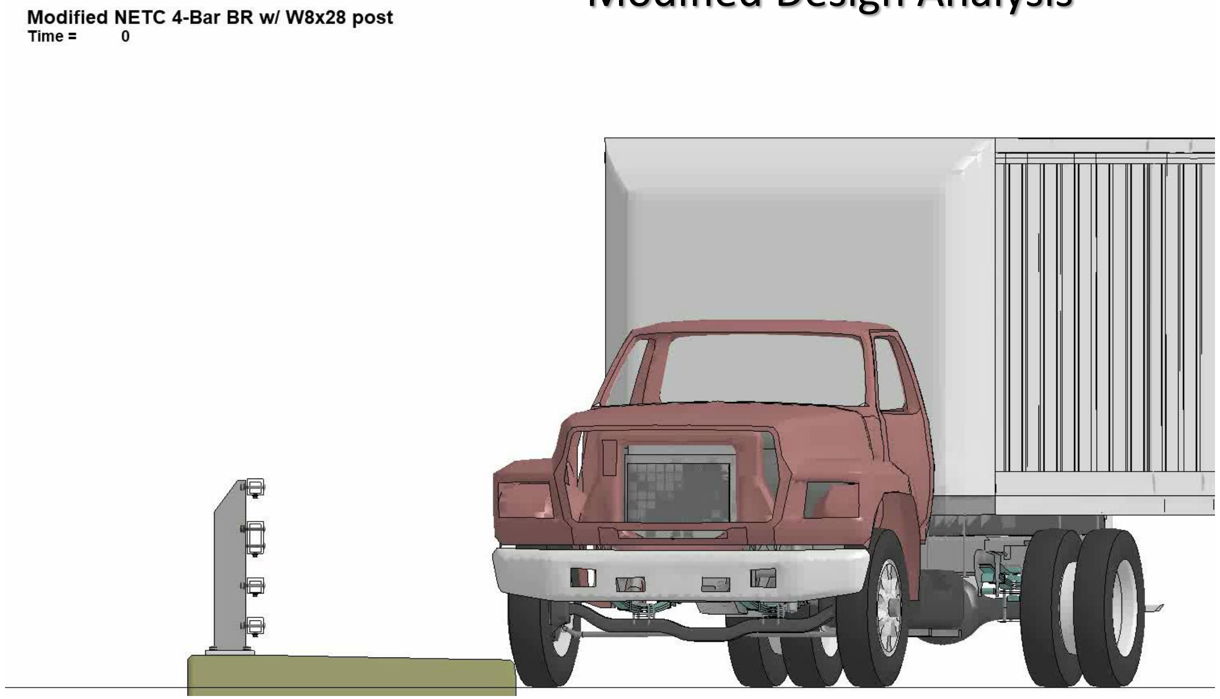


Movies

Original Design Analysis



Modified Design Analysis



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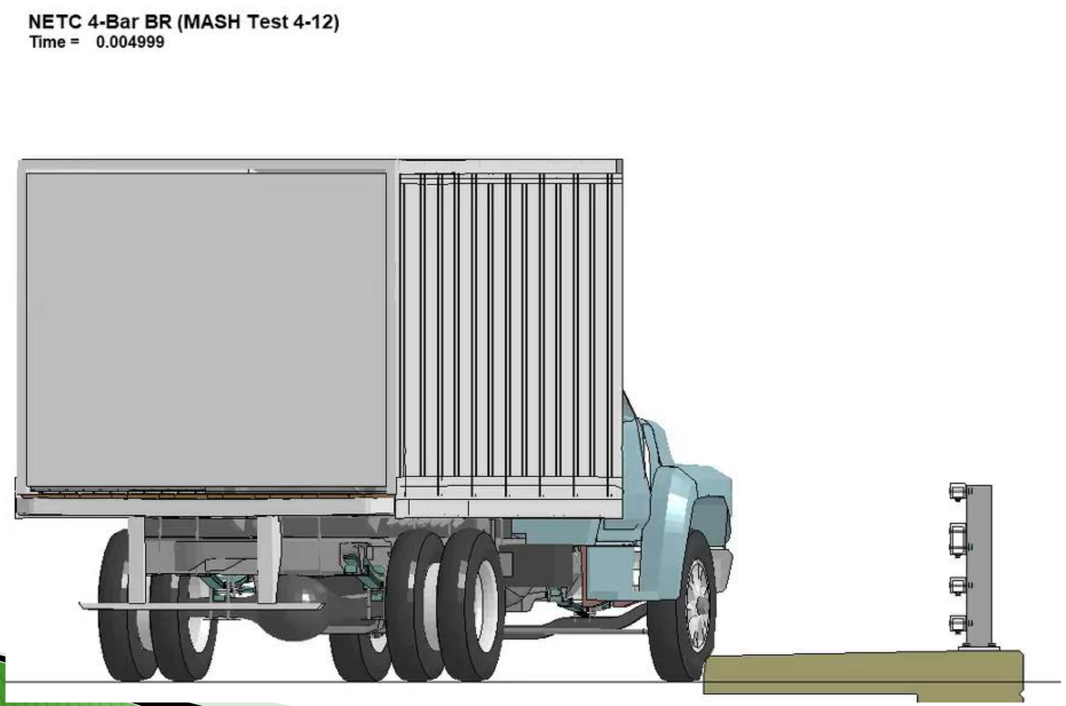
Movies

Original Design Analysis



Modified Design Analysis

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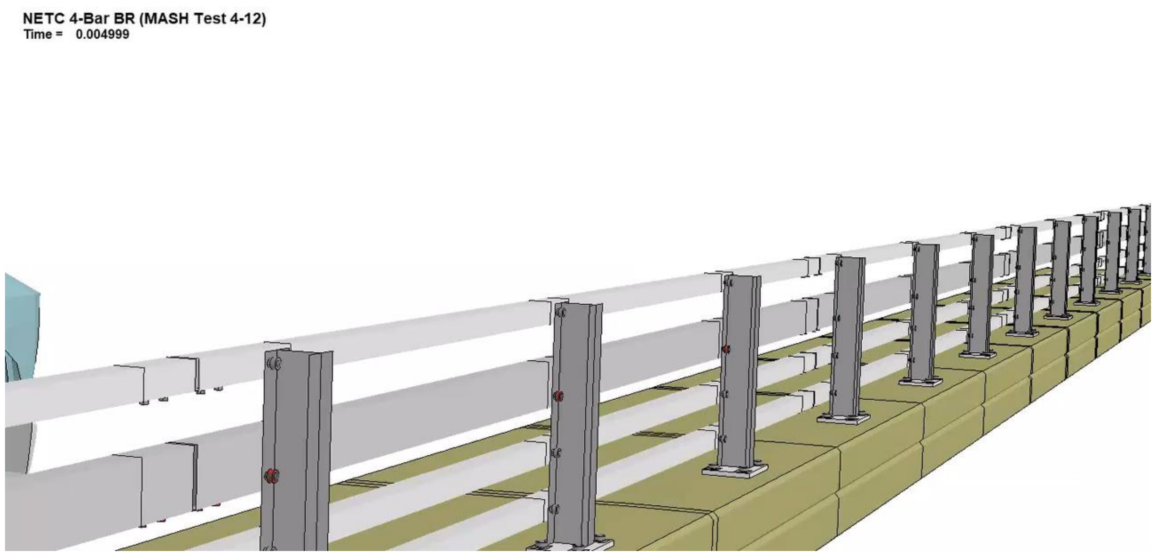

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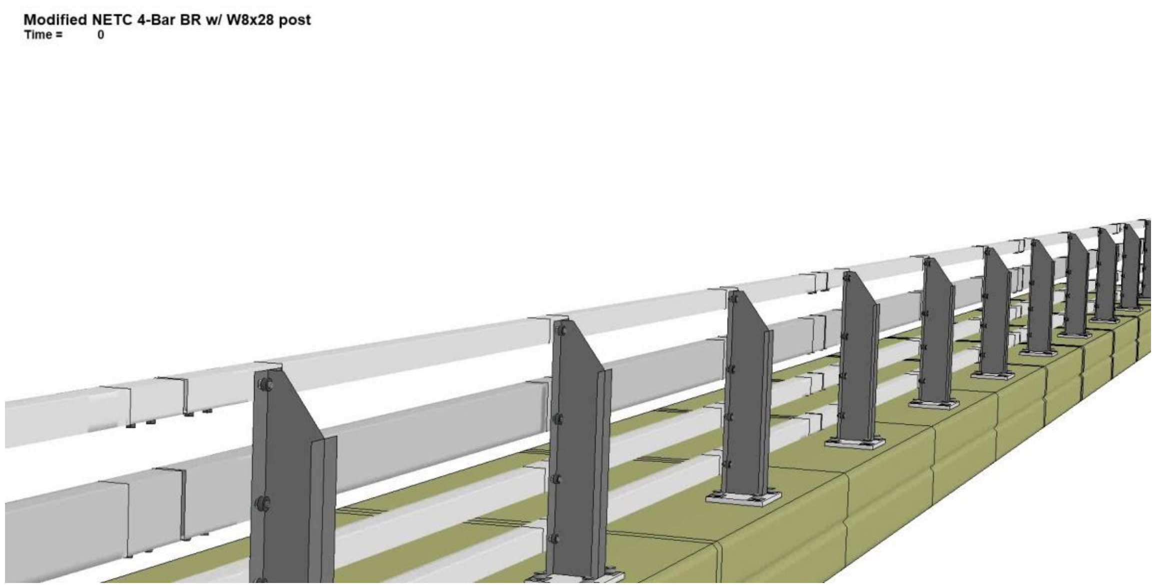

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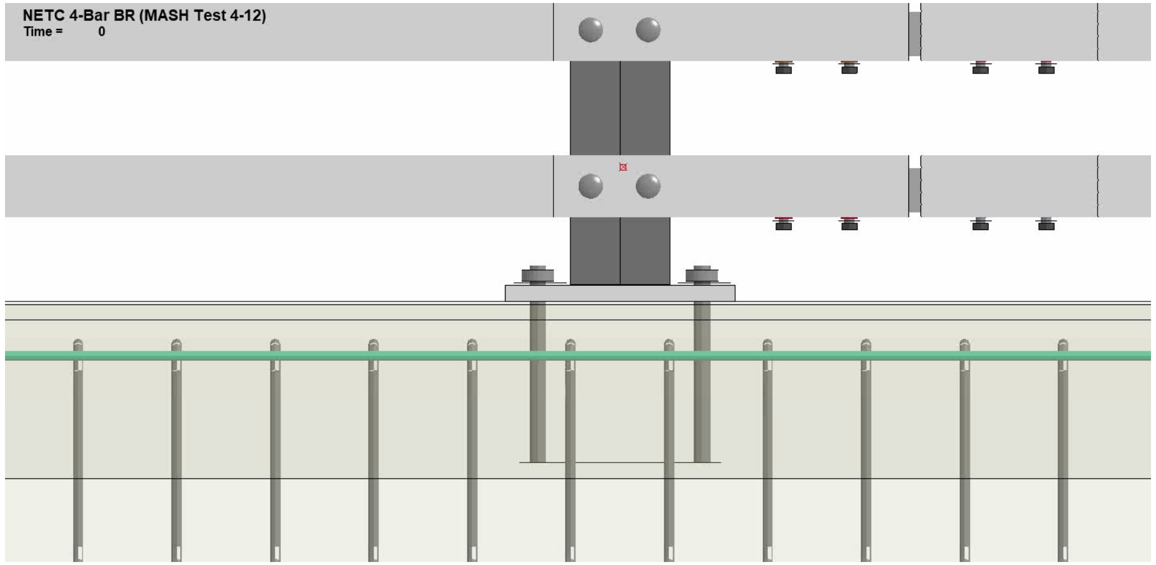
Movies

