Special Elite Engineers Webinar Sequence

An Insider's Perspective

Structural Challenges for Construction at Hudson Yards, East End Access & Harlem River Lift Bridge

Our Elite Engineer of the Month: Russell J. Jeck P.E.

Wednesday, May 20th, 2015

3:00 PM – 4:00 PM EST

Copyright Materials

Speaker Information

Russell J. Jeck, P.E.

Senior Design Engineer | Licensed PE in NY, CT, VA and MD

EXPERIENCE

Proven ability to supervise and coordinate the design and construction of large capital projects including bridges, buildings, stations, tract, and power facilities.

PROJECT

- Hudson Yards
- Verrazano Bridge
- MTA East Side Access
- Taconic Parkway over Croton Reservoir
- Yankee Stadium Station
- Harmon Rail Yard
- Moodna Viaduct
- Hudson Stations
- Hudson /Harlem Bridges

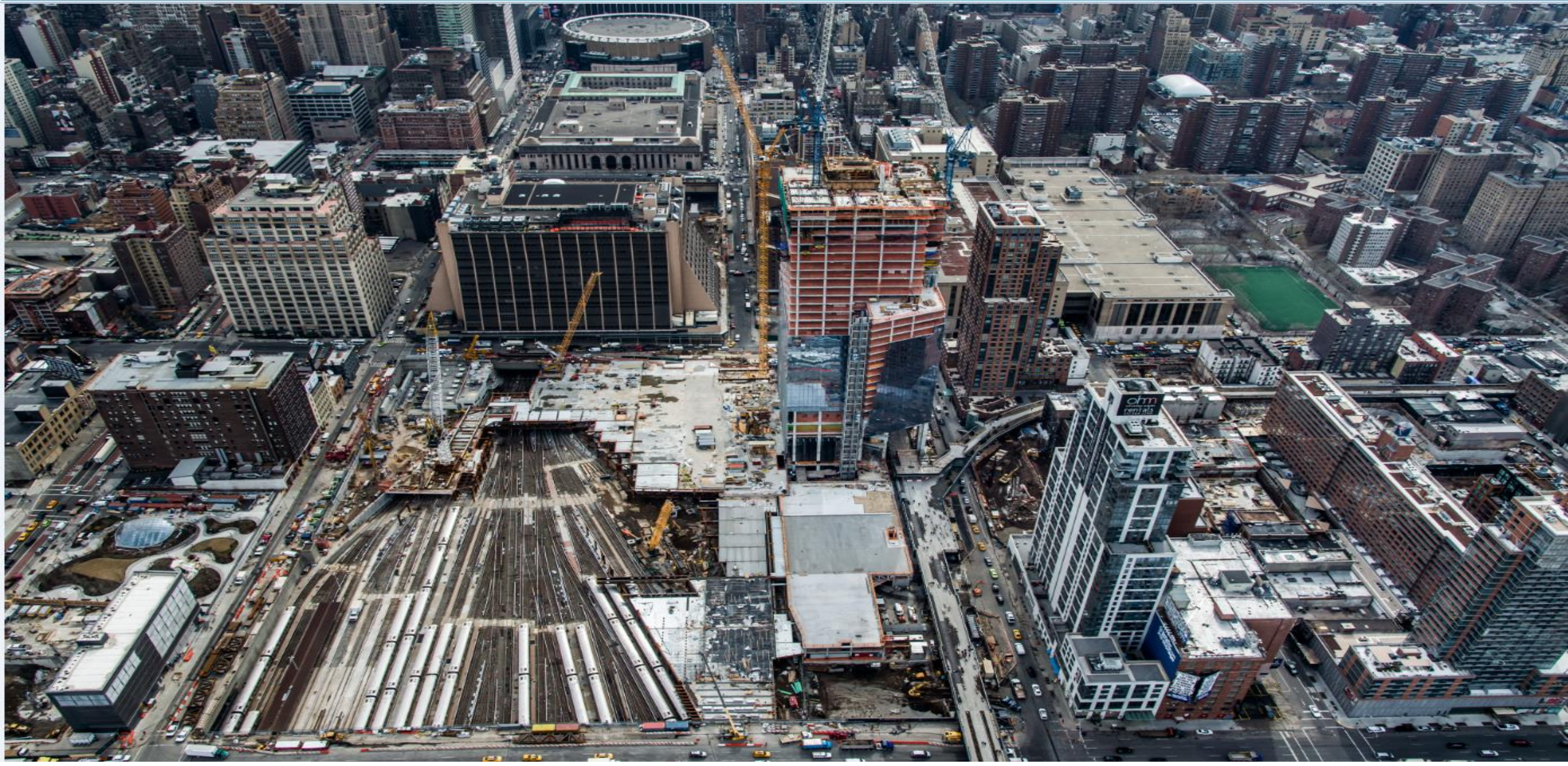
Learning Objectives

At the end of this course, participants will be able to understand:

1. Using Midas Civil to meet and analyze structural elements to account for
    1) fabrication tolerance
    2) member imperfection
    3) partial yielding of the cross-section
    4) boundary conditions that are not fully idealized

2. Using Midas Civil to model loads on structures from excavators, cranes, and other construction equipment

Hudson Yards Overview



Construction Engineering- Introduction

- Construction Engineering
- Part Design – Part Load Rating
- Designs of structural members for SOE's, crane runways, column restraints, anchor bolts, etc.
- Comparative Engineering
  - Sometimes better to show construction loads are less than design loads rather than providing calculations for member capacity based on a limited understanding of analysis assumptions that went into the design
  - Use of shoring and cribbing to spread loads

Hudson Yards - Introduction

Two Projects in One for Tutor Perini Corporation

Construct Gateway Tunnel Extension - Amtrak

Construct “Platform” – Lower Level for Hi-Rise and Mall

Tunnel – Structural Design - Parsons Brinkerhoff

Platform and Overbuild – Structural Design - Thornton Tomasetti

Crane Engineering – Howard Shapiro and Associates

Hudson Yards – Challenges / Interesting Facts

Access – Construction in an Active Railroad Yard

Hudson Yards stores trains for LIRR daily Operations – Penn Station

Strict Outage Requirements weekends and nights

Column Foundations are in between Yard Tracks – 6 ft. Clearance

Column Foundations are on Tunnel Roof

Several Column Loads are 15,000 to 30,000 kips

Hudson Yards – Construction Engineering Challenges

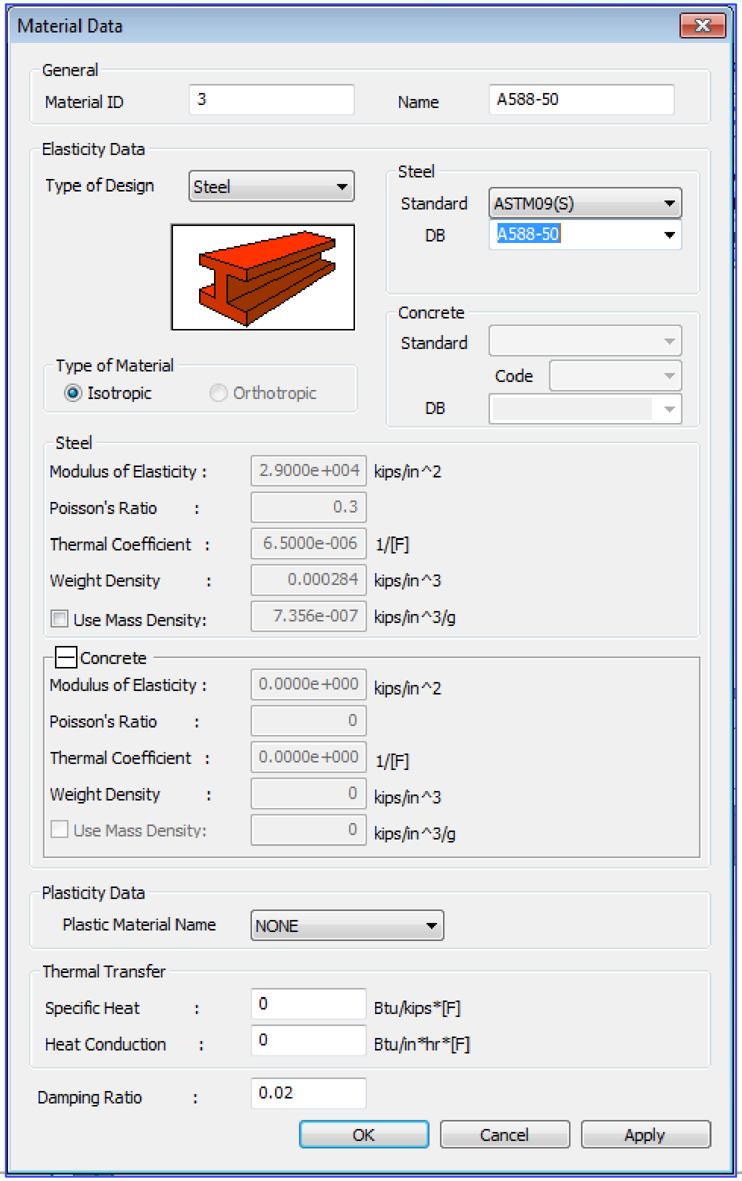
Calculations - Boundary Conditions

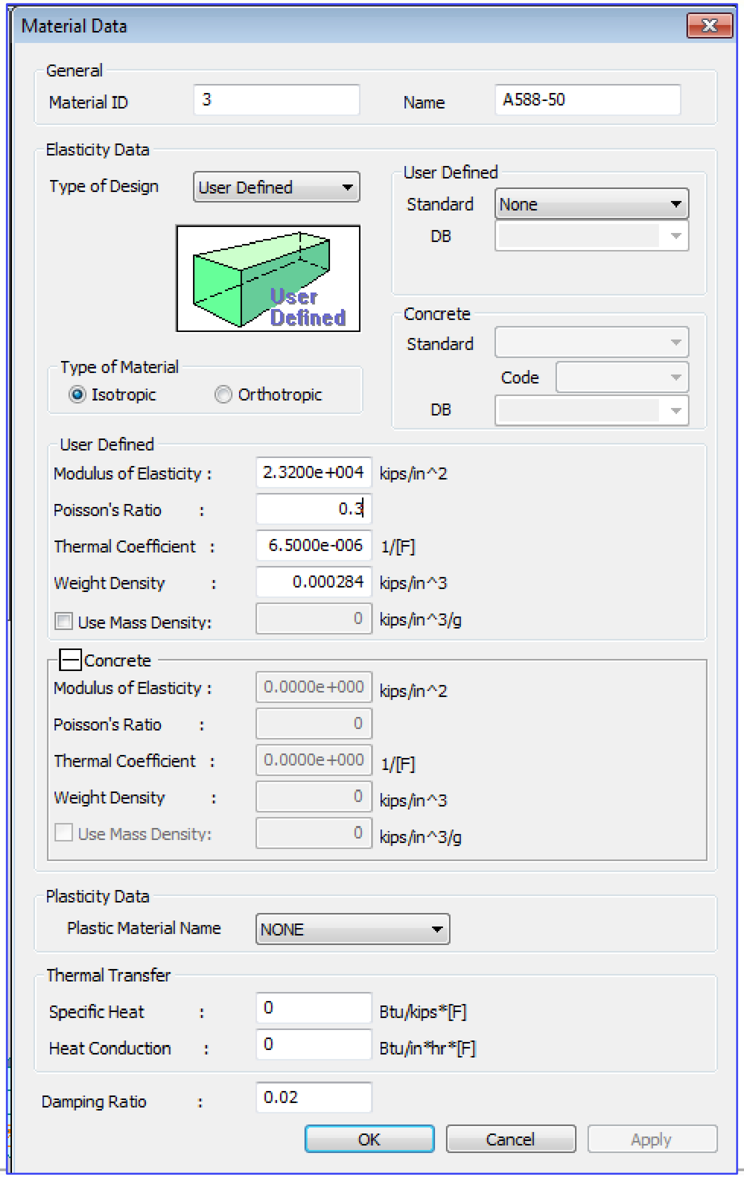
- AASHTO and AISC formulas meant for every engineer except for the ones that work for Contractors
- Must be aware of limitations of code formulas
- What is “K”?
- AISC Direct Analysis Method

Equipment - One Crane vs. Two Crane Picks

- One crane picks - cog of member to be lifted is critical
- Max 70% Capacity of Chart

User Defined Properties





Hudson Yards – Construction Engineering Challenges

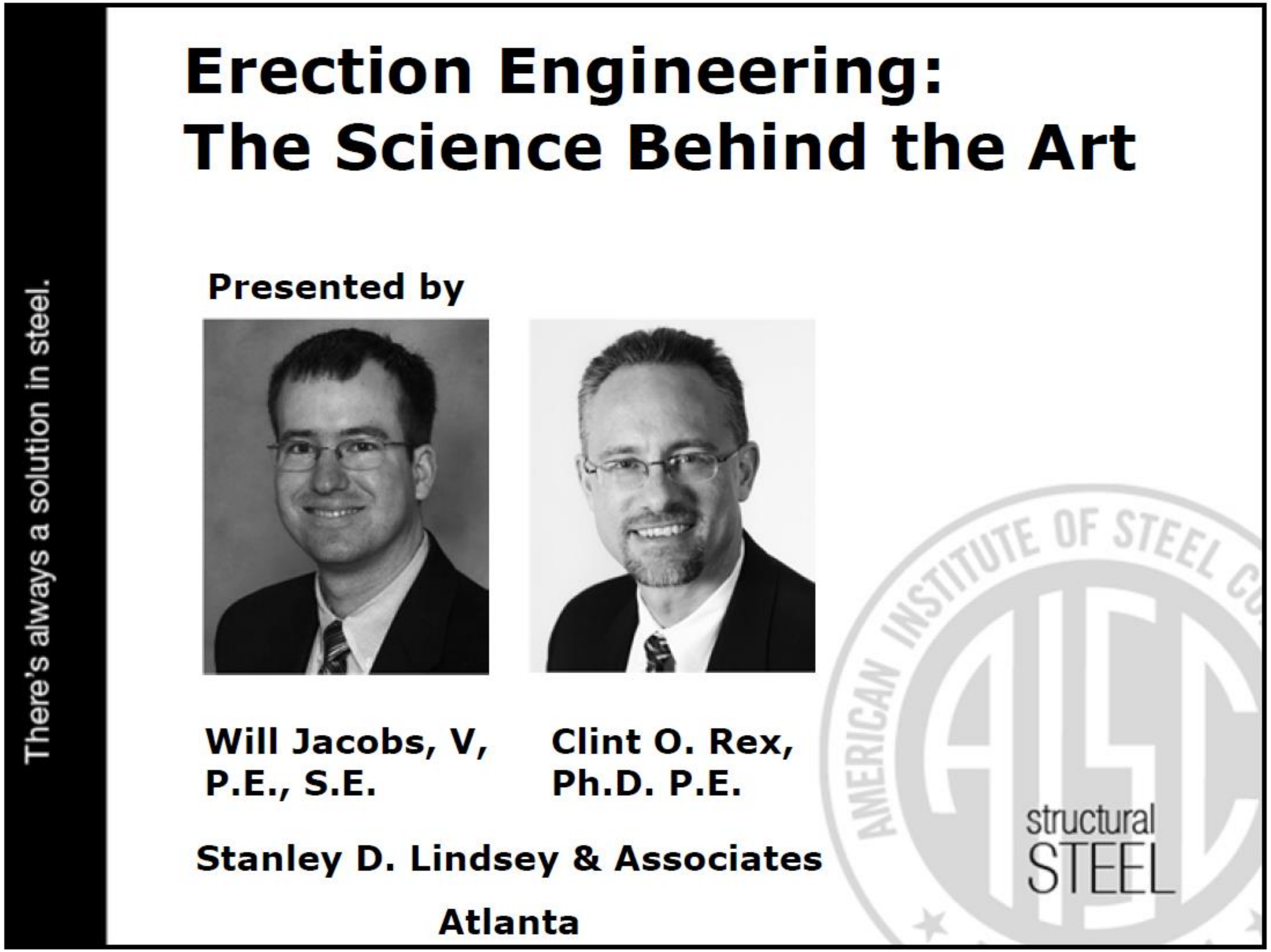
Challenges – Structural Analysis

- Responsible for determining effects of “Equilibrium on the Deflected Shape of the Structure”
- “Structure” for Construction Engineers can mean rebar cages, standees, single beams hanging from a crane to incomplete partially braced structures and structures during various states of demolition
- Frequent Use of AISC Direct Analysis Method – Reduced Stiffness to Account for Partial Yielding
- Including maximum fabrication tolerances in the models
- Loads at various stages of construction or demolition
- Use of shapes that are more square than deep to account for uncertain boundary conditions
- Deflections sometimes control …. Getting deflection right with uncertain boundary conditions is the trick

Hudson Yards – Construction Engineering Challenges

Excellent Webinar

Detailed examples of
Truss and beam
Erection calc's



Sliding Tower Crane

Hudson Yards – Construction Engineering Challenges Continued

Shipping Logistics – A-frame Columns and Trusses have to be Spliced on -site

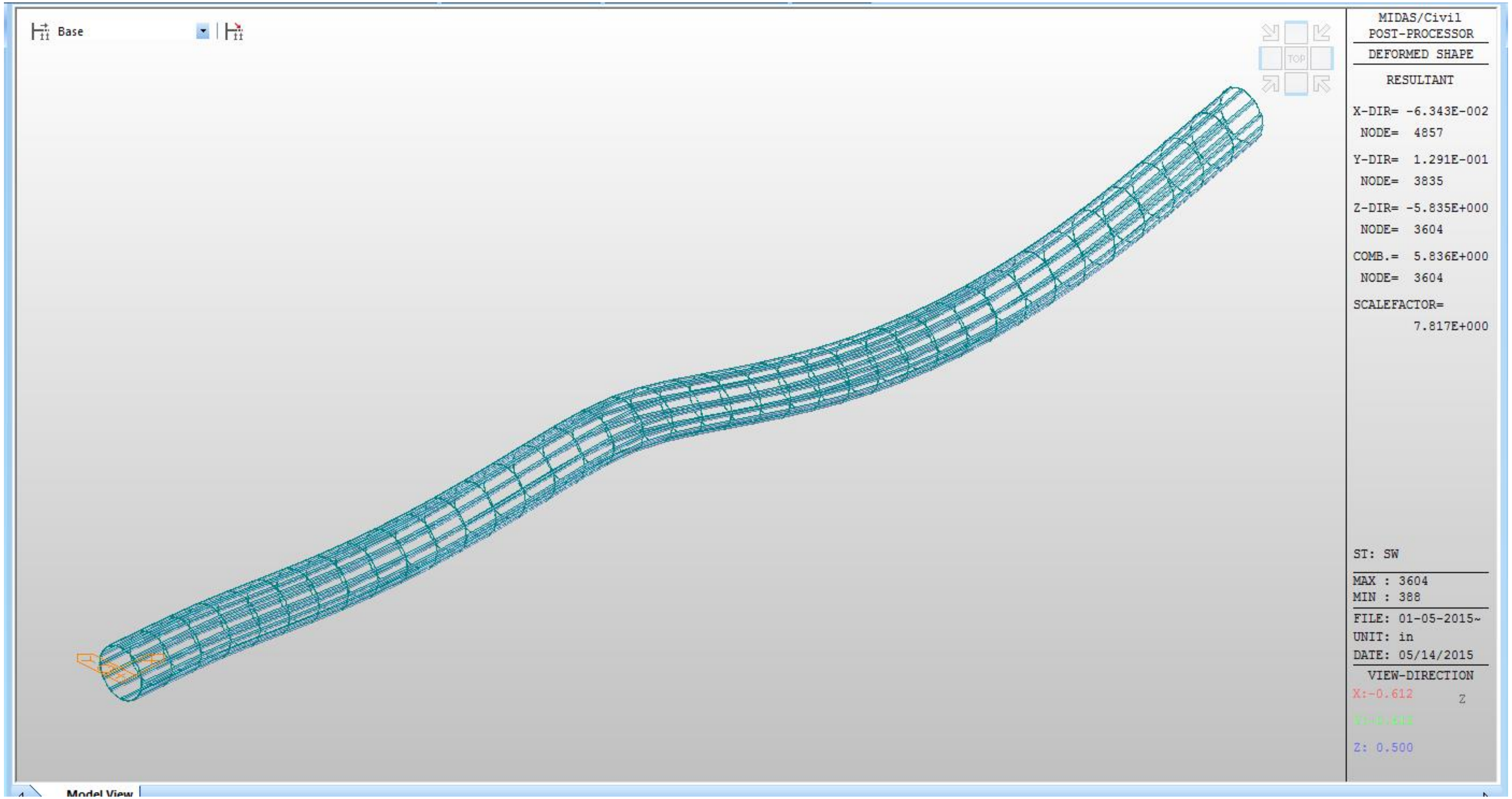
Lifting Lugs - Weld must be designed to resist bending

Concrete Tunnel Roof Construction – 12 ft. thick – rebar stands

Drilled Shaft Construction – Rebar Cage Installation – 85 ft. long

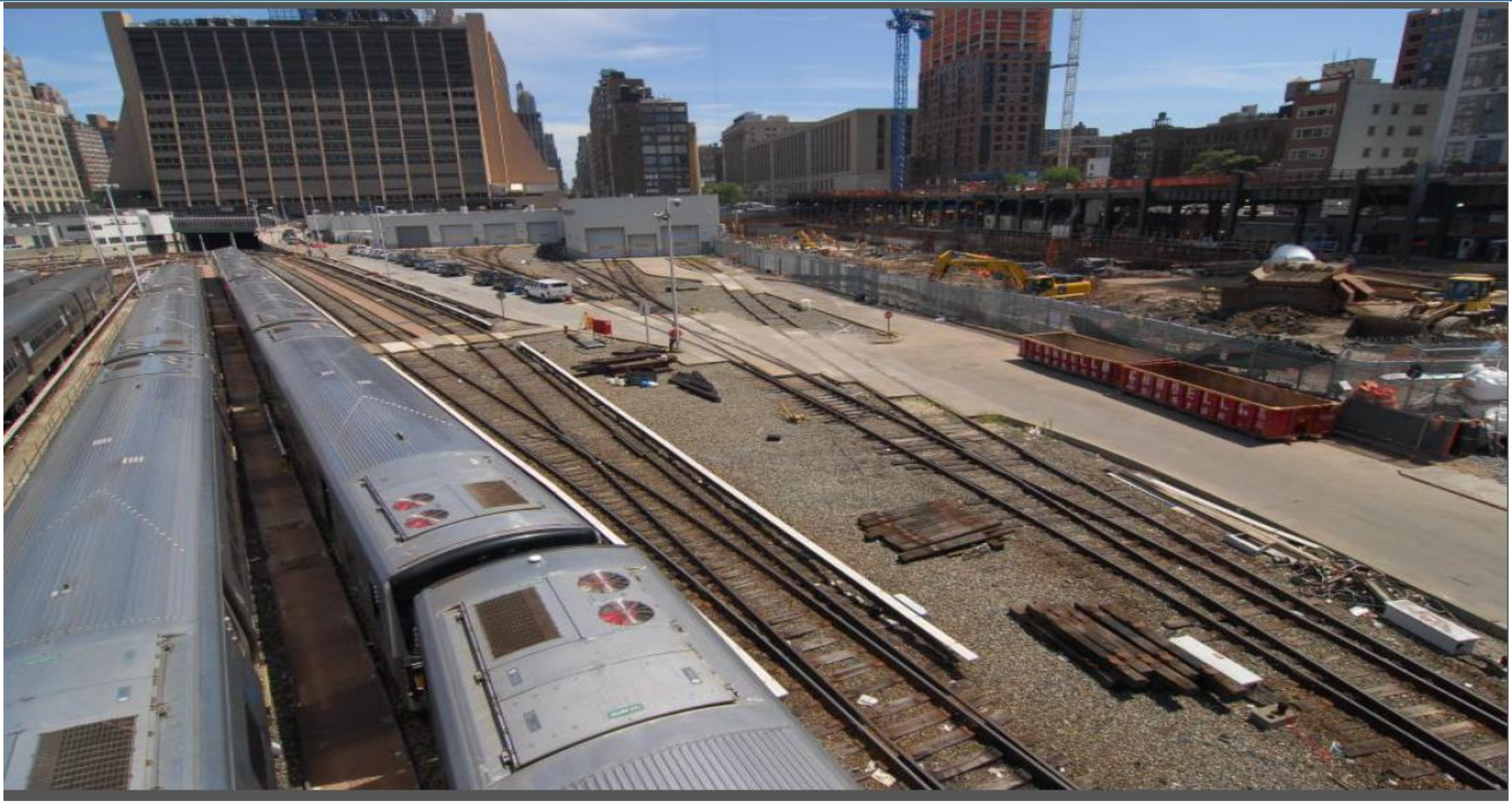
Rebar Cage Installation

Rebar Cage Installation



70 ton Caisson Core

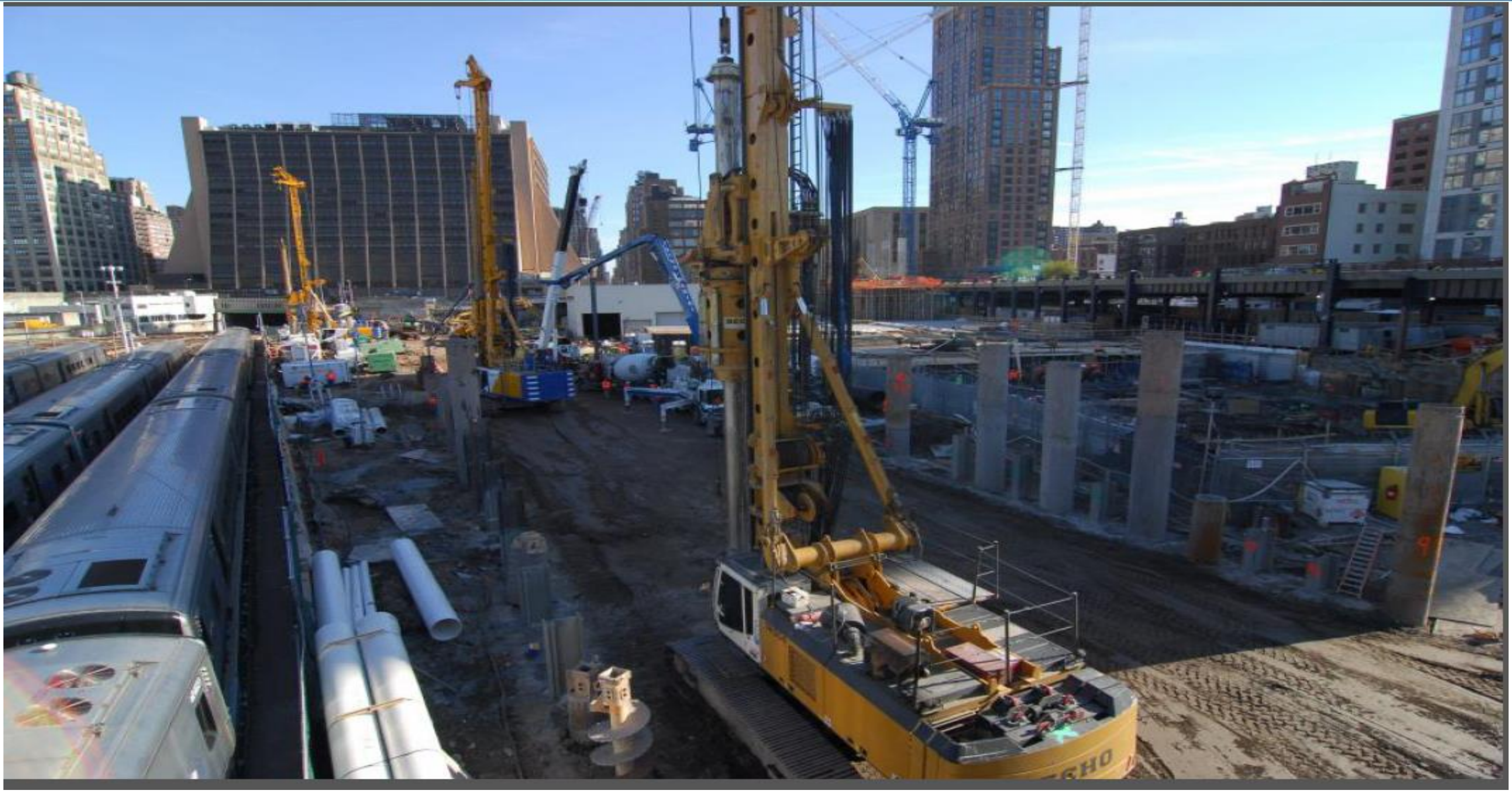
LIRR Railroad Yard - aka Hudson Yards - Pre-construction



