ORIL Bridge Updates

Professor Eric Steinberg, Ph.D., P.E.
Warren Schlatter, P.E., P.S.
ORIL Board

CEAO Bridge Conference
August 18, 2016

Ohio's Research Initiative for Locals (ORIL)

15 Person Voluntary Board

(Voting)

- County Engineers
- City Engineers
- Township Representative
- Academics
- ODOT Technical Experts

(non-Voting)

- Ohio LTAP Center Rep
- ODOT Research
- FHWA - Ohio Division

ORIL

September/October: Solicitation for Research Ideas

November/December: ORIL Board Review and Prioritization

January/February: Development of Requests for Proposals (RFPs)

March/April: Solicitation of Research Proposals

May/June: Selection of Research Proposals

Contact: oril@dot.ohio.gov

Website: http://oril.transportation.ohio.gov

Bridge Related Projects

2016:

Synthesis of Research on Load Capacity of Concrete Slabs without Plans – Professor Richard Miller, Univ. of Cincinnati

- Approximately 6,500 short span concrete slab bridge exist in Ohio with most on the on the local system
- About 20% do not have plans
- Many Counties rate these a "good 5" due to lack of info.
- Research will investigate methods to assist Counties in evaluating these bridges
- Survey to determine techniques that have been used and success
- Testing rebar samples from older removed bridges

Bridge Related Projects

2015:

Inspection, Repair, Retrofit Procedures, and Design Recommendations for Non-Redundant Steel Structures – Professor James Swanson, University of Cincinnati

- Approximately 1500 structures are fracture critical in OH
- About 900 Pony trusses exist on local system
- Fracture Critical Members (FCM) require arms length inspection
- Research to analytical evidence and protocols to possibly reduce number of FCM to inspect
- Develop repair/retrofit procedures to eliminate non-redundancy or FCM

Non-Redundant Steel Structures

Develop a Protocol for the “Advanced Analysis”

- Straight Forward 3D Model
- Fairly Standard Analysis Software
- Implementable by Consultants or County Engineers

Possibly Develop Blanket Conclusions for Pony Truss Bridges

- Floor Beams Spaced at 14’-0” or Greater
- Certain PTB Topologies or Deck Types
- Built-up Tension Members

Non-Redundant Steel Structures

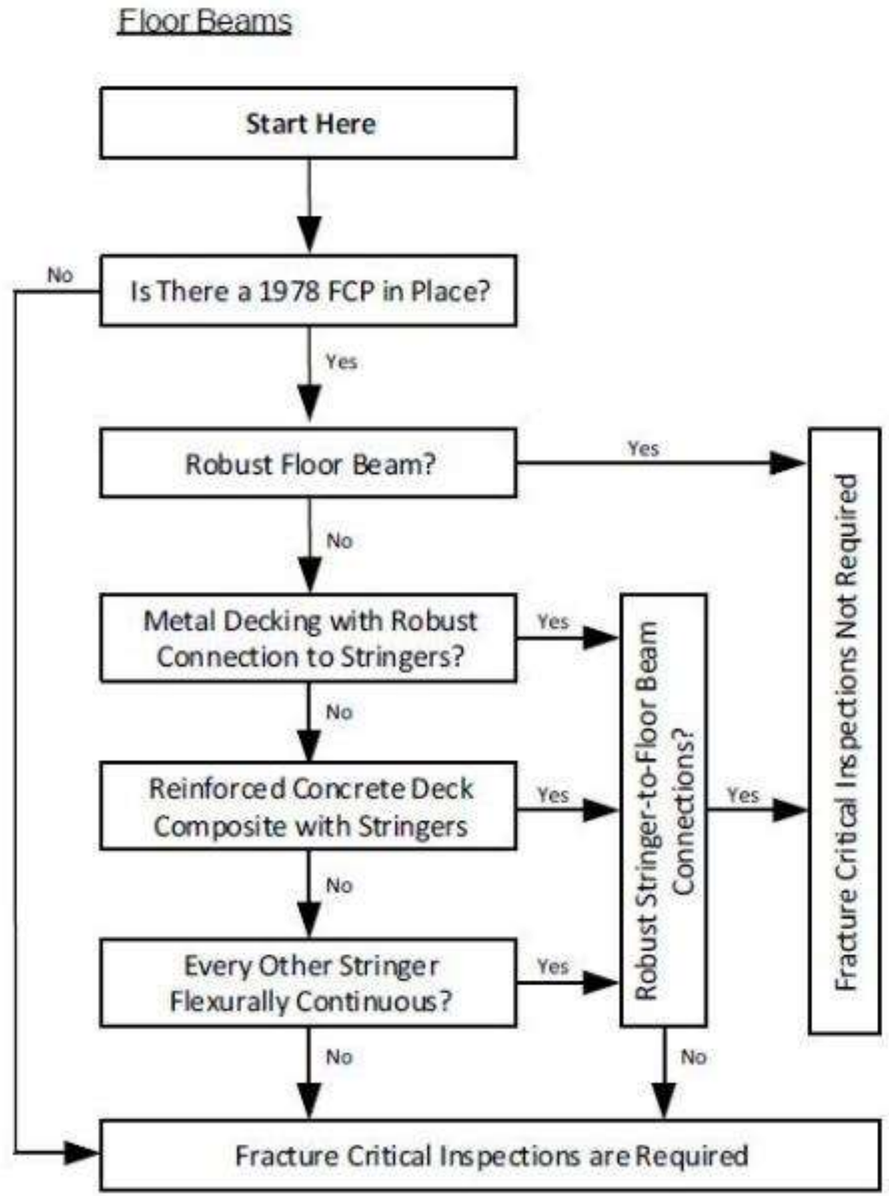


Figure 7-2: Suggested Flow Chart for Fracture Critical Inspections of Floor Beams

Bridge Related Projects

2015:

Evaluation and Design of a TL-3 Bridge Guardrail System Mounted to Steel Fascia Beams – Dr. Chuck Plaxico, RoadSafe, LLC

- Railing is often connected to Concrete Decks
- Locals typically have timber or asphalt filled stay-in-place forms as decks
- Railing often connected to fascia beam
- Crash tested design is not available which excludes federal funding
- Research 2-phases

Guardrail System Mounted to Steel Fascia Beams

- Phase 1 – Analytically evaluate steel fascia mounted railing design to obtain MASH TL-3.
- Phase 2 – If necessary for Federal Approval, crash test design.

Guardrail System Mounted to Steel Fascia Beams

There were three primary goals for the literature review:

1. To identify any existing fascia mounted bridge rails that are currently eligible for use on federal aid projects,
   - *None Found*
2. To identify any existing side-mounted bridge rails currently eligible for use on federal aid projects that could readily be modified to accommodate attachment to steel fascia beams (e.g., seek acceptance under the original eligibility letter),
   - *Four candidate systems identified*
3. Identify any other side-mount designs that are *not* currently eligible for use on federal aid projects, but have potential for successful performance under MASH TL3 impact conditions (e.g., modify existing design and perform full-scale MASH tests.
   - *Several systems identified but not selected for consideration*

Guardrail System Mounted to Steel Fascia Beams

- Technical report submitted to ODOT TAC on February 6, 2015 which detailed results of literature review.
- Teleconference February 11 discussed findings.
- The outcome of meeting was the selection of two candidate designs for further evaluation in Task 2.

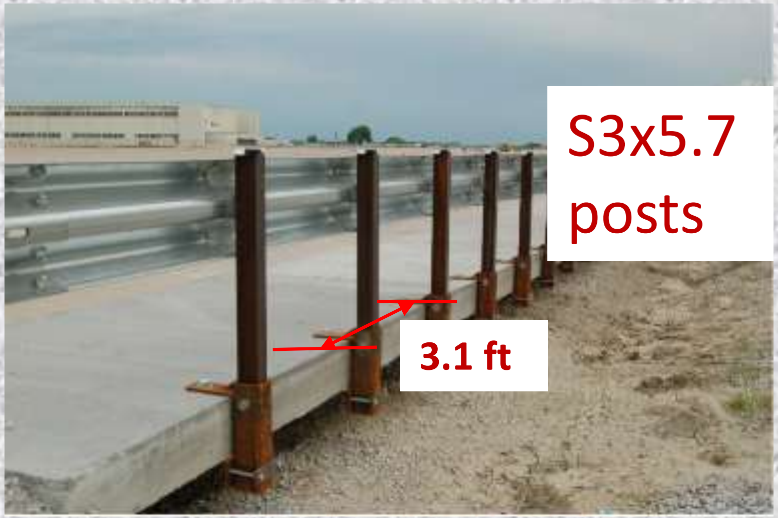
MGS
(MASH TL3)

Illinois Two-Tube
(R350 TL4)

Guardrail System Mounted to Steel Fascia Beams

MGS

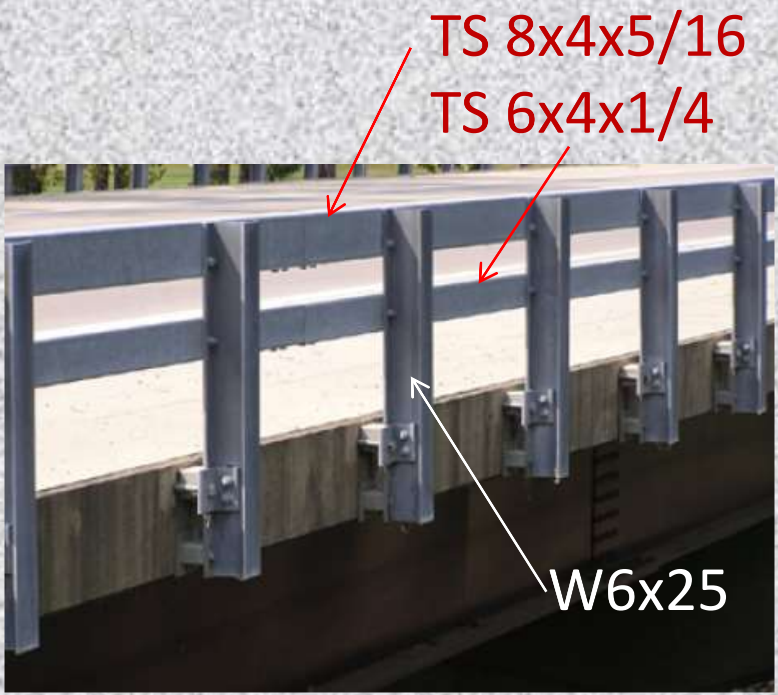
- **PROS**
  - MASH TL3
  - Simple w-beam and weak post design
  - Lower loads on mount
  - Low cost
  - FEA is an option for evaluation
  - No transition system required when attaching to the MGS guardrail
- **CONS**
  - Post spacing (3’-1.5”) – will require a lot of mount connections
  - Large deflections during impacts
  - Easily damaged – nuisance hits, snow plowing, etc.
  - Containment of heavier trucks at low impact conditions???
  - Vertical load capacity?



