

USER'S MANUAL FOR  
*LRFD SIGN STRUCTURE ANALYSIS*  
(SNLRFD)



**pennsylvania**  
DEPARTMENT OF TRANSPORTATION

Version 1.0.0.0

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**USER'S MANUAL FOR  
COMPUTER PROGRAM SNLRFD  
LRFD SIGN STRUCTURE ANALYSIS  
VERSION 1.0.0.0**

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## LRFD SIGN STRUCTURE ANALYSIS

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# LRFD SIGN STRUCTURE ANALYSIS

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# **1.0 PROGRAM IDENTIFICATION**

## **1.1 PROGRAM IDENTIFICATION**

**Program Title:** LRFD Sign Structure Analysis  
**Program Name:** SNLRFD  
**Version:** 1.0.0.0  
**Subsystem:** None  
**Authors:** Pennsylvania Department of Transportation,  
Michael Baker International

### **ABSTRACT:**

The LRFD Sign Structure program analyzes the loading conditions for seven different types of sign models using the criteria set forth in the AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. The types of sign models available for analysis are: two post tri-chord truss, four post tri-chord truss, four post four-chord truss, cantilever, centermount, cantilever monopipe, and monopipe frame structures.

## 1.2 ABBREVIATIONS

This section provides definitions of abbreviations that are commonly used throughout this User's Manual.

- AASHTO - American Association of State Highway and Transportation Officials.
- DM-4 - Pennsylvania Department of Transportation Design Manual Part 4, April 2015 Edition.  
This publication can be ordered from:  
Pennsylvania Department of Transportation  
Publication Sales  
P.O. Box 2028  
Harrisburg, PA 17105  
This publication can also be downloaded free of charge from PennDOT's website.
- FHWA - Federal Highway Administration
- LRFD Sign Specifications - LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, First Edition, 2015 with 2017 Interims, published by:  
American Association of State Highway and Transportation Officials  
444 North Capitol Street, N.W., Suite 249  
Washington, D.C. 20001
- LRFD Bridge Specifications - AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014, published by AASHTO.
- PennDOT - Pennsylvania Department of Transportation.
- SNLRFD - LRFD Sign Structure program.
- US - Customary United States units of measurement.

## **2.0 PROGRAM DESCRIPTION**

The Sign Structure program analyzes seven different types of sign models. A model generator preprocessor converts user input data into a finite element model that is then analyzed using the finite element analysis core of the program. Once the analysis is complete the program performs a specification check on all members of the structure based on the LRFD Sign Specifications. The results of the analysis and specification check including echo of user input, selected default values, member forces, cross section properties, combined stress ratios, and loadings are displayed in an output report file.

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# 3.0 *METHOD OF SOLUTION*

The program uses the SAPV finite element program to obtain forces and moments and the criteria set forth in the LRFD Sign Specifications.

The following sections explain the procedure used in various phases of the program.

## 3.1 NOTATIONS

The notations shown are the actual variable names used in the program Sign Structure. The purpose of this is to provide an invaluable documentation source for those who will maintain the program.

ANGCLR	=	Distance from the bottom chord of the truss to the top post strut (see Figure 3.3-4).
CATOFF	=	Catwalk offset - distance from the center of gravity of the catwalk to the center of the front chord (see Figure 3.4-3).
CATWT	=	Weight per foot of the catwalk and its attachments (see Figure 3.4-3).
CODIAM	=	Diameter of the chord.
CONOFF	=	Chord offset from the post.
LUMWT	=	Weight of a single luminaire.
NOLUM	=	Number of luminaires per sign (maximum of 3 per sign).
NOSUP	=	Number of sign supports (calculated internally).
PANOFF	=	Distance from the centerline of the post to the first vertical member of the truss.
PANWT	=	Weight per square foot of sign panel.
PDIAM	=	Diameter of the post for pipes.
PLEN	=	Distance between the top post strut and the bottom post strut (see Figure 3.3-4).
RBEND	=	Radius of pipe bend for Monopipe structures (see Figures 3.3-12 and 3.3-13).
SGNA	=	Area of the sign.
SGNHGT	=	Height of sign (see Figure 3.4-1).
SGNWID	=	Width of sign (see Figure 3.4-1).
SGNX	=	Distance of center of sign from the left post.

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- SGNY = Sign offset distance measured from the center of the front chord to the center of gravity of the sign and its support beams (see Figure 3.4-2).
- SGNWGT = Weight of each sign.
- STFCLR = Distance from the base of the post to the bottom post strut. This distance allows for the clearance of the stiffener (see Figure 3.3-4).
- STHGT = Structure height.
- STLEN = Structure length.
- STLENR = Right strut length (Centermount Only).
- SUPCOV = Distance from edge of sign to the centerline of the first sign support (see Figure 3.4-1). The program uses 2 feet as cover.
- SUPSPC = Maximum spacing of supports centerline to centerline (see Figure 3.4-1). The program uses a maximum spacing of 6 feet.
- SUPWT = Weight of a sign support per foot.
- TRDPTH = Horizontal distance between front and rear chords (see Figure 3.3-4)
- TRHGT = Distance between top and bottom chord/strut (see Figures 3.3-1, 3.3-4, 3.3-6, 3.3-8, 3.3-9 and 3.3-11).

## 3.2 GENERAL

The program reads a fixed format input file supplied by the user, and from the information provided constructs a finite element model with the appropriate loadings. The program then solves the model with the finite element analysis module.

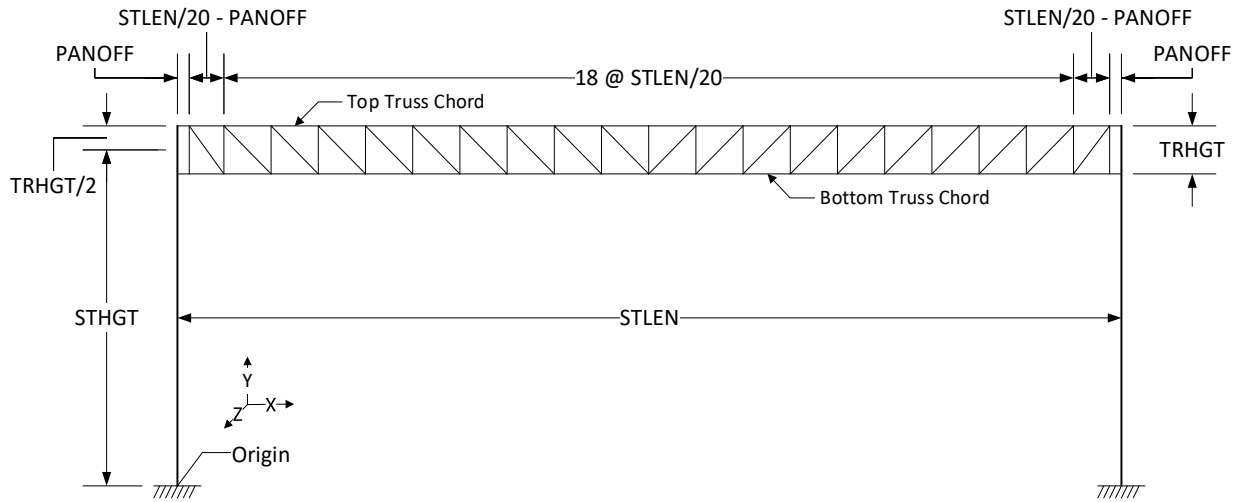
### 3.3 MODEL DESCRIPTION

This section describes the types of models available and description of the model built for each type. The following models are available:

- 1 - Two post tri-chord truss
- 2 - Four post tri-chord truss
- 3 - Four post four-chord truss
- 4 - Cantilever structure
- 5 - Centermount structure
- 6 - Cantilever monopipe
- 7 - Monopipe frame

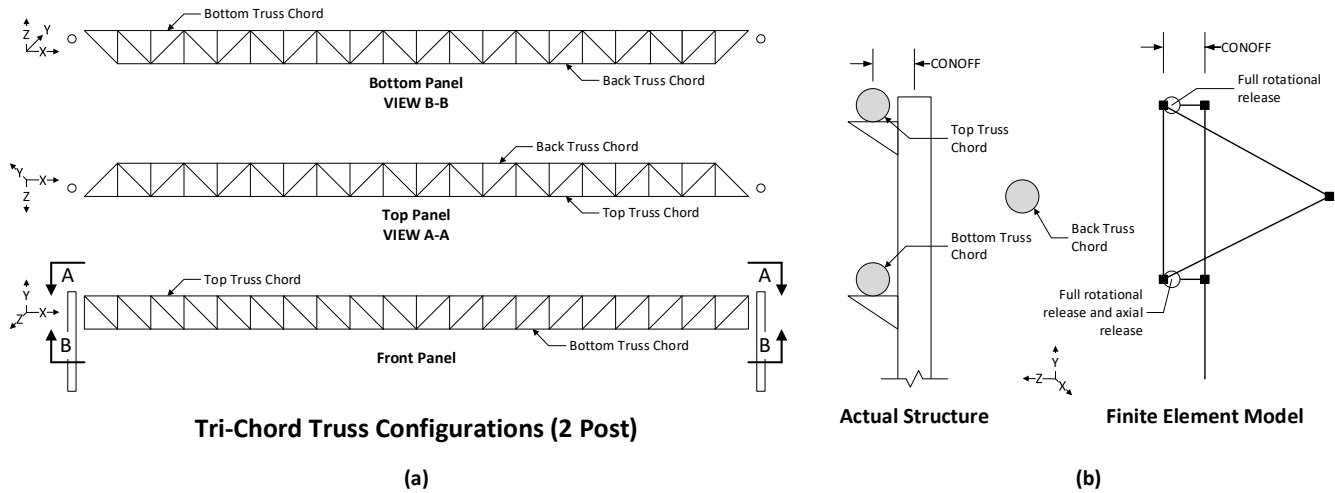
3.3.1 TWO POST TRI-CHORD TRUSS

The two post tri-chord truss has a front truss configuration as shown below:



**Figure 3.3-1 Two-Post Tri-Chord Configuration**

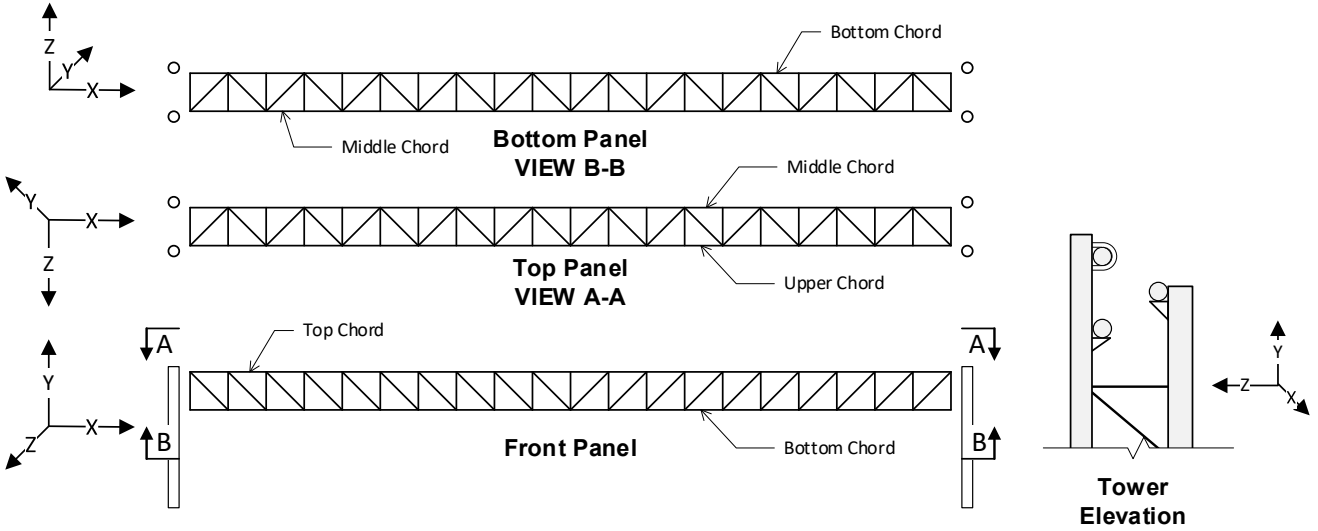
The length of the interior panels is equal to the Span Length divided by 20. The end panel length varies due to the offset to the end vertical. The front panel offset from the post is equal to the sum of half the post diameter and half the chord diameter plus  $3\frac{1}{2}$ " as detailed in BC-744M. The top and bottom truss configurations consist of diagonals and verticals with a configuration as shown in Figure 3.3-2 (a). The model is built using space frame elements with each post composed of two elements and one element for each vertical, diagonal, and chord member in each truss. The connection of the truss to the posts is accomplished with small elements that are rigidly connected to the post and have rotational releases at the connection with the truss (see Figure 3.3-2 (b)). Note that the front lower chord is axially released because the U-bolts are only hand tightened (BC-744M, Sheet 9 of 12, "Truss Seat Details").



**Figure 3.3-2 Two-Post Tri-Chord Configuration Detail**

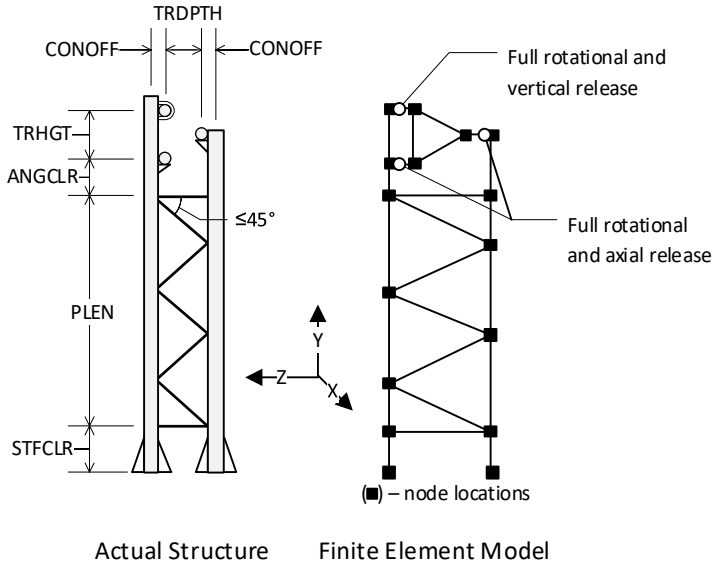
**3.3.2 FOUR POST TRI-CHORD TRUSS**

The truss configuration (Figure 3.3-3) is similar to that of the two-post tri-chord truss (see Figure 3.3-2) with the exception of two additional members located at the ends of the trusses. The connection of the truss to the posts is accomplished with small elements that are rigidly connected to the post and have rotational releases at the connection with the truss. The post supports are fixed.



**Figure 3.3-3 Four-Post Tri-Chord Configuration**

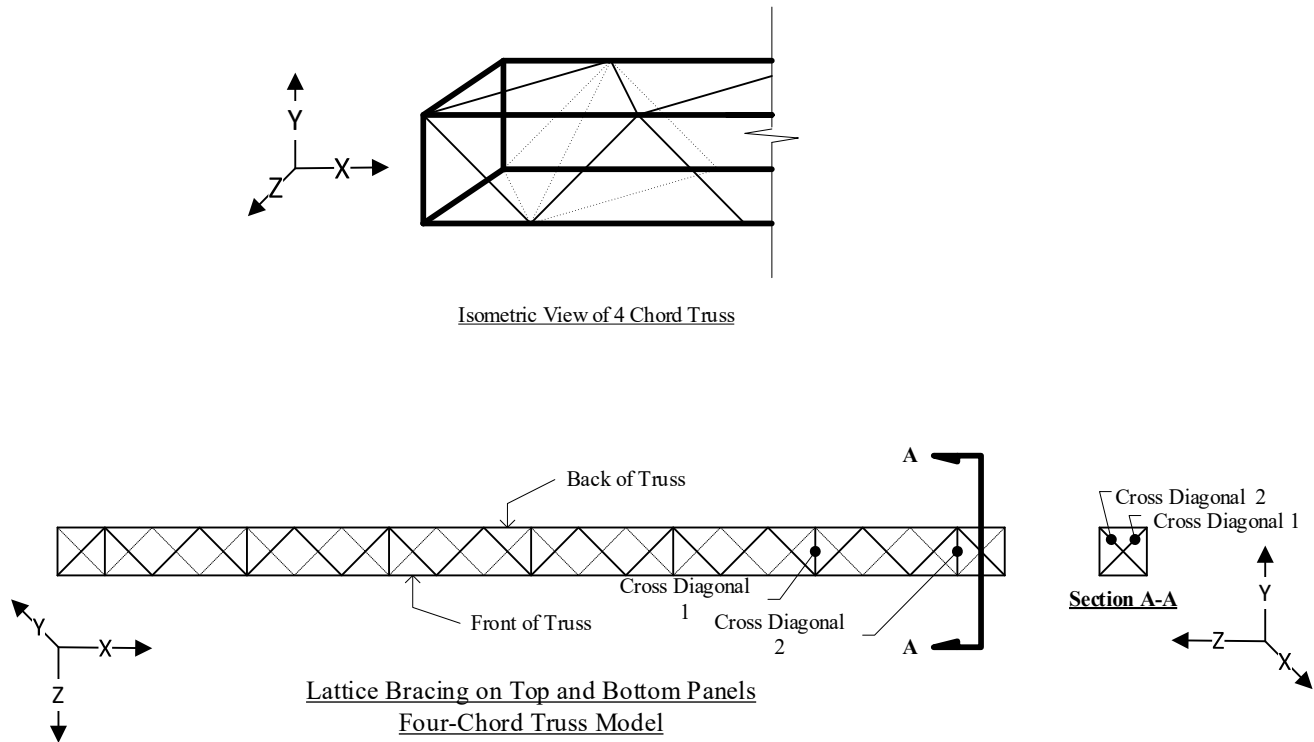
The post configuration and its accompanying finite element model are shown in Figure 3.3-4. The post bracing is modeled to transfer only axial and torsion loads. Note that the front upper chord is vertically released because there are no saddle blocks supporting it, and the front lower and back chords are axially released because the U-bolts are only hand tightened (BC-744M, Sheet 6 of 12, Section A-A).



**Figure 3.3-4 Four-Post Tri-Chord-Post Detail**

### 3.3.3 FOUR POST FOUR-CHORD TRUSS

The front and rear faces of the truss are similar to that of the top and bottom panels. The top and bottom truss consist of diagonal lattice bracing as shown in Figure 3.3-5. Note that vertical members are present only at the ends of the truss.



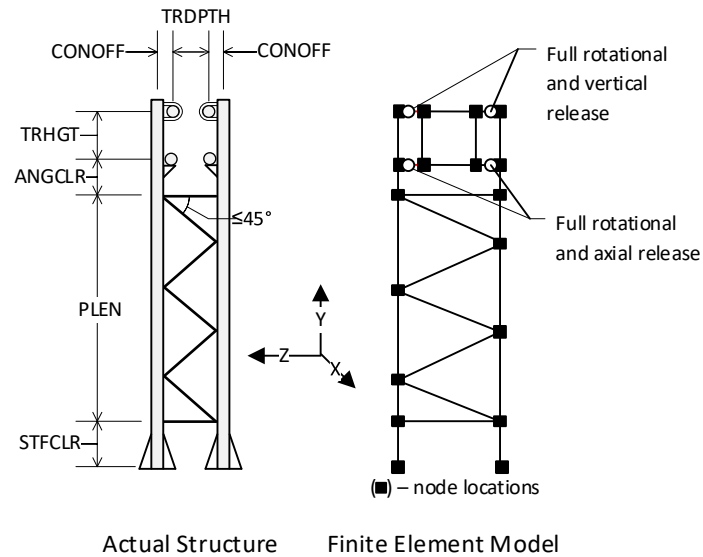
**Figure 3.3-5 Four-Chord Truss Configuration**

To satisfy BC-745, sheet 6 of 10, diagonal cross bracing from the top to bottom panel is provided at a maximum of every third panel location, except at the end of truss verticals (see **Section A-A** in Figure 3.3-5). SNLRFD does not move the cross bracing to accommodate chord splices and will warn the user if a chord splice has been defined at a cross bracing location. The first cross brace location is determined by finding the remainder of dividing half of the number of panels by three ( $\text{MOD}(\text{NPANELS}/2)/3$ ). If the remainder is zero, the first brace is placed at the right side of panel 3. If the remainder is one, the first cross brace is placed at the right of panel one (as shown in Figure 3.3-5). If the remainder is two, the first cross brace is placed at the right of panel two. Cross braces are then placed at the right of every third panel thereafter.

For example, given a truss with 40 panels, the first cross brace is placed at the right of panel 2 ( $(40 / 2) / 3 = 20 / 3 = 6 \text{ R } 2$ ), then at panels 5, 8, 11 ... 32, 35, 38.

The post configuration and its accompanying finite element model are shown in Figure 3.3-6. The post

bracing is modeled to transfer only axial and torsion loads. Note that both upper chords are vertically released because there are no saddle blocks supporting them, and both lower chords are axially released because the U-bolts are only hand tightened (BC-745M, Sheet 5 of 10, Section A-A).

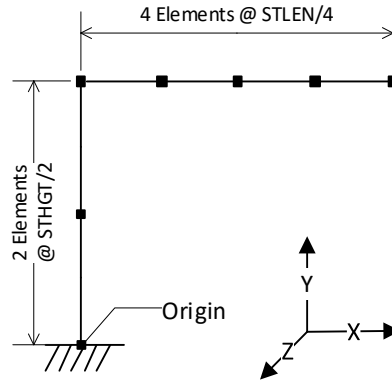


**Figure 3.3-6 Four Post Four-Chord-Post Detail**

The post supports are fixed.

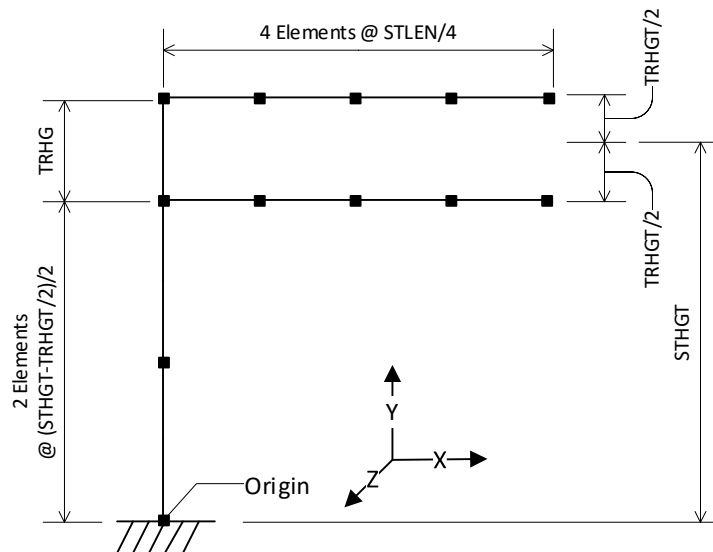
3.3.4 CANTILEVER STRUCTURE

The single strut cantilevered sign structure will be modeled as shown in Figure 3.3-7. The base of the structure is fixed against rotation and translation.