Original Design Analysis



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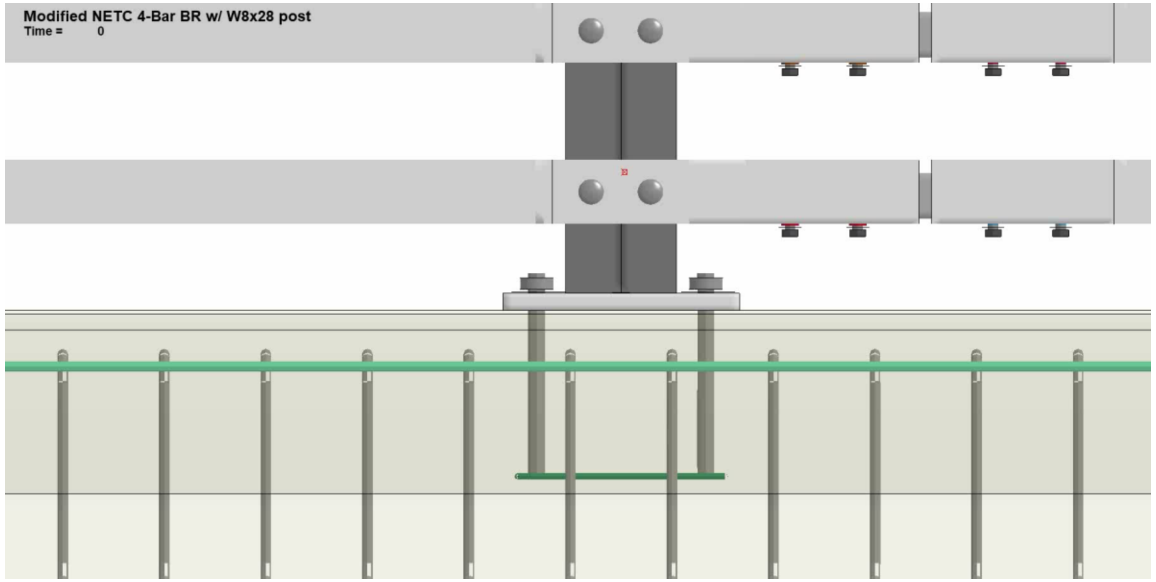

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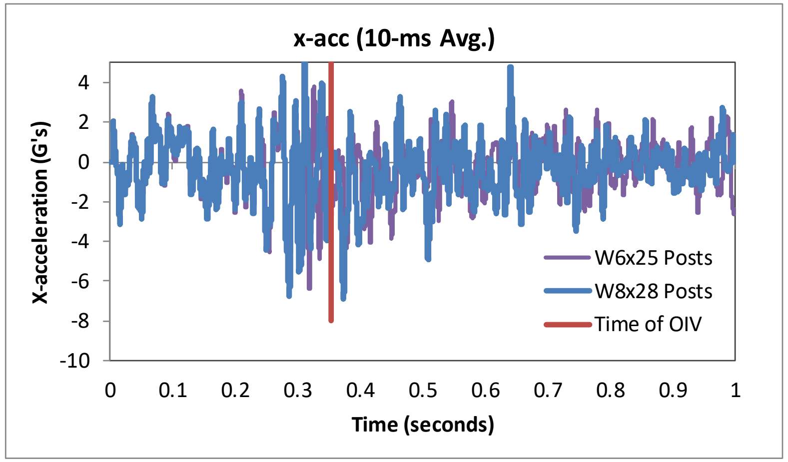
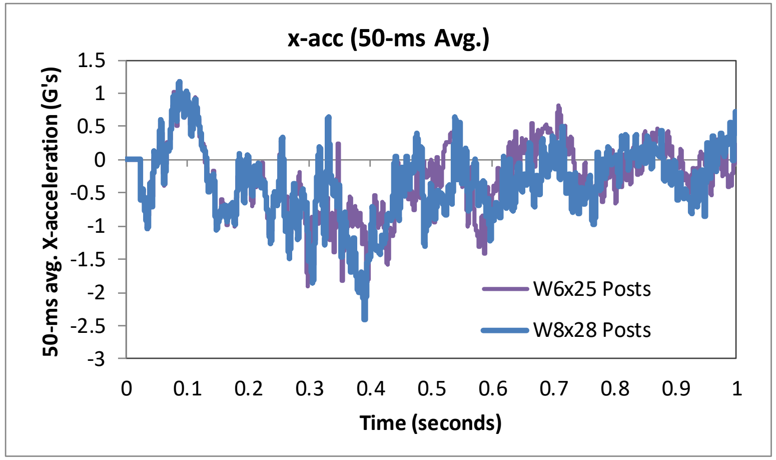
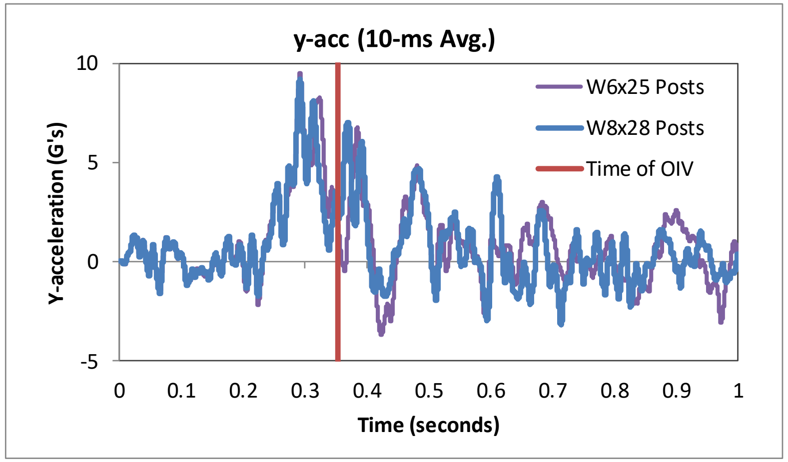
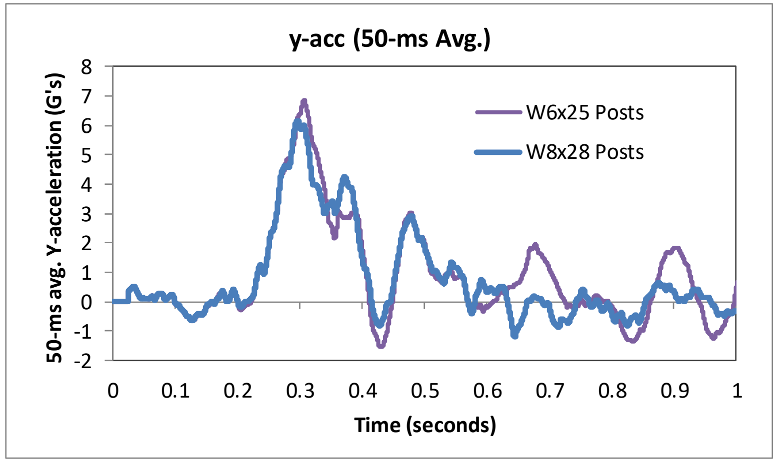
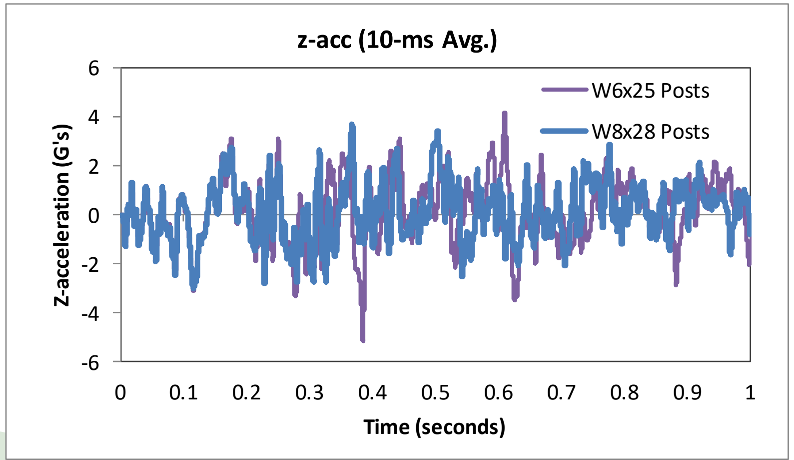
Acceleration Plots (cabin)

