# Replacement of Historic Umauma Stream Bridge

**Presenter:**
Stephen
Peters
KSF Inc.

# Key Points

- Multiple MIDAS Civil models were created to capture/compare results for differing load conditions
  - AASHTO LRFD Strength 1
    - Static Load (DC, DW, etc.)
    - Moving Load Analysis (LL)
  - AASHTO LRFD Extreme 1
    - Response Spectrum Analysis

# Umauma Stream Bridge

- **Owner**
  - Hawaii Department of Transportation (HDOT)
- **General Contractor**
  - Hawaiian Dredging Construction Company
- **Structural Engineer**
  - KSF Inc.
  - Value Engineered Design

# Project Location

Island of Hawaii

# Project Location

On the Mamalahoa Hwy along the Hamakua Coast

# Project Location

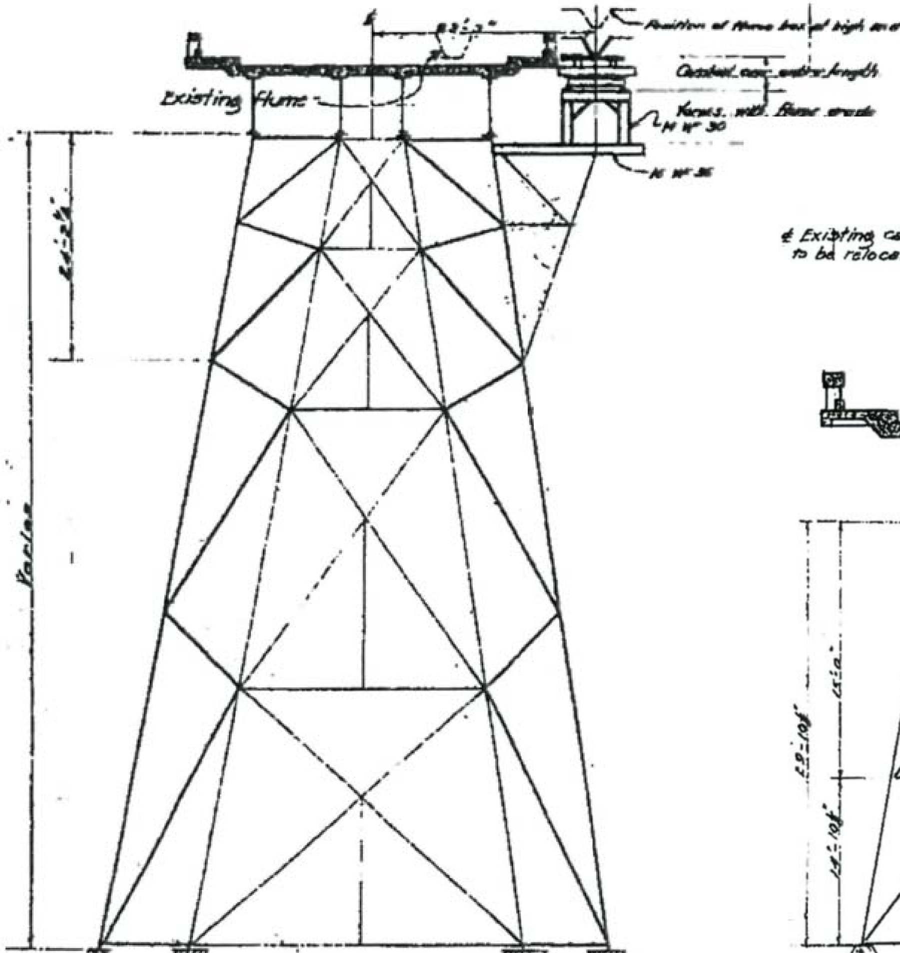
# Original Design (1910)

- Originally Constructed in 1910
  - 281’ long
  - 6 Simply Supported Spans
  - 2 Riveted Steel Plate Girder Lines
  - Carried Rail Line
  - Cane Flume

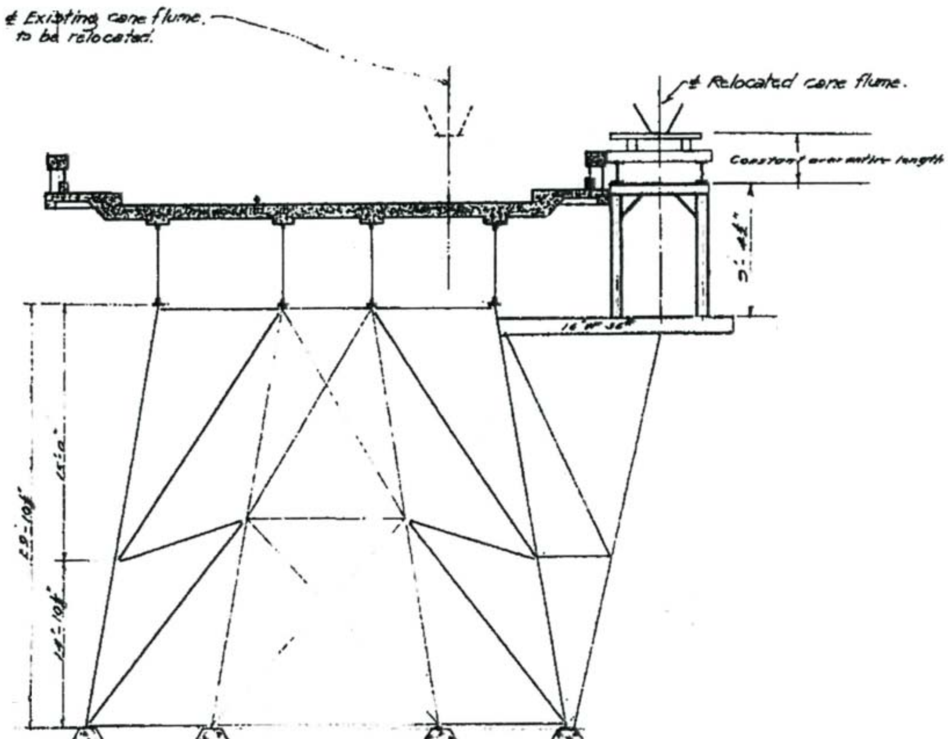
# Bridge Widening (1949)

- Changed to Vehicular Bridge
- Added 2 Additional Girder Lines
- Cast Concrete Deck with Sidewalks and Railings
- Trestle Modifications to accommodate additional girders

# Bridge Widening (1949)




BENTS 1-4 INC.




BENT #5

# Prior to Construction (2013)

# Prior to Construction (2013)

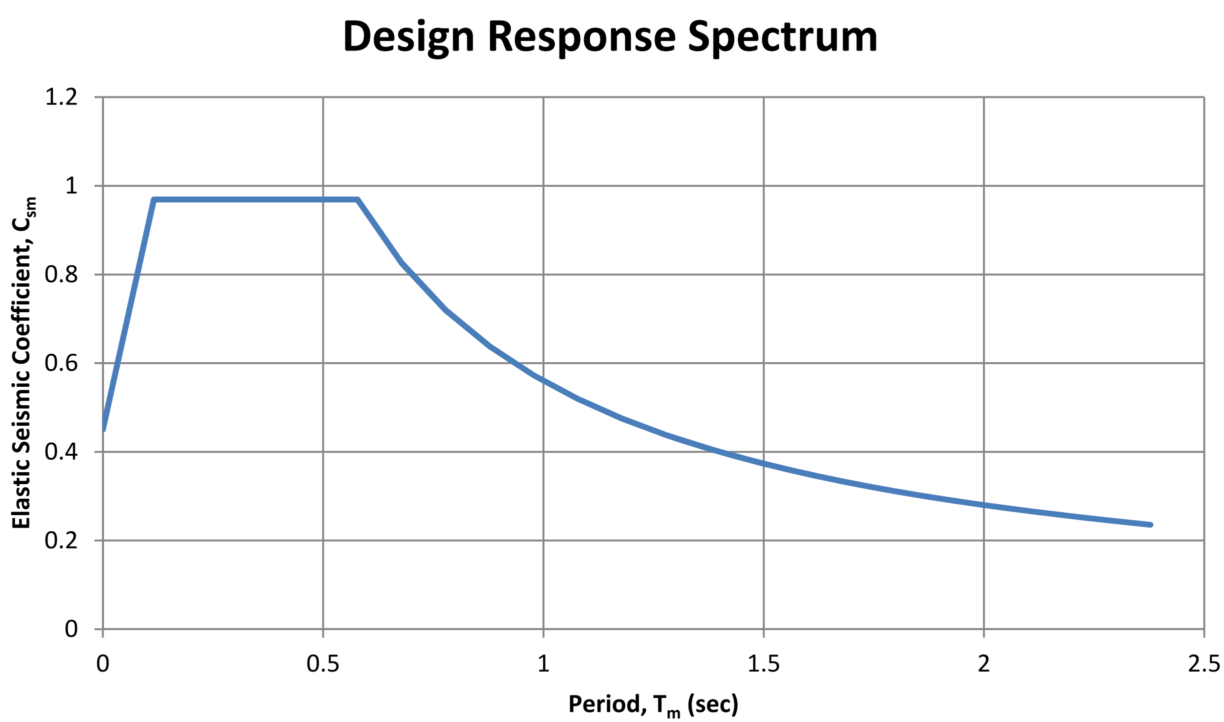
# Design Considerations

- Hurricane Prone Region (Coastal)
- Crane Capacities
- Shipping/Trucking Capacities
- How to deal with current vehicular traffic
- Listed on Historic Register
  - Steel Plate Girder Design
  - Maintain Original Girder Layout and Relatively Similar Girder Heights
  - Existing Steel Trestles to Remain
  - Aesthetic Concrete Railing

# Design Considerations

- Any added substructure will be tall
- High Seismic Area

- $A_S$ = 0.45g
- $S_{D1}$ = 0.56g
- $S_{DS}$ = 0.97g
- Seismic Zone 4

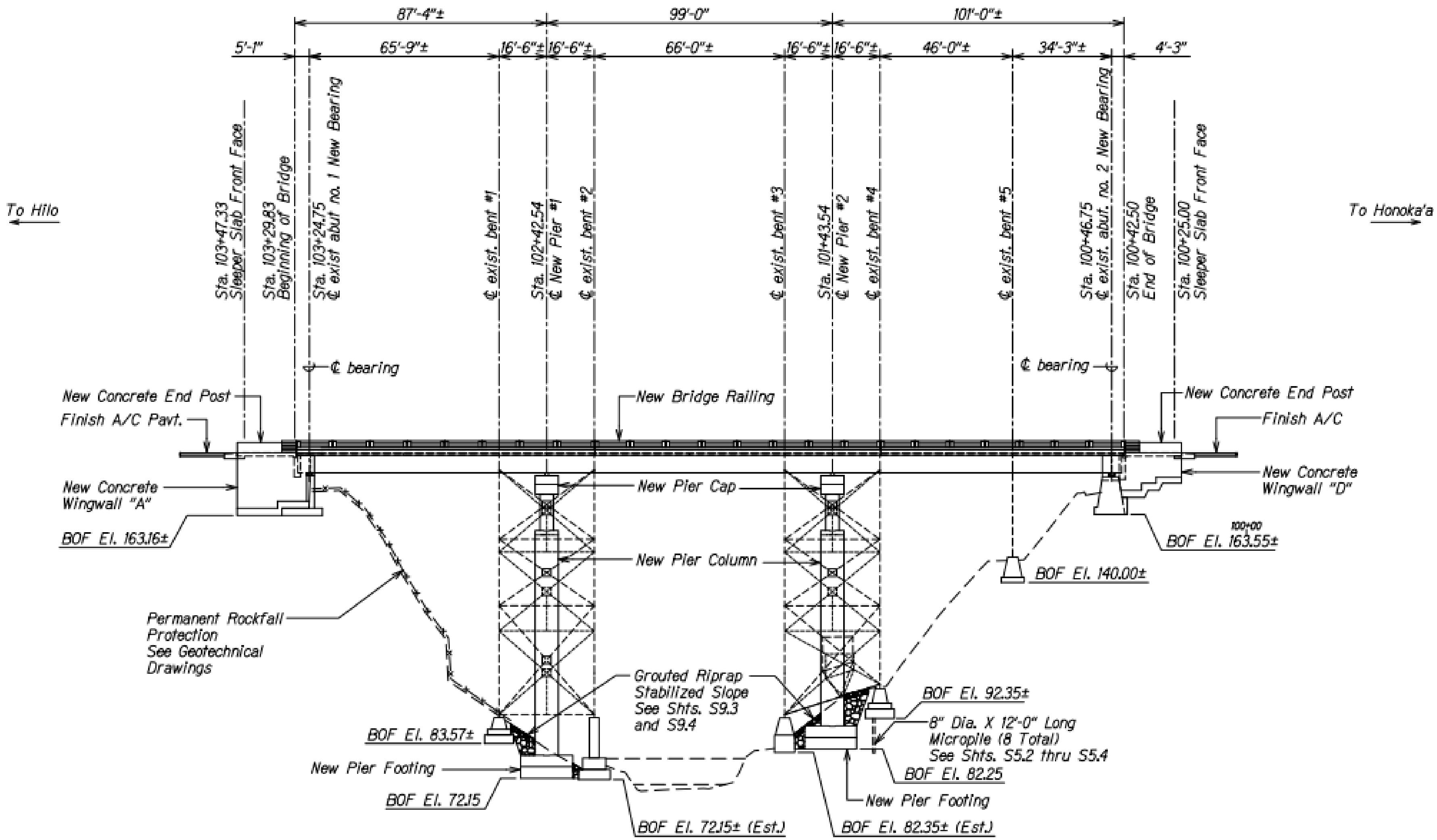


# Design Concepts

- **Replace existing steel girders with new**
  - Eliminate costly repairs and field painting ($Environmental concerns$)
- **Make girders continuous**
  - More efficient design
- **Eliminate deck joints**
  - Eliminates maintenance issues
- **Erect two new concrete piers on spread footings within limits of existing steel trestles**
  - Existing steel trestles no longer contribute to the bridge behavior
- **Reuse/Rehabilitate abutments with minimal foundation work**
  - Eliminates the need for drilled shafts

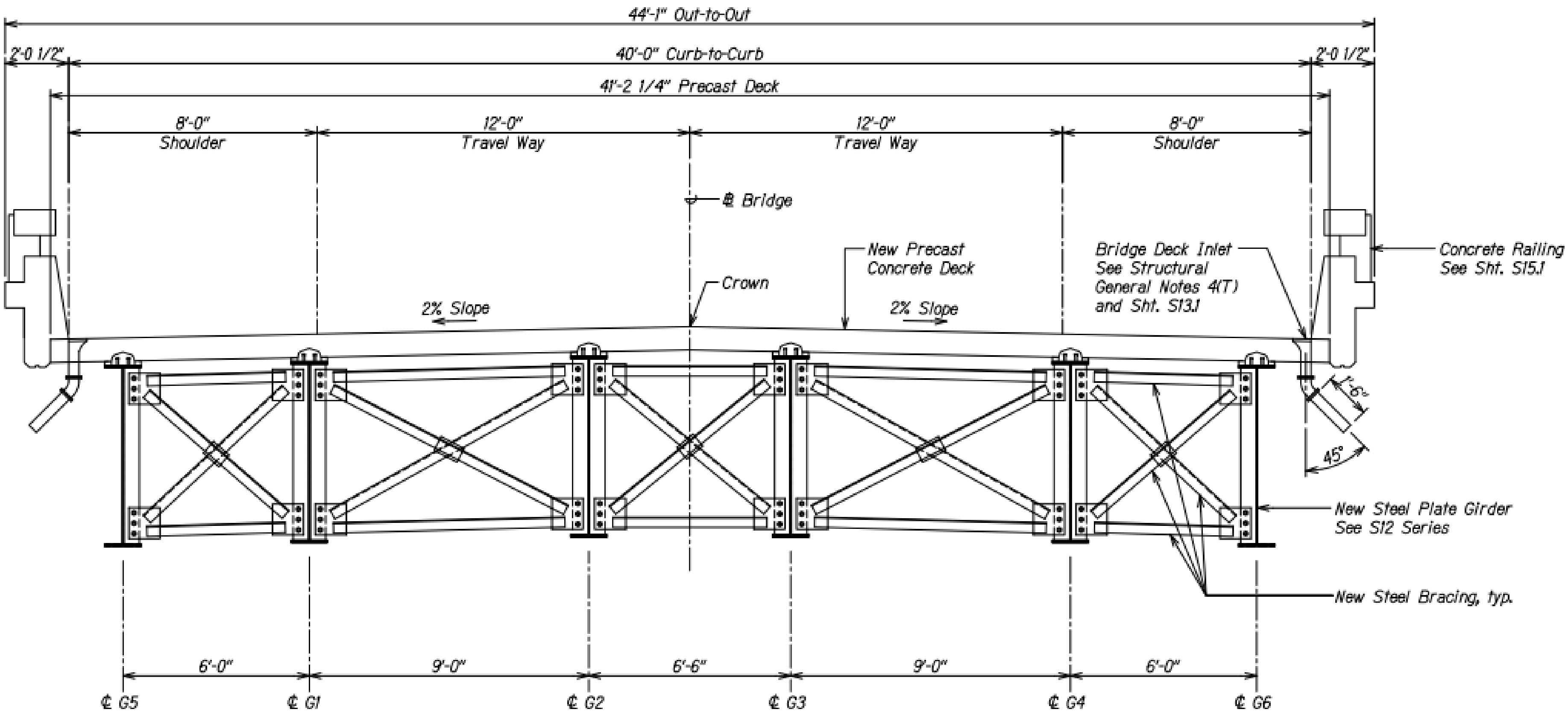
# Design Features

- Temporary Bridge to Detour Traffic
- Post-Tensioned Piers on Spread Footings
- Semi-Integral Abutment with GRS Backfill
- Triple Friction Pendulum Bearings
- Welded Steel Plate Girders
- Precast Post-Tensioned Deck Panels with UHPC




## DOWNSTREAM ELEVATION

Scale: 1" = 20'-0"




BRIDGE CROSS SECTION (A, S4.3 | S4.3)

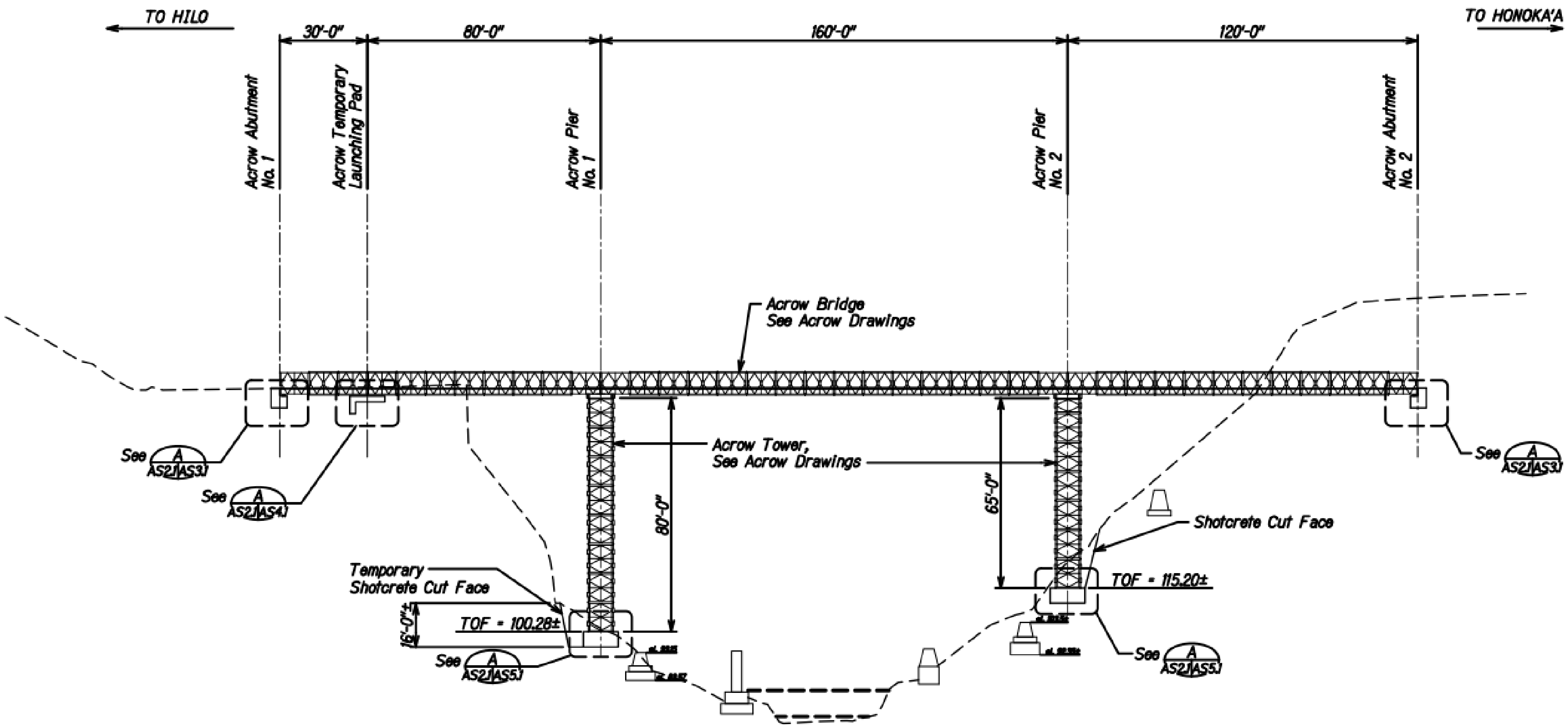
Scale: 1/2" = 1'-0"

Note:
Bridge section symmetrical about baseline.

