Structure Mounted Noise Abatement Walls (TL-5)

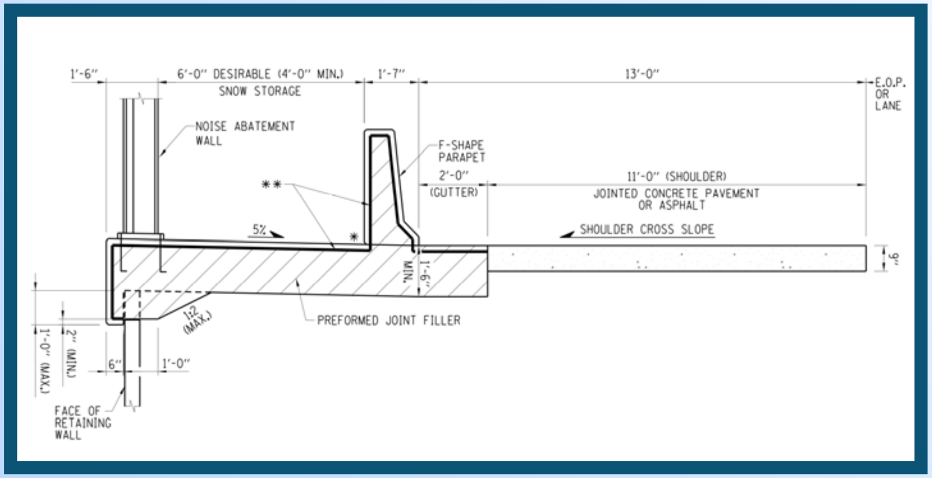
Ahmad Hammad, Ph.D., S.E., P.E., Illinois Tollway GEC

TL-5 Agenda

- Design Development
  - Design History
  - Necessity of Changes
- Summary of Structure Mounted Noise Abatement Wall (NAW) (TL-5)
  - Benefits
- Simulations and Results
- Implementation

Development History

- Existing standard - a TL-5 barrier, 4-foot space and NAW
- Consistent with AASHTO LRFD Section 15 – Design of Sound Barriers
  - **Case 4**: For sound barriers behind a crashworthy traffic railing with a sound barrier set back more than 4 feet: <u>vehicular collision forces need not be considered</u>.



Necessity of Changes

- Need for innovative design to address existing challenges:
  - Trash build-up in 4-foot gap between barrier and noise wall contributes to extensive maintenance burden
  - Maintenance is unable to remove snow build-up
  - Unutilized space for vehicle or maintenance use

Development History

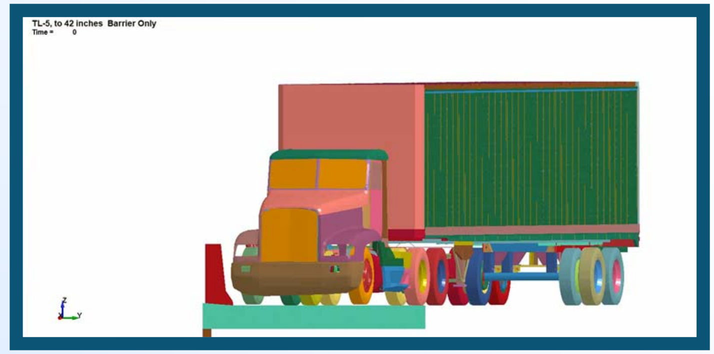
- Innovations were pursued for a NAW attached to a concrete barrier
- Coordinated effort – Iterations of various design solutions resulted from the Illinois Tollway, Texas Transportation Institute, PMO, CTS DCM/OR/Phase 1 DSE
- Consideration included:
  - ITS equipment locations
  - Types and designs of NAW
  - Crashworthiness
  - Barrier design and aesthetics
- Illinois Tollway is the first agency to begin TL-5 NAW implementation

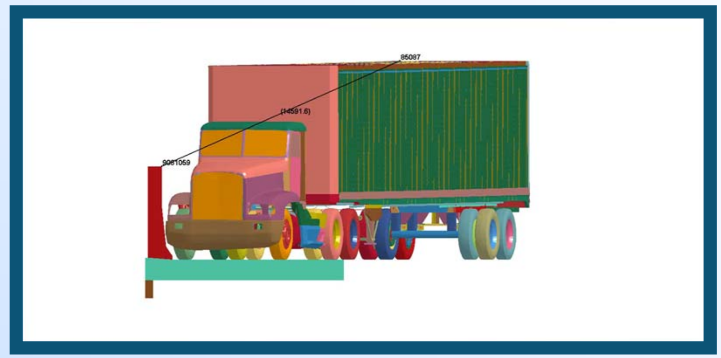
Design Development

Simulation Analysis TL-5:

Based on AASHTO MASH at TTI

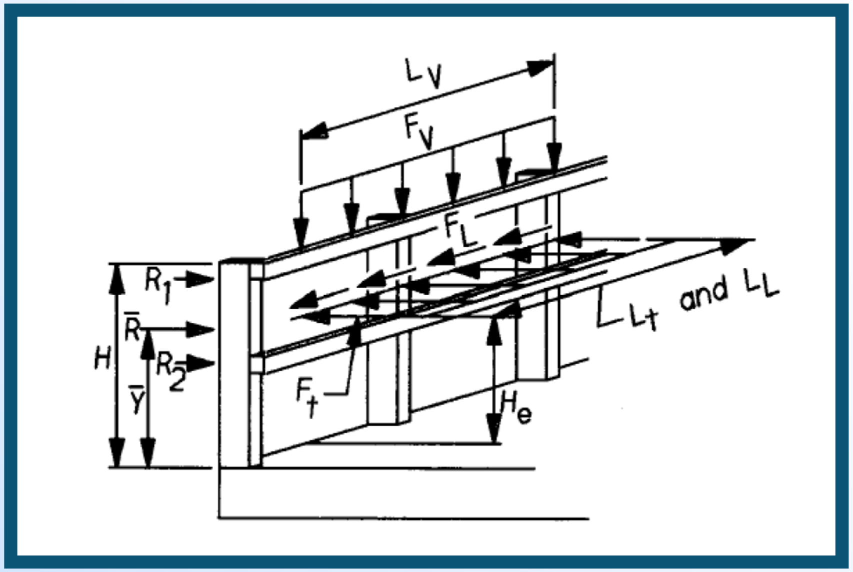
- 42-inch barrier with NAW attached to the back
- 72-inch barrier with NAW attached to the back