Utility Relocation

Secant Wall Construction

Secant Wall Construction



Secant Wall Construction

Tunnel Excavation

Tunnel Excavation

Tunnel Wall / Slab Construction

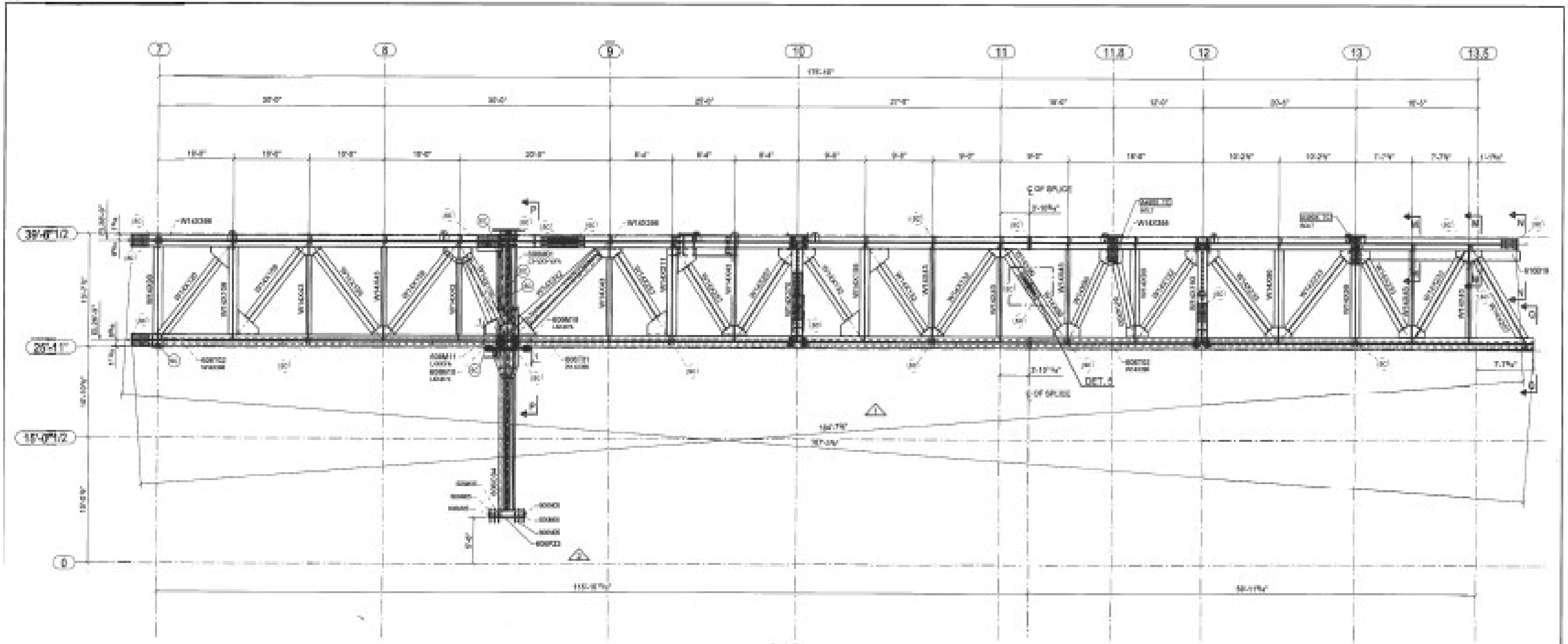
Tunnel Wall / Slab Construction

Tunnel Roof Construction

Tunnel Roof Construction

Tunnel Roof Backfilled

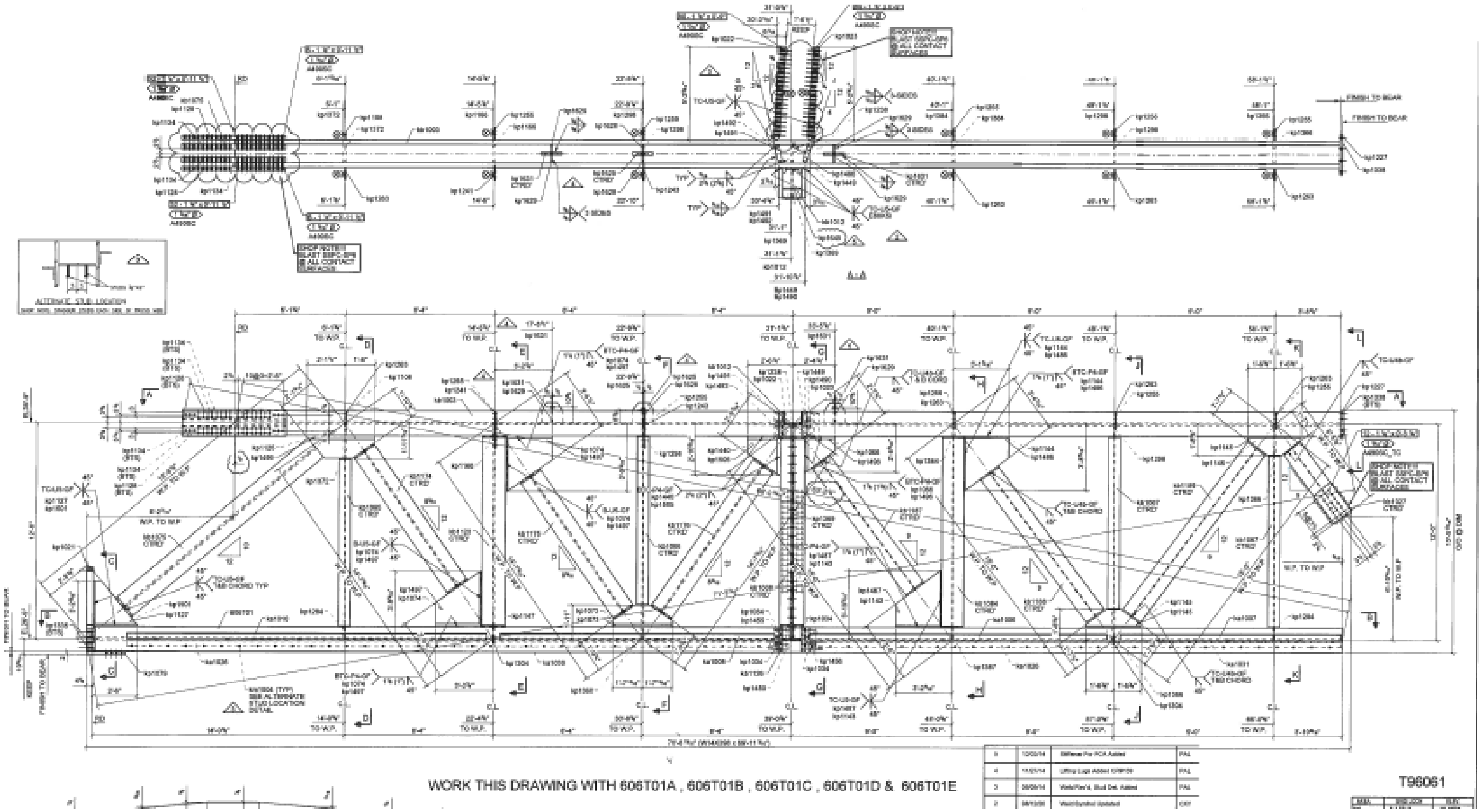
Plan Elevation of Truss



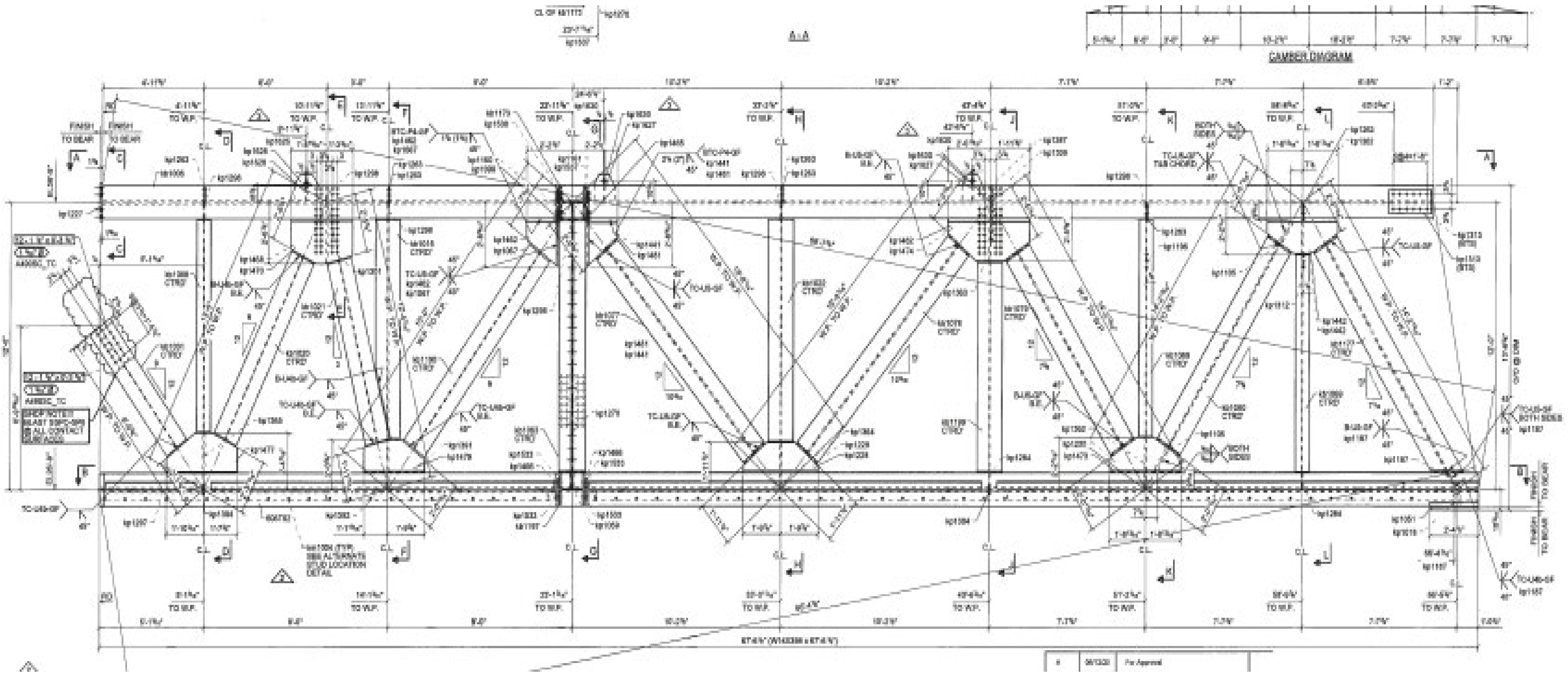
C - C

TRUSS TA1 & TA2 WEST OF LINE A.5

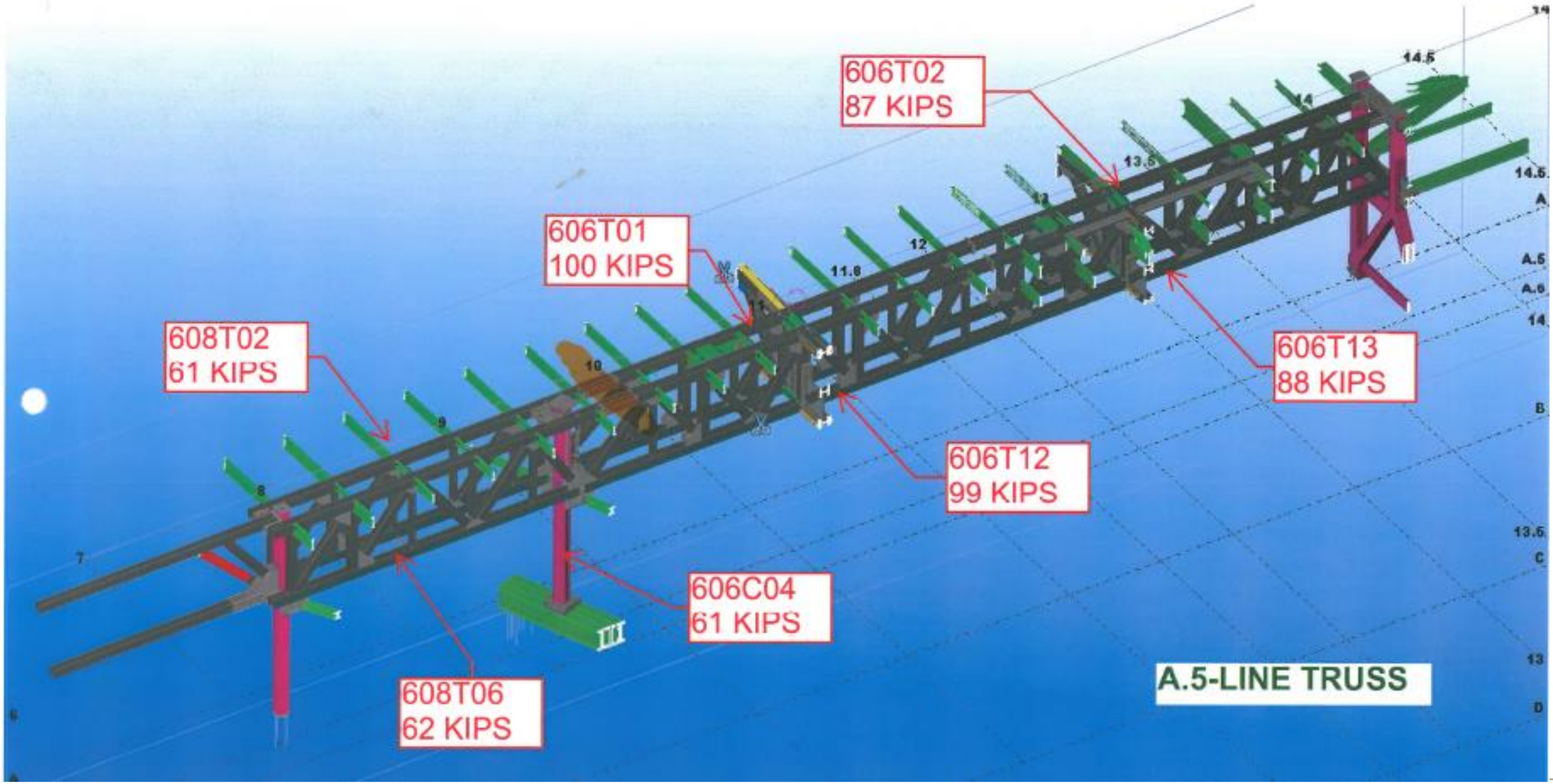
Truss Shop Drawing



Truss Shop Drawing



Tekla Model of Truss



Hudson Yards Truss Erection

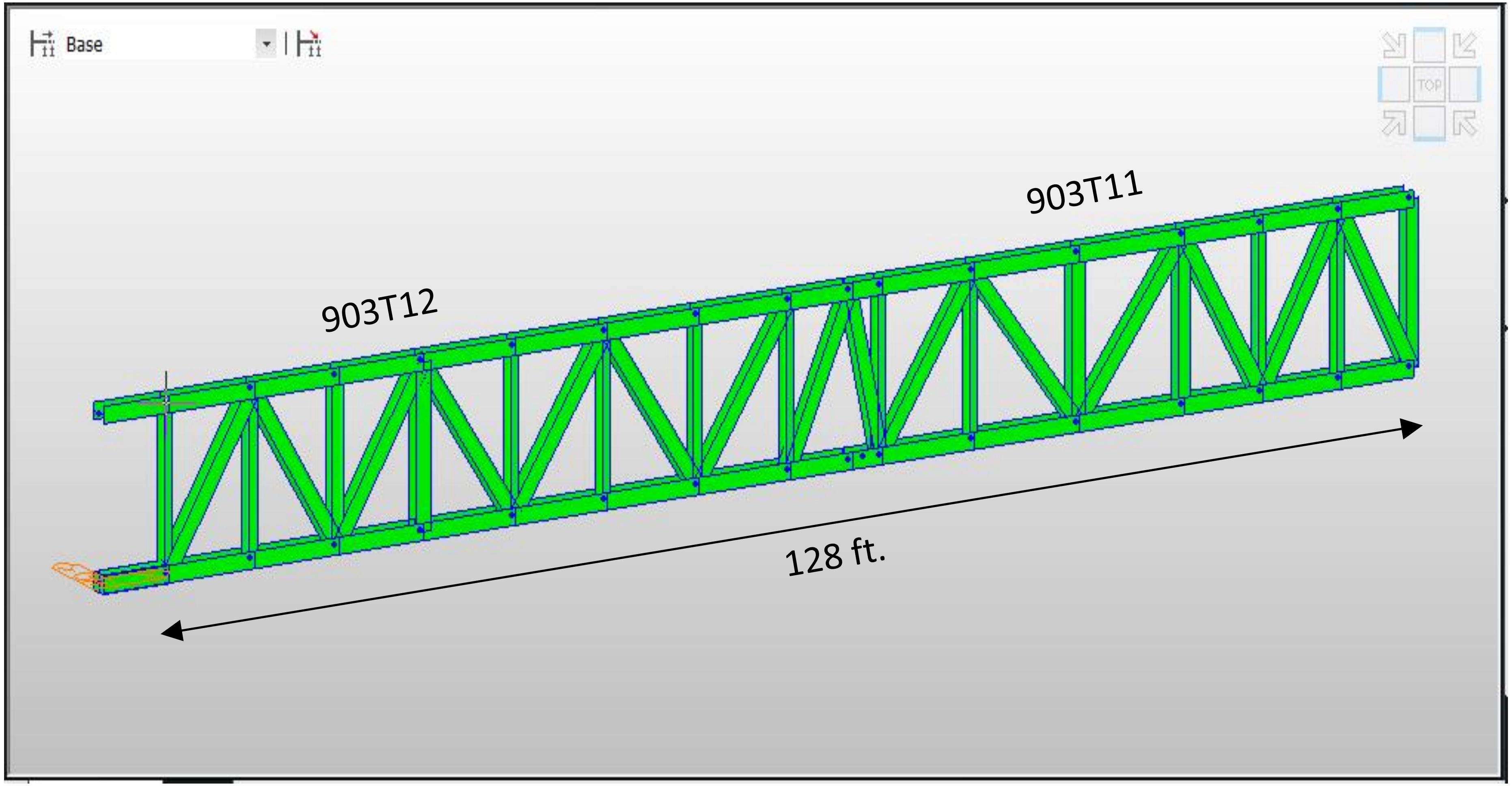
AISC Tolerances

$$^{1}/_{8}\ \text{in.}\ \text{x}\ \frac{(\text{Total Length, ft})}{10}$$

Apply Wind Loads

Conservatively Use 50 p.s.f. per AASHTO

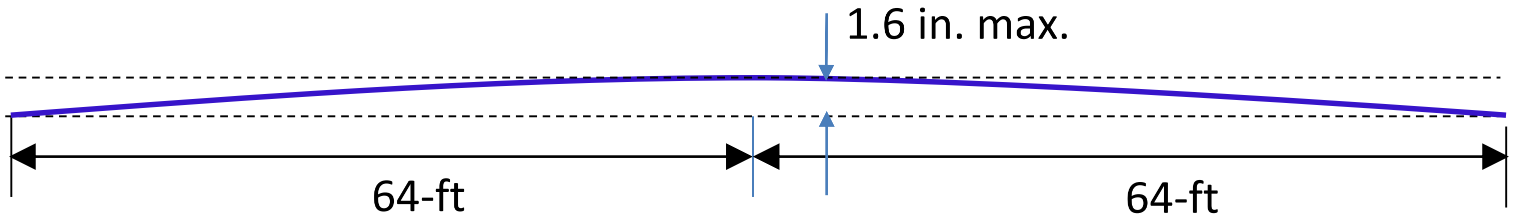
Hudson Yards Truss Erection - MIDAS Model



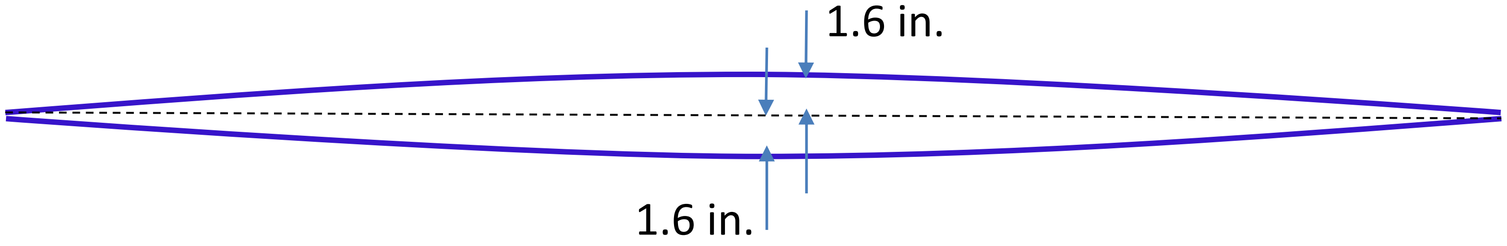
Hudson Yards Truss Erection

Modeling Nodes for Tolerances

Case 1 – Top and Bottom Chords both swept in same direction



Case 2 – Top and Bottom Chords swept in opposite directions

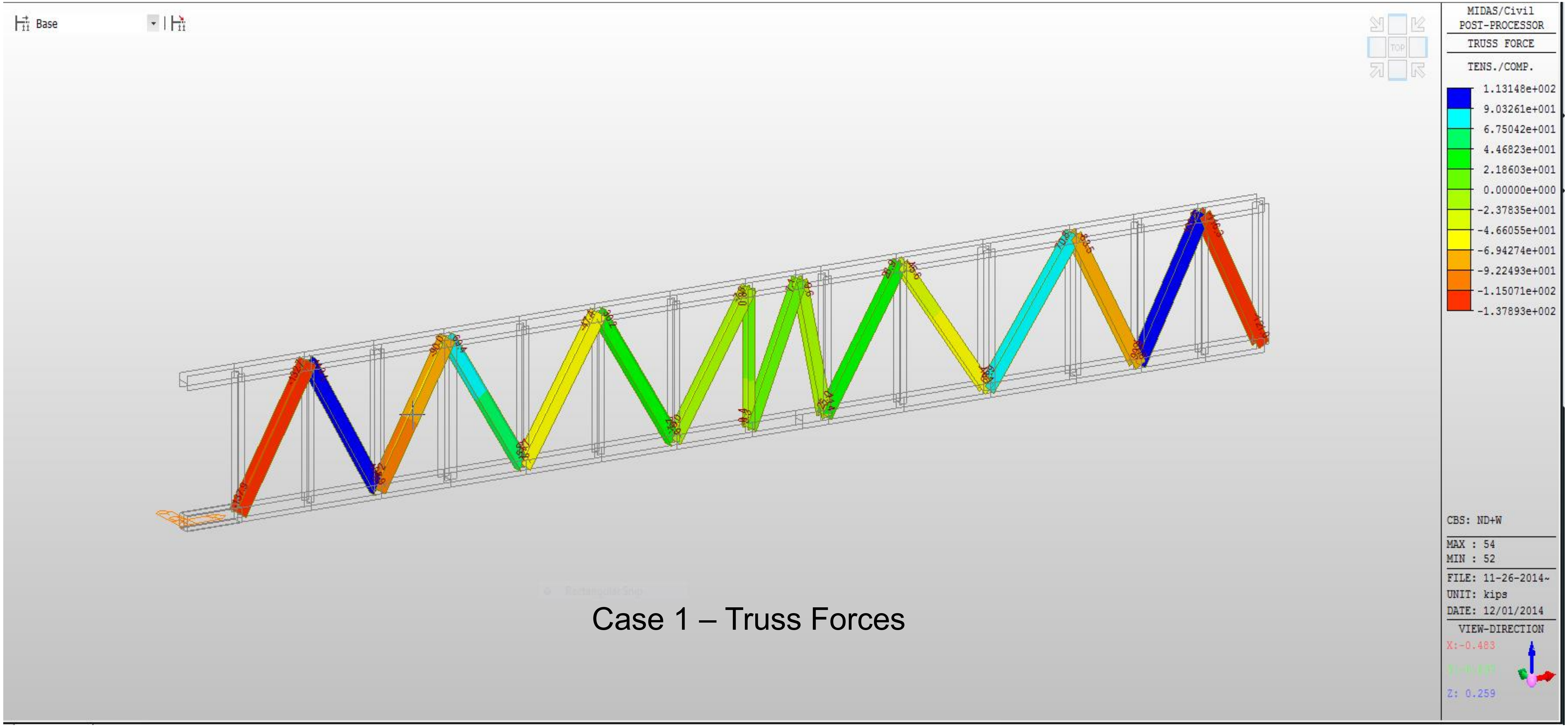


Hudson Yards Truss Erection

Axial Forces Case 1

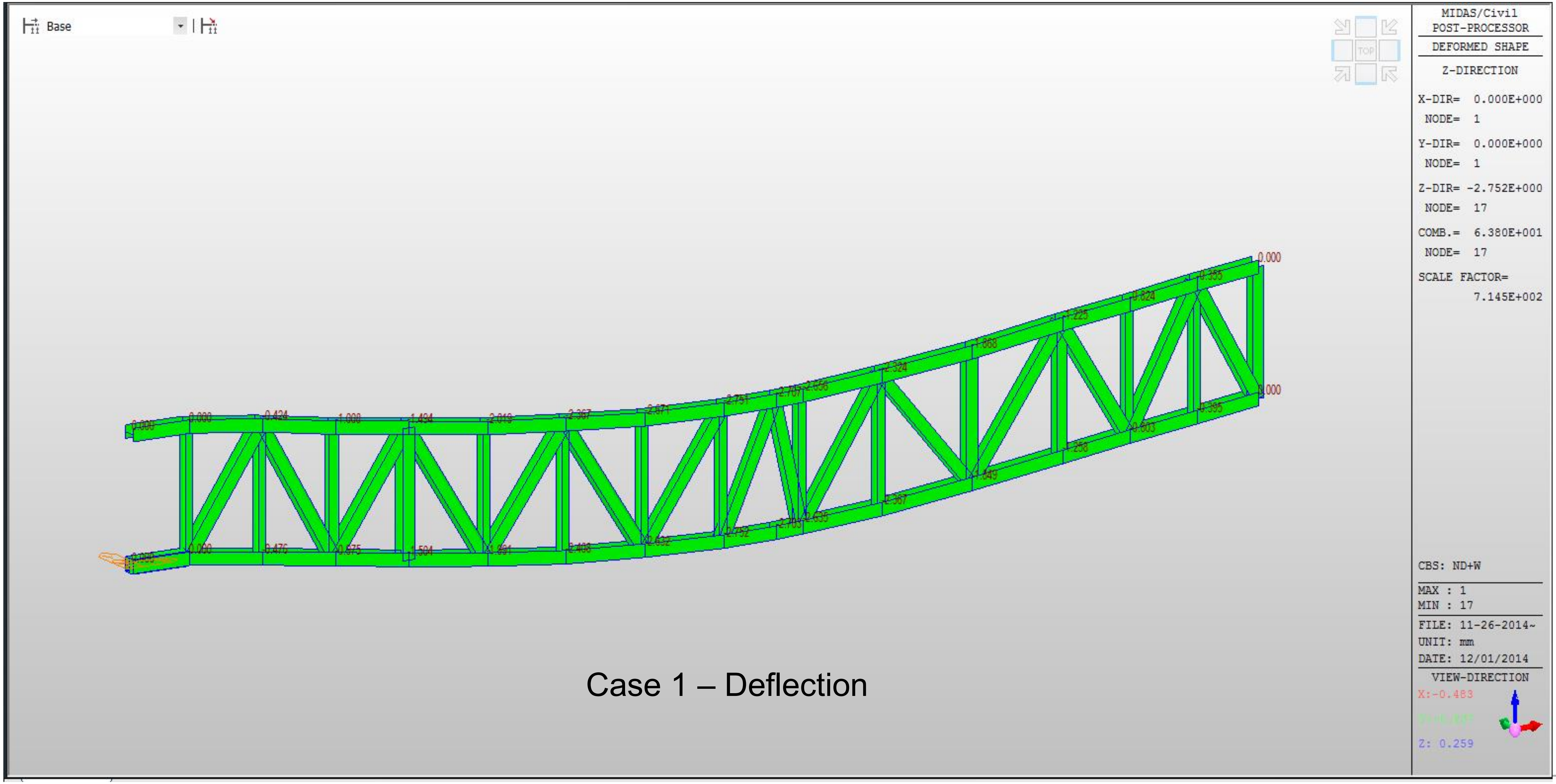
Case 1 – Bending Moments due to Wind Loads

Hudson Yards Truss Erection



Case 1 – Truss Forces

Hudson Yards Truss Erection



Case 1 – Deflection

Hudson Yards Truss Erection

```
==================================================================================
   [[[*]]]   CHECK AXIAL STRENGTH.
==================================================================================

      ( ). Check slenderness ratio of axial compression member (Kl/r).
           [ AASHTO-LRFD12 Specification 6.9.3 ]
           -. Kl/r  =   356.4  >   120.0  ---> NOT ACCEPTABLE !

--------------------------------------------------------------------------------------
 MIDAS/Civil - Steel Code Checking [ AASHTO-LRFD12 ]                 Version 8.3.5
======================================================================================


      ( ). Check width-thickness ratio of flange (BTR).
           [ AASHTO-LRFD12 Specification 6.9.4.2 ]
           -. Lambda_r  =  0.56*SQRT[Es/Fy]  =   13.49
           -. BTR  =  bf/2tf  =    2.91  <  Lambda_r  ---> NON-SLENDER SECTION !

      ( ). Calculate reduction factor of unstiffened elements (Qs).
           -. Qs  =  1.0 (Unstiffened elements are not Slender.)

      ( ). Check depth-thickness ratio of web (DTR).
           [ AASHTO-LRFD12 Specification 6.9.4.2 ]
           -. Lambda_r  =  1.49*SQRT[Es/Fy]  =   35.88
           -. Dweb  =  H-tf1-tf2  =    1.05 ft.
           -. DTR  =  Dweb/tw  =    7.12  <  Lambda_r  ---> NON-SLENDER SECTION !

      ( ). Calculate reduction factor of stiffened elements (Qa).
           -. Qa  =  1.0 (Stiffened elements are not Slender.)

      ( ). Full reduction factor for slender section (QsQa).
           [ AASHTO-LRFD12 Specification 6.9.4.2 ]
           -. Q  =  Qs*Qa  =   1.000

           -. Po  =  Q*Fy*Area  =   5850.0000 kips.

      ( ). Cal
           [ A

           -.
```

Hudson Yards Truss Erection

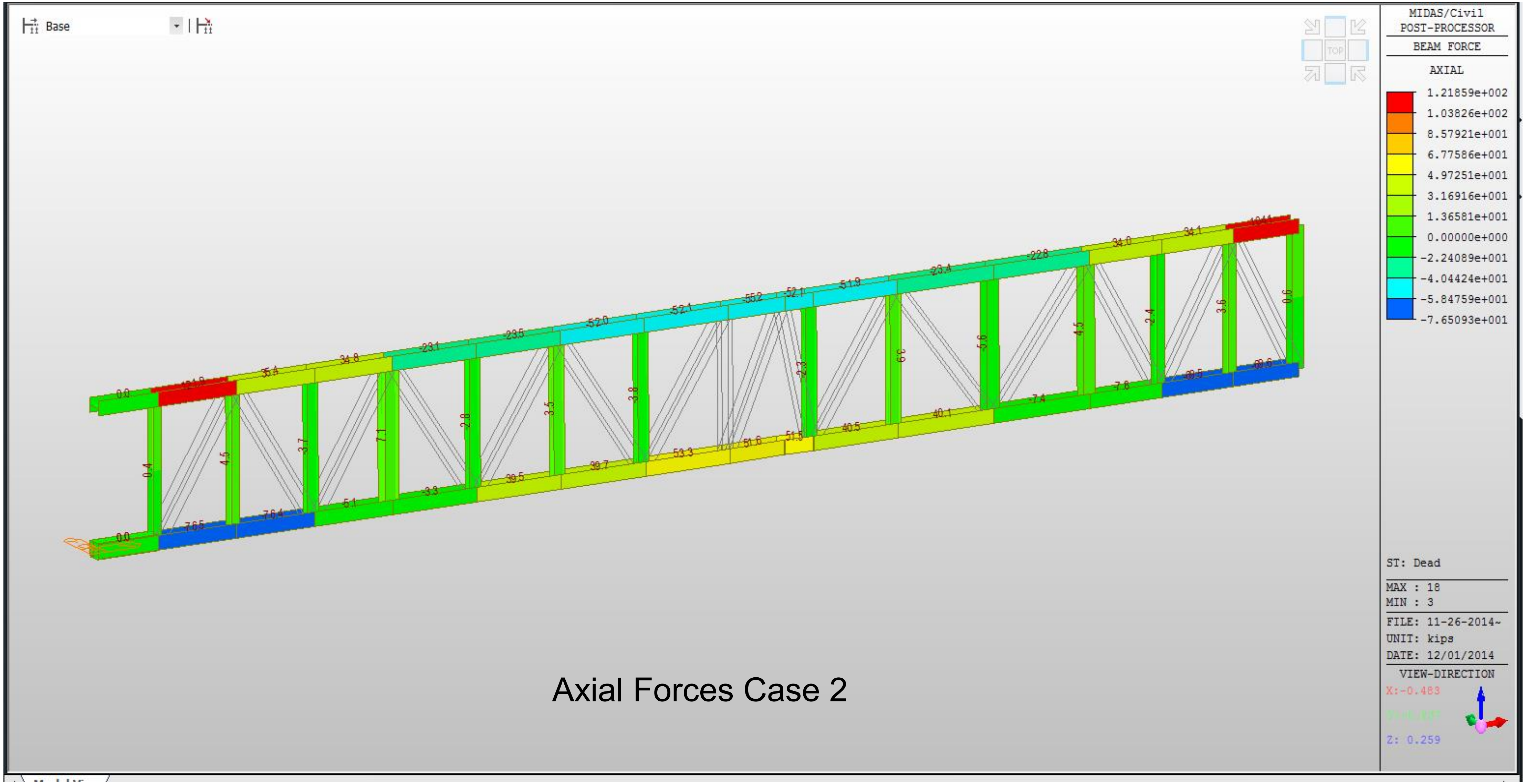
```
( ). Calculate Flexural Buckling Resistance (Pe_FB).
     [ AASHTO-LRFD12 Specification 6.9.4.1]
                pi^2 * E
     -. Pe_FB = -----------Area  =     263.6670 kips.
                 (Kl/r)^2

( ).  Elastic Critical Buckling Resistance (Pe).
     -. Pe = Pe_FB  =     263.6670 kips.

( ). Calculate axial compressive strength (phiPn).
     [ AASHTO-LRFD12 Specification 6.9.4.1.1 ]
     -. phi    =          0.90
     -. Pe/Po =           0.05 < 0.44
     -. Pn     = 0.877*Pe =         231.24 kips.
     -. phiPn =  phi*Pn   =         208.11 kips.

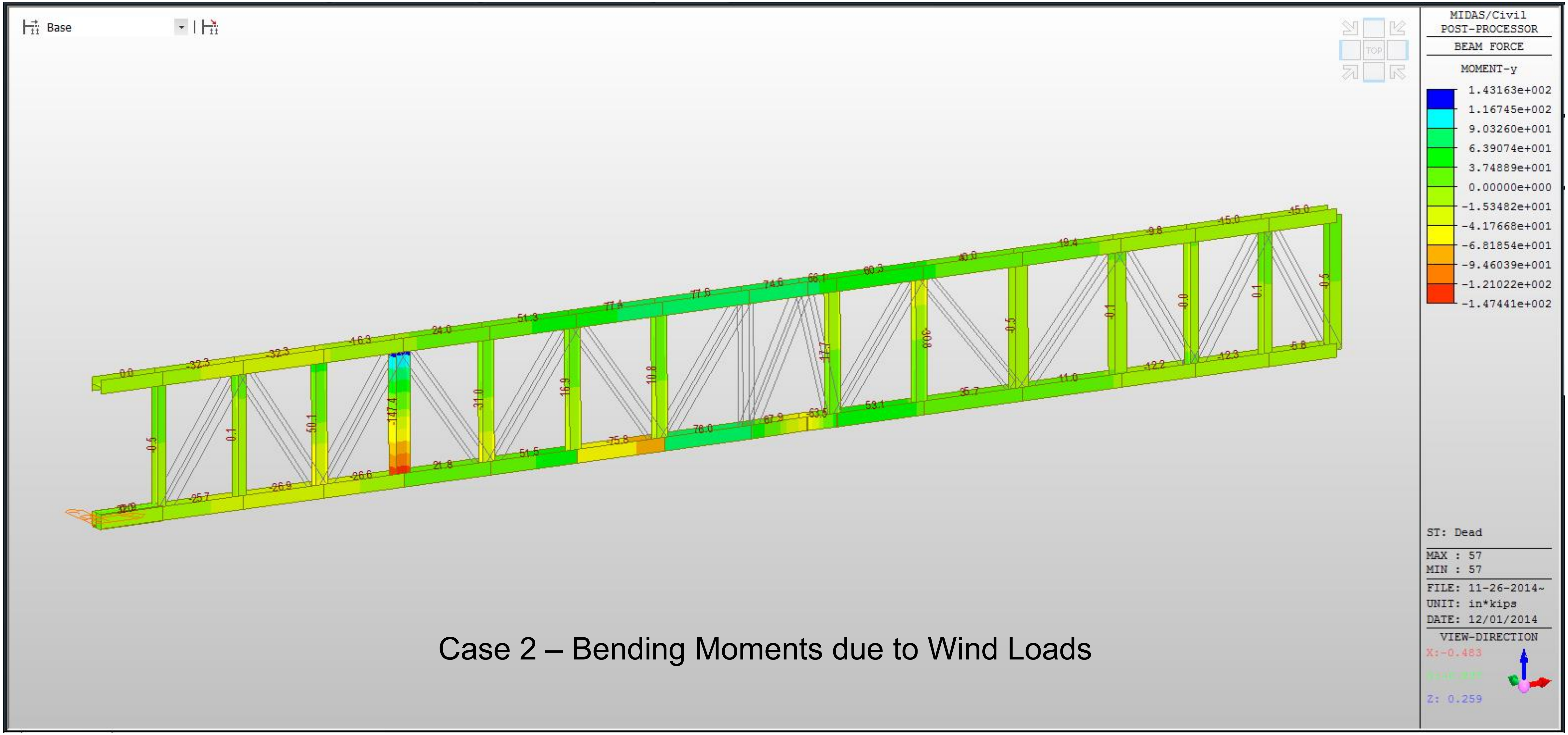
( ). Check ratio of axial strength (Pu/phiPn).
          Pu                136.12
     -. -------  =  ---------------  =          0.65  <  1.000  --->  O.K.
         phiPn              208.11
```

Hudson Yards Truss Erection



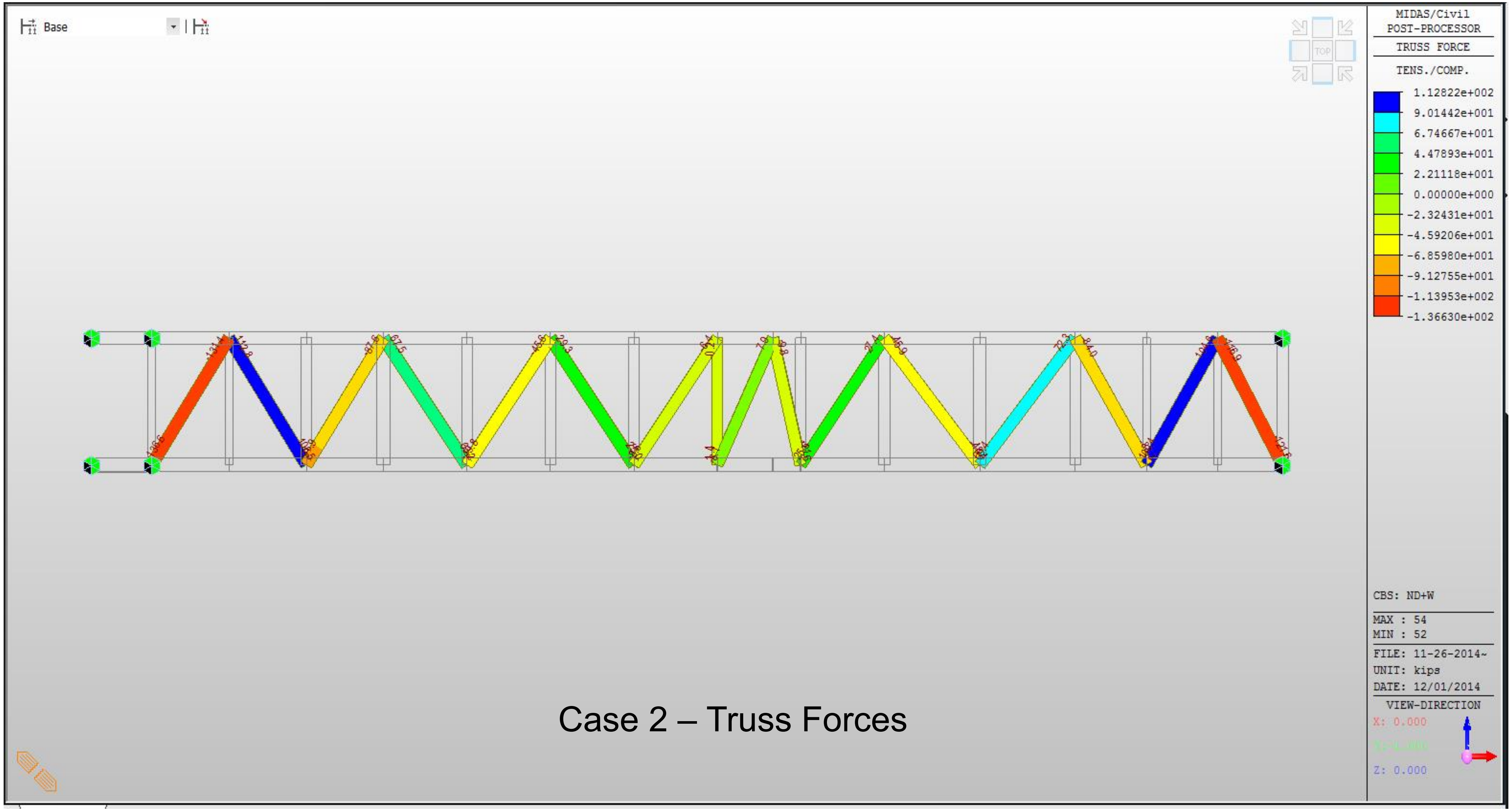
Axial Forces Case 2

Hudson Yards Truss Erection



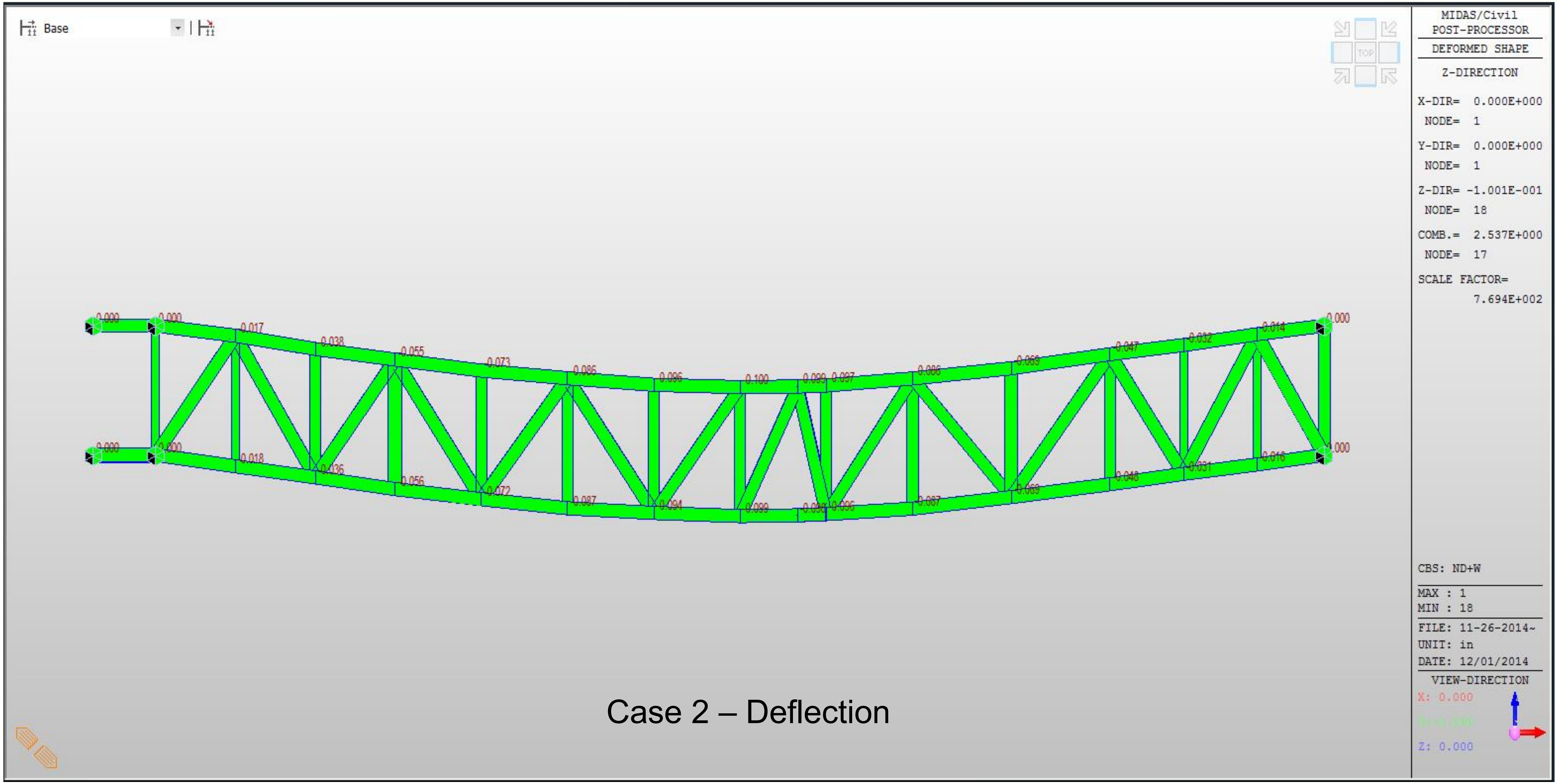
Case 2 – Bending Moments due to Wind Loads