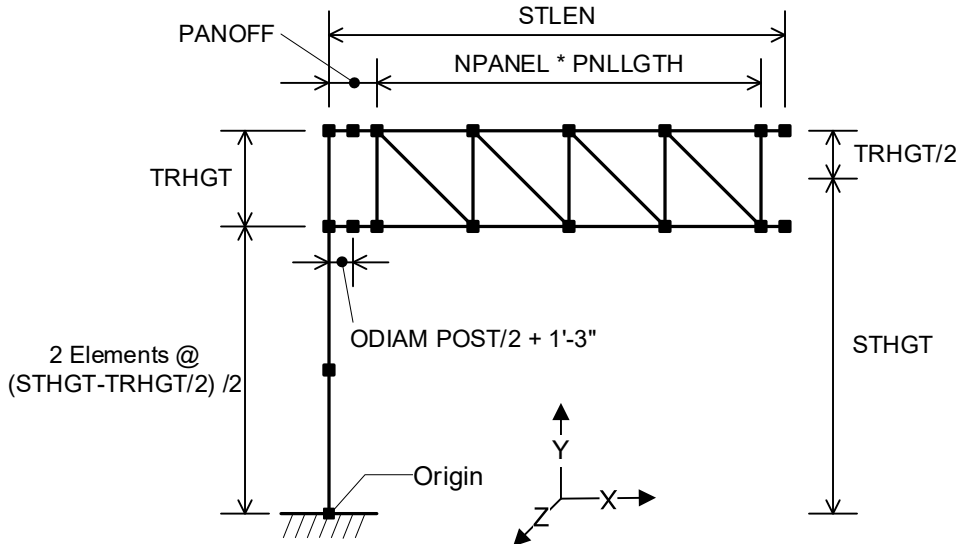
**Figure 3.3-7 Single Strut Cantilever Configuration**

The column and the strut are rigidly connected, with the strut consisting of four elements and the post consisting of two elements. The double strut cantilevered sign structure is modeled as shown in Figure 3.3-8. The configuration is similar to the single strut model, except an extra element is used in the column and an extra strut with four elements is placed at a distance of TRHGT below the top strut.



**Figure 3.3-8 Double Strut Cantilever Configuration**

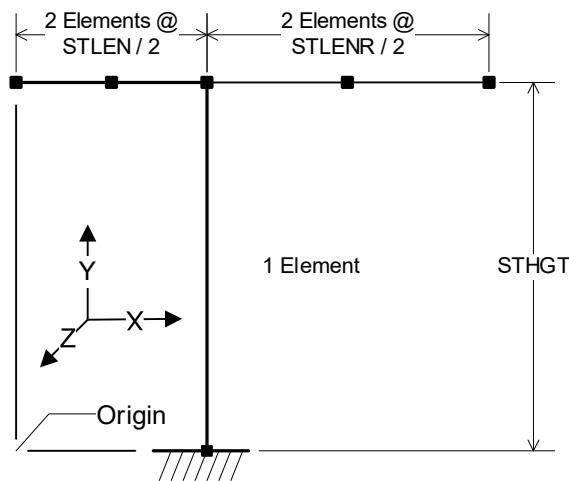
If the cantilever structure supports a DMS, the model includes vertical and diagonal bracing between the upper and lower struts (See Figure 3.3-9). Also, a chord splice for each strut is automatically generated at a distance of 1'-3" from the outside edge of the post.



**Figure 3.3-9 DMS Cantilever Configuration**

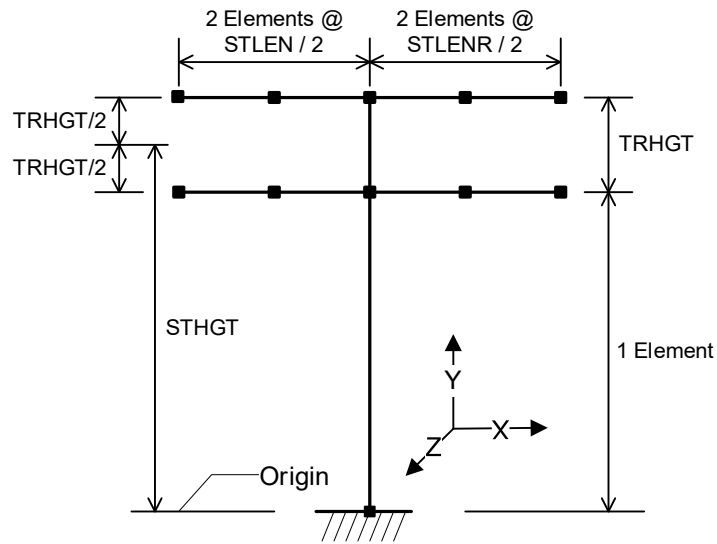
### 3.3.5 CENTERMOUNT STRUCTURE

The centermount structures can have either one or two struts. The single strut centermount structure is fixed at the column base with the column modeled as a single element and the strut comprised of four elements (see Figure 3.3-10). The strut may be unbalanced; that is, the strut may have different lengths on each side of the post, as shown in Figure 3.3-10. These lengths are defined using the SPAN/CANTILEVER LENGTH (STLEN) and RIGHT STRUT (STLENR) input items on the CRITERIA command (see Section 4.2). STLEN and STLENR are shown in Figures 3.3-10 and 3.3-11. The strut is modeled as a rigid connection to the column.



**Figure 3.3-10 Single Strut Centermount Configuration**

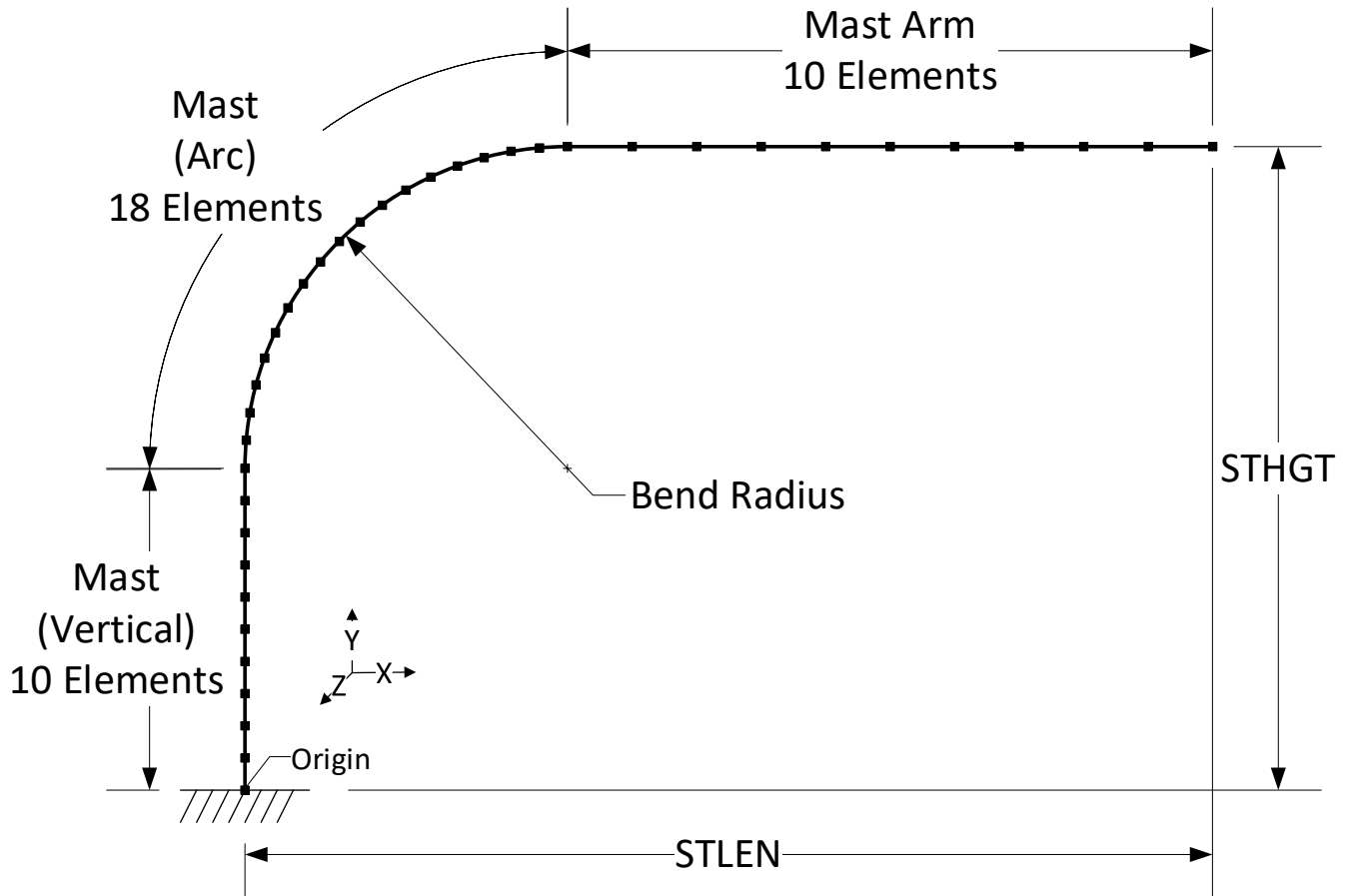
The double strut centermount structure is fixed at the column base with two elements comprising the column, and four elements comprising each of the two struts (see Figure 3.3-11). The struts are modeled as rigid connections to the column. The location of the first strut from the base will depend on the distance STHGT and the height of the sign.



**Figure 3.3-11 Double Strut Centermount Configuration**

### 3.3.6 CANTILEVER MONOPIPE STRUCTURE

The cantilever monopipe sign structure is modeled as shown in Figure 3.3-12. The base of the structure is fixed against rotation and translation.

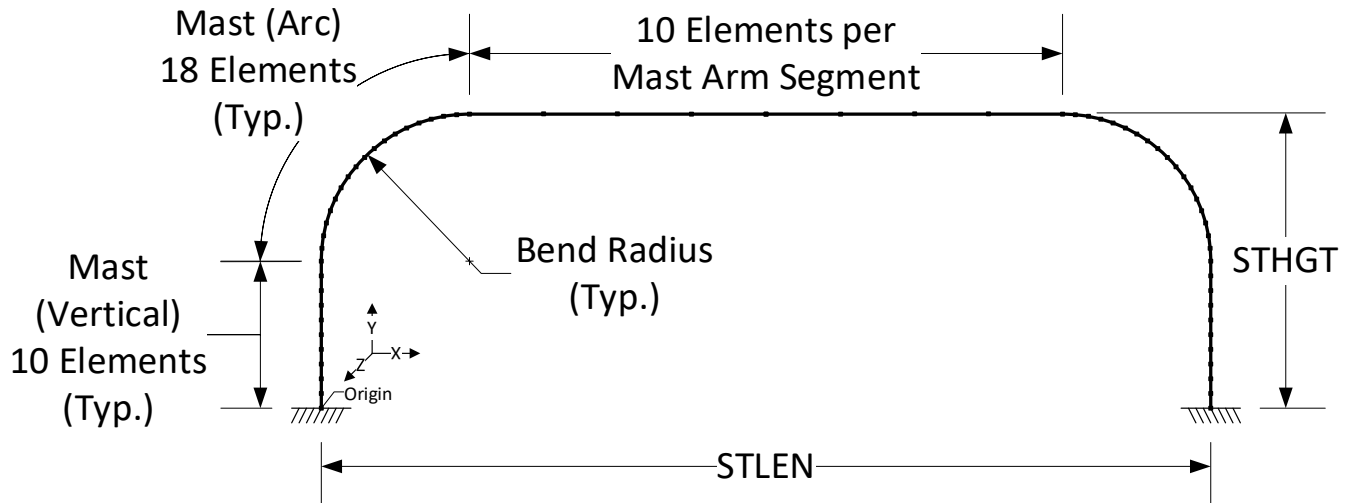


**Figure 3.3-12 Cantilever Monopipe Configuration**

The mast and mast arm are rigidly connected, with the mast arm consisting of four elements and the mast consisting of 28 elements. The circular arc of the mast is divided into 18 elements with each element corresponding to a five degree chord of the arc. The vertical portion of the mast is divided into 10 elements. For the vertical portion of the mast at the base of the structure, if a base plate stiffener height is specified on the Pipe Connection Detail input, the node closest to the top of the stiffener plate will be placed at the top of the stiffener plate to correspond to a fatigue location.

### 3.3.7 MONOPIPE FRAME STRUCTURE

The monopipe frame sign structure is modeled as shown in Figure 3.3-13. The two masts are fixed against rotation and translation at the bases.



**Figure 3.3-13 Monopipe Frame Configuration**

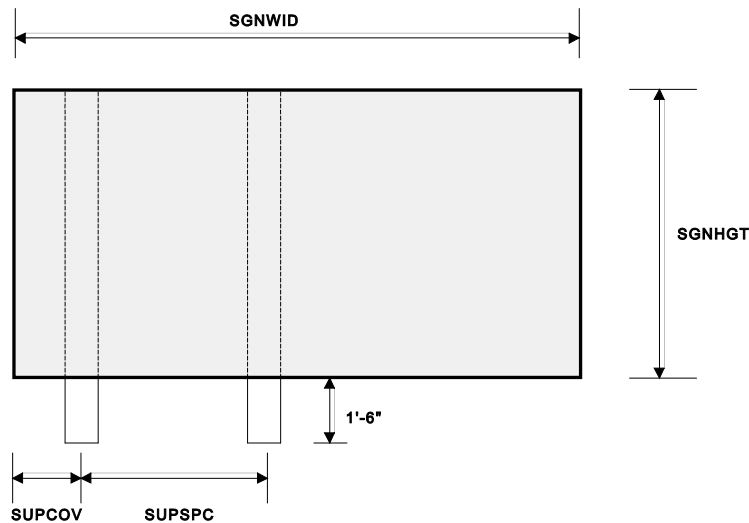
The two masts are rigidly connected to the mast arm, with the mast arm consisting of one to six segments with each segment consisting of 10 elements. The number of segments is based on the minimum and maximum length of mast arm segments as defined on sheet 4 of 5 of Standard BD-647M. Each mast consists of 28 elements. The circular arc of each mast is divided into 18 elements with each element corresponding to a five degree chord of the arc. The vertical portion of each mast is divided into 10 elements. For the vertical portion of the mast at the base of the structure, if a base plate stiffener height is specified on the Pipe Connection Detail input, the node closest to the top of the stiffener plate will be placed at the top of the stiffener plate to correspond to a fatigue location.

### 3.4 LOADING DESCRIPTION

This section describes the various loadings applied to the structure. The loadings include dead load, normal and transverse wind loads, and fatigue loads on the structure, the signs, and the structure attachments.

#### 3.4.1 DEAD LOAD ATTACHMENTS

The dead load applied to the structure includes self-weight of the members and the weight of the sign, the sign supports, the luminaires, and the catwalk. The calculation for the total sign weight is shown below using values described in Figure 3.4-1.

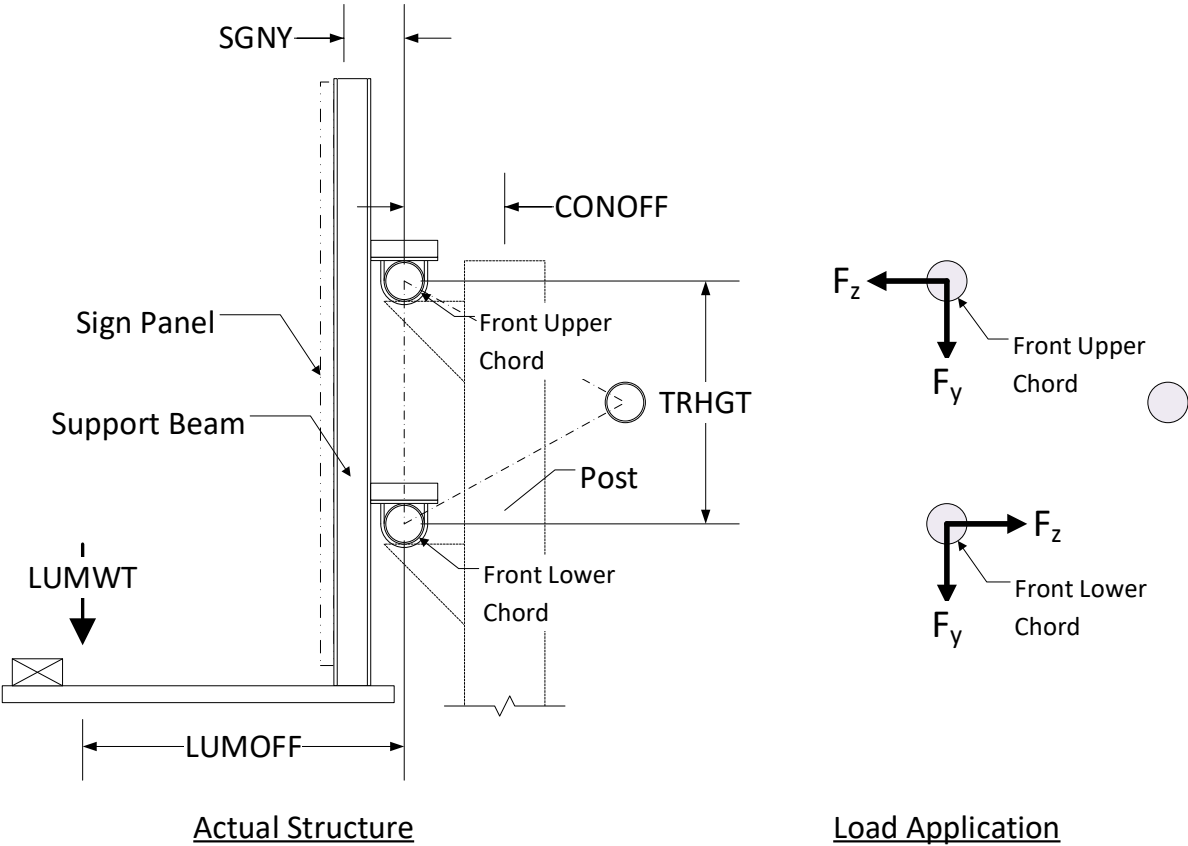


**Figure 3.4-1 Sign Dimensions**

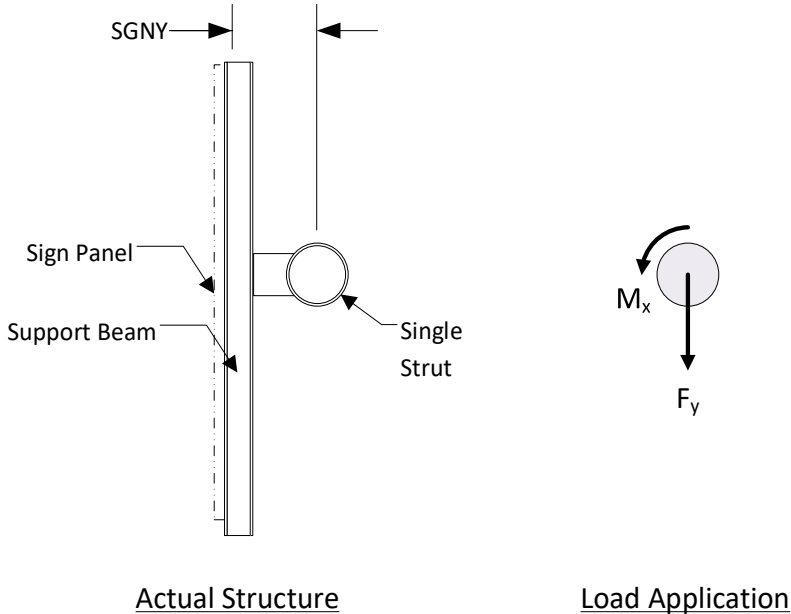
The following equation determines the weight of each sign and its attachments:

$$SGNWGT = SGNA * PANWT + NOSUP * SUPWT * (SGNHGT + 1'-6") + NOLUM * LUMWT$$

Once the total weight is computed the load is applied to the structure over the width of the sign. If the sign extends past the end of the chord/strut, the total weight of the sign is applied to the length of the sign covering the chord/strut. For two chord/strut structures (i.e., all truss type models and other models with two struts) half of the vertical load is applied to both the top and bottom chords/struts and a moment couple is applied over the two chords/struts (see Figure 3.4-2). For monopipe structures, if the sign extends past the end of the mast arm towards the circular curved mast, the weight of the sign is applied to the corresponding portion of the circular curved mast. For monopipe structures and structures with a single strut all of the vertical load is applied to the single strut and a moment (torque) is applied to the single strut (see Figure 3.4-2).