Guardrail System Mounted to Steel Fascia Beams

Illinois Two-Tube

- **PROS**
  - **Report 350 TL4**
  - **Simple two-tube and post design**
  - **Post spacing (6’-3”) (PRO??)**
  - **FEA is an option for evaluation**
- **CONS**
  - **Will require very stiff mount to achieve same stiffness as original system (i.e., for acceptance under original letter)**
    - **These loads have to be carried by the bridge fascia beam.**



Guardrail System Mounted to Steel Fascia Beams

Illinois Two-Tube Performance

- The small car test resulted in no noticeable damage to the bridge railing or bridge deck.
- The pickup truck test resulted in:
  - 1-inch permanent deformation of the top rail and
  - 3/4 inches deformation of the lower rail.
  - The flanges on two posts were deformed as well as the angle stiffeners.
- The SUT test resulted in moderate damage to the railing.
  - The upper and lower rails sustained gouges;
  - The head of the lower bolt on the top rail at one of the posts was torn off;
  - The angles at three of the posts were bent;
  - There was 2.5 inches deformation to the upper rail.

Guardrail System Mounted to Steel Fascia Beams

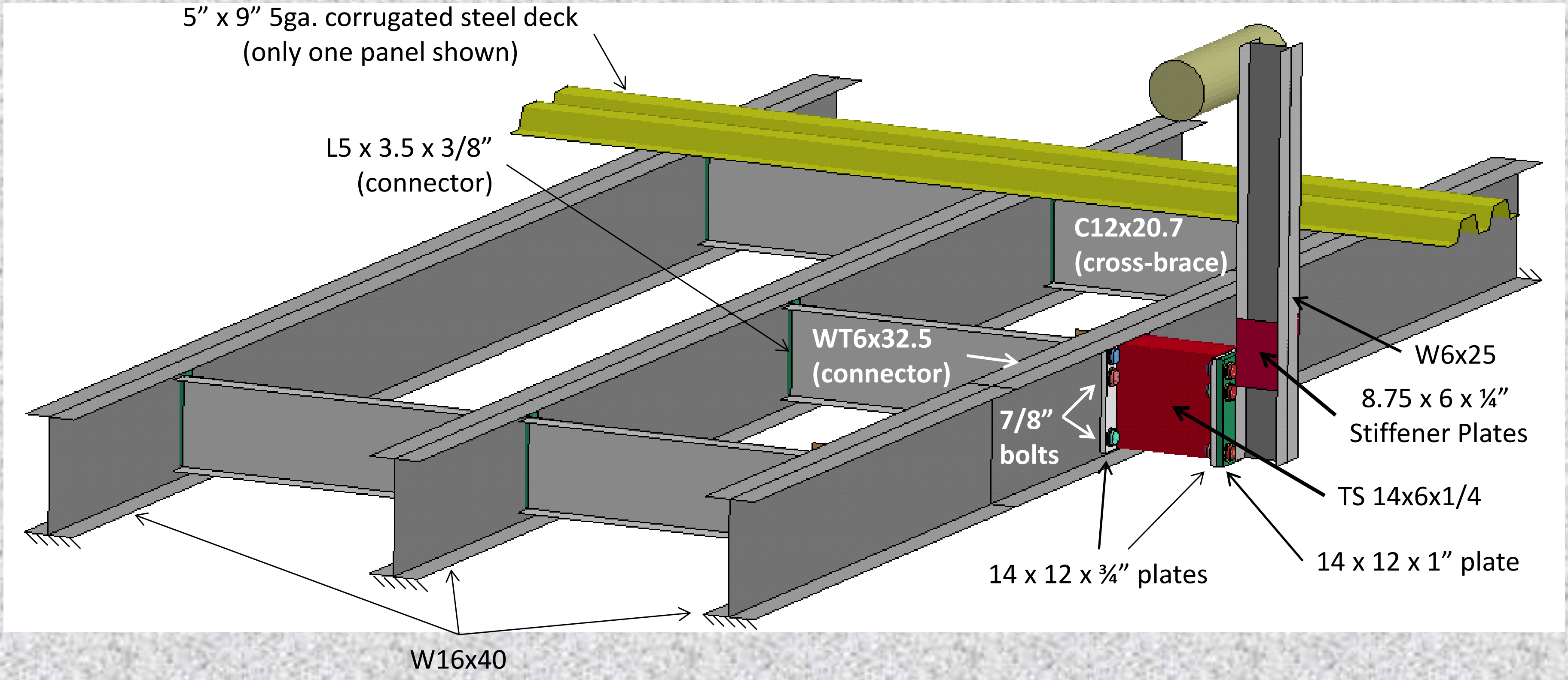
Illinois Two-Tube

Similar Design with Mounting to Fascia Beam (from US Bridge)