# To Date…Currently Under Construction

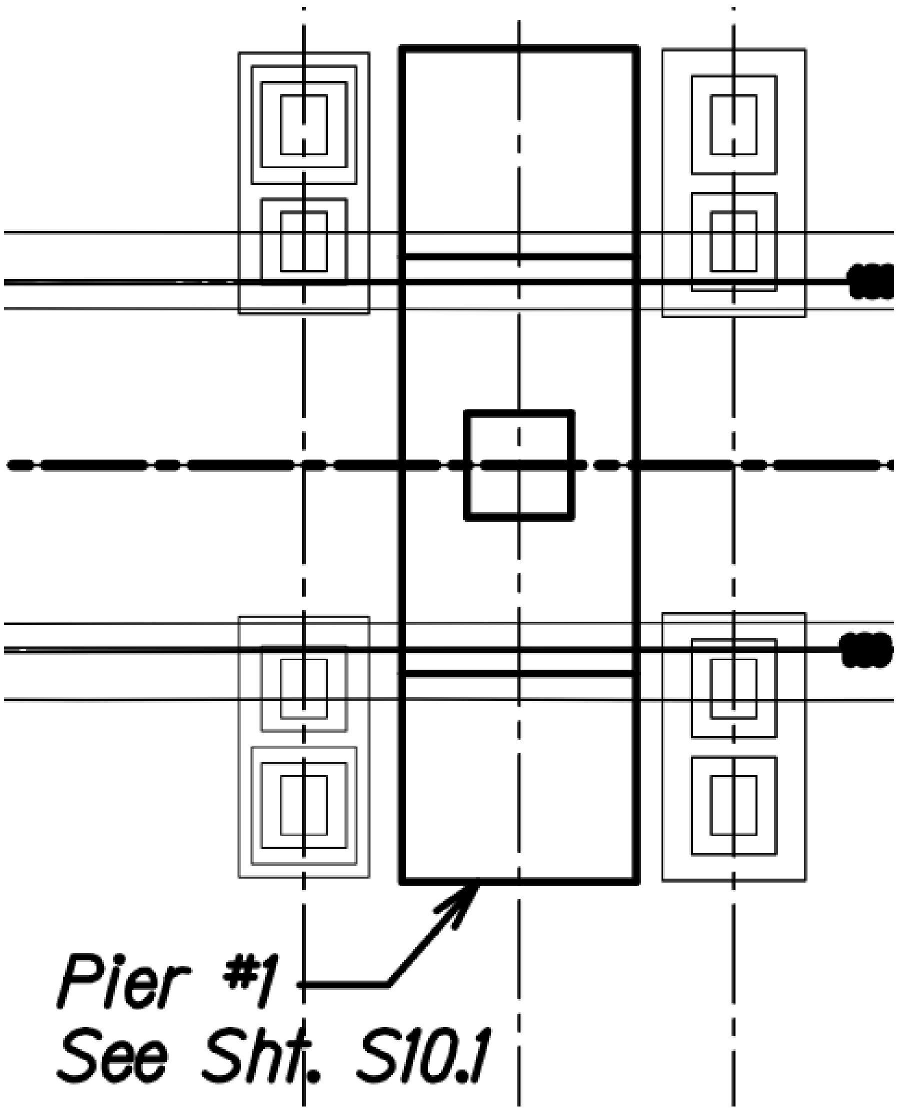
- Placing Friction Pendulum Bearings
- Setting Steel Girders
- Precasting Deck Panels

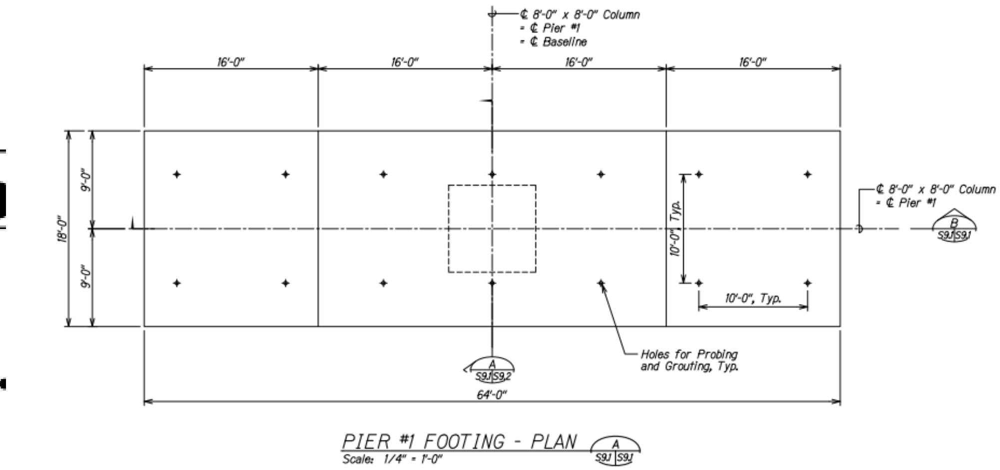
# Temporary Detour Bridge

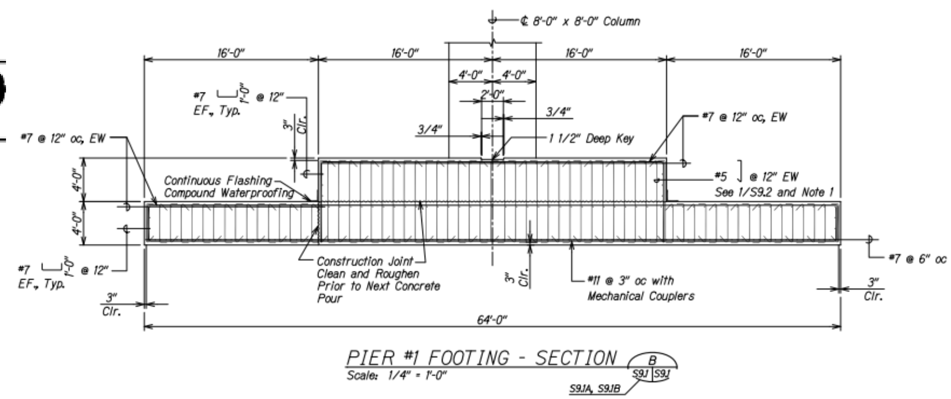


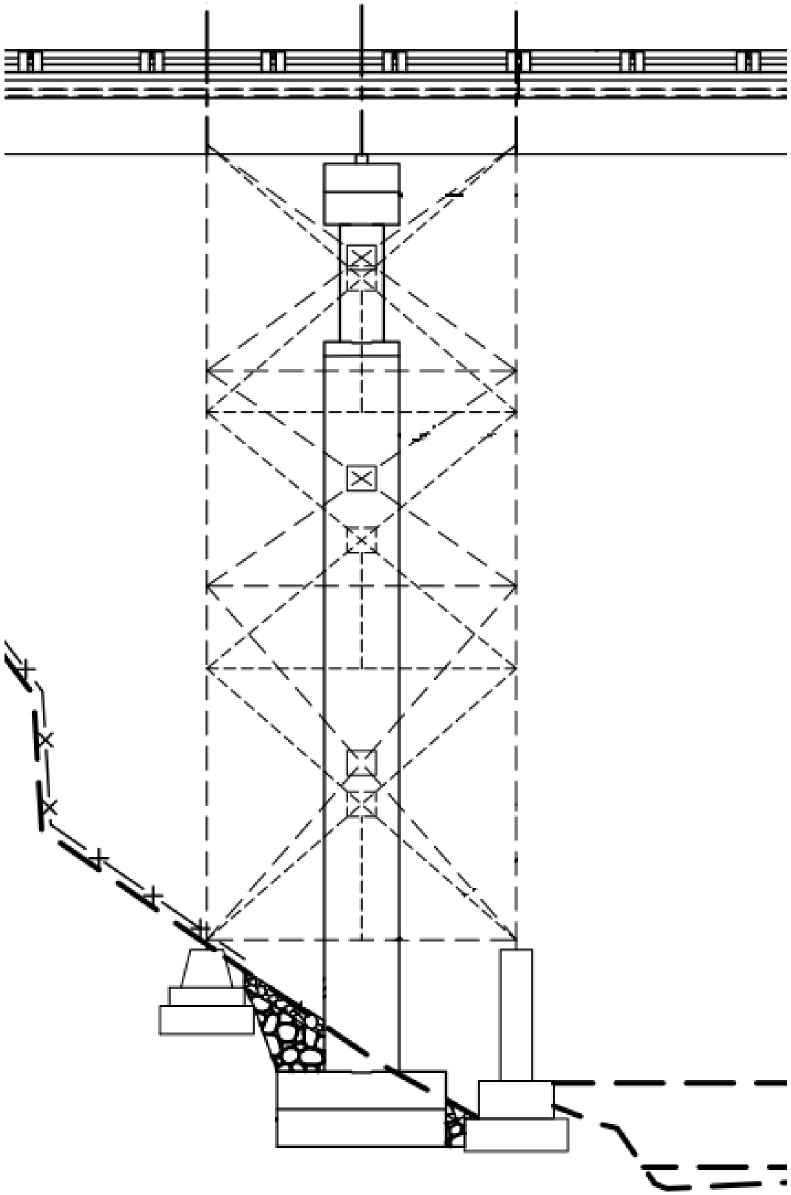
# Temporary Detour Bridge

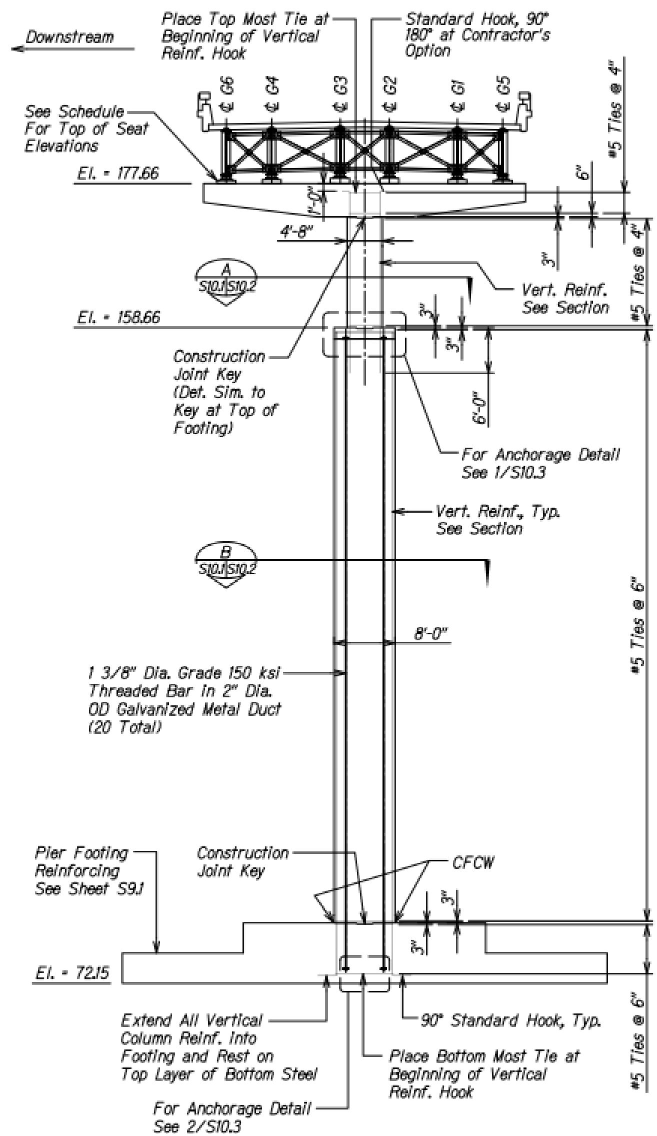

# Post-Tensioned Piers on Spread Footings



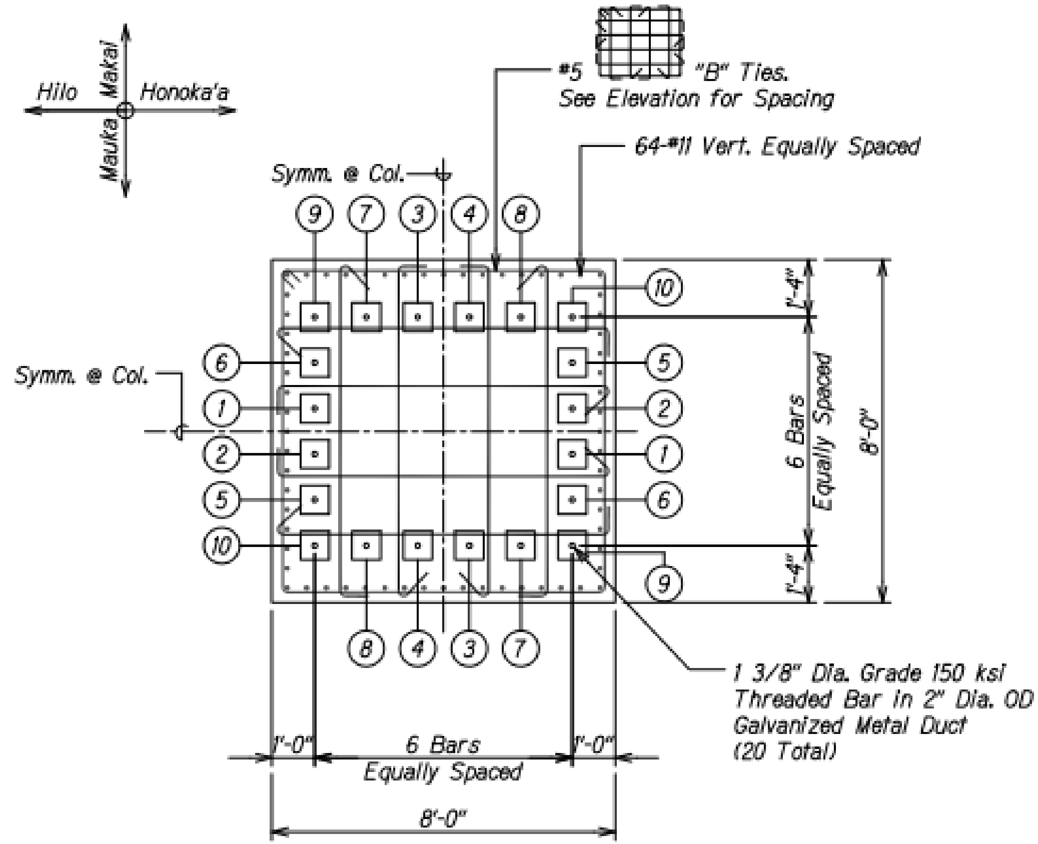





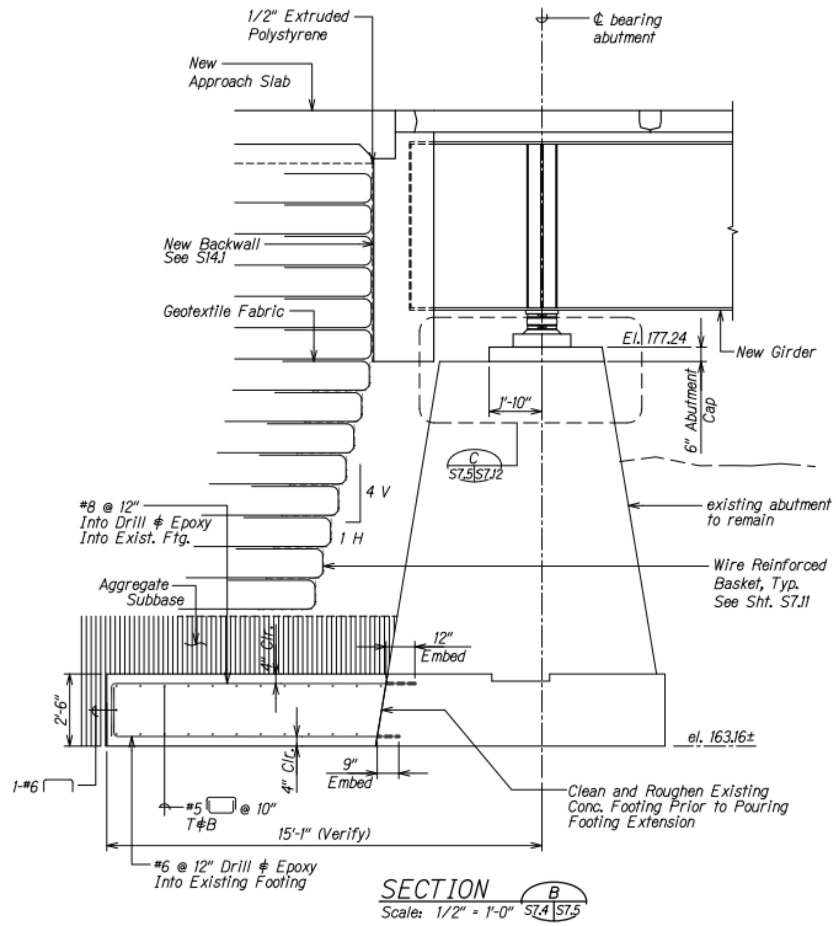



PIER 1 ELEVATION (A, S10.1 | S10.1)
Scale: 1/8" = 1'-0"