Hudson Yards Truss Erection



Case 2 – Truss Forces

Hudson Yards Truss Erection



Case 2 – Deflection

MIDAS Civil Advantages

Easy to Create Trusses and Modify Nodes

Accurate Deflection Calculations

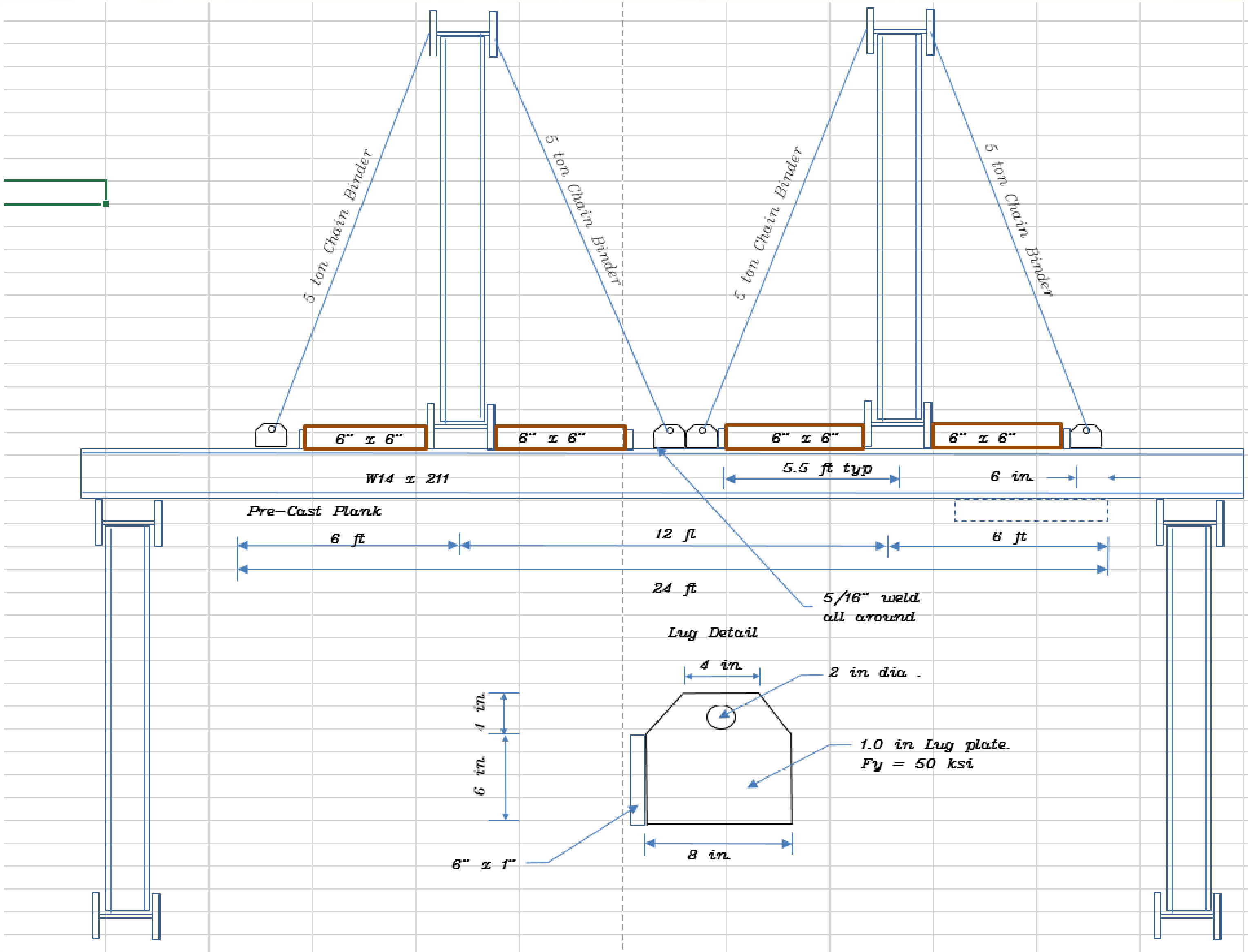
AASHTO Code Check

Easy to Apply Loads and Combinations

P-Delta and Buckling Analysis

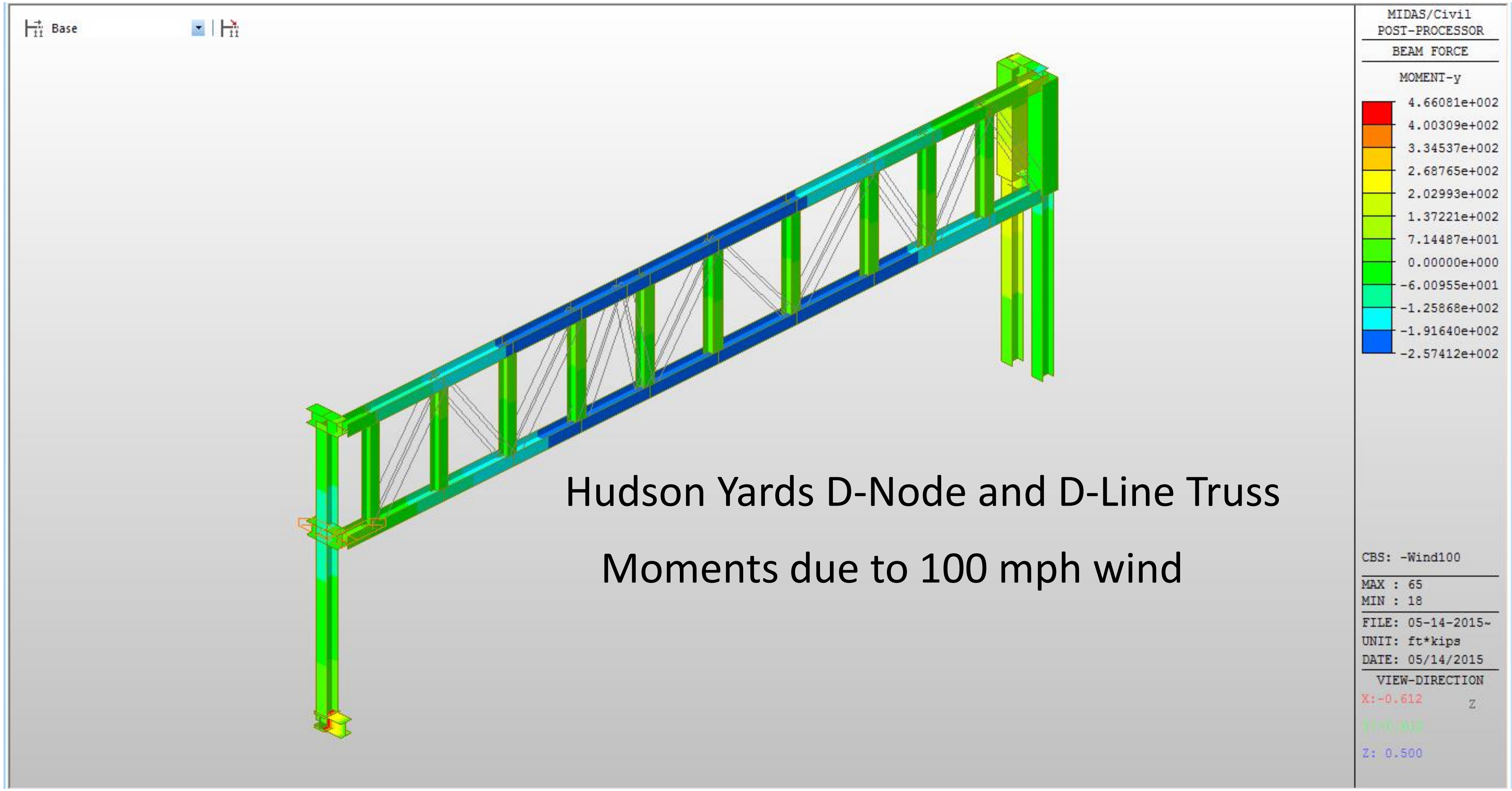
Hudson Yards D-Node and D-Line Truss

Hudson Yards Truss Assembly Jig



Hudson Yards D-Node and D-Line Truss

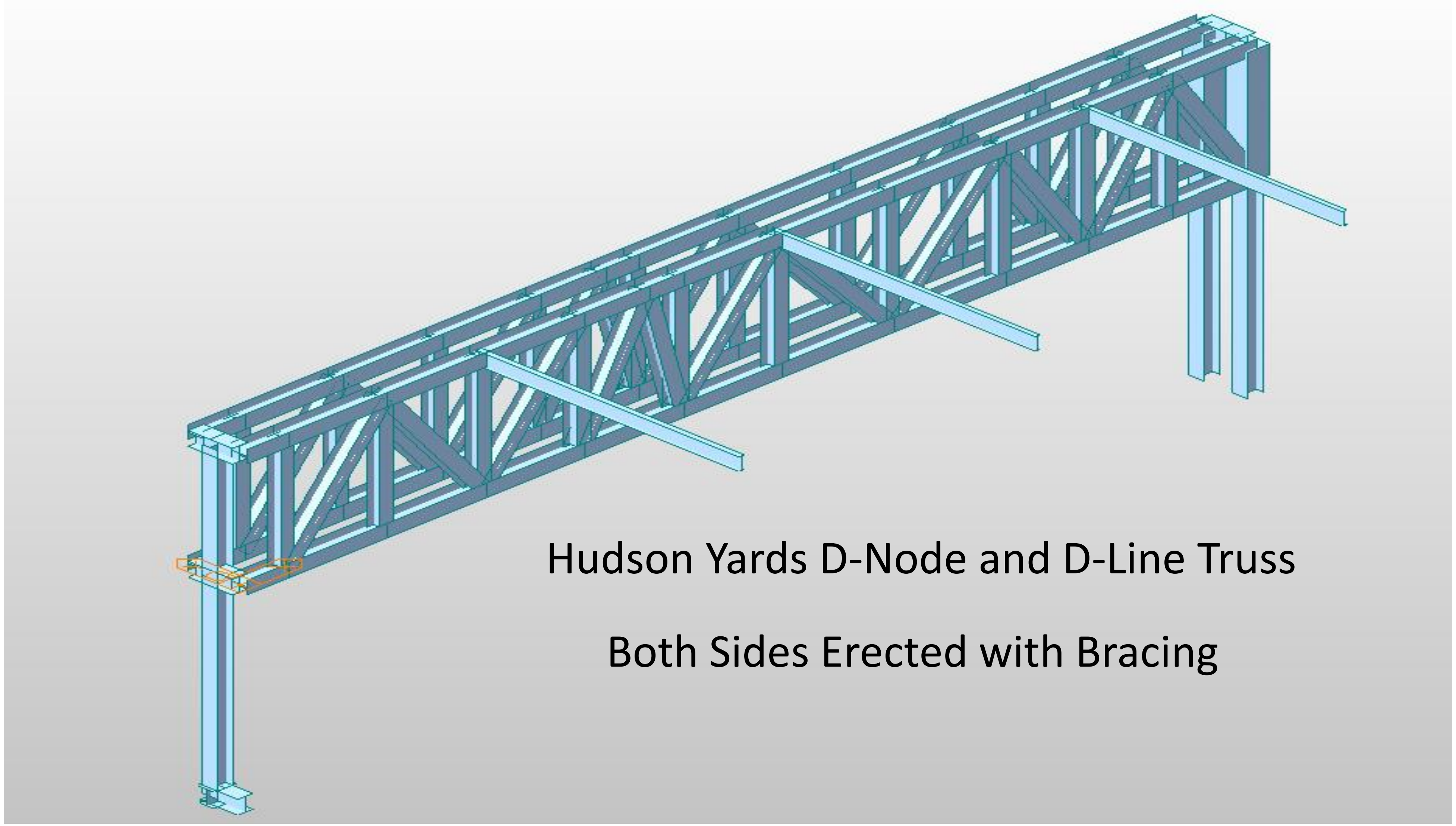
Hudson Yards D-Node and D-Line Truss



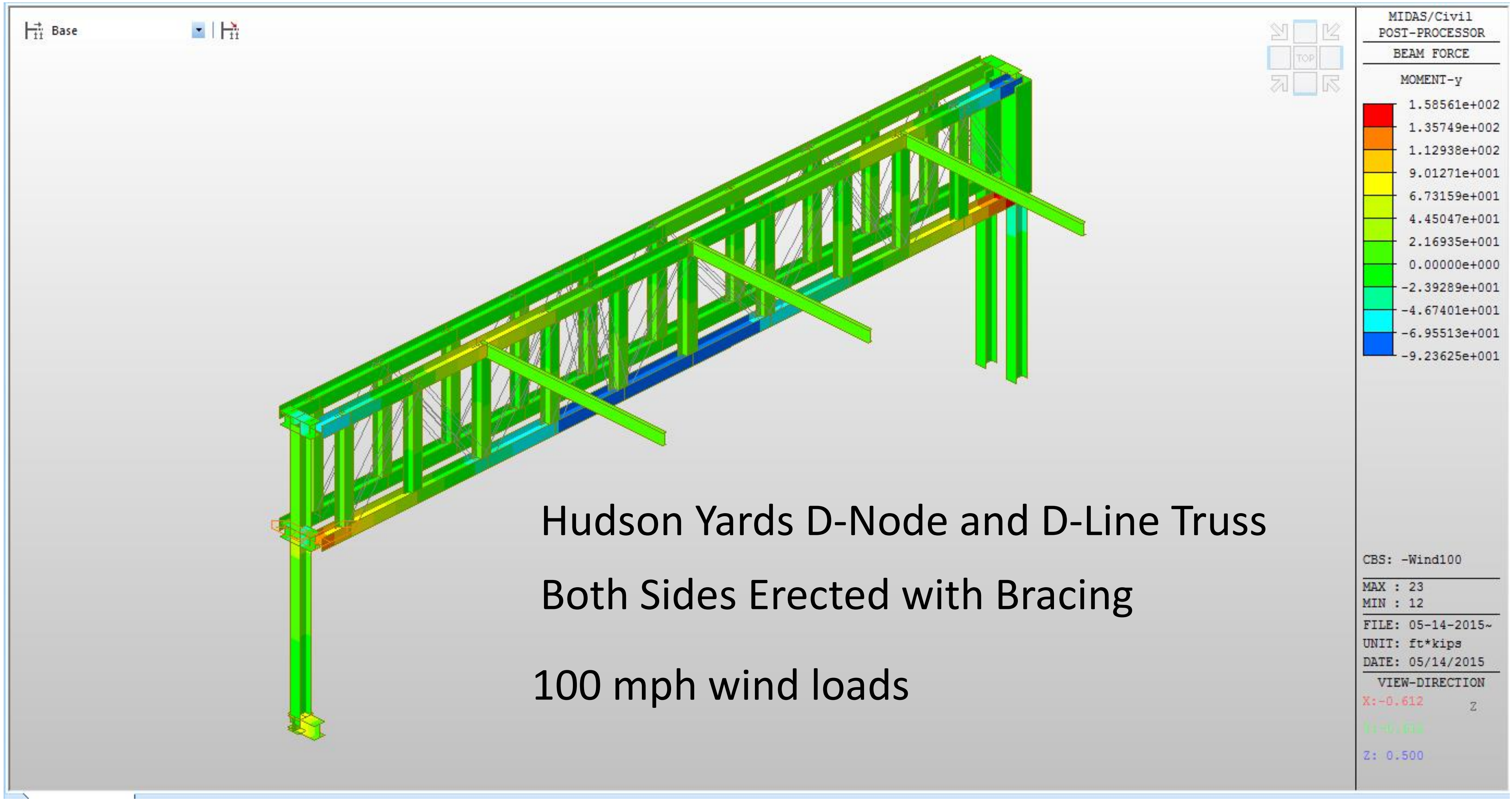
Hudson Yards D-Node and D-Line Truss

Moments due to 100 mph wind

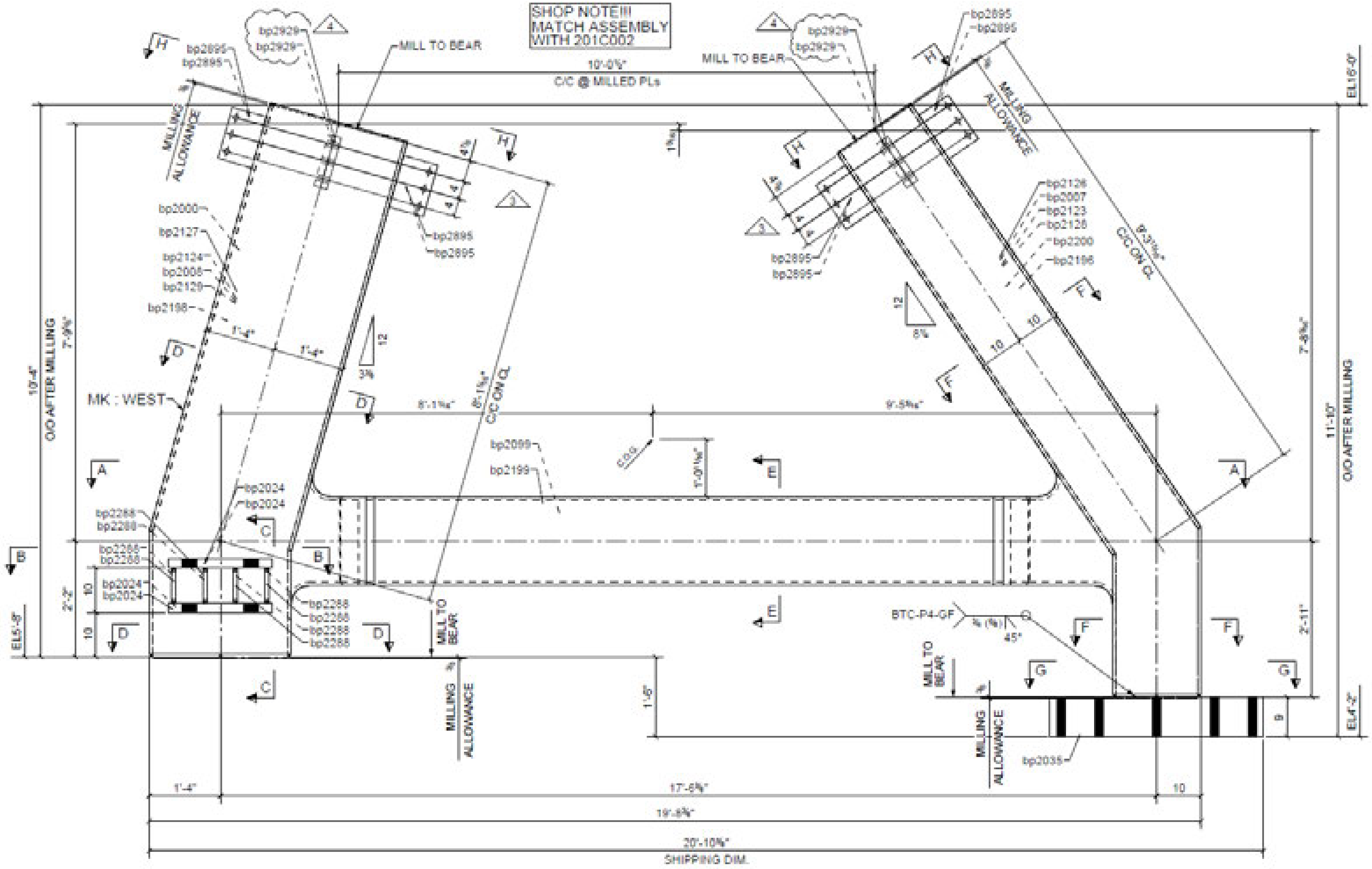
Hudson Yards D-Node and D-Line Truss



Hudson Yards D-Node and D-Line Truss

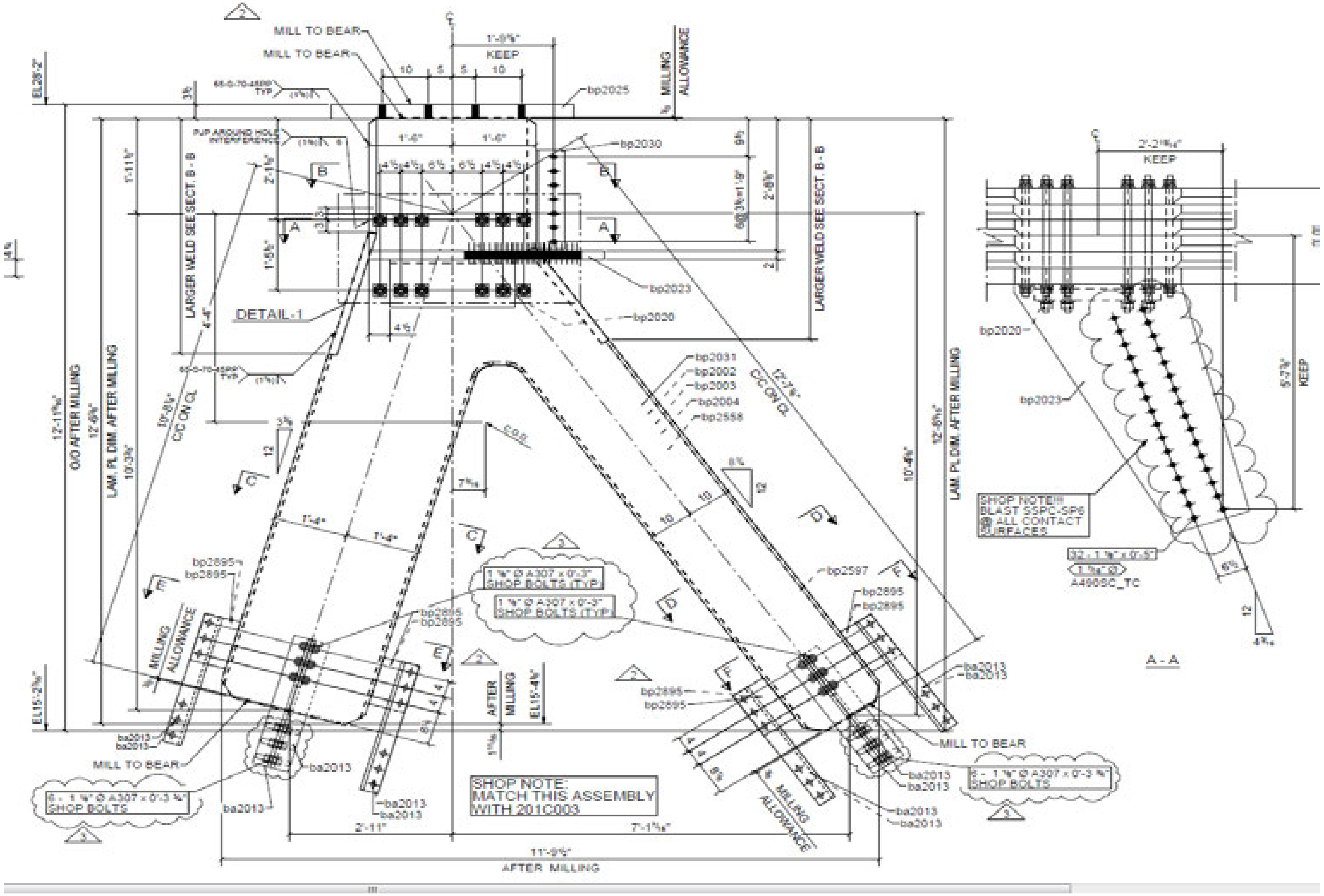


Hudson Yards Columns



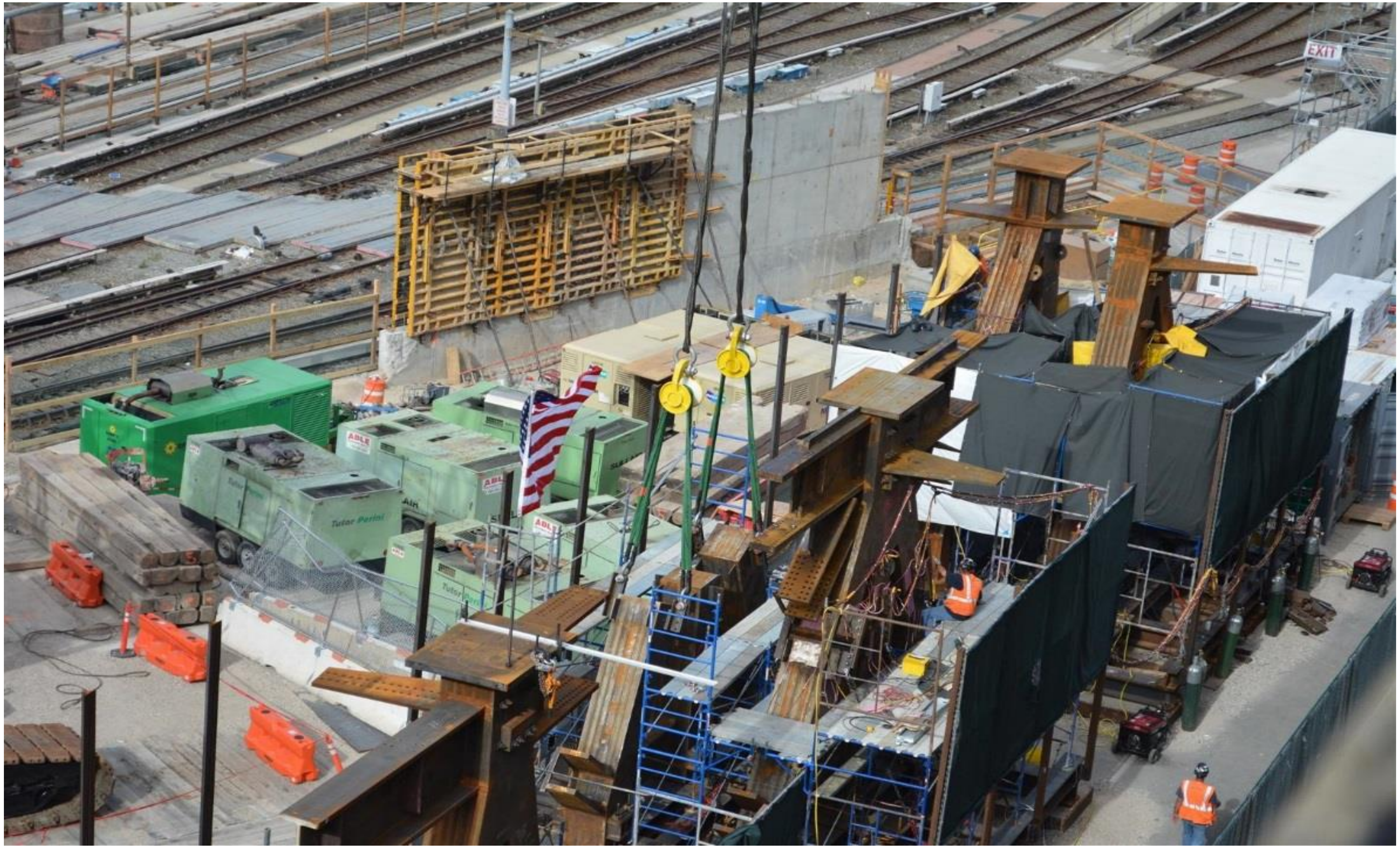
Column B-15 Lower Section

Hudson Yards Columns



Column B-15 Upper Section

Hudson Yards Columns



Hudson Yards Columns

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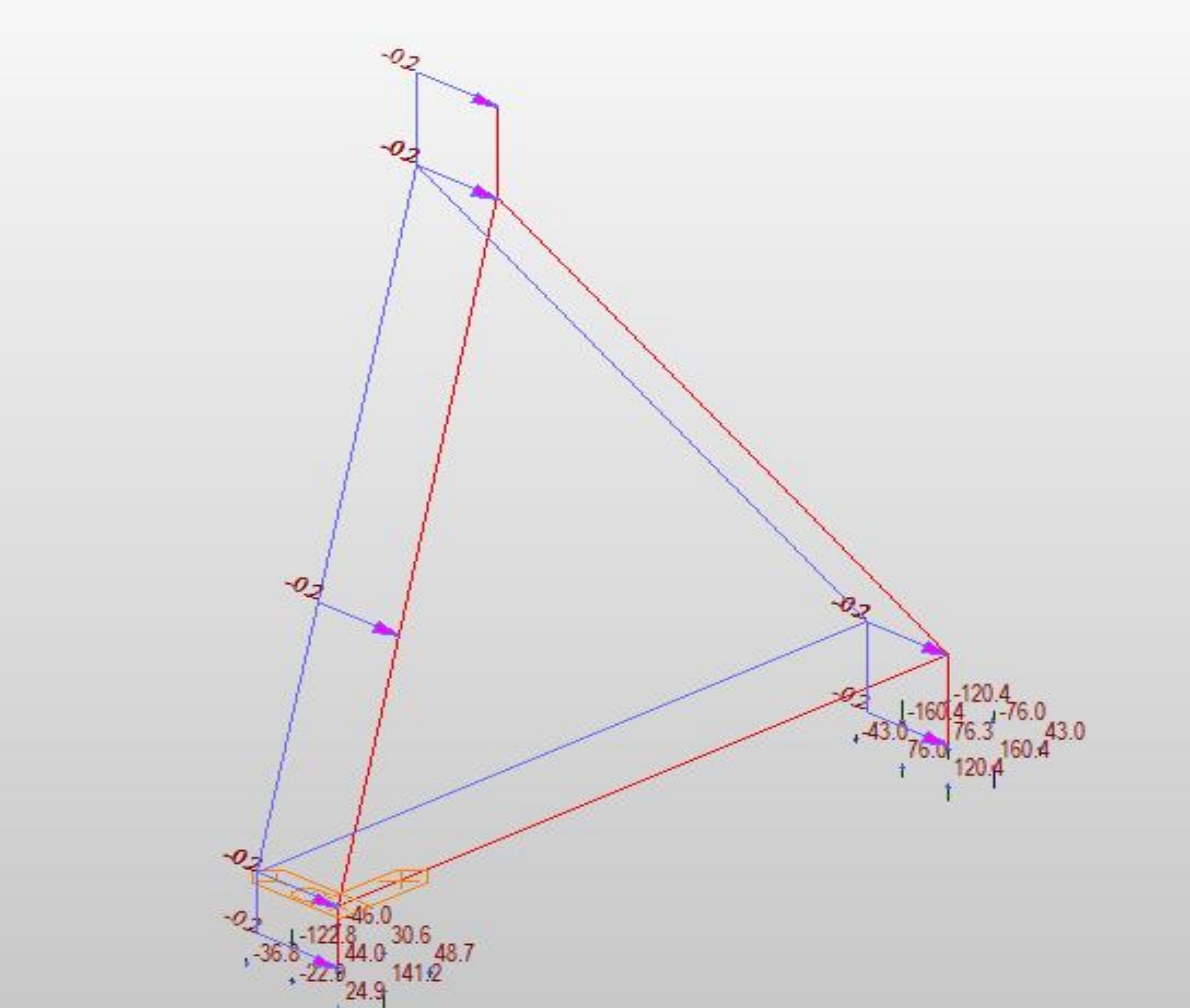
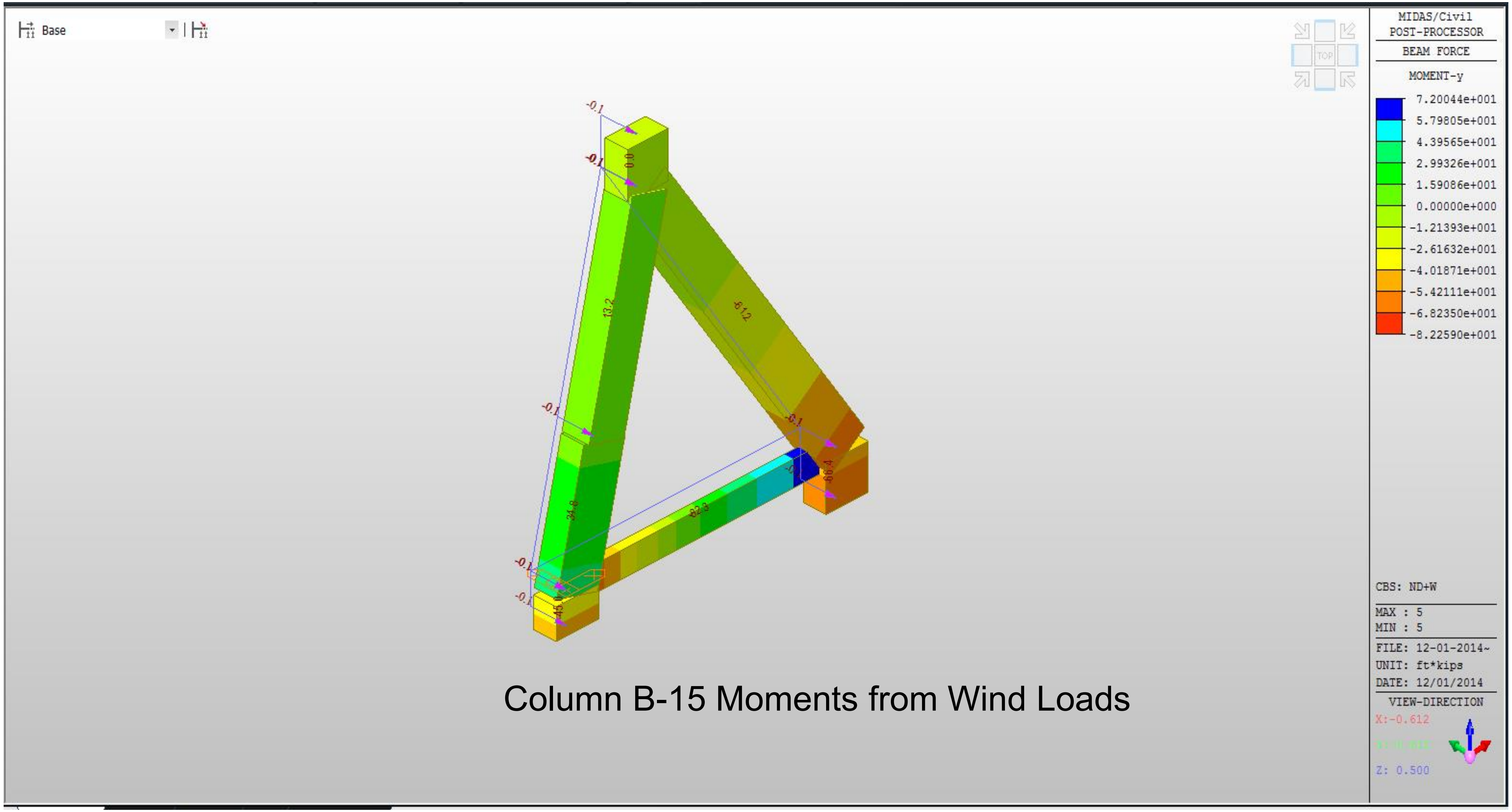


Column B-15 Loads and Reactions

Hudson Yards Columns



Column B-15 Moments from Wind Loads

Hudson Yards Columns

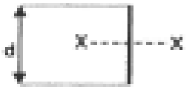
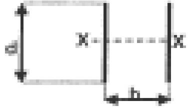
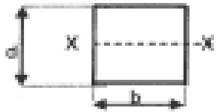
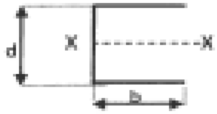
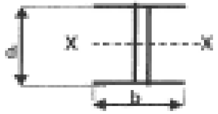
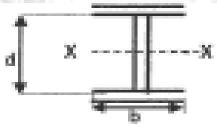
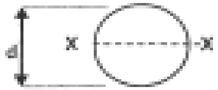
Check Bolts for Top Lug Plate:	Stage 1 Column is horizontal	
P =	32.3	kips
e =	16.0	in.
Design Moment =	516.8	kip-in
Total Shear =	32.3	kips
# of Bolts in shear =	4.0	
Shear per Bolt =	8.08	kips
# of Bolts in Tension =	2.0	
Distance between bolt lines =	30.0	in.
Tension per Bolt =	8.6	kips
Bolt Diameter =	1.125	in.
A_b =	0.99	in^2
F_{nt} =	90.0	(ksi)
F_{nv} =	54.0	(ksi)
Ω =	2.0	
Net Tension Capacity per bolt =	50.6	(kips)
Net Shear Capacity per Bolt =	30.4	(kips)
Tensile stress per bolt (f_{rt}) =	8.7	(ksi)
Shear stress per Bolt (f_{rv}) =	8.13	(ksi)
Modified tensile stress (F'_{nt}) =	90.0	(ksi) OK $F'_{nt} = 1.3F_{nt} - \frac{F_{nt}}{F_{rv}} f_{rv} \leq F_{nt}$

Check weld from plate dp1301 to top of column		
P =	25	kips
e =	8.5	in.
M_{bxw} =	212.5	kip-in.
S_x – weld =	48.00	in^2/in
f_{bxw} =	4.43	ksi
P_{shear} =	25.00	kips
A_x =	24.0	in^2
f_{shear} =	1.04	ksi
f_w =	4.55	ksi
F_w =	21.0	ksi
Required Throat Size =	0.306	in.

$$f_w = \sqrt{(f_{bx})^2 + (f_{shear})^2}$$

$$t_w = \frac{f_w}{\frac{F_w}{.707}} =$$

Hudson Yards Columns

Properties of a Weld Treated as a Line		
Outline of Welded Joint b=width d=depth	**Section Modulus Bending** (about horizontal axis X-X)	**Polar Moment of Inertia**
	$Z = \frac{d^2}{6}$	$J = \frac{d^3}{12}$
	$Z = \frac{d^2}{3}$	$J = \frac{d(3b^2 + d^2)}{6}$
	$Z = bd$	$J = \frac{b^3 + 3bd^2}{6}$
	$Z = bd + \frac{d^2}{3}$	$J = \frac{(b + d)^3}{6}$
	$Z = bd + \frac{d^2}{6}$	$J = \frac{(2b + d)^3}{12} - \frac{b^2(b + d)^2}{2b + d}$
	$Z = bd + \frac{d^2}{3}$	$J = \frac{b^3 + 3bd^2 + d^3}{6}$
	$Z = 2bd + \frac{d^2}{3}$	$J = \frac{2b^3 + 6bd^2 + d^3}{6}$
	$Z = \frac{\pi d^2}{4}$	$J = \frac{\pi d^3}{4}$