Guardrail System Mounted to Steel Fascia Beams

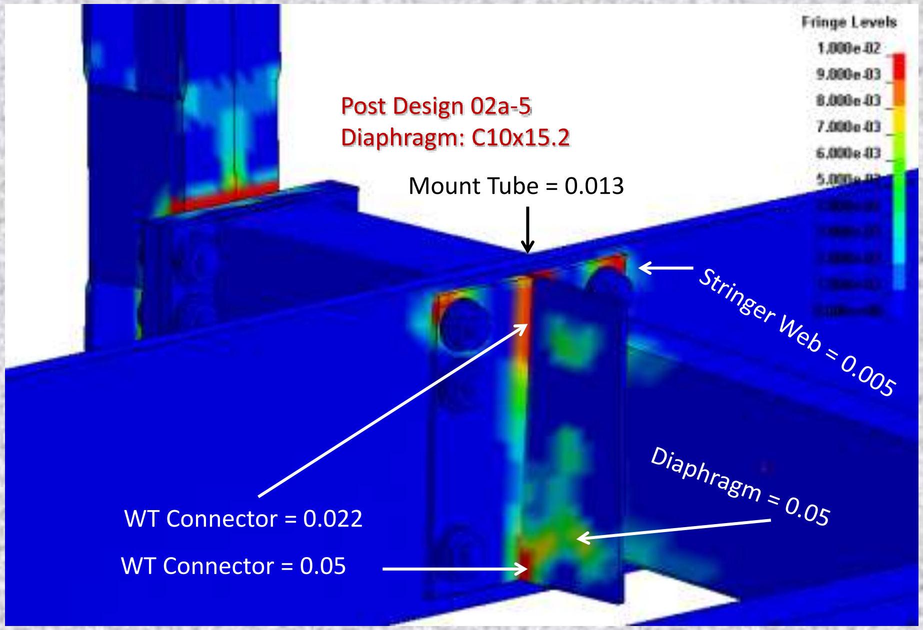
FEA Analysis

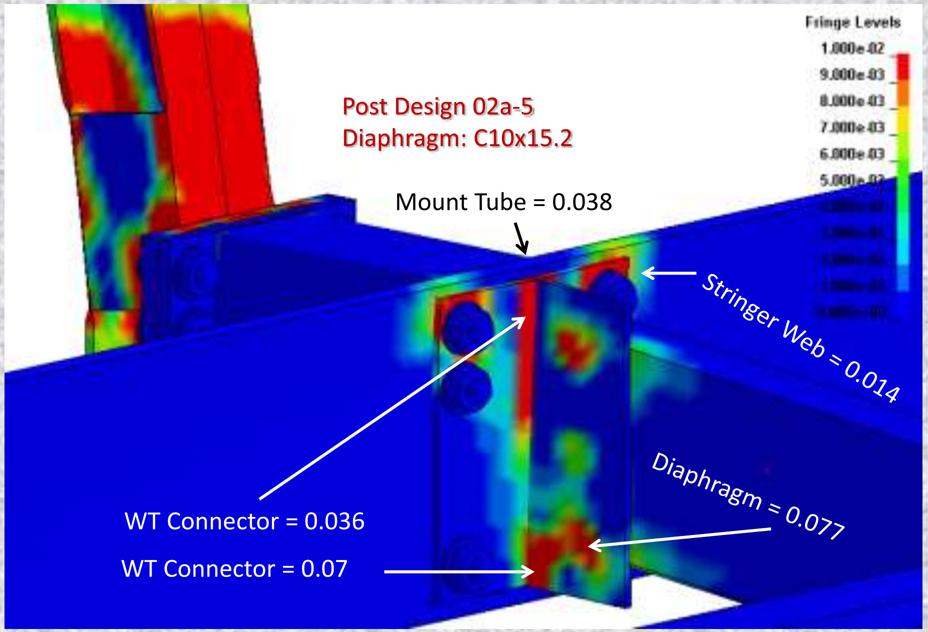
Model with Intermediate Level of Detail



Guardrail System Mounted to Steel Fascia Beams

FEA Analysis



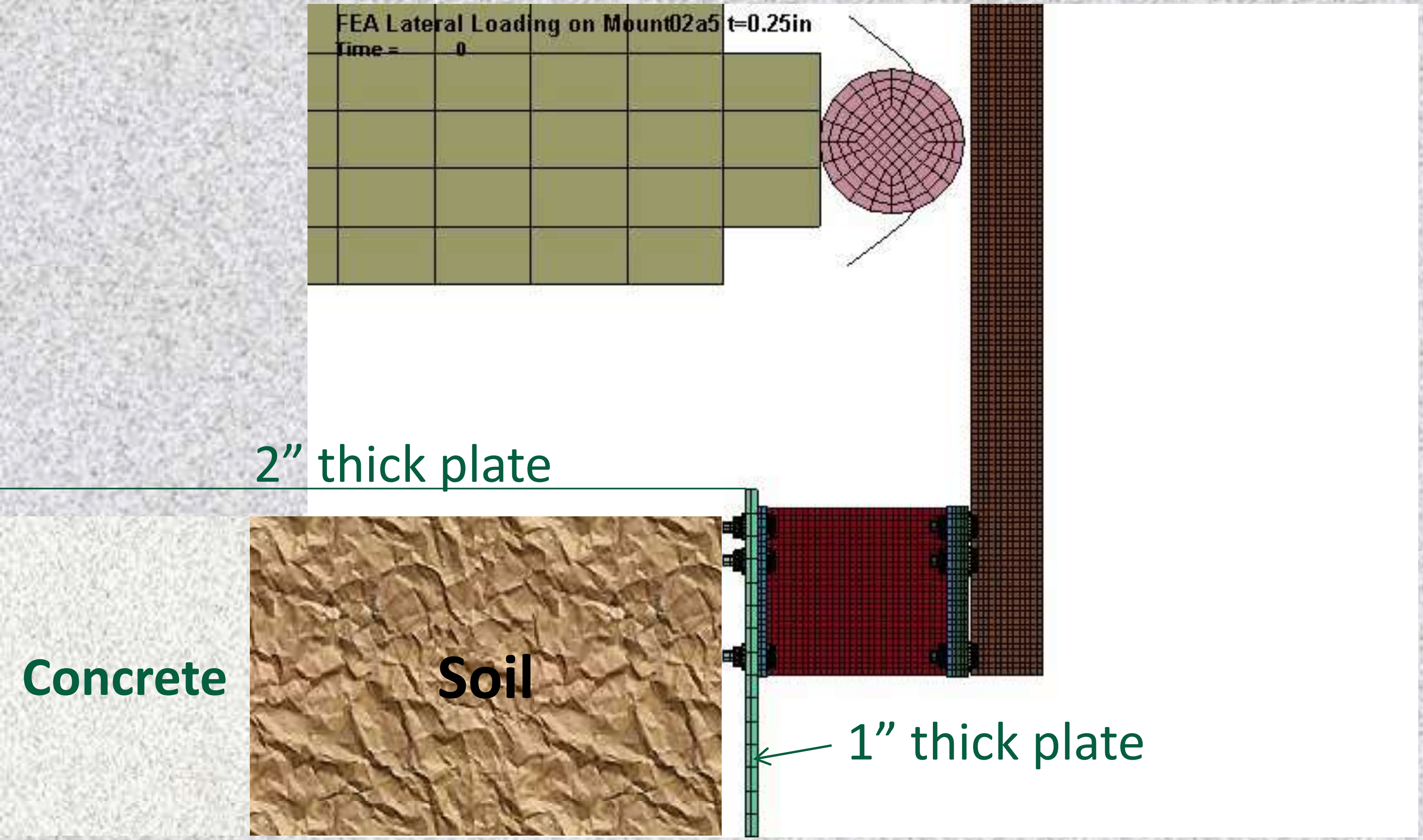


TL4 Loading Conditions

Ultimate Loading Conditions

Guardrail System Mounted to Steel Fascia Beams

Pendulum Testing for Model Verification



Guardrail System Mounted to Steel Fascia Beams

Pendulum Testing for Model Verification

Guardrail System Mounted to Steel Fascia Beams

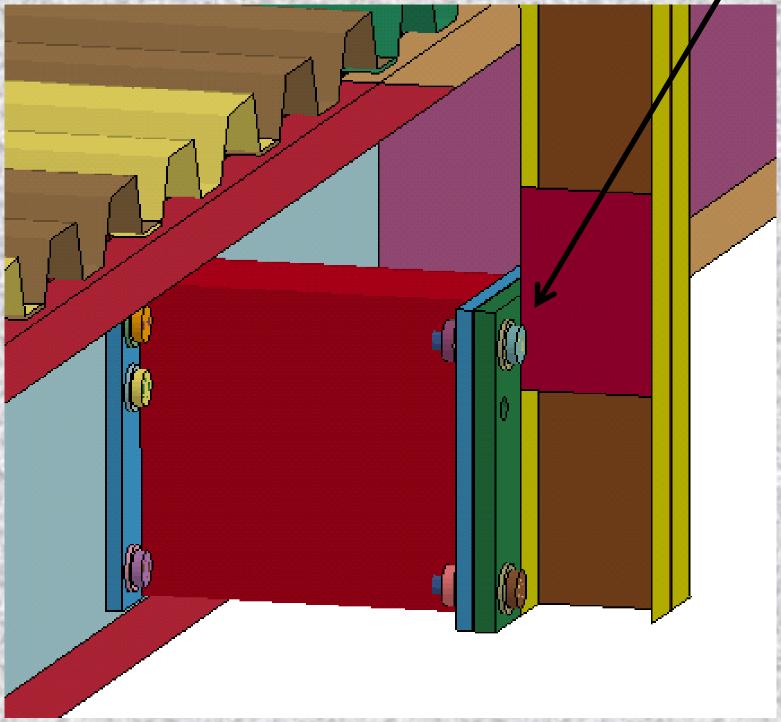
Pendulum Testing for Model Verification

Guardrail System Mounted to Steel Fascia Beams

Bolt Chart

Part No.	BOLTS				NUTS	FLAT WASHERS		LOCK WASHERS	
	Description	Diameter	Length	Class	Type	Type	QTY / bolt	Lock	QTY / bolt
B1	Top Bolts for D1SP1 to D1SP2	1"	3-1/4"	SAE J429 Grade 5	SAE J995 Grade 5 UNF	F436-1	2		1
B2	Bottom Bolts for D1SP1 to D1SP2	7/8"	3-1/4"	ASTM A325-1	ASTM A563-DH	ASTM F436-1	2		1
B3	D1SP3 to Fascia Beam	7/8"	2-11/16"	ASTM A325-1	ASTM A563-DH	ASTM F436-1	2		1

* All hardware is to be hot dip galvanize per ASTM A153 or ASTM F2329

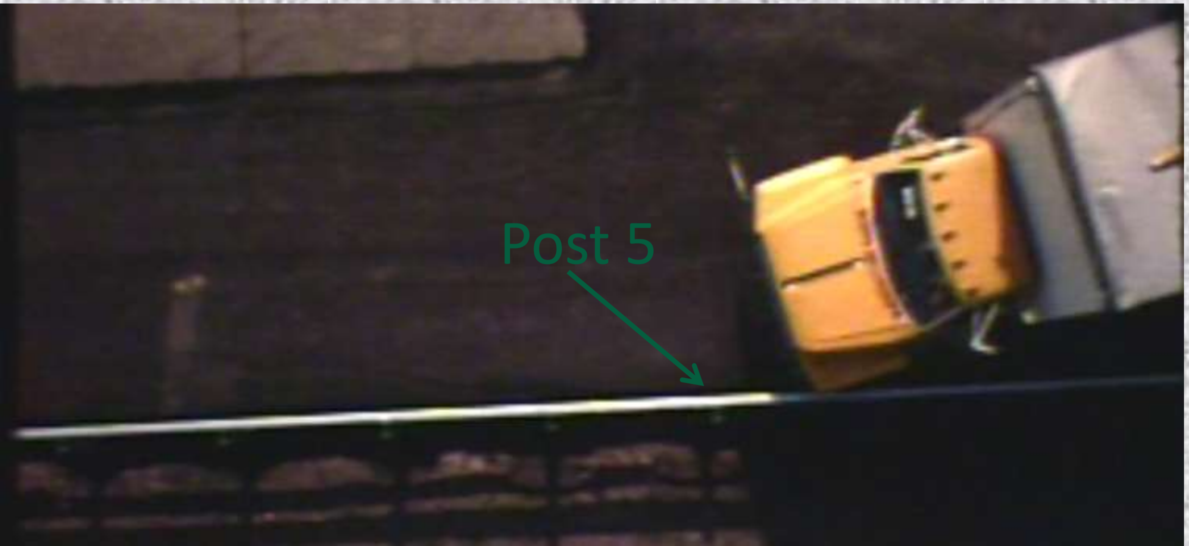


Bolt is a 1" diameter SAE J429 Grade 5 UNF bolts.

- strength properties equivalent to A325-1, but are available with fine threads (n=12 threads/inch).
- This bolt size results in stress values of 129-138 ksi, which is sufficient to fail the bolt before reaching excessive loads on the mount.
- In order to confirm that this bolt meets desired failure conditions for the post-mount, <u>it is recommended that physical testing be performed for one or more post-mount designs</u>

Guardrail System Mounted to Steel Fascia Beams

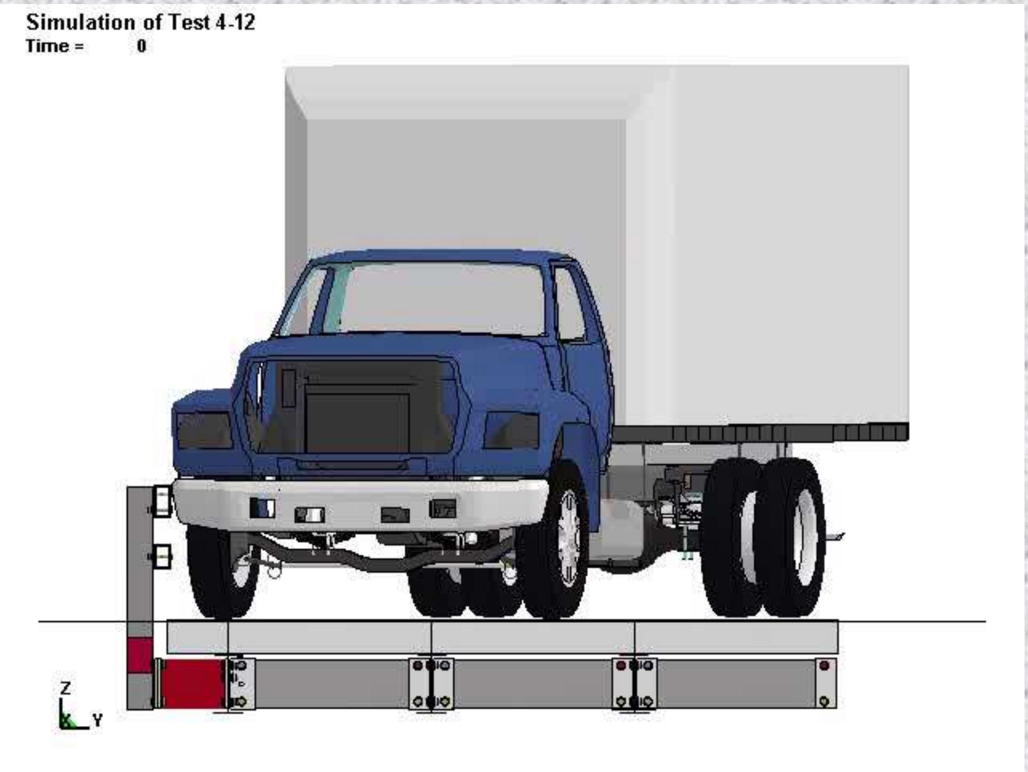
- Railing:
  - Illinois Two-Tube
  - Length = 84 ft
- Vehicle
  - 18-kip SUT
  - Impact speed = 51.4 mph
  - Impact angle = 14.7 deg.
- Impact Point

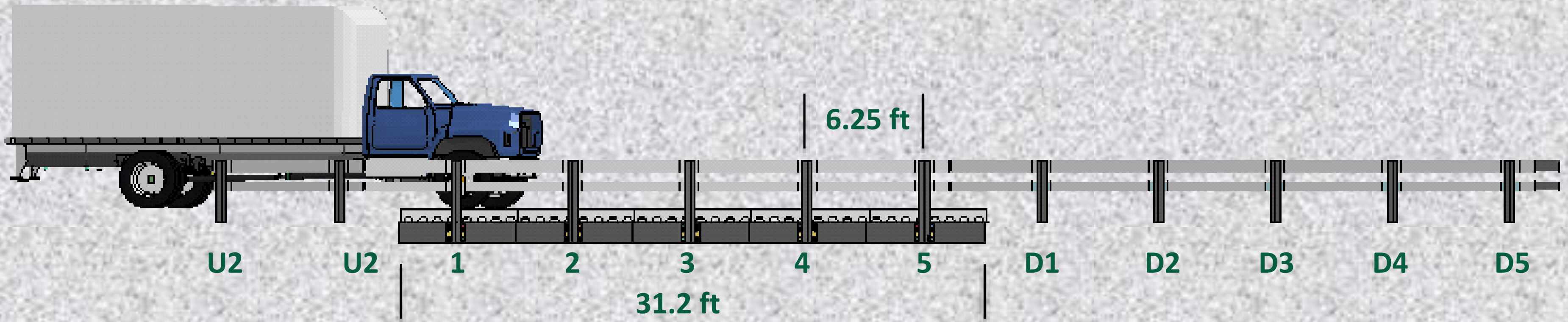


- Max permanent deflection = 2.5 inches
- Max dynamic deflection was not reported