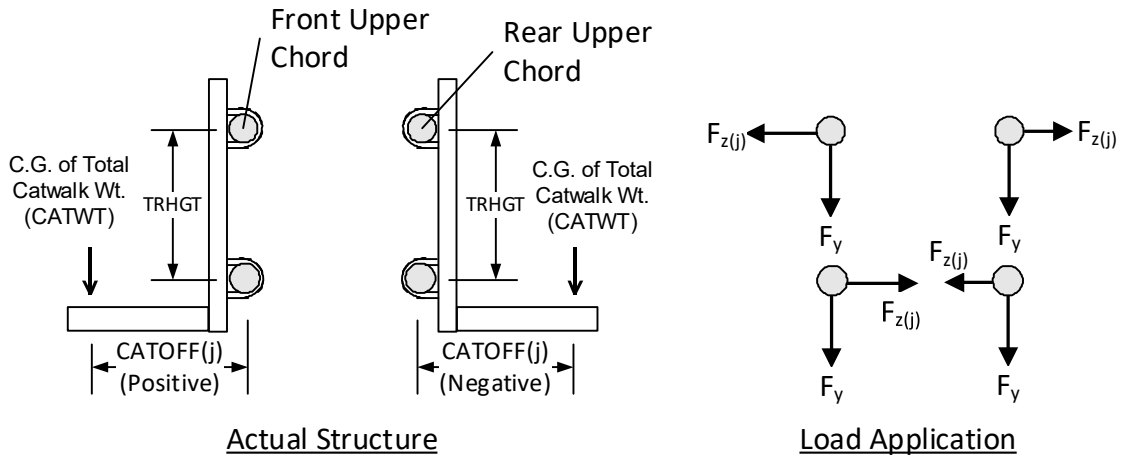
Where:  $F_z = [(SGNWGT * SGNY) + NOLUM * LUMWT * (LUMOFF - SGNY)] / TRHGT$   
 $F_y = SGNWGT/2$



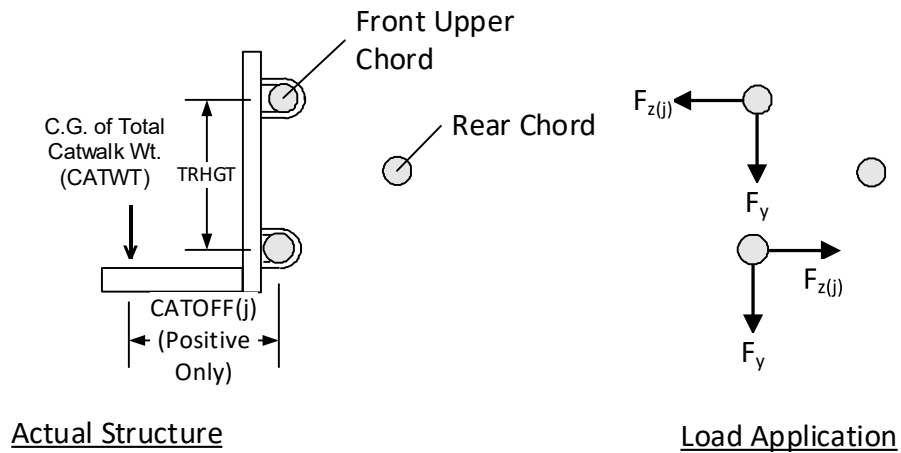
Where:  $F_y = SGNWGT$   
 $M_x = SGNWGT * SGNY$

**Figure 3.4-2 Sign Load Application**

The catwalk loading for tri-chord and four-chord models distributes the load to the front upper and front lower chords (see Figure 3.4-3), with the actual concentrated loads distributed as uniform loads along the length of the catwalk. Catwalk loads cannot extend beyond the ends of the chords. The start and end of the catwalk is entered by the user.



Catwalk Load Application Four-Chord Trusses



Catwalk Load Application Three-Chord Trusses

Where:  $F_{z(j)} = CATWT * CATOFF(j) / TRHGT$   
 $F_y = CATWT / 2$

**Figure 3.4-3 Catwalk Load Application**

**3.4.2 ICE LOAD**

The LRFD Sign Specifications, Article C3.7, notes that ice and wind on ice does not practically control the critical load effect and to simplify the LRFD Sign Specifications, these load combination have been eliminated. Therefore, Ice Load is not considered by this program.

**3.4.3 WIND LOAD**

The wind pressure calculations for the sign structure program are based on the LRFD Sign Specifications Equation 3.8.1-1:

$$P_z = 0.00256K_zK_dGV^2C_d$$

- where:  $P_z$  = Design Wind pressure in pounds per square foot
- $V$  = Basic wind speed (mph)
- $K_z$  = Height and exposure factor defined in Article 3.8.4
- $K_d$  = Directionality factor defined in Article 3.8.5
- $G$  = Gust effect factor defined in Article 3.8.6
- $C_d$  = Drag coefficient defined in Article 3.8.7

The value for  $V$  used by the program is input by the user or defaults to 120 mph for the Extreme limit state, corresponding to a Mean Recurrence Interval (MRI) of 1700 years for the state of Pennsylvania (LRFD Sign Specifications Table 3.8-1 and Figure 3.8-2b), and 76 mph for the Service limit state, corresponding to an MRI of 10 years (LRFD Sign Specifications Figure 3.8-4b and Article C3.8.2). See Section 4.9 in this User's Manual for how and when to use other wind speeds. The value for  $K_z$  is computed from the LRFD Sign Specifications Equation 3.8.4-1:

$$K_z = 2.0 \left( \frac{z}{z_g} \right)^{\frac{2}{\alpha}}$$

- where:  $z_g$  = 900 ft
- $\alpha$  = 9.5

The variable  $z$ , height above ground, is input by the user or defaults to the user input value of the structure height 'STHGT'. The directionality factor,  $K_d$ , equals 0.95 for Post members and equals 0.85 for all other members. The drag coefficient  $C_d$  is computed using LRFD Sign Specifications Table 3.8.7-1 including the 2017 Interim updates (See Table 3.4-1). The variable  $C_v$  equals 0.8 for the Extreme Limit State and equals 1.0 for all other limit states.

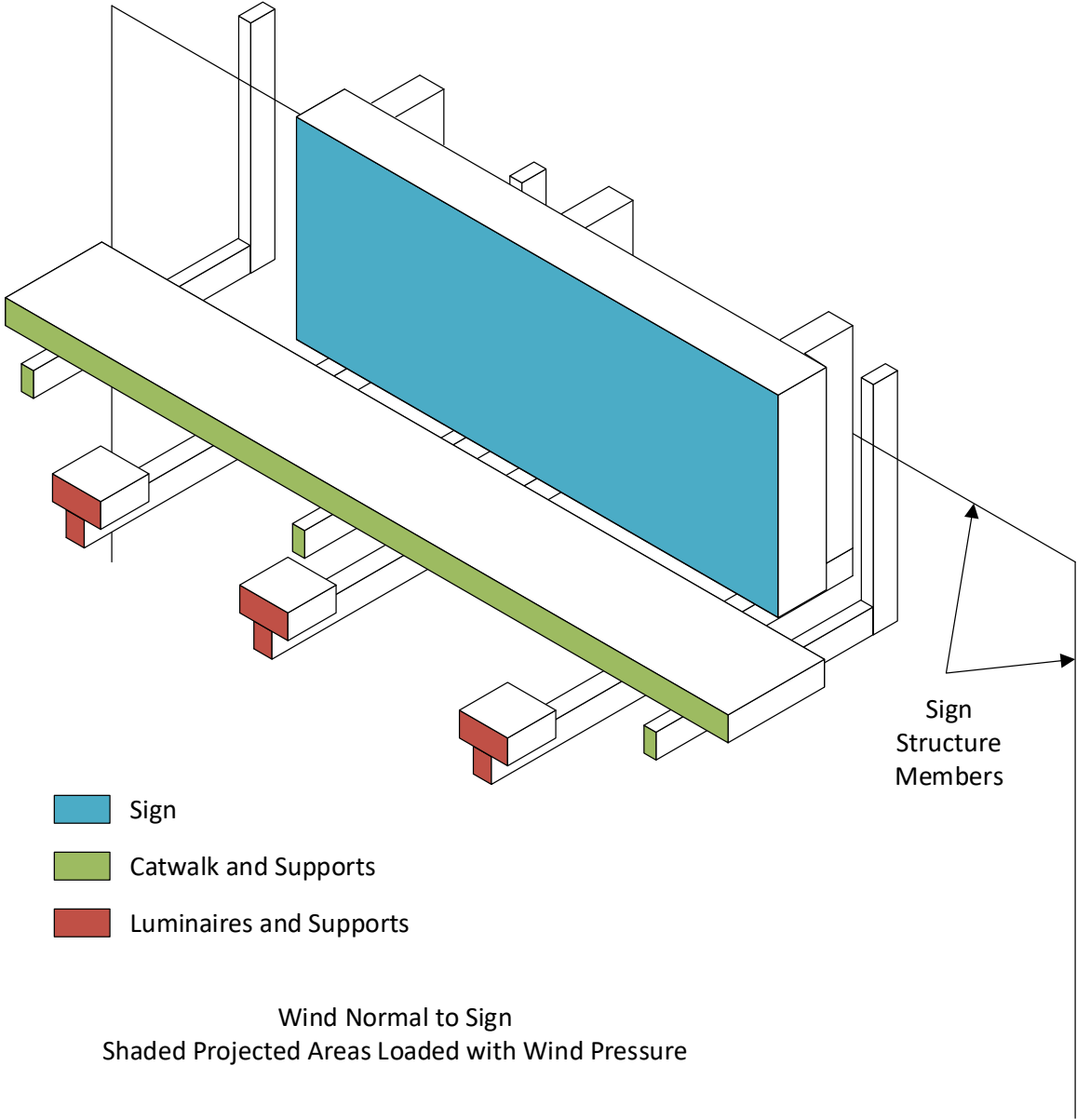
Table 3.4-1 Cd Values by Member

Type of Member	C <sub>d</sub> Value
Single member or Truss:	
Cylindrical	
C <sub>v</sub> Vd ≤ 39	1.10
39 < C <sub>v</sub> Vd < 78	129 / (C <sub>v</sub> Vd) <sup>1.3</sup>
C <sub>v</sub> Vd ≥ 78	0.45
Octagonal	1.2
Dodecagonal	
C <sub>v</sub> Vd ≤ 39	1.20
39 < C <sub>v</sub> Vd < 78	10.8 / (C <sub>v</sub> Vd) <sup>0.6</sup>
C <sub>v</sub> Vd ≥ 78	0.79
Hexadecagonal (0 ≤ r <sub>c</sub> < 0.26)	
C <sub>v</sub> Vd ≤ 39	1.10
39 < C <sub>v</sub> Vd < 78	1.37 + 1.08r <sub>c</sub> - C <sub>v</sub> Vd/145 - C <sub>v</sub> Vdr <sub>c</sub> /36
C <sub>v</sub> Vd ≥ 78	0.83 - 1.08r <sub>c</sub>
Hexadecagonal (r <sub>c</sub> ≥ 0.26)	
C <sub>v</sub> Vd ≤ 39	1.10
39 < Vd < 78	0.55 + (78.2 - C <sub>v</sub> Vd) / 71
C <sub>v</sub> Vd > 78 and r ≥ 0.26	0.55
Flat (also catwalks)	1.7
Sign Panel (by ratio of length to width) (values interpolated between ratios)	
L/W = 1.0	1.12
2.0	1.19
5.0	1.20
10.0	1.23
15.0	1.30
DMS Boxes	1.7
Luminaires (with rectangular flat side)	1.2

Where: L/W = maximum of SGNWID/SGNHGT or SGNHGT/SGNWID  
d = Depth (diameter) of the member in feet  
r<sub>c</sub> = Ratio of corner radius to radius of inscribed circle for polygonal tube

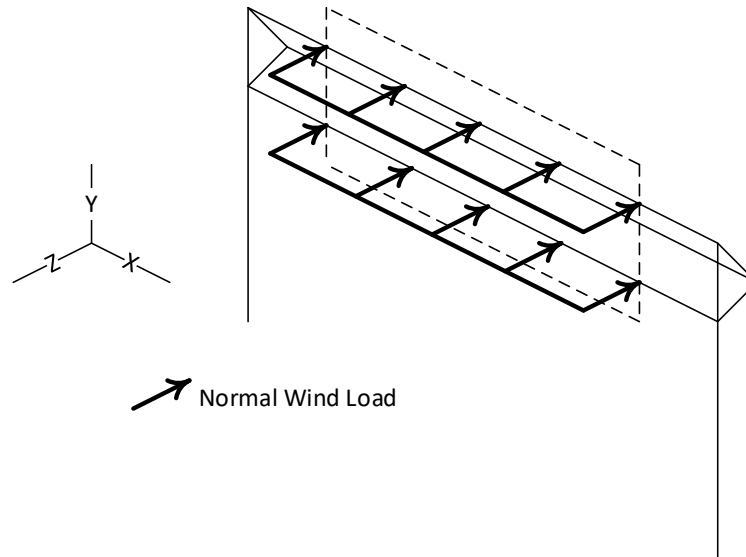
3.4.4 DESIGN WIND LOADS ON STRUCTURES

The wind pressures are applied horizontally to the projected normal areas of the supports, signs, luminaires and catwalk. Normal wind loads are computed normal to the plane of the structure. Figure 3.4-4 shows a sketch of the normal areas for signs, luminaires and catwalk.



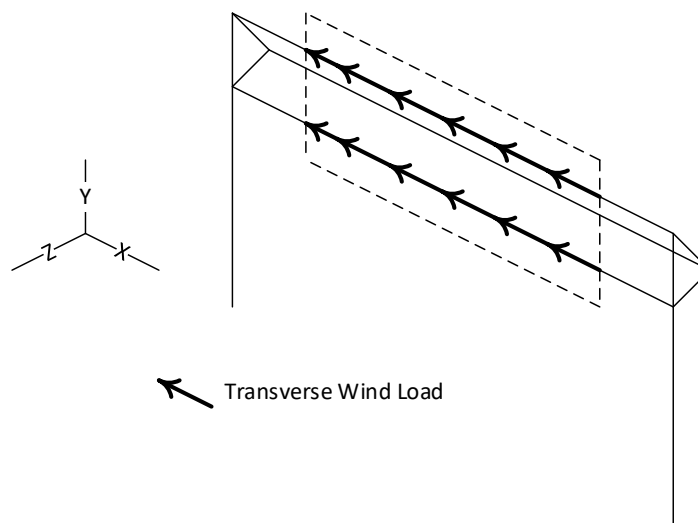
**Figure 3.4-4 Normal Wind Pressure Application on Attachments**

Normal wind pressures on attachments are modeled as uniform, global loads in the Z-direction applied along the length of the sign structure members supporting the attachments. Figure 3.4-5 shows how the normal wind load on the sign panel is applied to the sign structure members. Normal wind loads for catwalks and luminaries are applied in a similar manner.



**Figure 3.4-5 Normal Wind Load Application to Sign Structure**

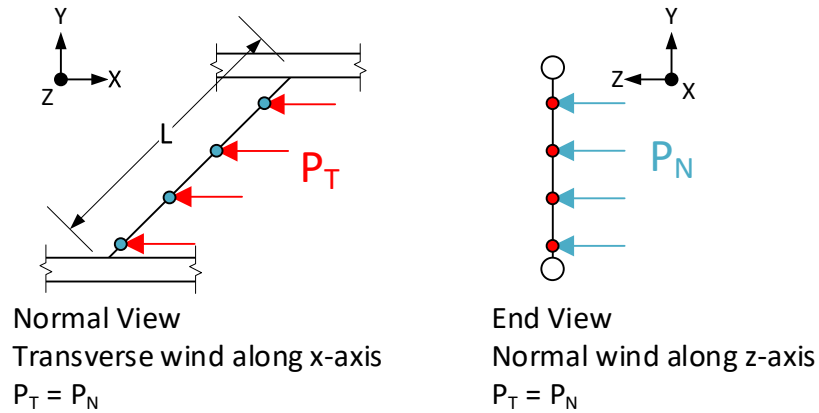
Transverse wind loads on attachments are equal to normal wind loads on attachments and are modeled as uniform, global loads in the X-direction along the length of the sign structure members supporting the attachments. Transverse wind loads do not depend on the transverse projected areas of the attachments. The magnitude of the transverse wind loads is equal to the magnitude of the normal wind loads. The transverse loads are applied to the same members that the normal wind load is applied to. Figure 3.4-6 shows how the transverse wind load on the sign panel is applied to the sign structure members. Transverse wind loads for catwalks and luminaries are applied in a similar manner.



**Figure 3.4-6 Transverse Wind Load Application to Sign Structure**

Wind pressures on members of the sign structure are modeled as uniform loads applied along the length

of each member. Normal wind loads are applied in the global Z direction. Transverse wind loads are applied in the global X direction as shown in Figure 3.4-7.



**Figure 3.4-7 - Wind Loads on Members**

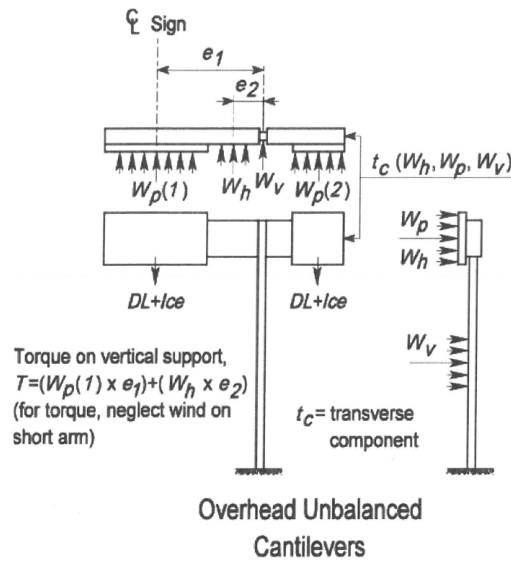
Applying the same wind load (force/length) along the length of the member ensures the total transverse wind load on the member is equal to the total normal wind load on the member.

The wind loads acting horizontally on members of the sign structure is computed from the depth of the member (or diameter for pipes) times the wind pressure.

Sign structure members that are located behind any attachments are loaded like all other sign structure members. The program, conservatively, does not consider any "shadow" effect due to other members or attachments.

For centermount structures, a torque due to wind on the signs, luminaires, and struts is calculated assuming that the signs, luminaires, and struts on only one side of the structure are loaded, as per the LRFD Sign Specifications, Article 3.9.4.1. When signs, luminaires, and struts are present on both sides, torques are calculated independently and the larger torque is applied to all of the post elements for the load cases including the normal wind load, using the same load factors as the normal wind load. Note that for this calculation, the full length of each strut is used; the program does not ignore portions of the struts that are behind the signs. In Figure 3.4-8, the  $W_h$  load shown is assumed to extend behind the sign, as well. In SNLRFD,  $W_p$  as shown in Figure 3.4-8 includes load from wind on the sign as well as wind on the luminaires. Figure 3.4-8 is an excerpt from Figure 3.9-1 of the LRFD Sign Specifications.

The centermount torque load is not applied to the SAPV model. The torque force on the post is determined outside of the SAPV model.



**Figure 3.4-8 Torque Due to Wind on Centermount Structures**

**3.4.5 GALLOPING FATIGUE LOAD**

Galloping wind pressure is applied to the sign panel only and is applicable to the signs on cantilever, centermount, and cantilever monopipe structures. The galloping wind pressure is based on the LRFD Sign Specifications Equation 11.7.1.1-1:

$$P_G = 21I_F$$

where:  $I_F$  = Importance Factor, see Article 11.6 and Table 11.6-1 of the LRFD Sign Specifications, as well as Section 4.9 of this User's Manual

**3.4.6 NATURAL WIND GUST FATIGUE LOAD**

Natural wind gust pressure is based on the LRFD Sign Specifications Equation 11.7.1.2-1:

$$P_{NW} = 5.2C_dI_F$$

where:  $I_F$  = Importance Factor, see Article 11.6 and Table 11.6-1 of the LRFD Sign Specifications, as well as Section 4.9 of this User's Manual

$C_d$  = Drag coefficient (See Table 3.4-1)

Natural wind gust pressure is based on a yearly mean wind speed of 11.2 mph. For sites with higher wind speeds or locations with more detailed records, a yearly mean wind speed may be entered onto the Loads Input Card and the equation to compute the gust pressure will be adjusted as follows (LRFD Sign Specifications Equation C11.7.1.2-1):

$$P_{NW} = 5.2C_d \left( \frac{V_{mean}}{11.2} \right)^2 I_F$$

where:  $V_{mean}$  = Yearly Mean Wind Speed

The natural wind gust pressure is applied horizontally in both the normal direction and the transverse direction just as the design wind pressure. (See Section 3.4.4 and Figure 3.4-4)

### 3.4.7 TRUCK-INDUCED GUST FATIGUE LOAD

Truck-induced gust pressure is based on the LRFD Sign Specifications Equation 11.7.1.3-1:

$$P_{TG} = 18.8C_d I_F$$

where:  $I_F$  = Importance Factor, see Article 11.6 and Table 11.6-1 of the LRFD Sign Specifications, as well as Section 4.9 of this User's Manual

$C_d$  = Drag coefficient (See Table 3.4-1)

Truck-induced gust pressure is applied to all members and attachments of the sign structure except for the posts and standard flat-panel signs. The program reduces the pressure applied by the truck gust dependent upon the elevation of specific members. The program assumes that the “low steel” of the sign structure is located 17'-6” above the roadway/shoulder high point to provide the required minimum vertical clearance. Based on this assumption, the program computes elevations corresponding to 20 ft and 33 ft above the high point of the roadway. For members located between the 20 ft elevation and the 33 ft elevation the pressure is reduced from full pressure at 20 ft to zero pressure at 33 ft (see Figure 3.4-9). The elevations are computed using the following equations:

Elevation 1 (Full Pressure):  $STHGT - (Max(SGNHGT(j)) / 2.0) - X + 2.5$

Elevation 2 (Zero Pressure): Elevation 1 + 13.0

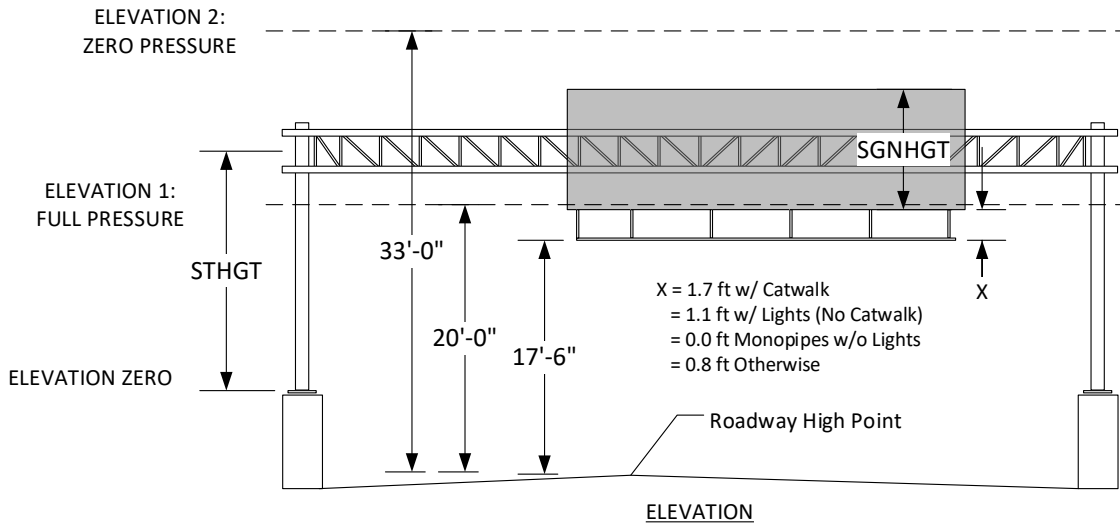
Where;  $X$  = the distance from the bottom of the sign to the “low steel” of the sign structure.