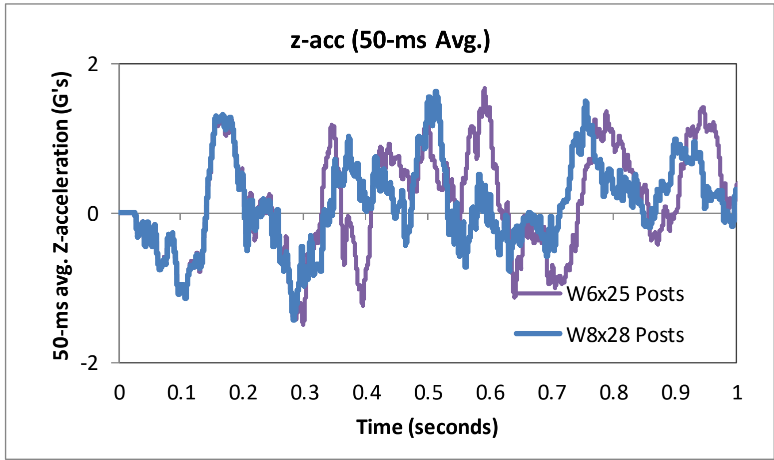




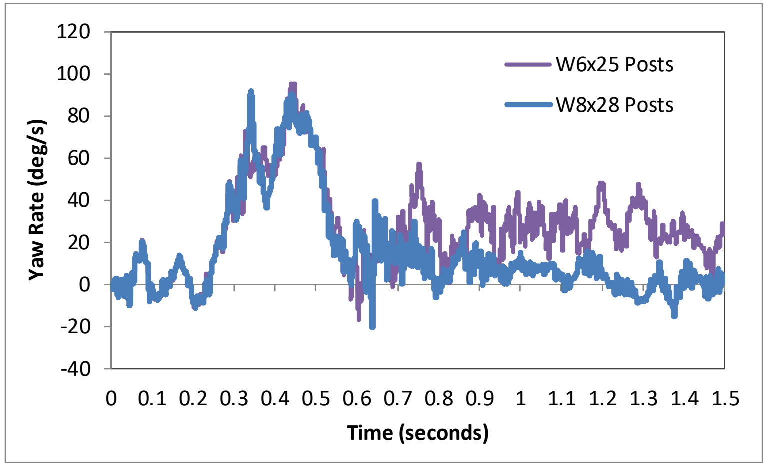


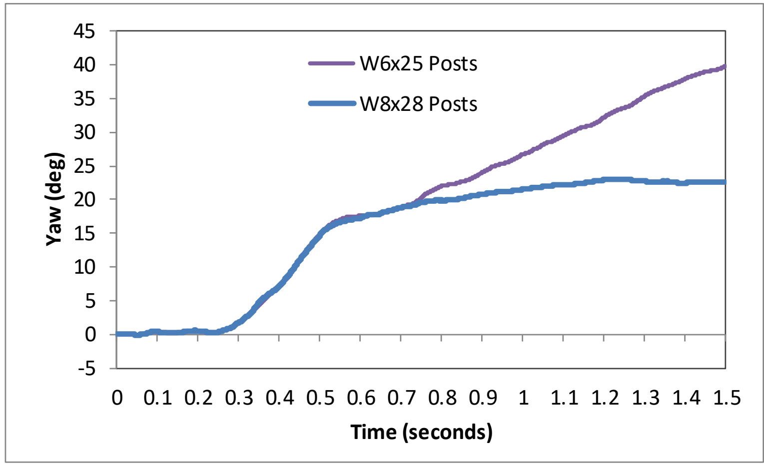


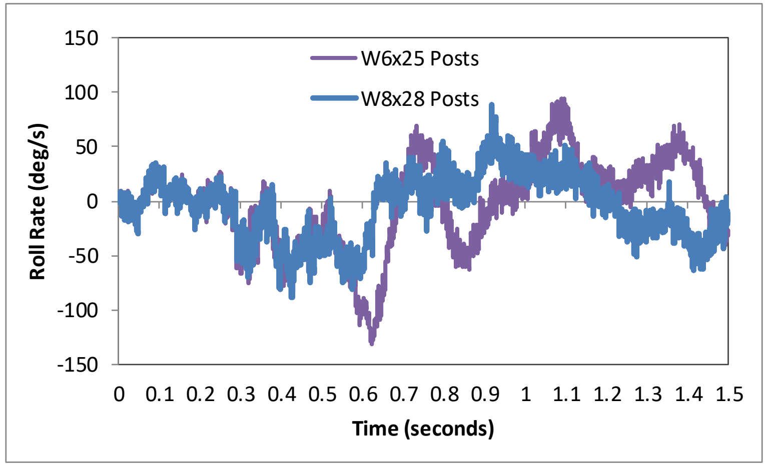


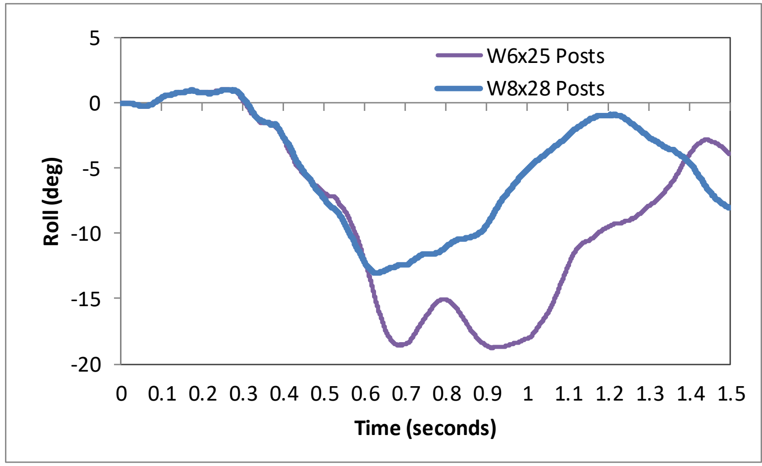


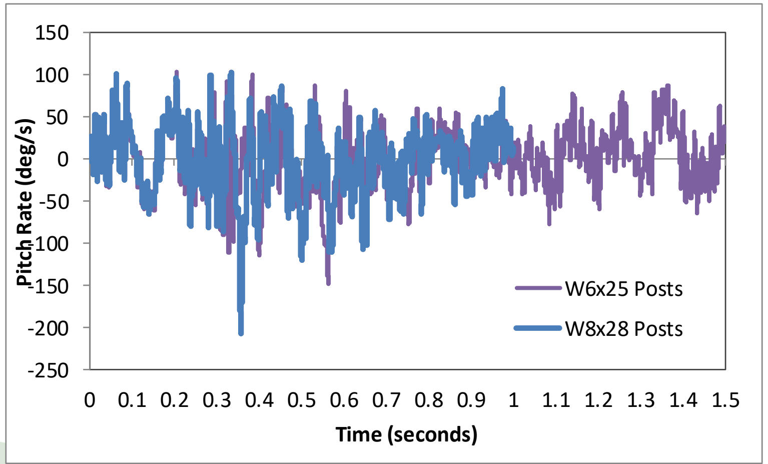
Angular Rate and Displacement Plots (cabin)

