Development of SDCL Bridge System for High Seismic Application

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2014- 2nd and 3rd quarter Issue of AISC Engineering Journal

1-Azizinamini, A. “Simple for Dead Load and Continuous for Live Load Steel Bridge Systems”, ***AISC Engineering Journal***. 2nd quarter, Volume 51, No.2, (2014)

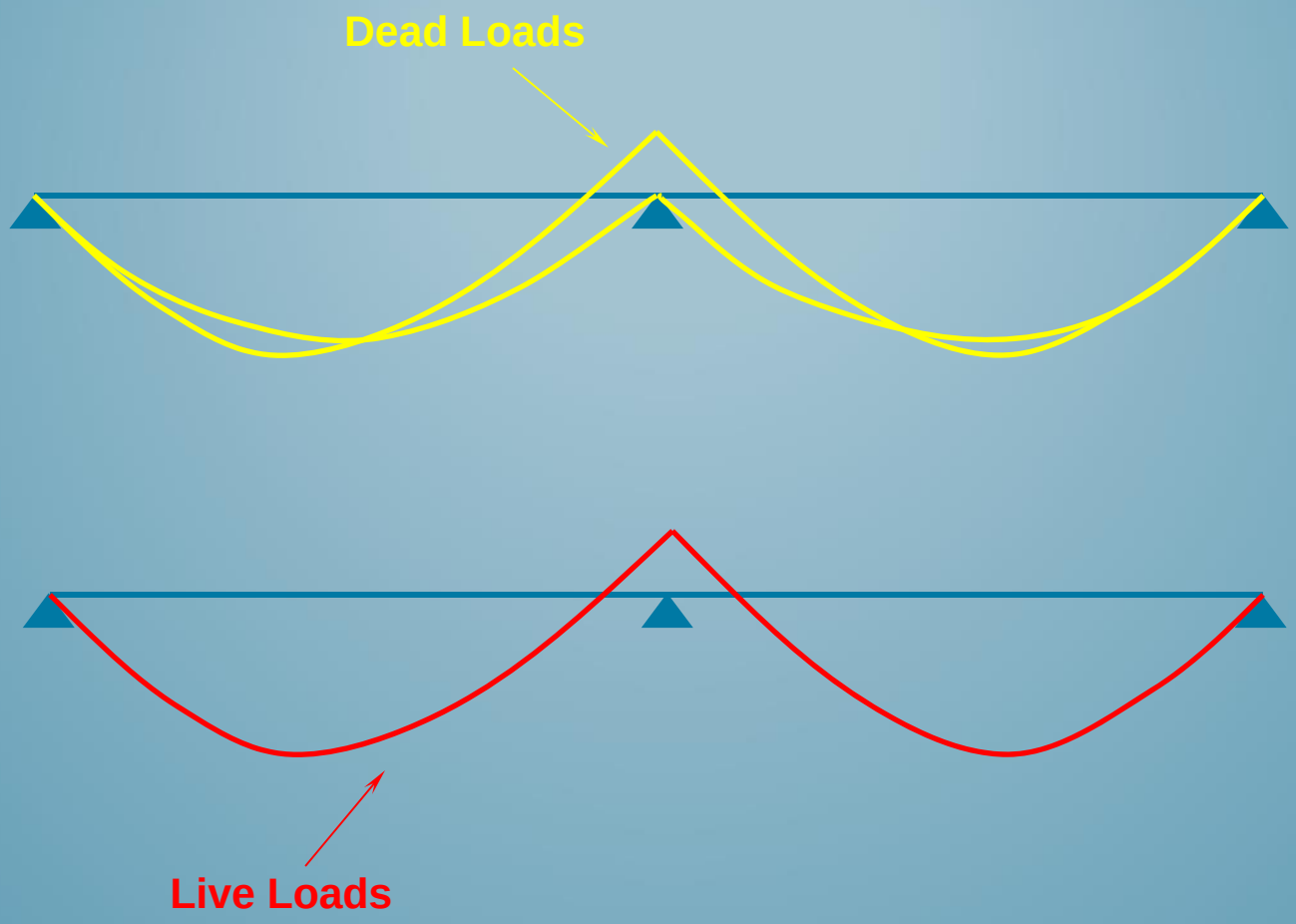
2-Lampe, N., Mossahebi, N., Yakel, A., Farimani, R. and Azizinamini, A., “Development and Experimental Testing of Connections for Simple for Dead Load – Continuous for Live Load Steel Bridge System”, ***AISC Engineering Journal.*** 2nd quarter, Volume 51, No.2, (2014)

3-Farimani, F., Javidi, S., Kowalski, D. and Azizinamini, A., “Numerical Analysis and Design Provision Development of Simple for Dead – Continuous for Live Bridge System”, ***AISC Engineering Journal.*** 2nd quarter, Volume 51, No.2, (2014)

4-Yakel, A., Azizinamini, A. “Field Application Case Studies and Long Term Monitoring of Bridges Utilizing the Simple for Dead – Continuous for Live Bridge System”, ***AISC Engineering Journal.*** 3rd quarter, Volume 51, No.3, (2014)

5-Javidi, S., Yakel, A. and Azizinamini, A. “Experimental Investigation, Application and Monitoring of Simple-made-continuous Bridge Connection for Modular Bridge Construction Method”, ***AISC Engineering Journal.*** 3rd quarter, Volume 51, No.3, (2014)

Moment Diagram



Conventional System

SDCL System

Construction Sequence
Conventional construction

Place steel girders over support

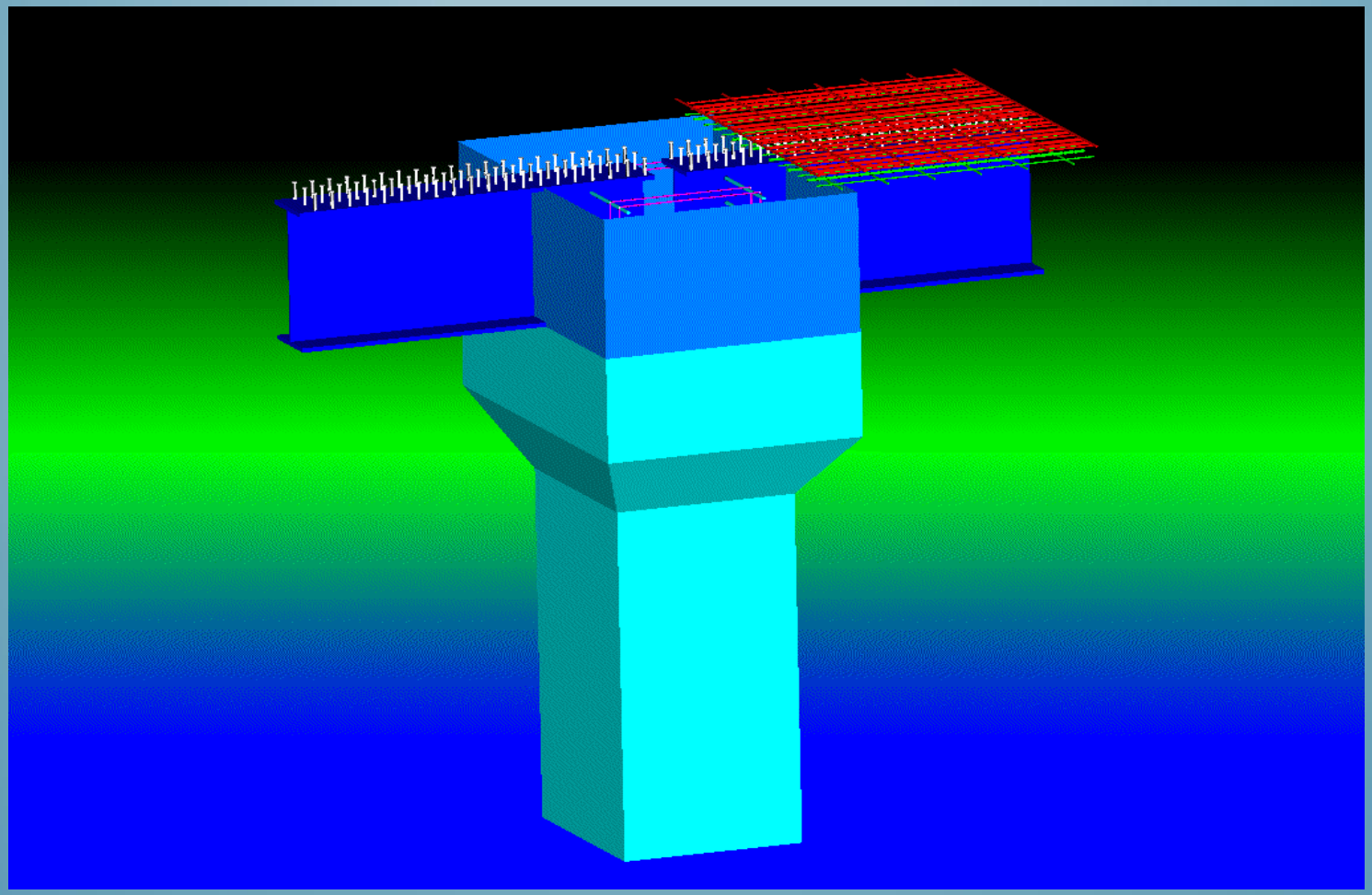
Connect the steel beams over the pier by filling ½ to 2/3 of the concrete diaphragm

This eliminates line of cross frames over the support
And enhances the durability of connection

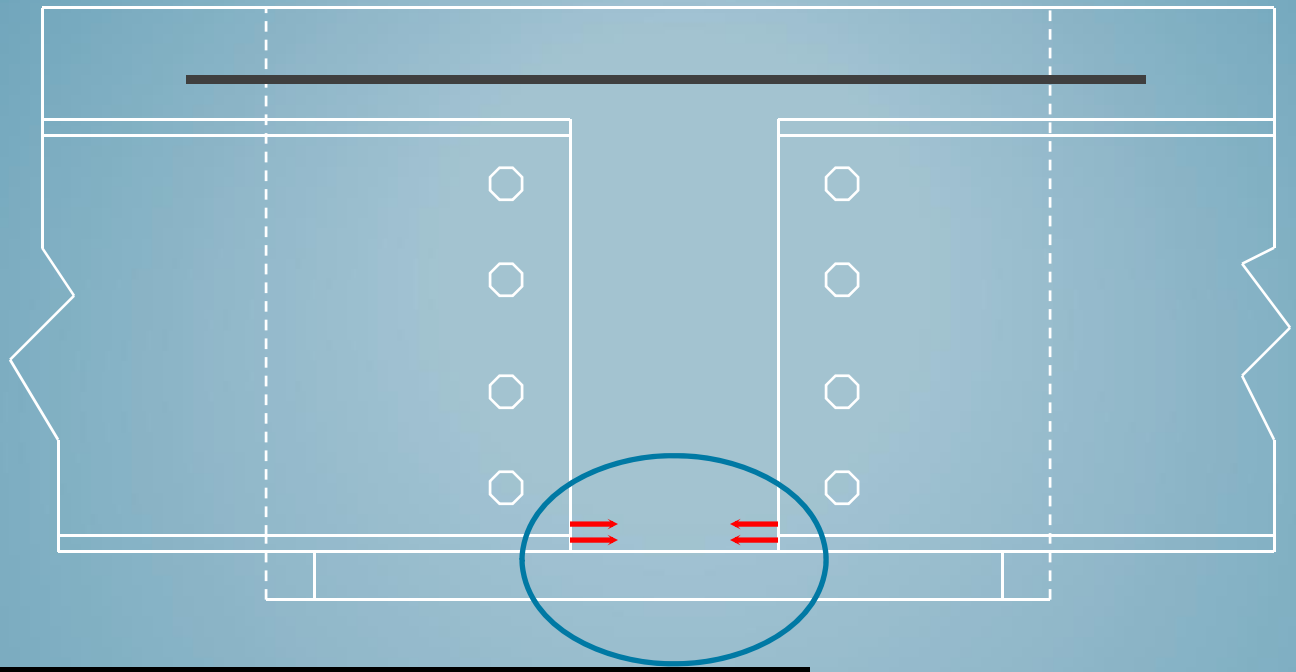
Construction Sequence
Conventional construction

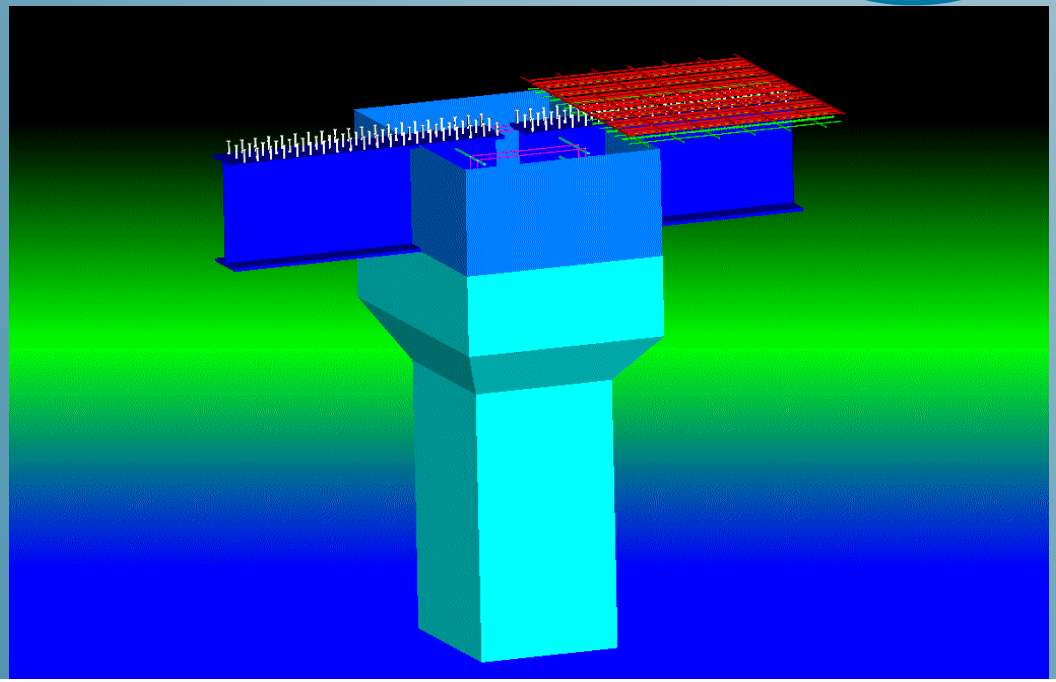
Final step- Place the deck

Under negative moment, tension over the support Is resisted by steel reinforcement