1.7 ft for structures with Catwalks

1.1 ft for structures with Lights (No Catwalk)

0.0 ft for Monopipe structures without Lights

0.8 ft for all other structures



**Figure 3.4-9 Truck-Induced Wind Load Reduction**

To reduce the truck-induced gust pressure applied to members in between these elevations, the following equation is applied:

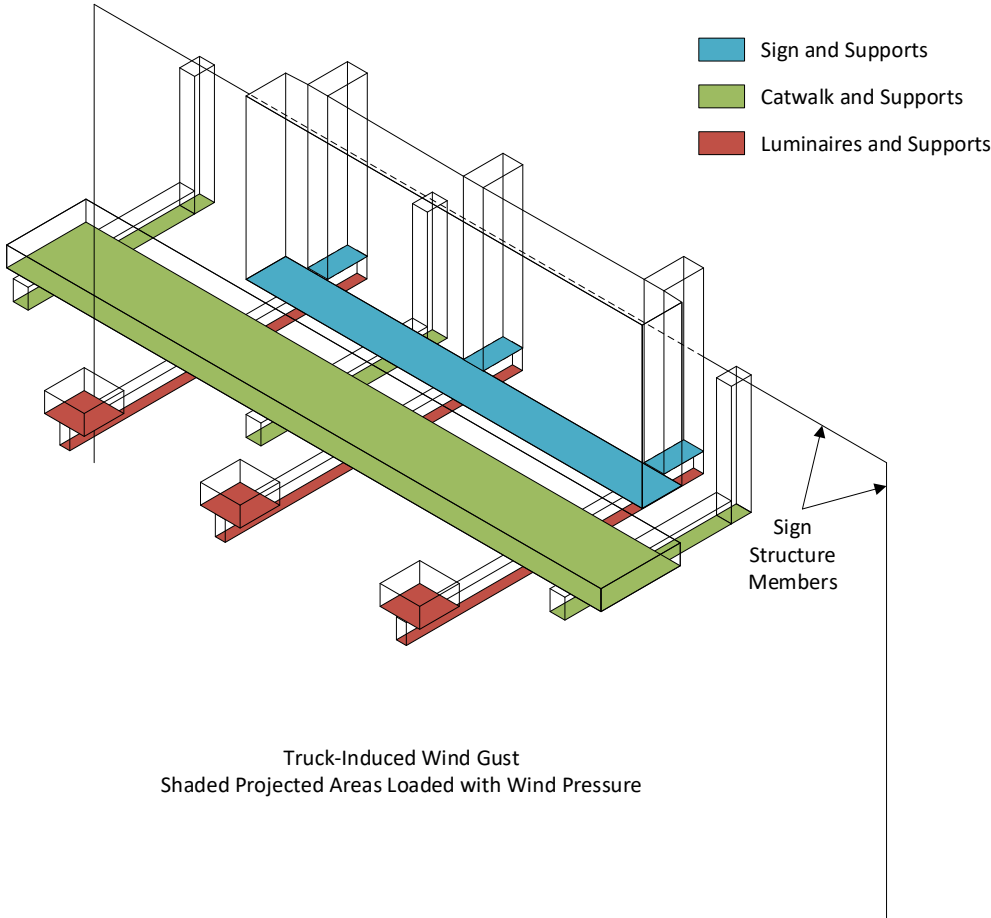
$$\text{Reduced Truck Gust} = \text{Truck Gust} * [1 - (\text{Elevation of the member} - \text{Elevation 1}) / (\text{Elevation 2} - \text{Elevation 1})]$$

For these calculations, the sign panel is assumed to be located symmetrical vertically about the mid-depth of the truss. For members at or above elevation 2, the truck-induced gust pressure is zero. The truck-induced gust pressure is applied only to signs that are DMS Boxes. Truck-induced pressure is based on a vehicle design speed of 65 mph. For locations where lower vehicle design speeds occur, a vehicle design speed may be entered onto the Loads Input Card and the equation to compute the truck-induced gust pressure will be adjusted as follows (LRFD Sign Specifications Equation C11.7.1.3-1):

$$P_{TG} = 18.8C_d \left( \frac{V_T}{65} \right)^2 I_F$$

where:  $V_T$  = Vehicle Design Speed

The truck-induced gust pressure is applied in a vertical direction to the horizontal projected area of horizontal supports, signs, luminaires, and catwalk as shown in Figure 3.4-10.



**Figure 3.4-10 Truck-Induced Wind Load Application on Attachments**

The wind pressure is applied to the horizontal projected area of the structure members in a vertical direction.

**3.4.8 LOAD COMBINATIONS**

The load combinations used for the program are based on the LRFD Sign Specifications Article 3.4 and LRFD Bridge Specifications Article 3.4 as shown in Tables 3.4-2, 3.4-3, and 3.4-4.

Table 3.4-2 Limit States

Loads	$\gamma_{DC}$	$\gamma_W$	$\gamma_{FAT}$	$\gamma_{EV}^*$ (Footing Only)
Strength-I: DC + EV	1.25			1.30
Extreme-I: DC + W + EV	1.1 / 0.9	1.0		1.3 / 0.9
Service-I: DC + W + EV	1.0	1.0		1.0
Fatigue-I: Fatigue	1.0		1.0	

\* Note: EV load factor based on Rigid Buried Structure in Table 3.4.1-2 of LRFD Bridge Specifications.

In Tables 3.4-3, 3.4-4, and 3.4-5 below, the following notation is used:

DC = Dead Components

W = Wind

GVW = Galloping Induced Vibration (fatigue load)

NWG = Natural Wind Gust Vibration (fatigue load)

TrG = Truck Gust (fatigue load)

EV = Vertical Earth Pressure

Table 3.4-3 Sign Structure Individual Loads

Load	Description	Comment
1	Self Weight Members	steel quantity
2	Self Weight panel, supports, and luminaires for Sign 1	
3	Self Weight panel, supports, and luminaires for Sign 2	
4	Self Weight panel, supports, and luminaires for Sign 3	
5	Self Weight Catwalk 1	
6	Self Weight Catwalk 2	
7	Extreme W on members, normal	
8	Extreme W on sign panel, supports, and luminaires for Sign 1, normal	
9	Extreme W on sign panel, supports, and luminaires for Sign 2, normal	
10	Extreme W on sign panel, supports, and luminaires for Sign 3, normal	
11	Extreme W on catwalk 1, normal	
12	Extreme W on catwalk 2, normal	
13	Extreme W on members, transverse	
14	Extreme W on sign panel, supports, and luminaires for Sign 1, transverse	
15	Extreme W on sign panel, supports, and luminaires for Sign 2, transverse	
16	Extreme W on sign panel, supports, and luminaires for Sign 3, transverse	
17	Extreme W on catwalk 1, transverse	
18	Extreme W on catwalk 2, transverse	
19	Service W on members, normal	
20	Service W on sign panel, supports, and luminaires for Sign 1, normal	
21	Service W on sign panel, supports, and luminaires for Sign 2, normal	
22	Service W on sign panel, supports, and luminaires for Sign 3, normal	
23	Service W on catwalk 1, normal	
24	Service W on catwalk 2, normal	

Table 3.4-3 Sign Structure Individual Loads (Cont.)

Load	Description	Comment
25	Service W on members, transverse	
26	Service W on sign panel, supports, and luminaires for Sign 1, transverse	
27	Service W on sign panel, supports, and luminaires for Sign 2, transverse	
28	Service W on sign panel, supports, and luminaires for Sign 3, transverse	
29	Service W on catwalk 1, transverse	
30	Service W on catwalk 2, transverse	
31	GVW on sign panel 1, vertical	
32	GVW on sign panel 2, vertical	
33	GVW on sign panel 3, vertical	
34	NWG on members, normal	
35	NWG on panel, supports, and luminaires for Sign 1, normal	
36	NWG on panel, supports, and luminaires for Sign 2, normal	
37	NWG on panel, supports, and luminaires for Sign 3, normal	
38	NWG on catwalk 1, normal	
39	NWG on catwalk 2, normal	
40	NWG on members, transverse	
41	NWG on panel, supports, and luminaires for Sign 1, transverse	
42	NWG on panel, supports, and luminaires for Sign 2, transverse	
43	NWG on panel, supports, and luminaires for Sign 3, transverse	
44	NWG on catwalk 1, transverse	
45	NWG on catwalk 2, transverse	
46	TrG on members (no columns), vertical	
47	TrG on Sign 1 (DMS boxes only), vertical	
48	TrG on Sign 2 (DMS boxes only), vertical	
49	TrG on Sign 3 (DMS boxes only), vertical	
50	TrG on catwalk 1, vertical	
51	TrG on catwalk 2, vertical	

Table 3.4-4 Sign Structure Load Combinations

Load Case	Description	Load Equation	Comments
1	Strength-I: DC	Load 1-6 * 1.25	
2	Extreme-I: DC+W, Wind Load Case 1	Load 1-6 * 1.1 + Load 7-12 * 1.0	+Wn
3	Extreme-I, DC+W, Wind Load Case 2	Load 1-6 * 1.1 + Load 13-18 * 1.0	+Wt
4	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * 0.75 + Load 13-18 * 0.75	+Wn, +Wt
5	Extreme-I: DC+W, Wind Load Case 1	Load 1-6 * 1.1 + Load 7-12 * -1.0	-Wn
6	Extreme-I, DC+W, Wind Load Case 2	Load 1-6 * 1.1 + Load 13-18 * -1.0	-Wt
7	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * -0.75 + Load 13-18 * 0.75	-Wn, +Wt
8	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * 0.75 + Load 13-18 * -0.75	+Wn, -Wt
9	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * -0.75 + Load 13-18 * -0.75	-Wn, -Wt
10	Extreme-I: DC+W, Wind Load Case 1	Load 1-6 * 0.9 + Load 7-12 * 1.0	+Wn
11	Extreme-I, DC+W, Wind Load Case 2	Load 1-6 * 0.9 + Load 13-18 * 1.0	+Wt
12	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * 0.75 + Load 13-18 * 0.75	+Wn, +Wt
13	Extreme-I: DC+W, Wind Load Case 1	Load 1-6 * 0.9 + Load 7-12 * -1.0	-Wn

Table 3.4-4 Sign Structure Load Combinations (continued)

Load Case	Description	Load Equation	Comments
14	Extreme-I, DC+W, Wind Load Case 2	Load 1-6 * 0.9 + Load 13-18 * -1.0	-Wt
15	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * -0.75 + Load 13-18 * 0.75	-Wn, +Wt
16	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * 0.75 + Load 13-18 * -0.75	+Wn, -Wt
17	Extreme-I, DC+W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * -0.75 + Load 13-18 * -0.75	-Wn, -Wt
18	Service-I: DC+W, Wind Load Case 1	Load 1-6 * 1.0 + Load 19-24 * 1.0	+Wn, Deflection for Overhead Supports
19	Service-I, DC+W, Wind Load Case 2	Load 1-6 * 1.0 + Load 25-30 * 1.0	+Wt, Deflection for Overhead Supports
20	Service-I, DC+W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * 0.75 + Load 25-30 * 0.75	+Wn, +Wt, Deflection for Overhead Supports
21	Service-I: DC+W, Wind Load Case 1	Load 1-6 * 1.0 + Load 19-24 * -1.0	-Wn , Deflection for Overhead Supports
22	Service-I, DC+W, Wind Load Case 2	Load 1-6 * 1.0 + Load 25-30 * -1.0	-Wt, Deflection for Overhead Supports
23	Service-I, DC+W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * -0.75 + Load 25-30 * 0.75	-Wn, +Wt, Deflection for Overhead Supports
24	Service-I, DC+W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * 0.75 + Load 25-30 * -0.75	+Wn, -Wt, Deflection for Overhead Supports
25	Service-I, DC+W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * -0.75 + Load 25-30 * -0.75	-Wn, -Wt, Deflection for Overhead Supports

Table 3.4-4 Sign Structure Load Combinations (continued)

Load Case	Description	Load Equation	Comments
26	Fatigue-I, GVW	Load 31-33 * 1.0	
27	Fatigue-I, GVW	Load 31-33 * -1.0	
28	Fatigue-I, NWG, Wind Load Case 1	Load 34-39 * 1.0	+NWGn
29	Fatigue-I, NWG, Wind Load Case 2	Load 40-45 * 1.0	+NWGt
30	Fatigue-I, NWG, Wind Load Case 1	Load 34-39 * -1.0	-NWGn
31	Fatigue-I, NWG, Wind Load Case 2	Load 40-45 * -1.0	-NWGt
32	Fatigue-I, NWG, Wind Load Case 3	Load 34-39 * 0.75 + Load 40-45 * 0.75	+NWGn, +NWGt
33	Fatigue-I, NWG, Wind Load Case 3	Load 34-39 * -0.75 + Load 40-45 * -0.75	-NWGn, -NWGt
34	Fatigue-I, NWG, Wind Load Case 3	Load 34-39 * 0.75 + Load 40-45 * -0.75	+NWGn, -NWGt
35	Fatigue-I, NWG, Wind Load Case 3	Load 34-39 * -0.75 + Load 40-45 * 0.75	-NWGn, +NWGt
36	Fatigue-I, TrG	Load 46-51 * 1.0	
37	Steel DL	Load 1 * 1.000	Structural Steel Dead Load
38	Other DL	Load 2-6 * 1.000	sign panels, luminaires, catwalks

Table 3.4-5 Footing Load Combinations

Load Case	Description	Load Equation	Comments*
1	Strength-I: DC+EV	Load 1-6 * 1.25 + EV * 1.3	
2	Extreme-I: DC+EV+W, Wind Load Case 1	Load 1-6 * 1.1 + Load 7-12 * 1.0 + EV * 1.3	+Wn
3	Extreme-I: DC+EV+W, Wind Load Case 2	Load 1-6 * 1.1 + Load 13-18 * 1.0 + EV * 1.3	+Wt
4	Extreme-I: DC+EV+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * 0.75 + Load 13-18 * 0.75 + EV * 1.3	+Wn, +Wt
5	Extreme-I: DC+EV+W, Wind Load Case 1	Load 1-6 * 1.1 + Load 7-12 * -1.0 + EV * 1.3	-Wn
6	Extreme-I: DC+EV+W, Wind Load Case 2	Load 1-6 * 1.1 + Load 13-18 * -1.0 + EV * 1.3	-Wt
7	Extreme-I: DC+EV+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * -0.75 + Load 13-18 * 0.75 + EV * 1.3	-Wn, +Wt
8	Extreme-I: DC+EV+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * 0.75 + Load 13-18 * -0.75 + EV * 1.3	+Wn, -Wt
9	Extreme-I: DC+EV+W, Wind Load Case 3	Load 1-6 * 1.1 + Load 7-12 * -0.75 + Load 13-18 * -0.75 + EV * 1.3	-Wn, -Wt
10	Extreme-I: DC+EV+W, Wind Load Case 1	Load 1-6 * 0.9 + Load 7-12 * 1.0 + EV * 0.9	+Wn
11	Extreme-I: DC+EV+W, Wind Load Case 2	Load 1-6 * 0.9 + Load 13-18 * 1.0 + EV * 0.9	+Wt
12	Extreme-I: DC+EV+W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * 0.75 + Load 13-18 * 0.75 + EV * 0.9	+Wn, +Wt
13	Extreme-I: DC+EV+W, Wind Load Case 1	Load 1-6 * 0.9 + Load 7-12 * -1.0 + EV * 0.9	-Wn

\* Note: DC includes the dead load of the sign structure and the weight of the footing and pedestal.

Table 3.4-5 Footing Load Combinations (continued)

Load Case	Description	Load Equation	Comments*
14	Extreme-I: DC+EV+W, Wind Load Case 2	Load 1-6 * 0.9 + Load 13-18 * -1.0 + EV * 0.9	-Wt
15	Extreme-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * -0.75 + Load 13-18 * 0.75 + EV * 0.9	-Wn, +Wt
16	Extreme-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * 0.75 + Load 13-18 * -0.75 + EV * 0.9	+Wn, -Wt
17	Extreme-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 0.9 + Load 7-12 * -0.75 + Load 13-18 * -0.75 + EV * 0.9	-Wn, -Wt
18	Service-I: DC+EV +W, Wind Load Case 1	Load 1-6 * 1.0 + Load 19-24 * 1.0 + EV * 1.0	+Wn, Deflection for Overhead Supports
19	Service-I: DC+EV +W, Wind Load Case 2	Load 1-6 * 1.0 + Load 25-30 * 1.0 + EV * 1.0	+Wt, Deflection for Overhead Supports
20	Service-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * 0.75 + Load 25-30 * 0.75 + EV * 1.0	+Wn, +Wt, Deflection for Overhead Supports
21	Service-I: DC+EV +W, Wind Load Case 1	Load 1-6 * 1.0 + Load 19-24 * -1.0 + EV * 1.0	-Wn , Deflection for Overhead Supports
22	Service-I: DC+EV +W, Wind Load Case 2	Load 1-6 * 1.0 + Load 25-30 * -1.0 + EV * 1.0	-Wt, Deflection for Overhead Supports
23	Service-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * -0.75 + Load 25-30 * 0.75 + EV * 1.0	-Wn, +Wt, Deflection for Overhead Supports
24	Service-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * 0.75 + Load 25-30 * -0.75 + EV * 1.0	+Wn, -Wt, Deflection for Overhead Supports
25	Service-I: DC+EV +W, Wind Load Case 3	Load 1-6 * 1.0 + Load 19-24 * -0.75 + Load 25-30 * -0.75 + EV * 1.0	-Wn, -Wt, Deflection for Overhead Supports

\* Note: DC includes the dead load of the sign structure and the weight of the footing and pedestal.

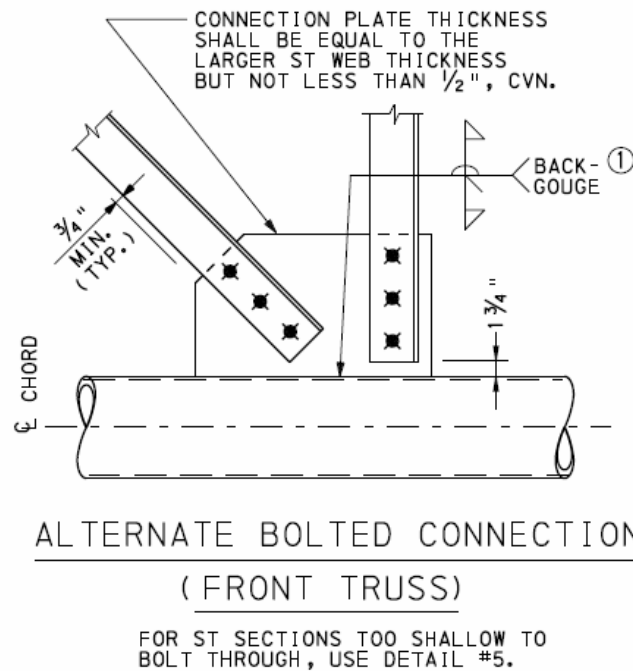
### 3.5 ANALYSIS

Once the model has been created, the Sign Structure program generates a finite element input file, which is processed by the SAPV analysis core. The model is comprised of space frame beam elements with configurations and loadings as described in the previous sections of this chapter. A listing of the nodal geometry and element connectivity can be obtained if the user input output level is set to levels 1 or 2. The SAPV program uses the stiffness method (or matrix method) of analysis. For a more detailed description of the stiffness method, see Computer Analysis of Structural Systems by John Fleming or any other structural book related to the matrix analysis of structures.

### 3.6 SPECIFICATION CHECKING

The criteria used for the specification checking performed in the sign structure program are based on the tables given on the following pages. These tables show the limiting lengths of members, limiting width to thickness ratios for compression elements, and slenderness ratio criteria. Figures accompany the tables in order to define any length variables and stress point locations.

NOTE: Specification checking for angle section types is not included in this release of the program. Specification checking is also not done of tee sections connected through the web to a connection plate because this detail requires the removal of a portion of the flange of the section (See Figure 1 for this detail). This detail is only used for verticals and diagonals of the front truss of a tri- or four-chord truss or the verticals and diagonals of the back truss of a four-chord truss.



**Figure 3.6-1 Structural Tee Bolted Connection, No Connection Plate (BC-744M, August 2017, Sheet 7)**

Manual specification checking of angles and these specific tee sections can be done by following the LRFD Sign Specifications and LRFD Bridge Specifications. Tee, channel, and angle sections are provided for the analysis of existing sign structures.