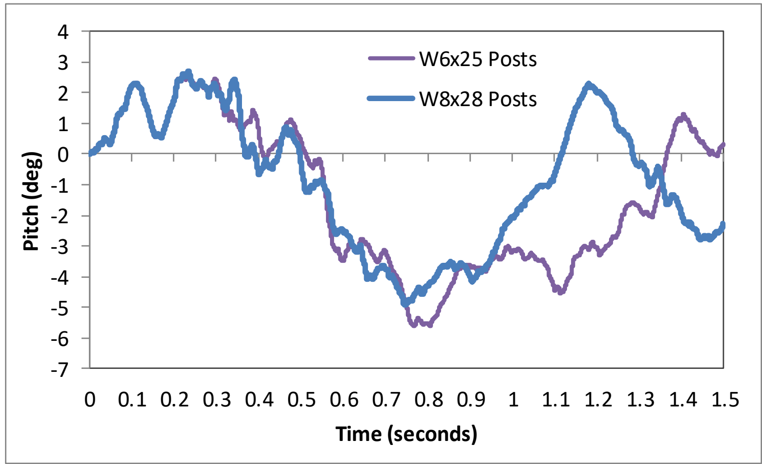




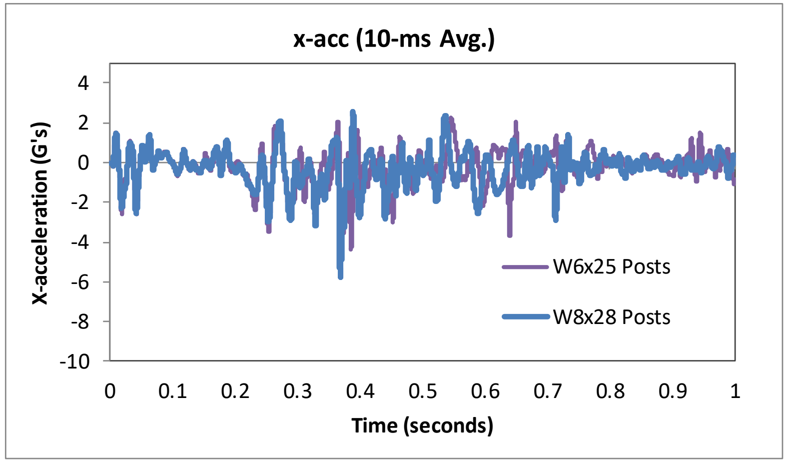


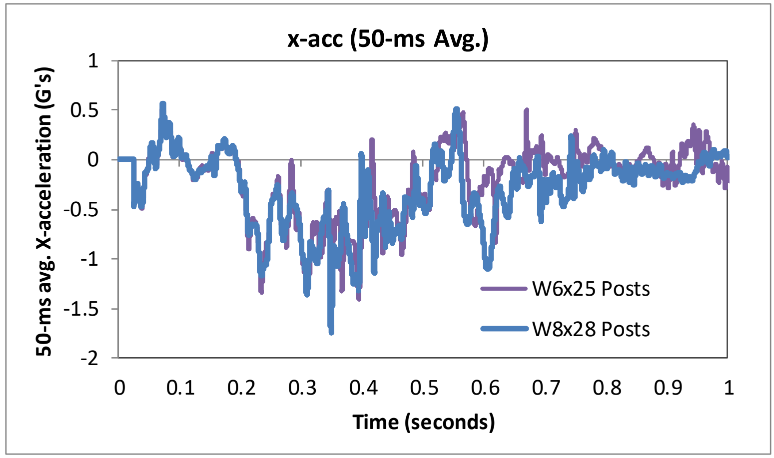


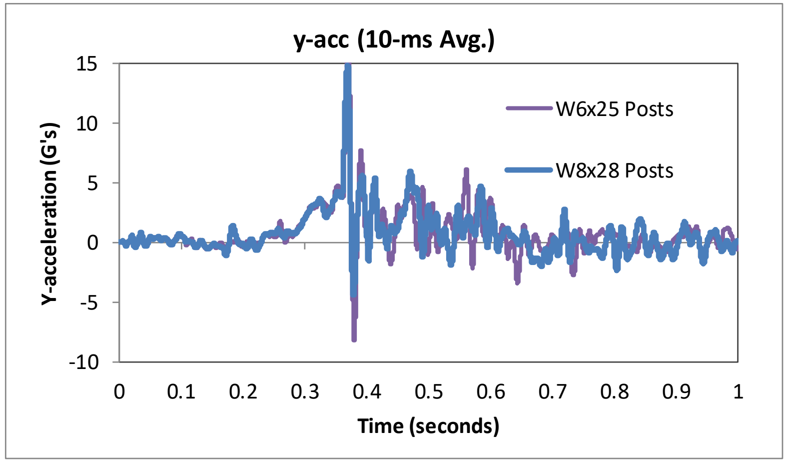


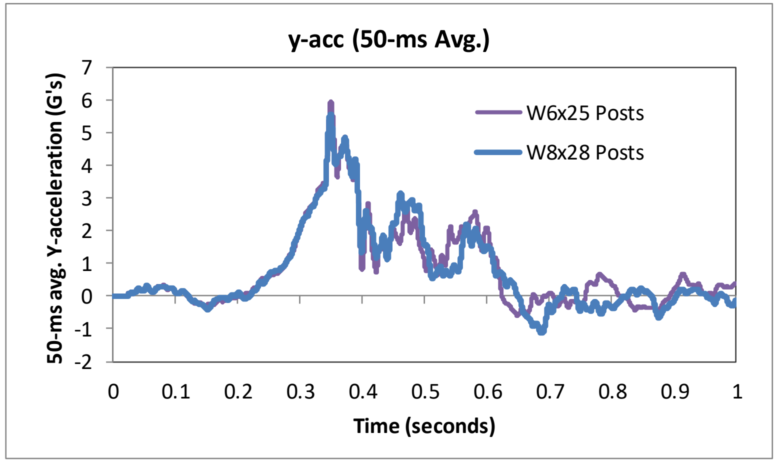


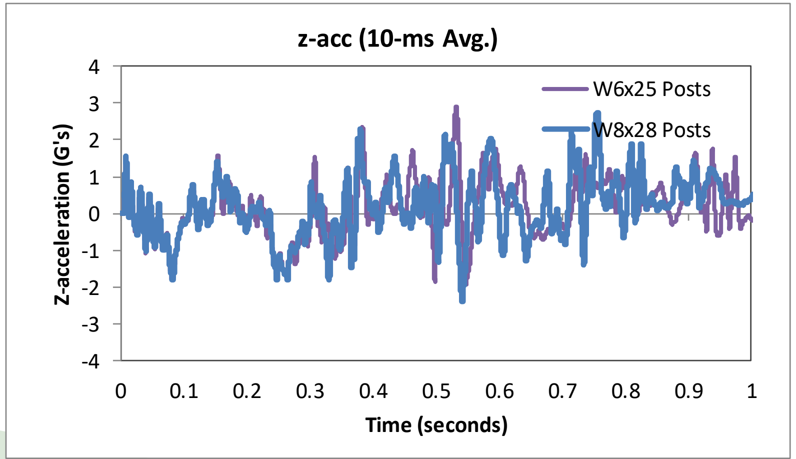
Acceleration Plots (c.g.)

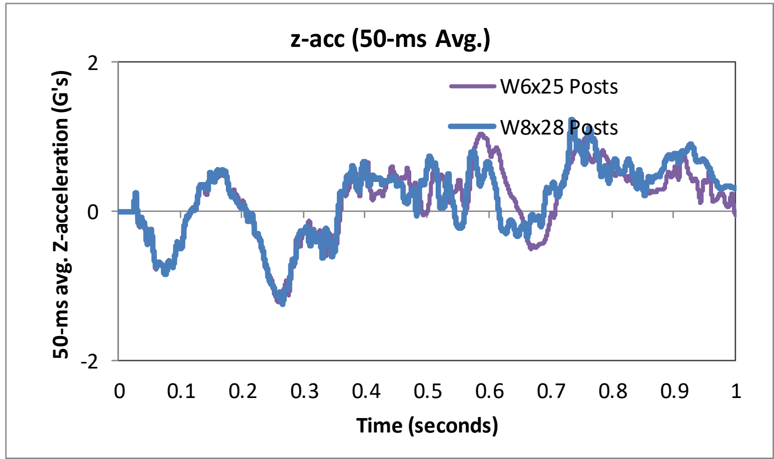












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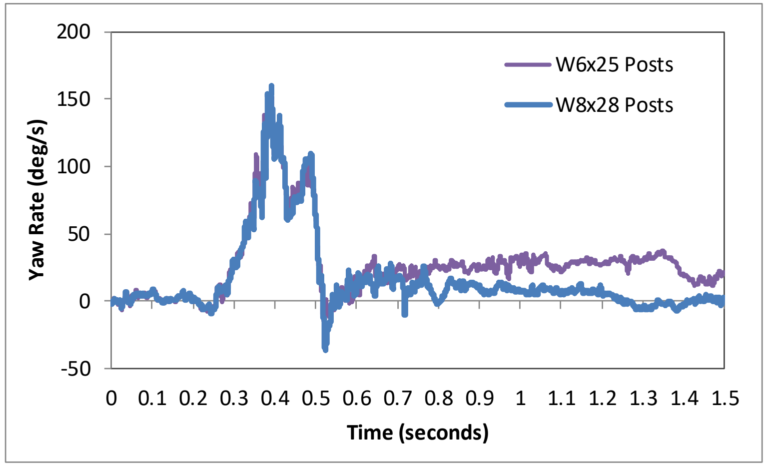

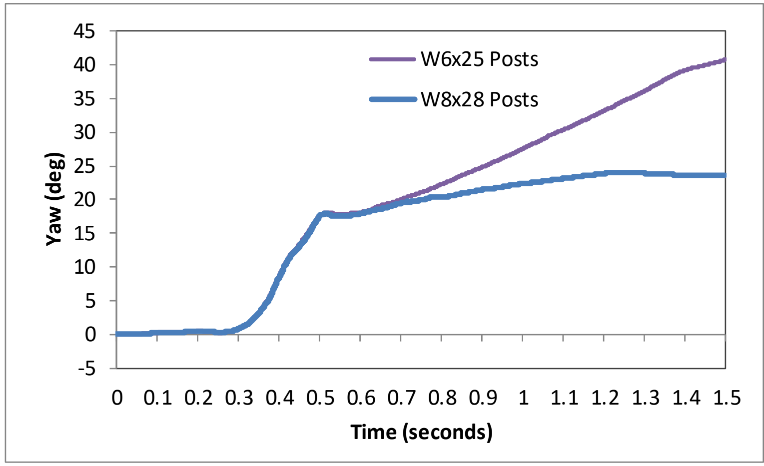

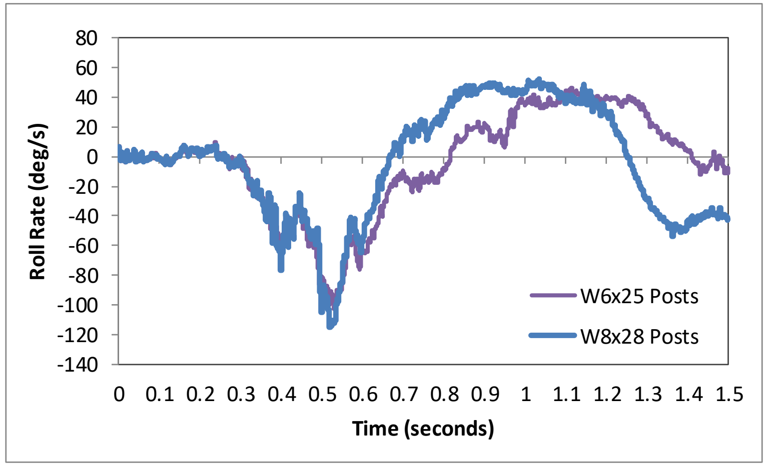

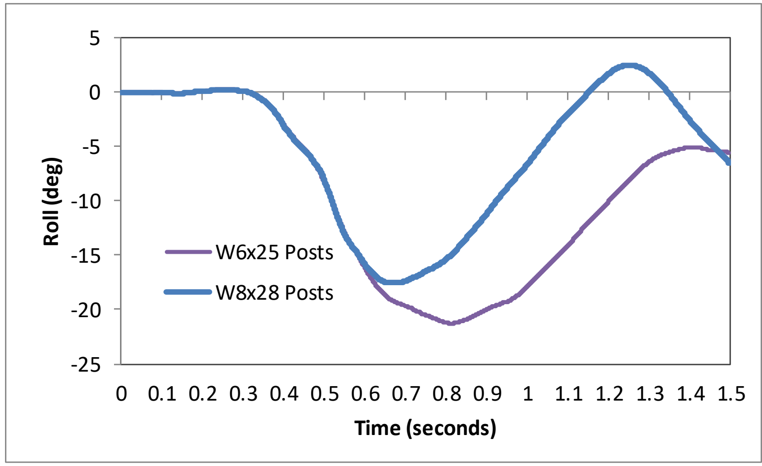

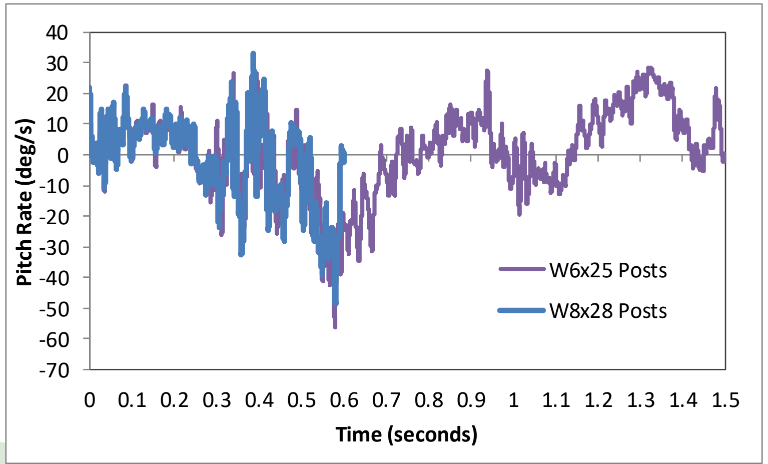

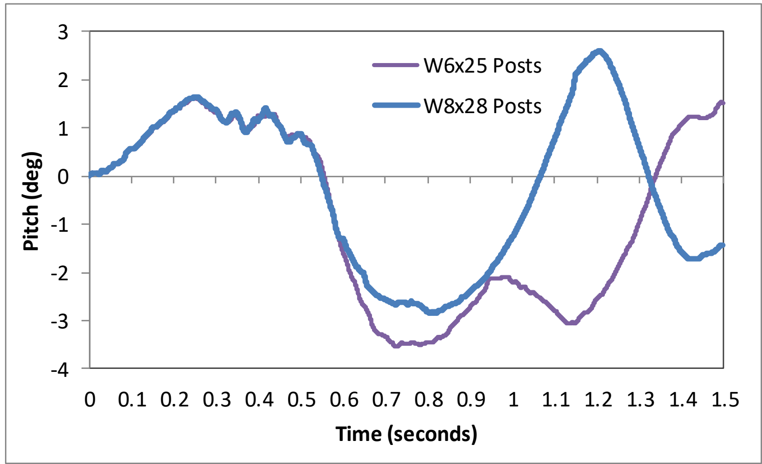

Occupant Risk – Summary

Cabin Accelerometers

Occupant Risk Factors		MASH W6x25 Posts	MASH W8x28 Posts
Occupant Impact Velocity (ft/s)	x-direction	3.9	3.6
	y-direction	-16.7	-15.1
	at time	at 0.3519 seconds on left side of interior	at 0.3535 seconds on left side of interior
THIV (ft/s)		17.4 at 0.3519 seconds on left side of interior	15.7 at 0.3535 seconds on left side of interior
Ridedown Acceleration (g's)	x-direction	-4.3 (0.3734 - 0.3834 seconds)	-6.9 (0.3684 - 0.3784 seconds)
	y-direction	6.7 (0.3793 - 0.3893 seconds)	7 (0.3646 - 0.3746 seconds)
PHD (g's)		6.7 (0.3791 - 0.3891 seconds)	9.1 (0.3677 - 0.3777 seconds)
ASI		0.77 (0.2828 - 0.3328 seconds)	0.69 (0.2743 - 0.3243 seconds)
Max 50-ms moving avg. acc. (g's)	x-direction	-1.9 (0.2735 - 0.3235 seconds)	-2.4 (0.3665 - 0.4165 seconds)
	y-direction	6.9 (0.2823 - 0.3323 seconds)	6.2 (0.2728 - 0.3228 seconds)
	z-direction	1.7 (0.5674 - 0.6174 seconds)	1.6 (0.4885 - 0.5385 seconds)
Maximum Angular Disp. (deg)	Roll	-18.8 (0.9140 seconds)	-13.1 (0.6320 seconds)
	Pitch	-5.6 (0.8050 seconds)	-4.9 (0.7466 seconds)
	Yaw	39.7 (1.4987 seconds)	23 (1.2150 seconds