Tensile forces are resisted by steel reinforcement



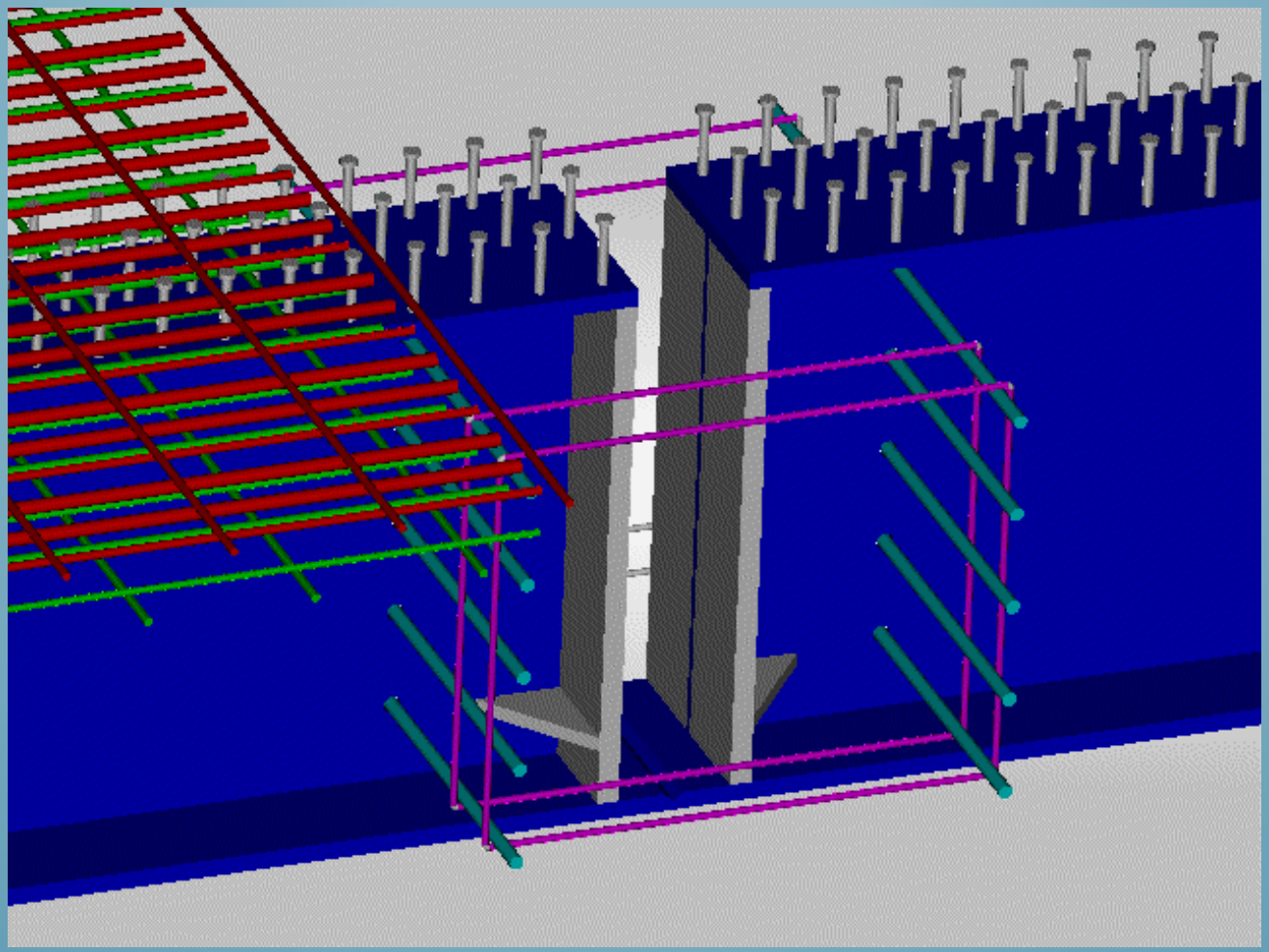


Need for mechanism that could resist the compression

Non-Seismic detail was developed Through selecting potential solutions and developing design Provisions through combination of Experimental, numerical and analytical work