Analysis and Design

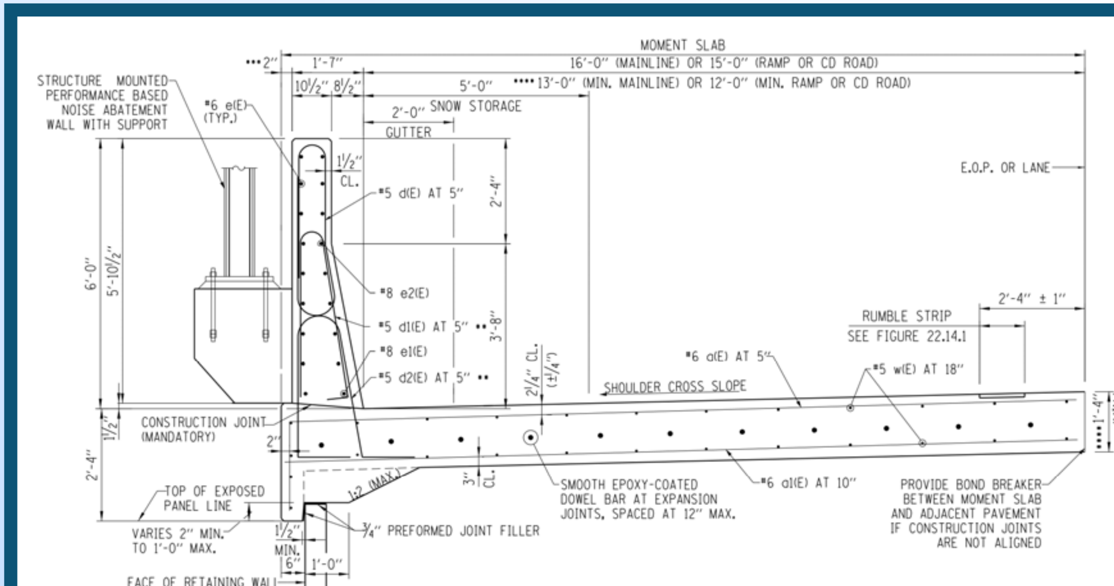
Design Forces and Designations	TL-3	TL-4	TL-4	TL-5	TL-6	TL-5-2
Rail Height, H (in)	27	32		42	90	
Rail Height, H (in)	32	36	≥36	42		>42
F_t Transverse (k)	54	54		124	175	
F_t Transverse (k)	70	70	80	160		260
F_L Longitudinal (k)	18	18		41	58	
F_L Longitudinal (k)	18	22	28	75		75
F_v Vertical (k)	4.5	18		80	80	
F_v Vertical (k)	4.5	38	33	160		80
L_L (ft)	4	3.5		8	8	
L_L (ft)	4	4	5	10		10
L_v (ft)	18	18		40	40	
L_v (ft)	18	18	18	40		40
H_e (in)	24	32		42	56	
H_e (in)	24	25	30	34		43
	AASHTO LRFD (8th Edition 2017)					
	NCHRP 22-20(2)					



Source: Table 13.2-1 and Figure A13.2-1, *AASHTO LRFD Bridge Design Specifications* (8th Edition, 2017)

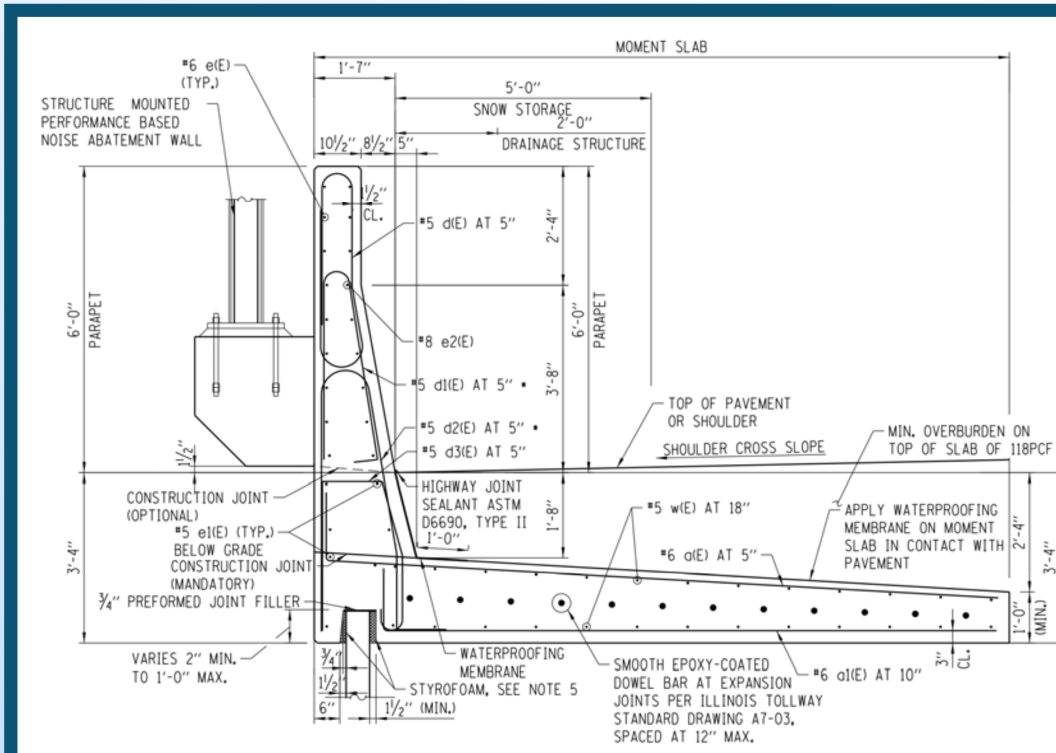
Summary of Structure Mounted NAW (TL-5)

- By designing a continuous surface from the edge of the pavement to the barrier face, it creates a continuous drivable shoulder
- Meeting of new safety requirements to meet Test Level 5
- Creating a new snow storage configuration when noise walls are present