C.G. Accelerometers

Occupant Risk Factors		MASH T4-12 W6x25 Posts	MASH T4-12 W8x28 Posts
Occupant Impact Velocity (ft/s)	x-direction	5.2	5.6
	y-direction	-14.1	-13.8
	at time	at 0.4012 seconds on left side of interior	at 0.4013 seconds on left side of interior
THIV (ft/s)		15.4 at 0.4012 seconds on left side of interior	15.4 at 0.4013 seconds on left side of interior
Ridedown Acceleration (g's)	x-direction	-3.7 (0.6347 - 0.6447 seconds)	-2.9 (0.7083 - 0.7183 seconds)
	y-direction	6.1 (0.5564 - 0.5664 seconds)	6 (0.4655 - 0.4755 seconds)
PHD (g's)		6.1 (0.5564 - 0.5664 seconds)	6 (0.4657 - 0.4757 seconds)
ASI		0.67 (0.3250 - 0.3750 seconds)	0.64 (0.3241 - 0.3741 seconds)
Max 50-ms moving avg. acc. (g's)	x-direction	-1.4 (0.3690 - 0.4190 seconds)	-1.7 (0.3237 - 0.3737 seconds)
	y-direction	6 (0.3249 - 0.3749 seconds)	5.6 (0.3242 - 0.3742 seconds)
	z-direction	-1.3 (0.2409 - 0.2909 seconds)	-1.9 (1.1810 - 1.2310 seconds)
Maximum Angular Disp. (deg)	Roll	-21.3 (0.8152 seconds)	-17.6 (0.6658 seconds)
	Pitch	-3.5 (0.7254 seconds)	-2.8 (0.8217 seconds)
	Yaw	40.8 (1.4987 seconds)	24.1 (1.2493 seconds)

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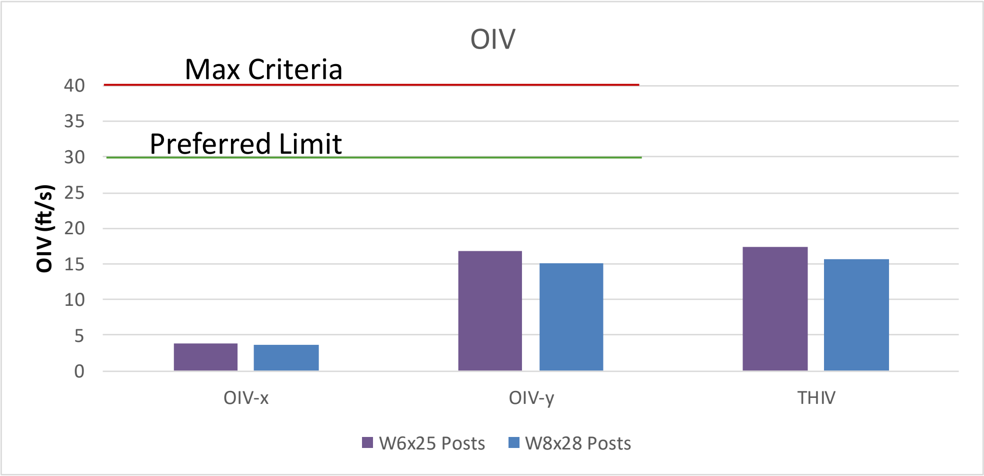
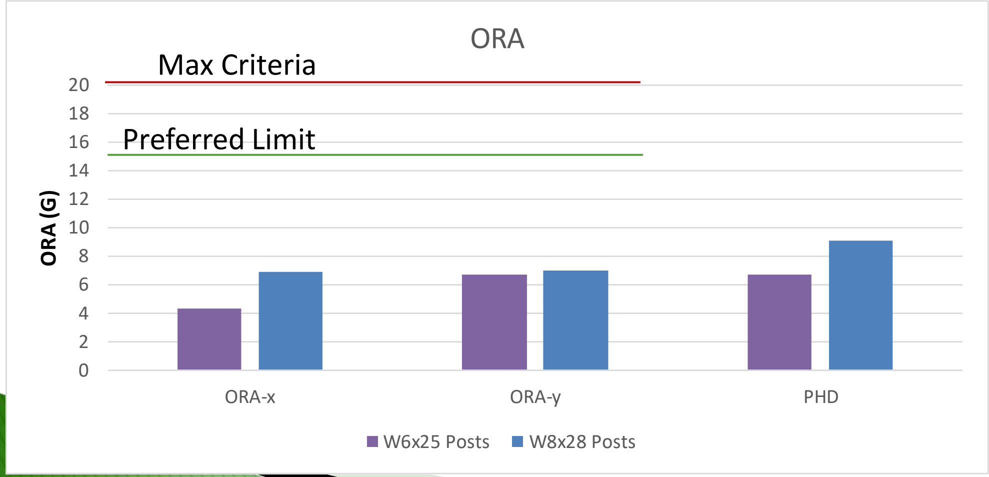
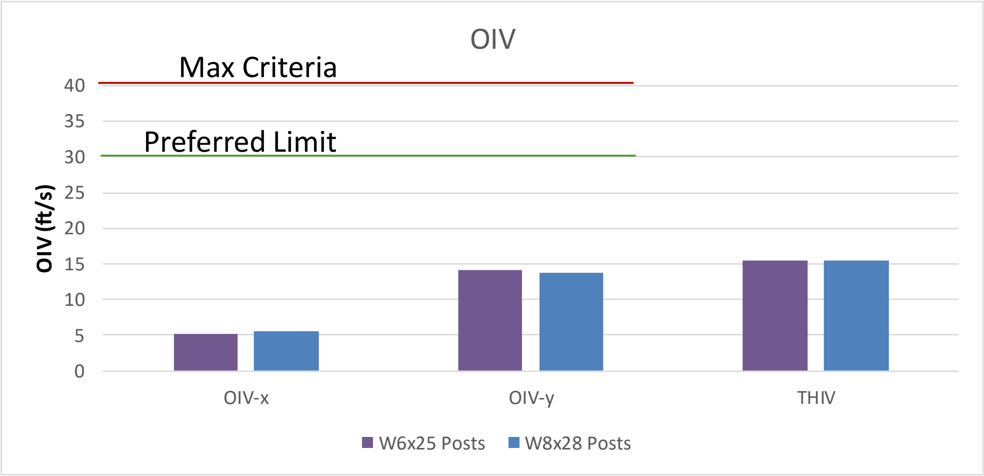
Occupant Risk – Summary