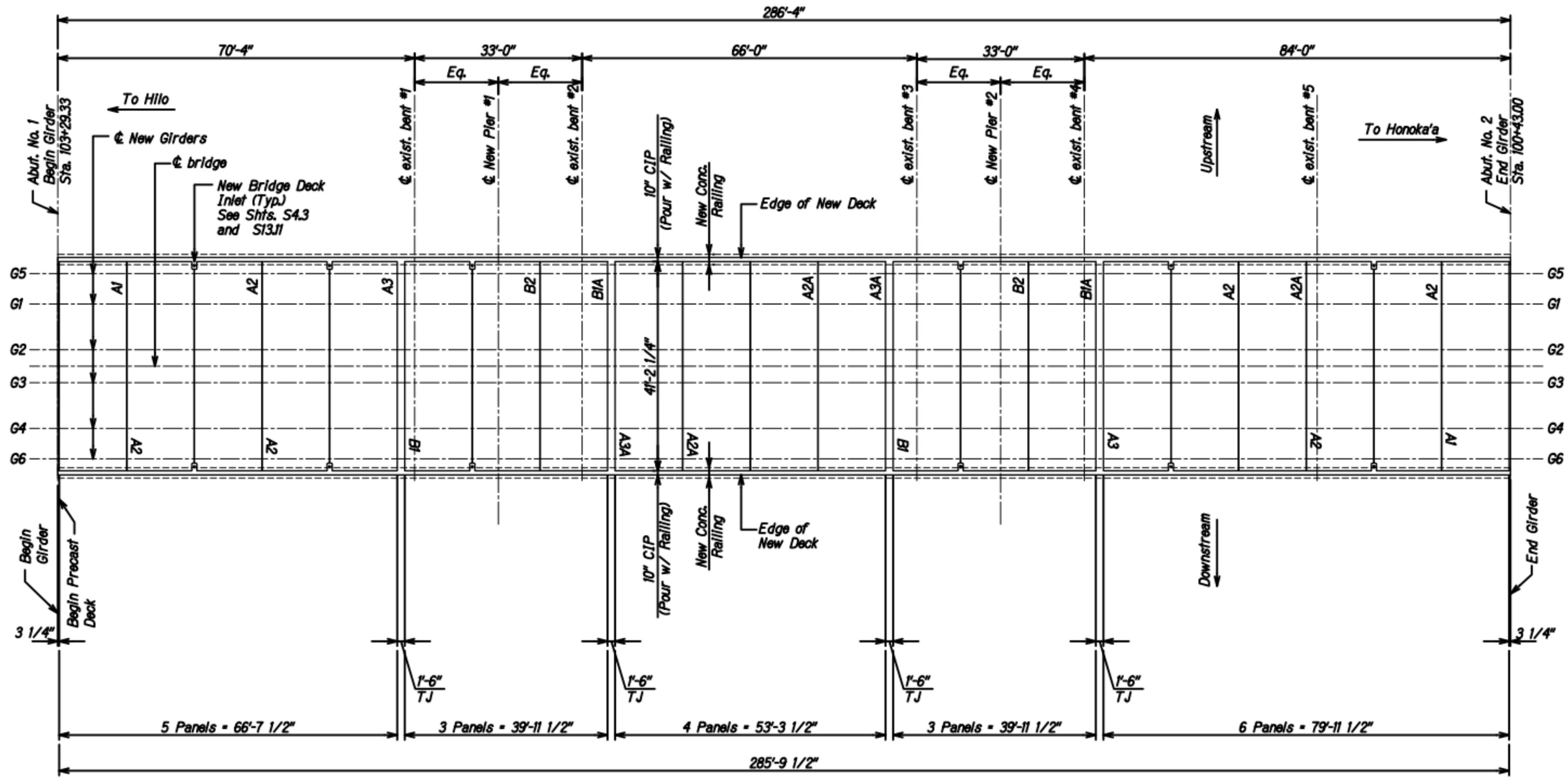

LOWER COLUMN SECTION (B, S10.1 | S10.2)
Scale: 1/2" = 1'-0"

# Semi-Integral Abutment with GRS Backfill

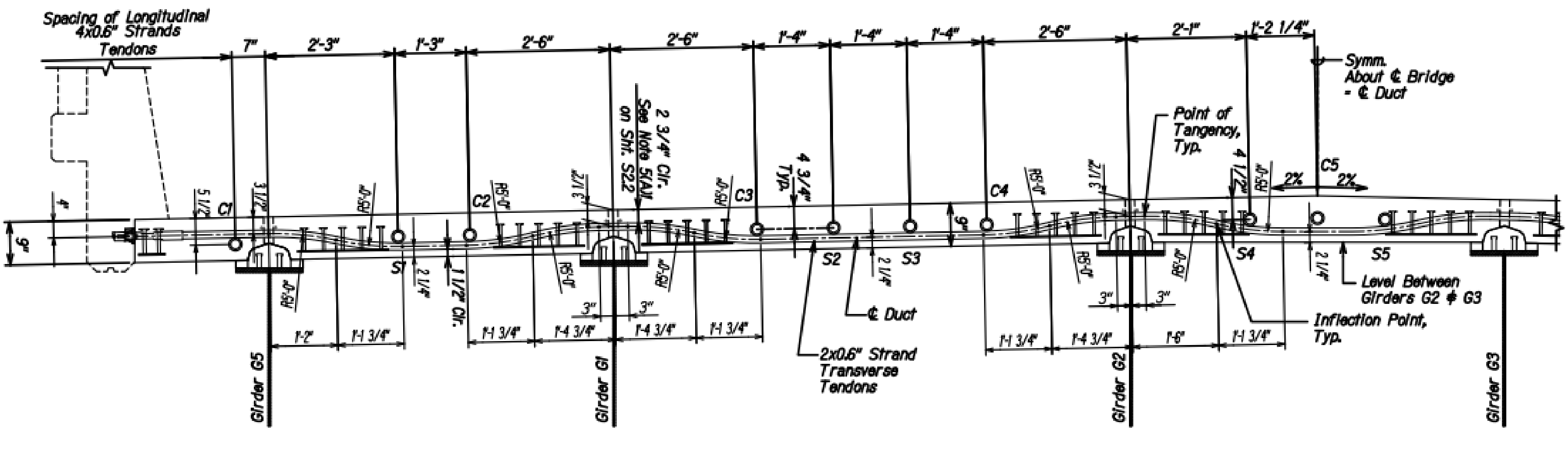


# Semi-Integral Abutment with GRS Backfill

# Precast Deck Panels



# Precast Deck Panels




DECK PANEL SECTION AT TRANSVERSE DUCT

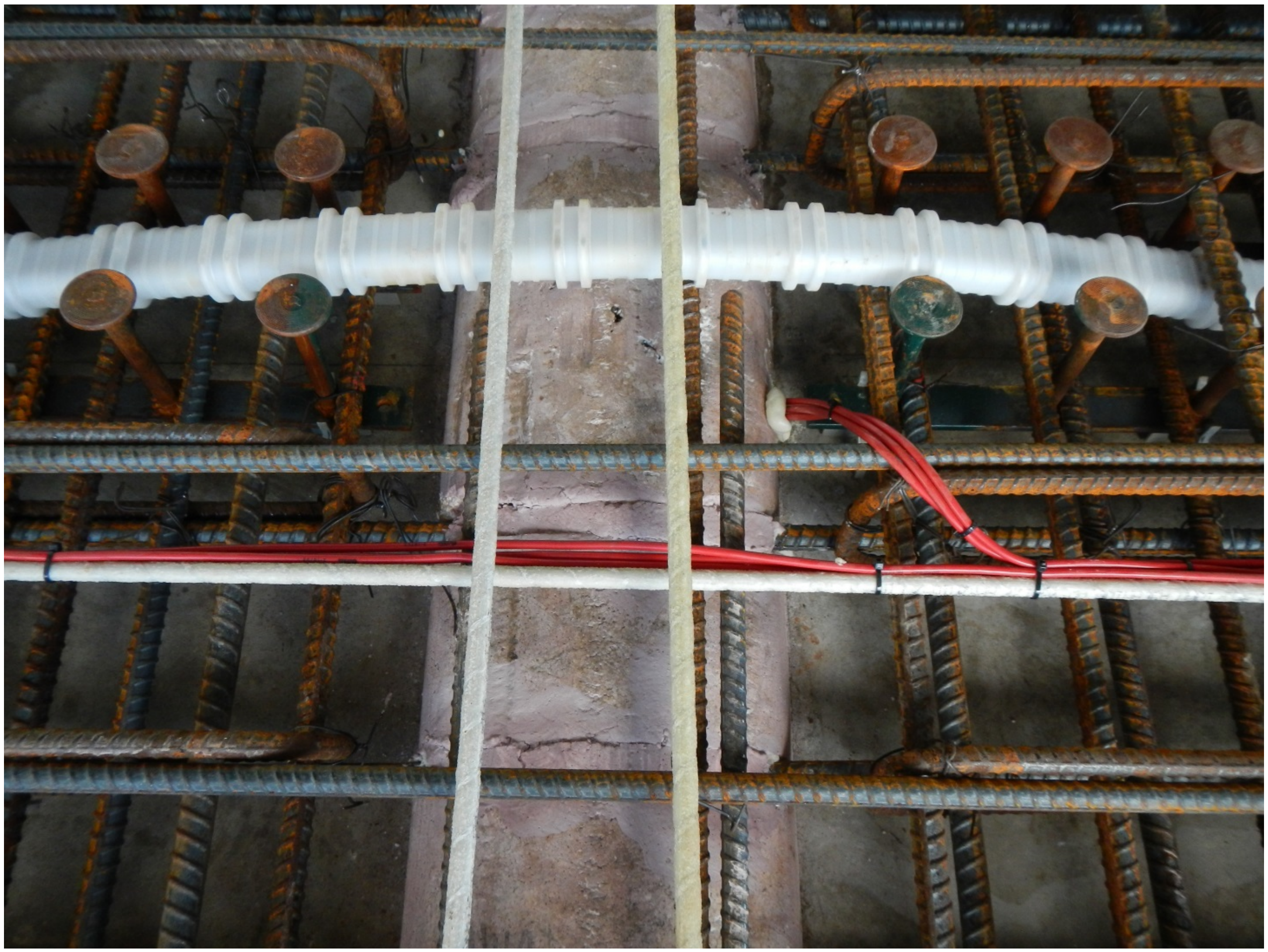
Scale: 1" = 1'-0"

# Precast Deck Panels

# Precast Deck Panels

# Precast Deck Panels

# Precast Deck Panels



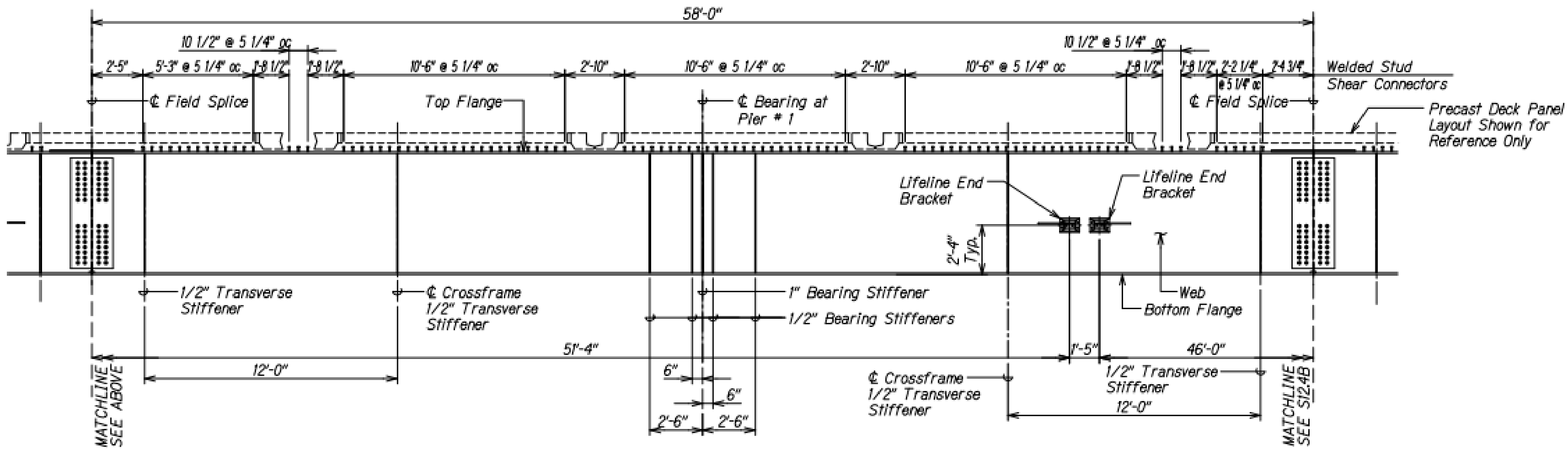
# Precast Deck Panels

# Precast Deck Panels

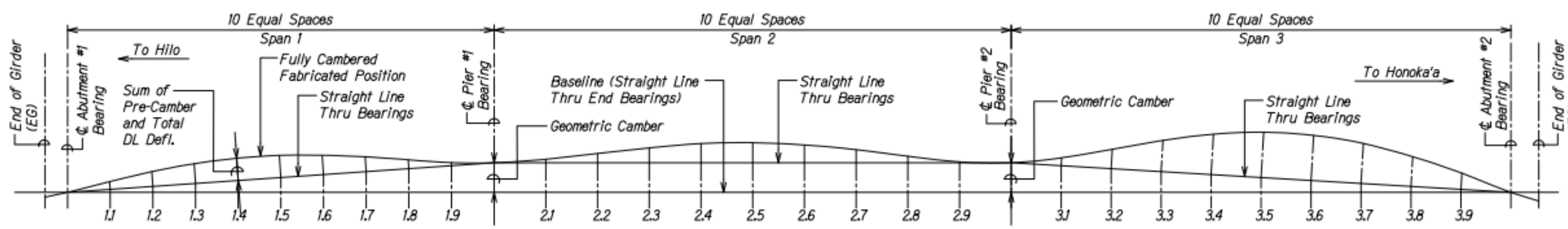
# Precast Deck Panels

# Precast Deck Panels

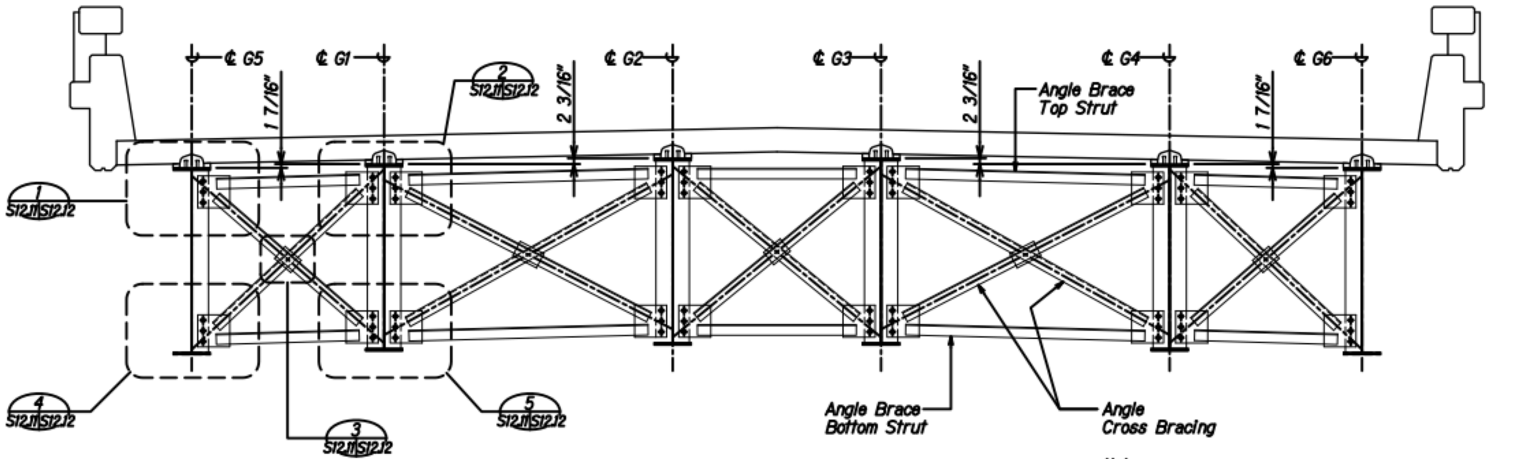
# Welded Steel Plate Girders




TYPICAL GIRDER ELEVATION A S124A S124A
Scale: 3/8" = 1'-0"

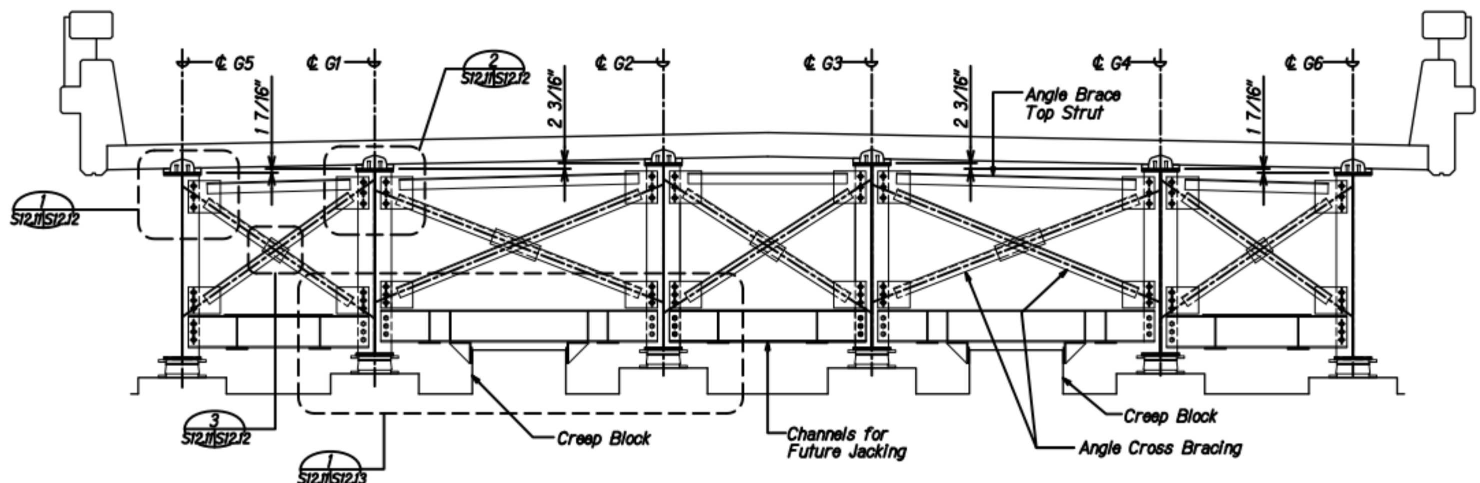


# Cross-Frames



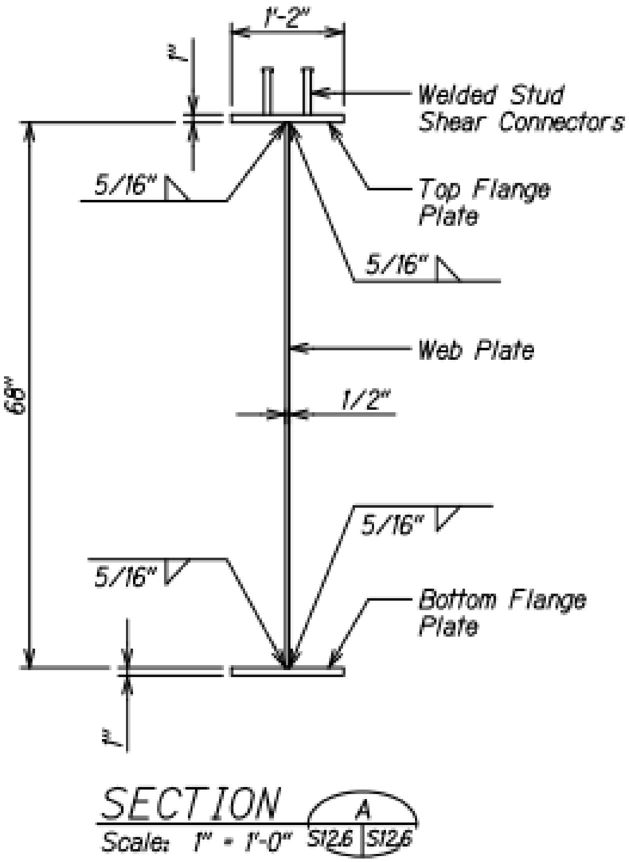

INTERMEDIATE CROSS-FRAME SECTION (A S12.11 S12.11)
Scale: 1/2" = 1'-0"