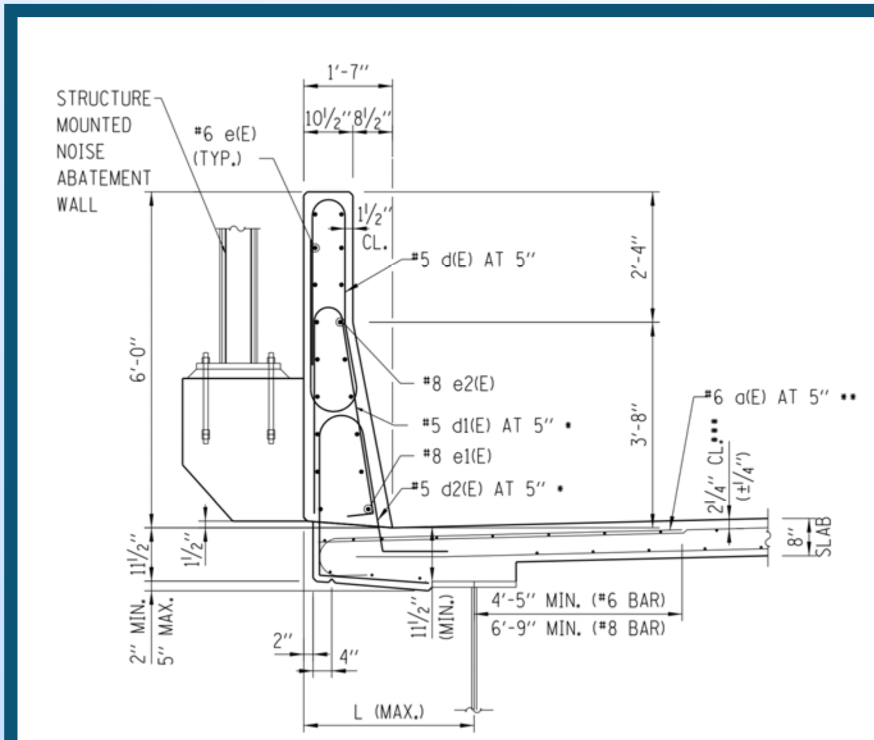
Summary of Structure Mounted NAW (TL-5)

- Provides 16 feet of continual shoulder and snow storage space
- Improves maintenance access
- 14 feet usable for Maintenance of Traffic (MOT)



Summary of Structure Mounted NAW (TL-5)

- Larger spread width allows for fewer inlets
- Ability to shrink typical in constrained ROW
- Can be used on bridges



Simulation

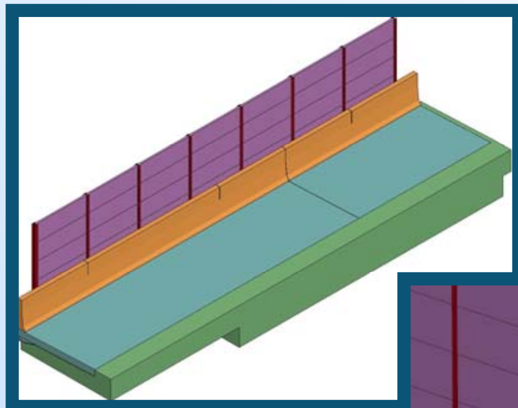
- These barriers have three key distinct features that set them aside from known previously tested bridge rails:
  - Taller barrier (6 foot, compared to 42 inches tall concrete barrier)
  - Sloped roadway (4% shoulder slope downward toward the barrier)
  - Presence of NAW on the field side of the barriers

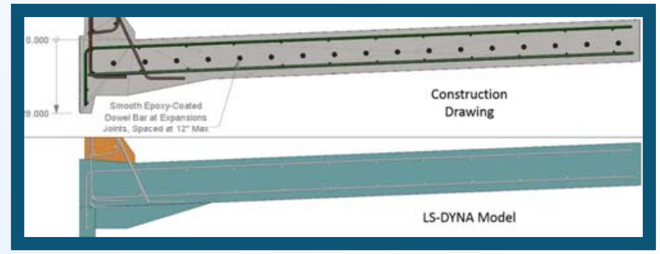
Simulation

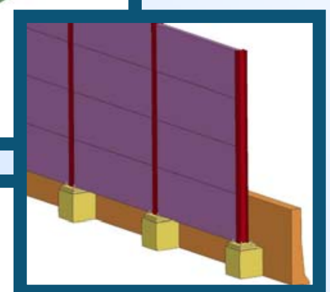
- Nonlinear finite element explicit dynamic integration
- Detailed modeling of:
  - Geometry
  - Material behavior
  - Connectivity
  - Contacts

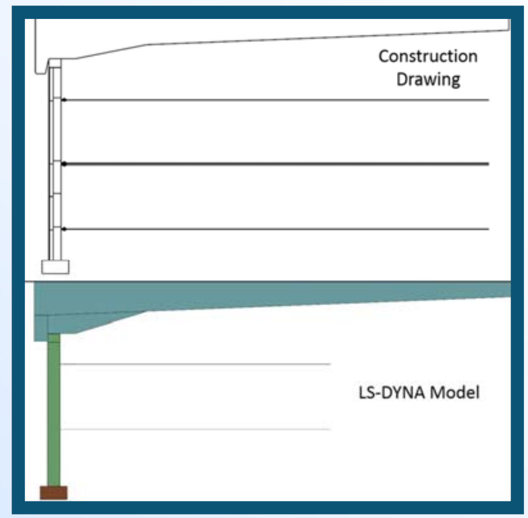
Simulation

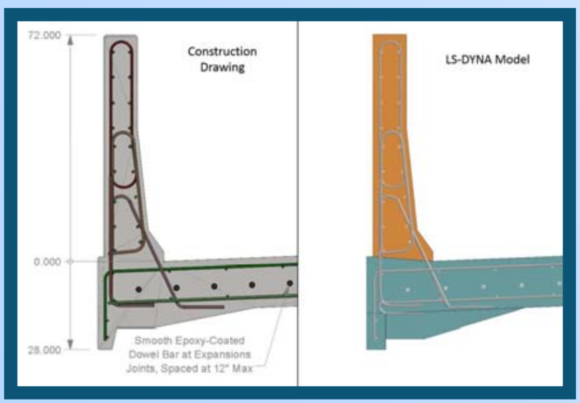
- F-Shape System attached to an exposed moment slab on MSE wall

