Extending Application of SDCL Steel Bridge System to ABC Applications in Seismic Regions

Graduate Student Seminar: ABC Solutions

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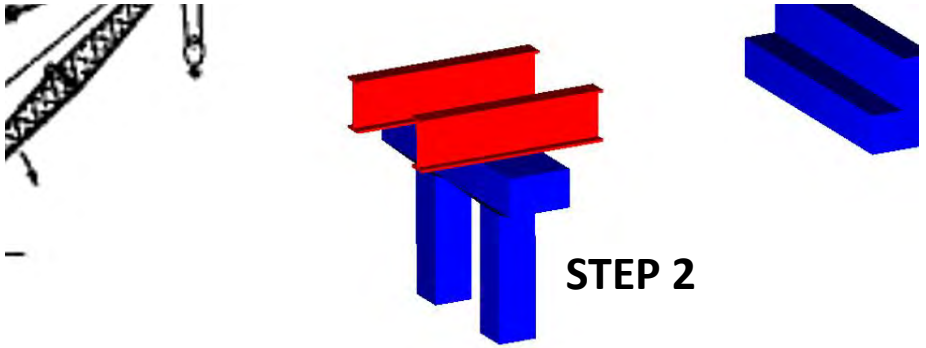
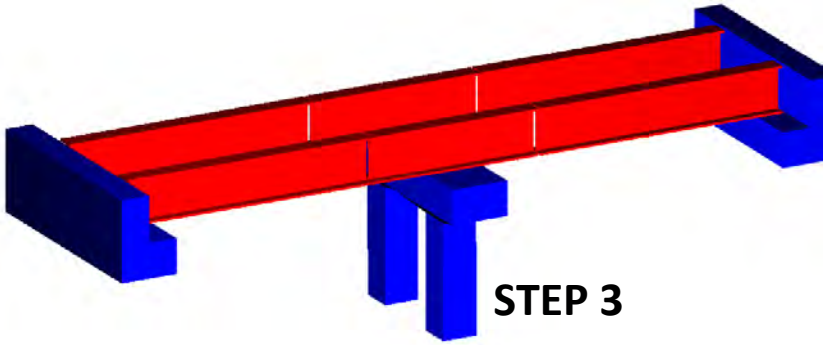
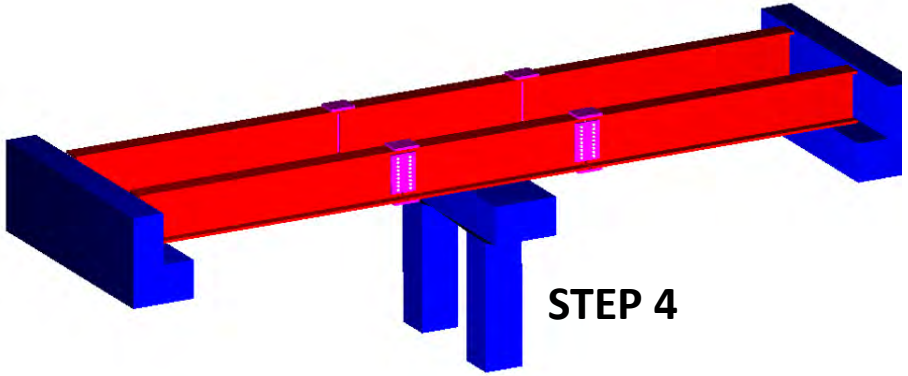
Dr. Aaron Yakel
Dr. Reza Farimani

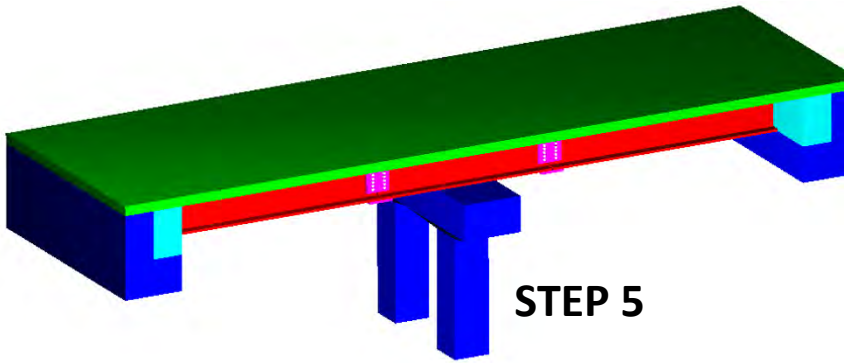
April 29 2016

Conventional Method

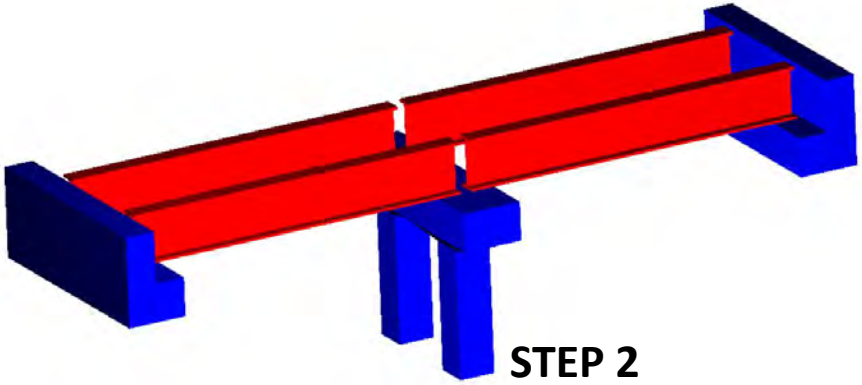


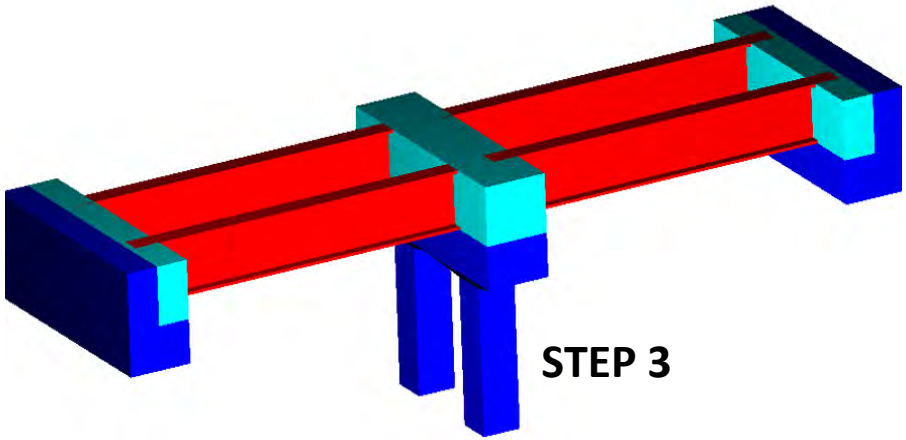


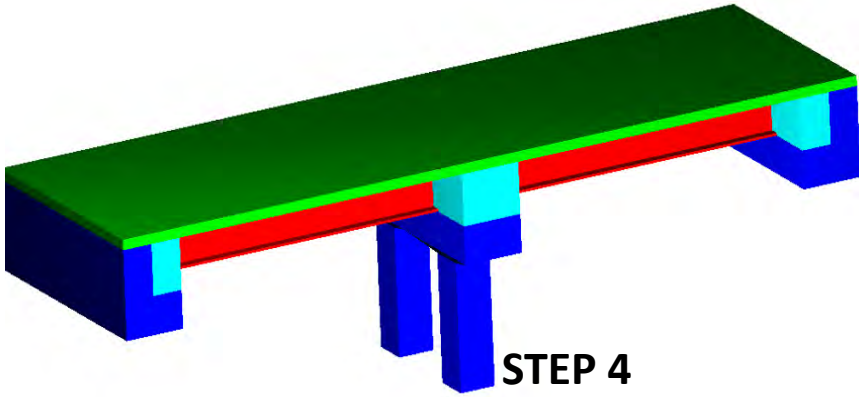




SDCL Method





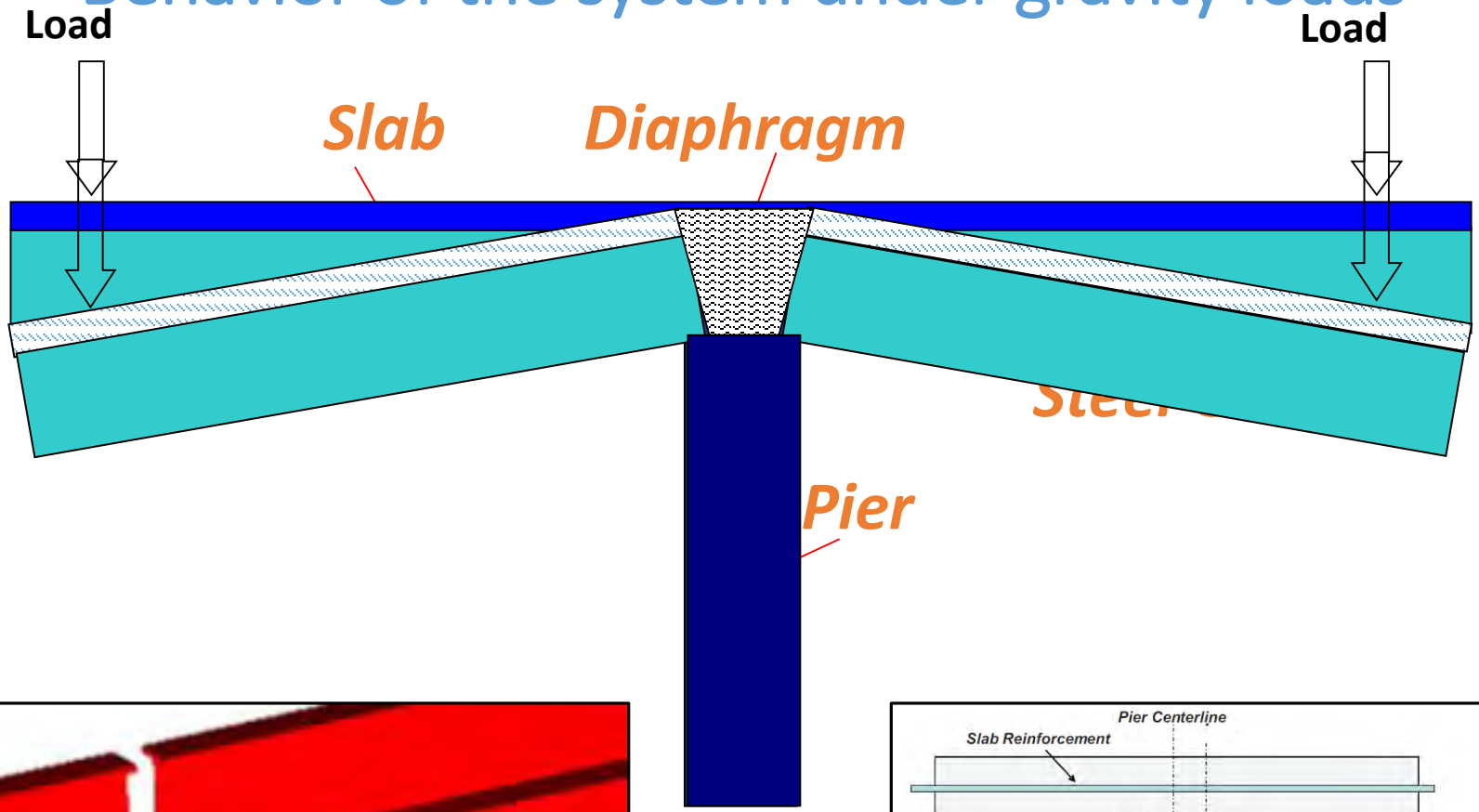


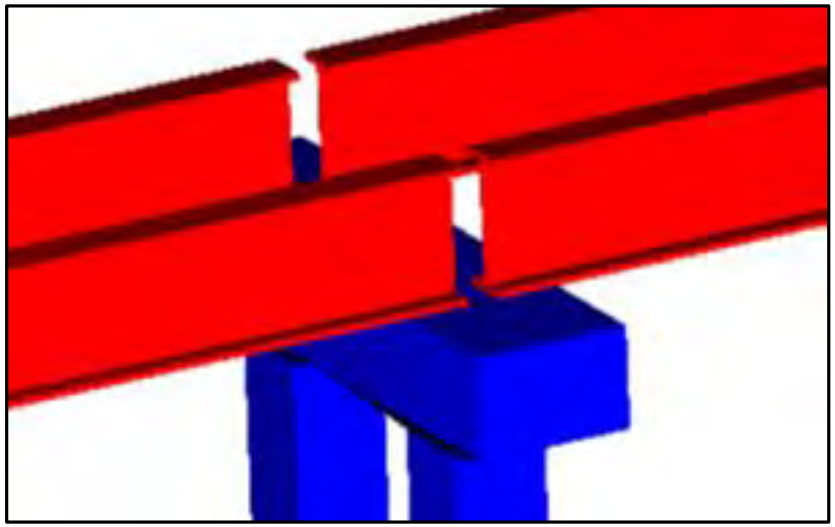
ABC application of SDCL

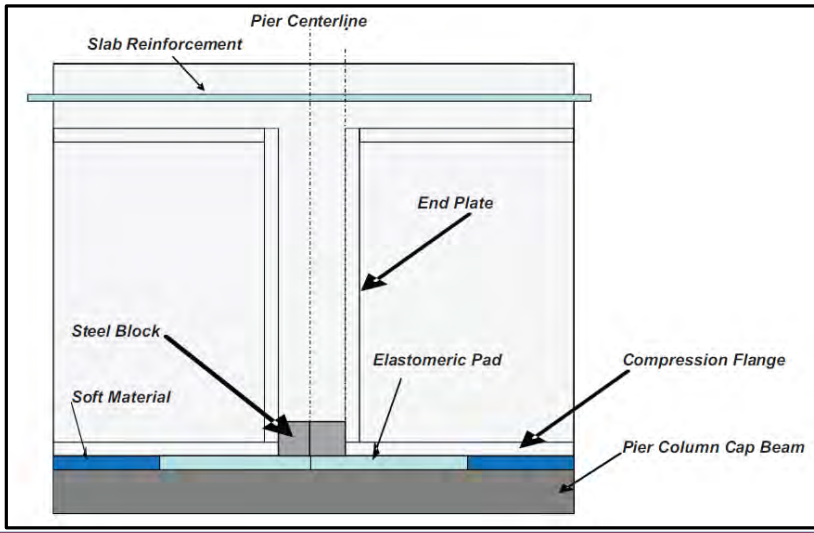
Advantage of SDCL to conventional bridge system

- Lower initial and life-cycle costs
- Easier inspection
- Reduced maintenance

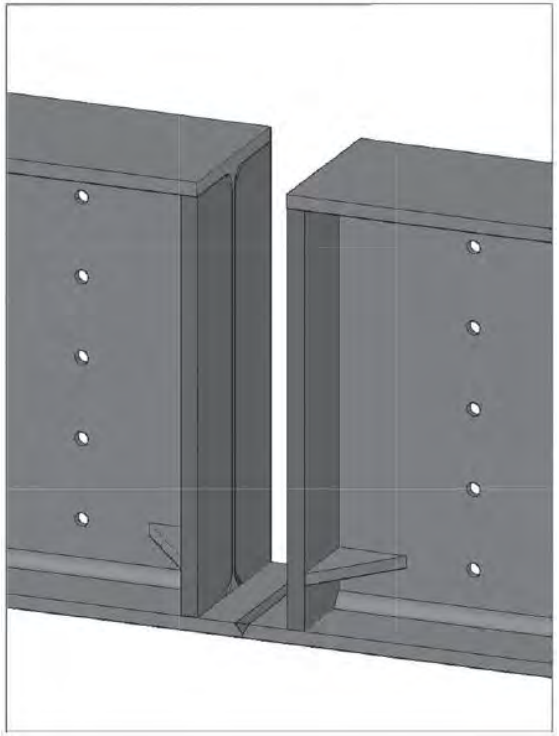
Behavior of the system under gravity loads



