VERIFICATION & VALIDATION REPORT of New Jersey Concrete Barrier Impact with 1100C Vehicle Using Toyota Yaris Coarse FE Model

CCSA VALIDATION/VERIFICATION REPORT

Project: **CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections**
Comparison Case: **1100C 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	MwRSF	CCSA-GMU
Test/Run Number	2214NJ-1	NA
Vehicle	2002 Kia Rio	CCSA 2010 Yaris_C V1e Model
Vehicle Mass (lb/kg)	2579 / 2290	2593 / 1176
Impact Speed (mph/kph)	60.8 / 97.9	60.8 / 97.9
Impact Angle (degrees)	26.1	26.1

Table B - Evaluation Parameters Summary:

Category	Subset	Values
Evaluation Method	MASH (V1, 2009)	
Hardware Type	Longitudinal	
Test Number	3-10	
Test Vehicle Required	1100C	
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.

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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		7	18.8	YES
	Y acceleration		11.6	18.1	YES
	Z acceleration		37.3	29.9	YES
	Yaw rate		4.4	7.1	YES
	Roll rate		45.6	27.3	NO
	Pitch rate		65.7	31.6	NO
P	***ANOVA Metrics***		**Mean**	**SD**	**Pass?**
	X acceleration/Peak		-2.1	11.75	YES
	Y acceleration/Peak		0.91	12.32	YES
	Z acceleration/Peak		9.92	15.57	NO
	Yaw rate		1.77	8.13	YES
	Roll rate		3.12	17.5	YES
	Pitch rate		3.34	35.2	NO
Multi-Channel Weighting Factors			**Time interval [0 sec; 0.5 sec]**		
Multi-Channel Weighting Method Peaks Area I Area II Inertial		**X Channel**	0.068377		
		Y Channel	0.2165		
		Z Channel	0.215123		
		Yaw Channel	0.407422		
		Roll Channel	0.032735		
		Pitch Channel	0.059843		
Sprauge-Geer Metrics			**M**	**P**	**Pass?**
	All Channels (weighted)		18.2	17.3	YES
ANOVA Metrics			**Mean**	**SD**	**Pass?**
	All Channels (weighted)		3.2	12.8	YES