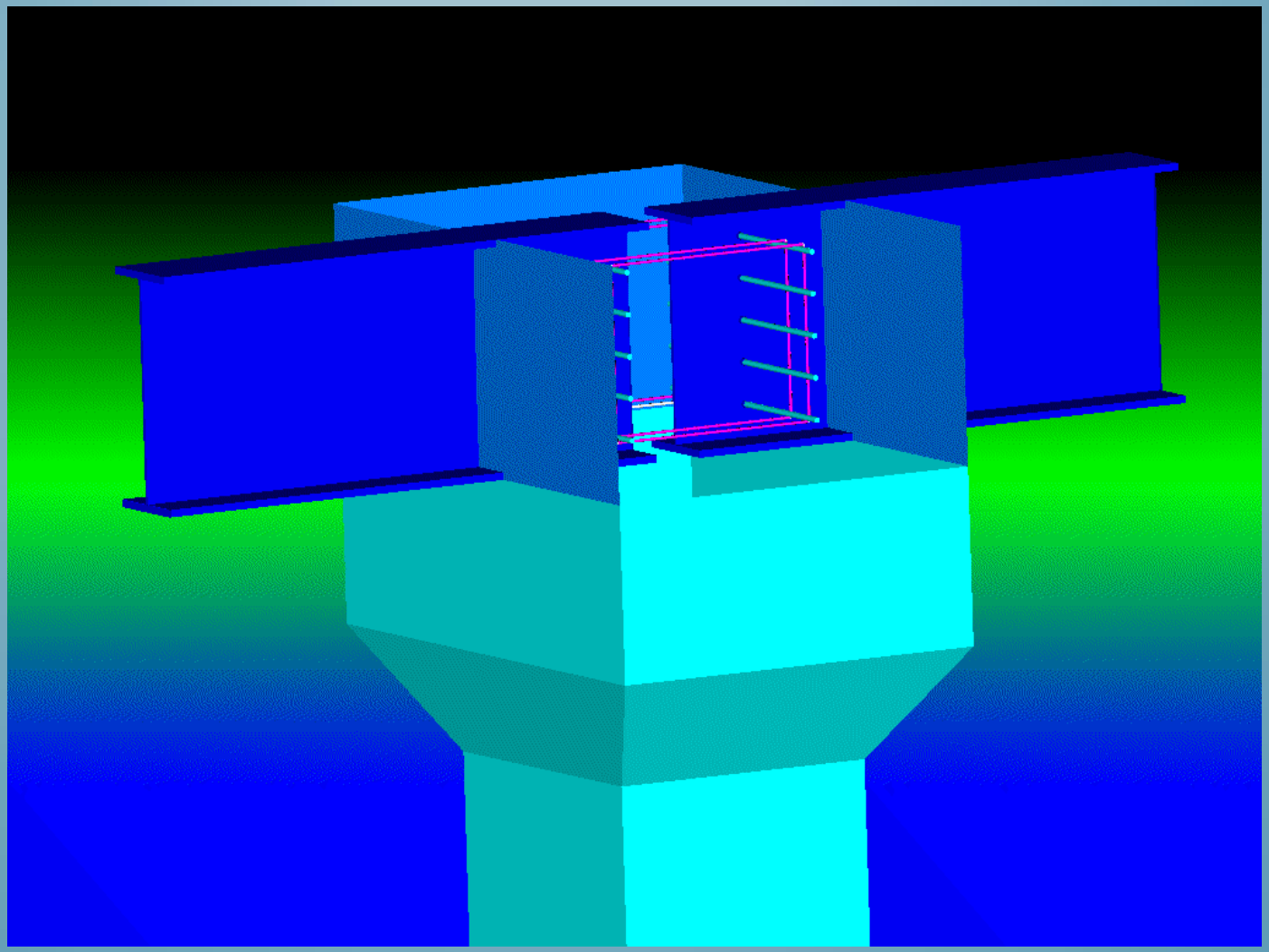
SPECIMEN No.1

Direct Transfer of Compression Force



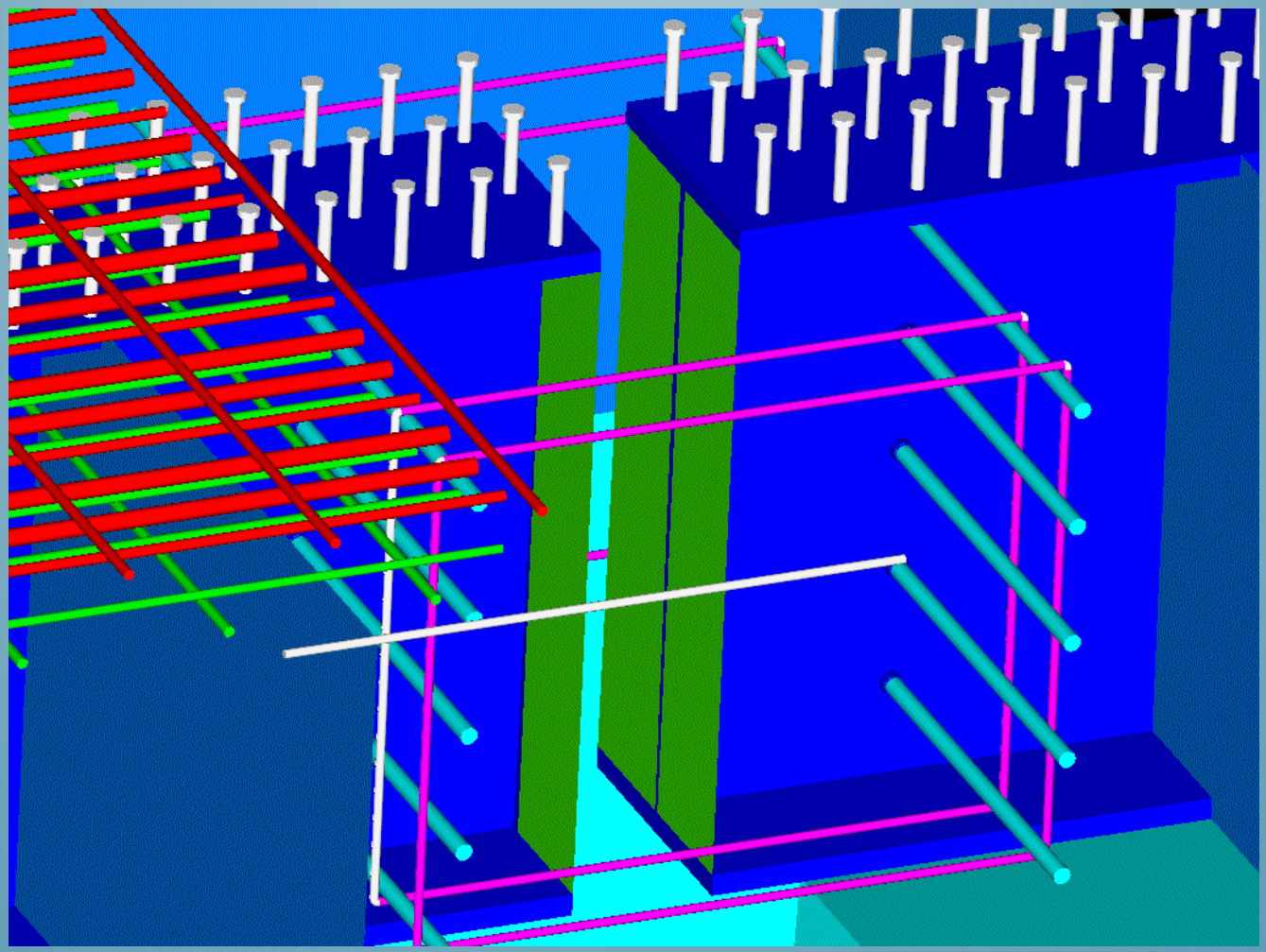
SPECIMEN No.2

No End Detail



SPECIMEN No.3

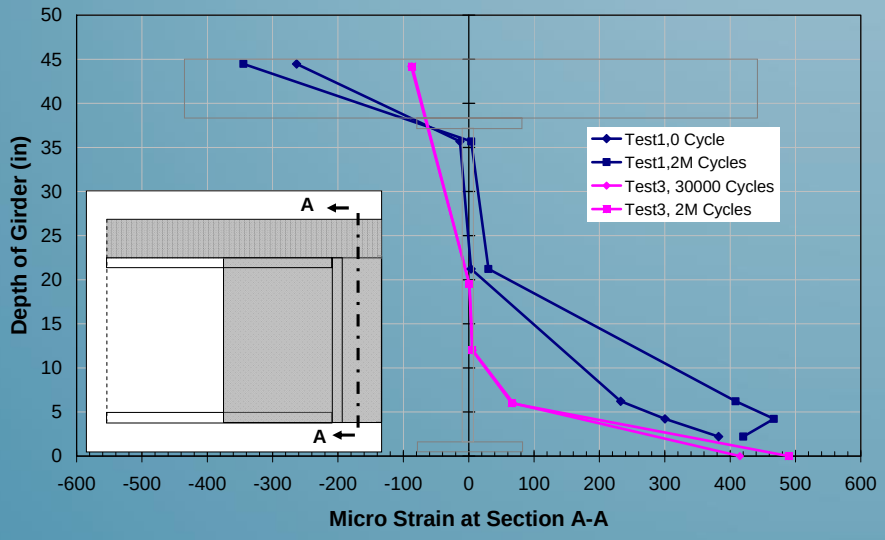
End Plate Only

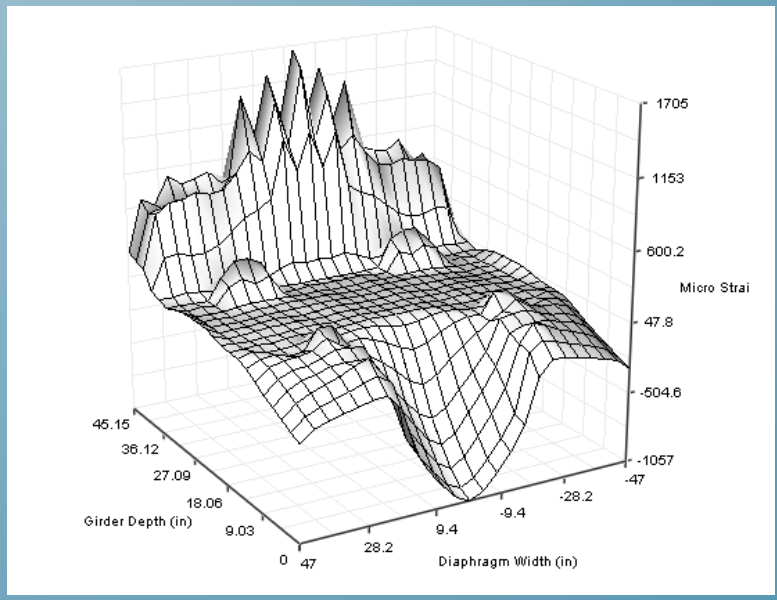


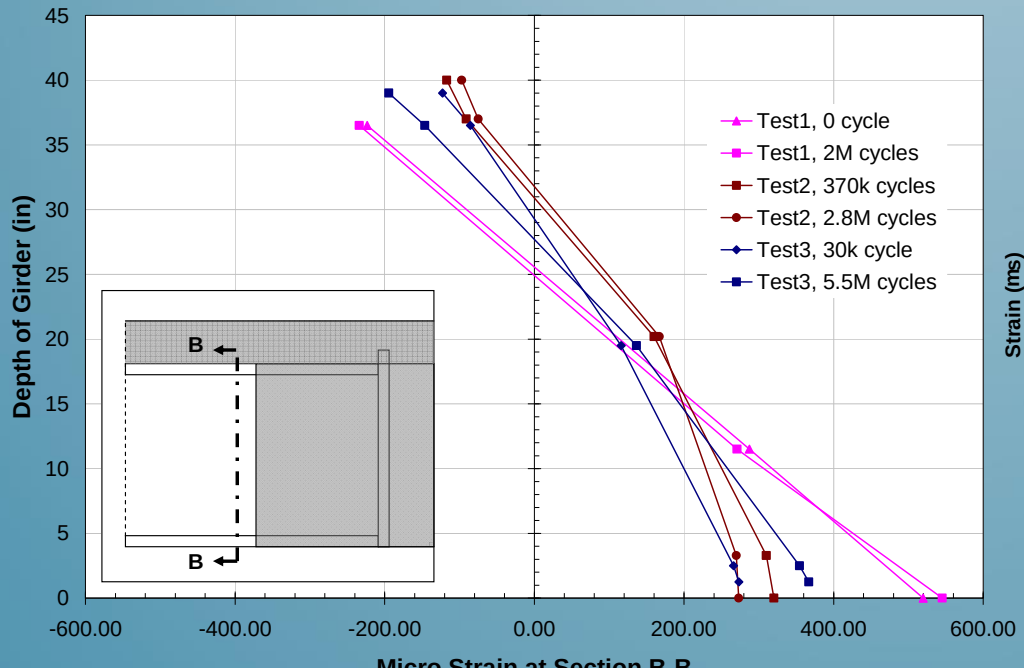

NDOR

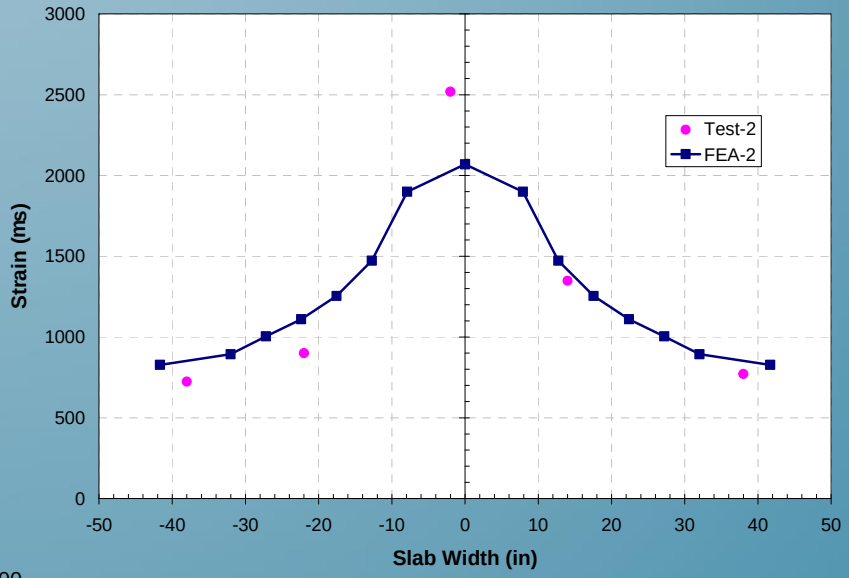

NDOR

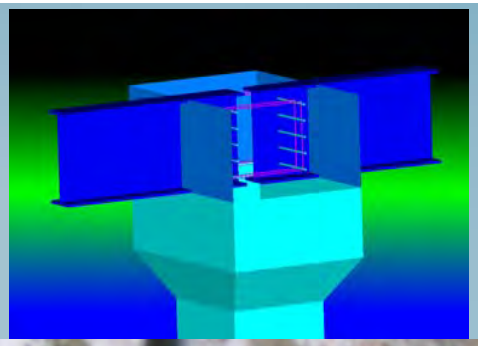
ULTIMATE LOAD TEST – Simulating Negative moment over middle support

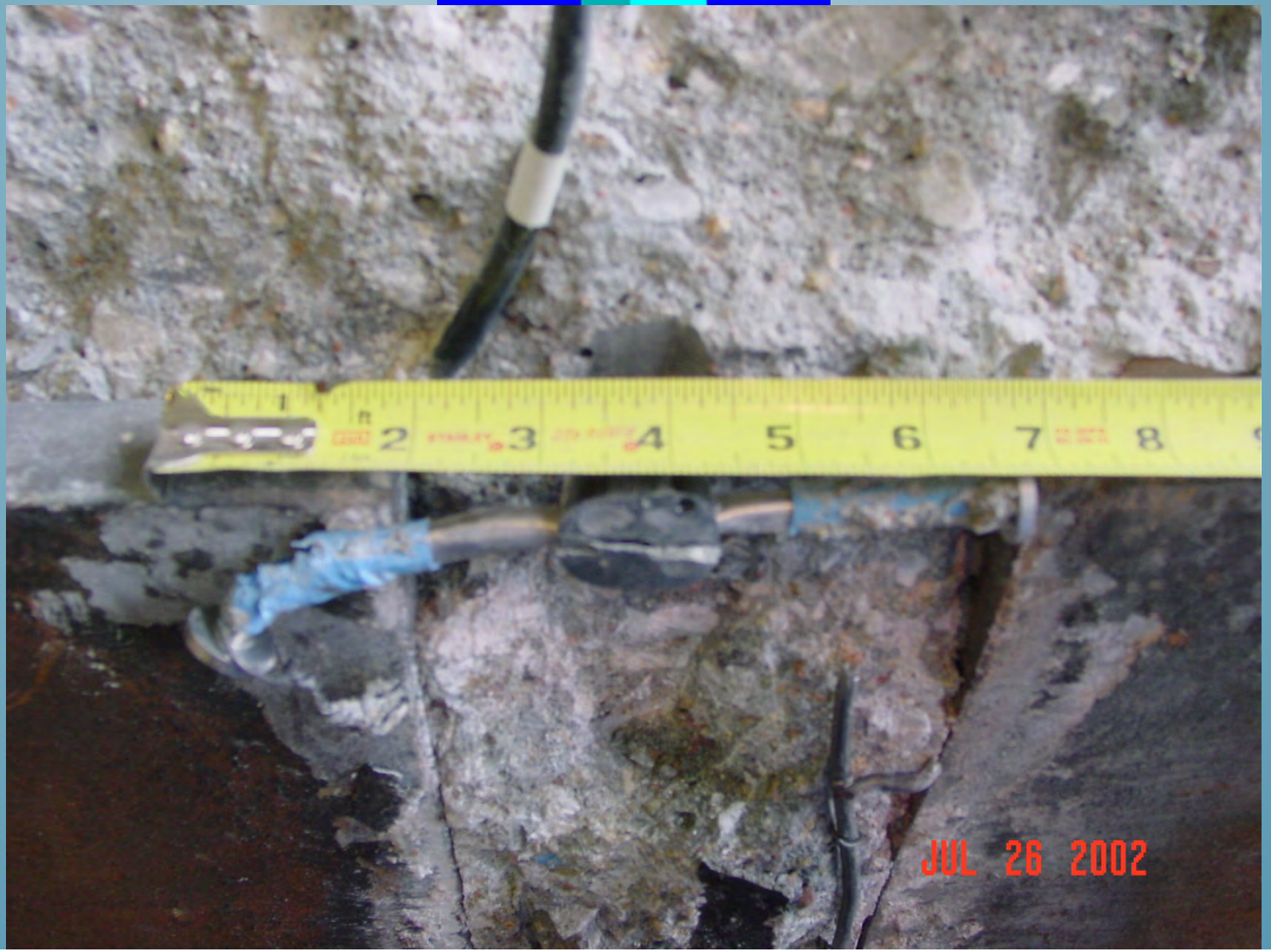

Depth of Girder (in)
Micro Strain at Section A-A
Test1,0 Cycle
Test1,2M Cycles
Test3, 30000 Cycles
Test3, 2M Cycles
A
A

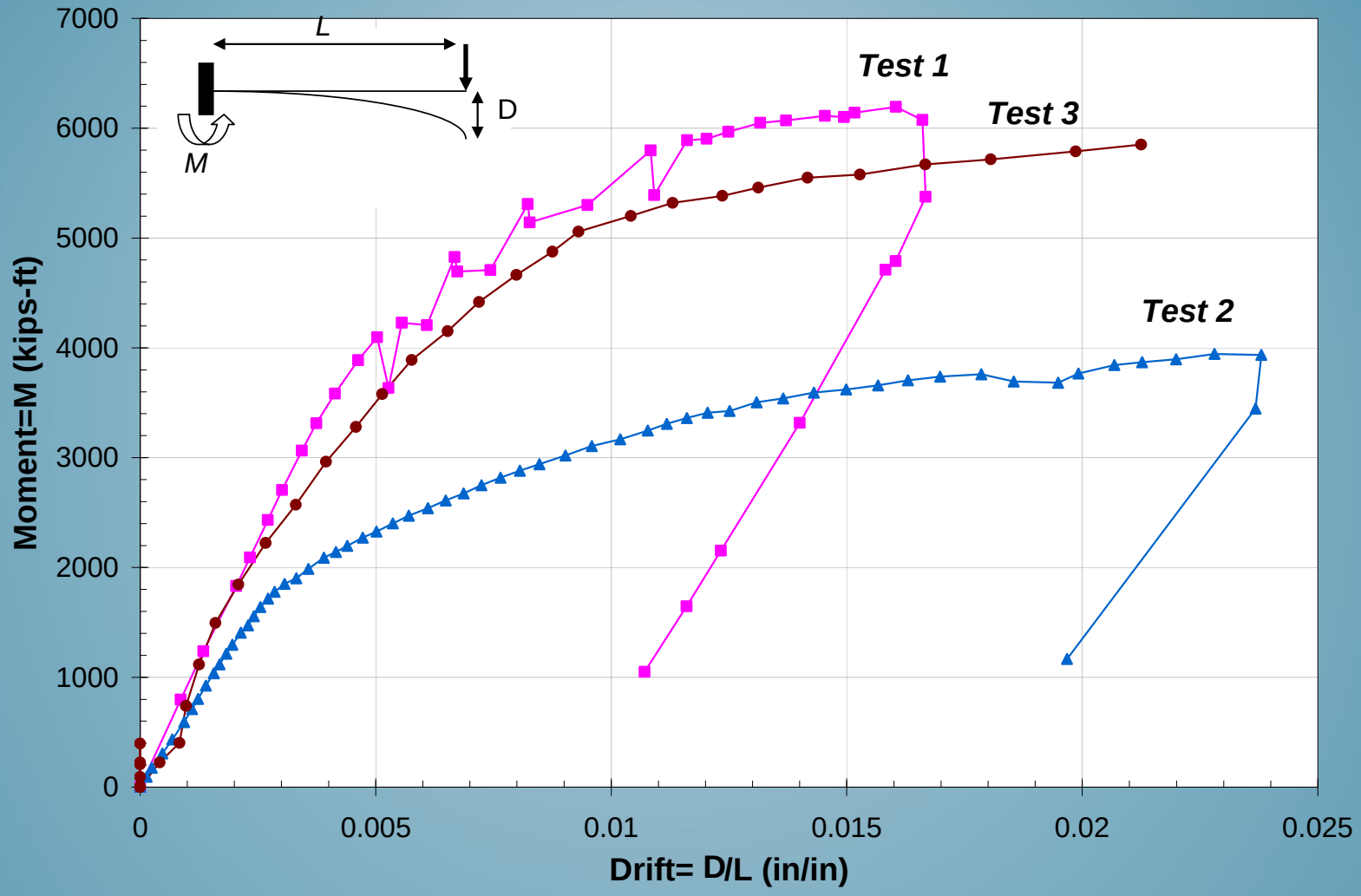

1705
1153
600.2
Micro Strai
47.8
-504.6
-1057
45.15
36.12
27.09
18.06
9.03
0
Girder Depth (in)
47
28.2
9.4
-9.4
-28.2
-47
Diaphragm Width (in)

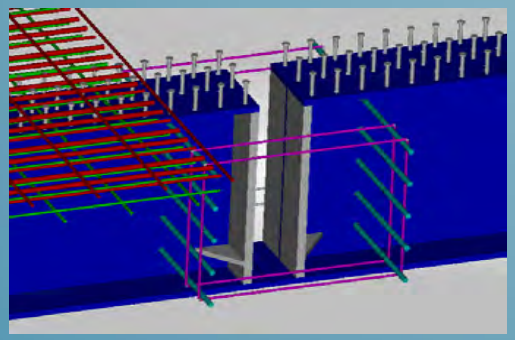

Depth of Girder (in)
Micro Strain at Section B-B
Test1, 0 cycle
Test1, 2M cycles
Test2, 370k cycles
Test2, 2.8M cycles
Test3, 30k cycle
Test3, 5.5M cycles
B
B

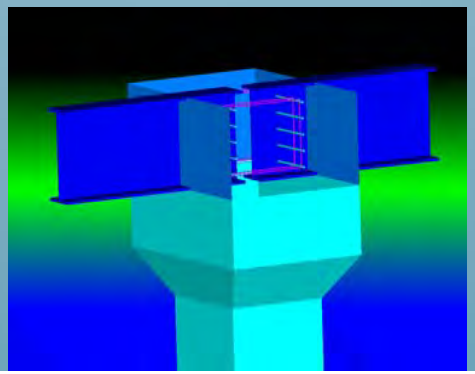

Strain (ms)
Slab Width (in)
Test-2
FEA-2

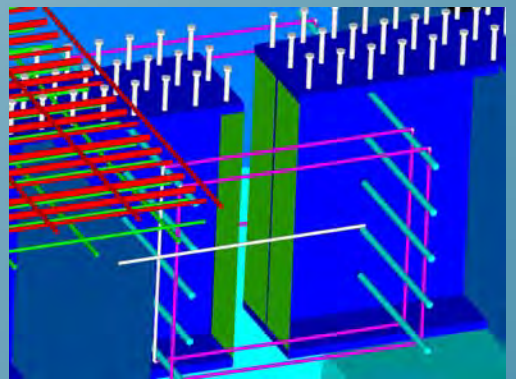


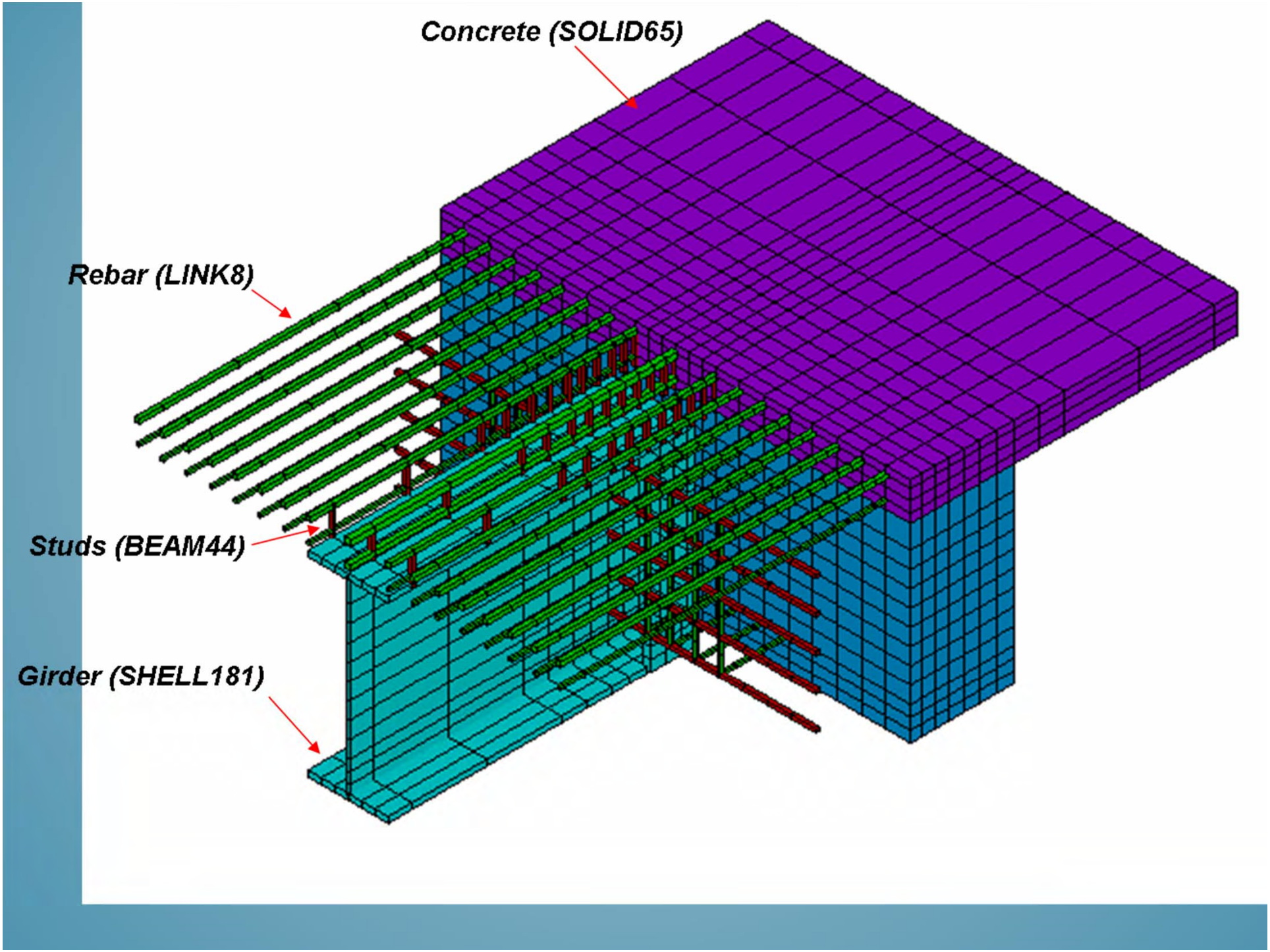

JUL 26 2002


L
D
M
Test 1
Test 3
Test 2
Moment=M (kips-ft)
7000
6000
5000
4000
3000
2000
1000
0
0
0.005
0.01
0.015
0.02
0.025
Drift= D/L (in/in)