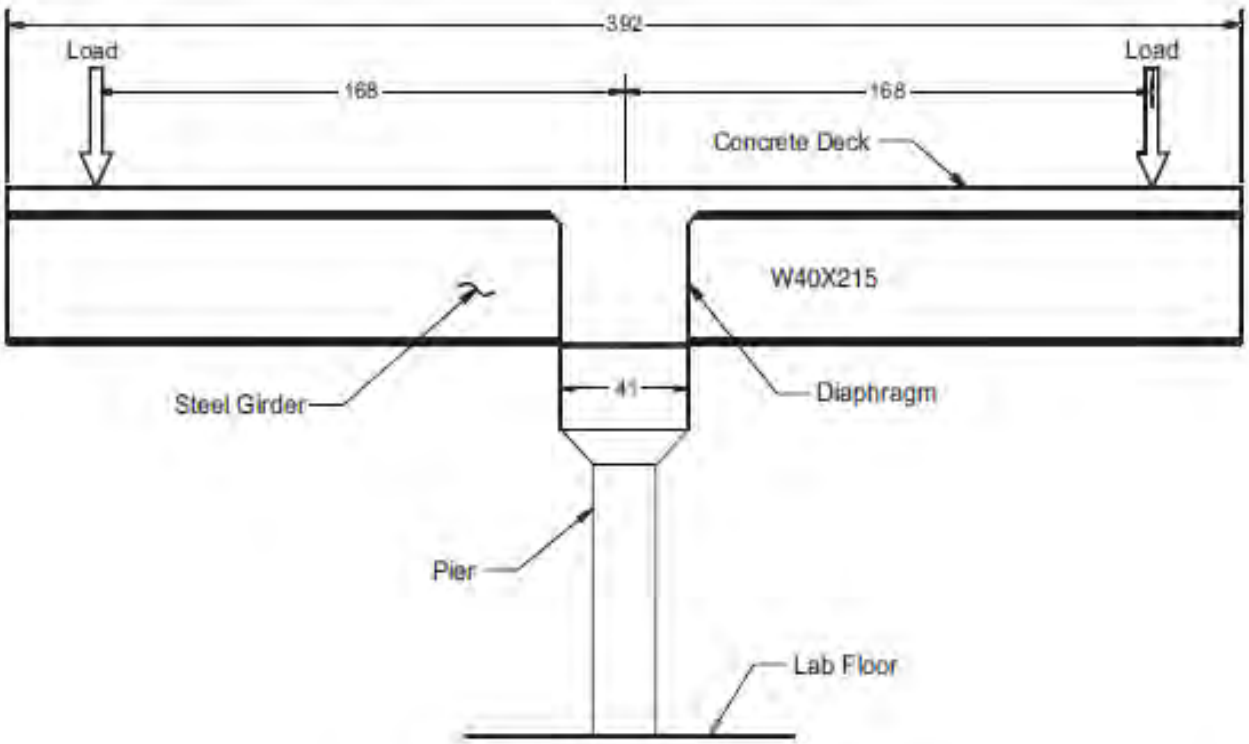


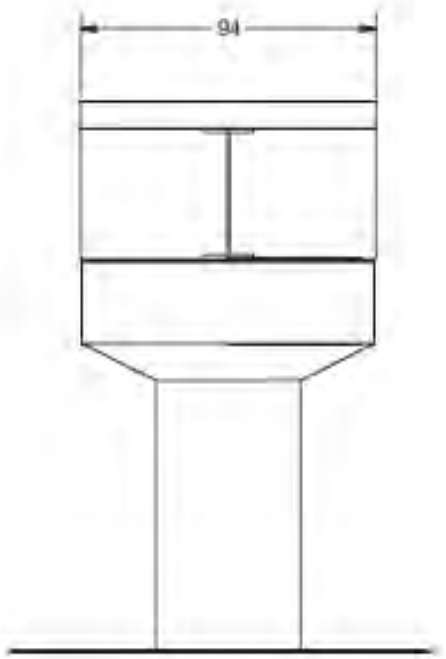


Details of test specimens inside the diaphragm

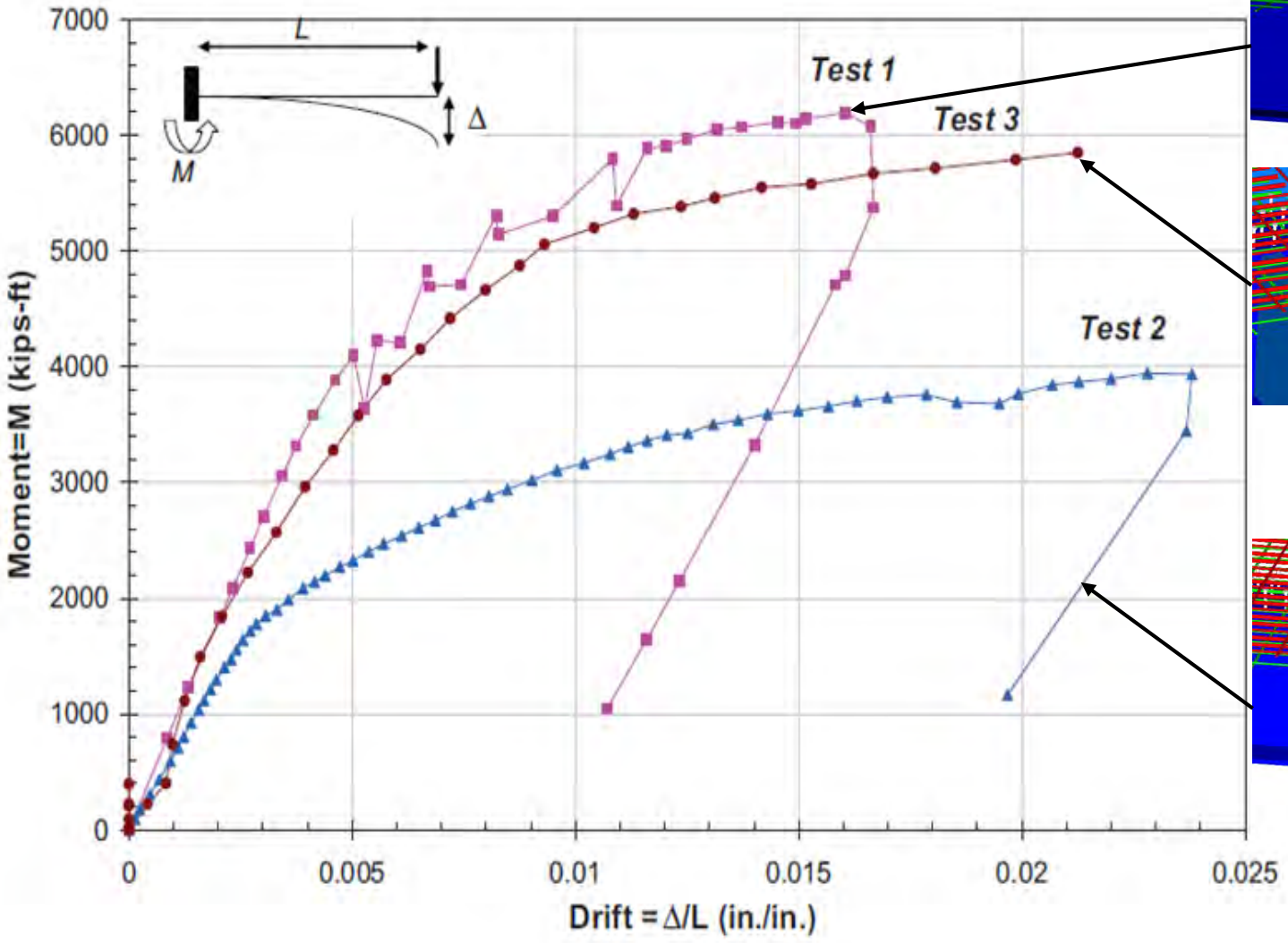


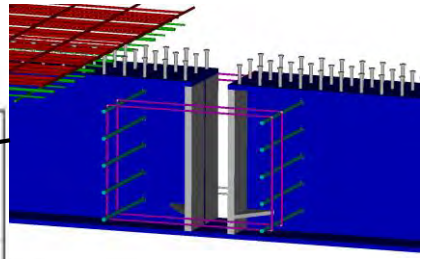
Conceptual test specimen

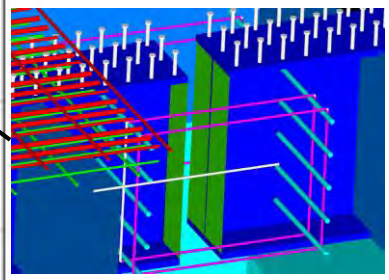


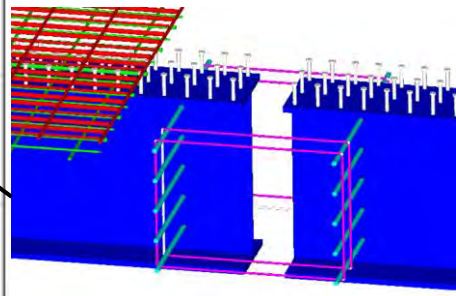


Effect of end details on ultimate moment







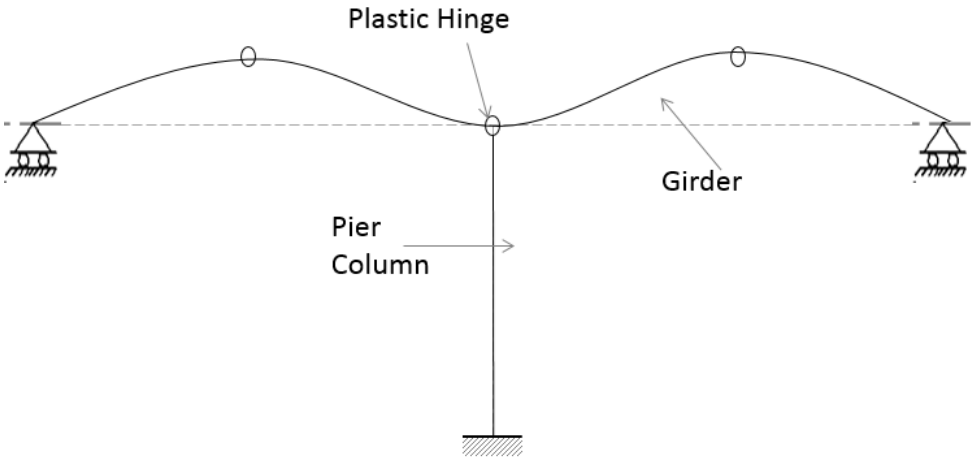


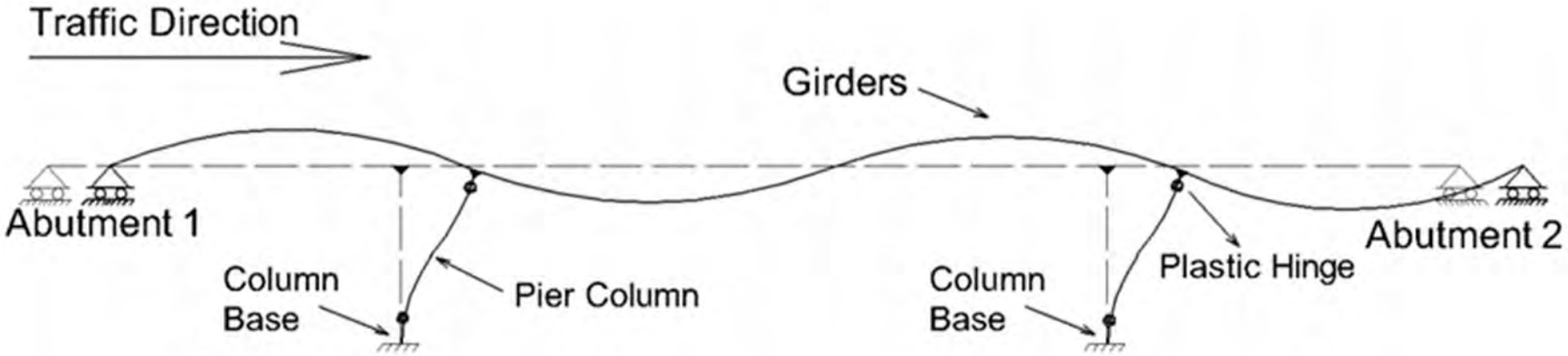
Performance of constructed SDCL bridges

N-2 over I-80 (box)

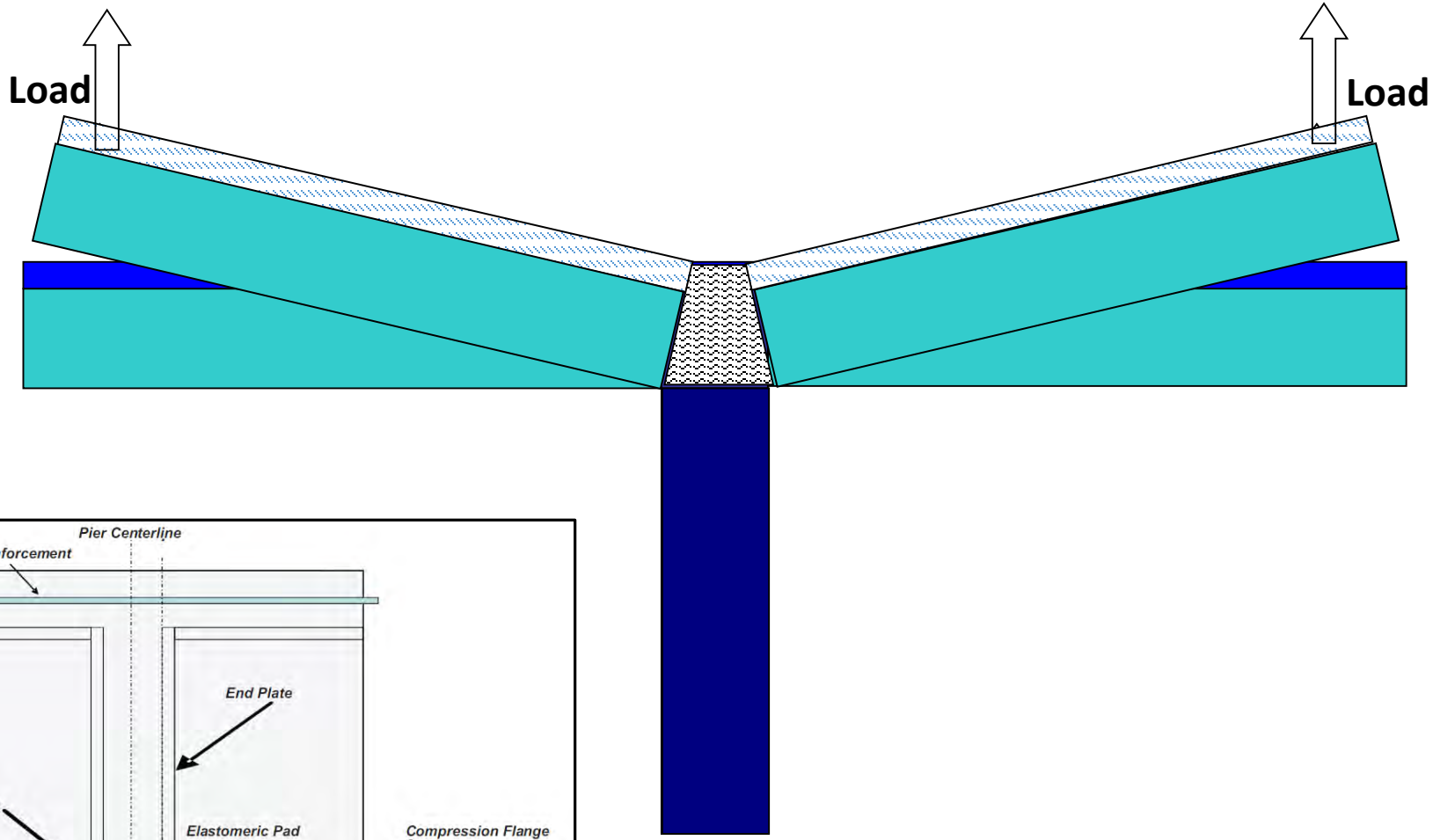
Sprague Street (I-girder)