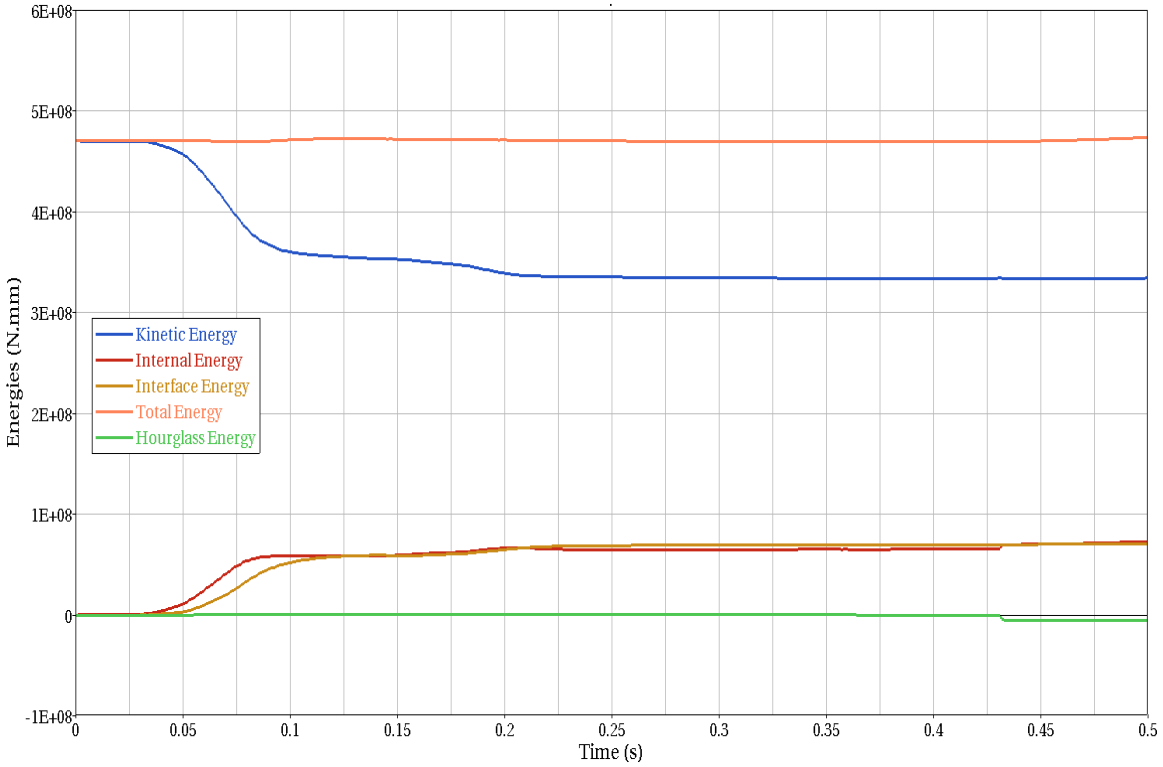


Figure 1: Simulation Energy Summary

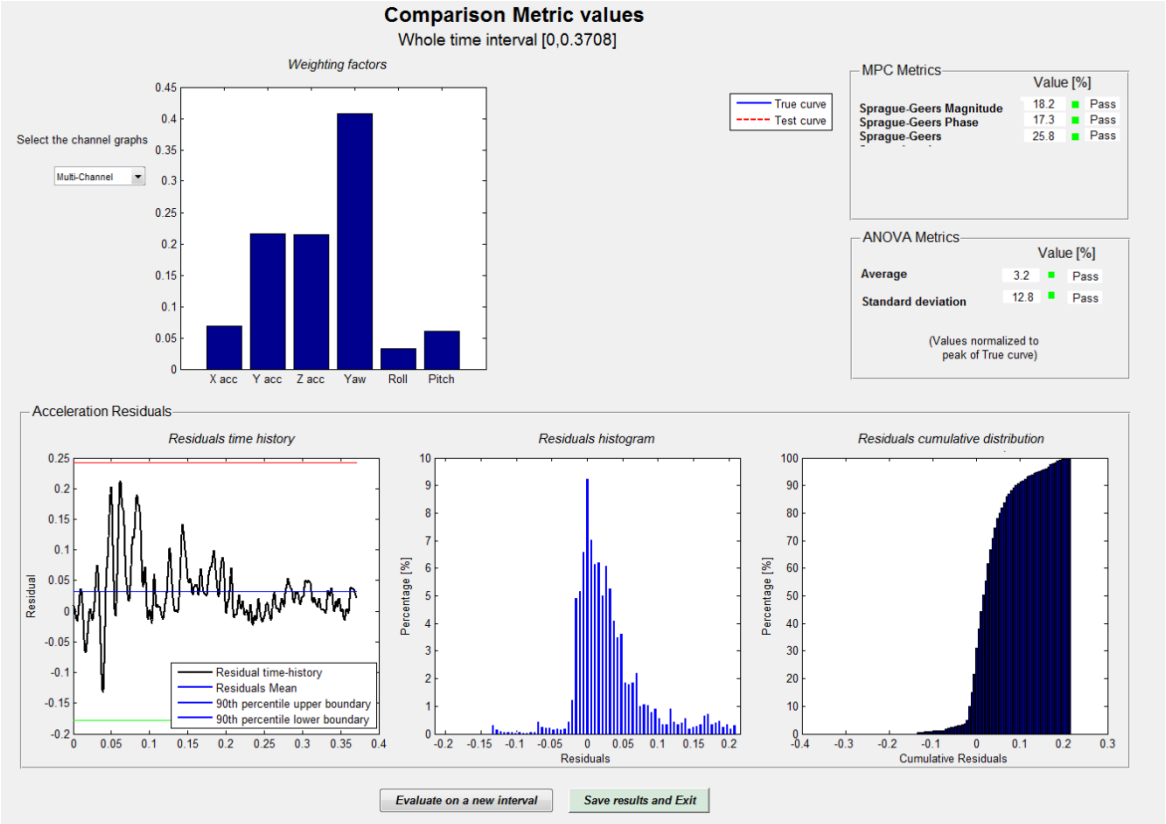