Www.RobertMarkoski.net/Engineering

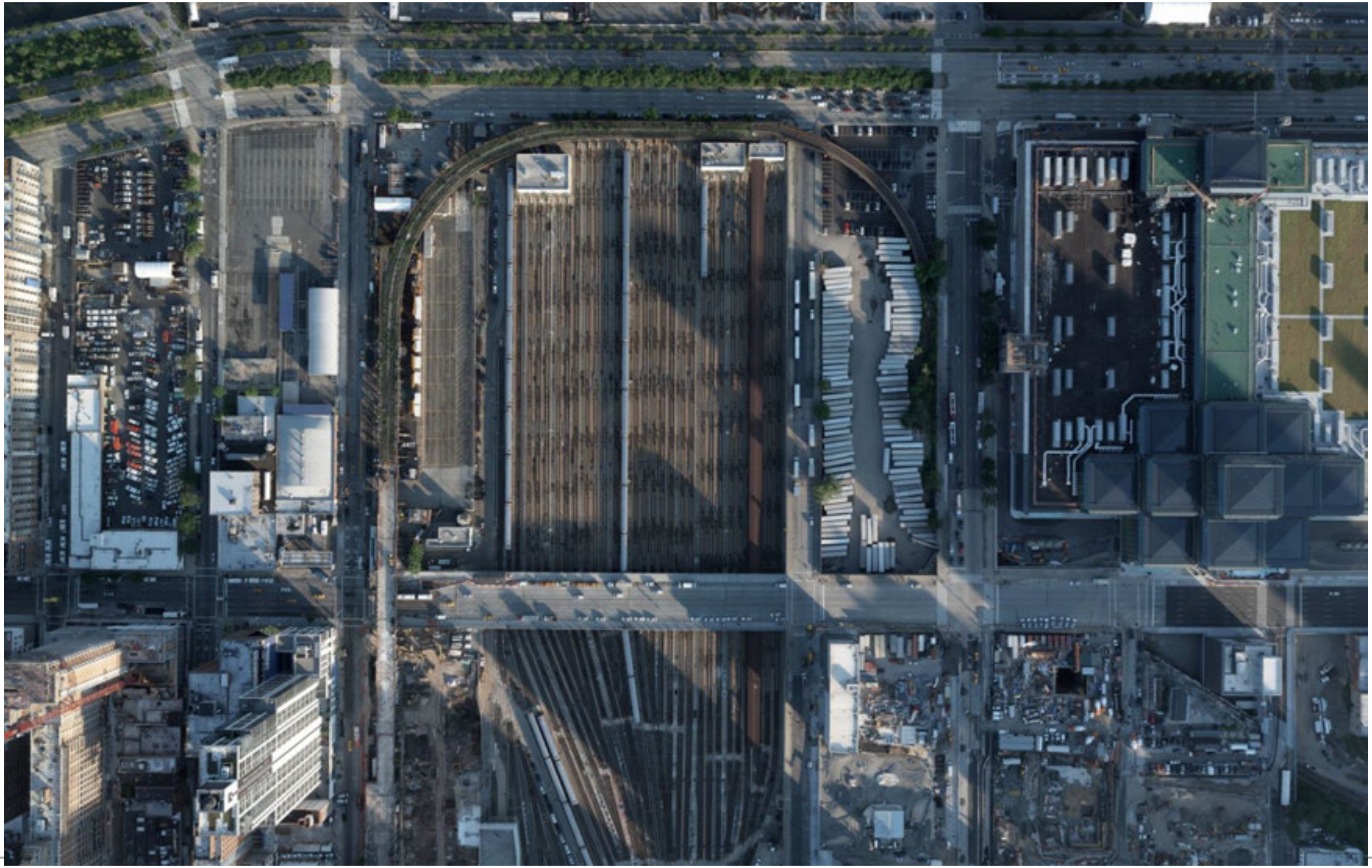
Hudson Yards Columns

Stage 2 – Loads on bolts: Upper Section is Vertical		
Total Assembly Weight =	64.6	kips
Out to Out Bolt Ditance = =	2.50	ft
Distance to CoG =	1.1	ft
% of total length = =	44.0%	
Lt Bolt Reaction =	36.2	kips
Rt Bolt Reaction =	28.4	kips
P =	36.2	kips
# of Bolts in Tension =	2.0	
Tension per Bolt =	18.1	kips
Bolt Diameter =	1.125	in.
A_b =	0.99	in^2
F_{nt} =	90.0	(ksi)
F_{nv} =	54.0	(ksi)
Ω =	2.0	
Net Tension Capacity per bolt =	50.6	(kips)
Tensile stress per bolt (f_{rt}) =	18.2	(ksi)

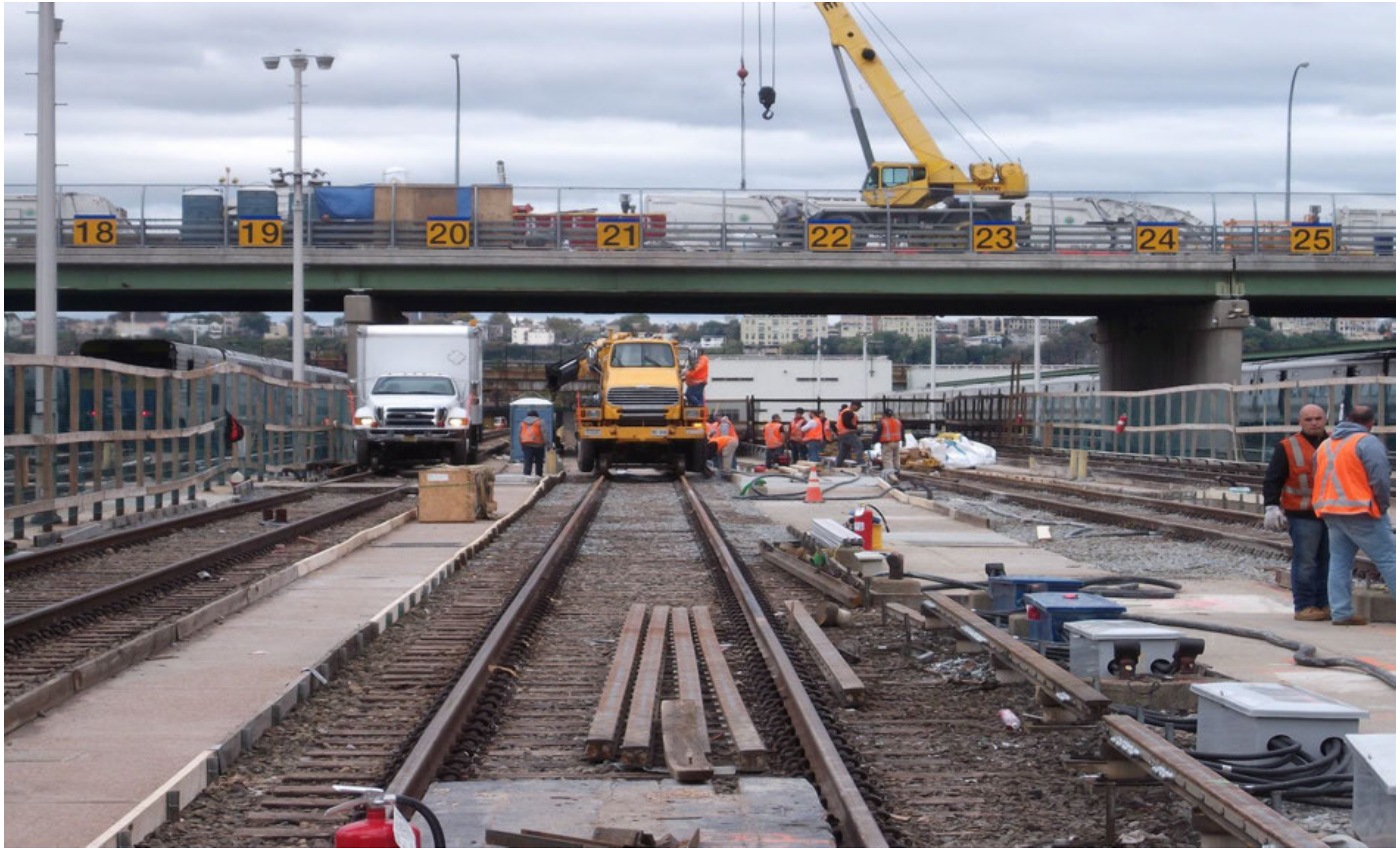
Hudson Yards Columns

Hudson Yards Columns

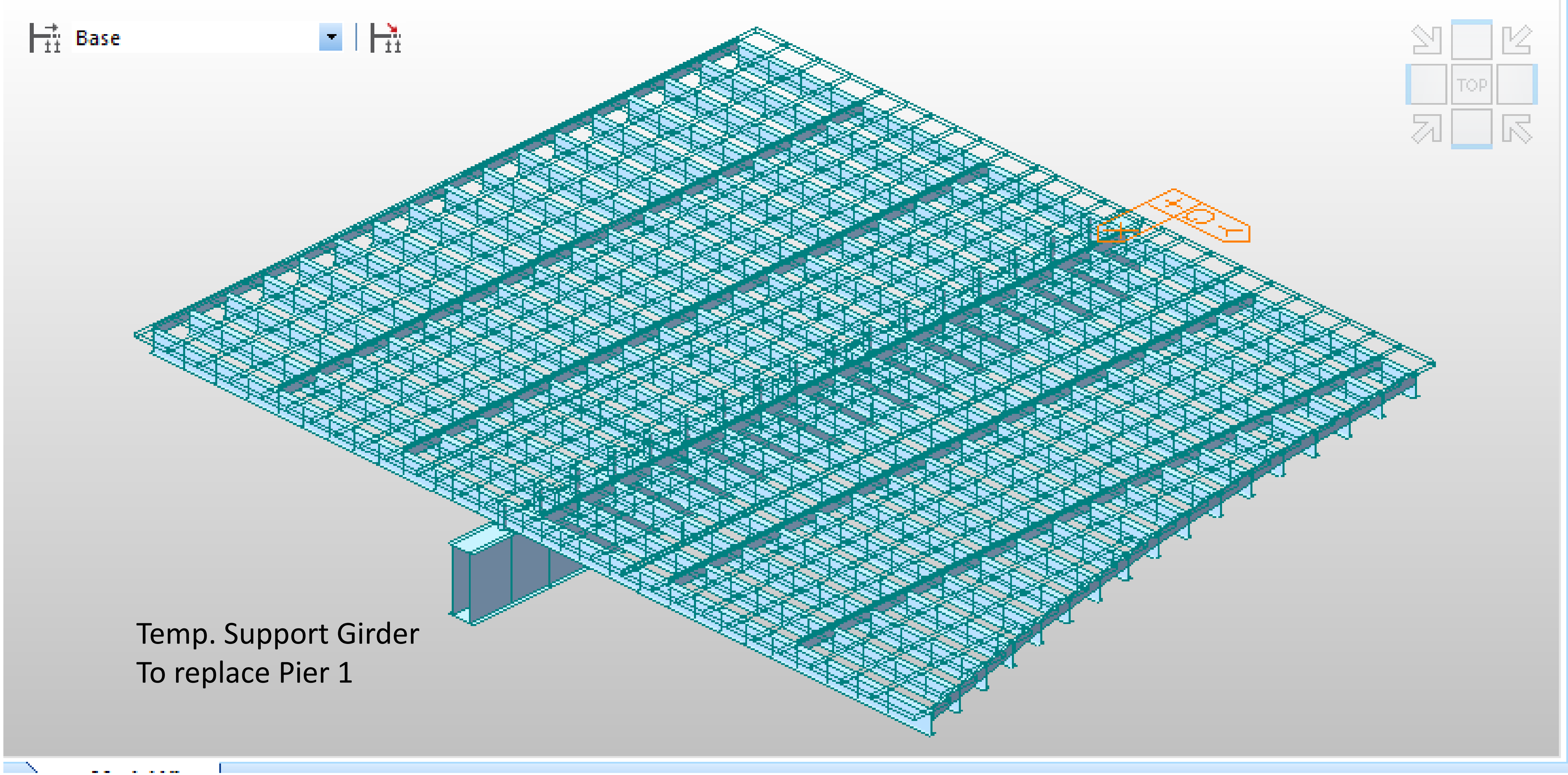
Hudson Yards 11th Ave Bridge



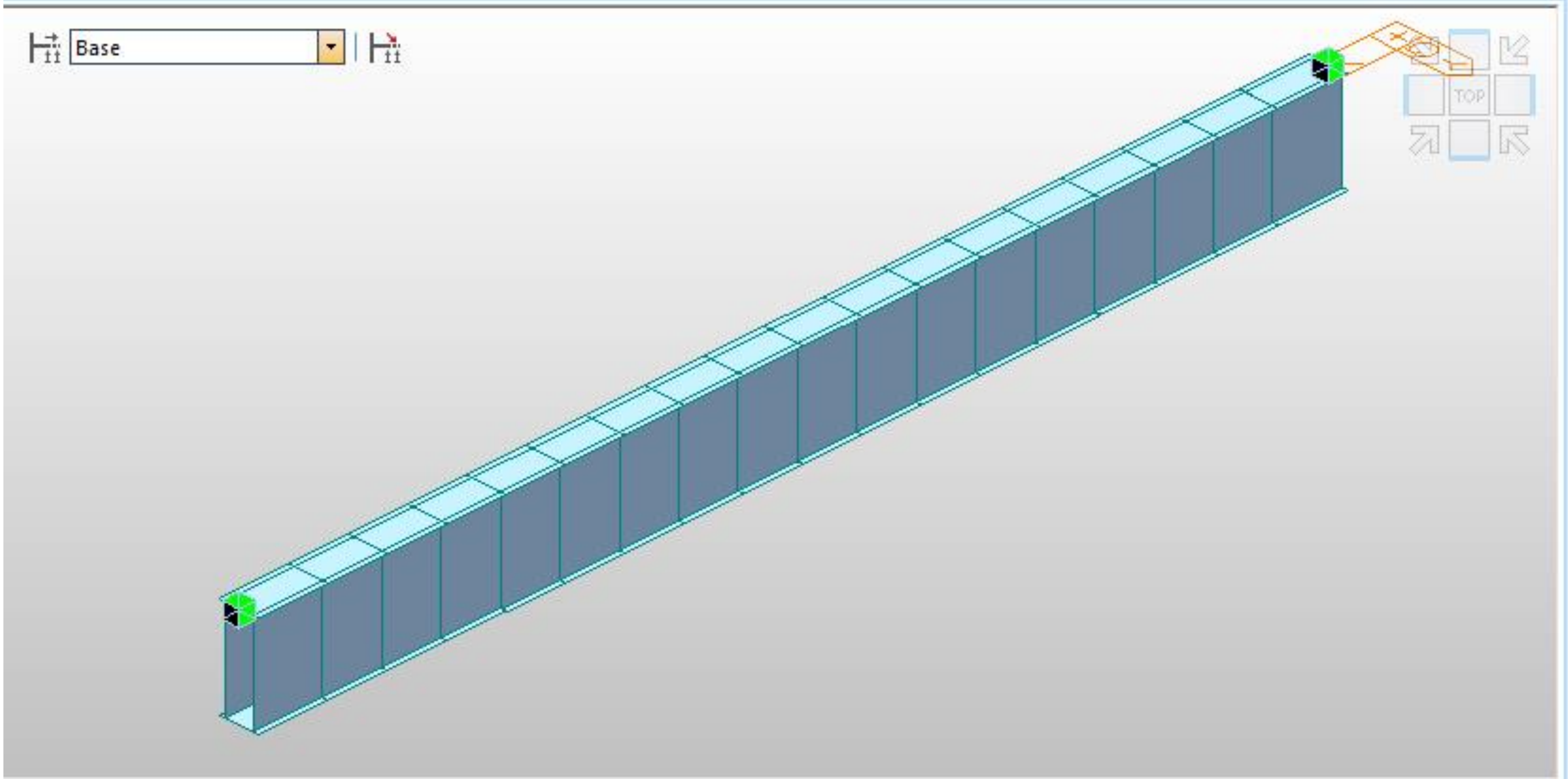
Hudson Yards 11th Ave Bridge



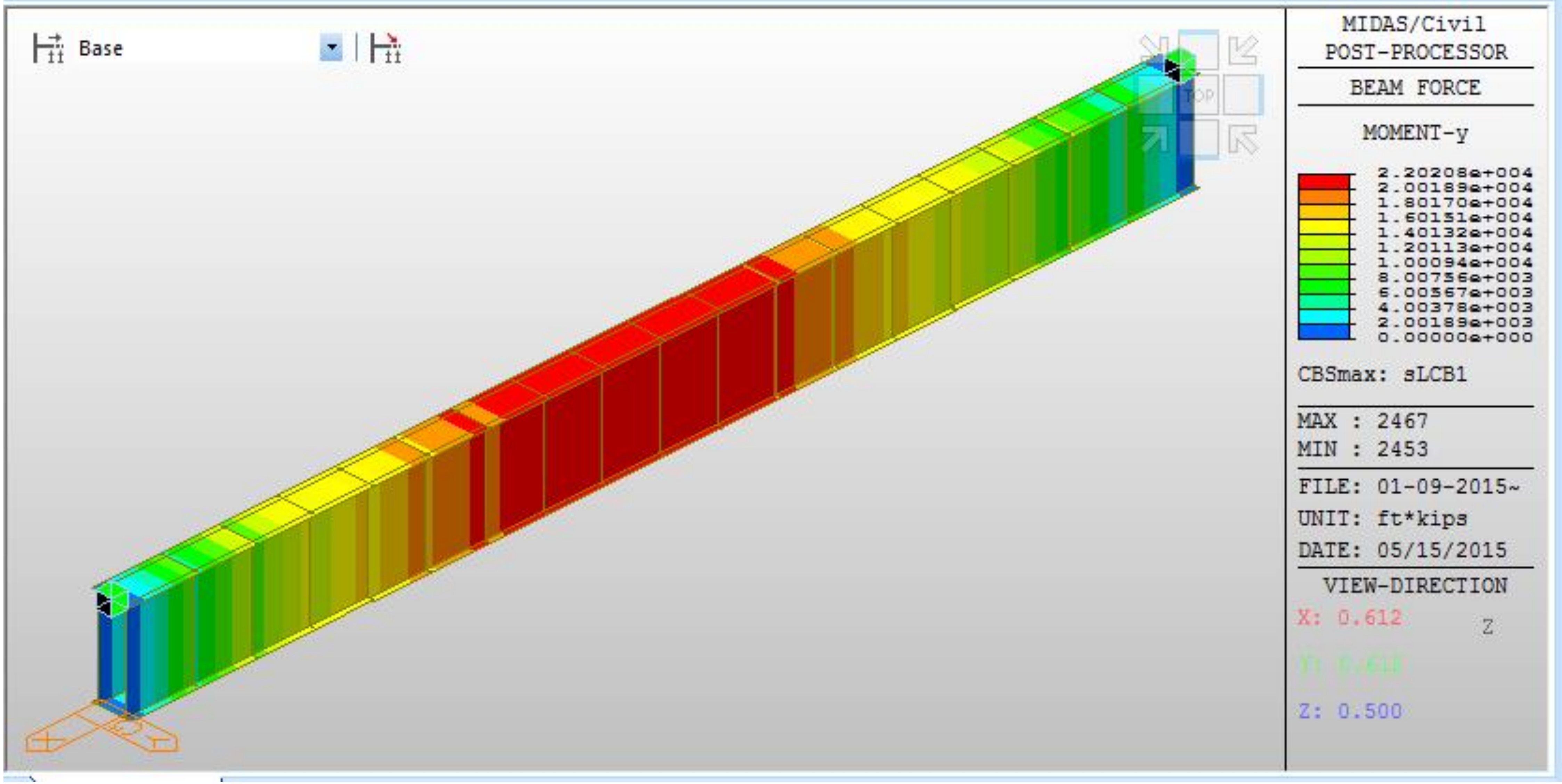
Hudson Yards 11th Ave Bridge



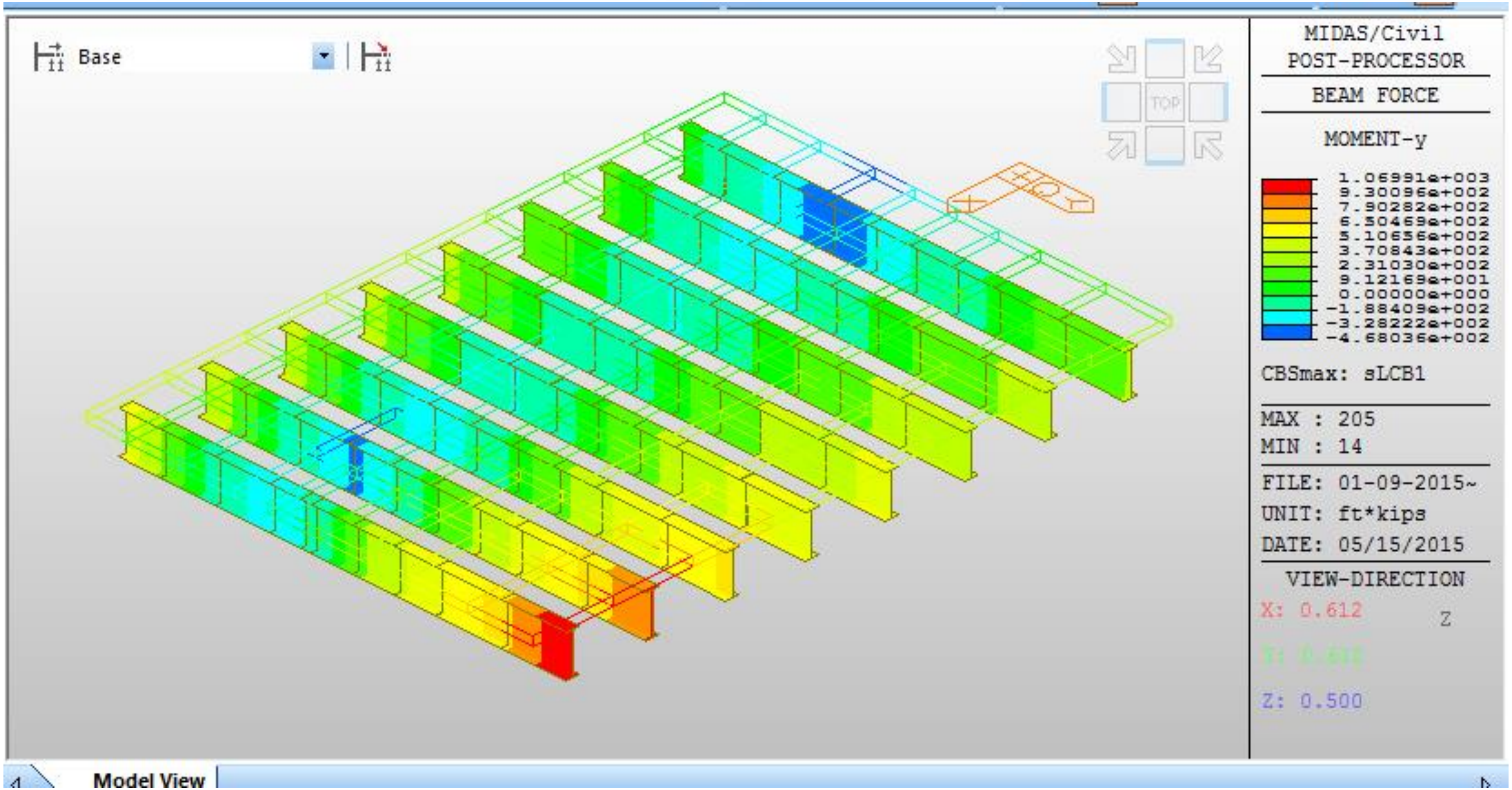
Hudson Yards 11th Ave Bridge



Hudson Yards 11th Ave Bridge



Hudson Yards 11th Ave Bridge



Hudson Yards 11th Ave Bridge

Element	275
Position	I
Moment Type	Beam

W36 x 160
Max Positve Bending =
Max Negatve Bending = -16575.96 kip-in.
Max Shear = -123.69 kips

I. Design Condition (Positive Flexure)

1. Section Properties

Position	Material	Thick (in)	f_y (ksi)	f_u (ksi)	Note
Compression Flange	A588-50	1.020	50.000	70.000	less than 2 in.
Tension Flange	A588-50	1.020	50.000	70.000	less than 2 in.
Web	A588-50	0.650	50.000	70.000	less than 2 in.

[Design Strength]

F_{yc} = 50.000 ksi (Compression Flange Yield Strength)
F_{yw} = 50.000 ksi (Web Yield Strength)
F_{yt} = 50.000 ksi (Tension Flange Yield Strength)
E_s = 29000.000 ksi (Elastic Modulus of Steel)

D = 34.000 in t_w = 0.650 in

Position	Material	Thick (in)	f_y (ksi)	f_u (ksi)	Note
Compression Flange	A588-50	1.020	50.000	70.000	less than 2 in.
Tension Flange	A588-50	1.020	50.000	70.000	less than 2 in.
Web	A588-50	0.650	50.000	70.000	less than 2 in.

[Design Strength]

F_{yc} = 50.000 ksi (Compression Flange Yield Strength)
F_{yw} = 50.000 ksi (Web Yield Strength)
F_{yt} = 50.000 ksi (Tension Flange Yield Strength)
E_s = 29000.000 ksi (Elastic Modulus of Steel)

5) Long-term Composite Section(Long. Reinforcement/3)

$A_{(R3)}$ (in^2)	48.233	$I_{y(R3)}$ (in^4)	10564.496	$I_{z(R3)}$ (in^4)	997.631
$d_{Top(R3)}$ (in)	17.197	$d_{Bot(R3)}$ (in)	18.843		
$S_{Top(R3)}$ (in^3)	614.335	$S_{Bot(R3)}$(in^3)	560.648		

V. Strength Limit State - Flexural Resistance

1. Flexure

■ **Negative moment**

1) Design Forces and Stresses

Loadcombination Name : scLCB1

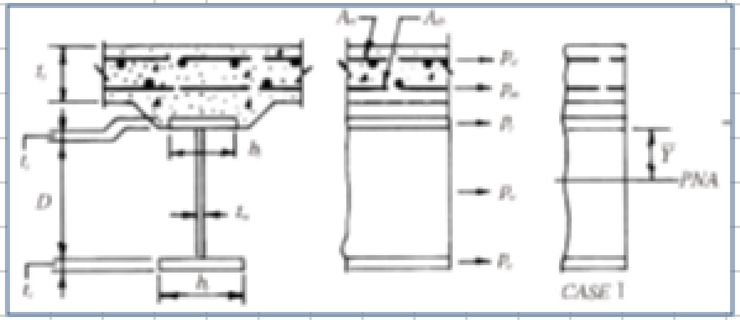
Loadcombination Type : -

Component		M_u (kips·in)				V_u (kips)	T (kips·in)
		Steel (M_{D1})	Long-term (M_{D2})	Short-term	Sum		
Forces	(-)	-4662.267	0.000	-11913.688	-16575.955	-123.694	-31.153

Component		$f_{c,t}$ (ksi)			
		Steel (M_{D1})	Long-term (M_{D2})	Short-term	Sum
Stresses	Top	8.718	0.000	15.286	24.004
	Bot	-8.718	0.000	-19.785	-28.503

- Plastic Moment

$$M_p = \frac{P_w}{2D} \cdot [Y^2 + (D - Y)^2 + [P_{rt} \cdot d_{rt} + P_{rb} \cdot d_{rb} + P_t \cdot d_t + P_c \cdot d_c] = 37291.817 \text{ kips-in}$$



▪ Yield Moment(My) (AASHTO LRFD Bridge, 2012, D6.2.2)

① Yield Moment of Top Flange

$$F_y = \frac{M_{D1}}{S_{Top}} + \frac{M_{D2}}{S_{Top(R)}} + \frac{M_{AD}}{S_{Top(R)}} = \frac{-4.662E+03}{5.348E+02} + \frac{0.000E+00}{6.143E+02} + \frac{M_{AD}}{7.794E+02} = 50.000 \text{ ksi}$$

M_{AD} = 45764.216 kips-in

$M_{yTop} = M_{D1} + M_{D2} + M_{AD} =$ 41101.948 kips-in

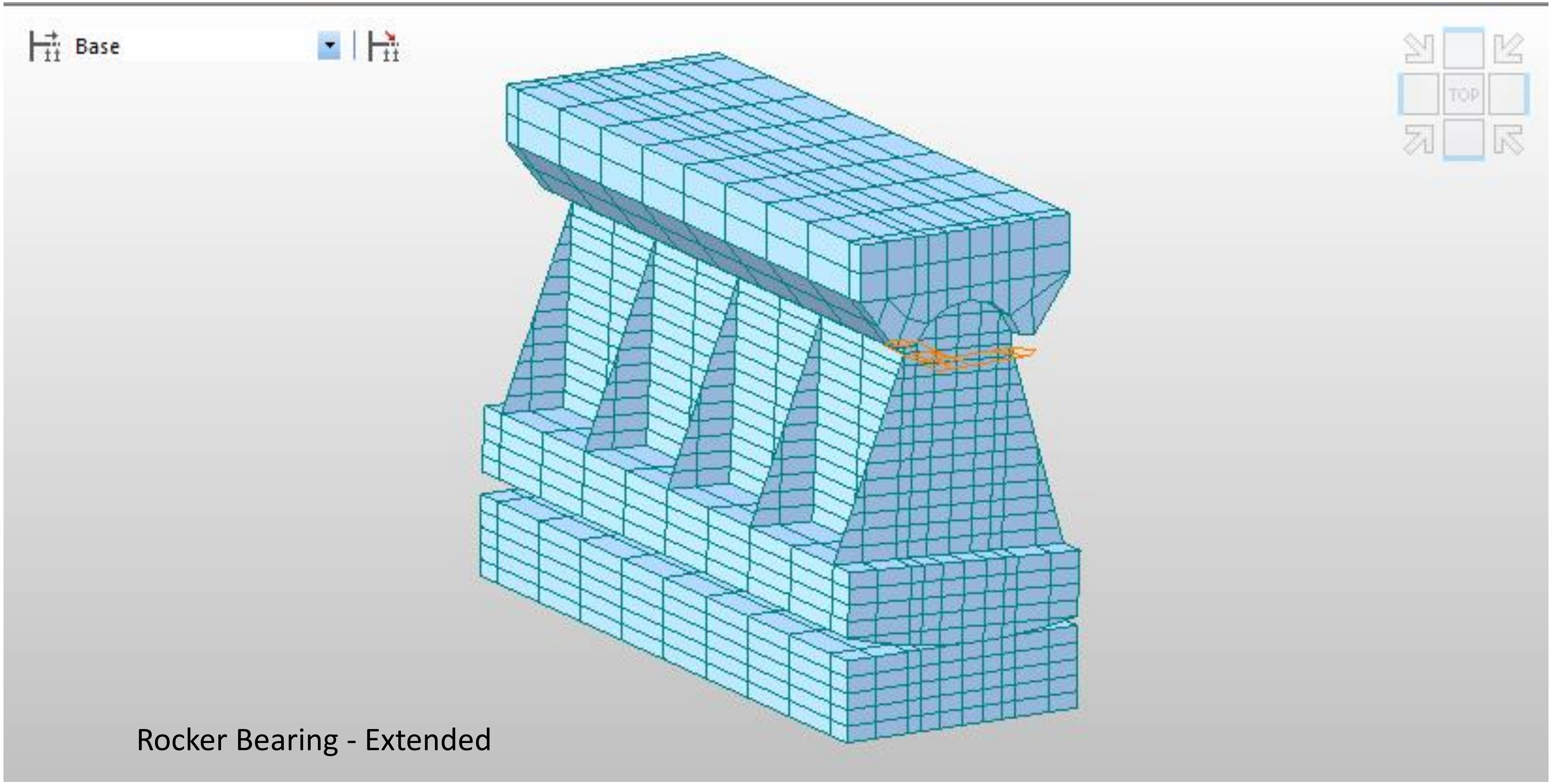
② Yield Moment of Bottom Flange

$$F_y = \frac{M_{D1}}{S_{Bot}} + \frac{M_{D2}}{S_{Bot(R)}} + \frac{M_{AD}}{S_{Bot(R)}} = \frac{-4.662E+03}{5.348E+02} + \frac{0.000E+00}{5.606E+02} + \frac{M_{AD}}{6.022E+02} = 50.000 \text{ ksi}$$

M_{AD} = 35357.948 kips-in

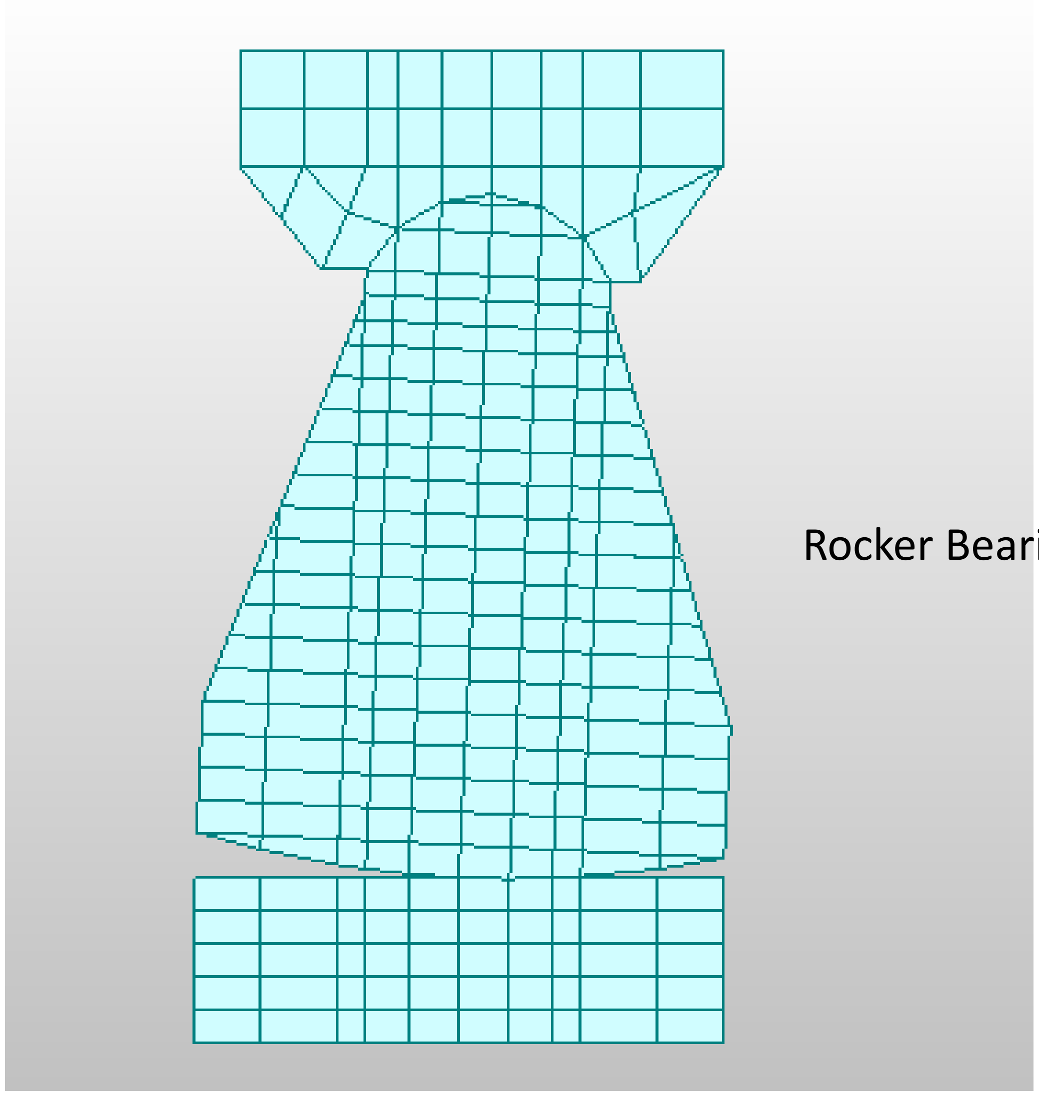
$M_{yBot} = M_{D1} + M_{D2} + M_{AD} =$ 30695.681 kips-in