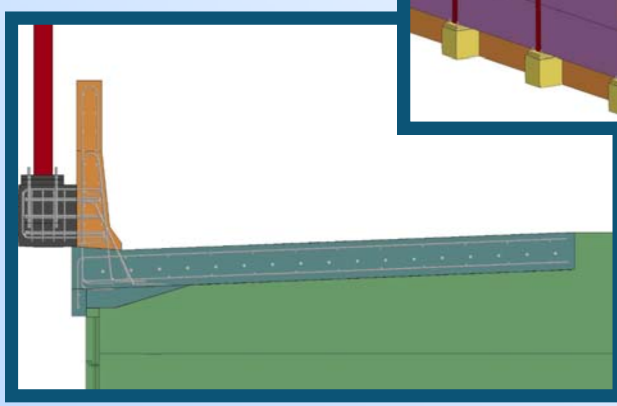






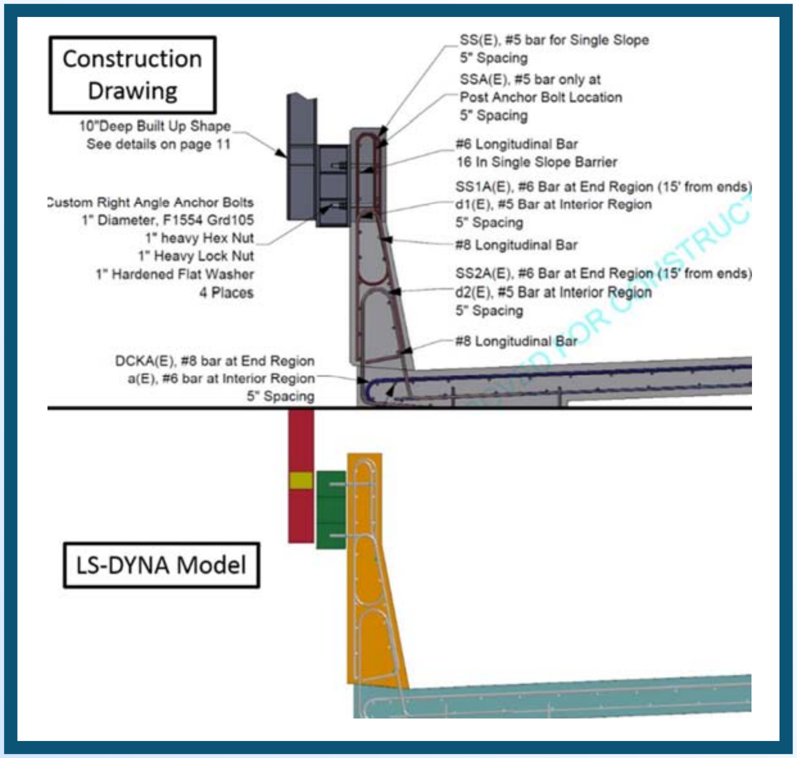






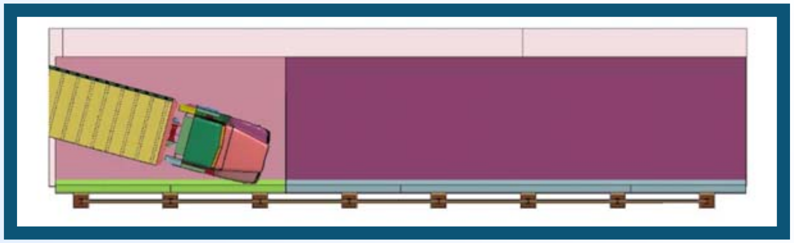
Simulation

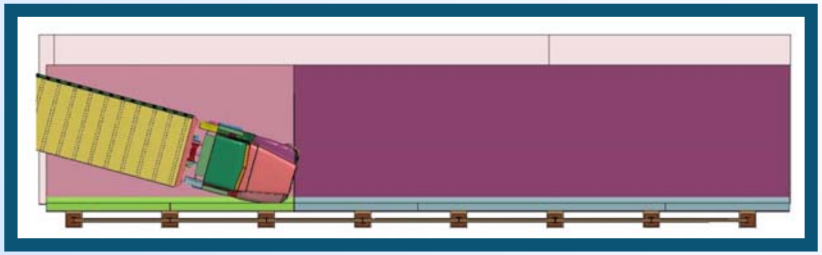
- Constant slope barrier on bridge deck
- Semi-truck model



Simulation Results

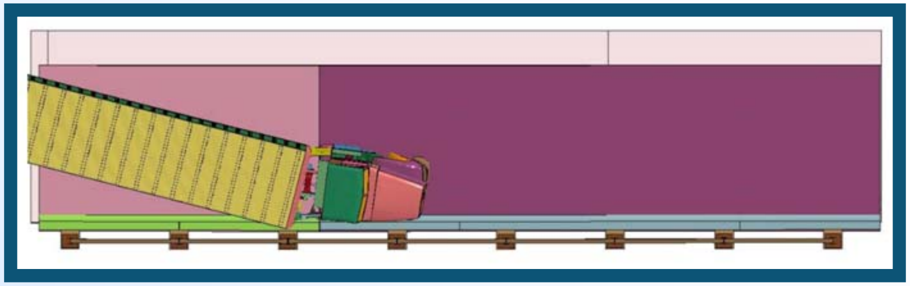
- Tractor-van trailer at impact time
- Interaction of major stiff components of the tractor frame with the barrier (0.035 s)

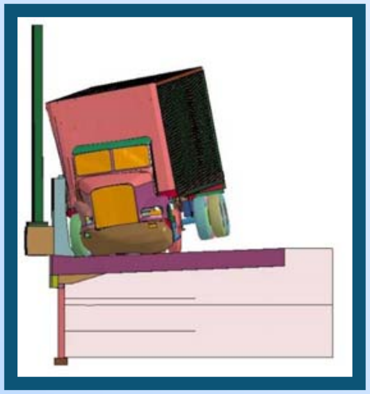


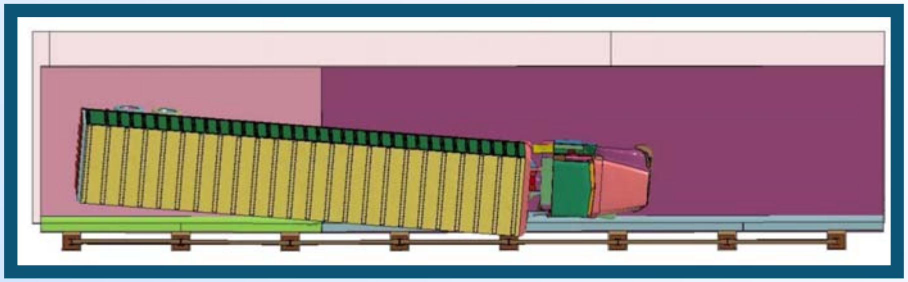
Simulation Results

- Font lower edge of the trailer and the back tandem axles of the tractor engage the barrier (0.19 s)