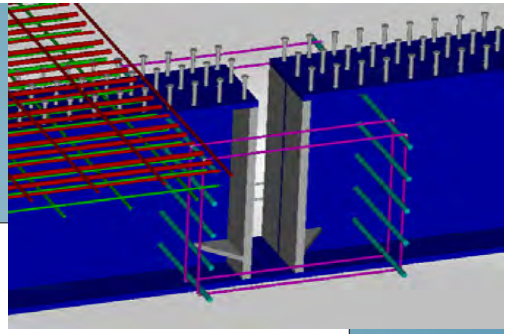


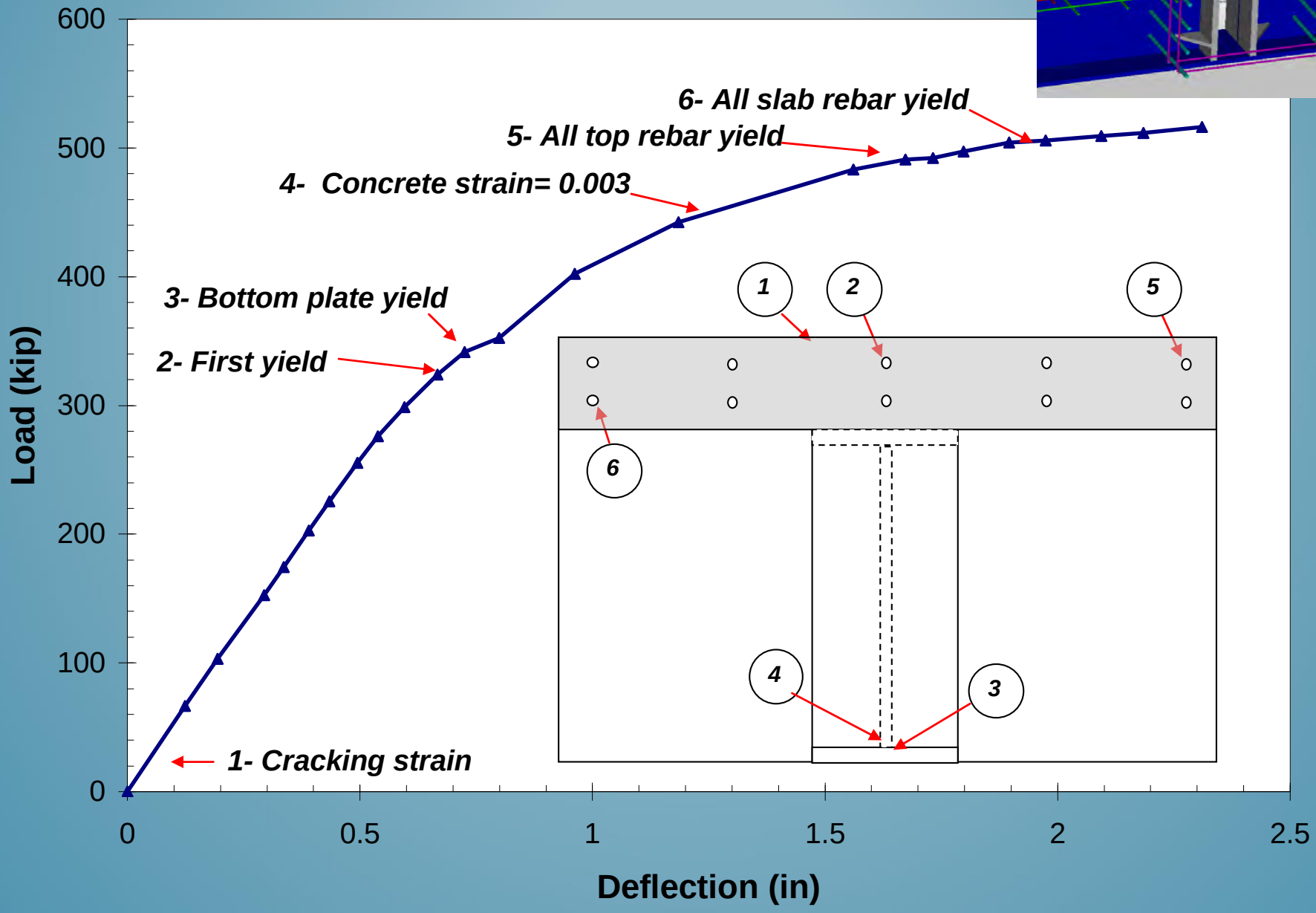


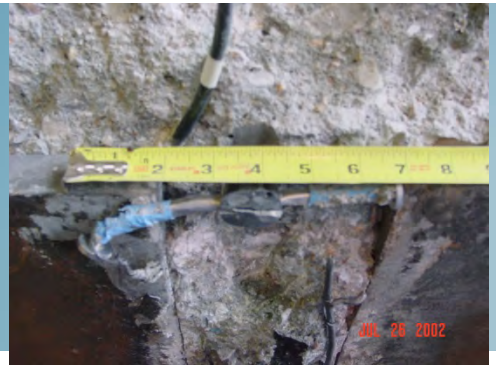


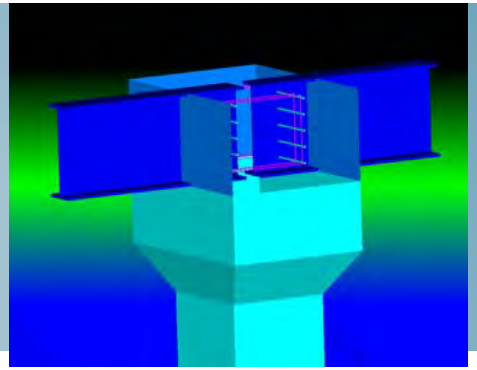

Concrete (SOLID65)
Rebar (LINK8)
Studs (BEAM44)
Girder (SHELL181)

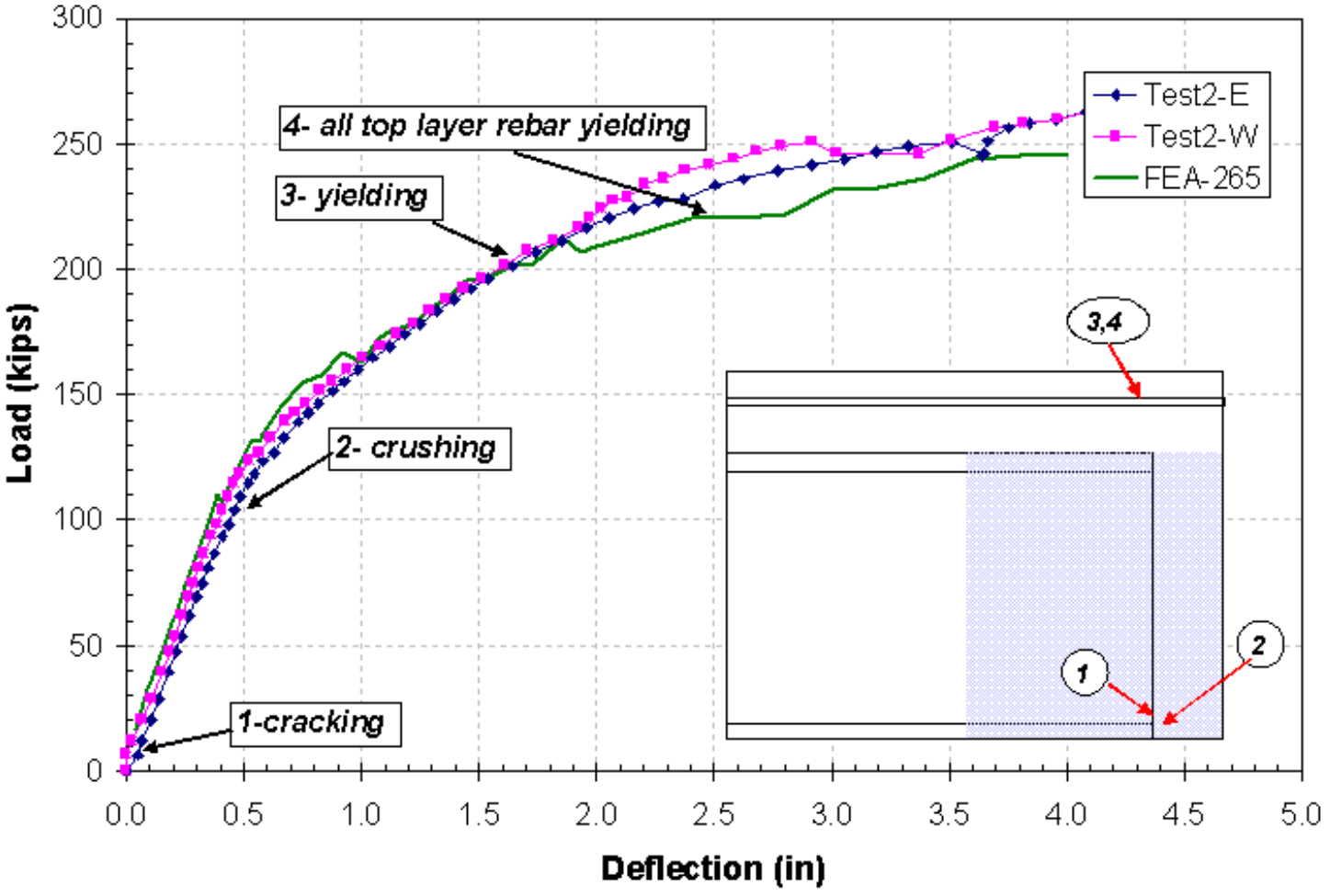
SPECIMEN 1




600
500
400
300
200
100
0
Load (kip)
0
0.5
1
1.5
2
2.5
Deflection (in)
6- All slab rebar yield
5- All top rebar yield
4- Concrete strain= 0.003
3- Bottom plate yield
2- First yield
1- Cracking strain
1
2
5
6
4
3






Load (kips)
Deflection (in)
0
50
100
150
200
250
300
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Test2-E
Test2-W
FEA-265
4- all top layer rebar yielding
3- yielding
2- crushing
1-cracking
3,4
1
2