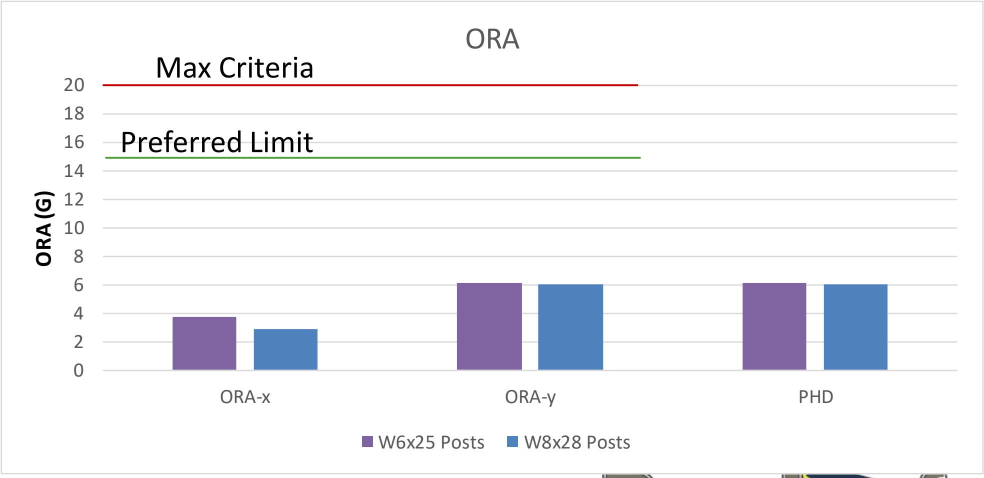
Cabin Accelerometers





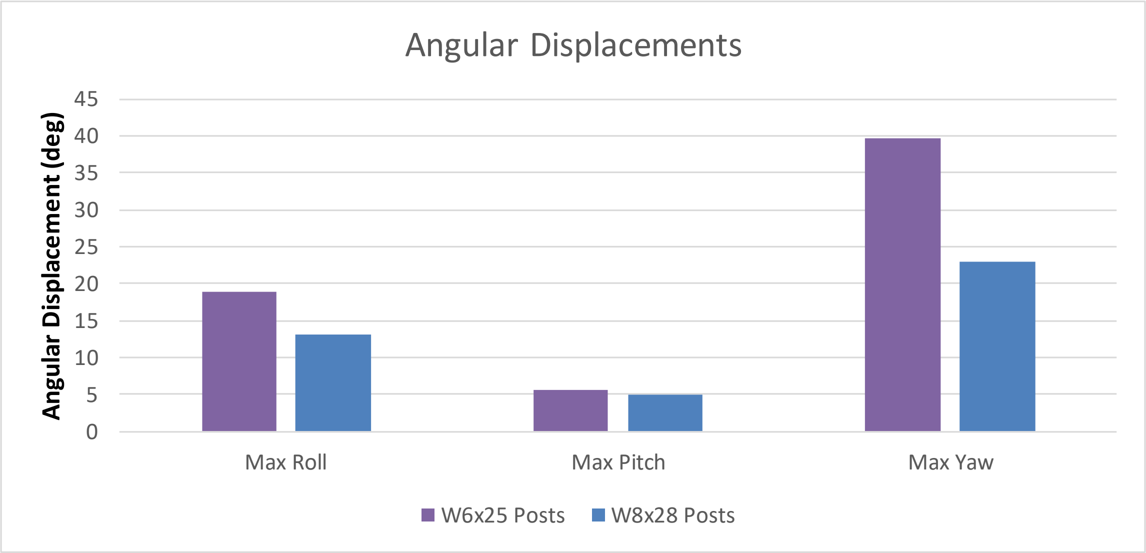
C.G. Accelerometers



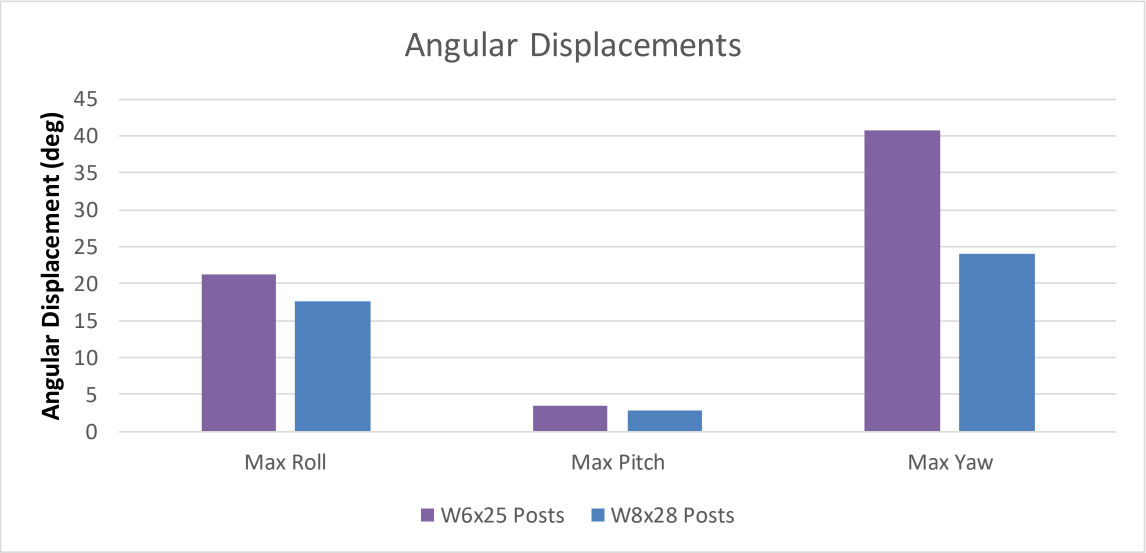


Peak Angular Displacements

Cabin Accelerometers



C.G. Accelerometers



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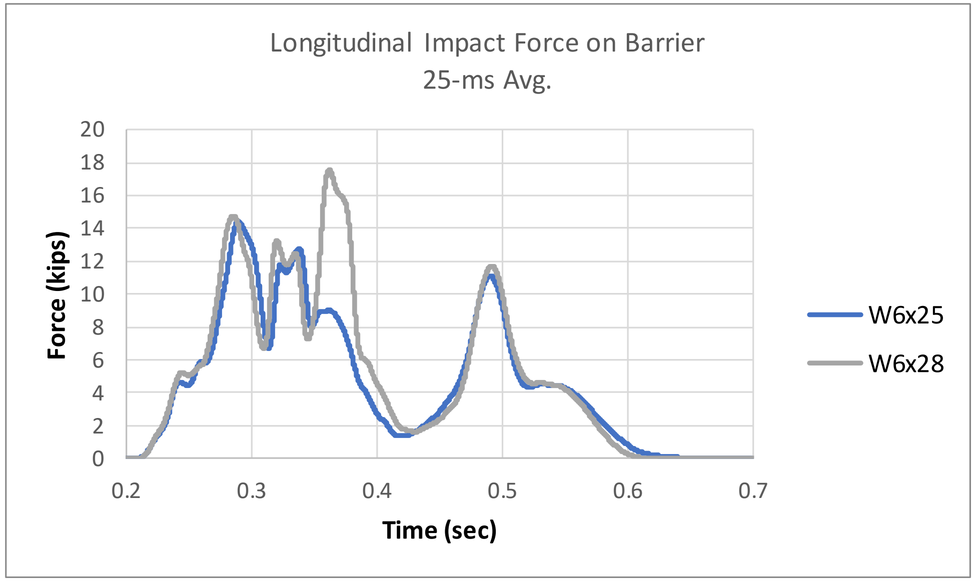
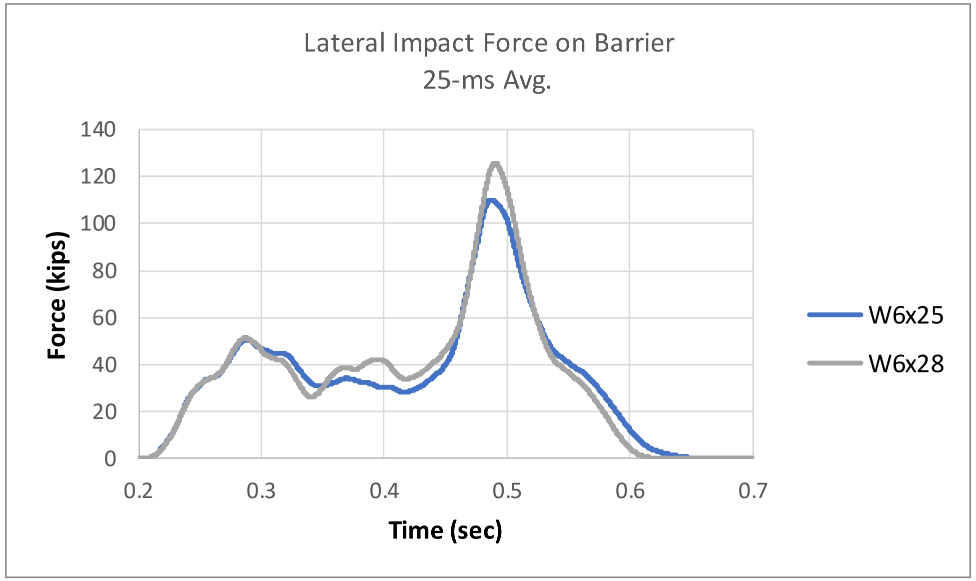
Impact Forces on Bridge Rail

- The impact forces on the barrier were only slightly higher for the modified design with the W8x28 post.





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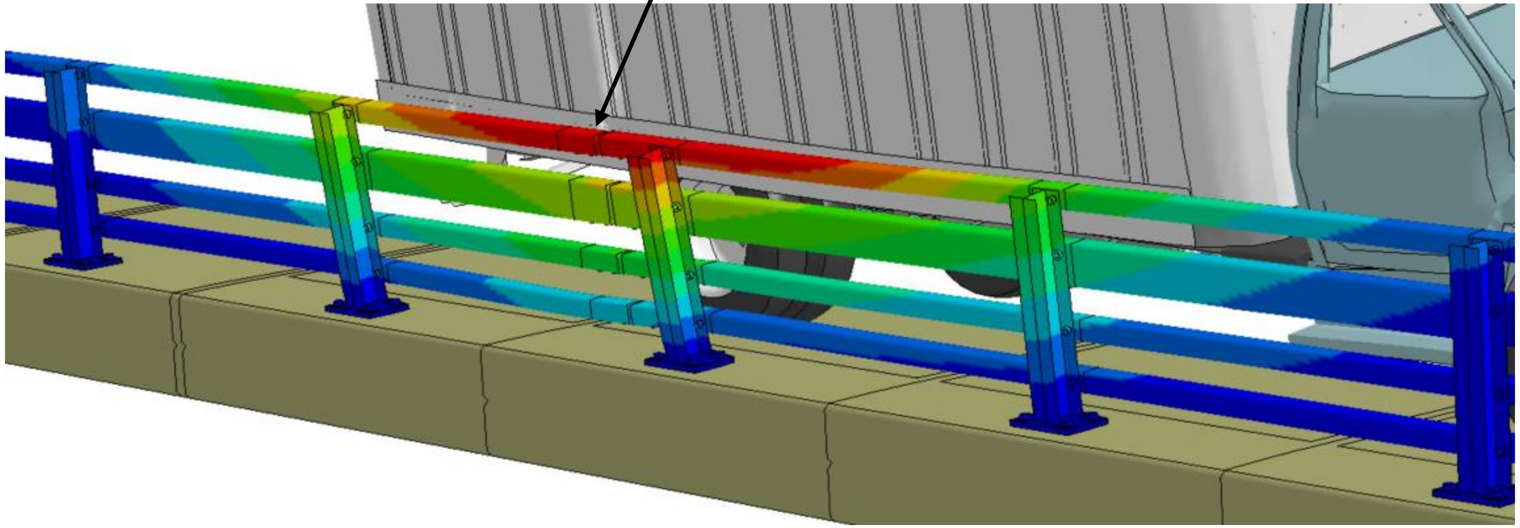
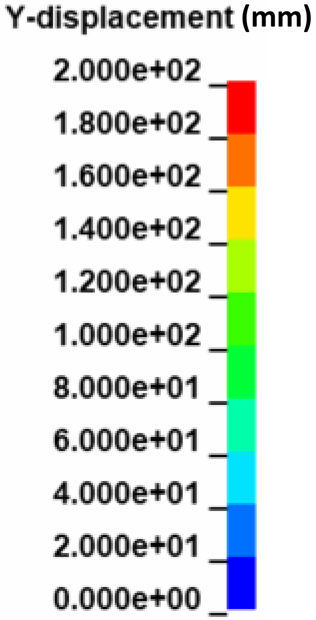
Lateral Dynamic Deflection