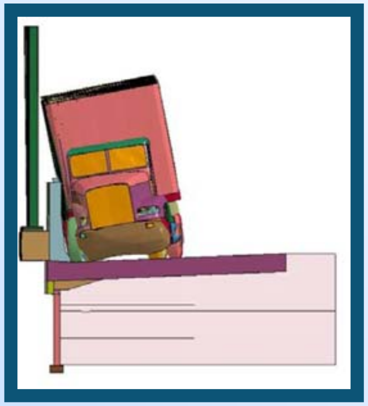
- Tractor unit starts to redirect while the trailer unit is still following the initial impact direction (0.535 s)

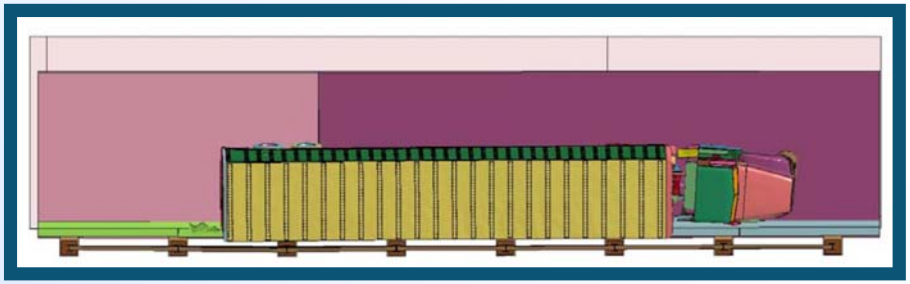




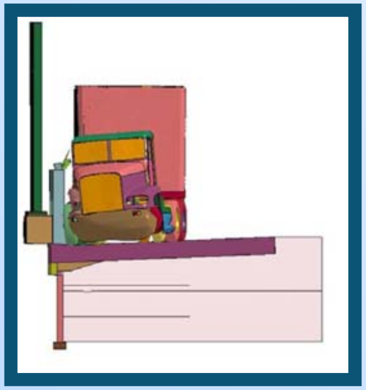
Simulation Results

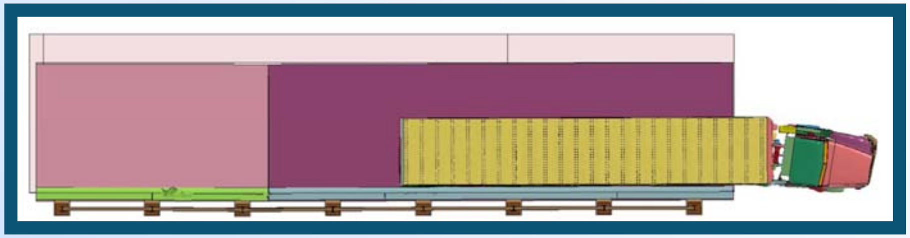
- Back tandem of trailer unit impacts the barrier (0.76 s)





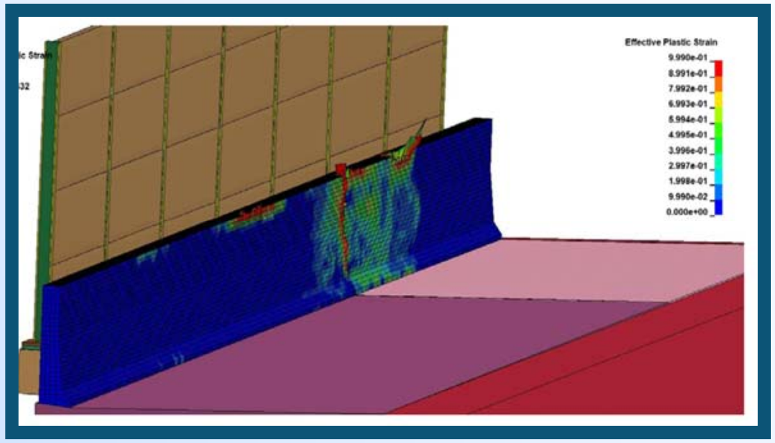
- Tractor-van trailer starts to exit the system model (1.205 s)