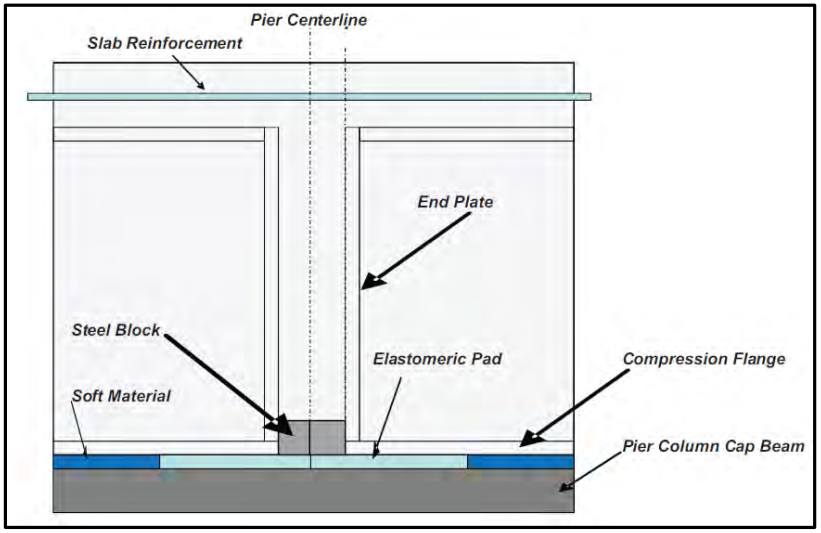
Deformation of the bridge under vertical and longitudinal direction



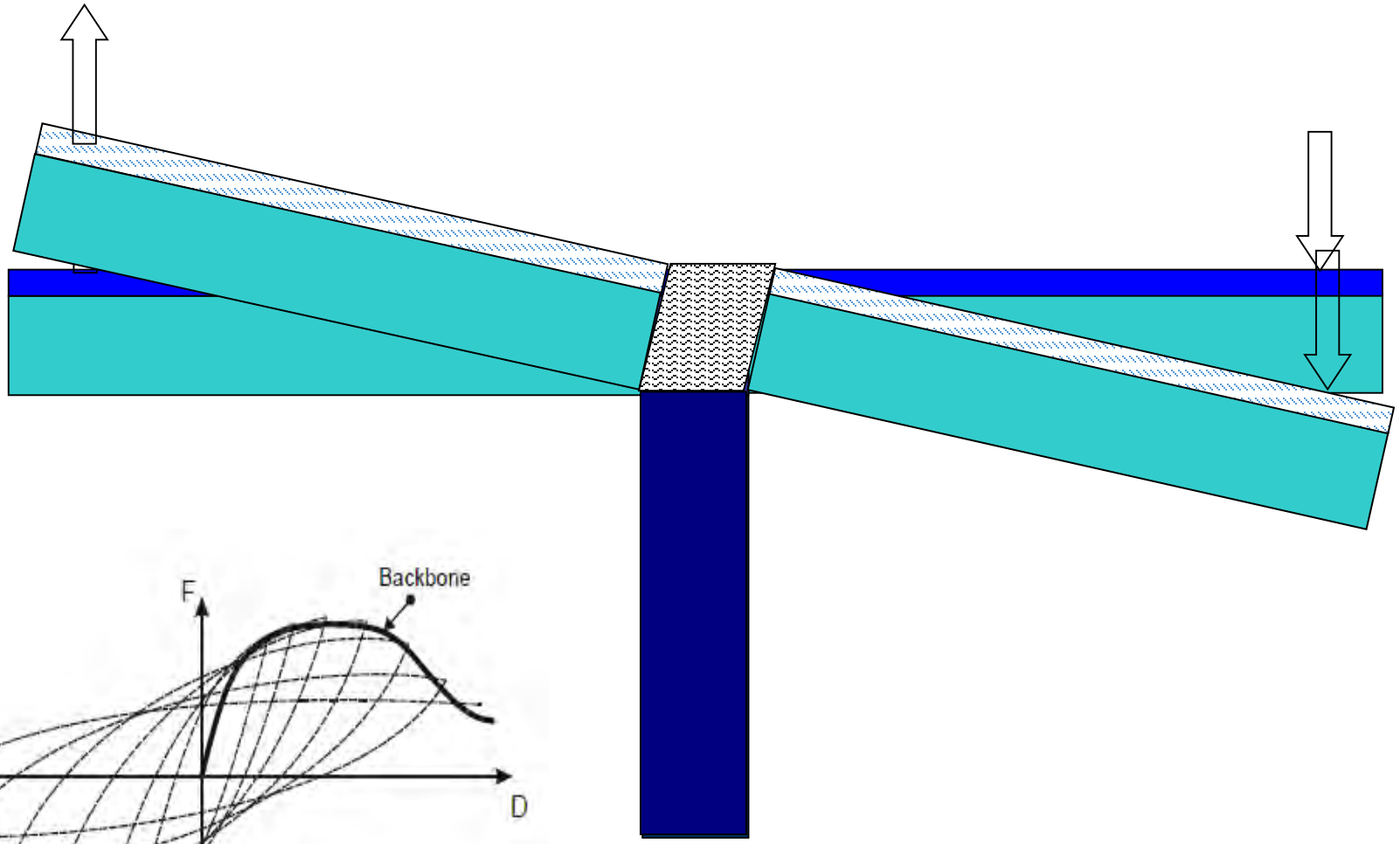


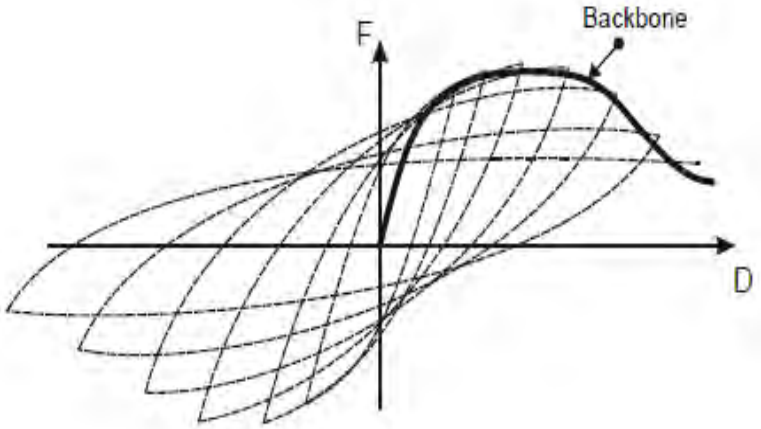
Behavior of the system under vertical component of seismic loads



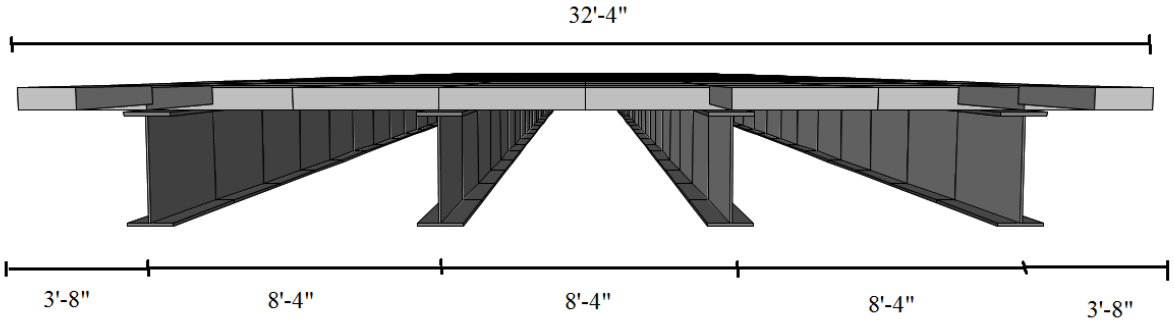


Behavior of the system under longitudinal component of seismic loads

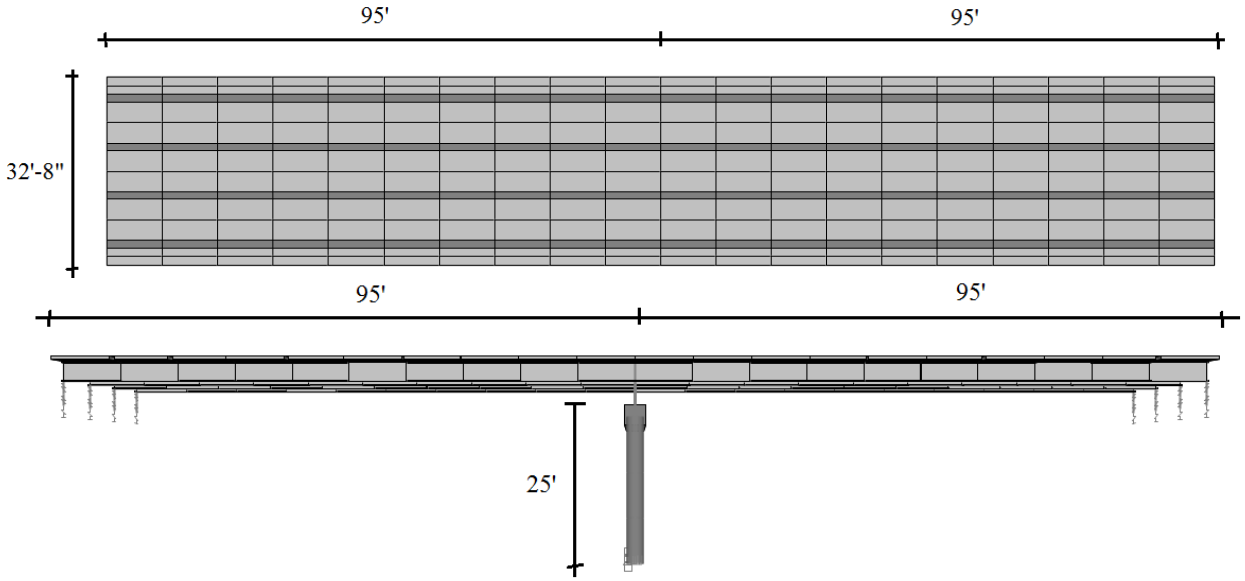




Prototype steel bridge to find the demand



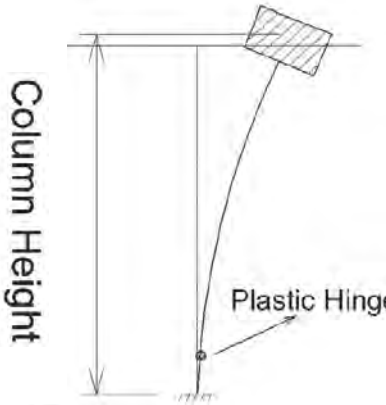
Deck section.



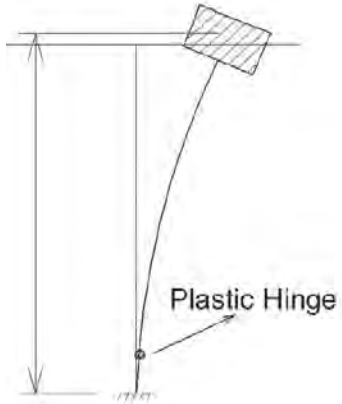
Dimensions in plane and elevation.

Non-Integral Bent Cap:

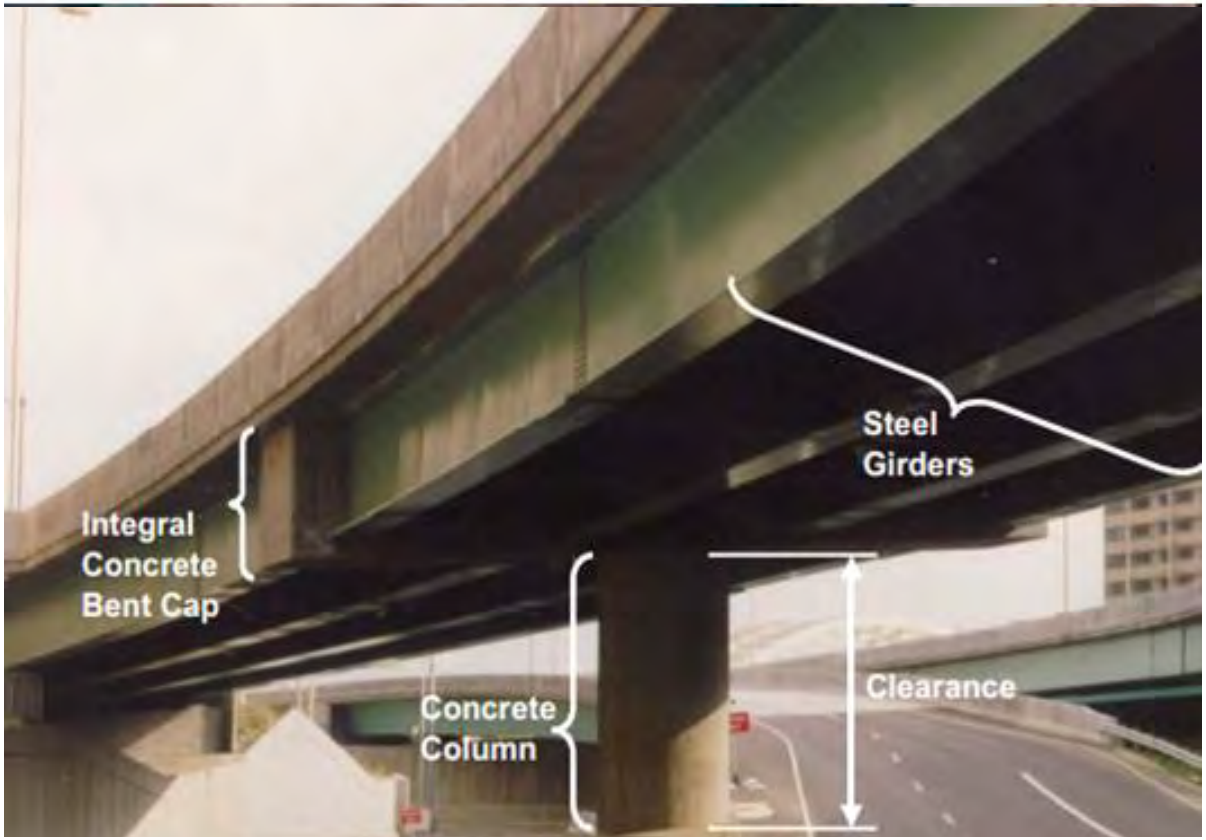
- More popular in Pacific States
- Easier to build



Longitudinal Deformation

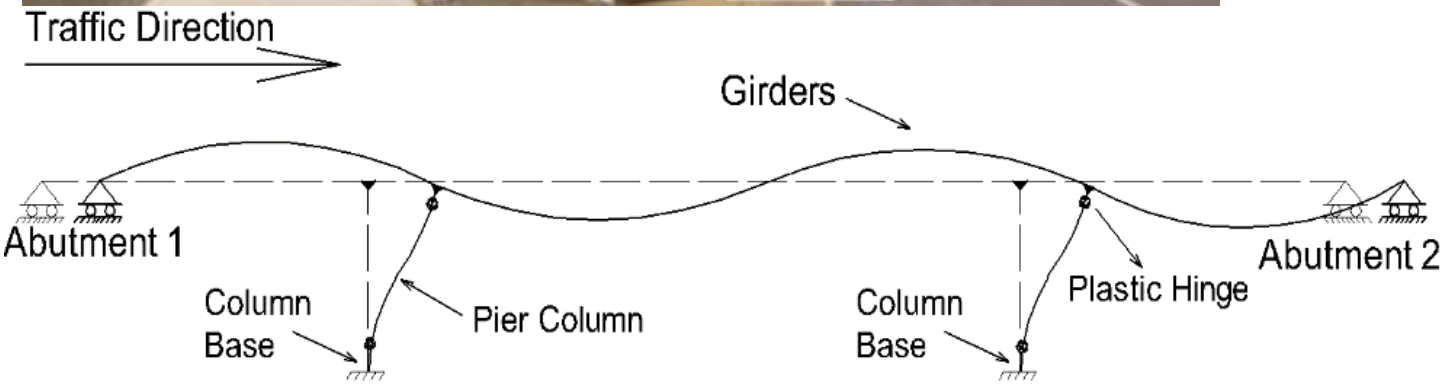


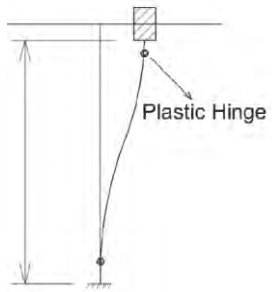
Transverse Deformation



Integral Bent Cap:

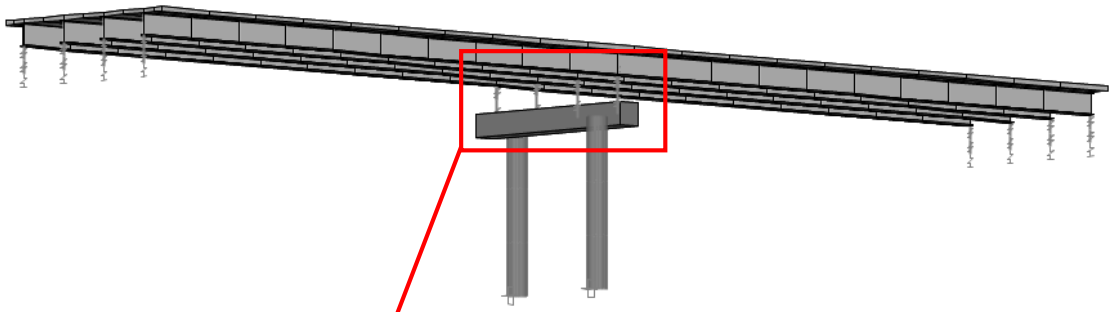
- Higher clearance
- More plastic hinge

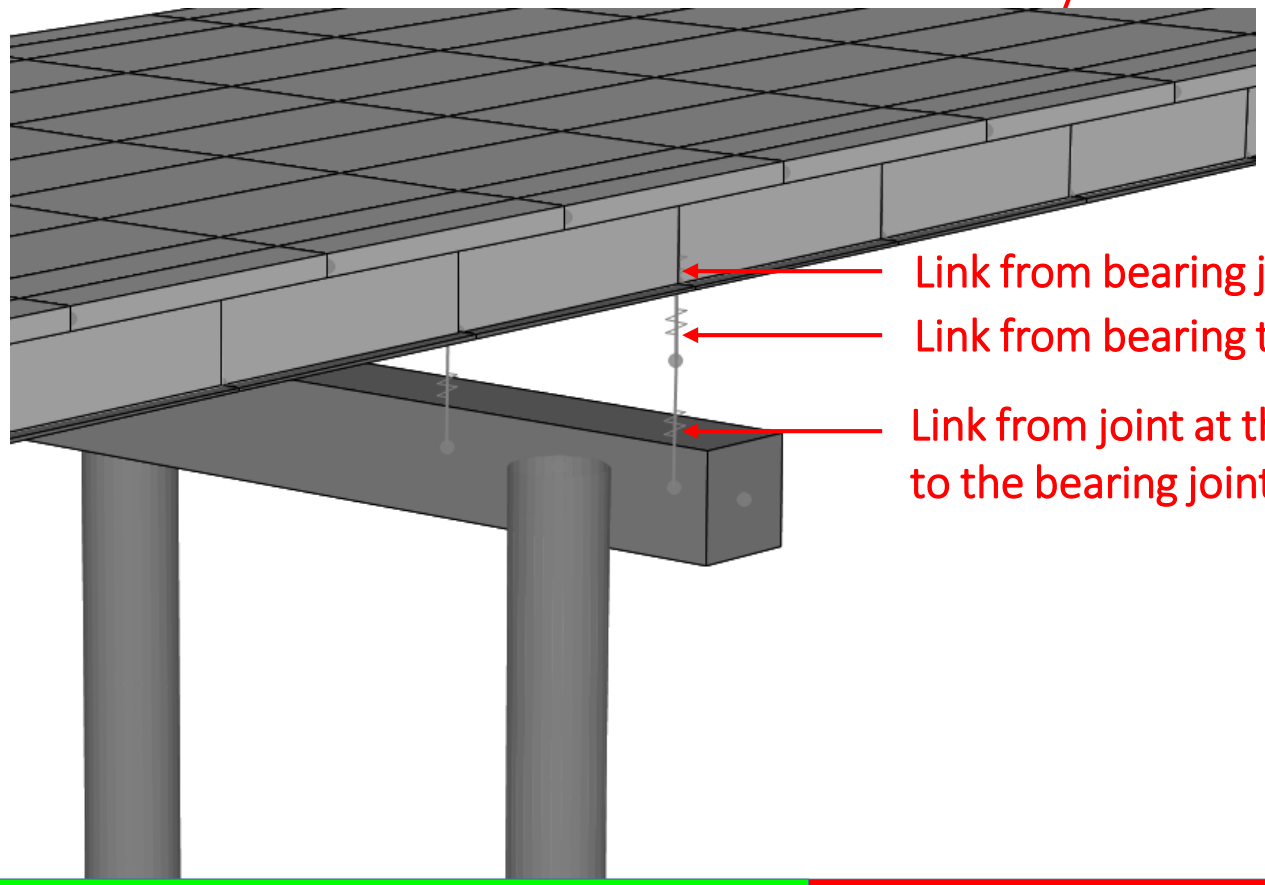




Longitudinal Deformation

Connection between superstructure and substructure





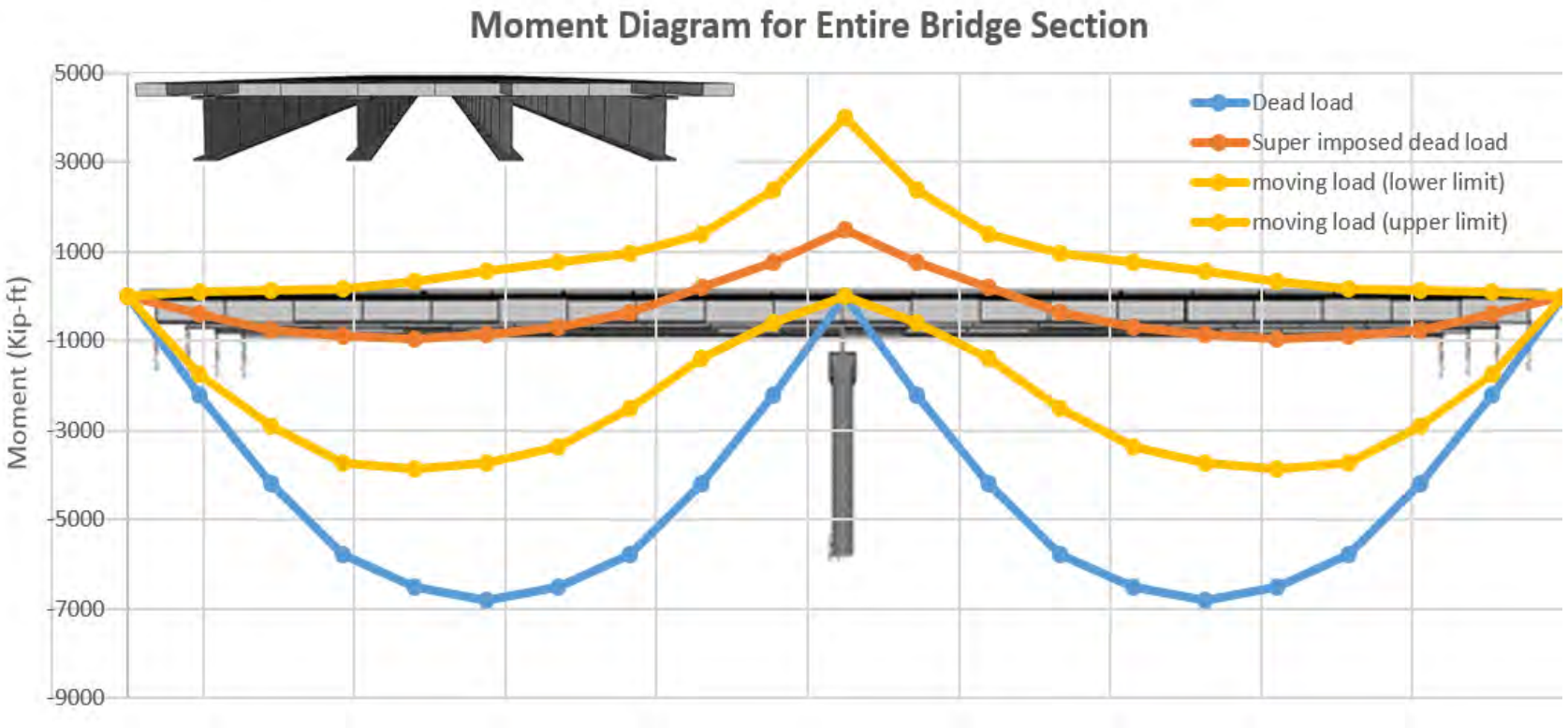
Link from bearing joint to top of girder (rigid)

Link from bearing to bottom of girder (rigid)

Link from joint at the centroid of bent cap to the bearing joint

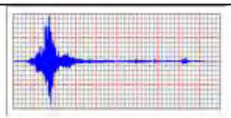
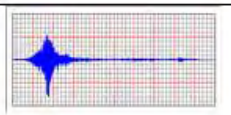
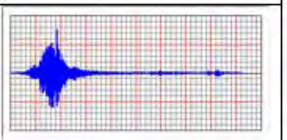
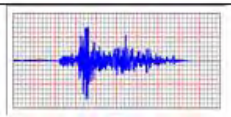
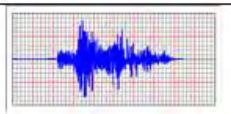
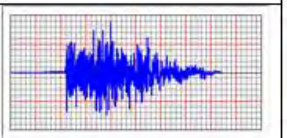
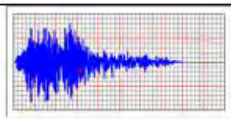
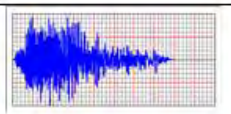
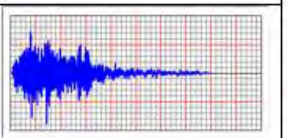
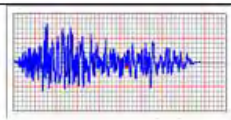
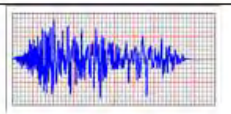
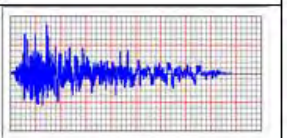
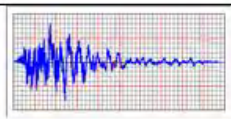
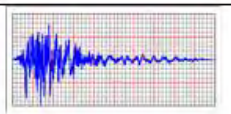
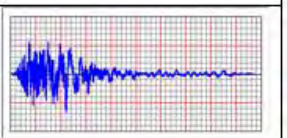
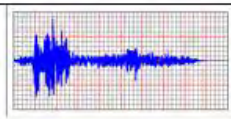
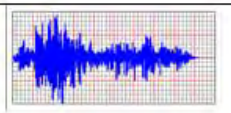
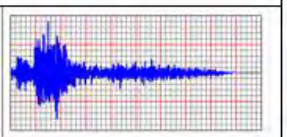
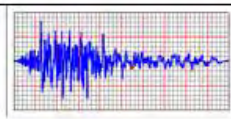
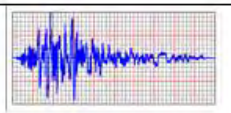
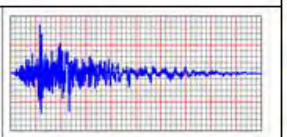
Staged construction analysis

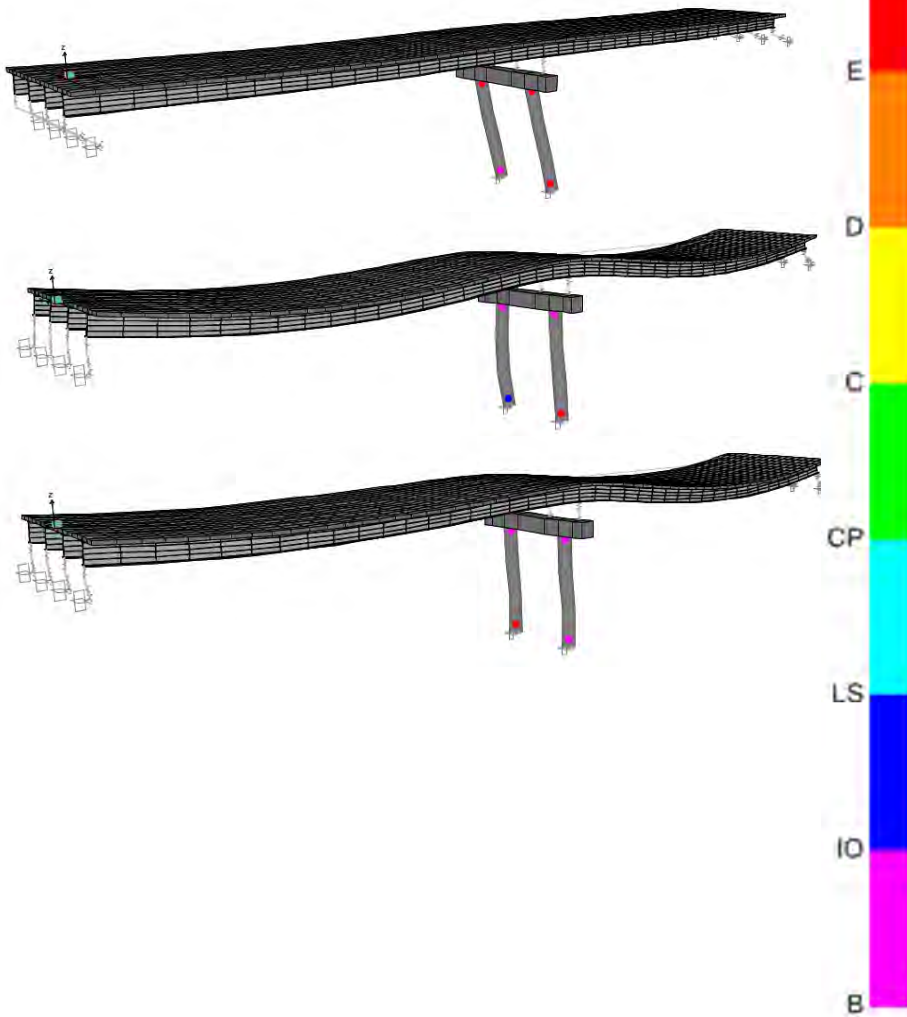
Before a nonlinear static and time history analysis a staged construction analysis performed to model SDCL system properly.



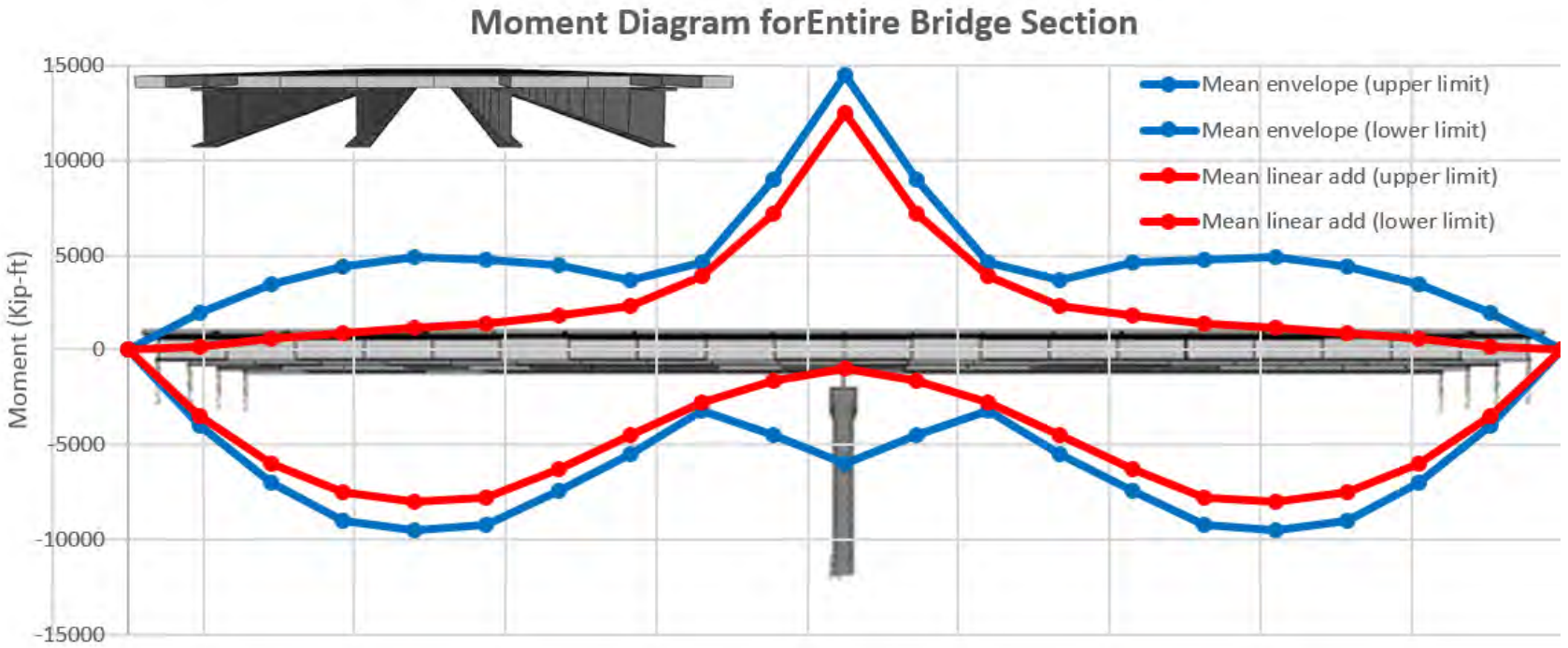
Distribution of moment under dead load, superimposed dead load and moving load based on SDCL construction sequence.