Hudson Yards 11th Ave Bridge



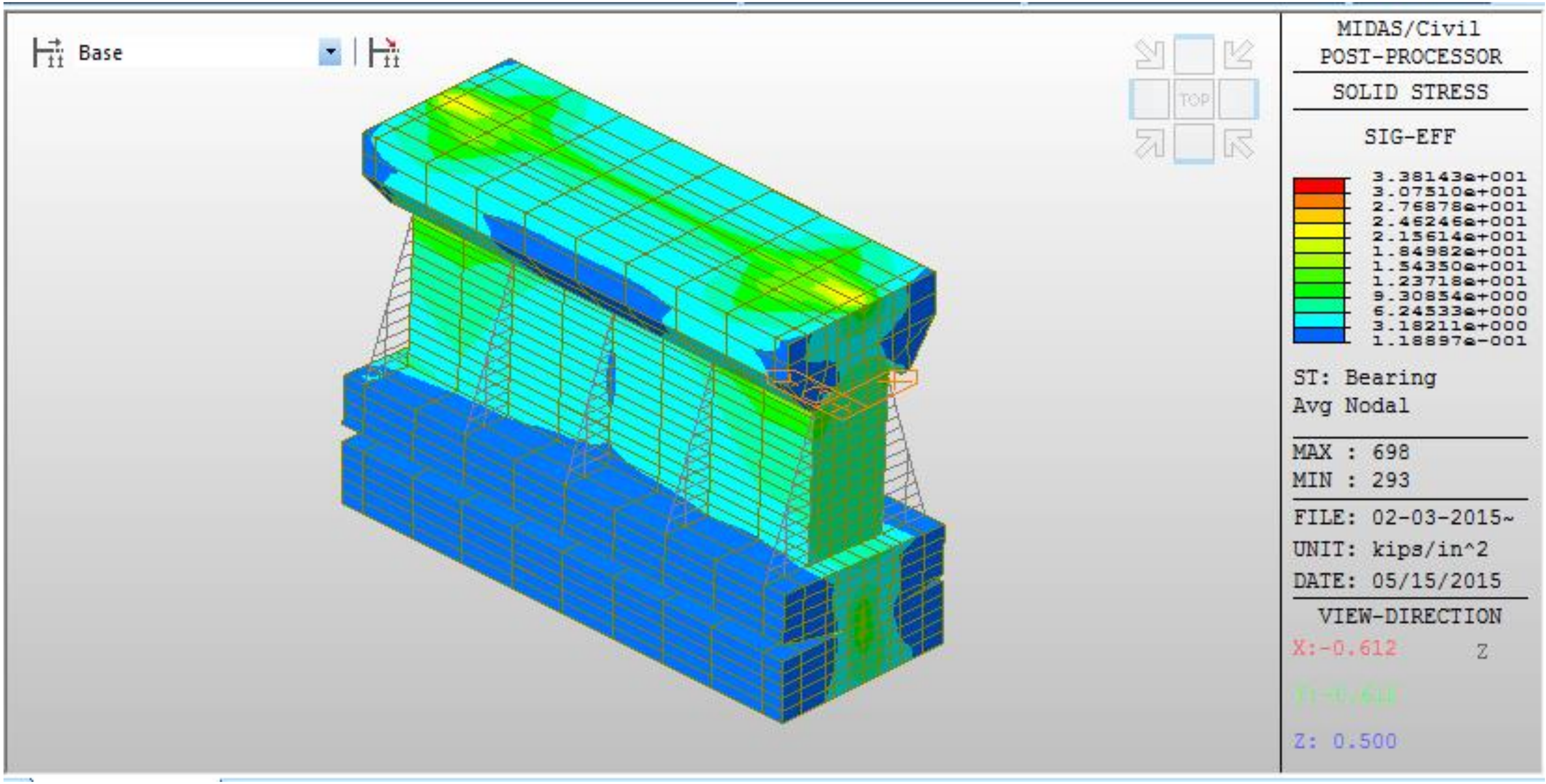
Rocker Bearing - Extended

Hudson Yards 11th Ave Bridge

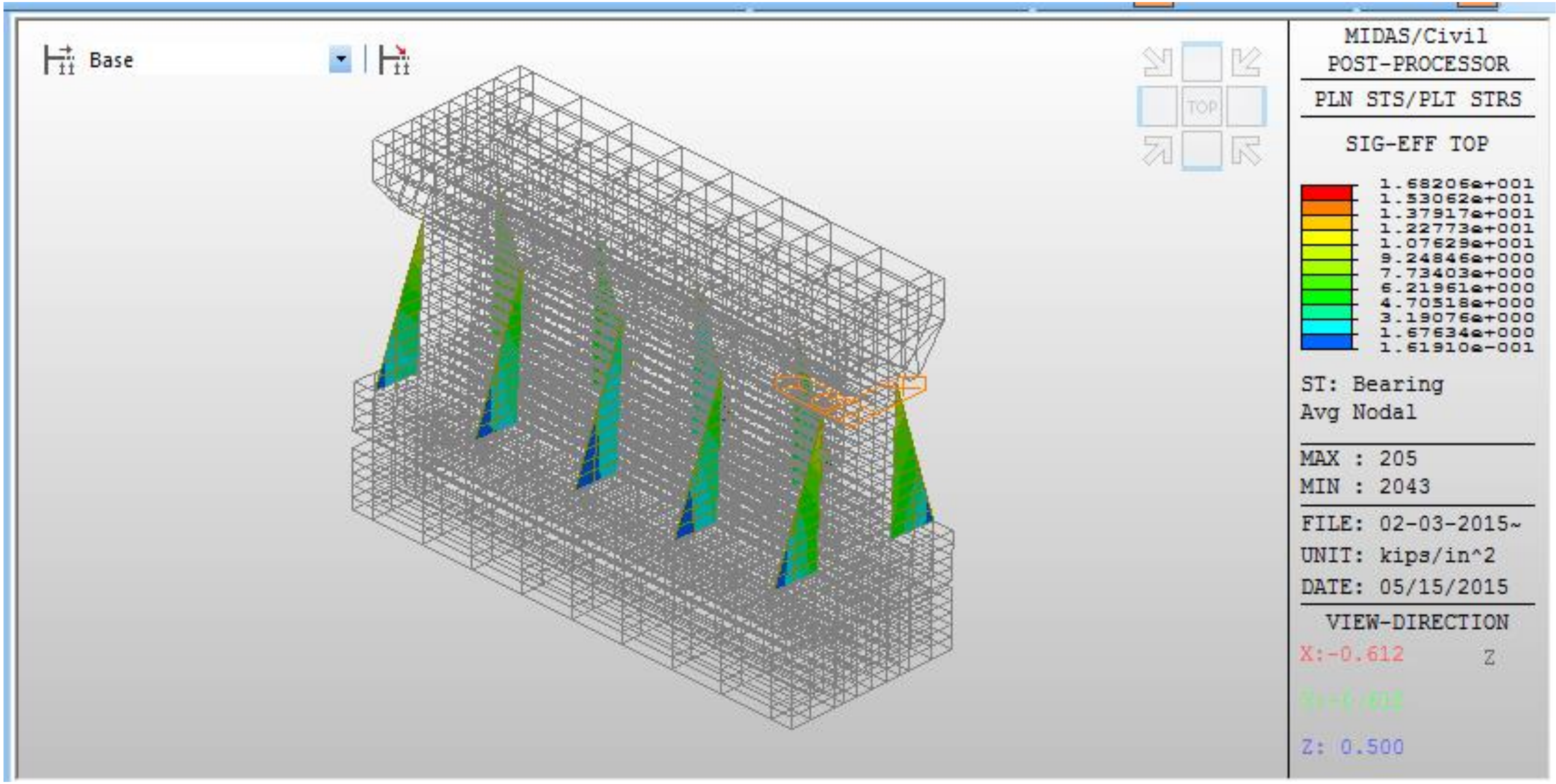


Rocker Bearing - Extended

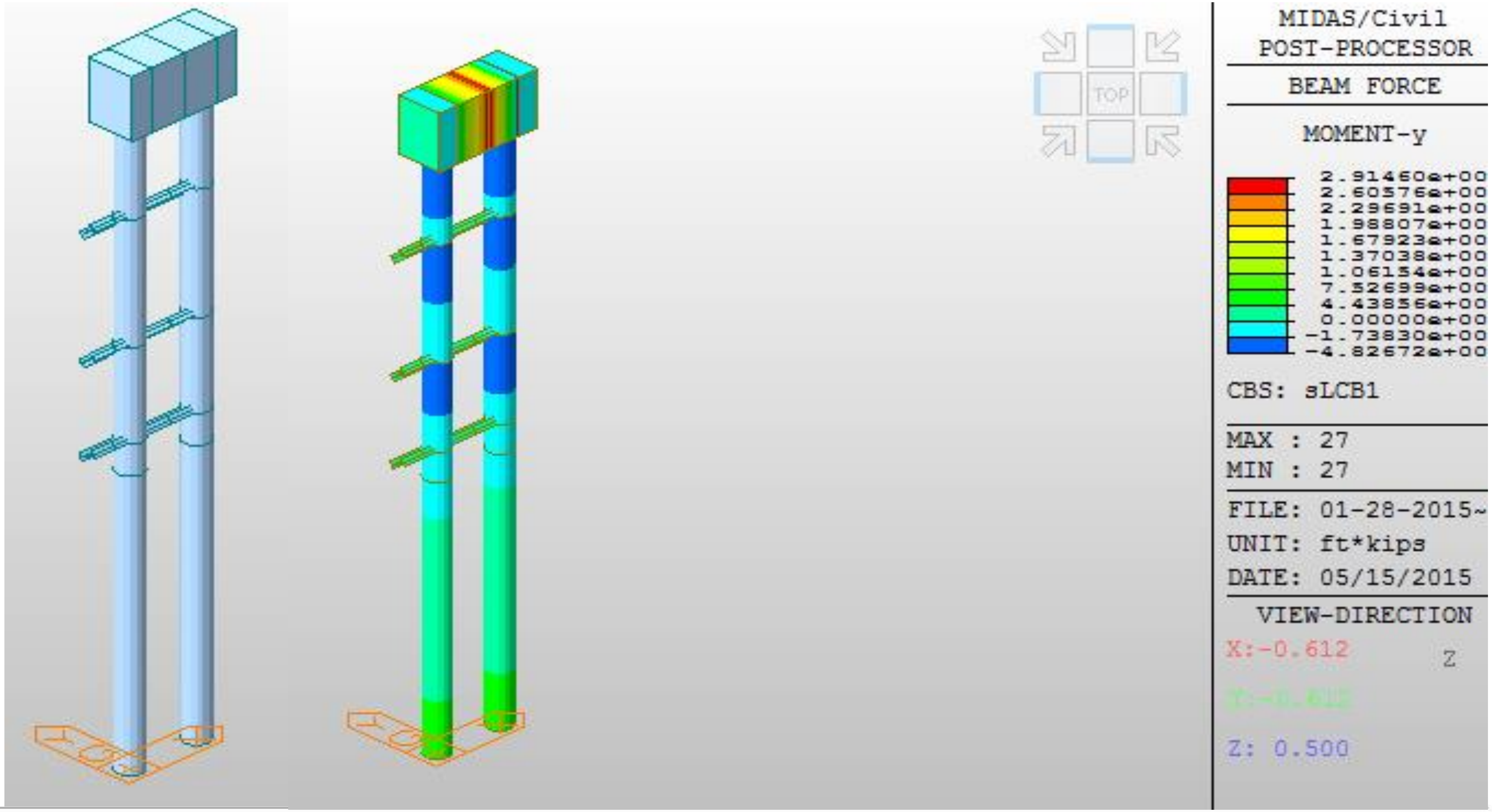
Hudson Yards 11th Ave Bridge



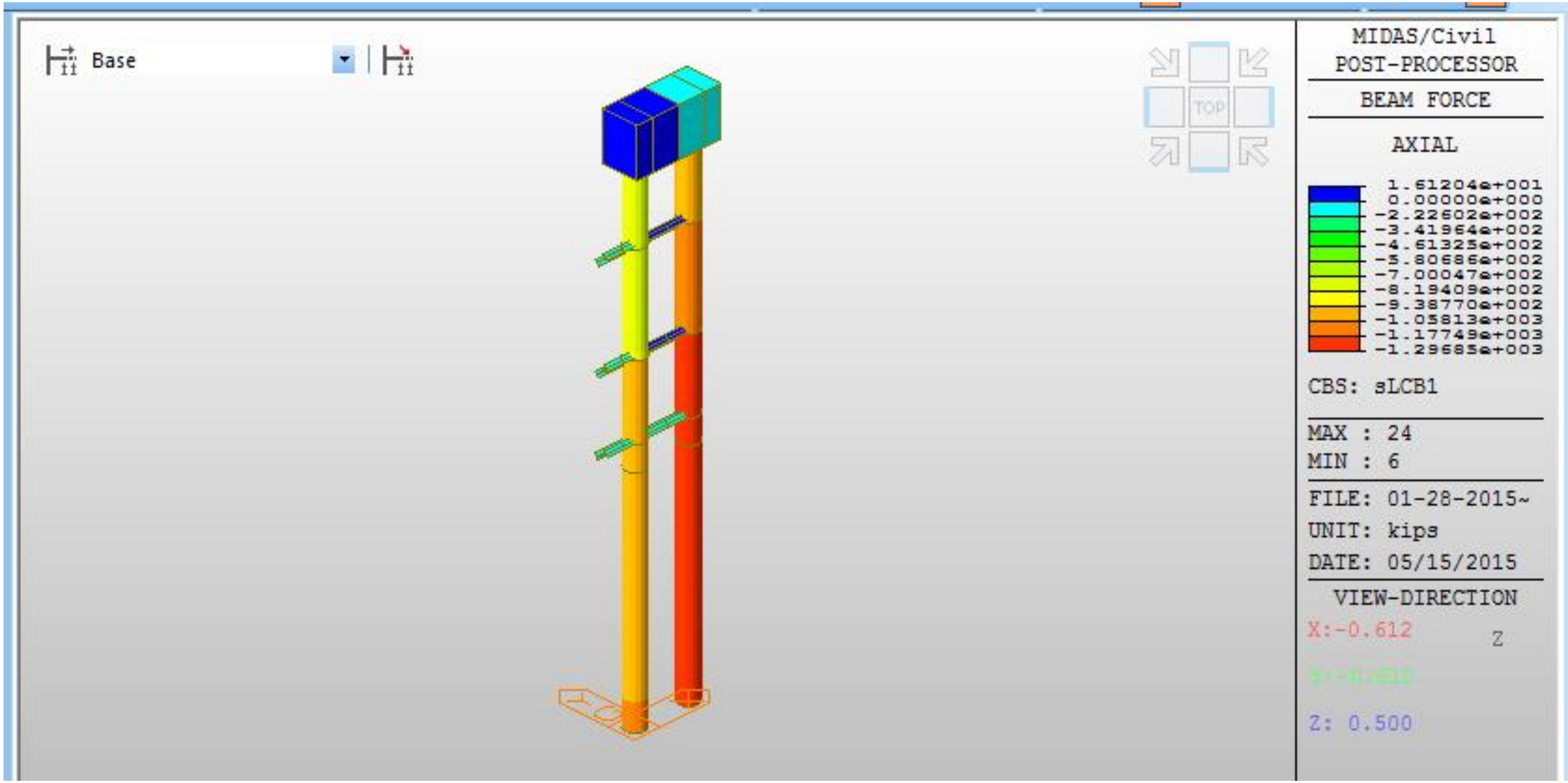
Hudson Yards 11th Ave Bridge



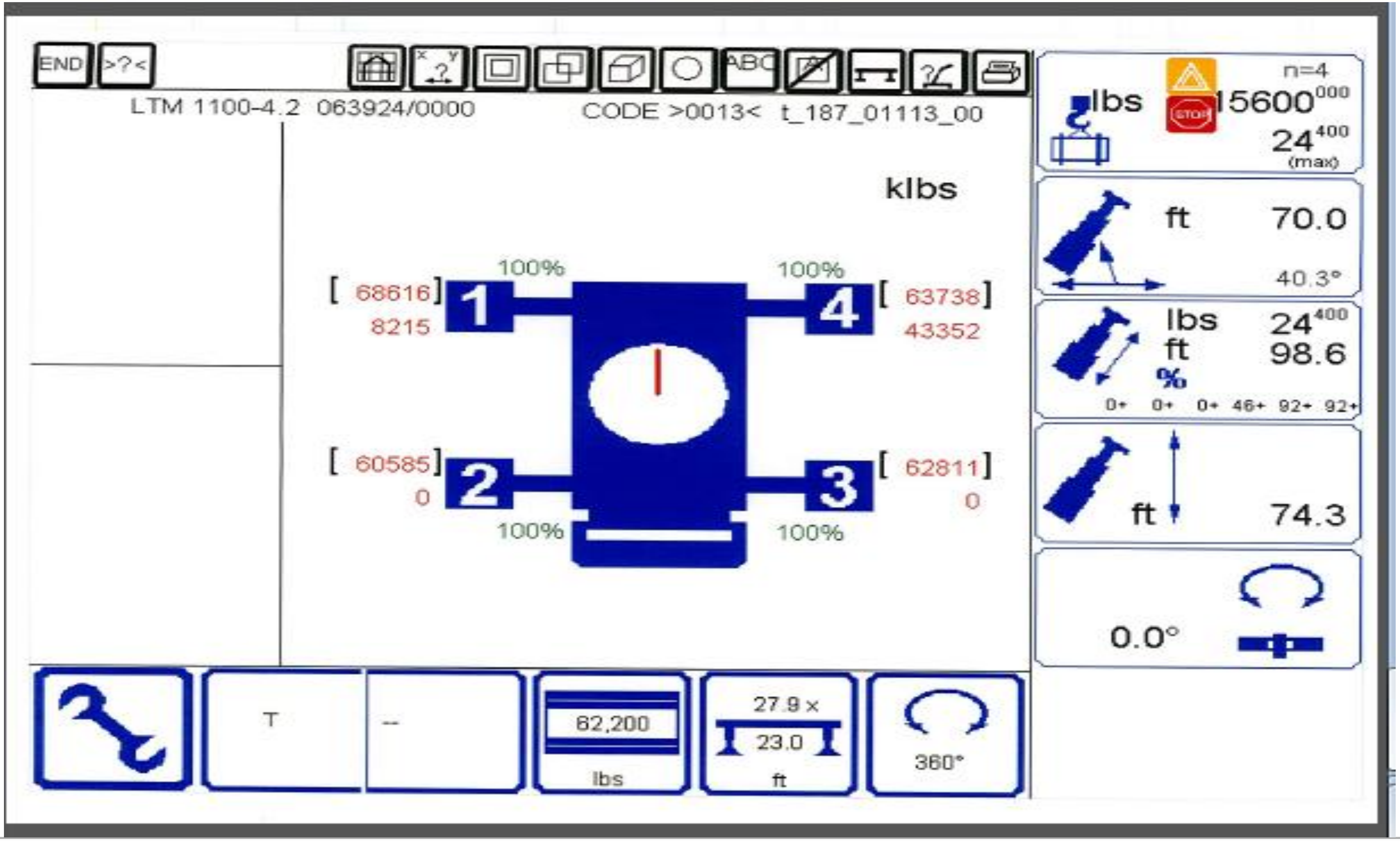
Hudson Yards 11th Ave Bridge



Hudson Yards 11th Ave Bridge



Crane Outrigger Loads



GBP - Crane Crawler Loads

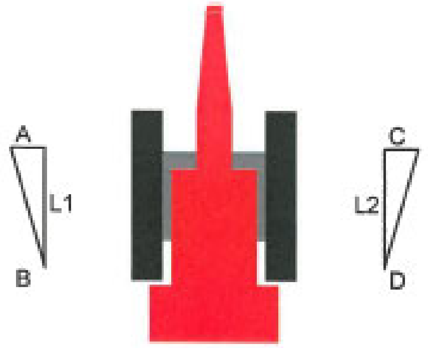
Manitowoc

Ground Bearing Pressure Estimator

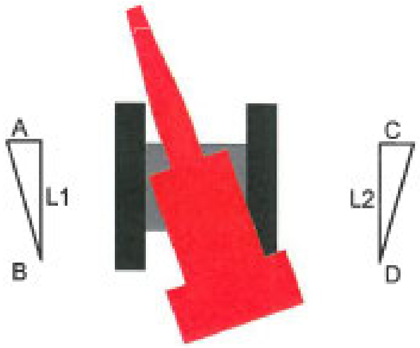
GBPressure ver: 1.0.6.0
4/23/2015 3:30 PM

Project:	Operating Surface: Soft - Tread Contact Width 47.3 Inches
Model: 14000 Series 2	Primary: 184FT (56M) #76 BOOM
Machine Counterweight: 168,000-LB (76,200-KG) + 53,000-LB (24,040-KG)	Secondary: 0FT (0M) No Attachment
Crawler:Fixed, Position: Gantry Up	Load: From Boom 14,000 LBS @ 140 ft radius

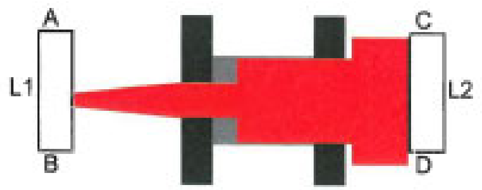
Imperial Pressure Conversion Factor: 1 PSI = 144 PSF



Boom Over Front or Rear



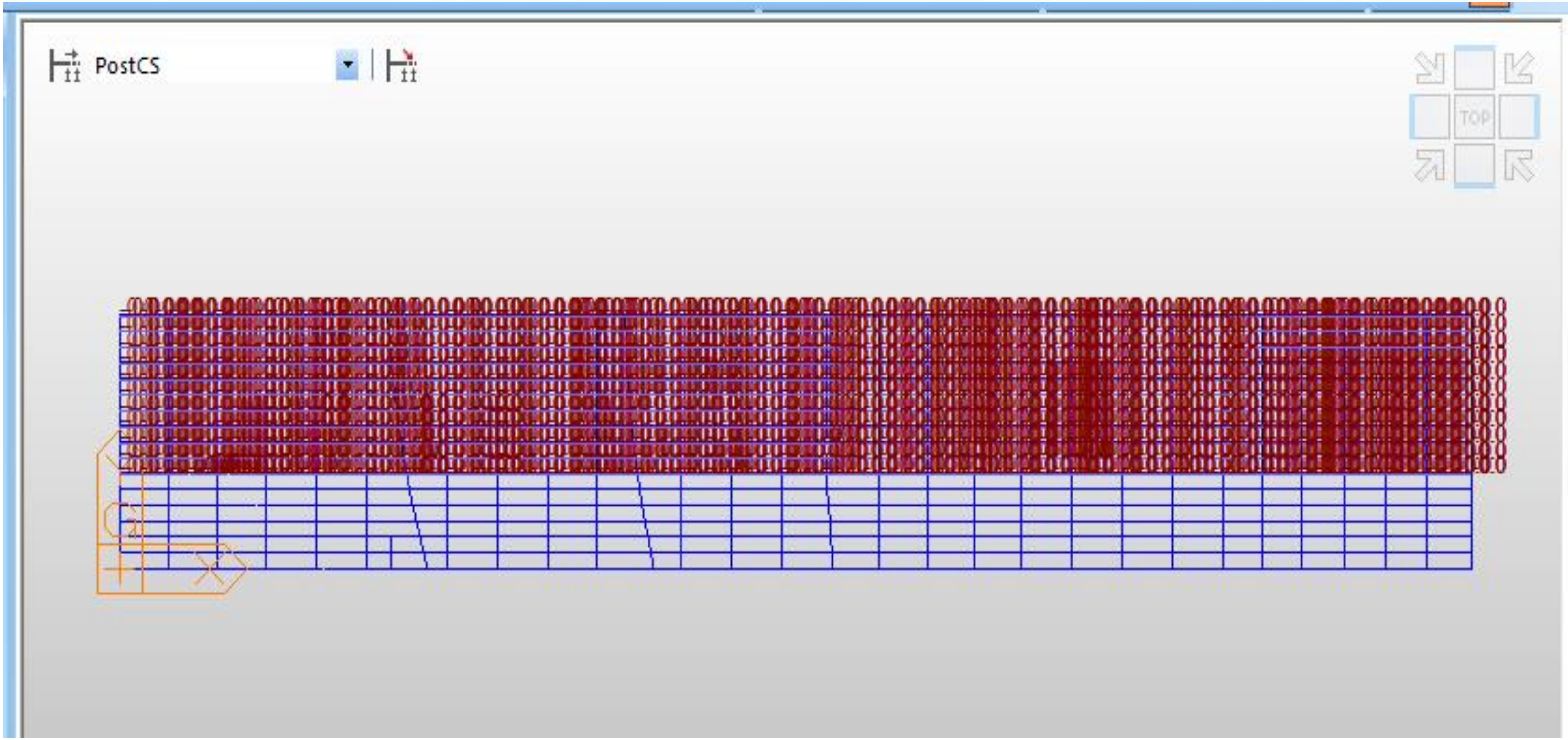
Boom at Critical 24 degree Swing



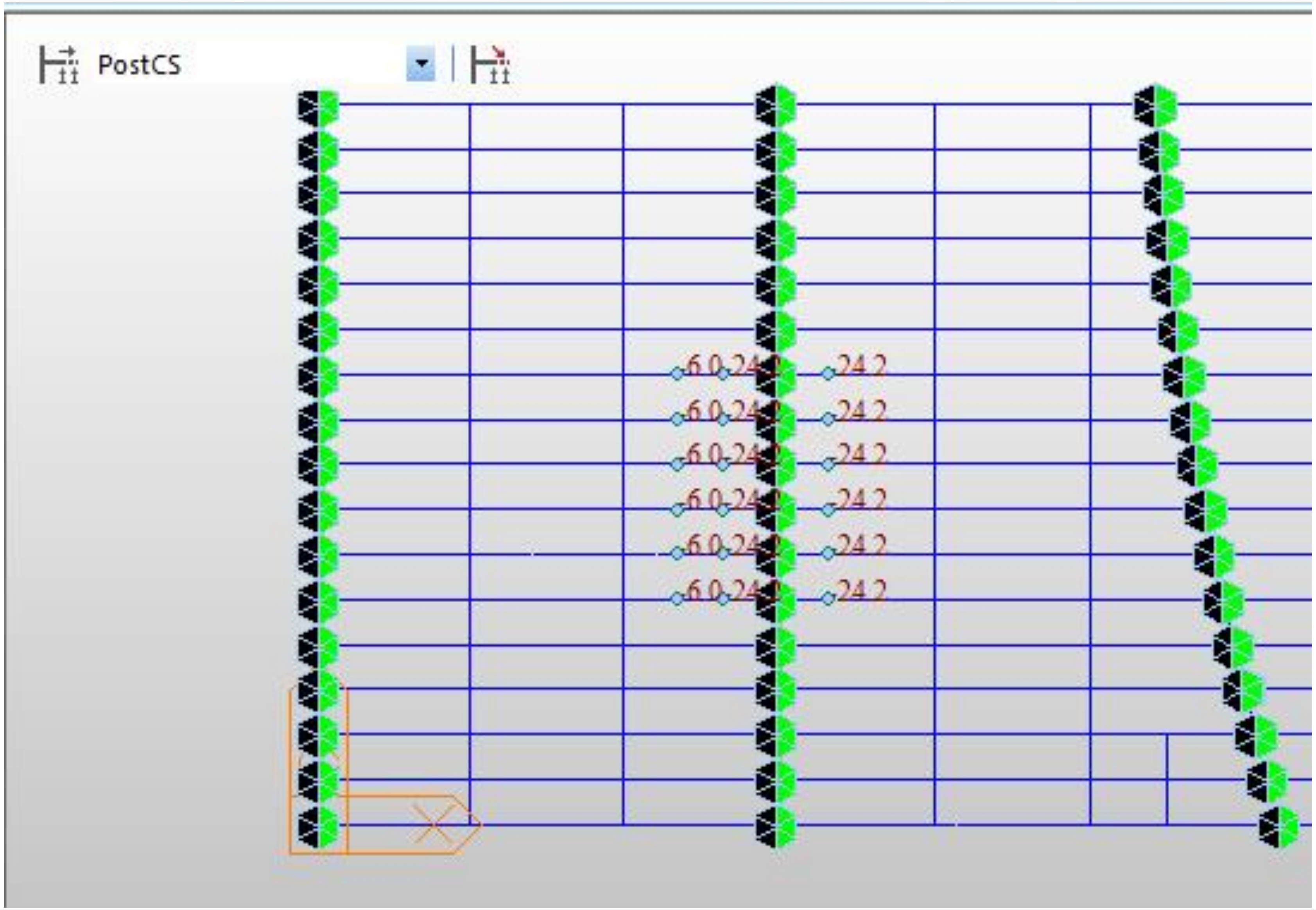
Boom Over Side

	Boom Over Front or Rear	Boom at Critical 24 degree Swing	Boom Over Side
	Center of Rotation to Fulcrum: 141.83 inch	Center of Rotation to Fulcrum: 141.83 inch	Center of Machine to Ctr of Crawlers: 109.7 inch
A	38.1 psi	40.3 psi	25.5 psi
B	0.0 psi	0.0 psi	25.5 psi
L1	245.0 inch	282.9 inch	283.7 inch
C	38.1 psi	32.2 psi	7.4 psi
D	0.0 psi	0.0 psi	7.4 psi
L2	245.0 inch	225.5 inch	283.7 inch

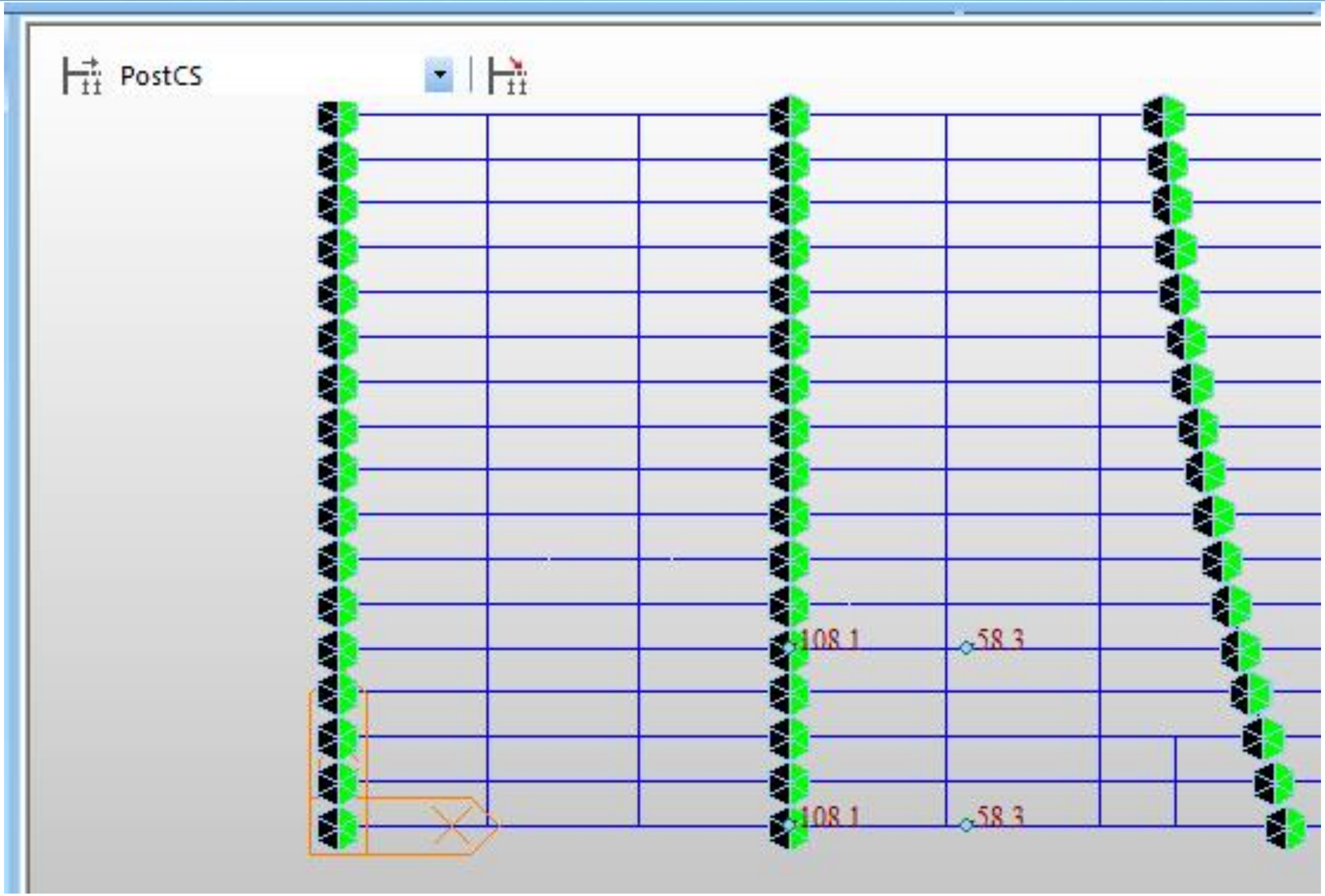
Crane on Bridge – Lane Loads



Factored HS20 Loads



Factored Crane Outrigger Loads



Composite Design Results

Analysis of RT600E on 11th Ave Bridge

Element	14
Position	I
Moment Type	Beam

W36 x 192		
Max Positve Bending =		
Max Negatve Bending =	-24701.36	kip-in.
Max Shear =	167.45	kips

I. Design Condition (Positive Flexure)

1. Section Properties

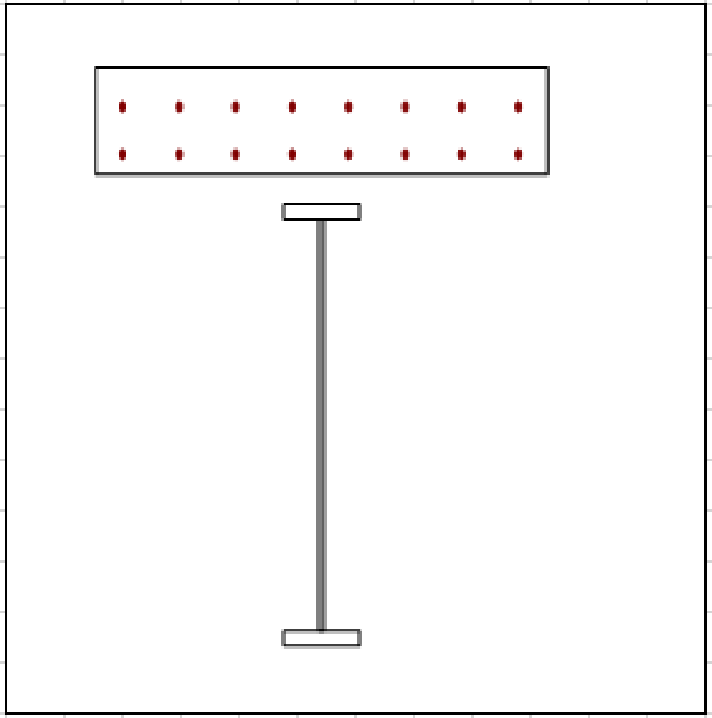
1) Slab Properties

B_s	=	72.000	in
t_s	=	9.000	in
t_h	=	3.760	in
f_c'	=	4.000	ksi
E_c	=	3644.147	ksi
A_r	=	4.960	in^2
F_{yr}	=	60.000	ksi

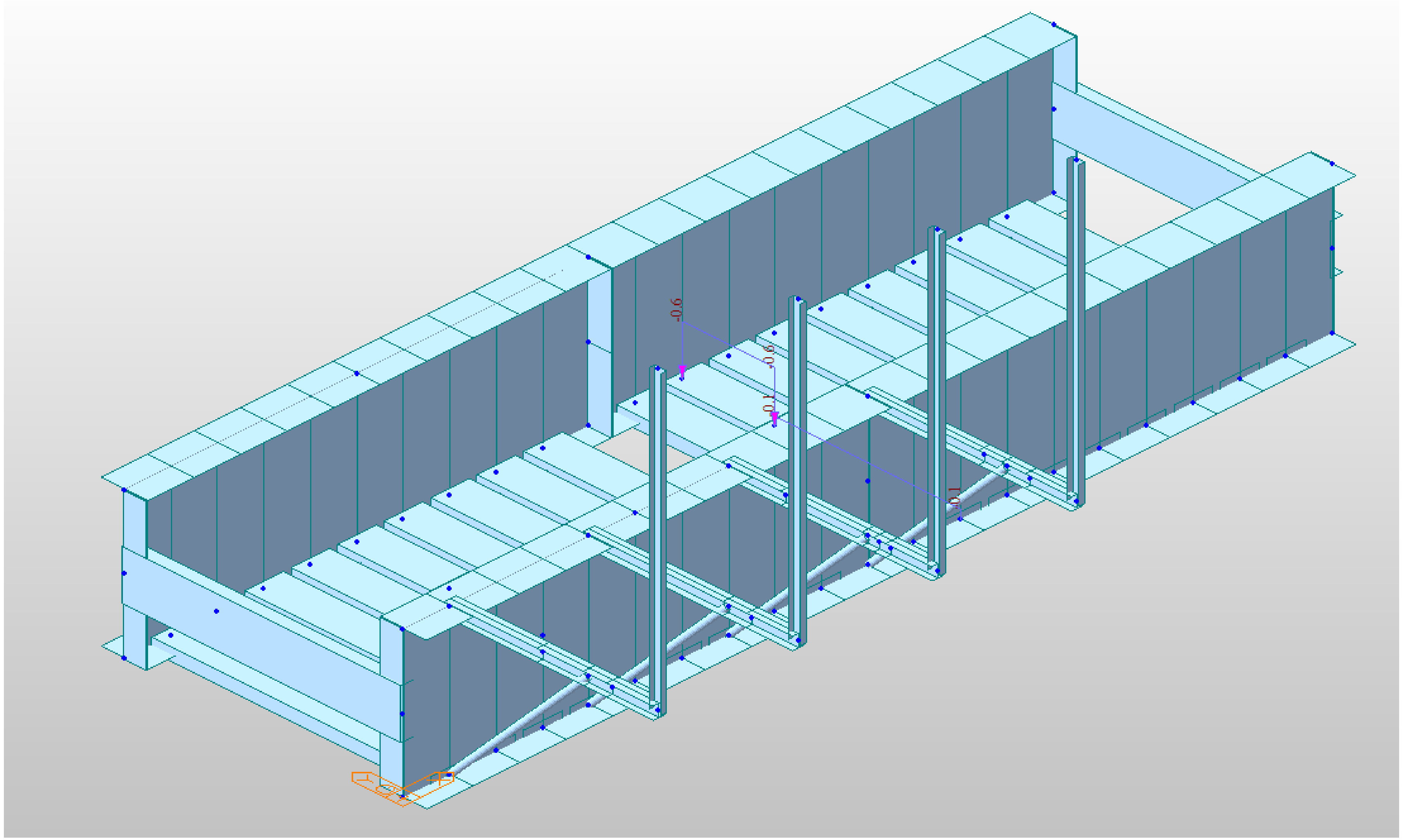
2) Girder Properties

[Section]

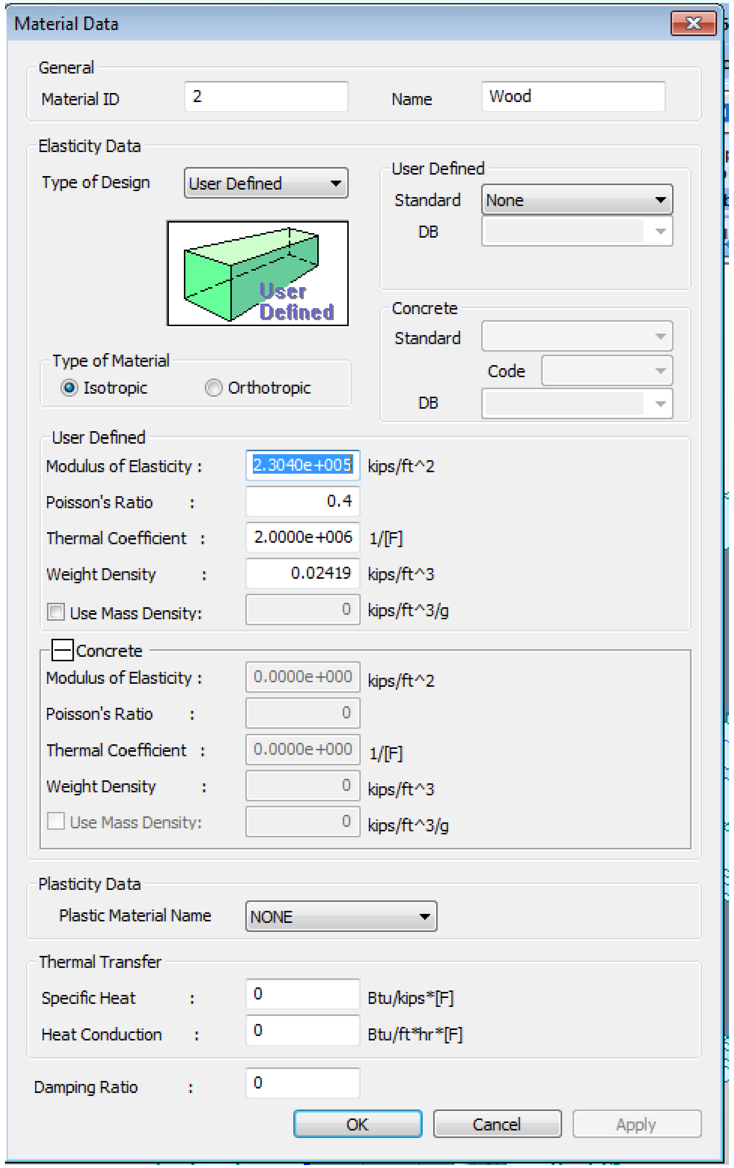
b_{fc}	=	12.100	in	b_{ft}	=	12.100	in
t_{fc}	=	1.260	in	t_{ft}	=	1.260	in
D	=	34.500	in	t_w	=	0.765	in