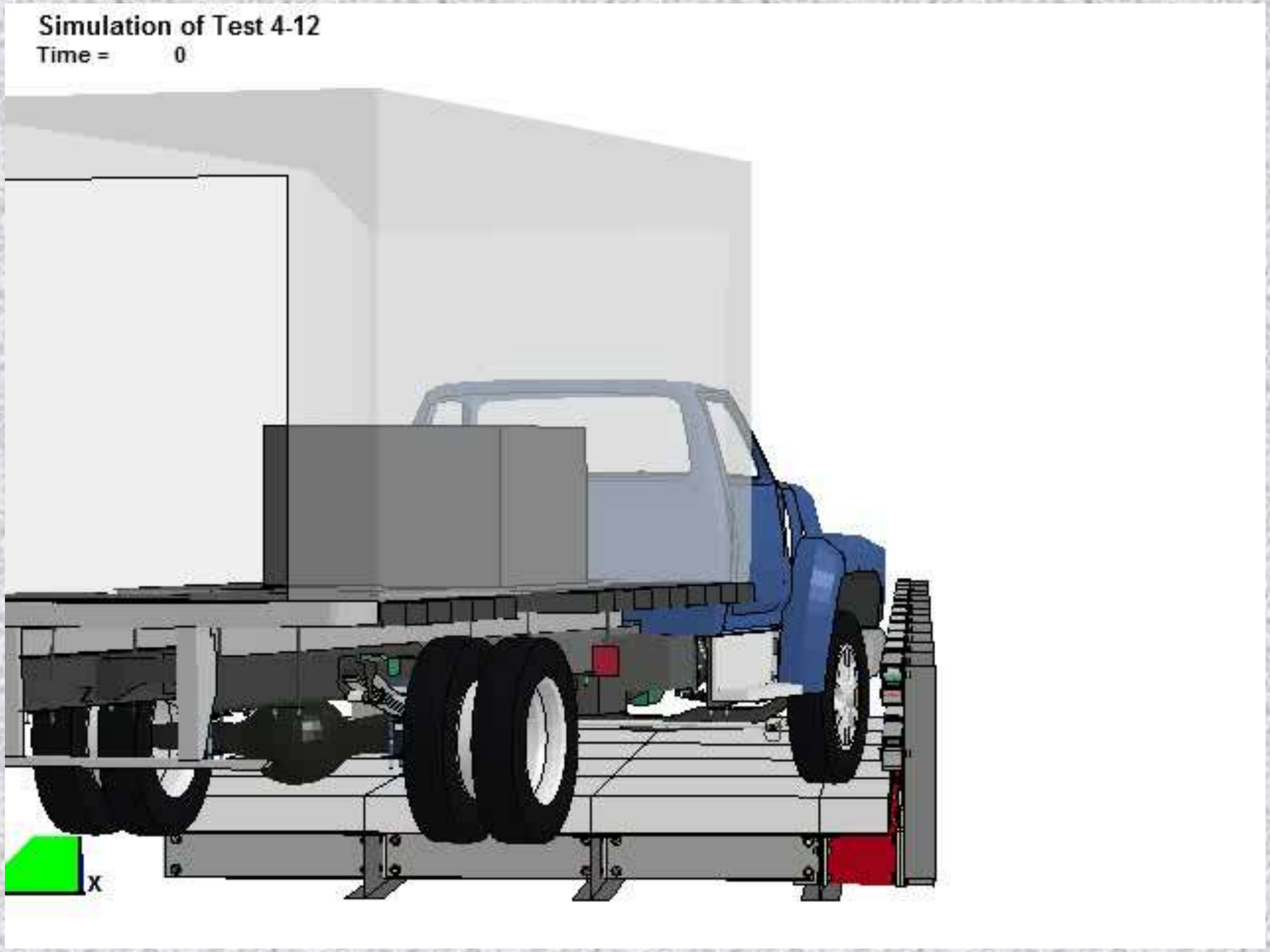
Guardrail System Mounted to Steel Fascia Beams

- Bridge Structure:
  - 14x48 / C10x20 / WT6x36 / HSS 12x6x0.25”
  - **(e.g., weaker proposed bridge option)**
- Railing:
  - Illinois Two-Tube
  - Post-Mount A with HSS 12x6x0.25” mounting tube.
- Vehicle
  - 18-kip SUT
  - Impact speed = 50 mph
  - Impact angle = 15 deg.
- Impact Point
  - 2.3 feet downstream of Post 1 (consistent with full-scale test)

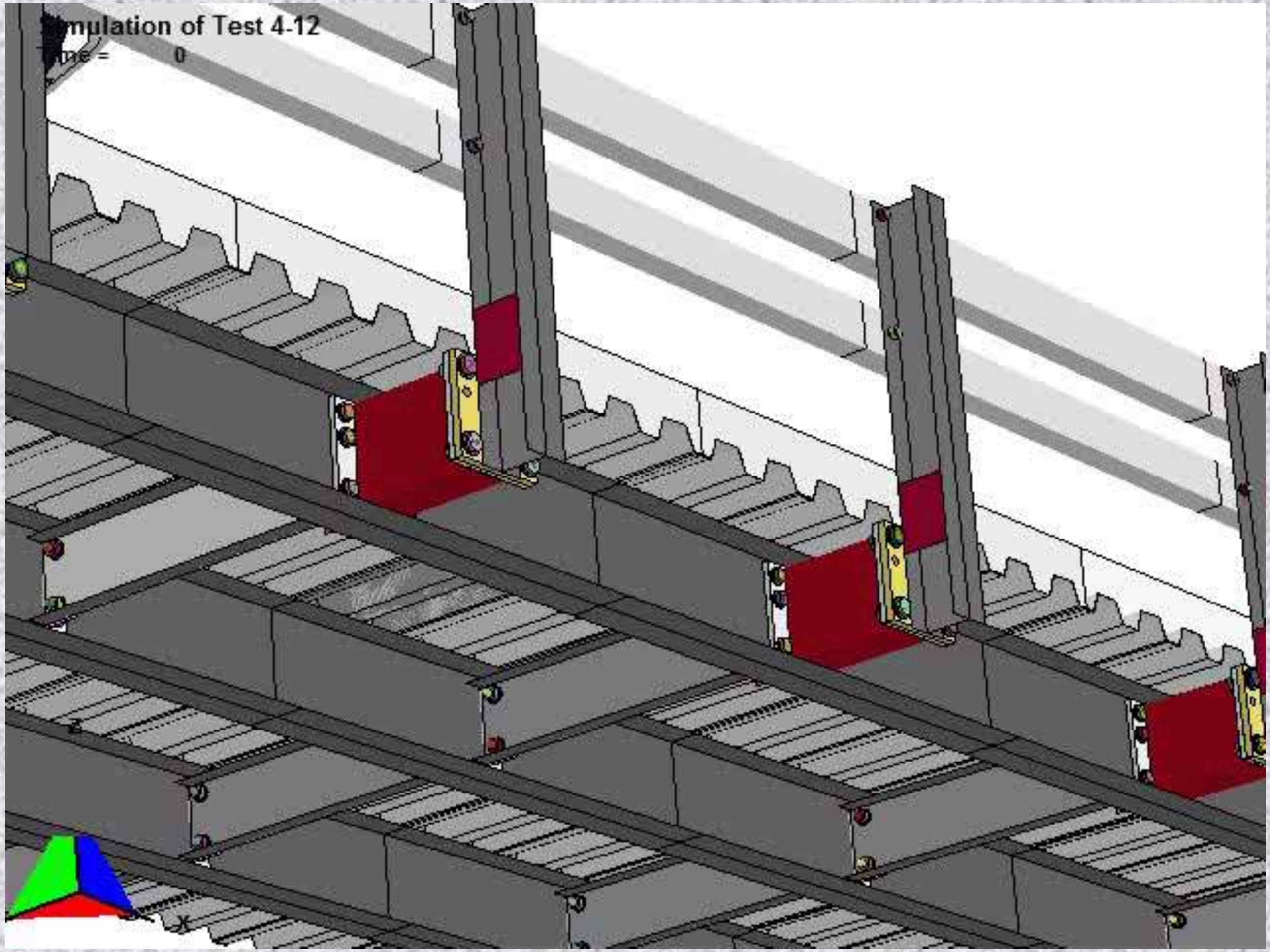




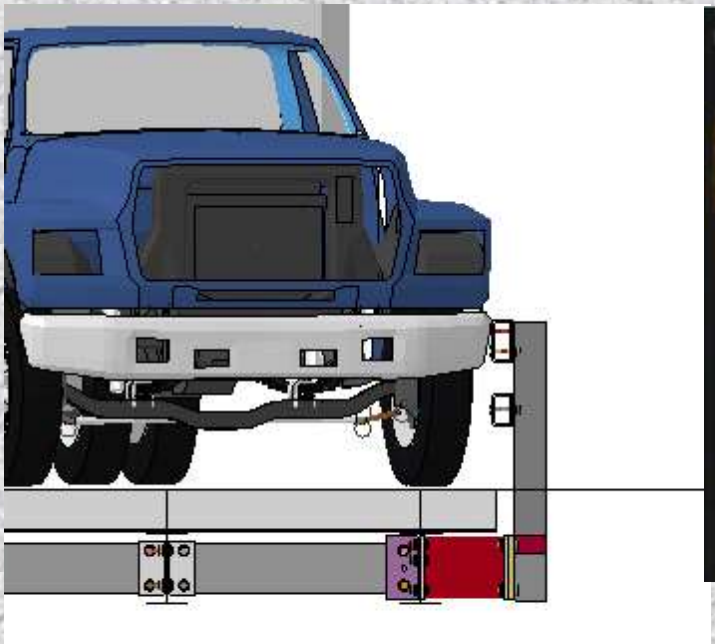
Guardrail System Mounted to Steel Fascia Beams