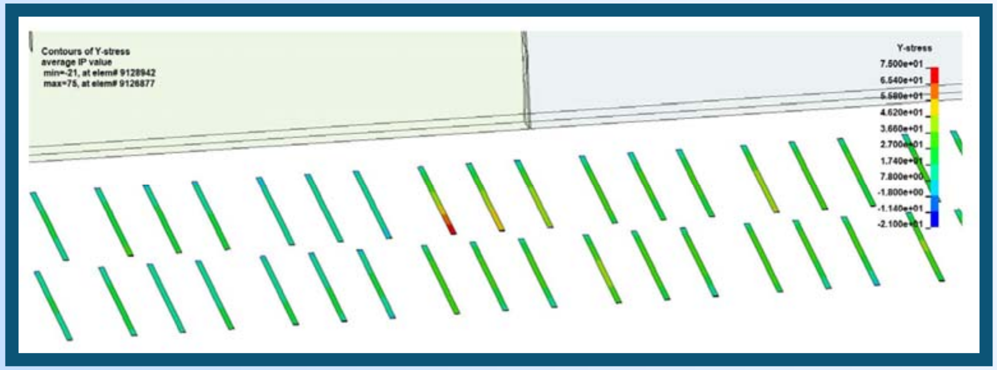


Simulation Results

- Overview of the damage profile to the concrete barrier due to impact

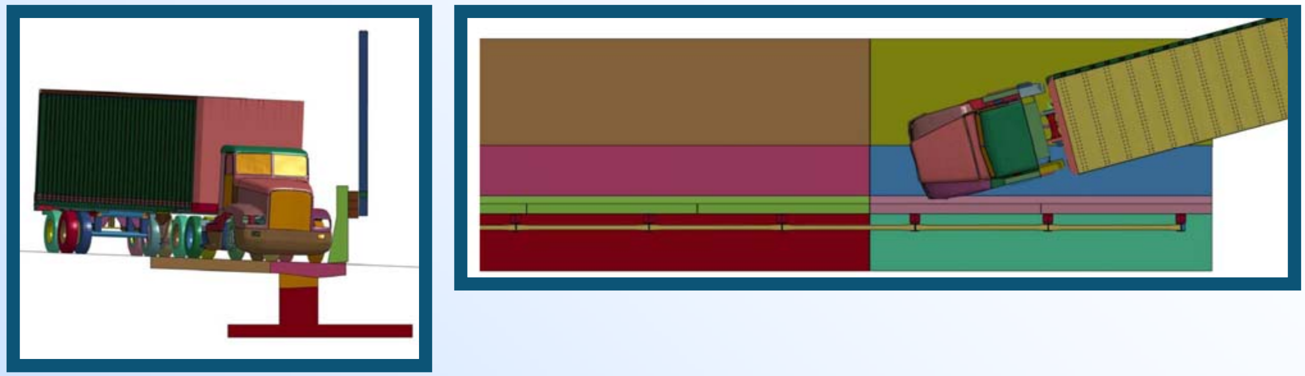


- Strip longitudinal stresses (lateral direction MPa) at 0.200 seconds

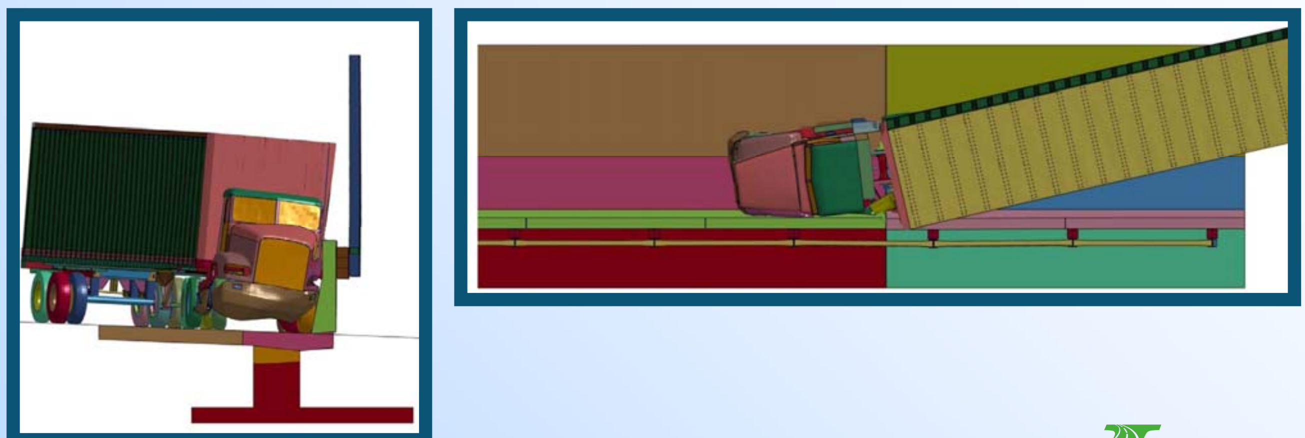


Simulation Results

- Tractor-van trailer at impact time with the single slope barrier on bridge

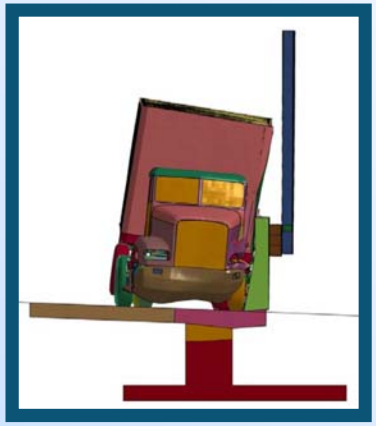


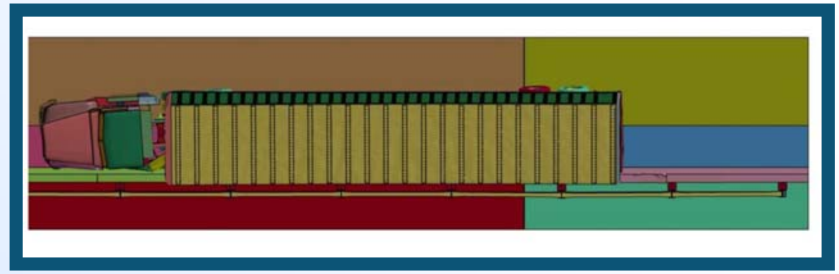
- Interaction of major stiff components of the tractor frame with the barrier (0.205 s)



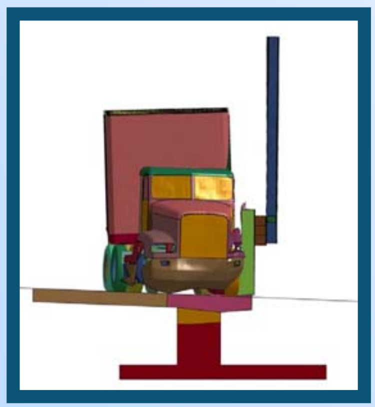
Simulation Results

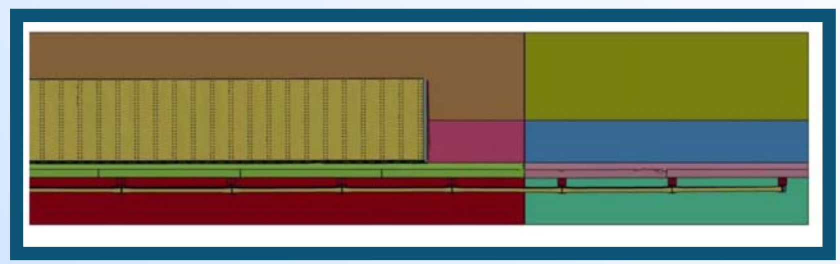
- Tractor unit starts to redirect and becomes parallel to the barrier around (0.795 S)





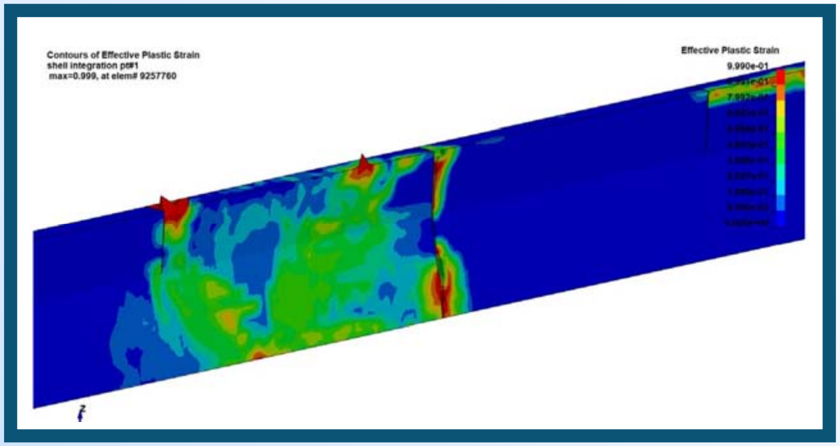
- Tractor-van trailer starts to exit the system model (1.125 s)