Figure 2a: RSVVP Results – All Channels

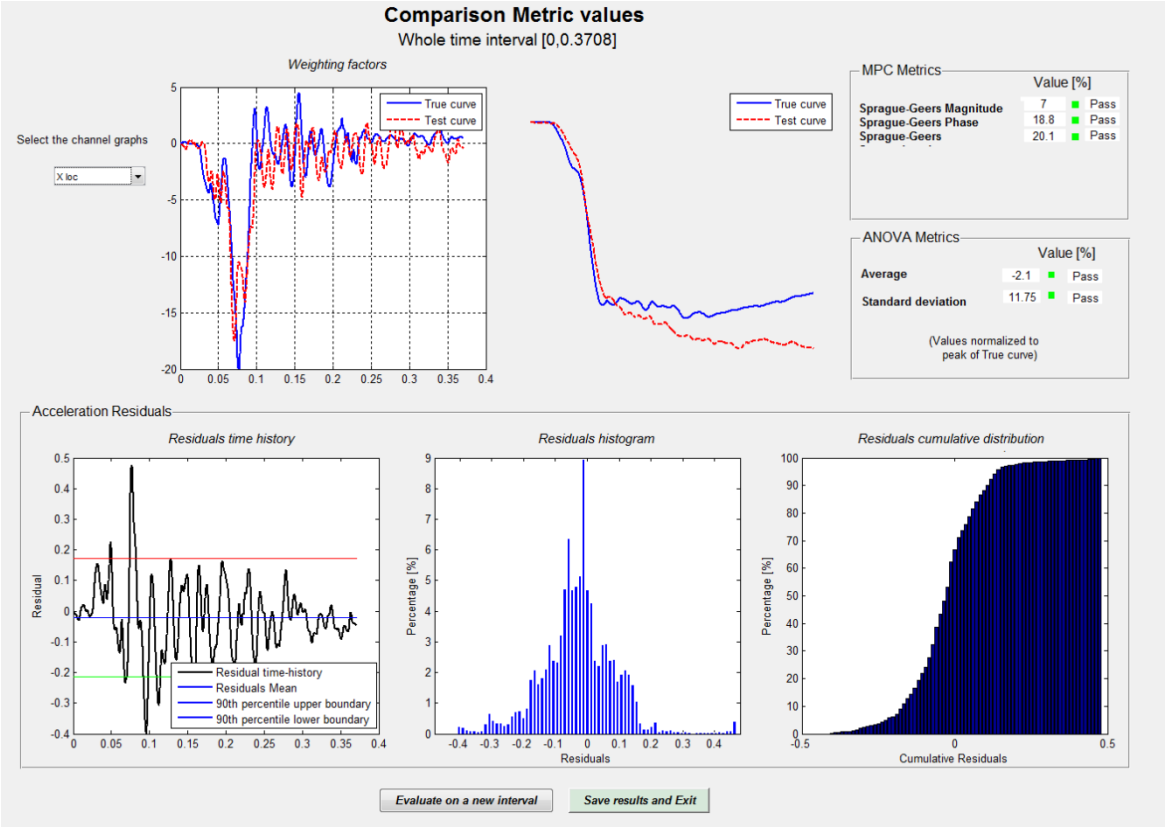


Figure 2b: RSVVP Results – Longitudinal Acceleration

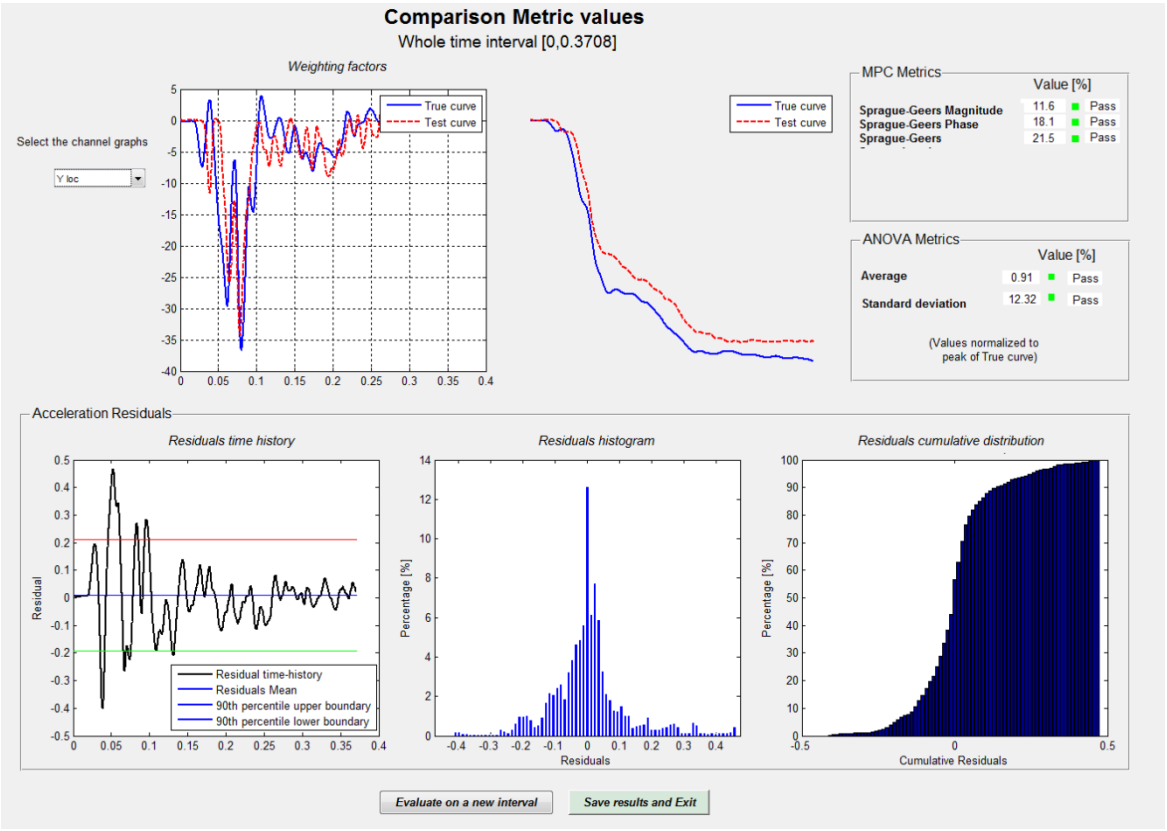