3.6.1 LIMITING LENGTHS OF MEMBERS

Table 3.6-1 Limiting Lengths of Members

Member Stress Type	Component	Range	Comment
Tension Member (Primary Members Not Subject to Stress Reversal)	Column (Post) Truss Chord Strut Chord	$(l/r)_x \text{ \& \ } (l/r)_y \leq 200$	<ul style="list-style-type: none"> <li>LRFD Bridge Design Specifications, 7th Edition Article 6.8.4 (Tension Members) Article 6.9.3 (Compression Members)</li> </ul> <p>NOTE: For centermount and cantilever structures, struts are designed based on the compression member criteria.</p>
Tension Member (Primary Members Subject to Stress Reversal)	Column (Post) Truss Chord Strut Chord Mast (Post) Mast Arm (Chord)	$(l/r)_x \text{ \& \ } (l/r)_y \leq 140$	
Tension Member (Secondary Members)	Web Vertical Front & Rear Diagonal Front & Rear Vertical Top & Bottom Diagonal Top & Bottom Vertical Tower Diagonal	$(l/r)_x \text{ \& \ } (l/r)_y \leq 240$	
Compression Member (Primary Members)	Column (Post) Truss Chord Strut Chord Mast (Post) Mast Arm (Chord)	$(Kl/r)_x \text{ \& \ } (Kl/r)_y \leq 120$	
Compression Member (Secondary Members)	Web Vertical Front & Rear Diagonal Front & Rear Vertical Top & Bottom Diagonal Top & Bottom Vertical Tower Diagonal	$(Kl/r)_x \text{ \& \ } (Kl/r)_y \leq 140$	

## 3.6.2 LIMITING WIDTH-THICKNESS RATIOS

Table 3.6-2 Limiting Width-Thickness Ratios for Compression Elements

Structural Shape	Shape Element	Limiting Ratio	Limiting Width-Thickness Ratios		
			Compact Limit, $\lambda_p$	Noncompact Limit, $\lambda_r$	Slender Limit Maximum, $\lambda_{max}$
<b>LRFD Sign Specifications Table 5.7.2-1</b>					
Round Tube (Compression)	Entire Cross Section	$\frac{D}{t}$	$0.07 \frac{E}{F_y}$	$0.11 \frac{E}{F_y}$	$0.45 \frac{E}{F_y}$
Round Tube (Flexure)	Entire Cross Section	$\frac{D}{t}$	$0.07 \frac{E}{F_y}$	$0.31 \frac{E}{F_y}$	$0.45 \frac{E}{F_y}$
16-sided tube (Hexadecagonal)	Entire Cross Section	$\frac{b}{t}$	$1.12 \sqrt{\frac{E}{F_y}}$	$1.26 \sqrt{\frac{E}{F_y}}$	$2.14 \sqrt{\frac{E}{F_y}}$
12-sided tube (Dodecagonal)	Entire Cross Section	$\frac{b}{t}$	$1.12 \sqrt{\frac{E}{F_y}}$	$1.41 \sqrt{\frac{E}{F_y}}$	$2.14 \sqrt{\frac{E}{F_y}}$
8-sided tube (Octagonal)	Entire Cross Section	$\frac{b}{t}$	$1.12 \sqrt{\frac{E}{F_y}}$	$1.53 \sqrt{\frac{E}{F_y}}$	$2.14 \sqrt{\frac{E}{F_y}}$
<b>LRFD Sign Specifications Table 5.7.3-1</b>					
Single Angle (Uniform Compression)	Legs of Angle	$\frac{b}{t}$	Not Applicable	$0.45 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
Single Angle (Flexure)	Legs of Angle	$\frac{b}{t}$	$0.54 \sqrt{\frac{E}{F_y}}$	$0.91 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
Channel (Uniform Compression)	Flange	$\frac{b}{t}$	Not Applicable	$0.56 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
	Web	$\frac{h}{t_w}$	Not Applicable	$1.49 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
Channel (Flexure)	Flange	$\frac{b}{t}$	$0.38 \sqrt{\frac{E}{F_y}}$	$1.0 \sqrt{\frac{E}{F_y}}$	$\lambda_r$

Table 3.6-2 Limiting Width-Thickness Ratios for Compression Elements (continued)

Structural Shape	Shape Element	Limiting Ratio	Limiting Width-Thickness Ratios		
			Compact Limit, $\lambda_p$	Noncompact Limit, $\lambda_r$	Slender Limit Maximum, $\lambda_{max}$
WT and ST (Tees) (Uniform Compression)	Flange	$\frac{b}{2t}$	Not Applicable	$0.45 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
	Stem	$\frac{d}{t}$	Not Applicable	$0.75 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
WT and ST (Tees) (Flexure)	Flange	$\frac{b}{2t}$	$0.38 \sqrt{\frac{E}{F_y}}$	$1.0 \sqrt{\frac{E}{F_y}}$	$\lambda_r$
	Stem	$\frac{d}{t}$	$0.84 \sqrt{\frac{E}{F_y}}$	$1.03 \sqrt{\frac{E}{F_y}}$	$\lambda_r$

3.6.3 SLENDERNESS RATIO CRITERIA

Table 3.6-3 Slenderness Ratio Criteria

Structure Type	Component	K	Length	Radius of Gyration	Figure
Centermount	Column (Post)	2.1	$L_c$	$r_{min}$	See Figure 3.6-5
	Strut	1.2	$L_s$	$r_{min}$	
Cantilever	Column (Post)	2.1	$L_c$	$r_{min}$	See Figures 3.6-6 and 3.6-7
	Strut	1.2	$L_s$	$r_{min}$	
	Diagonal (tee or angle)	1.0	$L_w$	$r_{min}$	
	Diagonal (other shapes)	0.75	$L_w$	$r_{min}$	
	Vertical (tee or angle)	1.0	$L_v$	$r_{min}$	
	Vertical (other shapes)	0.75	$L_v$	$r_{min}$	
2 Post Tri-Chord	Column (Post)	2.1	$L_c$	$r_{min}$	See Figure 3.6-8
	Chord	1.0	$l_s$	$r_{min}$	
	Vertical (tee or angle)	1.0	$l_v$	$r_{min}$	
	Vertical (other shapes)	0.75	$l_v$	$r_{min}$	
	Diagonal (tee or angle)	1.0	$l_w$	$r_{min}$	
	Diagonal (other shapes)	0.75	$l_w$	$r_{min}$	
4 Post Tri-Chord	Column (Post)	1.0	$l_c$	$r_x^*$	See Figure 3.6-9
		2.1	$L_c$	$r_y^*$	
	Chord	1.0	$l_s$	$r_{min}$	
	Vertical (tee or angle)	1.0	$l_v$	$r_{min}$	
	Vertical (other shapes)	0.75	$l_v$	$r_{min}$	
	Diagonal (tee or angle)	1.0	$l_w$	$r_{min}$	
	Diagonal (other shapes)	0.75	$l_w$	$r_{min}$	
	Tower Diagonal (tee or angle)	1.0	$l_d$	$r_{min}$	
	Tower Diagonal (other shapes)	0.75	$l_d$	$r_{min}$	

\* Based on orientation of member.

Table 3.6-3 Slenderness Ratio Criteria (continued)

Structure Type	Component	K	Length	Radius of Gyration	Figure
4 Post 4 Chord	Column (Post)	1.0	$l_c$	$r_x^*$	See Figure 3.6-10
		2.1	$L_c$	$r_y^*$	
	Chord	1.0	$l_s$	$r_{min}$	
	Front & Rear Diagonal (tees and angles)	1.0	$l_f$	$r_{min}$	
	Front & Rear Diagonal (other shapes)	0.75	$l_f$	$r_{min}$	
	Front & Rear Vertical (tees and angles)	1.0	$l_v$	$r_{min}$	
	Front & Rear Vertical (other shapes)	0.75	$l_v$	$r_{min}$	
	Top & Bottom Diagonal (tees and angles)	1.0	$l_t$	$r_{min}$	
	Top & Bottom Diagonal (other shapes)	0.75	$l_t$	$r_{min}$	
	Top & Bottom Vertical (tees and angles)	1.0	$l_{vt}$	$r_{min}$	
	Top & Bottom Vertical (other shapes)	0.75	$l_{vt}$	$r_{min}$	
	Tower Diagonal (tees and angles)	1.0	$l_d$	$r_{min}$	
	Tower Diagonal (other shapes)	0.75	$l_d$	$r_{min}$	
Cantilever Monopipe	Mast (Post)	2.1	$L_c$	$r_{min}$	See Figure 3.6-11
	Mast Arm (Chord)	1.2	$L_s$	$r_{min}$	
Monopipe Frame	Mast (Post)	2.1	$L_c$	$r_{min}$	See Figure 3.6-12
	Mast Arm (Chord)	1.0	$L_s$	$r_{min}$	

\* Based on orientation of member.

The values for K in Table 3 are used for members that are in compression. Members that are in tension do not use a K value when calculating the allowable slenderness.

### 3.6.4 MEMBER TENSILE RESISTANCE

The member tensile resistance is calculated as described in Article 5.9 of the LRFD Sign Structure Specifications.

Gross section yielding criteria are checked for all members, including connection plates when supplied.

Net section fracture criteria are checked only for structural tee or channel members used as vertical or diagonal truss members, cross bracing members, or tower bracing members.

Table 3.6-5 summarizes how the channels and tees are connected for the various locations and how to specify the presence of a connection plate, when desired. The effective areas used for the net section fracture criteria are calculated differently depending on how the members are connected, and where they are located, described below.

Structural tees bolted through the web to a gusset or welded via the web to a connection plate that is then bolted to the gusset plate have half of the flange removed, so they act as angles. Because of this, the program cannot calculate combined force interaction values, so no resistances are reported by the program for tees with half of the flange removed.

#### 3.6.4.1 WELDED CONNECTIONS

For members that are exclusively welded (no BOLTED CONNECTIONS input specified, so no connection plates either), a shear-lag reduction factor (U) of 0.6 is used for members welded via the flange. For members welded through the web, a U value of 0.9 is used (a summary of all of the U values used for the various connection types is shown in Table 3.6-4).

#### 3.6.4.2 BOLTED CONNECTIONS WITHOUT CONNECTION PLATES

For members that are bolted without connection plates (i.e. bolted directly to gusset plates; BOLTED CONNECTIONS input specified, but CONNECTION PLATE WIDTH and THICKNESS left blank), the net section fracture of the member only is checked.

For channels bolted through the web without a connection plate, the effective area (Equation 5.9.3-1 of the LRFD Sign Specifications) is calculated with a shear-lag reduction factor (U) of 0.70 (Case 7 of Table 6.8.2.2-1 of the LRFD Bridge Specifications).

For channels and tees bolted through their flanges without a connection plate, U is taken as 0.90 or 0.85, depending on whether the flange width is greater or less than 2/3 of the section depth (both in Table 6.8.2.2-1 and Article C5.9.3 of the LRFD Sign Specifications).

**3.6.4.3 BOLTED CONNECTIONS WITH CONNECTION PLATES**

For members that are specified as bolted and using a connection plate (BOLTED CONNECTIONS command entered with nonzero values for CONNECTION PLATE WIDTH and THICKNESS; see Figure 2 for a sample detail), the net section fracture of the connection plate is checked for both the bolt holes and welds, and net section fracture of the member due to welds is also checked.

When checking the connection plate for fracture due to bolts, the effective area of the connection plate (Equation 5.9.3-1 of the LRFD Sign Specifications) is equal to the gross area of the connection plate less hole area, but not greater than 85% of the gross area of the plate. A shear-lag reduction factor (U) of 1.0 is applied.

When the connection plate is checked for fracture due to the weld to the member, the effective area of the plate is the gross area of the connection plate multiplied by a shear-lag reduction factor (U) of 0.75.

For channels welded to the connection plate through the web, the effective area of the member is the gross area of the member multiplied by a U of 0.85.

For structural tees or channels welded to the connection plate through the flange, the effective area is the gross area of the member multiplied by a U of 0.60.

Table 3.6-4 Shear Lag Reduction Factors, U

Member	Bolted or Welded Through	Welded, No Connection Plate	Bolted, No Connection Plate	Bolted, With Connection Plate
Front truss vertical or diagonal	Web	0.9	0.7 (channels) 0.6 (tees with half of flange removed)	plate = 0.75 (welds) plate = 1.0 (bolt holes) member = 0.85
Top or bottom truss vertical or diagonal, Tower diagonal, Truss cross bracing	Flange	0.6	0.85 or 0.9, depending on flange width/section depth ratio	plate = 0.75 (welds) plate = 1.0 (bolt holes) member = 0.6

Table 3.6-5 Connection Information for Channels and Tees

Model Type	Member	Bolted or Welded Through	Connection Plate Criteria*
Two post tri-chord	Front truss vertical or diagonal	Web	Connection Plate 1
	Top or bottom truss vertical or diagonal	Flange	Connection Plate 2
Four post tri-chord	Front truss vertical or diagonal	Web	Connection Plate 1
	Top or bottom truss vertical or diagonal	Flange	Connection Plate 2
	Tower diagonal	Flange	Connection Plate 2
Four post four-chord	Front or back truss vertical or diagonal	Web	Connection Plate 1
	Top or bottom truss vertical or diagonal	Flange	Connection Plate 2
	Tower diagonal	Flange	Connection Plate 2
	Truss cross bracing	Flange	Connection Plate 2

\* Connection Plate Criteria refers to the Connection Plate Width and Connection Plate Thickness input items on the BOLTED CONNECTIONS command. For example, if the user enters nonzero values for Connection Plate 1 Width and Thickness on the BOLTED CONNECTIONS command, then the front truss vertical and diagonal members are considered to be welded to a connection plate, then the connection plate is bolted to the truss gusset plate, as shown in Figure 2.

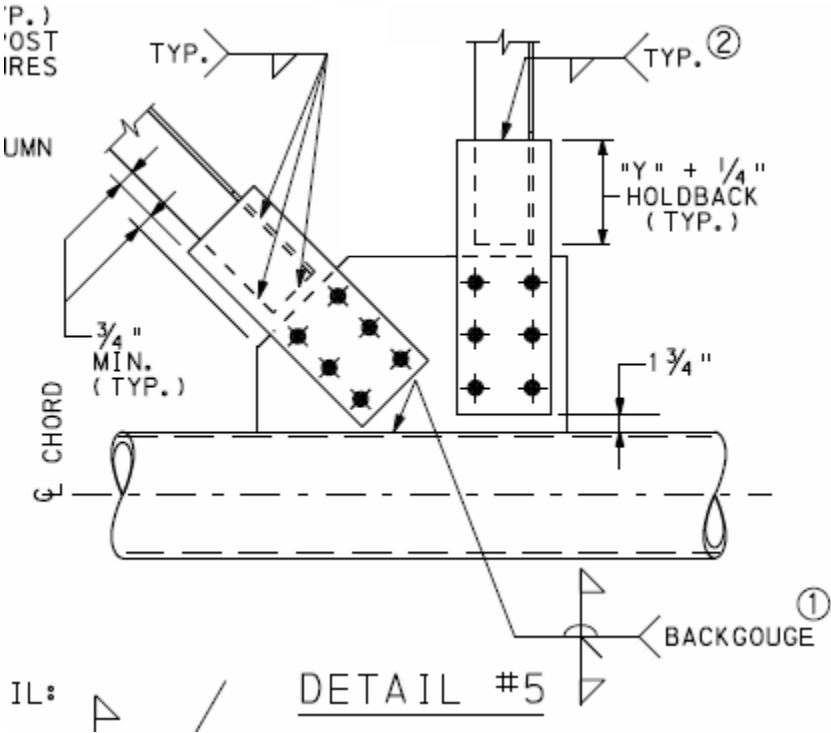


Figure 3.6-2 Structural Tee Bolted Connection, With Connection Plate (BC-744M, August 2017, Sheet 7)

### 3.6.5 MEMBER COMPRESSIVE RESISTANCE

The member compressive resistance is calculated as described in Article 5.10 of the LRFD Sign Specifications and Article 6.9.2 of the LRFD Bridge Specifications. Round and multi-sided pipe members are checked for flexural buckling in accordance with the LRFD Sign Specifications, while channel and structural tee sections are checked for flexural buckling and flexural torsional buckling in accordance with the LRFD Bridge Specifications.

When determining the compactness of the elements of a multi-sided pipe, the inside bend radius of the pipe is required for LRFD Sign Specifications equation C5.7.2-1. This value is calculated by multiplying the radius of the inscribed circle by the user-input "corner radius ratio". The radius of the inscribed circle is found by:

$$R = \frac{D'}{2} - t$$

where: R = radius of the inscribed circle

D' = outside distance from flat side to flat side of multi-sided tube (user input)

t = wall thickness

For channels and structural tees all required section properties are taken straight from the AISC database included with the program. The shear center (needed in Equation 6.9.4.1.3-3 of the LRFD Bridge Specifications) is included in the AISC database for channel members. For structural tees, the shear center is located at the intersection of the flange and stem, taken as the point located at intersection of the middepth of the flange and the centerline of stem.

For tees that are connected through the web (as shown in Table 3.6-4), the compressive resistance is calculated assuming that half of the flange has been removed. The compressive resistance is therefore calculated assuming the section acts like a single angle using the calculations of the LRFD Bridge Specifications, Articles 6.9 and 6.9.4.4.

### 3.6.6 MEMBER SHEAR RESISTANCE

The member shear resistance is calculated as described in Article 5.11.2 of the LRFD Sign Specifications, with the following assumptions and clarifications.

When computing the nominal shear stress capacity for round pipes, LRFD Sign Specifications Equation 5.11.2.1.1-1 will conservatively be neglected. The LRFD Sign Specifications take the maximum value of Equations 5.11.2.1.1-1 and 5.11.2.1.1-2, then the minimum of that value and  $0.6 * F_y$ . For standard pipe sizes for sign structures with yield strengths of 36, 50, and 70 ksi, Equation 5.11.2.1.1-1 never governs for shear capacity. Since the value  $L_v$  is not readily available for some member locations, this equation will not be used for shear resistance calculations.

For round and multi-sided pipes, the maximum factored shear in the section is calculated as:

$$V_u = \sqrt{V_x^2 + V_y^2}$$

where:  $V_u$  = Maximum factored shear  
 $V_x$  = Factored shear in the local x-direction  
 $V_y$  = Factored shear in the local y-direction

For tees and channels, the shear resistance is calculated in both x and y directions, and the governing factored shear and shear resistance are determined from the maximum ratio  $V_{ux}/V_{rx}$  or  $V_{uy}/V_{ry}$ .

Both factored shear and shear resistance are reported in terms of force (kips), not stress.

### 3.6.7 MEMBER TORSION RESISTANCE

The member torsion resistance is calculated as described in Article 5.11.3 of the LRFD Sign Specifications, with the following assumptions and clarifications.

As with the shear capacity calculations for round pipe sections, LRFD Sign Specifications Equation 5.11.3.1.1-1 will conservatively be neglected. Because of the nature of the specifications, this equation will not govern for usual pipe sizes and yield strengths.

For round and multi-sided pipes, the torsion calculated from the SAPV runs is compared to the calculated torsional resistance. For channels and tees, a torsional stress is calculated and compared to a torsional resistance of  $\phi_t * 0.6 * F_y$ .

For channel members, the torsional stress is calculated with the following expressions. "Points" are the locations shown on the channel cross-section in Figure 3.6-13:

Points 1 and 3:

$$V_T = \frac{\delta(|T| + |V_y e_o|) t_f}{J}$$

$$\delta = 1 + \frac{t_f}{4a}$$

Points 2 and 4:

$$V_T = \frac{(|T| + |V_y e_o|) t_f}{J}$$

where:  $V_T$  = Torsional shear stress

## LRFD Sign Structure Analysis

- $\delta$  = User input stress concentration factor calculated using the expression above from page 2.10-8 of "Design of Welded Structures" by Omar W. Blodgett; James F. Lincoln Arc Welding Foundation, 1966.
- $t_f$  = Flange thickness
- $a$  = Inside corner radius
- $T$  = Factored applied torsion
- $V_y$  = Factored applied shear in the y-direction
- $e_o$  = Shear center location (from AISC Manual)
- $J$  = Torsional constant

For tee members, torsional stress is calculated in a similar manner. "Points" correspond to Figure 3.6-14.

Points 1 and 2:

$$V_T = \left| \frac{T t_f}{J} \right|$$

Point 3:

$$V_T = \left| \frac{T \delta t_f}{J} \right|$$

Point 4:

$$V_T = \left| \frac{T t_w}{J} \right|$$

- where:  $V_T$  = Torsional shear stress
- $\delta$  = User input stress concentration factor taken from Figures 7.5 and 7.6 of "USS Steel Design Manual" by R.L. Brockenbrough; United States Steel Corporation, 1981. These figures are reproduced below.
- $T$  = Factored applied torsion
- $t_f$  = Flange thickness
- $J$  = Torsional constant