Maximum dynamic deflection = 8.15 in (207 mm) @ 0.51 seconds

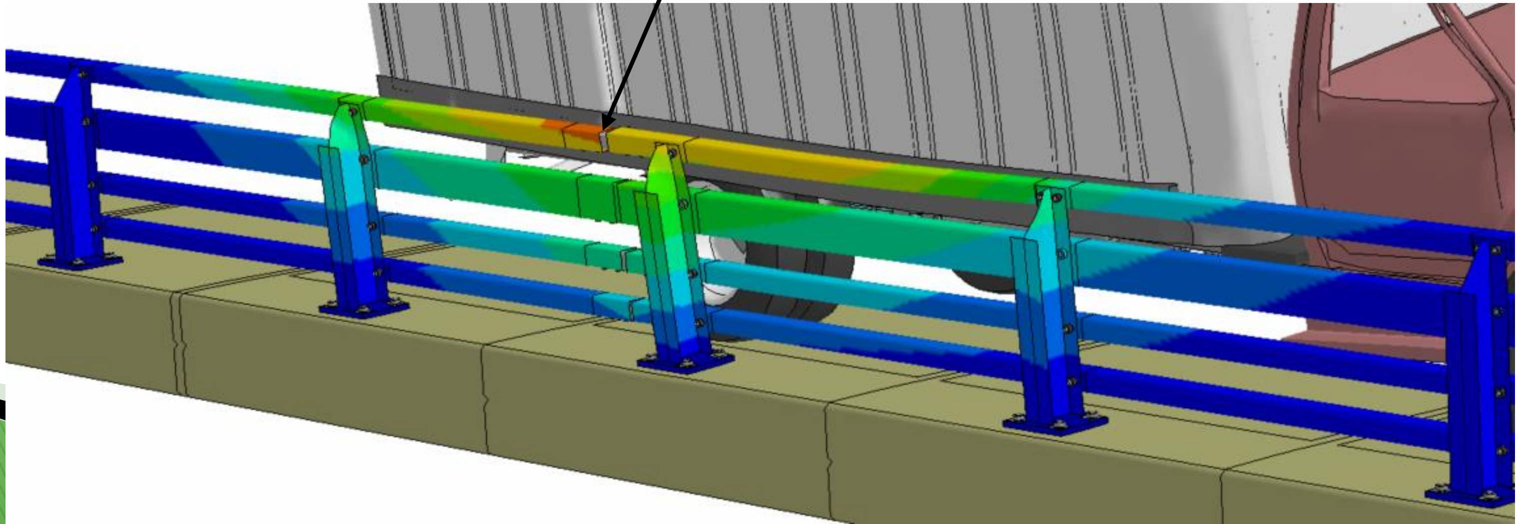
Original Design





Maximum dynamic deflection = 6.5 in (165 mm) @ 0.51 seconds

Modified Design



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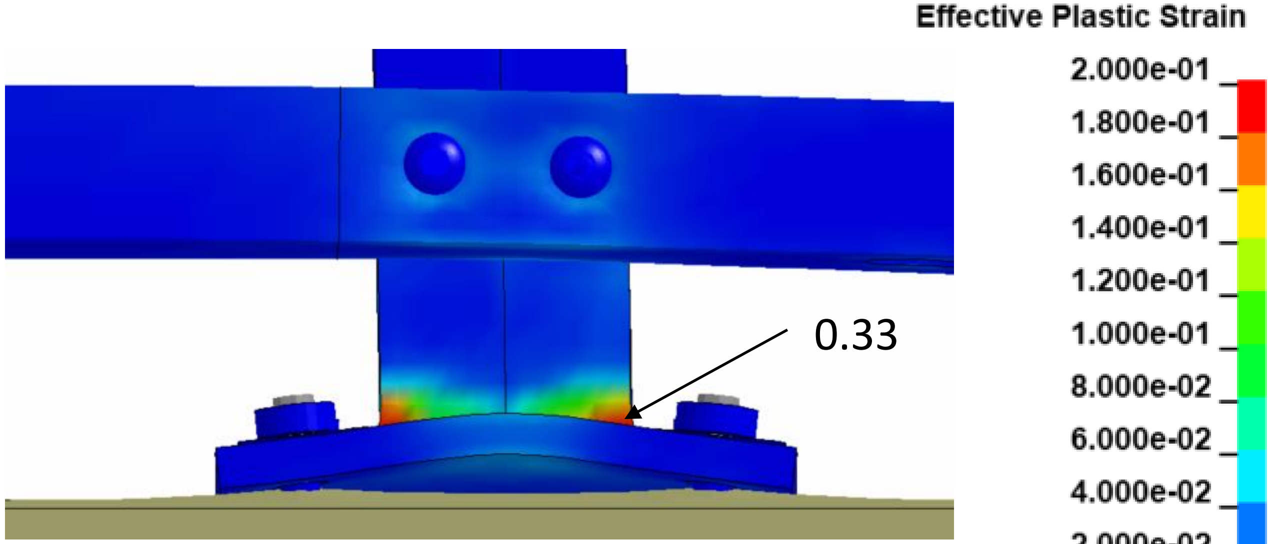
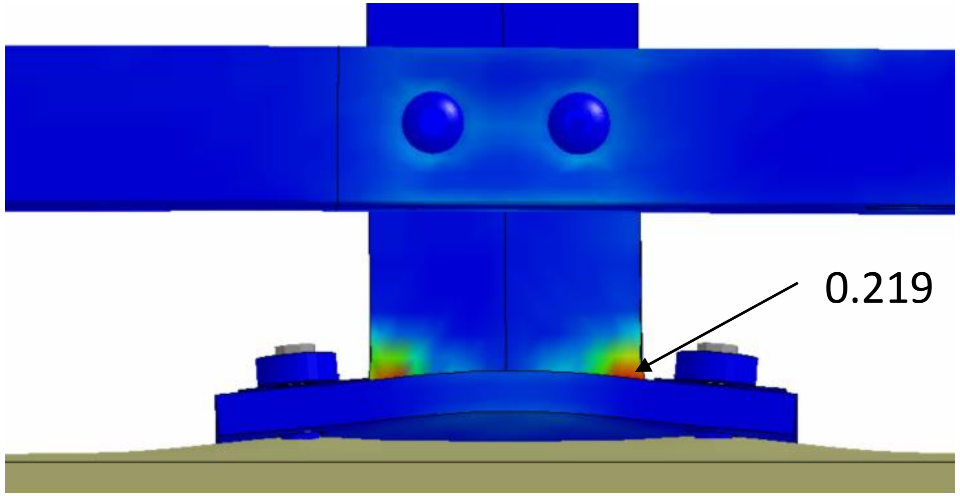
Damage to Posts

- The damage to the post and base plate was reduced significantly for the modified design with W8x28 Posts.
- The effective plastic strain at the base of the post was reduced 34% from 0.33 to 0.22.
- The vertical dynamic deflection of the base plate was reduced 8%.
- The vertical permanent deflection of the base plate was reduced 21%.

Design	Plastic Strain	Vertical Displacement	
		Dynamic (in)	Permanent (in)
Original (W6x25)	0.33	1.11	0.82
Modified (W8x28)	0.22	1.01	0.65



Original Design

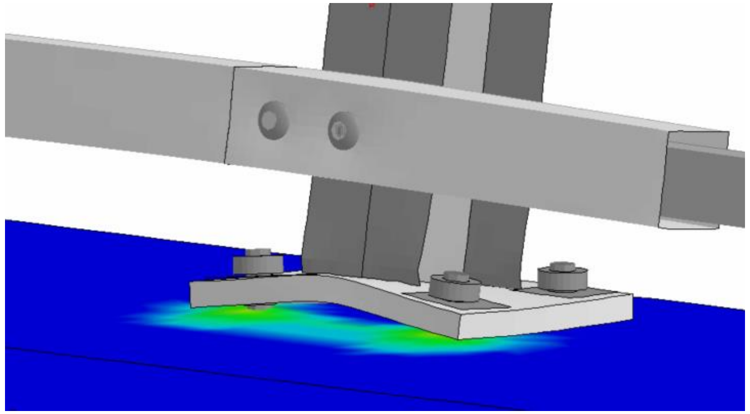


Modified Design

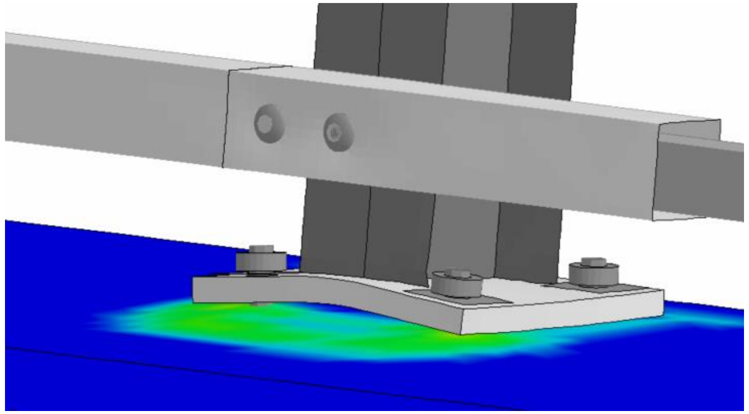
Concrete Damage

- The damage to the concrete increased for the modified design.
- The maximum dynamic strain in the concrete increased 11.5% from 0.079 to 0.099.
- The maximum permanent strain in the concrete increased 5.5% from 0.054 to 0.057.
- These values indicated significant crack opening in concrete at front anchor bolts at Post 7.