11th Avenue Bridge Deck Demolition



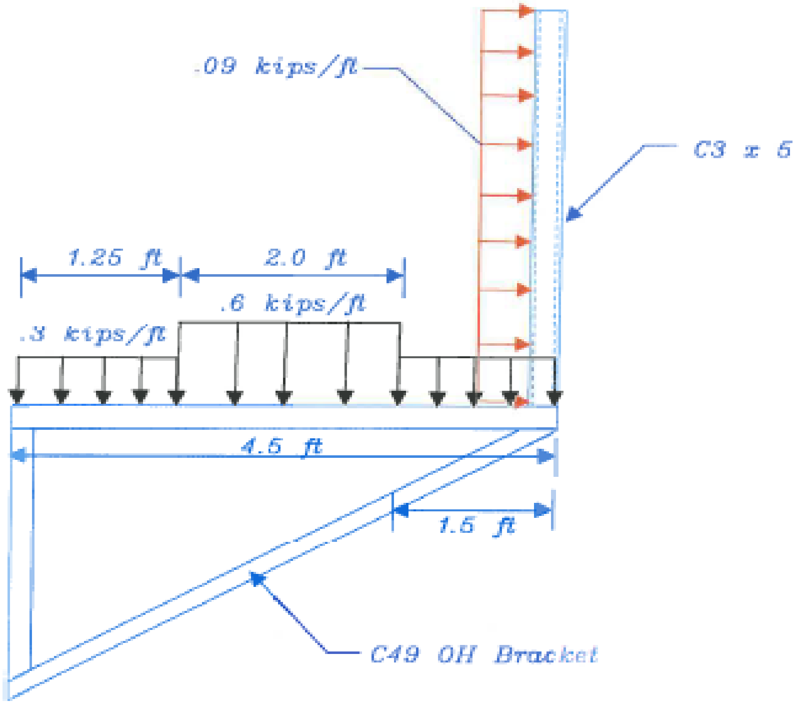
Section Properties
For Timber Planks



11th Avenue Bridge Deck Demolition

Loading on Overhang Brackets:

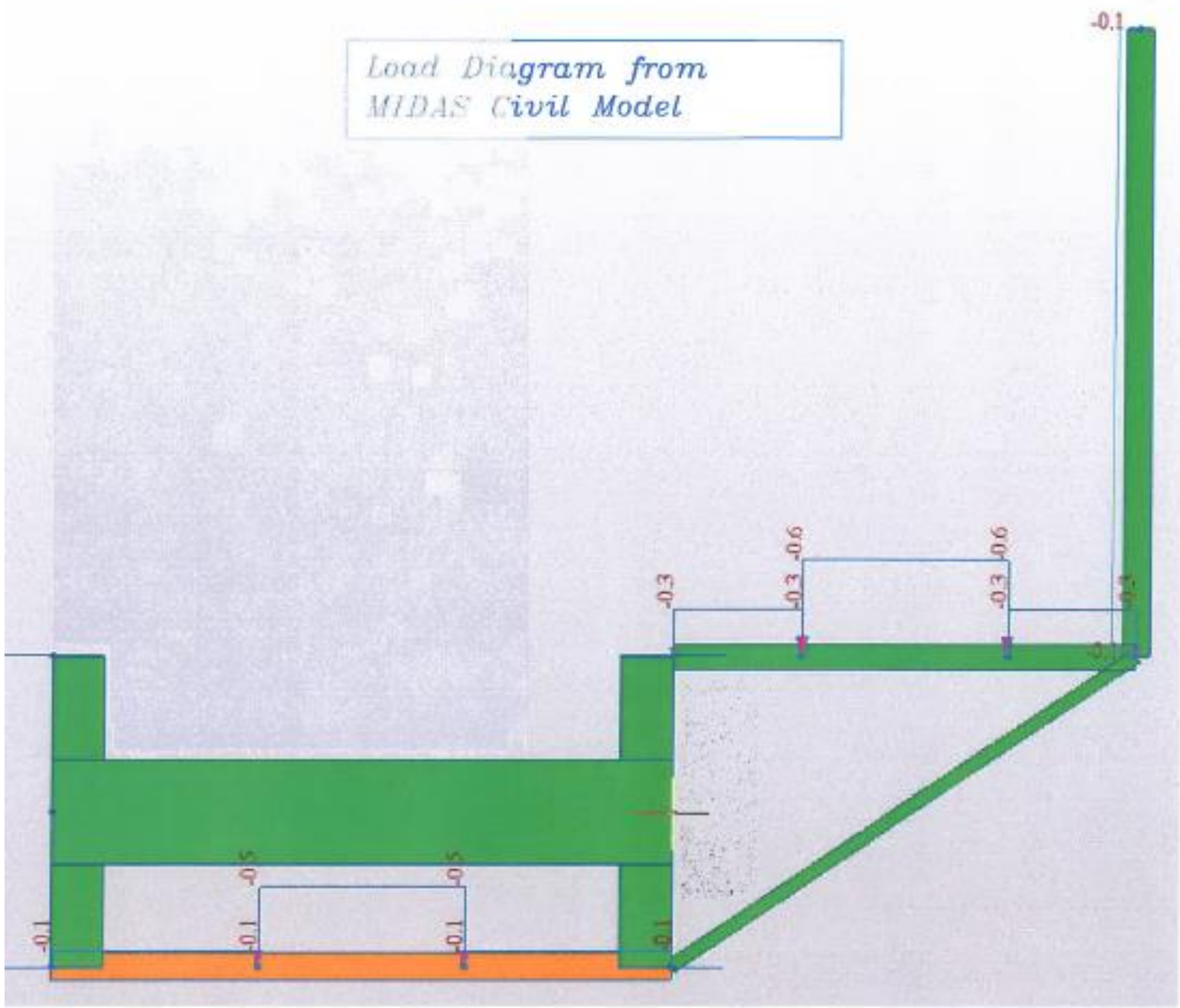
Bracket Spacing =	3.00	ft
Loading for 100 psf =	0.3	kips/ft
Loading for 2000 lb point Load = =	0.6	kips/ft



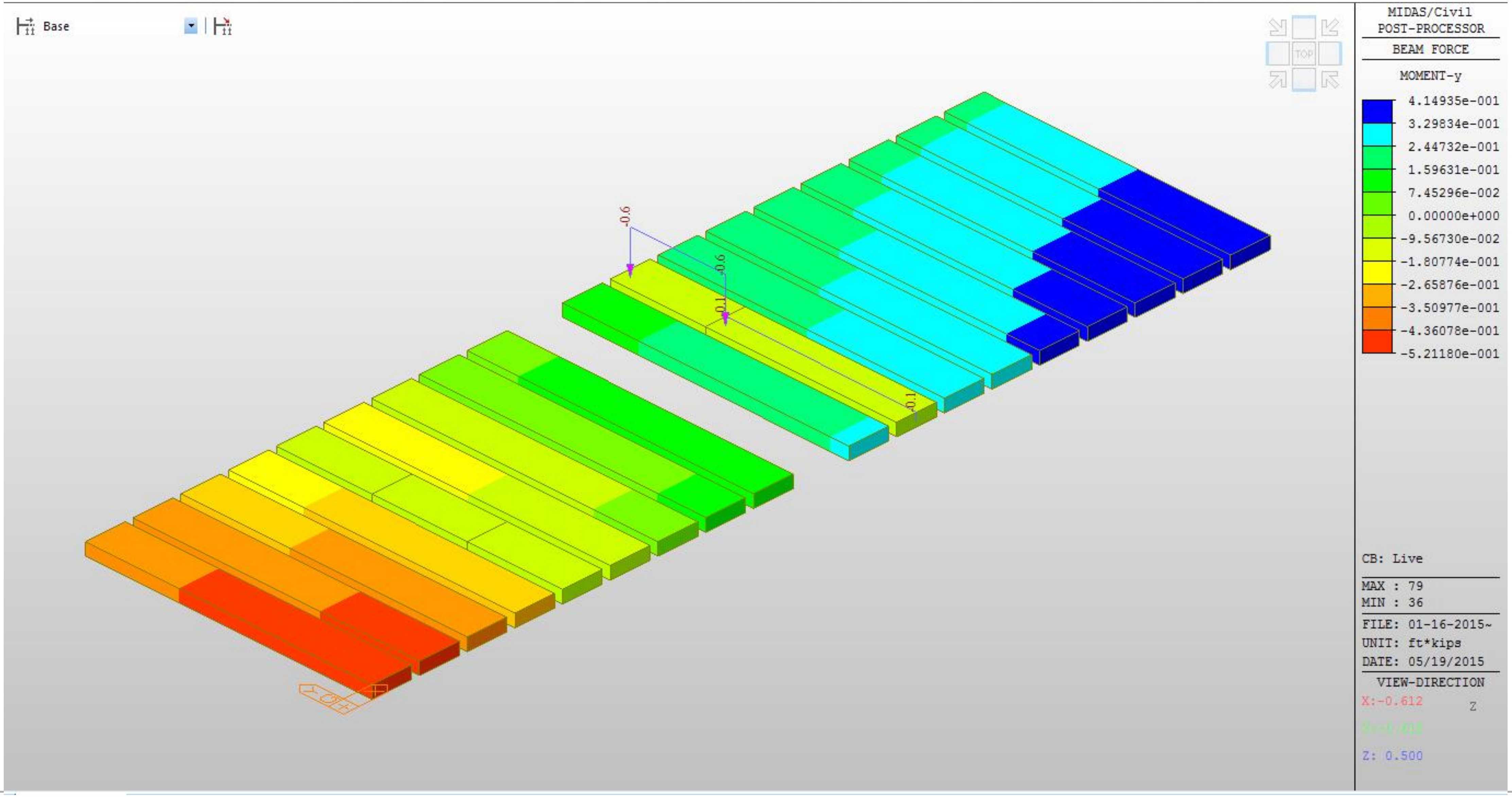
Loading on Vertical Post:

Post Spacing =	3.00	ft
Vertical Loading =	0.03	ksf
Load per Post =	0.09	kips/ft

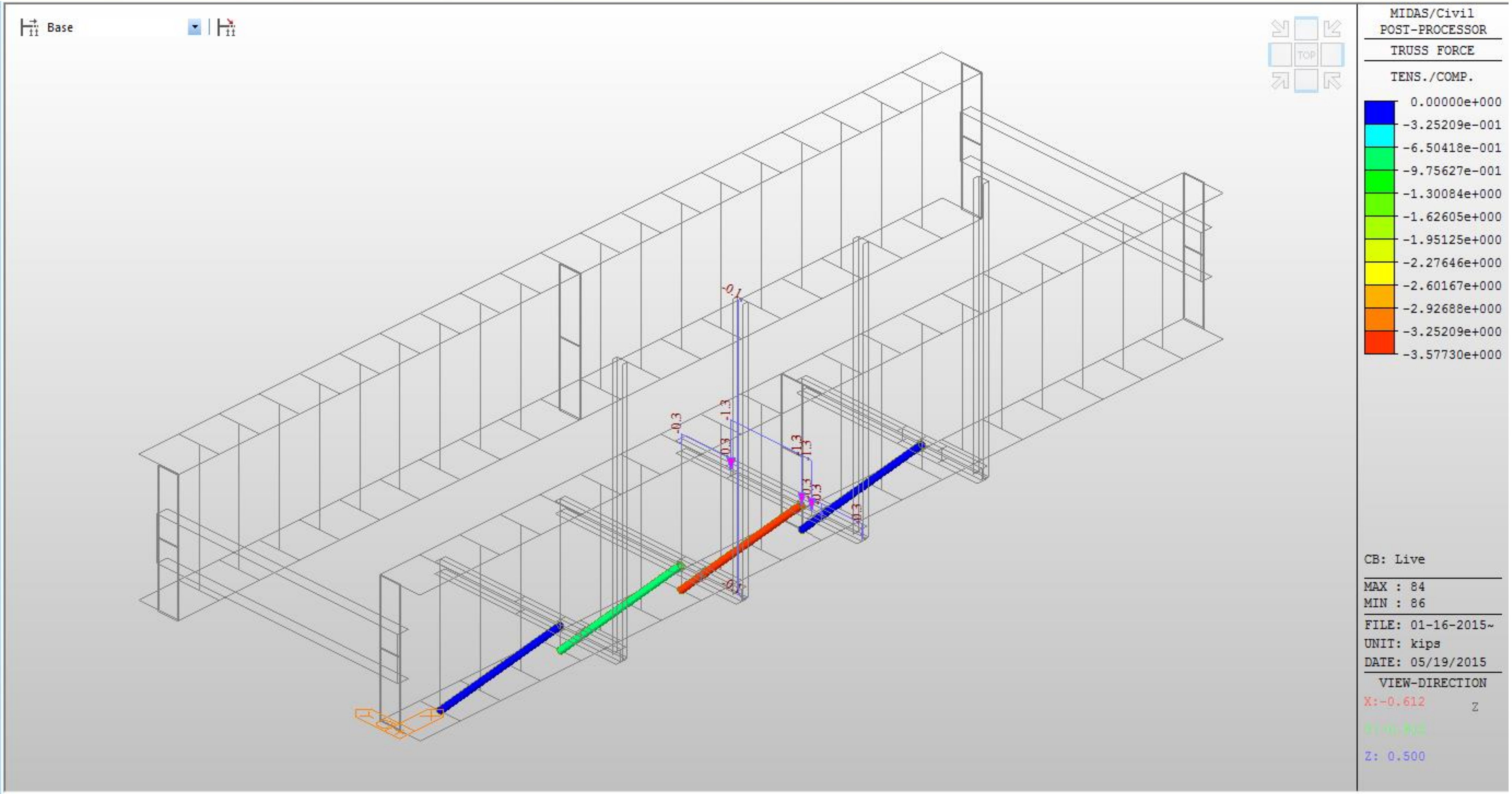
11th Avenue Bridge Deck Demolition



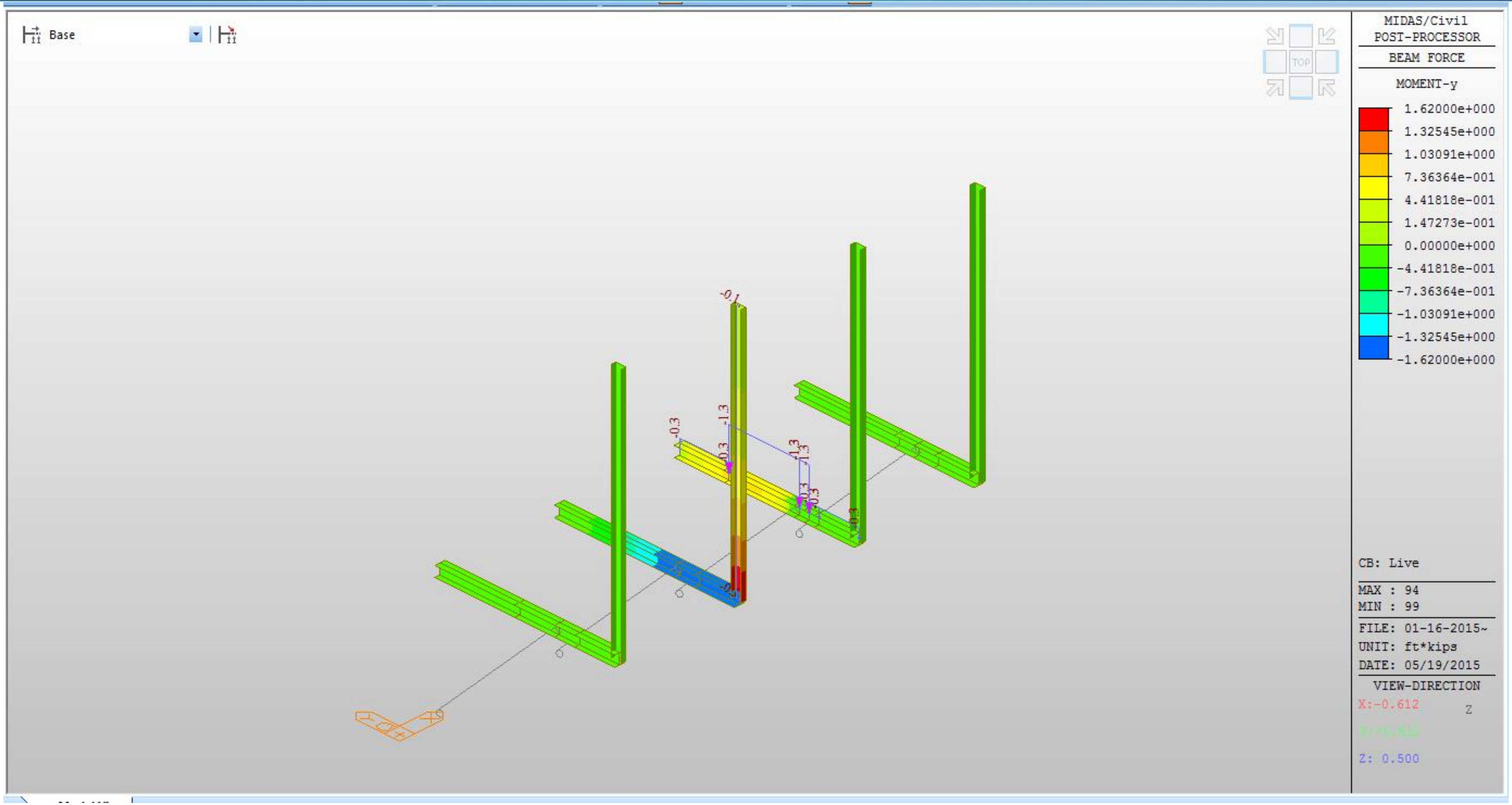
11th Avenue Bridge Deck Demolition



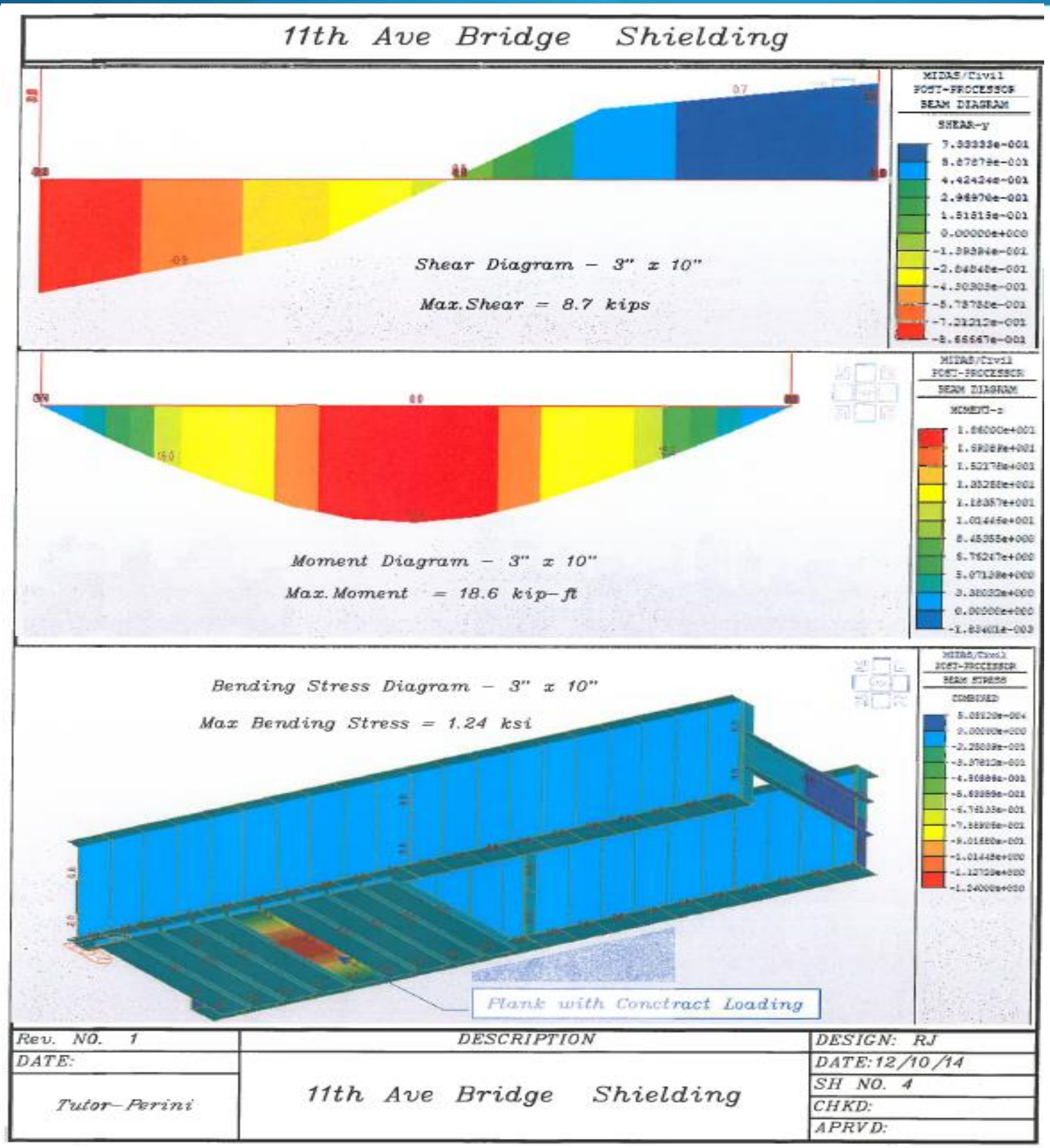
11^{th} Avenue Bridge Deck Demolition



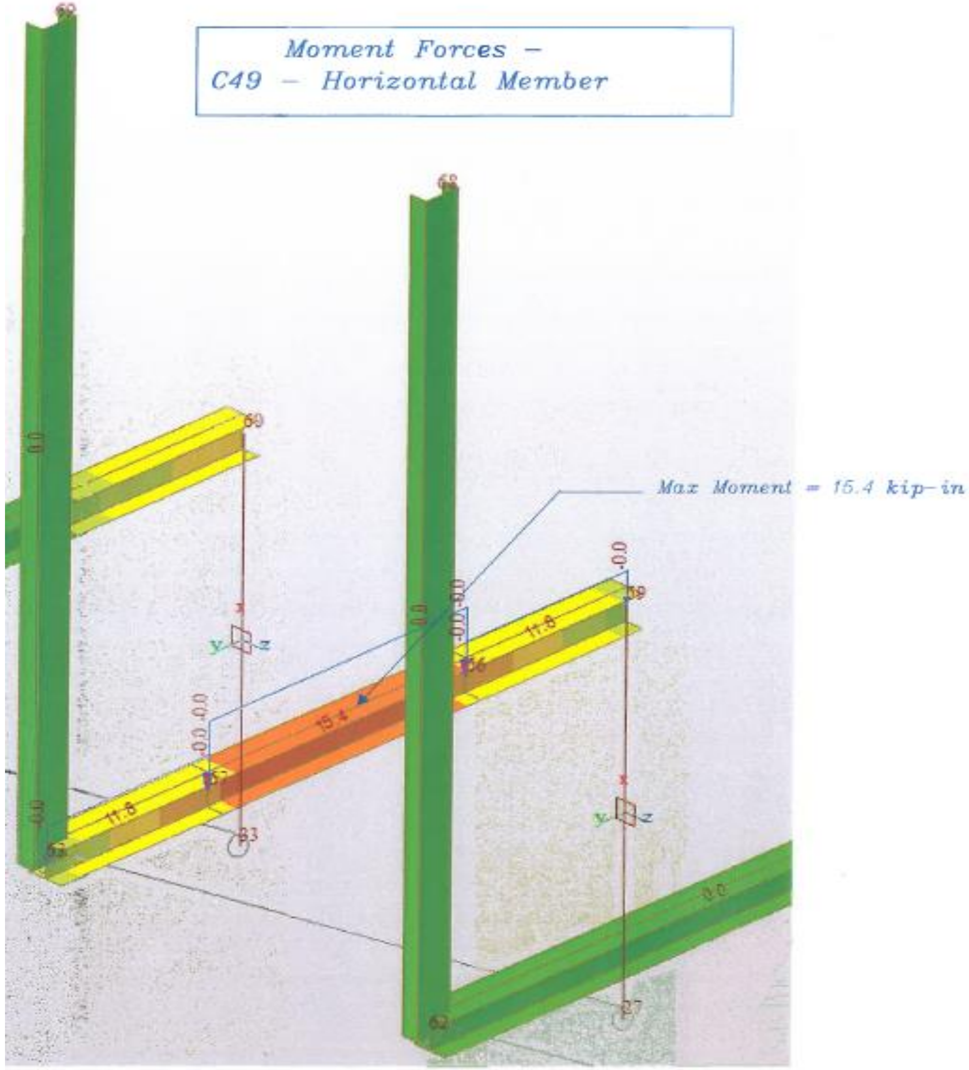
11th Avenue Bridge Deck Demolition



11th Avenue Bridge Deck Demolition



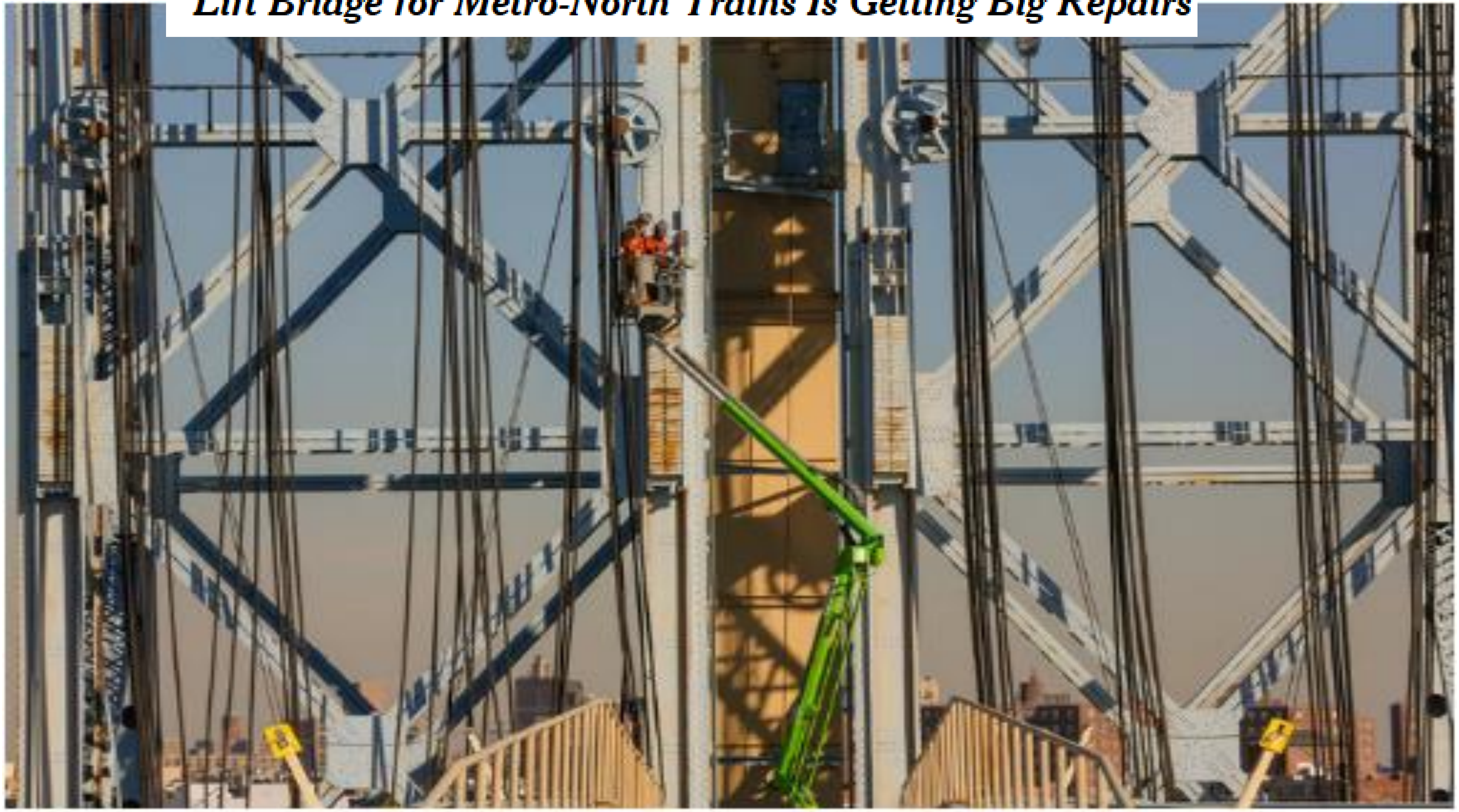
11th Avenue Bridge Deck Demolition



Harlem River Lift Bridge

Harlem River Lift Bridge

Lift Bridge for Metro-North Trains Is Getting Big Repairs



Repairs and improvements to the Harlem River Lift Bridge, at a cost of $47.2 million, are scheduled to be finished in mid-March. Ángel Franco/The New York Times

Project Introduction

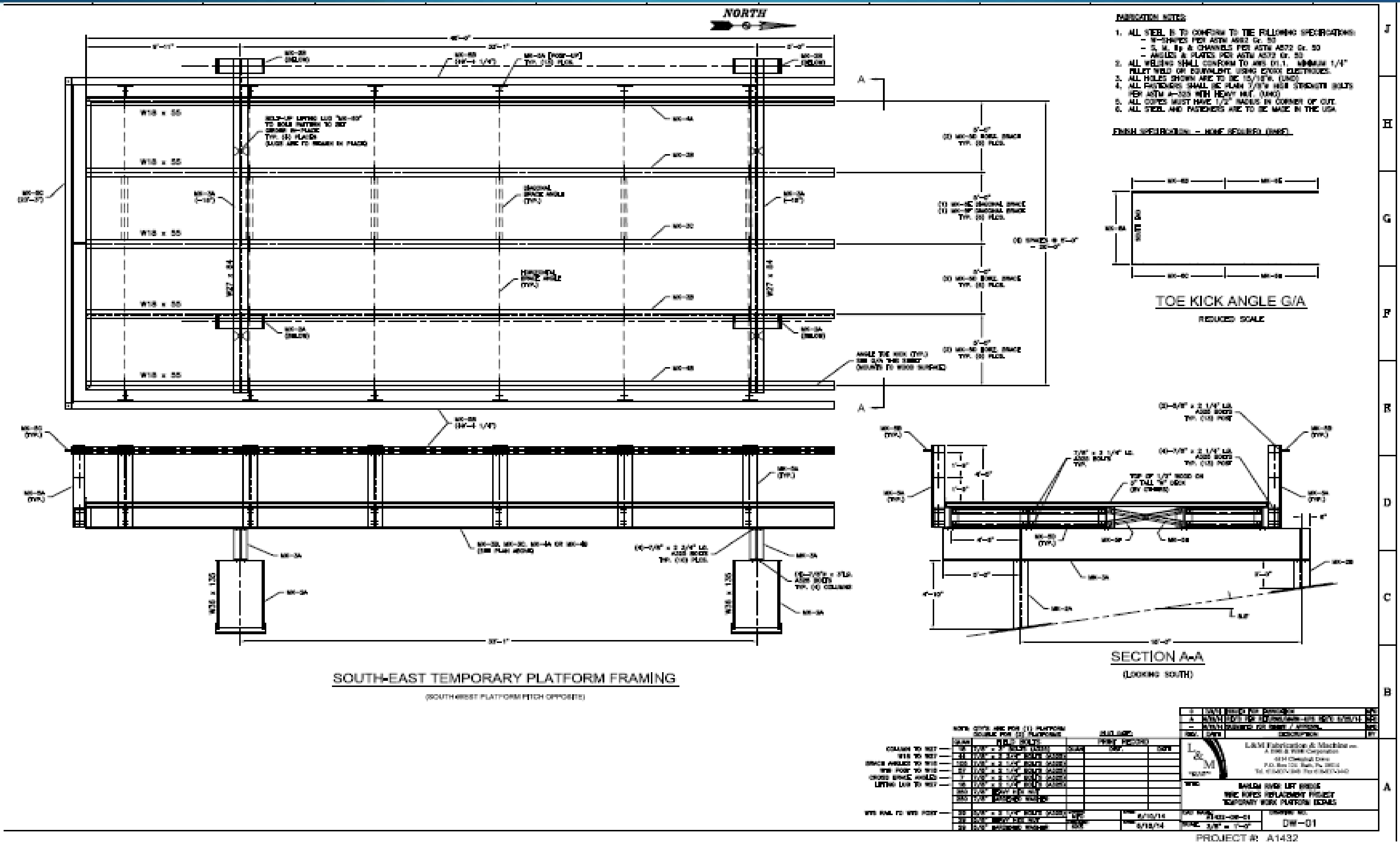
Electrical Upgrades

Remove and Replace Wire Ropes

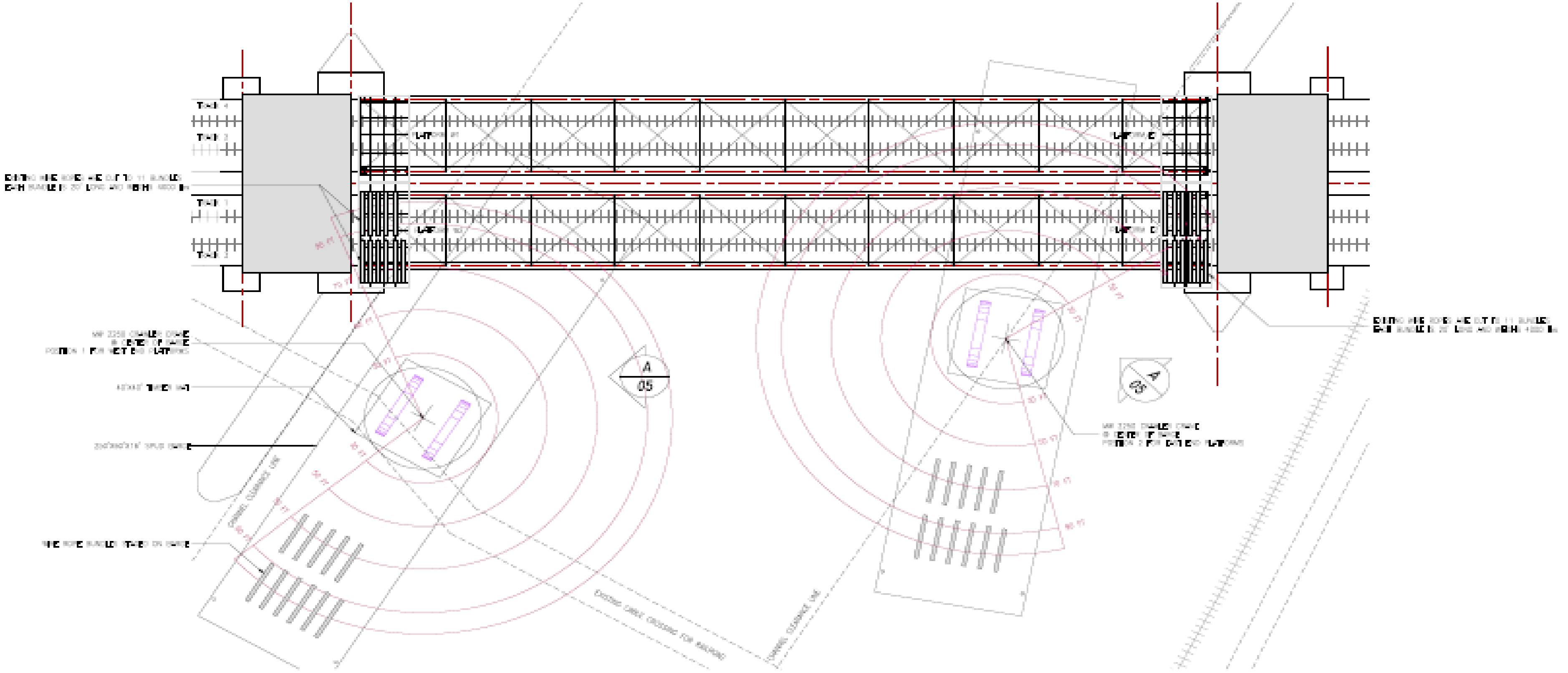
Design Work Platform

Harlem River Lift Bridge

Harlem River Lift Bridge



Harlem River Lift Bridge

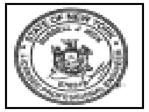


WIRE ROPE REMOVAL PLAN (OPTION I)

SCALE: 3/64" = 1'-0"