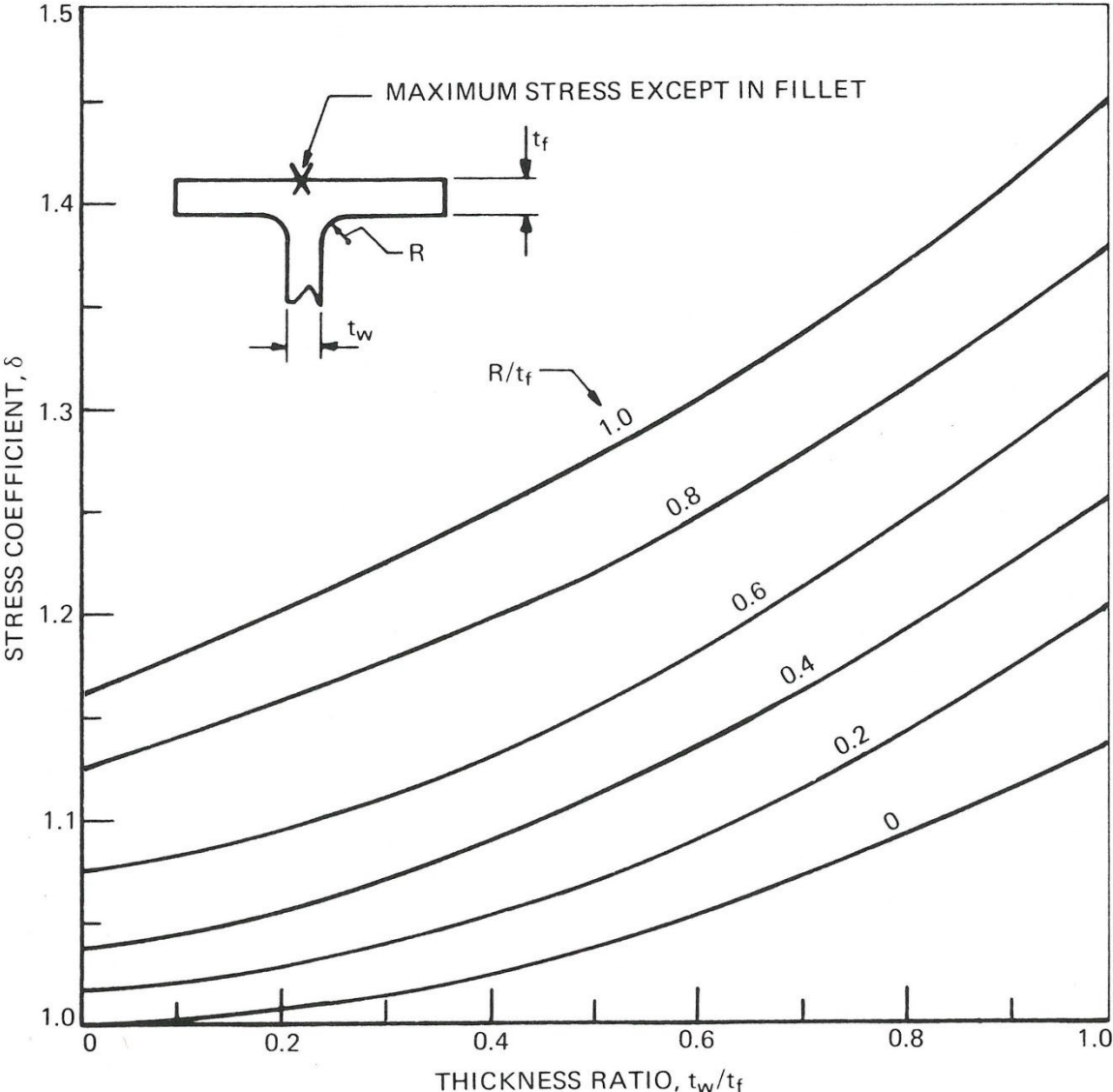


FIGURE 7.5 STRESS COEFFICIENTS FOR TEE OR W SHAPES WITH PARALLEL FLANGES

Figure 3.6-3 US Steel Figure 7.5

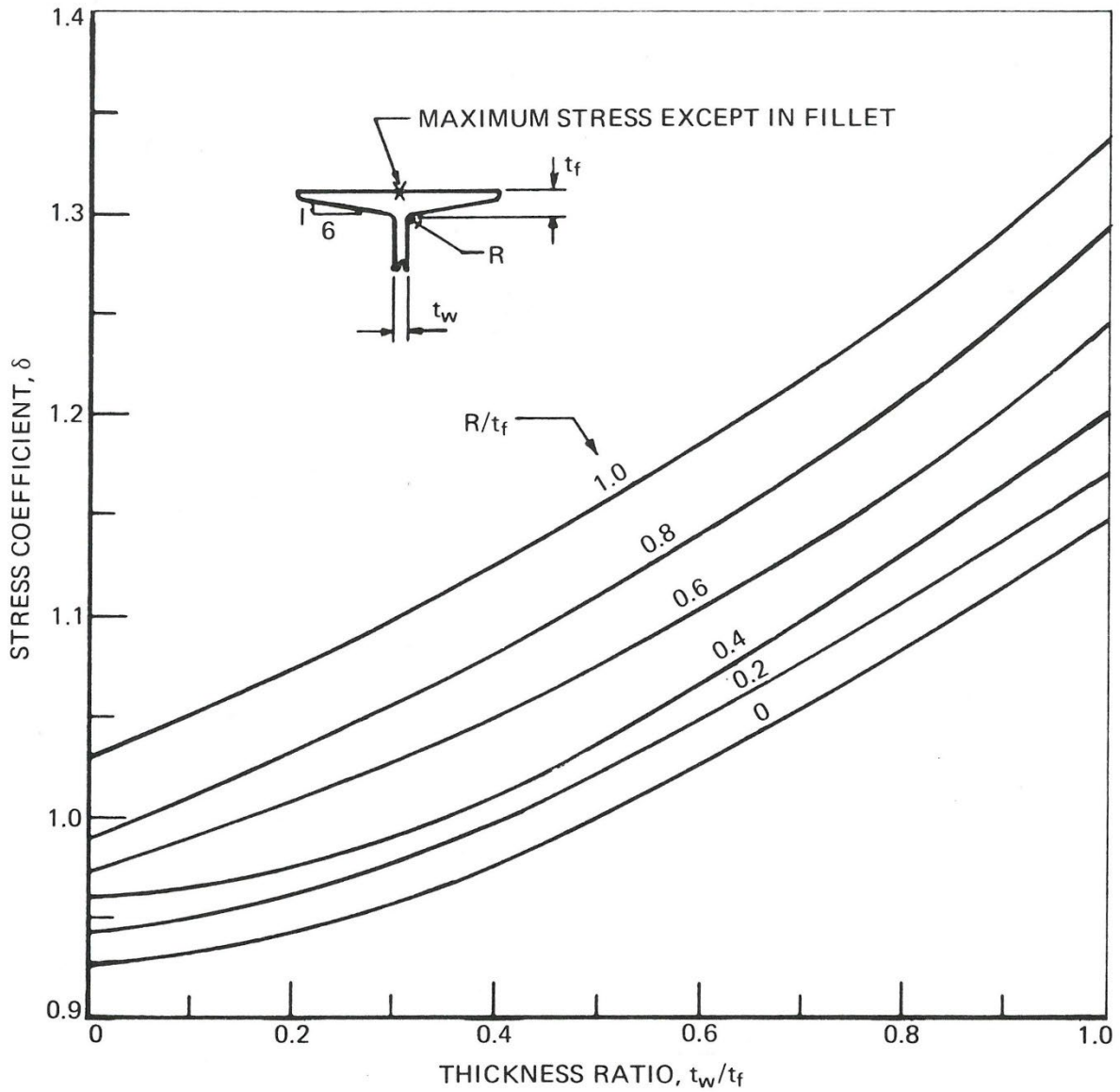


FIGURE 7.6 STRESS COEFFICIENTS FOR TEE OR S SHAPES WITH SLOPING INNER FLANGES

Figure 3.6-4 US Steel Figure 7.6

### 3.6.8 MEMBER FLEXURAL RESISTANCE

The member factored flexural resistance is calculated as described in Article 5.8 of the LRFD Sign Specifications, with the following assumptions and clarifications.

When calculating the lateral torsional buckling capacity of channels with Article 5.8.3.1.3,  $C_b$ , the moment gradient factor, is conservatively assumed to be 1.0.

The flexural capacity of multi-sided pipes shall not be greater than the flexural capacity of an equivalent round pipe. To calculate this, the compactness criteria is rechecked with the round pipe expressions, and an equivalent diameter equal to the total distance between the outside of the parallel sides of the multi-sided pipe.

On the COMBINED FORCE INTERACTION output report, for round and multi-sided pipes, a single moment, calculated with LRFD Sign Specifications Equation 5.12.1-4 is reported, which is the combination of the moments about each axis:

$$M_u = \sqrt{M_{ux}^2 + M_{uy}^2}$$

### 3.6.9 COMBINED FORCE INTERACTION

The combined force interaction ratio is calculated as described in Article 5.12.1 of the LRFD Sign Specifications.

Note that, as stated in Article 5.12.1 of the LRFD Sign Specification, if the ratio of factored torsion to torsion resistance ( $T_u / T_r$ ) is less than or equal to 0.20, then neither the shear nor torsion effects are included in the interaction expression.

For tees and channels, biaxial bending is checked, with the same moment magnification factor (B) applied to the moment ratio about each axis (x and y). For round and multi-sided pipes, the factored moments are combined using equation 5.12.1-4, so only one moment term is necessary in the force interaction equation.

All members are assumed to be prismatic, so Equation 5.12.1-10 can be used to calculate B for compression members. There is no moment magnification for tension members (B=1.0).

For tees bolted through the web (as described in Table 3.6-4), half of the flange is removed at the connection. Because of this, the section is treated as a structural angle and a combined stress ratio cannot be calculated because the flexural and torsional capacities are not calculated by the program.

### 3.6.10 FATIGUE COMBINED STRESS RATIO

The combined stress ratio for fatigue is calculated from the axial fatigue stress, the bending fatigue stresses about the member X-axis and Y-axis, and the Constant-Amplitude Fatigue Threshold stress.

The general equation for the fatigue combined stress ratio is given as:

$$CSR = \frac{f_a + f_b}{(\Delta F)_{TH}}$$

where:  $CSR$  = Combined stress ratio for fatigue

$f_a$  = axial fatigue stress

$f_b$  = maximum fatigue bending stress (combines  $f_{bx}$  and  $f_{by}$  based on cross-section type)

$(\Delta F)_{TH}$  = Constant-Amplitude Fatigue Threshold stress

$f_{bx}$  = maximum bending fatigue stress about the member X-axis

$f_{by}$  = maximum bending fatigue stress about the member Y-axis

The maximum bending fatigue stress,  $f_b$ , depends on the cross-section type as follows:

Round Tube

$$\sqrt{f_{bx}^2 + f_{by}^2}$$

Hexdecagonal Tube  $Max(0.199f_{bx} + f_{by}, 0.567f_{bx} + 0.848f_{by}, 0.848f_{bx} + 0.567f_{by}, f_{bx} + 0.199f_{by})$

Dodecagonal Tube  $Max(0.732(f_{bx} + f_{by}), f_{bx} + 0.268f_{by}, 0.268f_{bx} + f_{by})$

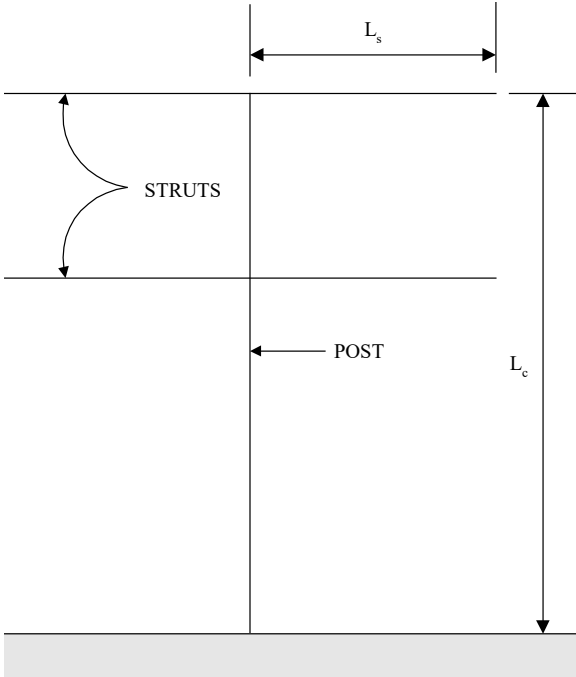
Octagonal Tube  $Max(f_{bx} + 0.414f_{by}, 0.414f_{bx} + f_{by})$

Channels, ST's and WT's  $Max_{i=1,4}(f_{bx_i} + f_{by_i})$

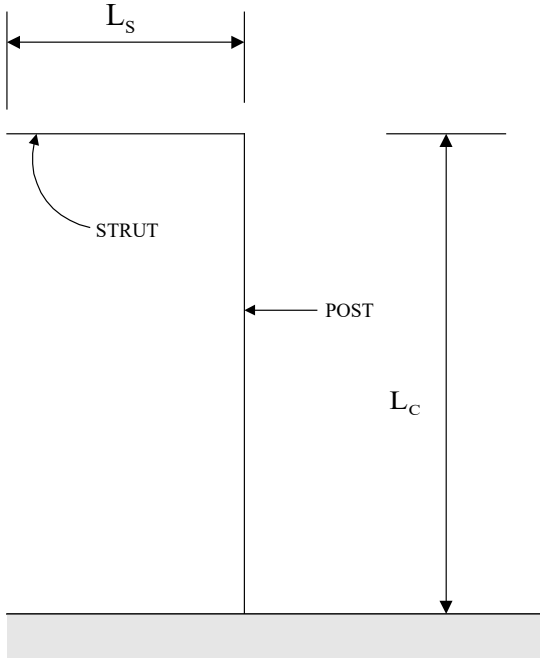
where:  $f_{bx_i}$  =  $f_{bx}$  at stress point  $i$  as defined for cross-section (Figures 3.6-13 & 14)

$f_{by_i}$  =  $f_{by}$  at stress point  $i$  as defined for cross-section (Figures 3.6-13 & 14)

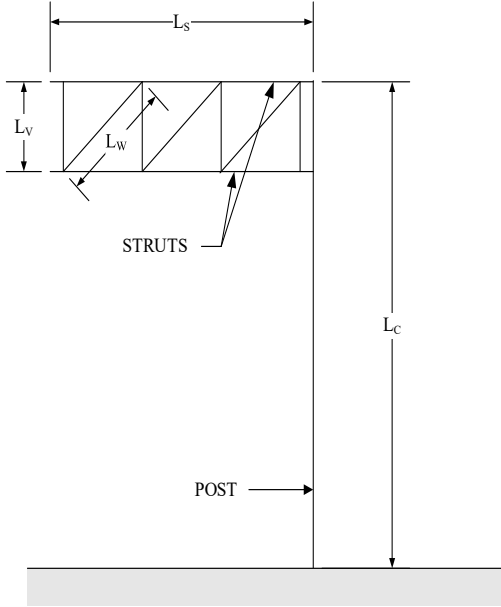
Note: Fatigue combined stress ratios are not computed for angles or tees, bolted through the web, to be consistent with their treatment for other specification checks.



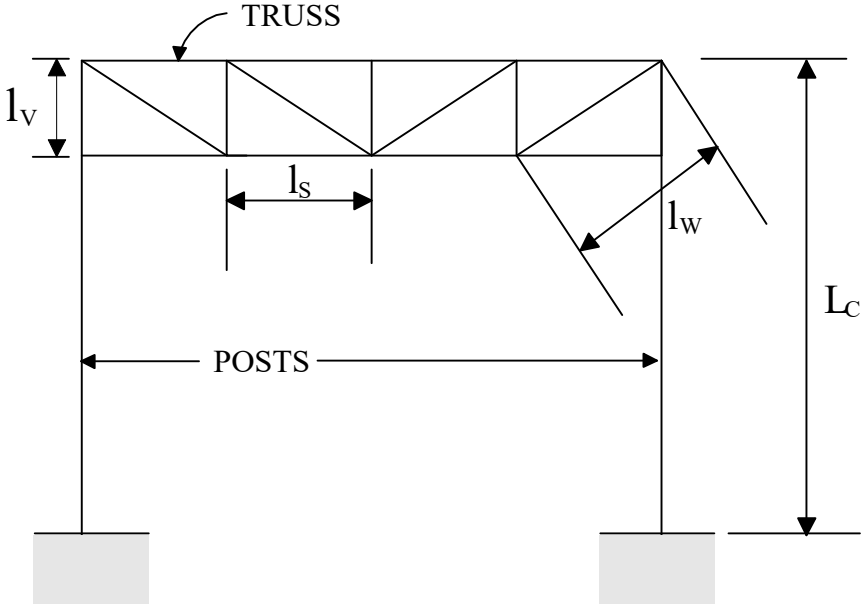
**Figure 3.6-5 Centermount**



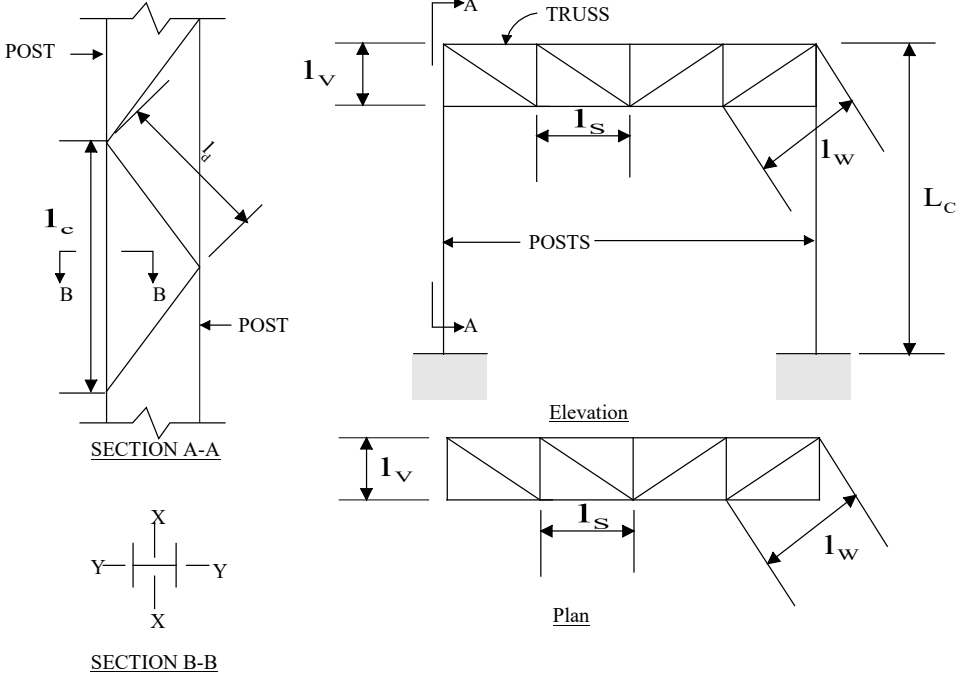
**Figure 3.6-6 Cantilever**



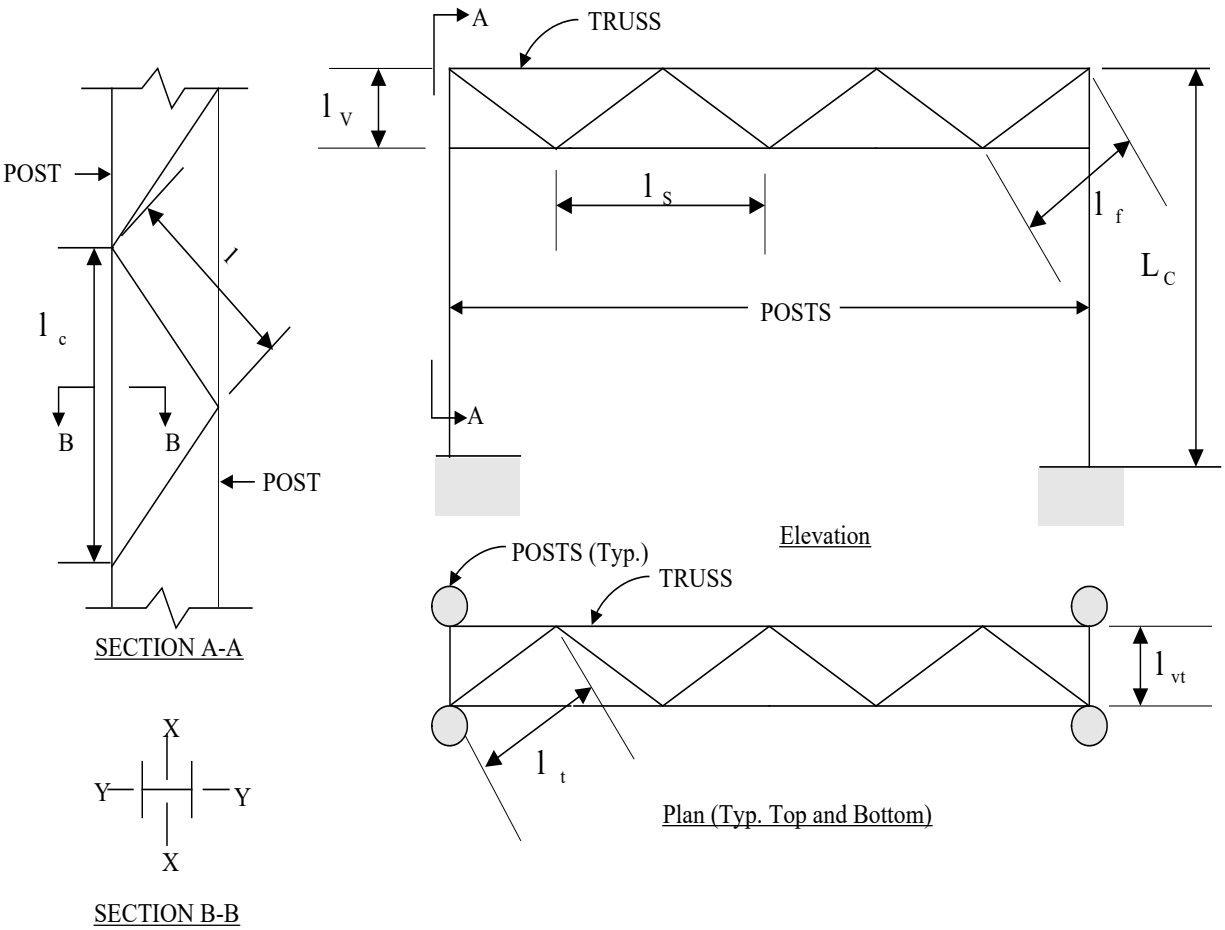
**Figure 3.6-7 Cantilever w/DMS**



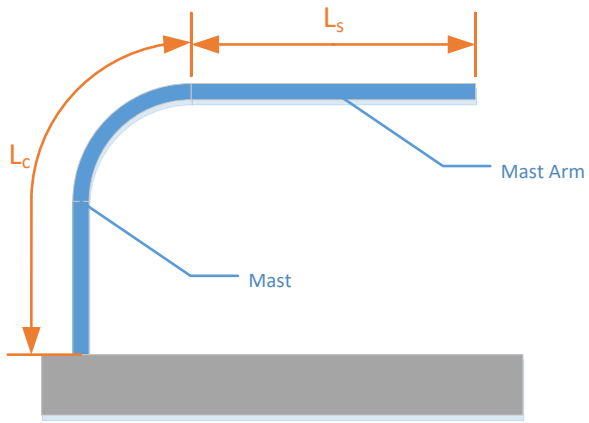
**Figure 3.6-8 Two-Post Tri-Chord**



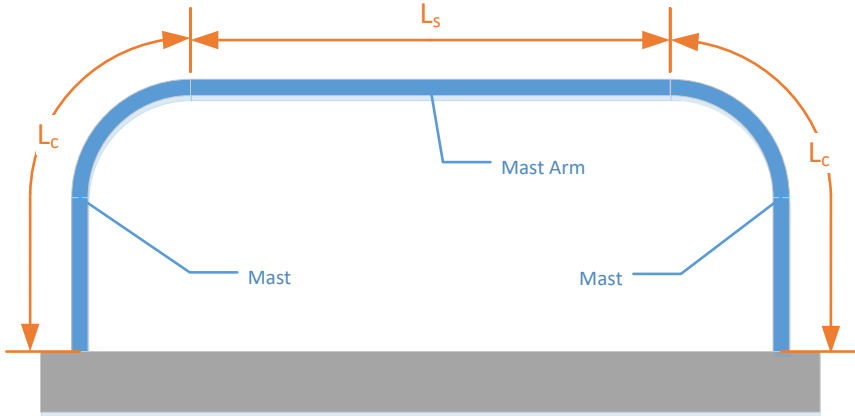
**Figure 3.6-9 Four-Post Tri-Chord**



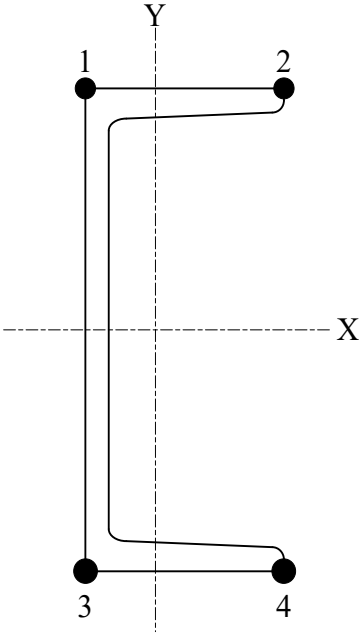
**Figure 3.6-10 Four-Post Four-Chord**



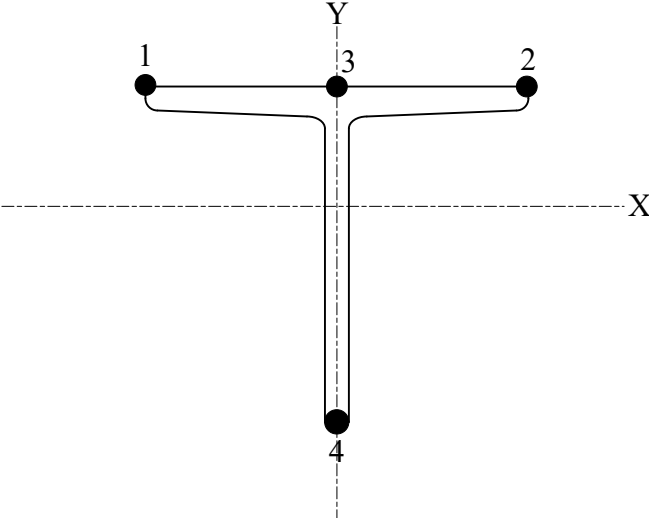
**Figure 3.6-11 Cantilever Monopipe**



**Figure 3.6-12 Monopipe Frame**



**Figure 3.6-13 Channel Stress Point Locations**



**Figure 3.6-14 WT and ST Section Stress Point Locations**

### 3.7 FOOTING DESIGN AND ANALYSIS

The footing program designs or checks spread footings using the AASHTO LRFD Bridge Design Specifications Seventh Edition, 2014 and the PennDOT Design Manual Part 4, April 2015 Edition. Factored load cases are obtained from the Sign Structure Analysis module. The factored weight of the footing, pedestal, and soil cover are added to each of these load cases. Refer to Section 3.7.6 for details of the additional loads included for the footing. The footing design / analysis is checked against each load case. When a load case violates any related design criteria, the footing size is increased to satisfy the subject criteria and the program then begins the check for every load case again. After a complete pass is successful, the program then designs the steel and computes the quantities.