Nonlinear Time History Analysis

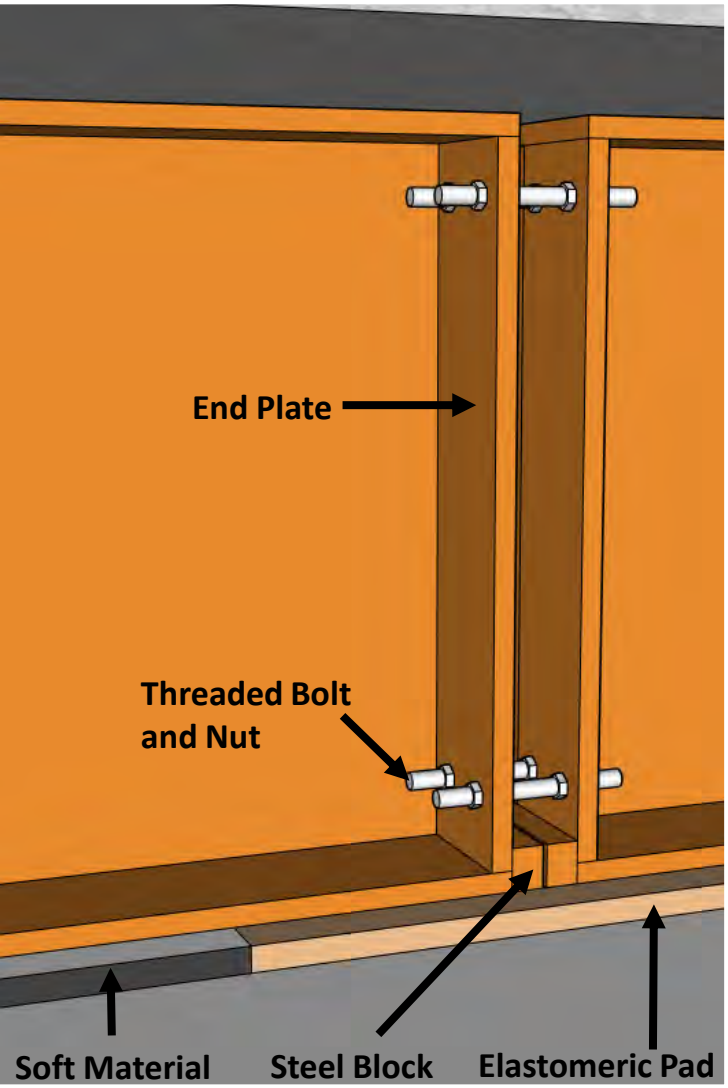
Selected ground motion acceleration	longitudinal	transverse	vertical
Darfield			
Duzce			
Imperial Valley			
Irpinia			
Loma Prieta			
Manjil			
Northridge			

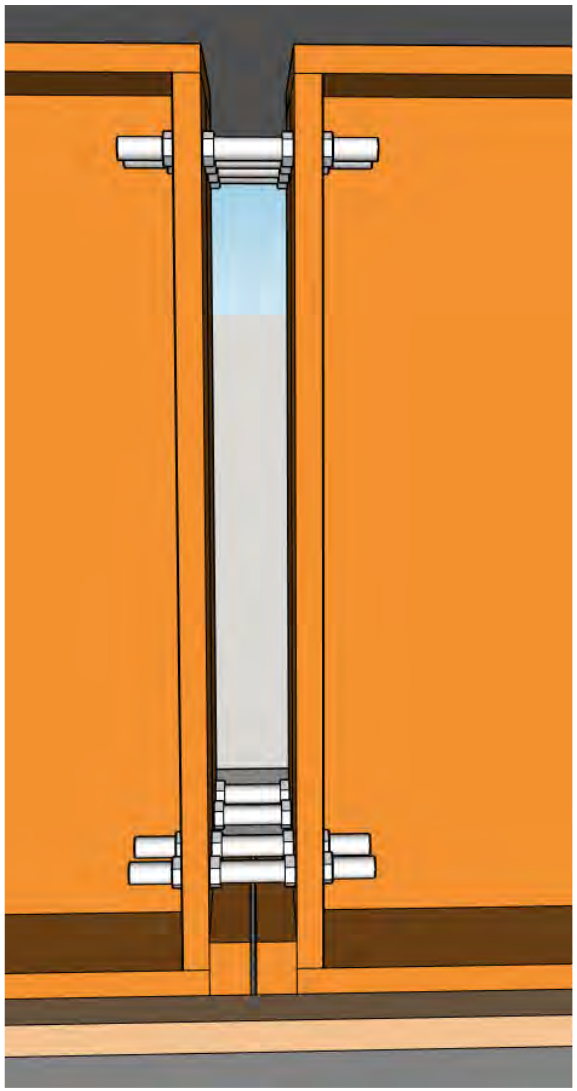


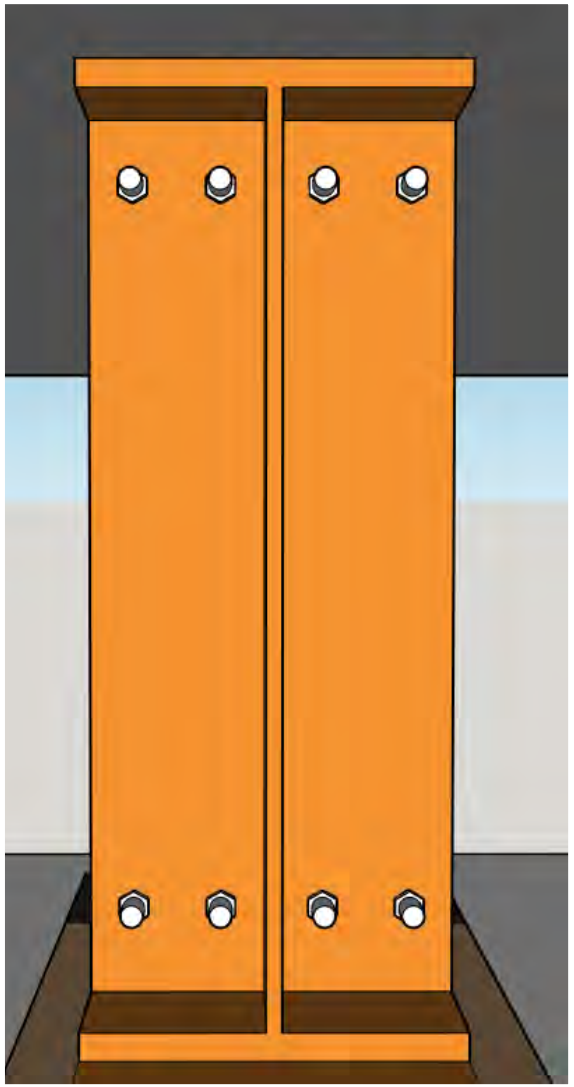
Mean envelope and mean linear add of moment plots for the entire bridge section for all selected ground motions



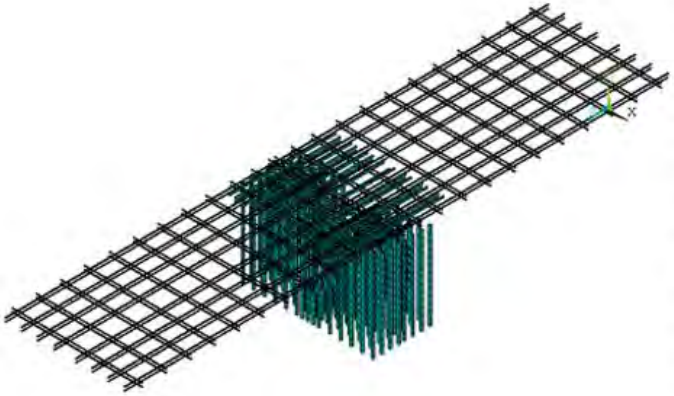
Initial proposed Seismic detail for SDCL

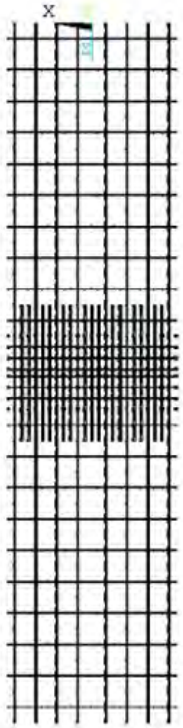


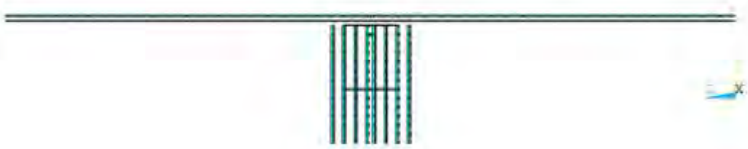


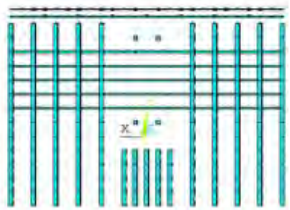


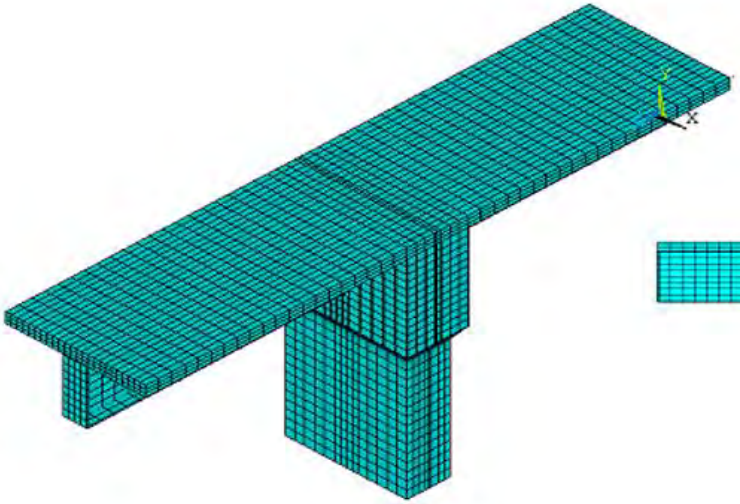
Isometric 3-D view and side views of finite element model

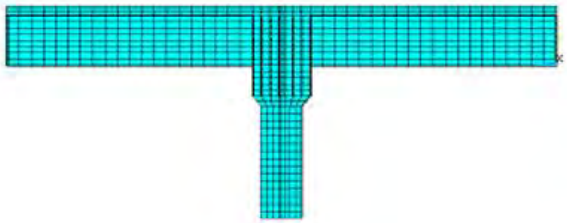


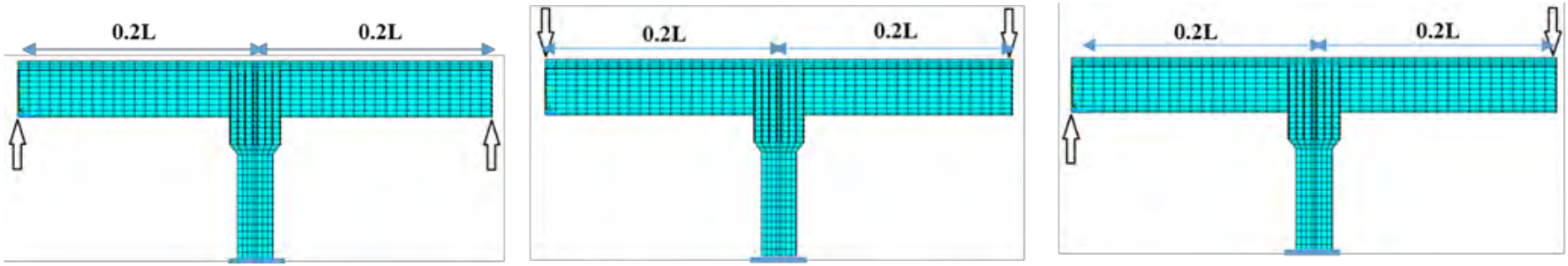












Finite-element model and boundary. Push-up, push-down and inverse loading simulate seismic loads.

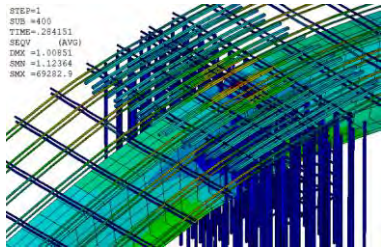
Results from preliminary finite element analysis

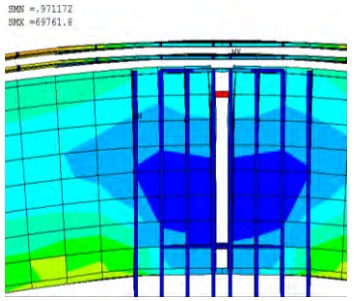
1- added bolts increased the moment capacity under push up forces (not significantly).

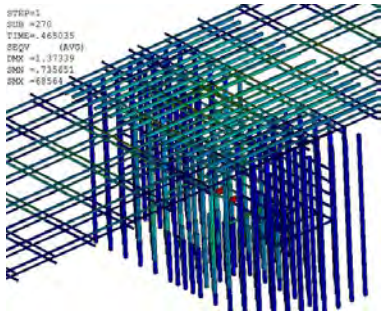
2- connecting bottom flange increased the moment capacity under push up forces (significantly).

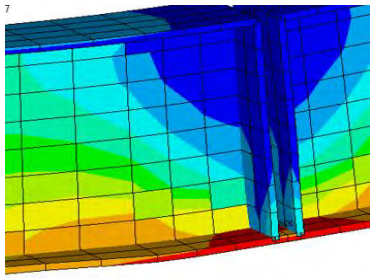
3-added bolts are not able to increase moment capacity of the system significantly.

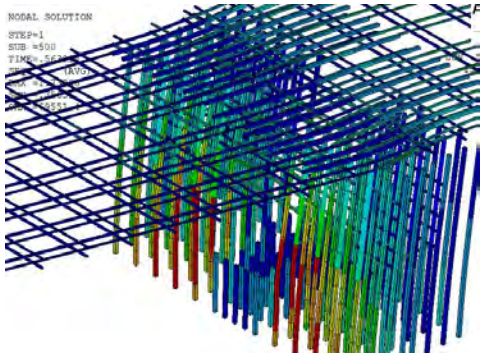
4-the vertical bars connecting bent cap to concrete diaphragm, are the main component of detail to carry loads under inverse loading.



