

**NISTIR 7886**

# **Finite-element Models of the National Fire Research Laboratory (NFRL) and Modular Support Structure**

Dat Duthinh

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**NIST**  
**National Institute of  
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U.S. Department of Commerce

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# **Finite-element Models of the National Fire Research Laboratory (NFRL) and Modular Support Structure**

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*Materials and Structural Systems Division  
Engineering Laboratory*

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U.S. Department of Commerce  
*Rebecca Blank, Acting Secretary*

National Institute of Standards and Technology  
*Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director*

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Finite-element models of the  
National Fire Research Laboratory (NFRL)  
and modular support structure

**Summary:** This report documents the development of finite-element models (FEM) of the National Fire Research Laboratory (NFRL) and its modular support structure. The models enable a future user of the NFRL to add a potential test structure and perform thermal and structural simulations of the test. This report consists of two parts. Part 1 covers the NFRL proper, namely the strong floor, strong wall, basement walls and slab. It describes the model and provides results of structural analyses of all the load cases that were specified in the design documents. Part 2 covers the modular support structure, with the various components developed individually, then assembled in an example test case.

**Keywords:** finite-element model; fire research; modular structure; prestressed concrete; reinforced concrete; steel; structural analysis; thermal analysis.

**Units:** As the design of the NFRL was specified and performed in customary units, so were the present calculations. SI units are included in parenthesis in the text.

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## Part 1, Chapter 1

### Finite-Element Model (FEM) of

### the National Fire Research Laboratory (NFRL)

This report documents the development of finite-element models (FEM) of the National Fire Research Laboratory (NFRL, Part 1) and its modular support structure (Part 2). The models enable a future user of the NFRL to add a potential test structure and perform thermal and structural simulations of the test. Part 1 covers the NFRL proper, namely the strong floor, strong wall, basement walls and slab. It describes the model and provides results of structural analyses of all the load cases that were specified in the design documents.

**Elements:** The model includes the strong wall, strong floor, basement walls and slab (Fig. 1.1), all represented by 59 400 solid elements (ANSYS 8-node SOLID 185 for structural and thermal analyses). As mesh nodes are defined at all loading and anchorage points, typical element size is 2 ft (0.61 m), which is the distance between two adjacent loading points in the strong floor and strong wall. To accommodate various geometric constraints, however, many elements are smaller than that. Also, for proper modeling of structural behavior, the through-thickness element dimension is much smaller than 2 ft (0.61 m). The 4 ft (1.22 m) thick strong floor is modeled with 5 layers of elements (including one layer for the topmost 6 inch (0.15 m) sacrificial layer), the 4 ft (1.22 m) thick strong wall with 4 layers, and the 16 inch (0.41 m)

Table 1.1 Properties

|                    |   |
|--------------------|---|
| Concrete           | Starting numbers  |
| Keypoints          | 0   |
| Lines              | 0   |
| Areas              | 0   |
| Volumes            | 0   |
| Elements           | 0   |
| Nodes              | 0   |
| Coordinates system | Global: x points North, y West, z up<br>Origin: Southeast corner, bottom of base slab, beneath overhang of strong floor (Fig. 2).   |
| Element type       | 1 BEAM188 (1 orientation + 2 end nodes)<br>2 SURF154 (4 nodes loading surface)<br>3 SOLID185 (8 nodes)  |
| Sections           | 1 rectangular solid (loading strip)   |
| Concrete Materials | 1 $f'_c = 3500$ psi (24 MPa) slab on grade;<br>2 $f'_c = 4000$ psi (28 MPa) basement North box walls;<br>3 $f'_c = 4000$ psi (28 MPa) basement walls;<br>4 $f'_c = 5000$ psi (34 MPa) columns;<br>5 $f'_c = 6000$ psi (41 MPa) strong floor;<br>6 $f'_c = 6000$ psi (41 MPa) strong wall. |

thick basement walls with 2 or 3 layers each (Figs. 1.2 - 1.4). The NFRL model also includes 5400 surface elements (ANSYS 4-node SURF 154) and 500 beam elements (ANSYS BEAM 188 with two end nodes and one orientation node) for applying surface and line loads. The coordinate system and other properties are listed in Table 1.1.

**Materials:** Since the NFRL is designed to operate well within the elastic range, the material properties are linearly elastic. The modulus of elasticity  $E$  of normal weight concrete is (ACI 318-05 § 8.5.1):

$$\frac{E}{psi} = 57000 \sqrt{\frac{f'_c}{psi}} \quad or \quad \frac{E}{MPa} = 4700 \sqrt{\frac{f'_c}{MPa}}$$

where  $f'_c$  is the specified compressive (cylinder crushing) strength. For the strong floor and strong wall,  $f'_c = 6000$  psi (41 MPa) and  $E = 4400$  ksi (30 GPa); for the basement walls,  $f'_c = 4000$  psi (28 MPa) and  $E = 3600$  ksi (25 GPa).

For normal weight concrete, the average splitting tensile strength  $f_{ct}$  is (ACI 318-05 § R11.2.1.1):

$$\frac{f_{ct}}{psi} = 6.7 \sqrt{\frac{f'_c}{psi}} \quad or \quad \frac{f_{ct}}{MPa} = 0.56 \sqrt{\frac{f'_c}{MPa}}$$

For the strong floor and strong wall,  $f_{ct} = 520$  psi (3.6 MPa); and for the basement walls,  $f_{ct} = 420$  psi (2.9 MPa). In the design of reinforced or post-tensioned concrete structures by finite-elements, the current practice is to calculate elastic stresses with plain concrete elements, and use the results to design the passive or tensioned reinforcements section by section. Since the present FEM is not intended to be used for structural design, which was already completed before this project was initiated, the second step is omitted.

**Load steps:** All the load steps that were specified in the design documents of the NFRL (Capital Improvements Group, 2010) were run for verification (Table 1.2). The results confirmed the soundness of the design and the validity of the elastic assumption. Only a few localized sections at corners and stress concentrations exceeded the concrete splitting strength. Considering that the design load cases are extremely demanding and unlikely to be reached ever, and the neglect of the tensile reinforcement in the model, these potential crack locations should not cause concern. Note that load step 7, (Figs. 1.16-1.17, is not part of the design basis.

The APDL (ANSYS Programming Design Language) commands for the model and the load steps are included at the end of the chapter.

Table 1.2 Load steps

| Load steps | Description  |
|------------|--|
| 3          | Gravity + Prestress (G + PS)   |
| 4          | G + PS + FX 10 k/ft (146 kN/m) top of strong wall  |
| 5          | G + PS – FX 10 k/ft (146 kN/m) top of strong wall  |
| 6          | G + PS – FZ 1.35 k/ft <sup>2</sup> (64.6 kPa) entire floor   |
| 7          | G + PS + FX 50 k/load point (222 kN/lp) facing wall – FX reaction at wall (not in design basis)  |
| 8          | G + PS + FX 50 k/load point (222 kN/lp) entire floor   |
| 9          | G + PS – FX 50 k/load point (222 kN/lp) entire floor   |
| 10         | G + PS + FY 50 k/load point (222 kN/lp) entire floor   |
| 11         | G + PS – FZ 1.80 k/ft <sup>2</sup> (86.2 kPa) over 20' x 20' (6.1 m x 6.1 m) at floor center   |
| 12         | G + PS – FZ 1.80 k/ft <sup>2</sup> (86.2 kPa) over 20' x 20' (6.1 m x 6.1 m) at floor Southwest corner                                   |
| 13         | G + PS – FZ 1.80 k/ft <sup>2</sup> (86.2 kPa) over 20' x 20' (6.1 m x 6.1 m) at floor Northeast corner                                   |
| 14         | G + PS + FZ 100 k (445 kN) every 4' (1.2 m)  |
| 15         | G + PS – FZ 100 k (445 kN) every 4' (1.2 m)  |
| 16         | G + PS ± FZ 100 k (445 kN) every 4' (1.2 m) alternate  |
| 17         | G + PS + FZ 100 k (445 kN) every 6' (1.8 m) – FZ 100 k (445 kN) every 2' (0.61 m) centered   |
| 18         | G + PS + FX 50 k/load point (222 kN/lp) entire floor + FZ 100 k (445 kN) every 6' (1.8 m) – FZ 100 k (445 kN) every 2' (0.61 m) centered |
| 19         | G + PS + FX 50 k/load point (222 kN/lp) entire floor + FZ 100 k (445 kN) every 4' (1.2 m)  |
| 20         | G + PS + FX 50 k/load point (222 kN/lp) entire floor – FZ 100 k (445 kN) every 4' (1.2 m)  |
| 21         | G + PS + FX 50 k/load point (222 kN/lp) entire floor ± FZ 100 k (445 kN) every 4' (1.2 m) alternate                                      |

**References:**

American Concrete Institute International (2005) *“Building Code Requirements for Structural Concrete,”* ACI 318-05, Farmington Hills, MI 48333

Capital Improvements Group (2010) *“Building 205 Addition and Modification 100 % Submission Design Drawings,”* National Institute of Standards and Technology, Gaithersburg, MD 20899

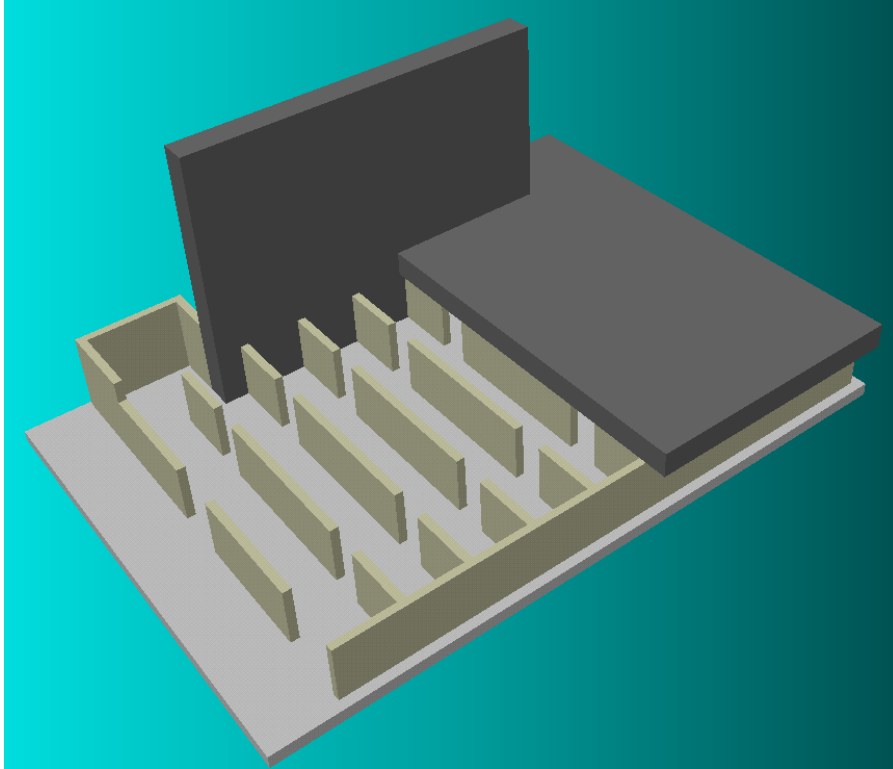


Fig. 1.1 View of NFRL with part of strong floor removed

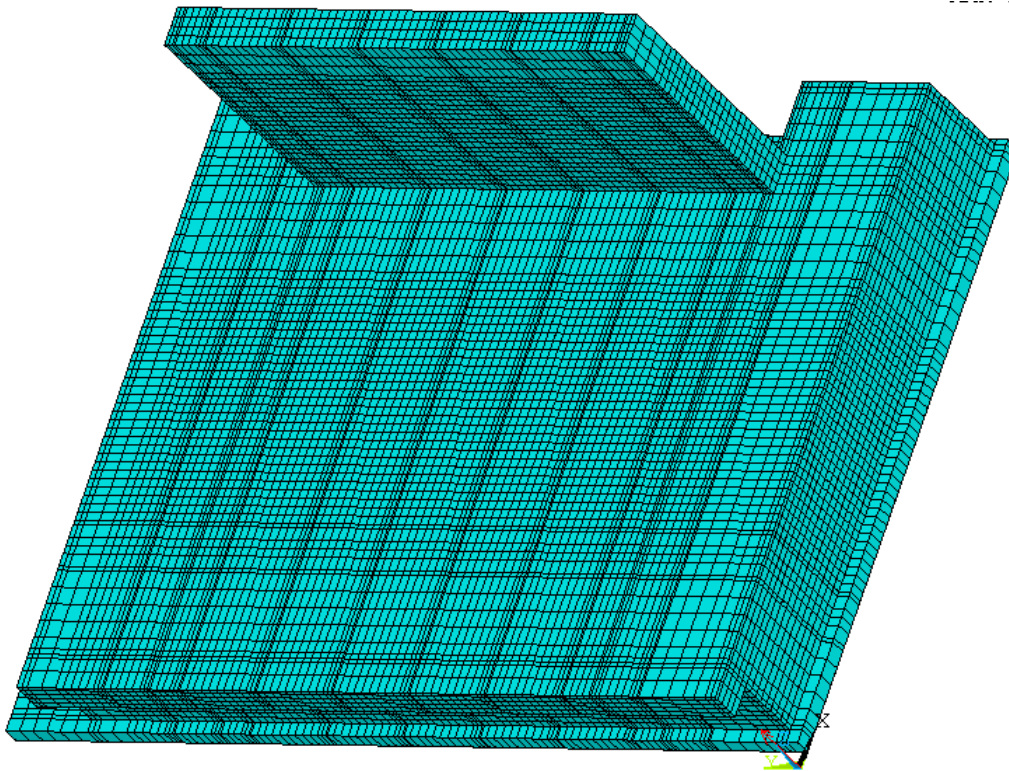


Fig. 1.2 Mesh of strong floor, strong wall and side wall



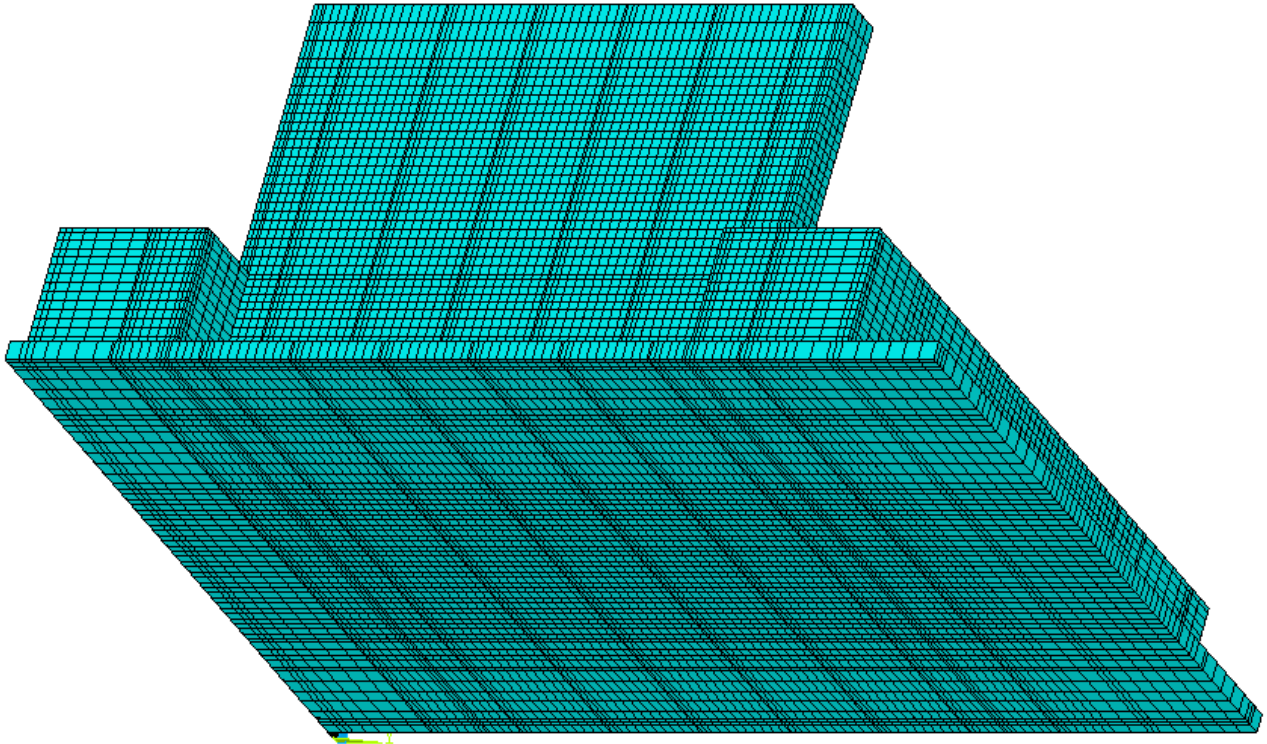


Fig. 1.3 Mesh of base slab, strong wall and back walls

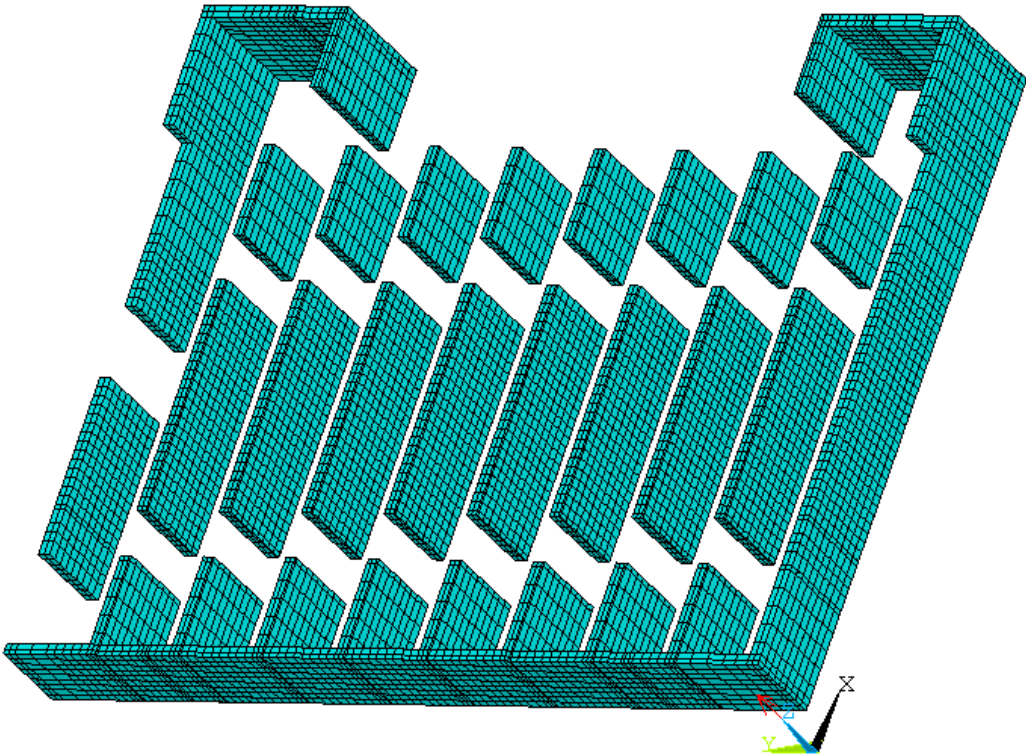


Fig. 1.4 Mesh of basement walls

STEP=3  
SUB =1  
TIME=3  
SX (AVG)  
RSYS=0  
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SMN =-.192446  
SMX =.041955

10:10:19

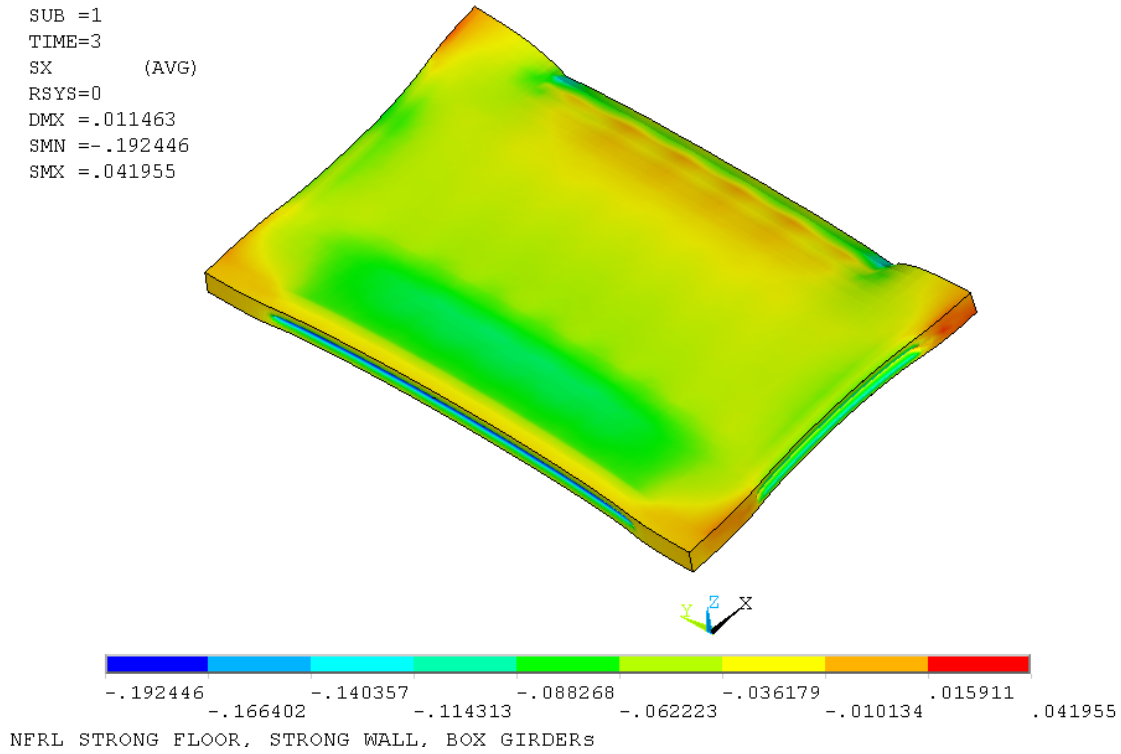


Fig. 1.5 LS 3: Gravity and prestress (G+PS). x - stress (1ksi=6.89 MPa), strong floor

STEP=3  
SUB =1  
TIME=3  
SY (AVG)  
RSYS=0  
DMX =.011463  
SMN =-.379878  
SMX =.04913

10:13:56

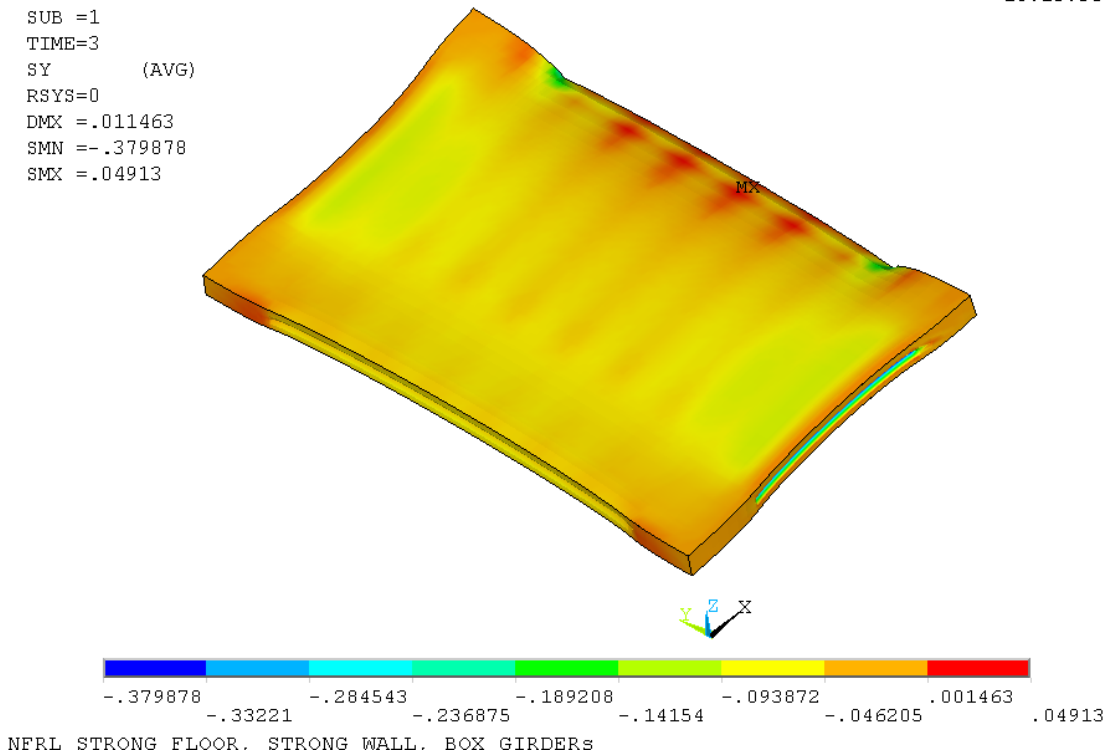


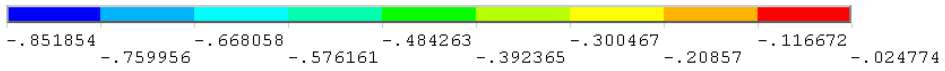
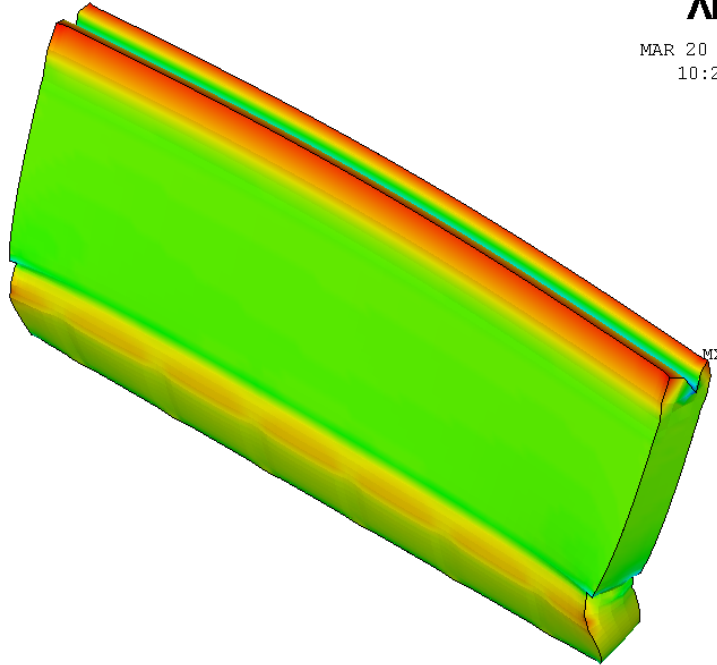
Fig. 1.6 LS 3: Gravity and prestress (G+PS). y - stress (1ksi=6.89 MPa), strong floor

1

NODAL SOLUTION  
STEP=3  
SUB =1  
TIME=3  
SZ (AVG)  
RSYS=0  
DMX =.055646  
SMN =-.851854  
SMX =-.024774

ANSYS

MAR 20 2012  
10:22:07



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.7 LS 3: Gravity and prestress (G+PS). Vertical stress (1ksi=6.89 MPa), strong wall

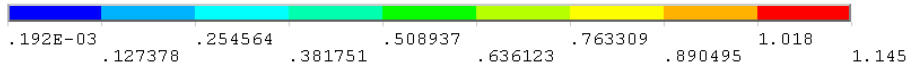
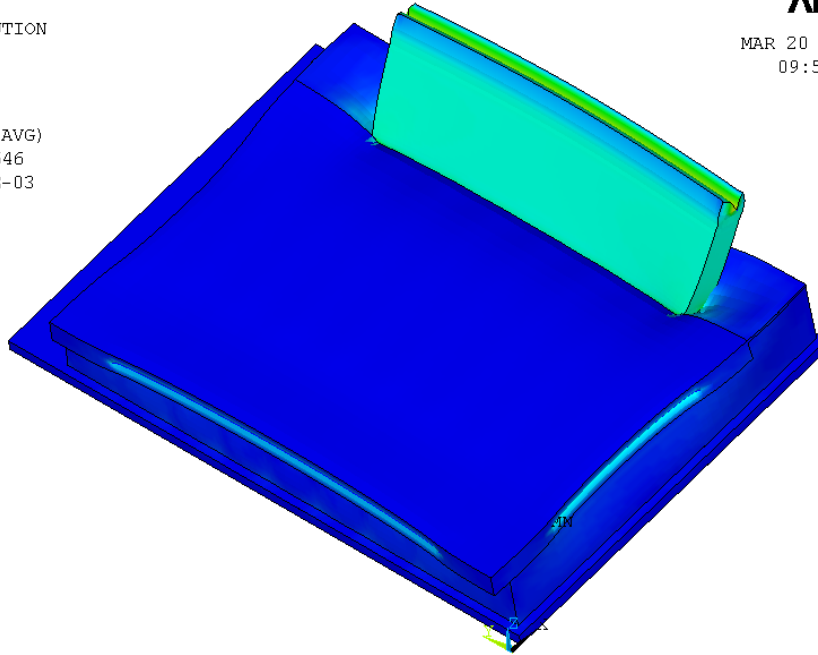
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NODAL SOLUTION

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SUB =1  
TIME=3  
SEQV (AVG)  
DMX =.055646  
SMN =.192E-03  
SMX =1.145

ANSYS

MAR 20 2012  
09:55:25



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.8 LS 3: Gravity and prestress (G+PS). Von Mises stress (1ksi=6.89 MPa), strong wall, floor

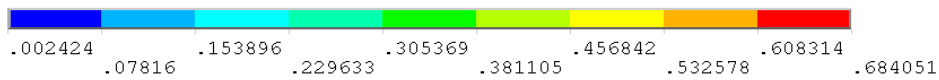
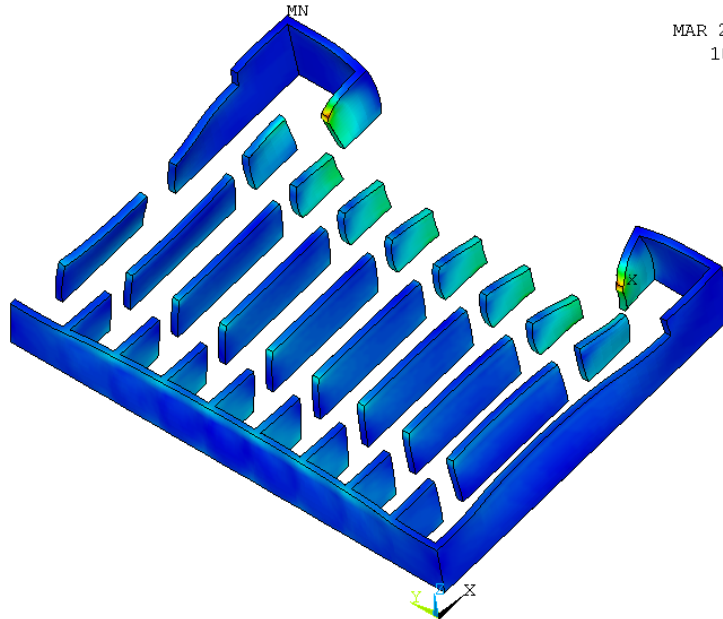
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NODAL SOLUTION

STEP=3  
SUB =1  
TIME=3  
SEQV (AVG)  
DMX =.013896  
SMN =.002424  
SMX =.684051

ANSYS

MAR 20 2012  
10:25:20



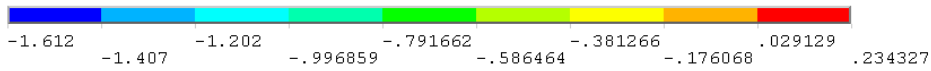
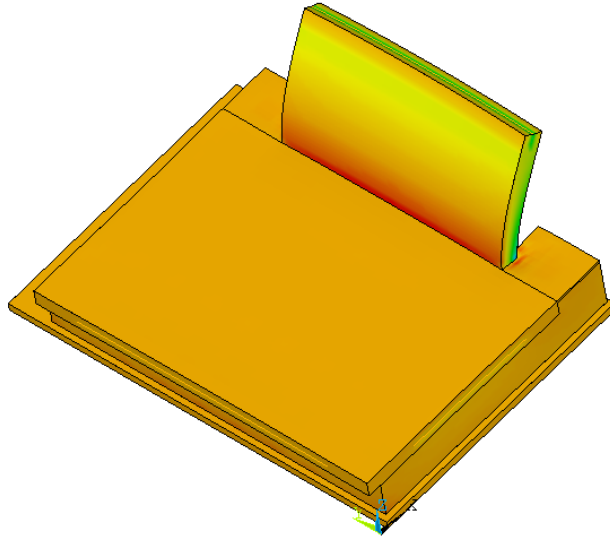
NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.9 LS 3: Gravity and prestress (G+PS). Von Mises stress (1ksi=6.89 MPa), basement

1  
 NODAL SOLUTION  
 STEP=4  
 SUB =1  
 TIME=4  
 SZ (AVG)  
 RSYS=0  
 DMX =.337257  
 SMN =-1.612  
 SMX =.234327

ANSYS

MAR 20 2012  
 10:31:05

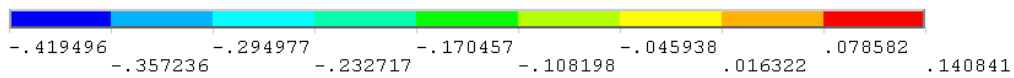
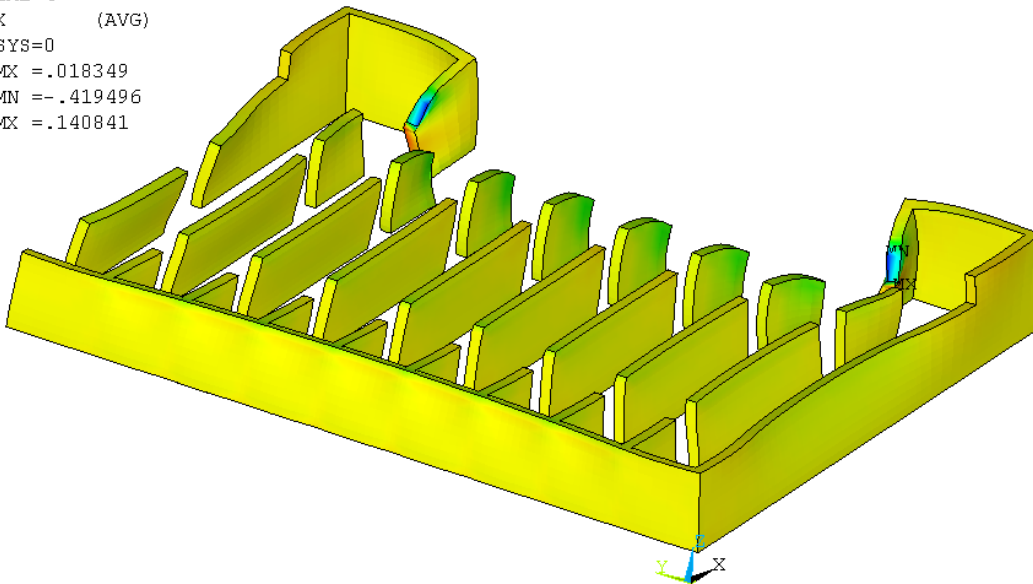


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.10 LS 4: G+PS+FX 10 kip/ft (146 kN/m) wall top. Vertical stress (1ksi=6.89 MPa), strong wall, floor

STEP=4  
 SUB =1  
 TIME=4  
 SX (AVG)  
 RSYS=0  
 DMX =.018349  
 SMN =-.419496  
 SMX =.140841

08:27:44



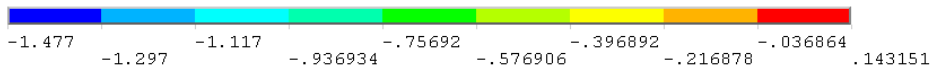
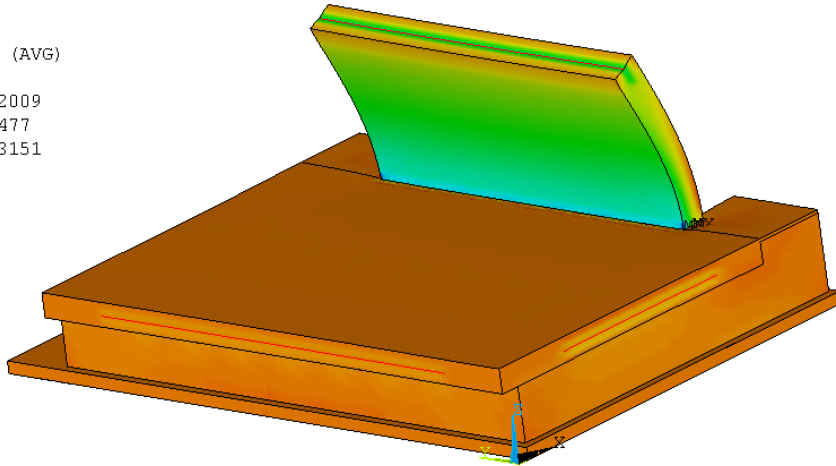
NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.11 LS 4: G+PS+FX 10 kip/ft (146 kN/m) top of wall. x stress (1ksi=6.89 MPa), basement walls

1  
 NODAL SOLUTION  
 STEP=5  
 SUB =1  
 TIME=5  
 SZ (AVG)  
 RSYS=0  
 DMX =.282009  
 SMN =-1.477  
 SMX =.143151

ANSYS

MAR 20 2012  
 10:36:58

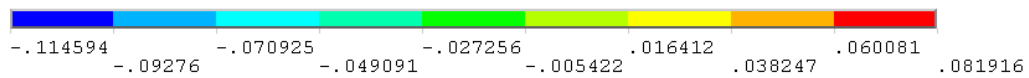
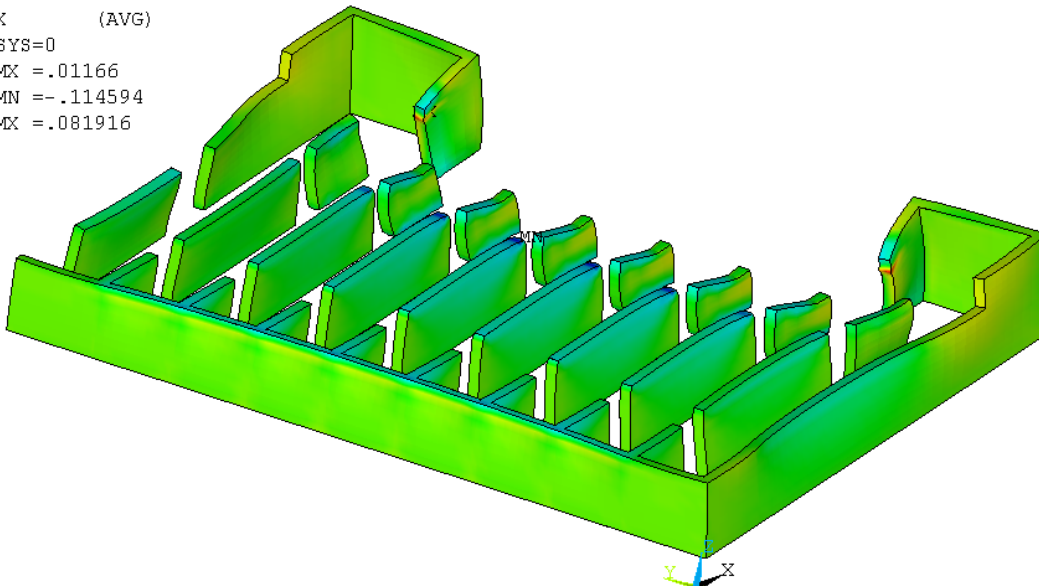


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.12 LS 5: G+PS-FX 10 kip/ft (146 kN/m) wall top. Vertical stress (1ksi=6.89 MPa), strong wall, floor

STEP=5  
 SUB =1  
 TIME=5  
 SX (AVG)  
 RSYS=0  
 DMX =.01166  
 SMN =-.114594  
 SMX =.081916

08:26:31



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

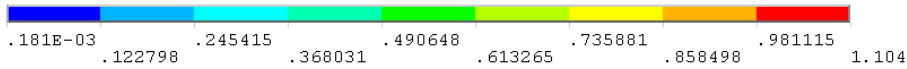
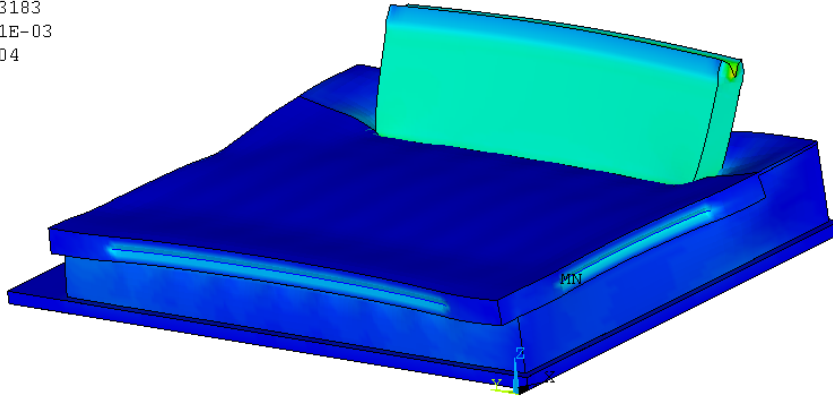
Fig. 1.13 LS 5: G+PS-FX 10 kip/ft (146 kN/m) top of wall. x stress (1ksi=6.89 MPa), basement walls

1  
NODAL SOLUTION

STEP=6  
SUB =1  
TIME=6  
SEQV (AVG)  
DMX =.053183  
SMN =.181E-03  
SMX =1.104

ANSYS

MAR 20 2012  
10:50:43



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

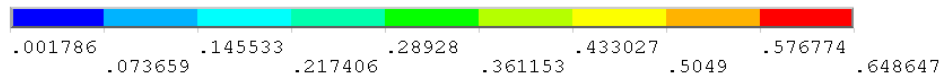
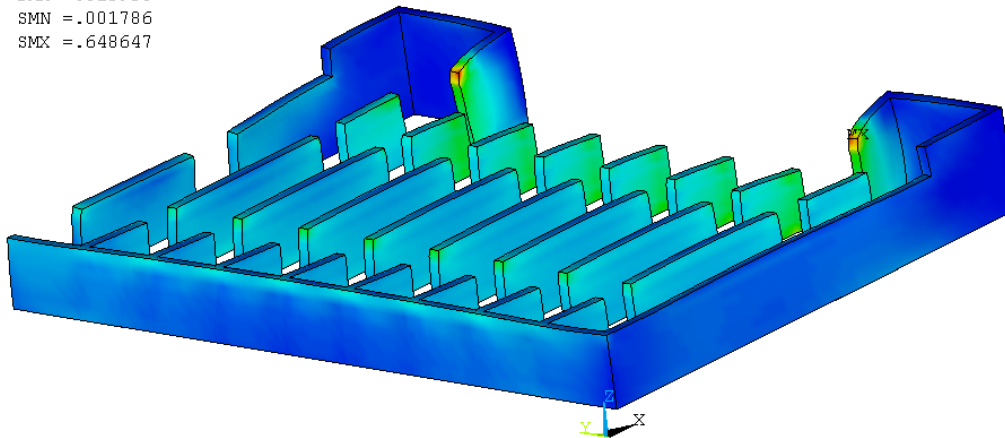
Fig.1.14 LS 6: G+PS-FZ 1.35 k/f<sup>2</sup> (64.6 kPa) on entire floor. Von Mises stress (1ksi=6.89 MPa), wall, floor

1  
NODAL SOLUTION

STEP=6  
SUB =1  
TIME=6  
SEQV (AVG)  
DMX =.013958  
SMN =.001786  
SMX =.648647

ANSYS

MAR 20 2012  
15:37:49

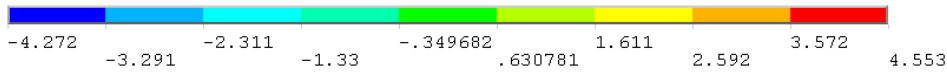
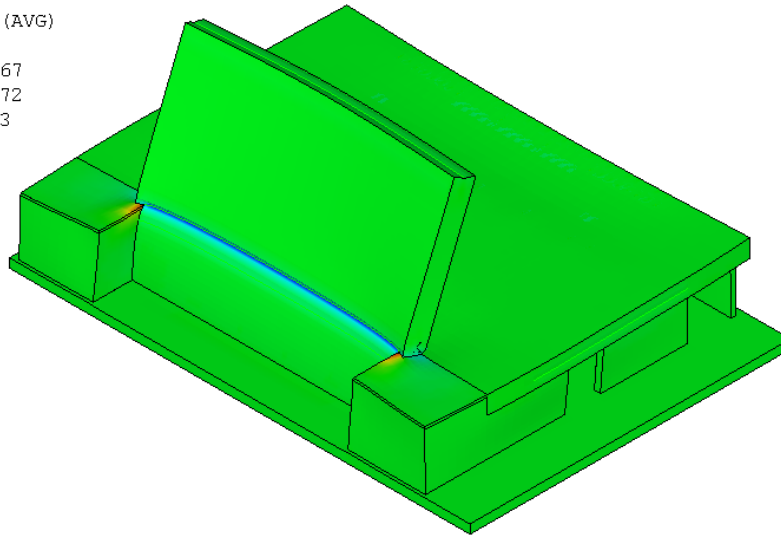


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.15 LS 6: G+PS-FZ 1.35 k/f<sup>2</sup> (64.6 kPa) on entire floor. Von Mises stress (1ksi=6.89 MPa), basement

STEP=7  
 SUB =1  
 TIME=7  
 SX (AVG)  
 RSYS=0  
 DMX =.36067  
 SMN =-4.272  
 SMX =4.553

08:02:05

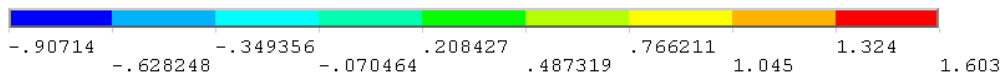
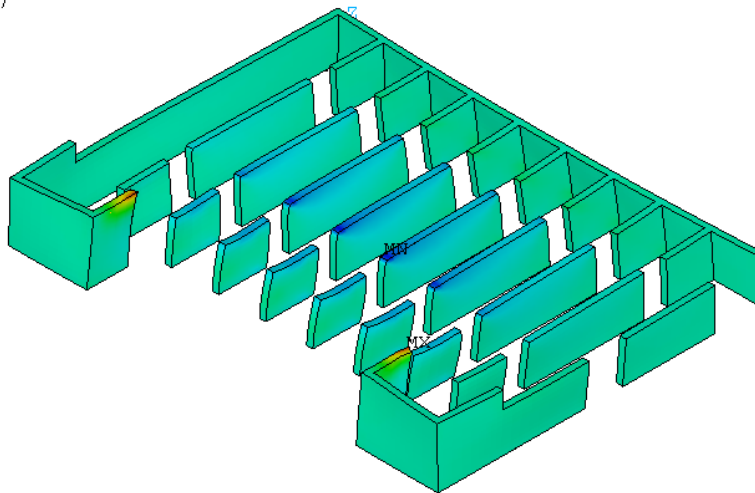


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.16 LS 7: G+PS+FX 50 k/floor load pt (222 kN/lp) facing wall+ wall reaction. Deformations and horizontal x stress (1ksi=6.89 MPa), strong wall and floor

STEP=7  
 SUB =1  
 TIME=7  
 SX (AVG)  
 RSYS=0  
 DMX =.051489  
 SMN =-.90714  
 SMX =1.603

08:15:45



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.17 LS 7: G+PS+FX 50 k/floor load pt (222 kN/lp) facing wall+ wall reaction. Deformations and x stress (1ksi=6.89 MPa), basement walls



1

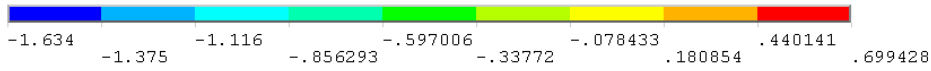
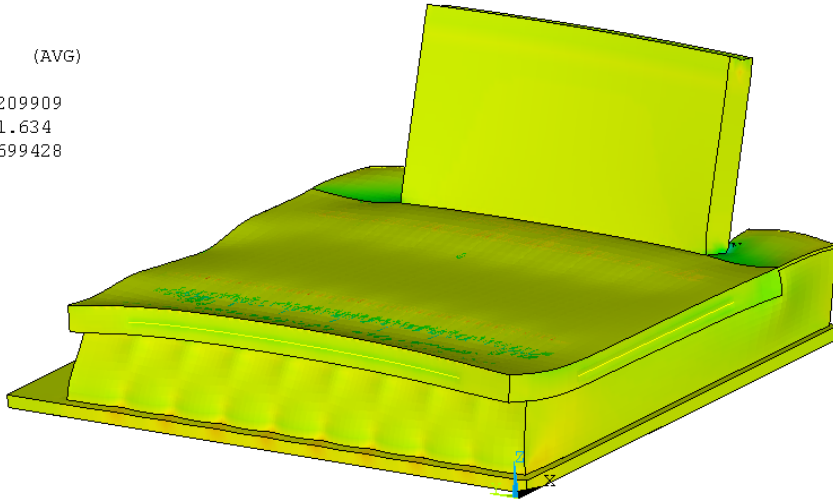
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NODAL SOLUTION
STEP=8
SUB =1
TIME=8
SX      (AVG)
RSYS=0
DMX =.209909
SMN =-1.634
SMX =.699428

```

ANSYS

MAR 20 2012  
11:22:23



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

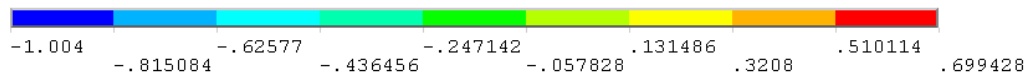
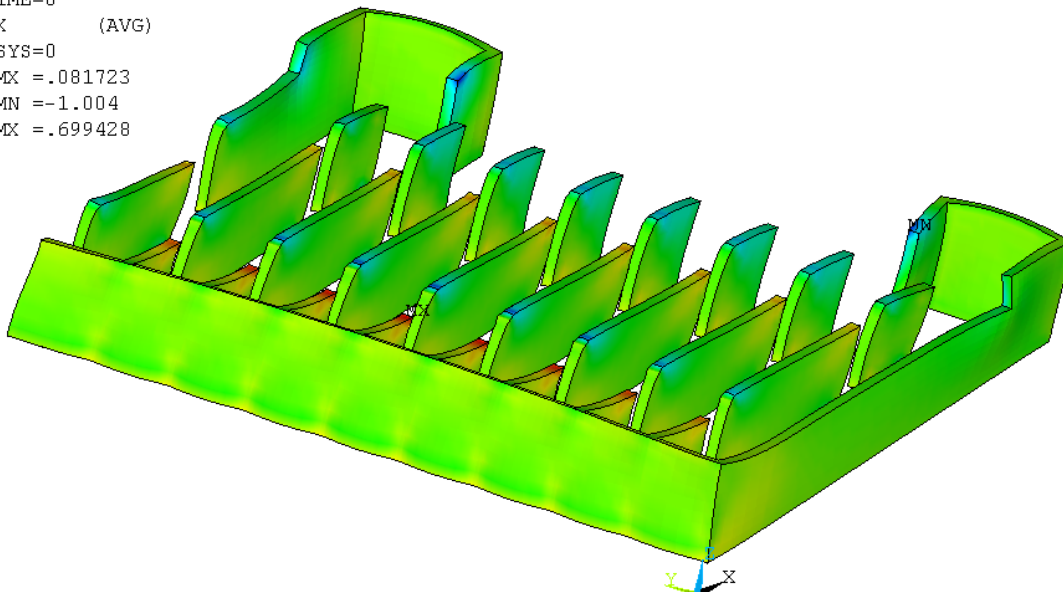
Fig. 1.18 LS 8: G+PS+FX 50 k/lD pt (222 kN/lp) entire floor. Horizontal x stress (1ksi=6.89 MPa), wall, floor

```

STEP=8
SUB =1
TIME=8
SX      (AVG)
RSYS=0
DMX =.081723
SMN =-1.004
SMX =.699428

```

08:32:57



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.19 LS 8: G+PS+FX 50 k/lD pt (222 kN/lp) entire floor. x stress (1ksi=6.89 MPa), basement

1

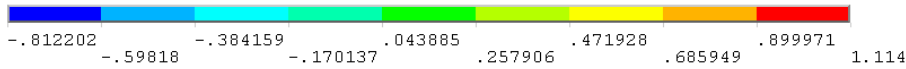
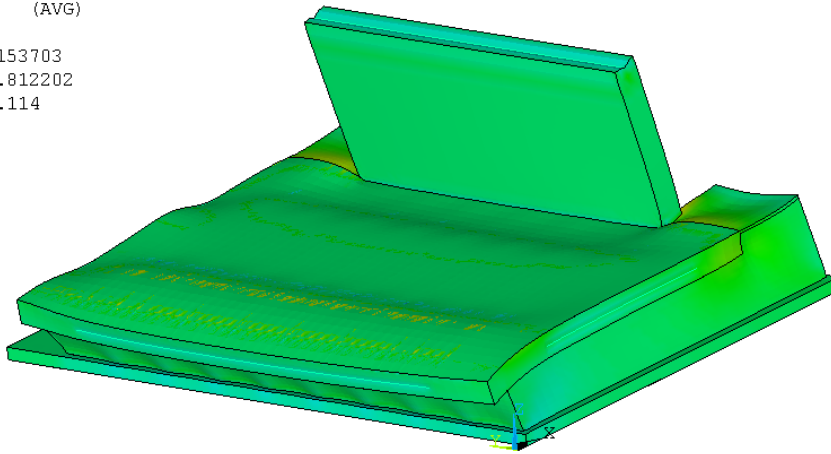
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STEP=9
SUB =1
TIME=9
SX      (AVG)
RSYS=0
DMX =.153703
SMN =-.812202
SMX =1.114

```

ANSYS

MAR 20 2012  
11:23:48



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.20 LS 9: G+PS-FX 50 k/lp pt (222 kN/lp) entire floor. Horizontal x stress (1ksi=6.89 MPa), wall, floor

1

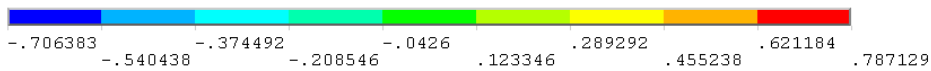
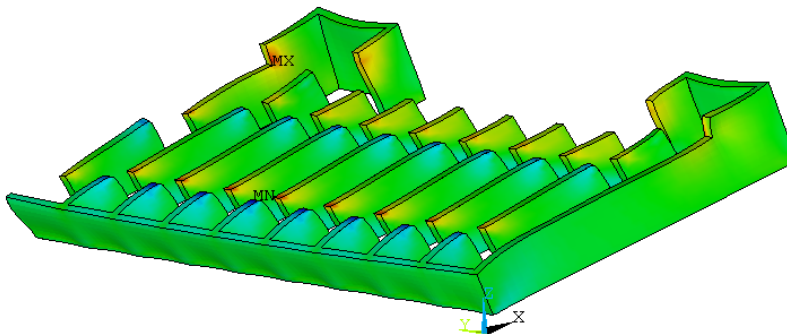
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NODAL SOLUTION
STEP=9
SUB =1
TIME=9
SX      (AVG)
RSYS=0
DMX =.073751
SMN =-.706383
SMX =.787129

```

ANSYS

MAR 20 2012  
11:26:41



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.21 LS 9: G+PS-FX 50 k/lp pt (222 kN/lp) entire floor. Horizontal x stress (1ksi=6.89 MPa), basement

1

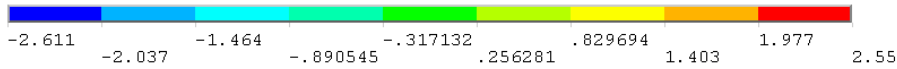
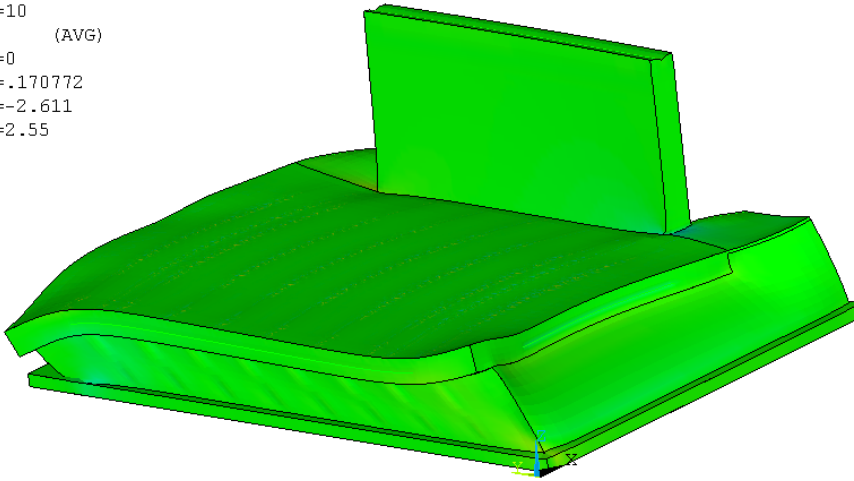
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NODAL SOLUTION
STEP=10
SUB =1
TIME=10
SY      (AVG)
RSYS=0
DMX =.170772
SMN =-2.611
SMX =2.55

```

ANSYS

MAR 20 2012  
11:33:10



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

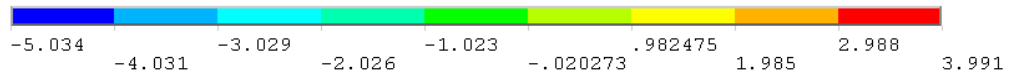
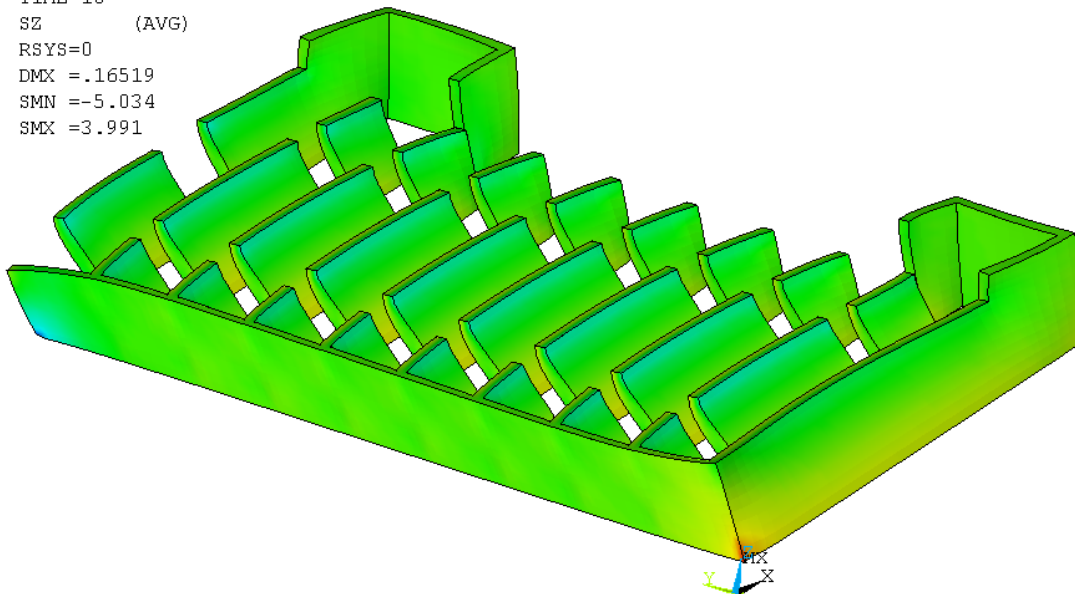
Fig.1.22 LS 10: G+PS+FY 50 k/lp (222 kN/lp) entire floor. Horizontal y stress (1ksi=6.89 MPa), wall, floor

```

STEP=10
SUB =1
TIME=10
SZ      (AVG)
RSYS=0
DMX =.16519
SMN =-5.034
SMX =3.991

```

08:37:07



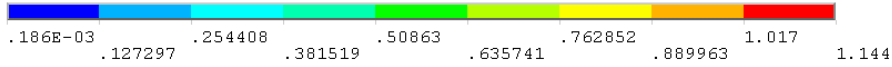
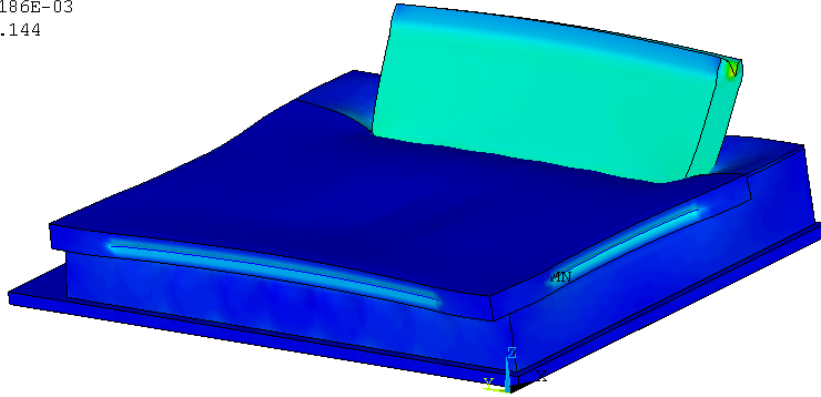
NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.23 LS 10: G+PS+FY 50 k/lp (222 kN/lp) entire floor. Vertical z stress (1ksi=6.89 MPa), basement

NODAL SOLUTION

MAR 20 2012  
11:42:10

STEP=11  
SUB =1  
TIME=11  
SEQV (AVG)  
DMX =.055611  
SMN =.186E-03  
SMX =1.144



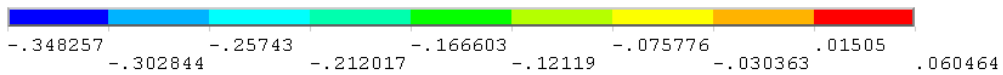
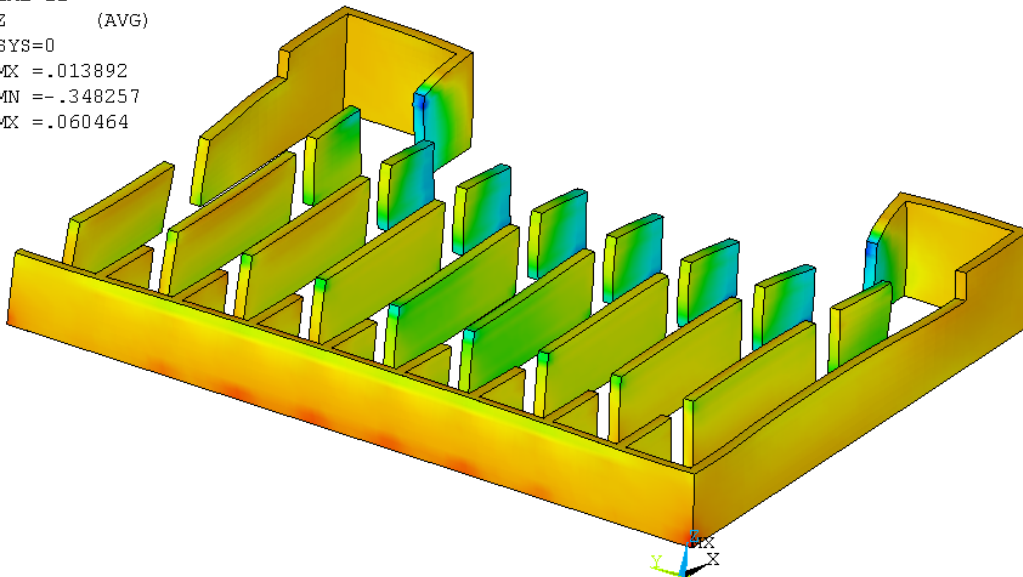
NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.24 LS 11: G+PS-FZ 1.8 k/ft<sup>2</sup> (86.2 kPa) over 20' by 20' (6.1 m x 6.1 m) floor center. Deformations, Von Mises stress (1ksi=6.89 MPa)

STEP=11

08:40:30

SUB =1  
TIME=11  
SZ (AVG)  
RSYS=0  
DMX =.013892  
SMN =-.348257  
SMX =.060464

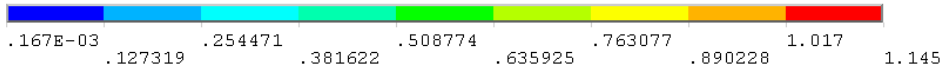
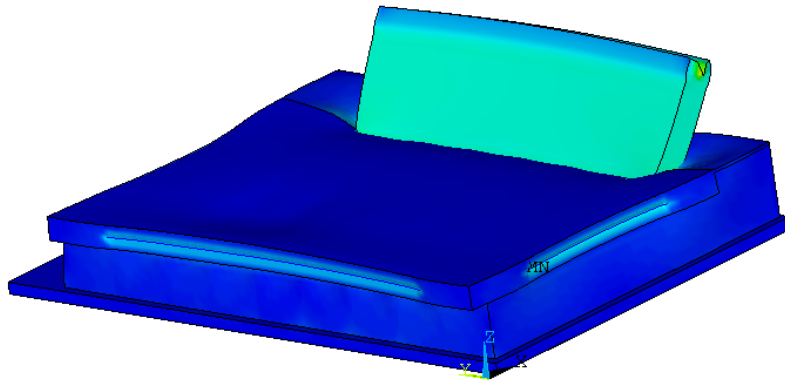


NFRL STRONG FLOOR. STRONG WALL. BOX GIRDERS

Fig. 1.25 LS 11: G+PS-FZ 1.8 k/ft<sup>2</sup> (86.2 kPa) over 20' by 20' (6.1 m x 6.1 m) floor center. Deformations, vertical z stress (1ksi=6.89 MPa), basement

STEP=12  
 SUB =1  
 TIME=12  
 SEQV (AVG)  
 DMX =.055635  
 SMN =.167E-03  
 SMX =1.145

13:57:06

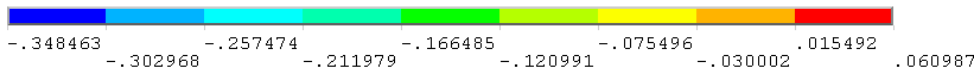
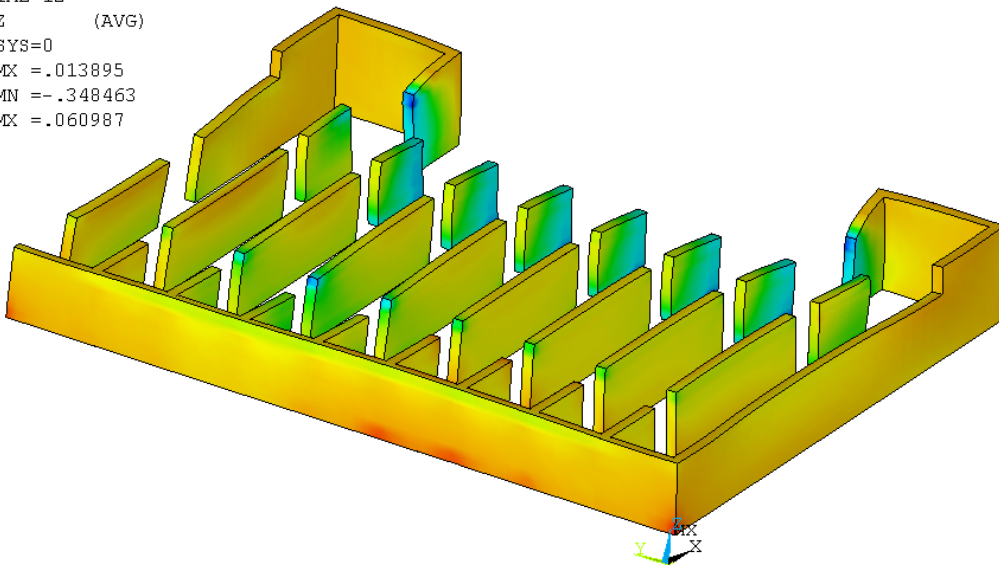


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.26 LS 12: G+PS-FZ 1.8 k/ft<sup>2</sup> (86.2 kPa) over 20' by 20' (6.1 m x 6.1 m) floor SW corner. Deformations, Von Mises stress (1ksi=6.89 MPa), strong floor and wall

STEP=12  
 SUB =1  
 TIME=12  
 SZ (AVG)  
 RSYS=0  
 DMX =.013895  
 SMN =-.348463  
 SMX =.060987

08:42:35

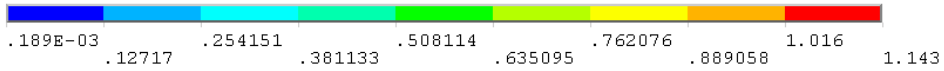
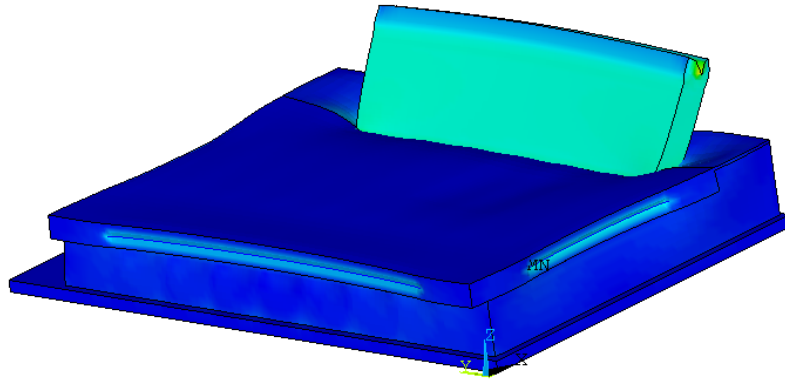


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.27 LS 12: G+PS-FZ 1.8 k/ft<sup>2</sup> (86.2 kPa) over 20' by 20' (6.1 m x 6.1 m) floor SW corner (x points North). Deformations, vertical z stress (1ksi=6.89 MPa)

STEP=13  
 SUB =1  
 TIME=13  
 SEQV (AVG)  
 DMX =.055442  
 SMN =.189E-03  
 SMX =1.143

14:00:13

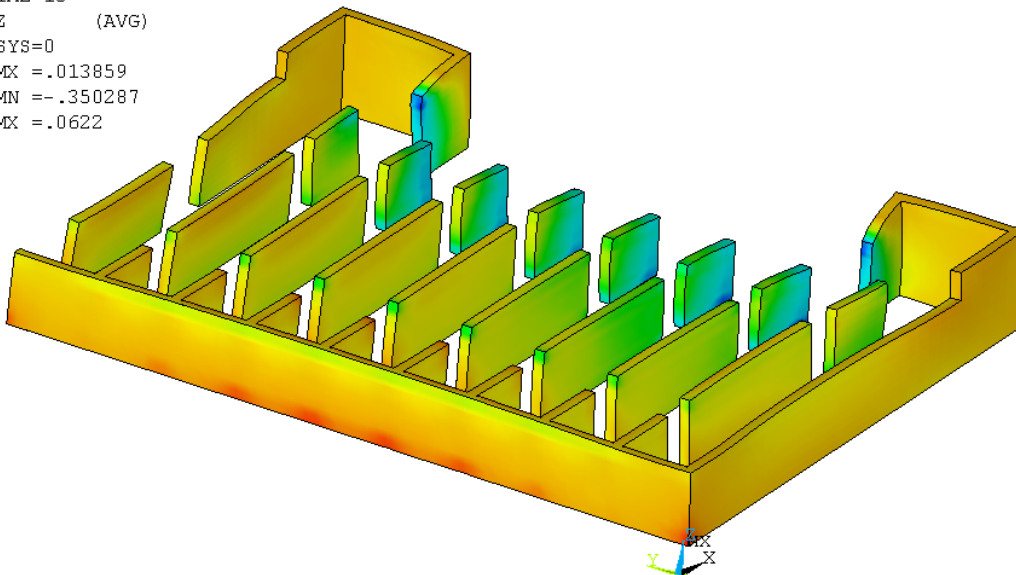


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.28 LS 13: G+PS-FZ 1.8 k/ft<sup>2</sup> (86.2 kPa) over 20' by 20' (6.1 m x 6.1 m) floor NE corner. Deformations, Von Mises stress (1ksi=6.89 MPa), strong floor and wall

STEP=13  
 SUB =1  
 TIME=13  
 SZ (AVG)  
 RSYS=0  
 DMX =.013859  
 SMN =-.350287  
 SMX =.0622

08:44:03



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.29 LS 13: G+PS-FZ 1.8 k/ft<sup>2</sup> (86.2 kPa) over 20' by 20' (6.1 m x 6.1 m) floor NE corner (x points North). Deformations, vertical z stress (1ksi=6.89 MPa), basement

NODAL SOLUTION

MAR 20 2012

STEP=14

14:11:10

SUB =1

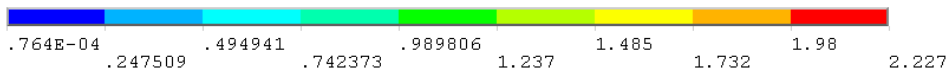
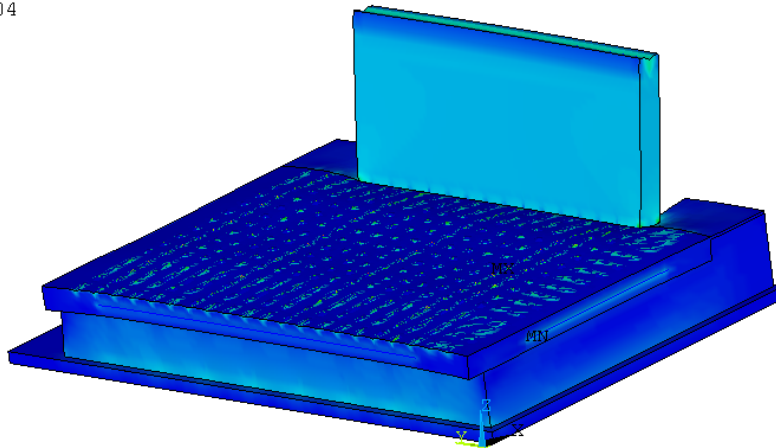
TIME=14

SEQV (AVG)

DMX =.07513

SMN =.764E-04

SMX =2.227



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.30 LS 14: G+PS+FZ 100 k (445 kN) every 4' (1.2 m). Von Mises stress (1ksi=6.89 MPa), floor and wall

NODAL SOLUTION

MAR 21 2012

STEP=14

11:42:35

SUB =1

TIME=14

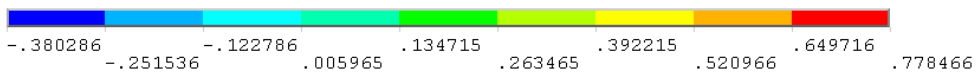
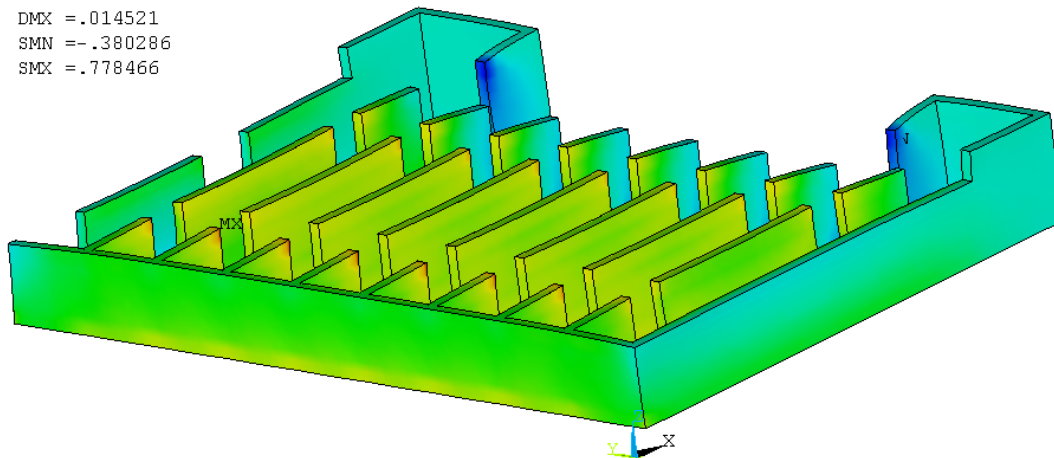
SZ (AVG)

RSYS=0

DMX =.014521

SMN =-.380286

SMX =.778466



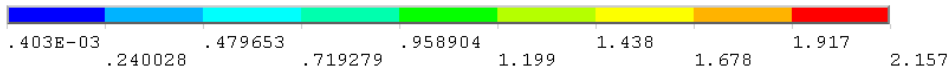
NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.31 LS 14: G+PS+FZ 100 k (445 kN) every 4' (1.2 m). Vertical z stress (1ksi=6.89 MPa), basement

NODAL SOLUTION

MAR 20 2012  
14:16:15

STEP=15  
SUB =1  
TIME=15  
SEQV (AVG)  
DMX =.051502  
SMN =.403E-03  
SMX =2.157



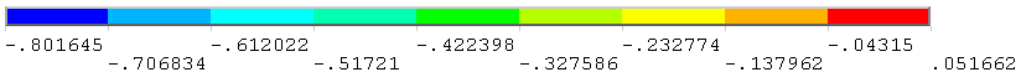
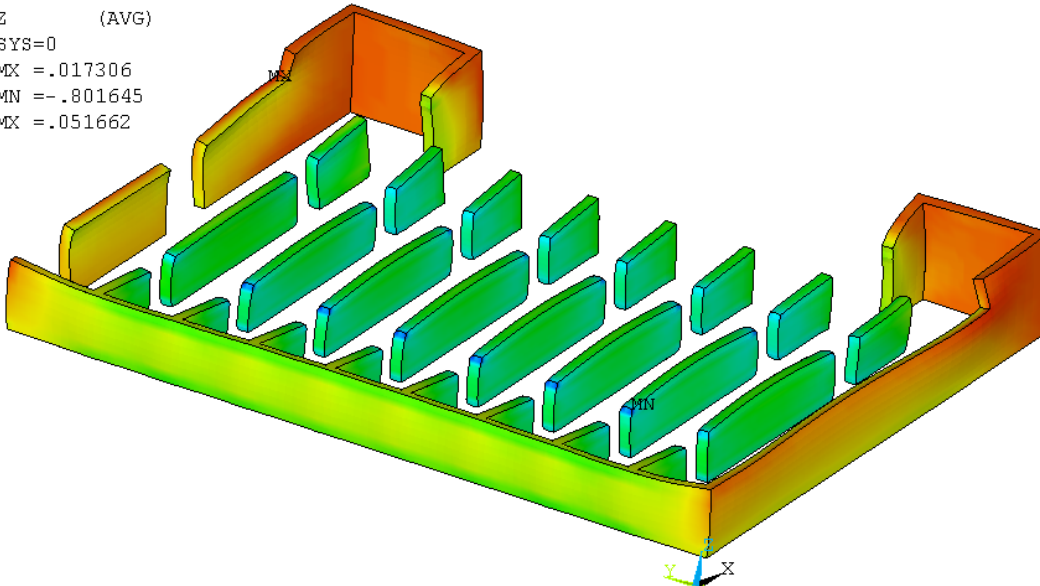
NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.32 LS 15: G+PS-FZ 100 k (445 kN) every 4' (1.2 m). Von Mises stress (1ksi=6.89 MPa), floor and wall

STEP=15

08:46:22

SUB =1  
TIME=15  
SZ (AVG)  
RSYS=0  
DMX =.017306  
SMN =-.801645  
SMX =.051662



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.33 LS 15: G+PS-FZ 100 k (445 kN) every 4' (1.2 m). Vertical z stress (1ksi=6.89 MPa), basement



STEP=16  
 SUB =1  
 TIME=16  
 SEQV (AVG)  
 DMX =.054936  
 SMN =.103E-03  
 SMX =2.101

MAR 20 2012  
 14:32:35

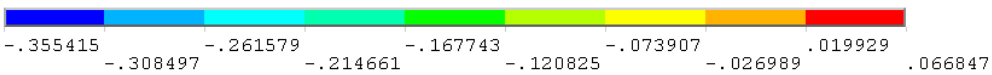
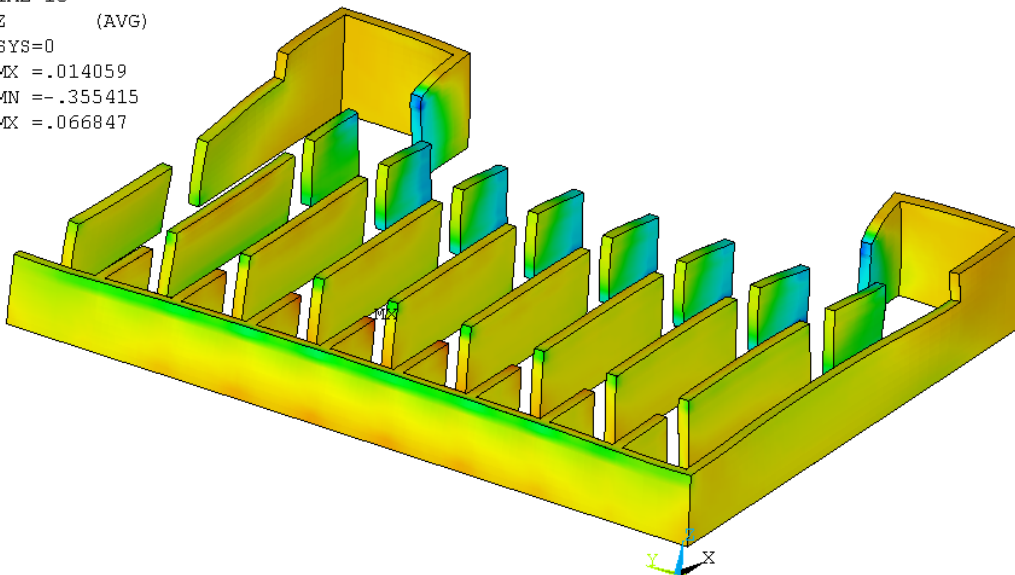