The footing is assumed infinitely rigid and the footing pressures are calculated from the static equations of equilibrium. The program considers uplift, calculates a line of zero pressure (neutral axis) and the percentage of total area of footing that is in uplift. The minimum bearing area for the footing is 95% for Service Limit States and 75% for Extreme and Strength Limit States.

The program requires a minimal amount of input data to design a footing. Items such as footing size, and rebar size are designed, yet the option exists such that an engineer can input these quantities if no design requirements are violated using the input values. The program has a design/analyze switch such that an engineer can perform a code check for a user-defined footing. Input items that are required for design are: Pedestal size, Minimum and maximum footing depth, Footing material properties, soil data and Fill material height.

In the design mode, the program will increment the footing thickness by 3" increments if any shear requirements are violated. The footing width is incremented by 1, 2, or 4 foot increments depending on the code violation and the severity of the violation. The footing length is also incremented by 1, 2, or 4 foot increments depending on the code violation and the severity of the violation. The incrementing is based on violations of shear and eccentricity in the respective directions. Details of the heuristic rules used to increment the footing length and width are provided in a separate section. The minimum footing size is 2 feet greater than the pedestal size. The program checks every standard rebar size from No. 4 to No. 11 and then uses the smallest bars with a resultant spacing of 6" or greater.

In the analysis mode, the program computes the actual bar spacing from the given rebar size and number. The minimum spacing based on DM-4 Section 5.10.3.1.1, Cast-in-Place Concrete, is also reported in the output. The criteria used to compute the minimum spacing is the maximum required clear distance of:

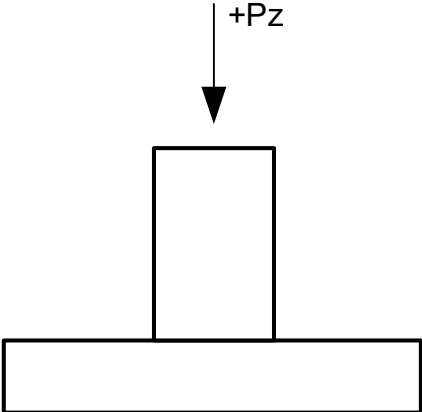
- 1)  $1.5 * \text{bar diameter}$ ,
- 2)  $1.5 * \text{max aggregate of } 1.5 \text{ in.}$ , and
- 3) 2.5 in. plus the bar diameter.

The resulting center-to-center bar spacing is rounded up to a multiple of 0.25 in.

The program reports the load effects from each load combination that applies to footings. Separate results are

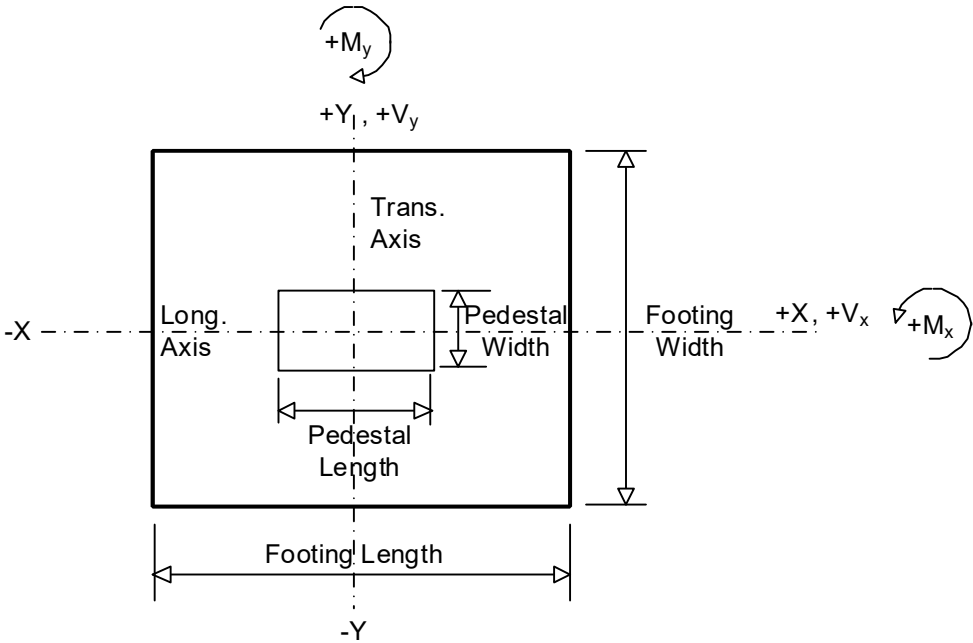
## **LRFD Sign Structure Analysis**

reported for the left and right footing for structures with two footings. Axial loads, horizontal shears, and biaxial bending moments are given at the footing centroid. In the case of a four-post sign structure, only one footing is assumed to support both posts at each end of the structure. Thus, the double reaction is converted into a concentric load with a given moment. The sign convention used for the load effects are shown in Figure 3.7-1.



Elevation View

Edge of Road



X-Axis is Parallel to the Centerline of Roadway

Plan View

**Figure 3.7-1 Footing Sign Convention**

A spread footing foundation is typically evaluated for the following failure conditions:

- Bearing Resistance – Strength & Extreme Limit States
- Settlement – Service I Limit State (Not to be evaluated by SNLRFD)

- Sliding Resistance – Strength & Extreme Limit States
- Limiting Eccentricity – Strength & Extreme Limit States
- Overall Stability – Service I Limit State (Not to be evaluated by SNLRFD)
- Structure Resistance – Service I, Strength & Extreme Limit States

The following section provides details for each of the failure conditions evaluated by the program.

### 3.7.1 BEARING RESISTANCE

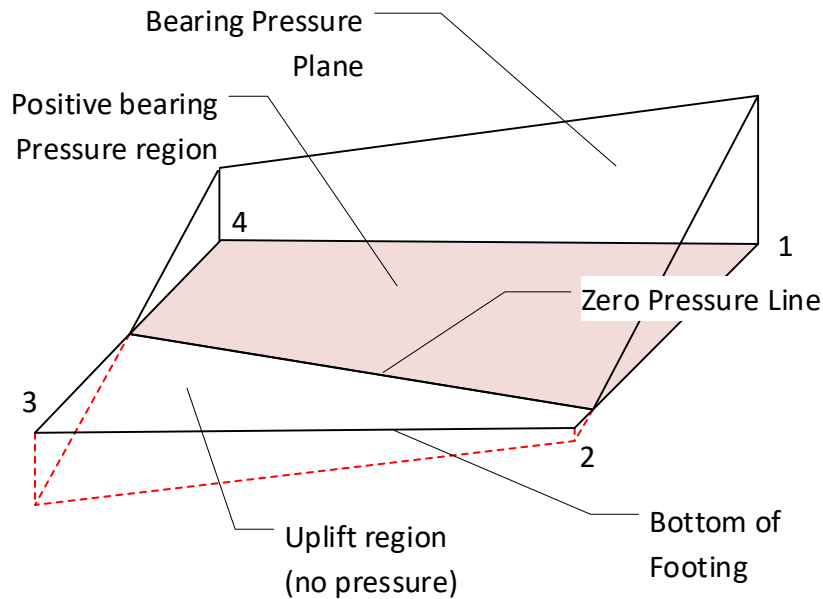
The bearing resistance check is done for the strength and extreme limit states. The footing output provides the reactions at the bottom of the sign structure post, which are the loads at the top of the pedestal. The bearing pressures are computed at the bottom of the footing and include the weight of the footing, pedestal, and the fill above the footing and around the pedestal. These additional loads are factored for the corresponding limit state. For each Limit State the Maximum Bearing Pressure is compared to the user input Factored Bearing Resistance. If the Maximum Bearing Pressure exceeds the resistance, then the footing size is incremented for design runs only.

The bearing pressures at the four corners are preliminarily computed using the following equations:

$$q = \frac{P}{A} \pm \frac{M_x}{S_x} \pm \frac{M_y}{S_y}$$

- where: P = Total factored vertical load at the bottom of the footing (kips)  
 A = Area of footing (ft<sup>2</sup>)  
 Mx = Moment about the X-axis (ft-kips)  
 Sx = Section modulus of footing about X-axis  
 My = Moment about the Y-axis (ft-kips)  
 Sy = Section modulus of footing about Y-axis

If any of the bearing pressures at the corners are negative, the footing has uplift and the bearing pressures are recomputed considering only the positive bearing pressure on the footing. The bearing pressures on the bottom of the footing can be represented as a plane. When the footing has uplift the bearing pressure plane intersects the bottom of the footing and that intersection is the zero-pressure line as shown in the figure below.



**Figure 3.7-2 Bearing Pressure Plane**

Each corner of the footing can be considered as a 3D point with the XY plane being the bottom of the footing and the bearing pressure being the Z value of the points. These points can be used to determine the equation of a plane passing through the points. For uplift conditions, the corners with uplift have negative pressures based on the geometry of the plane as shown in the figure. The equation of the bearing pressure plane can be used to compute the bearing pressure at any location within the footing. Only the positive bearing pressures are considered when computing forces on the footing.

### 3.7.2 SLIDING RESISTANCE

The Strength and Extreme Limit States are used for this analysis. Since the resistance is based on the reaction, minimum load factors on vertical loads will control. The Sliding Resistance Factor is always 0.80 for the Strength and Extreme limit states.

The Factored Sliding Resistance and the Sliding Force are computed using the following equations:

$$\text{Factored Sliding Resistance} = \phi_r \theta P$$

and

$$\text{Sliding Force} = \sqrt{(V_x)^2 + (V_y)^2}$$

- where:  $\phi_r$  = Sliding Resistance Factor (dimensionless)  
 $\phi$  = Friction coefficient (dimensionless)  
P = Total factored vertical load at the bottom of the footing (kips)

- V<sub>x</sub> = Horizontal force along the X-axis (kips)
- V<sub>y</sub> = Horizontal force along the Y-axis (kips)

### 3.7.3 LIMITING ECCENTRICITY

SNLRFD limits the eccentricity of vertical loads to the middle two-thirds of the footing dimension. Also, the SNLRFD requires a minimum percentage of the footing to be in contact with the soil. The current percentage is 95% for Service Limit State and 75% for Strength and Extreme Limit States.

The appropriate Limit States are Strength and Extreme Event for the eccentricity limit. The maximum eccentricity will be computed for load combinations using a minimum load factor for vertical loads. The eccentricity limit is always one-third of the footing dimension for the Strength and Extreme limit states.

The program computes the eccentricity in the X direction by dividing the moment about the Y axis by the vertical load at the bottom of the footing. The eccentricity limit in the X direction is one-third of the footing Length. The eccentricity ratio in the X direction is computed as the eccentricity limit divided by the eccentricity in the X direction.

$$Ratio_x = \frac{L/3}{Ecc_x}$$

- where:  $Ecc_x$  =  $M_y / P$  (ft)
- P = Total factored vertical load at the bottom of the footing (kips)
- L = Length of footing (ft)
- $M_y$  = Moment about the Y-axis (ft-kips)

The eccentricity in the Y direction is computed by dividing the moment about the X axis by the axial load. The eccentricity limit in the Y direction is one-third of the footing Width. The eccentricity ratio in the Y direction is computed as the eccentricity limit divided by the eccentricity in the Y direction.

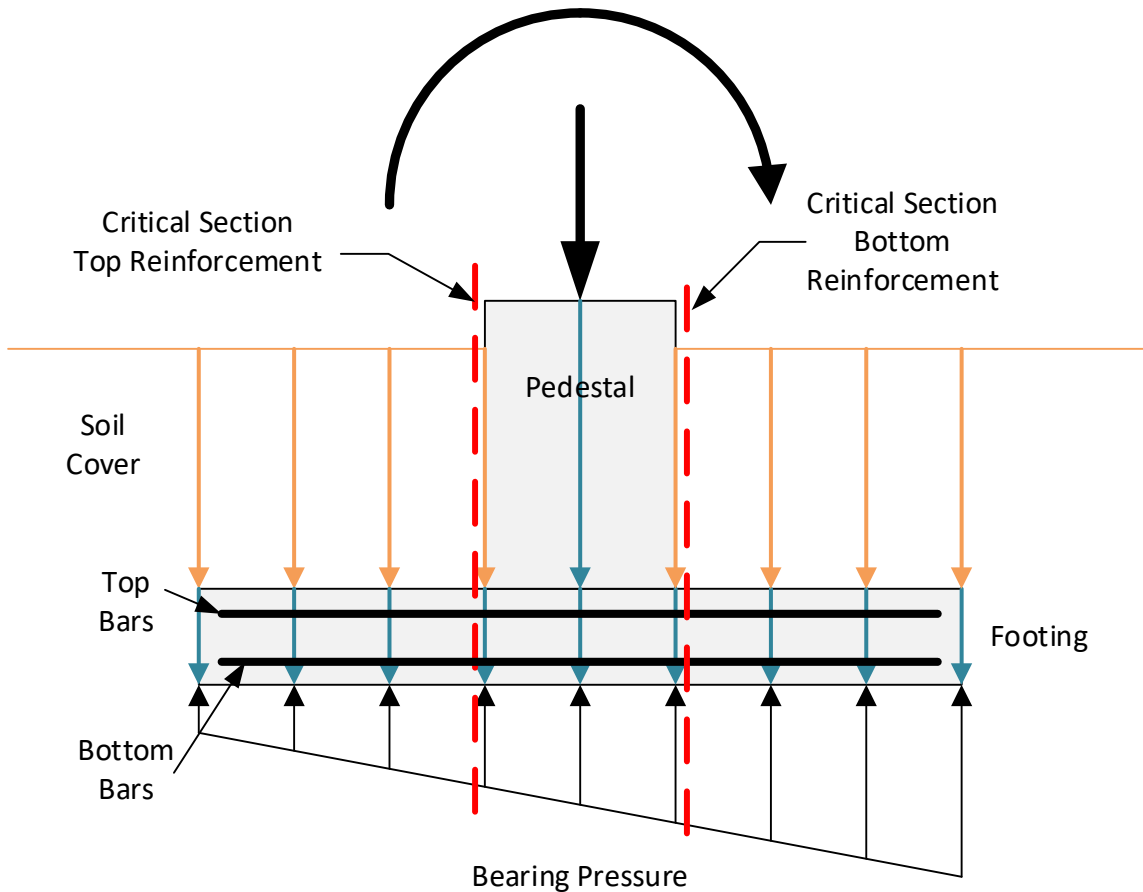
$$Ratio_y = \frac{W/3}{Ecc_y}$$

- where:  $Ecc_y$  =  $M_x / P$  (ft)
- P = Total factored vertical load at the bottom of the footing (kips)
- W = Width of footing (ft)
- $M_x$  = Moment about the X-axis (ft-kips)

### 3.7.4 FOOTING STRUCTURAL RESISTANCE

The top and bottom mats of reinforcement are designed for the critical moments parallel (X-axis) and perpendicular (Y-axis) to the centerline of the roadway. The critical location for moment is at the face of the pedestal. To determine the critical moment and shear the distribution of the soil stress must be known. A linear variation in the soil stress is assumed for the structural design of the footing. The total

moment on the critical section is used for the analysis and design of the footing. The following figure shows the location of the critical moments for the top and bottom reinforcement.



**Figure 3.7-3 Critical Moment Locations for Flexural Design**

The moments at the pedestal face are computed by summing the moments on the footing acting as a cantilever. The moments are from the weight of the soil cover, the weight of the footing, and the force of the bearing pressure. The moment from the bearing pressure is in an opposite direction from the other two moments. The critical section for the top reinforcement is on the side with the minimum pressure so that tension is in the top of the footing. The critical section for the bottom reinforcement is on the side with the maximum pressure so that tension is in the bottom of the footing. If the footing has uplift, only a portion of the footing will have a pressure that causes moment on the footing. The figure shows the reinforcement in one direction, either X-axis or Y-axis. The procedure is done for both the X and Y directions.

#### 3.7.4.1 CONTROL OF CRACKING

The footing must be checked for cracking loads. This section of the Specification applies to all members in which tension in the cross-section exceeds 80 percent of the modulus of rupture at the service limit state. The modulus of rupture is computed as follows:

$$f_r = 0.24\sqrt{f'_c}$$

where:  $f_r$  = Modulus of rupture (ksi)  
 $f'_c$  = Concrete design strength (ksi)

The tension in the cross-section is computed as follows:

$$f_s = \frac{M}{S_c}$$

where:  $f_s$  = Tension in concrete (ksi)  
 M = Service moment on the footing taken at the face of the pedestal (in-kips)  
 $S_c$  = Section modulus (in<sup>3</sup>)

When the tension in the concrete exceeds 80 percent of the modulus rupture, the following crack control criteria must be satisfied:

$$s \leq \frac{700\gamma_e}{\beta_s f_{ss}} - 2d_c$$

in which:

$$\beta_s = 1 + \frac{d_c}{0.7(h - d_c)}$$

where:  $\beta_s$  = ratio of flexural strain at the extreme tension face to the strain at the centroid of the reinforcement layer nearest the tension face  
 $\gamma_e$  = exposure factor, 1.00 for Class 1 exposure condition  
 $d_c$  = thickness of concrete cover measured from extreme tension fiber to center of the flexural reinforcement located closest thereto (in.) The 1 in. extra cover provided to account for uneven ground level of footing bottom mat reinforcement is not included.  
 $f_{ss}$  = calculated tensile stress in mild steel reinforcement at the service limit state not to exceed 0.60 Fy (ksi)  
 h = overall thickness of the footing (in)  
 s = spacing of mild steel reinforcement in the layer closest to the tension face (in)

### 3.7.4.2 FLEXURAL RESISTANCE

The flexural resistance must be greater than the largest factored moment. The critical moment location is at the face of the pedestal. The distribution of the soil pressure must be known to determine the applied moment. With the known moment the following quadratic equation is solved for the area of steel,  $A_s$ , with phi equal to 0.90:

$$\left[ \frac{f_y^2}{2(0.85)f'_c b} \right] A_s^2 - [f_y d_s] A_s + \frac{|M_u|}{\phi} = 0$$

$$A_s = \frac{-b_{coef} - \sqrt{b_{coef}^2 - 4a_{coef}c_{coef}}}{2a_{coef}}$$

$$a_{coef} = \frac{f_y^2}{2(0.85)f'_c b}$$

$$b_{coef} = -f_y d_s$$

$$c_{coef} = \frac{|M_u|}{\phi}$$

The number of reinforcement bars is computed as the smallest integer greater than or equal to the required area divided by the area of one bar. Using the total area of the computed number of bars, the nominal moment resistance is computed with the assumption that  $f_s$  is equal to  $f_y$  in the following equations:

$$c = \frac{A_s f_s}{0.85 f'_c \beta_1 b}$$

$$a = \beta_1 c$$

$$M_n = A_s f_s \left( d - \frac{a}{2} \right)$$

- where:  $c$  = distance from the extreme compression fiber to the neutral axis (in)  
 $A_s$  = area of tension reinforcement (in<sup>2</sup>)  
 $f_s$  = stress in mild steel tension reinforcement at nominal flexural resistance (ksi)  
 $f'_c$  = Concrete design strength (ksi)  
 $\beta_1$  = ratio of the depth of the equivalent uniformly stressed compression zone to the depth of the actual compression zone  
 $b$  = width of the compression face of the member (in)  
 $a$  = depth of equivalent rectangular stress block (in)  
 $M_n$  = nominal flexural resistance (in-kips)  
 $d$  = distance from compression face to centroid of tension reinforcement (in)

The net tensile strain and the stress in the reinforcement is computed from the following:

$$\epsilon_t = 0.003 \left( \frac{d_s}{c} - 1 \right)$$

$$f_s = \min(\epsilon_t \cdot E_s, f_y)$$

- where:  $\epsilon_t$  = net tensile strain in extreme tension steel at nominal resistance (in/in)  
 $d_s$  = distance from extreme compression fiber to the centroid of the nonprestressed tensile reinforcement (in)  
 $E_s$  = modulus of elasticity of reinforcing bars (ksi)

$f_y$  = specified minimum yield strength of reinforcing bars (ksi)

If the mild steel stress,  $f_s$ , is less than the yield strength,  $f_y$ , than the initial assumption was incorrect, and the nominal flexural resistance is determined based on conditions of equilibrium and strain compatibility.

The resistance factor  $\phi$  is computed with the net tensile strain using the following equation:

$$0.75 \leq \phi = 0.75 + \frac{0.15(\epsilon_t - \epsilon_{cl})}{(\epsilon_{tl} - \epsilon_{cl})} \leq 0.9$$

where:  $\epsilon_{cl}$  = compression-controlled strain limit, 0.002

$\epsilon_{tl}$  = tension-controlled strain limit, 0.005

Finally, the factored flexural resistance is computed by multiplying nominal flexural resistance by  $\phi$ . If the computed  $\phi$  factor is less than 0.90, then the process is repeated with  $\phi$  assumed to be 0.75 and a second steel area is computed from the quadratic equation. Using the second steel area a new factored flexural resistance is computed. If the new factored flexural resistance is less than the applied factored moment, then the cross section is considered inadequate and the section depth is incremented and the process is repeated. Otherwise, an iterative procedure is used to find an area of steel that results in a factored flexural resistance that equals (within a tolerance) the applied factored moment.

#### 3.7.4.3 MINIMUM REINFORCEMENT (AASHTO BRIDGE LRFD 5.7.3.3.2)

The AASHTO Bridge LRFD Specification specifies that all sections requiring reinforcing must have sufficient strength to resist a moment equal to at least the moment that causes a concrete section to crack or 1.33 times the factored moment. The cracking moment is computed by the following equation:

$$M_{cr} = \gamma_3(\gamma_1 f_r S_c)$$

where:  $\gamma_3$  = ratio of specified minimum yield strength to ultimate tensile strength of the reinforcement. For Grade 60 reinforcement DM-4 Article 5.7.3.3.2 specifies to use 0.67. The program computes the value from the yield strength and the ultimate strength entered by the user or defaulted in the program.