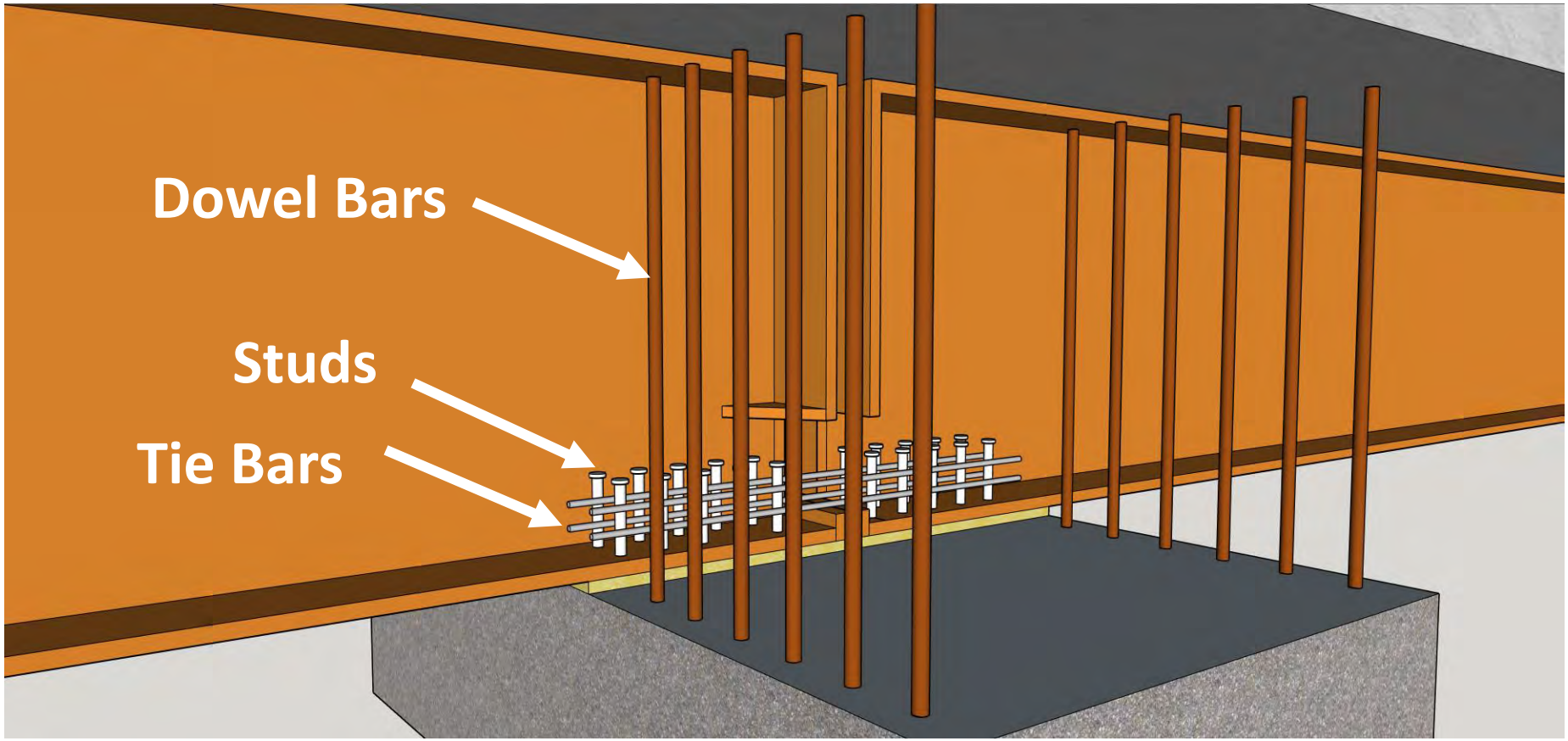




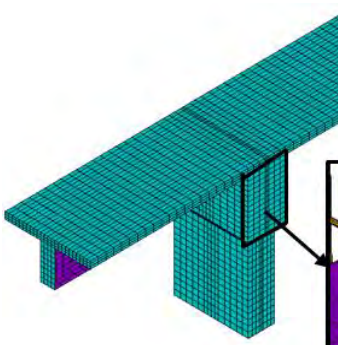




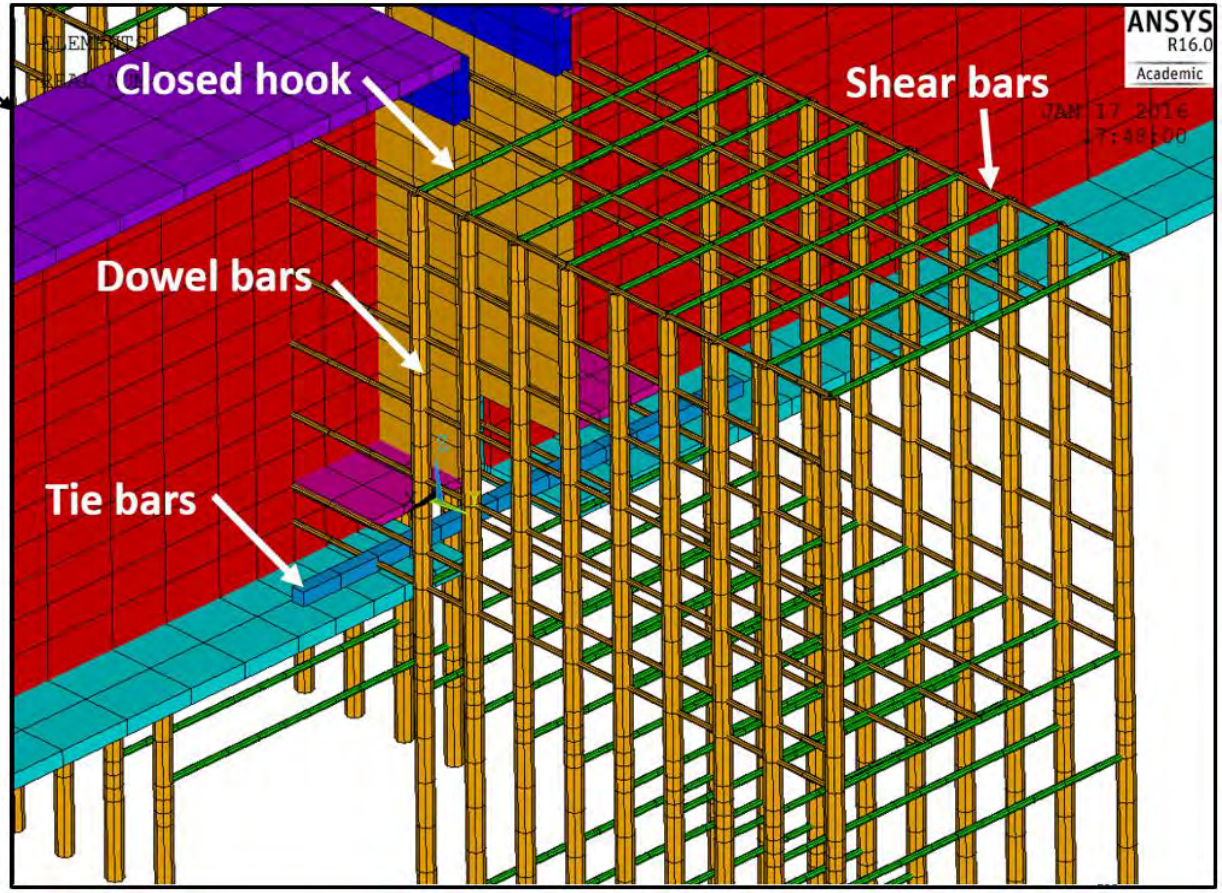
Removing top and bottom bolts, revising the seismic detail of SDCL

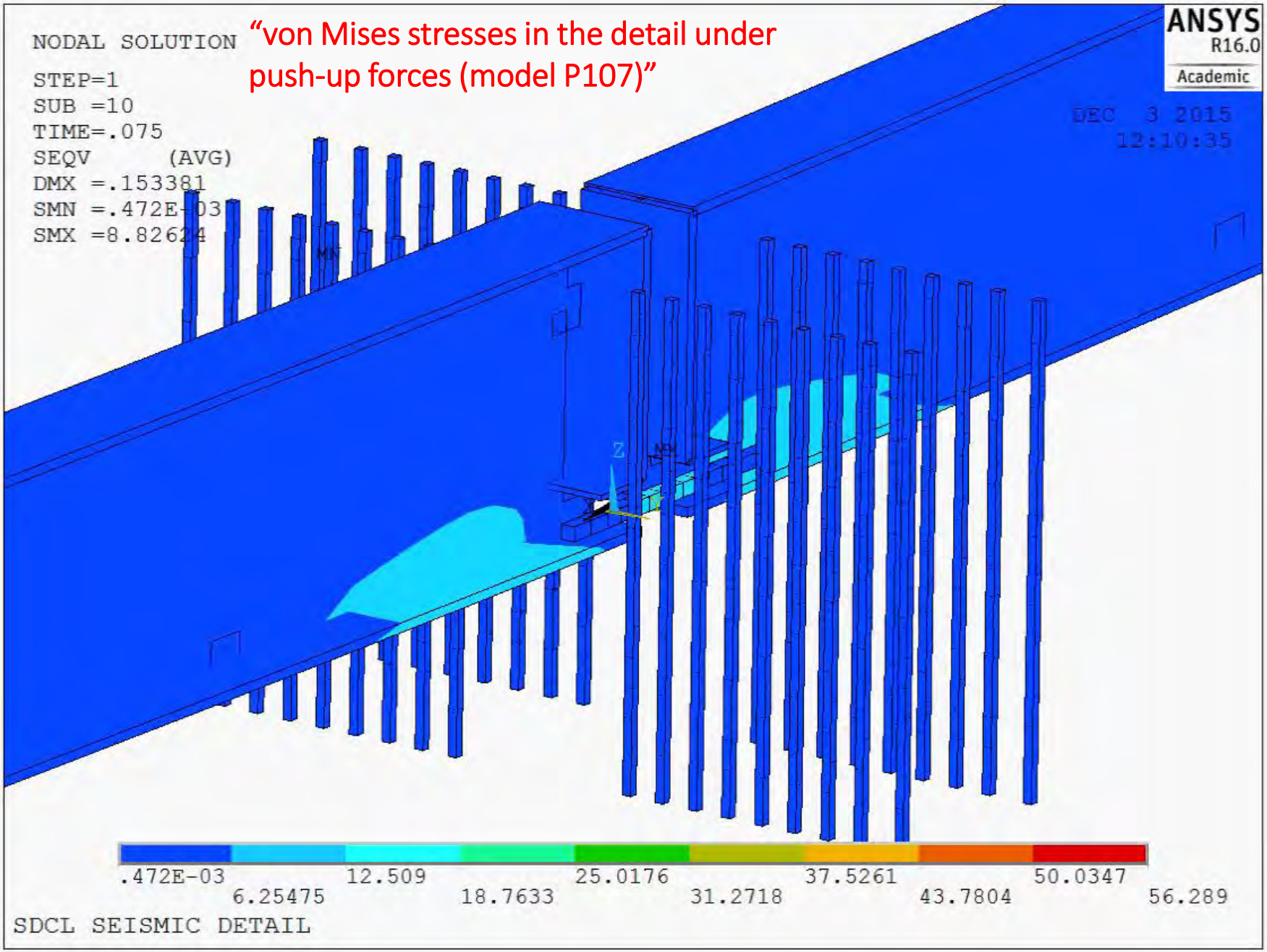


Revised finite element model (ANSYS)

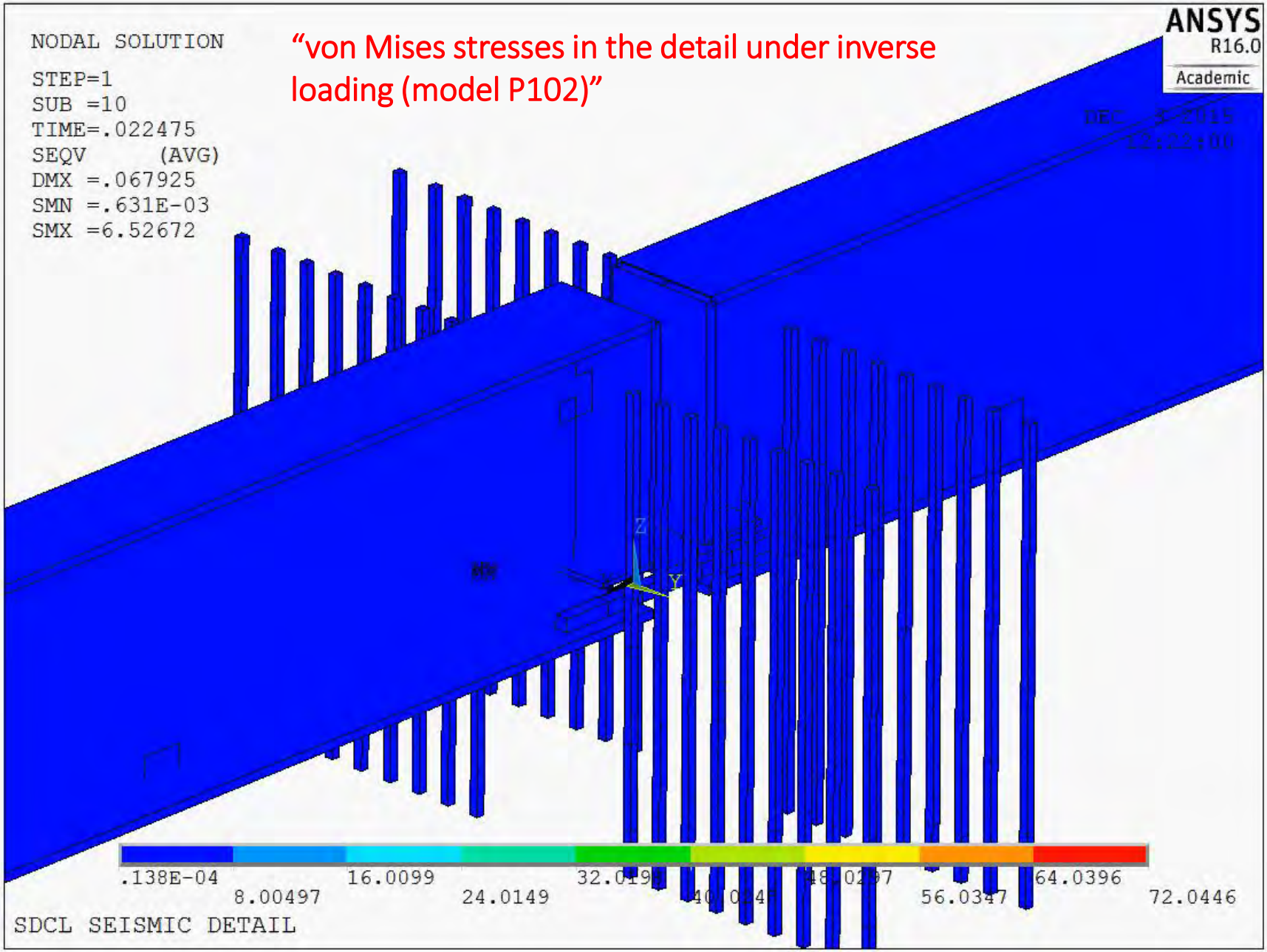


- **slab** (solid 65)
- **steel girder** (shell 181)
- **bars in slab** (link 180)
- **concrete diaphragm and bent cap** (solid 65)
- **dowel bars** (beam 188)
- **tie bars** (link 180)