Guardrail System Mounted to Steel Fascia Beams

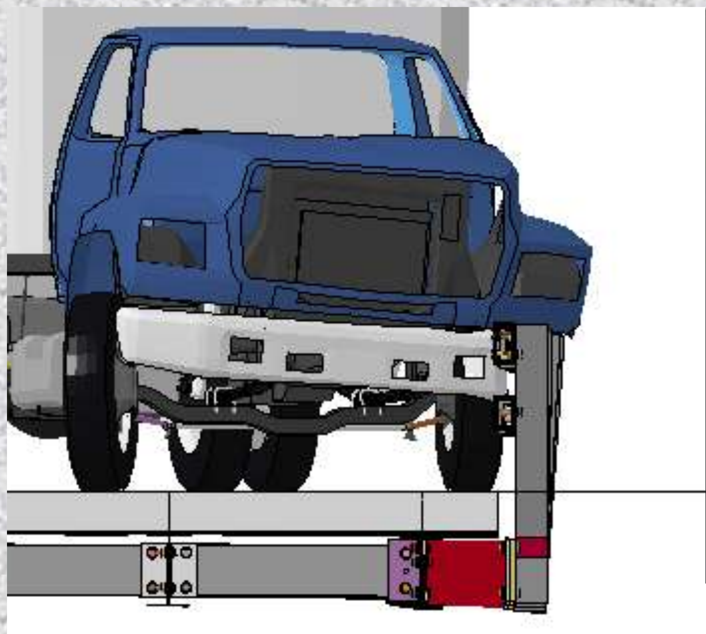


Guardrail System Mounted to Steel Fascia Beams



0.0 seconds

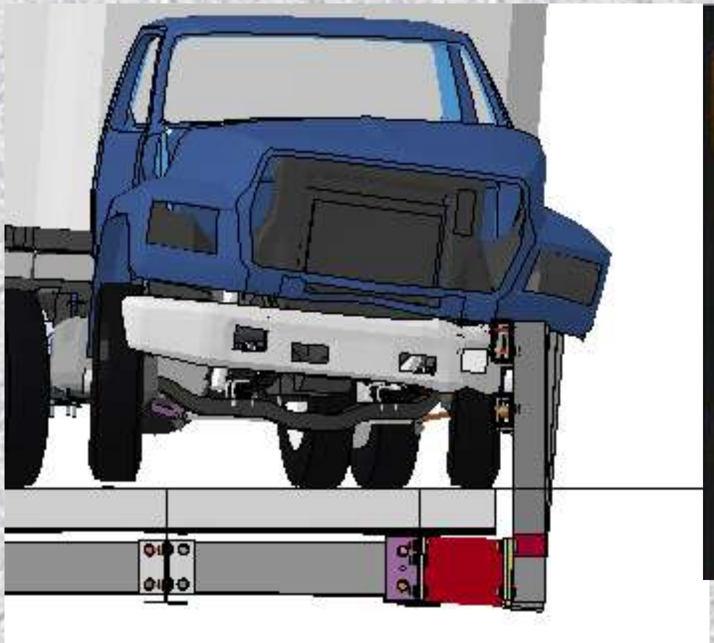
Guardrail System Mounted to Steel Fascia Beams



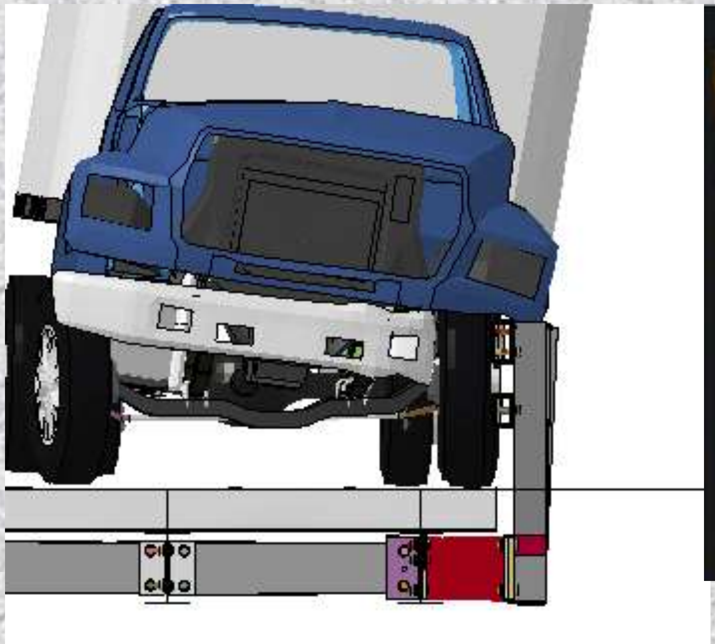
0.1 seconds

Guardrail System Mounted to Steel Fascia Beams

0.2 seconds



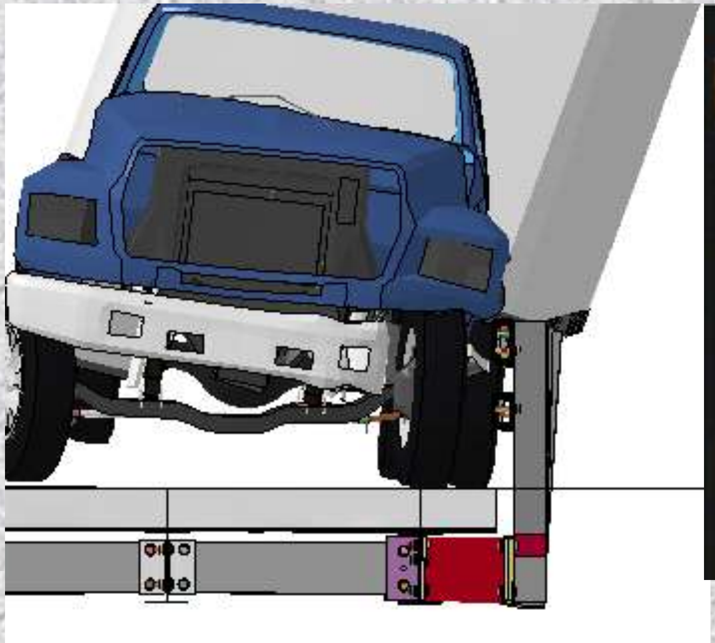
Guardrail System Mounted to Steel Fascia Beams



0.3 seconds

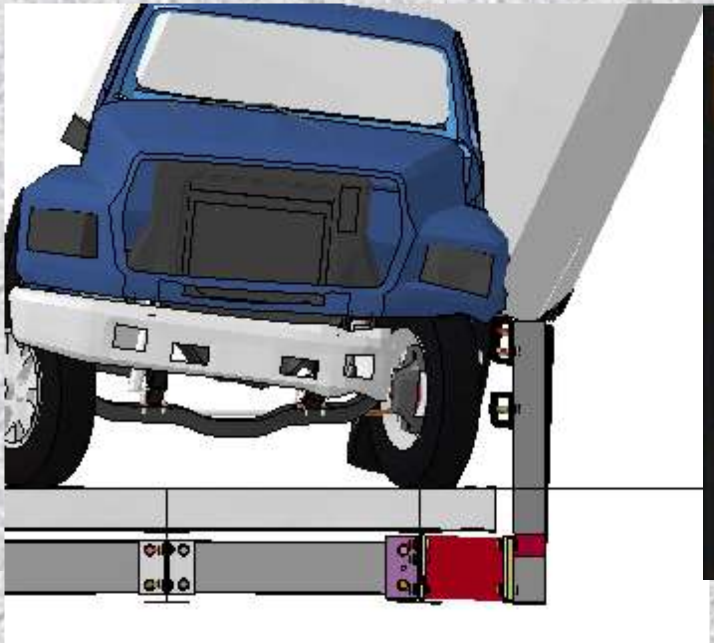
Guardrail System Mounted to Steel Fascia Beams