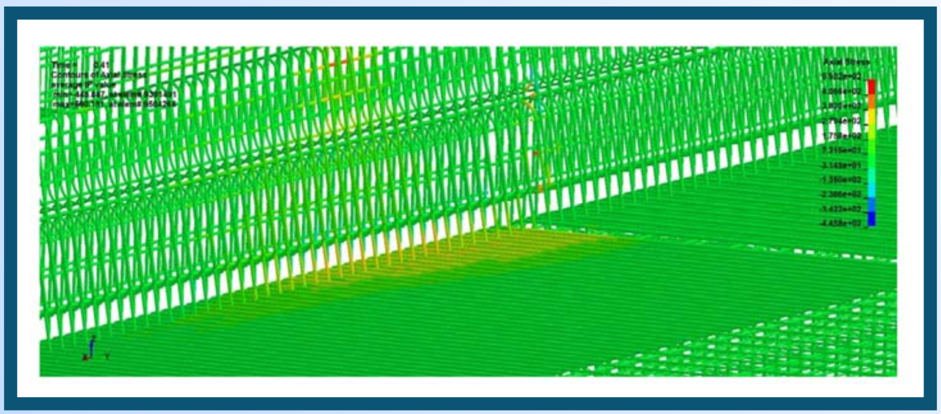


Simulation Results

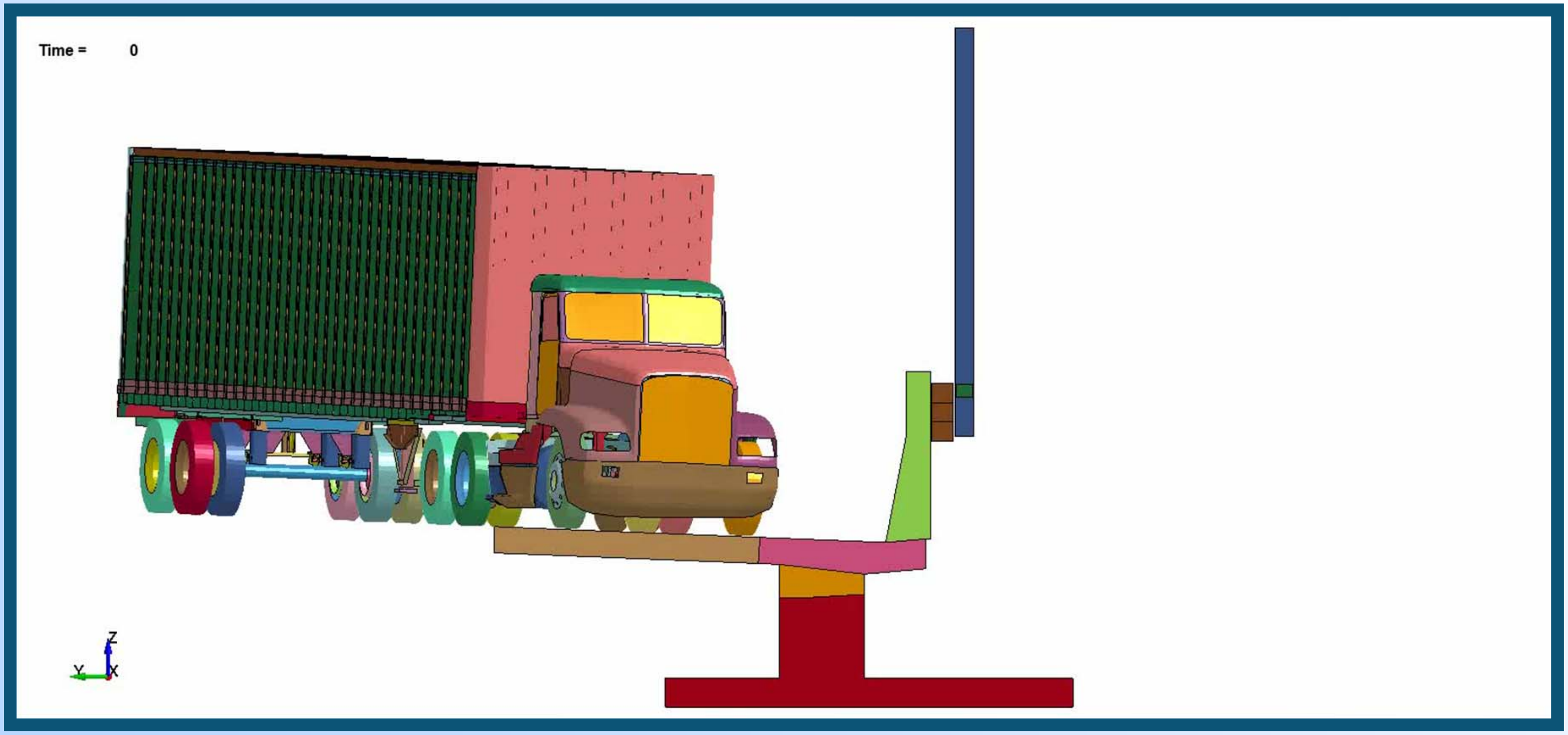
- Overview of the damage profile to the concrete barrier due to impact (0.74 S)