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.34 LS 16: G+PS+-FZ 100 k (445 kN) every 4' (1.2 m) alternate. Deformations, Von Mises stress (1ksi=6.89 MPa), strong floor and wall

STEP=16  
 SUB =1  
 TIME=16  
 SZ (AVG)  
 RSYS=0  
 DMX =.014059  
 SMN =-.355415  
 SMX =.066847

08:47:40



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.35 LS 16: G+PS+-FZ 100 k (445 kN) every 4' (1.2 m) alternate. Deformations, Vertical z stress (1ksi=6.89 MPa), basement

STEP=17  
 SUB =1  
 TIME=17  
 SEQV (AVG)  
 DMX =.050251  
 SMN =.909E-04  
 SMX =3.343

14:41:09

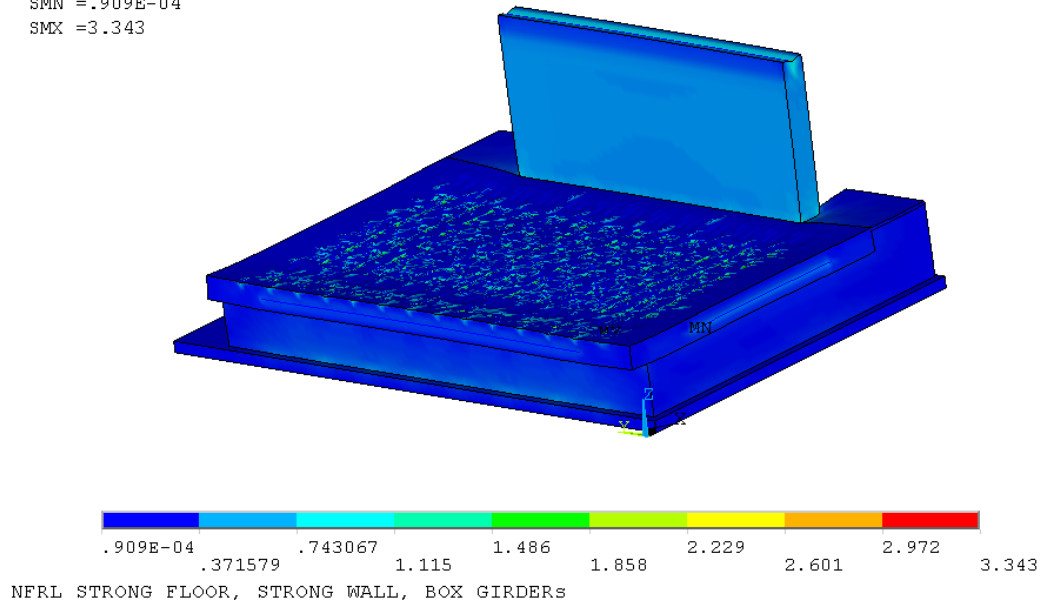


Fig. 1.36 LS 17: G+PS +floor 100 k (445 kN) up every 6' (1.8 m), down every 2' (0.61 m) centered. Deformations, Von Mises stress (1ksi=6.89 MPa), floor and wall

STEP=17  
 SUB =1  
 TIME=17  
 SZ (AVG)  
 RSYS=0  
 DMX =.022068  
 SMN =-1.091  
 SMX =.133956

08:48:32

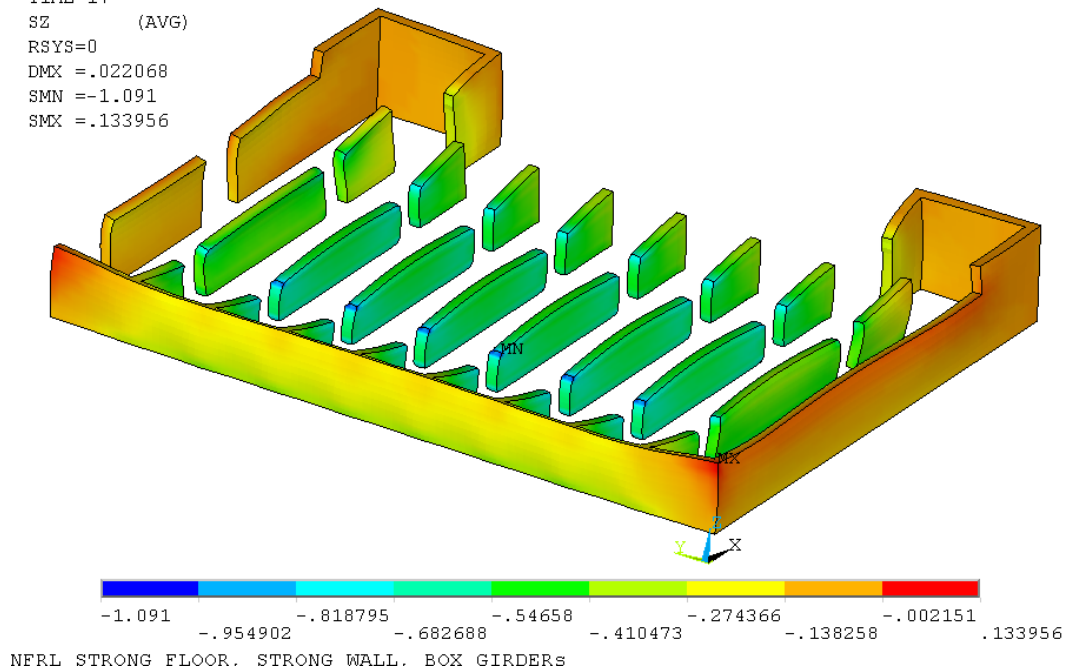


Fig.1.37 LS 17: G+PS +floor 100 k (445 kN) up every 6' (1.8 m), down every 2' (0.61 m) centered. Deformations, Vertical z stress (1ksi=6.89 MPa), basement

NODAL SOLUTION  
 STEP=18  
 SUB =1  
 TIME=18  
 SEQV (AVG)  
 DMX =.184324  
 SMN =.644E-03  
 SMX =4.708

MAR 20 2012  
 14:52:17

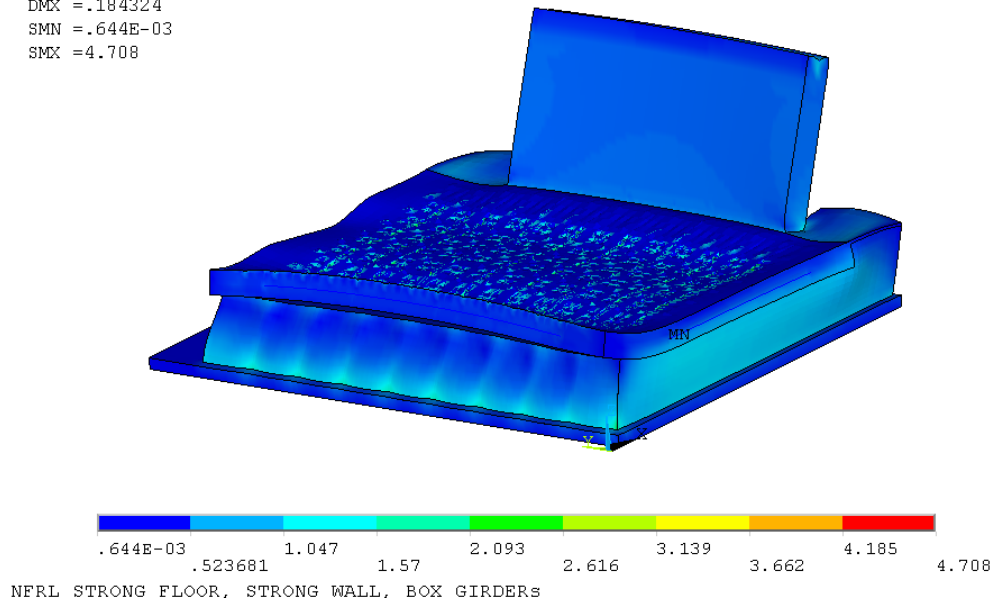


Fig. 1.38 LS 18: G+PS +floor 100 k (445 kN) up every 6' (1.8 m), down every 2' (0.61 m) centered + FX 50 k every floor load point (222 kN/lp). Deformations, Von Mises stress (1ksi=6.89 MPa), floor and wall

STEP=18  
 SUB =1  
 TIME=18  
 SX (AVG)  
 RSYS=0  
 DMX =.084329  
 SMN =-1.064  
 SMX =.582756

08:50:30

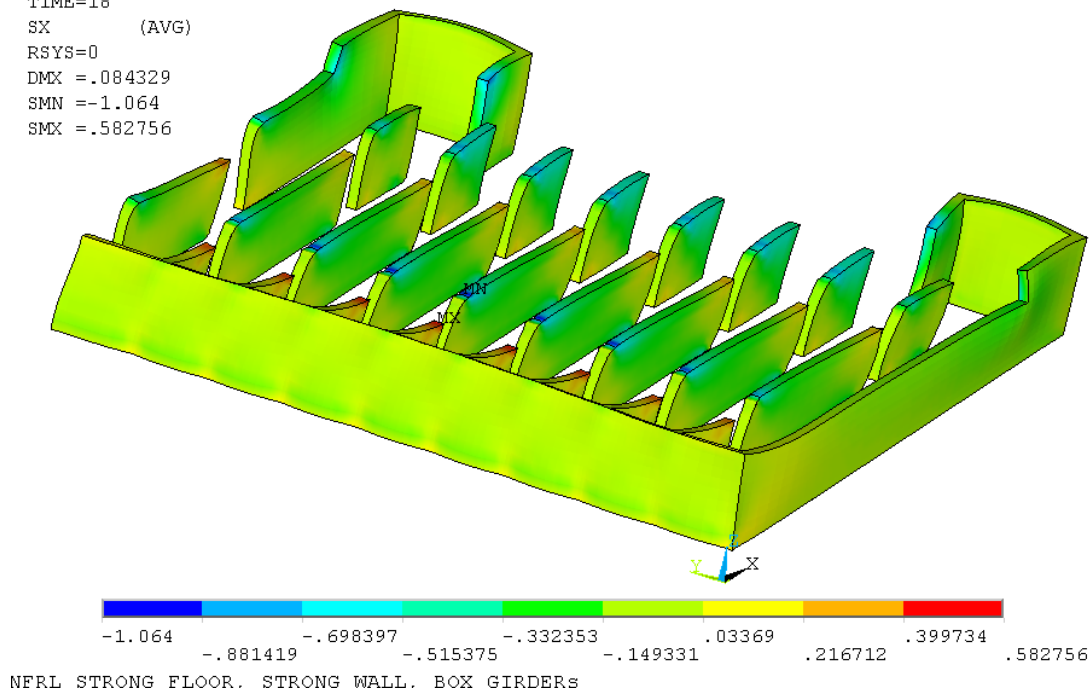
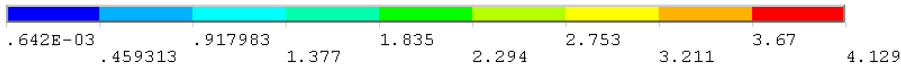
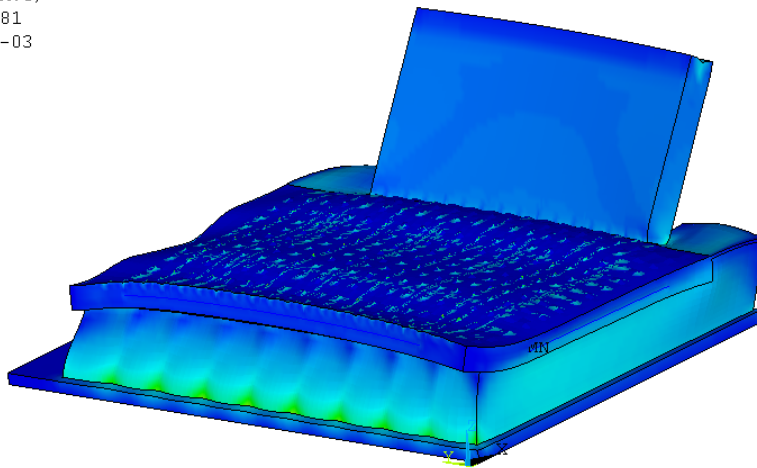


Fig. 1.39 LS 18: G+PS +floor 100 k (445 kN) up every 6' (1.8 m), down every 2' (0.61 m) centered + FX 50 k every floor load point (222 kN/lp). Deformations, horizontal x stress (1ksi=6.89 MPa), basement

NODAL SOLUTION  
 STEP=19  
 SUB =1  
 TIME=19  
 SEQV (AVG)  
 DMX =.240881  
 SMN =.642E-03  
 SMX =4.129

MAR 20 2012  
 14:53:05

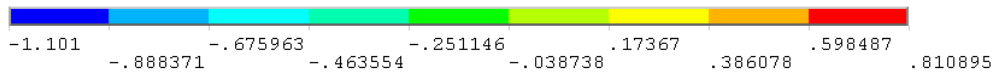
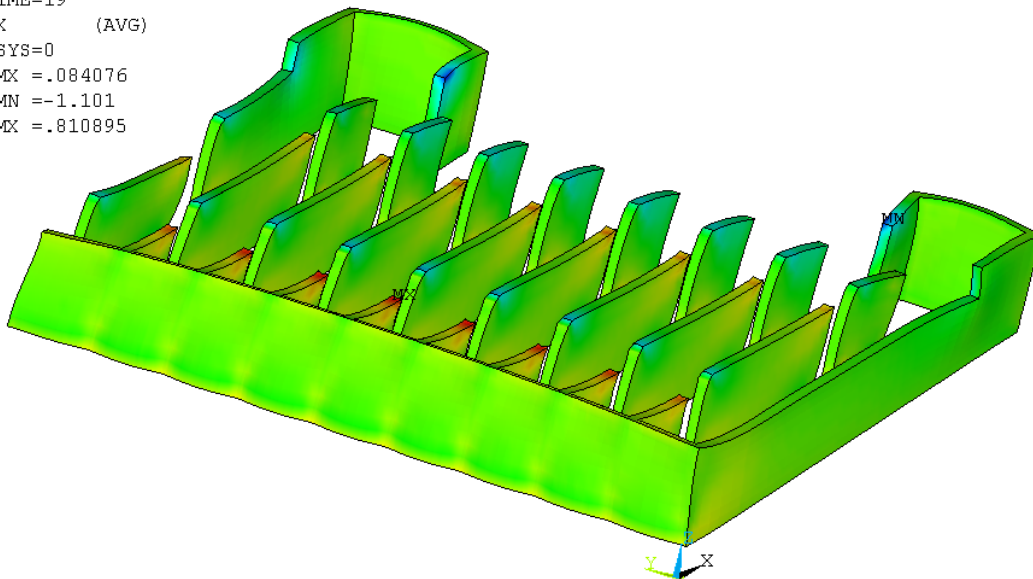


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.40 LS 19: G+PS +floor 100 k (445 kN) up every 4'(1.2 m) + FX 50 k every floor load point (222 kN/lp). Deformations, Von Mises stress (1ksi=6.89 MPa), strong floor and strong wall

STEP=19  
 SUB =1  
 TIME=19  
 SX (AVG)  
 RSYs=0  
 DMX =.084076  
 SMN =-1.101  
 SMX =.810895

08:51:31

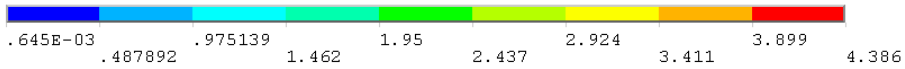
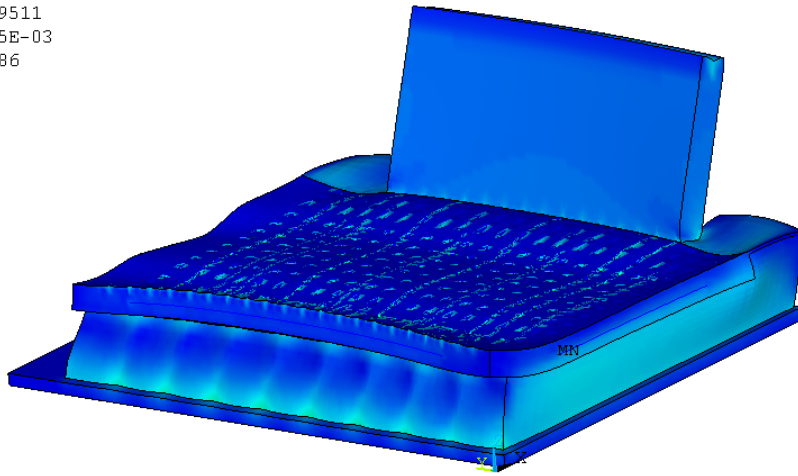


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.41 LS 19: G+PS +floor 100 k (445 kN) up every 4' (1.2 m) + FX 50 k every floor load point (222 kN/lp). Deformations, horizontal x stress (1ksi=6.89 MPa), basement

NODAL SOLUTION  
 STEP=20  
 SUB =1  
 TIME=20  
 SEQV (AVG)  
 DMX =.179511  
 SMN =.645E-03  
 SMX =4.386

MAR 20 2012  
 15:18:38

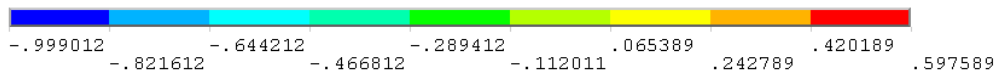
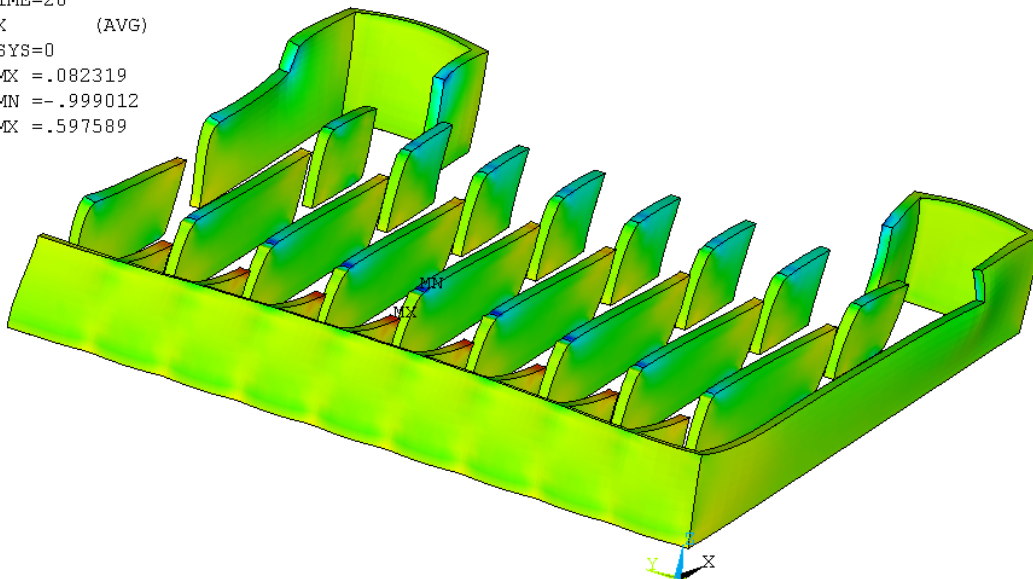


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.42 LS 20: G+PS -floor 100 k (445 kN) down every 4' (1.2 m) + FX 50 k every floor load point (222 kN/lp). Deformations, Von Mises stress (1ksi=6.89 MPa), strong floor and strong wall

STEP=20  
 SUB =1  
 TIME=20  
 SX (AVG)  
 RSYS=0  
 DMX =.082319  
 SMN =-.999012  
 SMX =.597589

08:52:19

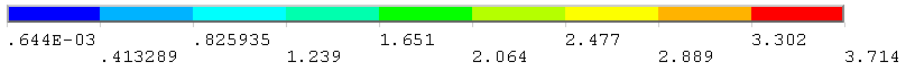
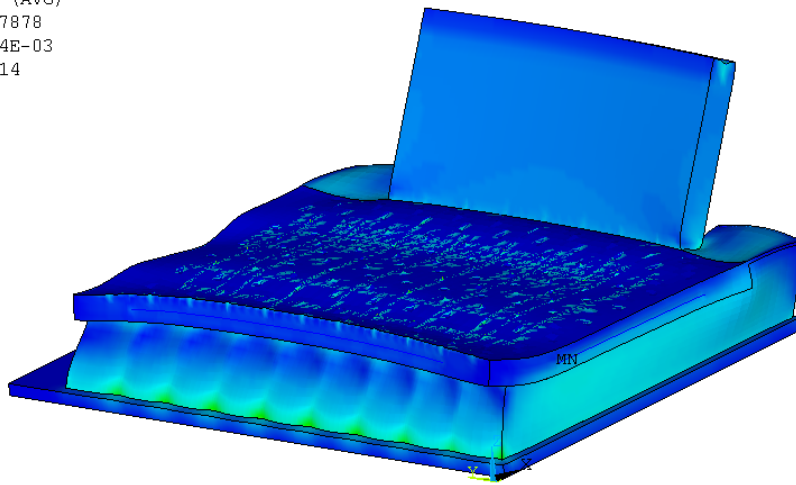


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.43 LS 20: G+PS -floor 100 k (445 kN) down every 4' (1.2 m) + FX 50 k every floor load point (222 kN/lp). Deformations, horizontal x stress (1ksi=6.89 MPa), basement

NODAL SOLUTION  
 STEP=21  
 SUB =1  
 TIME=21  
 SEQV (AVG)  
 DMX =.207878  
 SMN =.644E-03  
 SMX =3.714

MAR 20 2012  
 15:20:17

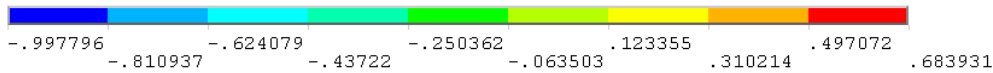
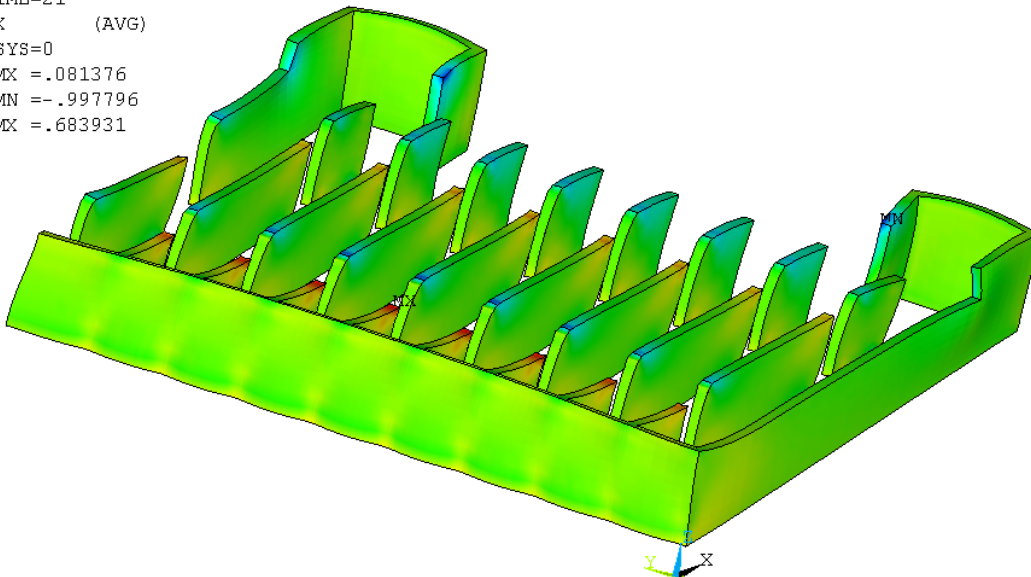


NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.44 LS 21: G+PS ±floor 100 k (445 kN) up down alternate every 4' (1.2 m) + FX 50 k every floor load point (222 kN/lp). Deformations, Von Mises stress (1ksi=6.89 MPa), strong floor and strong wall

STEP=21  
 SUB =1  
 TIME=21  
 SX (AVG)  
 RSYS=0  
 DMX =.081376  
 SMN =-.997796  
 SMX =.683931

08:52:56



NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

Fig. 1.45 LS 21: G+PS ±floor 100 k (445 kN) up down alternate every 4' (1.2 m) + FX 50 k every floor load point (222 kN/lp). Deformations, horizontal x stress (1ksi=6.89 MPa), basement

## ! NFRL CONCRETE

! begin slab at x=0. East wall closed. West wall special. West box correctly placed.  
! All floor loading points at KP. Prestressing KP both ways.  
! 20120418 constrained axial rotation of loading beams as SOLID 185 nodes have no rotation DOF.  
! A good alternative to BEAM188 as loading beam is SURF156,  
! which has an orientation node in addition to 2 end nodes and possibly a middle node.

FINISH

/CLEAR

/CWD,'C:\StrongFireLab'

/FILENAME,20120920,0

/TITLE,NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS

/REPLOT

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KEYOPT,2,12,0

R,2, , , , , ,

RMORE,.01,.01,.01,.01,

ET,3,SOLID185

ACEL,,,1 ! gravity

! x is S to N, y is E to W, z is down to up

! units, kips, inch, degree C

! Mat 1 is for slab on grade, f'c = 3500 psi

MPTEMP,,,,,,,,

MPTEMP,1,0

MPDATA,EX,1,,3372

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MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,DENS,1,,8.33E-5 ! 144 LBF/FT^3
```

! Mat 2 is for foundation North box walls, f'c = 4000 psi

```
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! Mat 3 is for foundation walls, f'c = 4000 psi

```
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MPDATA,DENS,3,,8.33E-5
```

! Mat 4 is for columns, f'c = 5000 psi

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,4,,4030
MPDATA,PRXY,4,,0.25
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,DENS,4,,8.33E-5
```

! Mat 5 is for strong floor, f'c = 6000 psi

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,5,,4415
MPDATA,PRXY,5,,0.25
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,DENS,5,,8.33E-5
```

! Mat 6 is for strong wall, f'c = 6000 psi

```
MPTEMP,,,,,,,,
```



```
MPTEMP,1,0
MPDATA,EX,6,,4415
MPDATA,PRXY,6,,0.25
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,DENS,6,,8.33E-5
```

! basement slab bottom, east edge

```
K,1,,,,
K,2,24,,,
K,3,42,,,
K,4,48,,,
K,5,56,,,
K,6,72,,,
K,7,168,,,
K,8,174,,,
K,9,192,,,
K,10,216,,,
K,11,234,,,

```

```
K,12,240,,,
K,13,408,,,
K,14,504,,,
K,15,528,,,
K,16,540,,,
K,17,552,,,
K,18,600,,,
K,19,720,,,
K,20,774,,,
K,21,864,,,
K,22,880,,,
K,23,888,,,

```

```
*DO,I,1,22,1
  LSTR,I,I+1
*ENDDO
```

```
*DO,I,1,22,1
  LESIZE,I,,1,,,,,1
*ENDDO
```

```
LESIZE,6,24,,,,,1
LESIZE,9,12,,,,,1
LESIZE,12,12,,,,,1
LESIZE,13,12,,,,,1
LESIZE,14,,2,,,,,1
LESIZE,17,12,,,,,1
```

LESIZE,18,24,,,,,,1  
LESIZE,19,,4,,,,,1  
LESIZE,20,,4,,,,,1  
LESIZE,21,,2,,,,,1

CM,BSMT\_EAST,LINE

! basement slab bottom, south edge, NOW AT X=0

K,30,,  
K,31,,18,  
K,32,,34,  
K,33,,69,  
K,34,,117,  
K,35,,138,  
K,36,,141,

K,37,,154, !PS  
K,38,,165,  
K,39,,189,  
K,40,,201,  
K,41,,213,

K,42,,217,  
K,43,,237,  
K,44,,258,  
K,45,,261,  
K,46,,274,

K,47,,285,  
K,48,,357,  
K,49,,378,  
K,50,,381,  
K,51,,394,

K,52,,405,  
K,53,,489,  
K,54,,498,  
K,55,,501,  
K,56,,514,

K,57,,525,  
K,58,,609,  
K,59,,618,  
K,60,,621,  
K,61,,634,

K,62,,645,

K,63,,729,  
K,64,,738,  
K,65,,741,  
K,66,,754,

K,67,,765,  
K,68,,837,  
K,69,,858,  
K,70,,861,  
K,71,,874,

K,72,,885,  
K,73,,905,  
K,74,,909,  
K,75,,921,  
K,76,,933,  
K,77,,957,

K,78,,978, !PS  
K,79,,981,  
K,80,,994,  
K,81,,1005,  
K,82,,1053,  
K,83,,1098,  
K,84,,1114,  
K,85,,1242,

\*DO,I,30,84,1  
LSTR,I,I+1  
\*ENDDO

\*DO,I,23,77,1  
LESIZE,I,,1,,,,1  
\*ENDDO

LESIZE,24,,2,,,,1  
LESIZE,25,,2,,,,1  
LESIZE,26,24,,,,,1  
LESIZE,29,,2,,,,1  
LESIZE,31,12,,,,,1  
LESIZE,33,,2,,,,1  
LESIZE,35,,2,,,,1  
LESIZE,36,,2,,,,1  
LESIZE,38,,2,,,,1  
LESIZE,40,12,,,,,1

LESIZE,41,,2,,,,1  
LESIZE,43,,2,,,,1

```
LESIZE,45,12,,,,,1
LESIZE,48,,2,,,,1
LESIZE,50,12,,,,,1
LESIZE,53,,2,,,,1
LESIZE,55,12,,,,,1
LESIZE,58,,2,,,,1
LESIZE,60,12,,,,,1
LESIZE,61,,2,,,,1
```

```
LESIZE,63,,2,,,,1
LESIZE,65,,2,,,,1
LESIZE,67,,2,,,,1
LESIZE,69,,2,,,,1
LESIZE,70,,2,,,,1
LESIZE,72,,2,,,,1
LESIZE,74,12,,,,,1
LESIZE,75,,2,,,,1
LESIZE,76,,2,,,,1
LESIZE,77,,6,,,,1
```

```
LSEL,S,LINE,,23,77,1,1
CM,BSMT_SOUTH,LINE
ALLSEL,ALL
```

! construct vertical edge of strong wall

```
K,100,774,201,,
K,200,774,201,24
K,300,774,201,132
K,400,774,201,174
K,500,774,201,180
K,600,774,201,252
K,700,774,201,468
K,800,774,201,540
```

```
*DO,I,100,700,100
LSTR,I,I+100
*ENDDO
```

```
LESIZE,78,,1,,,,1
LESIZE,79,,9,,,,1
LESIZE,80,,4,,,,1
LESIZE,81,,1,,,,1
LESIZE,82,12,,,,,1
LESIZE,83,12,,,,,1
LESIZE,84,24,,,,,1
```

! ORIENTATION KP FOR LOADING STRIPS

K,350,387,339,153  
K,510,747,561,180

! create loading strips for post-tensioning  
! create lines at east and west edges of midfloor thickness

LSEL,S,LOC,X,174,600,,  
LSEL,R,LOC,Y,,1,,  
LSEL,R,LOC,Z,,1,,  
CM,PS\_EAST,LINE  
LGEN,2,ALL,,,,,18,153,,,,

LSEL,S,LOC,X,174,600,,  
LSEL,R,LOC,Y,17,19,,  
LSEL,R,LOC,Z,152,154,,  
CM,PSFLOOR\_EAST,LINE

CMSEL,S,PS\_EAST,LINE  
LGEN,2,ALL,,,,,1114,153,,,,

LSEL,S,LOC,X,174,600,,  
LSEL,R,LOC,Y,1113,1115,,  
LSEL,R,LOC,Z,152,154,,  
CM,PSFLOOR\_WEST,LINE

! create lines at top and bottom of strong wall and corner with floor

LSEL,S,LOC,X,,1,,  
LSEL,R,LOC,Y,201,921,,  
LSEL,R,LOC,Z,,1,,  
CM,PS\_SOUTH,LINE  
LGEN,2,ALL,,,,,747,,540,,,,

LSEL,S,LOC,X,746,748,,  
LSEL,R,LOC,Y,201,921,,  
LSEL,R,LOC,Z,539,541,,  
CM,PSWALL\_TOP,LINE

CMSEL,S,PS\_SOUTH,LINE  
LGEN,2,ALL,,,,,747,,,,,

LSEL,S,LOC,X,746,748,,  
LSEL,R,LOC,Y,201,921,,  
LSEL,R,LOC,Z,,1,,  
CM,PSWALL\_BOTTOM,LINE

CMSEL,S,PS\_SOUTH,LINE

```
!LGEN,2,ALL,,,720,,180,,,, !9.20.2012 move to back of wall
LGEN,2,ALL,,,774,,180,,,,
```

```
!LSEL,S,LOC,X,719,721,, !9.20.2012 move to back of wall
LSEL,S,LOC,X,773,775,,
LSEL,R,LOC,Y,201,921,,
LSEL,R,LOC,Z,179,181,,
CM,WALL_FLOOR,LINE
```

! create lines at north and south edges of midfloor thickness

```
CMSEL,S,PS_SOUTH,LINE
LGEN,2,ALL,,,,,153,,,
CMSEL,S,PS_SOUTH,LINE
LGEN,2,ALL,,,774,,153,,,
```

! extend lines at north edge of midfloor thickness beyond y of strong wall

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,154,201,,
LSEL,R,LOC,Z,,1,,
CM,PS_SOUTHEAST,LINE
LGEN,2,ALL,,,720,,153,,,
CMSEL,S,PS_SOUTHEAST,LINE
LGEN,2,ALL,,,,,153,,,
```

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,921,978,,
LSEL,R,LOC,Z,,1,,
CM,PS_SOUTHWEST,LINE
LGEN,2,ALL,,,720,,153,,,
CMSEL,S,PS_SOUTHWEST,LINE
LGEN,2,ALL,,,,,153,,,
```

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,154,978,,
LSEL,R,LOC,Z,152,154,,
CM,PSFLOOR_SOUTH,LINE
```

! THE FOLLOWING IS A BETTER WAY TO SELECT LINES.  
! BY USING KEYPOINTS ONE AVOIDS LINES THAT INTERSECT WHAT IS SELECTED.

```
KSEL,S,LOC,Z,152,154,,
KSEL,R,LOC,X,720,774,,
KSEL,R,LOC,Y,154,978,,
LSLK,S,1
CM,PSFLOOR_NORTH,LINE
```

! construct basement bottom

```
ALLSEL,ALL
ADRAG,BSMT_SOUTH,,,,,BSMT_EAST,,,,,
ASEL,S,LOC,Z,,1
ASEL,R,LOC,X,24,888
ASEL,R,LOC,Y,,1242
CM,BSMT_BOTTOM,AREA
```

! construct basement slab

```
VDRAG,ALL,,,,,78,,,,,
VATT,1
CM,BSMT_SLAB,VOLU
```

! BASE OF STRONG FLOOR

```
ASEL,S,LOC,Z,,1
ASEL,R,LOC,X,,720
ASEL,R,LOC,Y,18,1114
CM,FLOOR,AREA
```

! bases of 4 north-South walls, southeast part

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,138,154
CM,BASE_SOUTH2,AREA
```

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,258,274
CM,BASE_SOUTH3,AREA
```

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,378,394
CM,BASE_SOUTH4,AREA
```

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,498,514
CM,BASE_SOUTH5,AREA
```

```
CMGRP,BASE_SOUTH_EAST,BASE_SOUTH2,BASE_SOUTH3,BASE_SOUTH4,BASE_SOUTH5
```

! bases of 4 north-South walls, southwest part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,618,634  
CM,BASE\_SOUTH6,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,738,754  
CM,BASE\_SOUTH7,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,858,874  
CM,BASE\_SOUTH8,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,978,994  
CM,BASE\_SOUTH9,AREA

CMGRP,BASE\_SOUTH\_WEST,BASE\_SOUTH6,BASE\_SOUTH7,BASE\_SOUTH8,BASE\_SOUTH9

! bases of 4 north-South walls, middle east part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,138,154  
CM,BASE\_MIDDLE2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,258,274  
CM,BASE\_MIDDLE3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,378,394  
CM,BASE\_MIDDLE4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,498,514  
CM,BASE\_MIDDLE5,AREA

CMGRP,BASE\_MIDDLE\_EAST,BASE\_MIDDLE2,BASE\_MIDDLE3,BASE\_MIDDLE4,BASE\_MIDDLE5

! bases of 5 north-South walls, middle west part



ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,618,634  
CM,BASE\_MIDDLE6,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,738,754  
CM,BASE\_MIDDLE7,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,858,874  
CM,BASE\_MIDDLE8,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,978,994  
CM,BASE\_MIDDLE9,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,174,408  
ASEL,R,LOC,Y,1098,1114  
CM,BASE\_MIDDLE10,AREA

CMGRP,BASE\_MIDDLE\_WEST,BASE\_MIDDLE6,BASE\_MIDDLE7,BASE\_MIDDLE8,BASE\_MIDDLE9,BASE\_MIDDLE10

! bases of 4 north-South walls, NORTH east part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,138,154  
CM,BASE\_NORTH2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,258,274  
CM,BASE\_NORTH3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,378,394  
CM,BASE\_NORTH4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,498,514

CM,BASE\_NORTH5,AREA

CMGRP,BASE\_NORTH\_EAST,BASE\_NORTH2,BASE\_NORTH3,BASE\_NORTH4,BASE\_NORTH5

! bases of 5 north-South walls, NORTH west part

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,600,720

ASEL,R,LOC,Y,618,634

CM,BASE\_NORTH6,AREA

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,600,720

ASEL,R,LOC,Y,738,754

CM,BASE\_NORTH7,AREA

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,600,720

ASEL,R,LOC,Y,858,874

CM,BASE\_NORTH8,AREA

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,600,720

ASEL,R,LOC,Y,978,994

CM,BASE\_NORTH9,AREA

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,504,720

ASEL,R,LOC,Y,1098,1114

CM,BASE\_NORTH10,AREA

CMGRP,BASE\_NORTH\_WEST,BASE\_NORTH6,BASE\_NORTH7,BASE\_NORTH8,BASE\_NORTH9,BASE\_NORTH10

CMGRP,BASE\_NS\_WALLS,BASE\_SOUTH\_EAST,BASE\_SOUTH\_WEST,BASE\_MIDDLE\_EAST,BASE\_MIDDLE\_WEST,BASE\_NORTH\_EAST,BASE\_NORTH\_WEST

! Northeast box

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,720,880

ASEL,R,LOC,Y,18,34

CM,BASE\_EBOX\_1,AREA

ASEL,S,LOC,Z,23,25

ASEL,R,LOC,X,864,880

ASEL,R,LOC,Y,34,201

CM,BASE\_EBOX\_2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,201,217  
CM,BASE\_EBOX\_3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,774  
ASEL,R,LOC,Y,18,201  
CM,BASE\_EBOX\_4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,18,217  
CM,BASE\_EBOX\_5,AREA

! NorthWest box

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,880  
ASEL,R,LOC,Y,1098,1114  
CM,BASE\_WBOX\_1,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,864,880  
ASEL,R,LOC,Y,921,1098  
CM,BASE\_WBOX\_2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,905,921  
CM,BASE\_WBOX\_3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,774  
ASEL,R,LOC,Y,921,1114  
CM,BASE\_WBOX\_4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,905,1114  
CM,BASE\_WBOX\_5,AREA

CMGRP,BASE\_BOX\_WALLS,BASE\_EBOX\_1,BASE\_EBOX\_2,BASE\_EBOX\_3,BASE\_WBOX\_1,BASE\_WBOX\_2,  
BASE\_WBOX\_3  
CMGRP,BASE\_BOXES,BASE\_EBOX\_4,BASE\_EBOX\_5,BASE\_WBOX\_4,BASE\_WBOX\_5

! EAST WALL

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,720  
ASEL,R,LOC,Y,18,34  
CM,BASE\_EASTWALL,AREA

! SOUTH WALL

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,42,56  
ASEL,R,LOC,Y,18,1114  
CM,BASE\_SOUTHWALL,AREA

! STRONG WALL

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,774  
ASEL,R,LOC,Y,201,921  
CM,BASE\_STRONGWALL,AREA

! BUILD BOX TOPS

ALLSEL,ALL  
CMSEL,S,BASE\_BOXES,AREA  
AGEN,2,ALL,,,,,150,,,  
ASEL,S,LOC,Z,173,175,,1  
VDRAG,ALL,,,,,81,,,,,

! BUILD STRONG FLOOR

ALLSEL,ALL  
CMSEL,S,FLOOR,AREA  
AGEN,2,ALL,,,,,132,,,  
ASEL,S,LOC,Z,131,133  
VDRAG,ALL,,,,,80,81,,,  
vSEL,S,LOC,Z,132,180,,1  
VATT,5  
CM,STRONG\_FLOOR,VOLU

! RAISE 26 WALLS

ALLSEL,ALL  
CMSEL,S,BASE\_NS\_WALLS,AREA  
VDRAG,ALL,,,,,79,,,,,  
vSEL,S,LOC,Z,24,132,,1  
!VSEL,U,VOLU,,STRONG\_FLOOR,,,  
VATT,3  
CM,THIRTY\_WALLS,VOLU

! RAISE EAST WALL

```
ALLSEL,ALL
CMSEL,S,BASE_EASTWALL,AREA
VDRAG,ALL,,,,,79,,,,
vSEL,S,LOC,Z,24,132,,1
vSEL,R,LOC,X,56,720,
vSEL,R,LOC,Y,18,34,
!VSEL,U,VOLU,,STRONG_FLOOR,,,
VATT,3
CM,EAST_WALL,VOLU
```

! RAISE SOUTH WALL

```
ALLSEL,ALL
CMSEL,S,BASE_SOUTHWALL,AREA
VDRAG,ALL,,,,,79,,,,
vSEL,S,LOC,Z,24,132,,1
vSEL,R,LOC,X,42,56,,
VATT,3
CM,SOUTH_WALL,VOLU
```

! RAISE STRONG WALL

```
ALLSEL,ALL
CMSEL,S,BASE_STRONGWALL,AREA
VDRAG,ALL,,,,,79,80,81,82,83,84
vSEL,S,LOC,Z,24,540,,1
vSEL,R,LOC,X,720,774,,
vSEL,R,LOC,Y,201,921,,
VATT,6
CM,STRONG_WALL,VOLU
```

! RAISE BOX WALLS

```
ALLSEL,ALL
CMSEL,S,BASE_BOX_WALLS,AREA
VDRAG,ALL,,,,,79,80,,,,
vSEL,S,LOC,Z,24,174,,1
vSEL,R,LOC,X,720,880,,
VSEL,U,VOLU,,STRONG_WALL,,,
VATT,2
CM,BOX_WALLS,VOLU
```

! ATTACH LOADING STRIPS TO EAST EDGE OF FLOOR

```
CMSEL,S,PSFLOOR_EAST,LINE
LATT,5,,1,,350,,1
```

```
LMESH,ALL
```

```
! ATTACH TO WEST EDGE OF FLOOR  
CMSEL,S,PSFLOOR_WEST,LINE  
LATT,5,,1,,350,,1  
LMESH,ALL
```

```
! ATTACH TO TOP OF STRONG WALL  
CMSEL,S,PSWALL_TOP,LINE  
LATT,6,,1,,510,,1  
LMESH,ALL
```

```
! ATTACH TO BOTTOM OF STRONG WALL  
CMSEL,S,PSWALL_BOTTOM,LINE  
LATT,1,,1,,510,,1  
LMESH,ALL
```

```
! ATTACH TO SOUTH EDGE OF FLOOR  
CMSEL,S,PSFLOOR_SOUTH,LINE  
LATT,5,,1,,350,,1  
LMESH,ALL
```

```
! ATTACH TO NORTH EDGE OF FLOOR VIA STRONG WALL  
CMSEL,S,PSFLOOR_NORTH,LINE  
LATT,5,,1,,350,,1  
LMESH,ALL
```

```
! ATTACH TO CORNER OF STRONG WALL AND FLOOR TO REACT SHEAR ON TOP OF FLOOR  
CMSEL,S,WALL_FLOOR,LINE  
LATT,5,,1,,510,,1  
LMESH,ALL
```

```
! mesh all volumes and merge all coincident items  
ALLSEL,ALL  
VMESH,ALL  
NUMMRG,ALL,,,,  
SAVE
```

```
/SOLU  
ANTYPE,0 ! static analysis
```

```
! constrain bottom of slab
```

```
ASEL,S,LOC,Z,0,1  
ASEL,R,LOC,X,24,888  
DA,ALL,UX,0  
DA,ALL,UY,0  
DA,ALL,UZ,0
```

! release constraints at prestressing anchors

```
CMSEL,S,PSWALL_BOTTOM,LINE
DLDELE,ALL,ALL
```

! constrain axial rotation of loading beams as SOLID185 has no rotation DOF

```
N = NODE(174,18,153) ! PSFLOOR_EAST
D,N,ROTX,,,,,,,,
N = NODE(174,1114,153) ! PSFLOOR_WEST
D,N,ROTX,,,,,,,,
```

```
N = NODE(747,921,540) ! PSWALL_TOP
D,N,ROTY,,,,,,,,
N = NODE(747,921,0) ! PSWALL_BOTTOM
D,N,ROTY,,,,,,,,
```

```
N = NODE(0,978,153) ! PSFLOOR_SOUTH
D,N,ROTY,,,,,,,,
N = NODE(720,978,153) ! PSFLOOR_NORTHWEST
D,N,ROTY,,,,,,,,
N = NODE(774,921,153) ! PSFLOOR_NORTHCENTRAL
D,N,ROTY,,,,,,,,
N = NODE(720,201,153) ! PSFLOOR_NORTHEAST
D,N,ROTY,,,,,,,,
```

```
N = NODE(720,201,180) ! WALL_FLOOR
D,N,ROTY,,,,,,,,
! LS1 = GRAVITY ONLY
```

```
ALLSEL,ALL
TIME,1
LSWRITE,1
```

! LS2 = APPLY UNBALANCED POST-TENSIONING LINE PRESSURE ON BEAMS  
! GRAVITY UNTOUCHED AND REMAINS

```
CMSEL,S,PSWALL_TOP,LINE
ESLL,S
CM,TOP_BEAM,ELEM
SFBEAM,ALL,1,PRES,-19.65,-19.65, , , ,
```

```
CMSEL,S,PSFLOOR_EAST,LINE
ESLL,S
CM,EAST_BEAM,ELEM
SFBEAM,ALL,1,PRES,-4.08,-4.08, , , ,
```

```
CMSEL,S,PSFLOOR_SOUTH,LINE
ESLL,S
CM,SOUTH_BEAM,ELEM
SFBEAM,ALL,1,PRES,-4.08,-4.08, , , ,
```

```
ALLSEL,ALL
TIME,2
LSWRITE,2
```

```
! LS3 = APPLY BALANCE OF POST-TENSIONING LINE PRESSURE ON BEAMS
! GRAVITY UNTOUCHED AND REMAINS
```

```
CMSEL,S,PSWALL_BOTTOM,LINE
ESLL,S
CM,BOTTOM_BEAM,ELEM
SFBEAM,ALL,1,PRES,-19.65,-19.65, , , ,
```

```
CMSEL,S,PSFLOOR_WEST,LINE
ESLL,S
CM,WEST_BEAM,ELEM
SFBEAM,ALL,1,PRES,-4.08,-4.08, , , ,
```

```
CMSEL,S,PSFLOOR_NORTH,LINE
ESLL,S
CM,NORTH_BEAM,ELEM
SFBEAM,ALL,1,PRES,-4.08,-4.08, , , ,
```

```
ALLSEL,ALL
TIME,3
LSWRITE,3
```

```
!LS4 = +X FORCE ON TOP OF STRONG WALL 10K/FT
```

```
CMSEL,S, TOP_BEAM,ELEM
SFBEAM,ALL,2,PRES,-0.833,-0.833, , , ,
ALLSEL,ALL
TIME,4
LSWRITE,4
```

```
!LS5 = -X FORCE ON TOP OF STRONG WALL 10K/FT
```

```
CMSEL,S, TOP_BEAM,ELEM
SFEDELE,ALL,2,PRES
SFBEAM,ALL,2,PRES,0.833,0.833, , , ,
ALLSEL,ALL
TIME,5
LSWRITE,5
```



! LS6 = -Z 1350 PSF OVER ENTIRE STRONG FLOOR  
! REMOVE SHEAR ON TOP OF STRONG WALL

CMSEL,S, TOP\_BEAM, ELEM  
SFEDELE, ALL, 2, PRES

! cover entire strong floor with surface elements

ESEL,S, MAT, , 5  
NSLE,S, ALL  
NSEL,R, LOC, Z, 179, 181, ,  
NSEL,R, LOC, X, 0, 720, ,  
NSEL,R, LOC, Y, 18, 1114, ,  
NSEL,R, EXT  
TYPE, 2  
MAT, 5  
REAL, 2  
ESURF

! apply 1350 psf normal pressure on surface elements

ESEL,S, TYPE, , 2  
SFE, ALL, 1, PRES, , 0.009375, 0.009375, 0.009375, 0.009375  
ALLSEL, ALL  
TIME, 6  
LSWRITE, 6

! LS7 = +X 50 K SHEAR AT EVERY LOAD POINT OF STRONG FLOOR FACING STRONG WALL

ESEL,S, TYPE, , 2  
SFEDELE, ALL, ALL, PRES  
NSLE,S, ALL

\*DO, I, 24, 696, 24  
\*DO, J, 213, 909, 24  
N = NODE(I, J, 180)  
F, N, Fx, 50, , ,  
\*ENDDO  
\*ENDDO

!NSEL,R, LOC, X, 12, 708, ,  
!NSEL,R, LOC, Y, 201, 921, ,  
!ESLN,S, 1, ALL  
!SFE, ALL, 3, PRES, , 0.0895, 0.0895, 0.0895, 0.0895

!NSEL,R, LOC, X, 24, 696, ,  
!NSEL,R, LOC, Y, 213, 909, ,  
!SFE, ALL, 3, PRES, , 0.0868, 0.0868, 0.0868, 0.0868

! REACTION AT CORNER WITH STRONG WALL

```
CMSEL,S,WALL_FLOOR,LINE
ESLL,S
CM,CORNER_BEAM,ELEM
ISFBEAM,ALL,1,PRES,60.417,60.417,,,,,
SFBEAM,ALL,1,PRES,-60.417,-60.417,,,,,
!LSEL,R,LOC,Y,213,909
ISFBEAM,ALL,1,PRES,62.5,62.5,,,,,
```

```
ALLSEL,ALL
TIME,7
LSWRITE,7
```

!LS8 = +X 50 K SHEAR AT EVERY LOAD POINT OF STRONG FLOOR

```
CMSEL,S,CORNER_BEAM,ELEM
SFEDELE,ALL,ALL,PRES
ESEL,S,TYPE,,2
NSLE,S,ALL
FDELE,ALL,FX
```

```
*DO,I,24,696,24
*DO,J,69,1053,24
  N = NODE(I,J,180)
  F,N,FX,50,,,
*ENDDO
*ENDDO
```

```
!SFEDELE,ALL,ALL,PRES
!NSLE,S,ALL
!INSEL,R,LOC,X,24,696,,
!INSEL,R,LOC,Y,69,1053,,
!ESLN,S,1,ALL
!SFE,ALL,3,PRES,,0.0921,0.0921,0.0921,0.0921
!INSEL,R,LOC,X,24,696,,
!INSEL,R,LOC,Y,69,1053,,
!SFE,ALL,3,PRES,,0.0868,0.0868,0.0868,0.0868
```

```
ALLSEL,ALL
TIME,8
LSWRITE,8
```

!LS9 = -X 50 K SHEAR AT EVERY LOAD POINT OF STRONG FLOOR

```
ESEL,S,TYPE,,2
NSLE,S,ALL
```

FDELE,ALL,FX

\*DO,I,24,696,24

\*DO,J,69,1053,24

N = NODE(I,J,180)

F,N,FX,-50,,,

\*ENDDO

\*ENDDO

!ESEL,S,TYPE,,2

!SFEDELE,ALL,ALL,PRES

!NSLE,S,ALL

!NSEL,R,LOC,X,12,708,,

!NSEL,R,LOC,Y,57,1065,,

!ESLN,S,1,ALL

!SFE,ALL,3,PRES,,-0.0921,-0.0921,-0.0921,-0.0921

!NSEL,R,LOC,X,24,696,,

!NSEL,R,LOC,Y,69,1053,,

!SFE,ALL,3,PRES,,-0.0868,-0.0868,-0.0868,-0.0868

ALLSEL,ALL

TIME,9

LSWRITE,9

!LS10 = +Y 50 K SHEAR AT EVERY LOAD POINT OF STRONG FLOOR

ESEL,S,TYPE,,2

NSLE,S,ALL

FDELE,ALL,FX

\*DO,I,24,696,24

\*DO,J,69,1053,24

N = NODE(I,J,180)

F,N,FY,50,,,

\*ENDDO

\*ENDDO

!ESEL,S,TYPE,,2

!SFEDELE,ALL,ALL,PRES

!NSLE,S,ALL

!NSEL,R,LOC,X,12,708,,

!NSEL,R,LOC,Y,57,1065,,

!ESLN,S,1,ALL

!SFE,ALL,2,PRES,,-0.0921,-0.0921,-0.0921,-0.0921

!NSEL,R,LOC,X,24,696,,

INSEL,R,LOC,Y,69,1053,,  
!SFE,ALL,2,PRES,,-0.0868,-0.0868,-0.0868,-0.0868

ALLSEL,ALL  
TIME,10  
LSWRITE,10

! LS11= 1800 PSF OVER 20'X 20' AT CENTER OF FLOOR

ESEL,S,TYPE,,2  
NSLE,S,ALL  
FDELE,ALL,FY

!ESEL,S,TYPE,,2  
!SFEDELE,ALL,ALL,PRES  
!NSLE,S,ALL

NSEL,R,LOC,X,216,456,,  
NSEL,R,LOC,Y,429,669,,  
ESLN,S,1,ALL  
SFE,ALL,1,PRES,,0.0125,0.0125,0.0125,0.0125

ALLSEL,ALL  
TIME,11  
LSWRITE,11

! LS12= 1800 PSF OVER 20'X 20' AT SW CORNER OF HOODED SLAB

ESEL,S,TYPE,,2  
SFEDELE,ALL,ALL,PRES  
NSLE,S,ALL  
NSEL,R,LOC,X,72,312,,  
NSEL,R,LOC,Y,621,861,,  
ESLN,S,1,ALL  
SFE,ALL,1,PRES,,0.0125,0.0125,0.0125,0.0125

ALLSEL,ALL  
TIME,12  
LSWRITE,12

! LS13= 1800 PSF OVER 20'X 20' AT NE CORNER OF HOODED SLAB

ESEL,S,TYPE,,2  
SFEDELE,ALL,ALL,PRES  
NSLE,S,ALL  
NSEL,R,LOC,X,360,600,,  
NSEL,R,LOC,Y,261,501,,  
ESLN,S,1,ALL

SFE,ALL,1,PRES,,0.0125,0.0125,0.0125,0.0125

ALLSEL,ALL  
TIME,13  
LSWRITE,13

! LS14= 100 K AT 4 FT UP

ESEL,S,TYPE,,2  
SFEDELE,ALL,ALL,PRES  
NSLE,S,ALL

\*DO,I,24,696,48  
\*DO,J,69,1029,48  
N = NODE(I,J,180)  
F,N,FZ,100,,,  
\*ENDDO  
\*ENDDO

ALLSEL,ALL  
TIME,14  
LSWRITE,14

! LS15= 100 K AT 4 FT DOWN

ESEL,S,TYPE,,2  
NSLE,S,ALL  
FDELE,ALL,ALL

\*DO,I,24,696,48  
\*DO,J,69,1029,48  
N = NODE(I,J,180)  
F,N,FZ,-100,,,  
\*ENDDO  
\*ENDDO

ALLSEL,ALL  
TIME,15  
LSWRITE,15

! LS16= 100 K AT 4 FT ALTERNATE UP AND DOWN

ESEL,S,TYPE,,2  
NSLE,S,ALL  
FDELE,ALL,ALL

\*DO,I,72,648,96  
\*DO,J,117,981,96

```
N = NODE(I,J,180)
F,N,FZ,100,,,
*ENDDO
*ENDDO
```

```
*DO,I,24,696,96
*DO,J,69,1029,96
N = NODE(I,J,180)
F,N,FZ,-100,,,
*ENDDO
*ENDDO
```

```
ALLSEL,ALL
TIME,16
LSWRITE,16
```

! LS17= 100 K up AT 6 FT AND DOWN at 2 ft centered

```
ESEL,S,TYPE,,2
NSLE,S,ALL
FDELE,ALL,ALL
```

```
*DO,I,24,672,72
*DO,J,93,1029,72
N = NODE(I,J,180)
F,N,FZ,100,,,
*ENDDO
*ENDDO
```

```
*DO,I,48,624,72
*DO,J,117,981,72
N1 = NODE(I,J,180)
F,N1,FZ,-100,,,
K=I+24
L=J+24
N2 = NODE(K,J,180)
F,N2,FZ,-100,,,
N3 = NODE(I,L,180)
F,N3,FZ,-100,,,
N4 = NODE(K,L,180)
F,N4,FZ,-100,,,
*ENDDO
*ENDDO
```

```
ALLSEL,ALL
TIME,17
LSWRITE,17
```

! LS18= LS17+LS8 = 100 K up AT 6 FT AND DOWN at 2 ft centered +X 50 K SHEAR AT EVERY LOAD POINT

```
ESEL,S,TYPE,,2
NSLE,S,ALL
*DO,I,24,696,24
  *DO,J,69,1053,24
    N = NODE(I,J,180)
    F,N,Fx,50,,,
  *ENDDO
*ENDDO
```

```
INSEL,R,LOC,X,12,708,,
INSEL,R,LOC,Y,57,1065,,
IESLN,S,1,ALL
ISFE,ALL,3,PRES,,0.0868,0.0868,0.0868,0.0868
```

```
ALLSEL,ALL
TIME,18
LSWRITE,18
```

! LS19= LS14+LS8 = 100 K AT 4 FT UP + X 50 K SHEAR AT EVERY LOAD POINT

```
ESEL,S,TYPE,,2
NSLE,S,ALL
FDELE,ALL,FZ
*DO,I,24,696,48
  *DO,J,69,1029,48
    N = NODE(I,J,180)
    F,N,FZ,100,,,
  *ENDDO
*ENDDO
```

```
ALLSEL,ALL
TIME,19
LSWRITE,19
```

! LS20= LS15+LS8 = 100 K AT 4 FT DOWN + X 50 K SHEAR AT EVERY LOAD POINT

```
ESEL,S,TYPE,,2
NSLE,S,ALL
FDELE,ALL,FZ
*DO,I,24,696,48
  *DO,J,69,1029,48
    N = NODE(I,J,180)
    F,N,FZ,-100,,,
  *ENDDO
*ENDDO
```

```
ALLSEL,ALL
TIME,20
LSWRITE,20
```

! LS21= LS16+LS8 =100 K AT 4 FT ALTERNATE UP AND DOWN + X 50 K SHEAR AT EVERY LOAD POINT

```
ESEL,S,TYPE,,2
NSLE,S,ALL
FDELE,ALL,FZ
```

```
*DO,I,72,648,96
*DO,J,117,981,96
  N = NODE(I,J,180)
  F,N,FZ,100,,,
*ENDDO
*ENDDO
```

```
*DO,I,24,696,96
*DO,J,69,1029,96
  N = NODE(I,J,180)
  F,N,FZ,-100,,,
*ENDDO
*ENDDO
```

```
ALLSEL,ALL
TIME,21
LSWRITE,21
```

```
LSSOLVE,1,21,1
```

```
/eof
```

! VDRAG WORKS BEST WHEN DRAG LINE IS SELECTED (ALLSELE,ALL)  
! AND ITS STARTING POINT TOUCHES SURFACE TO BE DRAGGED.  
! VATT WORKS ON UNMESHED, SELECTED VOLUMES.  
! A NEWLY CREATED VOLUME MUST STILL BE EXPLICITLY SELECTED.



## Part 2 Modular Support Structure

In the 2<sup>nd</sup> part of this report, a FEM of the modular support structure is described component by component, then assembled and load tested in an example. The models enable a future user of the NFRL to add a potential test structure and perform thermal and structural simulations of the test. This report thus serves as a user's manual for the future NFRL experimenter. Each component is self-contained, with its own coordinate and numbering system, and can be load tested on its own. In the assembly process, materials, element type, sections only need to be defined once. The numbering system for all ANSYS geometric entities (keypoints, lines, areas, volumes, elements and nodes) is designed so the components can be assembled with the concrete structure without interference. More details about the assembly process can be found in Chapter 13. Typical element size is 3 inches (76 mm), which is the distance between adjacent bolt holes.

Most structural components are defined in two versions: a structural version that uses ANSYS SHELL 181 (structural, 4 nodes) to model steel sections; and a thermal version that uses ANSYS SHELL 131 (thermal, 4 nodes) to model steel sections and a thermal blanket or wrap. Steel thermal properties are taken from Buchanan (2001), whereas the thermal blanket properties default to those of Blazeshield insulation material (NCSTAR 1) and a thickness of one inch (25 mm). The user can specify other properties.

Table 2.1 Steel properties

| $T$ °C     | 25    | 50    | 100   | 150   | 200   | 300   | 400   | 500   | 600   | 700  | 800   | 1200  |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|-------|-------|
| $E$        | 30000 |       | 30000 |       | 27000 | 24000 | 21000 | 18000 | 9300  | 3900 | 2700  |       |
| $K$        | 1.37  |       |       |       |       |       |       |       |       |      | 0.693 | 0.693 |
| $C$        | 199.5 | 208.5 | 221.2 | 231.5 | 240.3 |       | 274.8 | 302.3 | 344.7 |      |       |       |
| $\rho$     | .2636 |       |       |       |       |       |       |       |       |      |       |       |
| $\epsilon$ | 0.9   |       |       |       |       |       |       |       |       |      |       |       |

$T$  temperature °C;  $E$  Young's modulus ksi;  $K$  conductivity W/(in·C);  
 $C$  Heat capacity J/(lbm·C);  $\rho$  mass density lbm/in<sup>3</sup>;  $\epsilon$  emissivity.

Table 2.2 Insulation properties

| $T$ °C     | 25     | 377   | 677   |
|------------|--------|-------|-------|
| $K$        | .0013  | .0025 | .0051 |
| $C$        | 362.88 |       | 907.2 |
| $\rho$     | .00751 |       |       |
| $\epsilon$ | 0.9    |       |       |
| $t$        | 1.0    |       |       |

$t$  thickness inch

### References

Buchanan, A.H. (2001) "Structural Design for Fire Safety," Wiley, New York, NY 10158

NCSTAR 1 (2005) "Final Report on the Collapse of the World Trade Center," National Construction Safety Team Act Report 1, National Institute of Standards and Technology, Gaithersburg, MD 20899

## Chapter 2 Column-foot

Table 2.3 Properties

|                              |   |
|------------------------------|---|
| Column-foot                  | Starting numbers  |
| *Keypoints KP1               | 8 000   |
| *Lines LIN1                  | 19 000  |
| *Areas ARE1                  | 15 000  |
| *Volumes VOL1                | 5 000   |
| *Elements ELE1               | 67 000  |
| *Nodes NOD1                  | 85 000  |
| *Local coordinates system 11 | x parallel to flanges, point north;<br>y parallel to web, point west;<br>z points up;<br>origin : center of foot (Fig. 2.1) |
| Element type                 | 5 Shell 181   |
| Sections                     | *Column HEIGHT<br>2 (2 inch foot)<br>3 (flange W12x106)<br>4 (web W12x106)  |
| Materials                    | 10 (W section)<br>11 (foot)   |

\*user input or default option.

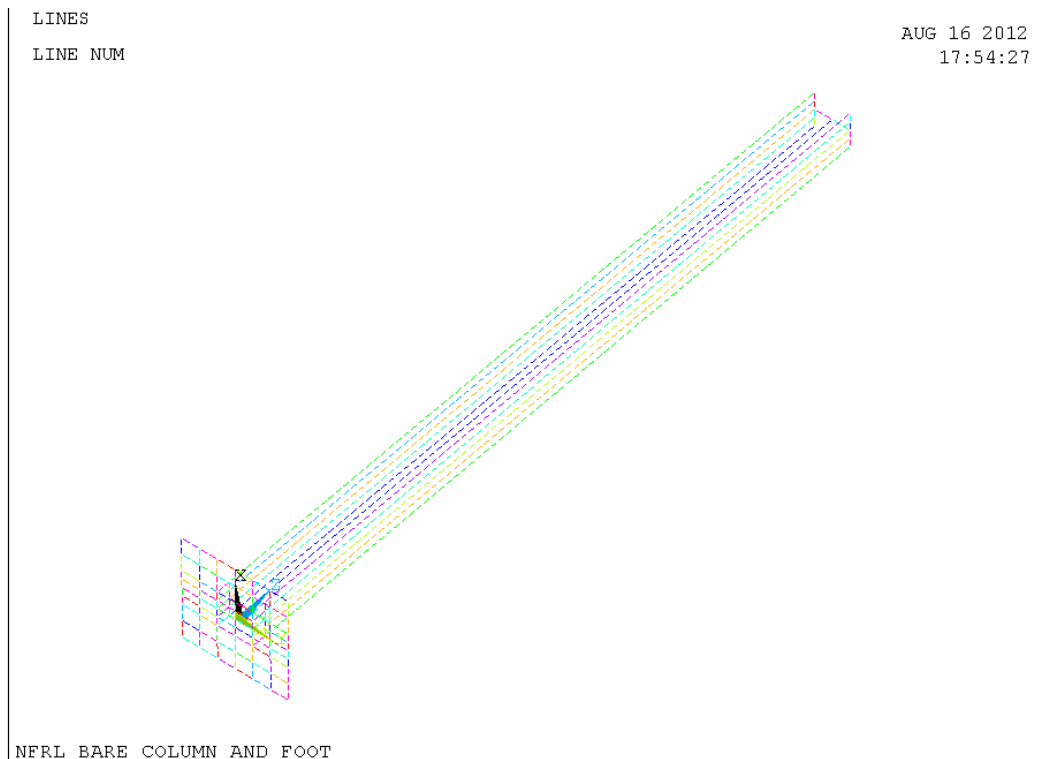
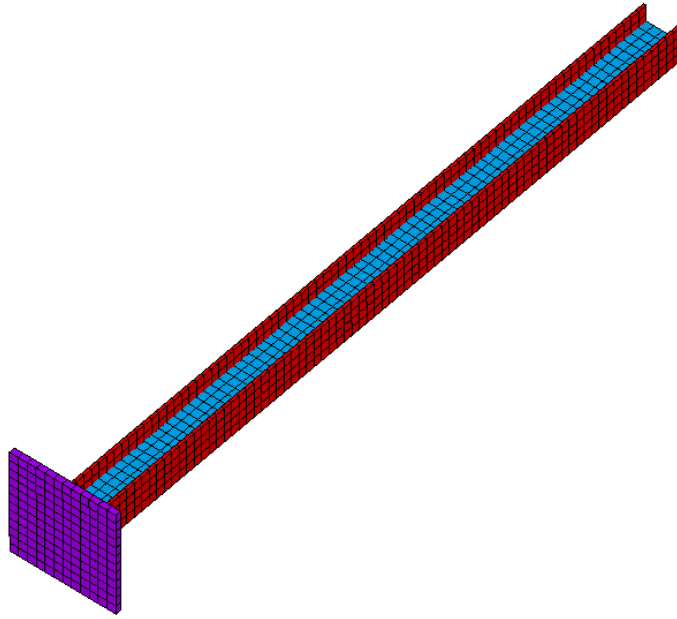


Fig.2.1 column-foot coordinate system

```
ELEMENTS
DSYS=11
SEC NUM
```

AUG 16 2012  
17:56:21



NFRL BARE COLUMN AND FOOT

Fig. 2.2 Column-foot

## ! Column-foot

```
FINISH
/CLEAR
/CWD,'C:\StrongFireLab'
/FILNAME,20120705D,0
/TITLE,NFRL BARE COLUMN AND FOOT
/REPLOT
```

```
KEYW,PR_SET,1
KEYW,PR_STRUC,1
KEYW,PR_THERM,0
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0
```

```
/PREP7
! UNITS SI for thermal W, J. degree C
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi
```

```
! ##### material properties
```

```
! # Material # 10 - Steel for W sections, 50 KSI STEEL
! thermal properties may be unnecessary for structural analysis
```

! Young's modulus and Poisson's ratio

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000
MPDATA,EX,10,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,10,,0.30
```

! thermal expansion

```
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

!# steel conductivity W/(in.C)

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,10,,1.37
MPDATA,KXX,10,,0.693
MPDATA,KXX,10,,0.693
```

!# steel heat capacity J/(kipm.C)

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,10,,199500
MPDATA,C,10,,208500
MPDATA,C,10,,221200
MPDATA,C,10,,231500
MPDATA,C,10,,240300
MPDATA,C,10,,274800
MPDATA,C,10,,302300
MPDATA,C,10,,344700
```

!# steel mass density

```
MPTEMP
```

MPTEMP,1,25  
MPDATA,DENS,10,,2.636E-4 ! kipm/in3

! # Material # 11 - Steel for foot, 36 KSI  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,11,1,29999,29999,27000,24000,21000,18000  
MPDATA,EX,11,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,11,,0.30

! thermal expansion  
TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,11,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.C)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,11,,1.37  
MPDATA,KXX,11,,0.693  
MPDATA,KXX,11,,0.693

!# steel heat capacity J/(kipm.C)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,11,,199500  
MPDATA,C,11,,208500  
MPDATA,C,11,,221200  
MPDATA,C,11,,231500  
MPDATA,C,11,,240300  
MPDATA,C,11,,274800  
MPDATA,C,11,,302300

MPDATA,C,11,,344700

!# steel mass density

MPTEMP

MPTEMP,1,25

MPDATA,DENS,11,,2.636E-4 ! kipm/in3

ET,5,SHELL181

KEYOPT,5,1,0 ! bending and membrane stiffness

KEYOPT,5,3,2 ! full integration with incompatible modes

KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer

KEYOPT,5,9,0 ! no user subroutine to define thickness

KEYOPT,5,10,0 ! no initial stress

sect,2,shell,,foot

secdata,2,11,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

sect,3,shell,,12106f

secdata,0.99,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W

secdata,0.61,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS, SUB 1=====

\*SET,KP1,8000

\*SET,LIN1,19000

\*SET,ARE1,15000

\*SET,VOL1,5000

\*SET,ELE1,67000

\*SET,NOD1,85000

! # define model geometry, sheet 11/15 lower left fig

! Local X parallel to flanges, point North.

! Local Y parallel to web, point West.

! Local Z points up.

! user input: origin of local coordinates = CENTER OF FOOT

LOCAL,11,0,100,100,180, , , 1,1,

CSYS,11,

HEIGHT=240 ! COLUMN HEIGHT INCLUDES FOOTING, INCHES

H=HEIGHT-1

! END OF user input=====

NUMSTR,KP,KP1  
NUMSTR,LINE,LIN1  
NUMSTR,AREA,ARE1  
NUMSTR,VOLU,VOL1  
NUMSTR,ELEM,ELE1  
NUMSTR,NODE,NOD1

! X SIDE OF FOOT

K,KP1,-18,-18,0,  
K,KP1+1,-12,-18,0,  
K,KP1+2,-6.11,-18,0,  
K,KP1+3,-3.0,-18,0, ! 8.3 4pm  
K,KP1+4,0,-18,0,  
K,KP1+5,3.0,-18,0, ! 8.3 4pm  
K,KP1+6,6.11,-18,0,  
K,KP1+7,12,-18,0,  
K,KP1+8,18,-18,0,

! Y SIDE OF FOOT

K,KP1+10,-18,-18,0,  
K,KP1+11,-18,-12,0,  
K,KP1+12,-18,-5.95,0,  
K,KP1+13,-18,0,0,  
K,KP1+14,-18,5.95,0,  
K,KP1+15,-18,12,0,  
K,KP1+16,-18,18,0,

! Z SIDE OF COLUMN OF HEIGHT 240 IN

K,KP1+20,,,-5.95,0,  
K,KP1+21,,,-5.95,5,  
K,KP1+22,,,-5.95,H,

! Z distance between KP1+21 and KP1+22 must be multiple of 3 inches

! HEIGHT = 3N HEIGHT INCLUDES THICKNESS OF FOOT

\*DO,I,KP1,KP1+7,1

LSTR,I,I+1

\*ENDDO

\*DO,I,KP1+10,KP1+15,1

LSTR,I,I+1

\*ENDDO

LSTR,KP1+20,KP1+21

LSEL,S,LINE,,LIN1+2,LIN1+5,,1

LESIZE,ALL,,,1,,,,,0

ALLSEL,ALL

LESIZE,ALL,,2,,,,,0

! ENSURE NODES AT HOLES ALONG COLUMN HEIGHT

```
LSTR,KP1+21,KP1+22
!KSEL,S,KP,,KP1+21,KP1+22,,
!LSLK,S,1
!*get, aa,line,0,num,min
!LESIZE,aa,3,, , , , ,1
LESIZE,LIN1+15,3,, , , , ,1
```

! BASE OF FOOT

```
KSEL,S,LOC,X,-18.1,18.1,,
KSEL,R,LOC,Y,-18.1,-17.9,,
KSEL,R,LOC,Z,0.1,,
LSLK,S,1
CM,FOOTX,LINE
```

```
KSEL,S,LOC,X,-18.1,-17.9,,
KSEL,R,LOC,Y,-18.1,18.1,,
KSEL,R,LOC,Z,0.1,,
LSLK,S,1
CM,FOOTY,LINE
```

! height of column

```
KSEL,S,LOC,X,-0.1,0.1,,
KSEL,R,LOC,Y,-6.0,-5.90,,
KSEL,R,LOC,Z,H,,
LSLK,S,1
CM,COLUMNZ,LINE
```

! foot area

```
ALLSEL,ALL
ADRAG,FOOTX,,,,,FOOTY,,,,,
```

! column flange 1

```
LSEL,S,LOC,X,-6.10,6.10,,
LSEL,R,LOC,Y,-6.0,-5.9,,
LSEL,R,LOC,Z,0.1,,
CM,COLFLAN1,LINE
```

! column flange 2

```
LSEL,S,LOC,X,-6.10,6.10,,
LSEL,R,LOC,Y,5.9,6.0,,
LSEL,R,LOC,Z,0.1,,
CM,COLFLAN2,LINE
```

! column WEB

```
LSEL,S,LOC,X,-.5,.5,,
LSEL,R,LOC,Y,-5.9,5.9,,
```



```
LSEL,R,LOC,Z,,0.1,,  
CM,COLWEB,LINE
```

```
! column areas  
ALLSEL,ALL  
ADRAG,COLFLAN1,,,,,COLUMNZ,,,,,  
ADRAG,COLFLAN2,,,,,COLUMNZ,,,,,  
ADRAG,COLWEB,,,,,COLUMNZ,,,,,
```

```
! MESH FOOT  
ASEL,S,LOC,Z,,0.1,,  
AATT,11,,5,11,2  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! mesh column web  
ASEL,S,LOC,X,-.5,.5,,  
ASEL,R,LOC,Y,-5.9,5.9,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH columnn flange 1  
ASEL,S,LOC,X,-6.10,6.10,,  
ASEL,R,LOC,Y,-6.0,-5.9,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH columnn flange 2  
ASEL,S,LOC,X,-6.10,6.10,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
ALLSEL,ALL  
NUMMRG,ALL,,,,  
SAVE
```

```
! the following is a load test
```

```
/SOLU
ANTYPE,0 ! static analysis

! constrain Z=0 end
NSEL,S,LOC,Z,0,0.1,,
D,ALL,UX,,,,,,,,
D,ALL,UY,,,,,,,,
D,ALL,UZ,,,,,,,,

! LOAD UPPER END Z=HEIGHT
ALLSEL,ALL
H1=H-.1
H2=H+.1
NSEL,S,LOC,Z,H1,H2,,
F,ALL,FY,1,,,

ALLSEL,ALL
OUTPR,STAT
OUTRES,STAT
SOLVE
/EOF
```

## Chapter 3 Wrapped column-foot

Table 3.1 Properties

|                              |   |
|------------------------------|---|
| Wrapped column-foot          | Starting numbers  |
| *Keypoints KP1               | 8 000   |
| *Lines LIN1                  | 19 000  |
| *Areas ARE1                  | 15 000  |
| *Volumes VOL1                | 5 000   |
| *Elements ELE1               | 67 000  |
| *Nodes NOD1                  | 85 000  |
| *Local coordinates system 11 | x parallel to flanges, point north;<br>y parallel to web, point west;<br>z points up;<br>origin : center of foot (Fig. 2.1)                           |
| Element type                 | 5 Shell 131   |
| Sections                     | *Column HEIGHT<br>2 (2 in foot)<br>3 (flange W12x106)<br>4 (web W12x106)<br>*5 (1 inch foot wrap)<br>*6 (1 inch flange wrap)<br>*7 (1 inch side wrap) |
| Materials                    | 10 (W section)<br>11 (foot)<br>*13 (insulation)   |

\*user input or default option.

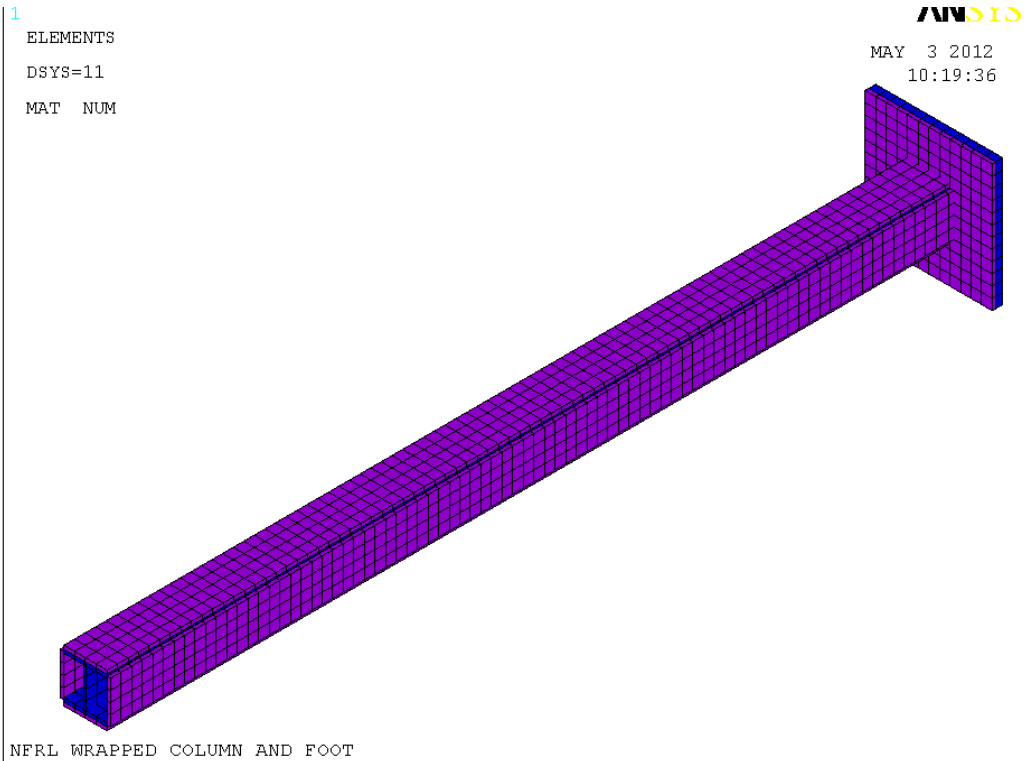


Fig. 3.1 Wrapped column-foot

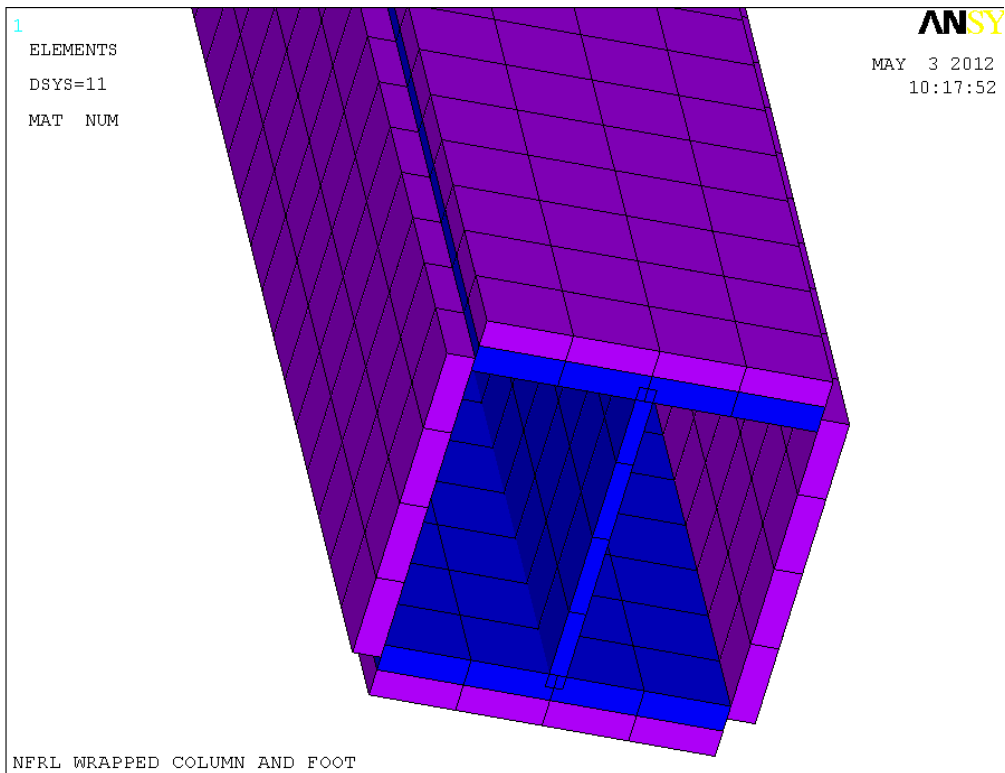


Fig. 3.2 Detail of wrapped column-foot

## ! Wrapped column-foot

! user input: insulation thickness and properties  
! user input: location of column (origin of local coordinates)