Figure 2c: RSVVP Results – Lateral Acceleration

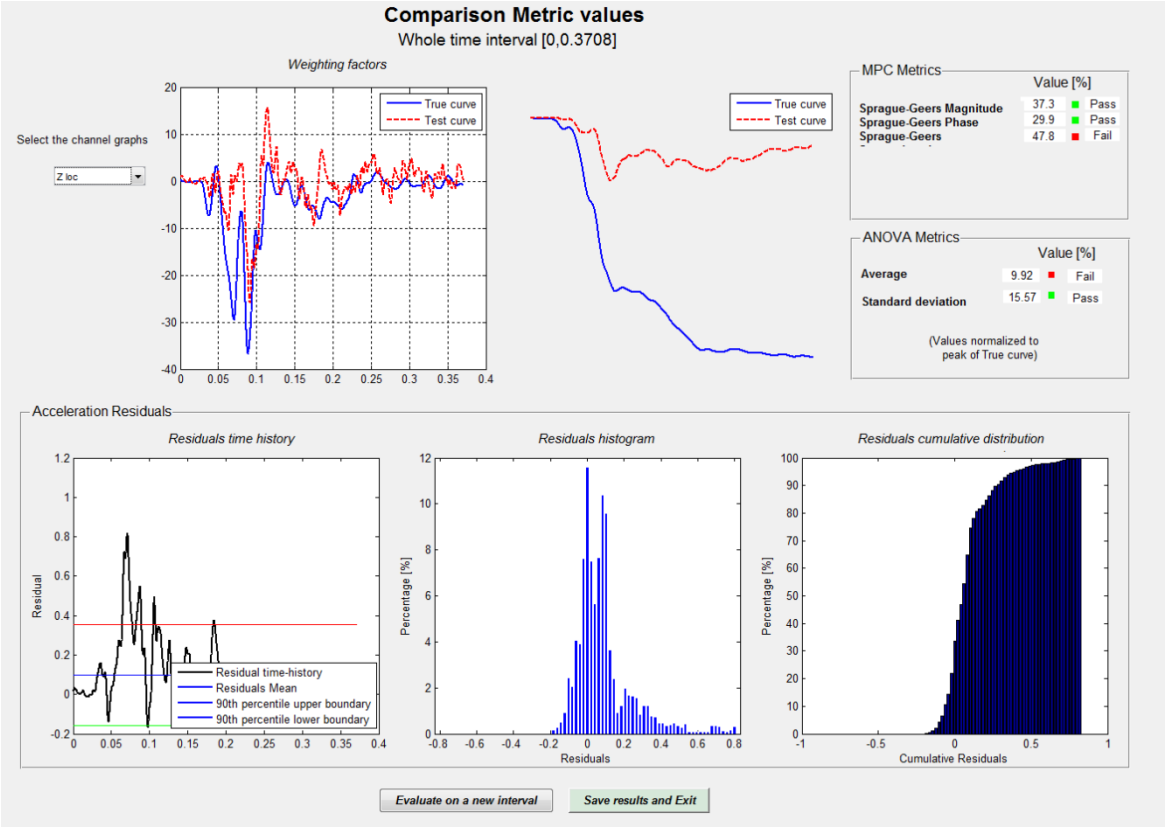


Figure 2d: RSVVP Results – Vertical Acceleration