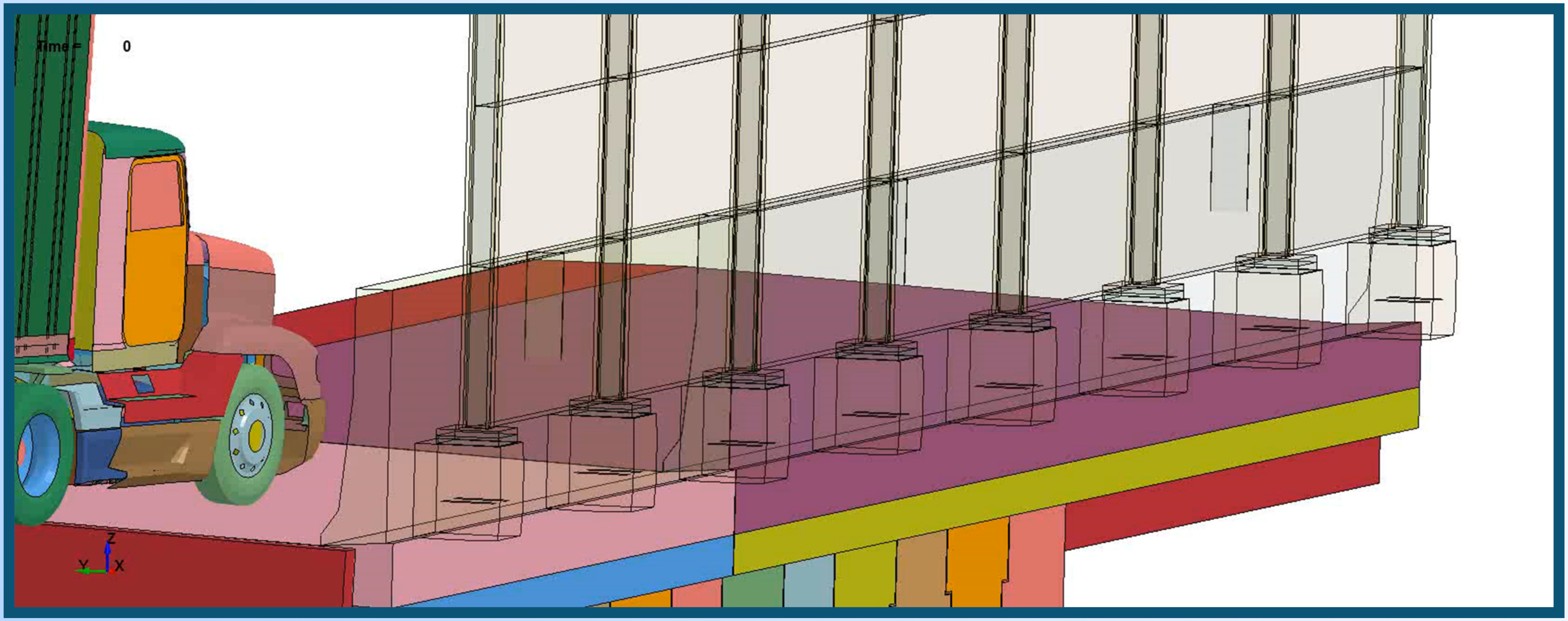
- Stresses in reinforcement



Simulation Results



Simulation Results

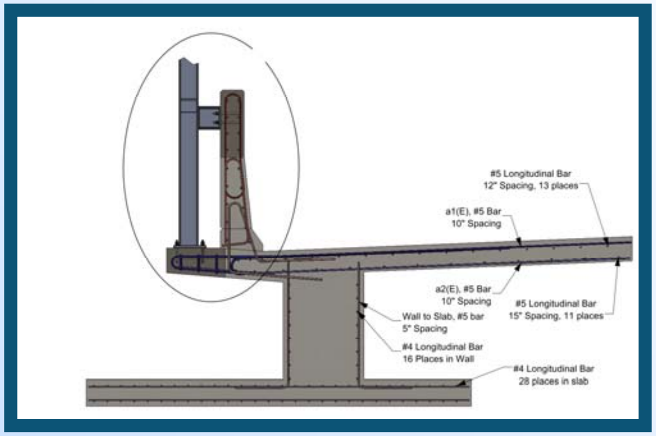


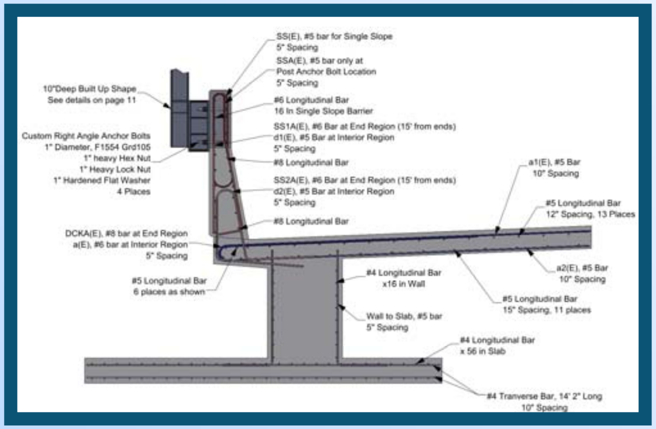
Simulation Results

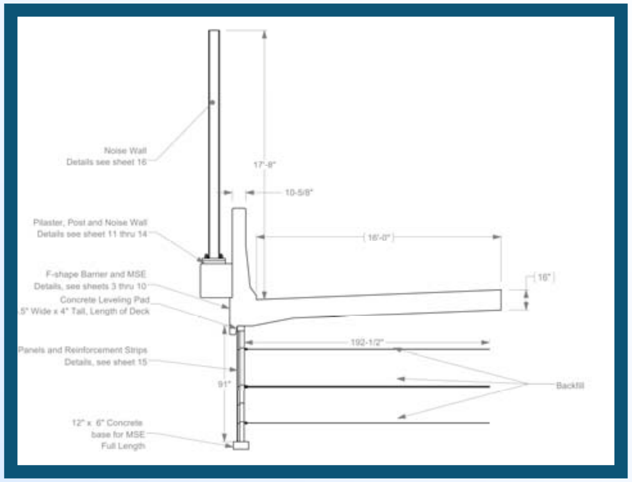
- The analyses indicated that both systems are able to contain and redirect the tractor-van trailer model with reasonable damage and deformation outcome to each system.
- The concrete barrier exhibits a damage profile where cracks are expected.
- Shows potential spalling of top and vertical edges (cover portion) of the barrier regions.
- Stresses in the reinforcement passed the yield mark in some steel bars but was not close to the ultimate strength.
- The simulation did not show a potential of catastrophic material damage for either the reinforcement or the surrounding concrete continuum.
- The trailer unit's lean did not result in contact with the NAW.
- An implementation plan is devised based on the results.

Implementation

- Models will be crash tested at the Texas Transportation Institute, per MASH TL-5:
  - NAW – F-Shape barrier, moment slab on MSE walls
  - NAW – Constant slope barrier on bridge deck
  - NAW – F-Shape barrier on bridge deck







Questions?