SDCL
Conventional Application
I girder

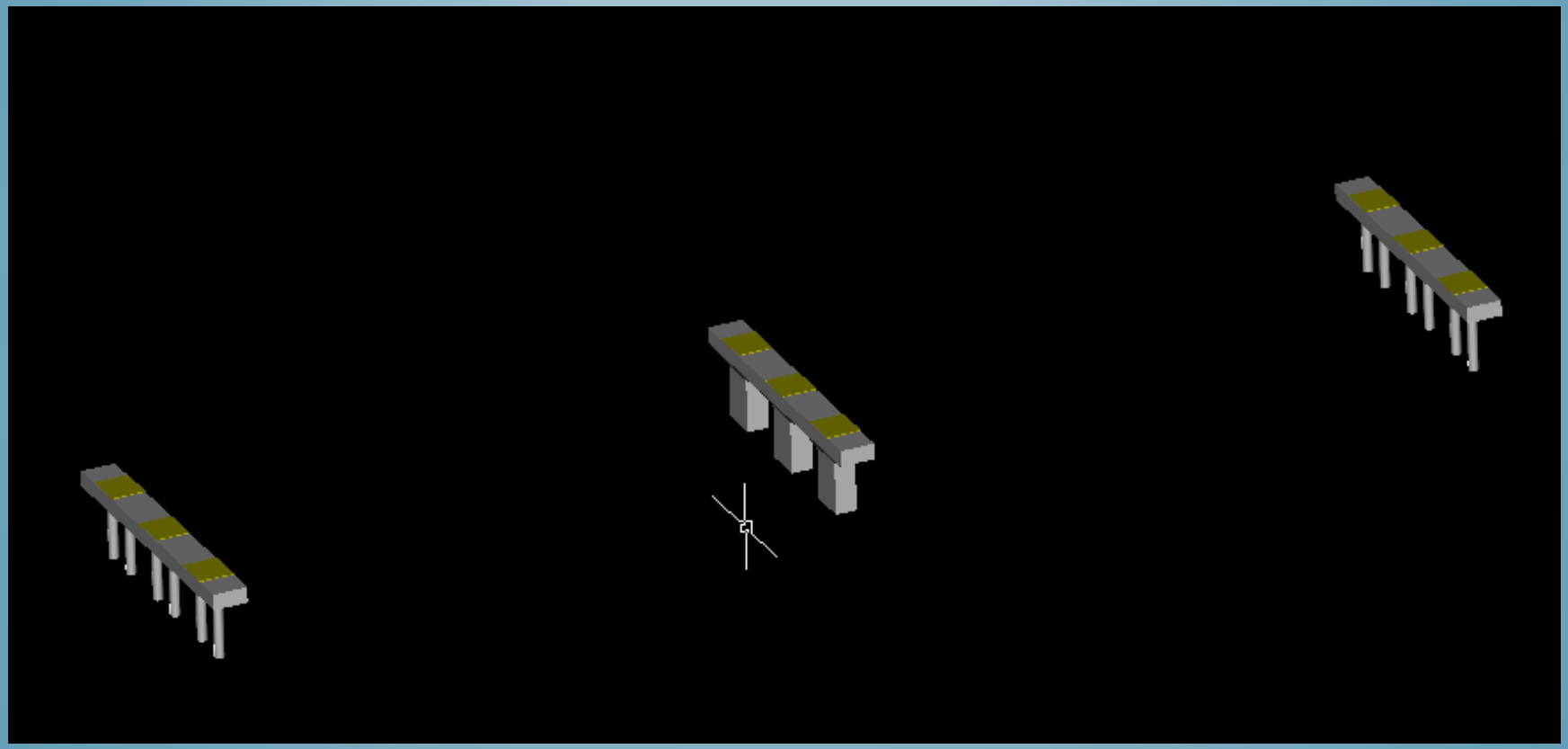

JLG LIFT

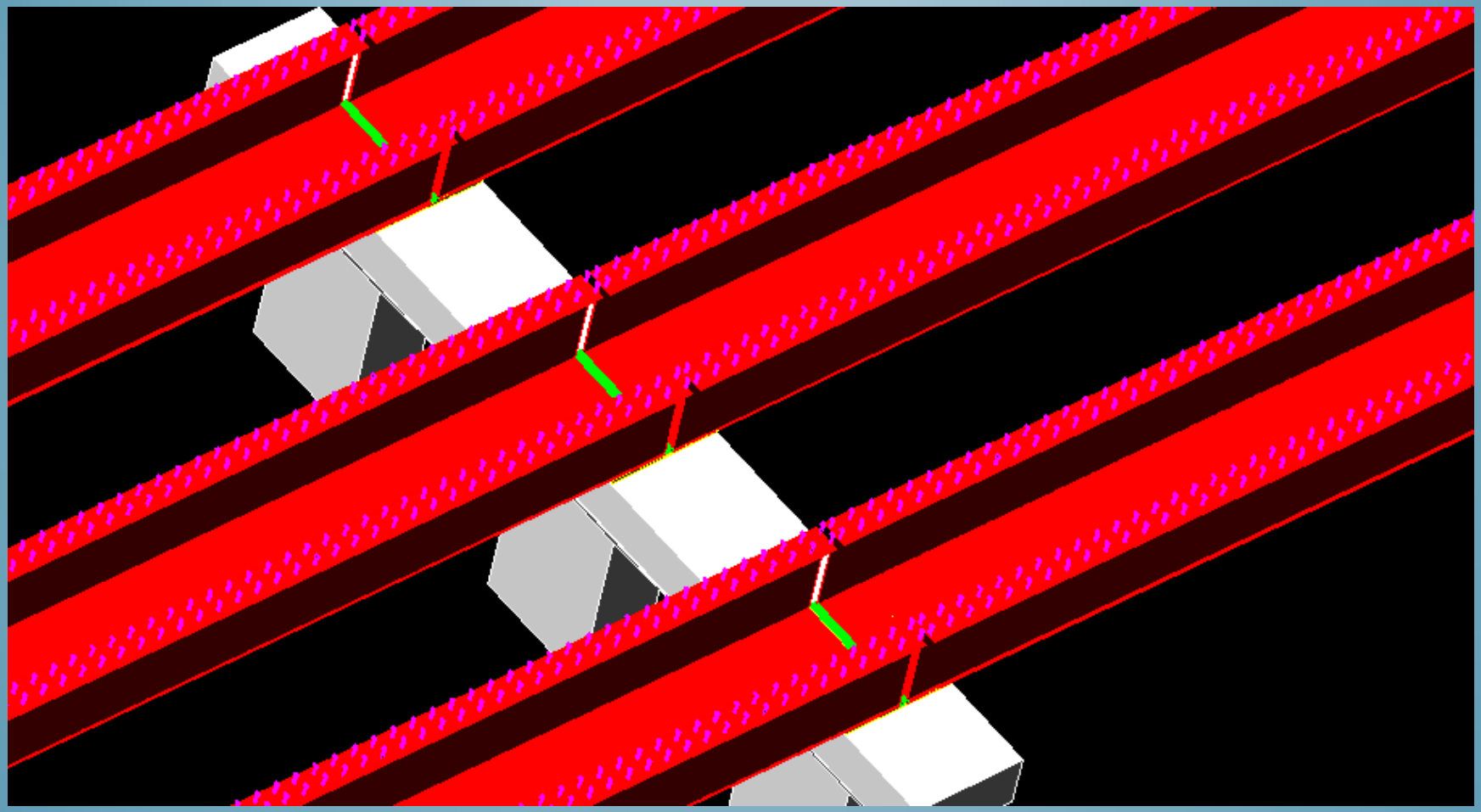

W13

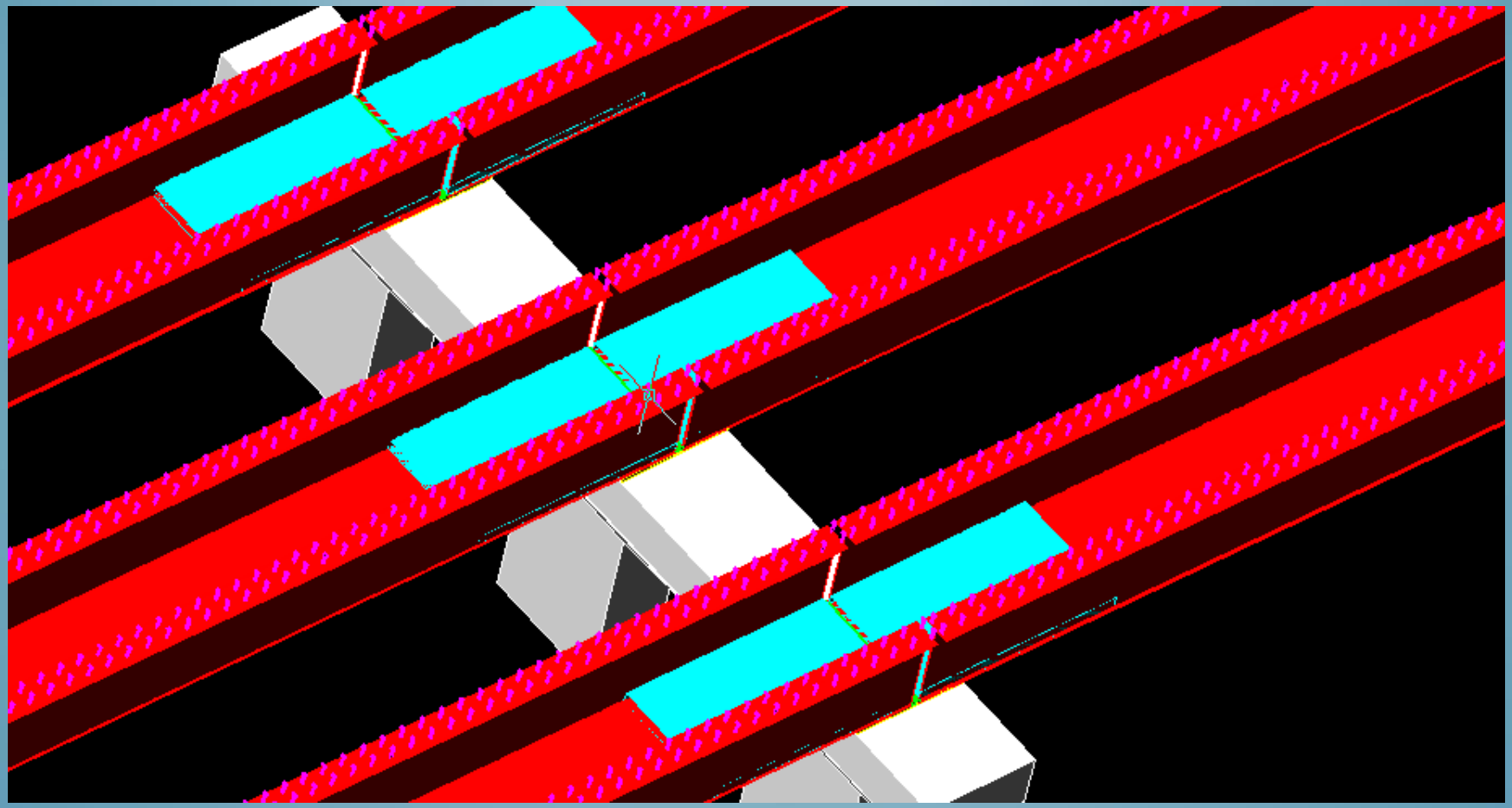

JLG

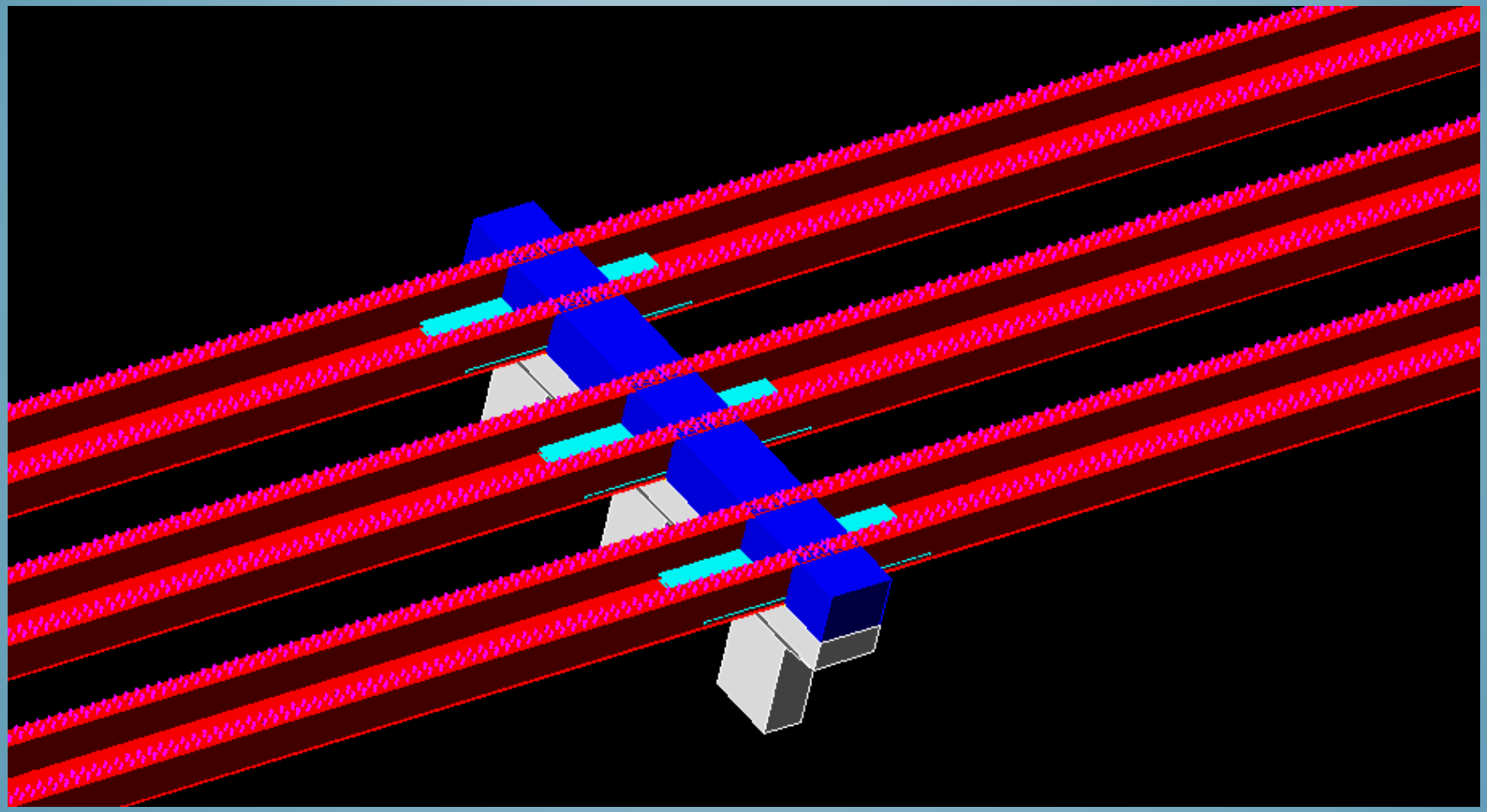

Model 5260
Strain Gauge Sensor

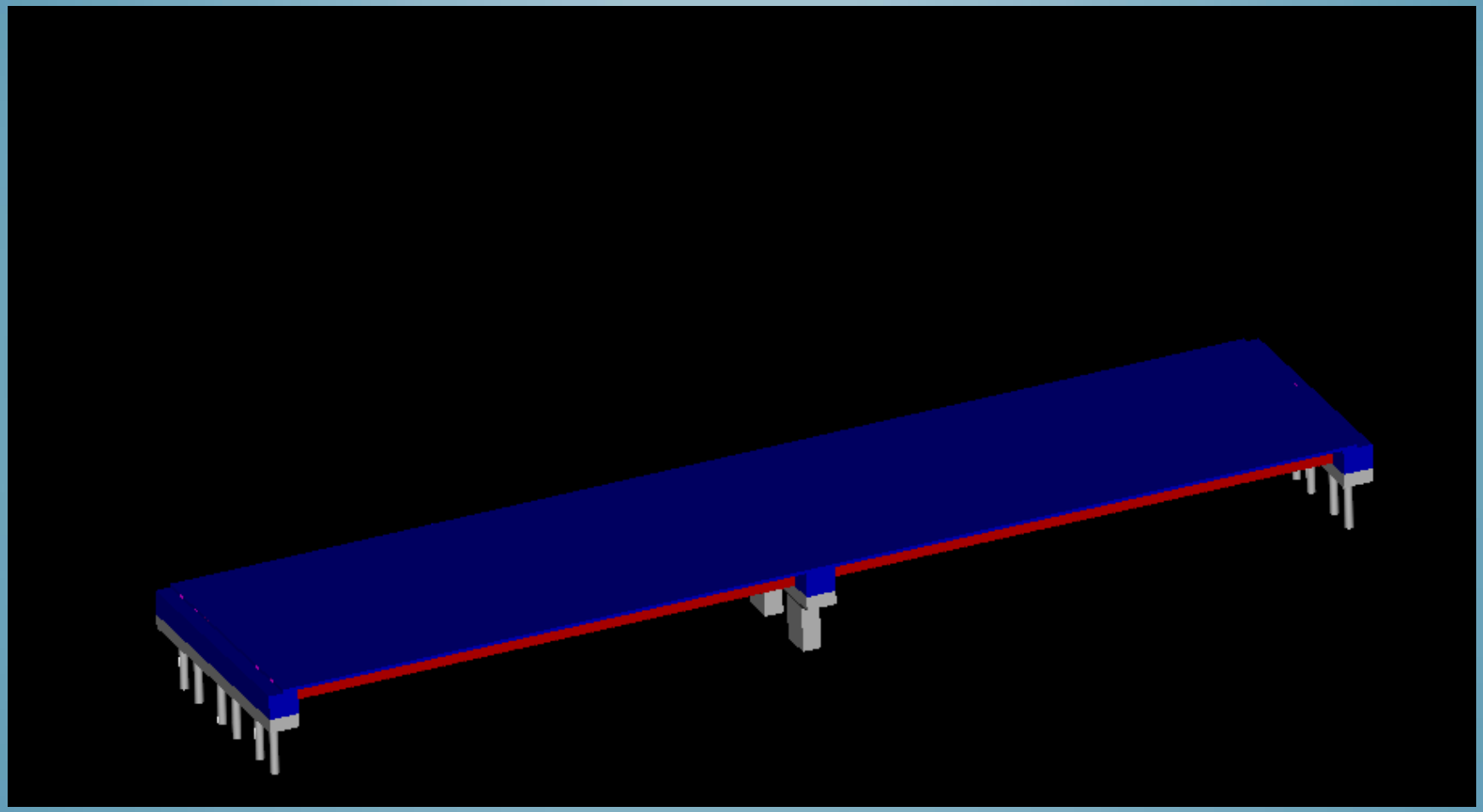
SDCL
Conventional Construction
Box Girder