Existing wire rope removal

Lifting sequence	Load Length	Weight of Load (kips)	Weight of Block+rope (kips)	Total Pick Load (kips)	Max Crane Radius (ft)	Boom Length (ft)	2-degree Capacity of Crane (kips)	Capacity / load ratio
		(A)	(B)	(D)=(A)+(B)			(E)	(E) / (D)
Manitowoc 2250 Series 3, No. 44 Boom with heavy lift top, CWT 249.2 kips + 120 kips carbody CWT								
(3) 20'-4000 lbs bundles on platform W2		12.00	5.00	17.00	100	210	73.60	4.33
(3) 20'-4000 lbs bundles on platform W2		12.00	5.00	17.00	100	210	73.60	4.33



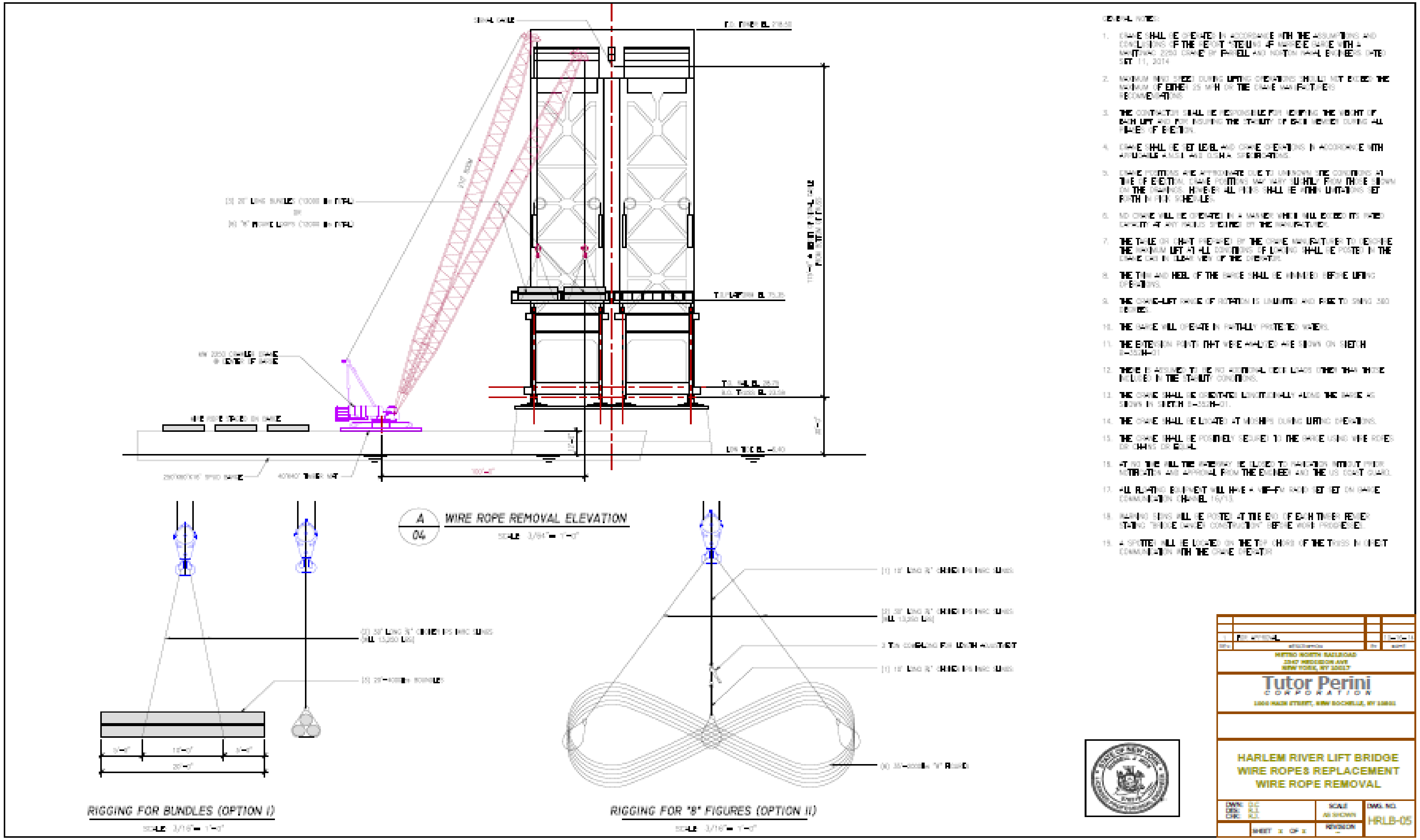
Tutor Perini
CORPORATION

HARLEM RIVER LIFT BRIDGE
WIRE ROPES REPLACEMENT
WIRE ROPE REMOVAL

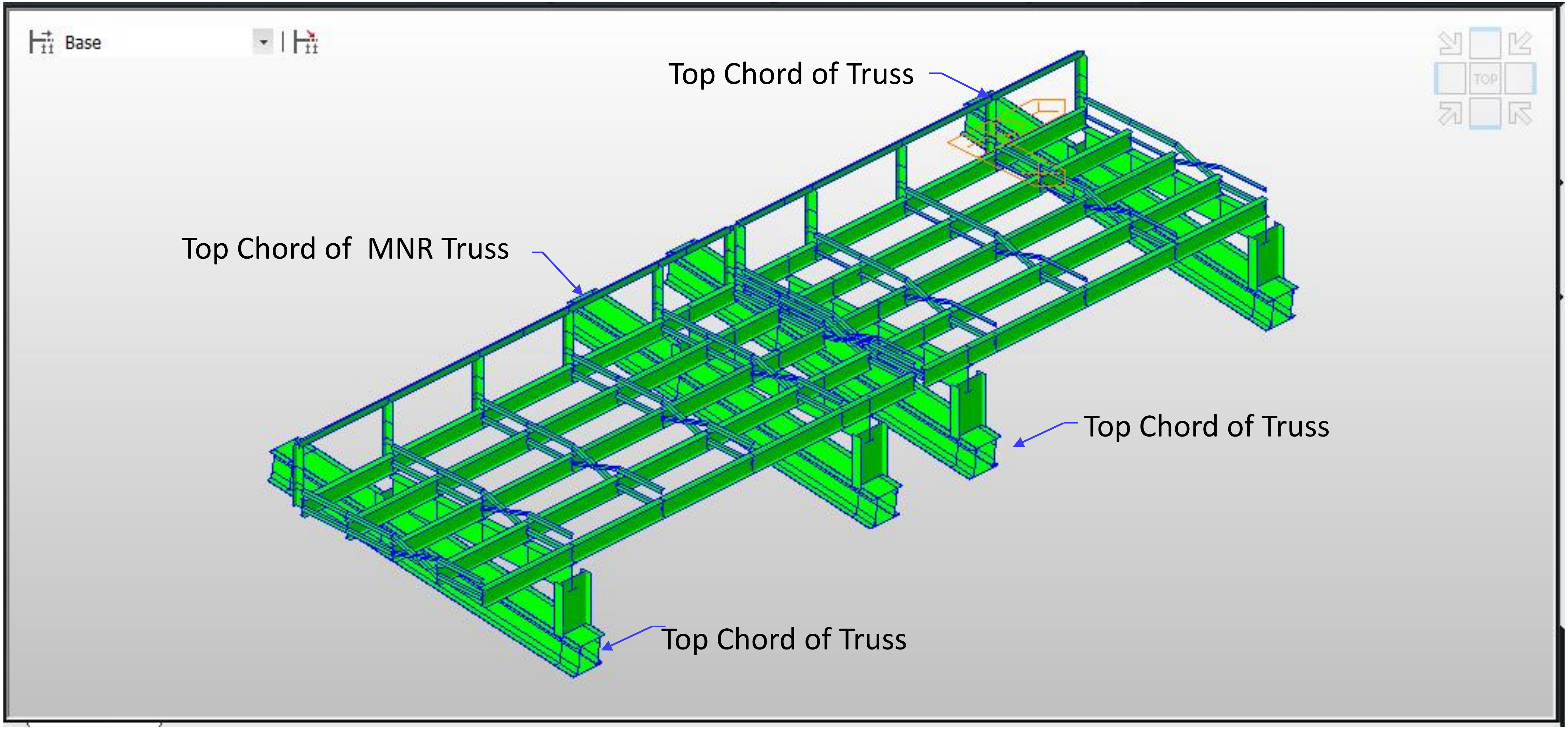
SCALE
AS SHOWN

DWG. NO.
HRLB-04

Harlem River Lift Bridge

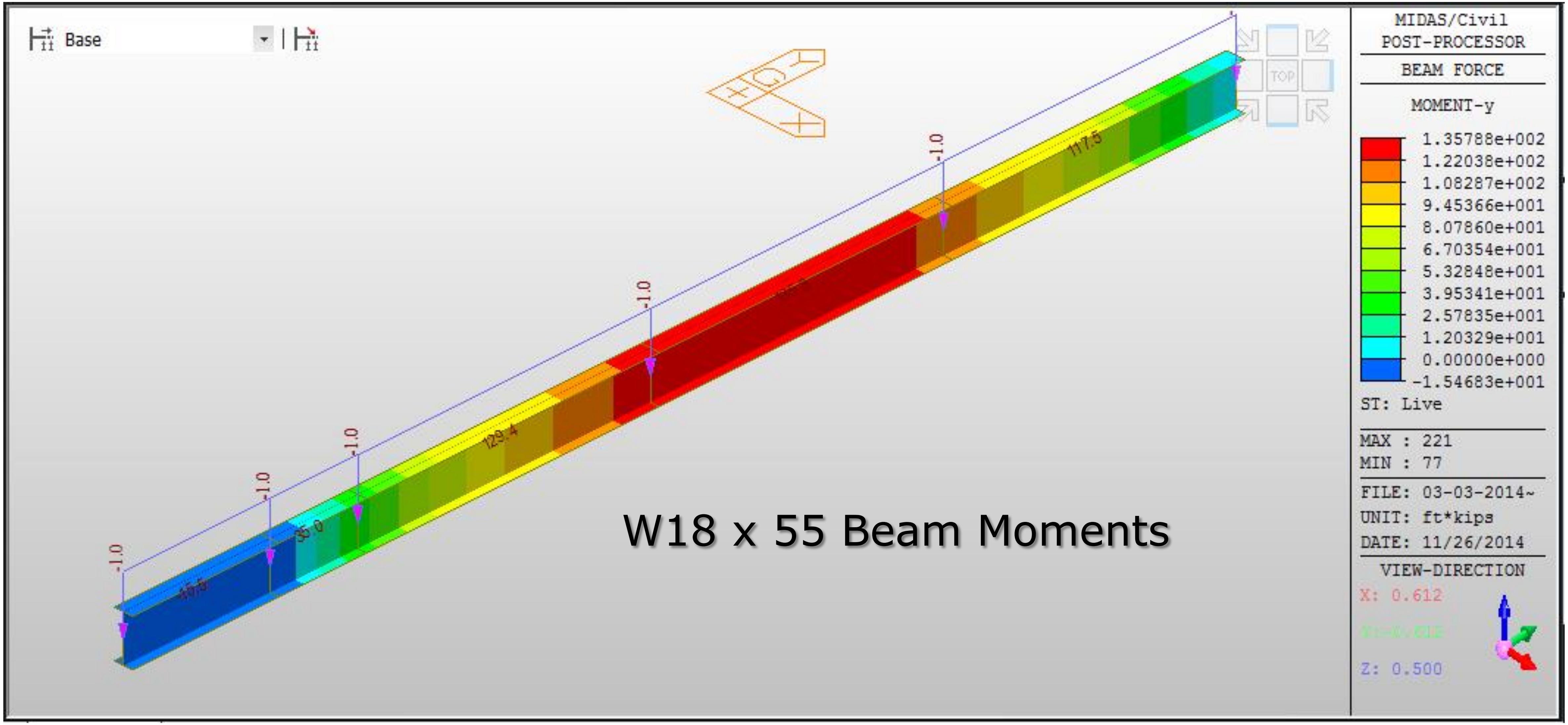


Harlem River Lift Bridge

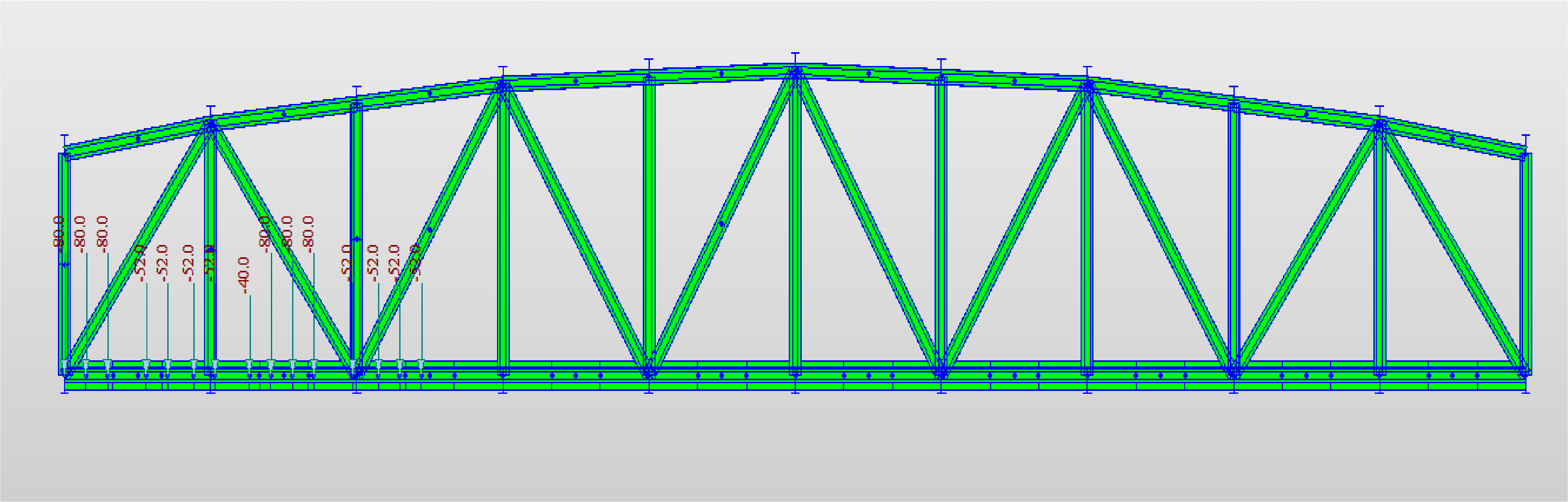


Work Platform for Wire Rope Removal

Harlem River Lift Bridge

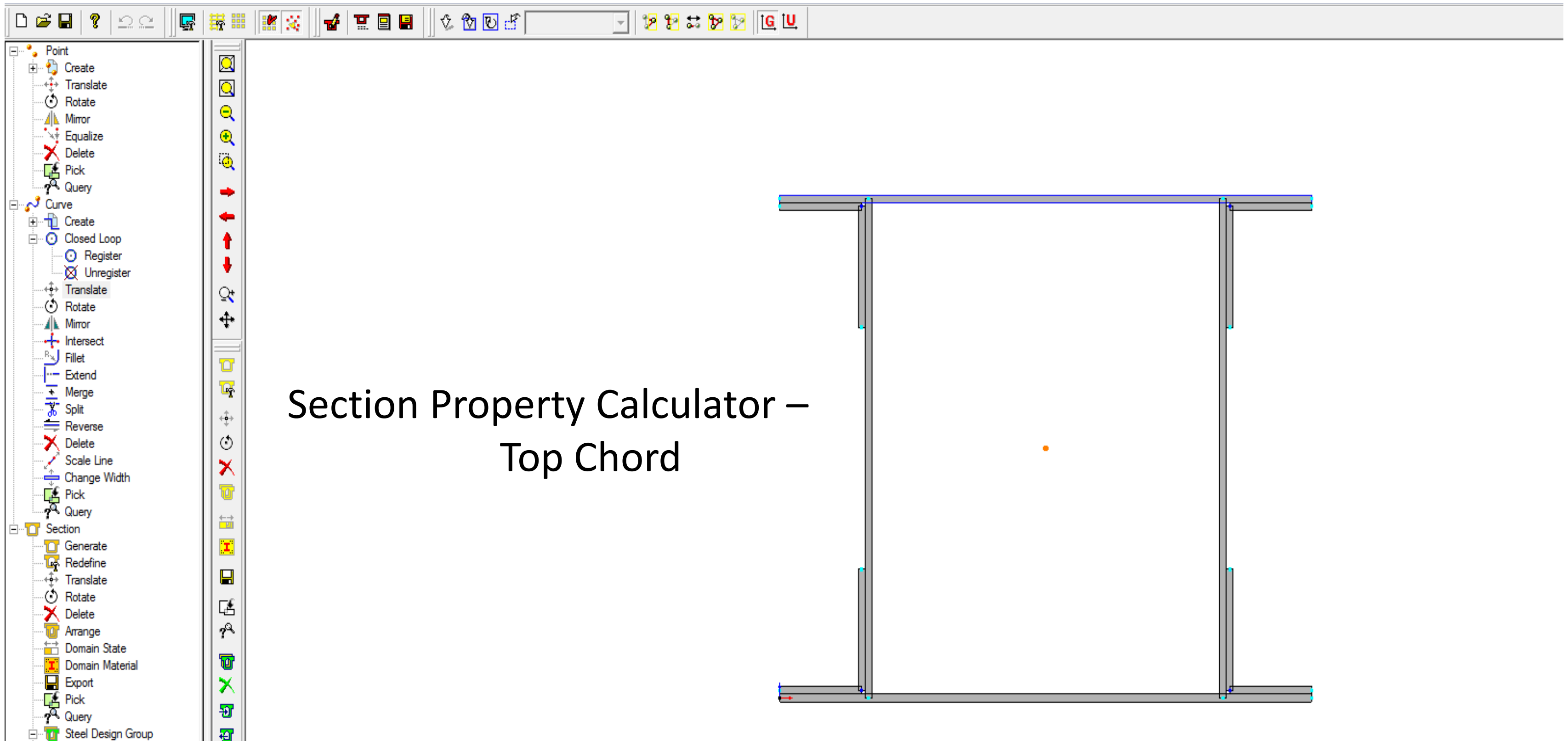


Harlem River Lift Bridge



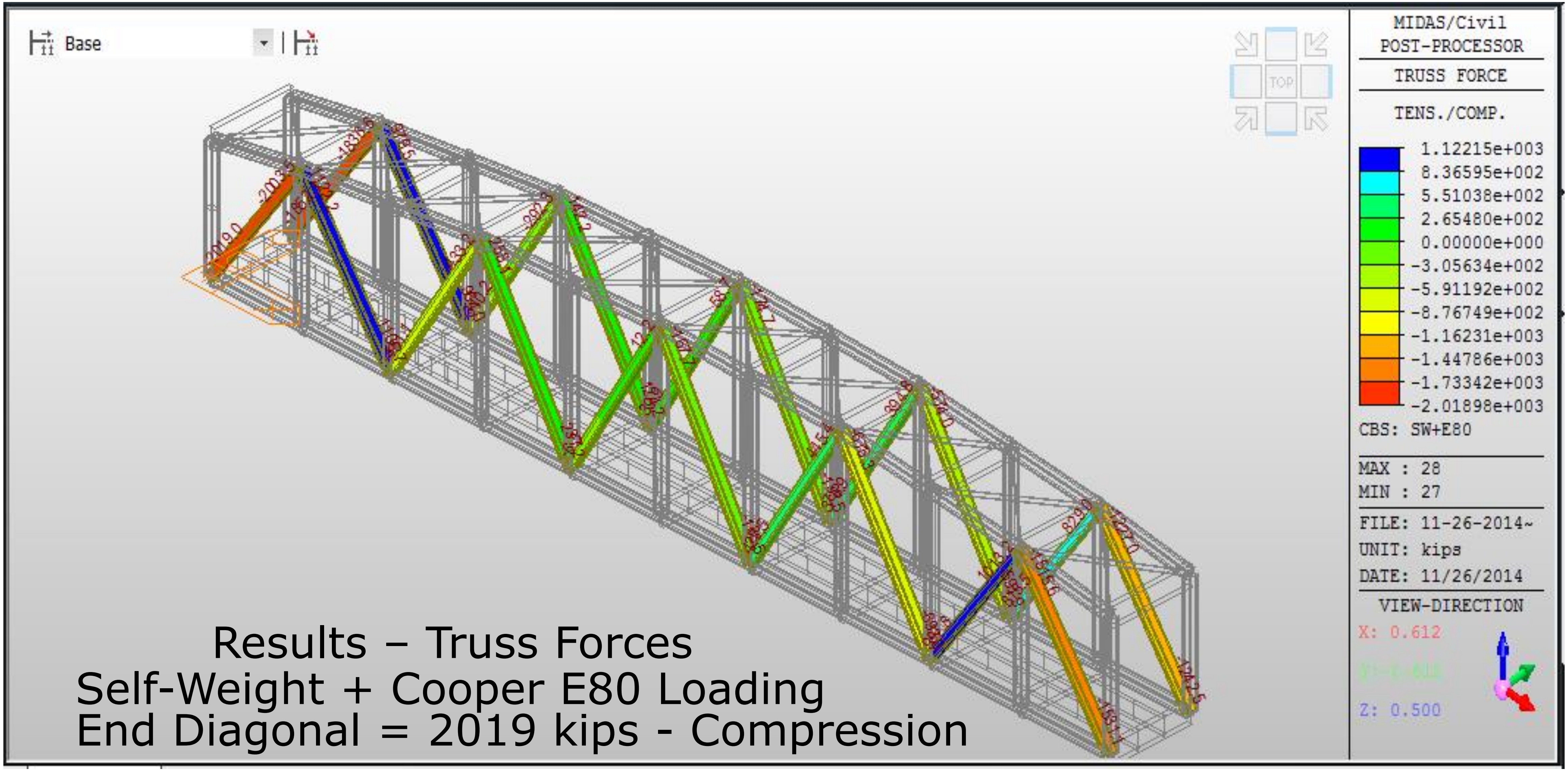
Cooper E80 Loading

Harlem River Lift Bridge

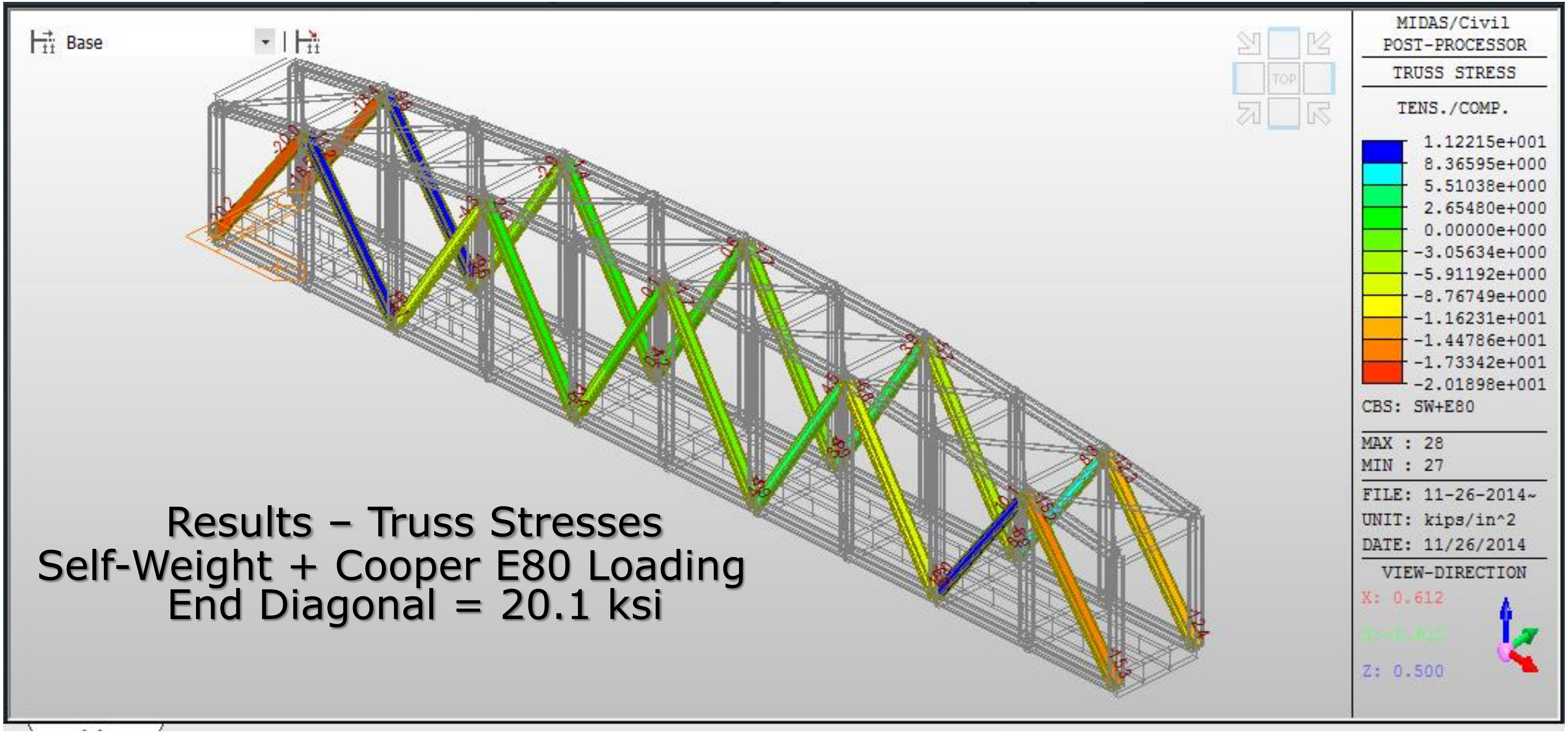


Section Property Calculator –
Top Chord

Harlem River Lift Bridge



Harlem River Lift Bridge



Harlem River Lift Bridge

Check Axial Capacity of End Diagonal:

K =	1.0	
L =	680.4	(in.)
r_x =	13.63	in.
r_y =	10.10	in.

$KL/r_x =$ 49.92 $\qquad KL/r_y =$ 67.36634

$0.629\sqrt{E/F_y} =$ 17.85 $\qquad 5.034\sqrt{E/F_y} =$ 142.88

Therefore:

$$F_{all} = 0.6F_y - \left(17500\frac{F_y}{E}\right)^{3/2}\left(\frac{KL}{r}\right) =$$

21548.44 (psi)

21.54844 (ksi) Controls

$$F_{cr} = F_y\left[1 - \frac{F_y}{4\pi^2 E}\left(\frac{KL}{r}\right)^2\right] =$$

30.9 (ksi)

Therefore the maximum compressive force allowed::

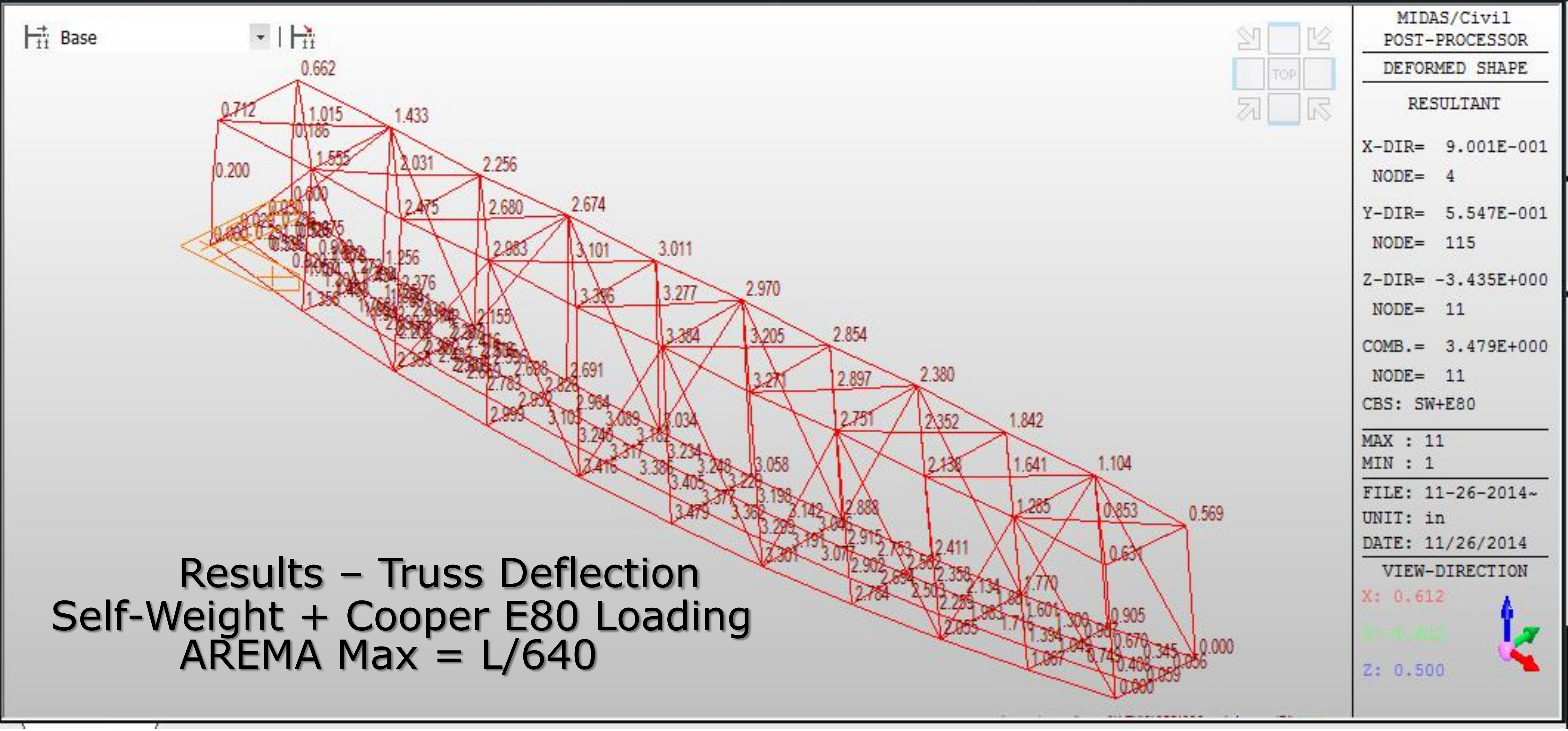
A =	121.2	(in^2)
C_{all} =	2612.3	(kips)

Max. Axial Load = 2019 (kips)

Percent capacity in Compression = 77.29%

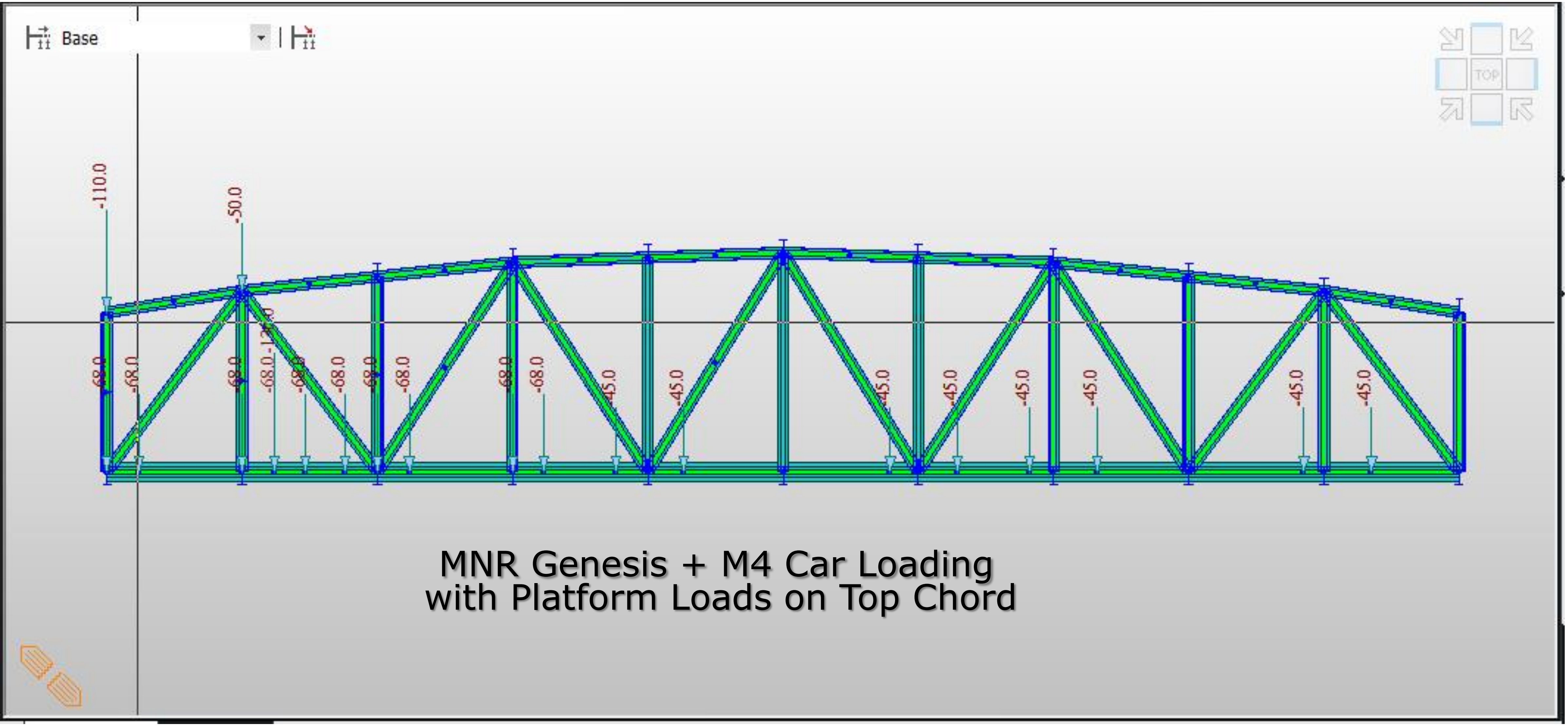
Interaction for bending and compression: 77.29%

Harlem River Lift Bridge

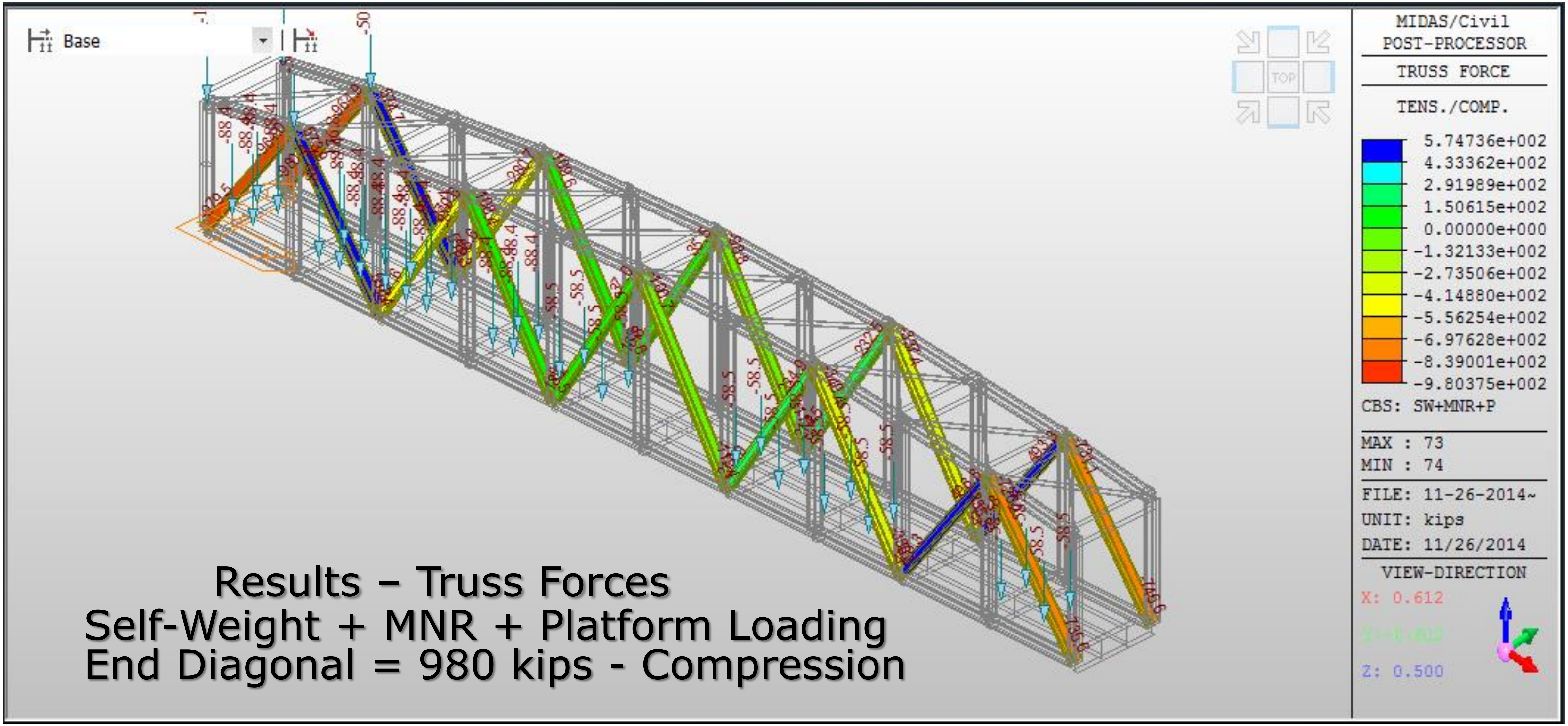


Results – Truss Deflection
Self-Weight + Cooper E80 Loading
AREMA Max = L/640

Harlem River Lift Bridge



Harlem River Lift Bridge



Harlem River Lift Bridge

Check Axial Capacity of End Diagonal:

K =	1.0		
L =	680.4	(in.)	
r_x =	13.63	in.	
r_y =	10.10	in.	