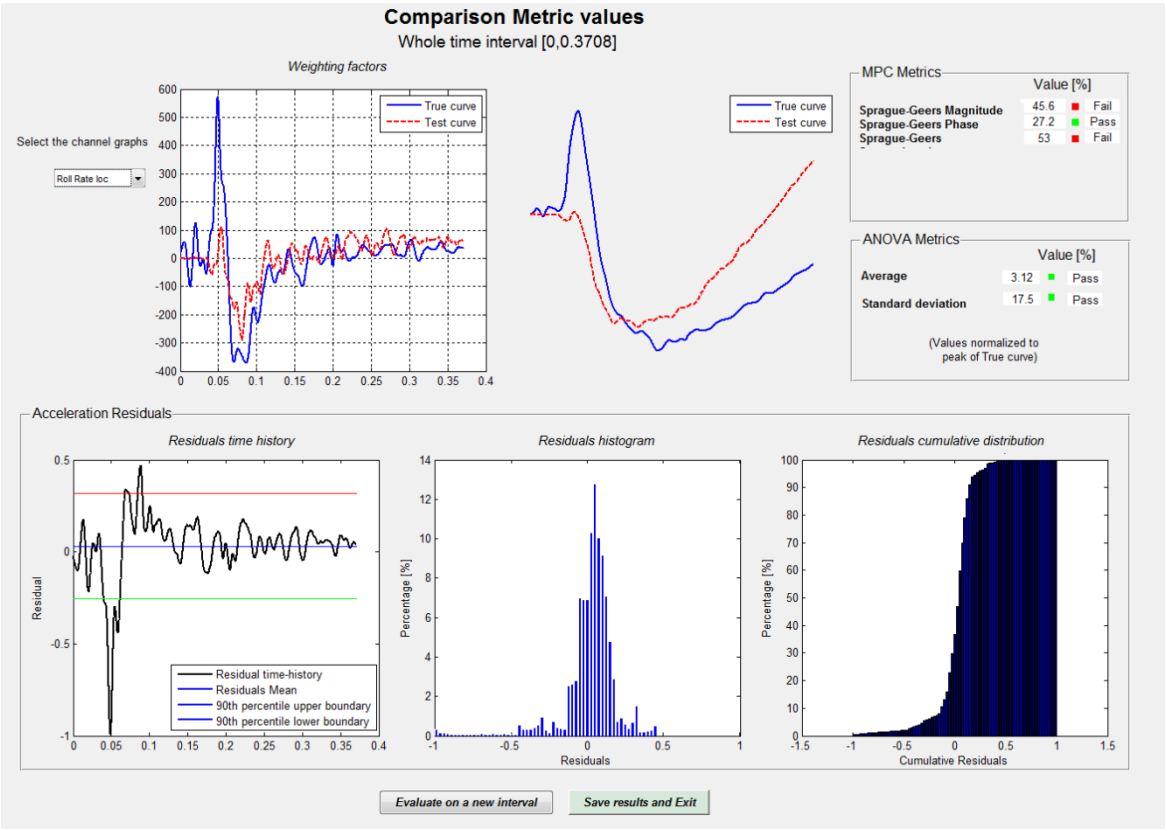


Figure 2e: RSVVP Results – Roll Angle

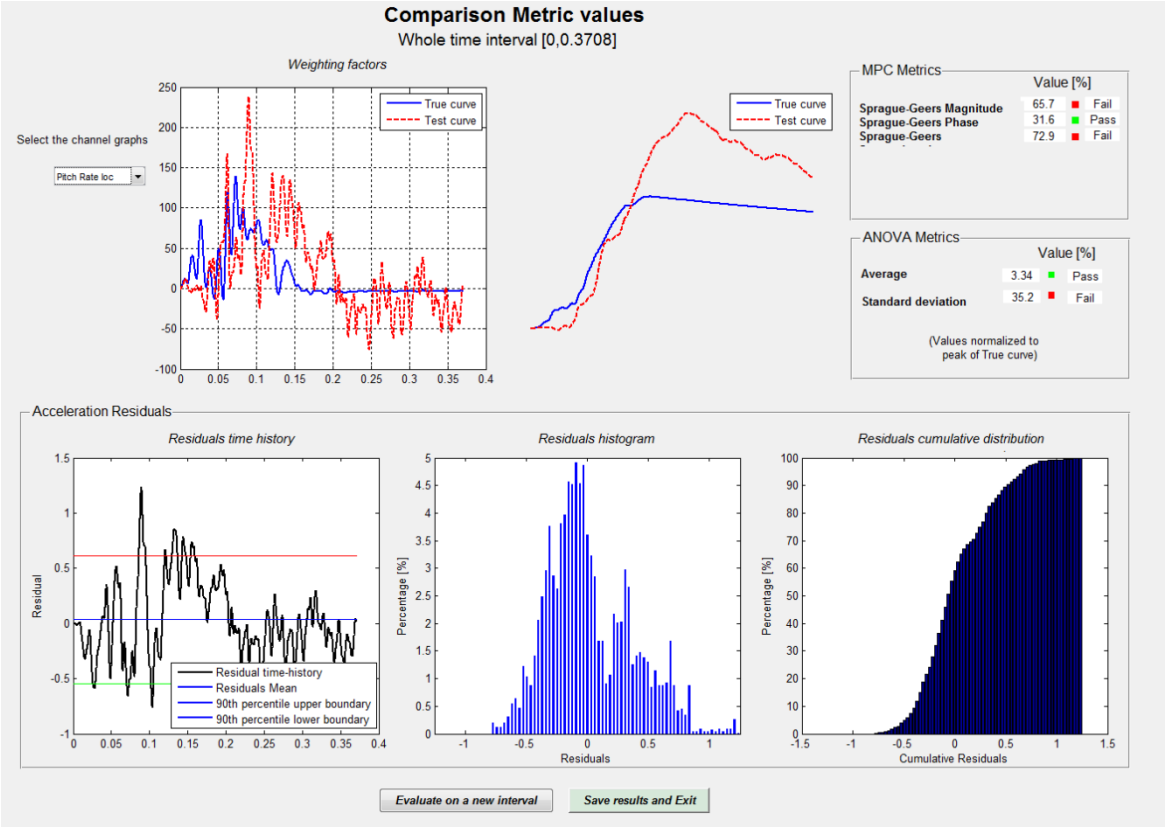