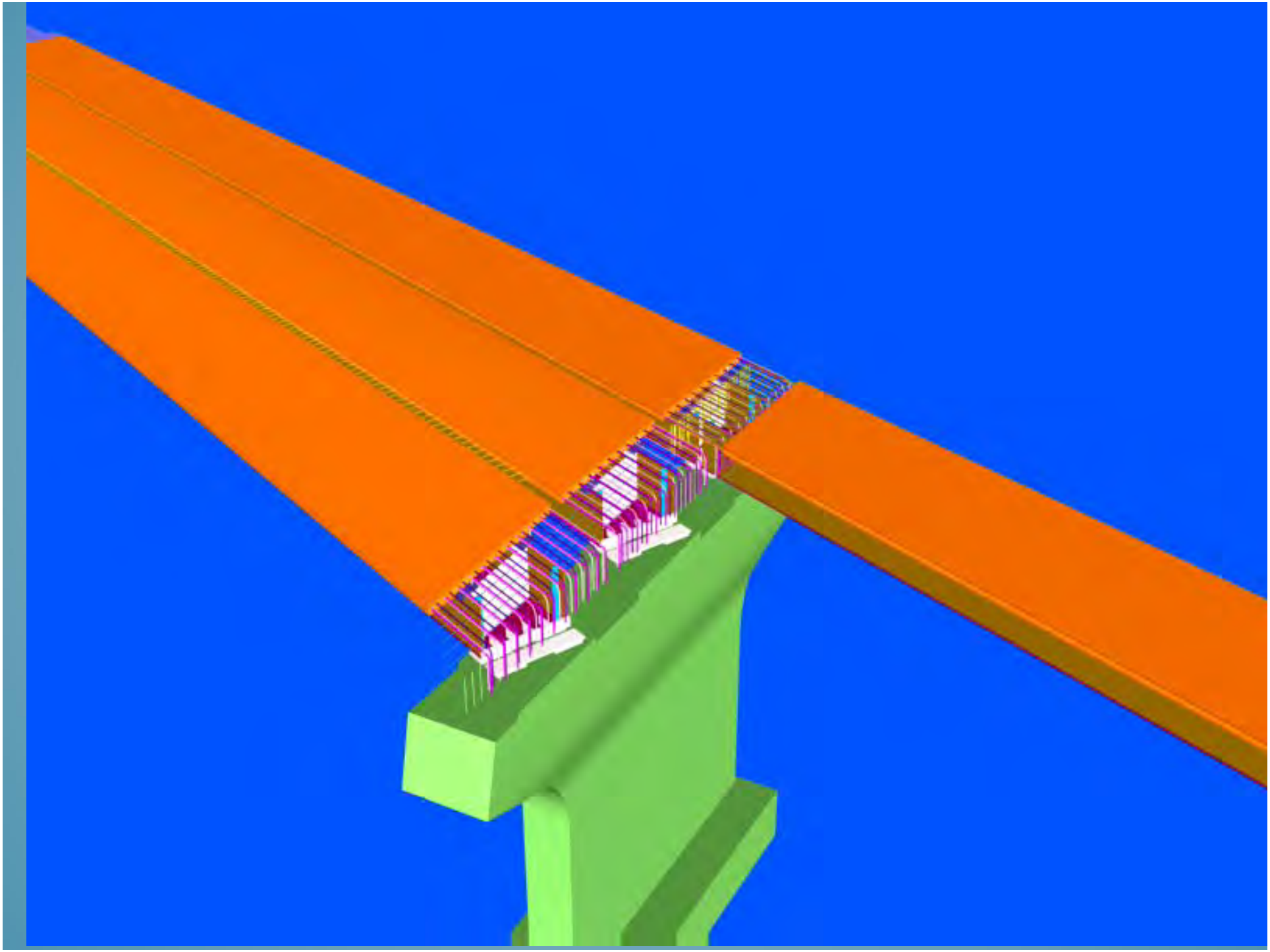




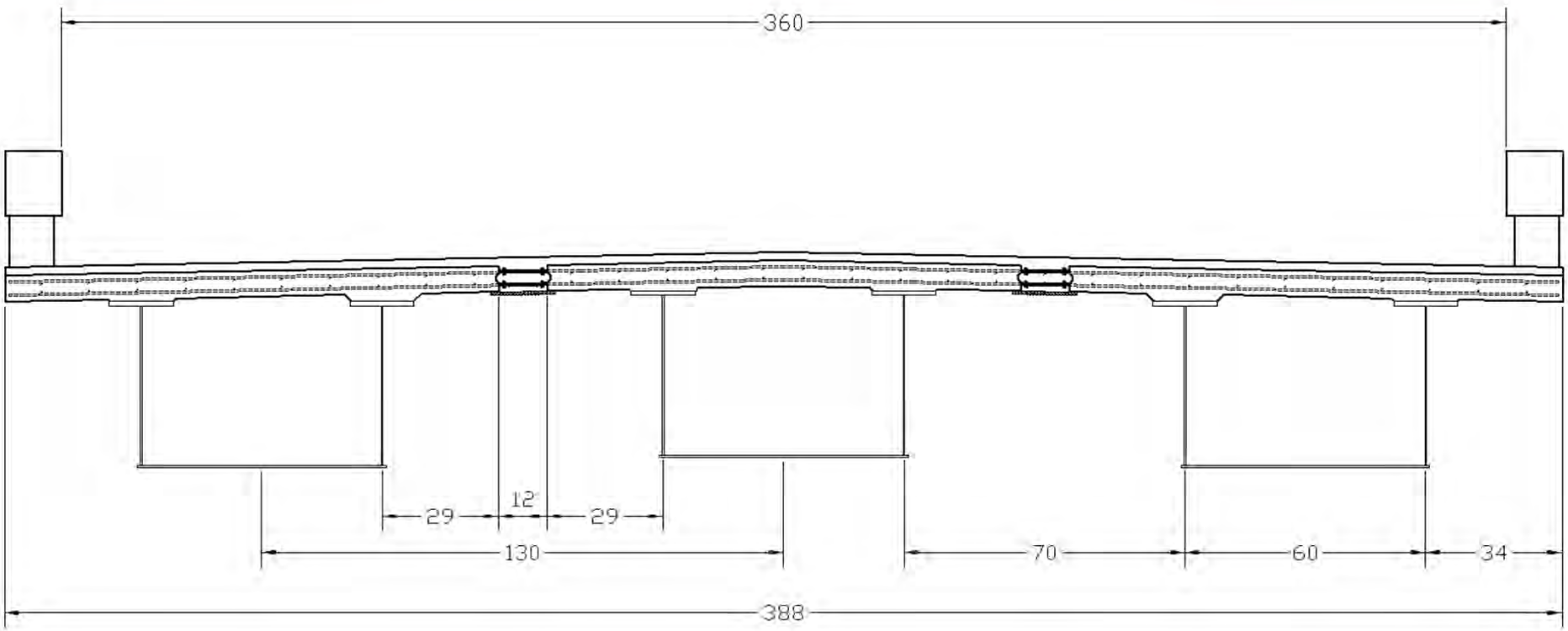
WEB – BOTTOM FLANGE


31817

SDCL
ABC Application- Non-Seismic Box Girder

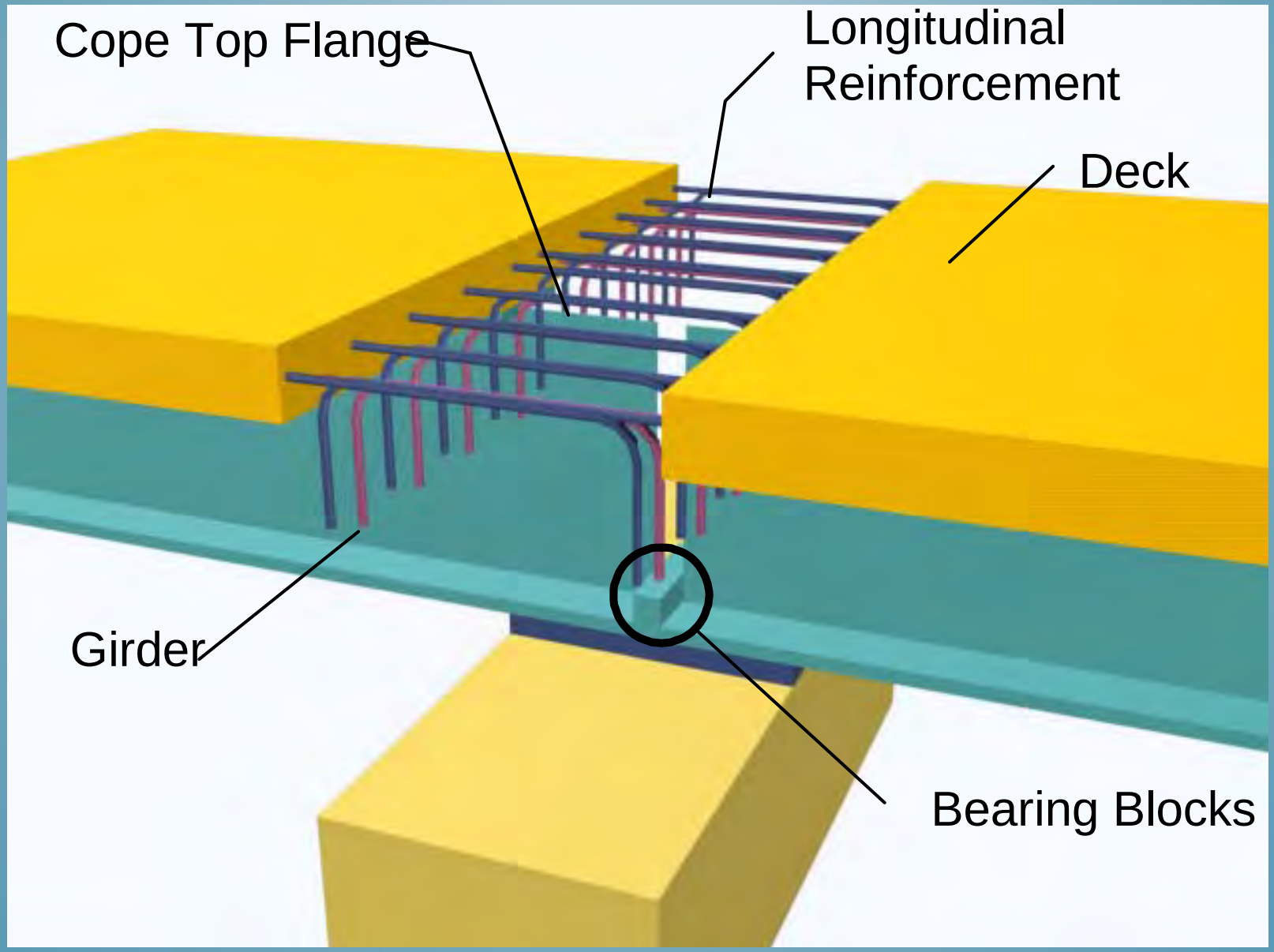


	6.5" SubDeck	8" Full Depth
Steel	25.6	25.6
Deck	58.1	71.5
Total	83.7	97.1
Rail	18.5	


360
29
12
29
130
70
60
34
388


HAWKINS
FIU
FLORIDA
INTERNATIONAL
UNIVERSITY

Detail over the pier – Non Seismic




NDOR
NaBRO
Nebraska

Temporary Bracings were not used

Pick up device

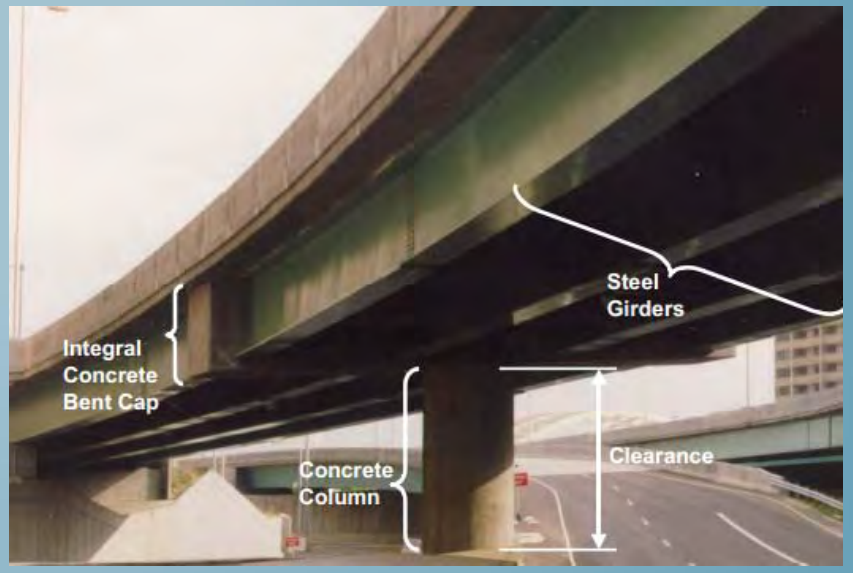

FIU
FLORIDA
INTERNATIONAL
UNIVERSITY


HAWKINS


CANNING

TWO SYSTEMS USED IN SEISMIC APPLICATIONS

Non-Integral Bent Cap:



Integral Bent Cap:

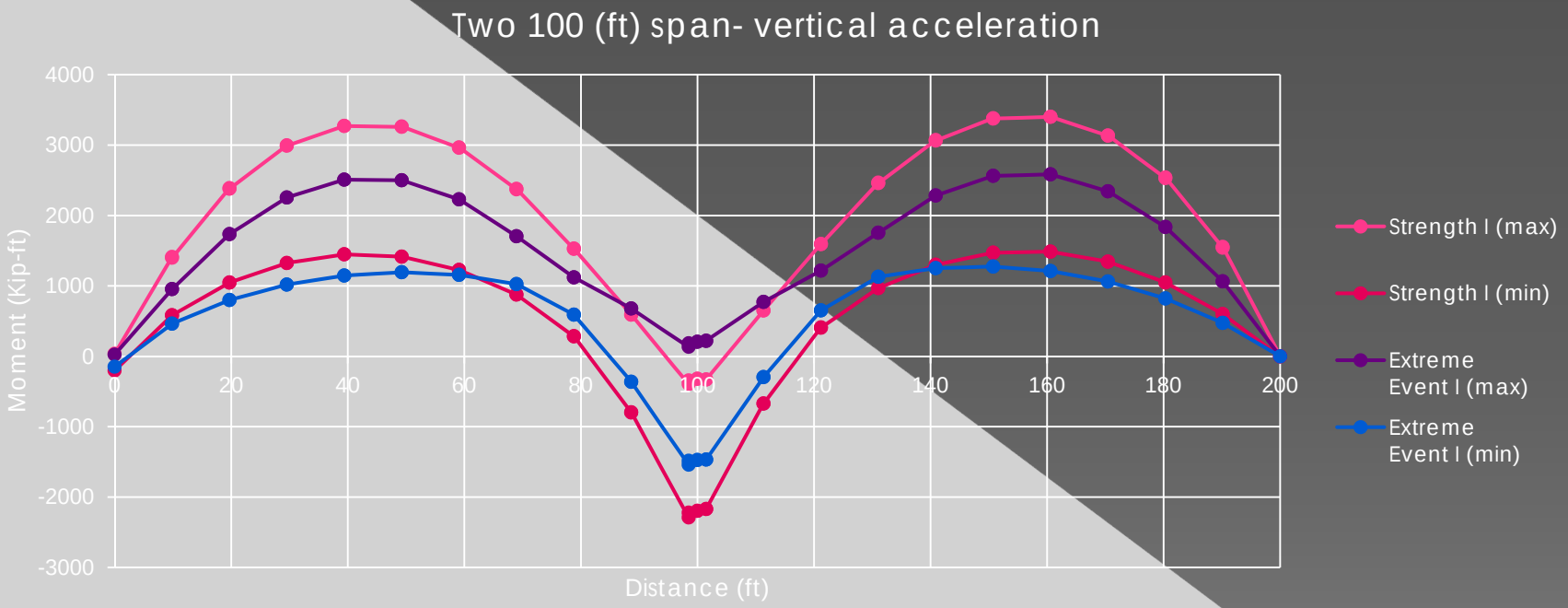
Examined the suitability of the same connection used for non-seismic area
For application in high seismic areas by subjecting a two span steel bridge to number of Ground motions.