0.4 seconds

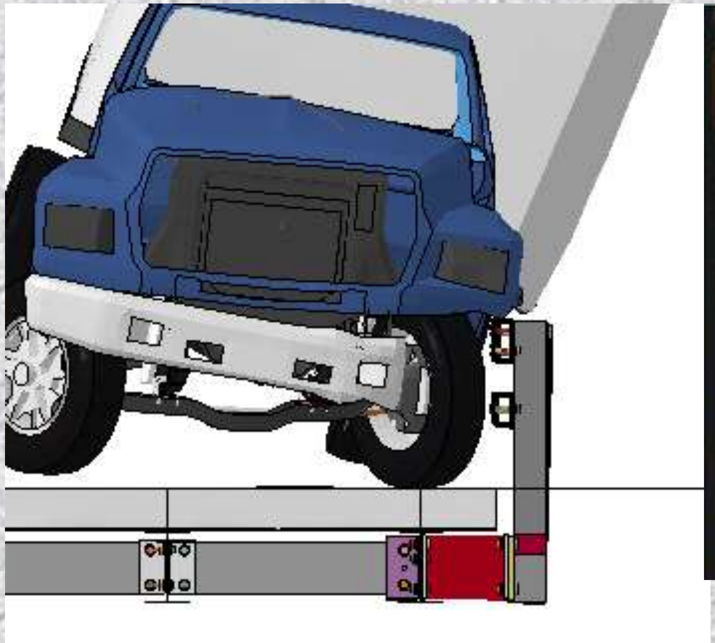


Guardrail System Mounted to Steel Fascia Beams

0.5 seconds

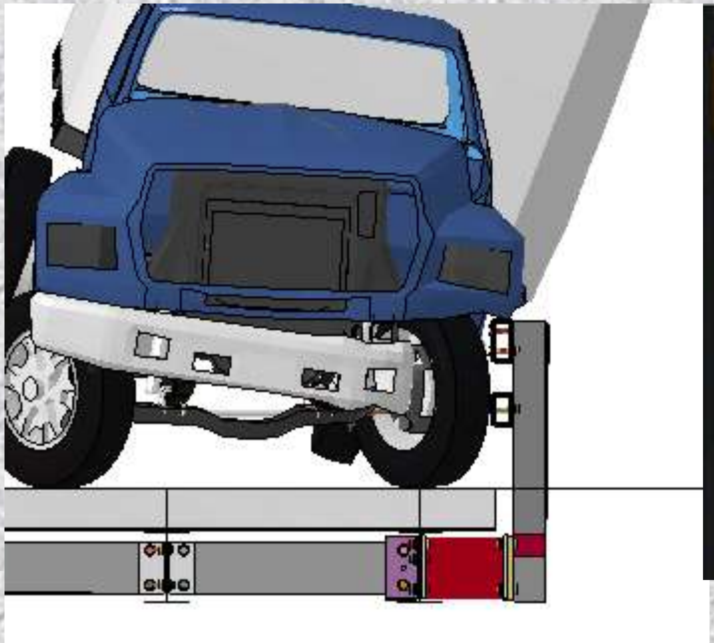


Guardrail System Mounted to Steel Fascia Beams



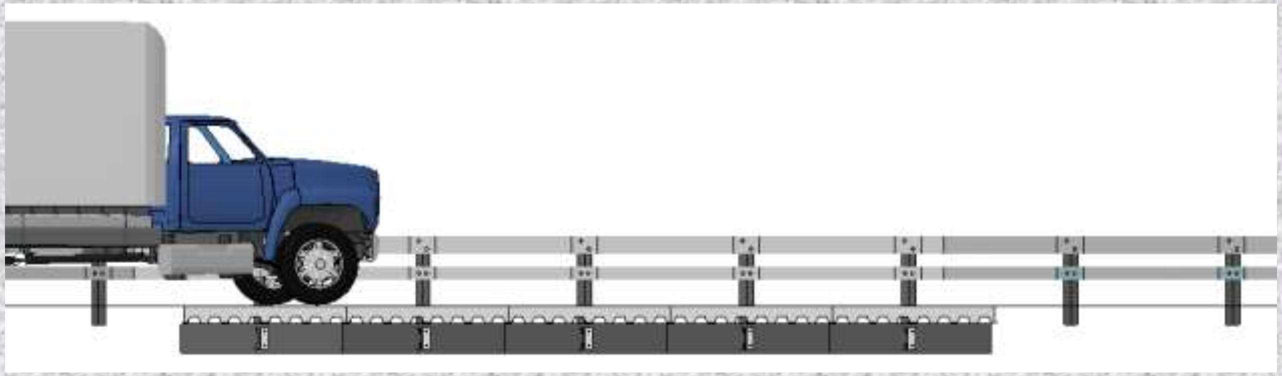
0.6 seconds

Guardrail System Mounted to Steel Fascia Beams



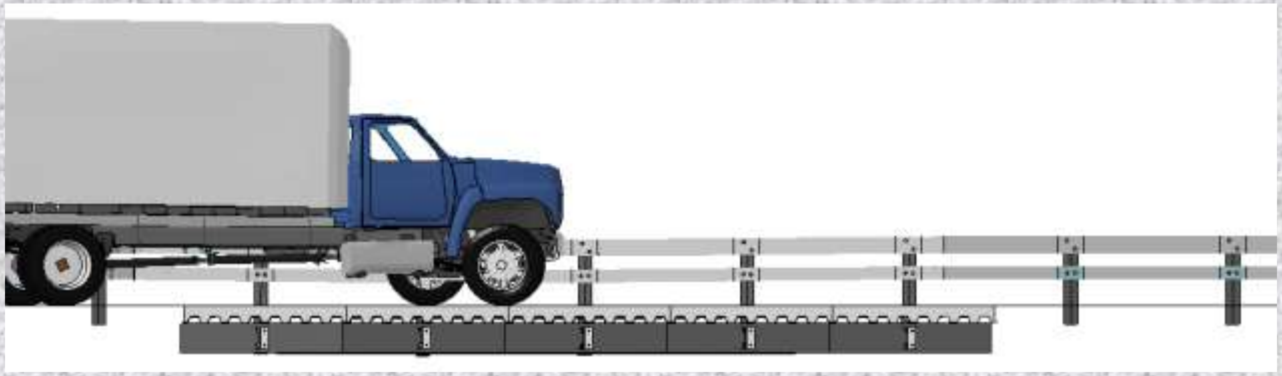
0.7 seconds

Guardrail System Mounted to Steel Fascia Beams



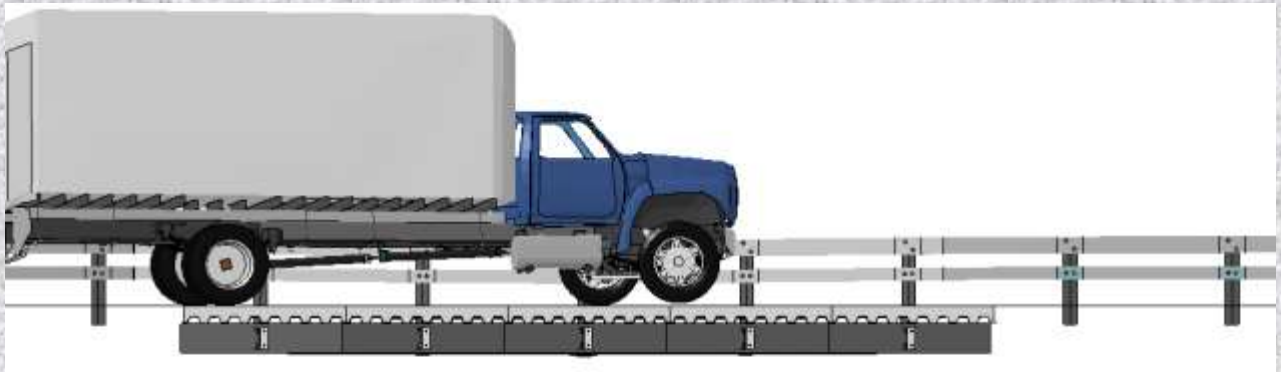
0.0 seconds

Guardrail System Mounted to Steel Fascia Beams



0.1 seconds

Guardrail System Mounted to Steel Fascia Beams



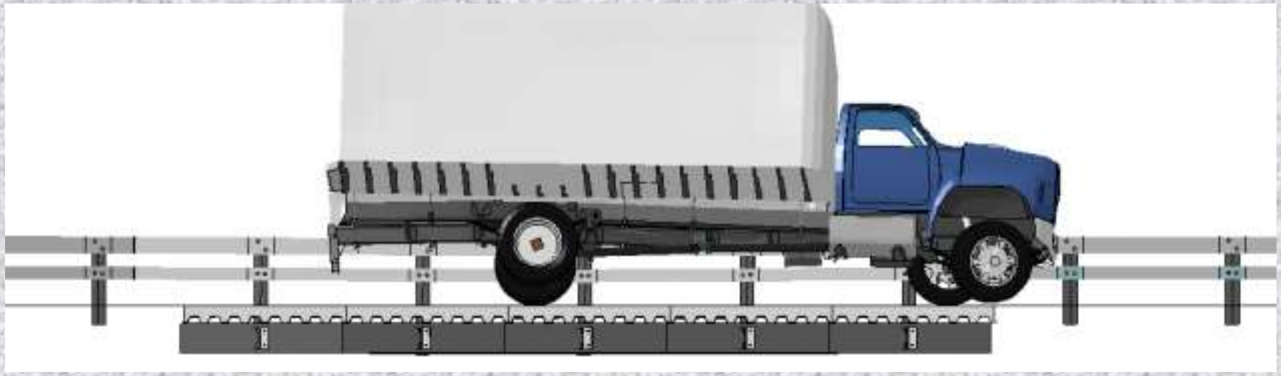
0.2 seconds

Guardrail System Mounted to Steel Fascia Beams

0.3 seconds

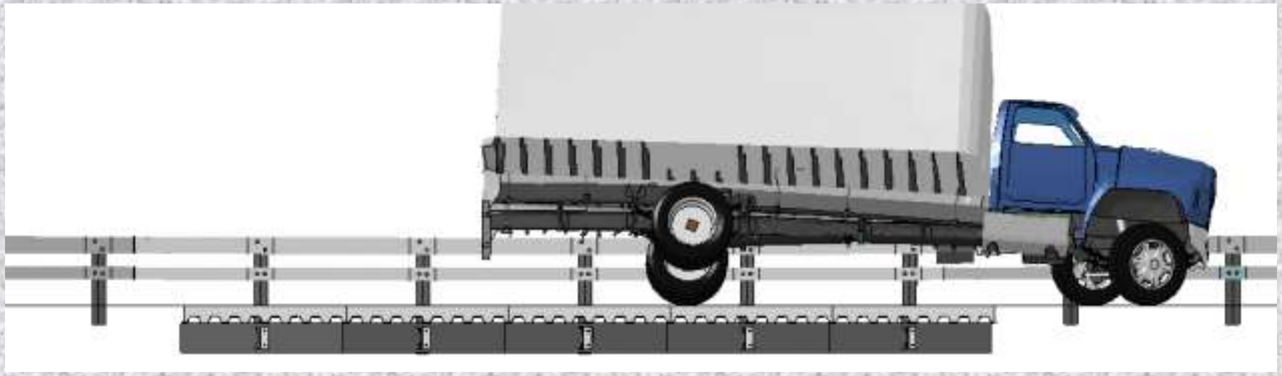
Guardrail System Mounted to Steel Fascia Beams

0.4 seconds



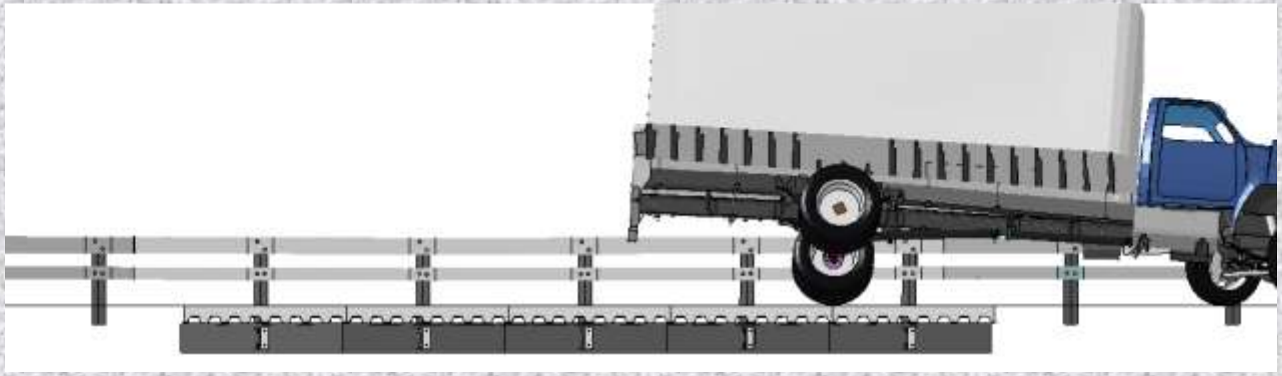
Guardrail System Mounted to Steel Fascia Beams

0.5 seconds



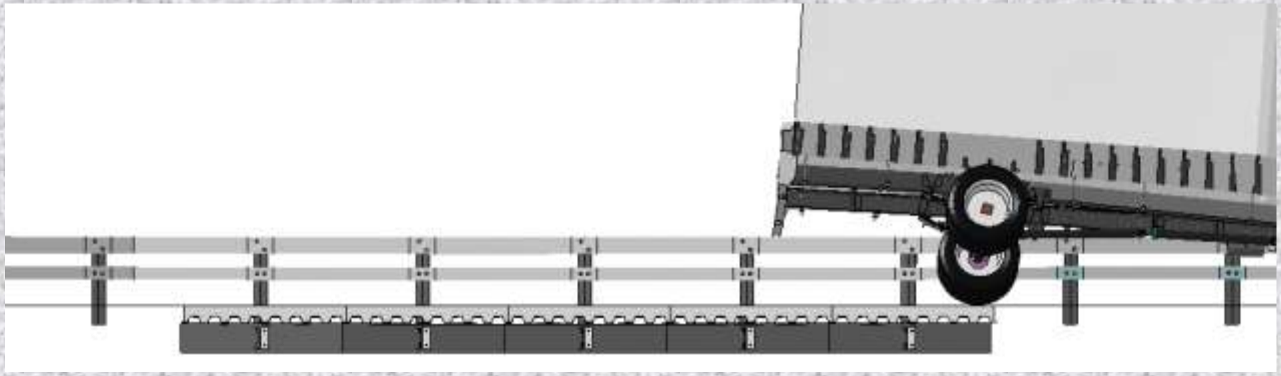
Guardrail System Mounted to Steel Fascia Beams