```
FINISH
/CLEAR
/CWD,'C:\StrongFireLab'
/FILNAME,20120709,0
/TITLE,NFRL WRAPPED COLUMN AND FOOT
/REPLOT

KEYW,PR_SET,1
KEYW,PR_STRUC,0
KEYW,PR_THERM,1
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0

/PREP7
! UNITS SI for thermal W, J. degree C
! use degree K for radiation
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! constants
SIG=3.6583E-11 ! Stefan-Boltzman constant W/(in^2.K^4)
EMS1=0.9 ! Emissivity of steel - outside
EMS2=0.9 ! Emissivity of steel - inside
Hf=15 ! Film coefficient of steel faces
tref,25
! ##### material properties

! # Material # 10 - Steel

!# steel conductivity W/(in.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,10,,1.37
MPDATA,KXX,10,,0.693
MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
```

MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,10,,199500  
MPDATA,C,10,,208500  
MPDATA,C,10,,221200  
MPDATA,C,10,,231500  
MPDATA,C,10,,240300  
MPDATA,C,10,,274800  
MPDATA,C,10,,302300  
MPDATA,C,10,,344700

!# steel mass density  
MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,10,,2.636E-4 ! kipm/in3

!# steel emissivity and film coefficient  
MPTEMP  
MPTEMP,1,25  
MPDATA,EMIS,10,,0.9

!user input: insulation thickness and properties=====

! # Material # 13 - Blazeshield insulation

!# insulation conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25 ! degree C  
MPTEMP,2,377  
MPTEMP,3,677  
MPDATA,KXX,13,,0.0013  
MPDATA,KXX,13,,0.0025  
MPDATA,KXX,13,,0.0051

!# insulation heat capacity J/(kipm.K)  
MPTEMP  
MPTEMP,1,25 ! C  
MPTEMP,2,677  
MPDATA,C,13,,362880  
MPDATA,C,13,,907200

!# insulation mass density kipm/in3  
MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,13,,7.51E-6

```
!# insulation emissivity
MPTEMP
MPTEMP,1,25
MPDATA,EMIS,13,,0.9
```

```
! Insulation blanket thickness is T
T = 1
! careful that same emissivity can be used for steel and insulation
! end user input=====
```

```
ET,5,SHELL131
KEYOPT,5,2,0 ! average film temperature
KEYOPT,5,3,0 ! quadratic temperature distribution through thickness
KEYOPT,5,4,0 ! use sect defined above
KEYOPT,5,6,0 ! no paint
!KEYOPT,5,8,2 use this option when insulation is present- data at top, bottom and mid of all layers
!SHELL,MID use this option when insulation is present-results calculated at mid, not averaged from
top and bottom
```

```
sect,2,shell,,foot ! bare steel
secdata,2,10,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,3,shell,,12106f ! bare steel
secdata,0.99,10,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,4,shell,,12106W ! bare steel
secdata,0.61,10,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,5,shell,,footw
secdata,2,10,0,3 ! steel layer 1 at bottom
secdata,T,13,0,3
secoffset,user,-T/2 ! relative to midthickness of shell
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,6,shell,,flangew
secdata,0.99,10,0,3 ! steel layer 1 at bottom
secdata,T,13,0,3
secoffset,user,-T/2 ! relative to midthickness of shell
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,7,shell,,sidew ! blanket
secdata,T,13,0,3
```

secoffset,bot  
seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS, SUB 1=====

\*SET,KP1,8000  
\*SET,LIN1,19000  
\*SET,ARE1,15000  
\*SET,VOL1,5000  
\*SET,ELE1,67000  
\*SET,NOD1,85000

! # define model geometry, sheet 11/15 lower left fig  
! Local X parallel to flanges, point North.  
! Local Y parallel to web, point West.  
! Local Z points up.

! user input: origin of local coordinates = CENTER OF FOOT  
LOCAL,11,0,100,100,180, , , 1,1,  
CSYS,11,

HEIGHT=240 ! COLUMN HEIGHT INCLUDES FOOTING, INCHES  
H=HEIGHT-1

! END OF user input=====

TREF,25  
NUMSTR,KP,KP1  
NUMSTR,LINE,LIN1  
NUMSTR,AREA,ARE1  
NUMSTR,VOLU,VOL1  
NUMSTR,ELEM,ELE1  
NUMSTR,NODE,NOD1

! X SIDE OF FOOT  
K,KP1,-18,-18,0,  
K,KP1+1,-12,-18,0,  
K,KP1+2,-6.11,-18,0,  
K,KP1+3,-3.0,-18,0, ! 8.3 4pm  
K,KP1+4,0,-18,0,  
K,KP1+5,3.0,-18,0, ! 8.3 4pm  
K,KP1+6,6.11,-18,0,  
K,KP1+7,12,-18,0,  
K,KP1+8,18,-18,0,

! Y SIDE OF FOOT  
K,KP1+10,-18,-18,0,  
K,KP1+11,-18,-12,0,  
K,KP1+12,-18,-5.95,0,  
K,KP1+13,-18,0,0,



```
K,KP1+14,-18,5.95,0,  
K,KP1+15,-18,12,0,  
K,KP1+16,-18,18,0,
```

```
! Z SIDE OF COLUMN OF HEIGHT 240 IN
```

```
K,KP1+20,,-5.95,0,  
K,KP1+21,,-5.95,5,  
K,KP1+22,,-5.95,H,
```

```
! z distance between KP1+21 and KP1+22 must be multiple of 3 inches
```

```
! HEIGHT = 3N
```

```
*DO,I,KP1,KP1+7,1  
LSTR,I,I+1  
*ENDDO
```

```
*DO,I,KP1+10,KP1+15,1  
LSTR,I,I+1  
*ENDDO
```

```
LSTR,KP1+20,KP1+21
```

```
LSEL,S,LINE,,LIN1+2,LIN1+5,,1  
LESIZE,ALL,,,1,,,,,0  
ALLSEL,ALL  
LESIZE,ALL, , , 2, , , , 0
```

```
! ENSURE NODES AT HOLES ALONG COLUMN HEIGHT
```

```
LSTR,KP1+21,KP1+22  
!KSEL,S,KP,,KP1+21,KP1+22,,  
!LSLK,S,1  
!*get, aa,line,0,num,min  
!LESIZE,aa,3, , , , , 1  
LESIZE,LIN1+15,3, , , , , 1
```

```
! BASE OF FOOT
```

```
KSEL,S,LOC,X,-18.1,18.1,,  
KSEL,R,LOC,Y,-18.1,-17.9,,  
KSEL,R,LOC,Z,0.1,,  
LSLK,S,1  
CM,FOOTX,LINE
```

```
KSEL,S,LOC,X,-18.1,-17.9,,  
KSEL,R,LOC,Y,-18.1,18.1,,  
KSEL,R,LOC,Z,0.1,,  
LSLK,S,1  
CM,FOOTY,LINE
```

```

! height of column
KSEL,S,LOC,X,-0.1,0.1,,
KSEL,R,LOC,Y,-6.0,-5.90,,
KSEL,R,LOC,Z,,H,,
LSLK,S,1
CM,COLUMNZ,LINE

! foot area
ALLSEL,ALL
ADRAG,FOOTX,,,,,,,,FOOTY,,,,,,,,

! columnn flange 1
LSEL,S,LOC,X,-6.10,6.10,,
LSEL,R,LOC,Y,-6.0,-5.9,,
LSEL,R,LOC,Z,,0.1,,
CM,COLFLAN1,LINE

! columnn flange 2
LSEL,S,LOC,X,-6.10,6.10,,
LSEL,R,LOC,Y,5.9,6.0,,
LSEL,R,LOC,Z,,0.1,,
CM,COLFLAN2,LINE

! column WEB
LSEL,S,LOC,X,-.5,.5,,
LSEL,R,LOC,Y,-5.9,5.9,,
LSEL,R,LOC,Z,,0.1,,
CM,COLWEB,LINE

! column side 1
LSEL,S,LOC,X,-6.12,-6.10,,
LSEL,R,LOC,Y,-5.9,5.9,,
LSEL,R,LOC,Z,,0.1,,
CM,COLSIDE1,LINE

! column side 2
LSEL,S,LOC,X,6.10,6.12,,
LSEL,R,LOC,Y,-5.9,5.9,,
LSEL,R,LOC,Z,,0.1,,
CM,COLSIDE2,LINE

! column areas
ALLSEL,ALL
ADRAG,COLFLAN1,,,,,,,,COLUMNZ,,,,,,,,
ADRAG,COLFLAN2,,,,,,,,COLUMNZ,,,,,,,,
ADRAG,COLWEB,,,,,,,,COLUMNZ,,,,,,,,

! SIDE WRAPS

```

```
ADRAG,COLSIDE1,,,,,,,,COLUMNZ,,,,,,,,  
ADRAG,COLSIDE2,,,,,,,,COLUMNZ,,,,,,,,
```

```
! MESH FOOT  
ASEL,S,LOC,Z,,0.1,,  
AATT,10,,5,11,5  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! mesh column web  
ASEL,S,LOC,X,-.5,.5,,  
ASEL,R,LOC,Y,-5.9,5.9,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH columnn flange 1  
ASEL,S,LOC,X,-6.10,6.10,,  
ASEL,R,LOC,Y,-6.0,-5.9,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,6  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH columnn flange 2  
ASEL,S,LOC,X,-6.10,6.10,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,,H,,  
AREVERSE,ALL  
AATT,10,,5,11,6  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH side wrap 1  
ASEL,S,LOC,X,-6.12,-6.10,,  
ASEL,R,LOC,Y,-5.9,5.9,,  
ASEL,R,LOC,Z,,H,,  
AREVERSE,ALL  
AATT,13,,5,11,7  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH side wrap 2
ASEL,S,LOC,X,6.10,6.12,,
ASEL,R,LOC,Y,-5.9,5.9,,
ASEL,R,LOC,Z,,H,,
AATT,13,,5,11,7
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
NUMMRG,ALL,,,,
/EOF
```

```
! 20120504 400 PM
! # Material # 11 is radiative face on the outside
MPTEMP
MPTEMP,1,25
MPDATA,EMIS,11,,EMS1
```

```
!user input: insulation thickness and properties
! # Material # 12 is radiative face on the inside
MPTEMP
MPTEMP,1,25
MPDATA,EMIS,12,,EMS2
```

# Chapter 4 Wall-column

Table 4.1 Properties

|                              |  |
|------------------------------|--|
| Wall-column                  | Starting numbers   |
| *Keypoints KPO               | 8 100  |
| *Lines LINO                  | 19 200   |
| *Areas AREO                  | 15 100   |
| *Volumes VOLO                | 5 000  |
| *Elements ELE0               | 69 000   |
| *Nodes NOD0                  | 88 000   |
| *Local coordinates system 12 | x parallel to flanges, points North;<br>y parallel to web, points West;<br>z points up;<br>origin: center of I-section at base (Fig. 4.1). |
| Element type                 | 5 Shell 181  |
| Sections                     | 2 (2.00 inch foot)<br>3 (0.99 inch flange W12x106)<br>4 (0.61 inch web W12x106 )<br>8 (1.00 inch shim)                                     |
| Materials                    | 10, 11 (W sections)<br>12 (shim)   |

\*user input or default option.

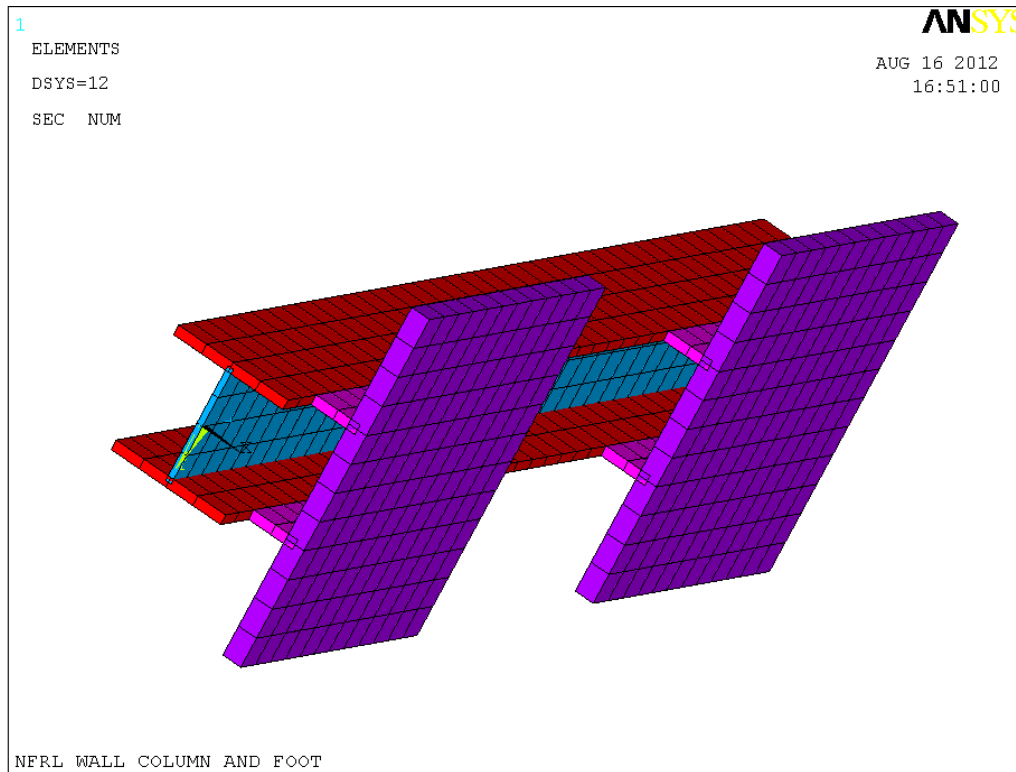


Fig. 4.1 Wall-column

! Wall-column LAST TESTED 7.20.2012

FINISH  
/CLEAR  
/CWD,'C:\StrongFireLab'  
/FILENAME,20120706,0  
/TITLE,NFRL WALL COLUMN AND FOOT  
/REPLOT

KEYW,PR\_SET,1  
KEYW,PR\_STRUC,1  
KEYW,PR\_THERM,0  
KEYW,PR\_FLUID,0  
KEYW,PR\_MULTI,0

/PREP7  
! UNITS SI for thermal W, J. degree C  
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! ##### material properties  
! # Material # 10 - Steel for W sections  
! thermal properties may be unnecessary for structural analysis  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000  
MPDATA,EX,10,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,10,,0.30

! thermal expansion  
TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693  
MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,50

MPTEMP,3,100

MPTEMP,4,150

MPTEMP,5,200

MPTEMP,6,400

MPTEMP,7,500

MPTEMP,8,600

MPDATA,C,10,,199500

MPDATA,C,10,,208500

MPDATA,C,10,,221200

MPDATA,C,10,,231500

MPDATA,C,10,,240300

MPDATA,C,10,,274800

MPDATA,C,10,,302300

MPDATA,C,10,,344700

!# steel mass density

MPTEMP

MPTEMP,1,25

MPDATA,DENS,10,,2.636E-4 ! kipm/in3

! # Material # 11 - Steel for foot

! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,

MPTEMP,1,25,100,200,300,400,500

MPTEMP,7,600,700,800

MPDATA,EX,11,1,29999,29999,27000,24000,21000,18000

MPDATA,EX,11,7,9300,3900,2700

MPTEMP,,,,,,,,

MPTEMP,1,0

MPDATA,PRXY,11,,0.30

! thermal expansion

MPTEMP,,,,,,,,

MPTEMP,1,0

MPDATA,ALPX,11,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,800

MPTEMP,3,1200

MPDATA,KXX,11,,1.37  
MPDATA,KXX,11,,0.693  
MPDATA,KXX,11,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,11,,199501  
MPDATA,C,11,,208501  
MPDATA,C,11,,221201  
MPDATA,C,11,,231501  
MPDATA,C,11,,240301  
MPDATA,C,11,,274801  
MPDATA,C,11,,302300  
MPDATA,C,11,,344700

!# steel mass density

MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,11,,2.636E-4 ! kipm/in3

! # Material # 12 - Steel for shim  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,12,1,29998,29998,27000,24000,21000,18000  
MPDATA,EX,12,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,12,,0.30

! thermal expansion

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,12,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)



```
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,12,,1.37
MPDATA,KXX,12,,0.693
MPDATA,KXX,12,,0.693
```

```
!# steel heat capacity J/(kipm.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,12,,199502
MPDATA,C,12,,208502
MPDATA,C,12,,221202
MPDATA,C,12,,231502
MPDATA,C,12,,240302
MPDATA,C,12,,274802
MPDATA,C,12,,302300
MPDATA,C,12,,344700
```

```
!# steel mass density
```

```
MPTEMP
MPTEMP,1,25
MPDATA,DENS,12,,2.636E-4 ! kipm/in3
```

```
ET,5,SHELL181
```

```
KEYOPT,5,1,0 ! bending and membrane stiffness
KEYOPT,5,3,2 ! full integration with incompatible modes
KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer
KEYOPT,5,9,0 ! no user subroutine to define thickness
KEYOPT,5,10,0 ! no initial stress
```

```
sect,2,shell,,foot
secdata,2,11,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,3,shell,,12106f
secdata,0.99,10,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,4,shell,,12106W
secdata,0.61,10,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,8,shell,,shim
secdata,1.0,12,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
! USER INPUT: STARTING NUMBERS, SUB ZERO (NOT LETTER O)=====
```

```
*SET,KP0,8100
*SET,LIN0,19200
*SET,ARE0,15100
*SET,VOLO,5000
*SET,ELE0,69000
*SET,NODO,88000
```

```
! # define model geometry
! user input:location of column (origin of local coordinates)
! ref: sheet 15/15 lower left fig
! Local X parallel to flanges, points North.
! Local Y parallel to web, points East.
! Local Z points up.
! location of WALL column (origin of local coordinates center of I at base)
LOCAL,12,0,709,250,204, , , 1,1,
CSYS,12,
```

```
! END OF user input=====
```

```
NUMSTR,KP,KP0
NUMSTR,LINE,LIN0
NUMSTR,AREA,ARE0
NUMSTR,VOLU,VOLO
NUMSTR,ELEM,ELE0
NUMSTR,NODE,NODO
```

```
! Y SIDE OF FOOT
K,KP0,11,-18,5.75,
K,KP0+1,11,-12,5.75,
K,KP0+2,11,-5.95,5.75,
K,KP0+3,11, ,5.75,
K,KP0+4,11,5.95,5.75,
K,KP0+5,11,12,5.75,
K,KP0+6,11,18,5.75,
```

```
! Z SIDE OF FOOT
K,KP0+10,11,-18,5.75
```

K,KP0+11,11,-18,11.75  
K,KP0+12,11,-18,35.75  
K,KP0+13,11,-18,41.75

\*DO,I,KP0,KP0+5,1  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KP0+10,KP0+12,1  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP0,KP0+13,,  
LSLK,S,1  
LESIZE,ALL,,2,,,,,1  
KSEL,S,KP,,KP0+11,KP0+12,,  
LSLK,S,1  
\*get, aa,line,0,num,min  
LESIZE,aa,3,,,,,1

KSEL,S,KP,,KP0,KP0+6,,  
LSLK,S,1  
CM,WALLFOOTY,LINE

KSEL,S,KP,,KP0+10,KP0+13,,  
LSLK,S,1  
CM,WALLFOOTZ,LINE

! X SIDE OF SHIM  
K,KP0+20,6.11,5.95,5.75  
K,KP0+21, 11,5.95,5.75  
LSTR,KP0+20,KP0+21  
KSEL,S,KP,,KP0+20,KP0+21,,  
LSLK,S,1  
LESIZE,ALL,,2,,,,,1  
CM,SHIMX,LINE

! Z SIDE OF SHIM  
K,KP0+30,6.11,5.95, 5.75  
K,KP0+31,6.11,5.95,41.75  
LSTR,KP0+30,KP0+31  
KSEL,S,KP,,KP0+30,KP0+31,,  
LSLK,S,1  
LESIZE,ALL,3,,,,,1  
CM,SHIMZ,LINE

! base of column web  
K,KP0+40,,,-5.95,

K,KP0+41,, -3.0,  
K,KP0+42,,, ,  
K,KP0+43,, 3.0,  
K,KP0+44,, 5.95,

\*DO,I,KP0+40,KP0+43,1  
LSTR,I,I+1  
\*ENDDO  
KSEL,S,KP,,KP0+40,KP0+44,,  
LSLK,S,1  
LESIZE,ALL, , ,1, , , ,1  
CM,webbase,LINE

! base of columnn flange1  
K,KP0+50,-6.11, 5.95,  
K,KP0+51,-3.0 , 5.95,  
K,KP0+52, , 5.95,  
K,KP0+53, 3.0 , 5.95,  
K,KP0+54, 6.11, 5.95,

\*DO,I,KP0+50,KP0+53,1  
LSTR,I,I+1  
\*ENDDO  
KSEL,S,KP,,KP0+50,KP0+54,,  
LSLK,S,1  
LESIZE,ALL, , ,1, , , ,1  
CM,flange1base,LINE

! base of columnn flange2  
K,KP0+60,-6.11,-5.95,  
K,KP0+61,-3.0 ,-5.95,  
K,KP0+62, ,-5.95,  
K,KP0+63, 3.0 ,-5.95,  
K,KP0+64, 6.11,-5.95,

\*DO,I,KP0+60,KP0+63,1  
LSTR,I,I+1  
\*ENDDO  
KSEL,S,KP,,KP0+60,KP0+64,,  
LSLK,S,1  
LESIZE,ALL, , ,1, , , ,1  
CM,flange2base,LINE

! columnn height  
K,KP0+70,,, ,  
K,KP0+71,,,2.75  
K,KP0+72,,,116.75  
K,KP0+73,,,119.5

```
LSTR,KP0+70,KP0+71
KSEL,S,KP,,KP0+70,KP0+71,,
LSLK,S,1
LESIZE,ALL,,1,,1
```

```
allsel,all
LSTR,KP0+71,KP0+72
KSEL,S,KP,,KP0+71,KP0+72,,
LSLK,S,1
LESIZE,ALL,3,,,,1
```

```
ALLSEL,ALL
LSTR,KP0+72,KP0+73
KSEL,S,KP,,KP0+72,KP0+73,,
LSLK,S,1
LESIZE,ALL,,1,,1
```

```
KSEL,S,KP,,KP0+70,KP0+73,,
LSLK,S,1
CM,wallcolhi,LINE
ALLSEL,ALL
```

```
! areas
ADRAG,webbase,,,,,wallcolhi,,,,,
ADRAG,flange1base,,,,,wallcolhi,,,,,
ADRAG,flange2base,,,,,wallcolhi,,,,,
ADRAG,SHIMX,,,,,SHIMZ,,,,,
ADRAG,WALLFOOTY,,,,,WALLFOOTZ,,,,,
```

```
! mesh column web
ASEL,S,LOC,y,-6,6,,
ASEL,R,LOC,x,-.1,.1,,
ASEL,R,LOC,Z,,120,,
AATT,10,,5,12,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH columnn flange 1
ASEL,S,LOC,X,-6.12,6.12,,
ASEL,R,LOC,Y,5.9,6.0,,
ASEL,R,LOC,Z,,120,,
AATT,10,,5,12,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
! MESH columnn flange 2
ASEL,S,LOC,X,-6.12,6.12,,
```

```
ASEL,R,LOC,Y,-5.9,-6.0,,
ASEL,R,LOC,Z,,120,,
AATT,10,,5,12,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH SHIM
ASEL,S,LOC,X,6.10,11.1,,
ASEL,R,LOC,Y,5.9,6.0,,
ASEL,R,LOC,Z,5.7,42,,
AATT,12,,5,12,8
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH FOOT
ASEL,S,LOC,X,10.9,11.1,,
ASEL,R,LOC,Y,-19,19,,
ASEL,R,LOC,Z,5.7,42,,
AATT,11,,5,12,2
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! DUPLICATE
ASEL,S,MAT,,12      ! shim
AGEN,2,ALL,,,,-11.9,,,,
ALLSEL,ALL
```

```
ASEL,S,LOC,X,10.9,11.1,, ! foot
ASEL,R,LOC,Y,-19,19,,
ASEL,R,LOC,Z,5.7,42,,
ASEL,A,MAT,,12      ! shims again
AGEN,2,ALL,,,,72,,,,
```

```
ALLSEL,ALL
NUMMRG,ALL,,,,
```

save

! the following is a load test

/SOLU

ANTYPE,0 ! static analysis

! constrain feet to wall

N = NODE(11,12,11.75)

D,N,UX,,,,,,,,

D,N,UY,,,,,,,,

```

D,N,UZ,,,,,,,,
N = NODE(11,12,35.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(11,12,83.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(11,12,107.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(11,-12,11.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(11,-12,35.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(11,-12,83.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(11,-12,107.75)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

! LOAD
!ACEL,,,1 ! gravity -Z
N = NODE(0,0,59.75)
F,N,Fx,5,,,

OUTPR,STAT
OUTRES,STAT
SOLVE
/EOF

```

## Chapter 5 Wrapped wall-column

Table 5.1 Properties

|                              |   |
|------------------------------|---|
| Wrapped wall-column          | Starting numbers  |
| *Keypoints KPO               | 8 100   |
| *Lines LINO                  | 19 200  |
| *Areas AREO                  | 15 100  |
| *Volumes VOLO                | 5 000   |
| *Elements ELEO               | 69 000  |
| *Nodes NODO                  | 88 000  |
| *Local coordinates system 12 | x parallel to flanges, points North;<br>y parallel to web, points West;<br>z points up;<br>origin: center of I-section at base (Fig. 4.1).  |
| Element type                 | 5 Shell 131   |
| Sections                     | 2 (2.00 inch foot)<br>3 (0.99 inch flange W12x106)<br>4 (0.61 inch web W12x106 )<br>*5 (1 inch foot wrap)<br>*6 (1 inch flange wrap)<br>*7 (1 inch side wrap)<br>8 (1.00 inch shim) |
| Materials                    | 10, 11 (W sections)<br>12 (shim)<br>*13 (insulation)  |

\*user input or default option.



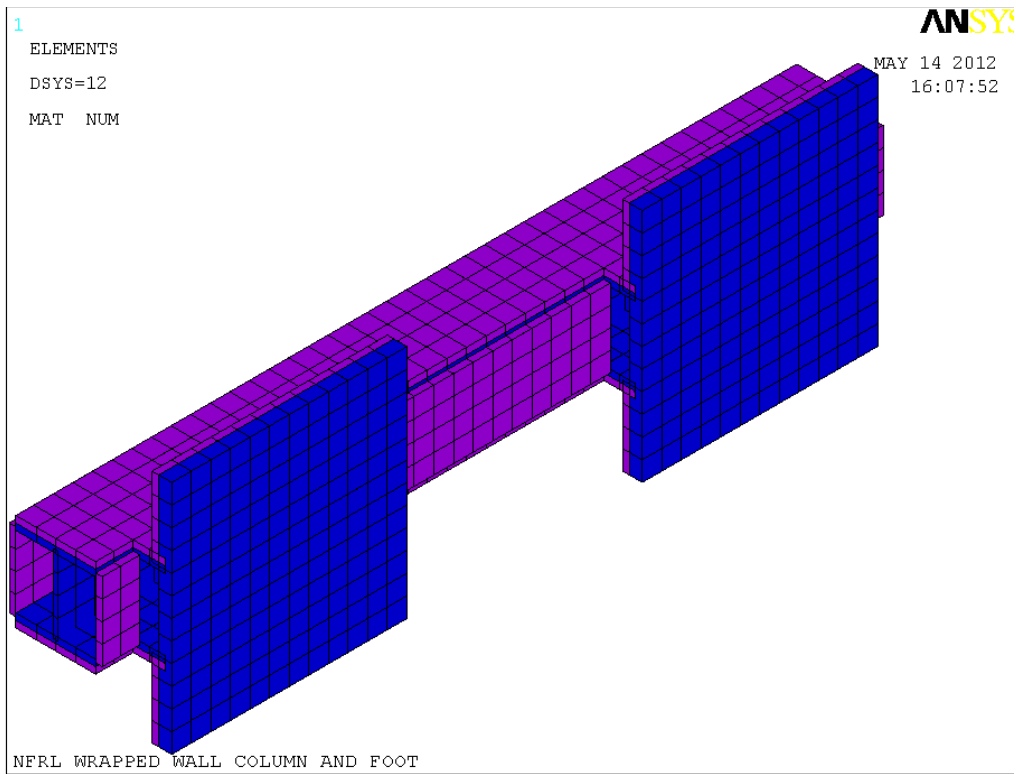


Fig. 5.1 Wrapped wall-column

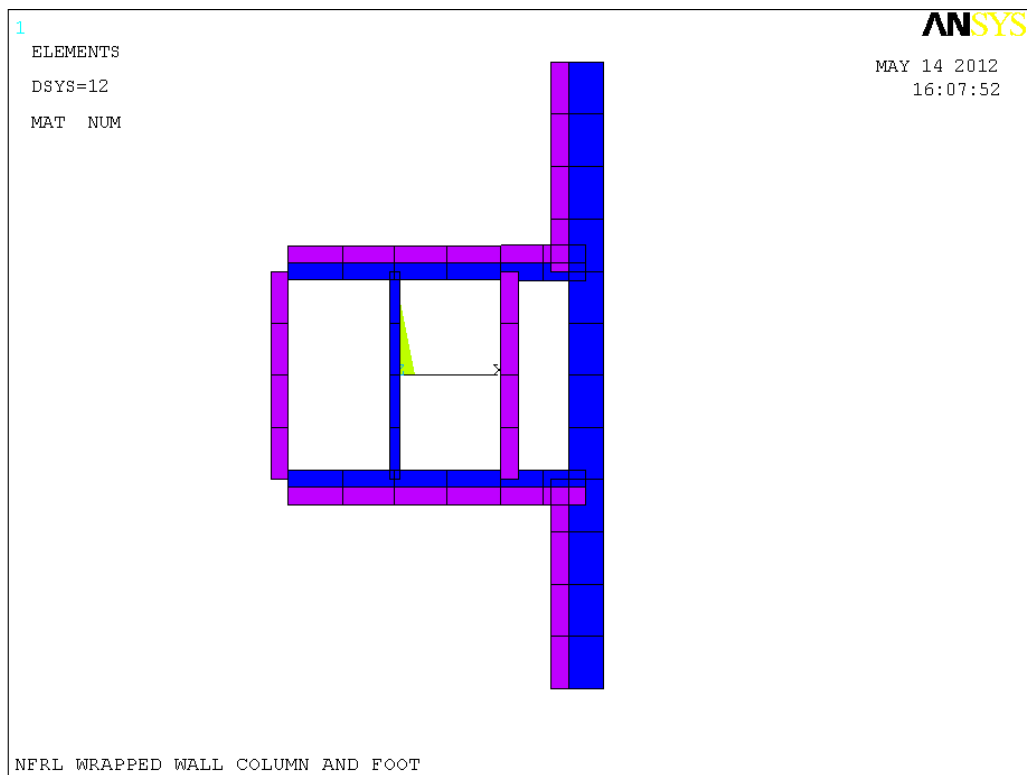


Fig. 5.2 Detail of wrapped wall-column

## ! Wrapped wall-column

```
FINISH
/CLEAR
/COM,ANSYS RELEASE 11.0 UP20070125 10:02:52 05/10/2012
/input,start110,ans,'C:\Program Files\ANSYS Inc\v110\ANSYS\apdl\',,,,,,,,,,1
/CWD,'C:\StrongFireLab'
/FILNAME,20120511,0
/TITLE,NFRL WRAPPED WALL COLUMN AND FOOT
/REPLOT
```

```
KEYW,PR_SET,1
KEYW,PR_STRUC,0
KEYW,PR_THERM,1
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0
```

```
/PREP7
! UNITS SI for thermal W, J. degree C or K
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi
! constants
*SET,SIG,3.6583E-11 ! Stefan-Boltzman constant W/(in^2.K^4)
*SET,EMS1,0.9 ! Emissivity of steel - outside
*SET,EMS2,0.9 ! Emissivity of steel - inside
*SET,Hf,15 ! Film coefficient of steel faces
```

```
! ##### material properties
! # Material # 10 - Steel for W sections
! thermal properties may be unnecessary for structural analysis
```

```
!# steel conductivity W/(in.K)
MPTEMP,
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,10,,1.37
MPDATA,KXX,10,,0.693
MPDATA,KXX,10,,0.693
```

```
!# steel heat capacity J/(kipm.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
```

MPDATA,C,10,,199500  
MPDATA,C,10,,208500  
MPDATA,C,10,,221200  
MPDATA,C,10,,231500  
MPDATA,C,10,,240300  
MPDATA,C,10,,274800

!# steel mass density  
MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,10,,2.636E-4 ! kipm/in3

! # Material # 11 is radiative face on the outside (update)  
! # Material # 11 - Steel for foot

!# steel emissivity and film coefficient  
MPTEMP  
MPTEMP,1,25  
MPDATA,EMIS,11,,EMS1

! # Material # 12 is radiative face on the inside

!# steel emissivity and film coefficient  
MPTEMP  
MPTEMP,1,25  
MPDATA,EMIS,12,,EMS2

!=====user input: insulation thickness and properties=====  
! # Material # 13 - Blazeshield insulation

!# insulation conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25 ! degree C  
MPTEMP,2,377  
MPTEMP,3,677  
MPDATA,KXX,13,,0.0013  
MPDATA,KXX,13,,0.0025  
MPDATA,KXX,13,,0.0051

!# insulation heat capacity J/(kipm.K)  
MPTEMP  
MPTEMP,1,25 ! C  
MPTEMP,2,677  
MPDATA,C,13,,362880  
MPDATA,C,13,,907200

!# insulation mass density kipm/in3  
MPTEMP

MPTEMP,1,25  
MPDATA,DENS,13,,7.51E-6

!# insulation emissivity  
MPTEMP  
MPTEMP,1,25  
MPDATA,EMIS,13,,0.9

! Insulation blanket thickness is T

T = 1

! careful that same emissivity can be used for steel and insulation

!=====end user input=====

Sect,2,shell,,foot ! bare steel  
secdata,2,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,3,shell,,12106f ! bare steel  
secdata,0.99,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W ! bare steel  
secdata,0.61,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,5,shell,,footw  
secdata,2,10,0,3 ! steel layer 1 at bottom  
secdata,T,13,0,3  
secoffset,user,-T/2 ! relative to midthickness of shell  
seccontrol,0,0,0, 0, 1, 1, 1

sect,6,shell,,flangew  
secdata,0.99,10,0,3 ! steel layer 1 at bottom  
secdata,T,13,0,3  
secoffset,user,-T/2 ! relative to midthickness of shell  
seccontrol,0,0,0, 0, 1, 1, 1

sect,7,shell,,sidew ! blanket  
secdata,T,13,0,3  
secoffset,bot  
seccontrol,0,0,0, 0, 1, 1, 1

sect,8,shell,,shimw  
secdata,1.0,10,0,3  
secdata,T,13,0,3

secoffset,user,-T/2 ! relative to midthickness of shell  
seccontrol,0,0,0, 0, 1, 1, 1

ET,5,SHELL131

KEYOPT,5,2,0 ! average film temperature

KEYOPT,5,3,0 ! quadratic temperature distribution through thickness

KEYOPT,5,4,0 ! use sect defined above

KEYOPT,5,6,0 ! no paint

!KEYOPT,5,8,2 use this option when insulation is present- data at top, bottom and mid of all layers

!SHELL,MID use this option when insulation is present-results calculated at mid, not averaged from top and bottom

! USER INPUT: STARTING NUMBERS, SUB ZERO (NOT LETTER O)=====

\*SET,KP0,8100

\*SET,LIN0,19200

\*SET,ARE0,15100

\*SET,VOLO,5000

\*SET,ELE0,69000

\*SET,NOD0,88000

! # define model geometry

! user input:location of column (origin of local coordinates)

! ref: sheet 15/15 lower left fig

! Local X parallel to flanges, points North.

! Local Y parallel to web, points West.

! Local Z points up.

! location of WALL column (origin of local coordinates center of I at base)

LOCAL,12,0,709,250,204, , , 1,1,

CSYS,12,

! END OF user input=====

TREF,25

NUMSTR,KP,KP0

NUMSTR,LINE,LIN0

NUMSTR,AREA,ARE0

NUMSTR,VOLU,VOLO

NUMSTR,ELEM,ELE0

NUMSTR,NODE,NOD0

! Y SIDE OF FOOT

K,KP0,11,-18,5.75,

K,KP0+1,11,-12,5.75,

K,KP0+2,11,-5.95,5.75,

K,KP0+3,11, ,5.75,

K,KP0+4,11,5.95,5.75,

K,KP0+5,11,12,5.75,

K,KP0+6,11,18,5.75,

! Z SIDE OF FOOT  
K,KP0+10,11,-18,5.75  
K,KP0+11,11,-18,11.75  
K,KP0+12,11,-18,35.75  
K,KP0+13,11,-18,41.75

\*DO,I,KP0,KP0+5,1  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KP0+10,KP0+12,1  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP0,KP0+13,,  
LSLK,S,1  
LESIZE,ALL,,2,,,,,1  
KSEL,S,KP,,KP0+11,KP0+12,,  
LSLK,S,1  
! \*get, aa,line,0,num,min  
! LESIZE,aa,3,,,,,1  
LESIZE,all,3,,,1,,1

KSEL,S,KP,,KP0,KP0+6,,  
LSLK,S,1  
CM,WALLFOOTY,LINE

KSEL,S,KP,,KP0+10,KP0+13,,  
LSLK,S,1  
CM,WALLFOOTZ,LINE

! X SIDE OF SHIM  
K,KP0+20,6.11,5.95,5.75  
K,KP0+21, 11,5.95,5.75  
LSTR,KP0+20,KP0+21  
KSEL,S,KP,,KP0+20,KP0+21,,  
LSLK,S,1  
LESIZE,ALL,,2,,,,,1  
CM,SHIMX,LINE

! Z SIDE OF SHIM  
K,KP0+30,6.11,5.95, 5.75  
K,KP0+31,6.11,5.95,41.75  
LSTR,KP0+30,KP0+31  
KSEL,S,KP,,KP0+30,KP0+31,,  
LSLK,S,1  
LESIZE,ALL,3,,,,,1  
CM,SHIMZ,LINE

! base of column web

K,KP0+40,, -5.95,  
K,KP0+41,, -3.0,  
K,KP0+42,,,  
K,KP0+43,, 3.0,  
K,KP0+44,, 5.95,

\*DO,I,KP0+40,KP0+43,1

LSTR,I,I+1

\*ENDDO

KSEL,S,KP,,KP0+40,KP0+44,,

LSLK,S,1

LESIZE,ALL, , , 1, , , , 1

CM,webbase,LINE

! base of column flange1

K,KP0+50,-6.11, 5.95,  
K,KP0+51,-3.0 , 5.95,  
K,KP0+52, , 5.95,  
K,KP0+53, 3.0 , 5.95,  
K,KP0+54, 6.11, 5.95,

\*DO,I,KP0+50,KP0+53,1

LSTR,I,I+1

\*ENDDO

KSEL,S,KP,,KP0+50,KP0+54,,

LSLK,S,1

LESIZE,ALL, , , 1, , , , 1

CM,flange1base,LINE

! base of column flange2

K,KP0+60,-6.11,-5.95,  
K,KP0+61,-3.0 ,-5.95,  
K,KP0+62, , -5.95,  
K,KP0+63, 3.0 ,-5.95,  
K,KP0+64, 6.11,-5.95,

\*DO,I,KP0+60,KP0+63,1

LSTR,I,I+1

\*ENDDO

KSEL,S,KP,,KP0+60,KP0+64,,

LSLK,S,1

LESIZE,ALL, , , 1, , , , 1

CM,flange2base,LINE

! column height

K,KP0+70,,,

K,KP0+71,,,2.75  
K,KP0+72,,,5.75  
K,KP0+73,,,41.75  
K,KP0+74,,,77.75  
K,KP0+75,,,113.75  
K,KP0+76,,,116.75  
K,KP0+77,,,119.5

\*DO,I,KP0+70,KP0+76,1  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP0+70,KP0+77,,  
LSLK,S,1  
LESIZE,ALL,3, , , , , ,1  
CM,wallcolhi,LINE

ALLSEL,ALL

! BASE OF WRAPS  
LSTR,KP0+60,KP0+50  
KSEL,S,KP,,KP0+50,KP0+60,10,  
LSLK,S,1  
LESIZE,ALL, , , 4, , , , ,1  
CM,OUTWRAPBASE,LINE  
ALLSEL,ALL

! areas  
ADRAG,webbase,,,,,wallcolhi,,,,,  
ADRAG,flange1base,,,,,wallcolhi,,,,,  
ADRAG,flange2base,,,,,wallcolhi,,,,,  
ADRAG,SHIMX,,,,,SHIMZ,,,,,  
ADRAG,WALLFOOTY,,,,,WALLFOOTZ,,,,,  
ADRAG,OUTWRAPBASE,,,,,wallcolhi,,,,,

! mesh column web  
ASEL,S,LOC,y,-6,6,,  
ASEL,R,LOC,x,-.1,.1,,  
ASEL,R,LOC,Z,,120,,  
AATT,10,,5,12,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH column flange 1  
ASEL,S,LOC,X,-6.12,6.12,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,,120,,



AREVERSE,ALL  
AATT,10,,5,12,6  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH columnn flange 2  
ASEL,S,LOC,X,-6.12,6.12,,  
ASEL,R,LOC,Y,-5.9,-6.0,,  
ASEL,R,LOC,Z,,120,,  
AATT,10,,5,12,6  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH SHIM1  
ASEL,S,LOC,X,6.10,11.1,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AATT,10,,5,12,8  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH FOOT LEFT  
ASEL,S,LOC,X,10.9,11.1,,  
ASEL,R,LOC,Y,-18.0,-5.9,,  
ASEL,R,LOC,Z,5.7,42,,  
AREVERSE,ALL  
AATT,10,,5,12,5  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH FOOT RIGHT  
ASEL,S,LOC,X,10.9,11.1,,  
ASEL,R,LOC,Y,5.9,18.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AREVERSE,ALL  
AATT,10,,5,12,5  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH FOOT MID  
ASEL,S,LOC,X,10.9,11.1,,  
ASEL,R,LOC,Y,-6.0,6.0,,  
ASEL,R,LOC,Z,5.7,42,,

AREVERSE,ALL  
AATT,10,,5,12,2  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH ouside wrap  
ASEL,S,LOC,X,-6.5,-6.0,,  
ASEL,R,LOC,Y,-6.0,6.0,,  
ASEL,R,LOC,Z,,120,,  
AATT,13,,5,12,7  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! COPY SHIM  
ASEL,S,LOC,X,6.10,11.1,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AGEN,2,ALL,,,,-11.9,,,,,

! REORIENT SHIM1  
ASEL,S,LOC,X,6.10,11.1,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AREVERSE,ALL

! COPY FOOT AND SHIMS  
ASEL,S,LOC,X,6.10,11.1,,  
ASEL,R,LOC,Y,-18,18.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AGEN,2,ALL,,,,,72,,,,,

! COPY LOW WRAP  
ASEL,S,LOC,X,-6.5,-6.0,,  
ASEL,R,LOC,Y,-6.0,6.0,,  
ASEL,R,LOC,Z,,5.75,,  
AGEN,2,ALL,,,,,12.22,,,,,

! COPY MID WRAP  
ASEL,S,LOC,X,-6.5,-6.0,,  
ASEL,R,LOC,Y,-6.0,6.0,,  
ASEL,R,LOC,Z,41,75,77.75,,  
AGEN,2,ALL,,,,,12.22,,,,,

! COPY HIGH WRAP  
ASEL,S,LOC,X,-6.5,-6.0,,  
ASEL,R,LOC,Y,-6.0,6.0,,

ASEL,R,LOC,Z,113.75,119.5,,  
AGEN,2,ALL,,,12.22,,,,,

! REORIENT outside wrap  
ASEL,S,LOC,X,-6.5,-6.0,,  
ASEL,R,LOC,Y,-6.0,6.0,,  
ASEL,R,LOC,Z,,120,,  
AREVERSE,ALL

ALLSEL,ALL  
NUMMRG,ALL,,,  
/EOF  
! 430pm MON 5/14

# Chapter 6 Frame

Table 6.1 Properties

|                              |  |
|------------------------------|--|
| Frame                        | Starting numbers   |
| *Keypoints KP2               | 8 400  |
| *Lines LIN2                  | 19 600   |
| *Areas ARE2                  | 15 300   |
| *Volumes VOL2                | 5 000  |
| *Elements ELE2               | 70 200   |
| *Nodes NOD2                  | 89 500   |
| *Local coordinates system 13 | x along bottom of lowest horizontal member (web);<br>y perpendicular to web, right hand system;<br>z along left edge of left vertical member (flange);<br>origin: base of frame, at intersection of horizontal, vertical and diagonal, lower left corner (Fig. 6.1). |
| Element type                 | 5 Shell 181  |
| Sections                     | 3 (0.99 inch flange W12x106)<br>4 (0.61 inch web W12x106 )   |
| Materials                    | 10 (W sections)  |

\*user input or default option.

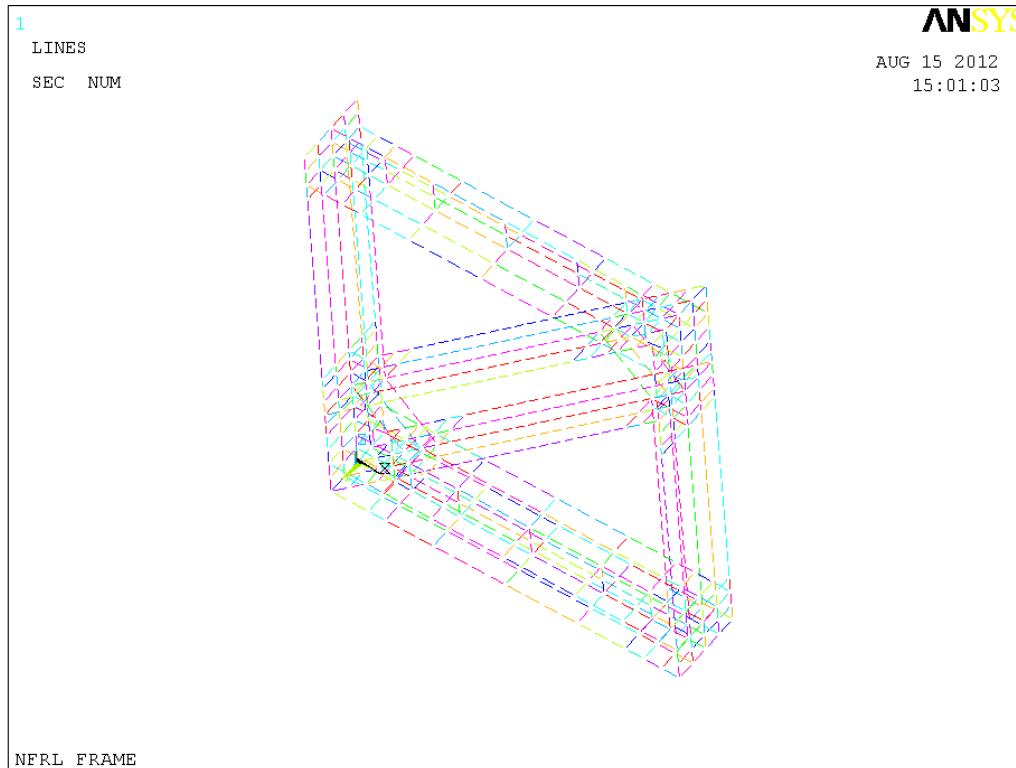


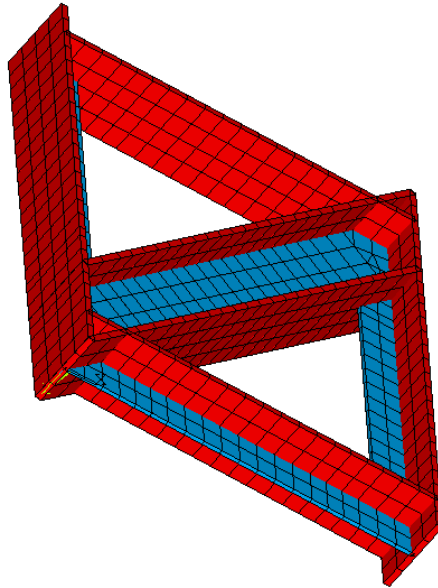
Fig. 6.1 Local coordinate system 13 of Frame

1

ELEMENTS  
DSYS=13  
SEC NUM

ANSYS

AUG 15 2012  
15:02:46



NFRL FRAME

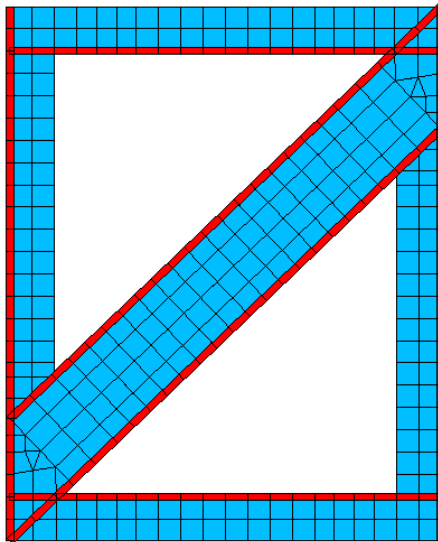
Fig. 6.2 3D view of Frame

1

ELEMENTS  
DSYS=13  
SEC NUM

ANSYS

AUG 15 2012  
15:02:46



NFRL FRAME

Fig. 6.3 Elevation view of Frame

! Structural model - Frame LAST TESTED on Thu 7.20.2012 4 pm

```
FINISH
/CLEAR
/COM,ANSYS RELEASE 11.0 UP20070125 10:02:52 05/10/2012
/input,start110,ans,'C:\Program Files\ANSYS Inc\v110\ANSYS\apdl\',,,,,,,,,,1
/CWD,'C:\StrongFireLab'
/FILNAME,20120703E,0
/TITLE,NFRL FRAME
/REPLOT
```

```
KEYW,PR_SET,1
KEYW,PR_STRUC,1
KEYW,PR_THERM,0
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0
```

```
/PREP7
! UNITS SI for thermal W, J. degree C
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi
```

```
! ##### material properties
! # Material # 10 - Steel for W sections
! thermal properties may be unnecessary for structural analysis
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000
MPDATA,EX,10,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,10,,0.30
```

```
! thermal expansion
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
```

```
MPDATA,KXX,10,,1.37
MPDATA,KXX,10,,0.693
MPDATA,KXX,10,,0.693
```

```
!# steel heat capacity J/(kipm.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,10,,199500
MPDATA,C,10,,208500
MPDATA,C,10,,221200
MPDATA,C,10,,231500
MPDATA,C,10,,240300
MPDATA,C,10,,274800
MPDATA,C,10,,302300
MPDATA,C,10,,344700
```

```
!# steel mass density
```

```
MPTEMP
MPTEMP,1,0
MPDATA,DENS,10,,2.636E-4 ! kipm/in3
```

```
! # Material # 11 - Steel for foot
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,11,1,29999,29999,27000,24000,21000,18000
MPDATA,EX,11,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,11,,0.30
```

```
! thermal expansion
```

```
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,11,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,11,,1.37
MPDATA,KXX,11,,0.693
MPDATA,KXX,11,,0.693
```

```
!# steel heat capacity J/(kipm.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,11,,199500
MPDATA,C,11,,208500
MPDATA,C,11,,221200
MPDATA,C,11,,231500
MPDATA,C,11,,240300
MPDATA,C,11,,274800
MPDATA,C,11,,302300
MPDATA,C,11,,344700
```

```
!# steel mass density
```

```
MPTEMP
MPTEMP,1,0
MPDATA,DENS,11,,2.636E-4 ! kipm/in3
```

```
! # Material # 12 - Steel for shim
```

```
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,12,1,29998,29998,27000,24000,21000,18000
MPDATA,EX,12,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,12,,0.30
```

```
! thermal expansion
```

```
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
```



MPTEMP,1,0  
MPDATA,ALPX,12,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,12,,1.37  
MPDATA,KXX,12,,0.693  
MPDATA,KXX,12,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,12,,199500  
MPDATA,C,12,,208500  
MPDATA,C,12,,221200  
MPDATA,C,12,,231500  
MPDATA,C,12,,240300  
MPDATA,C,12,,274800  
MPDATA,C,12,,302300  
MPDATA,C,12,,344700

!# steel mass density

MPTEMP  
MPTEMP,1,0  
MPDATA,DENS,12,,2.636E-4 ! kipm/in<sup>3</sup>

ET,5,SHELL181

KEYOPT,5,1,0 ! bending and membrane stiffness  
KEYOPT,5,3,2 ! full integration with incompatible modes  
KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer  
KEYOPT,5,9,0 ! no user subroutine to define thickness  
KEYOPT,5,10,0 ! no initial stress

sect,2,shell,,foot  
secdata,2,11,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,3,shell,,12106f  
secdata,0.99,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W  
secdata,0.61,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,8,shell,,shim  
secdata,1.0,12,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS=====

\*SET,KP2,8400  
\*SET,LIN2,19600  
\*SET,ARE2,15300  
\*SET,VOL2,5000  
\*SET,ELE2,70200  
\*SET,NOD2,89500

! # define model geometry  
! user input:local coord system and location of frame  
! ref: SHEET 1/15 LOWER LEFT FIG  
! Local X ALONG EDGE OF LOWEST HORIZ MEMBER.  
! Local Y perpendicular to web, right hand system.  
! Local Z ALONG RIGHT EDGE OF RIGHT VERTICAL MEMBER.  
! location of FRAME (origin of local coordinates: BASE OF FRAME,  
! INTERSECTION OF HORIZ, VERT AND DIAG,LOWER RIGHT CORNER)

LOCAL,13,0,200,200,200, , , ,1,1  
CSYS,13,

! END OF user input=====

NUMSTR,KP,KP2  
NUMSTR,LINE,LIN2  
NUMSTR,AREA,ARE2  
NUMSTR,VOLU,VOL2  
NUMSTR,ELEM,ELE2  
NUMSTR,NODE,NOD2

! x horiz edge of bottom web  
K,KP2,,,  
K,KP2+1,6.233,, ! diag at 43.693 deg to horiz  
K,KP2+2,9.06,,

K,KP2+3,17.06,,  
K,KP2+4,29.06,, ! reference hole at midlength  
K,KP2+5,41.06,,  
K,KP2+6,49.06,,  
K,KP2+7,52.165,,  
K,KP2+8,55.1425,,  
K,KP2+9,58.12,,

! Z vert midthickness of flange

K,KP2+10,,,  
K,KP2+11,,,3  
K,KP2+12,,,5.955 ! 5.955 = depth of WT 6X53 > half depth of I = 11.91/2  
K,KP2+13,,,9  
K,KP2+14,,,12  
K,KP2+15,,,14.319 ! worse mesh if hole at z = 15.0  
K,KP2+16,,,16.472,  
K,KP2+17,,,19.3165  
K,KP2+18,,,22.161  
K,KP2+19,,,24  
K,KP2+20,,,63  
K,KP2+21,,,66.045  
K,KP2+22,,,69  
K,KP2+23,,,72

! diagonal web lower edge

K,KP2+30,,,  
K,KP2+31,3.140,,3.  
K,KP2+32,6.233,,5.955  
K,KP2+33,8.227,,7.860  
K,KP2+34,11.2045,,10.705  
K,KP2+35,14.182 ,,13.550  
K,KP2+36,52.165 ,,49.839  
K,KP2+37,55.1425,,52.6835  
K,KP2+38,58.12 ,,55.528

! diagonal web upper edge

K,KP2+40,,,16.472  
K,KP2+41,2.9775,,19.3165  
K,KP2+42,5.955,,22.161  
K,KP2+43,43.938,,58.450  
K,KP2+44,46.9155,,61.295  
K,KP2+45,49.893,,64.140  
K,KP2+46,51.887,,66.045  
K,KP2+47,54.980,,69.  
K,KP2+48,58.12,,72

! FLANGE edges

! of lower horiz.

K,KP2+50,, ,  
K,KP2+51,, 3,  
K,KP2+52,, 6.11,  
K,KP2+53,, -3,  
K,KP2+56,,-6.11,

! flange edge of vertical at upper intersection with diagonal

K,KP2+60,, ,16.472  
K,KP2+61,, 3,16.472  
K,KP2+62,, 6.11,16.472  
K,KP2+63,, -3,16.472  
K,KP2+66,,-6.11,16.472

! vertical edge of web of horizontal

K,KP2+70,6.233,,  
K,KP2+71,6.233,,3.0  
K,KP2+72,6.233,,5.955

! diagonal web body

K,KP2+80, 8.227,,7.860  
K,KP2+81,6.17025,,10.013  
K,KP2+82, 4.1135,,12.166  
K,KP2+83,2.05675,,14.319  
K,KP2+84, ,,,16.472

! non extruded, disturbed zones

K,KP2+90, 2.9775,,22.161  
K,KP2+91, 3.1165,,5.955  
K,KP2+92,3.085125,,9.5065  
K,KP2+93, 2.05675,,12.083

! LINES

\*DO,I,KP2,KP2+8,1 ! x horiz edge of bottom web  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KP2+2,KP2+5,1 ! x horiz edge of bottom web

KSEL,S,KP,,I,I+1,,  
LSLK,S,1  
LESIZE,ALL,3.0, , , ,0 , , ,0  
\*ENDDO

ALLSEL,ALL

\*DO,I,KP2+10,KP2+22,1 ! Z vert midthickness of flange

LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+19,KP2+20,,

LSLK,S,1  
LESIZE,ALL,3.0,,,0,,,0  
ALLSEL,ALL

\*DO,I,KP2+30,KP2+37,1 ! diagonal web lower edge  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+35,KP2+36,,  
LSLK,S,1  
LESIZE,ALL,,,17,0,,,0  
ALLSEL,ALL

\*DO,I,KP2+40,KP2+47,1 ! diagonal web upper edge  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+42,KP2+43,,  
LSLK,S,1  
LESIZE,ALL,,,17,0,,,0  
ALLSEL,ALL

\*DO,I,KP2+33,KP2+38,1 ! diagonal web body  
LSTR,I,I+7  
KSEL,S,KP,,I,I+7,7,  
LSLK,S,1  
LESIZE,ALL,,,4,0,,,0  
ALLSEL,ALL  
\*ENDDO

LSTR,KP2+50,KP2+51 ! +y flange base of vertical  
LSTR,KP2+51,KP2+52  
LSTR,KP2+50,KP2+53 ! -y flange base of vertical  
LSTR,KP2+53,KP2+56  
LSTR,KP2+60,KP2+61 ! +y flange base of diagonal  
LSTR,KP2+61,KP2+62  
LSTR,KP2+60,KP2+63 ! -y flange base of diagonal  
LSTR,KP2+63,KP2+66

LSTR,KP2+70,KP2+71 ! web of horiz  
LSTR,KP2+71,KP2+72 ! save db L=19600 to 19650  
LSTR,KP2+18,KP2+90 ! web of vert  
LSTR,KP2+90,KP2+42 ! L=19651,2

! non extruded smaller zone  
LSTR,KP2+17,KP2+41 ! L=19653  
LSTR,KP2+41,KP2+90 ! L=19654

! non extruded larger zone

LSTR,KP2+15,KP2+83 ! L=19655

LSTR,KP2+14,KP2+93 ! L=19656

LSTR,KP2+93,KP2+82 ! L=19657

LSTR,KP2+13,KP2+92 ! L=19658

LSTR,KP2+92,KP2+81 ! L=19659

LSTR,KP2+12,KP2+91 ! L=19660

LSTR,KP2+91,KP2+32 ! L=19661

LSTR,KP2+91,KP2+92 ! L=19662

LSTR,KP2+92,KP2+93 ! L=19663

LSTR,KP2+93,KP2+83 ! L=19664

LSTR,KP2+32,KP2+81 ! L=19665

LSTR,KP2+92,KP2+82 ! L=19666

KSEL,S,KP,,KP2,KP2+93,,

LSLK,S,1

LESIZE,ALL,4.4, , , 0, , , 0 ! default element size

LSTR,KP2+16,KP2+41

KSEL,S,KP,,KP2+16,KP2+41,25,

LSLK,S,1

LESIZE,ALL,4.4, , 0, , 1, , , 0

ALLSEL,ALL

LSTR,KP2+16,KP2+83

KSEL,S,KP,,KP2+16,KP2+83,67,

LSLK,S,1

LESIZE,ALL,4.4, , 0, , 1, , , 0

ALLSEL,ALL

LSTR,KP2+41,KP2+42

KSEL,S,KP,,KP2+41,KP2+42,1,

LSLK,S,1

LESIZE,ALL,4.4, , 0, , 1, , , 0

ALLSEL,ALL

LSTR,KP2+33,KP2+81

KSEL,S,KP,,KP2+33,KP2+81,48,

LSLK,S,1

LESIZE,ALL,4.4, , 0, , 1, , , 0

ALLSEL,ALL

LSTR,KP2+81,KP2+82

KSEL,S,KP,,KP2+81,KP2+82,1,

LSLK,S,1

LESIZE,ALL,4.4, , 0, , 1, , , 0

ALLSEL,ALL

LSTR,KP2+82,KP2+83  
KSEL,S,KP,,KP2+82,KP2+83,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

SAVE

! AREAS  
! TRIANGLES  
A,KP2+90,KP2+42,KP2+41  
A,KP2+17,KP2+41,KP2+16  
A,KP2+16,KP2+83,KP2+15  
A,KP2+83,KP2+82,KP2+93  
A,KP2+82,KP2+81,KP2+92  
A,KP2+93,KP2+82,KP2+92  
A,KP2+81,KP2+33,KP2+32

ASEL,S,AREA,,ARE2,ARE2+6,,1  
CM,TRIAREA,AREA  
ALLSEL,ALL

! QUADS  
A,KP2+18,KP2+90,KP2+41,KP2+17  
A,KP2+15,KP2+83,KP2+93,KP2+14  
A,KP2+14,KP2+93,KP2+92,KP2+13  
A,KP2+13,KP2+92,KP2+91,KP2+12  
A,KP2+92,KP2+81,KP2+32,KP2+91

ASEL,S,AREA,,ARE2,ARE2+11,,1  
CM,DISTURB,AREA  
ALLSEL,ALL

KSEL,S,KP,,KP2,KP2+9,,  
LSLK,S,1  
CM,FULLX,LINE

KSEL,S,KP,,KP2+10,KP2+23,,  
LSLK,S,1  
CM,FULLZ,LINE

KSEL,S,KP,,KP2+18,KP2+21,,  
LSLK,S,1  
CM,PARTZ,LINE

KSEL,S,KP,,KP2+30,KP2+38,,  
LSLK,S,1

CM,lodiag,LINE

KSEL,S,KP,,KP2+40,KP2+48,,

LSLK,S,1

CM,hidiag,LINE

KSEL,S,KP,,KP2+50,KP2+52,1,

LSLK,S,1

CM,flangeplus,LINE

KSEL,S,KP,,KP2+50,KP2+56,3,

LSLK,S,1

CM,flangeminus,LINE

KSEL,S,KP,,KP2+60,KP2+62,1,

LSLK,S,1

CM,flandiagplus,LINE

KSEL,S,KP,,KP2+60,KP2+66,3,

LSLK,S,1

CM,flandiagminus,LINE

KSEL,S,KP,,KP2+70,KP2+72,1,

LSLK,S,1

CM,webhoriz,LINE

KSEL,S,KP,,KP2+18,KP2+42,24,

KSEL,A,KP,,KP2+90

LSLK,S,1

CM,webvert,LINE

ALLSEL,ALL

!!\*GET,AMAX1,AREA,0,NUM,MAX

! diagonal web areas

A,KP2+33,KP2+34,KP2+41,KP2+40

\*DO,I,KP2+34,KP2+37,1

A,I,I+1,I+8,I+7

\*ENDDO

ASEL,S,AREA,,ARE2,ARE2+16,,1

CM,DIAWEBTURB,AREA ! DIAGONAL WEB AND DISTURBED AREAS=D

ALLSEL,ALL

! areas

ADRAG,lodiag,,,,,flangeplus,,,,,

ASEL,S,AREA,,ARE2,ARE2+32,,1



```
CM,DLOPLUS,AREA ! DIAGONAL WEB,DISTURBED AND LOW PLUS DIAG FLANGE AREAS
ALLSEL,ALL
```

```
ADRAG,lodiag,,,,,flangeminus,,,,,
ASEL,S,AREA,,ARE2,ARE2+48,,1
CM,DLODIAG,AREA ! DIAGONAL WEB,DISTURBED AND LOW DIAG FLANGE AREAS
ALLSEL,ALL
```

```
ADRAG,hidiag,,,,,flandiagplus,,,,,
ASEL,S,AREA,,ARE2,ARE2+64,,1
CM,DLOHIPLUS,AREA ! DIAGONAL WEB,DISTURBED,LOW DIAG FLANGE AND HIGH PLUS DIAG FLANGE
AREAS
ALLSEL,ALL
```

```
ADRAG,hidiag,,,,,flandiagminus,,,,,
ASEL,S,AREA,,ARE2,ARE2+80,,1
CM,DLOHI,AREA ! DIAGONAL WEB,DISTURBED,LOW AND HIGH DIAG FLANGE AREAS
ALLSEL,ALL
```

```
ADRAG,FULLZ,,,,,flangeplus,,,,,
ADRAG,FULLZ,,,,,flangeminus,,,,,
ADRAG,partz,,,,,webvert,,,,,
ADRAG,fullx,,,,,flangeplus,,,,,
ADRAG,fullx,,,,,flangeminus,,,,,
ADRAG,fullx,,,,,WEBHORIZ,,,,,
```

```
ALLSEL,ALL
SAVE
```

```
! mesh webS
! MESH TRIANGLES
! much simpler to define elements by commands NKPT and E
CMSEL,S,TRIAREA,AREA
AATT,10,,5,13,4
MSHAPE,1,2D
MSHKEY,0
AMESH,ALL
```

```
! MESH QUADS
CMSEL,S,DISTURB,AREA
CMSEL,U,TRIAREA,AREA
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH DIAG WEB
CMSEL,S,DIWEBTURB,AREA
```

```
CMSEL,U,DISTURB,AREA
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH DIAG FLANGES
CMSEL,S,DLOHI,AREA
CMSEL,U,DIAWEBTURB,AREA
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH VERTICAL flange
ASEL,S,LOC,X,,.1,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,R,LOC,Z,,72,,
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,2
AMESH,ALL
```

```
! mesh VERTICAL web
ASEL,S,LOC,y,-.1,.1,,
ASEL,R,LOC,x,,6.0,,
ASEL,R,LOC,Z,22.0,72.0,,
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! mesh horizontal web
ASEL,S,LOC,y,-.1,.1,,
ASEL,R,LOC,x,,59.0,,
ASEL,R,LOC,Z,0,6.0,,
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! INVERT BOTTOM T
ASEL,S,LOC,Z,,0.1,,
AGEN,2,ALL,,,,,5.955,,,
```

```
! MESH HORIZONTAL FLANGE
ASEL,S,LOC,Z,5.9,6.0,,
AATT,10,,5,13,3
```

```
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
SAVE
```

```
! reflect and translate HORIZONTAL
```

```
ASEL,S,LOC,Z,,6.0,,
ASEL,R,LOC,Y,-0.1,0.1,,
ARSYM,X,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,5.9,6.0,,
ASEL,R,LOC,Y,-6.2,6.2,,
ARSYM,X,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,,6.0,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,U,LOC,X,,59,,
ARSYM,Z,ALL, , , ,0,1
```

```
ALLSEL,ALL
ASEL,S,LOC,Z,-6,6,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,U,LOC,X,,59,,
AGEN,2,ALL,,,58.12,,72,,,1
ALLSEL,ALL
```

```
SAVE
```

```
! reflect and translate vertical
```

```
ASEL,S,LOC,Z,22,66.1,,
ASEL,R,LOC,Y,-0.1,0.1,,
ASEL,R,LOC,X,,6,,
ARSYM,Z,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,,72,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,R,LOC,X,,0.1,,
ARSYM,Z,ALL, , , ,0,0
```

```
CMSEL,S,DISTURB,AREA
ARSYM,Z,ALL, , , ,0,0
```

```
ALLSEL,ALL
ASEL,S,LOC,Z,-72,72,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,R,LOC,X,,9,,
ASEL,U,LOC,Z,,72,,
```

ARSYM,X,ALL, , , ,0,1

ALLSEL,ALL  
ASEL,S,LOC,Z,-72,72,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,X,-9,9,,  
ASEL,U,LOC,Z,,72,,  
AGEN,2,ALL,,,58.12,,72,,,1

ALLSEL,ALL  
NUMMRG,ALL,5.0E-3,,,  
SAVE

! the following is a load test

/SOLU  
ANTYPE,0 ! static analysis

! constrain BOTTOM CORNERS

N = NODE(0,6.11,0)

D,N,UX,,,,,,,,

D,N,UY,,,,,,,,

D,N,UZ,,,,,,,,

N = NODE(0,-6.11,0)

D,N,UX,,,,,,,,

D,N,UY,,,,,,,,

D,N,UZ,,,,,,,,

N = NODE(58.12,6.11,0)

D,N,UX,,,,,,,,

D,N,UY,,,,,,,,

D,N,UZ,,,,,,,,

N = NODE(58.12,-6.11,0)

D,N,UX,,,,,,,,

D,N,UY,,,,,,,,

D,N,UZ,,,,,,,,

! LOAD

ACEL,,,1 ! gravity -Z

N = NODE(0,0,72)

F,N,Fx,50,,,

OUTPR,STAT  
OUTRES,STAT  
SOLVE

/EOF

## Chapter 7 Wrapped frame

Table 7.1 Properties

|                              |  |
|------------------------------|--|
| Wrapped frame                | Starting numbers   |
| *Keypoints KP2               | 8 400  |
| *Lines LIN2                  | 19 600   |
| *Areas ARE2                  | 15 300   |
| *Volumes VOL2                | 5 000  |
| *Elements ELE2               | 70 200   |
| *Nodes NOD2                  | 89 500   |
| *Local coordinates system 13 | x along bottom of lowest horizontal member (web);<br>y perpendicular to web, right hand system;<br>z along left edge of left vertical member (flange);<br>origin: base of frame, at intersection of horizontal, vertical and diagonal, lower left corner (Fig. 6.1). |
| Element type                 | 5 Shell 131  |
| Sections                     | 3 (0.99 inch flange W12x106)<br>4 (0.61 inch web W12x106 )<br>*6 (1 inch flange wrap)<br>*7 (1 inch side wrap)   |
| Materials                    | 10 (W sections)<br>*13 (insulation)  |

\*user input or default option.

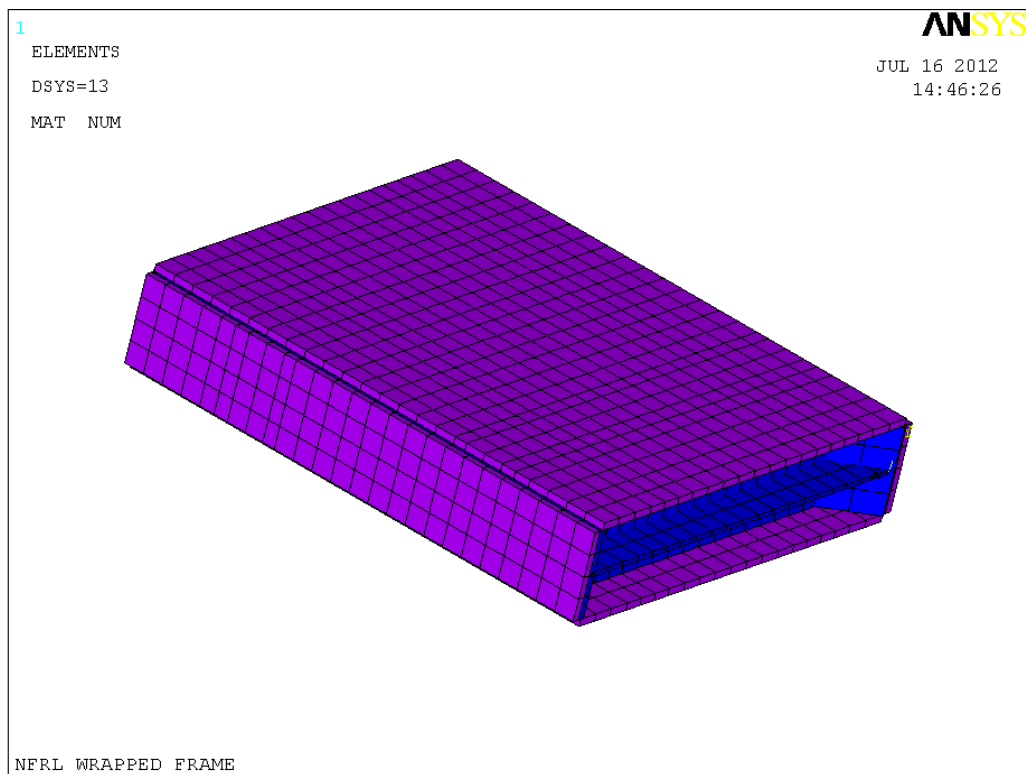


Fig. 7.1 Wrapped frame

## ! Wrapped frame

```
FINISH
/CLEAR
/COM,ANSYS RELEASE 11.0 UP20070125 10:02:52 05/10/2012
/input,start110,ans,'C:\Program Files\ANSYS Inc\v110\ANSYS\apdl\',,,,,,,,,,1
/CWD,'C:\StrongFireLab'
/FILNAME,20120713E,0
/TITLE,NFRL WRAPPED FRAME
/REPLOT
```

```
KEYW,PR_SET,1
KEYW,PR_STRUC,0
KEYW,PR_THERM,1
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0
```

```
/PREP7
! UNITS SI for thermal W, J. degree C
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi
```

```
! ##### material properties
! # Material # 10 - Steel for W sections
! thermal properties may be unnecessary for structural analysis
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000
MPDATA,EX,10,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,10,,0.30
```

```
! thermal expansion
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
```

```
MPDATA,KXX,10,,1.37
MPDATA,KXX,10,,0.693
MPDATA,KXX,10,,0.693
```

```
!# steel heat capacity J/(kipm.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,10,,199500
MPDATA,C,10,,208500
MPDATA,C,10,,221200
MPDATA,C,10,,231500
MPDATA,C,10,,240300
MPDATA,C,10,,274800
MPDATA,C,10,,302300
MPDATA,C,10,,344700
```

```
!# steel mass density
```

```
MPTEMP
MPTEMP,1,0
MPDATA,DENS,10,,2.636E-4 ! kipm/in3
```

```
! # Material # 11 - Steel for foot
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,11,1,29999,29999,27000,24000,21000,18000
MPDATA,EX,11,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,11,,0.30
```

```
! thermal expansion
```

```
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,11,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,11,,1.37
MPDATA,KXX,11,,0.693
MPDATA,KXX,11,,0.693
```

```
!# steel heat capacity J/(kipm.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,11,,199500
MPDATA,C,11,,208500
MPDATA,C,11,,221200
MPDATA,C,11,,231500
MPDATA,C,11,,240300
MPDATA,C,11,,274800
MPDATA,C,11,,302300
MPDATA,C,11,,344700
```

```
!# steel mass density
```

```
MPTEMP
MPTEMP,1,0
MPDATA,DENS,11,,2.636E-4 ! kipm/in3
```

```
! # Material # 12 - Steel for shim
```

```
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,12,1,29998,29998,27000,24000,21000,18000
MPDATA,EX,12,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,12,,0.30
```

```
! thermal expansion
```

```
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
```



MPTEMP,1,0  
MPDATA,ALPX,12,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,12,,1.37  
MPDATA,KXX,12,,0.693  
MPDATA,KXX,12,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,12,,199500  
MPDATA,C,12,,208500  
MPDATA,C,12,,221200  
MPDATA,C,12,,231500  
MPDATA,C,12,,240300  
MPDATA,C,12,,274800  
MPDATA,C,12,,302300  
MPDATA,C,12,,344700

!# steel mass density

MPTEMP  
MPTEMP,1,0  
MPDATA,DENS,12,,2.636E-4 ! kipm/in3

ET,5,SHELL131

KEYOPT,5,2,0 ! average film temperature

KEYOPT,5,3,0 ! quadratic temperature distribution through thickness

KEYOPT,5,4,0 ! use sect defined above

KEYOPT,5,6,0 ! no paint

!KEYOPT,5,8,2 use this option when insulation is present- data at top, bottom and mid of all layers

!SHELL,MID use this option when insulation is present-results calculated at mid, not averaged from top and bottom

sect,2,shell,,foot

secdata,2,11,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

sect,3,shell,,12106f  
secdata,0.99,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W  
secdata,0.61,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,8,shell,,shim  
secdata,1.0,12,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

!=====user input: insulation thickness and properties=====  
! # Material # 13 - Blazeshield insulation

!# insulation conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25 ! degree C  
MPTEMP,2,377  
MPTEMP,3,677  
MPDATA,KXX,13,,0.0013  
MPDATA,KXX,13,,0.0025  
MPDATA,KXX,13,,0.0051

!# insulation heat capacity J/(kipm.K)  
MPTEMP  
MPTEMP,1,25 ! C  
MPTEMP,2,677  
MPDATA,C,13,,362880  
MPDATA,C,13,,907200

!# insulation mass density kipm/in3  
MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,13,,7.51E-6

!# insulation emissivity  
MPTEMP  
MPTEMP,1,25  
MPDATA,EMIS,13,,0.9

! Insulation blanket thickness is T  
T = 1

! careful that same emissivity can be used for steel and insulation

! USER INPUT: STARTING NUMBERS=====

\*SET,KP2,8400  
\*SET,LIN2,19600  
\*SET,ARE2,15300  
\*SET,VOL2,5000  
\*SET,ELE2,70200  
\*SET,NOD2,89500

! # define model geometry  
! user input:local coord system and location of frame  
! ref: SHEET 1/15 LOWER LEFT FIG  
! Local X ALONG EDGE OF LOWEST HORIZ MEMBER.  
! Local Y perpendicular to web, right hand system.  
! Local Z ALONG RIGHT EDGE OF RIGHT VERTICAL MEMBER.  
! location of FRAME (origin of local coordinates: BASE OF FRAME,  
! INTERSECTION OF HORIZ, VERT AND DIAG,LOWER RIGHT CORNER)

LOCAL,13,0,200,200,200, , , ,1,1  
CSYS,13,

! END OF user input=====

sect,6,shell,,flangew  
secdata,0.99,10,0,3 ! steel layer 1 at bottom, NEEDS UPDATING  
secdata,T,13,0,3  
secoffset,user,-T/2 ! relative to midthickness of shell  
seccontrol,0,0,0, 0, 1, 1, 1

sect,7,shell,,sidew ! blanket  
secdata,T,13,0,3  
secoffset,bot  
seccontrol,0,0,0, 0, 1, 1, 1

NUMSTR,KP,KP2  
NUMSTR,LINE,LIN2  
NUMSTR,AREA,ARE2  
NUMSTR,VOLU,VOL2  
NUMSTR,ELEM,ELE2  
NUMSTR,NODE,NOD2

! x horiz edge of bottom web=====

K,KP2,,,  
K,KP2+1,6.233,, ! diag at 43.693 deg to horiz  
K,KP2+2,9.06,,  
K,KP2+3,17.06,,  
K,KP2+4,29.06,, ! reference hole at midlength

K,KP2+5,41.06,,  
K,KP2+6,49.06,,  
K,KP2+7,52.165,,  
K,KP2+8,55.1425,,  
K,KP2+9,58.12,,

! Z vert midthickness of flange

K,KP2+10,,,  
K,KP2+11,,,3  
K,KP2+12,,,5.955 ! 5.955 = depth of WT 6X53 > half depth of I = 11.91/2  
K,KP2+13,,,9  
K,KP2+14,,,12  
K,KP2+15,,,14.319 ! worse mesh if hole at z = 15.0  
K,KP2+16,,,16.472,  
K,KP2+17,,,19.3165  
K,KP2+18,,,22.161  
K,KP2+19,,,24  
K,KP2+20,,,63  
K,KP2+21,,,66.045  
K,KP2+22,,,69  
K,KP2+23,,,72

! diagonal web lower edge

K,KP2+30,,,  
K,KP2+31,3.140,,3.  
K,KP2+32,6.233,,5.955  
K,KP2+33,8.227,,7.860  
K,KP2+34,11.2045,,10.705  
K,KP2+35,14.182 ,,13.550  
K,KP2+36,52.165 ,,49.839  
K,KP2+37,55.1425,,52.6835  
K,KP2+38,58.12 ,,55.528

! diagonal web upper edge

K,KP2+40,,,16.472  
K,KP2+41,2.9775,,19.3165  
K,KP2+42,5.955,,22.161  
K,KP2+43,43.938,,58.450  
K,KP2+44,46.9155,,61.295  
K,KP2+45,49.893,,64.140  
K,KP2+46,51.887,,66.045  
K,KP2+47,54.980,,69.  
K,KP2+48,58.12,,72

! FLANGE edges

! of lower horiz.

K,KP2+50,, ,  
K,KP2+51,, 3,

K,KP2+52,, 6.11,  
K,KP2+53,, -3,  
K,KP2+56,,-6.11,

! flange edge of vertical at upper intersection with diagonal

K,KP2+60,, ,16.472  
K,KP2+61,, 3,16.472  
K,KP2+62,, 6.11,16.472  
K,KP2+63,, -3,16.472  
K,KP2+66,,-6.11,16.472

! vertical edge of web of horizontal

K,KP2+70,6.233,,  
K,KP2+71,6.233,,3.0  
K,KP2+72,6.233,,5.955

! diagonal web body

K,KP2+80, 8.227,,7.860  
K,KP2+81,6.17025,,10.013  
K,KP2+82, 4.1135,,12.166  
K,KP2+83,2.05675,,14.319  
K,KP2+84, ,,,16.472

! non extruded, disturbed zones

K,KP2+90, 2.9775,,22.161  
K,KP2+91, 3.1165,,5.955  
K,KP2+92,3.085125,,9.5065  
K,KP2+93, 2.05675,,12.083

! LINES

\*DO,I,KP2,KP2+8,1 ! x horiz edge of bottom web  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KP2+2,KP2+5,1 ! x horiz edge of bottom web  
KSEL,S,KP,,I,I+1,,  
LSLK,S,1  
LESIZE,ALL,3.0, , , ,0 , , ,0  
\*ENDDO  
ALLSEL,ALL

\*DO,I,KP2+10,KP2+22,1 ! Z vert midthickness of flange  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+19,KP2+20,,  
LSLK,S,1  
LESIZE,ALL,3.0, , , ,0 , , ,0

ALLSEL,ALL

\*DO,I,KP2+30,KP2+37,1 ! diagonal web lower edge  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+35,KP2+36,,  
LSLK,S,1  
LESIZE,ALL,,17,,0,,0  
ALLSEL,ALL

\*DO,I,KP2+40,KP2+47,1 ! diagonal web upper edge  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+42,KP2+43,,  
LSLK,S,1  
LESIZE,ALL,,17,,0,,0  
ALLSEL,ALL

\*DO,I,KP2+33,KP2+38,1 ! diagonal web body  
LSTR,I,I+7  
KSEL,S,KP,,I,I+7,7,  
LSLK,S,1  
LESIZE,ALL,,4,,0,,0  
ALLSEL,ALL  
\*ENDDO

LSTR,KP2+50,KP2+51 ! +y flange base of vertical  
LSTR,KP2+51,KP2+52  
LSTR,KP2+50,KP2+53 ! -y flange base of vertical  
LSTR,KP2+53,KP2+56  
LSTR,KP2+60,KP2+61 ! +y flange base of diagonal  
LSTR,KP2+61,KP2+62  
LSTR,KP2+60,KP2+63 ! -y flange base of diagonal  
LSTR,KP2+63,KP2+66

LSTR,KP2+70,KP2+71 ! web of horiz  
LSTR,KP2+71,KP2+72 ! save db L=19600 to 19650  
LSTR,KP2+18,KP2+90 ! web of vert  
LSTR,KP2+90,KP2+42 ! L=19651,2

! non extruded smaller zone  
LSTR,KP2+17,KP2+41 ! L=19653  
LSTR,KP2+41,KP2+90 ! L=19654

! non extruded larger zone  
LSTR,KP2+15,KP2+83 ! L=19655

LSTR,KP2+14,KP2+93 ! L=19656  
LSTR,KP2+93,KP2+82 ! L=19657  
LSTR,KP2+13,KP2+92 ! L=19658  
LSTR,KP2+92,KP2+81 ! L=19659  
LSTR,KP2+12,KP2+91 ! L=19660  
LSTR,KP2+91,KP2+32 ! L=19661

LSTR,KP2+91,KP2+92 ! L=19662  
LSTR,KP2+92,KP2+93 ! L=19663  
LSTR,KP2+93,KP2+83 ! L=19664  
LSTR,KP2+32,KP2+81 ! L=19665  
LSTR,KP2+92,KP2+82 ! L=19666

KSEL,S,KP,,KP2,KP2+93,,  
LSLK,S,1  
LESIZE,ALL,4.4, , , ,0, , ,0 ! default element size

LSTR,KP2+16,KP2+41  
KSEL,S,KP,,KP2+16,KP2+41,25,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+16,KP2+83  
KSEL,S,KP,,KP2+16,KP2+83,67,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+41,KP2+42  
KSEL,S,KP,,KP2+41,KP2+42,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+33,KP2+81  
KSEL,S,KP,,KP2+33,KP2+81,48,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+81,KP2+82  
KSEL,S,KP,,KP2+81,KP2+82,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+82,KP2+83

KSEL,S,KP,,KP2+82,KP2+83,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

SAVE

! AREAS  
! TRIANGLES  
A,KP2+90,KP2+42,KP2+41  
A,KP2+17,KP2+41,KP2+16  
A,KP2+16,KP2+83,KP2+15  
A,KP2+83,KP2+82,KP2+93  
A,KP2+82,KP2+81,KP2+92  
A,KP2+93,KP2+82,KP2+92  
A,KP2+81,KP2+33,KP2+32

ASEL,S,AREA,,ARE2,ARE2+6,,1  
CM,TRIAREA,AREA  
ALLSEL,ALL

! QUADS  
A,KP2+18,KP2+90,KP2+41,KP2+17  
A,KP2+15,KP2+83,KP2+93,KP2+14  
A,KP2+14,KP2+93,KP2+92,KP2+13  
A,KP2+13,KP2+92,KP2+91,KP2+12  
A,KP2+92,KP2+81,KP2+32,KP2+91

ASEL,S,AREA,,ARE2,ARE2+11,,1  
CM,DISTURB,AREA  
ALLSEL,ALL

KSEL,S,KP,,KP2,KP2+9,,  
LSLK,S,1  
CM,FULLX,LINE

KSEL,S,KP,,KP2+10,KP2+23,,  
LSLK,S,1  
CM,FULLZ,LINE

KSEL,S,KP,,KP2+18,KP2+21,,  
LSLK,S,1  
CM,PARTZ,LINE

KSEL,S,KP,,KP2+30,KP2+38,,  
LSLK,S,1  
CM,lodiag,LINE



KSEL,S,KP,,KP2+40,KP2+48,,  
LSLK,S,1  
CM,hidiag,LINE

KSEL,S,KP,,KP2+50,KP2+52,1,  
LSLK,S,1  
CM,flangeplus,LINE

KSEL,S,KP,,KP2+50,KP2+56,3,  
LSLK,S,1  
CM,flangeminus,LINE

KSEL,S,KP,,KP2+60,KP2+62,1,  
LSLK,S,1  
CM,flandiagplus,LINE

KSEL,S,KP,,KP2+60,KP2+66,3,  
LSLK,S,1  
CM,flandiagminus,LINE

KSEL,S,KP,,KP2+70,KP2+72,1,  
LSLK,S,1  
CM,webhoriz,LINE

KSEL,S,KP,,KP2+18,KP2+42,24,  
KSEL,A,KP,,KP2+90  
LSLK,S,1  
CM,webvert,LINE

ALLSEL,ALL

!!\*GET,AMAX1,AREA,0,NUM,MAX

! diagonal web areas  
A,KP2+33,KP2+34,KP2+41,KP2+40  
\*DO,I,KP2+34,KP2+37,1  
A,I,I+1,I+8,I+7  
\*ENDDO

ASEL,S,AREA,,ARE2,ARE2+16,,1  
CM,DIAWEBTURB,AREA ! DIAGONAL WEB AND DISTURBED AREAS=D  
ALLSEL,ALL

! areas  
ADRAG,lodiag,,,,,flangeplus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+32,,1  
CM,DLOPLUS,AREA ! DIAGONAL WEB,DISTURBED AND LOW PLUS DIAG FLANGE AREAS  
ALLSEL,ALL