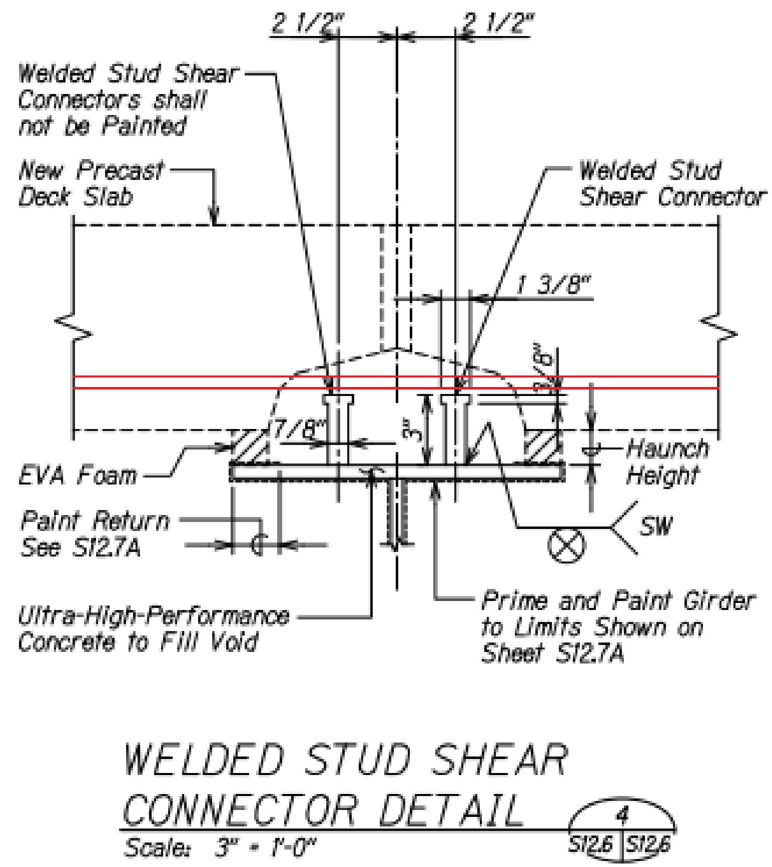
**Note:**
Intermediate cross-frame section is shown at mid-span but is similar over ℄ bearing at piers.




ABUTMENT CROSS-FRAME SECTION (B S12.11 S12.11)
Scale: 1/2" = 1'-0"

# Welded Steel Plate Girders



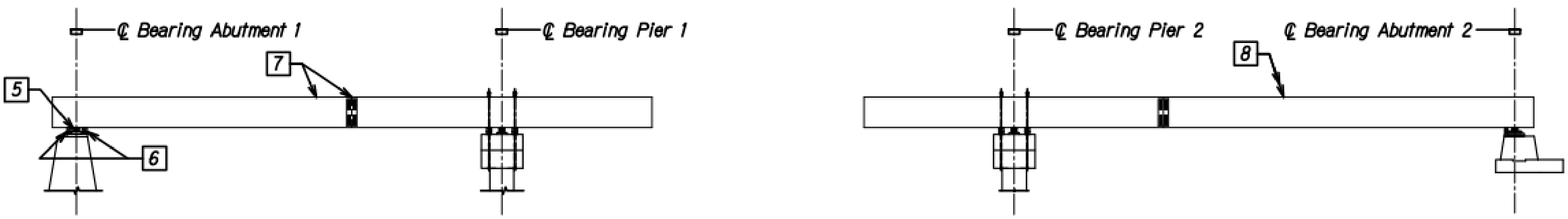

[1] Place temporary supports (timber blocking and sandjacks) and install wood bracing at bottom flange elevation. See SK-19.2.

[2] Attach friction pendulum bearing to bottom of girder. Set girders and bracing over Pier 1. Do not grout shear lugs, do not release shipping plates. See notes 3 and 4.

[3] Install temporary holddowns (post-tensioned) and tiedowns. See SK-19.1.

[4] Repeat steps [1] through [3] over Pier 2.

## GIRDER ERECTION SEQUENCE 1



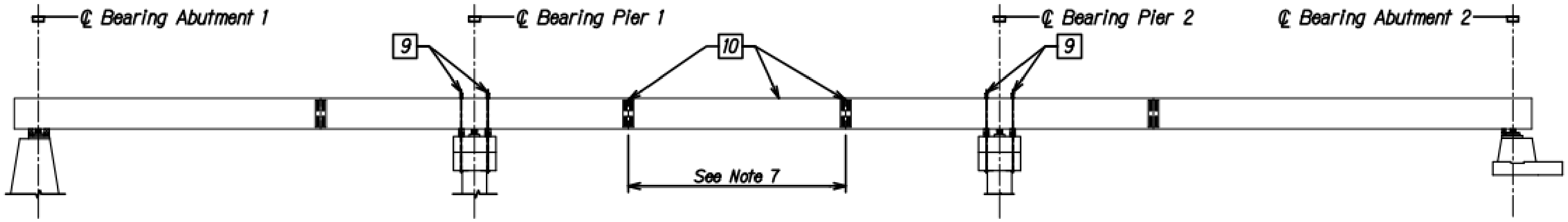

[5] Set friction pendulum bearing at Abutment 1. See note 3. Do not grout shear lugs. Do not release shipping plates.

[6] Place temporary supports (timber blocking). See note 1.

[7] Set girders and bracing between Abutment 1 and Pier 1. See note 5.

[8] Repeat steps [5] through [7] between Abutment 2 and Pier 2.

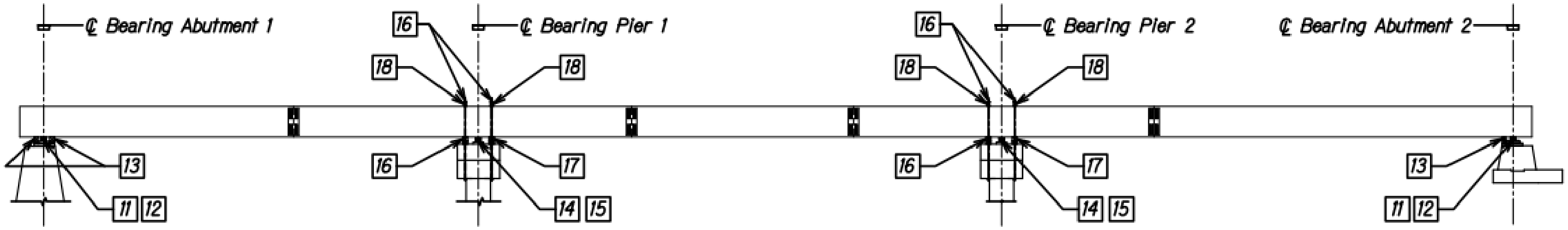
## GIRDER ERECTION SEQUENCE 2




[9] Remove Girder tie downs. Detension girder holddowns. Do not remove. See note 6.

[10] Set girders and bracing between Pier 1 and 2. See notes 5 and 7.

## GIRDER ERECTION SEQUENCE 3




[11] Loosen shipping plate bolts on friction pendulum bearing at Abutments 1 and 2 and connect bearing to bottom flange of girder. See Note 9.

[12] Grout space beneath friction pendulum bearing and inside shear lug blockout.

[13] Remove shipping plates, and remove timber blocking.

[14] Support bottom of friction pendulum bearing. Loosen shipping plates at Piers 1 and 2. Level bottom concave. See Note 9.

[15] Grout space beneath friction pendulum bearing and inside shear lug blockout.

[16] Remove girder holddowns. See note 8.

[17] Remove shipping plates, release sandjacks and remove timber blocking.

[18] Weld studs to top flange of girder at locations of jacking beam.

[19] Remove PVC blockout in pier cap for P.T. bars and fill with grout. Remove top of coil loop inserts for tie downs (See 1/S7.9) and patch with polymer-modified repair mortar.

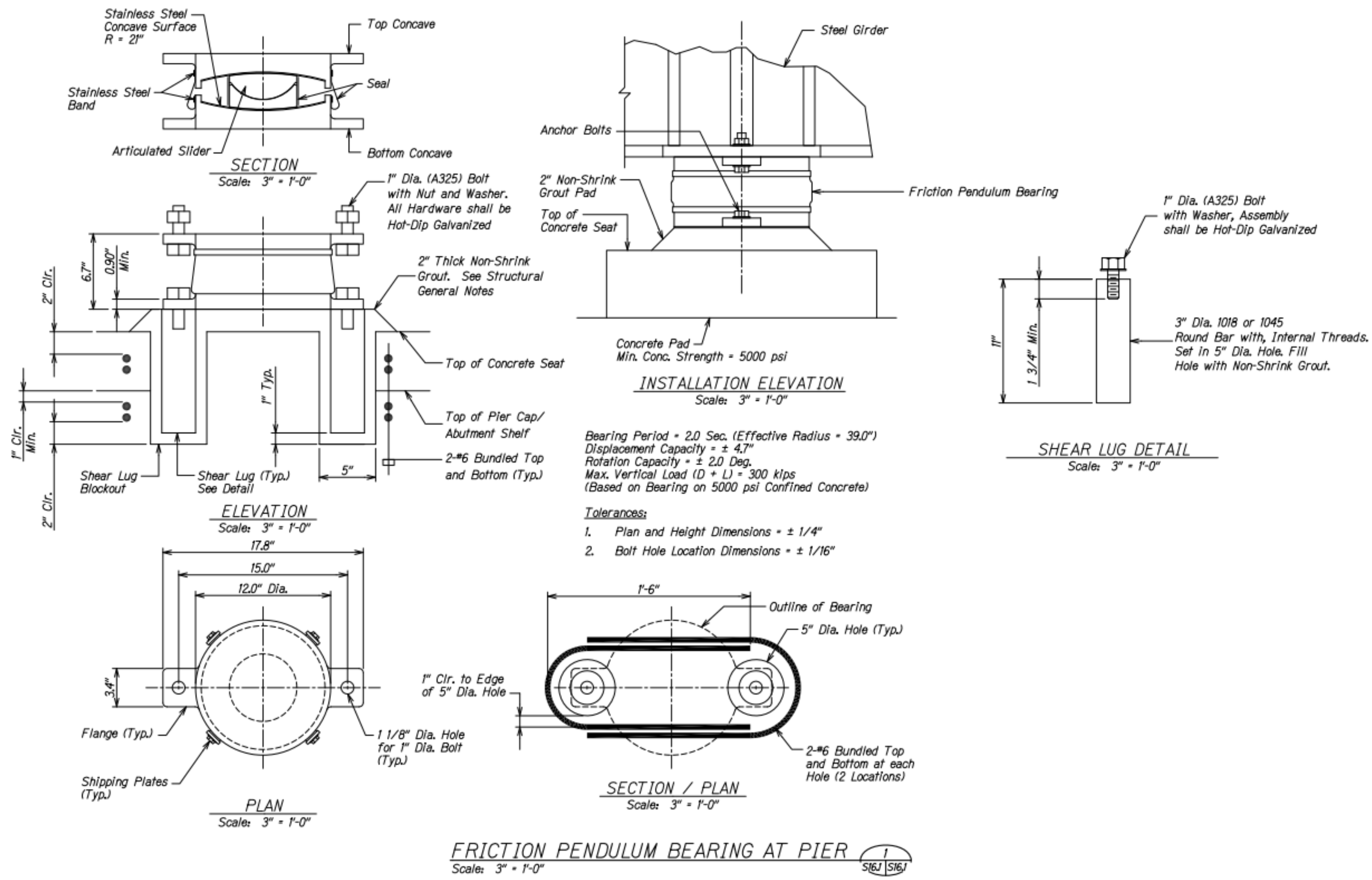
## GIRDER ERECTION SEQUENCE 4

# Welded Steel Plate Girders

# Welded Steel Plate Girders

# Welded Steel Plate Girders

# Friction Pendulum Bearing



# Friction Pendulum Bearing

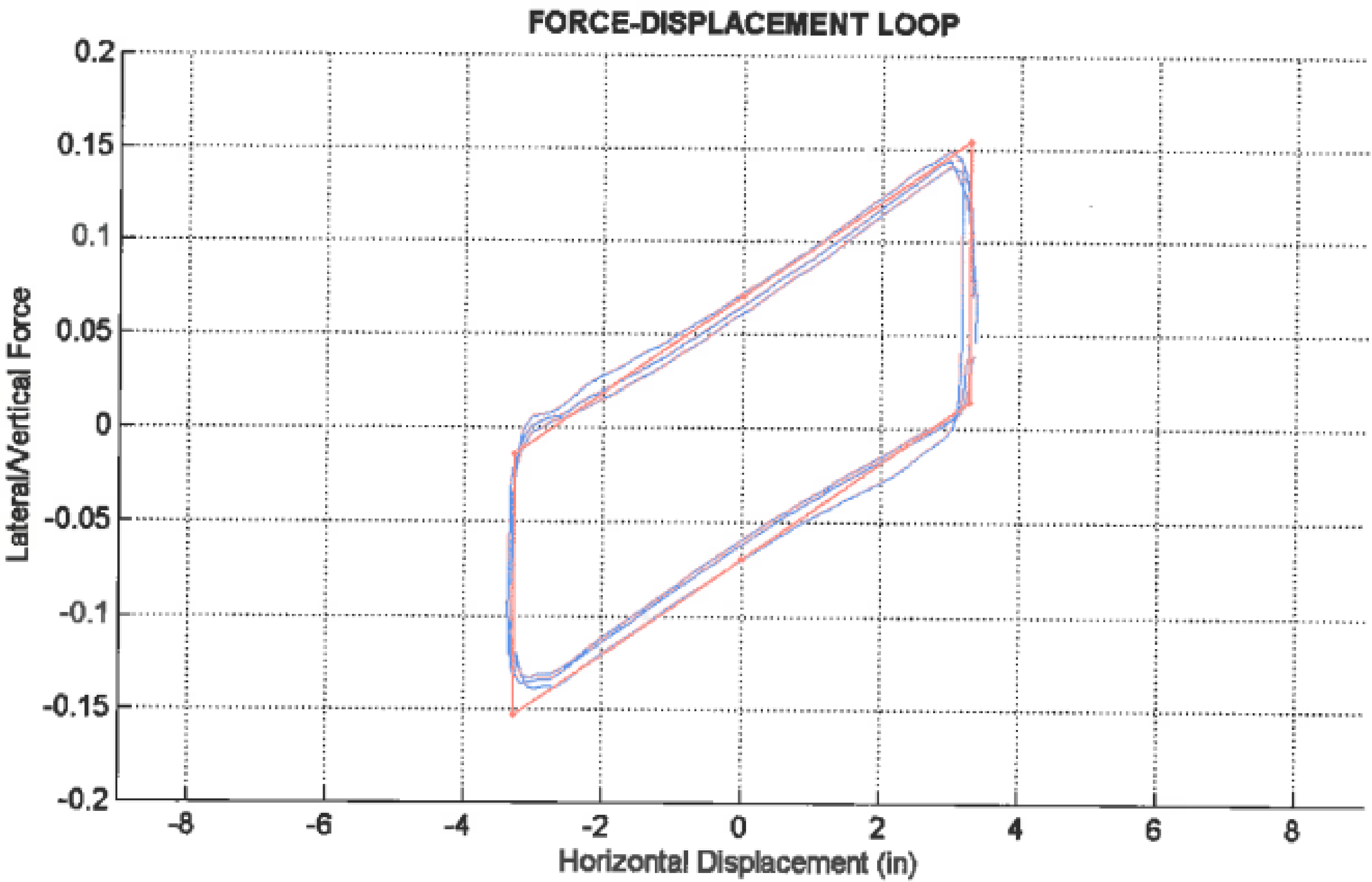
# Friction Pendulum Bearing


# Friction Pendulum Bearing

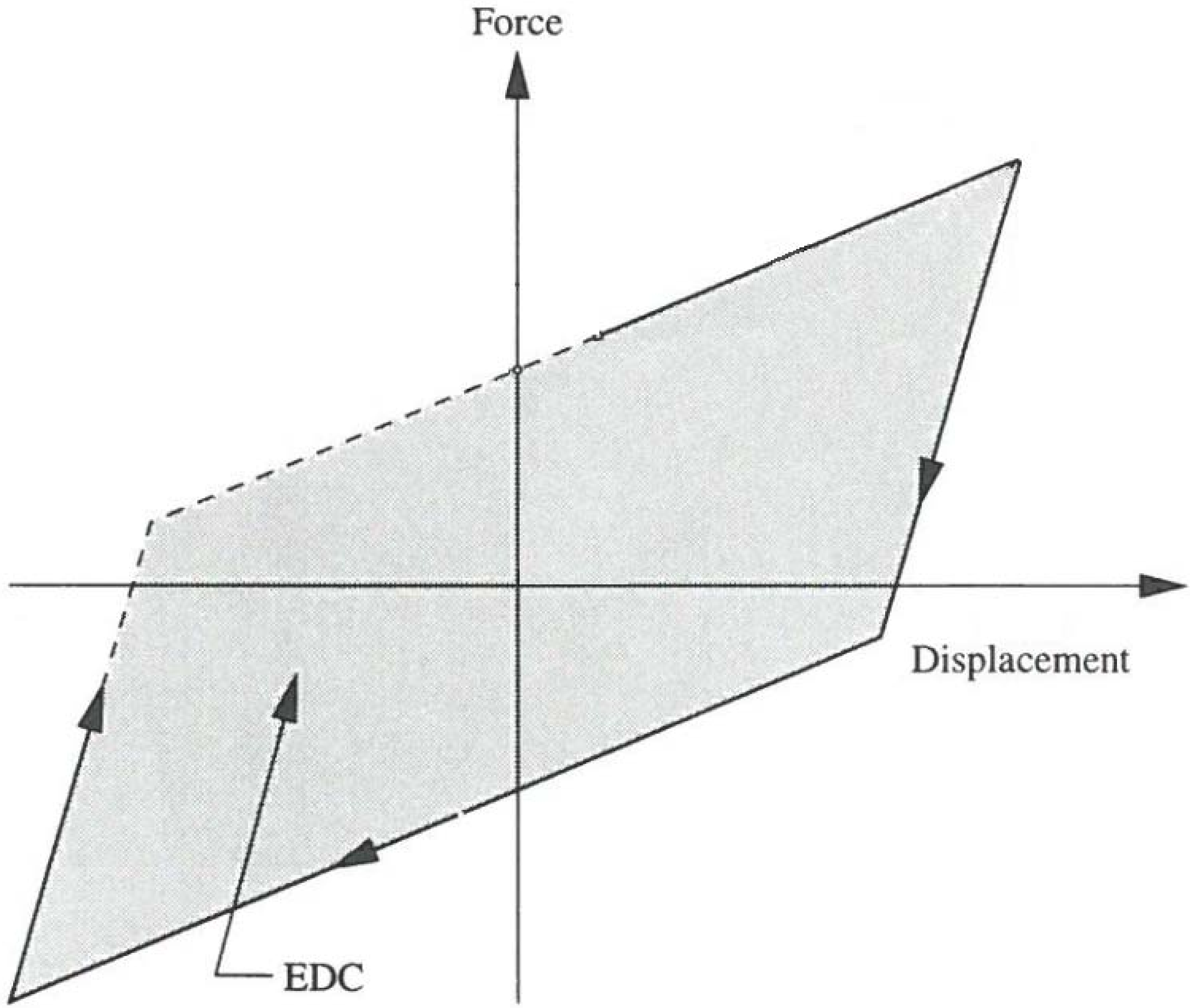
- Multimode Spectral Analysis
- Simplified method representing the isolator as a linear elastic element with effective stiffness
- Modify response spectrum for periods greater than $0.8T_{eff}$ to account for effective damping
- Iterative analysis that requires convergence on the assumed and calculated values of the isolator displacement
- Umauma Bridge
  - Straight and no skew
  - Similar heights on interior piers
  - Relatively equal span lengths
  - No other irregularities