0.6 seconds



Guardrail System Mounted to Steel Fascia Beams

0.7 seconds



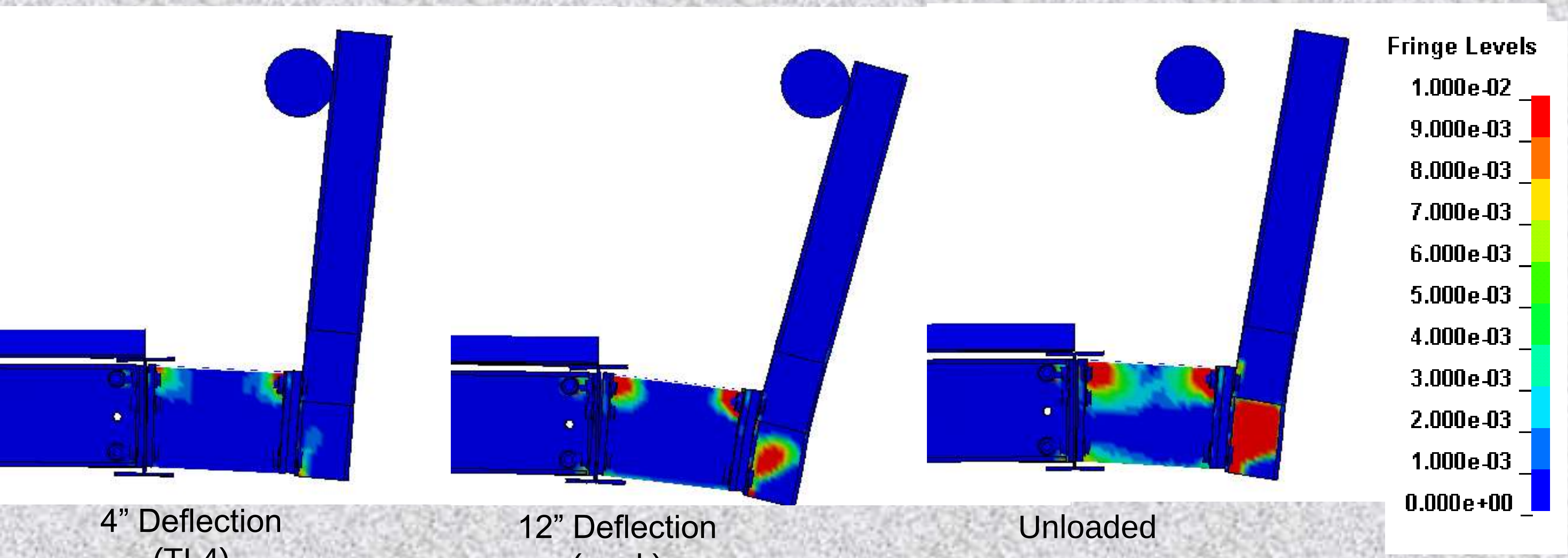
Guardrail System Mounted to Steel Fascia Beams

Analysis A

W14x30 Fascia Beam

12" x 6" x ¼" Mounting Tube (15 inches long)

Post Stiffener A



4" Deflection (TL4) | 12" Deflection (peak) | Unloaded

Guardrail System Mounted to Steel Fascia Beams

Analysis A

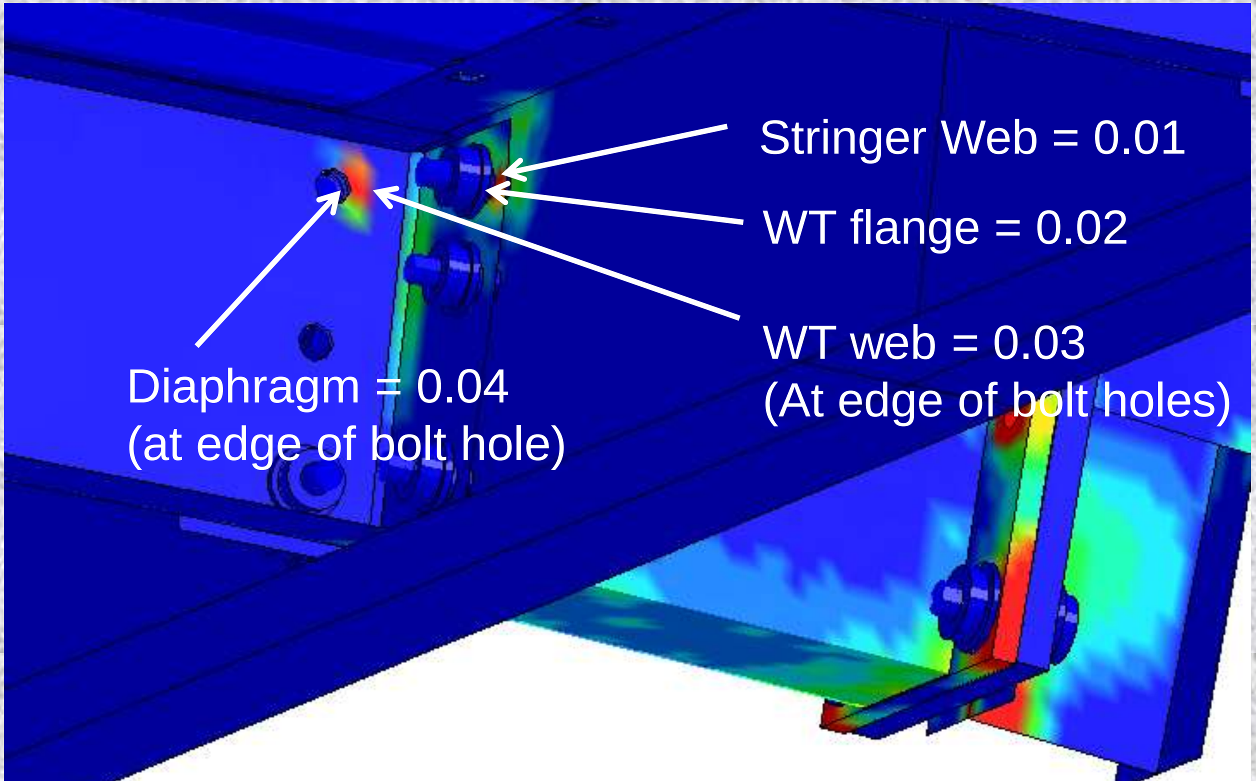
W14x30 Fascia Beam

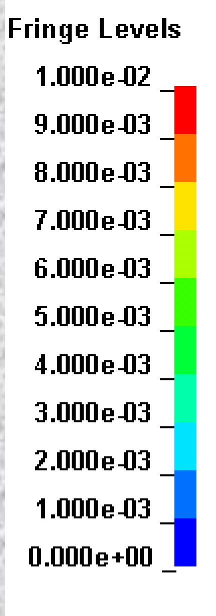
12” x 6” x ¼” Mounting Tube (15 inches long)

Post Stiffener A

At 4” Post Deflection (TL4 Loading)

Max Plastic Strains





Guardrail System Mounted to Steel Fascia Beams

Currently Finalizing Pendulum Testing of Final Design

Updated Drawings in Sept/Oct

Finalized Simulations in Oct/Nov

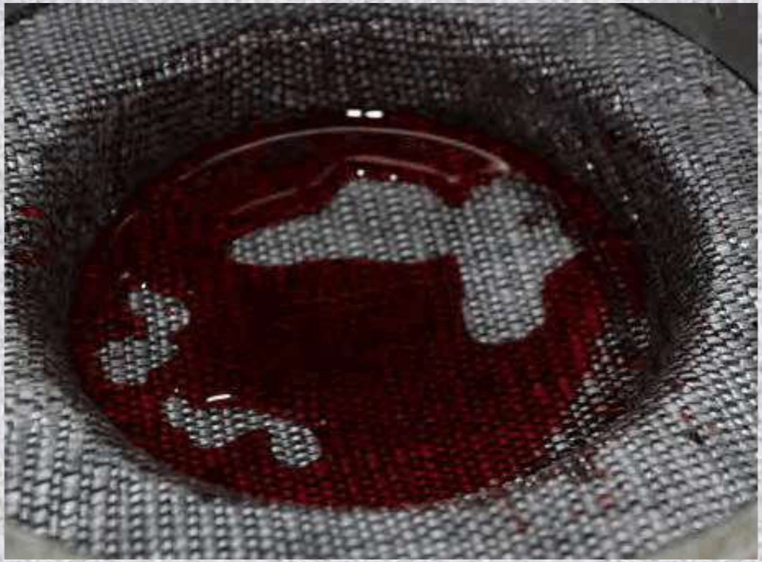
Final Report and Review – May 2017

Bridge Related Projects

2015:

Waterproofing Details of Connections for Adjacent Precast Concrete Box-Beam Bridges – Professor Anil Patnaik, University of Akron

- **Research to establish sources, causes, and effects of inadequate waterproofing at joints**
- **Develop preventative measures through evaluation of alternatives**



Waterproofing Details of Connections for Adjacent PC Box Beam Bridges

In order to address the problem and to develop potential solutions, a systematic study was conducted in this project to include the following major tasks:

(i) Waterproofing membrane performance in relation to box-beam longitudinal joints
(ii) Structural performance of key way joints
(iii) Study of grout material and the development of a new high-performance grout
(iv) Field measurements of vertical differential deflection and separation of longitudinal joints
(v) Beam assembly tests with symmetric loading
(vi) Analysis for eccentric loading and structural tests
(vii) Observation of construction practices
(viii) Investigation of a bridge that was in service for 32 years at the time of its demolition

Membrane testing

The vertical differential deflections and the horizontal differential movements under truck loading were measured on a bridge with 60 ft. span (Fig. 2). The maximum recorded vertical differential deflection was 0.005 inch. The maximum horizontal separation at the underside of the box beams was measured to be 0.015 inch. Comparison of these field measurements with those obtained for the five membranes from laboratory tests (over one inch) proves that these membranes can accommodate the vertical and horizontal differential deflections expected in a typical box-beam bridge under moving traffic loads.

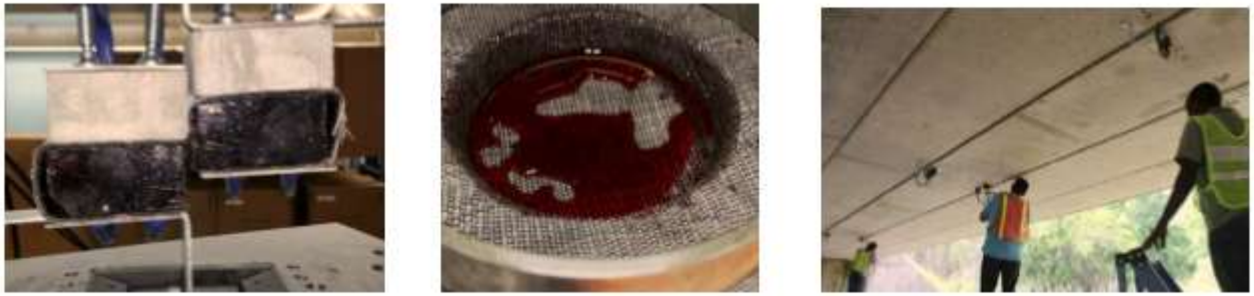
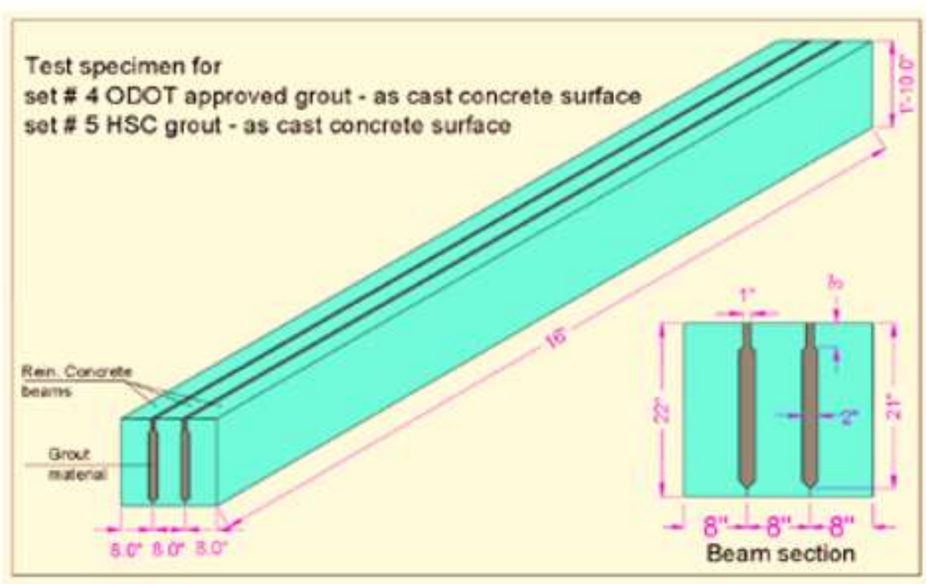
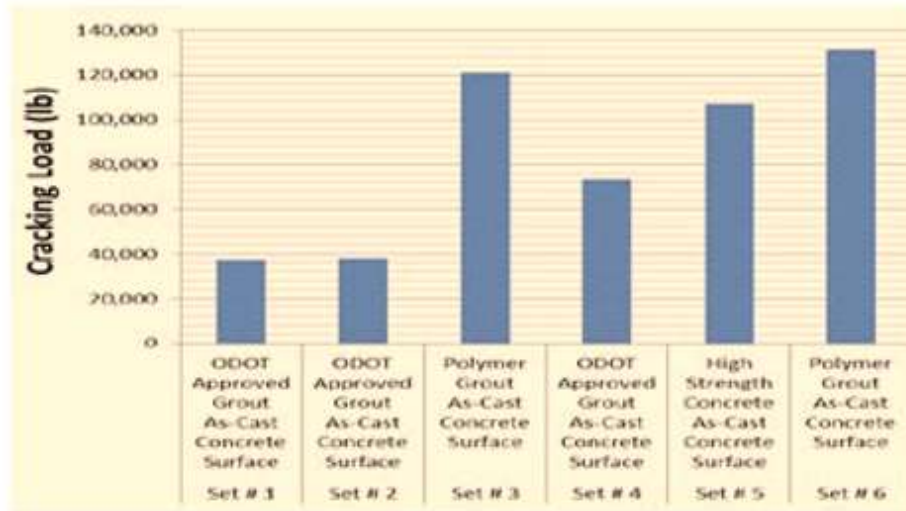