```
ADRAG,lodiag,,,,,flangeminus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+48,,1  
CM,DLODIAG,AREA ! DIAGONAL WEB,DISTURBED AND LOW DIAG FLANGE AREAS  
ALLSEL,ALL
```

```
ADRAG,hidiag,,,,,flandiagplus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+64,,1  
CM,DLOHIPLUS,AREA ! DIAGONAL WEB,DISTURBED,LOW DIAG FLANGE AND HIGH PLUS DIAG FLANGE  
AREAS  
ALLSEL,ALL
```

```
ADRAG,hidiag,,,,,flandiagminus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+80,  
CM,DLOHI,AREA ! DIAGONAL WEB,DISTURBED,LOW AND HIGH DIAG FLANGE AREAS  
ALLSEL,ALL
```

```
ADRAG,FULLZ,,,,,flangeplus,,,,,  
ADRAG,FULLZ,,,,,flangeminus,,,,,  
ADRAG,partz,,,,,webvert,,,,,  
ADRAG,fullx,,,,,flangeplus,,,,,  
ADRAG,fullx,,,,,flangeminus,,,,,  
ADRAG,fullx,,,,,WEBHORIZ,,,,,
```

```
ALLSEL,ALL  
SAVE
```

```
! mesh webS  
! MESH TRIANGLES  
! much simpler to define elements by commands NKPT and E  
CMSEL,S,TRIAREA,AREA  
AATT,10,,5,13,4  
MSHAPE,1,2D  
MSHKEY,0  
AMESH,ALL
```

```
! MESH QUADS  
CMSEL,S,DISTURB,AREA  
CMSEL,U,TRIAREA,AREA  
AATT,10,,5,13,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH DIAG WEB  
CMSEL,S,DIWEBTURB,AREA  
CMSEL,U,DISTURB,AREA  
AATT,10,,5,13,4  
MSHAPE,0,2D
```

MSHKEY,1  
AMESH,ALL

! MESH DIAG FLANGES  
CMSEL,S,DLOHI,AREA  
CMSEL,U,DIAWEBTURB,AREA  
AATT,10,,5,13,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH VERTICAL flange  
ASEL,S,LOC,X,,-1,,  
ASEL,R,LOC,Y,0,6.2,,  
ASEL,R,LOC,Z,,72,,  
AATT,10,,5,13,6  
MSHAPE,0,2D  
MSHKEY,2  
AMESH,ALL

! MESH VERTICAL flange  
ASEL,S,LOC,X,,-1,,  
ASEL,R,LOC,Y,-6.2,0,,  
ASEL,R,LOC,Z,,72,,  
AREVERSE,ALL  
AATT,10,,5,13,6  
MSHAPE,0,2D  
MSHKEY,2  
AMESH,ALL

! mesh VERTICAL web  
ASEL,S,LOC,y,-.1,.1,,  
ASEL,R,LOC,x,,6.0,,  
ASEL,R,LOC,Z,22.0,72.0,,  
AATT,10,,5,13,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! mesh horizontal web  
ASEL,S,LOC,y,-.1,.1,,  
ASEL,R,LOC,x,,59.0,,  
ASEL,R,LOC,Z,0,6.0,,  
AATT,10,,5,13,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

```
! INVERT BOTTOM T
ASEL,S,LOC,Z,,0.1,,
AGEN,2,ALL,,,,,5.955,,,
```

```
! MESH HORIZONTAL FLANGE
ASEL,S,LOC,Z,5.9,6.0,,
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
SAVE
```

```
! reflect and translate HORIZONTAL
ASEL,S,LOC,Z,,6.0,,
ASEL,R,LOC,Y,-0.1,0.1,,
ARSYM,X,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,5.9,6.0,,
ASEL,R,LOC,Y,-6.2,6.2,,
ARSYM,X,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,,6.0,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,U,LOC,X,,59,,
ARSYM,Z,ALL, , , ,0,1
```

```
ALLSEL,ALL
ASEL,S,LOC,Z,-6,6,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,U,LOC,X,,59,,
AGEN,2,ALL,,,,58.12,,72,,,1
ALLSEL,ALL
```

```
SAVE
```

```
! reflect and translate vertical
ASEL,S,LOC,Z,22,66.1,,
ASEL,R,LOC,Y,-0.1,0.1,,
ASEL,R,LOC,X,,6,,
ARSYM,Z,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,,72,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,R,LOC,X,,0.1,,
ARSYM,Z,ALL, , , ,0,0
```

```
CMSEL,S,DISTURB,AREA
```

ARSYM,Z,ALL, , , ,0,0

ALLSEL,ALL  
ASEL,S,LOC,Z,-72,72,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,X,,9,,  
ASEL,U,LOC,Z,,72,,  
ARSYM,X,ALL, , , ,0,1

ALLSEL,ALL  
ASEL,S,LOC,Z,-72,72,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,X,-9,9,,  
ASEL,U,LOC,Z,,72,,  
AGEN,2,ALL,,,58.12,,72,,,1

ALLSEL,ALL ! LINES 20430, areas 15652

! CREATE AREA AT MIDPLANE OF FRAME AND COPY TO +Y SIDE  
ADRAG,FULLX,,,,,FULLZ,,,,, ! areas 15653 to 15769  
AGEN,2,ARE2+353,ARE2+469,1,0,6.11,0,,, ! AREAS 15770 TO 15886

! MESH WITH INSULAITON  
ASEL,S,LOC,y,6.10,6.12,,  
AREVERSE,ALL  
AATT,13,,5,13,7  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! REFLECT  
ARSYM,Y,ALL, , , ,0,0

ALLSEL,ALL  
NUMMRG,ALL,5.0E-3,,  
SAVE  
/EOF

# Chapter 8 Web splice

Table 8.1 Structural components

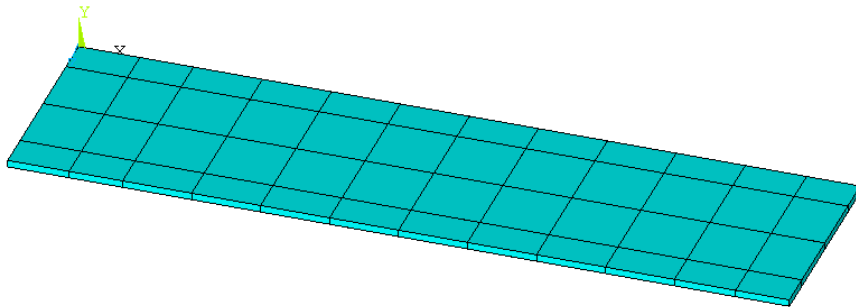
|                              |  |
|------------------------------|--|
| Web splice                   | Starting numbers   |
| *Keypoints KP3               | 9 350  |
| *Lines LIN3                  | 21 300   |
| *Areas ARE3                  | 16 100   |
| *Volumes VOL3                | 5 000  |
| *Elements ELE3               | 72 100   |
| *Nodes NOD3                  | 91 700   |
| *Local coordinates system 14 | x along lower edge of splice;<br>y perpendicular to web, right hand system;<br>z along left vertical edge of splice (Fig. 8.1);<br>connected by 3 holes to upper web of frame of coordinates 13. |
| Element type                 | 5 Shell 181  |
| Sections                     | 9 (0.313 in)   |
| Materials                    | 10 (W sections)  |

\*user input or default option.

1  
ELEMENTS  
DSYS=14



JUN 5 2012  
17:18:10



NFRL WEB SPLICE

Fig. 8.1 Web splice

! Web splice

FINISH  
/CLEAR

/CWD,'C:\StrongFireLab'  
/FILENAME,20120705C,0  
/TITLE,NFRL WEB SPLICE FOR FRAME  
/REPLOT

KEYW,PR\_SET,1  
KEYW,PR\_STRUC,1  
KEYW,PR\_THERM,0  
KEYW,PR\_FLUID,0  
KEYW,PR\_MULTI,0

/PREP7  
! UNITS SI for thermal W, J. degree C  
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! ##### material properties  
! # Material # 10 - Steel for W sections  
! thermal properties may be unnecessary for structural analysis  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000  
MPDATA,EX,10,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,10,,0.30

! thermal expansion  
TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693

MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,50

MPTEMP,3,100

MPTEMP,4,150

MPTEMP,5,200

MPTEMP,6,400

MPTEMP,7,500

MPTEMP,8,600

MPDATA,C,10,,199500

MPDATA,C,10,,208500

MPDATA,C,10,,221200

MPDATA,C,10,,231500

MPDATA,C,10,,240300

MPDATA,C,10,,274800

MPDATA,C,10,,302300

MPDATA,C,10,,344700

!# steel mass density

MPTEMP

MPTEMP,1,25

MPDATA,DENS,10,,2.636E-4 ! kipm/in3

ET,5,SHELL181

KEYOPT,5,1,0 ! bending and membrane stiffness

KEYOPT,5,3,2 ! full integration with incompatible modes

KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer

KEYOPT,5,9,0 ! no user subroutine to define thickness

KEYOPT,5,10,0 ! no initial stress

sect,9,shell,,WEBSPLICE

secdata,0.313,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS=====

\*SET,KP3,9350

\*SET,LIN3,21300

\*SET,ARE3,16100

\*SET,VOL3,5000

\*SET,ELE3,72100

\*SET,NOD3,91700

! # define model geometry

! user input:local coord system and location of WEB SPLICE



! ref: SHEET 10/15 LOWER LEFT FIG  
! Local X ALONG LOWER EDGE OF SPLICE.  
! Local Y perpendicular to web, right hand system.  
! Local Z ALONG LEFT VERTICAL EDGE OF SPLICE.  
! location of SPLICE (origin of local coordinates 14:  
! CONNECTED BY 3 HOLES TO UPPER WEB OF FRAME OF COORD 13)

LOCAL,14,0,212.06,200,267.375, , , ,1,1  
CSYS,14,

! END OF user input=====

NUMSTR,KP,KP3  
NUMSTR,LINE,LIN3  
NUMSTR,AREA,ARE3  
NUMSTR,VOLU,VOL3  
NUMSTR,ELEM,ELE3  
NUMSTR,NODE,NOD3

! x horiz edge of SPLICE bottom=====

K,KP3,,,  
K,KP3+1,2.6667,,  
K,KP3+2,5.0,,  
K,KP3+3,17.0,,  
K,KP3+4,29.0,,  
K,KP3+5,31.6667,,  
K,KP3+6,34.0,,

! Z vert midthickness of flange

K,KP3+10,,,  
K,KP3+11,,,1.625  
K,KP3+12,,,7.625  
K,KP3+13,,,9.25

! LINES

\*DO,I,KP3,KP3+5,1 ! x horiz bottom edge of SPLICE  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP3,KP3+6,,  
LSLK,S,1  
LESIZE,ALL,3.0, , , ,0 , , ,0  
CM,SPLICEX,LINE

ALLSEL,ALL

\*DO,I,KP3+10,KP3+12,1 ! Z vert LEFT EDGE OF SPLICE  
LSTR,I,I+1

```

*ENDDO

KSEL,S,KP,,KP3+10,KP3+13,,
LSLK,S,1
LESIZE,ALL,3.0,, , ,0 , , ,0
CM,SPLICEZ,LINE

! area
ALLSEL,ALL
ADRAG,SPLICEX,,,,,SPLICEZ,,,,,
asel,s,area,,are3,are3+17,,1
AATT,10,,5,14,9
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL

ALLSEL,ALL
NUMMRG,ALL
SAVE

! the following is a load test

/SOLU
ANTYPE,0 ! static analysis

! constrain X ends
NSEL,S,LOC,X,0,0.1,,
NSEL,A,LOC,X,33.9,34.1,,
D,ALL,UX,,,,,,
D,ALL,UY,,,,,,
D,ALL,UZ,,,,,,

! LOAD MIDDLE x=17
ALLSEL,ALL
NSEL,S,LOC,X,16.9,17.1,,
F,ALL,FY,-1,,,

ALLSEL,ALL
OUTPR,STAT
OUTRES,STAT
SOLVE

/EOF

```

# Chapter 9 Girder

Table 9.1 Properties

|                              |  |
|------------------------------|--|
| Girder                       | Starting numbers   |
| *Keypoints KP4               | 9 400  |
| *Lines LIN4                  | 21 700   |
| *Areas ARE4                  | 16 300   |
| *Volumes VOL4                | 5 000  |
| *Elements ELE4               | 72 400   |
| *Nodes NOD4                  | 92 100   |
| *Local coordinates system 15 | x along midheight of web;<br>y perpendicular to web, right hand system;<br>z along left vertical edge of web;<br>origin: end of girder (Figs. 9.1 and 9.2) |
| Element type                 | 5 Shell 181  |
| Sections                     | *Girder LENGTH<br>10 (0.55 inch web W 24x103)<br>11 (0.98 inch flange W 24x103)  |
| Materials                    | 10 (W sections)  |

\*user input or default option.

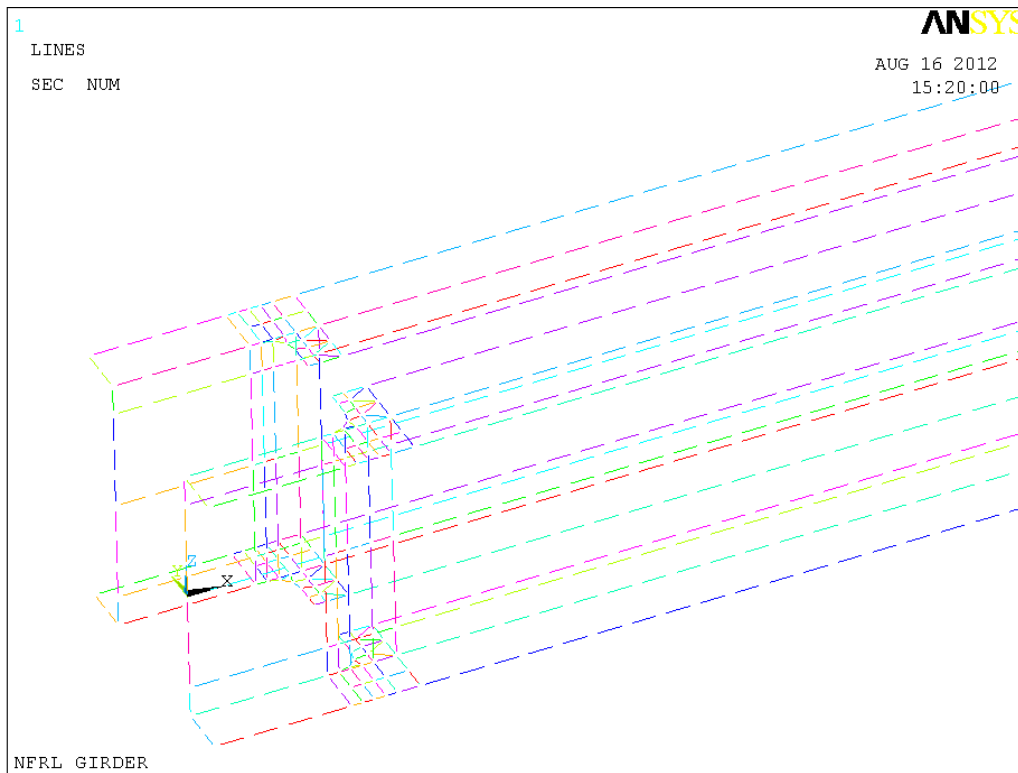


Fig. 9.1 Girder lines showing local coordinates

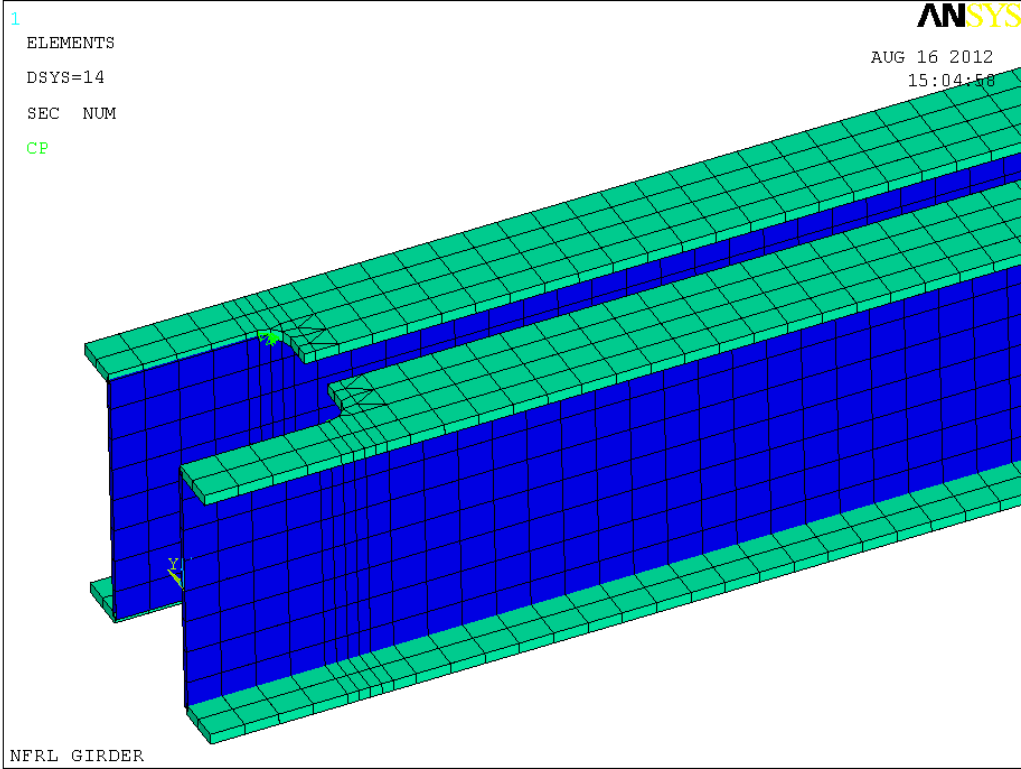


Fig. 9.2 Girder elements showing coordinate system

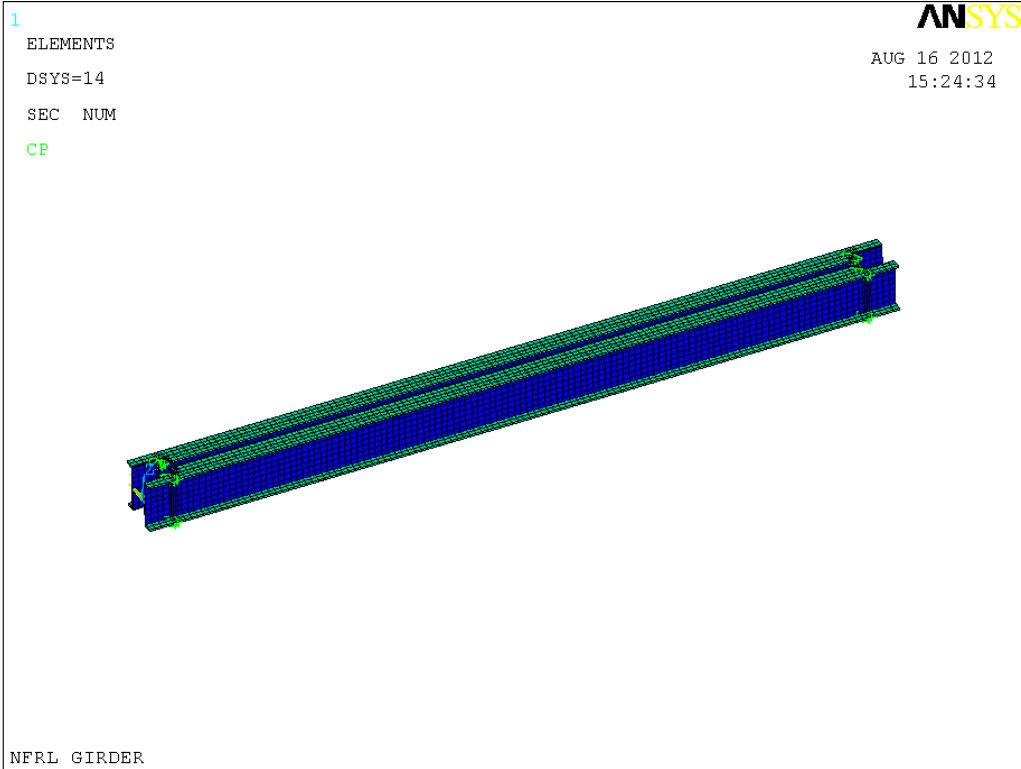


Fig. 9.3 Entire girder

! GIRDER LAST TESTED 9.18.2012

FINISH  
/CLEAR

/CWD,'C:\StrongFireLab'  
/FILENAME,20120918,0  
/TITLE,NFRL GIRDER  
/REPLOT

KEYW,PR\_SET,1  
KEYW,PR\_STRUC,1  
KEYW,PR\_THERM,0  
KEYW,PR\_FLUID,0  
KEYW,PR\_MULTI,0

/PREP7  
! UNITS SI for thermal W, J. degree C  
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! ##### material properties  
! # Material # 10 - Steel for W sections  
! thermal properties may be unnecessary for structural analysis  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000  
MPDATA,EX,10,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,10,,0.30

! thermal expansion  
TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693

MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,50

MPTEMP,3,100

MPTEMP,4,150

MPTEMP,5,200

MPTEMP,6,400

MPTEMP,7,500

MPTEMP,8,600

MPDATA,C,10,,199500

MPDATA,C,10,,208500

MPDATA,C,10,,221200

MPDATA,C,10,,231500

MPDATA,C,10,,240300

MPDATA,C,10,,274800

MPDATA,C,10,,302300

MPDATA,C,10,,344700

!# steel mass density

MPTEMP

MPTEMP,1,25

MPDATA,DENS,10,,2.636E-4 ! kipm/in3

ET,5,SHELL181

KEYOPT,5,1,0 ! bending and membrane stiffness

KEYOPT,5,3,2 ! full integration with incompatible modes

KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer

KEYOPT,5,9,0 ! no user subroutine to define thickness

KEYOPT,5,10,0 ! no initial stress

sect,10,shell,,girderweb24W103

secdata,0.550,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

sect,11,shell,,girderflange24W103

secdata,0.980,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS=====

\*SET,KP4,9400

\*SET,LIN4,21700

\*SET,ARE4,16300

\*SET,VOL4,5000

```
*SET,ELE4,72400
*SET,NOD4,92100
```

```
! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 12/15
! Local X ALONG midheight of web.
! Local Y perpendicular to web, right hand system.
! Local Z ALONG left vertical EDGE OF web.
```

```
LOCAL,15,0,10,100,200, , , ,1,1
CSYS,15,
```

```
LENGTH=186.0 !half - length of girder, must be > 126 and multiple of 3 inches
! If length > 186, user may have to increase element and node starting numbers
! of subsequent components.
!LENGTH=162.0
! END OF user input=====
```

```
NUMSTR,KP,KP4
NUMSTR,LINE,LIN4
NUMSTR,AREA,ARE4
NUMSTR,VOLU,VOL4
NUMSTR,ELEM,ELE4
NUMSTR,NODE,NOD4
```

```
! x horiz midheight of web, halfspan
K,KP4,,,
K,KP4+1,12.0,,
K,KP4+2,13.0,,
K,KP4+3,14.0,,
K,KP4+4,16.0,,
K,KP4+5,18.0,,
K,KP4+6,LENGTH,, !***
```

```
! Z vert midthickness of web
K,KP4+10,,,
K,KP4+11,,,9
!K,KP4+11,,,2.775
K,KP4+12,,,11.775
```

```
! y width of half flange
K,KP4+20,,,11.775
K,KP4+21,,-4.5,11.775
```

```
! y width of full flange
K,KP4+30,18,4.5,11.775
K,KP4+31,18,-4.5,11.775
```

! FLANGE TRANSITION KEYPOINTS

K,KP4+40,13, -4.5,11.775

K,KP4+41,13,-2.25,11.775

K,KP4+42,13, 0,11.775

K,KP4+50,14, -4.5,11.775

K,KP4+51,14, -2.25,11.775

K,KP4+52,14,.29795,11.775

K,KP4+60,15, -4.5,11.775

K,KP4+61,15, -2.25,11.775

K,KP4+62,15, 0,11.775

K,KP4+63,14.73205,1,11.775

K,KP4+64,15, 2.0,11.775

K,KP4+65,15, 3.375,11.775

K,KP4+66,15, 4.5,11.775

K,KP4+70,16, -4.5,11.775

K,KP4+71,16,-2.25,11.775

K,KP4+72,16, 0,11.775

K,KP4+73,16,1.125,11.775

K,KP4+74,16, 2.25,11.775

K,KP4+75,16,3.375,11.775

K,KP4+76,16, 4.5,11.775

K,KP4+80,18, -4.5,11.775

K,KP4+81,18,-2.25,11.775

K,KP4+82,18, 0,11.775

K,KP4+83,18, 2.25,11.775

K,KP4+84,18, 4.5,11.775

! LINES 0 to 5 x horiz midheight of web

\*DO,I,KP4,KP4+5,1

LSTR,I,I+1

\*ENDDO

LESIZE,lin4 ,3.0, ,0, ,0, , ,0

LESIZE,lin4+1,1.0, ,0, ,0, , ,0

LESIZE,lin4+2,1.0, ,0, ,0, , ,0

LESIZE,lin4+3,1.0, ,0, ,0, , ,0

LESIZE,lin4+4,2.0, ,0, ,0, , ,0

LESIZE,lin4+5,3.0, ,0, ,0, , ,0

LSEL,S,LINE,,LIN4,LIN4+5,,1

CM,halfspanx,line

ALLSEL,ALL

KSEL,S,KP,,KP4,KP4+2,1,

LSLK,S,1



CM,cutoffx,line

allsel,all

KSEL,S,KP,,KP4+5,KP4+6,1,

LSLK,S,1

CM,fullwidthx,line

allsel,all

! LINES 6 to 7 z vert midthickness of half web

\*DO,I,KP4+10,KP4+11,1

LSTR,I,I+1

\*ENDDO

LESIZE,lin4+6,3.0, ,0, ,0, , ,0

LESIZE,lin4+7, 0, ,1, ,0, , ,0

!LESIZE,lin4+6, 0, ,1, ,0, , ,0

!LESIZE,lin4+7,3.0, ,0, ,0, , ,0

KSEL,S,KP,,KP4+10,KP4+12,1,

LSLK,S,1

CM,webdepthz,line

allsel,all

LSTR,KP4+20,KP4+21 ! L8 y width of half flange

LESIZE,lin4+8,0, ,2, ,0, , ,0

LSEL,S,LINE,,LIN4+8,,,1

CM,halfwidthy,line

allsel,all

LSTR,KP4+30,KP4+31 ! L9 y width of full flange

LESIZE,lin4+9,0, ,4, ,0, , ,0

allsel,all

LSEL,S,LINE,,LIN4+9,,,1

CM,fullwidthy,line

ALLSEL,ALL

CMSEL,S,cutoffx,line

LGEN,2,ALL,,,,,11.775,,, ! L10 TO 11

LSEL,S,LINE,,LIN4+10,LIN4+11,1,1

CM,cutoffx2,line

allsel,all

CMSEL,S,fullwidthx,line

LGEN,2,ALL,,,,,4.5,11.775,,, ! L12 TO 13

LSEL,S,LINE,,LIN4+12,LIN4+13,,1

CM,fullwidthx2,line

allsel,all

LSEL,S,LINE,,LIN4,LIN4+12,1,1

CM,REGULAR,LINE  
allsel,all

! LINES IN CUTOFF REGION L14 TO L56

! Y LINES

LSTR,KP4+40,KP4+41

LSTR,KP4+41,KP4+42

LSTR,KP4+50,KP4+51

LSTR,KP4+51,KP4+52

\*DO,I,KP4+60,KP4+65,1

LSTR,I,I+1

\*ENDDO

\*DO,I,KP4+70,KP4+75,1

LSTR,I,I+1

\*ENDDO

\*DO,I,KP4+80,KP4+83,1

LSTR,I,I+1

\*ENDDO

! X LINES

\*DO,I,KP4+40,KP4+70,10

LSTR,I,I+10

\*ENDDO

\*DO,I,KP4+41,KP4+71,10

LSTR,I,I+10

\*ENDDO

\*DO,I,KP4+42,KP4+72,10

LSTR,I,I+10

\*ENDDO

LSTR,KP4+62,KP4+63

LSTR,KP4+63,KP4+52

LSTR,KP4+63,KP4+73

LSTR,KP4+73,KP4+82

LSTR,KP4+73,KP4+83

LSTR,KP4+64,KP4+74

LSTR,KP4+74,KP4+83

LSTR,KP4+65,KP4+75

LSTR,KP4+75,KP4+83

LSTR,KP4+75,KP4+84

LSTR,KP4+66,KP4+76

LSTR,KP4+76,KP4+84

ALLSEL,ALL

LSEL,S,LINE,,LIN4,LIN4+55,,1  
CM,ALLINES,LINES  
CMSEL,S,ALLINES,LINE  
CMSEL,U,REGULAR,LINE  
LESIZE,ALL,0,,1,,0,,0  
CM,IRREGULAR,LINE

ALLSEL,ALL

! areas

\*DO,I,KP4+40,KP4+70,10

A,I,I+10,I+11,I+1

\*ENDDO

\*DO,I,KP4+41,KP4+71,10

A,I,I+10,I+11,I+1

\*ENDDO

A,KP4+52,KP4+62,KP4+63

A,KP4+62,KP4+72,KP4+73,KP4+63

A,KP4+72,KP4+82,KP4+73

A,KP4+73,KP4+82,KP4+83

A,KP4+63,KP4+73,KP4+74,KP4+64

A,KP4+73,KP4+83,KP4+74

A,KP4+64,KP4+74,KP4+75,KP4+65

A,KP4+74,KP4+83,KP4+75

A,KP4+75,KP4+83,KP4+84

A,KP4+65,KP4+75,KP4+76,KP4+66

A,KP4+75,KP4+84,KP4+76

ADRAG,halfspanx,,,,,webdepthz,,,,, ! Areas 0 to 9

ADRAG,cutoffx2,,,,,halfwidthy,,,,, ! Areas 10 to 11

ADRAG,fullwidthx2,,,,,fullwidthy,,,,, ! Areas 12 to 13

! MESH WEB

ASEL,S,LOC,Y,-0.1,0.1,,1

ASEL,R,LOC,Z,0,11.7,,

AATT,10,,5,15,10

MSHAPE,0,2D

MSHKEY,1

AMESH,ALL

ALLSEL,ALL

! MESH FLANGE

ASEL,S,LOC,Z,11.7,11.8,,1

```
ASEL,U,LOC,X,13,18,,1
AATT,10,,5,15,11
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
```

```
! MESH FLANGE TRANSITION
```

```
ASEL,S,LOC,Z,11.7,11.8,,1
ASEL,R,LOC,X,13,18,,1
AATT,10,,5,15,11
MSHKEY,2
AMESH,ALL
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+33,,1
! reflect AND TRANSLATE
ARSYM,Z,ALL, , , ,0,0 ! from quarter to half
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+67,,1
ARSYM,x,ALL, , , ,0,0 ! from half to full
ALLSEL,ALL
```

```
!ASEL,S,LOC,x,-186,0,,1
ASEL,S,AREA,,ARE4+68,ARE4+135,,1 ! move new half to other end
L=LENGTH*2      !***
AGEN,2,ALL,,,L,,,,,1 !***
ALLSEL,ALL
```

```
! girder assembly A
! y distance between 2 beams is  $12.89 + 0.55 = 13.44$ 
! new beam is between  $y = -13.44 \pm 4.5$ 
! if spacing between beams changes, these values must change
```

```
ASEL,S,AREA,,ARE4,ARE4+135,,1
AGEN,2,ALL,,,0,-13.44,,,,0 ! double beam
ASEL,S,LOC,y,-18,-8.9,,1 ! reflect
ARSYM,Y,ALL, , , ,0,1
ALLSEL,ALL
```

```
! end of generation of 2nd beam and possible user input
```

```
NUMMRG,ALL
```

```
! CONSTRAIN TOP OF WEB WITH BEGINNING OF FULL FLANGE.
```

```
N1 = NODE(14,0,11.775)
N2 = NODE(14,.29795,11.775)
CP,NEXT,ALL,N1,N2
```

```
N3 = NODE(14,0,-11.775)
N4 = NODE(14,.29795,-11.775)
CP,NEXT,ALL,N3,N4
```

```
L1=LENGTH*2-14
```

```
N5 = NODE(L1,0,11.775)
N6 = NODE(L1,.29795,11.775)
CP,NEXT,ALL,N5,N6
```

```
N7 = NODE(L1,0,-11.775)
N8 = NODE(L1,.29795,-11.775)
CP,NEXT,ALL,N7,N8
```

```
! y location of couplings below depends on spacing between 2 beams
! 13.44-.29795 = 13.14205
```

```
N9 = NODE(14,13.44,11.775)
N10 = NODE(14,13.14205,11.775)
CP,NEXT,ALL,N9,N10
```

```
N11 = NODE(14,13.44,-11.775)
N12 = NODE(14,13.14205,-11.775)
CP,NEXT,ALL,N11,N12
```

```
N13 = NODE(L1,13.44,11.775)
N14 = NODE(L1,13.14205,11.775)
CP,NEXT,ALL,N13,N14
```

```
N15 = NODE(L1,13.44,-11.775)
N16 = NODE(L1,13.14205,-11.775)
CP,NEXT,ALL,N15,N16
```

```
ALLSEL,ALL
SAVE
```

```
! the following is a load test
```

```
/SOLU
ANTYPE,0 ! static analysis
```

```
! constrain ends x=0
NSEL,S,LOC,X,0,0.1,,
D,ALL,UX,,,,,,,,
```

```
D,ALL,UY,,,,,,,,  
D,ALL,UZ,,,,,,,,
```

```
! LOAD ends x=372  
ALLSEL,ALL  
L3=LENGTH*2-0.1  
L4=LENGTH*2+0.1  
NSEL,S,LOC,X,L3,L4,,  
F,ALL,FZ,-1,,,
```

```
ALLSEL,ALL  
OUTPR,STAT  
OUTRES,STAT  
SOLVE  
/eof
```

## Chapter 10 Wrapped girder

Table 10.1 Properties

|                              |  |
|------------------------------|--|
| Wrapped girder               | Starting numbers   |
| *Keypoints KP4               | 9 400  |
| *Lines LIN4                  | 21 700   |
| *Areas ARE4                  | 16 300   |
| *Volumes VOL4                | 5 000  |
| *Elements ELE4               | 72 400   |
| *Nodes NOD4                  | 92 100   |
| *Local coordinates system 15 | x along midheight of web;<br>y perpendicular to web, right hand system;<br>z along left vertical edge of web;<br>origin: end of girder (Figs. 9.1 and 9.2)     |
| Element type                 | 5 Shell 131  |
| Sections                     | *Girder LENGTH<br>*7 (1 inch side wrap)<br>10 (0.55 inch web W 24x103)<br>11 (0.98 inch flange W 24x103)<br>*13 (1 inch flange wrap)<br>*14 (1 inch side wrap) |
| Materials                    | 10 (W sections)<br>*13 (insulation)  |

\*user input or default option.

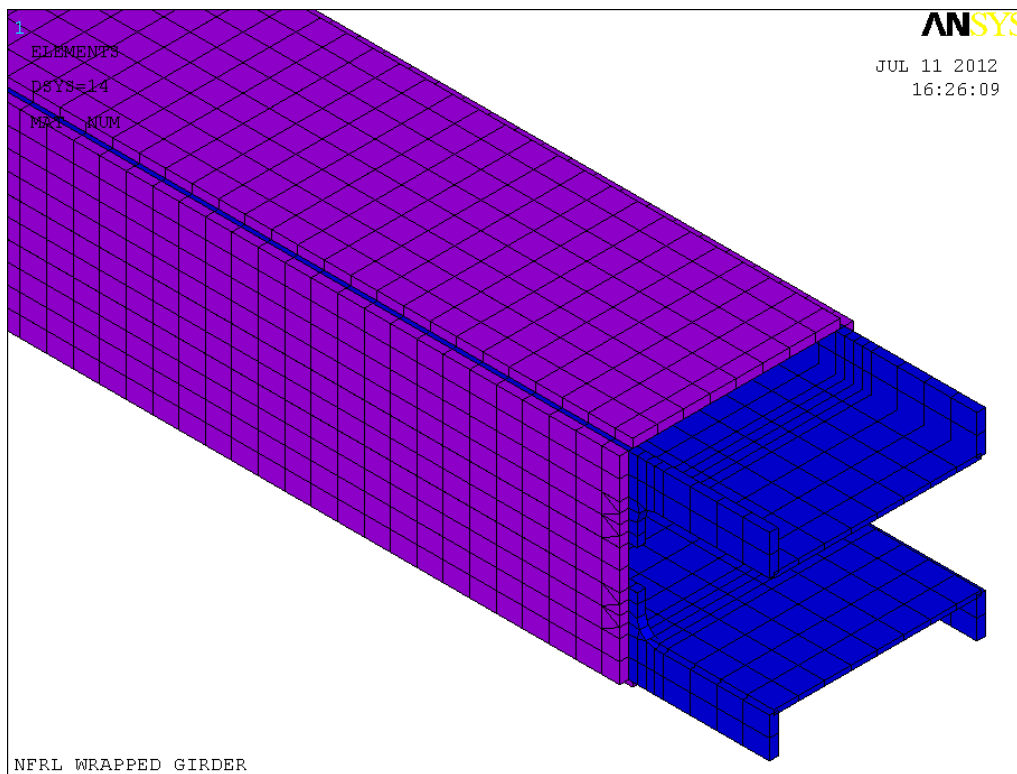


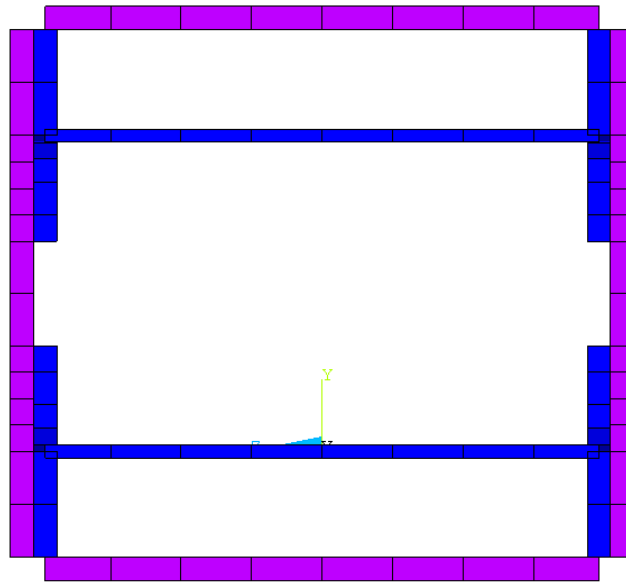
Fig. 10.1 Wrapped girder, with exposed end

1

ELEMENTS  
DSYS=14  
MAT NUM

ANSYS

JUL 11 2012  
16:26:09



NFRL WRAPPED GIRDER

Fig. 10.2 Wrapped girder, end view

## ! Wrapped girder

! last tested 9.19.2012

FINISH  
/CLEAR

/CWD,'C:\StrongFireLab'  
/FILENAME,20120919,0  
/TITLE,NFRL WRAPPED GIRDER  
/REPLOT

KEYW,PR\_SET,1  
KEYW,PR\_STRUC,0  
KEYW,PR\_THERM,1  
KEYW,PR\_FLUID,0  
KEYW,PR\_MULTI,0

/PREP7

! UNITS SI for thermal W, J, degree C  
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! ##### material properties  
! # Material # 10 - Steel for W sections  
! thermal properties may be unnecessary for structural analysis



! Young's modulus and Poisson's ratio  
! constants  
\*SET,SIG,3.6583E-11 ! Stefan-Boltzman constant  $W/(in^2.K^4)$   
\*SET,EMS1,0.9 ! Emissivity of steel - outside  
\*SET,EMS2,0.9 ! Emissivity of steel - inside  
\*SET,Hf,15 ! Film coefficient of steel faces

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000  
MPDATA,EX,10,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,10,,0.30

! thermal expansion  
TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity  $W/(in.K)$   
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693  
MPDATA,KXX,10,,0.693

!# steel heat capacity  $J/(kipm.K)$   
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,10,,199500  
MPDATA,C,10,,208500  
MPDATA,C,10,,221200  
MPDATA,C,10,,231500  
MPDATA,C,10,,240300  
MPDATA,C,10,,274800

MPDATA,C,10,,302300  
MPDATA,C,10,,344700

!# steel mass density  
MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,10,,2.636E-4 ! kipm/in3

ET,5,SHELL131  
KEYOPT,5,2,0 ! average film temperature  
KEYOPT,5,3,0 ! quadratic temperature distribution through thickness  
KEYOPT,5,4,0 ! use sect defined above  
KEYOPT,5,6,0 ! no paint  
!KEYOPT,5,8,2 use this option when insulation is present- data at top, bottom and mid of all layers  
!SHELL,MID use this option when insulation is present-results calculated at mid, not averaged from top and bottom

sect,10,shell,,girderweb24W103  
secdata,0.550,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,11,shell,,girderflange24W103  
secdata,0.980,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

!=====user input: insulation thickness and properties=====  
! # Material # 13 - Blazeshield insulation

!# insulation conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25 ! degree C  
MPTEMP,2,377  
MPTEMP,3,677  
MPDATA,KXX,13,,0.0013  
MPDATA,KXX,13,,0.0025  
MPDATA,KXX,13,,0.0051

!# insulation heat capacity J/(kipm.K)  
MPTEMP  
MPTEMP,1,25 ! C  
MPTEMP,2,677  
MPDATA,C,13,,362880  
MPDATA,C,13,,907200

!# insulation mass density kipm/in3  
MPTEMP

```
MPTEMP,1,25
MPDATA,DENS,13,,7.51E-6
```

```
!# insulation emissivity
MPTEMP
MPTEMP,1,25
MPDATA,EMIS,13,,0.9
```

```
! Insulation blanket thickness is T
T = 1
! careful that same emissivity can be used for steel and insulation
```

```
! USER INPUT: STARTING NUMBERS=====
*SET,KP4,9400
*SET,LIN4,21700
*SET,ARE4,16300
*SET,VOL4,5000
*SET,ELE4,72400
*SET,NOD4,92100
```

```
! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 12/15
! Local X ALONG midheight of web.
! Local Y perpendicular to web, right hand system.
! Local Z ALONG left vertical EDGE OF web.
```

```
LOCAL,15,0,10,100,200, , , ,1,1
CSYS,15,
DSYS,15, ! display
LENGTH=186.0 ! half length of girder, must be > 126 and multiple of 3 inches
! If length > 186, user may have to increase element and node starting numbers
! of subsequent components.
!LENGTH=162.0
! END OF user input=====
```

```
sect,13,shell,,flangew
secdata,0.98,10,0,3 ! steel layer 1 at bottom, NEEDS UPDATING
secdata,T,13,0,3
secoffset,user,-T/2 ! relative to midthickness of shell
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,7,shell,,sidew ! blanket
secdata,T,13,0,3
secoffset,bot
seccontrol,0,0,0, 0, 1, 1, 1
```

```
sect,14,shell,,sidew ! blanket
```

secdata,T,13,0,3  
secoffset,user,-T ! relative to midthickness of shell  
seccontrol,0,0,0, 0, 1, 1, 1

NUMSTR,KP,KP4  
NUMSTR,LINE,LIN4  
NUMSTR,AREA,ARE4  
NUMSTR,VOLU,VOL4  
NUMSTR,ELEM,ELE4  
NUMSTR,NODE,NOD4

! x horiz midheight of web, halfspan

K,KP4,,,  
K,KP4+1,12.0,,  
K,KP4+2,13.0,,  
K,KP4+3,14.0,,  
K,KP4+4,16.0,,  
K,KP4+5,18.0,,  
K,KP4+6,LENGTH,, !\*\*\*

! Z vert midthickness of web

K,KP4+10,,,  
K,KP4+11,,,9  
K,KP4+12,,,11.775

! y width of half flange

K,KP4+20,,,11.775  
K,KP4+21,,-4.5,11.775

! y width of full flange

K,KP4+30,18,4.5,11.775  
K,KP4+31,18,-4.5,11.775

! FLANGE TRANSITION KEYPOINTS

K,KP4+40,13, -4.5,11.775  
K,KP4+41,13,-2.25,11.775  
K,KP4+42,13, 0,11.775

K,KP4+50,14, -4.5,11.775  
K,KP4+51,14, -2.25,11.775  
K,KP4+52,14,.29795,11.775

K,KP4+60,15, -4.5,11.775  
K,KP4+61,15, -2.25,11.775  
K,KP4+62,15, 0,11.775  
K,KP4+63,14.73205,1,11.775  
K,KP4+64,15, 2.0,11.775  
K,KP4+65,15, 3.375,11.775

K,KP4+66,15, 4.5,11.775

K,KP4+70,16, -4.5,11.775 !\*\*

K,KP4+71,16,-2.25,11.775

K,KP4+72,16, 0,11.775

K,KP4+73,16,1.125,11.775

K,KP4+74,16, 2.25,11.775

K,KP4+75,16,3.375,11.775

K,KP4+76,16, 4.5,11.775 !\*\*

K,KP4+77,16, -4.5,9.0 !\*\*

K,KP4+78,16, -4.5,0 !\*\*

K,KP4+79,16, 6.72,11.775 !\*\*

K,KP4+80,18, -4.5,11.775

K,KP4+81,18,-2.25,11.775

K,KP4+82,18, 0,11.775

K,KP4+83,18, 2.25,11.775

K,KP4+84,18, 4.5,11.775

! LINES 0 to 5 x horiz midheight of web

\*DO,I,KP4,KP4+5,1

LSTR,I,I+1

\*ENDDO

LESIZE,lin4 ,3.0, ,0, ,0, , , ,0

LESIZE,lin4+1,1.0, ,0, ,0, , , ,0

LESIZE,lin4+2,1.0, ,0, ,0, , , ,0

LESIZE,lin4+3,1.0, ,0, ,0, , , ,0

LESIZE,lin4+4,2.0, ,0, ,0, , , ,0

LESIZE,lin4+5,3.0, ,0, ,0, , , ,0

LSEL,S,LINE,,LIN4,LIN4+5,,1

CM,halfspanx,line

ALLSEL,ALL

KSEL,S,KP,,KP4,KP4+2,1,

LSLK,S,1

CM,cutoffx,line

allsel,all

KSEL,S,KP,,KP4+5,KP4+6,1,

LSLK,S,1

CM,fullwidthx,line

allsel,all

! LINES 6 to 7 z vert midthickness of half web

\*DO,I,KP4+10,KP4+11,1

LSTR,I,I+1

\*ENDDO

```
LESIZE,lin4+6,3.0, ,0, ,0, , ,0
LESIZE,lin4+7, 0, ,1, ,0, , ,0
KSEL,S,KP,,KP4+10,KP4+12,1,
LSLK,S,1
CM,webdepthz,line
allsel,all
```

```
LSTR,KP4+20,KP4+21 ! L8 y width of half flange
LESIZE,lin4+8,0, ,2, ,0, , ,0
LSEL,S,LINE,,LIN4+8,,1
CM,halfwidthy,line
```

```
allsel,all
LSTR,KP4+30,KP4+31 ! L9 y width of full flange
LESIZE,lin4+9,0, ,4, ,0, , ,0
allsel,all
LSEL,S,LINE,,LIN4+9,,1
CM,fullwidthy,line
```

```
ALLSEL,ALL
CMSEL,S,cutoffx,line
LGEN,2,ALL,,,,,11.775,,, ! L10 TO 11
LSEL,S,LINE,,LIN4+10,LIN4+11,1,1
CM,cutoffx2,line
```

```
allsel,all
CMSEL,S,fullwidthx,line
LGEN,2,ALL,,,,,4.5,11.775,,, ! L12 TO 13
LSEL,S,LINE,,LIN4+12,LIN4+13,,1
CM,fullwidthx2,line
```

```
allsel,all
LSEL,S,LINE,,LIN4,LIN4+12,1,1
CM,REGULAR,LINE
allsel,all
```

```
! LINES IN CUTOFF REGION L14 TO L56
! Y LINES
LSTR,KP4+40,KP4+41
LSTR,KP4+41,KP4+42
LSTR,KP4+50,KP4+51
LSTR,KP4+51,KP4+52
```

```
*DO,I,KP4+60,KP4+65,1
LSTR,I,I+1
*ENDDO
```

```
*DO,I,KP4+70,KP4+75,1
LSTR,I,I+1
*ENDDO
```

```
*DO,I,KP4+80,KP4+83,1
LSTR,I,I+1
*ENDDO
```

```
! X LINES
*DO,I,KP4+40,KP4+70,10
LSTR,I,I+10
*ENDDO
```

```
*DO,I,KP4+41,KP4+71,10
LSTR,I,I+10
*ENDDO
```

```
*DO,I,KP4+42,KP4+72,10
LSTR,I,I+10
*ENDDO
```

```
LSTR,KP4+62,KP4+63
LSTR,KP4+63,KP4+52
LSTR,KP4+63,KP4+73
LSTR,KP4+73,KP4+82
LSTR,KP4+73,KP4+83
```

```
LSTR,KP4+64,KP4+74
LSTR,KP4+74,KP4+83
LSTR,KP4+65,KP4+75
LSTR,KP4+75,KP4+83
LSTR,KP4+75,KP4+84
LSTR,KP4+66,KP4+76
LSTR,KP4+76,KP4+84
```

```
ALLSEL,ALL
```

```
LSEL,S,LINE,,LIN4,LIN4+55,,1
CM,ALLINES,LINES
CMSEL,S,ALLINES,LINE
CMSEL,U,REGULAR,LINE
LESIZE,ALL,0, ,1, ,0, , ,0
CM,IRREGULAR,LINE
allsel,all ! L21055
```

```
! generate new lines for insulation
LGEN,2,LIN4+4,LIN4+5,1,0,6.72,11.775,,,! L21056,7 insulation flange edge
LGEN,2,LIN4+4,LIN4+5,1,0,-4.5,11.775,,,! L21058,9 flange edge
```

```
LSTR,KP4+70,KP4+77 ! L21060 side cover
LSTR,KP4+77,KP4+78 ! L21061 side cover
LSTR,KP4+76,KP4+79 ! L21062 flange cover
```

```
LESIZE,lin4+60,0, ,1, ,0, , ,0
LESIZE,lin4+61,3.0, ,0, ,0, , ,0
LESIZE,lin4+62,0, ,1, ,0, , ,0
```

```
ALLSEL,ALL
```

```
! areas
```

```
*DO,I,KP4+40,KP4+70,10
```

```
A,I,I+10,I+11,I+1 ! regular part of transition zone
```

```
*ENDDO ! A16000-3
```

```
*DO,I,KP4+41,KP4+71,10
```

```
A,I,I+10,I+11,I+1 ! next part of flange in +y direction
```

```
*ENDDO ! A16004-7
```

```
A,KP4+52,KP4+62,KP4+63
```

```
A,KP4+62,KP4+72,KP4+73,KP4+63
```

```
A,KP4+72,KP4+82,KP4+73
```

```
A,KP4+73,KP4+82,KP4+83
```

```
A,KP4+63,KP4+73,KP4+74,KP4+64
```

```
A,KP4+73,KP4+83,KP4+74
```

```
A,KP4+64,KP4+74,KP4+75,KP4+65
```

```
A,KP4+74,KP4+83,KP4+75
```

```
A,KP4+75,KP4+83,KP4+84
```

```
A,KP4+65,KP4+75,KP4+76,KP4+66
```

```
A,KP4+75,KP4+84,KP4+76 ! rest of flange transition A16008-18
```

```
ADRAG,halfspanx,,,,,webdepthz,,,,, ! Web areas A16019-30
```

```
ADRAG,cutoffx2,,,,,halfwidthy,,,,, ! flange areas end-transition A16031-2
```

```
ADRAG,fullwidthx2,,,,,fullwidthy,,,,, ! flange areas transition-midspan A16033
```

```
ADRAG,lin4+62,,,,,lin4+58,lin4+59,,,,, ! flange cover extension A16034-5
```

```
ADRAG,lin4+60,lin4+61,,,,,lin4+56,lin4+57,,,,, ! flange cover extension A16036-9
```

```
! MESH WEB, BARE STEEL
```

```
ASEL,S,LOC,Y,-0.1,0.1,,1
```

```
ASEL,R,LOC,Z,0,11.7,,
```

```
AATT,10,,5,15,10
```

```
MSHAPE,0,2D
```

```
MSHKEY,1
```

```
AMESH,ALL
```

```
ALLSEL,ALL
```

```
! MESH FLANGE END, BARE STEEL
```

```
ASEL,S,LOC,Z,11.7,11.8,,1
```

```
ASEL,R,LOC,X,0,13,,1
```



!ASEL,U,LOC,X,13,18,,1  
AATT,10,,5,15,11  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL  
ALLSEL,ALL

! MESH FLANGE TRANSITION, BARE STEEL  
ASEL,S,LOC,Z,11.7,11.8,,1  
ASEL,R,LOC,X,13,16,,1  
AATT,10,,5,15,11  
MSHKEY,2  
AMESH,ALL  
ALLSEL,ALL

! MESH FLANGE TRANSITION, INSULATED STEEL  
ASEL,S,LOC,Z,11.7,11.8,,1  
ASEL,R,LOC,X,16,18,,1  
ASEL,R,LOC,Y,-4.5,4.5,,1  
AATT,10,,5,15,13  
MSHKEY,2  
AMESH,ALL  
ALLSEL,ALL

! MESH FLANGE MIDDLE, INSULATED STEEL  
ASEL,S,LOC,Z,11.7,11.8,,1  
ASEL,R,LOC,X,18,LENGTH,,1 !\*\*  
ASEL,R,LOC,Y,-4.5,4.5,,1  
AREVERSE,ALL  
AATT,10,,5,15,13  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL  
ALLSEL,ALL

! MESH FLANGE INSULATION BETWEEN BEAMS  
ASEL,S,LOC,Z,11.7,11.8,,1  
ASEL,R,LOC,X,16,LENGTH,,1 !\*\*  
ASEL,R,LOC,Y,4.5,6.72,,1  
AREVERSE,ALL  
AATT,13,,5,15,14  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL  
ALLSEL,ALL

! MESH SIDE INSULATION PARALLEL TO WEB  
ASEL,S,LOC,Z,0,11.8,,1

```
ASEL,R,LOC,X,16,LENGTH,,1 !**
ASEL,R,LOC,Y,-4.55,-4.45,,1
AATT,13,,5,15,7
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+39,,1
! reflect AND TRANSLATE
ARSYM,Z,ALL, , , ,0,0 ! from quarter to half
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+79,,1
ARSYM,x,ALL, , , ,0,0 ! from half to full
ALLSEL,ALL
```

```
!ASEL,S,LOC,x,-186,0,,1
ASEL,S,AREA,,ARE4+80,ARE4+159,,1 ! move new half to other end
L=LENGTH*2 !***
AGEN,2,ALL,,,L,,,,,1 !***
ALLSEL,ALL
```

```
! girder assembly A
! y distance between 2 beams is  $12.89 + 0.55 = 13.44$ 
! new beam is between  $y = -13.44 +- 4.5$ 
! if spacing between beams changes, these values must change
```

```
ASEL,S,AREA,,ARE4,ARE4+159,,1
AGEN,2,ALL,,,0,-13.44,,,,0 ! double beam
ASEL,S,LOC,Y,-18,-6.7,,1 ! reflect
ASEL,R,LOC,X,0,L,, ! 9/26/2012
ASEL,R,LOC,Z,-11.8,11.8,, ! 9/26/2012
ARSYM,Y,ALL, , , ,0,1
ALLSEL,ALL
```

```
! end of generation of 2nd beam and possible user input
```

```
NUMMRG,ALL
```

```
! CONSTRAIN TOP OF WEB WITH BEGINNING OF FULL FLANGE.
```

```
N1 = NODE(14,0,11.775)
N2 = NODE(14,.29795,11.775)
CP,NEXT,ALL,N1,N2
```

```
N3 = NODE(14,0,-11.775)
N4 = NODE(14,.29795,-11.775)
```

CP,NEXT,ALL,N3,N4

L1=LENGTH\*2-14

N5 = NODE(L1,0,11.775)

N6 = NODE(L1,.29795,11.775)

CP,NEXT,ALL,N5,N6

N7 = NODE(L1,0,-11.775)

N8 = NODE(L1,.29795,-11.775)

CP,NEXT,ALL,N7,N8

! y location of couplings below depends on spacing between 2 beams

! 13.44-.29795 = 13.14205

N9 = NODE(14,13.44,11.775)

N10 = NODE(14,13.14205,11.775)

CP,NEXT,ALL,N9,N10

N11 = NODE(14,13.44,-11.775)

N12 = NODE(14,13.14205,-11.775)

CP,NEXT,ALL,N11,N12

N13 = NODE(L1,13.44,11.775)

N14 = NODE(L1,13.14205,11.775)

CP,NEXT,ALL,N13,N14

N15 = NODE(L1,13.44,-11.775)

N16 = NODE(L1,13.14205,-11.775)

CP,NEXT,ALL,N15,N16

ALLSEL,ALL

SAVE

/eof

# Chapter 11 Girder Angle

Table 11.1 Properties

|                              |  |
|------------------------------|--|
| Girder angle                 | Starting numbers   |
| *Keypoints KP5               | 10 000   |
| *Lines LIN5                  | 22 700   |
| *Areas ARE5                  | 16 700   |
| *Volumes VOL5                | 5 000  |
| *Elements ELE5               | 79 000   |
| *Nodes NOD5                  | 101 100  |
| *Local coordinates system 16 | x along leg with holes near middle;<br>y along leg with holes closer to edge;<br>z along length of angle;<br>origin at corner (Fig. 11.1). |
| Element type                 | 5 Shell 181  |
| Sections                     | 12 (0.75 in)   |
| Materials                    | 10   |

\*user input or default option.

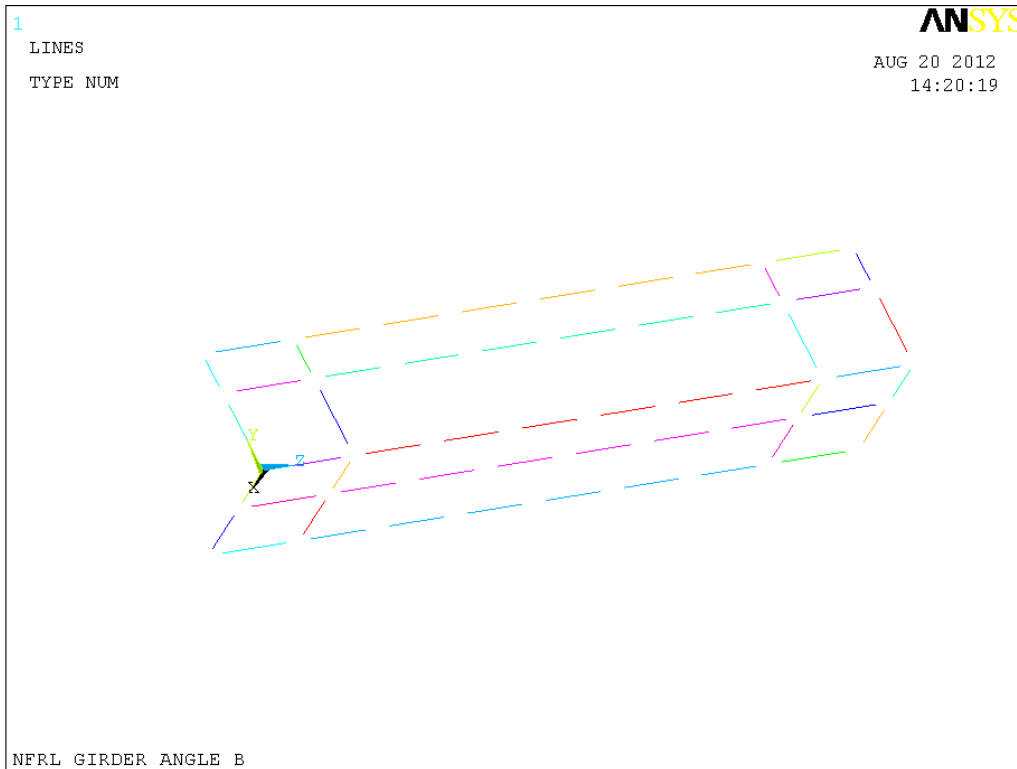


Fig. 11.1 Girder angle coordinates

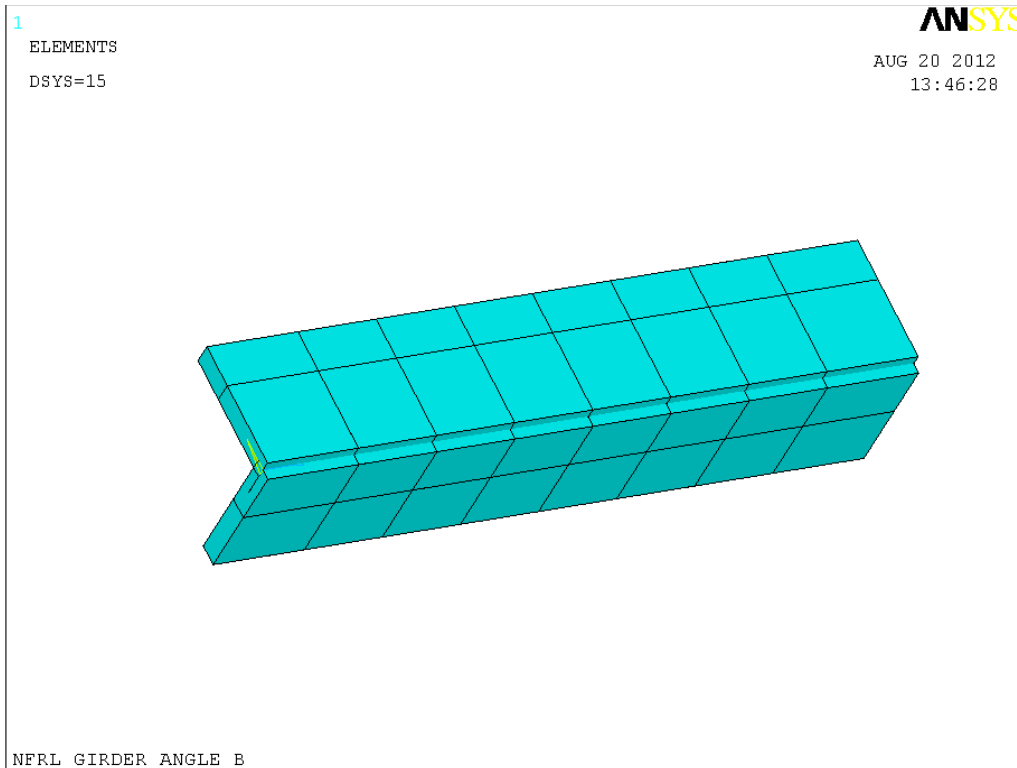


Fig. 11.2 Girder angle

## ! Girder angle

FINISH  
/CLEAR

/CWD,'C:\StrongFireLab'  
/FILENAME,20120705,0  
/TITLE,NFRL GIRDER ANGLE B  
/REPLOT

KEYW,PR\_SET,1  
KEYW,PR\_STRUC,1  
KEYW,PR\_THERM,0  
KEYW,PR\_FLUID,0  
KEYW,PR\_MULTI,0

/PREP7  
! UNITS SI for thermal W, J. degree C  
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! ##### material properties  
! # Material # 10 - Steel for W sections  
! thermal properties may be unnecessary for structural analysis

! Young's modulus and Poisson's ratio

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000
MPDATA,EX,10,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,10,,0.30
```

! thermal expansion

```
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

!# steel conductivity W/(in.K)

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,10,,1.37
MPDATA,KXX,10,,0.693
MPDATA,KXX,10,,0.693
```

!# steel heat capacity J/(kipm.K)

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,10,,199500
MPDATA,C,10,,208500
MPDATA,C,10,,221200
MPDATA,C,10,,231500
MPDATA,C,10,,240300
MPDATA,C,10,,274800
MPDATA,C,10,,302300
MPDATA,C,10,,344700
```

!# steel mass density

```
MPTEMP
```

```
MPTEMP,1,0
MPDATA,DENS,10,,2.636E-4 ! kipm/in3
```

```
ET,5,SHELL181
KEYOPT,5,1,0 ! bending and membrane stiffness
KEYOPT,5,3,2 ! full integration with incompatible modes
KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer
KEYOPT,5,9,0 ! no user subroutine to define thickness
KEYOPT,5,10,0 ! no initial stress
```

```
sect,12,shell,,girderangle L5x5x0.75
secdata,0.75,10,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
! USER INPUT: STARTING NUMBERS=====
```

```
*SET,KP5,10000
*SET,LIN5,22700
*SET,ARE5,16700
*SET,VOL5,5000
*SET,ELE5,79000
*SET,NOD5,101100
```

```
! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 13/15
! Local Y ALONG leg with holes closer to edge.
! Local X along leg with holes near middle.
! Local Z ALONG length of angle.
! origin at corner.
```

```
LOCAL,16,0,20,120,180, , , ,1,1
CSYS,16,
```

```
! END OF user input=====
```

```
NUMSTR,KP,KP5
NUMSTR,LINE,LIN5
NUMSTR,AREA,ARE5
NUMSTR,VOLU,VOL5
NUMSTR,ELEM,ELE5
NUMSTR,NODE,NOD5
```

```
K,KP5,,,
K,KP5+1,2.08,,
K,KP5+2,4.625,,
K,KP5+3,,3.07,
K,KP5+4,,4.625,
```

```

K,KP5+5,,,3.5
K,KP5+6,,,21.5
K,KP5+7,,,25.0

! LINES x
LSTR,KP5 ,KP5+1
LSTR,KP5+1,KP5+2
! LINES y
LSTR,KP5 ,KP5+3
LSTR,KP5+3,KP5+4
! LINES z
LSTR,KP5 ,KP5+5
LSTR,KP5+5,KP5+6
LSTR,KP5+6,KP5+7

*DO,I,LIN5,LIN5+6,1
LESIZE,I ,0, ,1, ,0, , ,0
*ENDDO
LESIZE,LIN5+5,3.0, ,0,,1,0, ,0

! AREAS
ADRAG,LIN5+4,LIN5+5,LIN5+6,,,,LIN5 ,LIN5+1,,,,, ! X Areas
ADRAG,LIN5+4,LIN5+5,LIN5+6,,,,LIN5+2,LIN5+3,,,,, ! Y Areas

asel,s,area,,are5,are5+11,,1
! MESH
AATT,10,,5,16,12
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL

ALLSEL,ALL
NUMMRG,ALL
SAVE

! the following is a load test 3 July 230pm #####

/SOLU
ANTYPE,0 ! static analysis

! constrain CORNERS
N = NODE(0,0,0)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(4.625,0,0)
D,N,UX,,,,,,,,

```



```
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

N = NODE(0,4.625,0)
D,N,UX,,,,,,,,
D,N,UY,,,,,,,,
D,N,UZ,,,,,,,,

! LOAD
ACEL,,1, ! gravity -y
N = NODE(0,0,25.0)
F,N,Fx,5,,,

OUTPR,STAT
OUTRES,STAT
SOLVE
/eof
```

## Chapter 12 Girder spacer

Table 12.1 Properties

|                              |  |
|------------------------------|--|
| Girder spacer                | Starting numbers   |
| *Keypoints KP6               | 10 100   |
| *Lines LIN6                  | 22 800   |
| *Areas ARE6                  | 16 800   |
| *Volumes VOL6                | 5 000  |
| *Elements ELE6               | 79 100   |
| *Nodes NOD6                  | 101 200  |
| *Local coordinates system 17 | x along flange;<br>y along web;<br>z along length of spacer;<br>origin: midthickness of junction web-flange (Fig. 12.1). |
| Element type                 | 5 Shell 181<br>6 (Beam 188)  |
| Sections                     | 3 (0.99 inch flange W12x106)<br>15 (tube 80)   |
| Materials                    | 10 (W sections)  |

\*user input or default option.

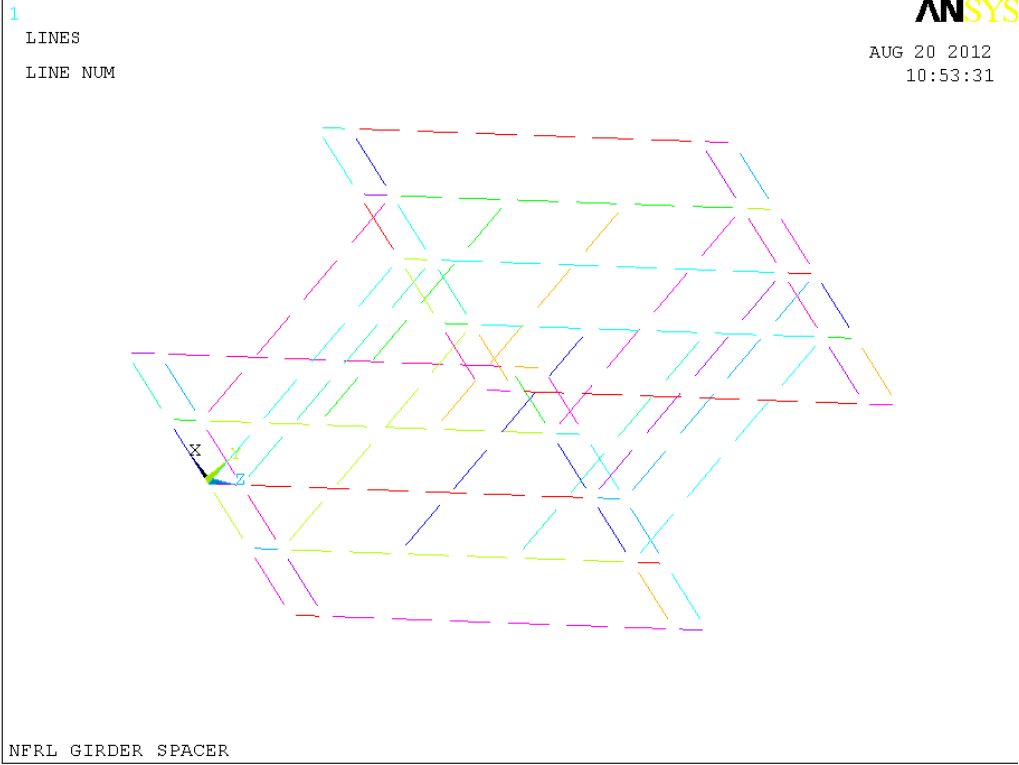


Fig. 12.1 Girder spacer coordinate system

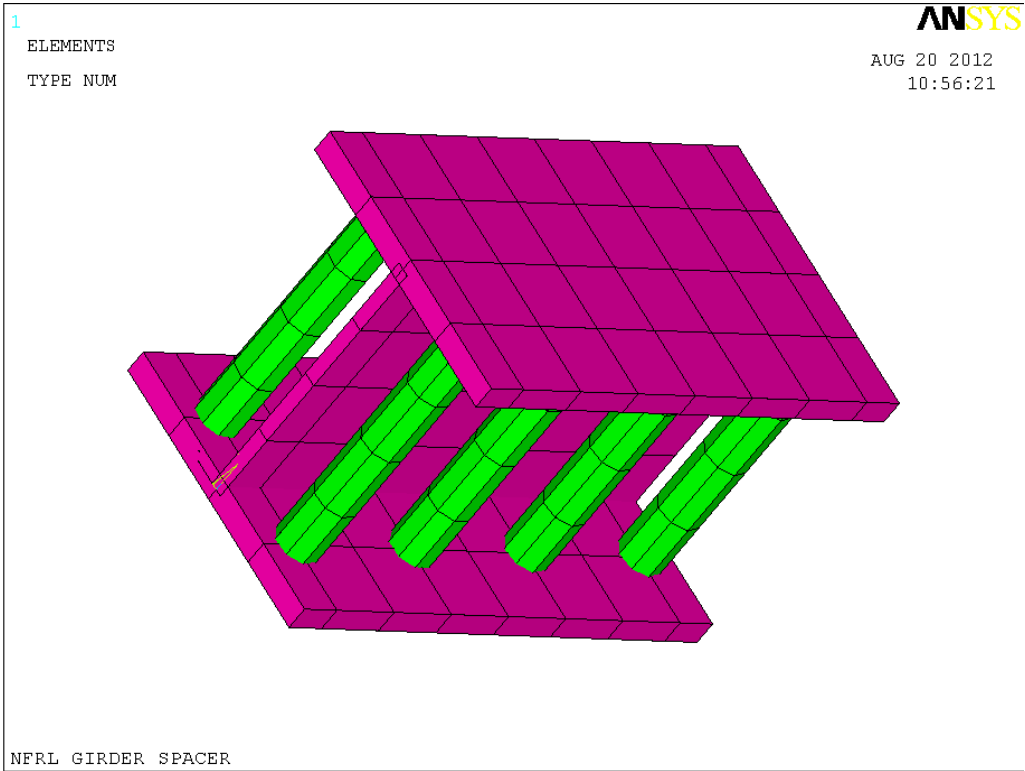


Fig. 12.2 Girder spacer

! Girder spacer

FINISH  
/CLEAR

/CWD,'C:\StrongFireLab'  
/FILENAME,20120703,0  
/TITLE,NFRL GIRDER SPACER  
/REPLOT

KEYW,PR\_SET,1  
KEYW,PR\_STRUC,1  
KEYW,PR\_THERM,0  
KEYW,PR\_FLUID,0  
KEYW,PR\_MULTI,0

/PREP7

! UNITS SI for thermal W, J. degree C  
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi

! ##### material properties  
! # Material # 10 - Steel for W sections  
! thermal properties may be unnecessary for structural analysis  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000  
MPDATA,EX,10,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,10,,0.30

! thermal expansion

TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693

MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,50

MPTEMP,3,100

MPTEMP,4,150

MPTEMP,5,200

MPTEMP,6,400

MPTEMP,7,500

MPTEMP,8,600

MPDATA,C,10,,199500

MPDATA,C,10,,208500

MPDATA,C,10,,221200

MPDATA,C,10,,231500

MPDATA,C,10,,240300

MPDATA,C,10,,274800

MPDATA,C,10,,302300

MPDATA,C,10,,344700

!# steel mass density

MPTEMP

MPTEMP,1,0

MPDATA,DENS,10,,2.636E-4 ! kipm/in3

ET,5,SHELL181

KEYOPT,5,1,0 ! bending and membrane stiffness

KEYOPT,5,3,2 ! full integration with incompatible modes

KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer

!KEYOPT,5,8,2 use this option when insulation is present- data at top, bottom and mid of all layers

!SHELL,MID use this option when insulation is present-results calculated at mid, not averaged from top and bottom

KEYOPT,5,9,0 ! no user subroutine to define thickness

KEYOPT,5,10,0 ! no initial stress

sect,3,shell,,12106f

secdata,0.99,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W

secdata,0.61,10,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

ET,6,BEAM188

SECTYPE, 15, BEAM, CTUBE, SCH80, 0

```

SECOFFSET, CENT
SECDATA,0.75,0.95,0,0,0,0,0,0,0,0 ! WHERE IS MAT DEFINED?
! USER INPUT: STARTING NUMBERS=====
*SET,KP6,10100
*SET,LIN6,22800
*SET,ARE6,16800
*SET,VOL6,5000
*SET,ELE6,79100
*SET,NOD6,101200

! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 14/15
! Local X ALONG flange.
! Local Y along web.
! Local Z ALONG length of spacer.
! origin at midthickness JUNCTION WEB-FLANGE.