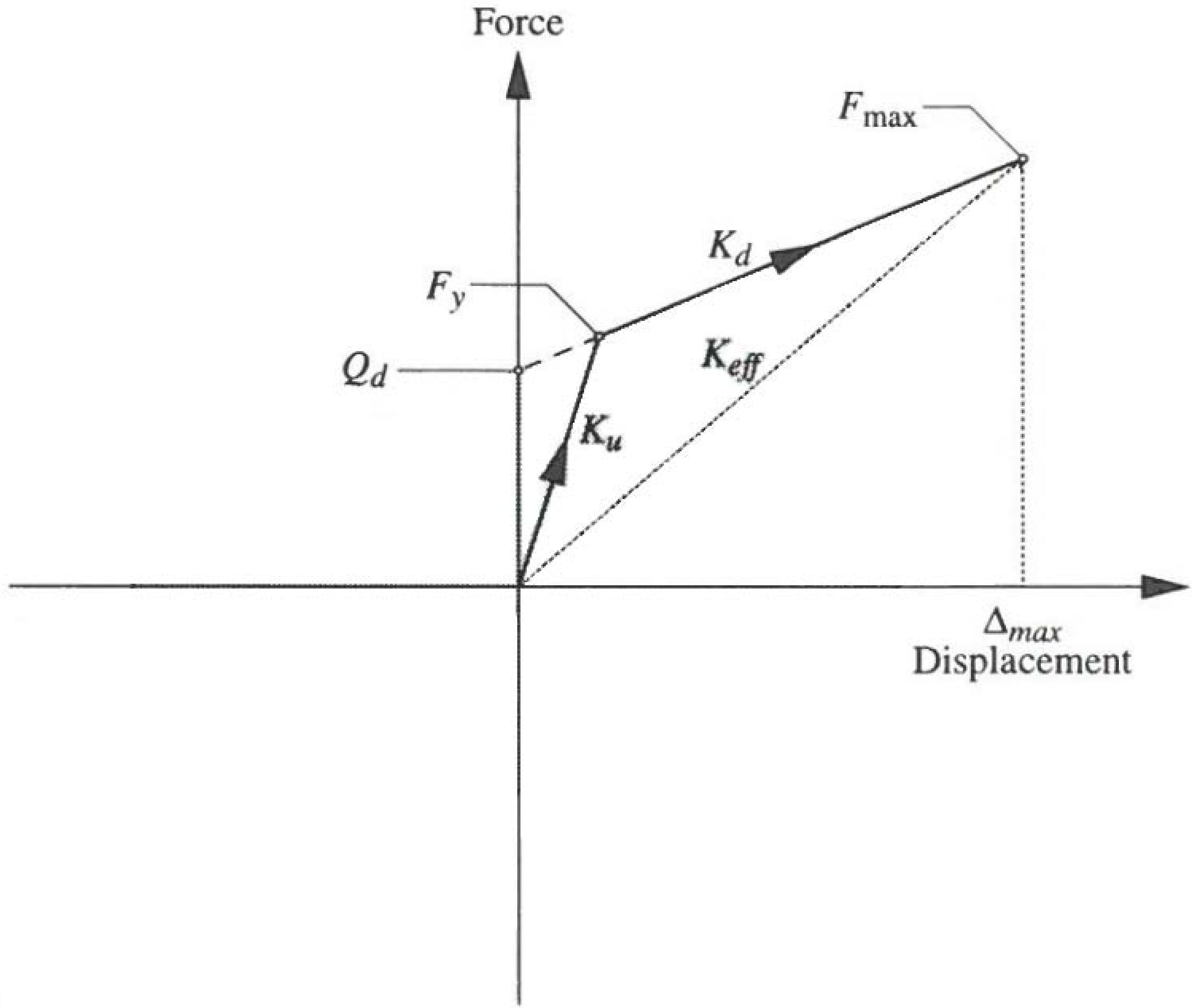
# Multimode Spectral Analysis

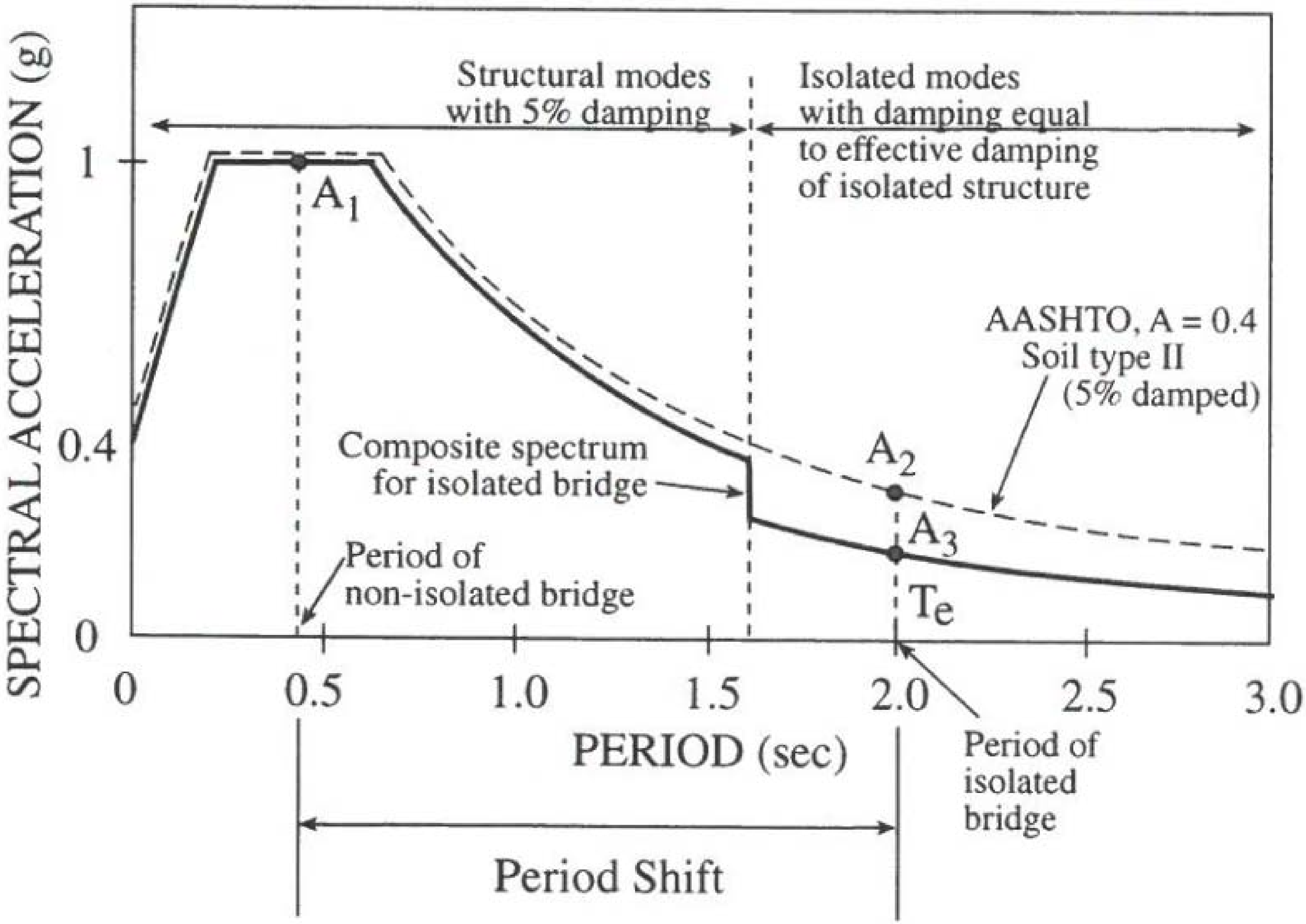
- Bridge must be classified as either “Essential” or “Other”
- Verify Effective Period is less than 3 seconds.
- Effective damping shall remain at or below 30% of the critical damping
- Reduce Response Modification Factor (R) by half for substructures… but need not be taken less than 1.5



FORCE-DISPLACEMENT LOOP
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Lateral/Vertical Force
-8
-6
-4
-2
0
2
4
6
8
Horizontal Displacement (in)