Time History Analysis

- *Eight earthquake records were selected, scaled to AASHTO's response spectrum and applied in the model*

Earthquake Name	Scale Factor	Year	Station Name
San Fernando	3.3358	1971	"Palmdale Fire Station"
Imperial Valley-06	1.9876	1979	"Cerro Prieto"
Irpinia	2.1188	1980	Italy
Loma Prieta	3.6419	1989	Anderson Dam (L Abut)
Northridge-01	2.4706	1994	Sunland - Mt Gleason Ave
Duzce	3.407	1999	Turkey
Manjil	0.7572	1990	Iran
Darfield	1.2595	2010	New Zealand

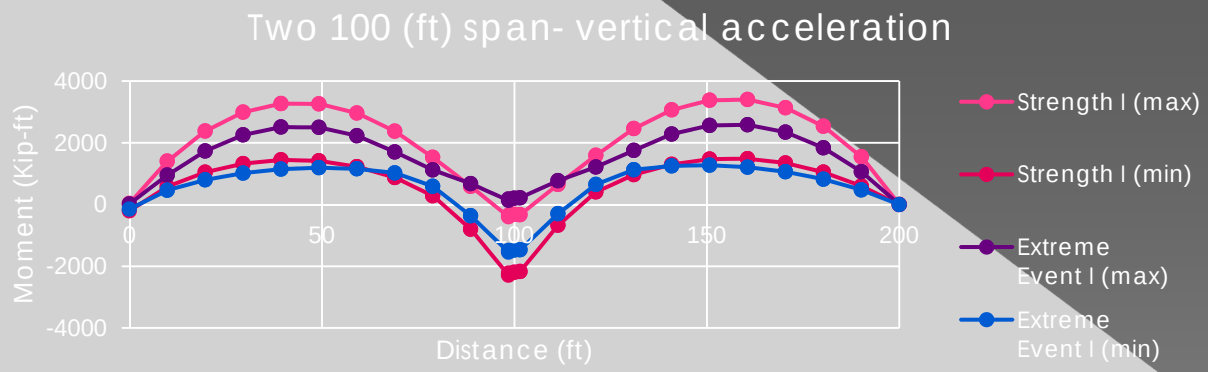
Moment demand along the girders Non-integral



Strength I=1.25DC+1.5DW+1.75LL

Extreme Event I=1.25DC+1.5DW+0.5LL+(mean)EQ

Results indicated that there is possibility of Bottom flanges being subjected to tensile, Forces, which demands bottom flanges To be connected.



To develop a better idea on demand side with Respect to internal forces in the concrete Diaphragm, detail FE analysis are carried out

It is also recognized that the type of forces that Connection over the pier will be subjected During major earthquake will be complex and That may not be well enveloped by merely Subjecting number of prototype bridges to Non-linear time history dynamic analysis.

Very detail FE model was developed to gain A better understanding of

a) Suitability of non-seismic detail for seismic Application

b) Modes of failure

c) Modifications to detail that are needed for Application to high seismic areas

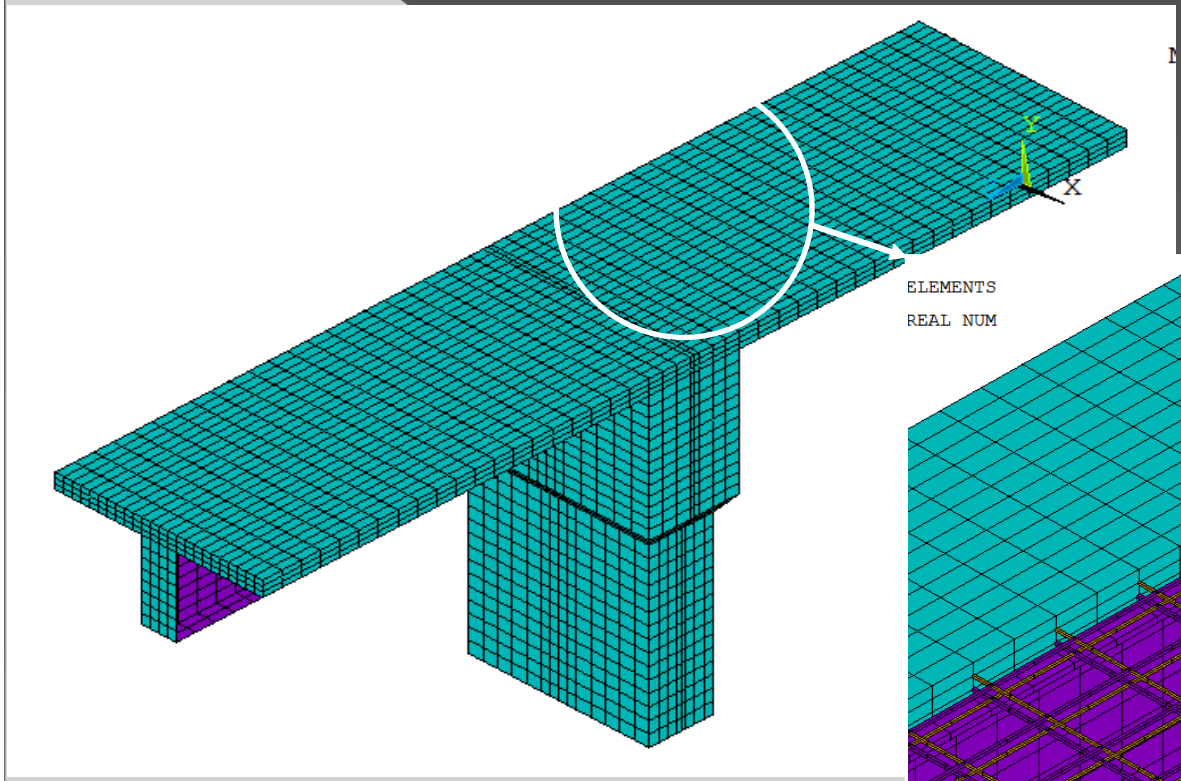
Very detail FE model was developed to gain A better understanding of

a) Suitability of non-seismic detail for seismic Application

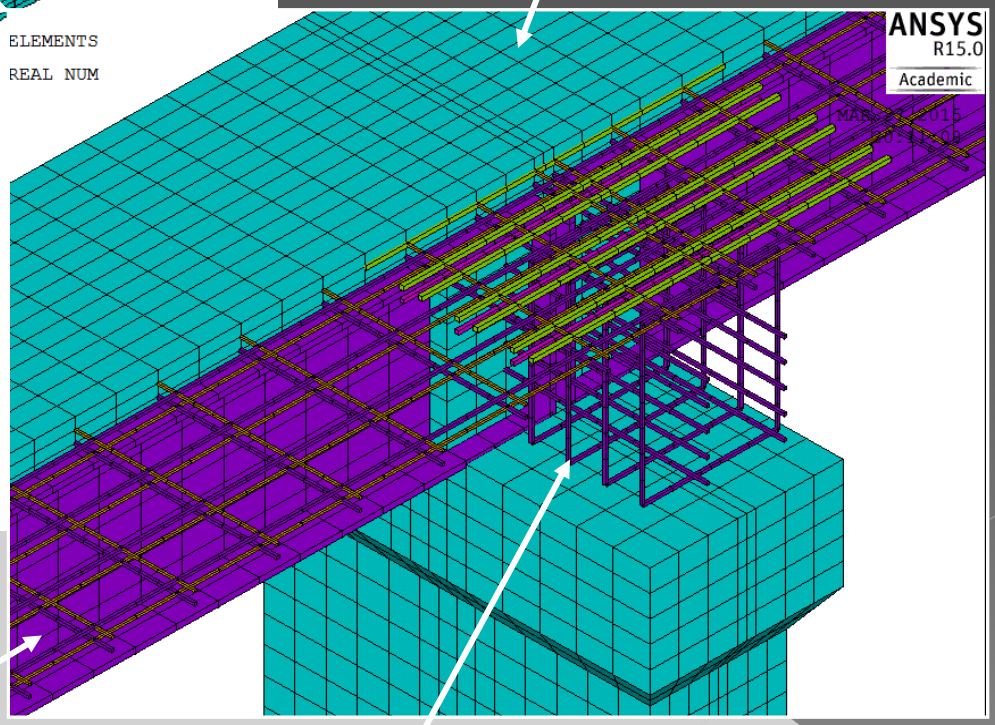
b) Modes of failure

c) Modifications to detail that are needed for Application to high seismic areas

Integral Connection- Bottom flange not connected



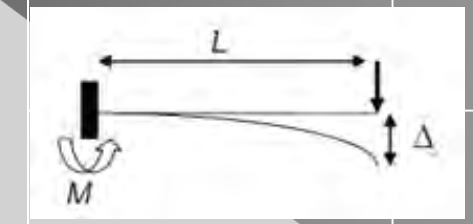
SOLID 65



SHELL181

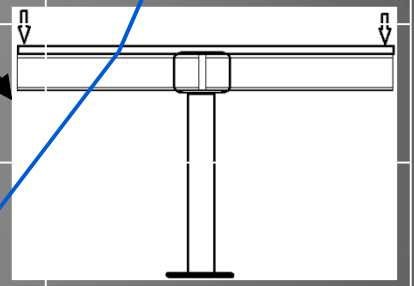
LINK180

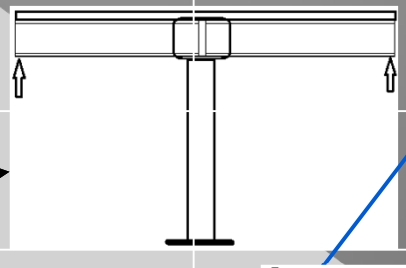
Moment -Drift

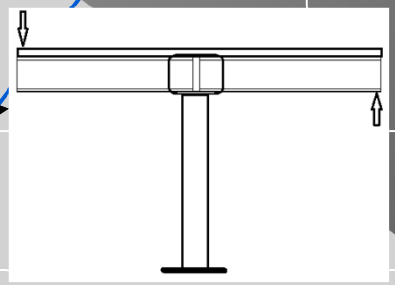


Experimental Results (Test 3)

Experimental Results (Test 1)







Moment (Kip-ft)