LOCAL,17,0,30,150,200, , , ,1,1
CSYS,17,

! END OF user input=====

NUMSTR,KP,KP6
NUMSTR,LINE,LIN6
NUMSTR,AREA,ARE6
NUMSTR,VOLU,VOL6
NUMSTR,ELEM,ELE6
NUMSTR,NODE,NOD6

K,KP6,-6.11,,
K,KP6+1,-3.0,,
K,KP6+2,,,
K,KP6+3,3.0,,
K,KP6+4,6.11,,
K,KP6+5,,11.9,
K,KP6+6,,,1.7
K,KP6+7,,,19.7
K,KP6+8,,,21.4

! LINES x
LSTR,KP6 ,KP6+1
LSTR,KP6+1,KP6+2
LSTR,KP6+2,KP6+3
LSTR,KP6+3,KP6+4

! LINES y
LSTR,KP6+2,KP6+5

```

```

! LINES z
LSTR,KP6+2,KP6+6
LSTR,KP6+6,KP6+7
LSTR,KP6+7,KP6+8

*DO,I,LIN6,LIN6+7,1
LESIZE,I ,0, ,1, ,0 , , ,0
*ENDDO

LESIZE,LIN6+4,0 ,4,,1,0, ,0
LESIZE,LIN6+6,3.0, ,0,,1,0, ,0

! bushing lines
LGEN,2,LIN6+4,,,,3.0,,1.7,,, !L8
LGEN,2,LIN6+8,,,,6.0,,, !L9
LGEN,2,LIN6+8,LIN6+9,1,,,12.0,,, !L10,11
LGEN,2,LIN6+8,LIN6+11,1,-6.0,,,, !L12 to 15

! AREAS
ADRAG,LIN6 ,LIN6+1,,,,LIN6+5,LIN6+6,LIN6+7,,,, ! flange- Areas
ADRAG,LIN6+5,LIN6+6,LIN6+7,,,,LIN6+2,LIN6+3,,,, ! flange+ Areas
ADRAG,LIN6+5,LIN6+6,LIN6+7,,,,LIN6+4,,,, ! web Areas

! MESH BUSHINGS
LSEL,S,LINE,,LIN6+8,LIN6+15,1,1
LATT,10,,6,,KP6+2,,15
LMESH,ALL

ALLSEL,ALL
! MESH WEB
ASEL,S,LOC,X,-.1,.1,,1
ASEL,R,LOC,Y,0,12,,1
ASEL,R,LOC,Z,0,21.5,,1
AATT,10,,5,17,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL

ALLSEL,ALL
! MESH LOWER FLANGE
ASEL,S,LOC,Y,-.1,.1,,1
ASEL,R,LOC,X,-6.11,6.11,,1
ASEL,R,LOC,Z,0,21.5,,1
AATT,10,,5,17,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL

```

```
! COPY FLANGE
AGEN,2,ALL,,,,,11.9,,,,
ALLSEL,ALL
```

```
NUMMRG,ALL
SAVE
```

```
! the following is a load test
```

```
/SOLU
ANTYPE,0 ! static analysis
```

```
! constrain CORNERS
N = NODE(6.11,0,0)
D,N,UX,,,,,,
D,N,UY,,,,,,
D,N,UZ,,,,,,
```

```
N = NODE(-6.11,0,0)
D,N,UX,,,,,,
D,N,UY,,,,,,
D,N,UZ,,,,,,
```

```
N = NODE(6.11,0,21.4)
D,N,UX,,,,,,
D,N,UY,,,,,,
D,N,UZ,,,,,,
```

```
N = NODE(-6.11,0,21.4)
D,N,UX,,,,,,
D,N,UY,,,,,,
D,N,UZ,,,,,,
```

```
! LOAD
ACEL,,1, ! gravity -y
N = NODE(0,11.90,10.7)
F,N,Fx,50,,,
```

```
OUTPR,STAT
OUTRES,STAT
SOLVE
/eof
```



## Chapter 13 Assembling the Support Structure

To assemble various structural components, the following procedure is recommended:

1. **Deploy:** Bring onto the assembly site (global coordinate system) various structural components in order of increasing keypoints (see Table 13.1). Just as in a real construction site, components should be placed some distance apart to ensure there is no interference during construction of the individual sets (the ANSYS command used to select various keypoints, lines or areas uses a volume of space that is bigger than the actual objects). It is recommended to place the girder in its final location from the start, as its formulation contains constraints that are cumbersome to move. See Fig. 13.1.
2. **Move:** The user can translate and rotate the various structural components into their final locations (Fig. 13.2) by using the AGEN and ATRAN commands respectively. As the ATRAN command operates from the current coordinate system to a destination coordinate system specified in the command, it is a good idea to explicitly define the current coordinate system again before issuing the ATRAN command if there is any doubt. This is particularly important as the LOCAL command not only defines the local coordinate system in terms of the global one, but also takes the user to the newly defined local system. The girder spacer can be duplicated by creating new elements in a new location, but the original cannot be moved (translation or rotation is performed in *one* step, but the spacer consists of area and line elements that would be movable in *two* steps, except they are connected). The original girder spacer used in constructing the assembly is selected out before starting the solution.
3. **Number:** Before creating new structural components by duplicating, the user should specify starting numbers (NUMSTR) for keypoints, lines, areas, volumes, elements and nodes at higher values than the maximum currently used. If this is not done, ANSYS starts numbering the newly created entities at the lowest available numbers, and thus fills in the gaps between the previous numbers. This can cause a numbering interference problem if, in step 1, the user did not bring in all the components needed. When the missing component is brought in later, it may find its numbers already occupied. The user should issue NUMSTR after bringing in additional components.
4. **Copy:** Duplication is performed by AGEN for area elements and LGEN for line elements (Figs. 13.3 and 13.4).
5. **Fit:** Correct placement of all components should be verified to ensure mesh lines and nodes, i.e., bolts and bolt holes match (Figs. 13.5 – 13.12).
6. **Constrain:** As shell elements are defined at their midplanes, perfectly matched adjacent steel plates are separated by half of their combined thicknesses. The nodes thus cannot be merged and must be constrained individually. This is the virtual equivalent of tightening bolts, and is performed in three steps by constraining the three degrees of translation for each pair of nodes.
7. **Restrain:** The assembly is bolted to the strong floor and strong wall at the appropriate nodes. The support conditions do not account for the prestress in the anchor rods, nor the involvement of the rest of a foot (contact with the floor) or a pad (contact with the wall). The resultant reaction at a foot or a pad is correct, but the compressive forces are concentrated at a couple of

bolt locations rather than distributed over, say, half of a foot or a pad. As compression is not a concern, this approximation only needs to be refined if the tension at any anchor exceeds the prestress and partial liftoff occurs. A detailed local model can be performed then of the foot or pad and portions of the concrete floor or wall, using properly prestressed anchors and contact elements.

8. Solve: Select out the construction girder spacer, load and run the model. The APDL (ANSYS Programming Design Language) commands are included at the end of this chapter for the example illustrated.

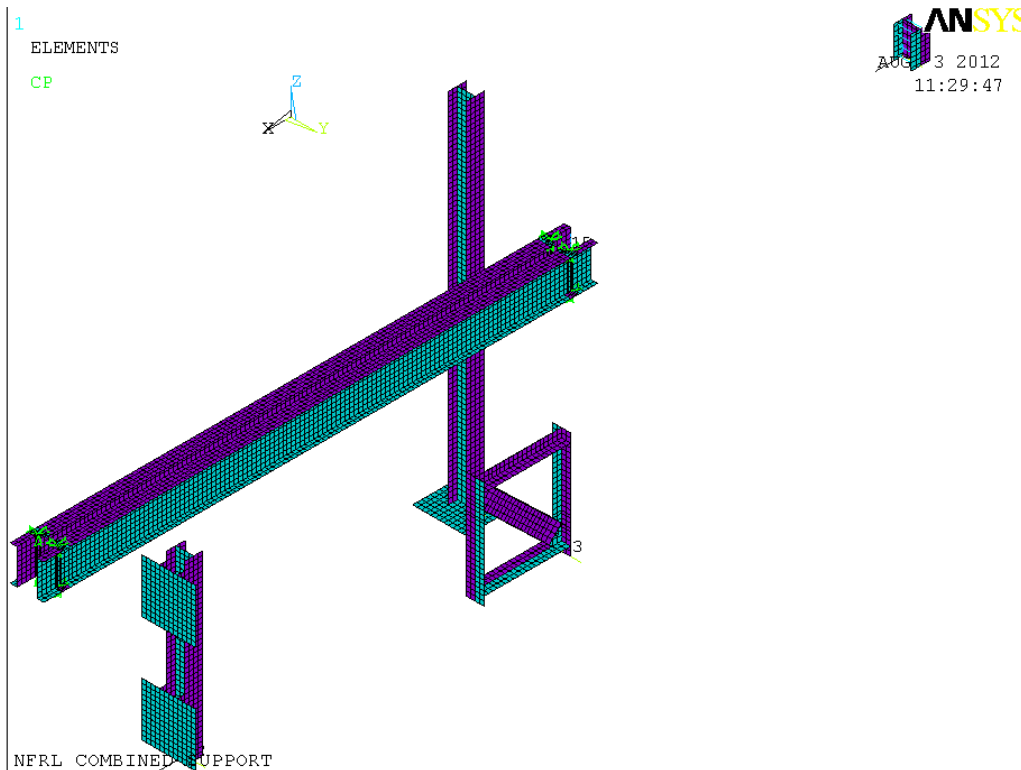


Fig. 13.1 Step 1: Deploy structural components onto construction site

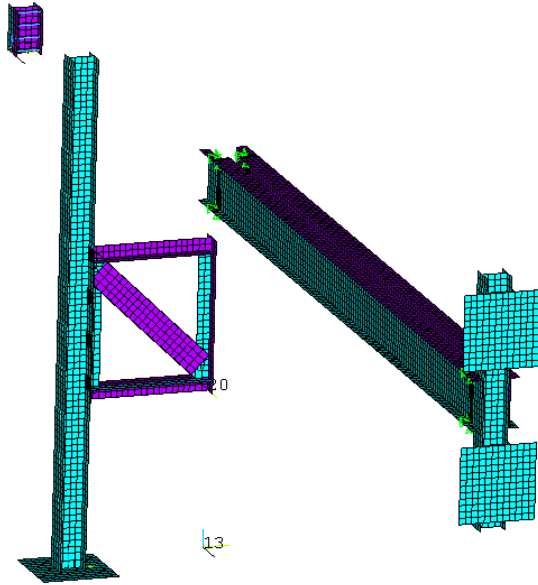
Table 13.1 Structural components

| Starting numbers         | Column-foot (index 1)                                  | Wall-column (0)      | Frame (2) | Web splice (3) | Girder (4)                                | B2 Girder assembly (5) | Girder spacer (6) |
|--------------------------|--|----------------------|-----------|----------------|---|------------------------|-------------------|
| Keypoints                | 8 000  | 8 100                | 8 400     | 9 350          | 9 400                                     | 10 000                 | 10 100            |
| Lines                    | 19 000   | 19 200               | 19 600    | 21 300         | 21 700                                    | 22 700                 | 22 800            |
| Areas                    | 15 000   | 15 100               | 15 300    | 16 100         | 16 300                                    | 16 700                 | 16 800            |
| Volumes                  | 5 000  | 5 000                | 5 000     | 5 000          | 5 000                                     | 5 000                  | 5 000             |
| Elements                 | 67 000   | 69 000               | 70 200    | 72 100         | 72 400                                    | 79 000                 | 79 100            |
| Nodes                    | 85 000   | 88 000               | 89 500    | 91 700         | 92 100                                    | 101 100                | 101 200           |
| Local coordinates system | 11   | 12                   | 13        | 14             | 15  | 16                     | 17                |
| Element type             | 5<br>Shell 181   | 5                    | 5         | 5              | 5   | 5                      | 5<br>6 (Beam 188) |
| Sections                 | 2 (2 in foot)<br>3 (flange W12x106)<br>4 (web W12x106) | 2, 3, 4,<br>8 (shim) | 3, 4      | 9 (0.313 in)   | 10 (web W 24x103)<br>11 (flange W 24x103) | 12 (0.75 in)           | 3<br>15 (tube 80) |
| Materials                | 10 (W section)<br>11 (foot)                            | 10, 11,<br>12 (shim) | 10        | 10             | 10  |                        | 10                |

1  
ELEMENTS  
CP

ANSYS

AUG 3 2012  
11:47:30



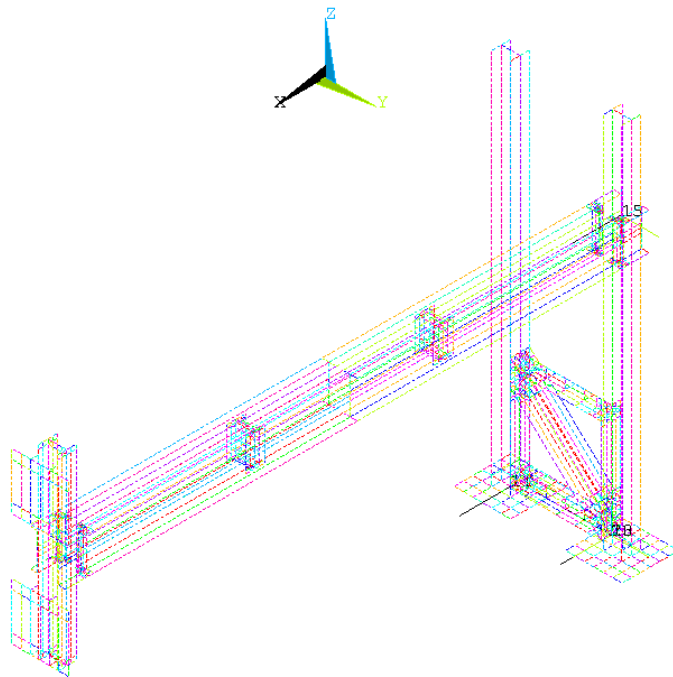
NFRL COMBINED SUPPORT

Fig. 13.2 Step 2: Move components into place

1  
LINES  
TYPE NUM

ANSYS

AUG 2 2012  
16:27:03



NFRL COMBINED SUPPORT

Fig. 13.3 Step 4: Copy components into place

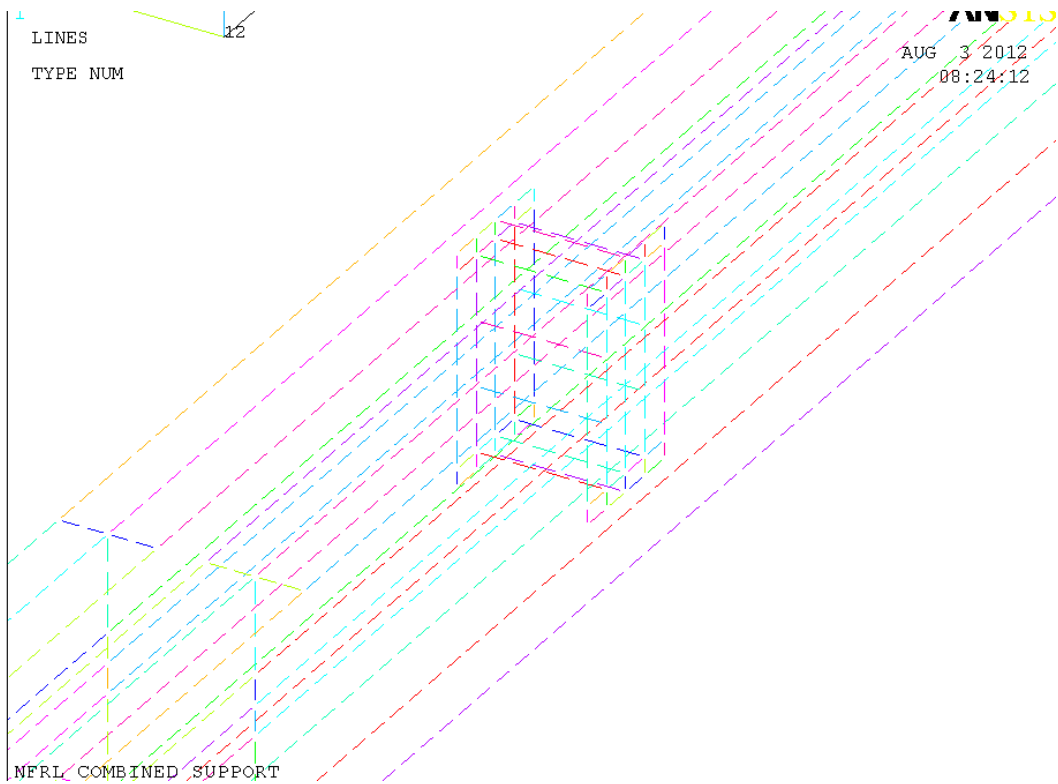


Fig. 13.4 Step 4 Copy: Detail of girder spacer in place

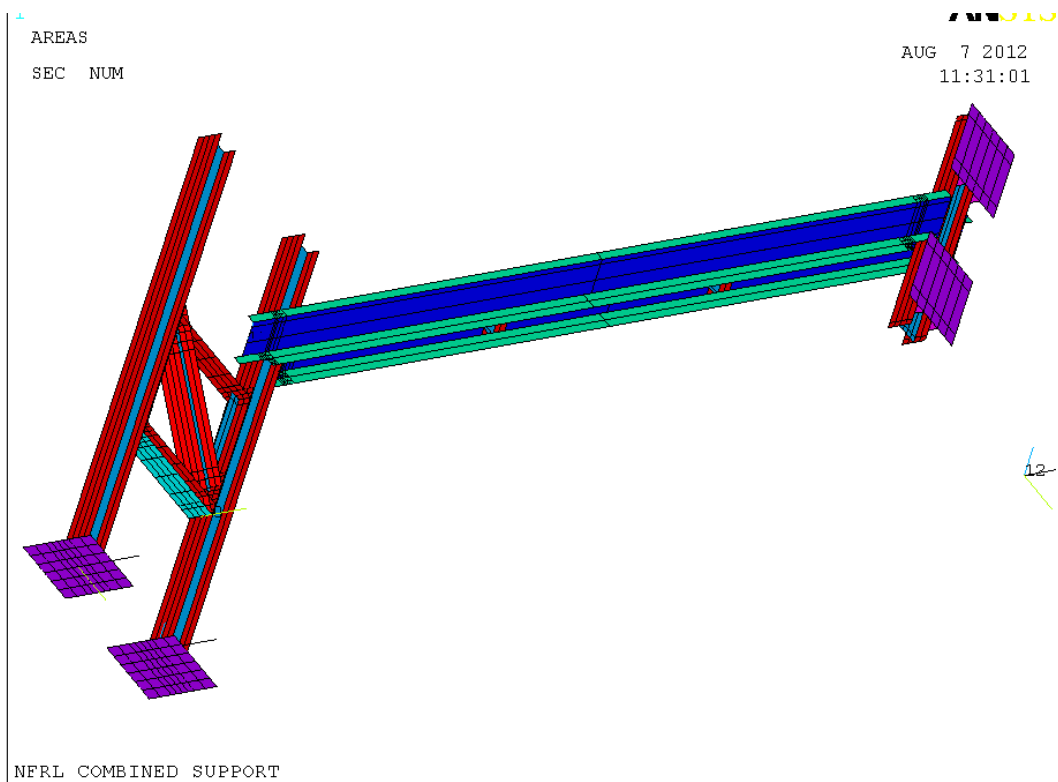


Fig. 13.5 Step 5: Fit components together

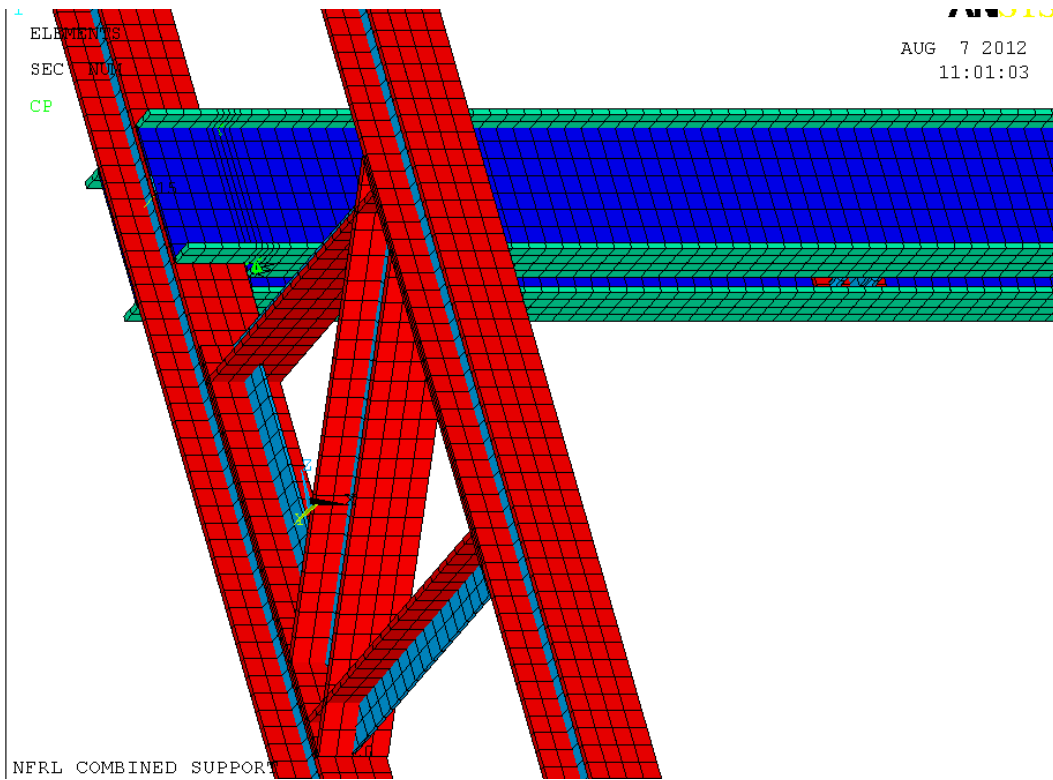


Fig. 13.6 Step 5 Fit: 3D detail of foot-columns, frame and girder

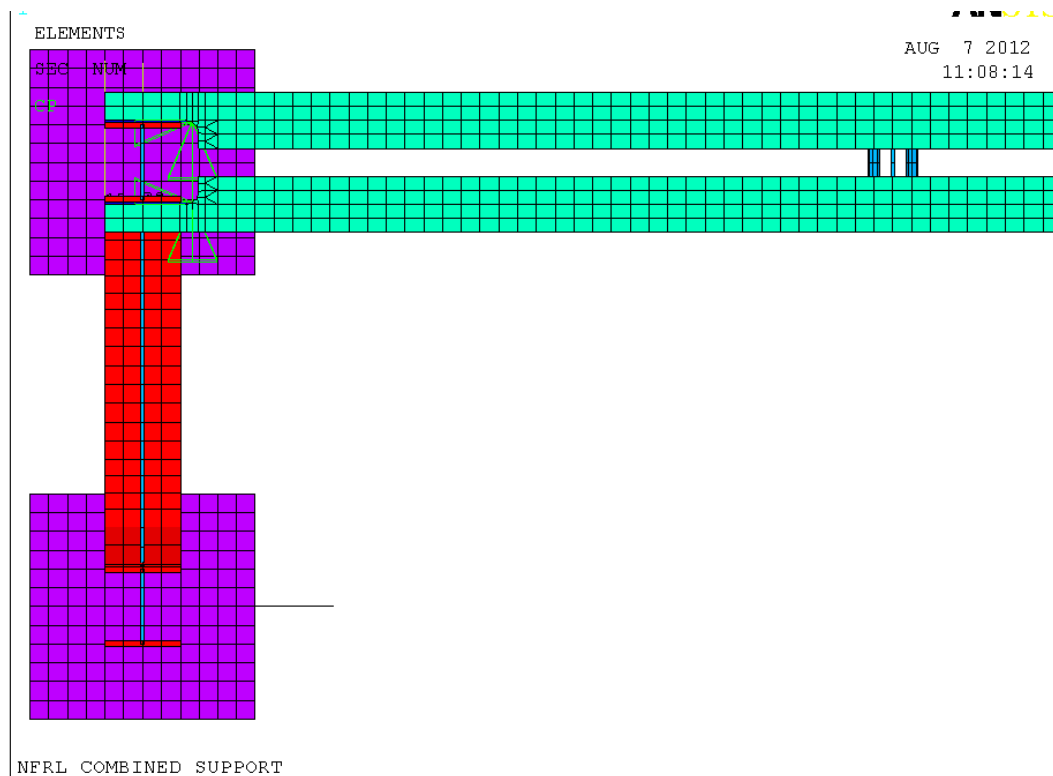


Fig. 13.7 Step 5 Fit: Top view of detail of foot-columns, frame, girder and spacer

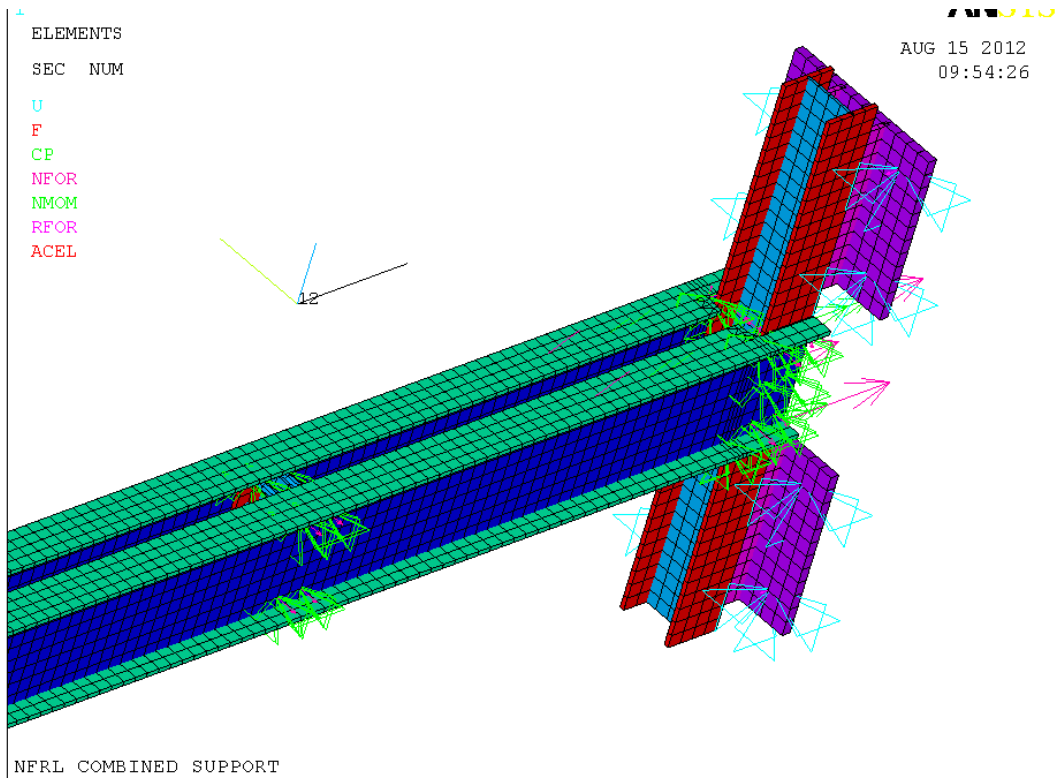


Fig. 13.8 Step 5 Fit: 3D detail of wall-column and girder

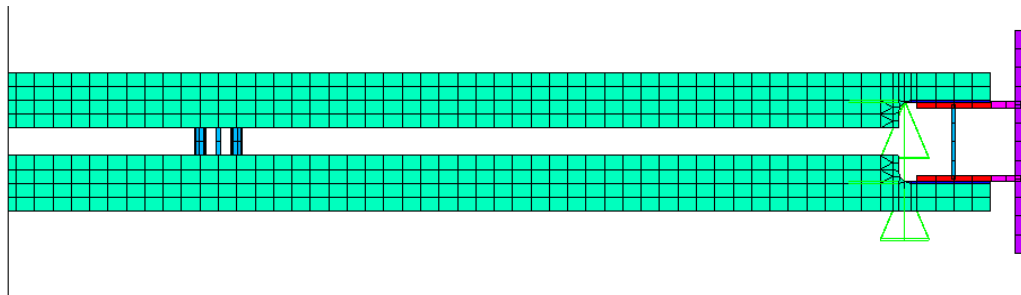


Fig. 13.9 Step 5 Fit: Top view of detail of wall-column, girder and spacer

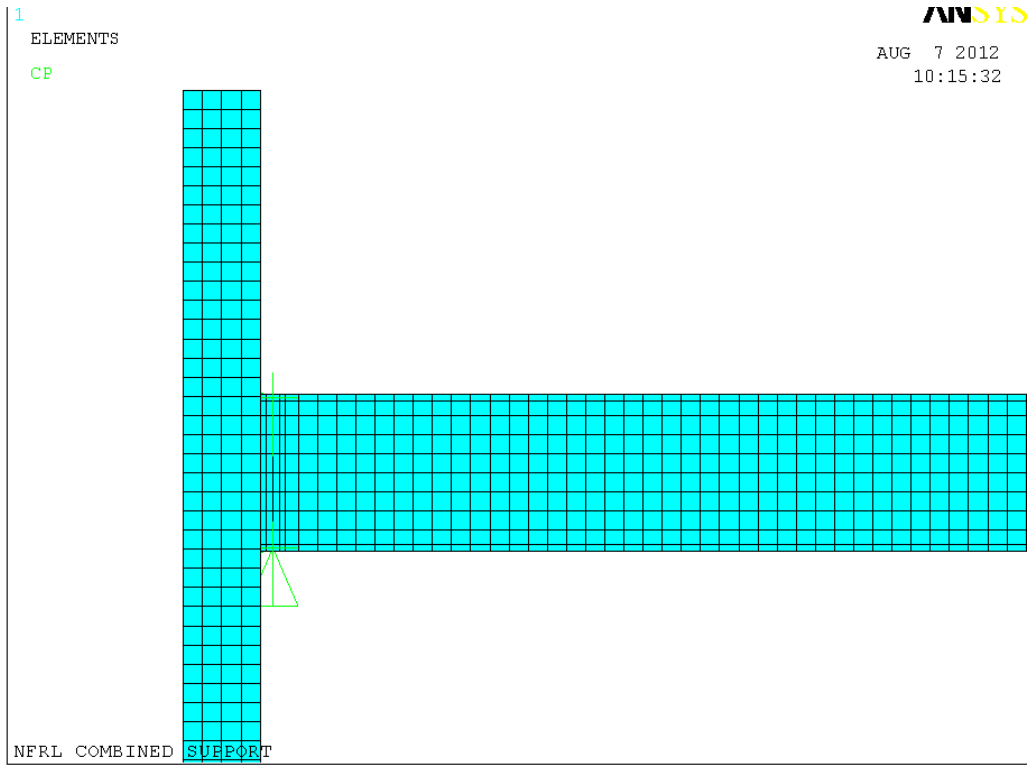


Fig. 13.10 Step 5 Fit: elevation view of girder and foot-column

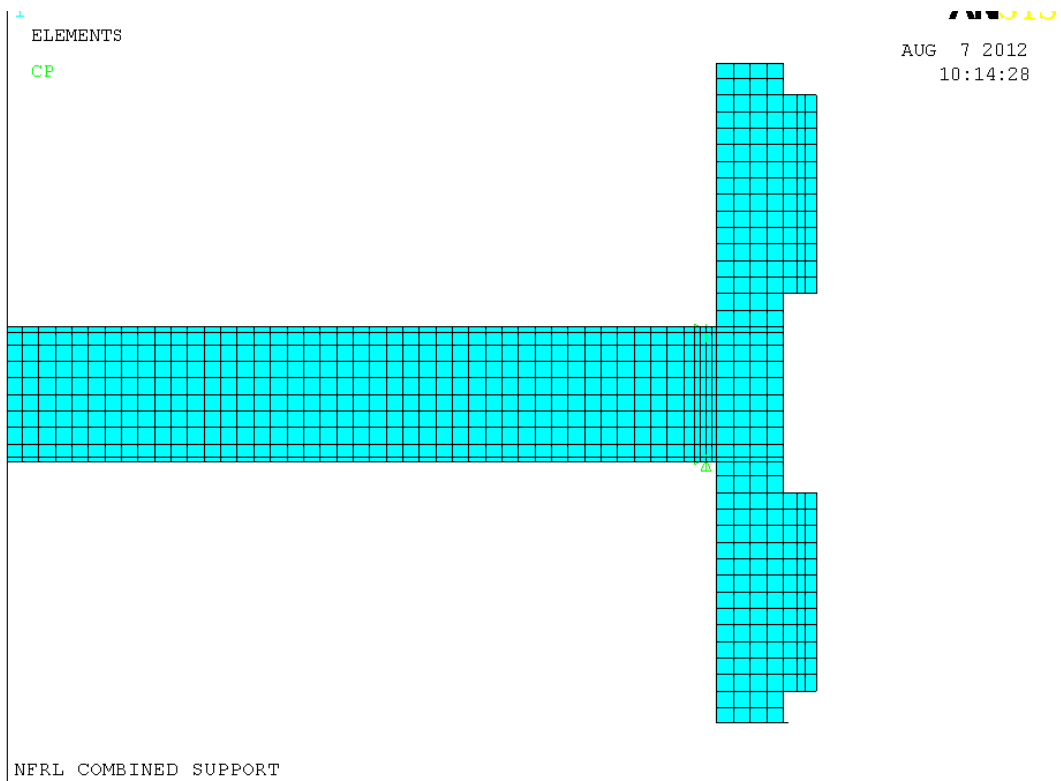


Fig. 13.11 Step5 Fit: elevation view of girder and wall-column



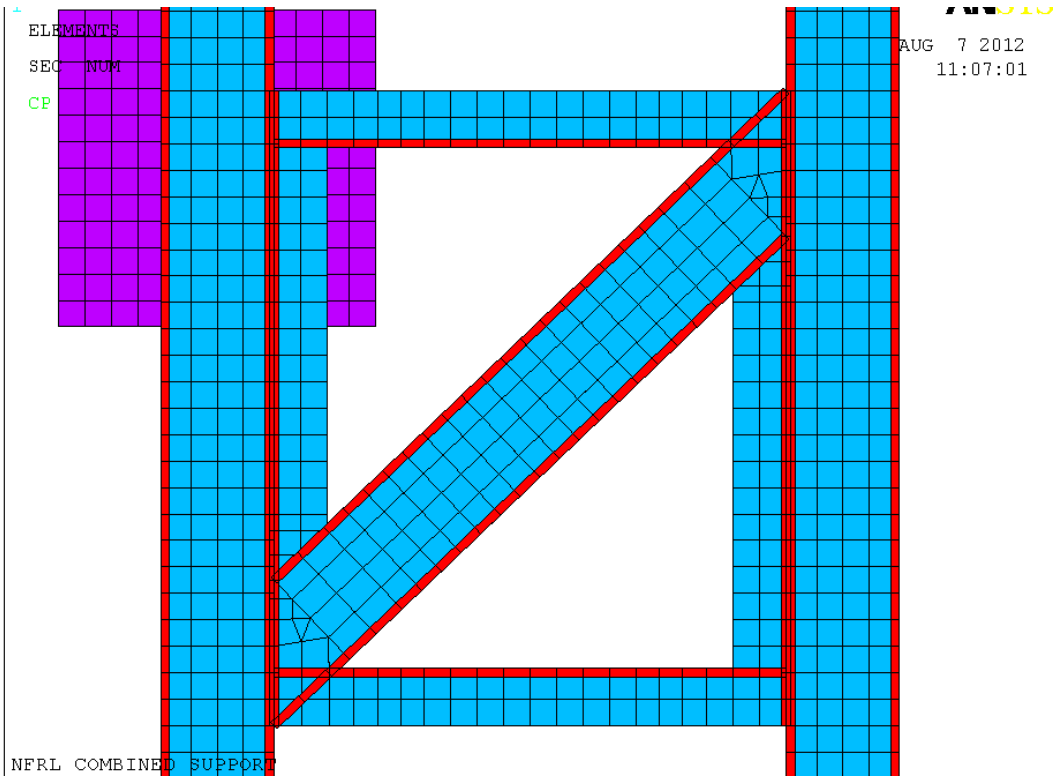


Fig. 13.12 Step 5 Fit: Detail of frame and foot-columns

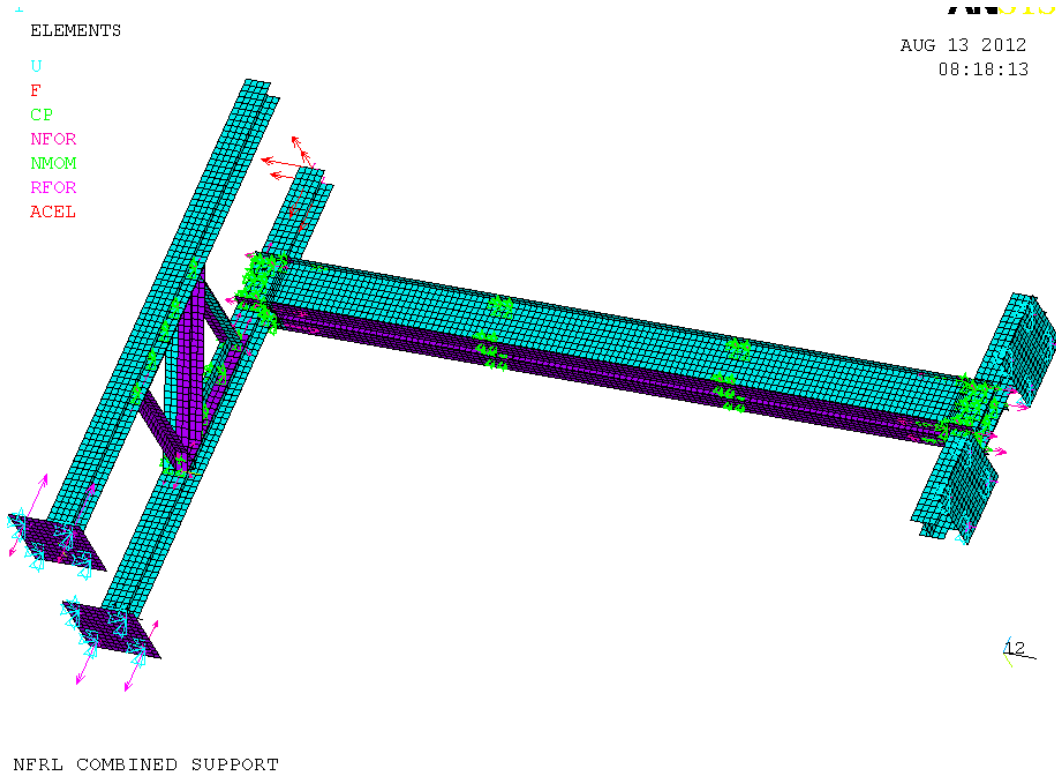


Fig. 13.13 Steps 6 Constrain, 7 Restrain, 8 Load: Bolt components together, to wall and floor, and load

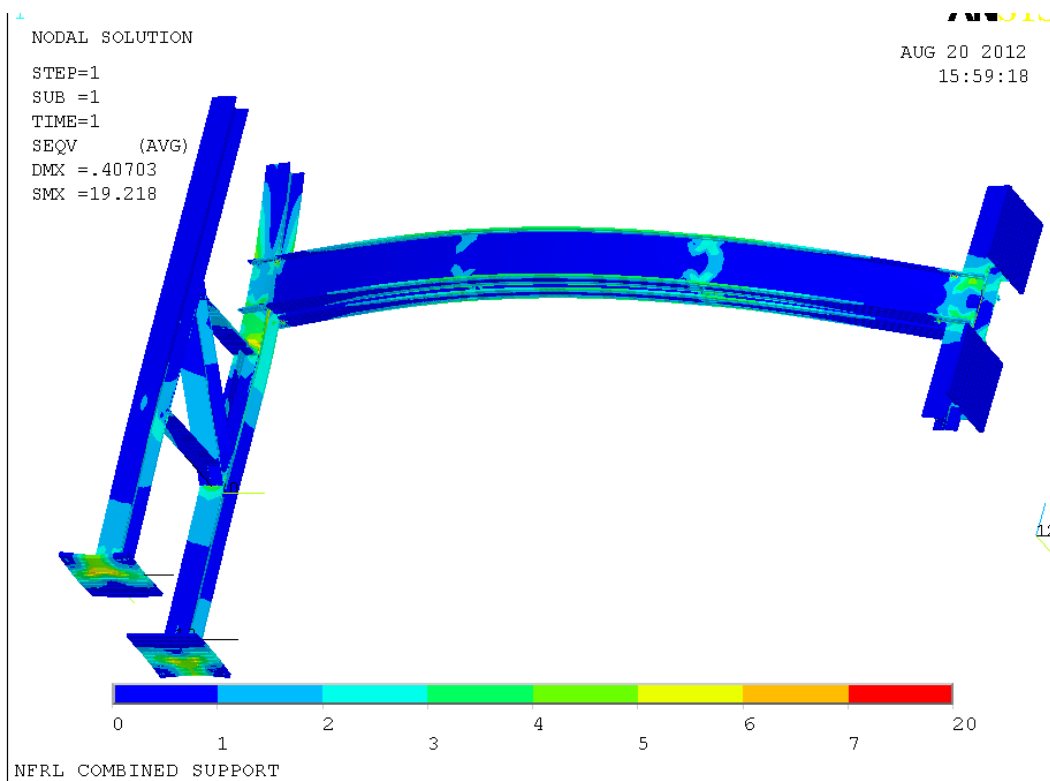


Fig. 13.14 Deformed shape and Von Mises stress (1 ksi=6.89 MPa)

## ! Combined structural support

```
FINISH
/CLEAR
/CWD,'C:\StrongFireLab'
/FILNAME,20120727,0
/TITLE,NFRL COMBINED SUPPORT
/REPLOT
```

```
KEYW,PR_SET,1
KEYW,PR_STRUC,1
KEYW,PR_THERM,0
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0
```

! column and foot

```
/PREP7
! UNITS SI for thermal W, J. degree C
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi
```

! ##### material properties

```
! # Material # 10 - Steel for W sections, 50 KSI STEEL
! thermal properties may be unnecessary for structural analysis
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000
MPDATA,EX,10,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,10,,0.30
```

```
! thermal expansion
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
```

MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693  
MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,10,,199500  
MPDATA,C,10,,208500  
MPDATA,C,10,,221200  
MPDATA,C,10,,231500  
MPDATA,C,10,,240300  
MPDATA,C,10,,274800  
MPDATA,C,10,,302300  
MPDATA,C,10,,344700

!# steel mass density

MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,10,,2.636E-4 ! kipm/in3

! # Material # 11 - Steel for foot, 36 KSI  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,11,1,29999,29999,27000,24000,21000,18000  
MPDATA,EX,11,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,11,,0.30

! thermal expansion

TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,11,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,800

MPTEMP,3,1200

MPDATA,KXX,11,,1.37

MPDATA,KXX,11,,0.693

MPDATA,KXX,11,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,50

MPTEMP,3,100

MPTEMP,4,150

MPTEMP,5,200

MPTEMP,6,400

MPTEMP,7,500

MPTEMP,8,600

MPDATA,C,11,,199500

MPDATA,C,11,,208500

MPDATA,C,11,,221200

MPDATA,C,11,,231500

MPDATA,C,11,,240300

MPDATA,C,11,,274800

MPDATA,C,11,,302300

MPDATA,C,11,,344700

!# steel mass density

MPTEMP

MPTEMP,1,25

MPDATA,DENS,11,,2.636E-4 ! kipm/in3

! COLUMN AND FOOT

ET,5,SHELL181

KEYOPT,5,1,0 ! bending and membrane stiffness

KEYOPT,5,3,2 ! full integration with incompatible modes

KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer

KEYOPT,5,9,0 ! no user subroutine to define thickness

KEYOPT,5,10,0 ! no initial stress

sect,2,shell,,foot

secdata,2,11,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

sect,3,shell,,12106f

secdata,0.99,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W  
secdata,0.61,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS, SUB 1=====

\*SET,KP1,8000  
\*SET,LIN1,19000  
\*SET,ARE1,15000  
\*SET,VOL1,5000  
\*SET,ELE1,67000  
\*SET,NOD1,85000

! # define model geometry, sheet 11/15 lower left fig  
! Local X parallel to flanges, point North.  
! Local Y parallel to web, point West.  
! Local Z points up.

! user input: origin of local coordinates = CENTER OF FOOT

LOCAL,11,0,348,465.98,182, , ,1,1,  
CSYS,11,

HEIGHT=240 ! COLUMN HEIGHT INCLUDES FOOTING, INCHES  
H=HEIGHT-1

! END OF user input=====

NUMSTR,KP,KP1  
NUMSTR,LINE,LIN1  
NUMSTR,AREA,ARE1  
NUMSTR,VOLU,VOL1  
NUMSTR,ELEM,ELE1  
NUMSTR,NODE,NOD1

! X SIDE OF FOOT  
K,KP1,-18,-18,0,  
K,KP1+1,-12,-18,0,  
K,KP1+2,-6.11,-18,0,  
K,KP1+3,-3.0,-18,0, ! 8.3 4pm  
K,KP1+4,0,-18,0,  
K,KP1+5,3.0,-18,0, ! 8.3 4pm  
K,KP1+6,6.11,-18,0,  
K,KP1+7,12,-18,0,

K,KP1+8,18,-18,0,

! Y SIDE OF FOOT

K,KP1+10,-18,-18,0,

K,KP1+11,-18,-12,0,

K,KP1+12,-18,-5.95,0,

K,KP1+13,-18,0,0,

K,KP1+14,-18,5.95,0,

K,KP1+15,-18,12,0,

K,KP1+16,-18,18,0,

! Z SIDE OF COLUMN OF HEIGHT 240 IN

K,KP1+20,,,-5.95,0,

K,KP1+21,,,-5.95,5,

K,KP1+22,,,-5.95,H,

! z distance between KP1+21 and KP1+22 must be multiple of 3 inches

! HEIGHT = 3N = H + half thickness of foot

\*DO,I,KP1,KP1+7,1

LSTR,I,I+1

\*ENDDO

\*DO,I,KP1+10,KP1+15,1

LSTR,I,I+1

\*ENDDO

LSTR,KP1+20,KP1+21

LSEL,S,LINE,,LIN1+2,LIN1+5,,1

LESIZE,ALL,,,1,,,,,0

ALLSEL,ALL

LESIZE,ALL, , , 2, , , , 0

! ENSURE NODES AT HOLES ALONG COLUMN HEIGHT

LSTR,KP1+21,KP1+22

!KSEL,S,KP,,KP1+21,KP1+22,,

!LSLK,S,1

!\*get, aa,line,0,num,min

!LESIZE,aa,3, , , , , 1

LESIZE,LIN1+15,3, , , , , 1

! BASE OF FOOT

KSEL,S,LOC,X,-18.1,18.1,,

KSEL,R,LOC,Y,-18.1,-17.9,,

KSEL,R,LOC,Z,,0.1,,

LSLK,S,1

CM,FOOTX,LINE

KSEL,S,LOC,X,-18.1,-17.9,,

KSEL,R,LOC,Y,-18.1,18.1,,

KSEL,R,LOC,Z,0,0.1,,

LSLK,S,1

CM,FOOTY,LINE

! height of column

KSEL,S,LOC,X,-0.1,0.1,,

KSEL,R,LOC,Y,-6.0,-5.90,,

KSEL,R,LOC,Z,,H,,

LSLK,S,1

CM,COLUMNZ,LINE

! foot area

ALLSEL,ALL

ADRAG,FOOTX,,,,,FOOTY,,,,,

! column flange 1

LSEL,S,LOC,X,-6.10,6.10,,

LSEL,R,LOC,Y,-6.0,-5.9,,

LSEL,R,LOC,Z,,0.1,,

CM,COLFLAN1,LINE

! column flange 2

LSEL,S,LOC,X,-6.10,6.10,,

LSEL,R,LOC,Y,5.9,6.0,,

LSEL,R,LOC,Z,,0.1,,

CM,COLFLAN2,LINE

! column WEB

LSEL,S,LOC,X,-.5,.5,,

LSEL,R,LOC,Y,-5.9,5.9,,

LSEL,R,LOC,Z,,0.1,,

CM,COLWEB,LINE

! column areas

ALLSEL,ALL

ADRAG,COLFLAN1,,,,,COLUMNZ,,,,,

ADRAG,COLFLAN2,,,,,COLUMNZ,,,,,

ADRAG,COLWEB,,,,,COLUMNZ,,,,,

! MESH FOOT

ASEL,S,LOC,Z,,0.1,,

AATT,11,,5,11,2

MSHAPE,0,2D

MSHKEY,1



AMESH,ALL

! mesh column web  
ASEL,S,LOC,X,-5,.5,,  
ASEL,R,LOC,Y,-5.9,5.9,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH columnn flange 1  
ASEL,S,LOC,X,-6.10,6.10,,  
ASEL,R,LOC,Y,-6.0,-5.9,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH columnn flange 2  
ASEL,S,LOC,X,-6.10,6.10,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,,H,,  
AATT,10,,5,11,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

ALLSEL,ALL  
NUMMRG,ALL,,,,

! components  
ASEL,S,AREA,,ARE1,ARE1+67,,1  
CM,COLUMNFOOT,AREA  
ALLSEL,ALL  
SAVE

! WALL COLUMN AND FOOT  
! WALL COLUMN

! # Material # 12 - Steel for shim  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,12,1,29998,29998,27000,24000,21000,18000

MPDATA,EX,12,7,9300,3900,2700

MPTEMP,,,,,,,,

MPTEMP,1,0

MPDATA,PRXY,12,,0.30

! thermal expansion

MPTEMP,,,,,,,,

MPTEMP,1,0

MPDATA,ALPX,12,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,800

MPTEMP,3,1200

MPDATA,KXX,12,,1.37

MPDATA,KXX,12,,0.693

MPDATA,KXX,12,,0.693

!# steel heat capacity J/(kipm.K)

MPTEMP

MPTEMP,1,25

MPTEMP,2,50

MPTEMP,3,100

MPTEMP,4,150

MPTEMP,5,200

MPTEMP,6,400

MPTEMP,7,500

MPTEMP,8,600

MPDATA,C,12,,199502

MPDATA,C,12,,208502

MPDATA,C,12,,221202

MPDATA,C,12,,231502

MPDATA,C,12,,240302

MPDATA,C,12,,274802

MPDATA,C,12,,302300

MPDATA,C,12,,344700

!# steel mass density

MPTEMP

MPTEMP,1,25

MPDATA,DENS,12,,2.636E-4 ! kipm/in3

sect,8,shell,,shim

secdata,1.0,12,0,3

secoffset,MID

seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS, SUB ZERO (NOT LETTER O)=====

\*SET,KP0,8100  
\*SET,LIN0,19200  
\*SET,ARE0,15100  
\*SET,VOLO,5000  
\*SET,ELE0,69000  
\*SET,NOD0,88000

! # define model geometry  
! user input:location of column (origin of local coordinates)  
! ref: sheet 15/15 lower left fig  
! Local X parallel to flanges, points North.  
! Local Y parallel to web, points West.  
! Local Z points up.  
! location of WALL column (origin of local coordinates center of I at base)

LOCAL,12,0,708,637,301.48, , , ,1,1,  
! move back by dy=-100  
CSYS,12,

! END OF user input=====

NUMSTR,KP,KP0  
NUMSTR,LINE,LIN0  
NUMSTR,AREA,ARE0  
NUMSTR,VOLU,VOLO  
NUMSTR,ELEM,ELE0  
NUMSTR,NODE,NOD0

! Y SIDE OF FOOT  
K,KP0,11,-18,5.75,  
K,KP0+1,11,-12,5.75,  
K,KP0+2,11,-5.95,5.75,  
K,KP0+3,11, ,5.75,  
K,KP0+4,11,5.95,5.75,  
K,KP0+5,11,12,5.75,  
K,KP0+6,11,18,5.75,

! Z SIDE OF FOOT  
K,KP0+10,11,-18,5.75  
K,KP0+11,11,-18,11.75  
K,KP0+12,11,-18,35.75  
K,KP0+13,11,-18,41.75

\*DO,I,KP0,KP0+5,1  
LSTR,I,I+1

```

*ENDDO

*DO,I,KP0+10,KP0+12,1
LSTR,I,I+1
*ENDDO

KSEL,S,KP,,KP0,KP0+13,,
LSLK,S,1
LESIZE,ALL,,2,,,,,1
KSEL,S,KP,,KP0+11,KP0+12,,
LSLK,S,1
*get, aa,line,0,num,min
LESIZE,aa,3,,,,,1

KSEL,S,KP,,KP0,KP0+6,,
LSLK,S,1
CM,WALLFOOTY,LINE

KSEL,S,KP,,KP0+10,KP0+13,,
LSLK,S,1
CM,WALLFOOTZ,LINE

! X SIDE OF SHIM
K,KP0+20,6.11,5.95,5.75
K,KP0+21, 11,5.95,5.75
LSTR,KP0+20,KP0+21
KSEL,S,KP,,KP0+20,KP0+21,,
LSLK,S,1
LESIZE,ALL,,2,,,,,1
CM,SHIMX,LINE

! Z SIDE OF SHIM
K,KP0+30,6.11,5.95, 5.75
K,KP0+31,6.11,5.95,41.75
LSTR,KP0+30,KP0+31
KSEL,S,KP,,KP0+30,KP0+31,,
LSLK,S,1
LESIZE,ALL,3,,,,,1
CM,SHIMZ,LINE

! base of column web
K,KP0+40,, -5.95,
K,KP0+41,, -3.0,
K,KP0+42,,,
K,KP0+43,, 3.0,
K,KP0+44,, 5.95,

*DO,I,KP0+40,KP0+43,1

```

```
LSTR,I,I+1
*ENDDO
KSEL,S,KP,,KPO+40,KPO+44,,
LSLK,S,1
LESIZE,ALL,,1,,,,1
CM,webbase,LINE
```

```
! base of columnn flange1
K,KPO+50,-6.11, 5.95,
K,KPO+51,-3.0 , 5.95,
K,KPO+52, , 5.95,
K,KPO+53, 3.0 , 5.95,
K,KPO+54, 6.11, 5.95,
```

```
*DO,I,KPO+50,KPO+53,1
LSTR,I,I+1
*ENDDO
KSEL,S,KP,,KPO+50,KPO+54,,
LSLK,S,1
LESIZE,ALL,,1,,,,1
CM,flange1base,LINE
```

```
! base of columnn flange2
K,KPO+60,-6.11,-5.95,
K,KPO+61,-3.0 ,-5.95,
K,KPO+62, ,-5.95,
K,KPO+63, 3.0 ,-5.95,
K,KPO+64, 6.11,-5.95,
```

```
*DO,I,KPO+60,KPO+63,1
LSTR,I,I+1
*ENDDO
KSEL,S,KP,,KPO+60,KPO+64,,
LSLK,S,1
LESIZE,ALL,,1,,,,1
CM,flange2base,LINE
```

```
! columnn height
K,KPO+70,,,
K,KPO+71,,,2.75
K,KPO+72,,,116.75
K,KPO+73,,,119.5
```

```
LSTR,KPO+70,KPO+71
KSEL,S,KP,,KPO+70,KPO+71,,
LSLK,S,1
LESIZE,ALL,,1,,,,1
```

```
allsel,all
LSTR,KPO+71,KPO+72
KSEL,S,KP,,KPO+71,KPO+72,,
LSLK,S,1
LESIZE,ALL,3, , , , ,1
```

```
ALLSEL,ALL
LSTR,KPO+72,KPO+73
KSEL,S,KP,,KPO+72,KPO+73,,
LSLK,S,1
LESIZE,ALL, , ,1, , , ,1
```

```
KSEL,S,KP,,KPO+70,KPO+73,,
LSLK,S,1
CM,wallcolhi,LINE
ALLSEL,ALL
```

```
! areas
ADRAG,webbase,,,,,,,,wallcolhi,,,,,,,,
ADRAG,flange1base,,,,,,,,wallcolhi,,,,,,,,
ADRAG,flange2base,,,,,,,,wallcolhi,,,,,,,,
ADRAG,SHIMX,,,,,,,,SHIMZ,,,,,,,,
ADRAG,WALLFOOTY,,,,,,,,WALLFOOTZ,,,,,,,,
```

```
! mesh column web
ASEL,S,LOC,y,-6,6,,
ASEL,R,LOC,x,-.1,.1,,
ASEL,R,LOC,Z,,120,,
AATT,10,,5,12,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH columnn flange 1
ASEL,S,LOC,X,-6.12,6.12,,
ASEL,R,LOC,Y,5.9,6.0,,
ASEL,R,LOC,Z,,120,,
AATT,10,,5,12,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH columnn flange 2
ASEL,S,LOC,X,-6.12,6.12,,
ASEL,R,LOC,Y,-5.9,-6.0,,
ASEL,R,LOC,Z,,120,,
AATT,10,,5,12,3
MSHAPE,0,2D
```

MSHKEY,1  
AMESH,ALL

! MESH SHIM  
ASEL,S,LOC,X,6.10,11.1,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AATT,12,,5,12,8  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH FOOT  
ASEL,S,LOC,X,10.9,11.1,,  
ASEL,R,LOC,Y,-19,19,,  
ASEL,R,LOC,Z,5.7,42,,  
AATT,11,,5,12,2  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! DUPLICATE  
ASEL,S,MAT,,12 ! shim  
AGEN,2,ALL,,,,-11.9,,,,  
ALLSEL,ALL

ASEL,S,LOC,X,10.9,11.1,, ! foot  
ASEL,R,LOC,Y,-19,19,,  
ASEL,R,LOC,Z,5.7,42,,  
ASEL,A,MAT,,12 ! shims again  
!ASEL,A,MAT,,11 ! foot  
AGEN,2,ALL,,,,72,,,,

ALLSEL,ALL  
NUMMRG,ALL,,,,

! components  
ASEL,S,AREA,,ARE0,ARE0+75,,1  
CM,WALLCOLUMNFOOT,AREA  
ALLSEL,ALL  
save

! FRAME  
! LAST TESTED on Thu 7.20.2012 4 pm

! USER INPUT: STARTING NUMBERS=====

```
*SET,KP2,8400
*SET,LIN2,19600
```

```
*SET,ARE2,15300
*SET,VOL2,5000
*SET,ELE2,70200
*SET,NOD2,89500
```

```
! # define model geometry
! user input:local coord system and location of frame
! ref: SHEET 1/15 LOWER LEFT FIG
! Local X ALONG EDGE OF LOWEST HORIZ MEMBER.
! Local Y perpendicular to web, right hand system.
! Local Z ALONG RIGHT EDGE OF RIGHT VERTICAL MEMBER.
! location of FRAME (origin of local coordinates: BASE OF FRAME,
! INTERSECTION OF HORIZ, VERT AND DIAG,LOWER RIGHT CORNER)
```

```
LOCAL,13,0,348,530.01,186, , , ,1,1
CSYS,13,
```

```
! END OF user input=====
```

```
NUMSTR,KP,KP2
NUMSTR,LINE,LIN2
NUMSTR,AREA,ARE2
NUMSTR,VOLU,VOL2
NUMSTR,ELEM,ELE2
NUMSTR,NODE,NOD2
```

```
! x horiz edge of bottom web
K,KP2,,,
K,KP2+1,6.233,, ! diag at 43.693 deg to horiz
K,KP2+2,9.06,,
K,KP2+3,17.06,,
K,KP2+4,29.06,, ! reference hole at midlength
K,KP2+5,41.06,,
K,KP2+6,49.06,,
K,KP2+7,52.165,,
K,KP2+8,55.1425,,
K,KP2+9,58.12,,
```

```
! Z vert midthickness of flange
K,KP2+10,,,
K,KP2+11,,,3
K,KP2+12,,,5.955 ! 5.955 = depth of WT 6X53 > half depth of I = 11.91/2
K,KP2+13,,,9
K,KP2+14,,,12
K,KP2+15,,,14.319 ! worse mesh if hole at z = 15.0
K,KP2+16,,,16.472,
K,KP2+17,,,19.3165
K,KP2+18,,,22.161
```



K,KP2+19,,,24  
K,KP2+20,,,63  
K,KP2+21,,,66.045  
K,KP2+22,,,69  
K,KP2+23,,,72

! diagonal web lower edge

K,KP2+30,,,  
K,KP2+31,3.140,,3.  
K,KP2+32,6.233,,5.955  
K,KP2+33,8.227,,7.860  
K,KP2+34,11.2045,,10.705  
K,KP2+35,14.182 ,,13.550  
K,KP2+36,52.165 ,,49.839  
K,KP2+37,55.1425,,52.6835  
K,KP2+38,58.12 ,,55.528

! diagonal web upper edge

K,KP2+40,,,16.472  
K,KP2+41,2.9775,,19.3165  
K,KP2+42,5.955,,22.161  
K,KP2+43,43.938,,58.450  
K,KP2+44,46.9155,,61.295  
K,KP2+45,49.893,,64.140  
K,KP2+46,51.887,,66.045  
K,KP2+47,54.980,,69.  
K,KP2+48,58.12,,72

! FLANGE edges

! of lower horiz.

K,KP2+50,, ,  
K,KP2+51,, 3,  
K,KP2+52,, 6.11,  
K,KP2+53,, -3,  
K,KP2+56,,-6.11,

! flange edge of vertical at upper intersection with diagonal

K,KP2+60,, ,16.472  
K,KP2+61,, 3,16.472  
K,KP2+62,, 6.11,16.472  
K,KP2+63,, -3,16.472  
K,KP2+66,,-6.11,16.472

! vertical edge of web of horizontal

K,KP2+70,6.233,,  
K,KP2+71,6.233,,3.0  
K,KP2+72,6.233,,5.955

! diagonal web body  
K,KP2+80, 8.227,,7.860  
K,KP2+81,6.17025,,10.013  
K,KP2+82, 4.1135,,12.166  
K,KP2+83,2.05675,,14.319  
K,KP2+84, ,,,16.472

! non extruded, disturbed zones  
K,KP2+90, 2.9775,,22.161  
K,KP2+91, 3.1165,,5.955  
K,KP2+92,3.085125,,9.5065  
K,KP2+93, 2.05675,,12.083

! LINES  
\*DO,I,KP2,KP2+8,1 ! x horiz edge of bottom web  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KP2+2,KP2+5,1 ! x horiz edge of bottom web  
KSEL,S,KP,,I,I+1,,  
LSLK,S,1  
LESIZE,ALL,3.0, , , ,0 , , ,0  
\*ENDDO  
ALLSEL,ALL

\*DO,I,KP2+10,KP2+22,1 ! Z vert midthickness of flange  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+19,KP2+20,,  
LSLK,S,1  
LESIZE,ALL,3.0, , , ,0 , , ,0  
ALLSEL,ALL

\*DO,I,KP2+30,KP2+37,1 ! diagonal web lower edge  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+35,KP2+36,,  
LSLK,S,1  
LESIZE,ALL, , ,17, ,0 , , ,0  
ALLSEL,ALL

\*DO,I,KP2+40,KP2+47,1 ! diagonal web upper edge  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KP2+42,KP2+43,,

```
LSLK,S,1
LESIZE,ALL,,17,,0,,0
ALLSEL,ALL
```

```
*DO,I,KP2+33,KP2+38,1 ! diagonal web body
LSTR,I,I+7
KSEL,S,KP,,I,I+7,7,
LSLK,S,1
LESIZE,ALL,,4,,0,,0
ALLSEL,ALL
*ENDDO
```

```
LSTR,KP2+50,KP2+51 ! +y flange base of vertical
LSTR,KP2+51,KP2+52
LSTR,KP2+50,KP2+53 ! -y flange base of vertical
LSTR,KP2+53,KP2+56
LSTR,KP2+60,KP2+61 ! +y flange base of diagonal
LSTR,KP2+61,KP2+62
LSTR,KP2+60,KP2+63 ! -y flange base of diagonal
LSTR,KP2+63,KP2+66
```

```
LSTR,KP2+70,KP2+71 ! web of horiz
LSTR,KP2+71,KP2+72 ! save db L=19600 to 19650
LSTR,KP2+18,KP2+90 ! web of vert
LSTR,KP2+90,KP2+42 ! L=19651,2
```

```
! non extruded smaller zone
LSTR,KP2+17,KP2+41 ! L=19653
LSTR,KP2+41,KP2+90 ! L=19654
```

```
! non extruded larger zone
LSTR,KP2+15,KP2+83 ! L=19655
LSTR,KP2+14,KP2+93 ! L=19656
LSTR,KP2+93,KP2+82 ! L=19657
LSTR,KP2+13,KP2+92 ! L=19658
LSTR,KP2+92,KP2+81 ! L=19659
LSTR,KP2+12,KP2+91 ! L=19660
LSTR,KP2+91,KP2+32 ! L=19661
```

```
LSTR,KP2+91,KP2+92 ! L=19662
LSTR,KP2+92,KP2+93 ! L=19663
LSTR,KP2+93,KP2+83 ! L=19664
LSTR,KP2+32,KP2+81 ! L=19665
LSTR,KP2+92,KP2+82 ! L=19666
```

```
KSEL,S,KP,,KP2,KP2+93,,
LSLK,S,1
LESIZE,ALL,4.4,,0,,0 ! default element size
```

LSTR,KP2+16,KP2+41  
KSEL,S,KP,,KP2+16,KP2+41,25,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+16,KP2+83  
KSEL,S,KP,,KP2+16,KP2+83,67,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+41,KP2+42  
KSEL,S,KP,,KP2+41,KP2+42,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+33,KP2+81  
KSEL,S,KP,,KP2+33,KP2+81,48,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+81,KP2+82  
KSEL,S,KP,,KP2+81,KP2+82,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+82,KP2+83  
KSEL,S,KP,,KP2+82,KP2+83,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

SAVE

! AREAS  
! TRIANGLES  
A,KP2+90,KP2+42,KP2+41  
A,KP2+17,KP2+41,KP2+16  
A,KP2+16,KP2+83,KP2+15  
A,KP2+83,KP2+82,KP2+93  
A,KP2+82,KP2+81,KP2+92  
A,KP2+93,KP2+82,KP2+92  
A,KP2+81,KP2+33,KP2+32

ASEL,S,AREA,,ARE2,ARE2+6,,1  
CM,TRIAREA,AREA  
ALLSEL,ALL

! QUADS

A,KP2+18,KP2+90,KP2+41,KP2+17  
A,KP2+15,KP2+83,KP2+93,KP2+14  
A,KP2+14,KP2+93,KP2+92,KP2+13  
A,KP2+13,KP2+92,KP2+91,KP2+12  
A,KP2+92,KP2+81,KP2+32,KP2+91

ASEL,S,AREA,,ARE2,ARE2+11,,1  
CM,DISTURB,AREA  
ALLSEL,ALL

KSEL,S,KP,,KP2,KP2+9,,  
LSLK,S,1  
CM,FULLX,LINE

KSEL,S,KP,,KP2+10,KP2+23,,  
LSLK,S,1  
CM,FULLZ,LINE

KSEL,S,KP,,KP2+18,KP2+21,,  
LSLK,S,1  
CM,PARTZ,LINE

KSEL,S,KP,,KP2+30,KP2+38,,  
LSLK,S,1  
CM,lodiag,LINE

KSEL,S,KP,,KP2+40,KP2+48,,  
LSLK,S,1  
CM,hidiag,LINE

KSEL,S,KP,,KP2+50,KP2+52,1,  
LSLK,S,1  
CM,flangeplus,LINE

KSEL,S,KP,,KP2+50,KP2+56,3,  
LSLK,S,1  
CM,flangeminus,LINE

KSEL,S,KP,,KP2+60,KP2+62,1,  
LSLK,S,1  
CM,flandiagplus,LINE

KSEL,S,KP,,KP2+60,KP2+66,3,  
LSLK,S,1  
CM,flandiagminus,LINE

KSEL,S,KP,,KP2+70,KP2+72,1,  
LSLK,S,1  
CM,webhoriz,LINE

KSEL,S,KP,,KP2+18,KP2+42,24,  
KSEL,A,KP,,KP2+90  
LSLK,S,1  
CM,webvert,LINE

ALLSEL,ALL

!!\*GET,AMAX1,AREA,0,NUM,MAX

! diagonal web areas  
A,KP2+33,KP2+34,KP2+41,KP2+40  
\*DO,I,KP2+34,KP2+37,1  
A,I,I+1,I+8,I+7  
\*ENDDO

ASEL,S,AREA,,ARE2,ARE2+16,,1  
CM,DIAWEBTURB,AREA ! DIAGONAL WEB AND DISTURBED AREAS=D  
ALLSEL,ALL

! areas  
ADRAG,lodiag,,,,,flangeplus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+32,,1  
CM,DLOPLUS,AREA ! DIAGONAL WEB,DISTURBED AND LOW PLUS DIAG FLANGE AREAS  
ALLSEL,ALL

ADRAG,lodiag,,,,,flangeminus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+48,,1  
CM,DLODIAG,AREA ! DIAGONAL WEB,DISTURBED AND LOW DIAG FLANGE AREAS  
ALLSEL,ALL

ADRAG,hidiag,,,,,flandiagplus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+64,,1  
CM,DLOHIPLUS,AREA ! DIAGONAL WEB,DISTURBED,LOW DIAG FLANGE AND HIGH PLUS DIAG FLANGE  
AREAS  
ALLSEL,ALL

ADRAG,hidiag,,,,,flandiagminus,,,,,  
ASEL,S,AREA,,ARE2,ARE2+80,,1  
CM,DLOHI,AREA ! DIAGONAL WEB,DISTURBED,LOW AND HIGH DIAG FLANGE AREAS  
ALLSEL,ALL

```
ADRAG,FULLZ,,,,,flangeplus,,,,,  
ADRAG,FULLZ,,,,,flangeminus,,,,,  
ADRAG,partz,,,,,webvert,,,,,  
ADRAG,fullx,,,,,flangeplus,,,,,  
ADRAG,fullx,,,,,flangeminus,,,,,  
ADRAG,fullx,,,,,WEBHORIZ,,,,,
```

```
ALLSEL,ALL  
SAVE
```

```
! mesh webS  
! MESH TRIANGLES  
! much simpler to define elements by commands NKPT and E  
CMSEL,S,TRIAREA,AREA  
AATT,10,,5,13,4  
MSHAPE,1,2D  
MSHKEY,0  
AMESH,ALL
```

```
! MESH QUADS  
CMSEL,S,DISTURB,AREA  
CMSEL,U,TRIAREA,AREA  
AATT,10,,5,13,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH DIAG WEB  
CMSEL,S,DIAWEBTURB,AREA  
CMSEL,U,DISTURB,AREA  
AATT,10,,5,13,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH DIAG FLANGES  
CMSEL,S,DLOHI,AREA  
CMSEL,U,DIAWEBTURB,AREA  
AATT,10,,5,13,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL
```

```
! MESH VERTICAL flange  
ASEL,S,LOC,X,,1,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,Z,,72,,
```

```
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,2
AMESH,ALL
```

```
! mesh VERTICAL web
ASEL,S,LOC,y,-.1,.1,,
ASEL,R,LOC,x,,6.0,,
ASEL,R,LOC,Z,22.0,72.0,,
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! mesh horizontal web
ASEL,S,LOC,y,-.1,.1,,
ASEL,R,LOC,x,,59.0,,
ASEL,R,LOC,Z,0,6.0,,
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! INVERT BOTTOM T
ASEL,S,LOC,Z,,0.1,,
AGEN,2,ALL,,,,,5.955,,,
```

```
! MESH HORIZONTAL FLANGE
ASEL,S,LOC,Z,5.9,6.0,,
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
SAVE
```

```
! reflect and translate HORIZONTAL
ASEL,S,LOC,Z,,6.0,,
ASEL,R,LOC,Y,-0.1,0.1,,
ARSYM,X,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,5.9,6.0,,
ASEL,R,LOC,Y,-6.2,6.2,,
ARSYM,X,ALL, , , ,0,0
```

```
ASEL,S,LOC,Z,,6.0,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,U,LOC,X,,59,,
```



ARSYM,Z,ALL, , , 0,1

ALLSEL,ALL

ASEL,S,LOC,Z,-6,6,,

ASEL,R,LOC,Y,-6.2,6.2,,

ASEL,U,LOC,X,,59,,

AGEN,2,ALL,,,58.12,,72,,,1

ALLSEL,ALL

SAVE

! reflect and translate vertical

ASEL,S,LOC,Z,22,66.1,,

ASEL,R,LOC,Y,-0.1,0.1,,

ASEL,R,LOC,X,,6,,

ARSYM,Z,ALL, , , 0,0

ASEL,S,LOC,Z,,72,,

ASEL,R,LOC,Y,-6.2,6.2,,

ASEL,R,LOC,X,,0.1,,

ARSYM,Z,ALL, , , 0,0

CMSEL,S,DISTURB,AREA

ARSYM,Z,ALL, , , 0,0

ALLSEL,ALL

ASEL,S,LOC,Z,-72,72,,

ASEL,R,LOC,Y,-6.2,6.2,,

ASEL,R,LOC,X,,9,,

ASEL,U,LOC,Z,,72,,

ARSYM,X,ALL, , , 0,1

ALLSEL,ALL

ASEL,S,LOC,Z,-72,72,,

ASEL,R,LOC,Y,-6.2,6.2,,

ASEL,R,LOC,X,-9,9,,

ASEL,U,LOC,Z,,72,,

AGEN,2,ALL,,,58.12,,72,,,1

ALLSEL,ALL

NUMMRG,ALL,5.0E-3,,

! COMPONENTS

ASEL,S,AREA,,ARE2,ARE2+352,,1

CM,FRAME,AREA

ALLSEL,ALL

SAVE

! girder LAST TESTED 9.19.2012

sect,10,shell,,girderweb24W103  
secdata,0.550,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,11,shell,,girderflange24W103  
secdata,0.980,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS=====

\*SET,KP4,9400  
\*SET,LIN4,21700  
\*SET,ARE4,16300  
\*SET,VOL4,5000  
\*SET,ELE4,72400  
\*SET,NOD4,92100

! # define model geometry  
! user input:local coord system and location of girder  
! ref: SHEET 12/15  
! Local X ALONG midheight of web.  
! Local Y perpendicular to web, right hand system.  
! Local Z ALONG left vertical EDGE OF web.

LOCAL,15,0,342,530.28,361, , , ,1,1  
CSYS,15,

LENGTH=186.0 ! half length of girder, must be > 126 and multiple of 3 inches.  
! If length > 186, user may have to increase element and node starting numbers  
! of subsequent components.  
!LENGTH=162.0  
! END OF user input=====

NUMSTR,KP,KP4  
NUMSTR,LINE,LIN4  
NUMSTR,AREA,ARE4  
NUMSTR,VOLU,VOL4  
NUMSTR,ELEM,ELE4  
NUMSTR,NODE,NOD4

! x horiz midheight of web, halfspan  
K,KP4,,,  
K,KP4+1,12.0,,  
K,KP4+2,13.0,,  
K,KP4+3,14.0,,  
K,KP4+4,16.0,,

K,KP4+5,18.0,,  
K,KP4+6,LENGTH,, !\*\*\*

! Z vert midthickness of web

K,KP4+10,,,  
K,KP4+11,,,9  
K,KP4+12,,,11.775

! y width of half flange

K,KP4+20,,,11.775  
K,KP4+21,,-4.5,11.775

! y width of full flange

K,KP4+30,18,4.5,11.775  
K,KP4+31,18,-4.5,11.775

! FLANGE TRANSITION KEYPOINTS

K,KP4+40,13, -4.5,11.775  
K,KP4+41,13,-2.25,11.775  
K,KP4+42,13, 0,11.775

K,KP4+50,14, -4.5,11.775  
K,KP4+51,14, -2.25,11.775  
K,KP4+52,14,.29795,11.775

K,KP4+60,15, -4.5,11.775  
K,KP4+61,15, -2.25,11.775  
K,KP4+62,15, 0,11.775  
K,KP4+63,14.73205,1,11.775  
K,KP4+64,15, 2.0,11.775  
K,KP4+65,15, 3.375,11.775  
K,KP4+66,15, 4.5,11.775

K,KP4+70,16, -4.5,11.775  
K,KP4+71,16,-2.25,11.775  
K,KP4+72,16, 0,11.775  
K,KP4+73,16,1.125,11.775  
K,KP4+74,16, 2.25,11.775  
K,KP4+75,16,3.375,11.775  
K,KP4+76,16, 4.5,11.775

K,KP4+80,18, -4.5,11.775  
K,KP4+81,18,-2.25,11.775  
K,KP4+82,18, 0,11.775  
K,KP4+83,18, 2.25,11.775  
K,KP4+84,18, 4.5,11.775

! LINES 0 to 5 x horiz midheight of web

```
*DO,I,KP4,KP4+5,1
  LSTR,I,I+1
*ENDDO
```

```
LESIZE,lin4 ,3.0, ,0, ,0, , ,0
LESIZE,lin4+1,1.0, ,0, ,0, , ,0
LESIZE,lin4+2,1.0, ,0, ,0, , ,0
LESIZE,lin4+3,1.0, ,0, ,0, , ,0
LESIZE,lin4+4,2.0, ,0, ,0, , ,0
LESIZE,lin4+5,3.0, ,0, ,0, , ,0
LSEL,S,LINE,,LIN4,LIN4+5,,1
CM,halfspanx,line
ALLSEL,ALL
```

```
KSEL,S,KP,,KP4,KP4+2,1,
LSLK,S,1
CM,cutoffx,line
```

```
allsel,all
KSEL,S,KP,,KP4+5,KP4+6,1,
LSLK,S,1
CM,fullwidthx,line
```

```
allsel,all
! LINES 6 to 7 z vert midthickness of half web
*DO,I,KP4+10,KP4+11,1
  LSTR,I,I+1
*ENDDO
```

```
LESIZE,lin4+6,3.0, ,0, ,0, , ,0
LESIZE,lin4+7, 0, ,1, ,0, , ,0
KSEL,S,KP,,KP4+10,KP4+12,1,
LSLK,S,1
CM,webdepthz,line
```

```
allsel,all
```

```
LSTR,KP4+20,KP4+21 ! L8 y width of half flange
LESIZE,lin4+8,0, ,2, ,0, , ,0
LSEL,S,LINE,,LIN4+8,,1
CM,halfwidthy,line
```

```
allsel,all
LSTR,KP4+30,KP4+31 ! L9 y width of full flange
LESIZE,lin4+9,0, ,4, ,0, , ,0
allsel,all
LSEL,S,LINE,,LIN4+9,,1
CM,fullwidthy,line
```

```
ALLSEL,ALL
CMSEL,S,cutoffx,line
LGEN,2,ALL,,,,,11.775,,, ! L10 TO 11
LSEL,S,LINE,,LIN4+10,LIN4+11,1,1
CM,cutoffx2,line
```

```
allsel,all
CMSEL,S,fullwidthx,line
LGEN,2,ALL,,,,,4.5,11.775,,, ! L12 TO 13
LSEL,S,LINE,,LIN4+12,LIN4+13,,1
CM,fullwidthx2,line
```

```
allsel,all
LSEL,S,LINE,,LIN4,LIN4+12,1,1
CM,REGULAR,LINE
allsel,all
```

```
! LINES IN CUTOFF REGION L14 TO L56
```

```
! Y LINES
```

```
LSTR,KP4+40,KP4+41
```

```
LSTR,KP4+41,KP4+42
```

```
LSTR,KP4+50,KP4+51
```

```
LSTR,KP4+51,KP4+52
```

```
*DO,I,KP4+60,KP4+65,1
```

```
LSTR,I,I+1
```

```
*ENDDO
```

```
*DO,I,KP4+70,KP4+75,1
```

```
LSTR,I,I+1
```

```
*ENDDO
```

```
*DO,I,KP4+80,KP4+83,1
```

```
LSTR,I,I+1
```

```
*ENDDO
```

```
! X LINES
```

```
*DO,I,KP4+40,KP4+70,10
```

```
LSTR,I,I+10
```

```
*ENDDO
```

```
*DO,I,KP4+41,KP4+71,10
```

```
LSTR,I,I+10
```

```
*ENDDO
```

```
*DO,I,KP4+42,KP4+72,10
```

```
LSTR,I,I+10
```

\*ENDDO

LSTR,KP4+62,KP4+63  
LSTR,KP4+63,KP4+52  
LSTR,KP4+63,KP4+73  
LSTR,KP4+73,KP4+82  
LSTR,KP4+73,KP4+83

LSTR,KP4+64,KP4+74  
LSTR,KP4+74,KP4+83  
LSTR,KP4+65,KP4+75  
LSTR,KP4+75,KP4+83  
LSTR,KP4+75,KP4+84  
LSTR,KP4+66,KP4+76  
LSTR,KP4+76,KP4+84

ALLSEL,ALL

LSEL,S,LINE,,LIN4,LIN4+55,,1  
CM,ALLINES,LINES  
CMSEL,S,ALLINES,LINE  
CMSEL,U,REGULAR,LINE  
LESIZE,ALL,0,,1,,0,,0  
CM,IRREGULAR,LINE

ALLSEL,ALL

! areas

\*DO,I,KP4+40,KP4+70,10  
A,I,I+10,I+11,I+1  
\*ENDDO

\*DO,I,KP4+41,KP4+71,10  
A,I,I+10,I+11,I+1  
\*ENDDO

A,KP4+52,KP4+62,KP4+63  
A,KP4+62,KP4+72,KP4+73,KP4+63  
A,KP4+72,KP4+82,KP4+73  
A,KP4+73,KP4+82,KP4+83  
A,KP4+63,KP4+73,KP4+74,KP4+64  
A,KP4+73,KP4+83,KP4+74  
A,KP4+64,KP4+74,KP4+75,KP4+65  
A,KP4+74,KP4+83,KP4+75  
A,KP4+75,KP4+83,KP4+84  
A,KP4+65,KP4+75,KP4+76,KP4+66  
A,KP4+75,KP4+84,KP4+76

ADRAG,halfspanx,,,,,,,,webdepthz,,,,,,,, ! Areas 0 to 9

```
ADRAG,cutoffx2,,,,,halfwidthy,,,, ! Areas 10 to 11
ADRAG,fullwidthx2,,,,,fullwidthy,,,, ! Areas 12 to 13
```

```
! MESH WEB
ASEL,S,LOC,Y,-0.1,0.1,,1
ASEL,R,LOC,Z,0,11.7,,
AATT,10,,5,15,10
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
```

```
! MESH FLANGE
ASEL,S,LOC,Z,11.7,11.8,,1
ASEL,U,LOC,X,13,18,,1
AATT,10,,5,15,11
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
```

```
! MESH FLANGE TRANSITION
ASEL,S,LOC,Z,11.7,11.8,,1
ASEL,R,LOC,X,13,18,,1
AATT,10,,5,15,11
MSHKEY,2
AMESH,ALL
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+33,,1
! reflect AND TRANSLATE
ARSYM,Z,ALL, , , ,0,0 ! from quarter to half
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+67,,1
ARSYM,x,ALL, , , ,0,0 ! from half to full
ALLSEL,ALL
```

```
!ASEL,S,LOC,x,-186,0,,1
ASEL,S,AREA,,ARE4+68,ARE4+135,,1 ! move new half to other end
L=LENGTH*2 !***
AGEN,2,ALL,,,L,,,,,1 !***
ALLSEL,ALL
```

```
! girder assembly A
! y distance between 2 beams is 12.89 + 0.55 = 13.44
```

! new beam is between  $y = -13.44 \pm 4.5$   
! if spacing between beams changes, these values must change

```
ASEL,S,AREA,,ARE4,ARE4+135,,1
AGEN,2,ALL,,,0,-13.44,,,,0 ! double beam
ASEL,S,LOC,y,-18,-8.9,,1 ! reflect
ARSYM,Y,ALL, , , ,0,1
ALLSEL,ALL
```

! end of generation of 2nd beam and possible user input

```
NUMMRG,ALL
```

! CONSTRAIN TOP OF WEB WITH BEGINNING OF FULL FLANGE.  
! moving or duplicating girder by AGEN may be difficult because of constraints.  
! best to move or duplicate girder without constraints, then reapply constraints at new location.