$KL/r_x =$	49.92	$KL/r_y =$	67.36634
$0.629\sqrt{E/F_y} =$	17.85	$5.034\sqrt{E/F_y} =$	142.88

Therefore:

$$F_{all} = 0.6F_y - \left(17500\frac{F_y}{E}\right)^{3/2}\left(\frac{KL}{r}\right) =$$ 21548.44 (psi)

21.54844 (ksi) Controls

$$F_{cr} = F_y\left[1 - \frac{F_y}{4\pi^2 E}\left(\frac{KL}{r}\right)^2\right] =$$ 30.9 (ksi)

Therefore the maximum compressive force allowed::

A =	121.2	(in^2)
C_{all} =	2612.3	(kips)

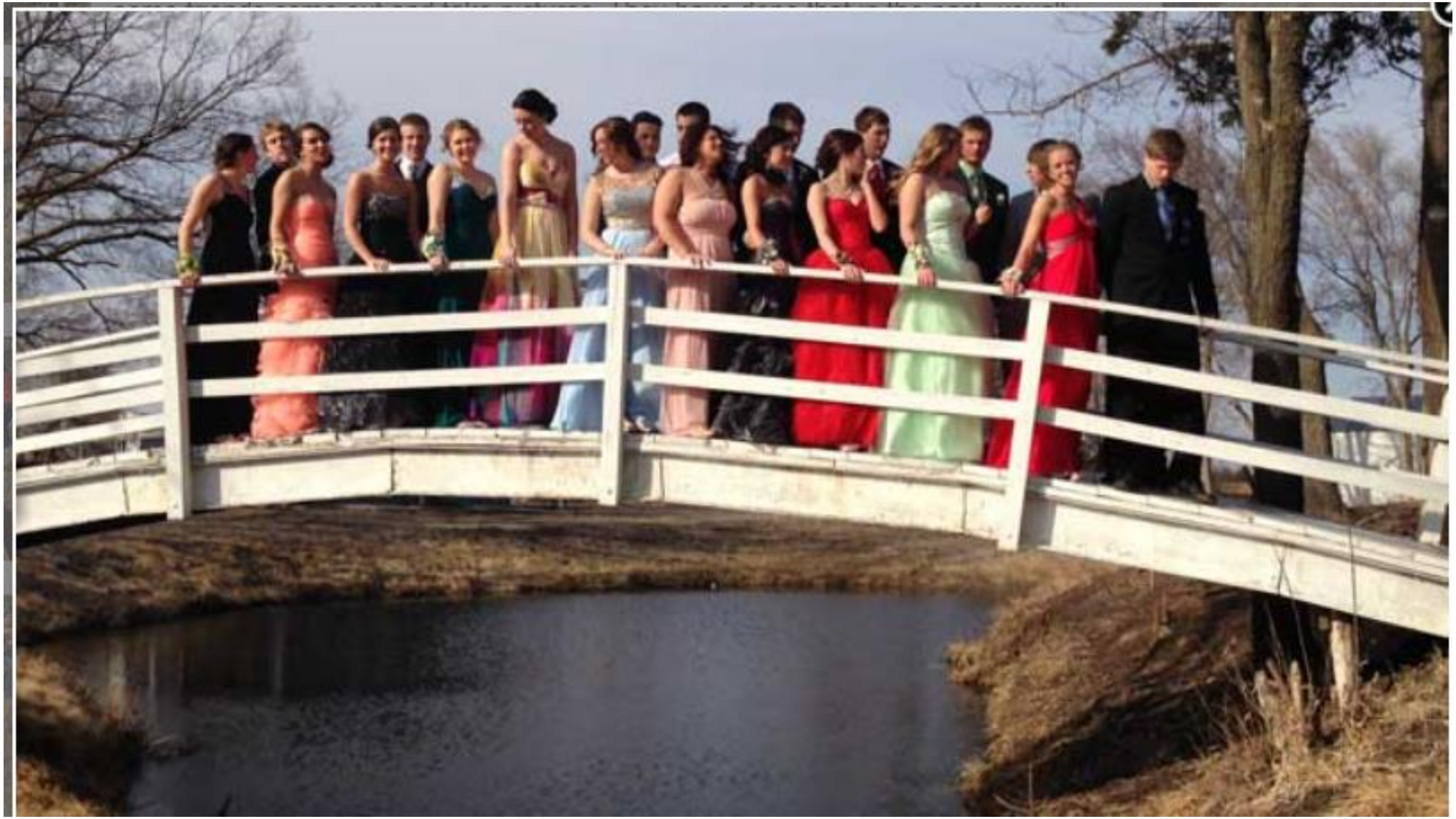
Max. Axial Load = 980 (kips)

Percent capacity in Compression = 37.51%

Interaction for bending and compression: 37.51%

HRLB Successful Completion

Why MIDAS for TPC?



Why MIDAS for TPC?

Why MIDAS for TPC?

60 Bridges – I95-I91 New Haven Ct

Curved Girders

Submittals to Designer And CDOT

Modeling Issues

Deflection Issues During Steel Erection

Cranes on New Bridge Decks

Project Challenges

Traffic Volume – Outage Limitations

Access Limitations

Temporary Diaphragm Spacing

Bolt Alignment

Shoring Towers - Jacking

Overhang brackets

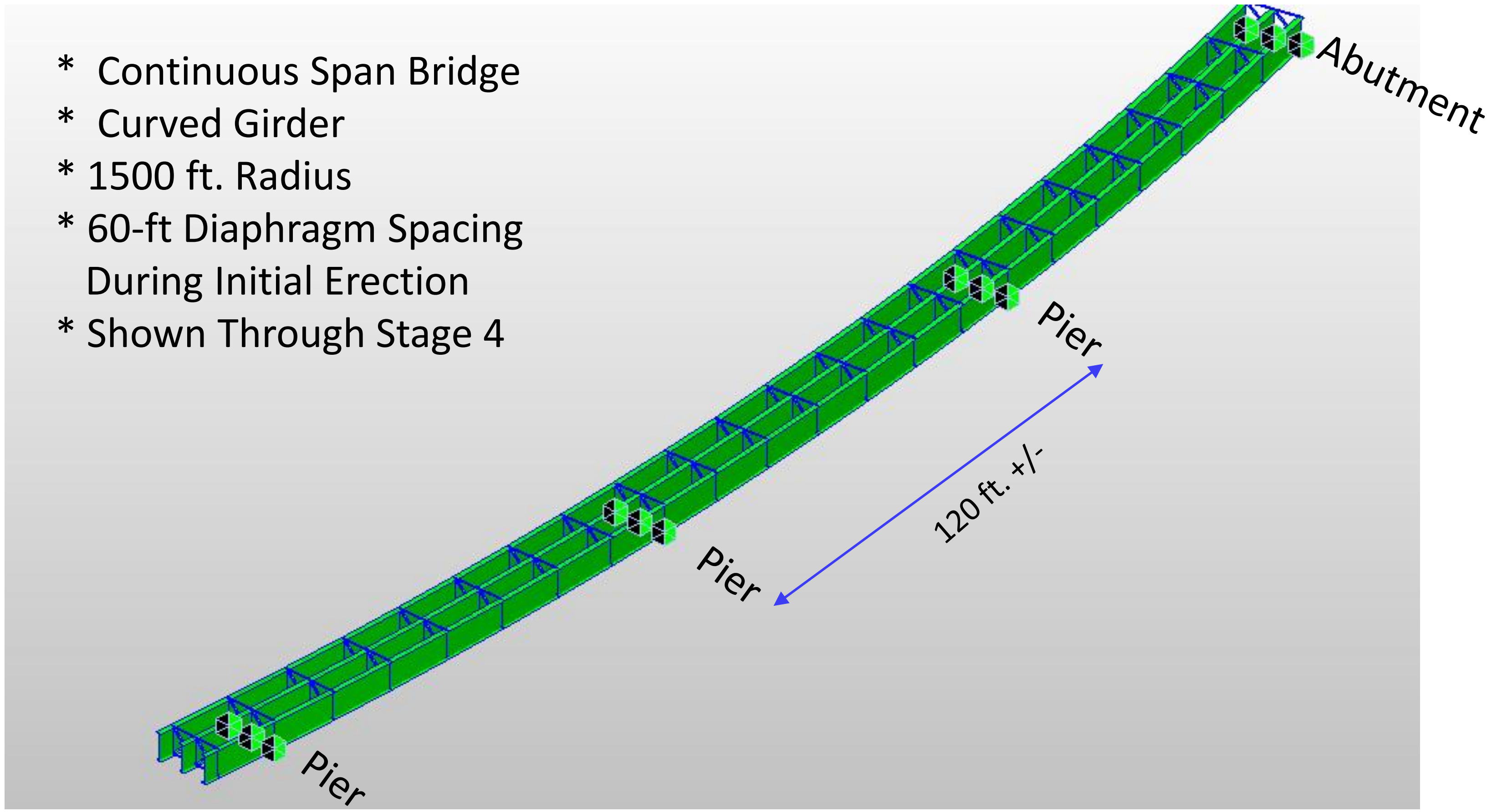
Cranes on New bridge deck

Lateral Loads on Girders

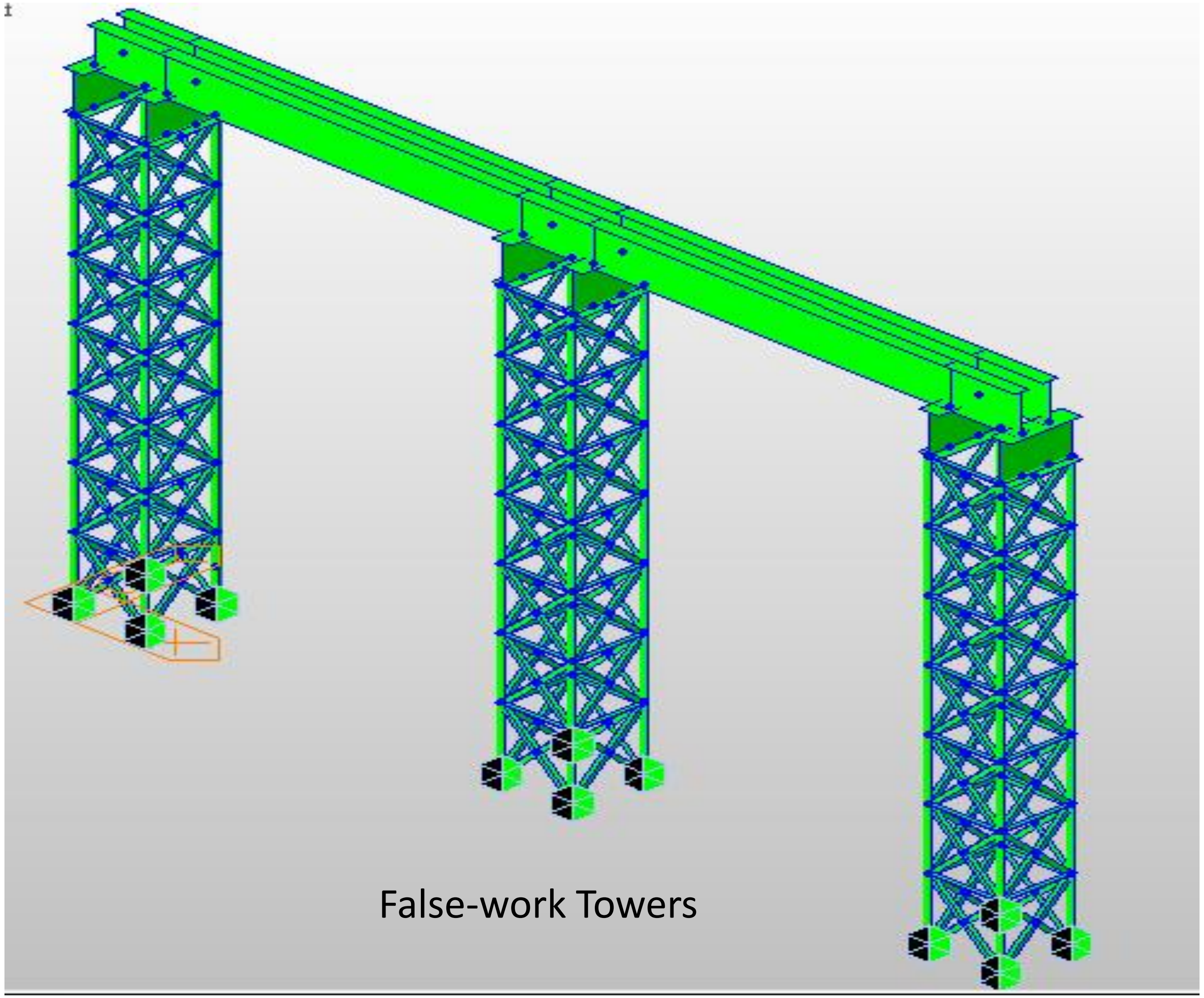
CDOT – I95-I91 Replacement - New Haven Ct. Bridge

CDOT – I95-I91 Replacement - New Haven Ct. Bridge

* Continuous Span Bridge
* Curved Girder
* 1500 ft. Radius
* 60-ft Diaphragm Spacing
  During Initial Erection
* Shown Through Stage 4



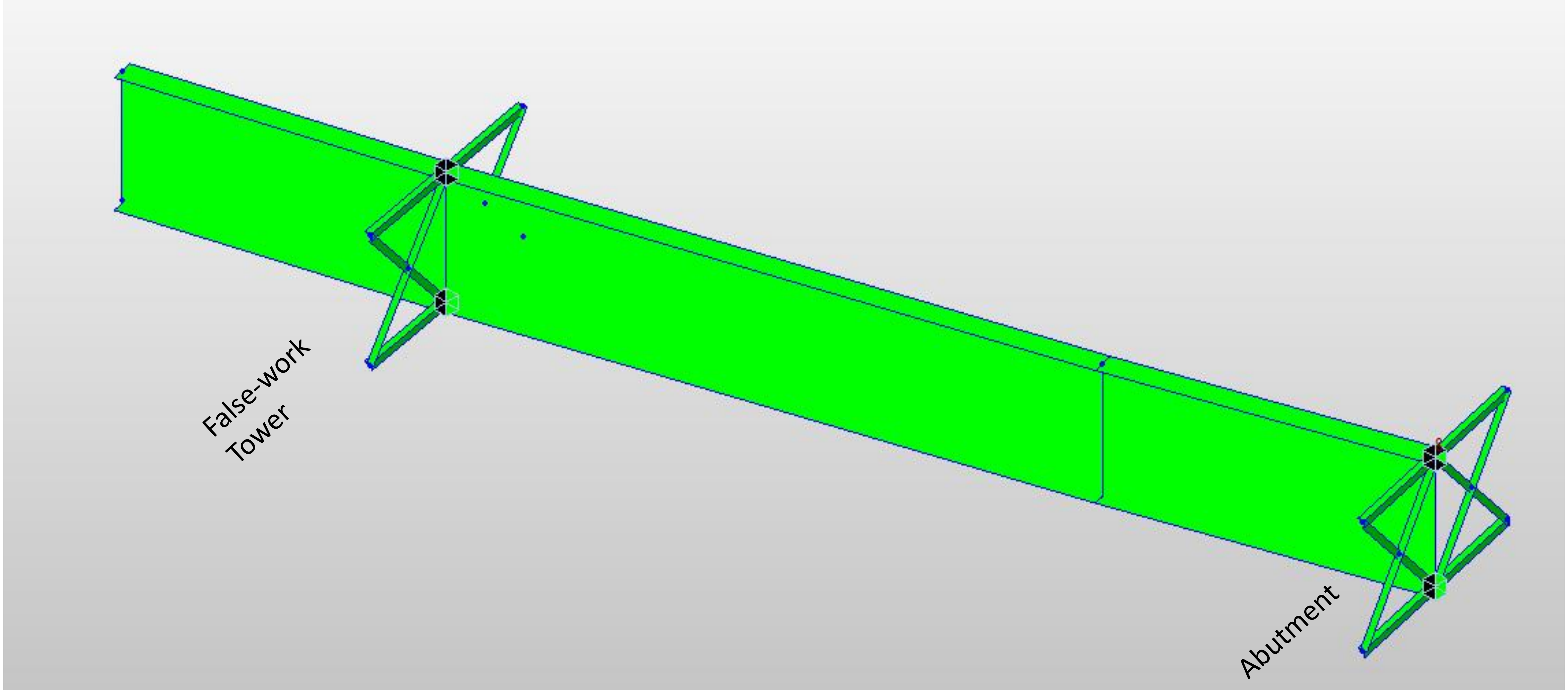
CDOT – I95-I91 Replacement - New Haven Ct. Bridge



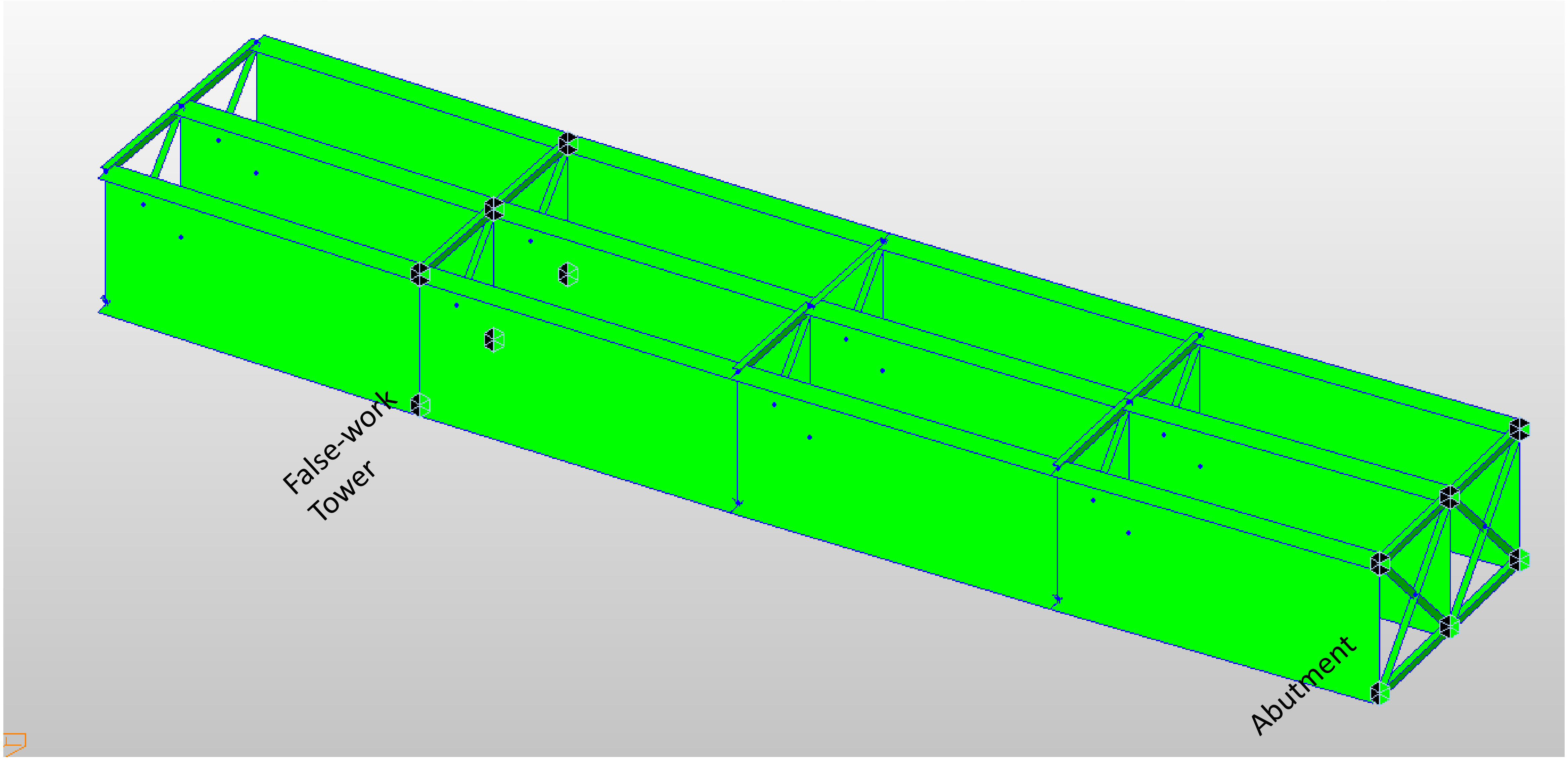
False-work Towers

CDOT – I95-I91 Replacement - New Haven Ct.

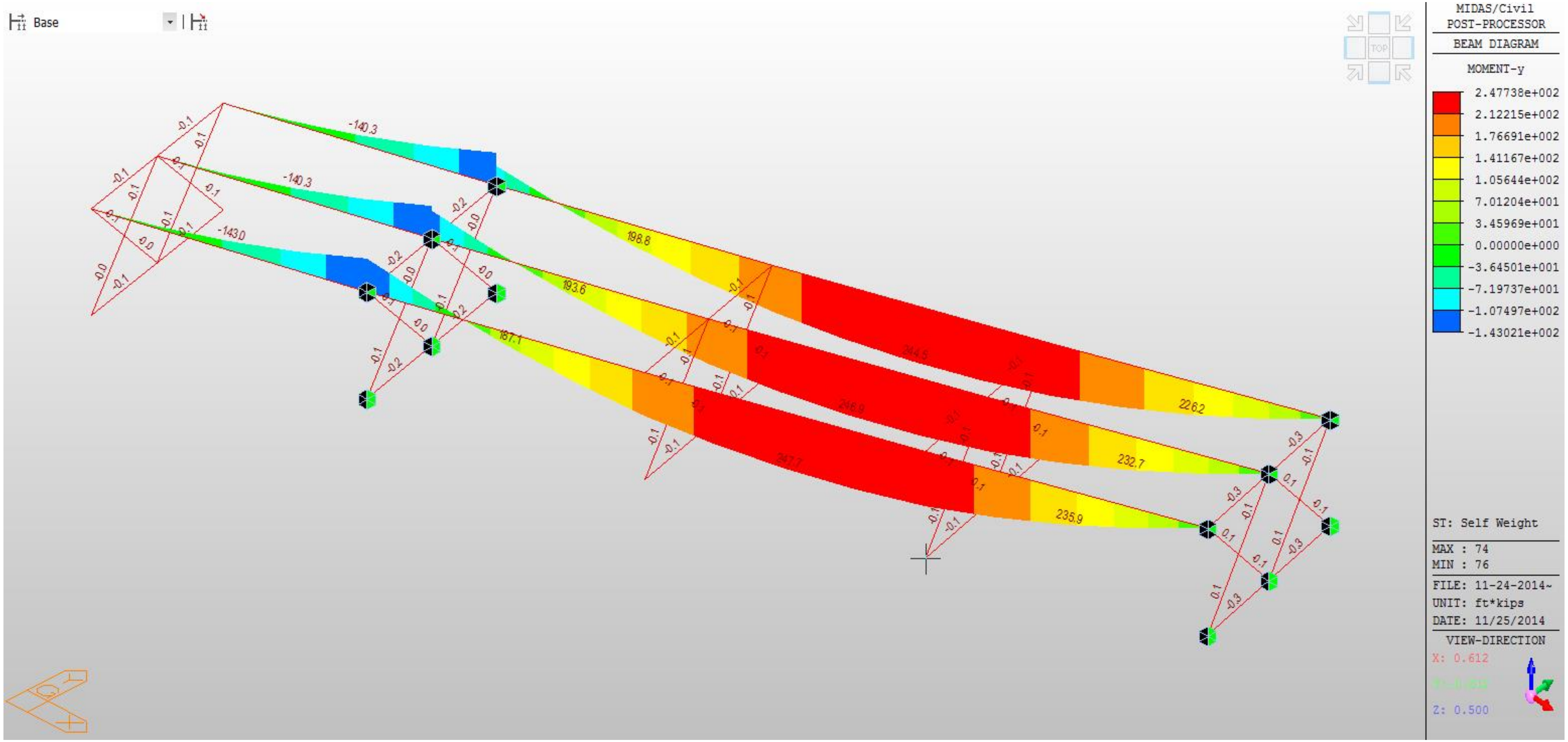
CDOT – I95-I91 Replacement - New Haven Ct.



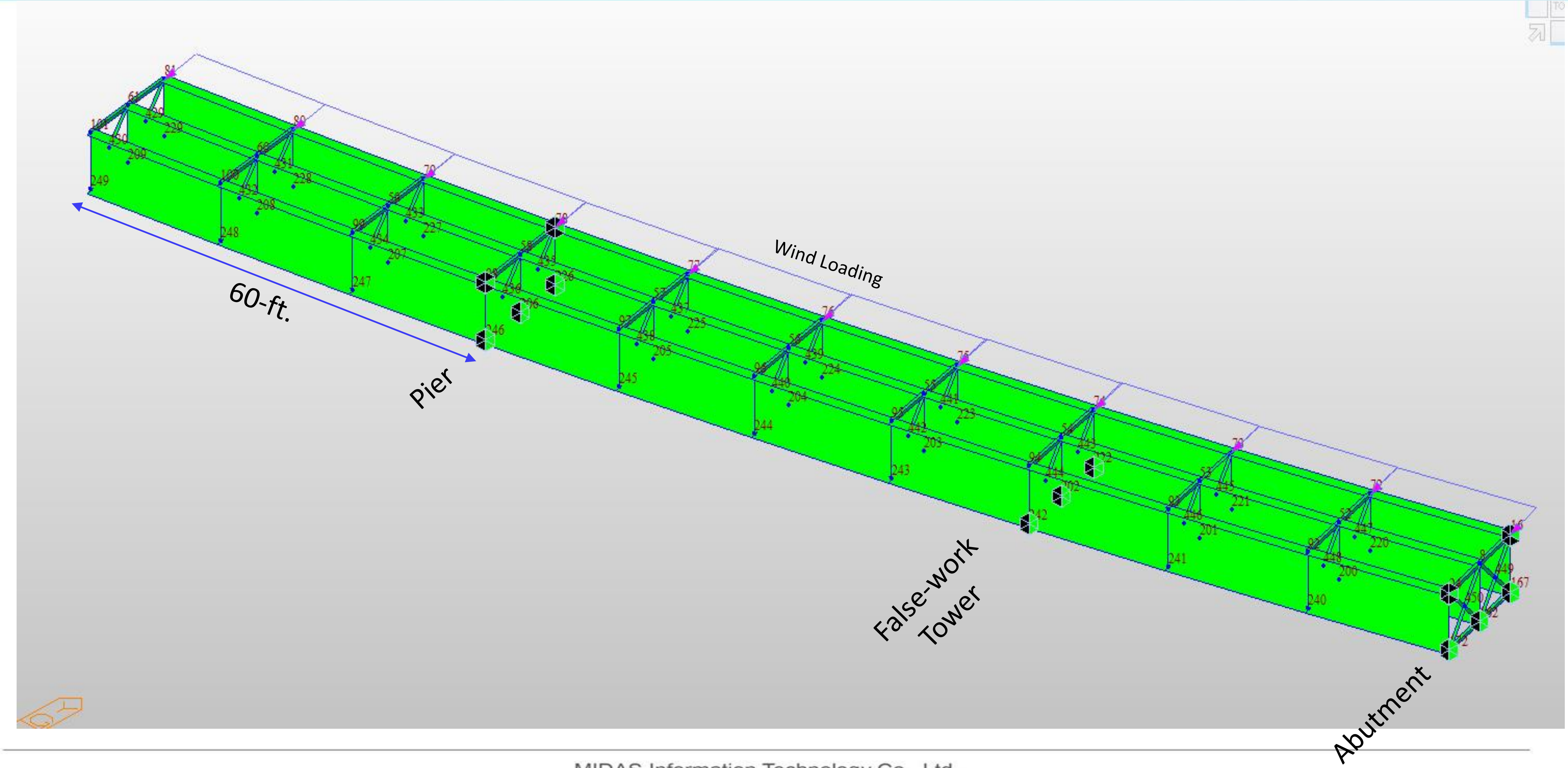
CDOT – I95-I91 Replacement - New Haven Ct.



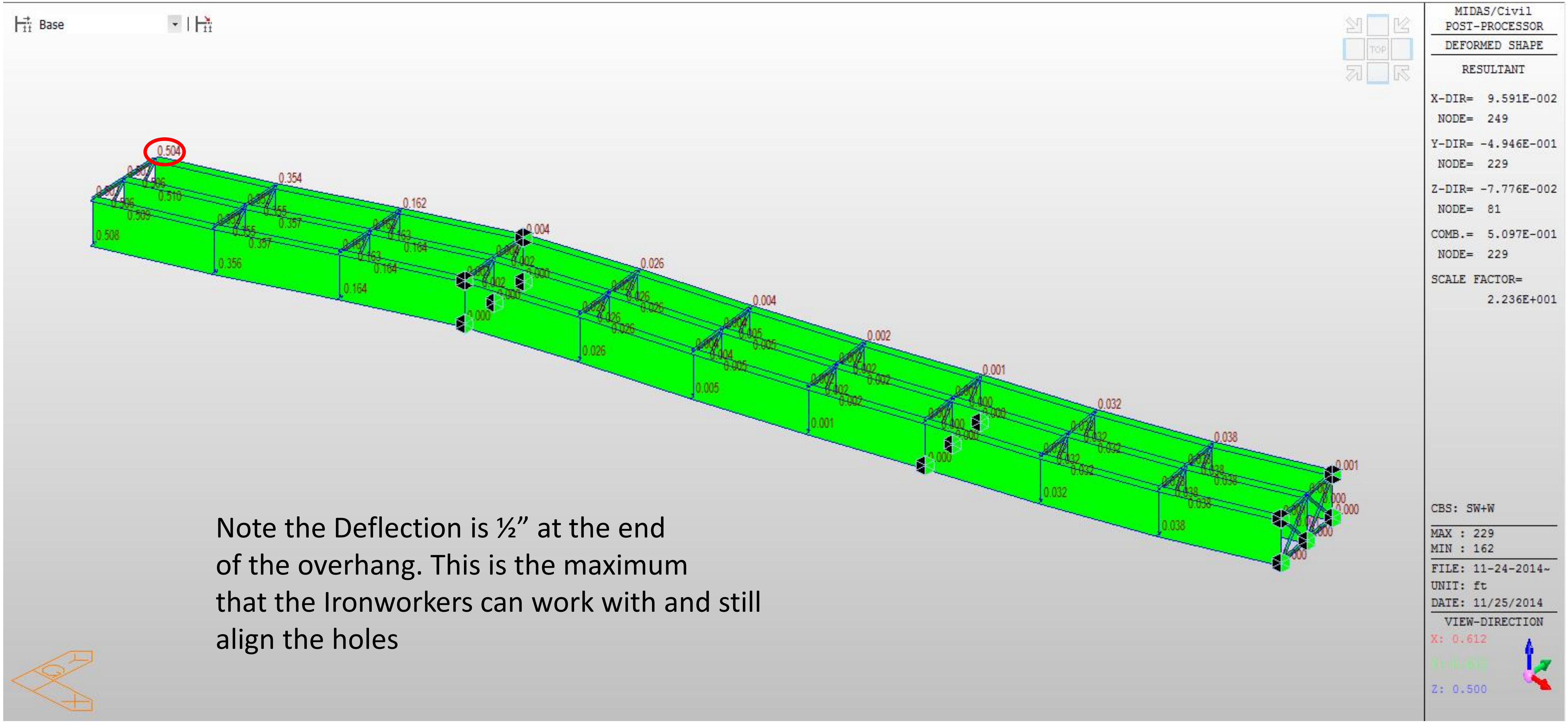
CDOT – I95-I91 Replacement - New Haven Ct.



CDOT – I95-I91 Replacement - New Haven Ct.

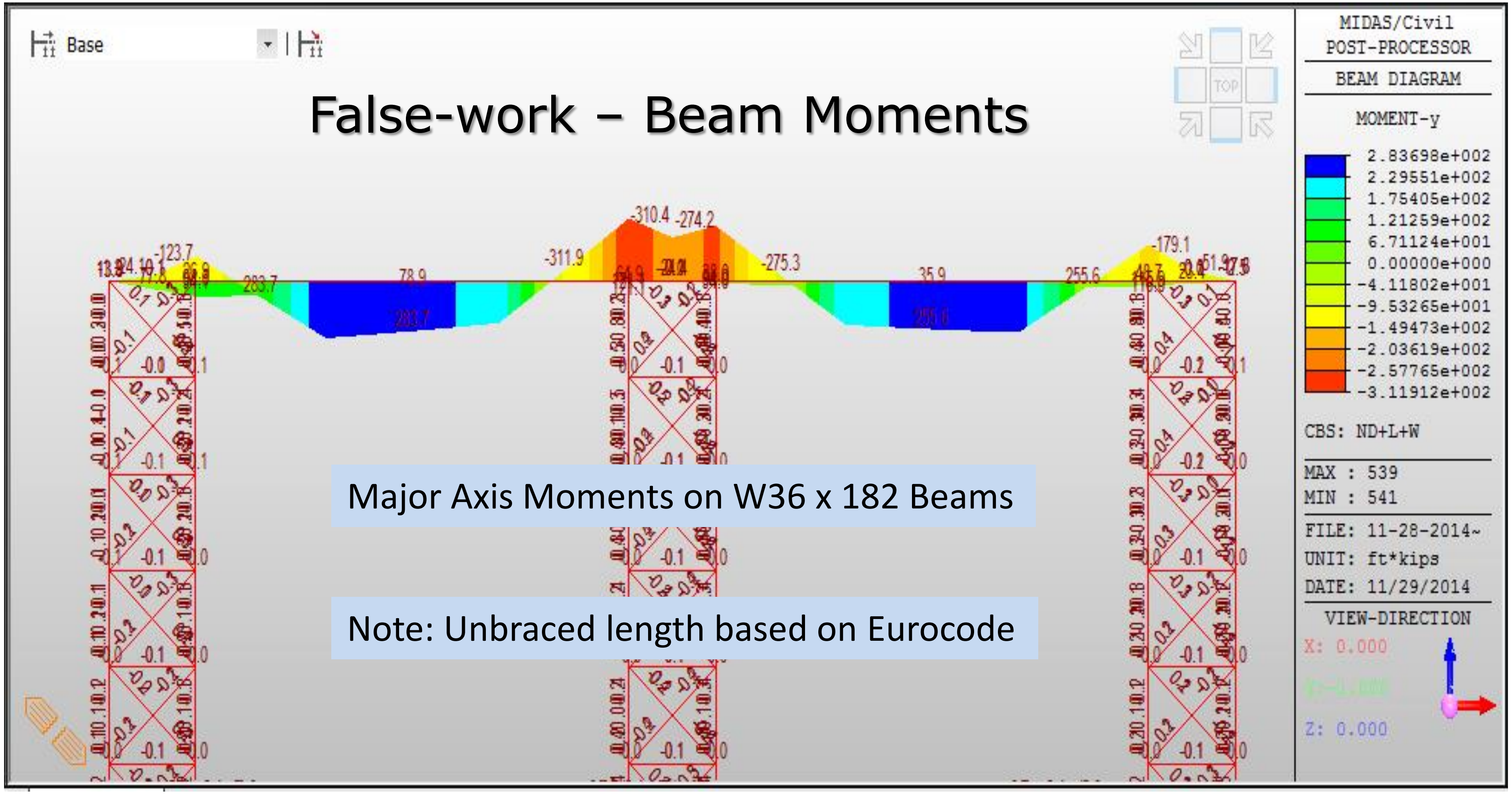


CDOT – I95-I91 Replacement - New Haven Ct.



Note the Deflection is ½" at the end of the overhang. This is the maximum that the Ironworkers can work with and still align the holes

CDOT – I95-I91 Replacement - New Haven Ct.



Major Axis Moments on W36 x 182 Beams

Note: Unbraced length based on Eurocode

False-work – Code Check on Beams

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 MIDAS/Civil - Steel Code Checking [ AASHTO-LRFD12 ]                          Version 8.3.5
============================================================================================

      ( ). Compute Lateral Torsional Buckling Resistance of Compression Flange (Mnc_LTB)
           [ AASHTO-LRFD12 Specification A6.3.3 ]
           -. Y1   =  Cb*pi^2*Es/(Lb/rt)^2  = 2472.95
           -. Y2   =  1+0.0079*J/(Sxc*h)*(Lb/rt)^2   =    2.23
           -. Fcr   =  Y1 *SQRT[Y2] = 3690.12 ksf.
           -. Mnc_lim  = Rpc*Myc  = 2374.30 ft-kips.
           -. Mnc_cal  = Fcr*Sxc  = 1329.53 ft-kips.
           -. Mnc_LTB  = min[Mnc_calc, Mnc_lim]    = 1329.53 ft-kips.

      ( ). Compute nominal flexural strength of Compression Flange (Mnc)
           -. Mnc   =  min[Mnc_FLB, Mnc_LTB] = 1329.53 ft-kips.

      ( ). Compute nominal flexural strength of Tension Flange (Mnt).
           [ AASHTO-LRFD12 Specification A6.4]
           -. Rpt   =    1.14
           -. Myt   =       2075.30 ft-kips.
           -. Mnt   =  Rpt*Myt  =       2374.30 ft-kips.

           -. Mn  =  min(Mnc, Mnt)  =       1329.53 ft-kips.

      ( ). Compute flexural strength about major axis (phiMny).
           -. Resistance factor for flexure  :  phi = 1.00
           -. phiMny  =  phi*Mny  =       1329.53 ft-kips.

      ( ). Check ratio of flexural strength (Muy/phiMny).
                Muy                339.02
           -. --------  =  ---------------  =  0.255  <  1.000  ---> O.K.
               phiMny             1329.53
```

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East End Access – ML4 - SOE

East End Access – ML4 - SOE

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East End Access – ML4 - SOE

East End Access – ML4 - SOE

East End Access – ML4 - SOE

East End Access – ML4 - SOE

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East End Access – ML4 - SOE

East End Access – ML4 - SOE

East End Access – ML4 - SOE

East End Access – ML4 - SOE

East End Access – ML4 - SOE

CQ32 East End Access

CQ32 East End Access

CQ32 East End Access

CQ32 East End Access

CQ32 East End Access

CQ32 East End Access

CQ32 East End Access

Special Thanks

- Angela Kim, Jin Ko, and Grace An – MIDAS Civil
- Ali Catik – President Tutor Perini Corp.
- Henry Cheung Vice President Tutor Perini Corp
- Bob Cooper – General Sup't Tutor- Perini Corp.
- Dong Chang Phd. – Asst. Chief Engineer Tutor Perini Corp.
- Special Thanks – Terry Flynn – Vice President / Chief Engineer Tutor Perini Corporation

Questions?

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