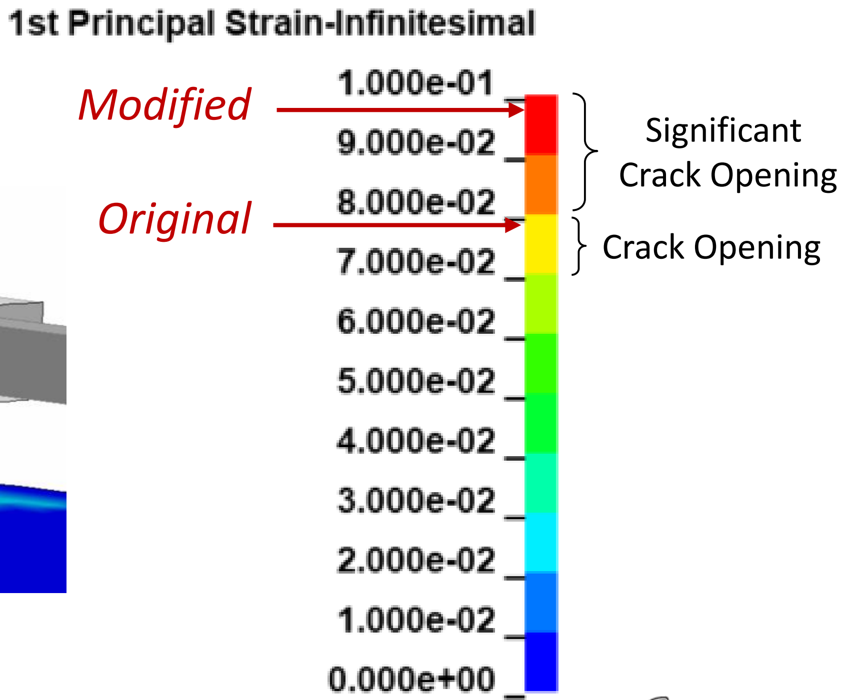
Dynamic strain at 0.51 seconds



Original Design



Modified Design



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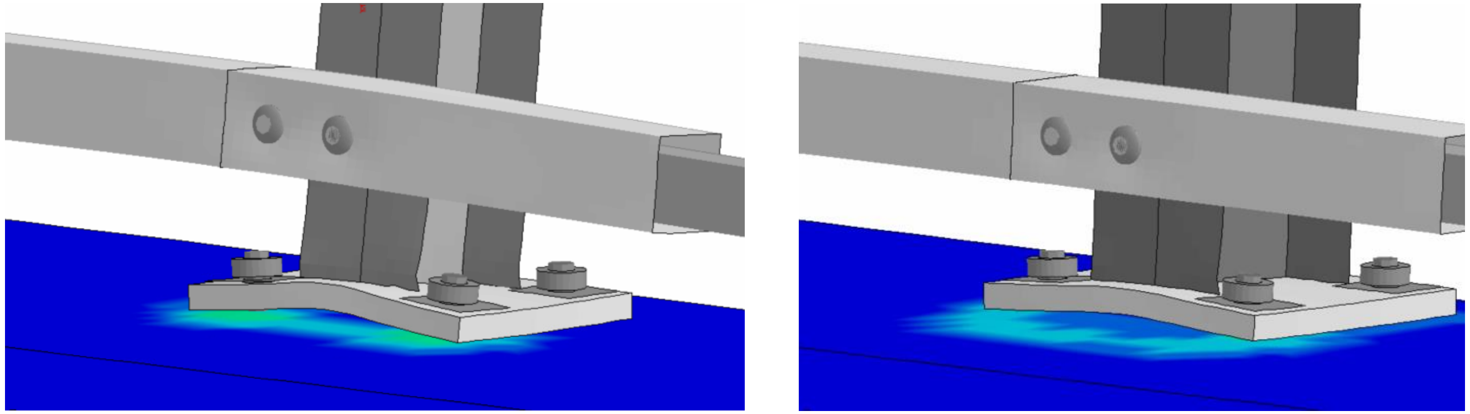
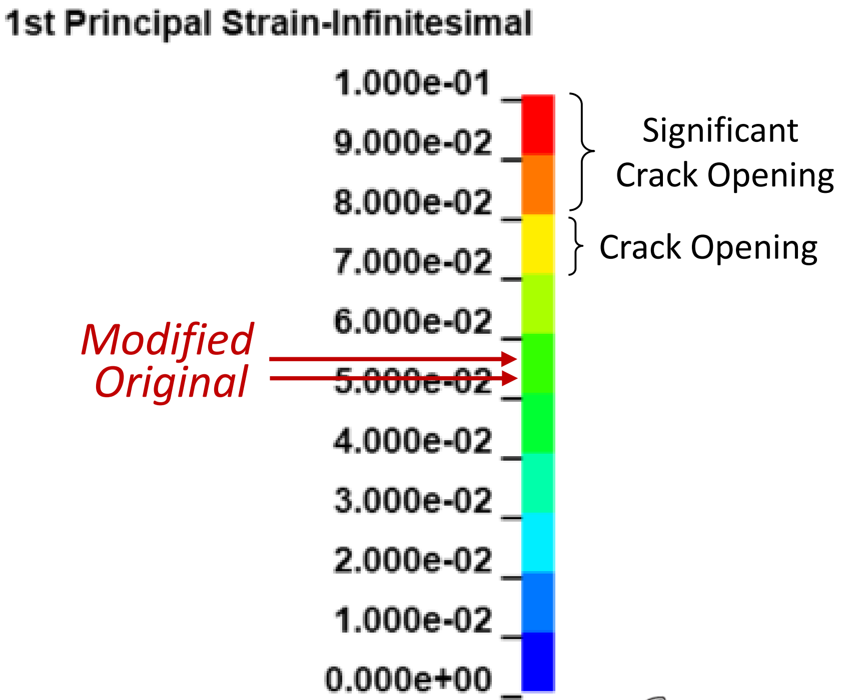
Permanent Strain in Concrete



Original Design

Modified Design



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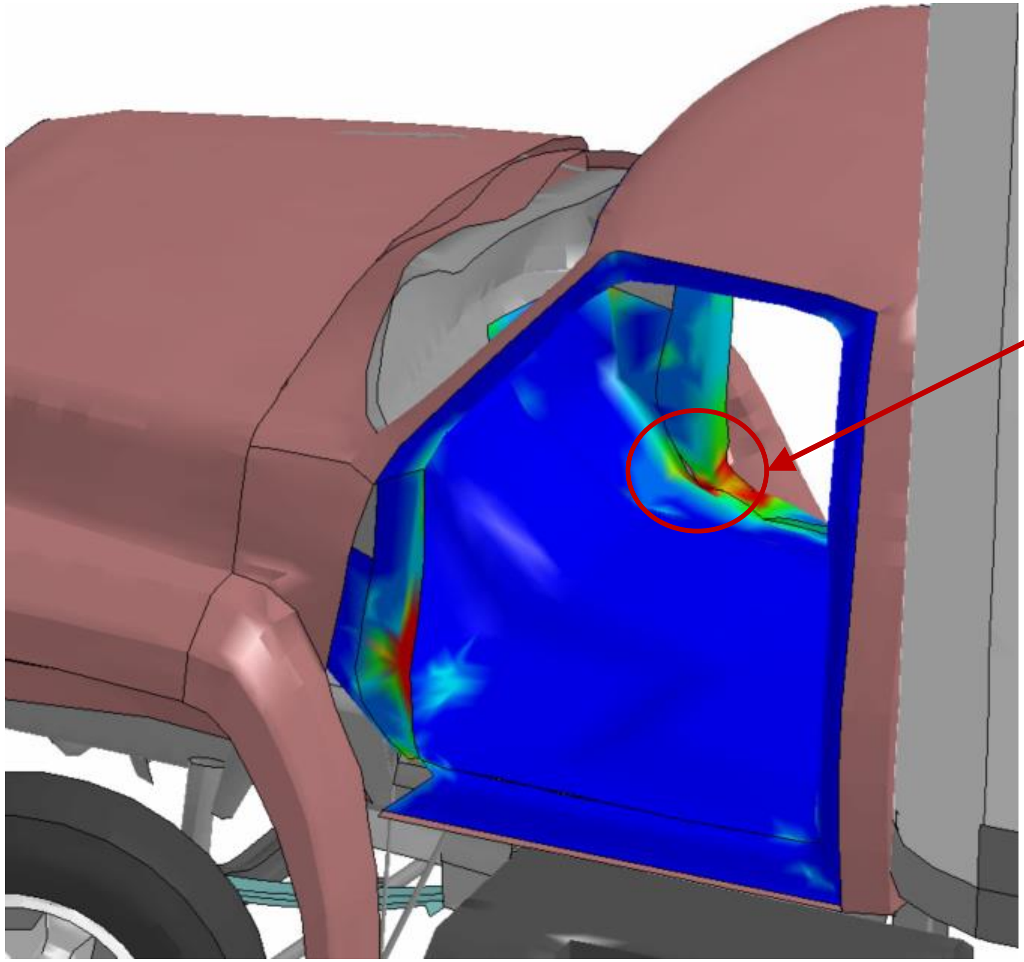
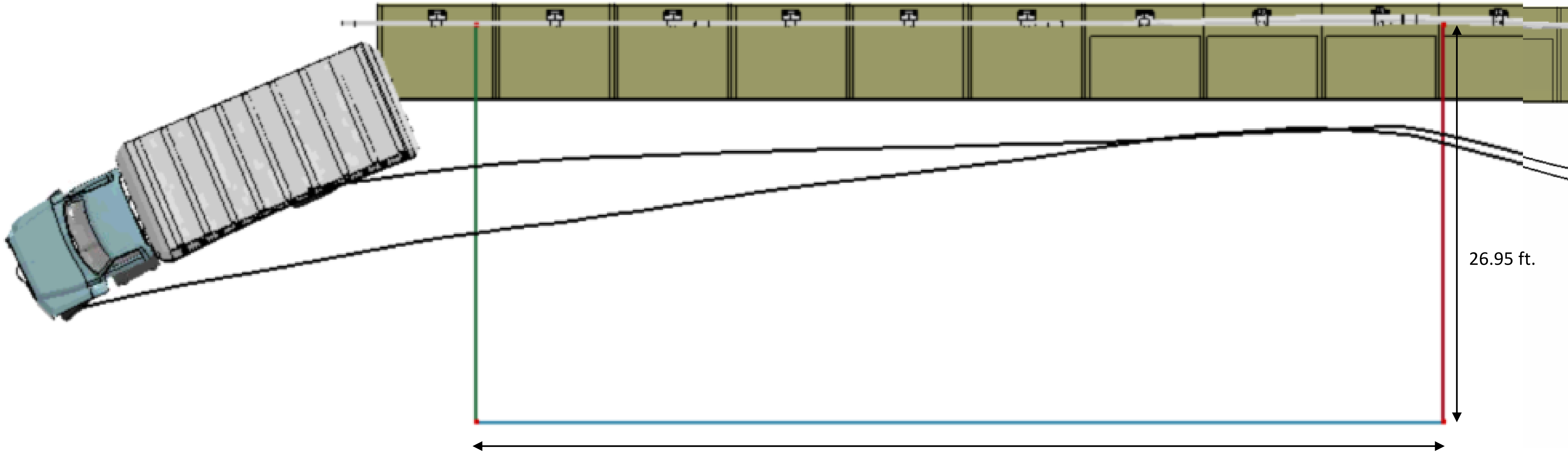
Occupant Compartment Intrusion (OCI)



Maximum OCI was ≈ 4.1 inch (104 mm) and occurred at the lower right-front corner of the top-pan at the wheel well.

Exit Box – Bed Height = 47.5” – Test 4-12

The driver-side front tire wheel track was used to determine the beginning location of the exit box. From MASH pg. 97: “All wheel tracks of the vehicle should not cross the parallel line within the distance B.”



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Conclusions for Test 4-12 on the Modified NETC 4-Bar with W8x28 Posts

- The analysis showed that barrier adequately contained and redirected the 10,000S vehicle.
- Occupant compartment intrusion was minimal.
- Vehicle stability was slightly improved compared to original design:
  - The **maximum roll angle** of the vehicle:
    - Cabin= 13.1 degrees (18.8 deg for original design).
    - Cargo Box = 17.6 degrees (21.3 deg for original design).
  - The **maximum pitch angle** of the vehicle:
    - Cabin = 4.9 degrees (5.6 deg for original design).
    - Cargo Box = 2.8 degrees (3.5 deg for original design).
- The **damage to the barrier** compared to original design included:
  - Increased damage to curb around the front anchor bolts (probable large cracks).
  - Reduced plastic deformation of posts and base plates.
  - Reduced maximum dynamic barrier deflection (6.5” vs. of 8.2”).

Conclusions for Test 4-12 on the Modified NETC 4-Bar with W8x28 Posts

Evaluation Factors		Evaluation Criteria – MASH Test 4-12	Results
Structural Adequacy	A	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.	Pass
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 undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, to occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E.	Pass
	G	It is preferable, although not essential, that the vehicle remain upright during and after collision.	Pass