```
N1 = NODE(14,0,11.775)
N2 = NODE(14,.29795,11.775)
CP,NEXT,ALL,N1,N2
```

```
N3 = NODE(14,0,-11.775)
N4 = NODE(14,.29795,-11.775)
CP,NEXT,ALL,N3,N4
```

```
L1=LENGTH*2-14
```

```
N5 = NODE(L1,0,11.775)
N6 = NODE(L1,.29795,11.775)
CP,NEXT,ALL,N5,N6
```

```
N7 = NODE(L1,0,-11.775)
N8 = NODE(L1,.29795,-11.775)
CP,NEXT,ALL,N7,N8
```

! y location of couplings below depends on spacing between 2 beams  
!  $13.44 - .29795 = 13.14205$

```
N9 = NODE(14,13.44,11.775)
N10 = NODE(14,13.14205,11.775)
CP,NEXT,ALL,N9,N10
```

```
N11 = NODE(14,13.44,-11.775)
N12 = NODE(14,13.14205,-11.775)
CP,NEXT,ALL,N11,N12
```

```
N13 = NODE(L1,13.44,11.775)
N14 = NODE(L1,13.14205,11.775)
```



```

CP,NEXT,ALL,N13,N14

N15 = NODE(L1,13.44,-11.775)
N16 = NODE(L1,13.14205,-11.775)
CP,NEXT,ALL,N15,N16 ! set 48 last

ALLSEL,ALL

ASEL,S,AREA,,ARE4,ARE4+271,,1
CM,GIRDER,AREA
ALLSEL,ALL
SAVE

! girder spacer

ET,6,BEAM188
SECTYPE, 15, BEAM, CTUBE, SCH80, 0
SECOFFSET, CENT
SECDATA,0.75,0.95,0,0,0,0,0,0,0,0 ! WHERE IS MAT DEFINED?

! USER INPUT: STARTING NUMBERS=====
*SET,KP6,10100
*SET,LIN6,22800
*SET,ARE6,16800
*SET,VOL6,5000
*SET,ELE6,79100
*SET,NOD6,101200

! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 14/15
! Local X ALONG flange.
! Local Y along web.
! Local Z ALONG length of spacer.
! origin at midthickness JUNCTION WEB-FLANGE.

LOCAL,17,0,108,519.05,350.3, , , ,1,1
CSYS,17,

! END OF user input=====

NUMSTR,KP,KP6
NUMSTR,LINE,LIN6
NUMSTR,AREA,ARE6
NUMSTR,VOLU,VOL6
NUMSTR,ELEM,ELE6
NUMSTR,NODE,NOD6

```

```
K,KP6,-6.11,,
K,KP6+1,-3.0,,
K,KP6+2,,,
K,KP6+3,3.0,,
K,KP6+4,6.11,,
K,KP6+5,,11.9,
K,KP6+6,,,1.7
K,KP6+7,,,19.7
K,KP6+8,,,21.4
```

```
! LINES x
LSTR,KP6 ,KP6+1
LSTR,KP6+1,KP6+2
LSTR,KP6+2,KP6+3
LSTR,KP6+3,KP6+4
```

```
! LINES y
LSTR,KP6+2,KP6+5
```

```
! LINES z
LSTR,KP6+2,KP6+6
LSTR,KP6+6,KP6+7
LSTR,KP6+7,KP6+8
```

```
*DO,I,LIN6,LIN6+7,1
LESIZE,I ,0, ,1, ,0, , ,0
*ENDDO
```

```
LESIZE,LIN6+4,0, ,4,,1,0, ,0
LESIZE,LIN6+6,3.0, ,0,,1,0, ,0
```

```
! bushing lines
LGEN,2,LIN6+4,,,3.0,,1.7,,, !L8
LGEN,2,LIN6+8,,,,,6.0,,, !L9
LGEN,2,LIN6+8,LIN6+9,1,,,12.0,,, !L10,11
LGEN,2,LIN6+8,LIN6+11,1,-6.0,,,,, !L12 to 15
```

```
! AREAS
ADRAG,LIN6 ,LIN6+1,,,,,LIN6+5,LIN6+6,LIN6+7,,,, ! flange- Areas
ADRAG,LIN6+5,LIN6+6,LIN6+7,,,,,LIN6+2,LIN6+3,,,,, ! flange+ Areas
ADRAG,LIN6+5,LIN6+6,LIN6+7,,,,,LIN6+4,,,,, ! web Areas
```

```
! MESH BUSHINGS
LSEL,S,LINE,,LIN6+8,LIN6+15,1,1
LATT,10,,6,,KP6+2,,15
LMESH,ALL
```

```
ALLSEL,ALL
```

```
ASEL,S,LOC,X,-.1,.1,,1
ASEL,R,LOC,Y,0,12,,1
ASEL,R,LOC,Z,0,21.5,,1
AATT,10,,5,17,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
! MESH LOWER FLANGE
ASEL,S,LOC,Y,-.1,.1,,1
ASEL,R,LOC,X,-6.11,6.11,,1
ASEL,R,LOC,Z,0,21.5,,1
AATT,10,,5,17,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! COPY FLANGE
AGEN,2,ALL,,,,,11.9,,,,,
ALLSEL,ALL
NUMMRG,ALL
!even with no merge, spacer can only be copied in 2 steps,
!not moved (i.e. no new elements created).
SAVE
```

```
! COMPONENTS
ASEL,S,AREA,,ARE6,ARE6+26,,1
CM,GIRDERSPACER,AREA
ALLSEL,ALL
```

```
LSEL,S,LINE,,LIN6,LIN6+85,,1
CM,BUSHING,LINE
ALLSEL,ALL
SAVE
```

```
! finished with girder spacer
```

```
! ROTATE FRAME
LOCAL,20,0,348,530.55,262,-90,,,1,1
CSYS,13
CMSEL,S,FRAME,AREA
ATRA,20,ALL,,,,,1
CSYS,0
ALLSEL,ALL
SAVE
```

```
! MOVE WALLCOLUMNFOOT
```

```
CMSEL,S,WALLCOLUMNFOOT,AREA
AGEN,2,ALL,,,0,-100.0,0,,,1
ALLSEL,ALL
SAVE
```

```
! COPY COLUMNFOOT
```

```
*SET,KP7,10200
*SET,LIN7,22900
*SET,ARE7,16900
*SET,VOL7,5000
*SET,ELE7,79300
*SET,NOD7,101500
```

```
NUMSTR,KP,KP7
NUMSTR,LINE,LIN7
NUMSTR,AREA,ARE7
NUMSTR,VOLU,VOL7
NUMSTR,ELEM,ELE7
NUMSTR,NODE,NOD7
```

```
CSYS,0
CMSEL,S,COLUMNFOOT,AREA
AGEN,2,ALL,,,0,71.02,0,,,
ALLSEL,ALL
```

```
! components
ASEL,S,AREA,,ARE7,ARE7+67,,1
CM,COLUMNFOOT2,AREA
ALLSEL,ALL
SAVE
```

```
! COPY SPACER 1
*SET,KP8,10300
*SET,LIN8,23100
*SET,ARE8,17000
*SET,VOL8,5000
*SET,ELE8,80450
*SET,NOD8,102750
```

```
NUMSTR,KP,KP8
NUMSTR,LINE,LIN8
NUMSTR,AREA,ARE8
NUMSTR,VOLU,VOL8
NUMSTR,ELEM,ELE8
NUMSTR,NODE,NOD8
```

```
CMSEL,S,BUSHING,LINE
```

LGEN,2,ALL,,,360,12,0,,,0  
ALLSEL,ALL

CMSEL,S,GIRDERSPACER,AREA  
AGEN,2,ALL,,,360,12,0,,,0  
ALLSEL,ALL  
NUMMRG,ALL

! COMPONENTS  
LSEL,S,LINE,,LIN8,LIN8+85,,1  
CM,BUSHING1,LINE  
ALLSEL,ALL

ASEL,S,AREA,,ARE8,ARE8+26,,1  
CM,GIRDERSPACER1,AREA  
ALLSEL,ALL  
SAVE

! copy SPACER 2  
\*SET,KP9,10400  
\*SET,LIN9,23250  
\*SET,ARE9,17050  
\*SET,VOL9,5000  
\*SET,ELE9,81000  
\*SET,NOD9,103000

NUMSTR,KP,KP9  
NUMSTR,LINE,LIN9  
NUMSTR,AREA,ARE9  
NUMSTR,VOLU,VOL9  
NUMSTR,ELEM,ELE9  
NUMSTR,NODE,NOD9

CMSEL,S,BUSHING,LINE  
LGEN,2,ALL,,,480,12,0,,,0  
ALLSEL,ALL

CMSEL,S,GIRDERSPACER,AREA  
AGEN,2,ALL,,,480,12,0,,,0  
ALLSEL,ALL  
NUMMRG,ALL

! COMPONENTS  
LSEL,S,LINE,,LIN9,LIN9+85,,1  
CM,BUSHING2,LINE  
ALLSEL,ALL

ASEL,S,AREA,,ARE9,ARE9+26,,1

CM,GIRDERSPACER2,AREA  
ALLSEL,ALL  
SAVE

! bolt girder to column-foot2  
! nod4=92100, nod7=101500  
! could use notation nod4+x. nod7+y in case different numbering used

CP,NEXT,UX,94768,102374  
CP,NEXT,UY,94768,102374  
CP,NEXT,UZ,94768,102374

CP,NEXT,UX,95426,102368  
CP,NEXT,UY,95426,102368  
CP,NEXT,UZ,95426,102368

CP,NEXT,UX,94759,102137  
CP,NEXT,UY,94759,102137  
CP,NEXT,UZ,94759,102137

CP,NEXT,UX,94766,102140  
CP,NEXT,UY,94766,102140  
CP,NEXT,UZ,94766,102140

CP,NEXT,UX,95424,102134  
CP,NEXT,UY,95424,102134  
CP,NEXT,UZ,95424,102134

CP,NEXT,UX,94761,102371  
CP,NEXT,UY,94761,102371  
CP,NEXT,UZ,94761,102371

CP,NEXT,UX,92794,101968  
CP,NEXT,UY,92794,101968  
CP,NEXT,UZ,92794,101968

CP,NEXT,UX,92111,101974  
CP,NEXT,UY,92111,101974  
CP,NEXT,UZ,92111,101974

CP,NEXT,UX,92104,101971  
CP,NEXT,UY,92104,101971  
CP,NEXT,UZ,92104,101971

CP,NEXT,UX,92792,101734  
CP,NEXT,UY,92792,101734  
CP,NEXT,UZ,92792,101734

CP,NEXT,UX,92102,101737  
CP,NEXT,UY,92102,101737  
CP,NEXT,UZ,92102,101737

CP,NEXT,UX,92109,101740  
CP,NEXT,UY,92109,101740  
CP,NEXT,UZ,92109,101740 ! set 84 last

! bolt girder to wall-column  
! nod4=92100, nod0=88000  
! could use notation nod4+x. nod0+y in case different numbering used

CP,NEXT,UX,94108,88550  
CP,NEXT,UY,94108,88550  
CP,NEXT,UZ,94108,88550

CP,NEXT,UX,93443,88553  
CP,NEXT,UY,93443,88553  
CP,NEXT,UZ,93443,88553

CP,NEXT,UX,93450,88556  
CP,NEXT,UY,93450,88556  
CP,NEXT,UZ,93450,88556

CP,NEXT,UX,96740,88345  
CP,NEXT,UY,96740,88345  
CP,NEXT,UZ,96740,88345

CP,NEXT,UX,96075,88348  
CP,NEXT,UY,96075,88348  
CP,NEXT,UZ,96075,88348

CP,NEXT,UX,96082,88351  
CP,NEXT,UY,96082,88351  
CP,NEXT,UZ,96082,88351

CP,NEXT,UX,96742,88231  
CP,NEXT,UY,96742,88231  
CP,NEXT,UZ,96742,88231

CP,NEXT,UX,96077,88234  
CP,NEXT,UY,96077,88234  
CP,NEXT,UZ,96077,88234

CP,NEXT,UX,96084,88237  
CP,NEXT,UY,96084,88237  
CP,NEXT,UZ,96084,88237

CP,NEXT,UX,94110,88436  
CP,NEXT,UY,94110,88436  
CP,NEXT,UZ,94110,88436

CP,NEXT,UX,93445,88439  
CP,NEXT,UY,93445,88439  
CP,NEXT,UZ,93445,88439

CP,NEXT,UX,93452,88442  
CP,NEXT,UY,93452,88442  
CP,NEXT,UZ,93452,88442 ! set 120 last

! bolt frame to column-foot2  
! nod2=89500, nod7=101500  
! could use notation nod2+x. nod7+y in case different numbering used

CP,NEXT,UX,89832,101939  
CP,NEXT,UY,89832,101939  
CP,NEXT,UZ,89832,101939

CP,NEXT,UX,89901,101705  
CP,NEXT,UY,89901,101705  
CP,NEXT,UZ,89901,101705

CP,NEXT,UX,89872,101961  
CP,NEXT,UY,89872,101961  
CP,NEXT,UZ,89872,101961

CP,NEXT,UX,89925,101727  
CP,NEXT,UY,89925,101727  
CP,NEXT,UZ,89925,101727

CP,NEXT,UX,89858,101948  
CP,NEXT,UY,89858,101948  
CP,NEXT,UZ,89858,101948

CP,NEXT,UX,89913,101714  
CP,NEXT,UY,89913,101714  
CP,NEXT,UZ,89913,101714

CP,NEXT,UX,89920,101721  
CP,NEXT,UY,89920,101721  
CP,NEXT,UZ,89920,101721

CP,NEXT,UX,89865,101955  
CP,NEXT,UY,89865,101955  
CP,NEXT,UZ,89865,101955



CP,NEXT,UX,89910,101712  
CP,NEXT,UY,89910,101712  
CP,NEXT,UZ,89910,101712

CP,NEXT,UX,89842,101946  
CP,NEXT,UY,89842,101946  
CP,NEXT,UZ,89842,101946 ! set 150 last, save

! bolt frame to column-foot1  
! nod2=89500, nod1=85000  
! could use notation nod2+x. nod1+y in case different numbering used

CP,NEXT,UX,90371,86261  
CP,NEXT,UY,90371,86261  
CP,NEXT,UZ,90371,86261

CP,NEXT,UX,90447,86027  
CP,NEXT,UY,90447,86027  
CP,NEXT,UZ,90447,86027

CP,NEXT,UX,90388,86254  
CP,NEXT,UY,90388,86254  
CP,NEXT,UZ,90388,86254

CP,NEXT,UX,90456,86022  
CP,NEXT,UY,90456,86022  
CP,NEXT,UZ,90456,86022

CP,NEXT,UX,90418,86239  
CP,NEXT,UY,90418,86239  
CP,NEXT,UZ,90418,86239

CP,NEXT,UX,90471,86005  
CP,NEXT,UY,90471,86005  
CP,NEXT,UZ,90471,86005

CP,NEXT,UX,90411,86245  
CP,NEXT,UY,90411,86245  
CP,NEXT,UZ,90411,86245

CP,NEXT,UX,90466,86011  
CP,NEXT,UY,90466,86011  
CP,NEXT,UZ,90466,86011

CP,NEXT,UX,90406,86250  
CP,NEXT,UY,90406,86250  
CP,NEXT,UZ,90406,86250

CP,NEXT,UX,90461,86016  
CP,NEXT,UY,90461,86016  
CP,NEXT,UZ,90461,86016 ! set 180 last, save

! bolt girder to spacer 1  
! nod4=92100, nod8=102750  
! could use notation nod4+x. nod8+y in case different numbering used

CP,NEXT,UX,92235,102777  
CP,NEXT,UY,92235,102777  
CP,NEXT,UZ,92235,102777

CP,NEXT,UX,92918,102750  
CP,NEXT,UY,92918,102750  
CP,NEXT,UZ,92918,102750

CP,NEXT,UX,95550,102751  
CP,NEXT,UY,95550,102751  
CP,NEXT,UZ,95550,102751

CP,NEXT,UX,94892,102778  
CP,NEXT,UY,94892,102778  
CP,NEXT,UZ,94892,102778

CP,NEXT,UX,94890,102814  
CP,NEXT,UY,94890,102814  
CP,NEXT,UZ,94890,102814

CP,NEXT,UX,95548,102787  
CP,NEXT,UY,95548,102787  
CP,NEXT,UZ,95548,102787

CP,NEXT,UX,92916,102786  
CP,NEXT,UY,92916,102786  
CP,NEXT,UZ,92916,102786

CP,NEXT,UX,92233,102813  
CP,NEXT,UY,92233,102813  
CP,NEXT,UZ,92233,102813 ! set 204 last, save

! bolt girder to spacer 2  
! nod4=92100, nod9=103000  
! could use notation nod4+x. nod9+y in case different numbering used

CP,NEXT,UX,96206,103028  
CP,NEXT,UY,96206,103028  
CP,NEXT,UZ,96206,103028

CP,NEXT,UX,93574,103027  
CP,NEXT,UY,93574,103027  
CP,NEXT,UZ,93574,103027

CP,NEXT,UX,96864,103001  
CP,NEXT,UY,96864,103001  
CP,NEXT,UZ,96864,103001

CP,NEXT,UX,94232,103000  
CP,NEXT,UY,94232,103000  
CP,NEXT,UZ,94232,103000

CP,NEXT,UX,96208,103064  
CP,NEXT,UY,96208,103064  
CP,NEXT,UZ,96208,103064

CP,NEXT,UX,96866,103037  
CP,NEXT,UY,96866,103037  
CP,NEXT,UZ,96866,103037

CP,NEXT,UX,93576,103063  
CP,NEXT,UY,93576,103063  
CP,NEXT,UZ,93576,103063

CP,NEXT,UX,94234,103036  
CP,NEXT,UY,94234,103036  
CP,NEXT,UZ,94234,103036 ! set 228 last, save

! BOLT foot 2 to strong floor  
! Nod7=101500 could be used in notation

D,101617,UX,,,,,,,,,  
D,101617,UY,,,,,,,,,  
D,101617,UZ,,,,,,,,,

D,101635,UX,,,,,,,,,  
D,101635,UY,,,,,,,,,  
D,101635,UZ,,,,,,,,,

D,101529,UX,,,,,,,,,  
D,101529,UY,,,,,,,,,  
D,101529,UZ,,,,,,,,,

D,101503,UX,,,,,,,,,  
D,101503,UY,,,,,,,,,  
D,101503,UZ,,,,,,,,,

! BOLT foot 1 to strong floor

! Nod1=85000 could be used in notation

D,85135,UX,,,,,,,,  
D,85135,UY,,,,,,,,  
D,85135,UZ,,,,,,,,

D,85029,UX,,,,,,,,  
D,85029,UY,,,,,,,,  
D,85029,UZ,,,,,,,,

D,85117,UX,,,,,,,,  
D,85117,UY,,,,,,,,  
D,85117,UZ,,,,,,,,

D,85003,UX,,,,,,,,  
D,85003,UY,,,,,,,,  
D,85003,UZ,,,,,,,,

! bolt pad 1 to strong wall  
! Nod0=88000 could be used in notation

D,88683,UX,,,,,,,,  
D,88683,UY,,,,,,,,  
D,88683,UZ,,,,,,,,

D,88657,UX,,,,,,,,  
D,88657,UY,,,,,,,,  
D,88657,UZ,,,,,,,,

D,88693,UX,,,,,,,,  
D,88693,UY,,,,,,,,  
D,88693,UZ,,,,,,,,

D,88765,UX,,,,,,,,  
D,88765,UY,,,,,,,,  
D,88765,UZ,,,,,,,,

! bolt pad 2 to strong wall  
! Nod0=88000 could be used in notation

D,88930,UX,,,,,,,,  
D,88930,UY,,,,,,,,  
D,88930,UZ,,,,,,,,

D,89012,UX,,,,,,,,  
D,89012,UY,,,,,,,,  
D,89012,UZ,,,,,,,,

```
D,88904,UX,,,,,,,,
D,88904,UY,,,,,,,,
D,88904,UZ,,,,,,,,
```

```
D,88940,UX,,,,,,,,
D,88940,UY,,,,,,,,
D,88940,UZ,,,,,,,,
```

```
! the following is a load test
/SOLU
ANTYPE,0 ! static analysis
```

```
! LOAD
ACEL,,,1 ! gravity -z
```

```
! LOAD TOP OF COLUMN 2 AT JUNCTIONS WEB-FLANGE
! Nod7=101500 could be used in notation
```

```
F,101835,Fx,-2,,,
F,101835,FY,-2,,,
F,101835,FZ,-2,,,
```

```
F,102235,Fx,-2,,,
F,102235,FY,-2,,,
F,102235,FZ,-2,,,
```

```
ALLSEL,ALL
! UNSELECT CONSTRUCTION SPACER
ESEL,U,ELEM,,ELE6,ELE6+127,,
```

```
OUTPR,STAT
OUTRES,STAT
SAVE
```

```
SOLVE
/eof
```

## Chapter 14 Assembling the Support and the Concrete Structures

To assemble the modular support structure (and potential future experimental structures) inside the concrete structure with proper connections and restraints, the same procedure is used as in Chapter 13.

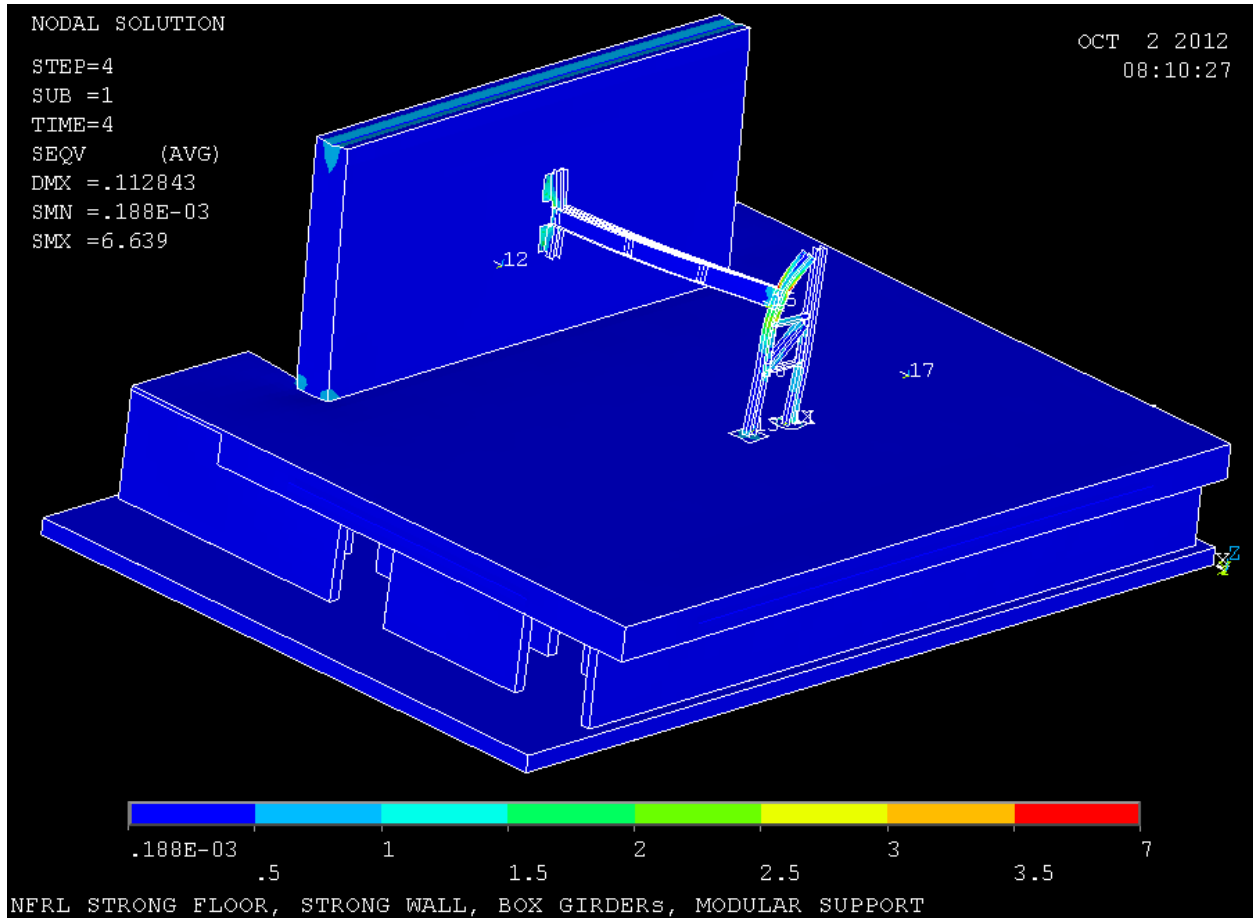


Fig. 14.1 Deformations and von Mises stress. Reaction is at base of slab.

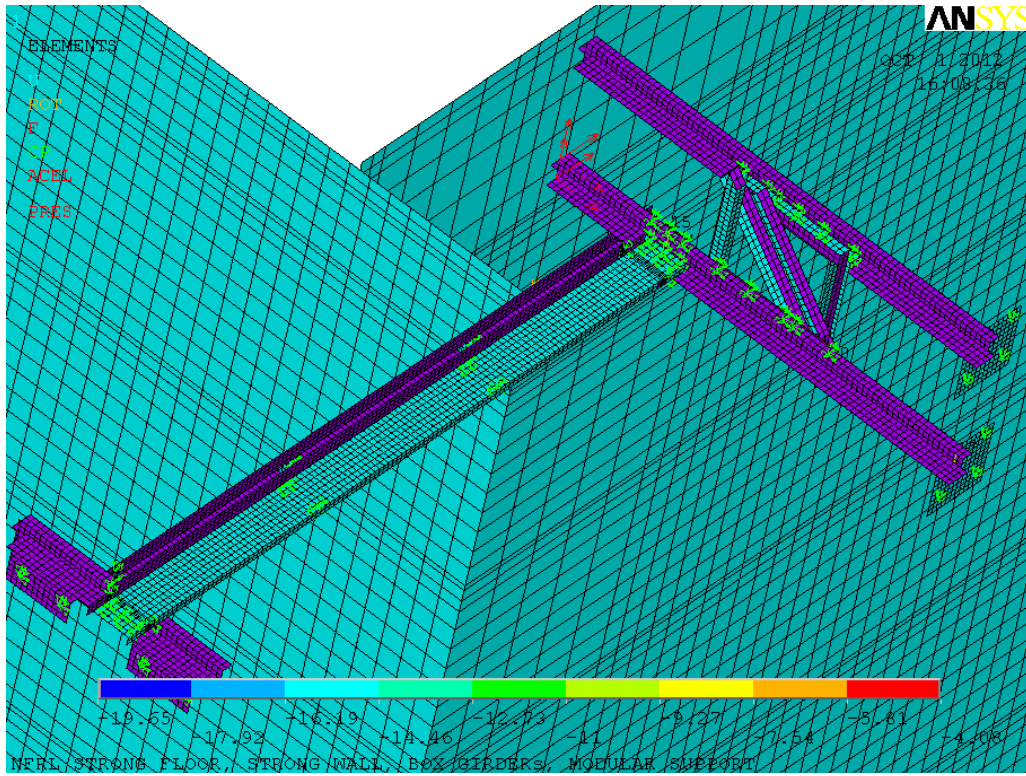


Fig. 14.2 Bolting the support structure together, to the strong floor and strong wall

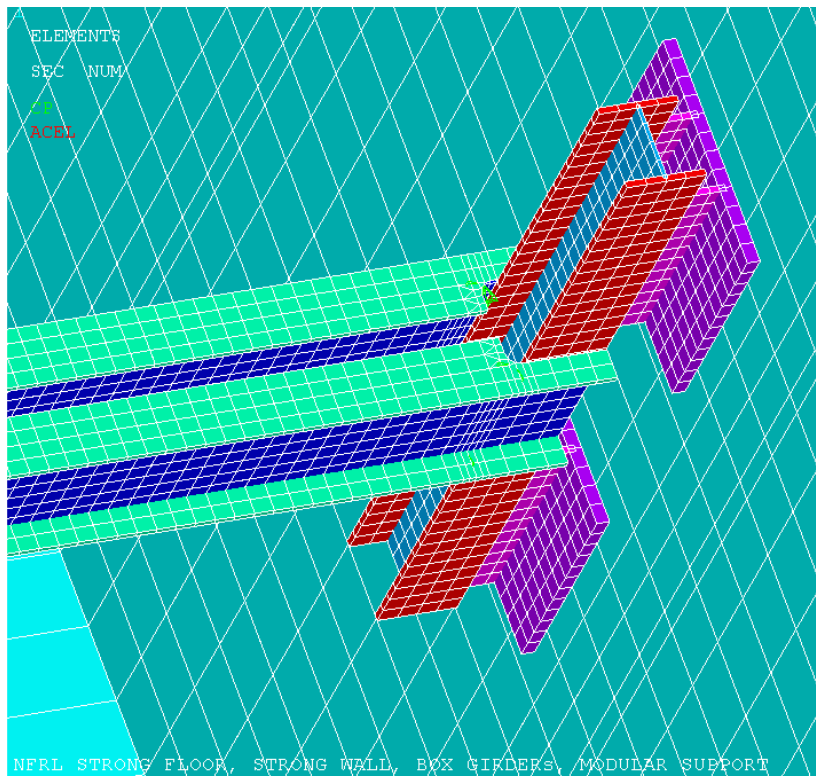


Fig. 14.3 Girder and wall-column at strong wall

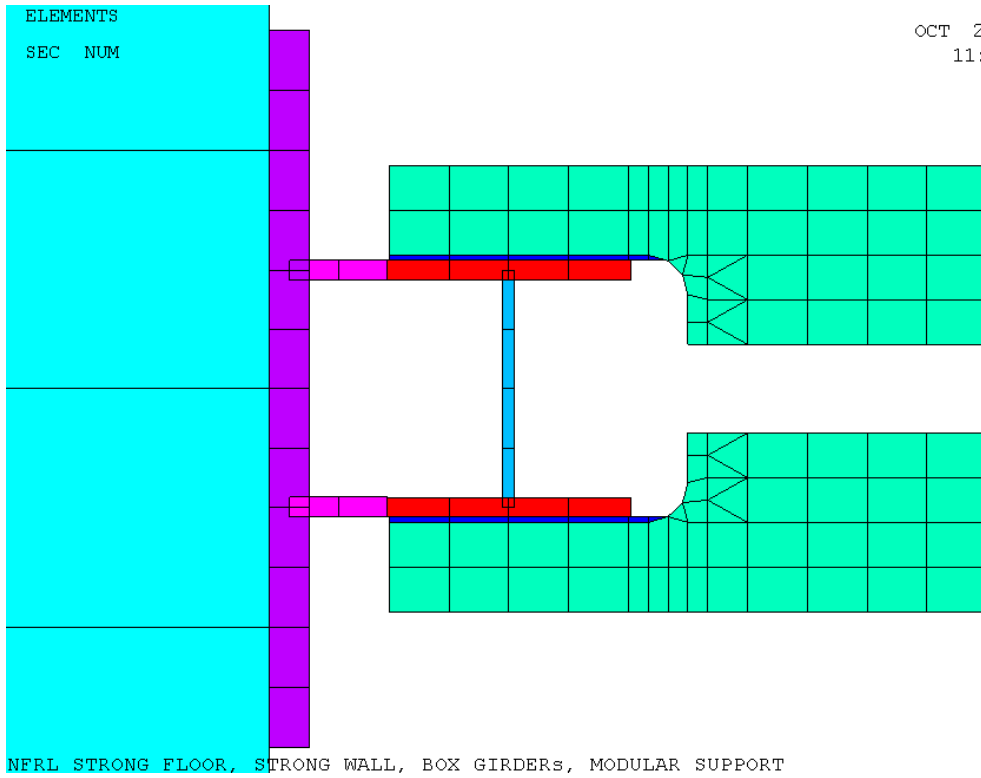


Fig. 14.4 Fitting wall-column to strong wall

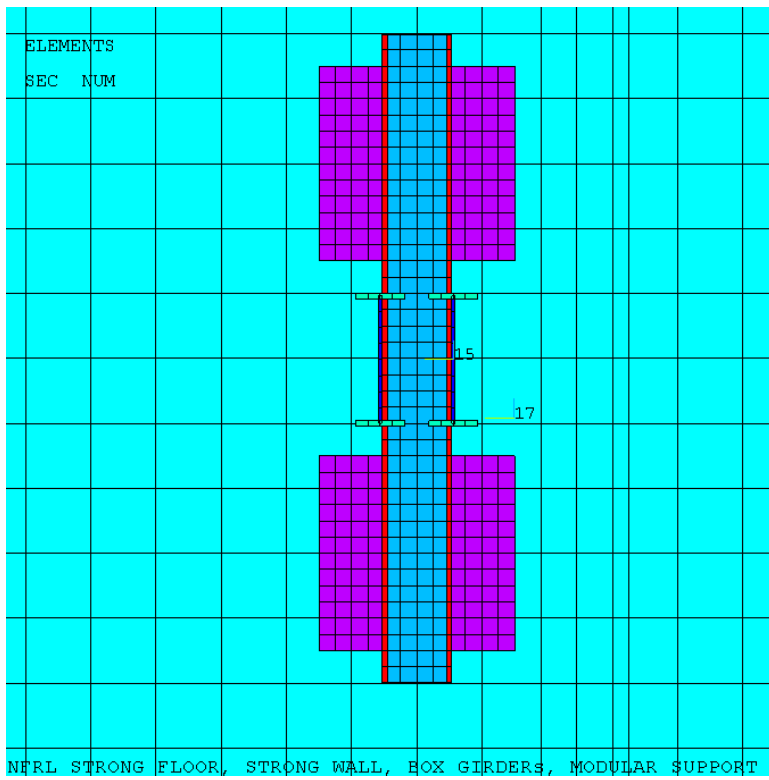


Fig. 14.5 Bolting wall-column to strong wall



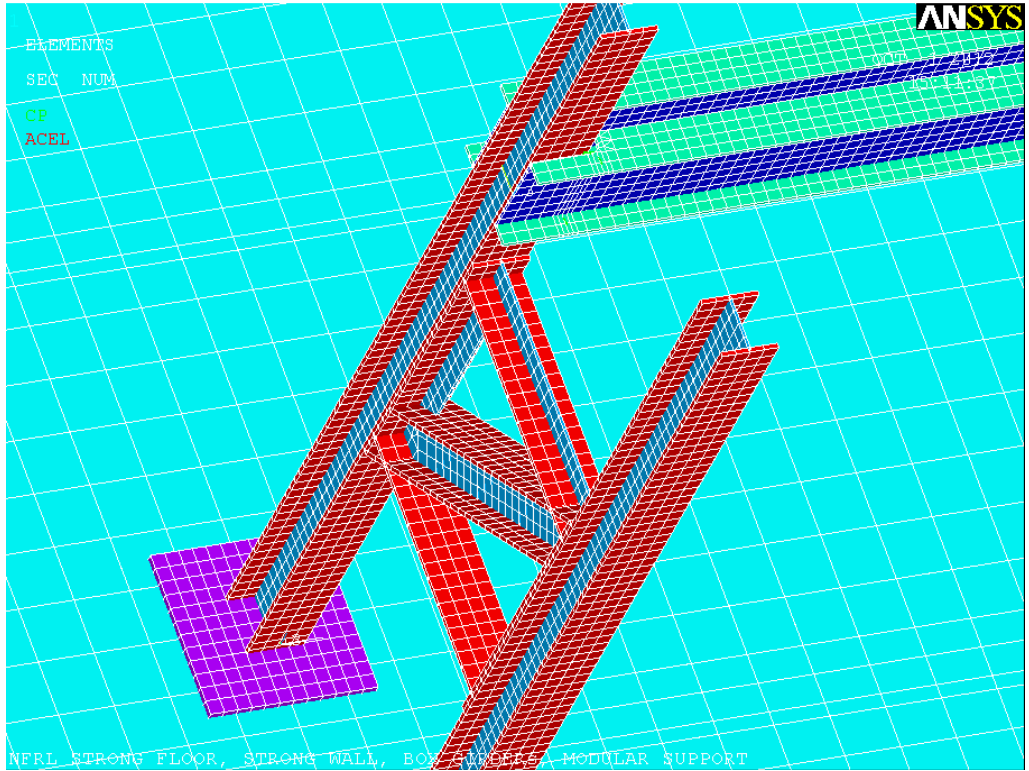


Fig. 14.6 Girder, column-foot and frame

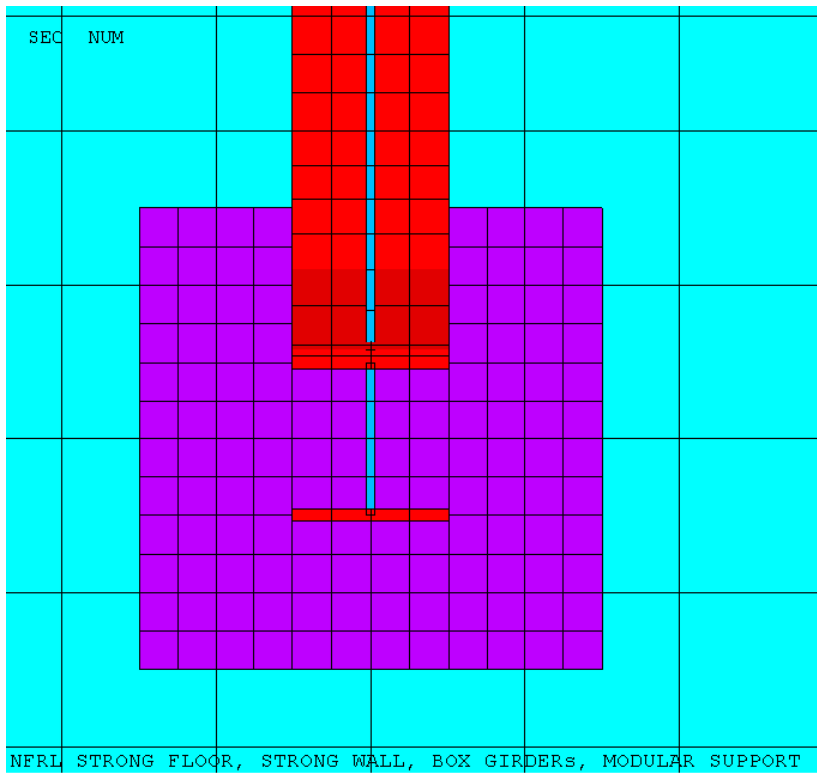


Fig. 14.7 Fitting foot 1 onto strong floor

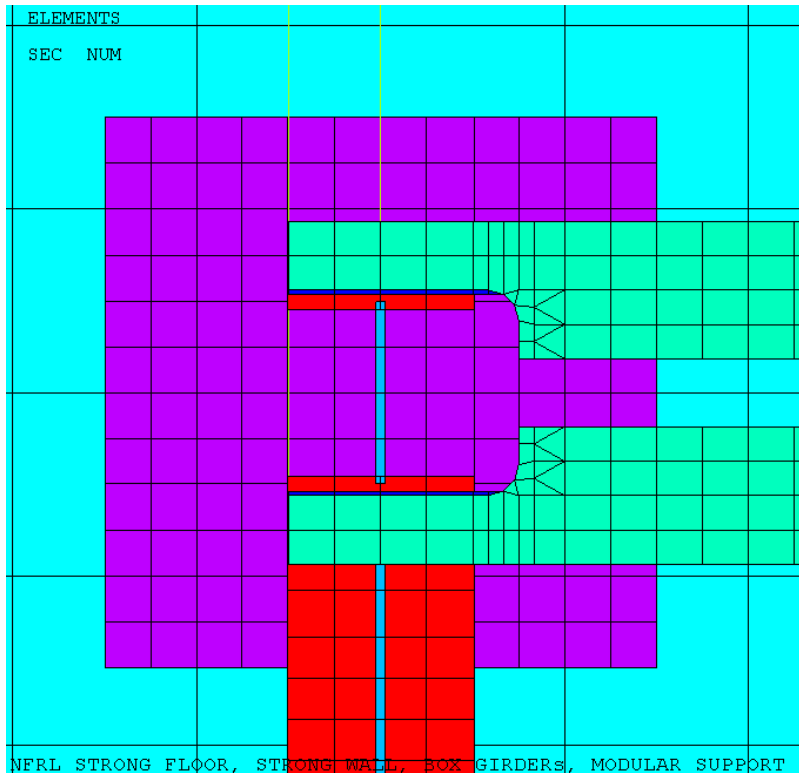


Fig. 14.8 Fitting foot 2 onto strong floor

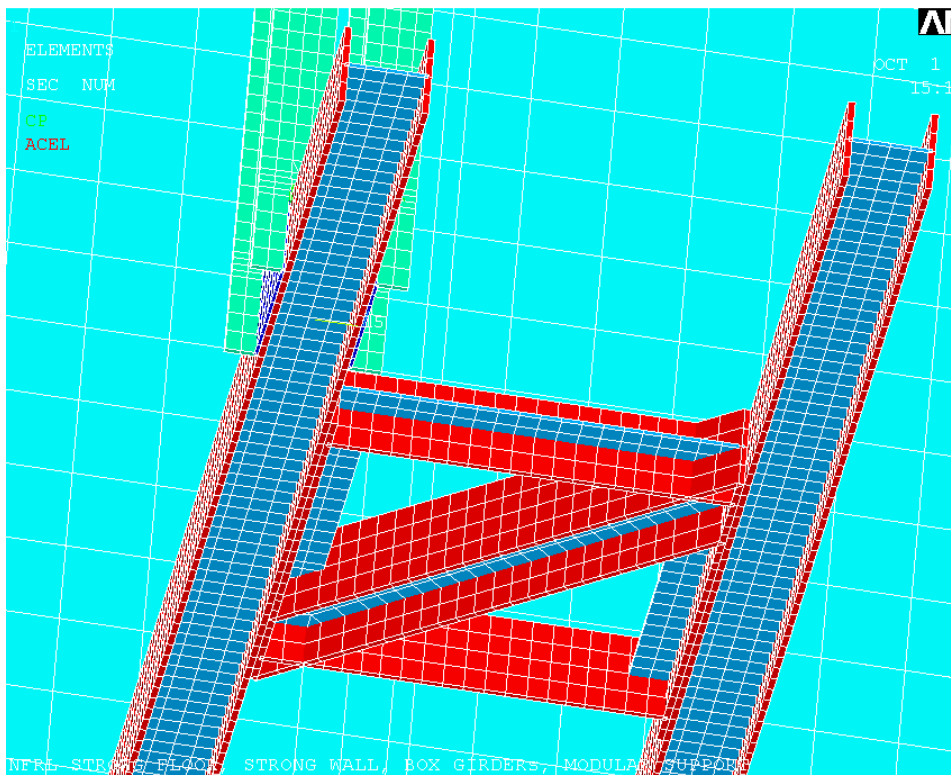


Fig. 14.9 Columns and frame

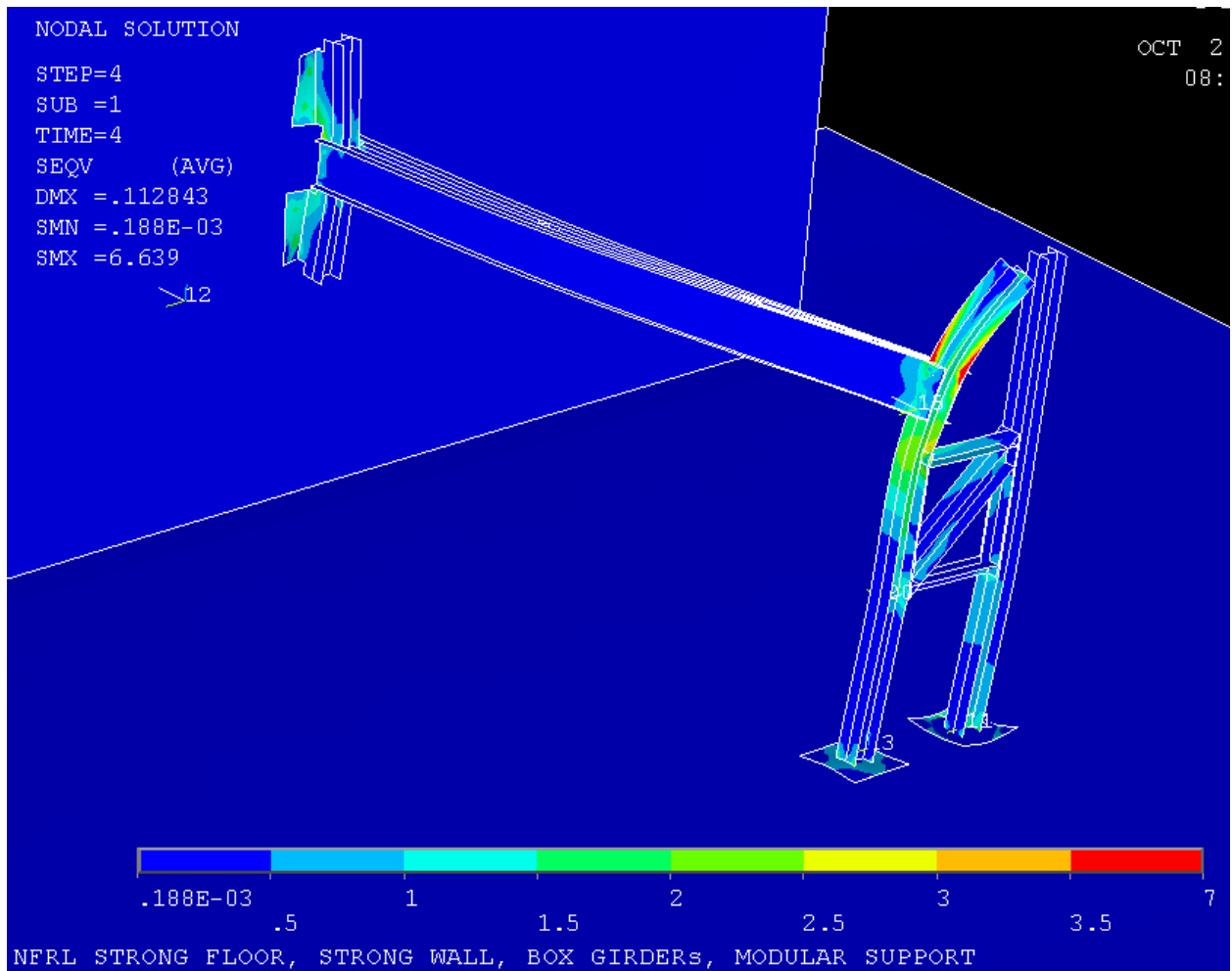


Fig. 14.10 Deformations and von Mises stress, detail.

! GRAND COMBINATION 20121002

! begin slab at x=0. East wall closed. west wall special. West box correctly placed.  
! all floor loading points at KP. prestressing KP both ways.  
! input to run 20120319 3pm success, equilibrium satisfied.  
! 20120418 constrained axial rotation of loading beams as SOLID 185 nodes have no rotation DOF.  
! A good alternative to using BEAM188 as loading beam is to use SURF156,  
! which has an orientation node in addition to 2 end nodes and possibly a middle node.

```
FINISH
/CLEAR
/CWD,'C:\StrongFireLab'
/FILNAME,20121001,0
/TITLE,NFRL STRONG FLOOR, STRONG WALL, BOX GIRDERS, MODULAR SUPPORT
/REPLOT
```

```
KEYW,PR_SET,1
KEYW,PR_STRUC,1
KEYW,PR_THERM,0
KEYW,PR_FLUID,0
KEYW,PR_MULTI,0
```

```
/PREP7
```

```
ET,1,BEAM188
SECTYPE, 1, BEAM, RECT, , 0
SECOFFSET, CENT
SECDATA,1,0.5,0,0,0,0,0,0,0
```

```
ET,2,SURF154
KEYOPT,2,2,0
KEYOPT,2,4,1
KEYOPT,2,6,0
KEYOPT,2,11,0
KEYOPT,2,12,0
R,2, , , , , ,
RMORE,.01,.01,.01,.01,
```

```
ET,3,SOLID185
```

```
ACEL,,1 ! gravity
```

```
! x is S to N, y is E to W, z is down to up
! units, kips, inch, degree C
! Mat 1 is for slab on grade, f'c = 3500 psi
TREF,25 ! T REFERENCE 25 C, also default TUNIF 9/25/2012
MPTEMP,,,,,,,,
MPTEMP,1,0
```

MPDATA,EX,1,,3372  
MPDATA,PRXY,1,,0.25  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,DENS,1,,8.33E-5 ! 144 LBF/FT^3

! Mat 2 is for foundation North box walls, f'c = 4000 psi

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,EX,2,,3605  
MPDATA,PRXY,2,,0.25  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,DENS,2,,8.33E-5

! Mat 3 is for foundation walls, f'c = 4000 psi

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,EX,3,,3605  
MPDATA,PRXY,3,,0.25  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,DENS,3,,8.33E-5

! Mat 4 is for columns, f'c = 5000 psi

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,EX,4,,4030  
MPDATA,PRXY,4,,0.25  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,DENS,4,,8.33E-5

! Mat 5 is for strong floor, f'c = 6000 psi

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,EX,5,,4415  
MPDATA,PRXY,5,,0.25  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,DENS,5,,8.33E-5

! Mat 6 is for strong wall, f'c = 6000 psi

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,6,,4415
MPDATA,PRXY,6,,0.25
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,DENS,6,,8.33E-5
```

! basement slab bottom, east edge

```
K,1,,,,
K,2,24,,,
K,3,42,,,
K,4,48,,,
K,5,56,,,
K,6,72,,,
K,7,168,,,
K,8,174,,,
K,9,192,,,
K,10,216,,,
K,11,234,,,

```

```
K,12,240,,,
K,13,408,,,
K,14,504,,,
K,15,528,,,
K,16,540,,,
K,17,552,,,
K,18,600,,,
K,19,720,,,
K,20,774,,,
K,21,864,,,
K,22,880,,,
K,23,888,,,

```

```
*DO,I,1,22,1
  LSTR,I,I+1
*ENDDO
```

```
*DO,I,1,22,1
  LESIZE,I,,1,,,,,1
*ENDDO
```

```
LESIZE,6,24,,,,,,1
LESIZE,9,12,,,,,,1
LESIZE,12,12,,,,,,1
LESIZE,13,12,,,,,,1
LESIZE,14,,2,,,,,1
```

LESIZE,17,12,,,,,1  
LESIZE,18,24,,,,,1  
LESIZE,19,,4,,,,1  
LESIZE,20,,4,,,,1  
LESIZE,21,,2,,,,1

CM,BSMT\_EAST,LINE

! basement slab bottom, south edge, NOW AT X=0

K,30,,  
K,31,,18,  
K,32,,34,  
K,33,,69,  
K,34,,117,  
K,35,,138,  
K,36,,141,

K,37,,154, !PS  
K,38,,165,  
K,39,,189,  
K,40,,201,  
K,41,,213,

K,42,,217,  
K,43,,237,  
K,44,,258,  
K,45,,261,  
K,46,,274,

K,47,,285,  
K,48,,357,  
K,49,,378,  
K,50,,381,  
K,51,,394,

K,52,,405,  
K,53,,489,  
K,54,,498,  
K,55,,501,  
K,56,,514,

K,57,,525,  
K,58,,609,  
K,59,,618,  
K,60,,621,  
K,61,,634,

K,62,,645,  
K,63,,729,  
K,64,,738,  
K,65,,741,  
K,66,,754,

K,67,,765,  
K,68,,837,  
K,69,,858,  
K,70,,861,  
K,71,,874,

K,72,,885,  
K,73,,905,  
K,74,,909,  
K,75,,921,  
K,76,,933,  
K,77,,957,

K,78,,978, !PS  
K,79,,981,  
K,80,,994,  
K,81,,1005,  
K,82,,1053,  
K,83,,1098,  
K,84,,1114,  
K,85,,1242,

\*DO,I,30,84,1  
LSTR,I,I+1  
\*ENDDO

\*DO,I,23,77,1  
LESIZE,I,,1,,,,,1  
\*ENDDO

LESIZE,24,,2,,,,,1  
LESIZE,25,,2,,,,,1  
LESIZE,26,24,,,,,,1  
LESIZE,29,,2,,,,,1  
LESIZE,31,12,,,,,,1  
LESIZE,33,,2,,,,,1  
LESIZE,35,,2,,,,,1  
LESIZE,36,,2,,,,,1  
LESIZE,38,,2,,,,,1  
LESIZE,40,12,,,,,,1

LESIZE,41,,2,,,,,1



```
LESIZE,43,,2,,,,1
LESIZE,45,12,,,,,1
LESIZE,48,,2,,,,1
LESIZE,50,12,,,,,1
LESIZE,53,,2,,,,1
LESIZE,55,12,,,,,1
LESIZE,58,,2,,,,1
LESIZE,60,12,,,,,1
LESIZE,61,,2,,,,1
```

```
LESIZE,63,,2,,,,1
LESIZE,65,,2,,,,1
LESIZE,67,,2,,,,1
LESIZE,69,,2,,,,1
LESIZE,70,,2,,,,1
LESIZE,72,,2,,,,1
LESIZE,74,12,,,,,1
LESIZE,75,,2,,,,1
LESIZE,76,,2,,,,1
LESIZE,77,,6,,,,1
```

```
LSEL,S,LINE,,23,77,1,1
CM,BSMT_SOUTH,LINE
ALLSEL,ALL
```

! construct vertical edge of strong wall

```
K,100,774,201,,
K,200,774,201,24
K,300,774,201,132
K,400,774,201,174
K,500,774,201,180
K,600,774,201,252
K,700,774,201,468
K,800,774,201,540
```

```
*DO,I,100,700,100
LSTR,I,I+100
*ENDDO
```

```
LESIZE,78,,1,,,,1
LESIZE,79,,9,,,,1
LESIZE,80,,4,,,,1
LESIZE,81,,1,,,,1
LESIZE,82,12,,,,,1
LESIZE,83,12,,,,,1
LESIZE,84,24,,,,,1
```

! ORIENTATION KP FOR LOADING STRIPS

K,350,387,339,153

K,510,747,561,180

! create loading strips for post-tensioning

! create lines at east and west edges of midfloor thickness

```
LSEL,S,LOC,X,174,600,,
LSEL,R,LOC,Y,,1,,
LSEL,R,LOC,Z,,1,,
CM,PS_EAST,LINE
LGEN,2,ALL,,,,18,153,,,,
```

```
LSEL,S,LOC,X,174,600,,
LSEL,R,LOC,Y,17,19,,
LSEL,R,LOC,Z,152,154,,
CM,PSFLOOR_EAST,LINE
```

```
CMSEL,S,PS_EAST,LINE
LGEN,2,ALL,,,,1114,153,,,,
```

```
LSEL,S,LOC,X,174,600,,
LSEL,R,LOC,Y,1113,1115,,
LSEL,R,LOC,Z,152,154,,
CM,PSFLOOR_WEST,LINE
```

! create lines at top and bottom of strong wall and corner with floor

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,201,921,,
LSEL,R,LOC,Z,,1,,
CM,PS_SOUTH,LINE
LGEN,2,ALL,,,,747,,540,,,,
```

```
LSEL,S,LOC,X,746,748,,
LSEL,R,LOC,Y,201,921,,
LSEL,R,LOC,Z,539,541,,
CM,PSWALL_TOP,LINE
```

```
CMSEL,S,PS_SOUTH,LINE
LGEN,2,ALL,,,,747,,,,,
```

```
LSEL,S,LOC,X,746,748,,
LSEL,R,LOC,Y,201,921,,
LSEL,R,LOC,Z,,1,,
CM,PSWALL_BOTTOM,LINE
```

```
CMSEL,S,PS_SOUTH,LINE
!LGEN,2,ALL,,,720,,180,,,, !9.20.2012 move to back of wall
LGEN,2,ALL,,,774,,180,,,,
```

```
!LSEL,S,LOC,X,719,721,, !9.20.2012 move to back of wall
LSEL,S,LOC,X,773,775,,
LSEL,R,LOC,Y,201,921,,
LSEL,R,LOC,Z,179,181,,
CM,WALL_FLOOR,LINE
```

! create lines at north and south edges of midfloor thickness

```
CMSEL,S,PS_SOUTH,LINE
LGEN,2,ALL,,,,,153,,,
CMSEL,S,PS_SOUTH,LINE
LGEN,2,ALL,,,774,,153,,,,
```

! extend lines at north edge of midfloor thickness beyond y of strong wall

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,154,201,,
LSEL,R,LOC,Z,,1,,
CM,PS_SOUTHEAST,LINE
LGEN,2,ALL,,,720,,153,,,,
CMSEL,S,PS_SOUTHEAST,LINE
LGEN,2,ALL,,,,,153,,,,
```

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,921,978,,
LSEL,R,LOC,Z,,1,,
CM,PS_SOUTHWEST,LINE
LGEN,2,ALL,,,720,,153,,,,
CMSEL,S,PS_SOUTHWEST,LINE
LGEN,2,ALL,,,,,153,,,,
```

```
LSEL,S,LOC,X,,1,,
LSEL,R,LOC,Y,154,978,,
LSEL,R,LOC,Z,152,154,,
CM,PSFLOOR_SOUTH,LINE
```

! THE FOLLOWING IS A BETTER WAY TO SELECT LINES.  
! BY USING KEYPOINTS ONE AVOIDS LINES THAT INTERSECT WHAT IS SELECTED.

```
KSEL,S,LOC,Z,152,154,,
KSEL,R,LOC,X,720,774,,
KSEL,R,LOC,Y,154,978,,
LSLK,S,1
CM,PSFLOOR_NORTH,LINE
```

! construct basement bottom

```
ALLSEL,ALL
ADRAG,BSMT_SOUTH,,,,,BSMT_EAST,,,,,
ASEL,S,LOC,Z,,1
ASEL,R,LOC,X,24,888
ASEL,R,LOC,Y,,1242
CM,BSMT_BOTTOM,AREA
```

! construct basement slab

```
VDRAG,ALL,,,,,78,,,,,
VATT,1
CM,BSMT_SLAB,VOLU
```

! BASE OF STRONG FLOOR

```
ASEL,S,LOC,Z,,1
ASEL,R,LOC,X,,720
ASEL,R,LOC,Y,18,1114
CM,FLOOR,AREA
```

! bases of 4 north-South walls, southeast part

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,138,154
CM,BASE_SOUTH2,AREA
```

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,258,274
CM,BASE_SOUTH3,AREA
```

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,378,394
CM,BASE_SOUTH4,AREA
```

```
ASEL,S,LOC,Z,23,25
ASEL,R,LOC,X,56,174
ASEL,R,LOC,Y,498,514
CM,BASE_SOUTH5,AREA
```

```
CMGRP,BASE_SOUTH_EAST,BASE_SOUTH2,BASE_SOUTH3,BASE_SOUTH4,BASE_SOUTH5
```

! bases of 4 north-South walls, southwest part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,618,634  
CM,BASE\_SOUTH6,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,738,754  
CM,BASE\_SOUTH7,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,858,874  
CM,BASE\_SOUTH8,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,174  
ASEL,R,LOC,Y,978,994  
CM,BASE\_SOUTH9,AREA

CMGRP,BASE\_SOUTH\_WEST,BASE\_SOUTH6,BASE\_SOUTH7,BASE\_SOUTH8,BASE\_SOUTH9

! bases of 4 north-South walls, middle east part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,138,154  
CM,BASE\_MIDDLE2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,258,274  
CM,BASE\_MIDDLE3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,378,394  
CM,BASE\_MIDDLE4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,498,514  
CM,BASE\_MIDDLE5,AREA

CMGRP,BASE\_MIDDLE\_EAST,BASE\_MIDDLE2,BASE\_MIDDLE3,BASE\_MIDDLE4,BASE\_MIDDLE5

! bases of 5 north-South walls, middle west part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,618,634  
CM,BASE\_MIDDLE6,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,738,754  
CM,BASE\_MIDDLE7,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,858,874  
CM,BASE\_MIDDLE8,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,234,540  
ASEL,R,LOC,Y,978,994  
CM,BASE\_MIDDLE9,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,174,408  
ASEL,R,LOC,Y,1098,1114  
CM,BASE\_MIDDLE10,AREA

CMGRP,BASE\_MIDDLE\_WEST,BASE\_MIDDLE6,BASE\_MIDDLE7,BASE\_MIDDLE8,BASE\_MIDDLE9,BASE\_MIDDLE10

! bases of 4 north-South walls, NORTH east part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,138,154  
CM,BASE\_NORTH2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,258,274  
CM,BASE\_NORTH3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,378,394  
CM,BASE\_NORTH4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720

ASEL,R,LOC,Y,498,514  
CM,BASE\_NORTH5,AREA

CMGRP,BASE\_NORTH\_EAST,BASE\_NORTH2,BASE\_NORTH3,BASE\_NORTH4,BASE\_NORTH5

! bases of 5 north-South walls, NORTH west part

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,618,634  
CM,BASE\_NORTH6,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,738,754  
CM,BASE\_NORTH7,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,858,874  
CM,BASE\_NORTH8,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,600,720  
ASEL,R,LOC,Y,978,994  
CM,BASE\_NORTH9,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,504,720  
ASEL,R,LOC,Y,1098,1114  
CM,BASE\_NORTH10,AREA

CMGRP,BASE\_NORTH\_WEST,BASE\_NORTH6,BASE\_NORTH7,BASE\_NORTH8,BASE\_NORTH9,BASE\_NORTH10

CMGRP,BASE\_NS\_WALLS,BASE\_SOUTH\_EAST,BASE\_SOUTH\_WEST,BASE\_MIDDLE\_EAST,BASE\_MIDDLE\_WEST,BASE\_NORTH\_EAST,BASE\_NORTH\_WEST

! Northeast box

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,880  
ASEL,R,LOC,Y,18,34  
CM,BASE\_EBOX\_1,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,864,880  
ASEL,R,LOC,Y,34,201

CM,BASE\_EBOX\_2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,201,217  
CM,BASE\_EBOX\_3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,774  
ASEL,R,LOC,Y,18,201  
CM,BASE\_EBOX\_4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,18,217  
CM,BASE\_EBOX\_5,AREA

! NorthWest box

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,880  
ASEL,R,LOC,Y,1098,1114  
CM,BASE\_WBOX\_1,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,864,880  
ASEL,R,LOC,Y,921,1098  
CM,BASE\_WBOX\_2,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,905,921  
CM,BASE\_WBOX\_3,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,774  
ASEL,R,LOC,Y,921,1114  
CM,BASE\_WBOX\_4,AREA

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,774,880  
ASEL,R,LOC,Y,905,1114  
CM,BASE\_WBOX\_5,AREA

CMGRP,BASE\_BOX\_WALLS,BASE\_EBOX\_1,BASE\_EBOX\_2,BASE\_EBOX\_3,BASE\_WBOX\_1,BASE\_WBOX\_2,  
BASE\_WBOX\_3  
CMGRP,BASE\_BOXES,BASE\_EBOX\_4,BASE\_EBOX\_5,BASE\_WBOX\_4,BASE\_WBOX\_5



! EAST WALL

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,56,720  
ASEL,R,LOC,Y,18,34  
CM,BASE\_EASTWALL,AREA

! SOUTH WALL

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,42,56  
ASEL,R,LOC,Y,18,1114  
CM,BASE\_SOUTHWALL,AREA

! STRONG WALL

ASEL,S,LOC,Z,23,25  
ASEL,R,LOC,X,720,774  
ASEL,R,LOC,Y,201,921  
CM,BASE\_STRONGWALL,AREA

! BUILD BOX TOPS

ALLSEL,ALL  
CMSEL,S,BASE\_BOXES,AREA  
AGEN,2,ALL,,,,,150,,,  
ASEL,S,LOC,Z,173,175,,1  
VDRAG,ALL,,,,,,81,,,,,

! BUILD STRONG FLOOR

ALLSEL,ALL  
CMSEL,S,FLOOR,AREA  
AGEN,2,ALL,,,,,132,,,  
ASEL,S,LOC,Z,131,133  
VDRAG,ALL,,,,,,80,81,,,,  
vSEL,S,LOC,Z,132,180,,1  
VATT,5  
CM,STRONG\_FLOOR,VOLU

! RAISE 26 WALLS

ALLSEL,ALL  
CMSEL,S,BASE\_NS\_WALLS,AREA  
VDRAG,ALL,,,,,,79,,,,,  
vSEL,S,LOC,Z,24,132,,1  
!VSEL,U,VOLU,,STRONG\_FLOOR,,,  
VATT,3

CM,THIRTY\_WALLS,VOLU

! RAISE EAST WALL

ALLSEL,ALL  
CMSEL,S,BASE\_EASTWALL,AREA  
VDRAG,ALL,,,,,79,,,,,  
vSEL,S,LOC,Z,24,132,,1  
vSEL,R,LOC,X,56,720,  
vSEL,R,LOC,Y,18,34,  
!VSEL,U,VOLU,,STRONG\_FLOOR,,,  
VATT,3  
CM,EAST\_WALL,VOLU

! RAISE SOUTH WALL

ALLSEL,ALL  
CMSEL,S,BASE\_SOUTHWALL,AREA  
VDRAG,ALL,,,,,79,,,,,  
vSEL,S,LOC,Z,24,132,,1  
vSEL,R,LOC,X,42,56,,  
VATT,3  
CM,SOUTH\_WALL,VOLU

! RAISE STRONG WALL

ALLSEL,ALL  
CMSEL,S,BASE\_STRONGWALL,AREA  
VDRAG,ALL,,,,,79,80,81,82,83,84  
vSEL,S,LOC,Z,24,540,,1  
vSEL,R,LOC,X,720,774,,  
vSEL,R,LOC,Y,201,921,,  
VATT,6  
CM,STRONG\_WALL,VOLU

! RAISE BOX WALLS

ALLSEL,ALL  
CMSEL,S,BASE\_BOX\_WALLS,AREA  
VDRAG,ALL,,,,,79,80,,,,  
vSEL,S,LOC,Z,24,174,,1  
vSEL,R,LOC,X,720,880,,  
VSEL,U,VOLU,,STRONG\_WALL,,,  
VATT,2  
CM,BOX\_WALLS,VOLU

! ATTACH LOADING STRIPS TO EAST EDGE OF FLOOR  
CMSEL,S,PSFLOOR\_EAST,LINE

```
LATT,5,,1,,350,,1
LMESH,ALL
```

```
! ATTACH TO WEST EDGE OF FLOOR
CMSEL,S,PSFLOOR_WEST,LINE
LATT,5,,1,,350,,1
LMESH,ALL
```

```
! ATTACH TO TOP OF STRONG WALL
CMSEL,S,PSWALL_TOP,LINE
LATT,6,,1,,510,,1
LMESH,ALL
```

```
! ATTACH TO BOTTOM OF STRONG WALL
CMSEL,S,PSWALL_BOTTOM,LINE
LATT,1,,1,,510,,1
LMESH,ALL
```

```
! ATTACH TO SOUTH EDGE OF FLOOR
CMSEL,S,PSFLOOR_SOUTH,LINE
LATT,5,,1,,350,,1
LMESH,ALL
```

```
! ATTACH TO NORTH EDGE OF FLOOR VIA STRONG WALL
CMSEL,S,PSFLOOR_NORTH,LINE
LATT,5,,1,,350,,1
LMESH,ALL
```

```
! ATTACH TO CORNER OF STRONG WALL AND FLOOR TO REACT SHEAR ON TOP OF FLOOR
CMSEL,S,WALL_FLOOR,LINE
LATT,5,,1,,510,,1
LMESH,ALL
```

```
! mesh all volumes and merge all coincident items
ALLSEL,ALL
VMESH,ALL
NUMMRG,ALL,,,,
SAVE
```

```
! MODULAR SUPPORT ASSEMBLY
```

```
! column and foot
```

```
! UNITS SI for thermal W, J, degree C
! UNITS CUSTOMARY for structural in, kipm, kipf, ksi
```

```
! ##### material properties
```

! # Material # 10 - Steel for W sections, 50 KSI STEEL  
! thermal properties may be unnecessary for structural analysis  
! Young's modulus and Poisson's ratio

MPTEMP,,,,,,,,  
MPTEMP,1,25,100,200,300,400,500  
MPTEMP,7,600,700,800  
MPDATA,EX,10,1,30000,30000,27000,24000,21000,18000  
MPDATA,EX,10,7,9300,3900,2700

MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,PRXY,10,,0.30

! thermal expansion  
TREF,25 ! T REFERENCE 25 C, also default TUNIF  
MPTEMP,,,,,,,,  
MPTEMP,1,0  
MPDATA,ALPX,10,,14E-6 ! PER DEG C, EC3, Buchanan p. 194

!# steel conductivity W/(in.K)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,800  
MPTEMP,3,1200  
MPDATA,KXX,10,,1.37  
MPDATA,KXX,10,,0.693  
MPDATA,KXX,10,,0.693

!# steel heat capacity J/(kipm.K)  
MPTEMP  
MPTEMP,1,25  
MPTEMP,2,50  
MPTEMP,3,100  
MPTEMP,4,150  
MPTEMP,5,200  
MPTEMP,6,400  
MPTEMP,7,500  
MPTEMP,8,600  
MPDATA,C,10,,199500  
MPDATA,C,10,,208500  
MPDATA,C,10,,221200  
MPDATA,C,10,,231500  
MPDATA,C,10,,240300  
MPDATA,C,10,,274800  
MPDATA,C,10,,302300  
MPDATA,C,10,,344700

```
!# steel mass density
MPTEMP
MPTEMP,1,25
MPDATA,DENS,10,,2.636E-4 ! kipm/in3
```

```
! # Material # 11 - Steel for foot, 36 KSI
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,11,1,29999,29999,27000,24000,21000,18000
MPDATA,EX,11,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,11,,0.30
```

```
! thermal expansion
TREF,25 ! T REFERENCE 25 C, also default TUNIF
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,11,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,11,,1.37
MPDATA,KXX,11,,0.693
MPDATA,KXX,11,,0.693
```

```
!# steel heat capacity J/(kipm.K)
MPTEMP
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,11,,199500
MPDATA,C,11,,208500
MPDATA,C,11,,221200
MPDATA,C,11,,231500
MPDATA,C,11,,240300
```

MPDATA,C,11,,274800  
MPDATA,C,11,,302300  
MPDATA,C,11,,344700

!# steel mass density  
MPTEMP  
MPTEMP,1,25  
MPDATA,DENS,11,,2.636E-4 ! kipm/in3

! COLUMN AND FOOT

ET,5,SHELL181  
KEYOPT,5,1,0 ! bending and membrane stiffness  
KEYOPT,5,3,2 ! full integration with incompatible modes  
KEYOPT,5,8,0 ! store data at bottom of bottom layer and top of top layer  
KEYOPT,5,9,0 ! no user subroutine to define thickness  
KEYOPT,5,10,0 ! no initial stress

sect,2,shell,,foot  
secdata,2,11,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,3,shell,,12106f  
secdata,0.99,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,4,shell,,12106W  
secdata,0.61,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS, SUB 1=====

\*SET,KP1,8000  
\*SET,LIN1,19000  
\*SET,ARE1,15000  
\*SET,VOL1,5000  
\*SET,ELE1,67000  
\*SET,NOD1,85000

! # define model geometry, sheet 11/15 lower left fig  
! Local X parallel to flanges, point North.  
! Local Y parallel to web, point West.  
! Local Z points up.

! user input: origin of local coordinates = CENTER OF FOOT

```
!LOCAL,11,0,348,465.98,182, , , ,1,1,  
LOCAL,11,0,348,465.0,180.77, , , ,1,1,  
CSYS,11,
```

```
HEIGHT=240 ! COLUMN HEIGHT INCLUDES FOOTING, INCHES  
H=HEIGHT-1
```

```
! END OF user input=====
```

```
NUMSTR,KP,KP1  
NUMSTR,LINE,LIN1  
NUMSTR,AREA,ARE1  
NUMSTR,VOLU,VOL1  
NUMSTR,ELEM,ELE1  
NUMSTR,NODE,NOD1
```

```
! X SIDE OF FOOT  
K,KP1,-18,-18,0,  
K,KP1+1,-12,-18,0,  
K,KP1+2,-6.11,-18,0,  
K,KP1+3,-3.0,-18,0, ! 8.3 4pm  
K,KP1+4,0,-18,0,  
K,KP1+5,3.0,-18,0, ! 8.3 4pm  
K,KP1+6,6.11,-18,0,  
K,KP1+7,12,-18,0,  
K,KP1+8,18,-18,0,
```

```
! Y SIDE OF FOOT  
K,KP1+10,-18,-18,0,  
K,KP1+11,-18,-12,0,  
K,KP1+12,-18,-5.95,0,  
K,KP1+13,-18,0,0,  
K,KP1+14,-18,5.95,0,  
K,KP1+15,-18,12,0,  
K,KP1+16,-18,18,0,
```

```
! Z SIDE OF COLUMN OF HEIGHT 240 IN  
K,KP1+20,,,-5.95,0,  
K,KP1+21,,,-5.95,5,  
K,KP1+22,,,-5.95,H,  
! z distance between KP1+21 and KP1+22 must be multiple of 3 inches  
! HEIGHT = 3N = H + half thickness of foot
```

```
*DO,I,KP1,KP1+7,1  
LSTR,I,I+1  
*ENDDO
```

```
*DO,I,KP1+10,KP1+15,1
```

```

LSTR,I,I+1
*ENDDO

LSTR,KP1+20,KP1+21

LSEL,S,LINE,,LIN1+2,LIN1+5,,1
LESIZE,ALL,,,1,,,,0
ALLSEL,ALL
LESIZE,ALL,,2,,,,0

```

! ENSURE NODES AT HOLES ALONG COLUMN HEIGHT

```

LSTR,KP1+21,KP1+22
!KSEL,S,KP,,KP1+21,KP1+22,,
!LSLK,S,1
!*get, aa,line,0,num,min
!LESIZE,aa,3,,,,,1
LESIZE,LIN1+15,3,,,,,1

```

! BASE OF FOOT

```

KSEL,S,LOC,X,-18.1,18.1,,
KSEL,R,LOC,Y,-18.1,-17.9,,
KSEL,R,LOC,Z,,0.1,,
LSLK,S,1
CM,FOOTX,LINE

```

```

KSEL,S,LOC,X,-18.1,-17.9,,
KSEL,R,LOC,Y,-18.1,18.1,,
KSEL,R,LOC,Z,0,0.1,,
LSLK,S,1
CM,FOOTY,LINE

```

! height of column

```

KSEL,S,LOC,X,-0.1,0.1,,
KSEL,R,LOC,Y,-6.0,-5.90,,
KSEL,R,LOC,Z,,H,,
LSLK,S,1
CM,COLUMNZ,LINE

```

! foot area

```

ALLSEL,ALL
ADRAG,FOOTX,,,,,FOOTY,,,,,

```

! column flange 1

```

LSEL,S,LOC,X,-6.10,6.10,,
LSEL,R,LOC,Y,-6.0,-5.9,,
LSEL,R,LOC,Z,,0.1,,

```



CM,COLFLAN1,LINE

! column flange 2

LSEL,S,LOC,X,-6.10,6.10,,

LSEL,R,LOC,Y,5.9,6.0,,

LSEL,R,LOC,Z,,0.1,,

CM,COLFLAN2,LINE

! column WEB

LSEL,S,LOC,X,-.5,.5,,

LSEL,R,LOC,Y,-5.9,5.9,,

LSEL,R,LOC,Z,,0.1,,

CM,COLWEB,LINE

! column areas

ALLSEL,ALL

ADRAG,COLFLAN1,,,,,COLUMNZ,,,,,

ADRAG,COLFLAN2,,,,,COLUMNZ,,,,,

ADRAG,COLWEB,,,,,COLUMNZ,,,,,

! MESH FOOT

ASEL,S,LOC,Z,,0.1,,

AATT,11,,5,11,2

MSHAPE,0,2D

MSHKEY,1

AMESH,ALL

! mesh column web

ASEL,S,LOC,X,-.5,.5,,

ASEL,R,LOC,Y,-5.9,5.9,,

ASEL,R,LOC,Z,,H,,

AATT,10,,5,11,4

MSHAPE,0,2D

MSHKEY,1

AMESH,ALL

! MESH column flange 1

ASEL,S,LOC,X,-6.10,6.10,,

ASEL,R,LOC,Y,-6.0,-5.9,,

ASEL,R,LOC,Z,,H,,

AATT,10,,5,11,3

MSHAPE,0,2D

MSHKEY,1

AMESH,ALL

! MESH column flange 2

ASEL,S,LOC,X,-6.10,6.10,,

ASEL,R,LOC,Y,5.9,6.0,,

```
ASEL,R,LOC,Z,,H,,
AATT,10,,5,11,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
NUMMRG,ALL,,,,
```

```
! components
ASEL,S,AREA,,ARE1,ARE1+67,,1
CM,COLUMNFOOT,AREA
ALLSEL,ALL
SAVE
```

```
! WALL COLUMN AND FOOT
! WALL COLUMN
```

```
! # Material # 12 - Steel for shim
! Young's modulus and Poisson's ratio
```

```
MPTEMP,,,,,,,,
MPTEMP,1,25,100,200,300,400,500
MPTEMP,7,600,700,800
MPDATA,EX,12,1,29998,29998,27000,24000,21000,18000
MPDATA,EX,12,7,9300,3900,2700
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,PRXY,12,,0.30
```

```
! thermal expansion
```

```
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,ALPX,12,,14E-6 ! PER DEG C, EC3, Buchanan p. 194
```

```
!# steel conductivity W/(in.K)
```

```
MPTEMP
MPTEMP,1,25
MPTEMP,2,800
MPTEMP,3,1200
MPDATA,KXX,12,,1.37
MPDATA,KXX,12,,0.693
MPDATA,KXX,12,,0.693
```

```
!# steel heat capacity J/(kipm.K)
```

```
MPTEMP
```

```
MPTEMP,1,25
MPTEMP,2,50
MPTEMP,3,100
MPTEMP,4,150
MPTEMP,5,200
MPTEMP,6,400
MPTEMP,7,500
MPTEMP,8,600
MPDATA,C,12,,199502
MPDATA,C,12,,208502
MPDATA,C,12,,221202
MPDATA,C,12,,231502
MPDATA,C,12,,240302
MPDATA,C,12,,274802
MPDATA,C,12,,302300
MPDATA,C,12,,344700
```

```
!# steel mass density
MPTEMP
MPTEMP,1,25
MPDATA,DENS,12,,2.636E-4 ! kipm/in3
```

```
sect,8,shell,,shim
secdata,1.0,12,0,3
secoffset,MID
seccontrol,0,0,0, 0, 1, 1, 1
```

```
! USER INPUT: STARTING NUMBERS, SUB ZERO (NOT LETTER O)=====
```

```
*SET,KP0,8100
*SET,LINO,19200
*SET,ARE0,15100
*SET,VOLO,5000
*SET,ELE0,69000
*SET,NODO,88000
```

```
! # define model geometry
! user input:location of column (origin of local coordinates)
! ref: sheet 15/15 lower left fig
! Local X parallel to flanges, points North.
! Local Y parallel to web, points West.
! Local Z points up.
! location of WALL column (origin of local coordinates center of I at base)
```

```
!LOCAL,12,0,708,637,301.48, , , ,1,1,
LOCAL,12,0,708,637,300.25, , , ,1,1,
```

```
CSYS,12,
```

! END OF user input=====

NUMSTR,KP,KPO  
NUMSTR,LINE,LINO  
NUMSTR,AREA,AREO  
NUMSTR,VOLU,VOLO  
NUMSTR,ELEM,ELEO  
NUMSTR,NODE,NODO

! Y SIDE OF FOOT  
K,KPO,11,-18,5.75,  
K,KPO+1,11,-12,5.75,  
K,KPO+2,11,-5.95,5.75,  
K,KPO+3,11, ,5.75,  
K,KPO+4,11,5.95,5.75,  
K,KPO+5,11,12,5.75,  
K,KPO+6,11,18,5.75,

! Z SIDE OF FOOT  
K,KPO+10,11,-18,5.75  
K,KPO+11,11,-18,11.75  
K,KPO+12,11,-18,35.75  
K,KPO+13,11,-18,41.75

\*DO,I,KPO,KPO+5,1  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KPO+10,KPO+12,1  
LSTR,I,I+1  
\*ENDDO

KSEL,S,KP,,KPO,KPO+13,,  
LSLK,S,1  
LESIZE,ALL, , ,2, , , ,1  
KSEL,S,KP,,KPO+11,KPO+12,,  
LSLK,S,1  
\*get, aa,line,0,num,min  
LESIZE,aa,3, , , , ,1

KSEL,S,KP,,KPO,KPO+6,,  
LSLK,S,1  
CM,WALLFOOTY,LINE

KSEL,S,KP,,KPO+10,KPO+13,,  
LSLK,S,1  
CM,WALLFOOTZ,LINE

! X SIDE OF SHIM  
K,KP0+20,6.11,5.95,5.75  
K,KP0+21, 11,5.95,5.75  
LSTR,KP0+20,KP0+21  
KSEL,S,KP,,KP0+20,KP0+21,,  
LSLK,S,1  
LESIZE,ALL, , ,2, , , , ,1  
CM,SHIMX,LINE

! Z SIDE OF SHIM  
K,KP0+30,6.11,5.95, 5.75  
K,KP0+31,6.11,5.95,41.75  
LSTR,KP0+30,KP0+31  
KSEL,S,KP,,KP0+30,KP0+31,,  
LSLK,S,1  
LESIZE,ALL,3,, , , , , ,1  
CM,SHIMZ,LINE

! base of column web  
K,KP0+40,, -5.95,  
K,KP0+41,, -3.0,  
K,KP0+42,,,  
K,KP0+43,, 3.0,  
K,KP0+44,, 5.95,

\*DO,I,KP0+40,KP0+43,1  
LSTR,I,I+1  
\*ENDDO  
KSEL,S,KP,,KP0+40,KP0+44,,  
LSLK,S,1  
LESIZE,ALL, , ,1, , , , ,1  
CM,webbase,LINE

! base of column flange1  
K,KP0+50,-6.11, 5.95,  
K,KP0+51,-3.0 , 5.95,  
K,KP0+52, , 5.95,  
K,KP0+53, 3.0 , 5.95,  
K,KP0+54, 6.11, 5.95,

\*DO,I,KP0+50,KP0+53,1  
LSTR,I,I+1  
\*ENDDO  
KSEL,S,KP,,KP0+50,KP0+54,,  
LSLK,S,1  
LESIZE,ALL, , ,1, , , , ,1  
CM,flange1base,LINE

! base of columnn flange2

K,KP0+60,-6.11,-5.95,  
K,KP0+61,-3.0,-5.95,  
K,KP0+62,,-5.95,  
K,KP0+63,3.0,-5.95,  
K,KP0+64,6.11,-5.95,

\*DO,I,KP0+60,KP0+63,1

LSTR,I,I+1

\*ENDDO

KSEL,S,KP,,KP0+60,KP0+64,,

LSLK,S,1

LESIZE,ALL,,1,,,,1

CM,flange2base,LINE

! columnn height

K,KP0+70,,,

K,KP0+71,,,2.75

K,KP0+72,,,116.75

K,KP0+73,,,119.5

LSTR,KP0+70,KP0+71

KSEL,S,KP,,KP0+70,KP0+71,,

LSLK,S,1

LESIZE,ALL,,1,,,,1

allsel,all

LSTR,KP0+71,KP0+72

KSEL,S,KP,,KP0+71,KP0+72,,

LSLK,S,1

LESIZE,ALL,3,,,,,1

ALLSEL,ALL

LSTR,KP0+72,KP0+73

KSEL,S,KP,,KP0+72,KP0+73,,

LSLK,S,1

LESIZE,ALL,,1,,,,1

KSEL,S,KP,,KP0+70,KP0+73,,

LSLK,S,1

CM,wallcolhi,LINE

ALLSEL,ALL

! areas

ADRAG,webbase,,,,,wallcolhi,,,,,

ADRAG,flange1base,,,,,wallcolhi,,,,,

ADRAG,flange2base,,,,,wallcolhi,,,,,

ADRAG,SHIMX,,,,,SHIMZ,,,,,

ADRAG,WALLFOOTY,,,,,,WALLFOOTZ,,,,,,

! mesh column web

ASEL,S,LOC,y,-6,6,,  
ASEL,R,LOC,x,-1,.1,,  
ASEL,R,LOC,Z,,120,,  
AATT,10,,5,12,4  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH columnn flange 1

ASEL,S,LOC,X,-6.12,6.12,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,,120,,  
AATT,10,,5,12,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH columnn flange 2

ASEL,S,LOC,X,-6.12,6.12,,  
ASEL,R,LOC,Y,-5.9,-6.0,,  
ASEL,R,LOC,Z,,120,,  
AATT,10,,5,12,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH SHIM

ASEL,S,LOC,X,6.10,11.1,,  
ASEL,R,LOC,Y,5.9,6.0,,  
ASEL,R,LOC,Z,5.7,42,,  
AATT,12,,5,12,8  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! MESH FOOT

ASEL,S,LOC,X,10.9,11.1,,  
ASEL,R,LOC,Y,-19,19,,  
ASEL,R,LOC,Z,5.7,42,,  
AATT,11,,5,12,2  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

! DUPLICATE

```
ASEL,S,MAT,,12      ! shim
AGEN,2,ALL,,,,-11.9,,,,
ALLSEL,ALL
```

```
ASEL,S,LOC,X,10.9,11.1,, ! foot
ASEL,R,LOC,Y,-19,19,,
ASEL,R,LOC,Z,5.7,42,,
ASEL,A,MAT,,12      ! shims again
!ASEL,A,MAT,,11     ! foot
AGEN,2,ALL,,,,72,,,,
```

```
ALLSEL,ALL
NUMMRG,ALL,,,,
```

```
! components
ASEL,S,AREA,,ARE0,ARE0+75,,1
CM,WALLCOLUMNFOOT,AREA
ALLSEL,ALL
save
```

```
! FRAME
! LAST TESTED on Thu 7.20.2012 4 pm
```

```
! USER INPUT: STARTING NUMBERS=====
*SET,KP2,8400
*SET,LIN2,19600
*SET,ARE2,15300
*SET,VOL2,5000
*SET,ELE2,70200
*SET,NOD2,89500
```

```
! # define model geometry
! user input:local coord system and location of frame
! ref: SHEET 1/15 LOWER LEFT FIG
! Local X ALONG EDGE OF LOWEST HORIZ MEMBER.
! Local Y perpendicular to web, right hand system.
! Local Z ALONG RIGHT EDGE OF RIGHT VERTICAL MEMBER.
! location of FRAME (origin of local coordinates: BASE OF FRAME,
! INTERSECTION OF HORIZ, VERT AND DIAG,LOWER RIGHT CORNER)
```

```
!LOCAL,13,0,348,530.01,186, , , ,1,1
LOCAL,13,0,348,530.01,184.77, , , ,1,1
CSYS,13,
```

```
! END OF user input=====
```

```
NUMSTR,KP,KP2
NUMSTR,LINE,LIN2
```



NUMSTR,AREA,ARE2  
NUMSTR,VOLU,VOL2  
NUMSTR,ELEM,ELE2  
NUMSTR,NODE,NOD2

! x horiz edge of bottom web

K,KP2,,,  
K,KP2+1,6.233,, ! diag at 43.693 deg to horiz  
K,KP2+2,9.06,,  
K,KP2+3,17.06,,  
K,KP2+4,29.06,, ! reference hole at midlength  
K,KP2+5,41.06,,  
K,KP2+6,49.06,,  
K,KP2+7,52.165,,  
K,KP2+8,55.1425,,  
K,KP2+9,58.12,,

! Z vert midthickness of flange

K,KP2+10,,,  
K,KP2+11,,,3  
K,KP2+12,,,5.955 ! 5.955 = depth of WT 6X53 > half depth of I = 11.91/2  
K,KP2+13,,,9  
K,KP2+14,,,12  
K,KP2+15,,,14.319 ! worse mesh if hole at z = 15.0  
K,KP2+16,,,16.472,  
K,KP2+17,,,19.3165  
K,KP2+18,,,22.161  
K,KP2+19,,,24  
K,KP2+20,,,63  
K,KP2+21,,,66.045  
K,KP2+22,,,69  
K,KP2+23,,,72

! diagonal web lower edge

K,KP2+30,,,  
K,KP2+31,3.140,,3.  
K,KP2+32,6.233,,5.955  
K,KP2+33,8.227,,7.860  
K,KP2+34,11.2045,,10.705  
K,KP2+35,14.182 ,,13.550  
K,KP2+36,52.165 ,,49.839  
K,KP2+37,55.1425,,52.6835  
K,KP2+38,58.12 ,,55.528

! diagonal web upper edge

K,KP2+40,,,16.472  
K,KP2+41,2.9775,,19.3165  
K,KP2+42,5.955,,22.161

K,KP2+43,43.938,,58.450  
K,KP2+44,46.9155,,61.295  
K,KP2+45,49.893,,64.140  
K,KP2+46,51.887,,66.045  
K,KP2+47,54.980,,69.  
K,KP2+48,58.12,,72

! FLANGE edges  
! of lower horiz.