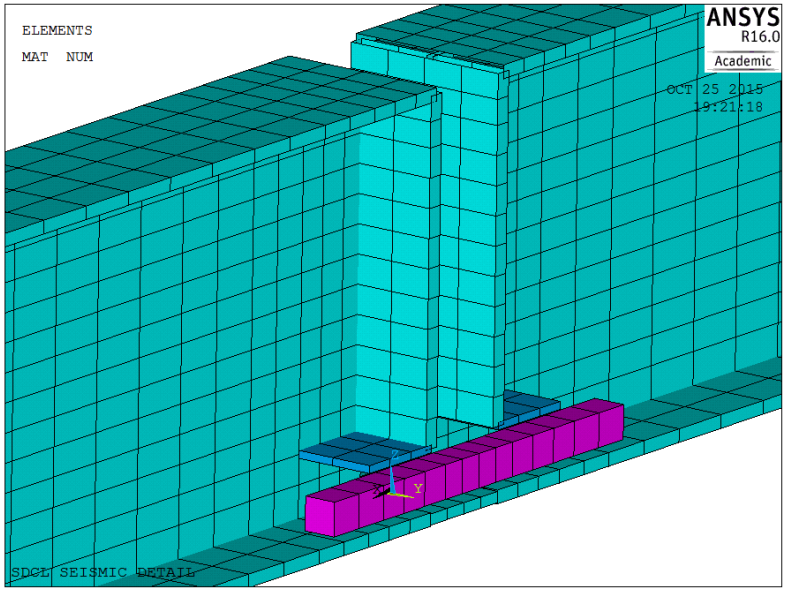




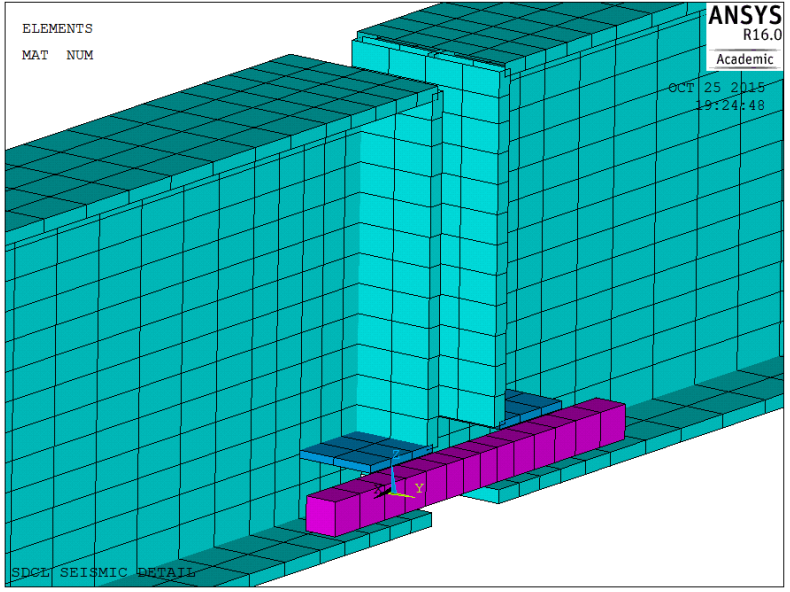
"von Mises stresses in the detail under push-up forces (model P107)"



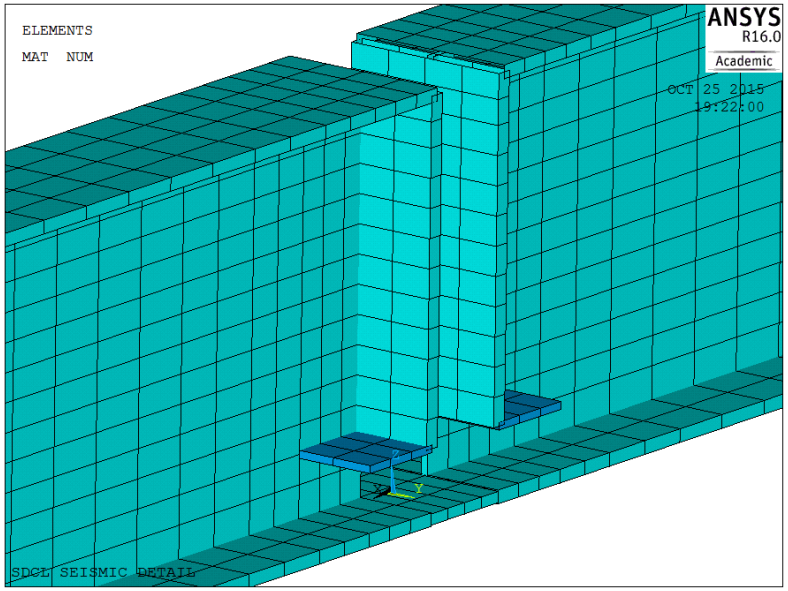
"von Mises stresses in the detail under inverse loading (model P102)"



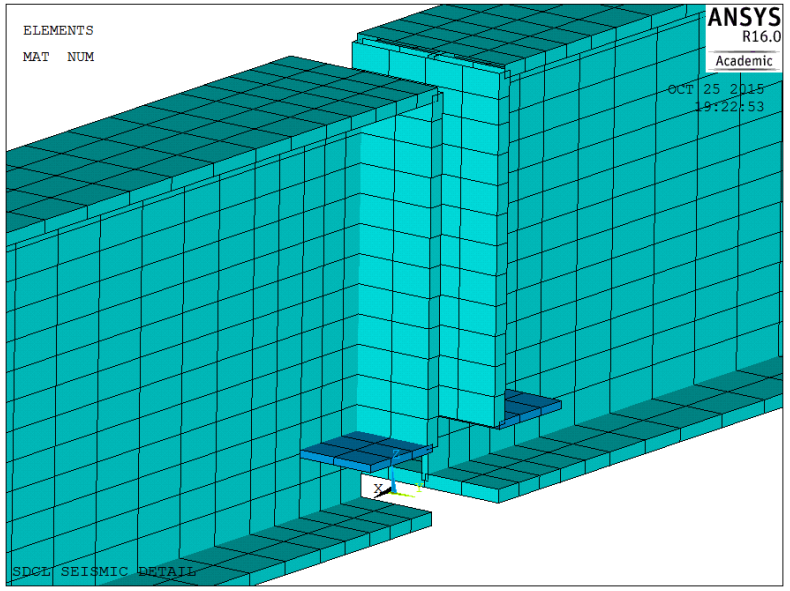
bottom flange connected+bars (modelP49)



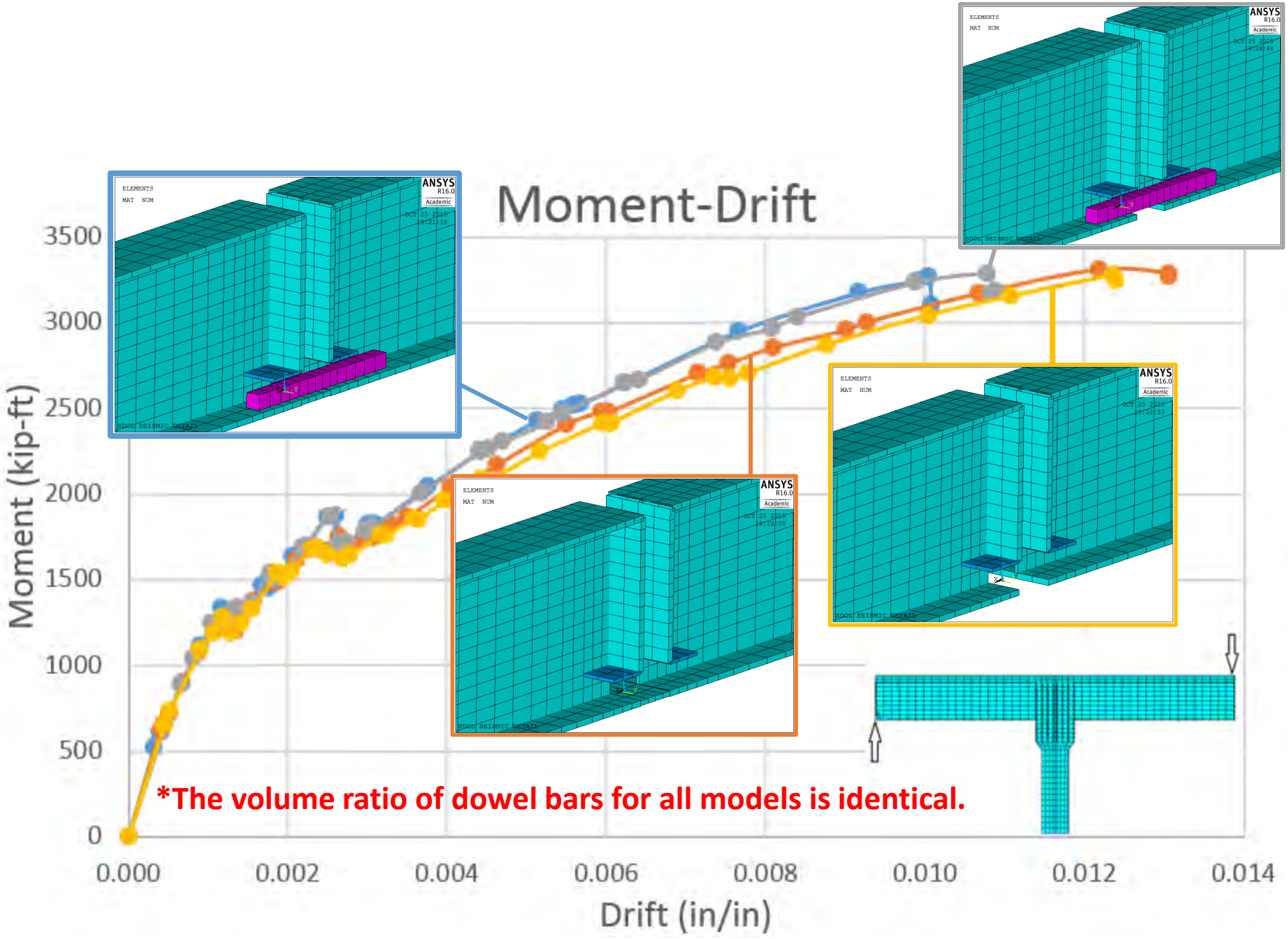
bottom flange not connected+bars (modelP50)



bottom flange connected+ no bars (modelP51)

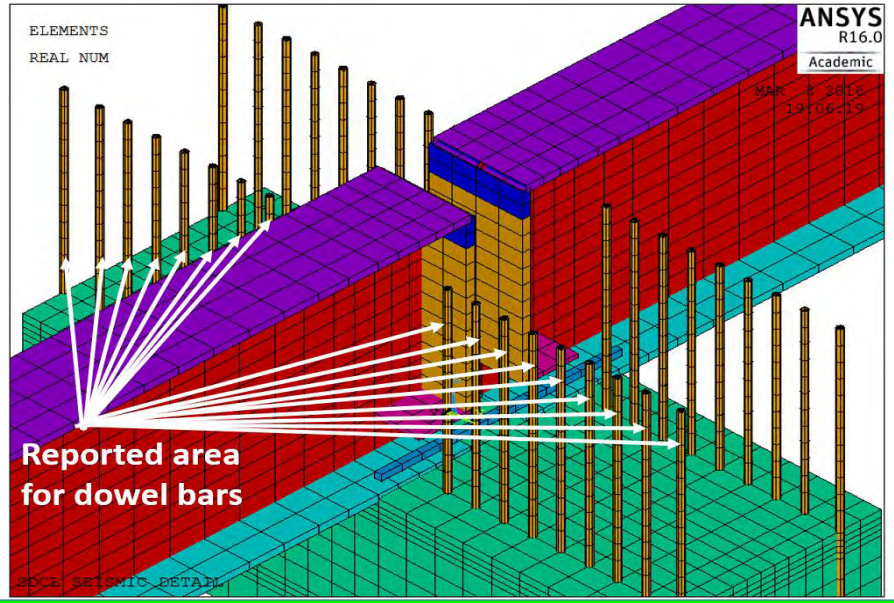


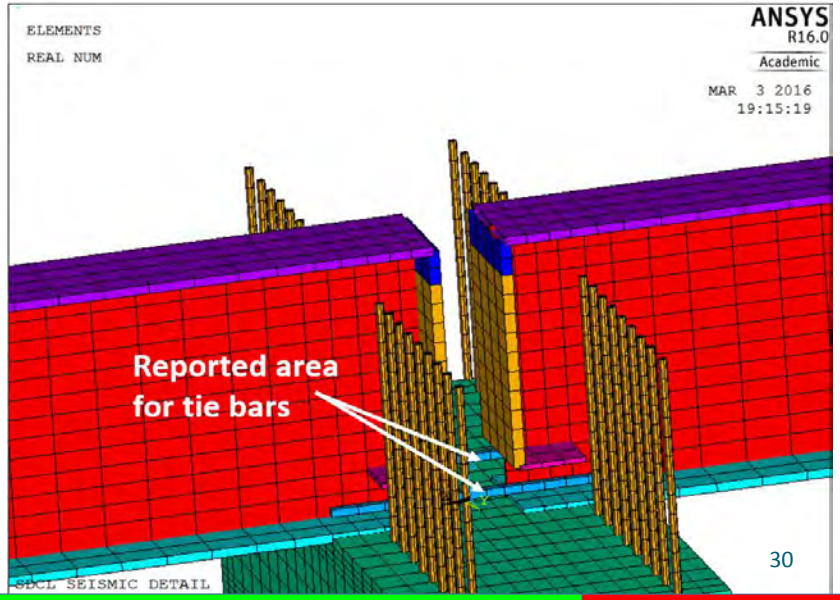
bottom flange not connected+no bars (modelP52)


Moment-Drift
Moment (kip-ft)
3500
3000
2500
2000
1500
1000
500
0
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Drift (in/in)
*The volume ratio of dowel bars for all models is identical.

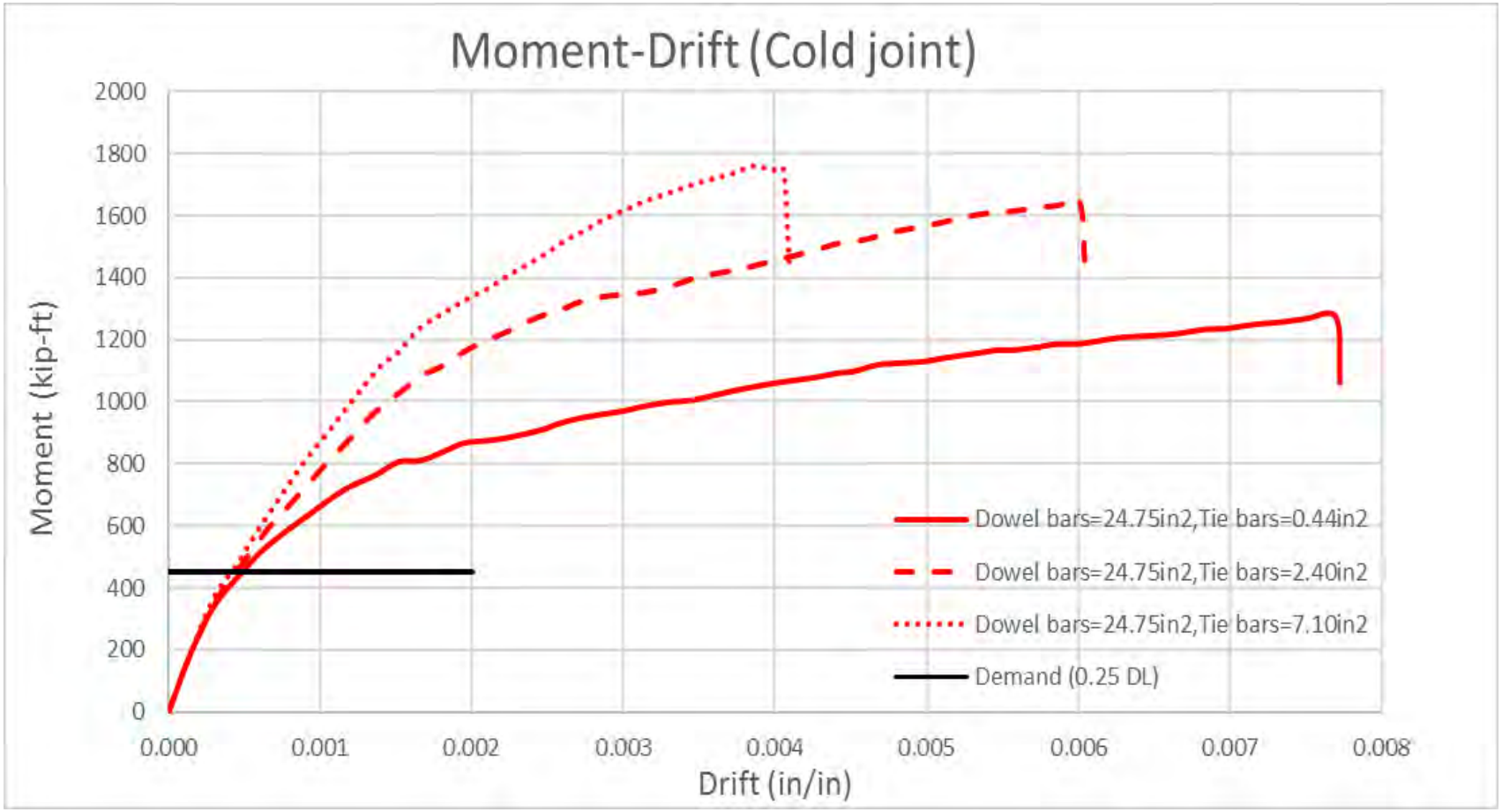
Varying amount of steel for dowel and tie bars for the parametric finite element models (FEM)