Figure 2f: RSVVP Results – Pitch Angle

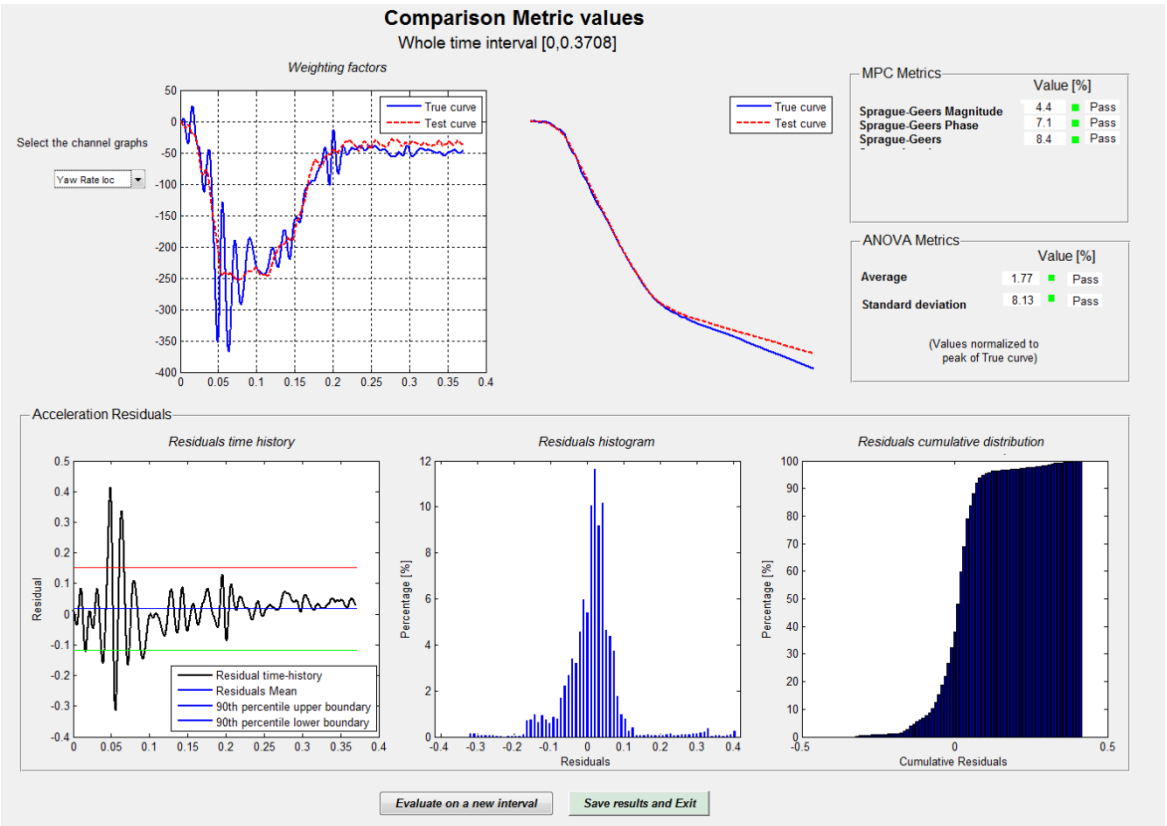


Figure 2g: RSVVP Results – Yaw Angle

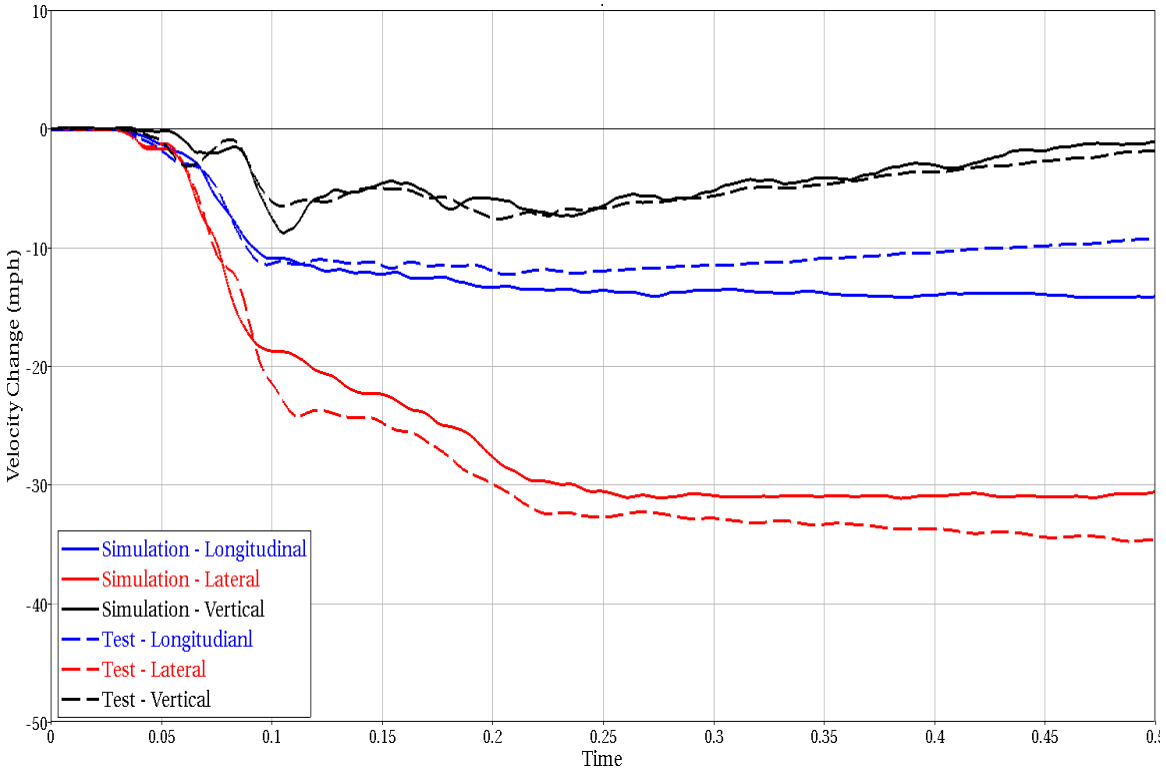