K,KP2+50,, ,  
K,KP2+51,, 3,  
K,KP2+52,, 6.11,  
K,KP2+53,, -3,  
K,KP2+56,,-6.11,

! flange edge of vertical at upper intersection with diagonal

K,KP2+60,, ,16.472  
K,KP2+61,, 3,16.472  
K,KP2+62,, 6.11,16.472  
K,KP2+63,, -3,16.472  
K,KP2+66,,-6.11,16.472

! vertical edge of web of horizontal

K,KP2+70,6.233,,  
K,KP2+71,6.233,,3.0  
K,KP2+72,6.233,,5.955

! diagonal web body

K,KP2+80, 8.227,,7.860  
K,KP2+81,6.17025,,10.013  
K,KP2+82, 4.1135,,12.166  
K,KP2+83,2.05675,,14.319  
K,KP2+84, ,,,16.472

! non extruded, disturbed zones

K,KP2+90, 2.9775,,22.161  
K,KP2+91, 3.1165,,5.955  
K,KP2+92,3.085125,,9.5065  
K,KP2+93, 2.05675,,12.083

! LINES

\*DO,I,KP2,KP2+8,1 ! x horiz edge of bottom web  
LSTR,I,I+1  
\*ENDDO

\*DO,I,KP2+2,KP2+5,1 ! x horiz edge of bottom web  
KSEL,S,KP,,I,I+1,,  
LSLK,S,1

```

LESIZE,ALL,3.0, , , ,0 , , ,0
*ENDDO
ALLSEL,ALL

*DO,I,KP2+10,KP2+22,1 ! Z vert midthickness of flange
LSTR,I,I+1
*ENDDO

KSEL,S,KP,,KP2+19,KP2+20,,
LSLK,S,1
LESIZE,ALL,3.0, , , ,0 , , ,0
ALLSEL,ALL

*DO,I,KP2+30,KP2+37,1 ! diagonal web lower edge
LSTR,I,I+1
*ENDDO

KSEL,S,KP,,KP2+35,KP2+36,,
LSLK,S,1
LESIZE,ALL, , ,17, ,0 , , ,0
ALLSEL,ALL

*DO,I,KP2+40,KP2+47,1 ! diagonal web upper edge
LSTR,I,I+1
*ENDDO

KSEL,S,KP,,KP2+42,KP2+43,,
LSLK,S,1
LESIZE,ALL, , ,17, ,0 , , ,0
ALLSEL,ALL

*DO,I,KP2+33,KP2+38,1 ! diagonal web body
LSTR,I,I+7
KSEL,S,KP,,I,I+7,7,
LSLK,S,1
LESIZE,ALL, , ,4, ,0 , , ,0
ALLSEL,ALL
*ENDDO

LSTR,KP2+50,KP2+51 ! +y flange base of vertical
LSTR,KP2+51,KP2+52
LSTR,KP2+50,KP2+53 ! -y flange base of vertical
LSTR,KP2+53,KP2+56
LSTR,KP2+60,KP2+61 ! +y flange base of diagonal
LSTR,KP2+61,KP2+62
LSTR,KP2+60,KP2+63 ! -y flange base of diagonal
LSTR,KP2+63,KP2+66

```

LSTR,KP2+70,KP2+71 ! web of horiz  
LSTR,KP2+71,KP2+72 ! save db L=19600 to 19650  
LSTR,KP2+18,KP2+90 ! web of vert  
LSTR,KP2+90,KP2+42 ! L=19651,2

! non extruded smaller zone  
LSTR,KP2+17,KP2+41 ! L=19653  
LSTR,KP2+41,KP2+90 ! L=19654

! non extruded larger zone  
LSTR,KP2+15,KP2+83 ! L=19655  
LSTR,KP2+14,KP2+93 ! L=19656  
LSTR,KP2+93,KP2+82 ! L=19657  
LSTR,KP2+13,KP2+92 ! L=19658  
LSTR,KP2+92,KP2+81 ! L=19659  
LSTR,KP2+12,KP2+91 ! L=19660  
LSTR,KP2+91,KP2+32 ! L=19661

LSTR,KP2+91,KP2+92 ! L=19662  
LSTR,KP2+92,KP2+93 ! L=19663  
LSTR,KP2+93,KP2+83 ! L=19664  
LSTR,KP2+32,KP2+81 ! L=19665  
LSTR,KP2+92,KP2+82 ! L=19666

KSEL,S,KP,,KP2,KP2+93,,  
LSLK,S,1  
LESIZE,ALL,4.4, , , ,0, , ,0 ! default element size

LSTR,KP2+16,KP2+41  
KSEL,S,KP,,KP2+16,KP2+41,25,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+16,KP2+83  
KSEL,S,KP,,KP2+16,KP2+83,67,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+41,KP2+42  
KSEL,S,KP,,KP2+41,KP2+42,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+33,KP2+81  
KSEL,S,KP,,KP2+33,KP2+81,48,

LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+81,KP2+82  
KSEL,S,KP,,KP2+81,KP2+82,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

LSTR,KP2+82,KP2+83  
KSEL,S,KP,,KP2+82,KP2+83,1,  
LSLK,S,1  
LESIZE,ALL,4.4, ,0, ,1, , ,0  
ALLSEL,ALL

SAVE

! AREAS

! TRIANGLES

A,KP2+90,KP2+42,KP2+41  
A,KP2+17,KP2+41,KP2+16  
A,KP2+16,KP2+83,KP2+15  
A,KP2+83,KP2+82,KP2+93  
A,KP2+82,KP2+81,KP2+92  
A,KP2+93,KP2+82,KP2+92  
A,KP2+81,KP2+33,KP2+32

ASEL,S,AREA,,ARE2,ARE2+6,,1  
CM,TRIAREA,AREA  
ALLSEL,ALL

! QUADS

A,KP2+18,KP2+90,KP2+41,KP2+17  
A,KP2+15,KP2+83,KP2+93,KP2+14  
A,KP2+14,KP2+93,KP2+92,KP2+13  
A,KP2+13,KP2+92,KP2+91,KP2+12  
A,KP2+92,KP2+81,KP2+32,KP2+91

ASEL,S,AREA,,ARE2,ARE2+11,,1  
CM,DISTURB,AREA  
ALLSEL,ALL

KSEL,S,KP,,KP2,KP2+9,,  
LSLK,S,1  
CM,FULLX,LINE

KSEL,S,KP,,KP2+10,KP2+23,,

LSLK,S,1  
CM,FULLZ,LINE

KSEL,S,KP,,KP2+18,KP2+21,,  
LSLK,S,1  
CM,PARTZ,LINE

KSEL,S,KP,,KP2+30,KP2+38,,  
LSLK,S,1  
CM,lodiag,LINE

KSEL,S,KP,,KP2+40,KP2+48,,  
LSLK,S,1  
CM,hidiag,LINE

KSEL,S,KP,,KP2+50,KP2+52,1,  
LSLK,S,1  
CM,flangeplus,LINE

KSEL,S,KP,,KP2+50,KP2+56,3,  
LSLK,S,1  
CM,flangeminus,LINE

KSEL,S,KP,,KP2+60,KP2+62,1,  
LSLK,S,1  
CM,flandiagplus,LINE

KSEL,S,KP,,KP2+60,KP2+66,3,  
LSLK,S,1  
CM,flandiagminus,LINE

KSEL,S,KP,,KP2+70,KP2+72,1,  
LSLK,S,1  
CM,webhoriz,LINE

KSEL,S,KP,,KP2+18,KP2+42,24,  
KSEL,A,KP,,KP2+90  
LSLK,S,1  
CM,webvert,LINE

ALLSEL,ALL

!!\*GET,AMAX1,AREA,0,NUM,MAX

! diagonal web areas  
A,KP2+33,KP2+34,KP2+41,KP2+40  
\*DO,I,KP2+34,KP2+37,1  
A,I,I+1,I+8,I+7

```

*ENDDO

ASEL,S,AREA,,ARE2,ARE2+16,,1
CM,DIAWEBTURB,AREA ! DIAGONAL WEB AND DISTURBED AREAS=D
ALLSEL,ALL

! areas
ADRAG,lodiag,,,,,flangeplus,,,,,
ASEL,S,AREA,,ARE2,ARE2+32,,1
CM,DLOPLUS,AREA ! DIAGONAL WEB,DISTURBED AND LOW PLUS DIAG FLANGE AREAS
ALLSEL,ALL

ADRAG,lodiag,,,,,flangeminus,,,,,
ASEL,S,AREA,,ARE2,ARE2+48,,1
CM,DLODIAG,AREA ! DIAGONAL WEB,DISTURBED AND LOW DIAG FLANGE AREAS
ALLSEL,ALL

ADRAG,hidiag,,,,,flandiagplus,,,,,
ASEL,S,AREA,,ARE2,ARE2+64,,1
CM,DLOHIPLUS,AREA ! DIAGONAL WEB,DISTURBED,LOW DIAG FLANGE AND HIGH PLUS DIAG FLANGE
AREAS
ALLSEL,ALL

ADRAG,hidiag,,,,,flandiagminus,,,,,
ASEL,S,AREA,,ARE2,ARE2+80,,1
CM,DLOHI,AREA ! DIAGONAL WEB,DISTURBED,LOW AND HIGH DIAG FLANGE AREAS
ALLSEL,ALL

ADRAG,FULLZ,,,,,flangeplus,,,,,
ADRAG,FULLZ,,,,,flangeminus,,,,,
ADRAG,partz,,,,,webvert,,,,,
ADRAG,fullx,,,,,flangeplus,,,,,
ADRAG,fullx,,,,,flangeminus,,,,,
ADRAG,fullx,,,,,WEBHORIZ,,,,,

ALLSEL,ALL
SAVE

! mesh webS
! MESH TRIANGLES
! much simpler to define elements by commands NKPT and E
CMSEL,S,TRIAREA,AREA
AATT,10,,5,13,4
MSHAPE,1,2D
MSHKEY,0
AMESH,ALL

! MESH QUADS

```

```
CMSEL,S,DISTURB,AREA
CMSEL,U,TRIAREA,AREA
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH DIAG WEB
CMSEL,S,DIWEBTURB,AREA
CMSEL,U,DISTURB,AREA
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH DIAG FLANGES
CMSEL,S,DLOHI,AREA
CMSEL,U,DIWEBTURB,AREA
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! MESH VERTICAL flange
ASEL,S,LOC,X,,.1,,
ASEL,R,LOC,Y,-6.2,6.2,,
ASEL,R,LOC,Z,,72,,
AATT,10,,5,13,3
MSHAPE,0,2D
MSHKEY,2
AMESH,ALL
```

```
! mesh VERTICAL web
ASEL,S,LOC,y,-.1,.1,,
ASEL,R,LOC,x,,6.0,,
ASEL,R,LOC,Z,22.0,72.0,,
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! mesh horizontal web
ASEL,S,LOC,y,-.1,.1,,
ASEL,R,LOC,x,,59.0,,
ASEL,R,LOC,Z,0,6.0,,
AATT,10,,5,13,4
MSHAPE,0,2D
MSHKEY,1
```



AMESH,ALL

! INVERT BOTTOM T

ASEL,S,LOC,Z,,0.1,,  
AGEN,2,ALL,,,,,5.955,,

! MESH HORIZONTAL FLANGE

ASEL,S,LOC,Z,5.9,6.0,,  
AATT,10,,5,13,3  
MSHAPE,0,2D  
MSHKEY,1  
AMESH,ALL

SAVE

! reflect and translate HORIZONTAL

ASEL,S,LOC,Z,,6.0,,  
ASEL,R,LOC,Y,-0.1,0.1,,  
ARSYM,X,ALL, , , ,0,0

ASEL,S,LOC,Z,5.9,6.0,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ARSYM,X,ALL, , , ,0,0

ASEL,S,LOC,Z,,6.0,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,U,LOC,X,,59,,  
ARSYM,Z,ALL, , , ,0,1

ALLSEL,ALL

ASEL,S,LOC,Z,-6,6,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,U,LOC,X,,59,,  
AGEN,2,ALL,,,,58.12,,72,,,,1  
ALLSEL,ALL

SAVE

! reflect and translate vertical

ASEL,S,LOC,Z,22,66.1,,  
ASEL,R,LOC,Y,-0.1,0.1,,  
ASEL,R,LOC,X,,6,,  
ARSYM,Z,ALL, , , ,0,0

ASEL,S,LOC,Z,,72,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,X,,0.1,,  
ARSYM,Z,ALL, , , ,0,0

CMSEL,S,DISTURB,AREA  
ARSYM,Z,ALL, , , 0,0

ALLSEL,ALL  
ASEL,S,LOC,Z,-72,72,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,X,,9,,  
ASEL,U,LOC,Z,,72,,  
ARSYM,X,ALL, , , 0,1

ALLSEL,ALL  
ASEL,S,LOC,Z,-72,72,,  
ASEL,R,LOC,Y,-6.2,6.2,,  
ASEL,R,LOC,X,-9,9,,  
ASEL,U,LOC,Z,,72,,  
AGEN,2,ALL,,,58.12,,72,,,1

ALLSEL,ALL  
NUMMRG,ALL,5.0E-3,,

! COMPONENTS  
ASEL,S,AREA,,ARE2,ARE2+352,,1  
CM,FRAME,AREA  
ALLSEL,ALL  
SAVE

! girder

! LAST TESTED 9.26.2012

sect,10,shell,,girderweb24W103  
secdata,0.550,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

sect,11,shell,,girderflange24W103  
secdata,0.980,10,0,3  
secoffset,MID  
seccontrol,0,0,0, 0, 1, 1, 1

! USER INPUT: STARTING NUMBERS=====

\*SET,KP4,9400  
\*SET,LIN4,21700  
\*SET,ARE4,16300  
\*SET,VOL4,5000  
\*SET,ELE4,72400  
\*SET,NOD4,92100

```

! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 12/15
! Local X ALONG midheight of web.
! Local Y perpendicular to web, right hand system.
! Local Z ALONG left vertical EDGE OF web.

!LOCAL,15,0,342,530.28,361, , , ,1,1
LOCAL,15,0,342,530.28,359.77, , , ,1,1
CSYS,15,
LENGTH=186.0 !half length of girder, must be > 126 and multiple of 3 inches.
!If length > 186, user may have to increase element and node starting numbers of subsequent
components.
!LENGTH=162.0
! END OF user input=====

NUMSTR,KP,KP4
NUMSTR,LINE,LIN4
NUMSTR,AREA,ARE4
NUMSTR,VOLU,VOL4
NUMSTR,ELEM,ELE4
NUMSTR,NODE,NOD4

! x horiz midheight of web, halfspan
K,KP4,,,
K,KP4+1,12.0,,
K,KP4+2,13.0,,
K,KP4+3,14.0,,
K,KP4+4,16.0,,
K,KP4+5,18.0,,
K,KP4+6,LENGTH,, !***

! Z vert midthickness of web
K,KP4+10,,,
K,KP4+11,,,9
K,KP4+12,,,11.775

! y width of half flange
K,KP4+20,,,11.775
K,KP4+21,,-4.5,11.775

! y width of full flange
K,KP4+30,18,4.5,11.775
K,KP4+31,18,-4.5,11.775

! FLANGE TRANSITION KEYPOINTS
K,KP4+40,13, -4.5,11.775

```

K,KP4+41,13,-2.25,11.775  
K,KP4+42,13, 0,11.775

K,KP4+50,14, -4.5,11.775  
K,KP4+51,14, -2.25,11.775  
K,KP4+52,14,.29795,11.775

K,KP4+60,15, -4.5,11.775  
K,KP4+61,15, -2.25,11.775  
K,KP4+62,15, 0,11.775  
K,KP4+63,14.73205,1,11.775  
K,KP4+64,15, 2.0,11.775  
K,KP4+65,15, 3.375,11.775  
K,KP4+66,15, 4.5,11.775

K,KP4+70,16, -4.5,11.775  
K,KP4+71,16,-2.25,11.775  
K,KP4+72,16, 0,11.775  
K,KP4+73,16,1.125,11.775  
K,KP4+74,16, 2.25,11.775  
K,KP4+75,16,3.375,11.775  
K,KP4+76,16, 4.5,11.775

K,KP4+80,18, -4.5,11.775  
K,KP4+81,18,-2.25,11.775  
K,KP4+82,18, 0,11.775  
K,KP4+83,18, 2.25,11.775  
K,KP4+84,18, 4.5,11.775

! LINES 0 to 5 x horiz midheight of web

\*DO,I,KP4,KP4+5,1

LSTR,I,I+1

\*ENDDO

LESIZE,lin4 ,3.0, ,0, ,0, , , ,0  
LESIZE,lin4+1,1.0, ,0, ,0, , , ,0  
LESIZE,lin4+2,1.0, ,0, ,0, , , ,0  
LESIZE,lin4+3,1.0, ,0, ,0, , , ,0  
LESIZE,lin4+4,2.0, ,0, ,0, , , ,0  
LESIZE,lin4+5,3.0, ,0, ,0, , , ,0  
LSEL,S,LINE,,LIN4,LIN4+5,,1  
CM,halfspanx,line  
ALLSEL,ALL

KSEL,S,KP,,KP4,KP4+2,1,  
LSLK,S,1  
CM,cutoffx,line

```
allsel,all
KSEL,S,KP,,KP4+5,KP4+6,1,
LSLK,S,1
CM,fullwidthx,line
```

```
allsel,all
! LINES 6 to 7 z vert midthickness of half web
*DO,I,KP4+10,KP4+11,1
LSTR,I,I+1
*ENDDO
```

```
LESIZE,lin4+6,3.0, ,0, ,0 , , ,0
LESIZE,lin4+7, 0, ,1, ,0 , , ,0
KSEL,S,KP,,KP4+10,KP4+12,1,
LSLK,S,1
CM,webdepthz,line
```

```
allsel,all
```

```
LSTR,KP4+20,KP4+21 ! L8 y width of half flange
LESIZE,lin4+8,0, ,2, ,0 , , ,0
LSEL,S,LINE,,LIN4+8,,,1
CM,halfwidthy,line
```

```
allsel,all
LSTR,KP4+30,KP4+31 ! L9 y width of full flange
LESIZE,lin4+9,0, ,4, ,0 , , ,0
allsel,all
LSEL,S,LINE,,LIN4+9,,,1
CM,fullwidthy,line
```

```
ALLSEL,ALL
CMSEL,S,cutoffx,line
LGEN,2,ALL,,,,,11.775,,, ! L10 TO 11
LSEL,S,LINE,,LIN4+10,LIN4+11,1,1
CM,cutoffx2,line
```

```
allsel,all
CMSEL,S,fullwidthx,line
LGEN,2,ALL,,,,,4.5,11.775,,, ! L12 TO 13
LSEL,S,LINE,,LIN4+12,LIN4+13,,1
CM,fullwidthx2,line
```

```
allsel,all
LSEL,S,LINE,,LIN4,LIN4+12,1,1
CM,REGULAR,LINE
allsel,all
```

! LINES IN CUTOFF REGION L14 TO L56

! Y LINES

LSTR,KP4+40,KP4+41

LSTR,KP4+41,KP4+42

LSTR,KP4+50,KP4+51

LSTR,KP4+51,KP4+52

\*DO,I,KP4+60,KP4+65,1

LSTR,I,I+1

\*ENDDO

\*DO,I,KP4+70,KP4+75,1

LSTR,I,I+1

\*ENDDO

\*DO,I,KP4+80,KP4+83,1

LSTR,I,I+1

\*ENDDO

! X LINES

\*DO,I,KP4+40,KP4+70,10

LSTR,I,I+10

\*ENDDO

\*DO,I,KP4+41,KP4+71,10

LSTR,I,I+10

\*ENDDO

\*DO,I,KP4+42,KP4+72,10

LSTR,I,I+10

\*ENDDO

LSTR,KP4+62,KP4+63

LSTR,KP4+63,KP4+52

LSTR,KP4+63,KP4+73

LSTR,KP4+73,KP4+82

LSTR,KP4+73,KP4+83

LSTR,KP4+64,KP4+74

LSTR,KP4+74,KP4+83

LSTR,KP4+65,KP4+75

LSTR,KP4+75,KP4+83

LSTR,KP4+75,KP4+84

LSTR,KP4+66,KP4+76

LSTR,KP4+76,KP4+84

ALLSEL,ALL

```
LSEL,S,LINE,,LIN4,LIN4+55,,1
CM,ALLINES,LINES
CMSEL,S,ALLINES,LINE
CMSEL,U,REGULAR,LINE
LESIZE,ALL,0,,1,,0,,0
CM,IRREGULAR,LINE
```

```
ALLSEL,ALL
! areas
*DO,I,KP4+40,KP4+70,10
A,I,I+10,I+11,I+1
*ENDDO
```

```
*DO,I,KP4+41,KP4+71,10
A,I,I+10,I+11,I+1
*ENDDO
```

```
A,KP4+52,KP4+62,KP4+63
A,KP4+62,KP4+72,KP4+73,KP4+63
A,KP4+72,KP4+82,KP4+73
A,KP4+73,KP4+82,KP4+83
A,KP4+63,KP4+73,KP4+74,KP4+64
A,KP4+73,KP4+83,KP4+74
A,KP4+64,KP4+74,KP4+75,KP4+65
A,KP4+74,KP4+83,KP4+75
A,KP4+75,KP4+83,KP4+84
A,KP4+65,KP4+75,KP4+76,KP4+66
A,KP4+75,KP4+84,KP4+76
```

```
ADRAG,halfspanx,,,,,webdepthz,,,,, ! Areas 0 to 9
ADRAG,cutoffx2,,,,,halfwidthy,,,,, ! Areas 10 to 11
ADRAG,fullwidthx2,,,,,fullwidthy,,,,, ! Areas 12 to 13
```

```
! MESH WEB
ASEL,S,LOC,Y,-0.1,0.1,,1
ASEL,R,LOC,Z,0,11.7,,
AATT,10,,5,15,10
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
ALLSEL,ALL
```

```
! MESH FLANGE
ASEL,S,LOC,Z,11.7,11.8,,1
ASEL,U,LOC,X,13,18,,1
AATT,10,,5,15,11
MSHAPE,0,2D
```

MSHKEY,1  
AMESH,ALL

ALLSEL,ALL

! MESH FLANGE TRANSITION

ASEL,S,LOC,Z,11.7,11.8,,1  
ASEL,R,LOC,X,13,18,,1  
AATT,10,,5,15,11  
MSHKEY,2  
AMESH,ALL  
ALLSEL,ALL

ASEL,S,AREA,,ARE4,ARE4+33,,1  
! reflect AND TRANSLATE  
ARSYM,Z,ALL, , , 0,0 ! from quarter to half  
ALLSEL,ALL

ASEL,S,AREA,,ARE4,ARE4+67,,1  
ARSYM,x,ALL, , , 0,0 ! from half to full  
ALLSEL,ALL

!ASEL,S,LOC,x,-186,0,,1  
ASEL,S,AREA,,ARE4+68,ARE4+135,,1 ! move new half to other end  
L=LENGTH\*2 !\*\*\*  
AGEN,2,ALL,,,L,,,,,1 !\*\*\*  
ALLSEL,ALL  
SAVE

! girder assembly A  
! y distance between 2 beams is  $12.89 + 0.55 = 13.44$   
! new beam is between  $y = -13.44 \pm 4.5$   
! if spacing between beams changes, these values must change

ASEL,S,AREA,,ARE4,ARE4+135,,1  
AGEN,2,ALL,,,0,-13.44,,,,0 ! double beam  
ASEL,S,LOC,y,-18,-8.9,,1 ! reflect  
ASEL,R,LOC,X,0,L,, ! 9/26/2012  
ASEL,R,LOC,Z,-11.8,11.8,, ! 9/26/2012  
ARSYM,Y,ALL, , , 0,1  
ALLSEL,ALL

! end of generation of 2nd beam and possible user input

NUMMRG,ALL

! CONSTRAIN TOP OF WEB WITH BEGINNING OF FULL FLANGE.  
! moving or duplicating girder by AGEN may be difficult because of constraints.



! best to move or duplicate girder without constraints, then reapply constraints at new location.

```
N1 = NODE(14,0,11.775)
N2 = NODE(14,.29795,11.775)
CP,NEXT,ALL,N1,N2
```

```
N3 = NODE(14,0,-11.775)
N4 = NODE(14,.29795,-11.775)
CP,NEXT,ALL,N3,N4
```

```
L1=LENGTH*2-14
```

```
N5 = NODE(L1,0,11.775)
N6 = NODE(L1,.29795,11.775)
CP,NEXT,ALL,N5,N6
```

```
N7 = NODE(L1,0,-11.775)
N8 = NODE(L1,.29795,-11.775)
CP,NEXT,ALL,N7,N8
```

! y location of couplings below depends on spacing between 2 beams  
! 13.44-.29795 = 13.14205

```
N9 = NODE(14,13.44,11.775)
N10 = NODE(14,13.14205,11.775)
CP,NEXT,ALL,N9,N10
```

```
N11 = NODE(14,13.44,-11.775)
N12 = NODE(14,13.14205,-11.775)
CP,NEXT,ALL,N11,N12
```

```
N13 = NODE(L1,13.44,11.775)
N14 = NODE(L1,13.14205,11.775)
CP,NEXT,ALL,N13,N14
```

```
N15 = NODE(L1,13.44,-11.775)
N16 = NODE(L1,13.14205,-11.775)
CP,NEXT,ALL,N15,N16 ! set 48 last
```

```
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE4,ARE4+271,,1
CM,GIRDER,AREA
ALLSEL,ALL
SAVE
```

! girder spacer

```
ET,6,BEAM188
SECTYPE, 15, BEAM, CTUBE, SCH80, 0
SECOFFSET, CENT
SECDATA,0.75,0.95,0,0,0,0,0,0,0,0 ! WHERE IS MAT DEFINED?
```

```
! USER INPUT: STARTING NUMBERS=====
```

```
*SET,KP6,10100
*SET,LIN6,22800
*SET,ARE6,16800
*SET,VOL6,5000
*SET,ELE6,79100
*SET,NOD6,101200
```

```
! # define model geometry
! user input:local coord system and location of girder
! ref: SHEET 14/15
! Local X ALONG flange.
! Local Y along web.
! Local Z ALONG length of spacer.
! origin at midthickness JUNCTION WEB-FLANGE.
```

```
!LOCAL,17,0,108,519.05,350.3, , , ,1,1
LOCAL,17,0,108,519.05,349.07, , , ,1,1
CSYS,17,
```

```
! END OF user input=====
```

```
NUMSTR,KP,KP6
NUMSTR,LINE,LIN6
NUMSTR,AREA,ARE6
NUMSTR,VOLU,VOL6
NUMSTR,ELEM,ELE6
NUMSTR,NODE,NOD6
```

```
K,KP6,-6.11,,
K,KP6+1,-3.0,,
K,KP6+2,,,
K,KP6+3,3.0,,
K,KP6+4,6.11,,
K,KP6+5,,11.9,
K,KP6+6,,,1.7
K,KP6+7,,,19.7
K,KP6+8,,,21.4
```

```
! LINES x
LSTR,KP6 ,KP6+1
LSTR,KP6+1,KP6+2
LSTR,KP6+2,KP6+3
```

```

LSTR,KP6+3,KP6+4

! LINES y
LSTR,KP6+2,KP6+5

! LINES z
LSTR,KP6+2,KP6+6
LSTR,KP6+6,KP6+7
LSTR,KP6+7,KP6+8

*DO,I,LIN6,LIN6+7,1
LESIZE,I ,0, ,1, ,0, , ,0
*ENDDO

LESIZE,LIN6+4,0, ,4,,1,0, ,0
LESIZE,LIN6+6,3.0, ,0,,1,0, ,0

! bushing lines
LGEN,2,LIN6+4,,,,3.0,,1.7,,, !L8
LGEN,2,LIN6+8,,,,,6.0,,, !L9
LGEN,2,LIN6+8,LIN6+9,1,,,12.0,,, !L10,11
LGEN,2,LIN6+8,LIN6+11,1,-6.0,,,,, !L12 to 15

! AREAS
ADRAG,LIN6 ,LIN6+1,,,,,LIN6+5,LIN6+6,LIN6+7,,,, ! flange- Areas
ADRAG,LIN6+5,LIN6+6,LIN6+7,,,,,LIN6+2,LIN6+3,,,,, ! flange+ Areas
ADRAG,LIN6+5,LIN6+6,LIN6+7,,,,,LIN6+4,,,,, ! web Areas

! MESH BUSHINGS
LSEL,S,LINE,,LIN6+8,LIN6+15,1,1
LATT,10,,6,,KP6+2,,15
LMESH,ALL

ALLSEL,ALL
ASEL,S,LOC,X,-.1,.1,,1
ASEL,R,LOC,Y,0,12,,1
ASEL,R,LOC,Z,0,21.5,,1
AATT,10,,5,17,4
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL

ALLSEL,ALL
! MESH LOWER FLANGE
ASEL,S,LOC,Y,-.1,.1,,1
ASEL,R,LOC,X,-6.11,6.11,,1
ASEL,R,LOC,Z,0,21.5,,1
AATT,10,,5,17,3

```

```
MSHAPE,0,2D
MSHKEY,1
AMESH,ALL
```

```
! COPY FLANGE
AGEN,2,ALL,,,,,11.9,,,,,
ALLSEL,ALL
NUMMRG,ALL
!even with no merge, spacer can only be copied in 2 steps,
!not moved (i.e. no new elements created).
SAVE
```

```
! COMPONENTS
ASEL,S,AREA,,ARE6,ARE6+26,,1
CM,GIRDERSPACER,AREA
ALLSEL,ALL
```

```
LSEL,S,LINE,,LIN6,LIN6+85,,1
CM,BUSHING,LINE
ALLSEL,ALL
SAVE
```

```
! finished with girder spacer
```

```
! ROTATE FRAME
!LOCAL,20,0,348,530.55,262,-90,,,1,1
LOCAL,20,0,348,530.06,260.77,-90,,,1,1
CSYS,13
CMSEL,S,FRAME,AREA
ATRA,20,ALL,,,,,1
CSYS,0
ALLSEL,ALL
SAVE
```

```
! MOVE WALLCOLUMNFOOT
CMSEL,S,WALLCOLUMNFOOT,AREA
AGEN,2,ALL,,,0,-100.0,0,,,1
ALLSEL,ALL
SAVE
```

```
! COPY COLUMNFOOT
```

```
*SET,KP7,10200
*SET,LIN7,22900
*SET,ARE7,16900
*SET,VOL7,5000
*SET,ELE7,79300
*SET,NOD7,101500
```

NUMSTR,KP,KP7  
NUMSTR,LINE,LIN7  
NUMSTR,AREA,ARE7  
NUMSTR,VOLU,VOL7  
NUMSTR,ELEM,ELE7  
NUMSTR,NODE,NOD7

CSYS,0  
CMSEL,S,COLUMNFOOT,AREA  
!AGEN,2,ALL,,,0,71.02,0,,,  
AGEN,2,ALL,,,0,72.00,0,,,  
ALLSEL,ALL

! components  
ASEL,S,AREA,,ARE7,ARE7+67,,1  
CM,COLUMNFOOT2,AREA  
ALLSEL,ALL  
SAVE

! COPY SPACER 1  
\*SET,KP8,10300  
\*SET,LIN8,23100  
\*SET,ARE8,17000  
\*SET,VOL8,5000  
\*SET,ELE8,80450  
\*SET,NOD8,102750

NUMSTR,KP,KP8  
NUMSTR,LINE,LIN8  
NUMSTR,AREA,ARE8  
NUMSTR,VOLU,VOL8  
NUMSTR,ELEM,ELE8  
NUMSTR,NODE,NOD8

CMSEL,S,BUSHING,LINE  
LGEN,2,ALL,,,360,12,0,,,0  
ALLSEL,ALL

CMSEL,S,GIRDERSPACER,AREA  
AGEN,2,ALL,,,360,12,0,,,0  
ALLSEL,ALL  
NUMMRG,ALL

! COMPONENTS  
LSEL,S,LINE,,LIN8,LIN8+85,,1  
CM,BUSHING1,LINE  
ALLSEL,ALL

```
ASEL,S,AREA,,ARE8,ARE8+26,,1
CM,GIRDERSPACER1,AREA
ALLSEL,ALL
SAVE
```

```
! copy SPACER 2
*SET,KP9,10400
*SET,LIN9,23250
*SET,ARE9,17050
*SET,VOL9,5000
*SET,ELE9,81000
*SET,NOD9,103000
```

```
NUMSTR,KP,KP9
NUMSTR,LINE,LIN9
NUMSTR,AREA,ARE9
NUMSTR,VOLU,VOL9
NUMSTR,ELEM,ELE9
NUMSTR,NODE,NOD9
```

```
CMSEL,S,BUSHING,LINE
LGEN,2,ALL,,,480,12,0,,,0
ALLSEL,ALL
```

```
CMSEL,S,GIRDERSPACER,AREA
AGEN,2,ALL,,,480,12,0,,,0
ALLSEL,ALL
NUMMRG,ALL
```

```
! COMPONENTS
LSEL,S,LINE,,LIN9,LIN9+85,,1
CM,BUSHING2,LINE
ALLSEL,ALL
```

```
ASEL,S,AREA,,ARE9,ARE9+26,,1
CM,GIRDERSPACER2,AREA
ALLSEL,ALL
SAVE
```

```
! bolt girder to column-foot2
! nod4=92100, nod7=101500
! could use notation nod4+x. nod7+y in case different numbering used
```

```
CP,NEXT,UX,94768,102374
CP,NEXT,UY,94768,102374
CP,NEXT,UZ,94768,102374
```

CP,NEXT,UX,95426,102368  
CP,NEXT,UY,95426,102368  
CP,NEXT,UZ,95426,102368

CP,NEXT,UX,94759,102137  
CP,NEXT,UY,94759,102137  
CP,NEXT,UZ,94759,102137

CP,NEXT,UX,94766,102140  
CP,NEXT,UY,94766,102140  
CP,NEXT,UZ,94766,102140

CP,NEXT,UX,95424,102134  
CP,NEXT,UY,95424,102134  
CP,NEXT,UZ,95424,102134

CP,NEXT,UX,94761,102371  
CP,NEXT,UY,94761,102371  
CP,NEXT,UZ,94761,102371

CP,NEXT,UX,92794,101968  
CP,NEXT,UY,92794,101968  
CP,NEXT,UZ,92794,101968

CP,NEXT,UX,92111,101974  
CP,NEXT,UY,92111,101974  
CP,NEXT,UZ,92111,101974

CP,NEXT,UX,92104,101971  
CP,NEXT,UY,92104,101971  
CP,NEXT,UZ,92104,101971

CP,NEXT,UX,92792,101734  
CP,NEXT,UY,92792,101734  
CP,NEXT,UZ,92792,101734

CP,NEXT,UX,92102,101737  
CP,NEXT,UY,92102,101737  
CP,NEXT,UZ,92102,101737

CP,NEXT,UX,92109,101740  
CP,NEXT,UY,92109,101740  
CP,NEXT,UZ,92109,101740 ! set 84 last

! bolt girder to wall-column  
! nod4=92100, nod0=88000  
! could use notation nod4+x. nod0+y in case different numbering used

CP,NEXT,UX,94108,88550  
CP,NEXT,UY,94108,88550  
CP,NEXT,UZ,94108,88550

CP,NEXT,UX,93443,88553  
CP,NEXT,UY,93443,88553  
CP,NEXT,UZ,93443,88553

CP,NEXT,UX,93450,88556  
CP,NEXT,UY,93450,88556  
CP,NEXT,UZ,93450,88556

CP,NEXT,UX,96740,88345  
CP,NEXT,UY,96740,88345  
CP,NEXT,UZ,96740,88345

CP,NEXT,UX,96075,88348  
CP,NEXT,UY,96075,88348  
CP,NEXT,UZ,96075,88348

CP,NEXT,UX,96082,88351  
CP,NEXT,UY,96082,88351  
CP,NEXT,UZ,96082,88351

CP,NEXT,UX,96742,88231  
CP,NEXT,UY,96742,88231  
CP,NEXT,UZ,96742,88231

CP,NEXT,UX,96077,88234  
CP,NEXT,UY,96077,88234  
CP,NEXT,UZ,96077,88234

CP,NEXT,UX,96084,88237  
CP,NEXT,UY,96084,88237  
CP,NEXT,UZ,96084,88237

CP,NEXT,UX,94110,88436  
CP,NEXT,UY,94110,88436  
CP,NEXT,UZ,94110,88436

CP,NEXT,UX,93445,88439  
CP,NEXT,UY,93445,88439  
CP,NEXT,UZ,93445,88439

CP,NEXT,UX,93452,88442  
CP,NEXT,UY,93452,88442  
CP,NEXT,UZ,93452,88442 ! set 120 last



! bolt frame to column-foot2  
! nod2=89500, nod7=101500  
! could use notation nod2+x. nod7+y in case different numbering used

CP,NEXT,UX,89832,101939  
CP,NEXT,UY,89832,101939  
CP,NEXT,UZ,89832,101939

CP,NEXT,UX,89901,101705  
CP,NEXT,UY,89901,101705  
CP,NEXT,UZ,89901,101705

CP,NEXT,UX,89872,101961  
CP,NEXT,UY,89872,101961  
CP,NEXT,UZ,89872,101961

CP,NEXT,UX,89925,101727  
CP,NEXT,UY,89925,101727  
CP,NEXT,UZ,89925,101727

CP,NEXT,UX,89858,101948  
CP,NEXT,UY,89858,101948  
CP,NEXT,UZ,89858,101948

CP,NEXT,UX,89913,101714  
CP,NEXT,UY,89913,101714  
CP,NEXT,UZ,89913,101714

CP,NEXT,UX,89920,101721  
CP,NEXT,UY,89920,101721  
CP,NEXT,UZ,89920,101721

CP,NEXT,UX,89865,101955  
CP,NEXT,UY,89865,101955  
CP,NEXT,UZ,89865,101955

CP,NEXT,UX,89910,101712  
CP,NEXT,UY,89910,101712  
CP,NEXT,UZ,89910,101712

CP,NEXT,UX,89842,101946  
CP,NEXT,UY,89842,101946  
CP,NEXT,UZ,89842,101946 ! set 150 last, save

! bolt frame to column-foot1  
! nod2=89500, nod1=85000  
! could use notation nod2+x. nod1+y in case different numbering used

CP,NEXT,UX,90371,86261  
CP,NEXT,UY,90371,86261  
CP,NEXT,UZ,90371,86261

CP,NEXT,UX,90447,86027  
CP,NEXT,UY,90447,86027  
CP,NEXT,UZ,90447,86027

CP,NEXT,UX,90388,86254  
CP,NEXT,UY,90388,86254  
CP,NEXT,UZ,90388,86254

CP,NEXT,UX,90456,86022  
CP,NEXT,UY,90456,86022  
CP,NEXT,UZ,90456,86022

CP,NEXT,UX,90418,86239  
CP,NEXT,UY,90418,86239  
CP,NEXT,UZ,90418,86239

CP,NEXT,UX,90471,86005  
CP,NEXT,UY,90471,86005  
CP,NEXT,UZ,90471,86005

CP,NEXT,UX,90411,86245  
CP,NEXT,UY,90411,86245  
CP,NEXT,UZ,90411,86245

CP,NEXT,UX,90466,86011  
CP,NEXT,UY,90466,86011  
CP,NEXT,UZ,90466,86011

CP,NEXT,UX,90406,86250  
CP,NEXT,UY,90406,86250  
CP,NEXT,UZ,90406,86250

CP,NEXT,UX,90461,86016  
CP,NEXT,UY,90461,86016  
CP,NEXT,UZ,90461,86016 ! set 180 last, save

! connect girder to spacer 1

CP,NEXT,UX,92235,102777  
CP,NEXT,UY,92235,102777  
CP,NEXT,UZ,92235,102777

CP,NEXT,UX,92918,102750  
CP,NEXT,UY,92918,102750

CP,NEXT,UZ,92918,102750

CP,NEXT,UX,95550,102751

CP,NEXT,UY,95550,102751

CP,NEXT,UZ,95550,102751

CP,NEXT,UX,94892,102778

CP,NEXT,UY,94892,102778

CP,NEXT,UZ,94892,102778

CP,NEXT,UX,94890,102814

CP,NEXT,UY,94890,102814

CP,NEXT,UZ,94890,102814

CP,NEXT,UX,95548,102787

CP,NEXT,UY,95548,102787

CP,NEXT,UZ,95548,102787

CP,NEXT,UX,92916,102786

CP,NEXT,UY,92916,102786

CP,NEXT,UZ,92916,102786

CP,NEXT,UX,92233,102813

CP,NEXT,UY,92233,102813

CP,NEXT,UZ,92233,102813 ! set 204 last, save

! connect girder to spacer 2

CP,NEXT,UX,96206,103028

CP,NEXT,UY,96206,103028

CP,NEXT,UZ,96206,103028

CP,NEXT,UX,93574,103027

CP,NEXT,UY,93574,103027

CP,NEXT,UZ,93574,103027

CP,NEXT,UX,96864,103001

CP,NEXT,UY,96864,103001

CP,NEXT,UZ,96864,103001

CP,NEXT,UX,94232,103000

CP,NEXT,UY,94232,103000

CP,NEXT,UZ,94232,103000

CP,NEXT,UX,96208,103064

CP,NEXT,UY,96208,103064

CP,NEXT,UZ,96208,103064

CP,NEXT,UX,96866,103037  
CP,NEXT,UY,96866,103037  
CP,NEXT,UZ,96866,103037

CP,NEXT,UX,93576,103063  
CP,NEXT,UY,93576,103063  
CP,NEXT,UZ,93576,103063

CP,NEXT,UX,94234,103036  
CP,NEXT,UY,94234,103036  
CP,NEXT,UZ,94234,103036 ! set 228 last, save

save

!ET,7,MPC184

! BOLT foot 2 (at end of girder) to strong floor  
! southwest

CP,NEXT,UX,101617,45796  
CP,NEXT,UY,101617,45796  
CP,NEXT,UZ,101617,45796

! northwest

CP,NEXT,UX,101635,45798  
CP,NEXT,UY,101635,45798  
CP,NEXT,UZ,101635,45798

! southeast

CP,NEXT,UX,101503,45750  
CP,NEXT,UY,101503,45750  
CP,NEXT,UZ,101503,45750

! Northeast

CP,NEXT,UX,101529,45752  
CP,NEXT,UY,101529,45752  
CP,NEXT,UZ,101529,45752

! BOLT foot 1 to strong floor

! southwest

CP,NEXT,UX,85117,45680  
CP,NEXT,UY,85117,45680  
CP,NEXT,UZ,85117,45680

! northwest

CP,NEXT,UX,85135,45682  
CP,NEXT,UY,85135,45682  
CP,NEXT,UZ,85135,45682

! southeast  
CP,NEXT,UX,85003,45654  
CP,NEXT,UY,85003,45654  
CP,NEXT,UZ,85003,45654

! Northeast  
CP,NEXT,UX,85029,45656  
CP,NEXT,UY,85029,45656  
CP,NEXT,UZ,85029,45656

! bolt (UPPER)pad 2 to strong wall  
! downwest  
CP,NEXT,UX,88930,76450  
CP,NEXT,UY,88930,76450  
CP,NEXT,UZ,88930,76450

! upwest  
CP,NEXT,UX,89012,76452  
CP,NEXT,UY,89012,76452  
CP,NEXT,UZ,89012,76452

! downeast  
CP,NEXT,UX,88904,76320  
CP,NEXT,UY,88904,76320  
CP,NEXT,UZ,88904,76320

! upeast  
CP,NEXT,UX,88940,76322  
CP,NEXT,UY,88940,76322  
CP,NEXT,UZ,88940,76322

! bolt (LOWER)pad 1 to strong wall  
! downwest  
CP,NEXT,UX,88683,76444  
CP,NEXT,UY,88683,76444  
CP,NEXT,UZ,88683,76444

! upwest  
CP,NEXT,UX,88765,76446  
CP,NEXT,UY,88765,76446  
CP,NEXT,UZ,88765,76446

! downeast  
CP,NEXT,UX,88657,76314  
CP,NEXT,UY,88657,76314  
CP,NEXT,UZ,88657,76314

! upeast

```
CP,NEXT,UX,88693,76316
CP,NEXT,UY,88693,76316
CP,NEXT,UZ,88693,76316
```

```
save
```

```
/SOLU
ANTYPE,0 ! static analysis
```

```
! constrain bottom of slab
```

```
ASEL,S,LOC,Z,0,1
ASEL,R,LOC,X,24,888
DA,ALL,UX,0
DA,ALL,UY,0
DA,ALL,UZ,0
```

```
! release constraints at prestressing anchors
```

```
CMSEL,S,PSWALL_BOTTOM,LINE
DLDELE,ALL,ALL
```

```
! constrain axial rotation of loading beams as SOLID185 has no rotation DOF
```

```
N = NODE(174,18,153) ! PSFLOOR_EAST
D,N,ROTX,,,,,,,,
N = NODE(174,1114,153) ! PSFLOOR_WEST
D,N,ROTX,,,,,,,,
```

```
N = NODE(747,921,540) ! PSWALL_TOP
D,N,ROTY,,,,,,,,
N = NODE(747,921,0) ! PSWALL_BOTTOM
D,N,ROTY,,,,,,,,
```

```
N = NODE(0,978,153) ! PSFLOOR_SOUTH
D,N,ROTY,,,,,,,,
N = NODE(720,978,153) ! PSFLOOR_NORTHWEST
D,N,ROTY,,,,,,,,
N = NODE(774,921,153) ! PSFLOOR_NORTHCENTRAL
D,N,ROTY,,,,,,,,
N = NODE(720,201,153) ! PSFLOOR_NORTHEAST
D,N,ROTY,,,,,,,,
```

```
N = NODE(720,201,180) ! WALL_FLOOR
D,N,ROTY,,,,,,,,
! LS1 = GRAVITY ONLY
```

```
ALLSEL,ALL
```

TIME,1  
LSWRITE,1

! LS2 = APPLY UNBALANCED POST-TENSIONING LINE PRESSURE ON BEAMS  
! GRAVITY UNTOUCHED AND REMAINS

CMSEL,S,PSWALL\_TOP,LINE  
ESLL,S  
CM, TOP\_BEAM, ELEM  
SFBEAM, ALL, 1, PRES, -19.65, -19.65, , , , ,

CMSEL,S,PSFLOOR\_EAST,LINE  
ESLL,S  
CM, EAST\_BEAM, ELEM  
SFBEAM, ALL, 1, PRES, -4.08, -4.08, , , , ,

CMSEL,S,PSFLOOR\_SOUTH,LINE  
ESLL,S  
CM, SOUTH\_BEAM, ELEM  
SFBEAM, ALL, 1, PRES, -4.08, -4.08, , , , ,

ALLSEL, ALL  
TIME, 2  
LSWRITE, 2

! LS3 = APPLY BALANCE OF POST-TENSIONING LINE PRESSURE ON BEAMS  
! GRAVITY UNTOUCHED AND REMAINS

CMSEL,S,PSWALL\_BOTTOM,LINE  
ESLL,S  
CM, BOTTOM\_BEAM, ELEM  
SFBEAM, ALL, 1, PRES, -19.65, -19.65, , , , ,

CMSEL,S,PSFLOOR\_WEST,LINE  
ESLL,S  
CM, WEST\_BEAM, ELEM  
SFBEAM, ALL, 1, PRES, -4.08, -4.08, , , , ,

CMSEL,S,PSFLOOR\_NORTH,LINE  
ESLL,S  
CM, NORTH\_BEAM, ELEM  
SFBEAM, ALL, 1, PRES, -4.08, -4.08, , , , ,

ALLSEL, ALL  
TIME, 3  
LSWRITE, 3

! LOAD support

!ACEL,,,1 ! gravity -z

! LOAD TOP OF COLUMN 2 AT JUNCTIONS WEB-FLANGE

! Nod7=101500 could be used in notation

F,101835,Fx,-2,,,

F,101835,FY,-2,,,

F,101835,FZ,-2,,,

F,102235,Fx,-2,,,

F,102235,FY,-2,,,

F,102235,FZ,-2,,,

ALLSEL,ALL

TIME,4

LSWRITE,4

! UNSELECT CONSTRUCTION SPACER

ESEL,U,ELEM,,ELE6,ELE6+127,,

OUTPR,STAT

OUTRES,STAT

SAVE

LSSOLVE,1,4,1

/eof



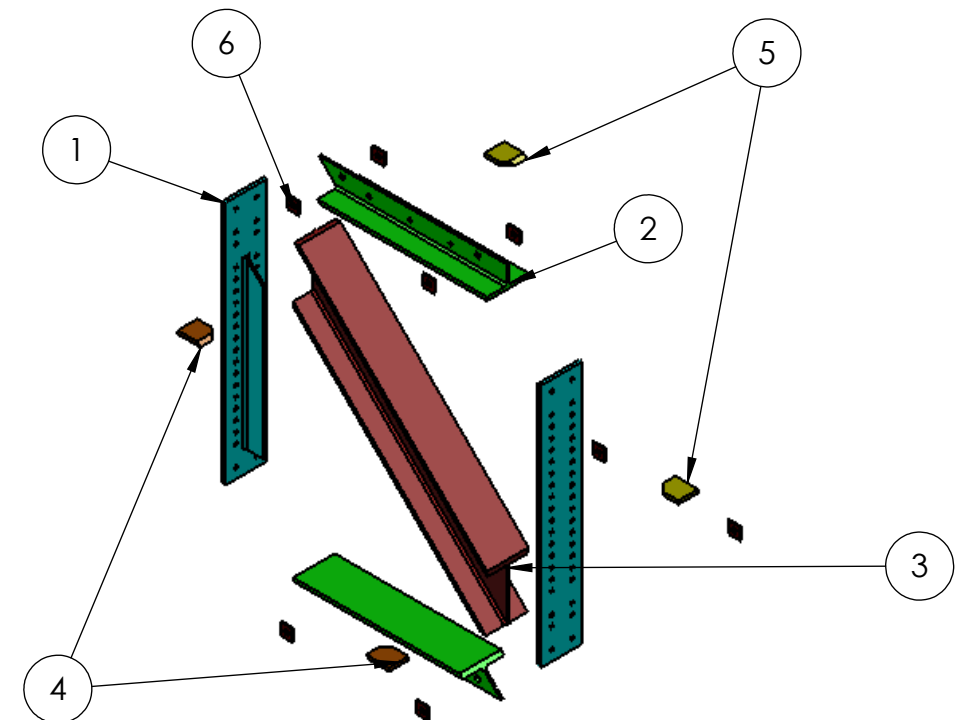
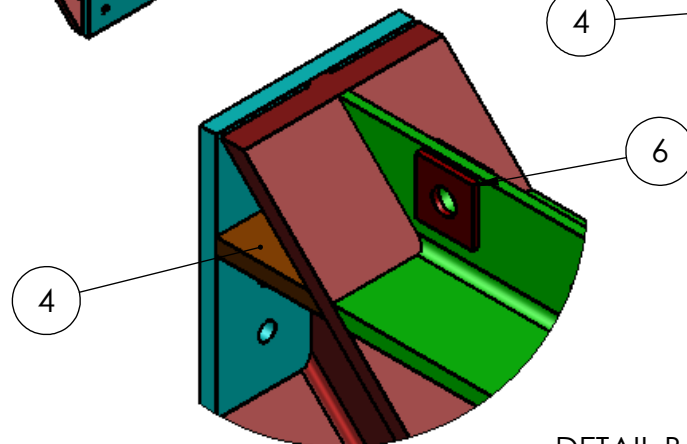
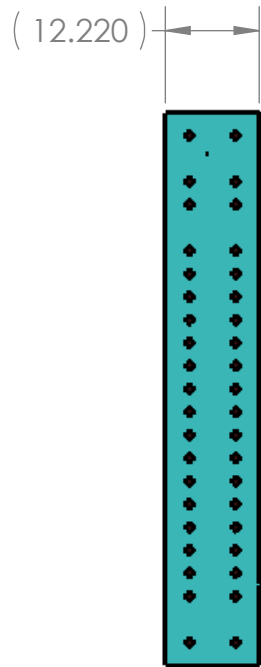
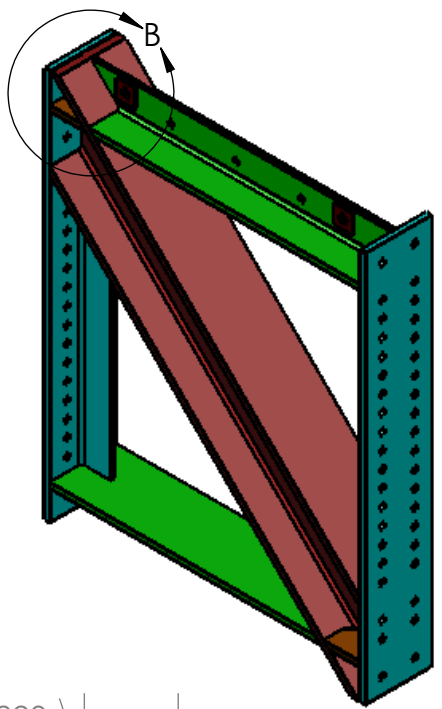
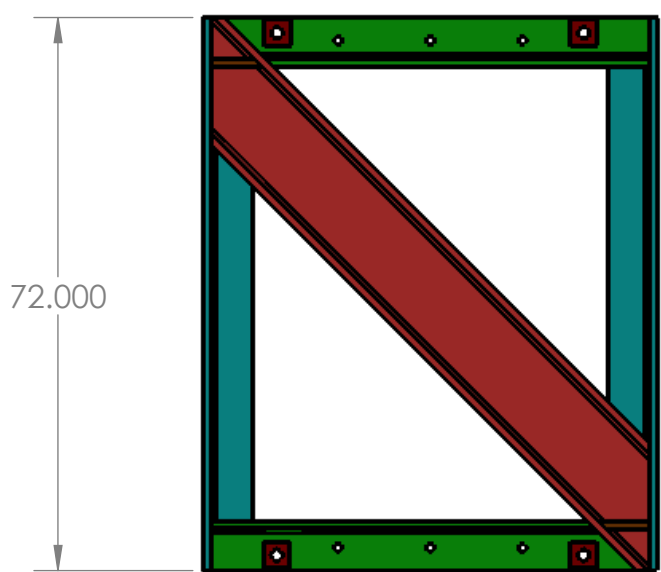
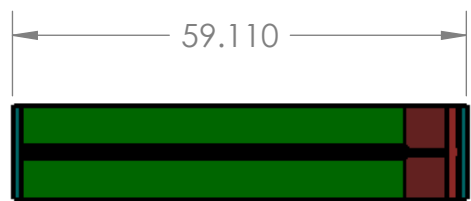
# Appendix

## Modular Support Drawings

8 7 6 5 4 3 2 1

D  
C  
B  
A

D  
C  
B  
A



DETAIL B  
SCALE 3 : 25

NOTES:  
 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.  
 2) APPROXIMATE WEIGHT OF ASSEMBLY IS 1,756 LBS.

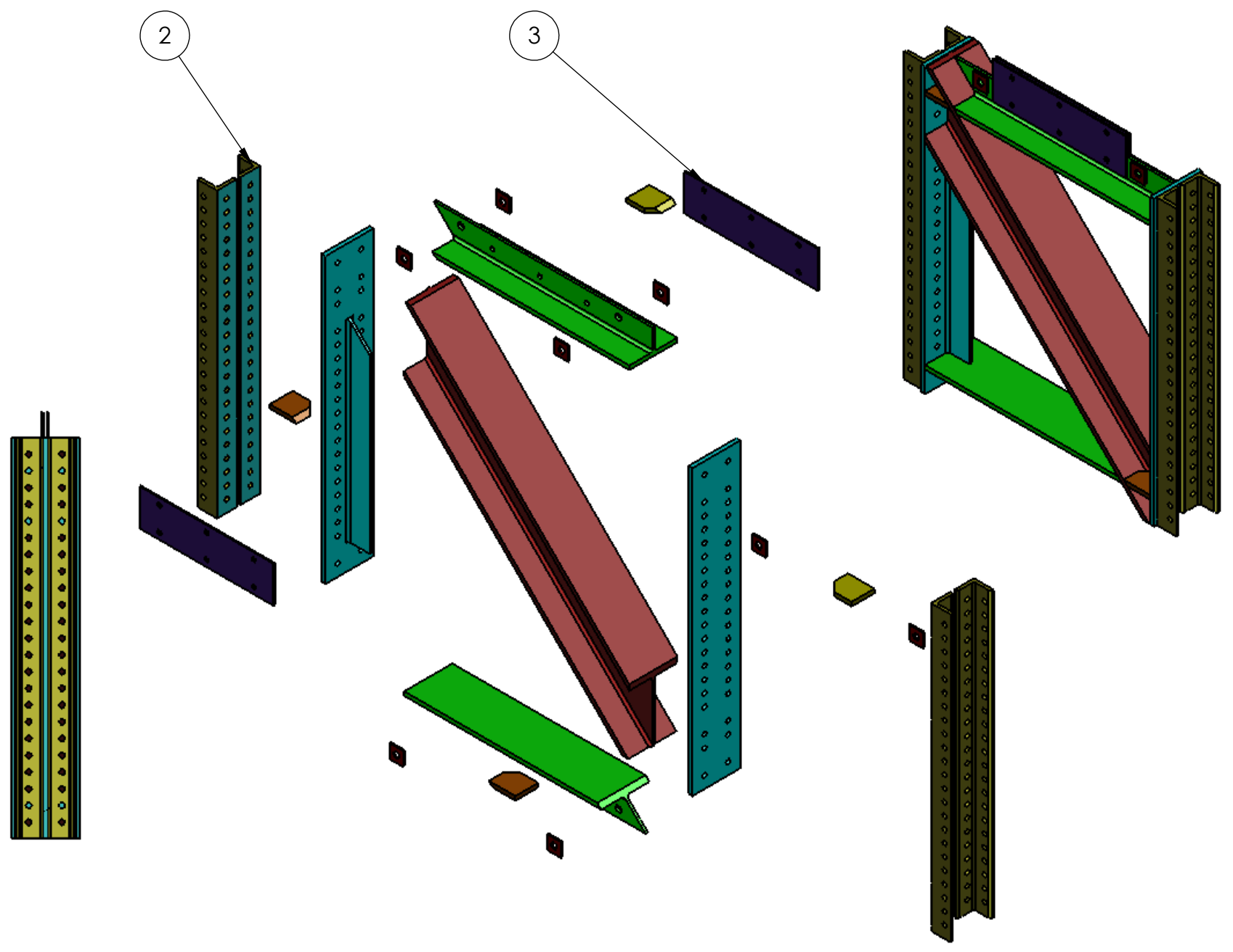
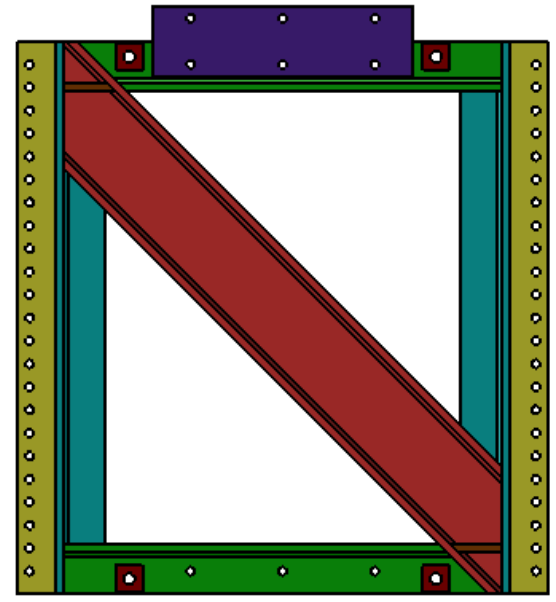
| ITEM NO. | PART NUMBER                   | DESCRIPTION                   | QTY. |
|----------|-------------------------------|-------------------------------|------|
| 1        | Vert-T_WT6x53                 | VERTICAL T                    | 2    |
| 2        | Hor-T_WT6x53                  | HORIZONTAL T WT6x53           | 2    |
| 3        | W12x106x1.0                   | DIAGONAL BRACE W12x1006x1.0   | 1    |
| 4        | flange-continuity-plate_A     | FLANGE CONTINUITY PLATE A     | 2    |
| 5        | flange-continuity-plate_B     | FLANGE CONTINUITY PLATE B     | 2    |
| 6        | washer-plate_MRF-brace-module | WASHER PLATE MRF BRACE MODULE | 8    |

**NIST**

|                                      |         |                      |             |
|--------------------------------------|---------|----------------------|-------------|
| UNLESS OTHERWISE SPECIFIED:          |         | NAME                 | DATE        |
| DIMENSIONS ARE IN INCHES             |         | DRAWN                | J. Swerdlow |
| TOLERANCES:                          |         | CHECKED              |             |
| FRACTIONAL ±                         |         | ENG APPR.            |             |
| ANGULAR: MACH ± .1 BEND ±            |         | MFG APPR.            |             |
| TWO PLACE DECIMAL ±.01               |         | Q.A.                 |             |
| THREE PLACE DECIMAL ±.005            |         | COMMENTS:            |             |
| INTERPRET GEOMETRIC TOLERANCING PER: |         |                      |             |
| MATERIAL                             |         |                      |             |
| FINISH                               |         |                      |             |
| NEXT ASSY                            | USED ON |                      |             |
| APPLICATION                          |         | DO NOT SCALE DRAWING |             |

|                                   |          |                 |
|-----------------------------------|----------|-----------------|
| TITLE:<br><b>MRF BRACE MODULE</b> |          |                 |
| SIZE<br><b>B</b>                  | DWG. NO. | REV<br><b>2</b> |
| SCALE: 1:25 WEIGHT:               |          | SHEET 1 OF 15   |

8 7 6 5 4 3 2 1



**NOTES:**

- 1) "BRACE MODULE ANGLE A ADAPTER" (7) ENABLES BRACE MODULE TO FASTEN TO COLUMN BETWEEN FLANGES. QUANTITY: 4X PER MODULE
- 2) "WEB SPLICE PLATE" (8) ENABLES BRACE MODULE TO FASTEN TO ANOTHER VERTICALLY STACKED BRACE MODULE. QUANTITY: 2X PER MODULE
- 3) APPROXIMATE WEIGHT OF ASSEMBLY IS 2,346 LBS.