		Tie Bars		
		0.44 in2 (4#3)	2.40 in2 (4#7)	7.10 in2 (4#11)
Dowel Bars	6.18 in2 (18#5)	FEM11	FEM12	FEM13
	15.3 in2 (18#8)	FEM21	FEM22	FEM23
	24.75 in2 (18#10)	FEM31	FEM32	FEM33

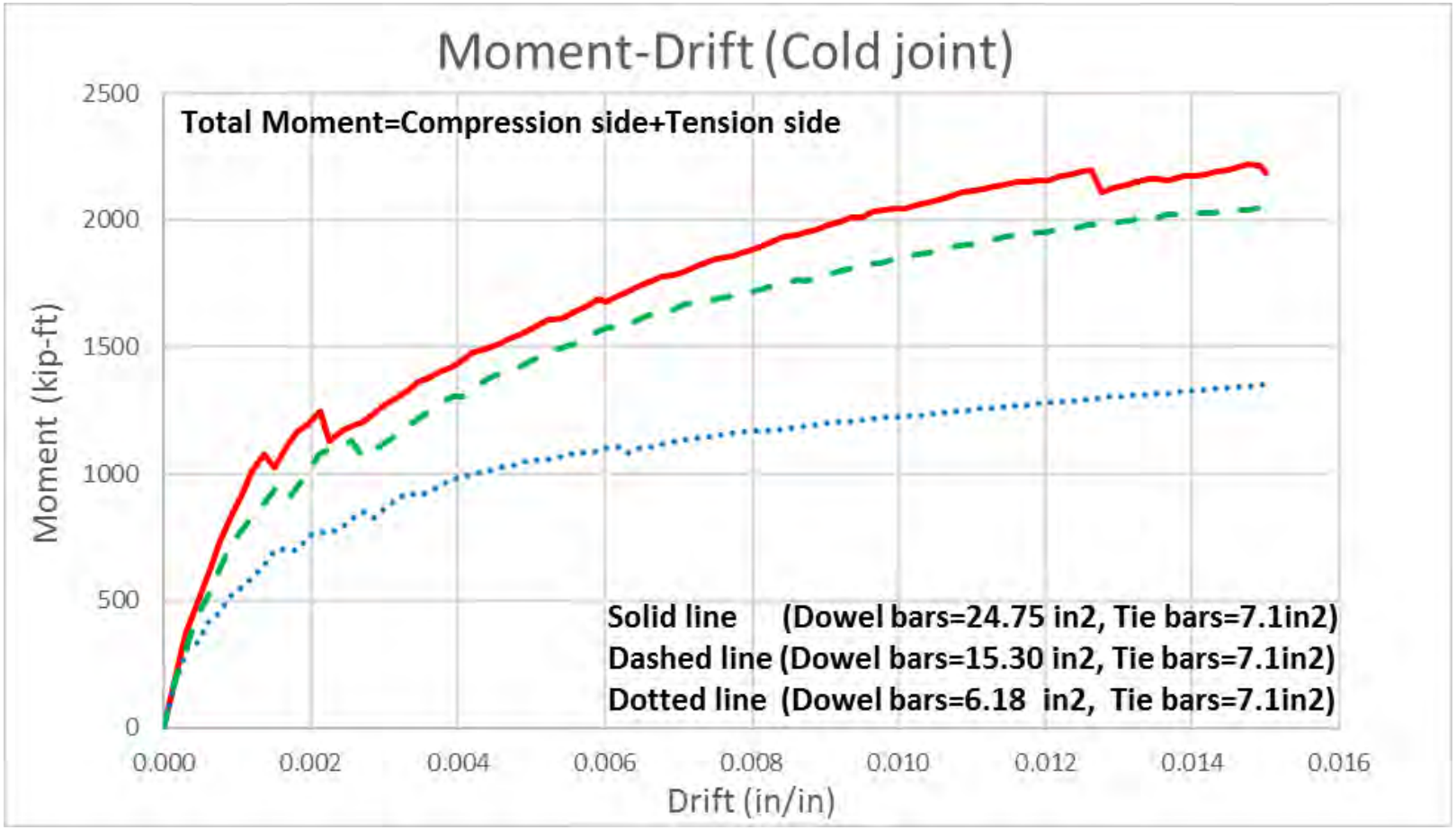




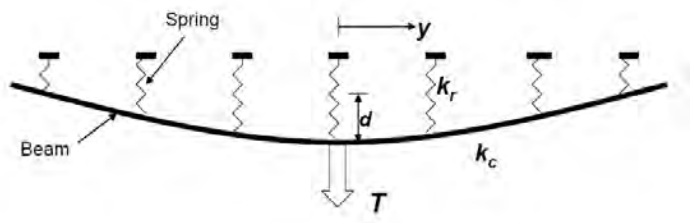
Effect of dowel bars and tie bars in the moment capacity under push-up loading



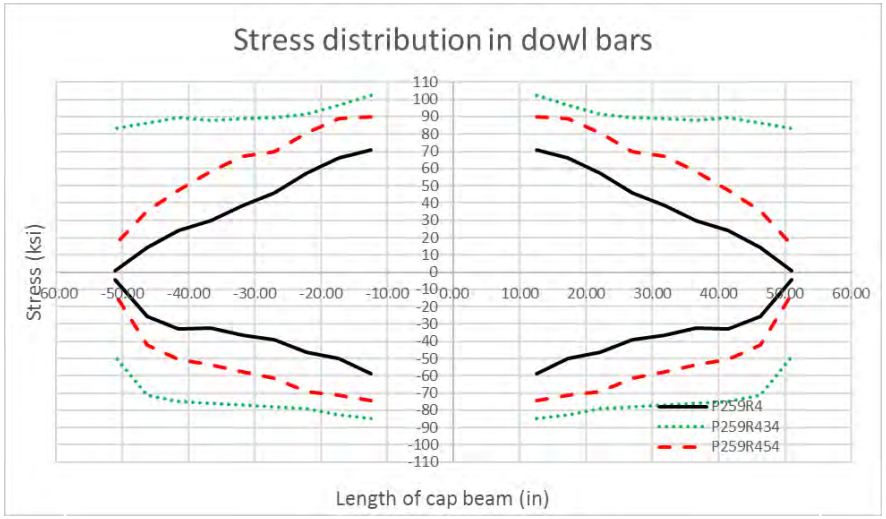
Effect of dowel bars in the moment capacity under inverse loading

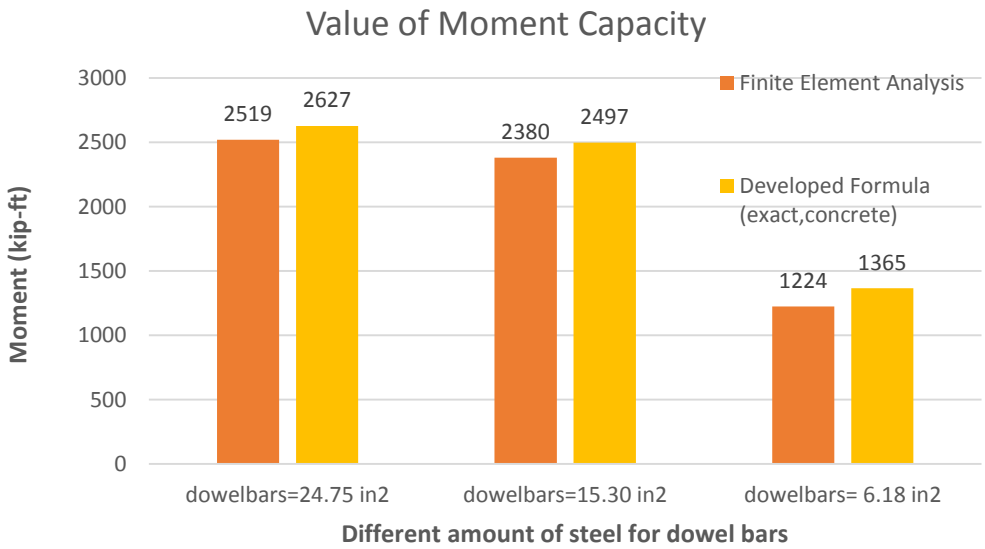


Developed formula (Winkler method)



Beam-spring model for a slice of the concrete diaphragm and the dowel bars





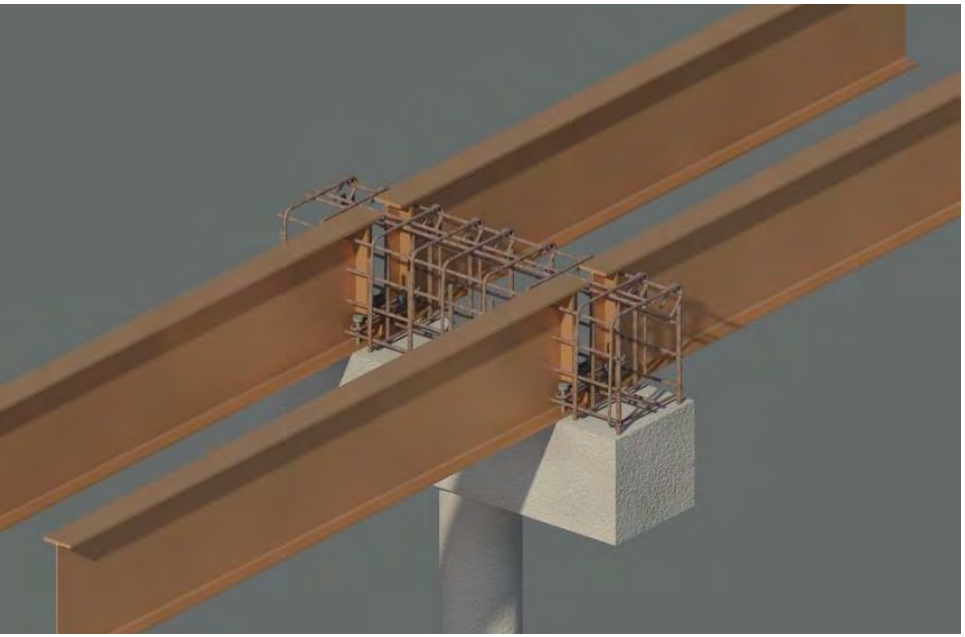
$$F_s = \frac{b_e}{b_s} A_s F_{yr} + \frac{2E_s \varepsilon_s A_s e^{\frac{\lambda b_f}{2}}}{\lambda b_s} \left(e^{\frac{-\lambda b_e}{2}} - e^{\frac{-\lambda b_s}{2}} \right)$$

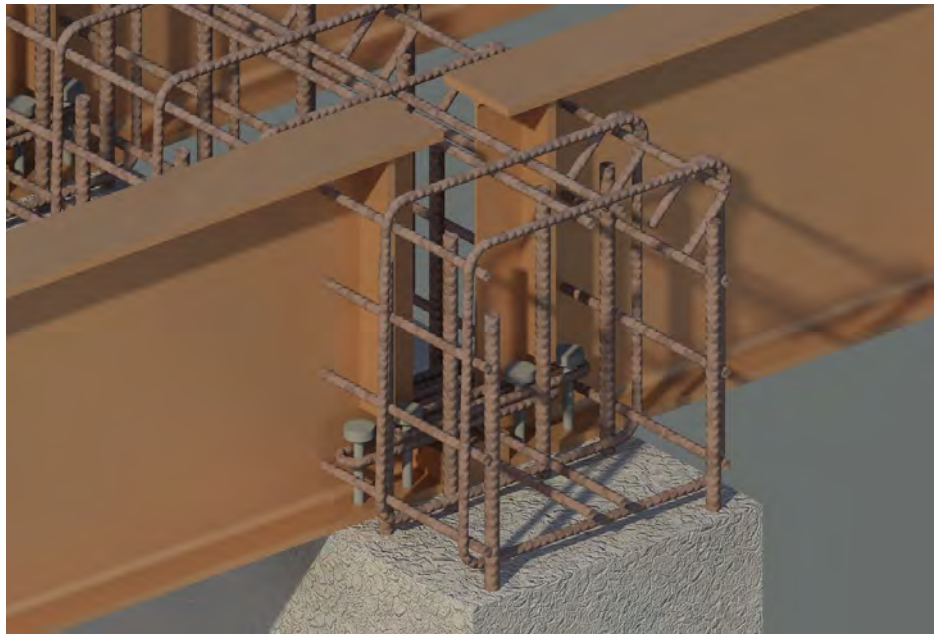
Seismic detail of SDCL bridge system

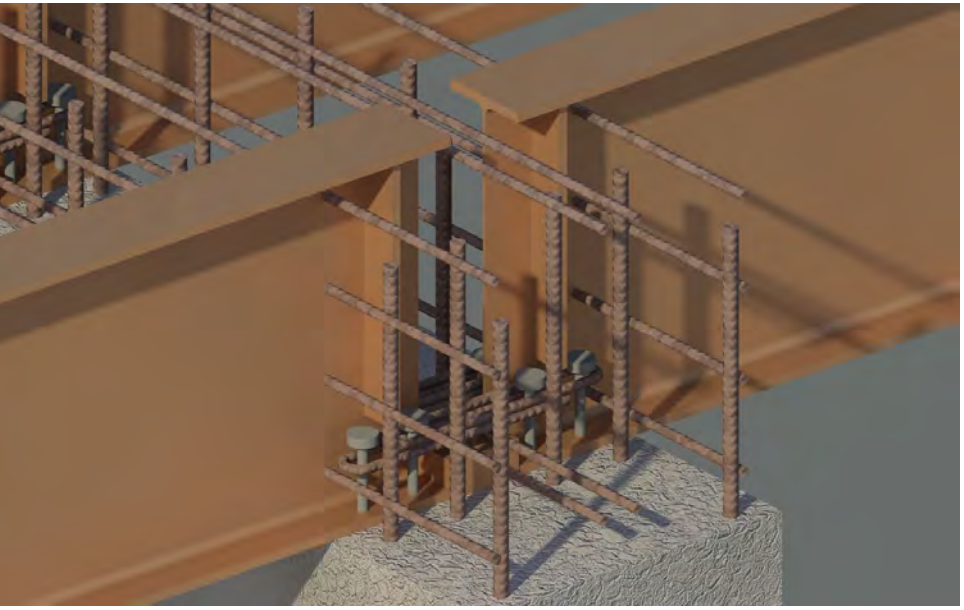
1-phase one (numerical and finite element investigation)

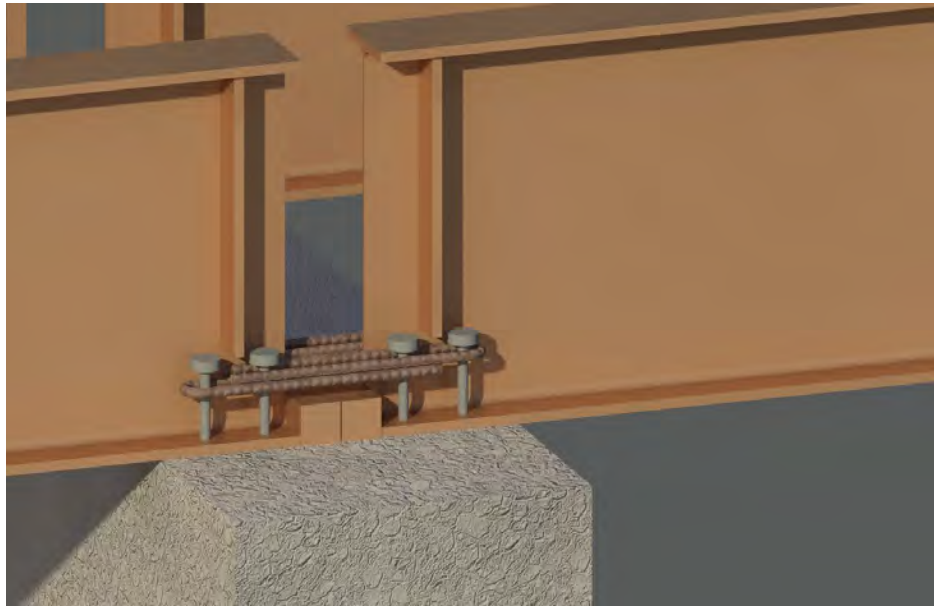
2- phase two (Component test)

3-shake table test









Thank you for your attention