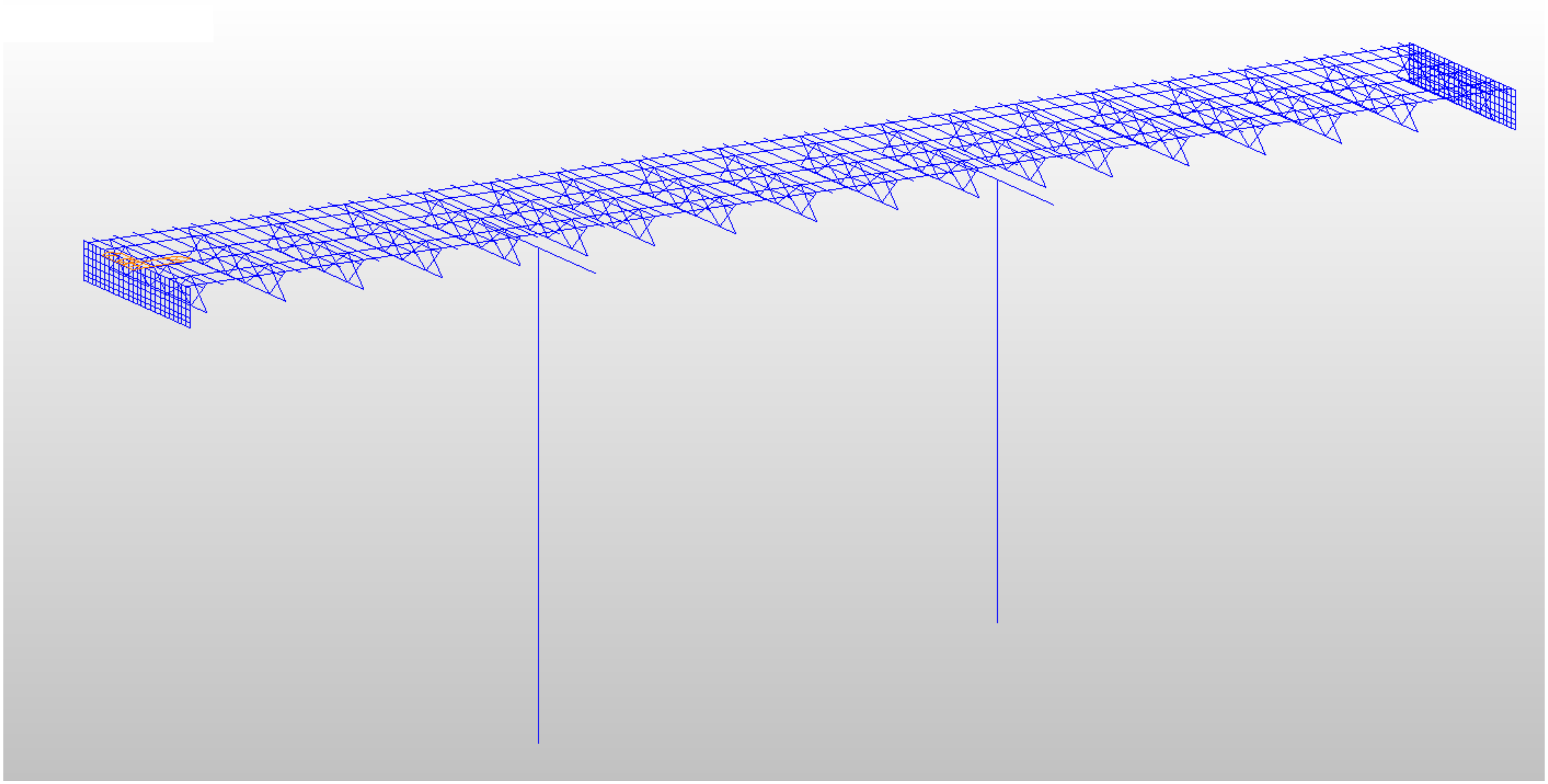

Force
Displacement
EDC

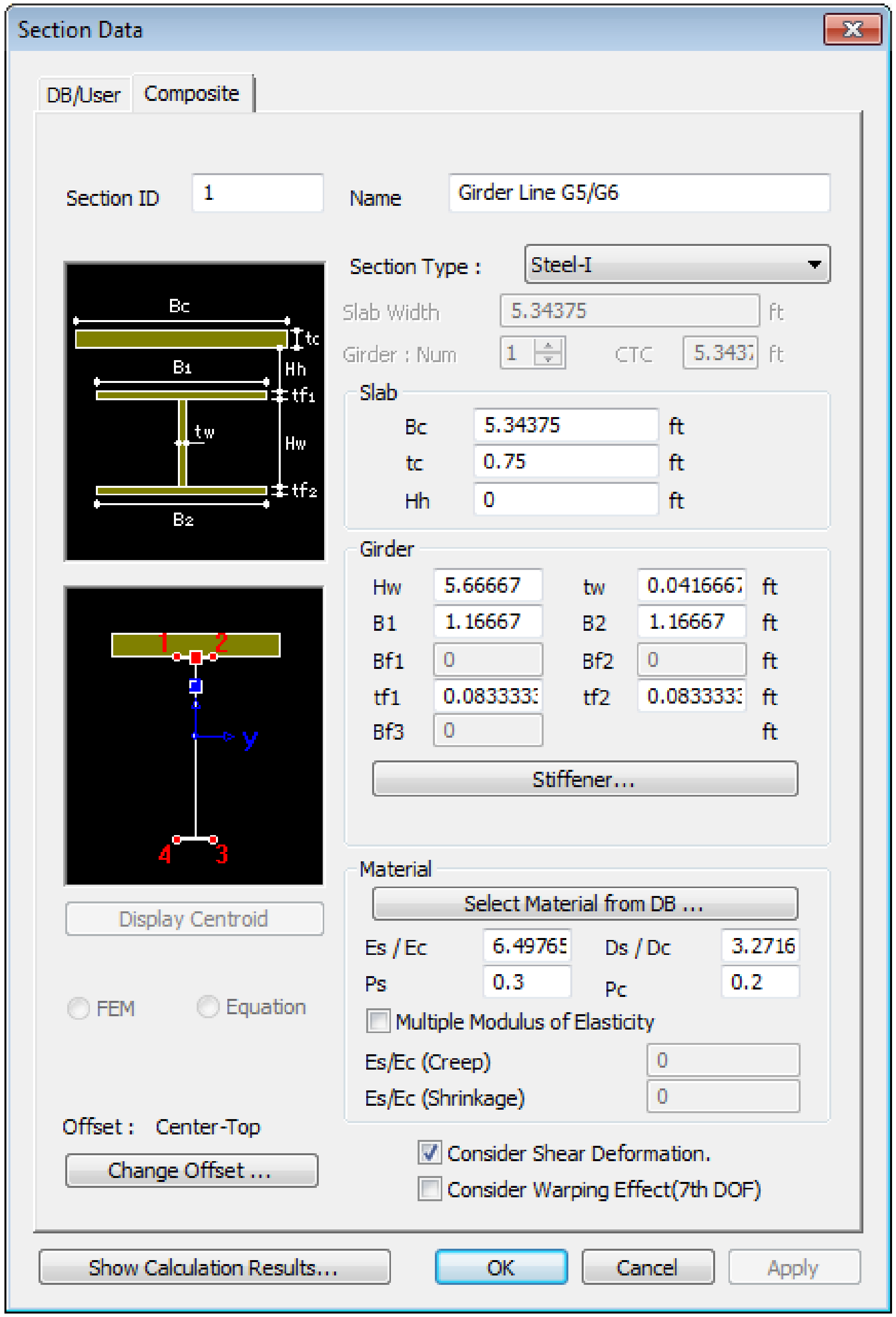

Force
$F_{\max}$
$K_d$
$F_y$
$Q_d$
$K_{eff}$
$K_u$
$\Delta_{max}$
Displacement

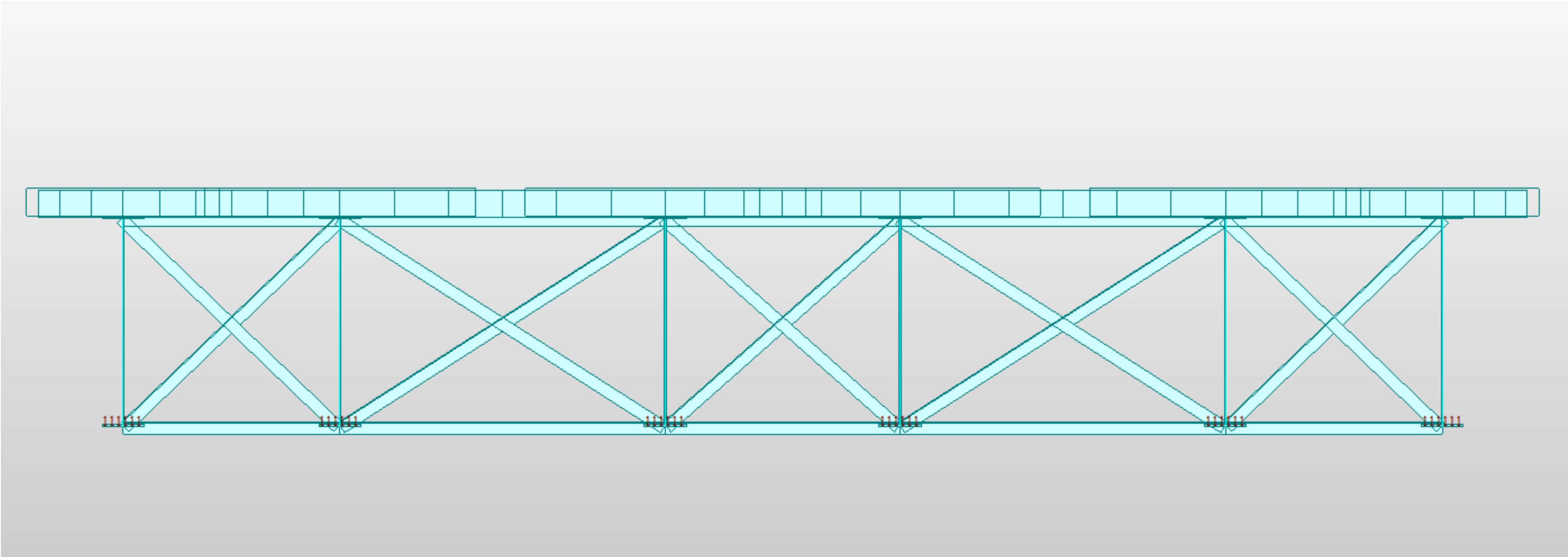


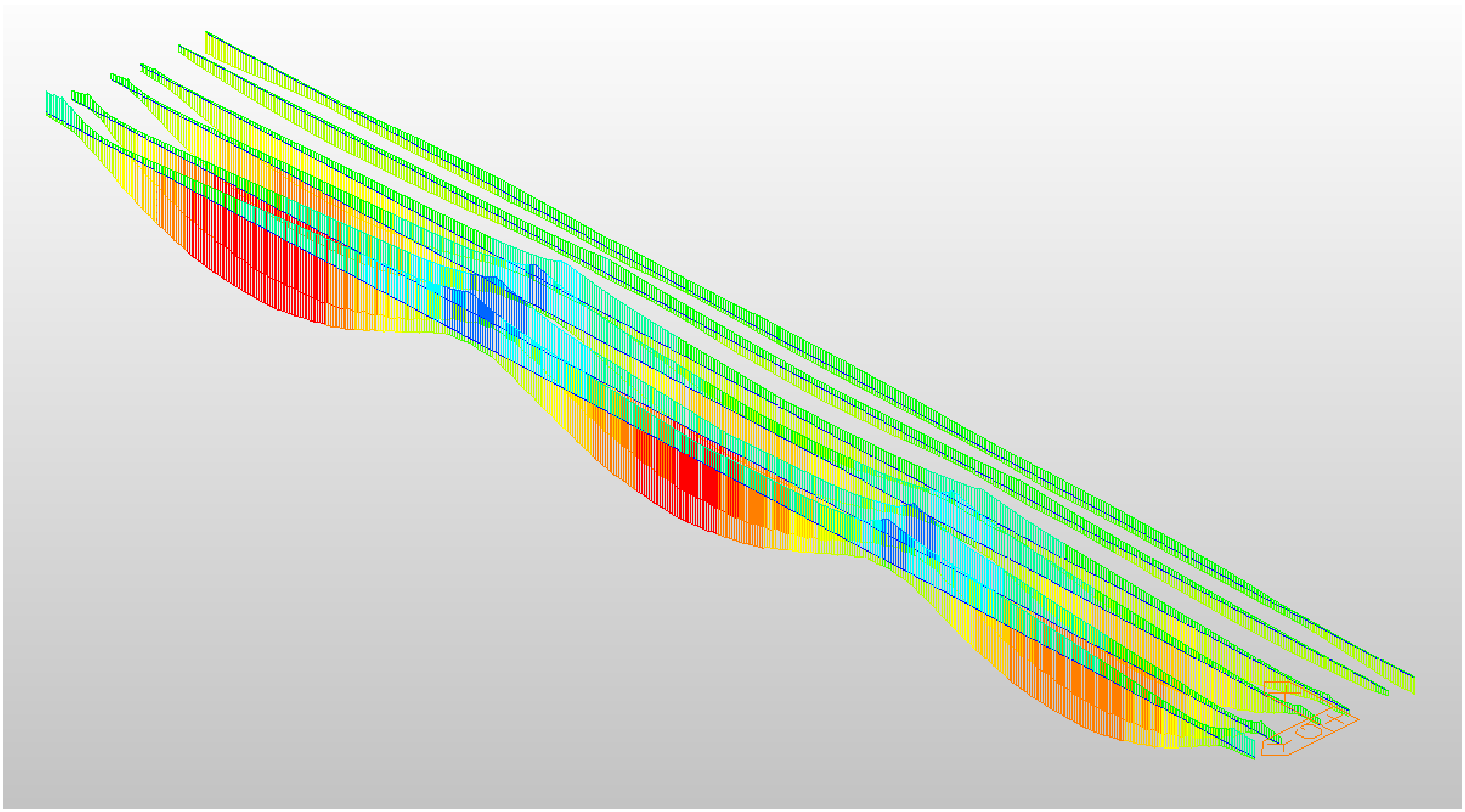
SPECTRAL ACCELERATION (g)
1
0.4
0
Structural modes
with 5% damping
Isolated modes
with damping equal
to effective damping
of isolated structure
A1
AASHTO, A = 0.4
Soil type II
(5% damped)
Composite spectrum
for isolated bridge
A2
A3
Period of
non-isolated bridge
Te
0
0.5
1.0
1.5
2.0
2.5
3.0
PERIOD (sec)
Period of
isolated
bridge
Period Shift

# Grillage Model

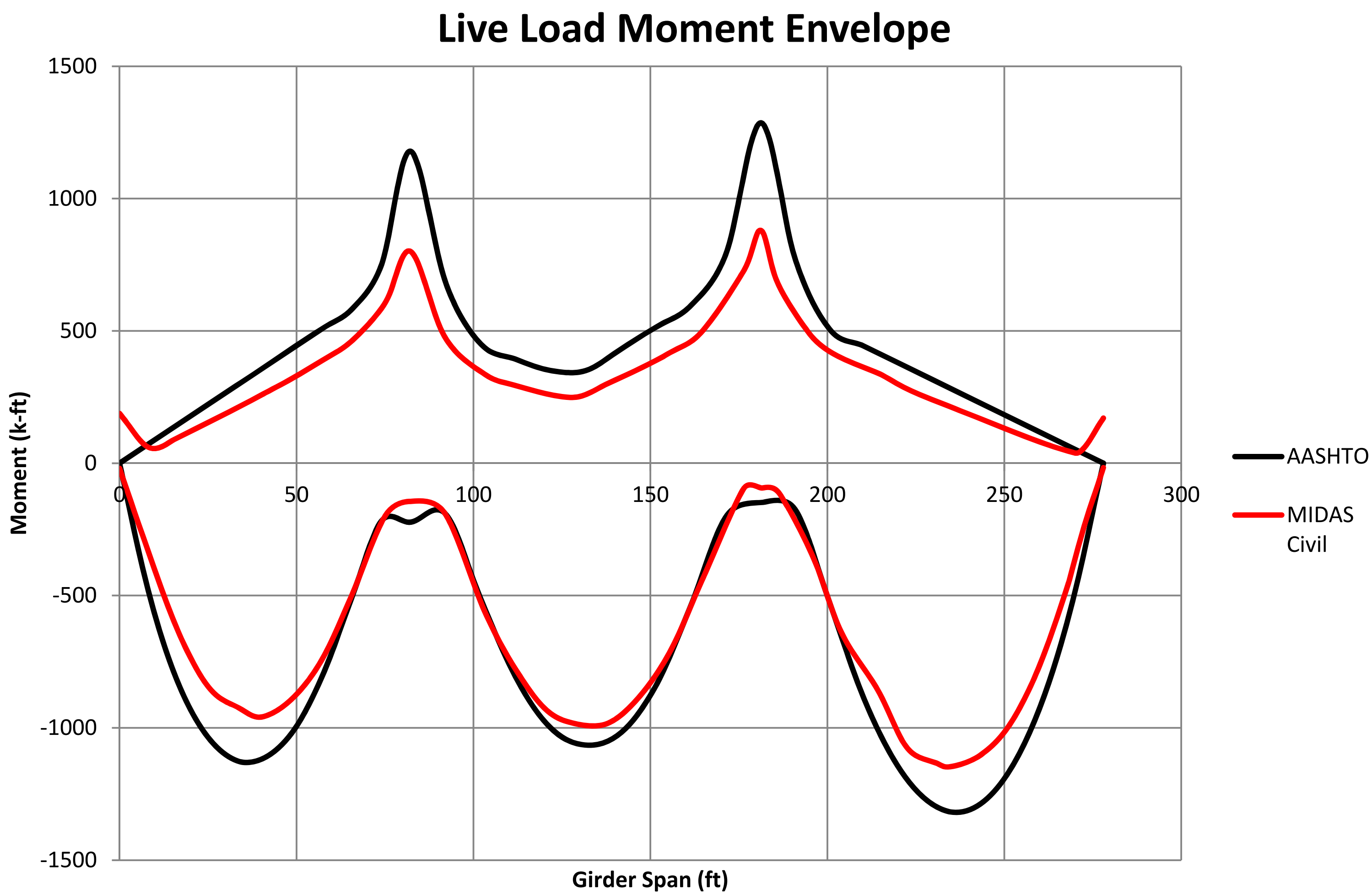



Section Data
DB/User
Composite
Section ID
1
Name
Girder Line G5/G6
Section Type :
Steel-I
Slab Width
5.34375
ft
Girder : Num
1
CTC
5.3437
ft
Slab
Bc
5.34375
ft
tc
0.75
ft
Hh
0
ft
Girder
Hw
5.66667
tw
0.041666
ft
B1
1.16667
B2
1.16667
ft
Bf1
0
Bf2
0
ft
tf1
0.083333
tf2
0.083333
ft
Bf3
0
ft
Stiffener...
Material
Select Material from DB ...
Es / Ec
6.49765
Ds / Dc
3.2716
Ps
0.3
Pc
0.2
Multiple Modulus of Elasticity
Es/Ec (Creep)
0
Es/Ec (Shrinkage)
0
Bc
tc
B1
Hh
tf1
tw
Hw
tf2
B2
1
2
y
4
3
Display Centroid
FEM
Equation
Offset : Center-Top
Change Offset ...
Consider Shear Deformation.
Consider Warping Effect(7th DOF)
Show Calculation Results...
OK
Cancel
Apply