**NIST**

| ITEM NO. | PART NUMBER      | DESCRIPTION                  | QTY. |
|----------|------------------|------------------------------|------|
| 1        | MRF_brace-module | MRF BRACE MODULE             | 1    |
| 2        | L5x5x0.75        | BRACE MODULE ANGLE A ADAPTER | 4    |
| 3        | web-splice_plate | WEB SPLICE PLATE             | 2    |

|                                      |                      |           |      |   |
|--------------------------------------|----------------------|-----------|------|---|
| UNLESS OTHERWISE SPECIFIED:          |                      | NAME      | DATE | TITLE:<br><b>MRF BRACE MODULE<br/>                 ALT. CONFIGURATION</b> |
| DIMENSIONS ARE IN INCHES             |                      | DRAWN     |      |   |
| TOLERANCES:                          |                      | CHECKED   |      |   |
| FRACTIONAL ±                         |                      | ENG APPR. |      |   |
| ANGULAR: MACH ± BEND ±               |                      | MFG APPR. |      |   |
| TWO PLACE DECIMAL ±                  |                      | Q.A.      |      | SIZE DWG. NO. REV   |
| THREE PLACE DECIMAL ±                |                      | COMMENTS: |      | <b>B</b>  |
| INTERPRET GEOMETRIC TOLERANCING PER: |                      |           |      | SCALE: 1:25 WEIGHT: SHEET 2 OF 15   |
| MATERIAL                             |                      |           |      |   |
| FINISH                               |                      |           |      |   |
| NEXT ASSY                            | USED ON              |           |      |   |
| APPLICATION                          | DO NOT SCALE DRAWING |           |      |   |

8 7 6 5 4 3 2 1

D

D

C

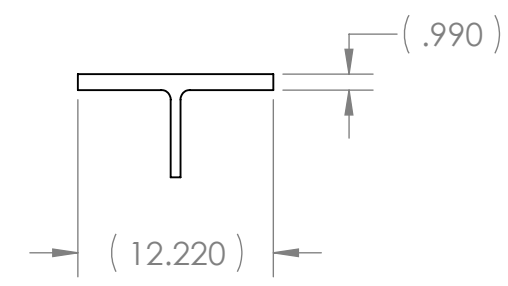
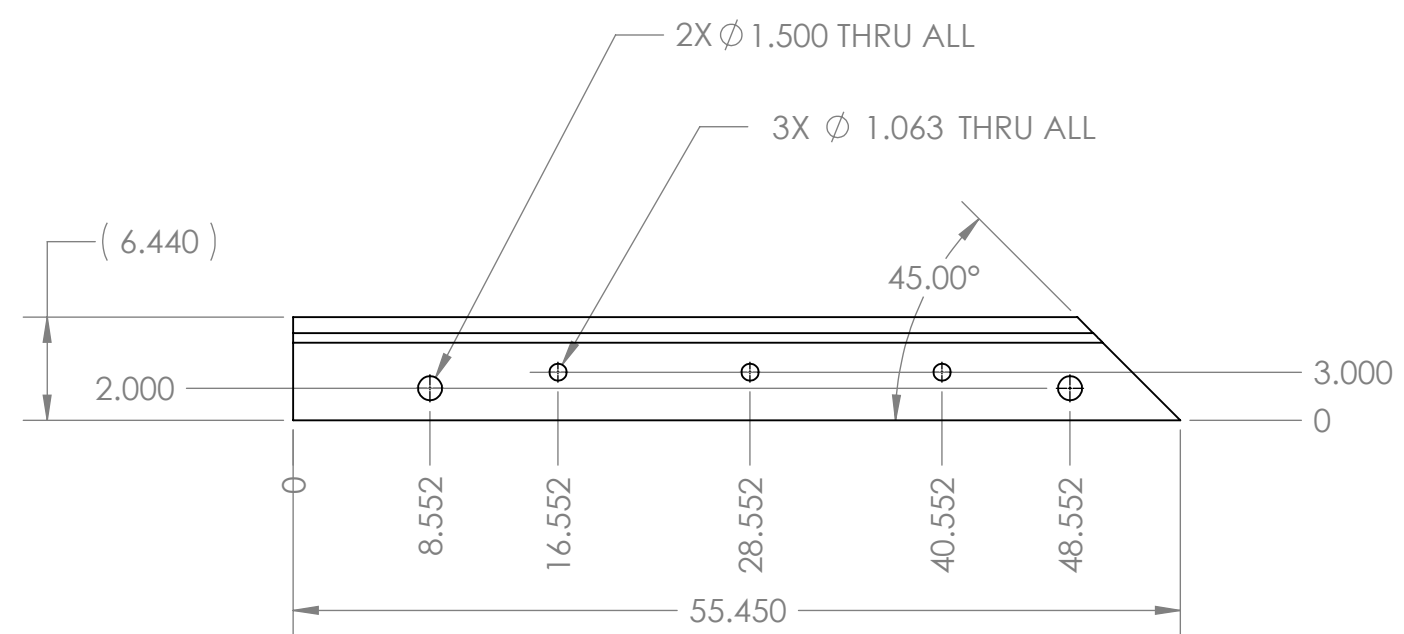
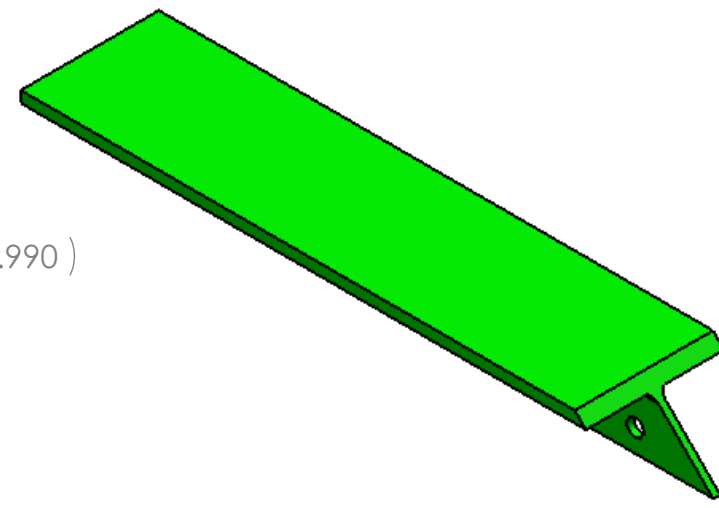
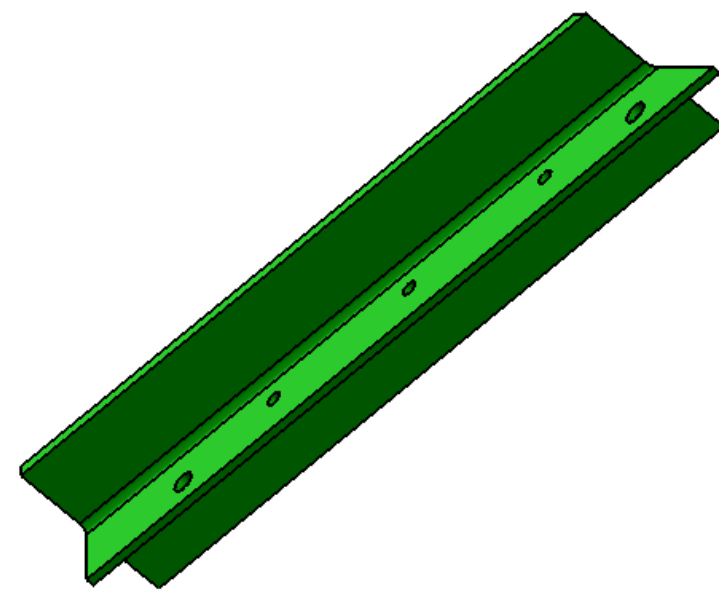
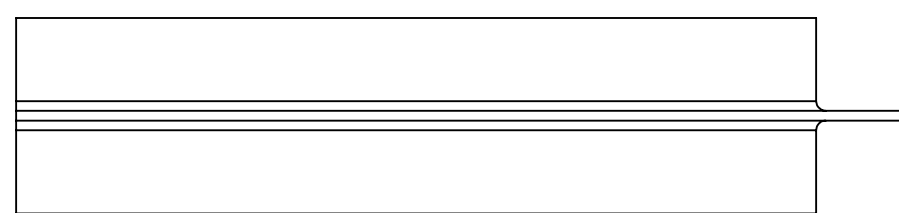
C

B

B

A

A



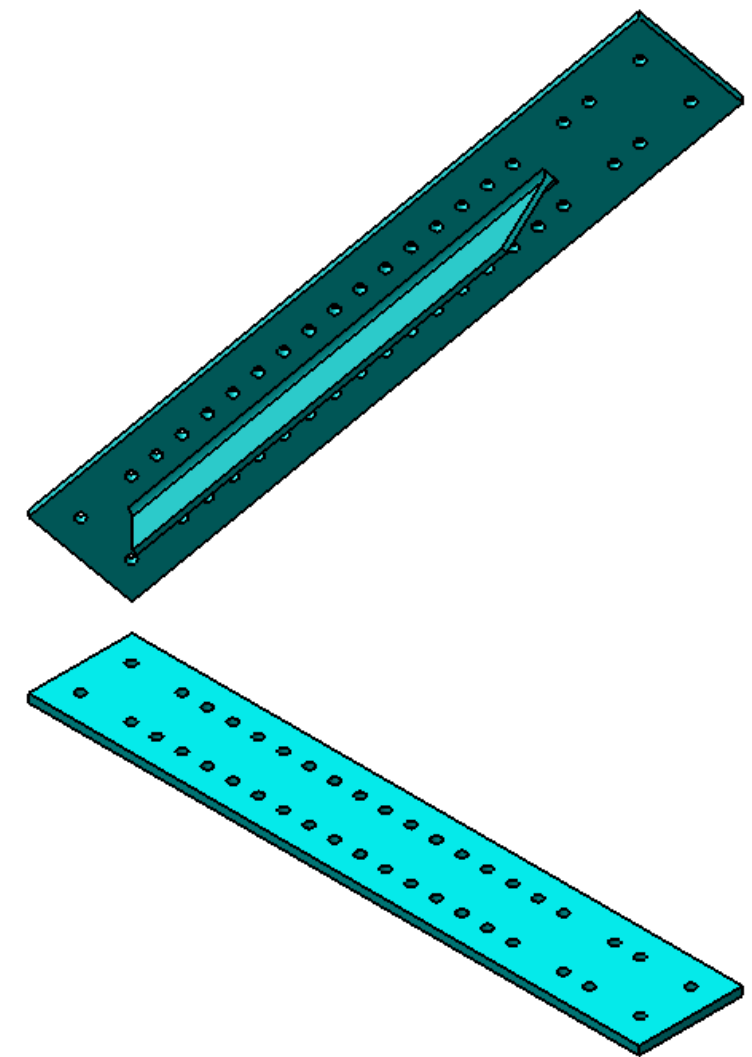
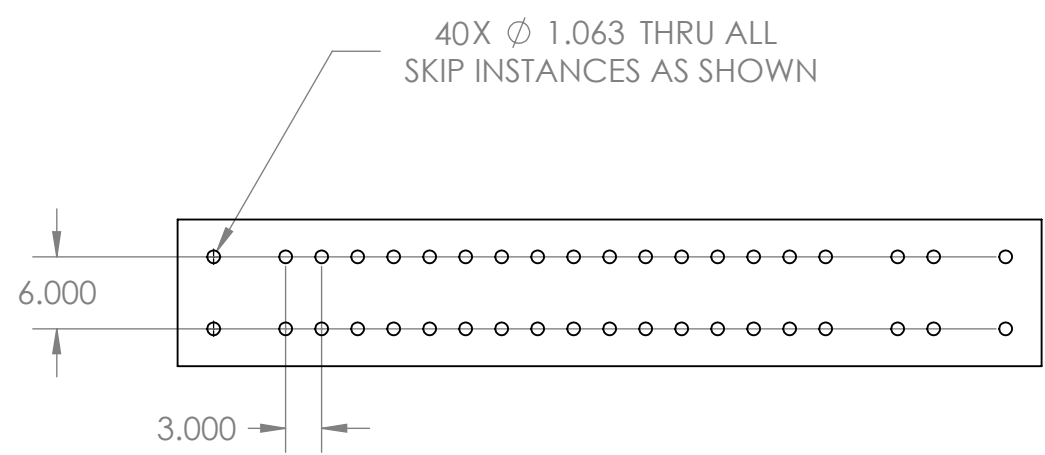
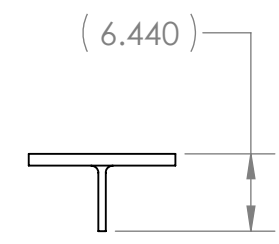
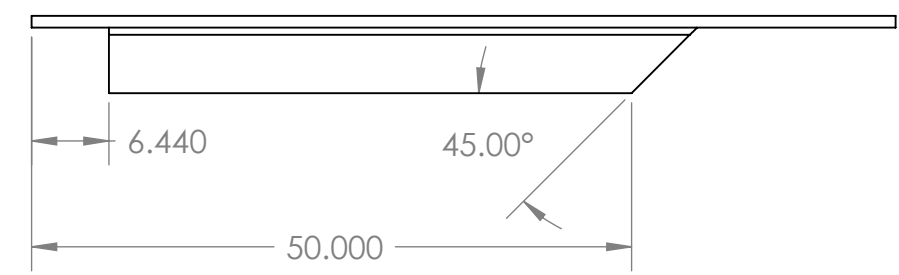
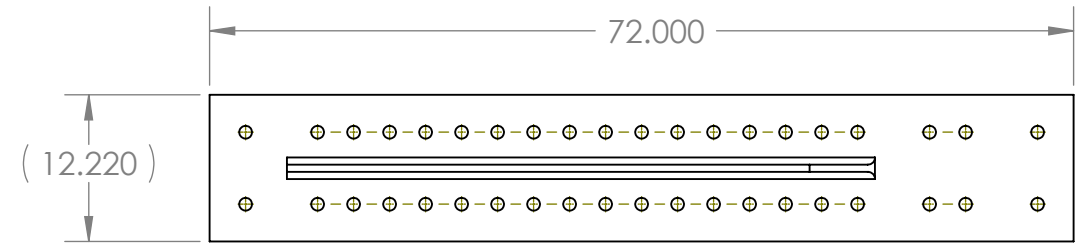
**NOTES:**

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) APPROXIMATE WEIGHT OF PART IS 221 LBS.
- 3) MATERIAL: WT6x53
- 4) QUANTITY: SEE SHEET 1

**NIST**

|                                       |          |                                      |  |               |      |
|---------------------------------------|----------|--------------------------------------|--|---------------|------|
|                                       |          | UNLESS OTHERWISE SPECIFIED:          |  | NAME          | DATE |
|                                       |          | DIMENSIONS ARE IN INCHES             |  | DRAWN         |      |
|                                       |          | TOLERANCES:                          |  | CHECKED       |      |
|                                       |          | FRACTIONAL ±                         |  | ENG APPR.     |      |
|                                       |          | ANGULAR: MACH ± BEND ±               |  | MFG APPR.     |      |
|                                       |          | TWO PLACE DECIMAL ±                  |  | Q.A.          |      |
|                                       |          | THREE PLACE DECIMAL ±                |  | COMMENTS:     |      |
|                                       |          | INTERPRET GEOMETRIC TOLERANCING PER: |  |               |      |
|                                       |          | MATERIAL                             |  |               |      |
|                                       |          | FINISH                               |  |               |      |
| NEXT ASSY                             | USED ON  |                                      |  |               |      |
| APPLICATION                           |          | DO NOT SCALE DRAWING                 |  |               |      |
| TITLE: <b>HORIZONTAL T<br/>WT6x53</b> |          |                                      |  |               |      |
| SIZE                                  | DWG. NO. |                                      |  | REV           |      |
| <b>B</b>                              |          |                                      |  |               |      |
| SCALE: 1:12 WEIGHT:                   |          |                                      |  | SHEET 3 OF 15 |      |

8 7 6 5 4 3 2 1



- NOTES:**
- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
  - 2) APPROXIMATE WEIGHT OF PART IS 281 LBS.
  - 3) MATERIAL WTx35
  - 4) QUANTITY: SEE SHEET 1

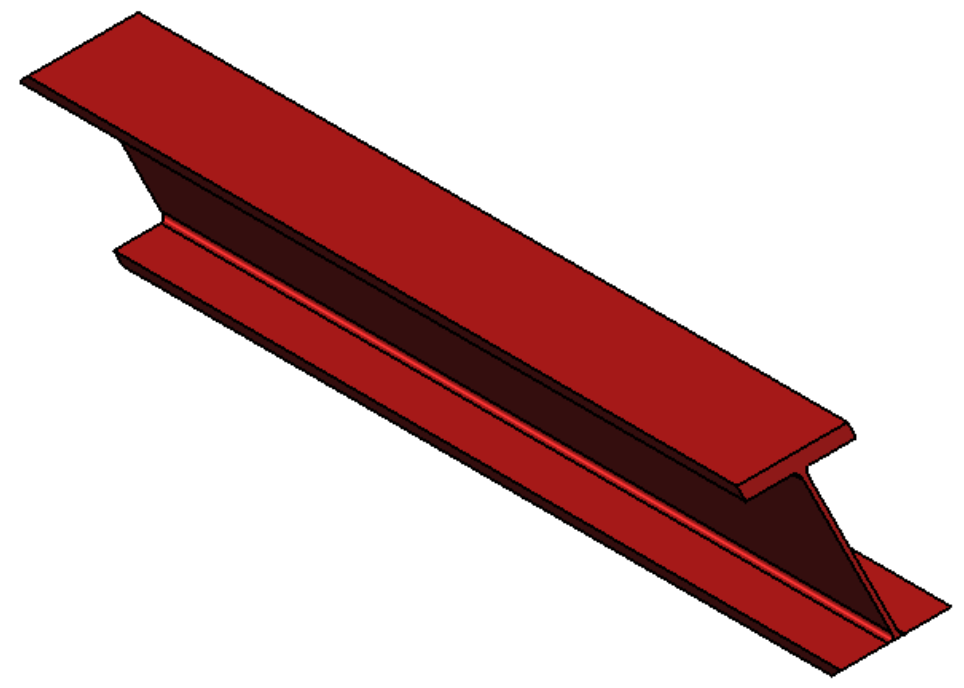
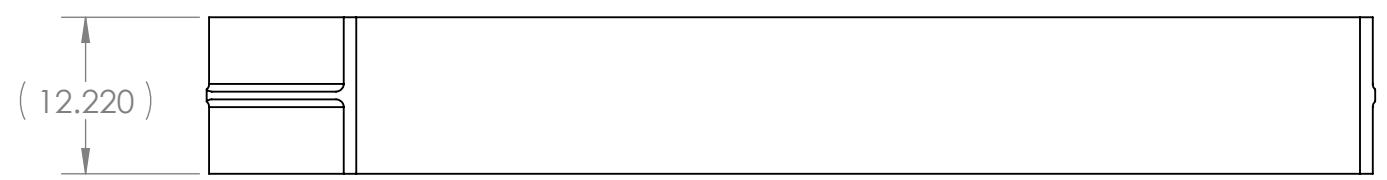
**NIST**

|             |         |                                      |           |      |                          |               |
|-------------|---------|--------------------------------------|-----------|------|--------------------------|---------------|
|             |         | UNLESS OTHERWISE SPECIFIED:          | NAME      | DATE |                          |               |
|             |         | DIMENSIONS ARE IN INCHES             | DRAWN     |      |                          |               |
|             |         | TOLERANCES:                          | CHECKED   |      | TITLE: <b>VERTICAL T</b> |               |
|             |         | FRACTIONAL ±                         | ENG APPR. |      | WT6x53                   |               |
|             |         | ANGULAR: MACH ± BEND ±               | MFG APPR. |      | SIZE <b>B</b>            | DWG. NO.      |
|             |         | TWO PLACE DECIMAL ±                  | Q.A.      |      |                          | REV           |
|             |         | THREE PLACE DECIMAL ±                | COMMENTS: |      | SCALE: 1:16              | WEIGHT:       |
|             |         | INTERPRET GEOMETRIC TOLERANCING PER: |           |      |                          | SHEET 4 OF 15 |
|             |         | MATERIAL                             |           |      |                          |               |
| NEXT ASSY   | USED ON | FINISH                               |           |      |                          |               |
| APPLICATION |         | DO NOT SCALE DRAWING                 |           |      |                          |               |

8 7 6 5 4 3 2 1

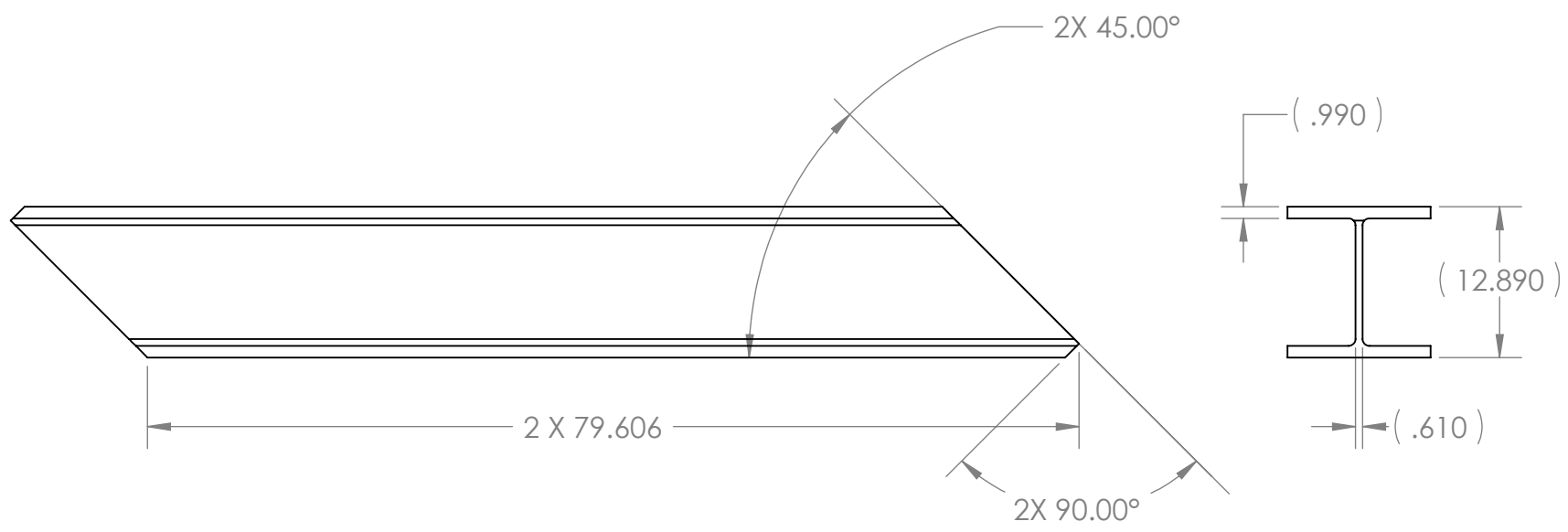
D

D



C

C



B

B

NOTES:

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) APPROXIMATE WEIGHT OF PART IS 704 LBS.
- 3) MATERIAL: W12x106
- 4) QUANTITY: SEE SHEET 1

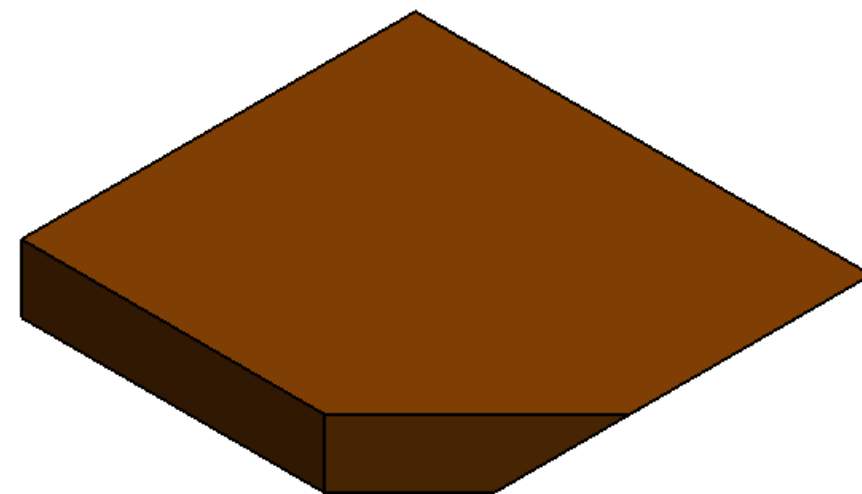
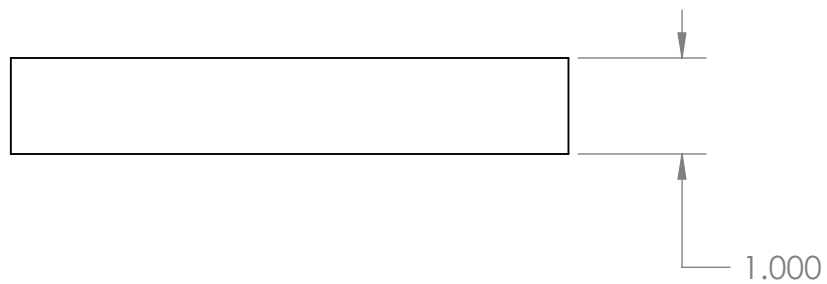
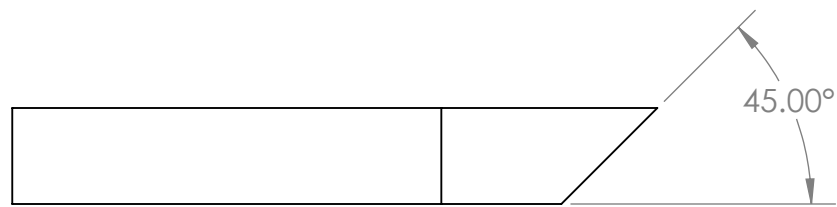
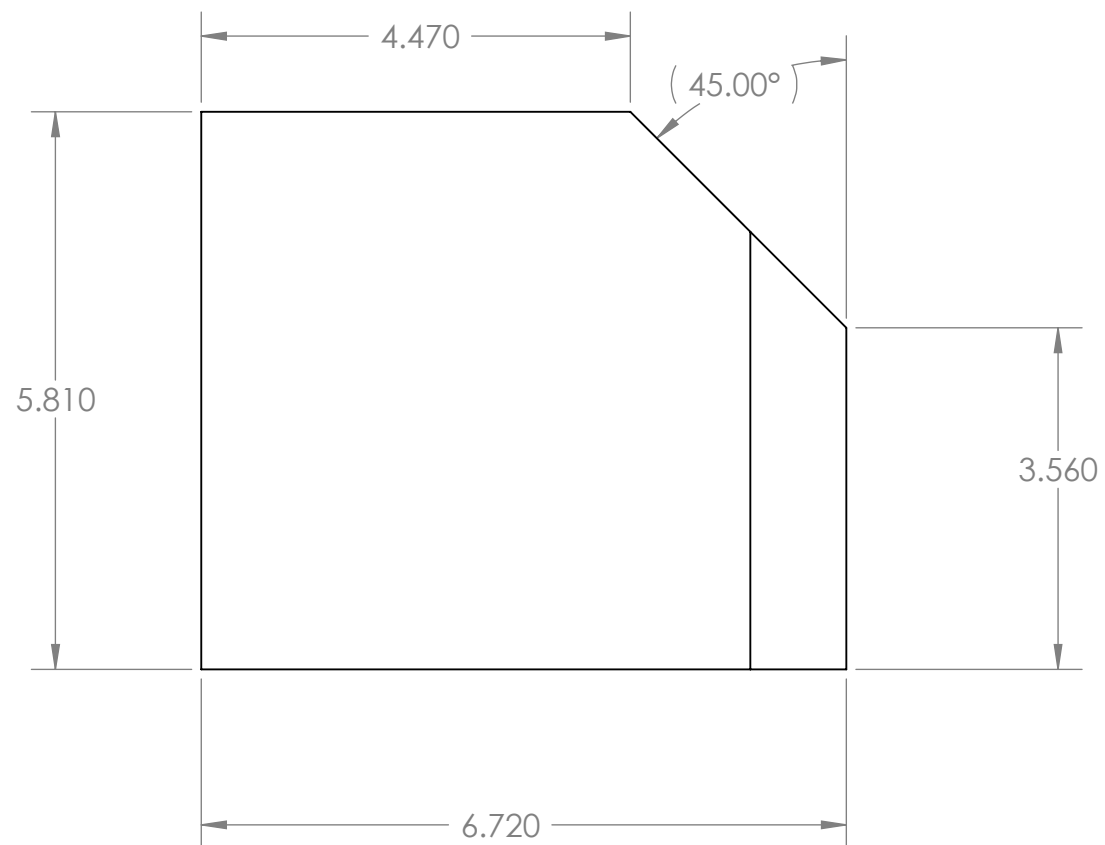
**NIST**

|             |         |                                      |           |      |                |               |         |
|-------------|---------|--------------------------------------|-----------|------|----------------|---------------|---------|
|             |         | UNLESS OTHERWISE SPECIFIED:          | NAME      | DATE |                |               |         |
|             |         | DIMENSIONS ARE IN INCHES             | DRAWN     |      |                |               |         |
|             |         | TOLERANCES:                          | CHECKED   |      | TITLE:         |               |         |
|             |         | FRACTIONAL ±                         | ENG APPR. |      | DIAGONAL BRACE |               |         |
|             |         | ANGULAR: MACH ± BEND ±               | MFG APPR. |      | W12x106        |               |         |
|             |         | TWO PLACE DECIMAL ±                  | Q.A.      |      | SIZE           | DWG. NO.      |         |
|             |         | THREE PLACE DECIMAL ±                | COMMENTS: |      | <b>B</b>       | REV           |         |
|             |         | INTERPRET GEOMETRIC TOLERANCING PER: |           |      |                | SCALE: 1:15   | WEIGHT: |
|             |         | MATERIAL                             |           |      |                | SHEET 5 OF 15 |         |
| NEXT ASSY   | USED ON | FINISH                               |           |      |                |               |         |
| APPLICATION |         | DO NOT SCALE DRAWING                 |           |      |                |               |         |

A

A

8 7 6 5 4 3 2 1



**NOTES:**

1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.

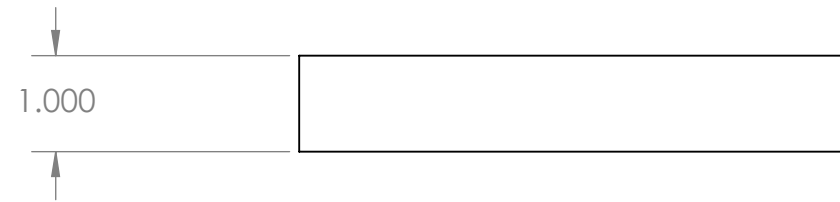
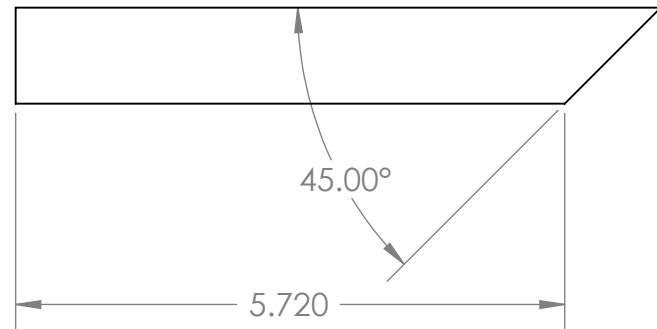
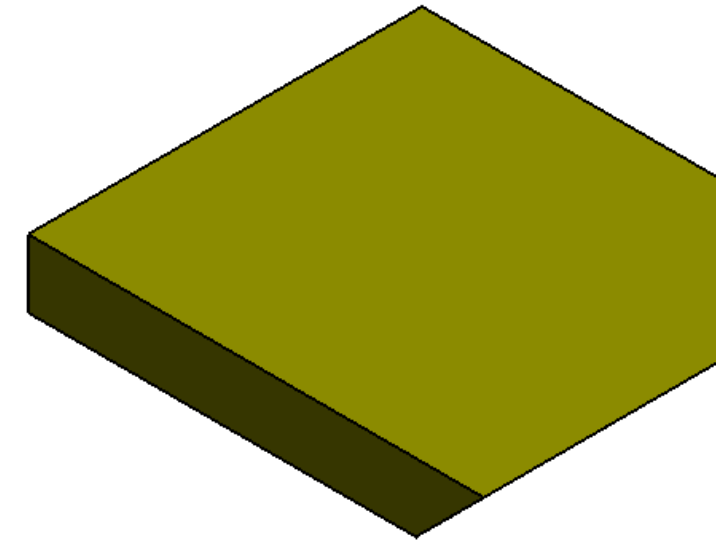
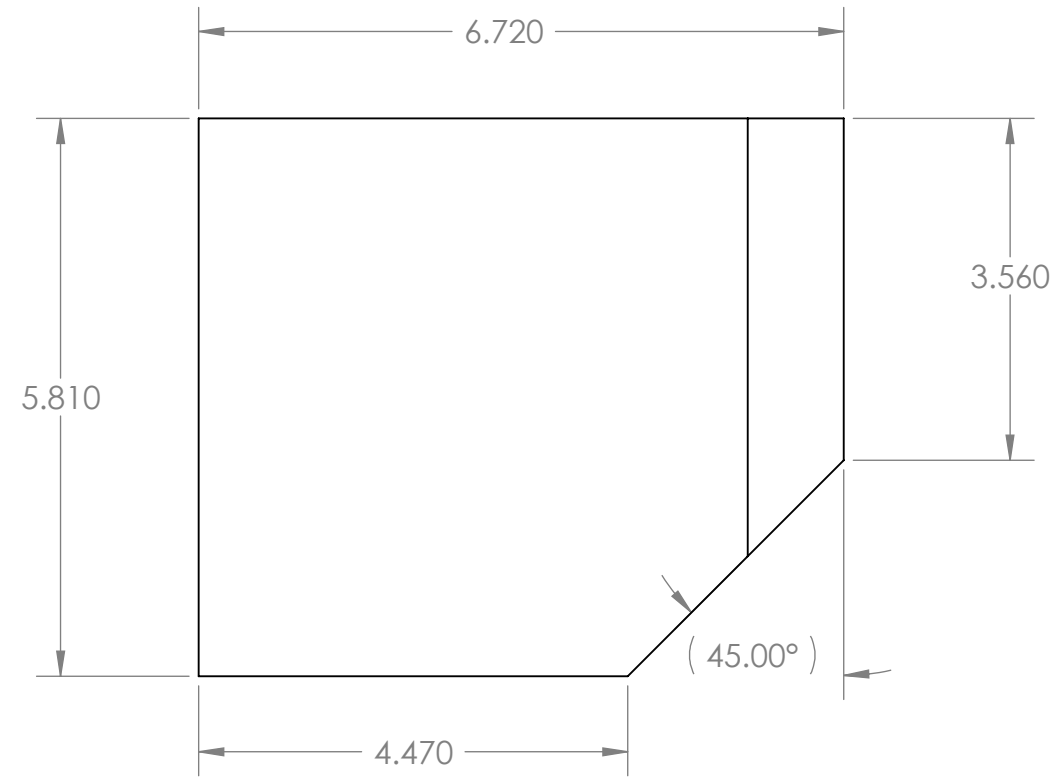
2) APPROXIMATE WEIGHT OF PART IS 10 LBS.

3) MATERIAL: A36 STEEL OR EQUIVALENT

4) QUANTITY: SEE SHEET 1

**NIST**

|             |         |   |           |      |  |
|-------------|---------|---|-----------|------|--|
|             |         | UNLESS OTHERWISE SPECIFIED:   | NAME      | DATE | TITLE:<br><b>FLANGE CONTINUITY<br/>PLATE A</b> |
|             |         | DIMENSIONS ARE IN INCHES  | DRAWN     |      |  |
|             |         | TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | CHECKED   |      |  |
|             |         | INTERPRET GEOMETRIC<br>TOLERANCING PER:   | ENG APPR. |      |  |
|             |         | MATERIAL  | MFG APPR. |      | SIZE   |
| NEXT ASSY   | USED ON | FINISH  | Q.A.      |      | DWG. NO.                                       |
| APPLICATION |         | DO NOT SCALE DRAWING  | COMMENTS: |      | REV  |
|             |         |   |           |      | SCALE: 1:2                                     |
|             |         |   |           |      | WEIGHT:  |
|             |         |   |           |      | SHEET 6 OF 15                                  |



**NOTES:**

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) APPROXIMATE WEIGHT OF PART IS 10 LBS.
- 3) MATERIAL: A36 STEEL OR EQUIVALENT
- 4) QUANTITY: SEE SHEET 1

**NIST**

|  |             |                             |           |      |                   |          |
|--|-------------|-----------------------------|-----------|------|-------------------|----------|
|  |             | UNLESS OTHERWISE SPECIFIED: | NAME      | DATE |                   |          |
|  |             | DIMENSIONS ARE IN INCHES    | DRAWN     |      |                   |          |
|  |             | TOLERANCES:                 | CHECKED   |      | TITLE:            |          |
|  |             | FRACTIONAL ±                | ENG APPR. |      | FLANGE CONTINUITY |          |
|  |             | ANGULAR: MACH ± BEND ±      | MFG APPR. |      | PLATE B           |          |
|  |             | TWO PLACE DECIMAL ±         | Q.A.      |      | SIZE              | DWG. NO. |
|  |             | THREE PLACE DECIMAL ±       | COMMENTS: |      | <b>B</b>          | REV      |
|  | NEXT ASSY   | MATERIAL                    |           |      | SCALE: 1:2        | WEIGHT:  |
|  | USED ON     | FINISH                      |           |      | SHEET 7 OF 15     |          |
|  | APPLICATION | DO NOT SCALE DRAWING        |           |      |                   |          |



8 7 6 5 4 3 2 1

D

D

C

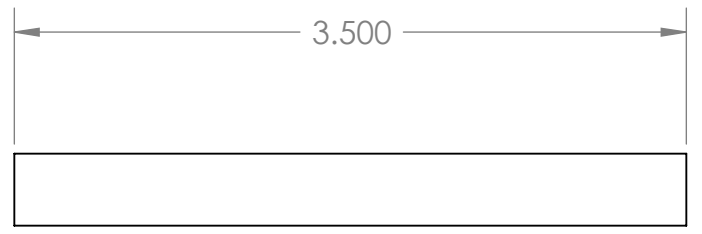
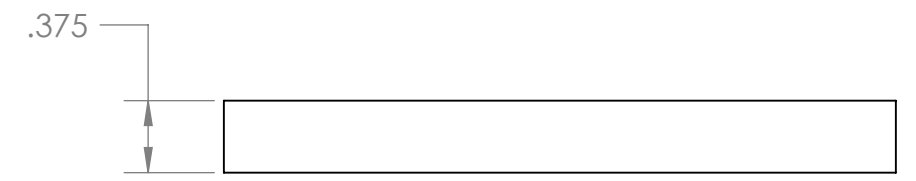
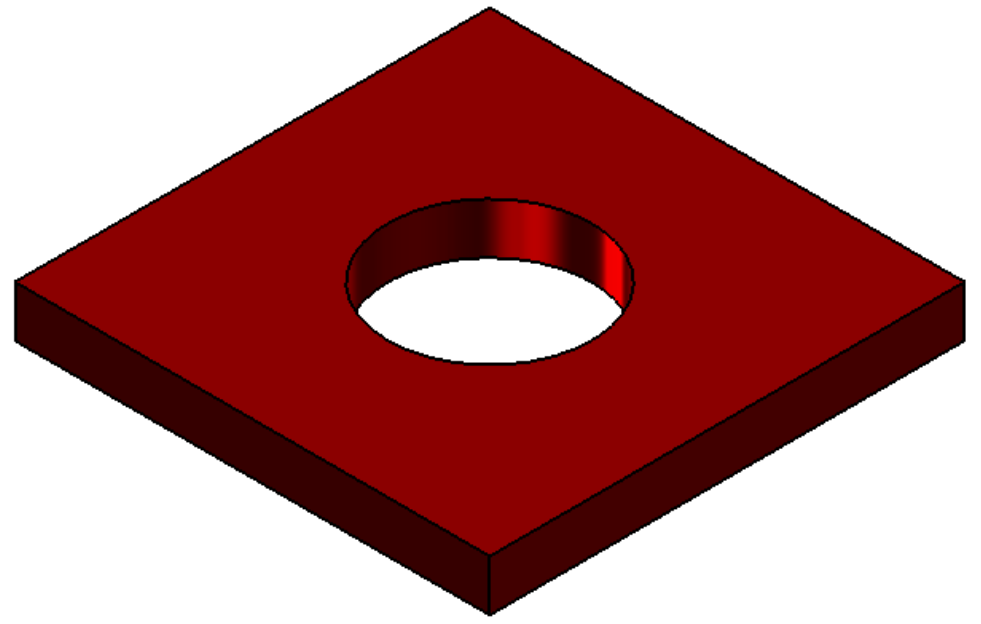
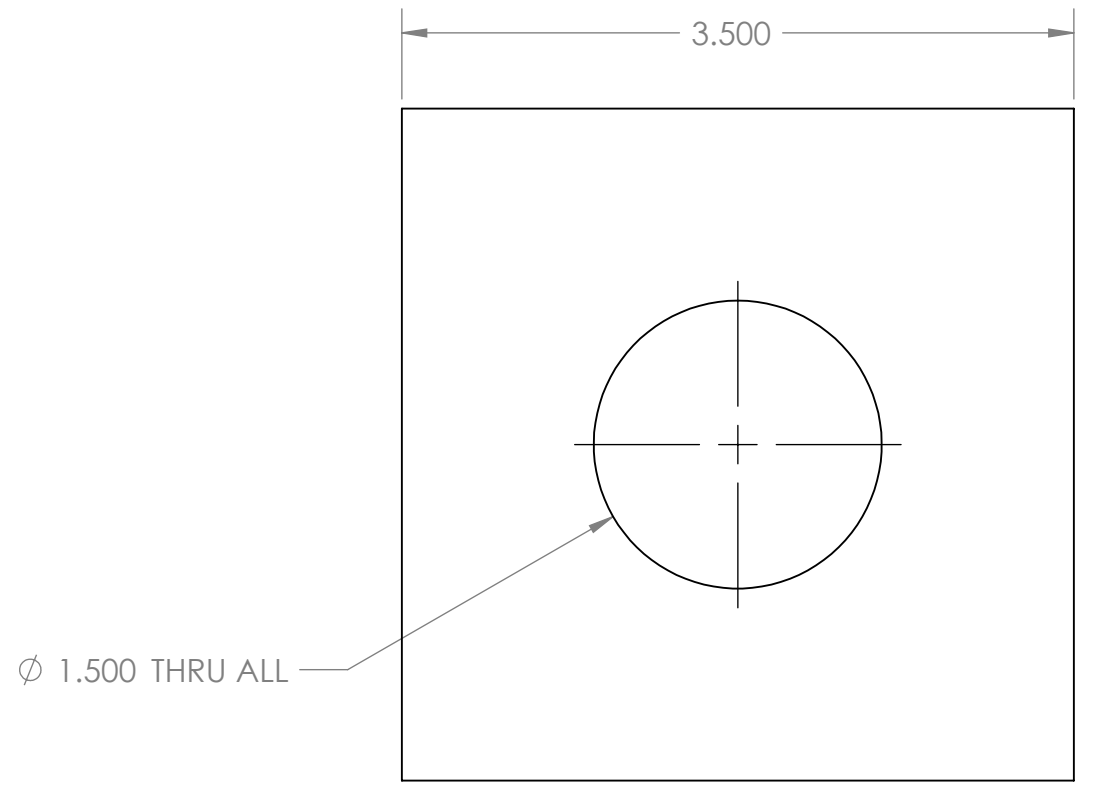
C

B

B

A

A



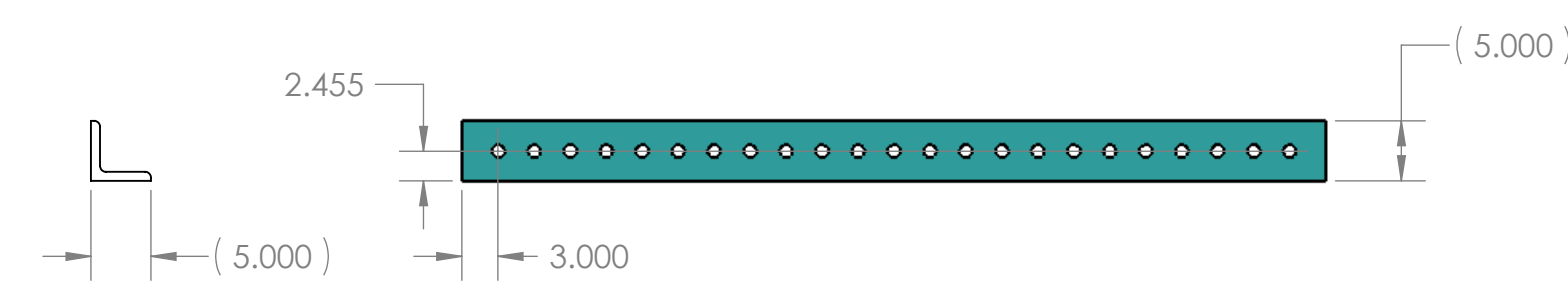
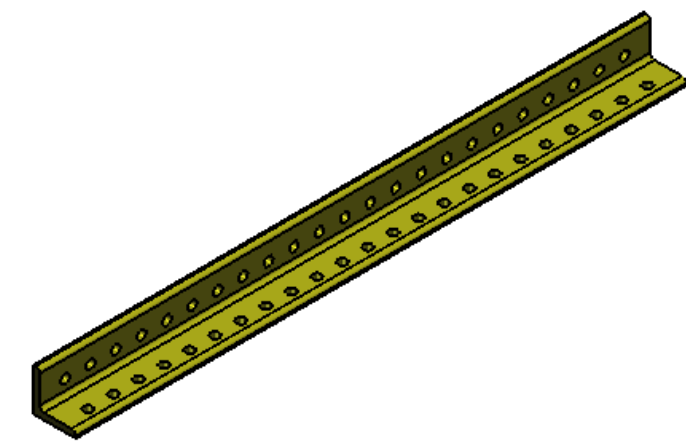
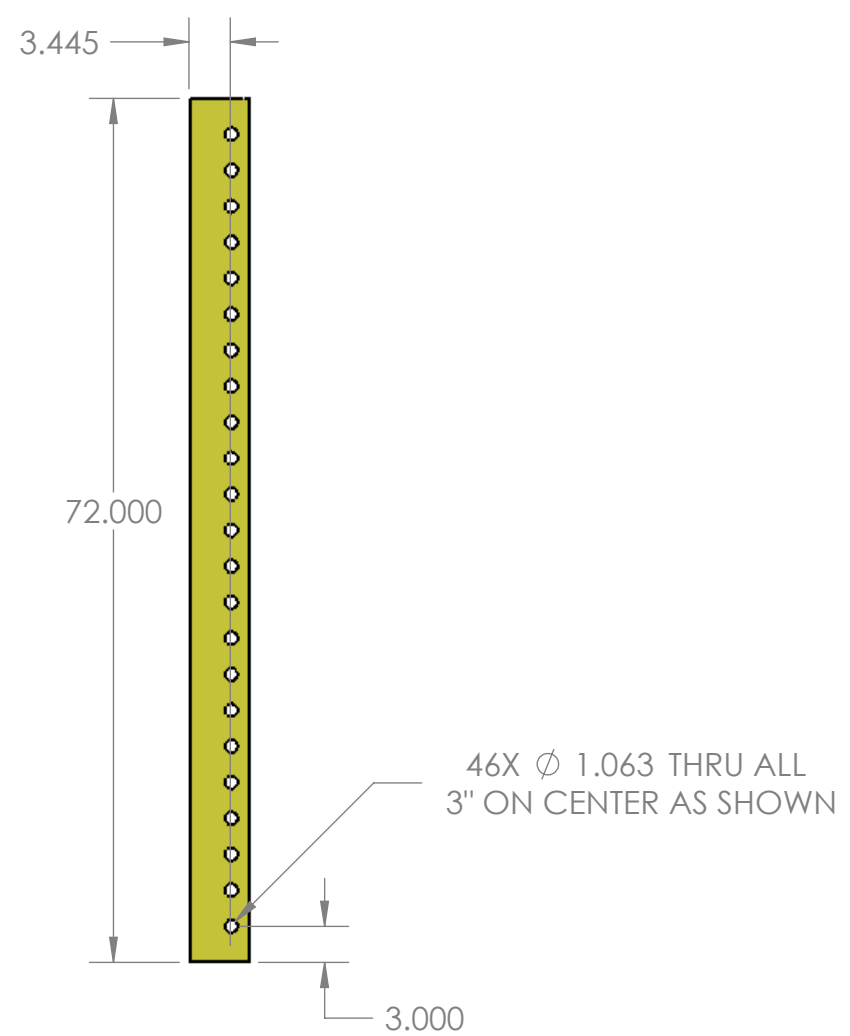
**NOTES:**

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) APPROXIMATE WEIGHT OF PART IS 2 LBS.
- 3) MATERIAL: A36 STEEL OR EQUIVALENT
- 4) QUANTITY: SEE SHEET 1

**NIST**

|             |          |                                      |                               |      |      |
|-------------|----------|--------------------------------------|-------------------------------|------|------|
|             |          | UNLESS OTHERWISE SPECIFIED:          |                               | NAME | DATE |
|             |          | DIMENSIONS ARE IN INCHES             | DRAWN                         |      |      |
|             |          | TOLERANCES:                          | CHECKED                       |      |      |
|             |          | FRACTIONAL ±                         | ENG APPR.                     |      |      |
|             |          | ANGULAR: MACH ± BEND ±               | MFG APPR.                     |      |      |
|             |          | TWO PLACE DECIMAL ±                  | Q.A.                          |      |      |
|             |          | THREE PLACE DECIMAL ±                | COMMENTS:                     |      |      |
|             |          | INTERPRET GEOMETRIC TOLERANCING PER: |                               |      |      |
|             |          | MATERIAL                             |                               |      |      |
|             |          | FINISH                               |                               |      |      |
| NEXT ASSY   | USED ON  |                                      |                               |      |      |
| APPLICATION |          | DO NOT SCALE DRAWING                 |                               |      |      |
| TITLE:      |          |                                      | WASHER PLATE MRF BRACE MODULE |      |      |
| SIZE        | DWG. NO. | REV                                  |                               |      |      |
| <b>B</b>    |          |                                      |                               |      |      |
| SCALE: 1:1  | WEIGHT:  | SHEET 8 OF 15                        |                               |      |      |

8 7 6 5 4 3 2 1



**NOTES:**

1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.

2) APPROXIMATE WEIGHT OF PART IS 132 LBS.

3) MATERIAL: L5x5x0.75 A36 STEEL OR EQUIVALENT

4) QUANTITY: SEE SHEET 1

5) SEE SHEET 2 FOR PROPER ASSEMBLY ORIENTATION VIA COLOR CODE

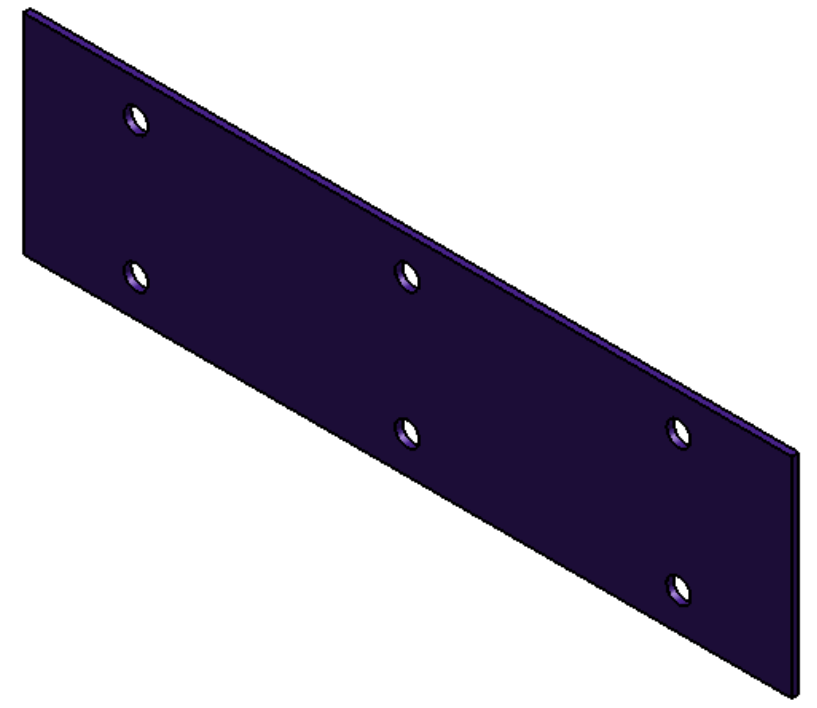
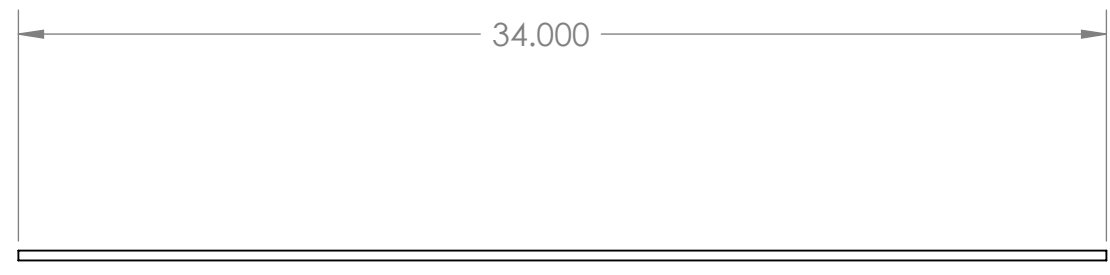
**NIST**

|   |         |                                      |          |               |      |
|---|---------|--------------------------------------|----------|---------------|------|
|   |         | UNLESS OTHERWISE SPECIFIED:          |          | NAME          | DATE |
|   |         | DIMENSIONS ARE IN INCHES             |          | DRAWN         |      |
|   |         | TOLERANCES:                          |          | CHECKED       |      |
|   |         | FRACTIONAL $\pm$                     |          | ENG APPR.     |      |
|   |         | ANGULAR: MACH $\pm$ BEND $\pm$       |          | MFG APPR.     |      |
|   |         | TWO PLACE DECIMAL $\pm$              |          | Q.A.          |      |
|   |         | THREE PLACE DECIMAL $\pm$            |          | COMMENTS:     |      |
|   |         | INTERPRET GEOMETRIC TOLERANCING PER: |          |               |      |
|   |         | MATERIAL                             |          |               |      |
|   |         | FINISH                               |          |               |      |
| NEXT ASSY   | USED ON | DO NOT SCALE DRAWING                 |          |               |      |
| APPLICATION   |         |                                      |          |               |      |
| TITLE: BRACE MODULE<br>ANGLE A ADAPTER<br>L5x5x0.75 |         |                                      | SIZE     | DWG. NO.      | REV  |
|   |         |                                      | <b>B</b> |               |      |
| SCALE: 1:16   |         |                                      | WEIGHT:  | SHEET 9 OF 15 |      |

8 7 6 5 4 3 2 1

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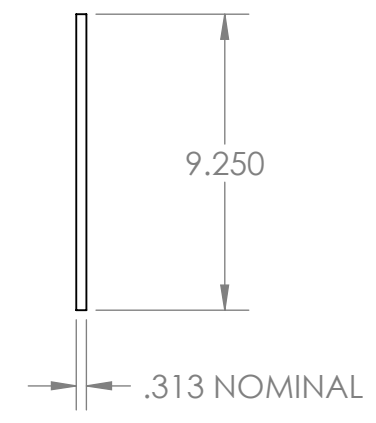
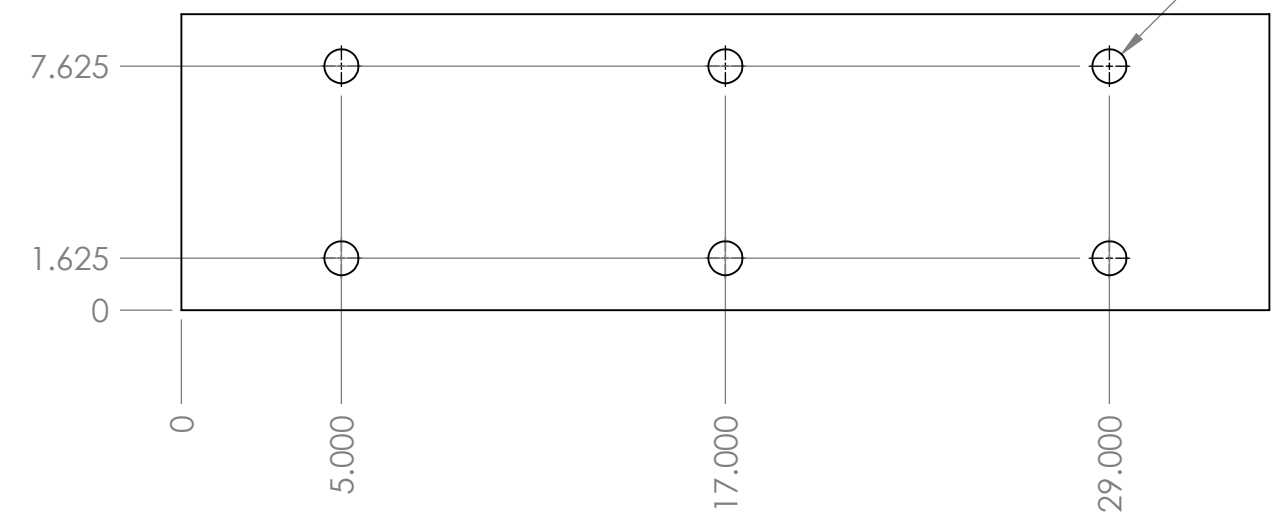
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NOTES:

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) APPROXIMATE WEIGHT OF PART IS 27 LBS.
- 3) MATERIAL: 5/16" SHEET A36 STEEL OR EQUIVALENT
- 4) QUANTITY: SEE SHEET 2

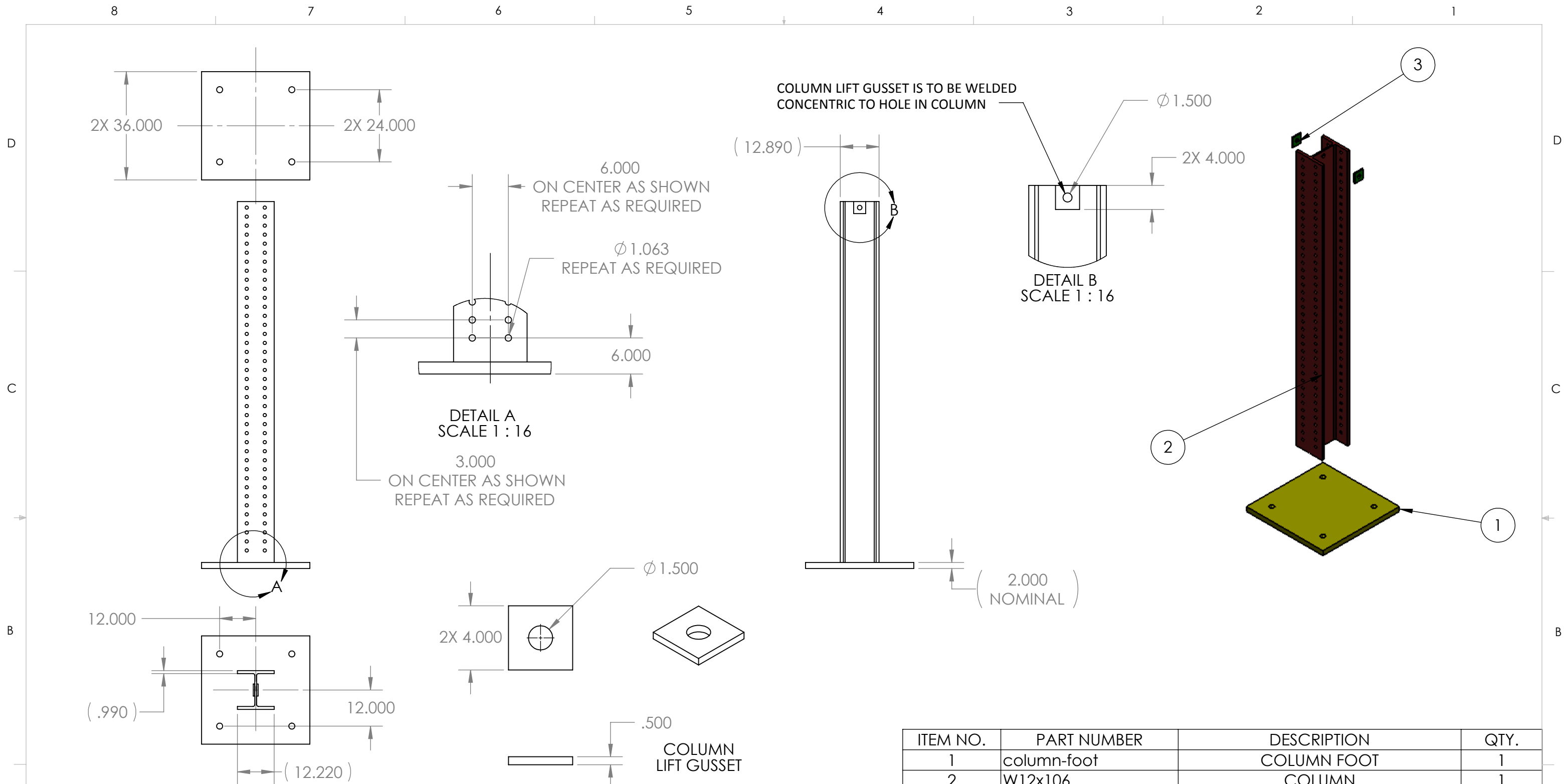
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|             |         |                                      |           |      |                                   |  |
|-------------|---------|--------------------------------------|-----------|------|-----------------------------------|--|
|             |         | UNLESS OTHERWISE SPECIFIED:          | NAME      | DATE |                                   |  |
|             |         | DIMENSIONS ARE IN INCHES             | DRAWN     |      | TITLE:<br><b>WEB SPLCE PLATE</b>  |  |
|             |         | TOLERANCES:                          | CHECKED   |      |                                   |  |
|             |         | FRACTIONAL ±                         | ENG APPR. |      |                                   |  |
|             |         | ANGULAR: MACH ± BEND ±               | MFG APPR. |      |                                   |  |
|             |         | TWO PLACE DECIMAL ±                  | Q.A.      |      | SIZE DWG. NO. REV                 |  |
|             |         | THREE PLACE DECIMAL ±                | COMMENTS: |      | SCALE: 1:6 WEIGHT: SHEET 10 OF 15 |  |
|             |         | INTERPRET GEOMETRIC TOLERANCING PER: |           |      |                                   |  |
|             |         | MATERIAL                             |           |      |                                   |  |
| NEXT ASSY   | USED ON | FINISH                               |           |      |                                   |  |
| APPLICATION |         | DO NOT SCALE DRAWING                 |           |      |                                   |  |

8 7 6 5 4 3 2 1



**NOTES:**

1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.

2) COLUMN HEIGHT MAY VARY

3) GIRDER BEAM MATERIAL: W12x106

4) COLUMN FOOT MATERIAL: A36 STEEL OR EQUIVALENT

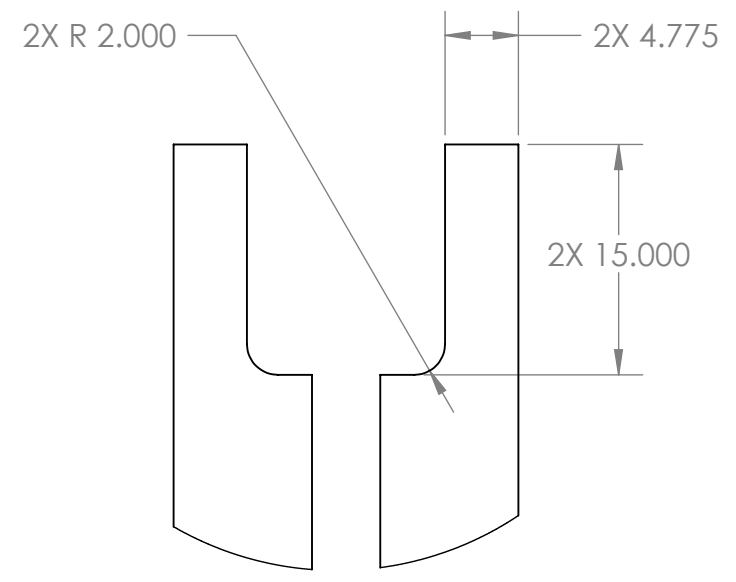
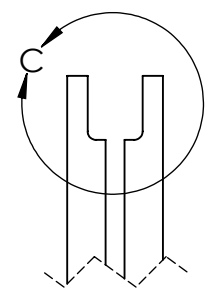
5) COLUMN GUSSET MATERIAL: A36 STEEL OR EQUIVALENT

3) APPROXIMATE WEIGHT OF 10' COLUMN ASSEMBLY IS 1,753 LBS

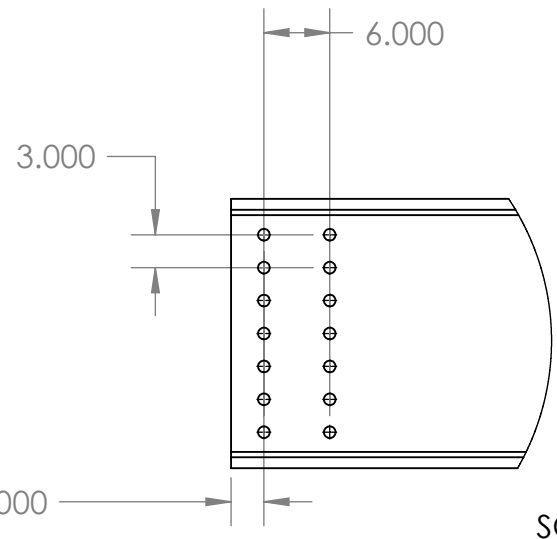
**NIST**

| ITEM NO. | PART NUMBER              | DESCRIPTION              | QTY. |
|----------|--------------------------|--------------------------|------|
| 1        | column-foot              | COLUMN FOOT              | 1    |
| 2        | W12x106                  | COLUMN                   | 1    |
| 3        | washer-plate_column-lift | WASHER PLATE COLUMN LIFT | 2    |

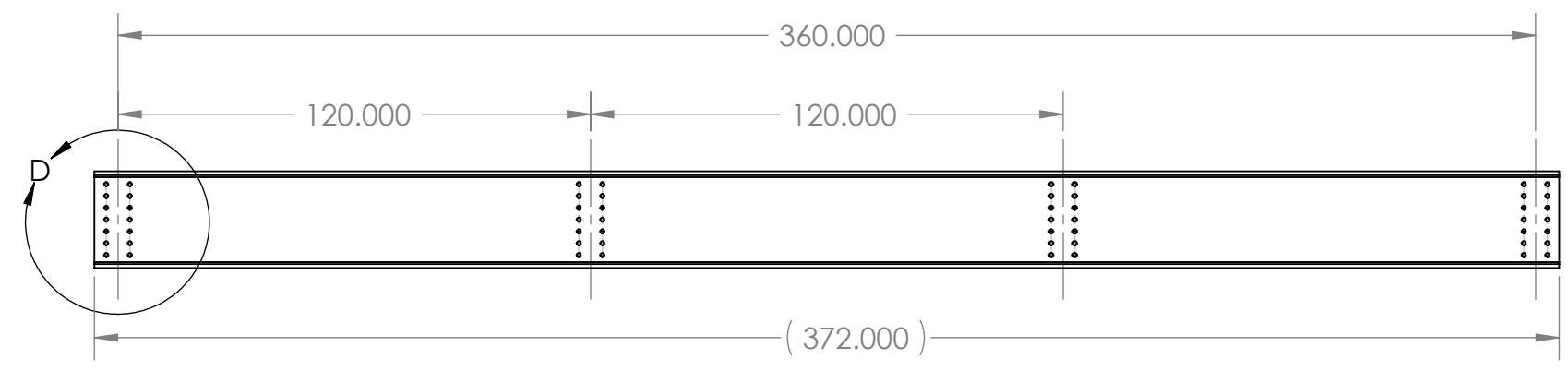
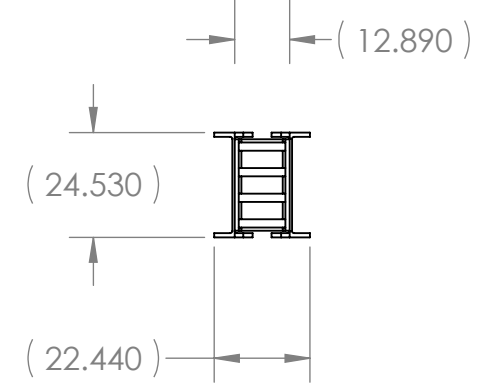
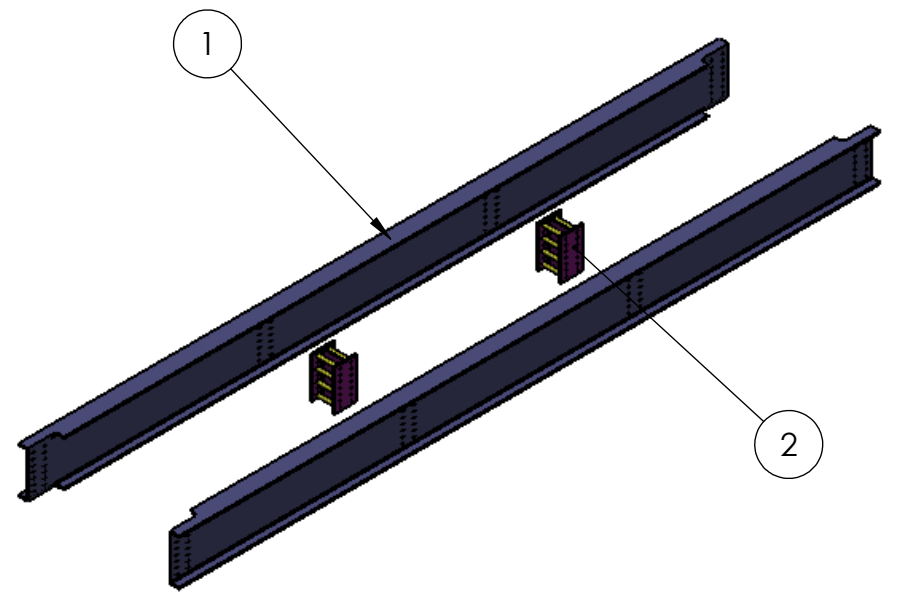
|                                      |         |                      |      |   |
|--------------------------------------|---------|----------------------|------|---|
| UNLESS OTHERWISE SPECIFIED:          |         | NAME                 | DATE | <b>TITLE:</b><br><b>GENERIC COLUMN ASSEMBLY</b> |
| DIMENSIONS ARE IN INCHES             |         | DRAWN                |      |   |
| TOLERANCES:                          |         | CHECKED              |      |   |
| FRACTIONAL ±                         |         | ENG APPR.            |      |   |
| ANGULAR: MACH ± BEND ±               |         | MFG APPR.            |      |   |
| TWO PLACE DECIMAL ±                  |         | Q.A.                 |      | <b>SIZE</b> DWG. NO. REV<br><b>B</b>            |
| THREE PLACE DECIMAL ±                |         | COMMENTS:            |      |   |
| INTERPRET GEOMETRIC TOLERANCING PER: |         |                      |      | SCALE: 1:32 WEIGHT:                             |
| MATERIAL                             |         |                      |      | SHEET 11 OF 15                                  |
| FINISH                               |         |                      |      |   |
| NEXT ASSY                            | USED ON |                      |      |   |
| APPLICATION                          |         | DO NOT SCALE DRAWING |      |   |



DETAIL C  
SCALE 2 : 25



DETAIL D  
SCALE 2 : 35



NOTES:

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) GIRDER LENGTH MAY ONLY VARY IN 24" INCREMENTS
- 3) HOLE PATTERNS TO ACCOMMODATE GIRDER SPACER SHALL BE SPACED A MAXIMUM OF 120" APART AS SHOWN
- 4) NO GIRDER SPACER NECESSARY FOR GIRDER SPAN OF 10'
- 5) APPROXIMANT WEIGHT OF GIRDER A ASSEMBLY AS SHOWN (30') IS 6,657 LBS., FOR 20' 4,392 LBS., FOR 10' 1,783 LBS.

| ITEM NO. | PART NUMBER   | DESCRIPTION   | Default/ QTY. |
|----------|---------------|---------------|---------------|
| 1        | W24x103       | GIRDER A      | 2             |
| 2        | girder-spacer | GIRDER SPACER | 2             |

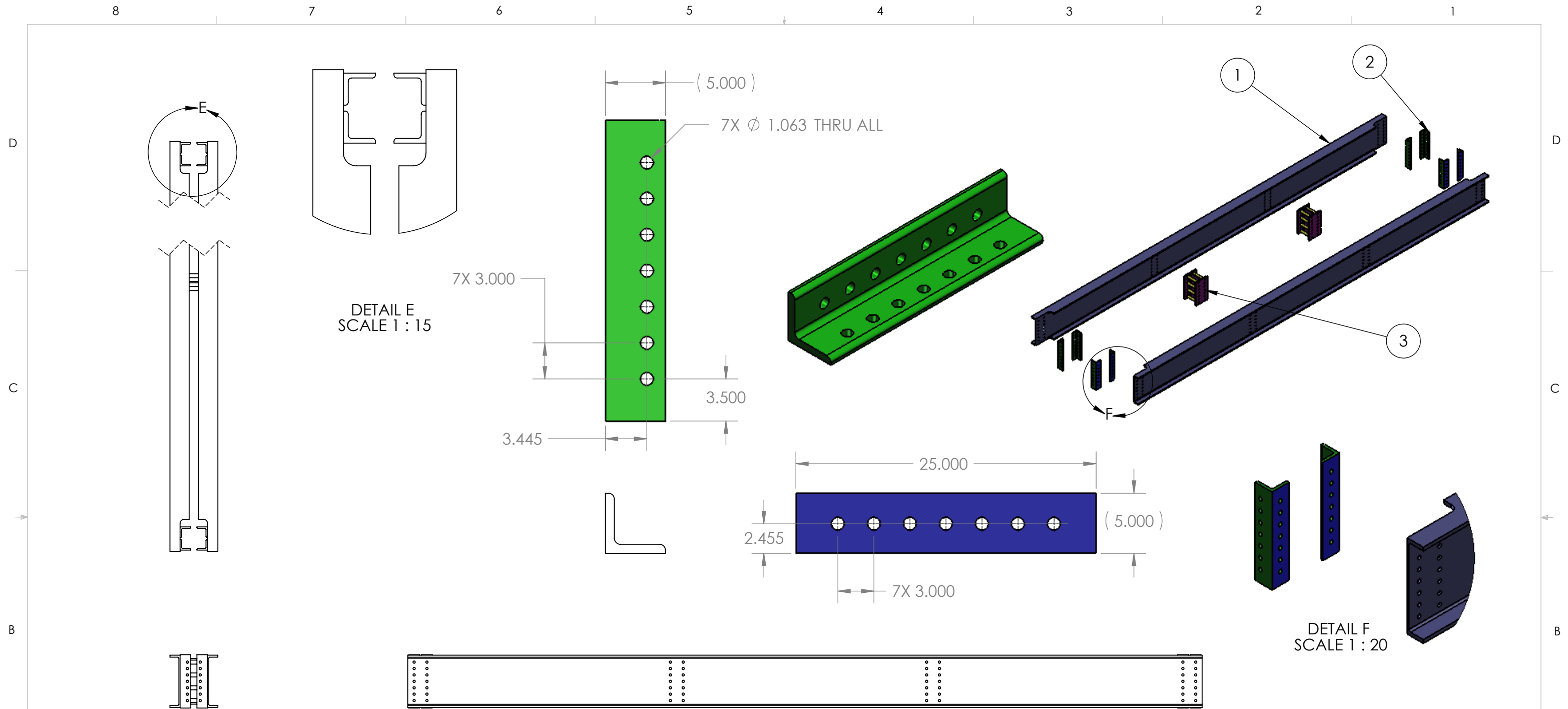
NIST

|                                      |         |                      |      |
|--------------------------------------|---------|----------------------|------|
| UNLESS OTHERWISE SPECIFIED:          |         | NAME                 | DATE |
| DIMENSIONS ARE IN INCHES             |         | DRAWN                |      |
| TOLERANCES:                          |         | CHECKED              |      |
| FRACTIONAL ±                         |         | ENG APPR.            |      |
| ANGULAR: MACH ± BEND ±               |         | MFG APPR.            |      |
| TWO PLACE DECIMAL ±                  |         | Q.A.                 |      |
| THREE PLACE DECIMAL ±                |         | COMMENTS:            |      |
| INTERPRET GEOMETRIC TOLERANCING PER: |         |                      |      |
| MATERIAL                             |         |                      |      |
| FINISH                               |         |                      |      |
| NEXT ASSY                            | USED ON |                      |      |
| APPLICATION                          |         | DO NOT SCALE DRAWING |      |

TITLE:  
**GENERIC GIRDER A ASSEMBLY**

SIZE **B** DWG. NO. REV

SCALE: 1:45 WEIGHT: SHEET 12 OF 15



**NOTES:**

1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDOR IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.

2) GIRDER LENGTH MAY ONLY VARY IN 24" INCREMENTS

3) HOLE PATTERNS TO ACCOMMODATE GIRDER SPACER SHALL BE SPACED A MAXIMUM OF 120" APART AS SHOWN

4) NO GIRDER SPACER NECESSARY FOR GIRDER SPAN OF 10'

5) GIRDER ANGLE B ADAPTER MATERIAL: L5x5x0.75

6) APPROXIMANT WEIGHT OF GIRDER B ADAPTER: 46 LBS.

5) APPROXIMANT WEIGHT OF GIRDER B ASSEMBLY AS SHOWN (30') IS 7,025 LBS., FOR 20' 4,760 LBS., FOR 10' 1,783 LBS.

| ITEM NO. | PART NUMBER   | DESCRIPTION            | QTY. |
|----------|---------------|------------------------|------|
| 1        | W24x103       | GIRDER A               | 2    |
| 2        | L5x5x0.75     | GIRDER ANGLE B ADAPTER | 8    |
| 3        | girder-spacer | GIRDER SPACER          | 2    |

|                                      |         |                      |      |
|--------------------------------------|---------|----------------------|------|
| UNLESS OTHERWISE SPECIFIED:          |         | NAME                 | DATE |
| DIMENSIONS ARE IN INCHES             |         | DRAWN                |      |
| TOLERANCES:                          |         | CHECKED              |      |
| FRACTIONAL ±                         |         | ENG APPR.            |      |
| ANGULAR: MACH ± BEND ±               |         | MFG APPR.            |      |
| TWO PLACE DECIMAL ±                  |         | Q.A.                 |      |
| THREE PLACE DECIMAL ±                |         | COMMENTS:            |      |
| INTERPRET GEOMETRIC TOLERANCING PER: |         |                      |      |
| MATERIAL                             |         |                      |      |
| FINISH                               |         |                      |      |
| NEXT ASSY                            | USED ON |                      |      |
| APPLICATION                          |         | DO NOT SCALE DRAWING |      |

**NIST**

TITLE:  
**GENERIC GIRDER B ASSEMBLY**

SIZE **B** DWG. NO. REV

SCALE: 1:45 WEIGHT: SHEET 13 OF 15

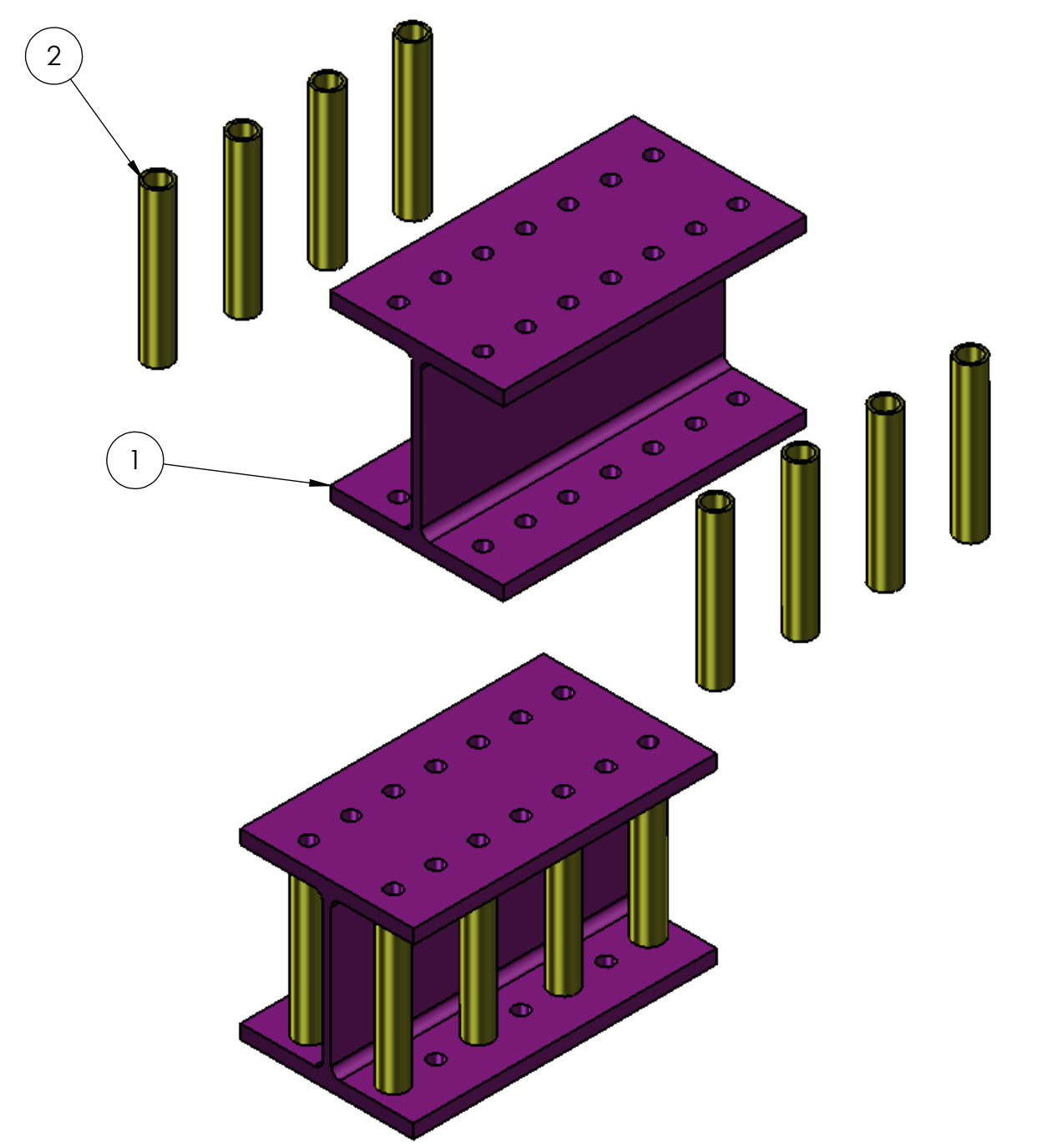
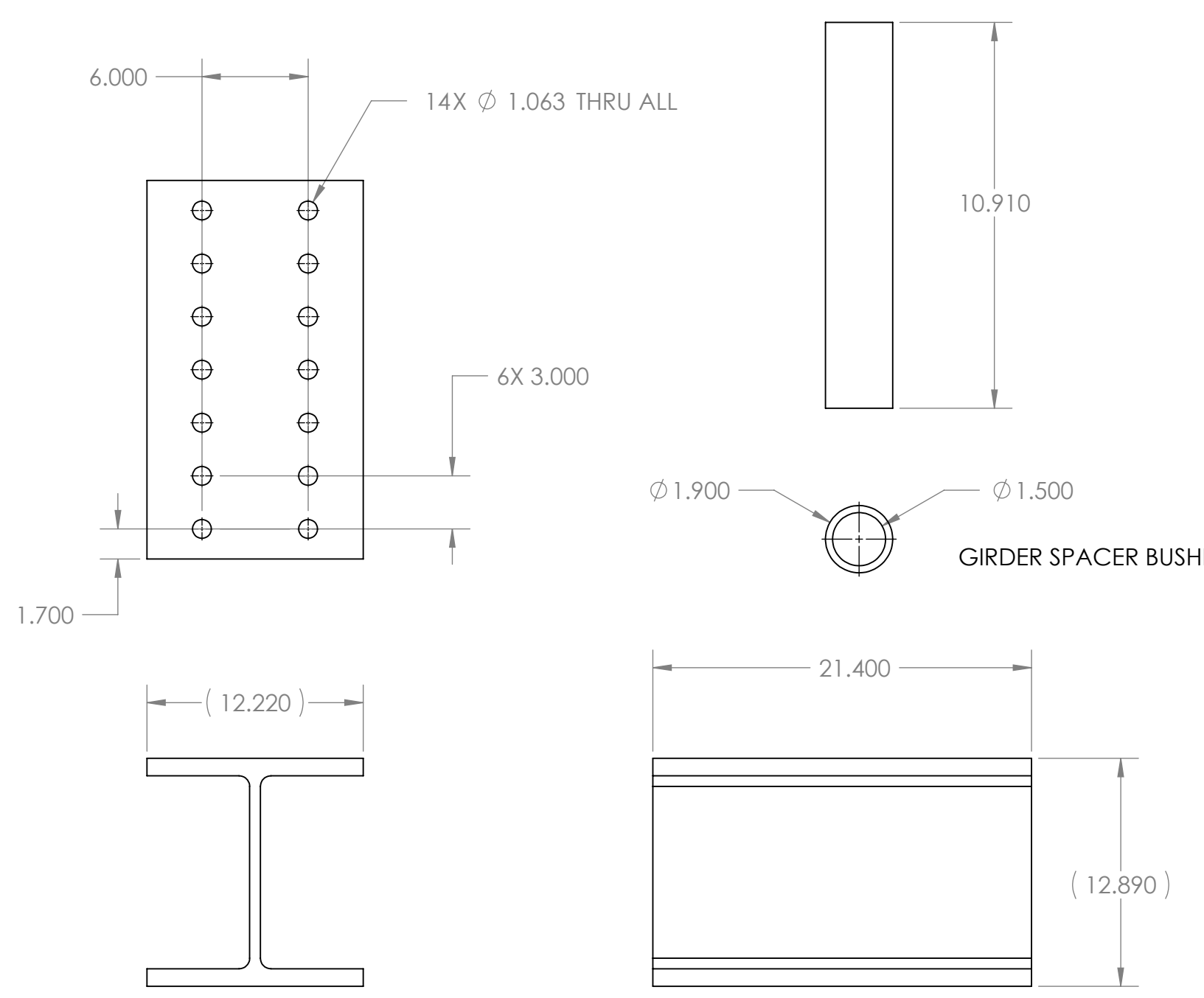
8 7 6 5 4 3 2 1

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NOTES:

- 1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.
- 2) GIRDER SPACER MATERIAL: W12x106
- 3) GIRDER SPACER BUSHING MATERIAL: 1.5x1.9 SCH 80 PIPE
- 4) APPROXIMATE WEIGHT: 210 LBS



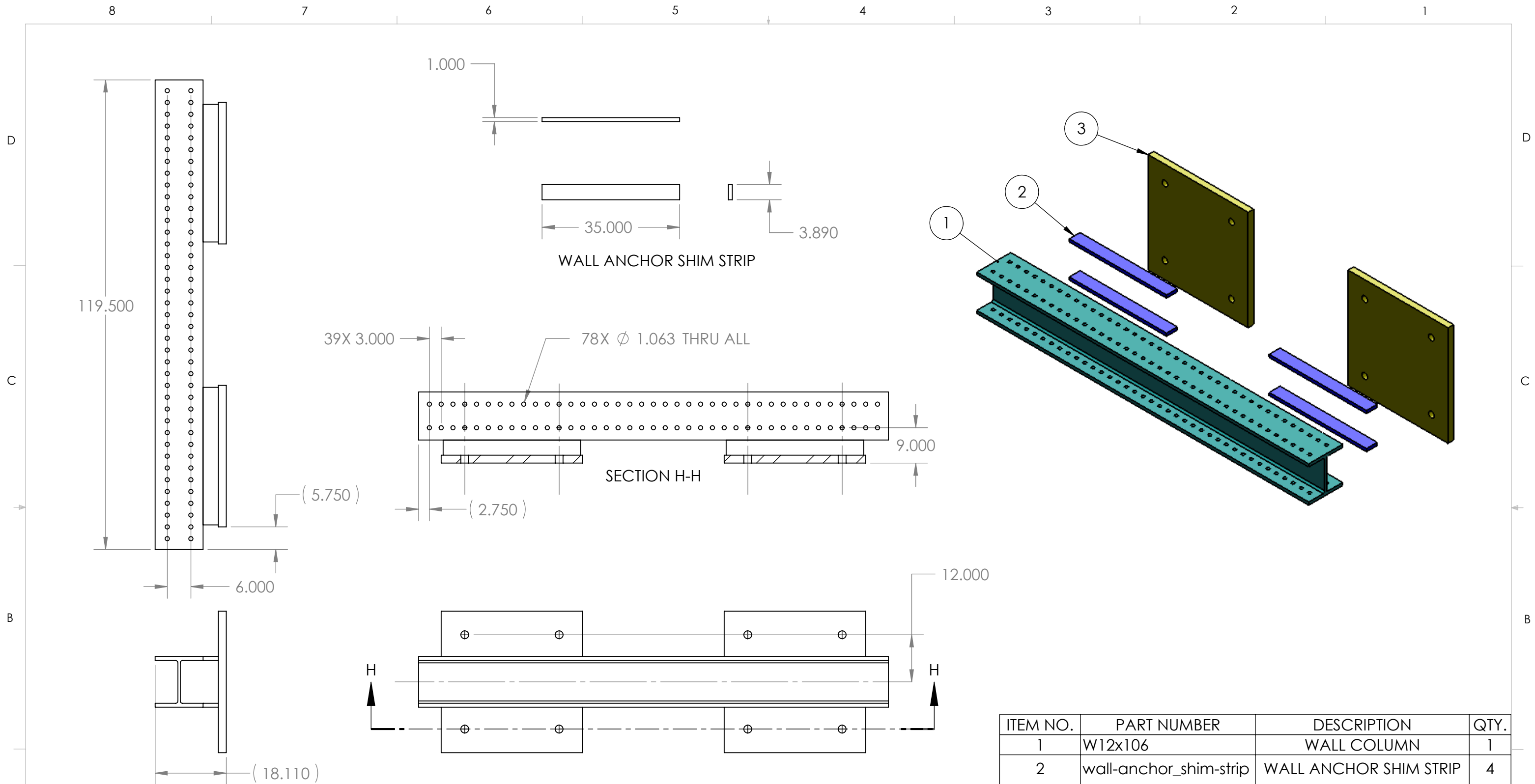
| ITEM NO. | PART NUMBER                  | DESCRIPTION           | QTY. |
|----------|------------------------------|-----------------------|------|
| 1        | W12x106                      | GIRDER SPACER         | 1    |
| 2        | girder_spacer-bushing_SCH-80 | GIRDER SPACER BUSHING | 8    |

|                                      |         |                      |      |
|--------------------------------------|---------|----------------------|------|
| UNLESS OTHERWISE SPECIFIED:          |         | NAME                 | DATE |
| DIMENSIONS ARE IN INCHES             |         | DRAWN                |      |
| TOLERANCES:                          |         | CHECKED              |      |
| FRACTIONAL ±                         |         | ENG APPR.            |      |
| ANGULAR: MACH ± BEND ±               |         | MFG APPR.            |      |
| TWO PLACE DECIMAL ±                  |         | Q.A.                 |      |
| THREE PLACE DECIMAL ±                |         | COMMENTS:            |      |
| INTERPRET GEOMETRIC TOLERANCING PER: |         |                      |      |
| MATERIAL                             |         |                      |      |
| FINISH                               |         |                      |      |
| NEXT ASSY                            | USED ON |                      |      |
| APPLICATION                          |         | DO NOT SCALE DRAWING |      |

TITLE:  
**GIRDER SPACER**

SIZE **B** DWG. NO. REV  
SCALE: 1:8 WEIGHT: SHEET 14 OF 15

8 7 6 5 4 3 2 1



**NOTES:**

1) ALL PART DIMENSIONS DO NOT CONTAIN NECESSARY CLEARANCES FOR FABRICATION. VENDER IS RESPONSIBLE FOR DETERMINING ALL APPROPRIATE CLEARANCES AND TOLERANCES FOR PART, WELDMENT AND MODULAR REACTION FRAME SYSTEM ASSEMBLY.

2) WALL COLUMN MATERIAL: W12x106

3) WALL ANCHOR SHIM STRIP MATERIAL: A36 OR EQIVLENT

4) APPROXIMATE WEIGHT: 2,634 LBS

| ITEM NO. | PART NUMBER            | DESCRIPTION            | QTY. |
|----------|------------------------|------------------------|------|
| 1        | W12x106                | WALL COLUMN            | 1    |
| 2        | wall-anchor_shim-strip | WALL ANCHOR SHIM STRIP | 4    |
| 3        | column-foot            | COLUMN FOOT            | 2    |

| UNLESS OTHERWISE SPECIFIED:          |         | NAME      | DATE |
|--------------------------------------|---------|-----------|------|
| DIMENSIONS ARE IN INCHES             |         | DRAWN     |      |
| TOLERANCES:                          |         | CHECKED   |      |
| FRACTIONAL ±                         |         | ENG APPR. |      |
| ANGULAR: MACH ± BEND ±               |         | MFG APPR. |      |
| TWO PLACE DECIMAL ±                  |         | Q.A.      |      |
| THREE PLACE DECIMAL ±                |         | COMMENTS: |      |
| INTERPRET GEOMETRIC TOLERANCING PER: |         |           |      |
| MATERIAL                             |         |           |      |
| FINISH                               |         |           |      |
| NEXT ASSY                            | USED ON |           |      |
| APPLICATION                          |         |           |      |
| DO NOT SCALE DRAWING                 |         |           |      |

TITLE:  
**WALL COLUMN ASSEMBLY**

SIZE **B** DWG. NO. REV

SCALE: 1:24 WEIGHT: SHEET 15 OF 15

**NIST**