Figure 3: Change in Vehicle Velocities

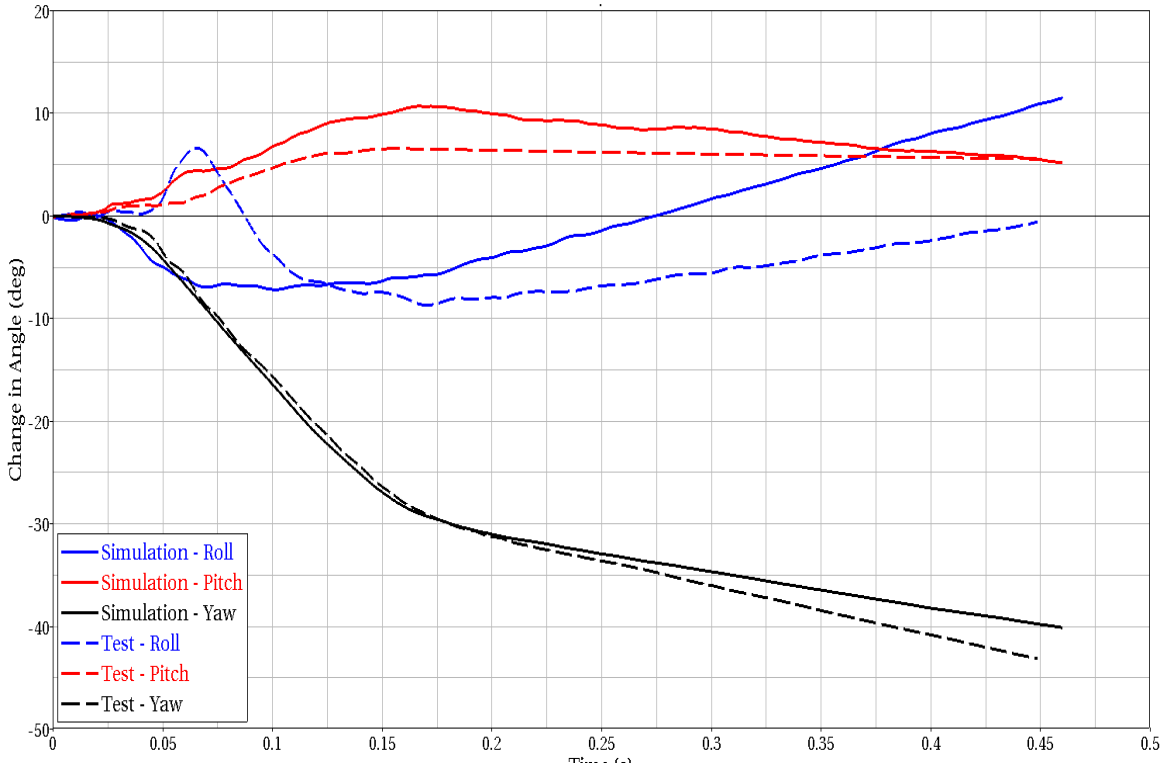
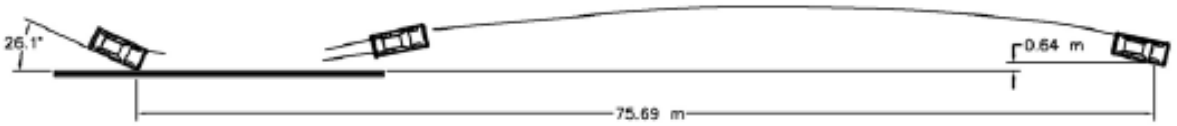