Fig. 2 Differential Deflection Test (Left); Leakage Test (Middle); and Deflection Measurements (Right)

Waterproofing Details of Connections for Adjacent PC Box Beam Bridges

Sample beams were tested with a variety of grouts, keyway geometries and surface preparations under symmetric loading





Waterproofing Details of Connections for Adjacent PC Box Beam Bridges

Analysis and testing of eccentric loading was also done

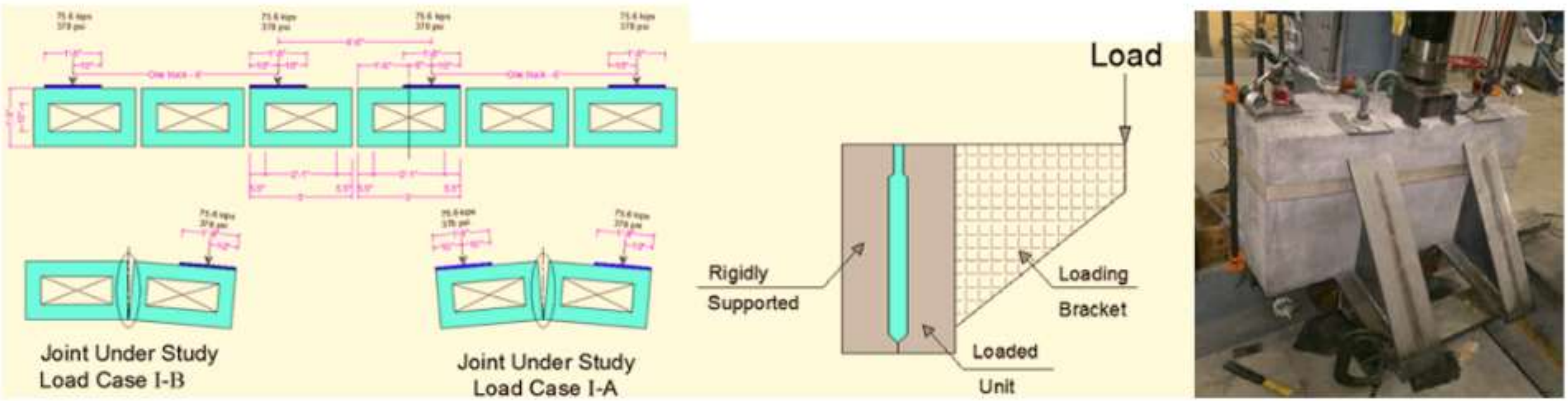
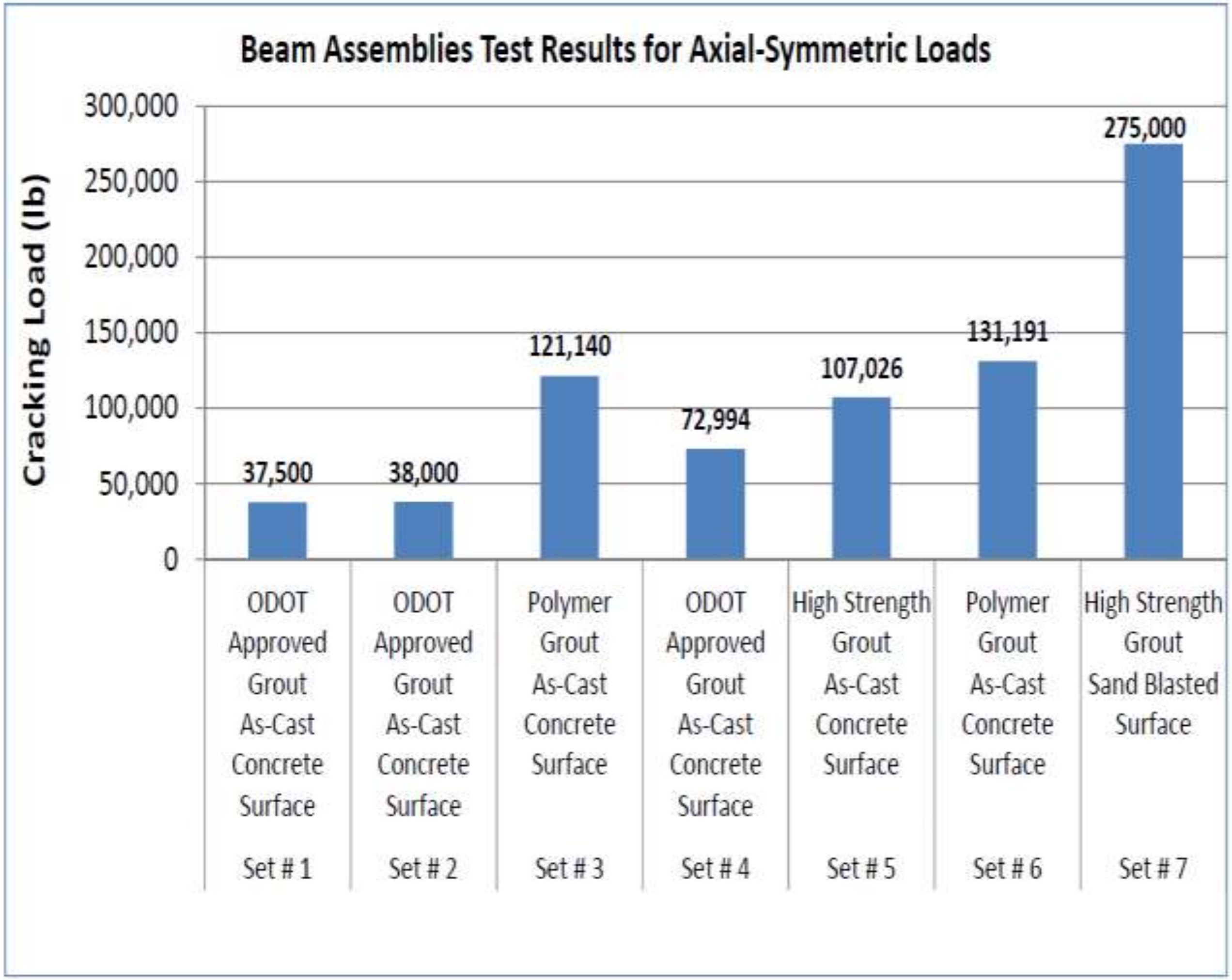


Fig. 4 Typical Structural Model (Left); Setup for Eccentric Load Tests (Middle and Right)


Beam Assemblies Test Results for Axial-Symmetric Loads
Cracking Load (lb)
300,000
250,000
200,000
150,000
100,000
50,000
0
37,500
38,000
121,140
72,994
107,026
131,191
275,000
ODOT Approved Grout As-Cast Concrete Surface
Set # 1
ODOT Approved Grout As-Cast Concrete Surface
Set # 2
Polymer Grout As-Cast Concrete Surface
Set # 3
ODOT Approved Grout As-Cast Concrete Surface
Set # 4
High Strength Grout As-Cast Concrete Surface
Set # 5
Polymer Grout As-Cast Concrete Surface
Set # 6
High Strength Grout Sand Blasted Surface
Set # 7

Key Way Depth	Grout Materail	# of Specimes	Surface Roughness	Set #	Failure Load (lb)
Partial depth	ODOT-Approved List	2	Sandblasted Surface	1	800
Full depth	ODOT-Approved List	2	As-Cast	1	300
Full depth	ODOT-Approved List	2	Sandblasted Surface	1	Failure in Concrete Unit
Full depth	ODOT-Approved List	2	Sandblasted Surface	2	20,000
Full depth	HSC-Grout	2	As-Cast	1	Failure in Concrete Unit
Full depth	HSC-Grout	2	Sandblasted Surface	1	Failure in Concrete Unit
Full depth	HSC-Grout	2	Sandblasted Surface	2	32,000
Full depth	UHPG	2	Sandblasted Surface	1	Failure in Concrete Unit
Full depth	UHPG	2	Sandblasted Surface	2	8,500
Full depth	Polymer Grout	2	Sandblasted Surface	1	Failure in Concrete Unit
Full depth	Polymer Grout	2	Sandblasted Surface	2	13,000

Eccentric Load Test Matrix

Waterproofing Details of Connections for Adjacent PC Box Beam Bridges

Conclusions

1. The waterproofing membranes themselves seem to have the strength and watertightness needed.
2. Construction practices during grouting, waterproofing and paving are likely to blame for many of todays problems
3. Deeper and wider keyways, together with better grout, could provide an appropriate factor of safety to resist the eccentric loading experienced

Waterproofing Details of Connections for Adjacent PC Box Beam Bridges

Old Lessons reaffirmed

1. Grout needs to be mixed properly, too wet – too weak.
2. Sandblast grout joints
3. Take care before, during and after applying waterproofing

ORIL

September/October: Solicitation for Research Ideas

November/December: ORIL Board Review and Prioritization

January/February: Development of Requests for Proposals (RFPs)

March/April: Solicitation of Research Proposals

May/June: Selection of Research Proposals

Contact: oril@dot.ohio.gov

Website: http://oril.transportation.ohio.gov

Any Questions?
Thank you!

RUSS COLLEGE OF ENGINEERING AND TECHNOLOGY

Create for Good.