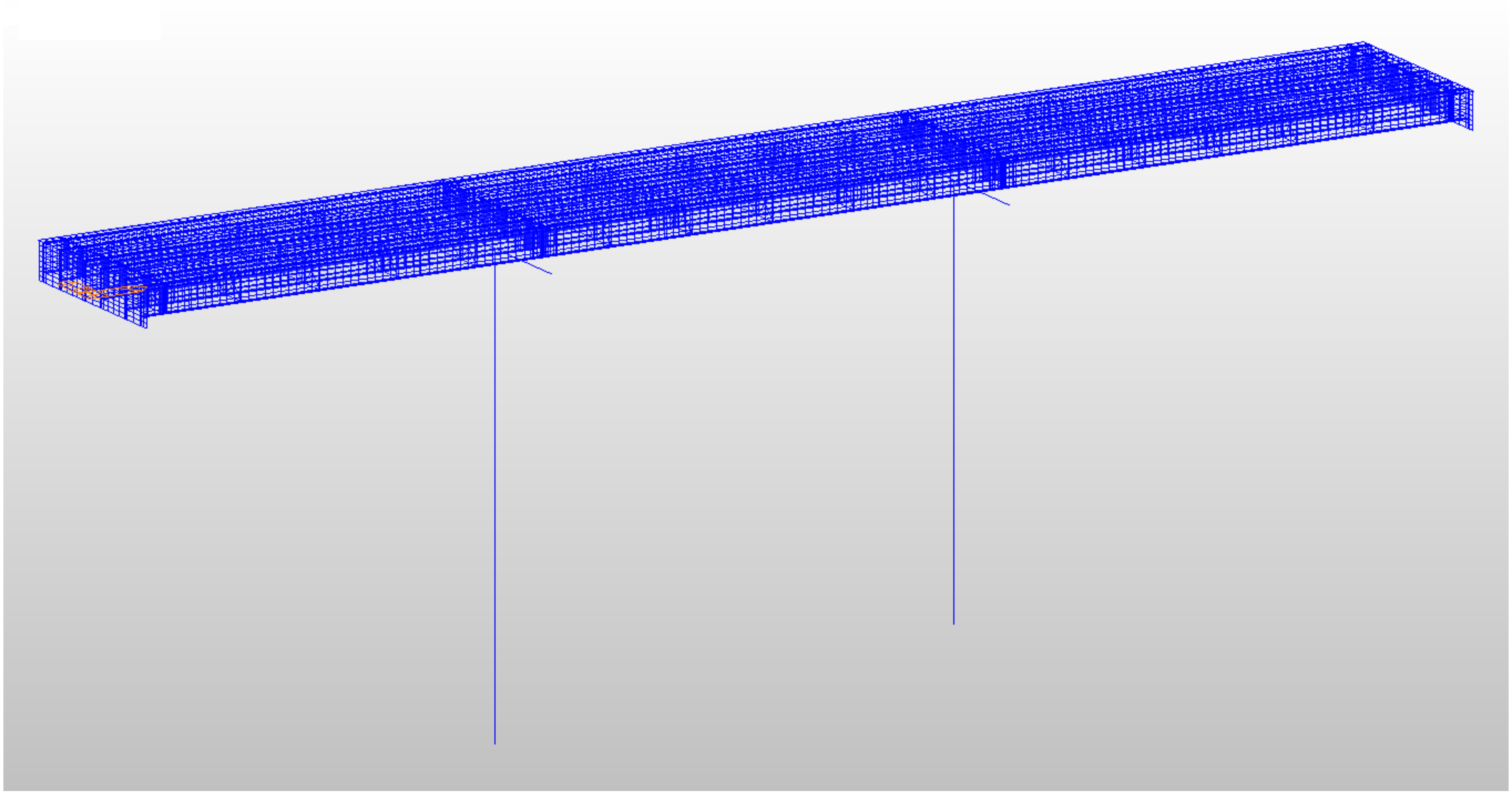


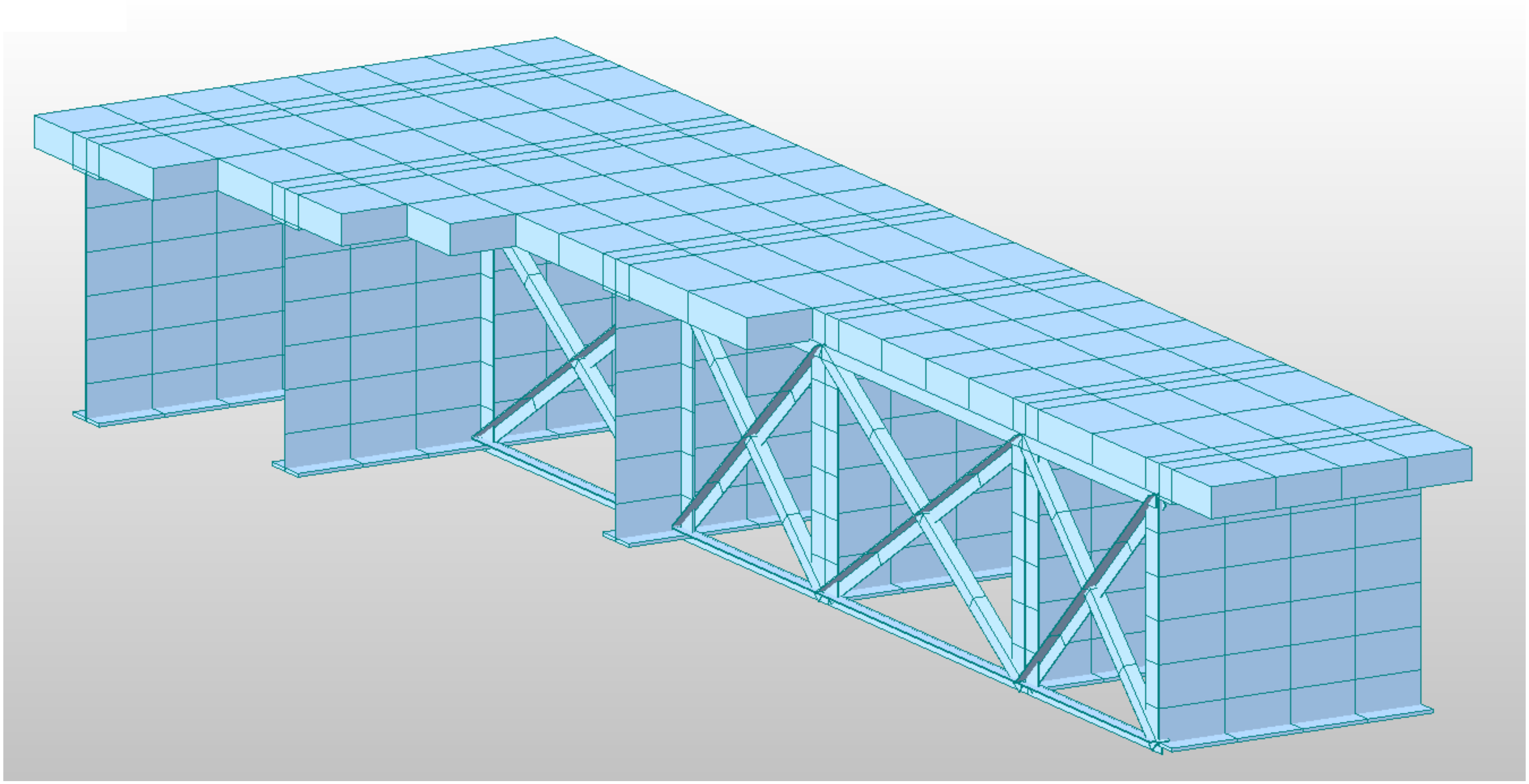


# Live Load Moment Envelope

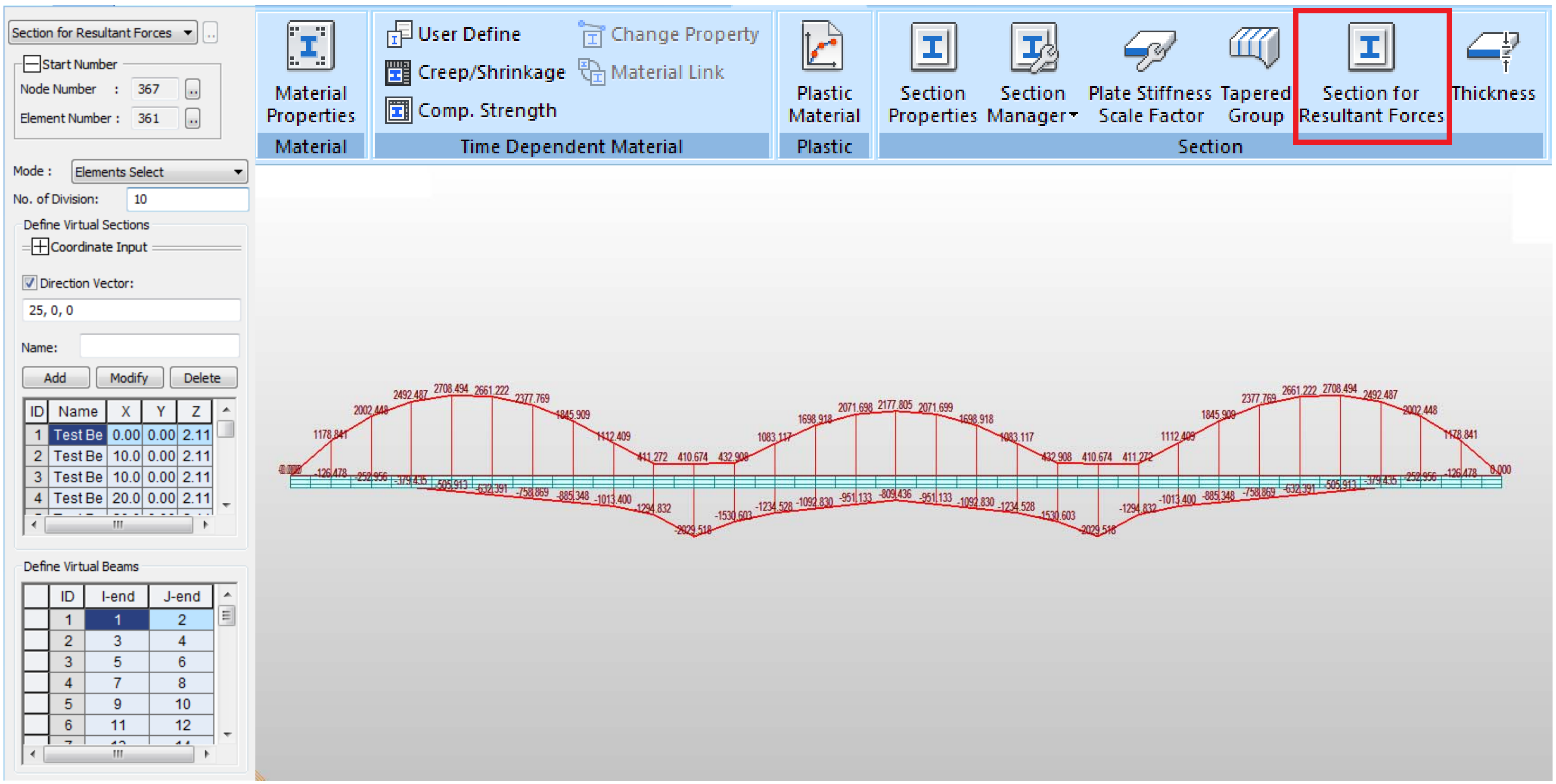


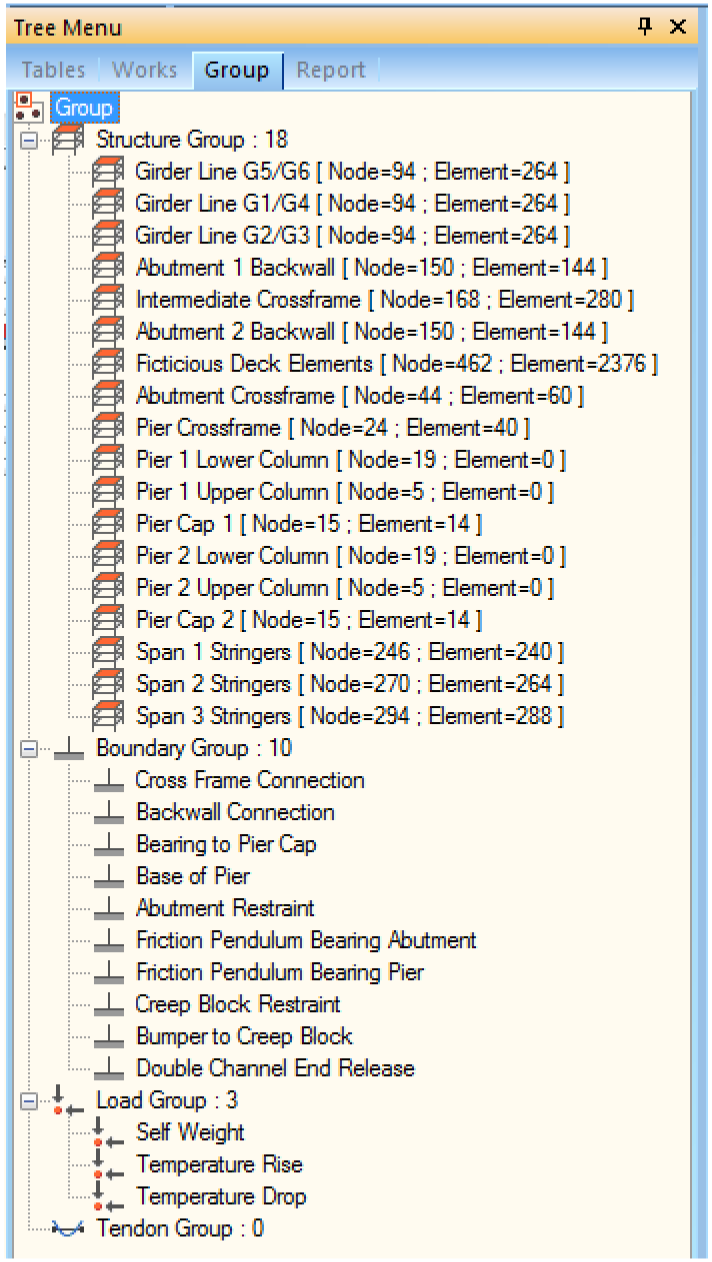
# FEA Model



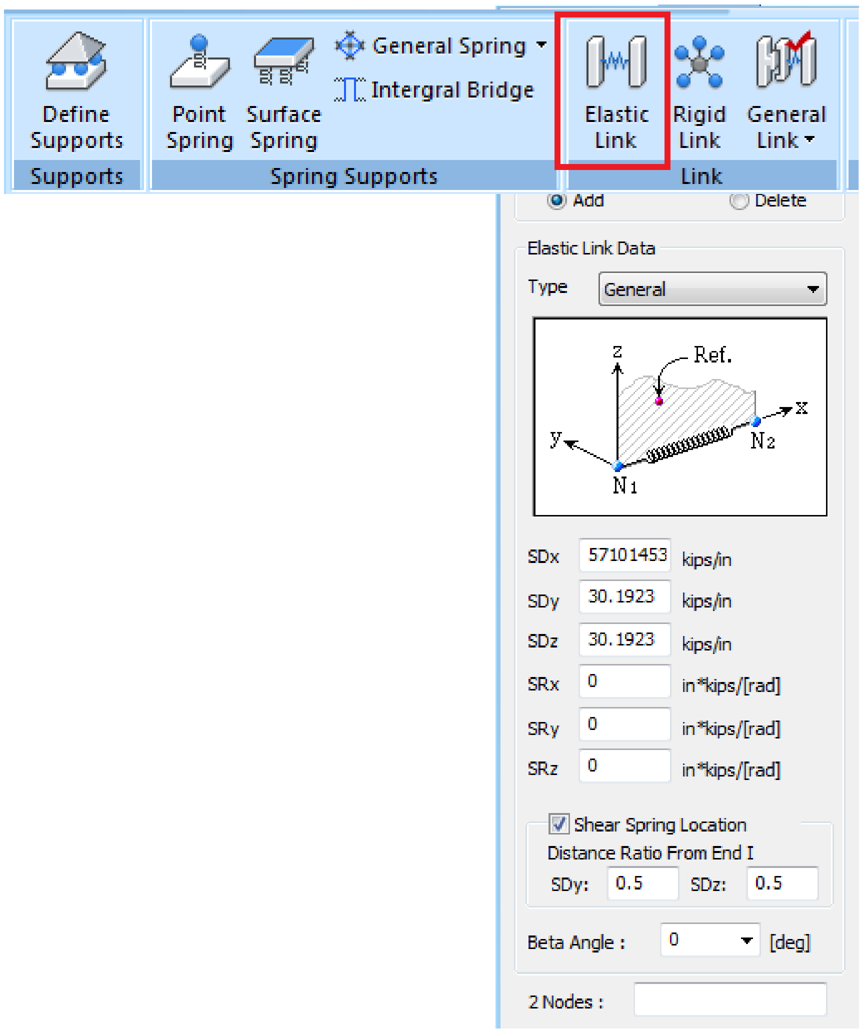


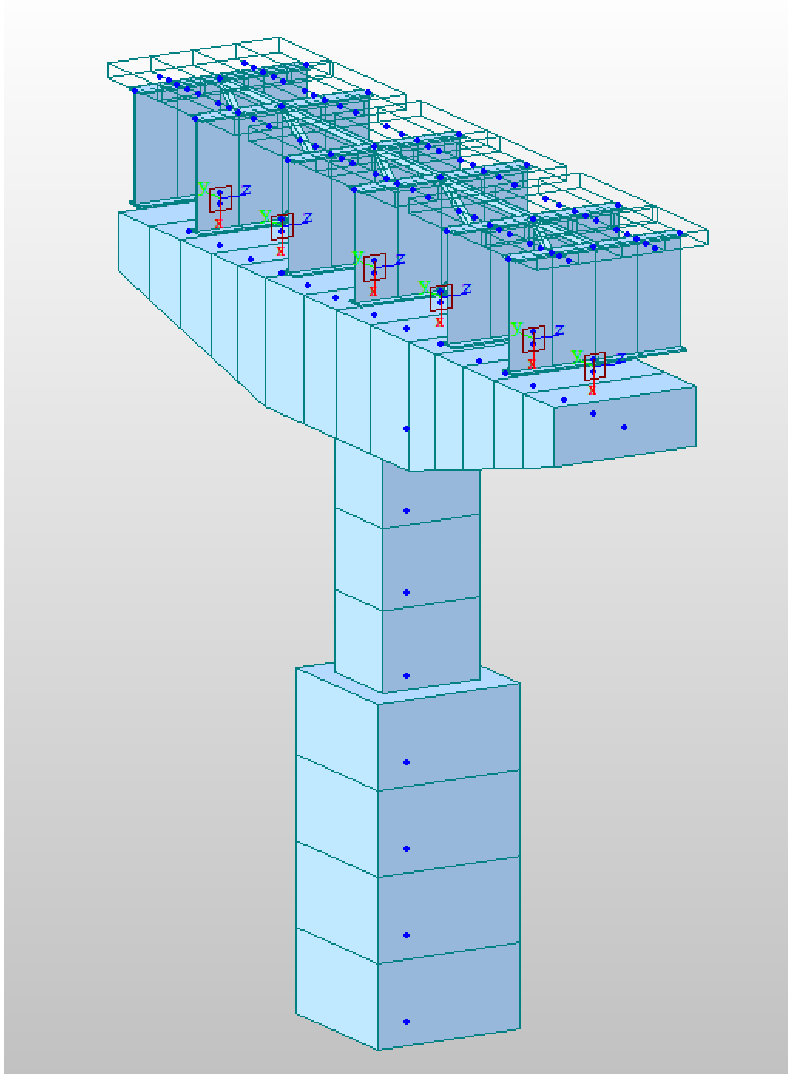
# Virtual Beam



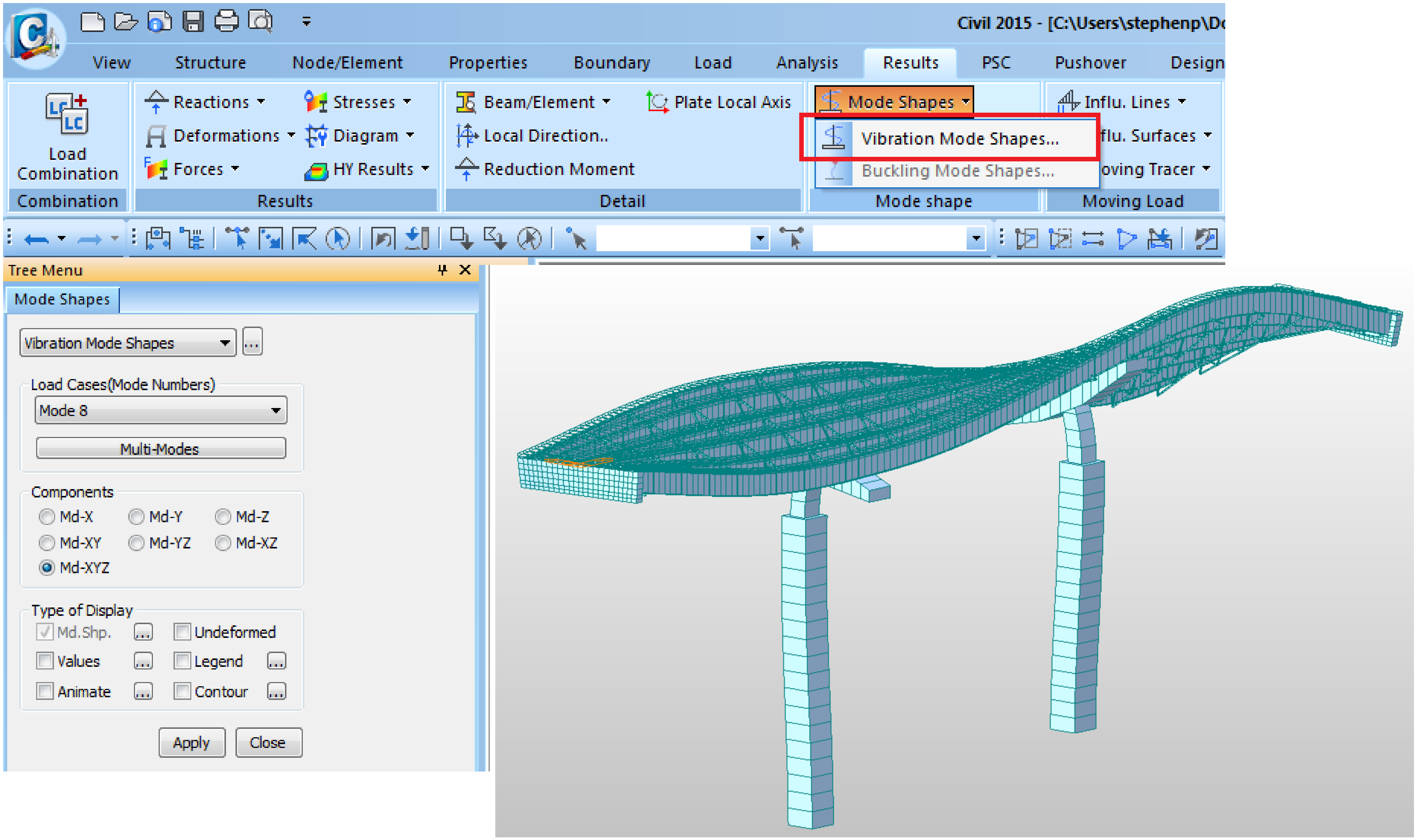

Tree Menu
Tables
Works
Group
Report
Group
Structure Group : 18
Girder Line G5/G6 [ Node=94 ; Element=264 ]
Girder Line G1/G4 [ Node=94 ; Element=264 ]
Girder Line G2/G3 [ Node=94 ; Element=264 ]
Abutment 1 Backwall [ Node=150 ; Element=144 ]
Intermediate Crossframe [ Node=168 ; Element=280 ]
Abutment 2 Backwall [ Node=150 ; Element=144 ]
Ficticious Deck Elements [ Node=462 ; Element=2376 ]
Abutment Crossframe [ Node=44 ; Element=60 ]
Pier Crossframe [ Node=24 ; Element=40 ]
Pier 1 Lower Column [ Node=19 ; Element=0 ]
Pier 1 Upper Column [ Node=5 ; Element=0 ]
Pier Cap 1 [ Node=15 ; Element=14 ]
Pier 2 Lower Column [ Node=19 ; Element=0 ]
Pier 2 Upper Column [ Node=5 ; Element=0 ]
Pier Cap 2 [ Node=15 ; Element=14 ]
Span 1 Stringers [ Node=246 ; Element=240 ]
Span 2 Stringers [ Node=270 ; Element=264 ]
Span 3 Stringers [ Node=294 ; Element=288 ]
Boundary Group : 10
Cross Frame Connection
Backwall Connection
Bearing to Pier Cap
Base of Pier
Abutment Restraint
Friction Pendulum Bearing Abutment
Friction Pendulum Bearing Pier
Creep Block Restraint
Bumper to Creep Block
Double Channel End Release
Load Group : 3
Self Weight
Temperature Rise
Temperature Drop
Tendon Group : 0

# Elastic Links



# Mode Shapes


Civil 2015 - [C:\Users\stephenp\D
View
Structure
Node/Element
Properties
Boundary
Load
Analysis
Results
PSC
Pushover
Design
Load Combination
Combination
Reactions
Stresses
Deformations
Diagram
Forces
HY Results
Results
Beam/Element
Plate Local Axis
Local Direction..
Reduction Moment
Detail
Mode Shapes
Vibration Mode Shapes...
Buckling Mode Shapes...
Mode shape
Influ. Lines
flu. Surfaces
oving Tracer
Moving Load
Tree Menu
Mode Shapes
Vibration Mode Shapes
Load Cases(Mode Numbers)
Mode 8
Multi-Modes
Components
Md-X
Md-Y
Md-Z
Md-XY
Md-YZ
Md-XZ
Md-XYZ
Type of Display
Md.Shp.
Undeformed
Values
Legend
Animate
Contour
Apply
Close