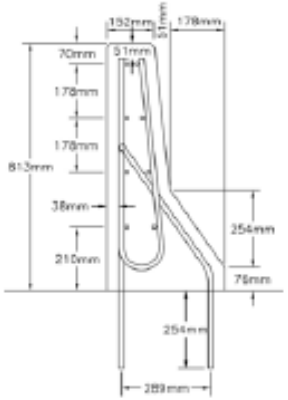
Figure 4: Change in Vehicle Angles

CCSA VALIDATION/VERIFICATION REPORT

Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 1100C 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.	0.265 m	0.226 s	15	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.	7 (.5s)	11 (.5s)	57% 4 deg	YES
		F3	Maximum vehicle pitch – relative difference is less than 20% or absolute difference is less than 5 deg.	10 (.5s)	7 (.5s)	30% 3 deg	YES
		F4	Maximum vehicle yaw – relative difference is less than 20% or absolute difference is less than 5 deg.	43 (.5s)	40 (.5s)	7% 3 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	5.0	4.8	4% 0.2 m/s	YES
		H3	Lateral OIV (m/s - Relative difference is less than 20% or absolute difference is less than 2 m/s	10.7	8.7	19% 2 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	5.5	2.5	55% 3 g	YES
		I3	Lateral ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g's	8.1	8.2	1% 0.1 g	YES
Vehicle Trajectory			The vehicle rebounded within the exit box. (Answer Yes or No)	Yes	Yes		YES





- Test Agency ..... MwRSF
- Test Number 2214NJ-1
- Date 5/28/04
- NCHRP 350 Update Test Designation .. 3-10
- Appurtenance ..... Permanent New Jersey Safety Shape Barrier
- Total Length ..... 24.38 m
- Key Elements - Barrier
  - Description ..... Half-Section New Jersey Shape Barrier
  - Base Width ..... 381 mm
  - Height ..... 813 mm
  - Concrete Material ..... Nebraska 47-BD Mix
  - Reinforcing Steel Material ..... Grade 60 Rebar
- Type of Soil ..... NA
- Test Vehicle
  - Type/Designation 1170C
  - Make and Model ..... 2002 Kia Rio
  - Curb ..... 1,053 kg
  - Test Inertial ..... 1,095 kg
  - Gross Static ..... 1,170 kg
- Impact Conditions
  - Speed ..... 97.9 km/h
  - Angle ..... 26.1 degrees
  - Impact Location ..... 5.63 m downstream from upstream end
- Exit Conditions
  - Speed ..... 79.4 km/h
  - Angle ..... 6.6 degrees
  - Exit Box Criterion ..... Pass
- Post-Impact Trajectory
  - Vehicle Stability ..... Satisfactory
  - Stopping Distance ..... 75.69 m downstream
    0.64 m traffic-side face
- Occupant Impact Velocity (350 Update)
  - Longitudinal ..... 5.02 m/s < 12 m/s
  - Lateral ..... 10.67 m/s < 12 m/s
- Occupant Ridedown Deceleration (350 Update)
  - Longitudinal ..... 5.49 Gs < 20 Gs
  - Lateral ..... 8.08 Gs < 20 Gs
- THIV (not required) ..... 12.38 m/s
- PHD (not required) ..... 8.10 Gs
- Test Article Damage ..... Minimal
- Test Article Deflections
  - Permanent Set ..... NA
  - Dynamic ..... NA
  - Working Width ..... 485 mm
- Vehicle Damage ..... Moderate
  - VDS[4] 1-RFQ-4
  - CDC[5] 1-RYEW5
  - Maximum Deformation ..... 57 mm at right-front floorpan

Figure 5: Full-Scale Test Summary

Figure 6a: Sequential Comparisons – Front View

Figure 6b: Sequential Comparisons – Rear View

Figure 6c: Sequential Comparisons – Top View

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Table F - Composite Verification and Validation Summary:

List the Report MASH08 Test Number		
Table C – Analysis Solution Verification	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)