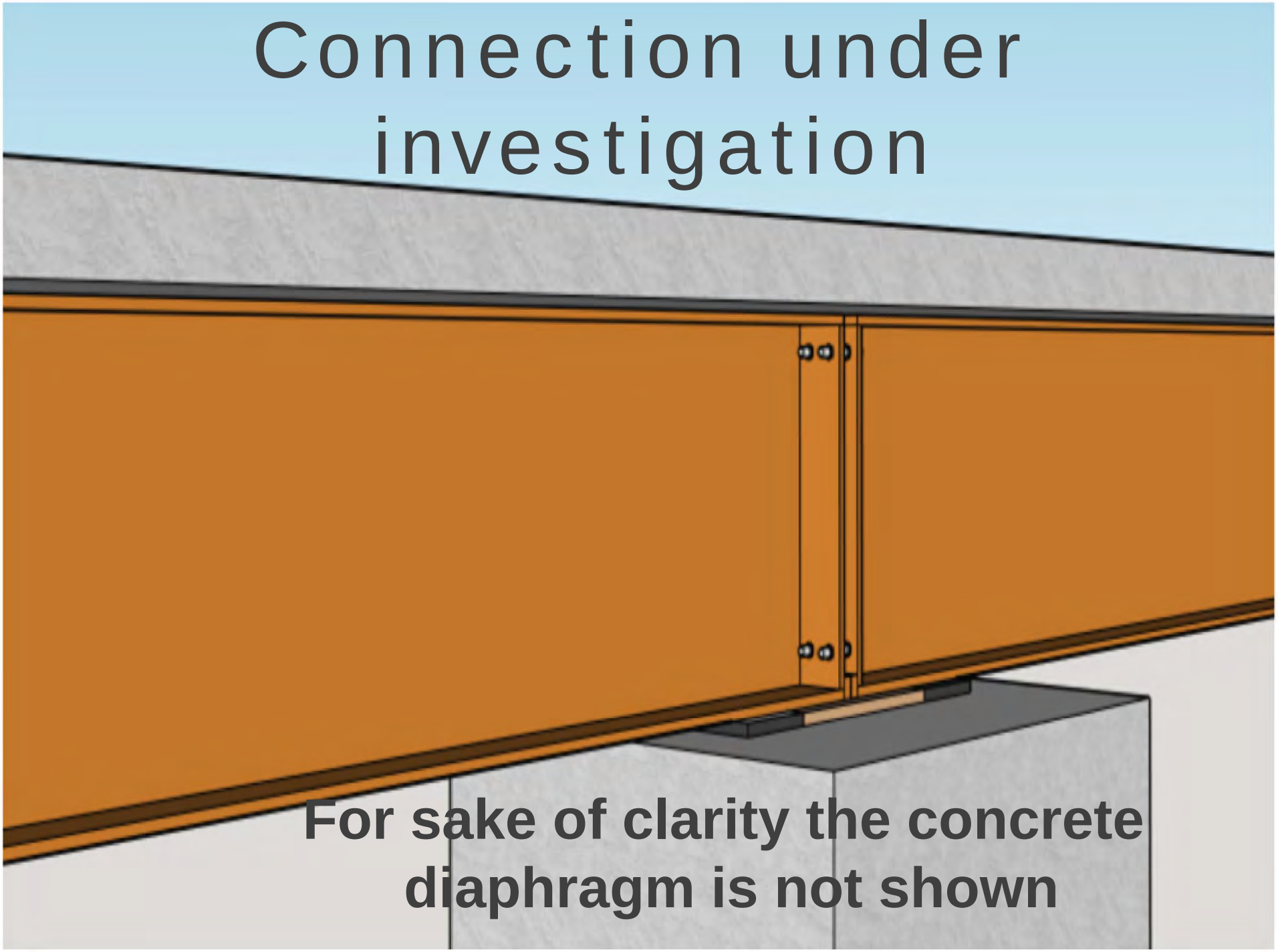
7000
6000
5000
4000
3000
2000
1000
0

0.000
0.005
0.010
0.015
0.020

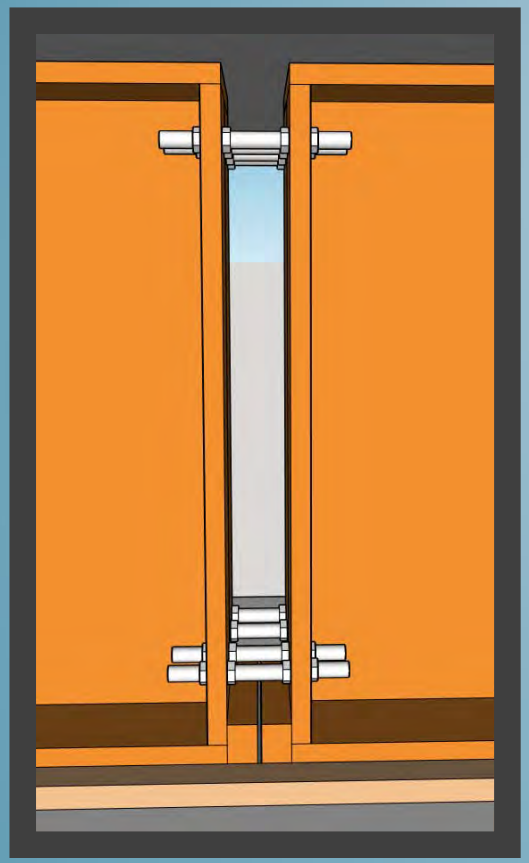
Drift

Results clearly shows that non-seismic Detail needs modifications

Connection under investigation

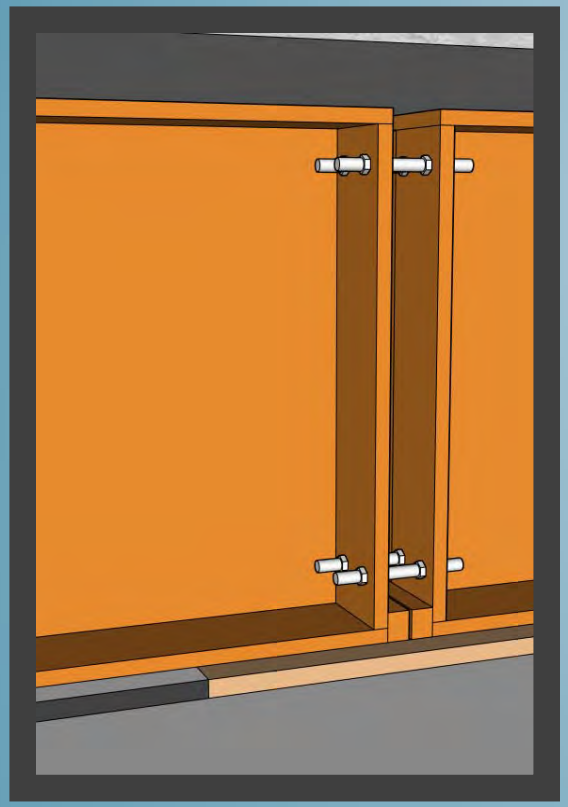


For ABC or Conventional Construction



For sake of clarity the concrete diaphragm is not shown

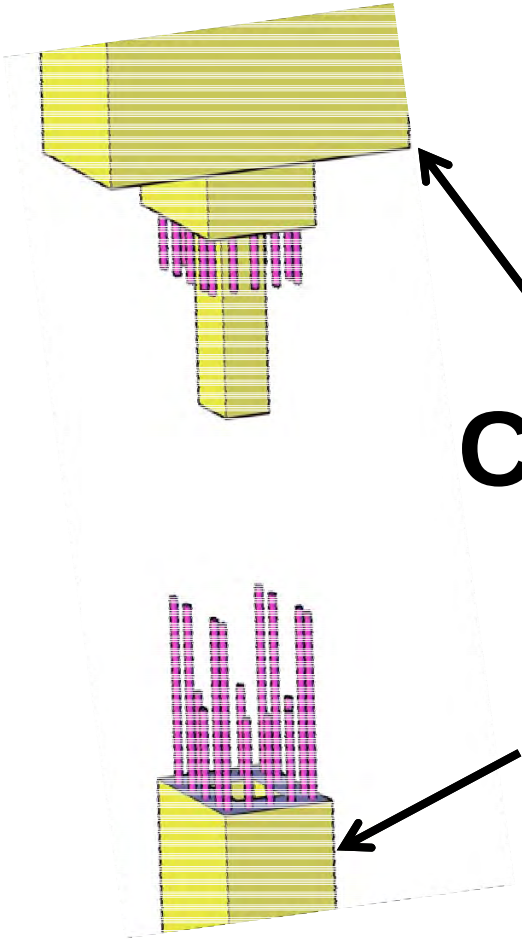
For ABC or Conventional Construction

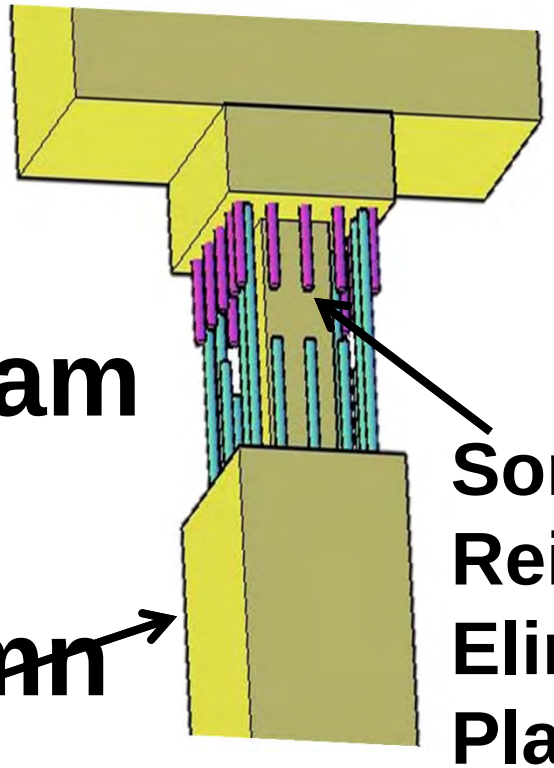


For sake of clarity the concrete diaphragm is not shown

Connection detail for Pier Cap Beam to Column Using UHPC for ABC Application in High Seismic Areas

Beam to Column Connection Detail to be tested



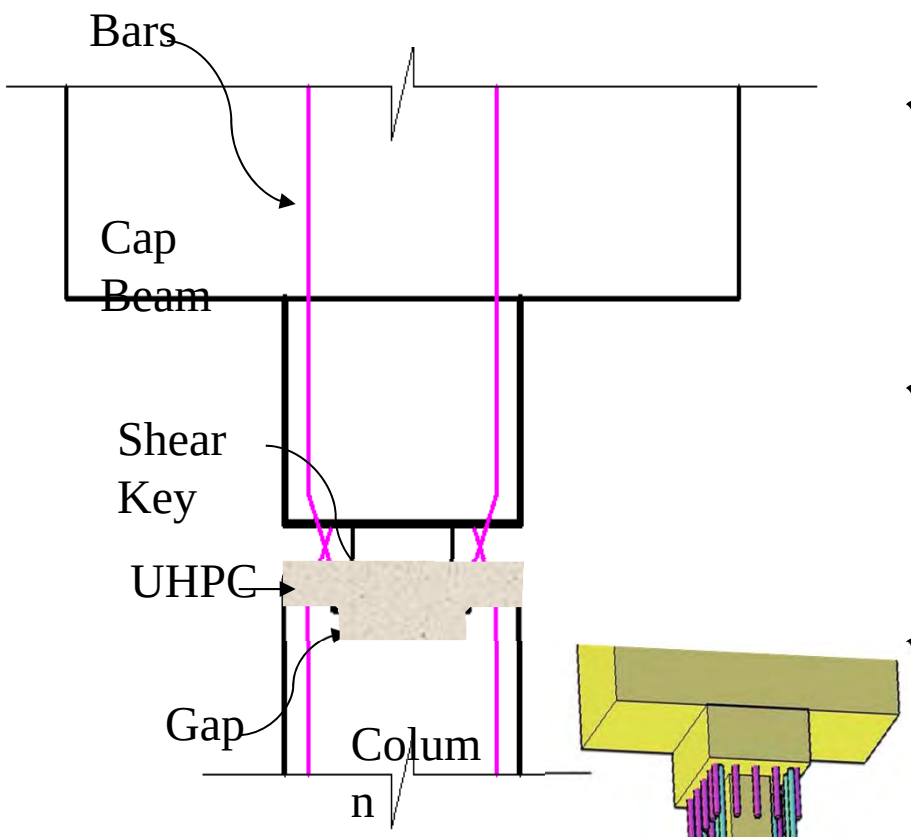


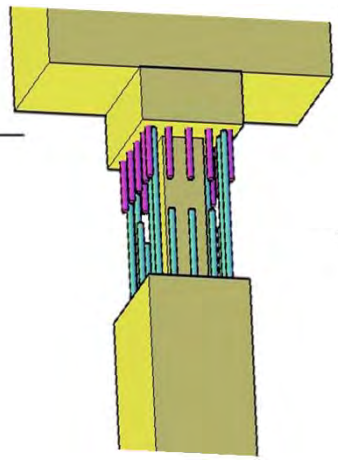
Cap Beam

Column

Some of the Reinforcemer Eliminated to Plastic Hinge Formation

Connection Detail

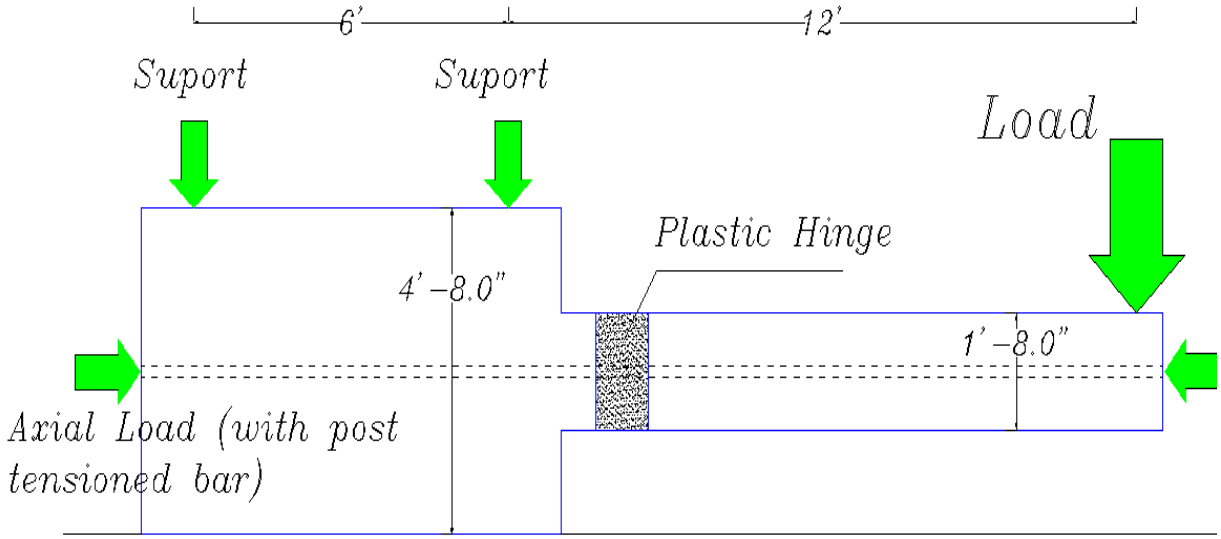


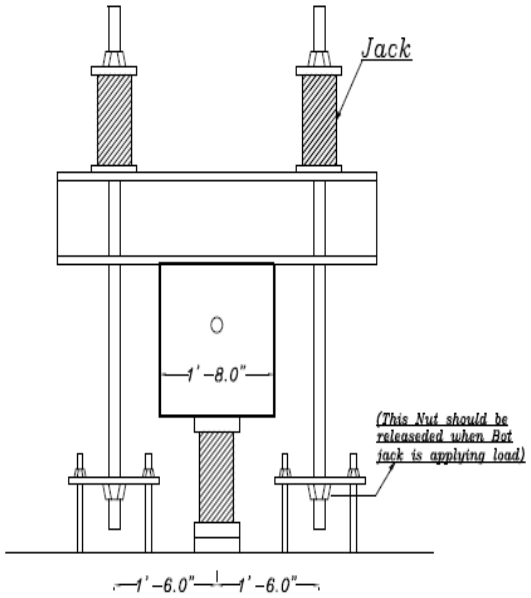


Advantages

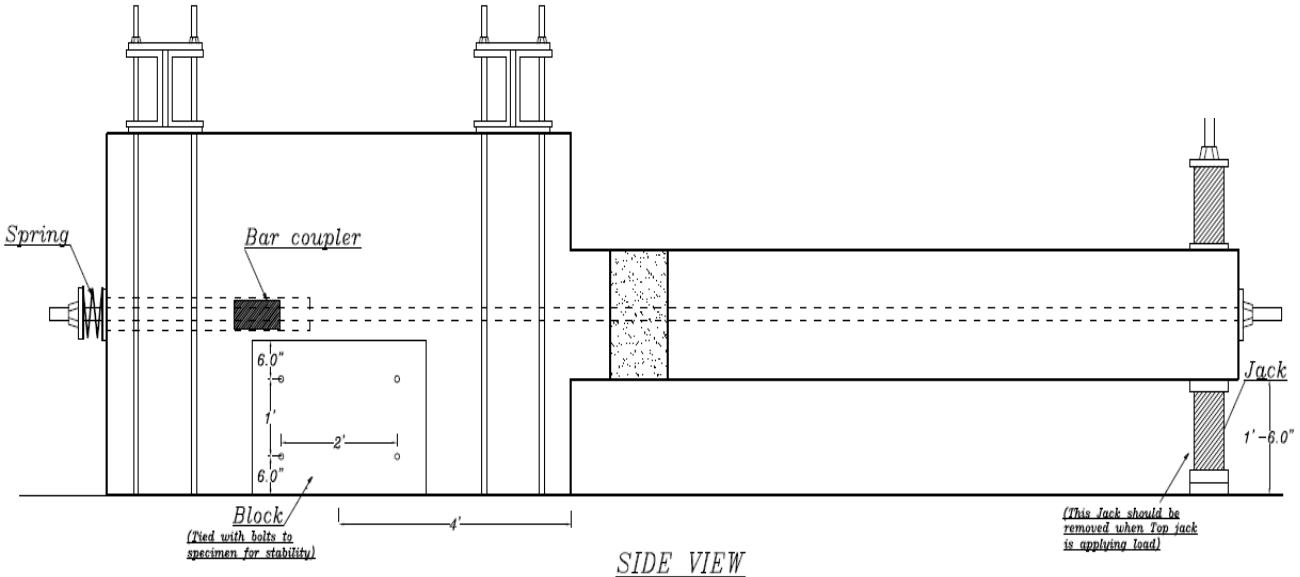
- ✓ **Eliminates modifications needed for cap beam reinforcement**
- ✓ **Large tolerances**
- ✓ **Plastic hinge forms at a distance away from cap beam**
- ✓ **Use of UHPC allows development of reinforcement using smaller length**

Test Setup (Loading Detail)



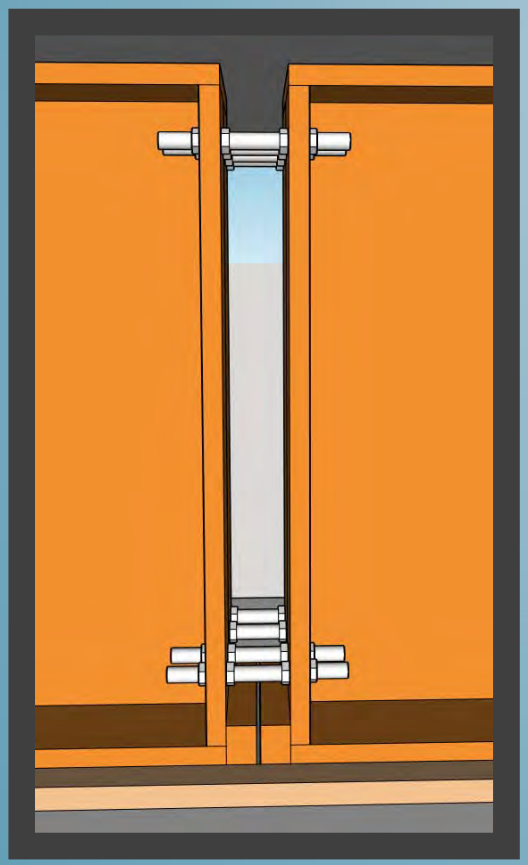


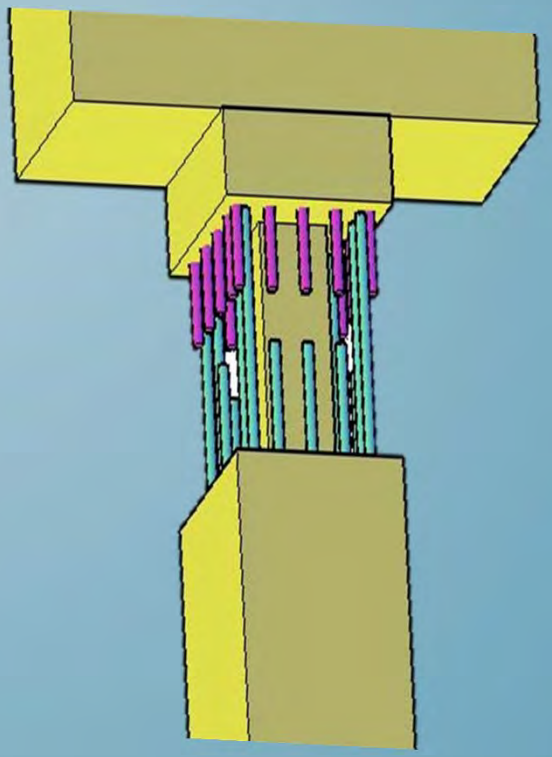
FRONT VIEW



SIDE VIEW

Thank You





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