# Period and Modal Participation

| Node | Mode | UX | UY | UZ | RX | RY | RZ |
|---|---|---|---|---|---|---|---|

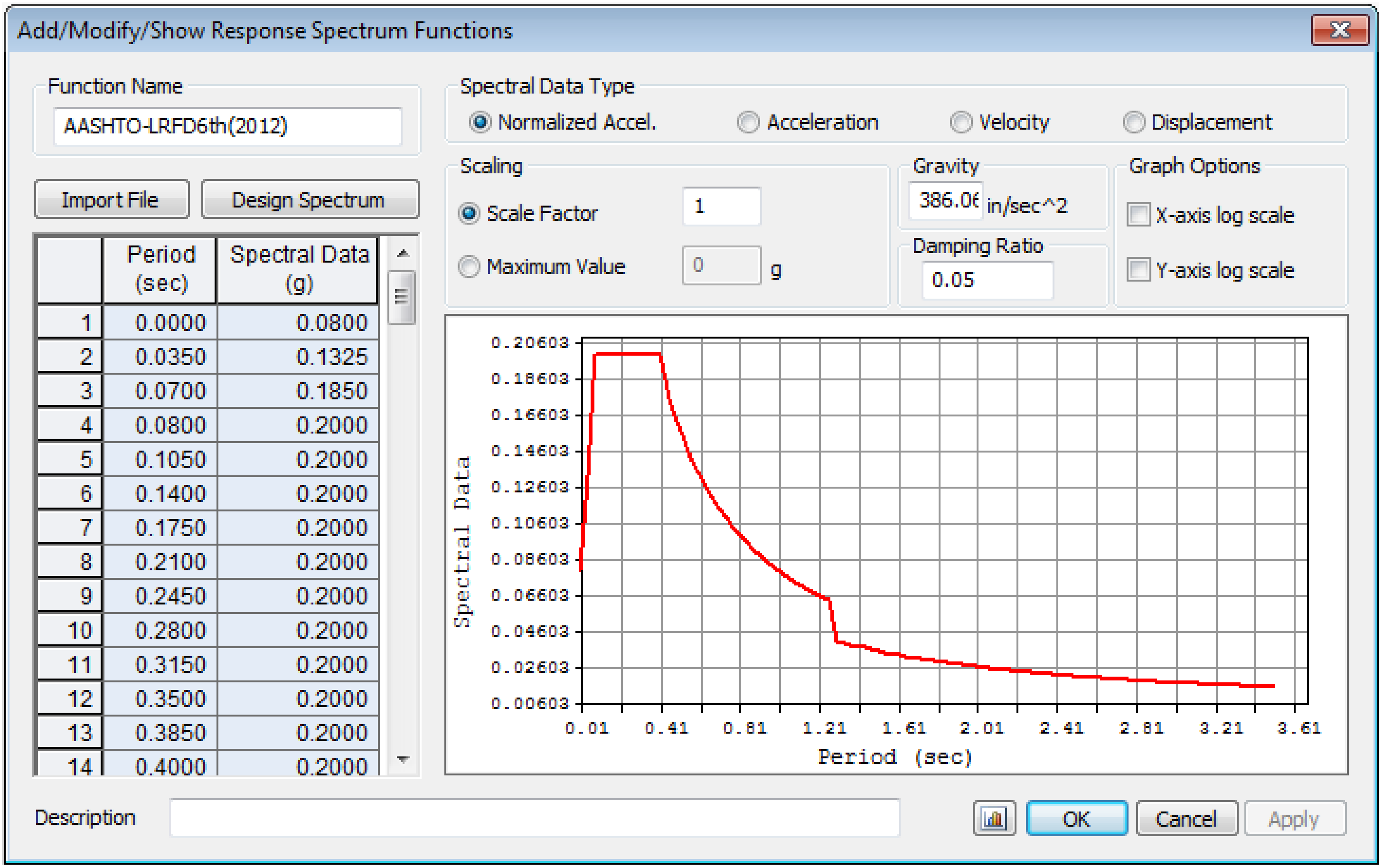
**EIGENVALUE ANALYSIS**

| Mode No | Frequency (rad/sec) | Frequency (cycle/sec) | Period (sec) | Tolerance |
|---|---|---|---|---|
| 1 | 3.639826 | 0.579296 | 1.726232 | 0.0000e+000 |
| 2 | 4.001487 | 0.636856 | 1.570213 | 0.0000e+000 |
| 3 | 4.276331 | 0.680599 | 1.469294 | 9.7138e-016 |
| 4 | 14.108509 | 2.245439 | 0.445347 | 1.4279e-016 |
| 5 | 15.619062 | 2.485851 | 0.402277 | 1.1650e-016 |
| 6 | 15.767837 | 2.509529 | 0.398481 | 4.5726e-016 |
| 7 | 17.417843 | 2.772136 | 0.360733 | 1.8737e-016 |
| 8 | 18.231100 | 2.901570 | 0.344641 | 6.3278e-015 |
| 9 | 18.981985 | 3.021077 | 0.331008 | 1.5776e-016 |
| 10 | 21.518424 | 3.424764 | 0.291991 | 1.7125e-013 |
| 11 | 21.767444 | 3.464396 | 0.288651 | 1.6915e-014 |
| 12 | 22.521224 | 3.584364 | 0.278990 | 1.2216e-014 |
| 13 | 23.661029 | 3.765770 | 0.265550 | 4.8940e-014 |
| 14 | 25.255346 | 4.019513 | 0.248786 | 2.9819e-013 |
| 15 | 27.795231 | 4.423748 | 0.226053 | 1.1741e-011 |

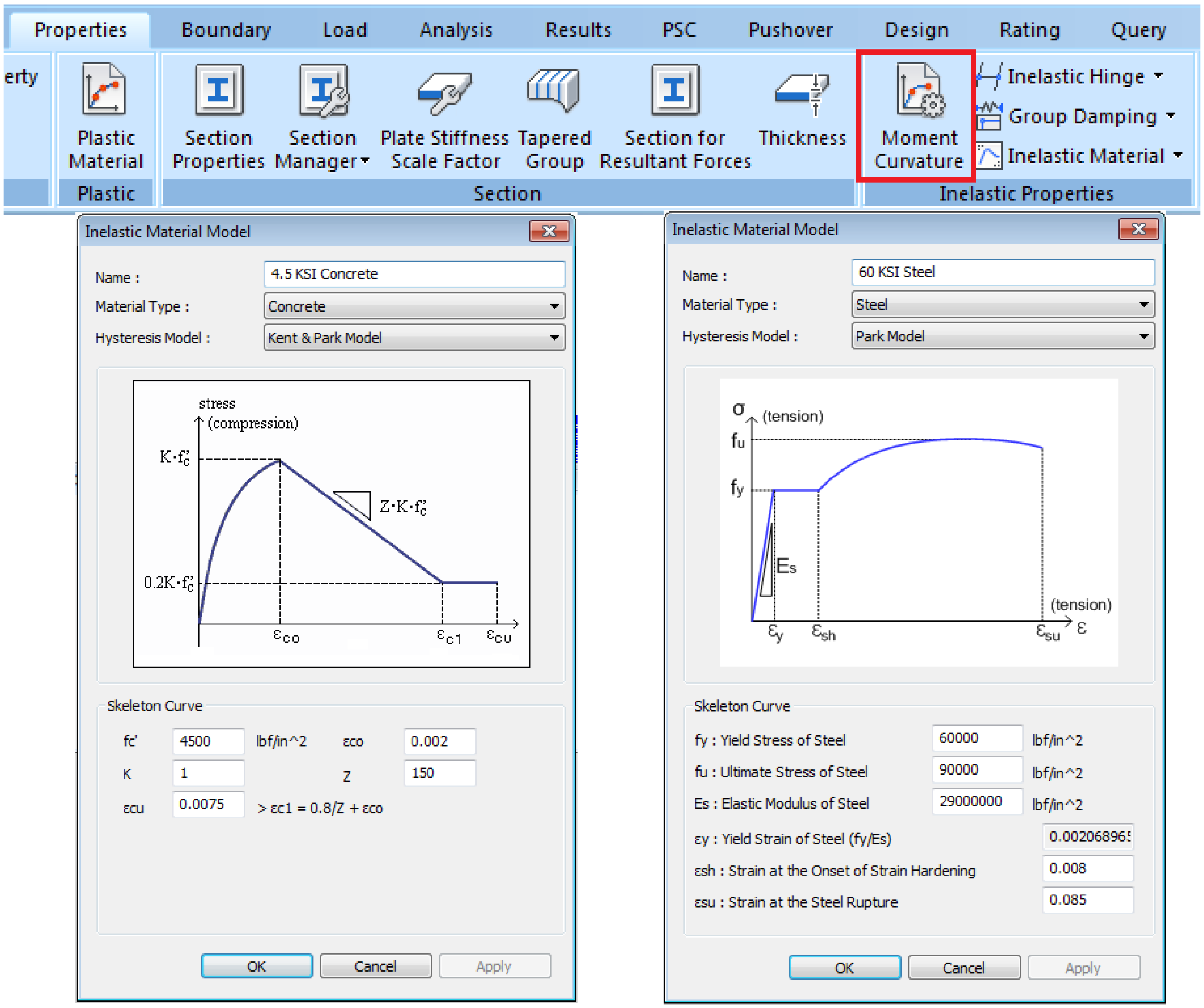
**MODAL PARTICIPATION MASSES PRINTOUT**

| Mode No | TRAN-X MASS(%) | TRAN-X SUM(%) | TRAN-Y MASS(%) | TRAN-Y SUM(%) | TRAN-Z MASS(%) | TRAN-Z SUM(%) | ROTN-X MASS(%) | ROTN-X SUM(%) | ROTN-Y MASS(%) | ROTN-Y SUM(%) | ROTN-Z MASS(%) | ROTN-Z SUM(%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 38.74 | 38.74 | 32.71 | 32.71 | 0.00 | 0.00 | 0.50 | 0.50 | 0.08 | 0.08 | 16.49 | 16.49 |
| 2 | 10.01 | 48.75 | 9.93 | 42.64 | 0.00 | 0.01 | 0.07 | 0.58 | 0.00 | 0.08 | 56.69 | 73.18 |
| 3 | 22.08 | 70.82 | 42.60 | 85.25 | 0.00 | 0.01 | 0.41 | 0.99 | 0.12 | 0.20 | 0.10 | 73.29 |
| 4 | 0.12 | 70.94 | 0.00 | 85.25 | 4.80 | 4.81 | 1.47 | 2.46 | 2.34 | 2.54 | 0.01 | 73.30 |
| 5 | 17.04 | 87.98 | 4.98 | 90.23 | 0.05 | 4.86 | 1.22 | 3.67 | 1.53 | 4.07 | 0.50 | 73.80 |
| 6 | 1.40 | 89.38 | 0.29 | 90.52 | 0.65 | 5.51 | 2.37 | 6.04 | 0.94 | 5.01 | 0.00 | 73.80 |
| 7 | 2.03 | 91.41 | 0.65 | 91.17 | 0.03 | 5.54 | 0.09 | 6.13 | 9.99 | 15.01 | 1.65 | 75.45 |
| 8 | 0.91 | 92.32 | 0.34 | 91.51 | 0.00 | 5.54 | 0.01 | 6.14 | 0.12 | 15.12 | 16.11 | 91.56 |
| 9 | 0.59 | 92.91 | 0.20 | 91.71 | 0.29 | 5.82 | 0.04 | 6.18 | 7.97 | 23.09 | 0.85 | 92.40 |
| 10 | 5.29 | 98.20 | 4.40 | 96.11 | 0.91 | 6.73 | 2.58 | 8.77 | 0.02 | 23.11 | 0.23 | 92.63 |
| 11 | 0.02 | 98.22 | 0.00 | 96.11 | 6.35 | 13.08 | 9.80 | 18.57 | 0.23 | 23.34 | 0.09 | 92.72 |
| 12 | 0.07 | 98.29 | 0.06 | 96.18 | 2.07 | 15.16 | 6.41 | 24.98 | 1.66 | 25.00 | 0.01 | 92.73 |
| 13 | 0.01 | 98.30 | 0.02 | 96.20 | 17.01 | 32.17 | 5.17 | 30.15 | 0.20 | 25.20 | 0.02 | 92.75 |
| 14 | 0.01 | 98.32 | 0.00 | 96.20 | 3.88 | 36.05 | 11.00 | 41.15 | 2.37 | 27.57 | 0.01 | 92.76 |
| 15 | 0.07 | 98.38 | 0.14 | 96.34 | 3.55 | 39.60 | 1.27 | 42.42 | 0.01 | 27.58 | 0.41 | 93.17 |

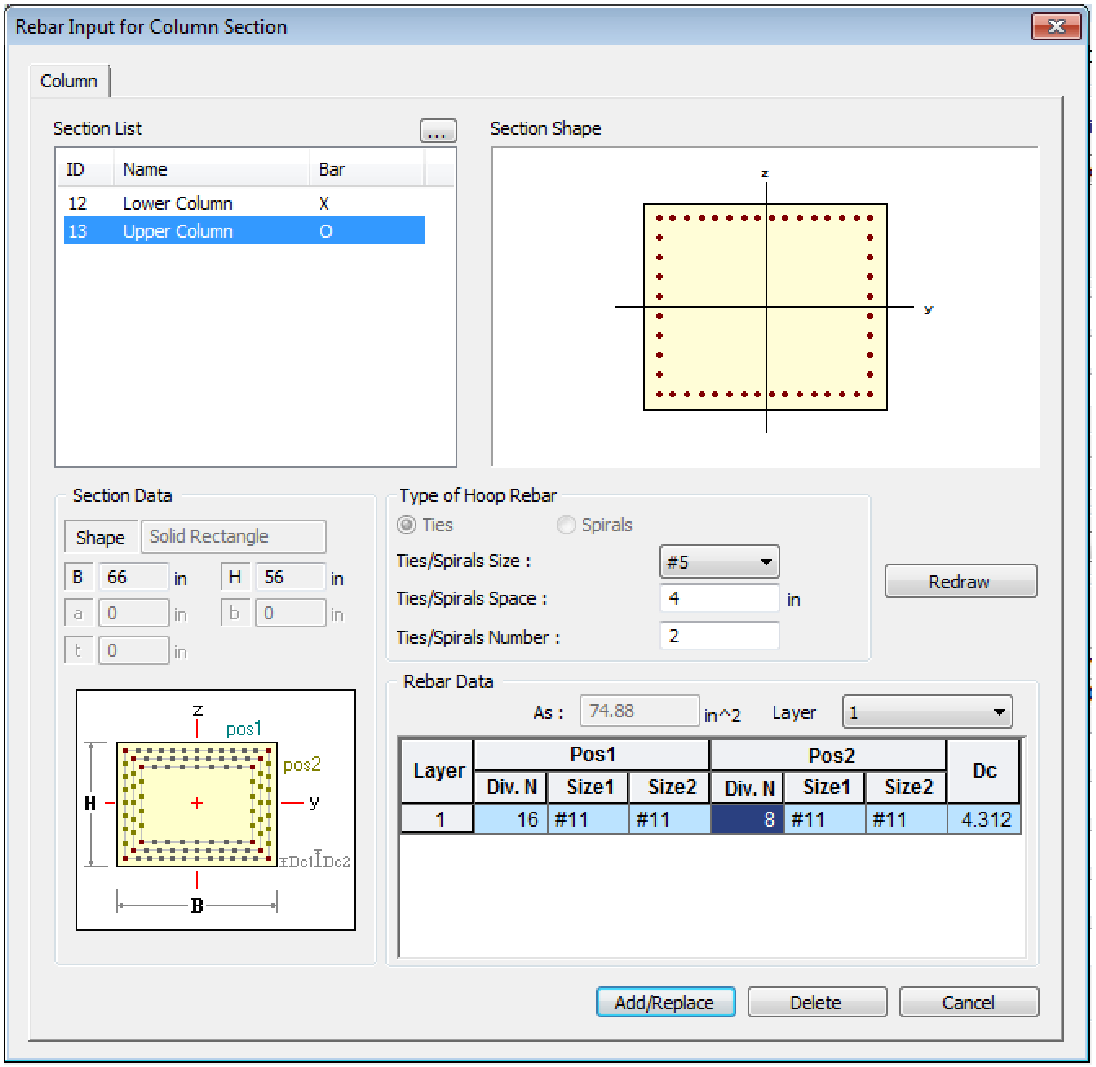
# Spectral Acceleration



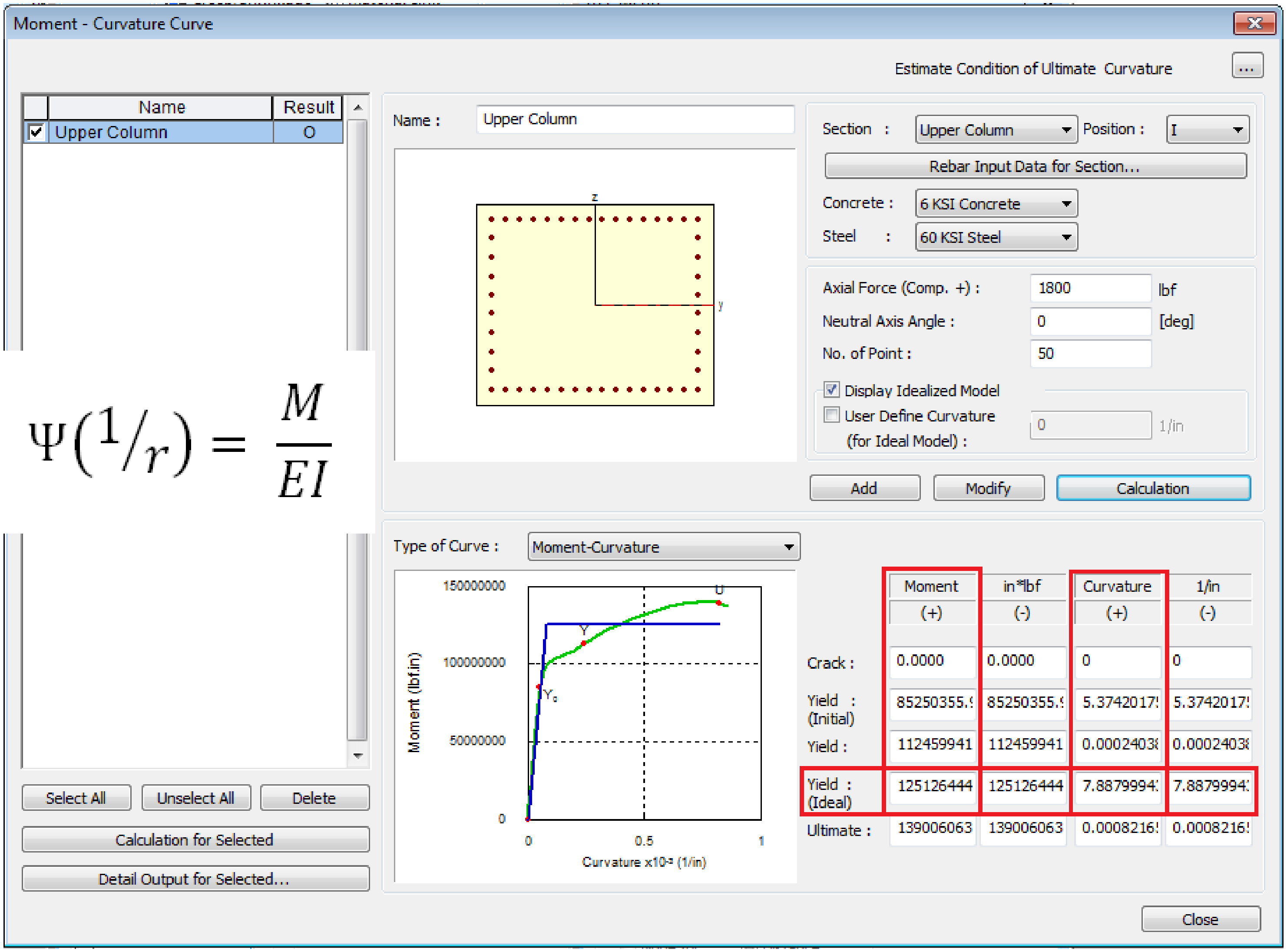
# Moment Curvature Toolbox



# Moment Curvature Toolbox



# Moment Curvature Toolbox




$$\Psi({}^{1}/_{r}) = \frac{M}{EI}$$

# Questions?