$\gamma_1$  = flexural cracking variability factor, 1.6

$f_r$  = modulus of rupture (ksi)

$S_c$  = section modulus for the extreme fiber of the section where tensile stress is caused by externally applied load (in<sup>3</sup>)

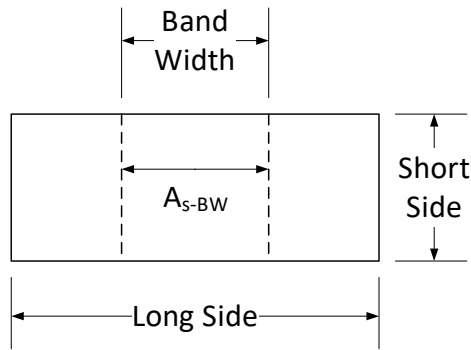
#### 3.7.4.4 MINIMUM REINFORCEMENT (DM-4 5.10.8.1P)

DM-4 requires any member subject to loading or stress to have minimum steel reinforcement of No. 4 bars at 12 in. or No. 5 bars at 18 in.

Additionally, DM-4 Article 5.10.3.2 specifies a maximum spacing of reinforcing bars of 1.5 times the thickness of the member or 24.0 in. PennDOT Bridge Office was asked about this discrepancy and indicated that DM-4 5.10.3.2 will be corrected to 18". The AASHTO Bridge LRFD Specification Article 5.10.3.2 specifies the maximum spacing as 18.0 in. The AASHTO spacing limit is used by the program.

**3.7.4.5 DISTRIBUTION OF MOMENT REINFORCEMENT (AASHTO BRIDGE LRFD 5.13.3.5)**

According to AASHTO Bridge LRFD 5.13.3.5, for two-way rectangular footings, in the short direction a portion of the total reinforcement is required to be distributed uniformly over a band width equal to the length of the short side of the footing and centered on the centerline of the pedestal. The remainder of the reinforcement required in the short direction is distributed uniformly outside of the center band width of the footing. This results in two different reinforcement spacing in the short direction. The spacing of reinforcement in the center band will be less than the spacing outside of the center band.



**Figure 3.7-4 Distribution of Reinforcement in Band Width**

Rather than having two different spacings of reinforcement in the short direction, the program increases the required reinforcement area so that the reinforcement distribution required in the band width is used for the full width of the long side. The required reinforcement area in the band width is given by the following equation:

$$A_{s-BW} = A_{s-SD} \left( \frac{2}{\beta + 1} \right)$$

where:

- $\beta$  = ratio of the long side to the short side of the footing
- $A_{s-BW}$  = area of steel in the band width (in.<sup>2</sup>)
- $A_{s-SD}$  = total area of steel in short direction (in.<sup>2</sup>)

The required increased reinforcement area is computed by the following equation:

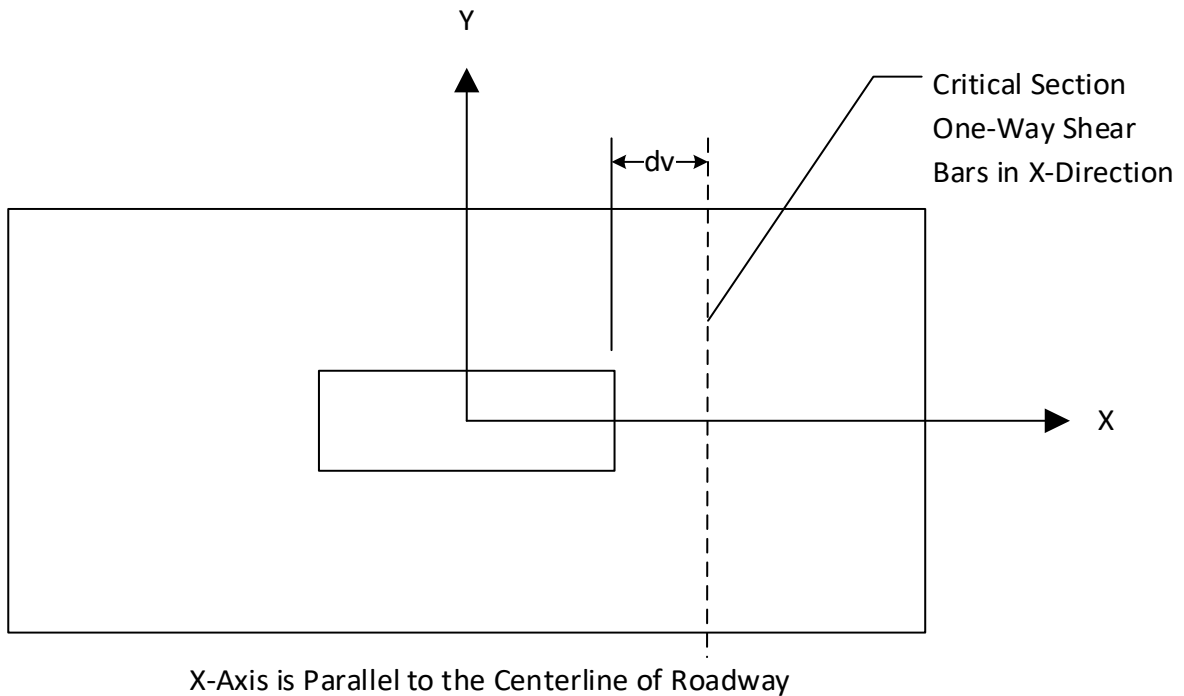
$$A_{s-INC} = A_{s-BW} \times \beta = A_{s-SD} \frac{2\beta}{\beta + 1}$$

where:

- $A_{s-INC}$  = total increased area of steel in short direction (in.<sup>2</sup>)

**3.7.4.6 SHEAR DESIGN - ONE-WAY ACTION**

For one-way action, the shear resistance and factored shear is computed at a distance,  $d_v$ , from the face of the pedestal.



**Figure 3.7-5 Location of Critical Section, One-way Shear**

The shear depth,  $d_v$ , is determined as the greatest of the following criteria:

1.  $d_s - \frac{a}{2}$
2.  $0.9d_s$
3.  $0.72h$

The nominal shear resistance from concrete,  $V_c$ , is calculated as follows:

$$V_c = 0.0316\beta\sqrt{f'_c}b_vd_v$$

- where:  $\beta$  = factor relating effect of longitudinal strain on the shear capacity of concrete, taken as 2.0
- $f'_c$  = Concrete design strength (ksi)
- $b_v$  = width of section resisting shear (in)
- $d_v$  = effective shear depth (in)

The nominal shear strength is the lesser of:

- 1)  $V_n = V_c + V_s + V_p$
- 2)  $V_n = 0.25f'_cb_vd_v + V_p$

Where  $V_s$  and  $V_p$  are both zero.

The factored shear resistance is computed as:

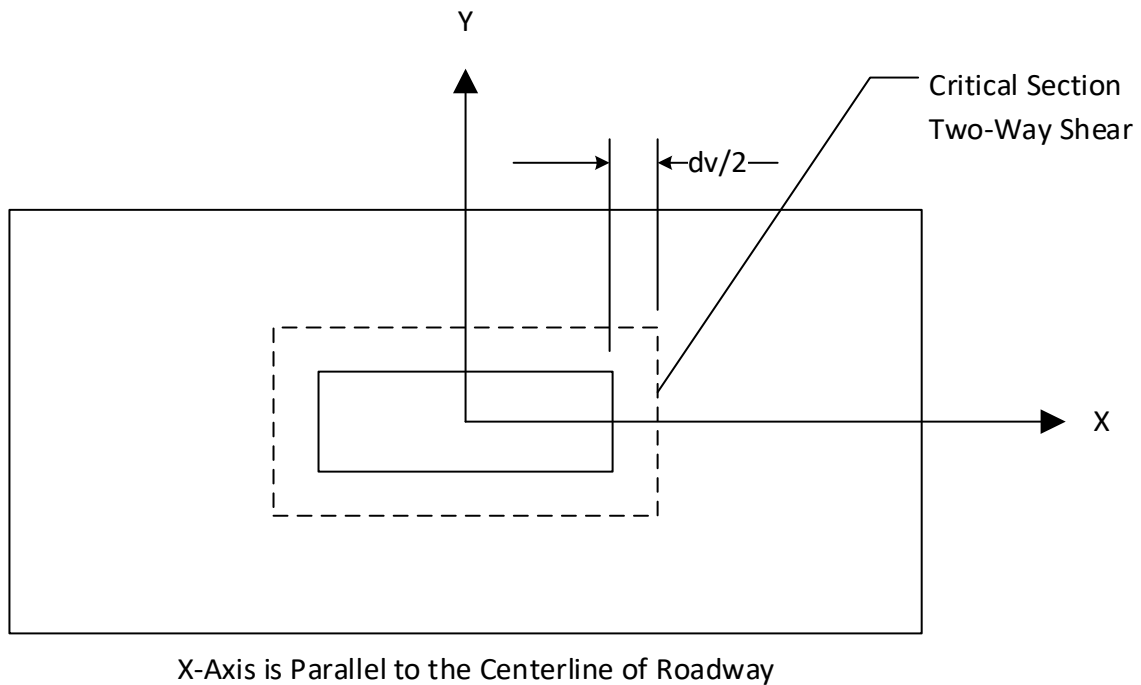
$$V_r = \phi V_n$$

Where  $\phi$  for shear is 0.90.

One-way shear is also checked for the reinforcement in the Y-Direction using the same procedures as used in the X-Direction.

### 3.7.4.7 SHEAR DESIGN - TWO-WAY ACTION

For two-way shear the location of the critical section is the perimeter at  $d_v/2$  from the pedestal.



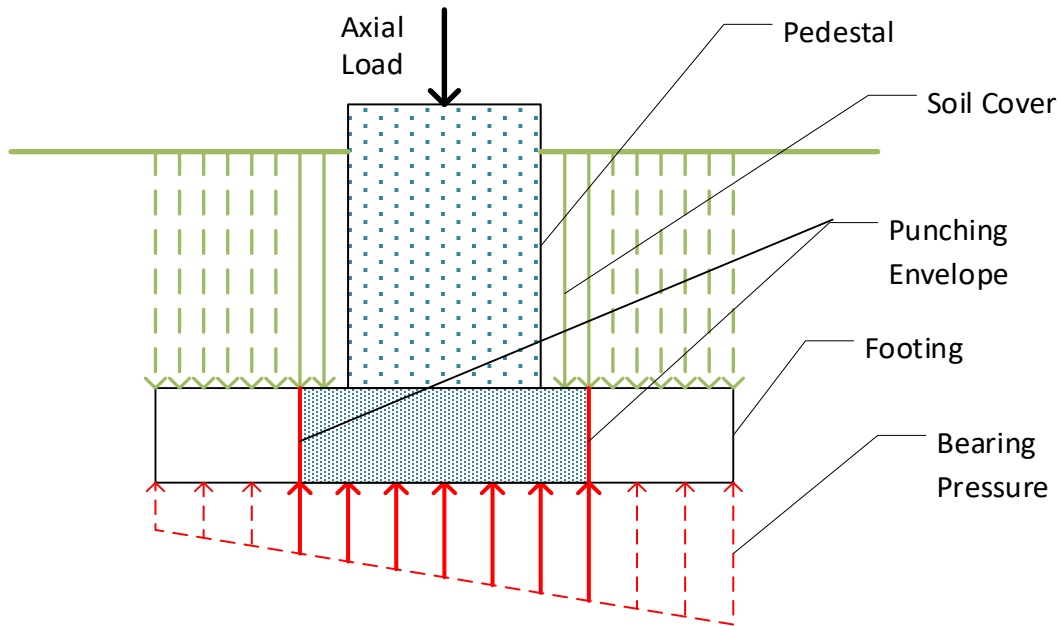
**Figure 3.7-6 Location of Critical Section, Two-way Shear**

The effective shear depth is taken as the average of the shear depth in the X-direction and the Y-direction.

#### 3.7.4.7.1 Factored Punching Shear Force

The factored punching shear force is the sum of the forces acting on the footing in the area defined by the critical section for two-way shear. These forces include the weight of the pedestal, the axial load from the sign structure, the weight of the soil cover on the area defined by the critical section, the weight of the

footing for the area defined by the critical section, and the bearing pressure on the punching shear envelope. All these forces act downward and are positive except for the bearing pressure which acts upward as shown in Figure 3.7-7.



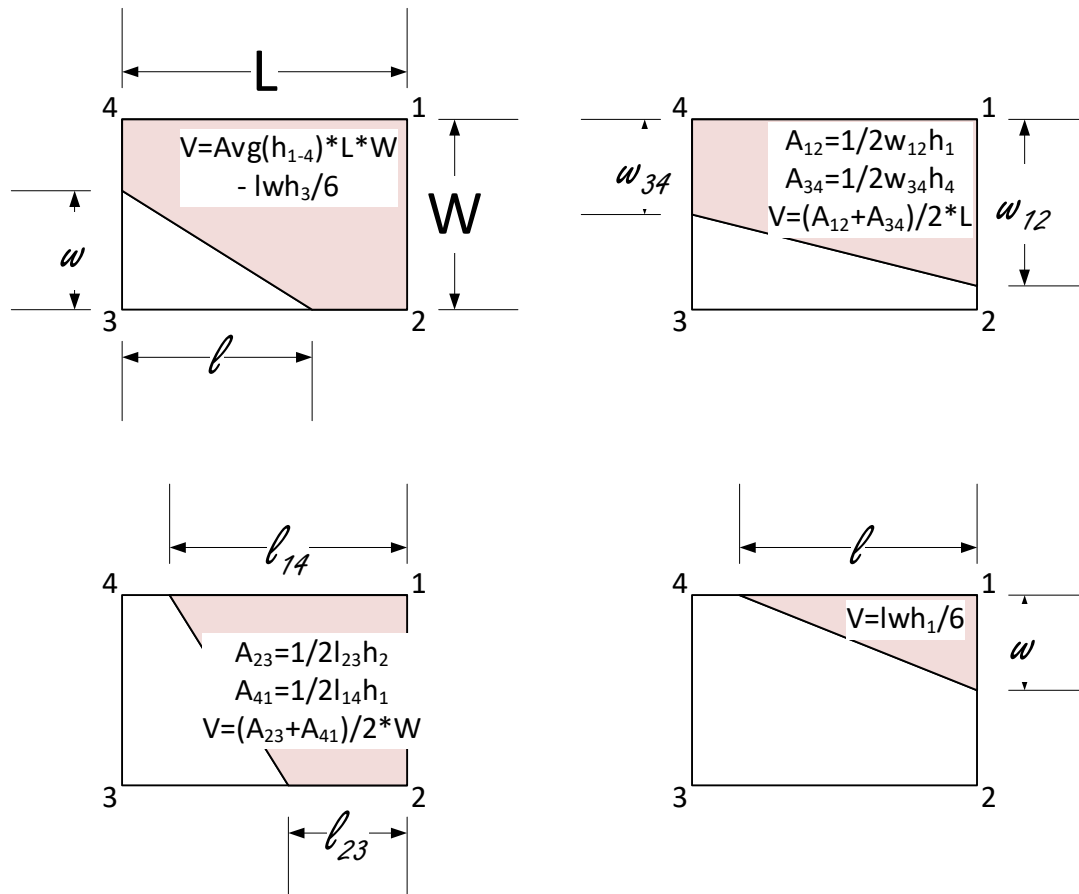
**Figure 3.7-7 Forces Acting on Punching Shear Envelope**

The force from the bearing pressure is computed as the average pressure on the footing times the area of the punching shear envelope when the footing has no uplift. When the footing has uplift the pressures at each corner of the punching shear envelope are computed using the equation of the bearing pressure plane (refer to Section 3.7.1). If all four corners of the punching shear envelope have positive bearing pressures the average of the four corner pressures times the area of the punching shear envelope is used to compute the bearing force on the envelope.

When all the corner pressures on the punching shear envelope are not positive the following pressure configurations are possible:

- Negative pressure at punching shear corner 3
- Negative pressure at punching shear corners 2 and 3
- Negative pressure at punching shear corners 3 and 4
- Negative pressure at punching shear corners 2, 3, and 4

The figure below shows the four configurations and the equations to compute the force on the punching shear envelope. The shaded area is in contact with the soil and the unshaded region has zero pressure.



**Figure 3.7-8 Pressure Configurations on Punching Shear Envelope**

where:

$L$  = length of punching shear envelope

$W$  = width of punching shear envelope

$w$  = distance along width of envelope

$l$  = distance along length of envelope

$A$  = area of end section of pressure diagram

$h_i$  = pressure at corner  $i$

$V$  = force on punching shear envelope from bearing pressure

### 3.7.4.7.2 Punching Shear Resistance

The equation for the nominal shear resistance of the concrete for two-way action is:

$$V_n = \left( 0.063 + \frac{0.126}{\beta_c} \right) \sqrt{f'_c} b_o d_v \leq 0.126 \sqrt{f'_c} b_o d_v$$

where:  $\beta_c$  = ratio of long side to short side of the rectangle through which the concentrated load or reaction force is transmitted (i.e. the pedestal length and width).

$f'_c$  = Concrete design strength (ksi)

$b_o$  = perimeter of the critical section (in)

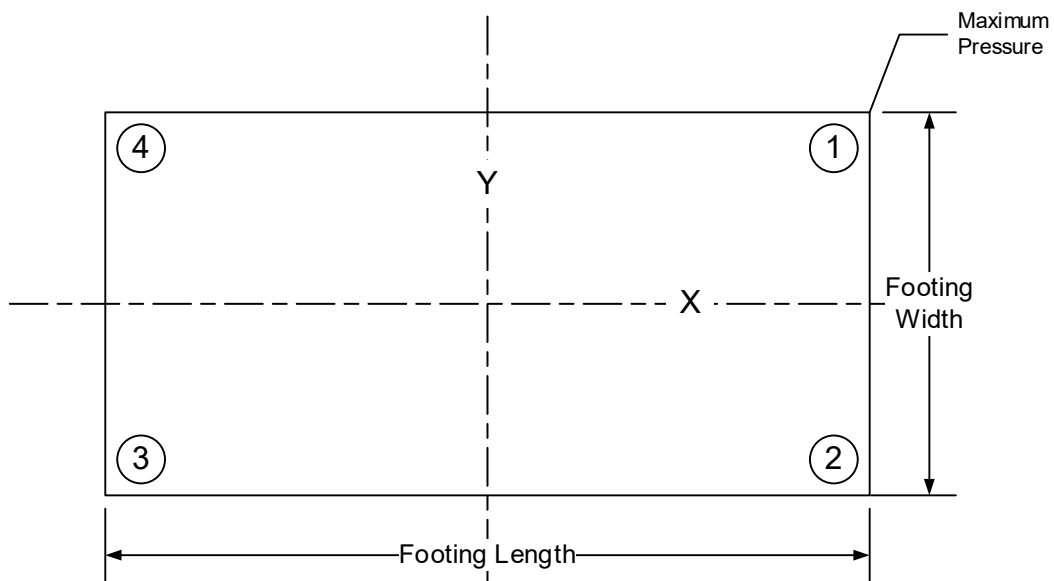
$d_v$  = effective shear depth (in)

Again, the factored shear resistance is computed as:

$$V_r = \phi V_n$$

### 3.7.5 HEURISTIC RULES TO SIZE FOOTING

The program sizes the footing using a set of heuristic rules to increase the length and width of the footing. The heuristic rules employ a practical method not guaranteed to be optimal or perfect, but sufficient to size the footing. Figure 3.7-4 shows the orientation of the footing and the numbering of the corners of the footing.



X-Axis is Parallel to the Centerline of Roadway

**Figure 3.7-9 Footing Orientation**

The rules are as follows:

If the Area of footing in contact with the soil is less than 95% for Service Limit State or 75% for Strength and Extreme Limit States or if the maximum bearing pressure at corner 1 is greater than the bearing resistance then,

If the maximum eccentricity in the X-direction is greater than one-half of the footing length and the maximum eccentricity in the Y-direction is greater than one-half of the footing width then,

The footing width is increased by minimum of 2 feet or 25% of the width.

The footing length is increased by minimum of 2 feet or 25% of the length.

Else if the maximum eccentricity in the X-direction is greater than one-half of the footing length then,

The footing length is increased by minimum of 2 feet or 25% of the length.

The footing width is set to at least one-quarter of the footing length and a multiple of 6 inches.

Else if the maximum eccentricity in the Y-direction is greater than one-half of the footing width then,

The footing width is increased by minimum of 2 feet or 25% of the width.

The footing length is set to at least one-quarter of the footing width and a multiple of 6 inches.

Else if the Area of footing in contact with the soil is less than 95% for Service Limit State or 75% for Strength and Extreme Limit States then,

If the minimum bearing pressure at corner 2 is less than zero then,

If the Area of footing in contact with the soil is less than 85% of the limit above (either 75% or 95%) then,

The footing width is increased by 1 foot.

The footing length is set to at least one-quarter of the footing width and a multiple of 6 inches.

Else

The footing width is increased by 6 inches.

Else if the minimum bearing pressure at corner 4 is less than zero then,

If the Area of footing in contact with the soil is less than 85% of either 75% or 95% then,

The footing length is increased by 1 foot.

The footing width is set to at least one-quarter of the footing length and a multiple of 6 inches.

Else

The footing length is increased by 6 inches.

Else

If the ratio of minimum bearing pressure at corner 4 to the minimum bearing pressure at corner 2 is greater than 1 then,

The footing width is increased by 6 inches.

Else if the ratio of minimum bearing pressure at corner 2 to the minimum bearing pressure at corner 4 is greater than 1 then,

The footing length is increased by 6 inches.

Else

The footing width is increased by 6 inches.

The footing length is increased by 6 inches.

Else

If the maximum bearing pressure at corner 2 is greater than the bearing resistance then,

The footing length is increased by 6 inches.

The footing width is set to at least one-quarter of the footing length and a multiple of 6 inches.

Else if the maximum bearing pressure at corner 4 is greater than the bearing resistance then,

The footing width is increased by 6 inches.

The footing length is set to at least one-quarter of the footing width and a multiple of 6 inches.

Else

The footing width is increased by 6 inches.

The footing length is increased by 6 inches.

Else if the maximum sliding force is greater than the sliding resistance then,

If the footing width is less than the footing length plus 6 inches then

The footing width is increased by 6 inches.

Else

The footing length is increased by 6 inches.

Else if the maximum eccentricity in the X-direction is greater than the eccentricity limit in the X-direction then,

The footing length is increased by 6 inches.

Else if the maximum eccentricity in the Y-direction is greater than the eccentricity limit in the Y-direction then,

The footing width is increased by 6 inches.

If the maximum footing width has been specified, then any increment to the footing width is limited to the maximum footing width. When the maximum footing width causes neither the length nor the width to be increased, the footing length is increased by 6 inches so that the next footing iteration has a new footing size.

### 3.7.6 FOOTING LOADS

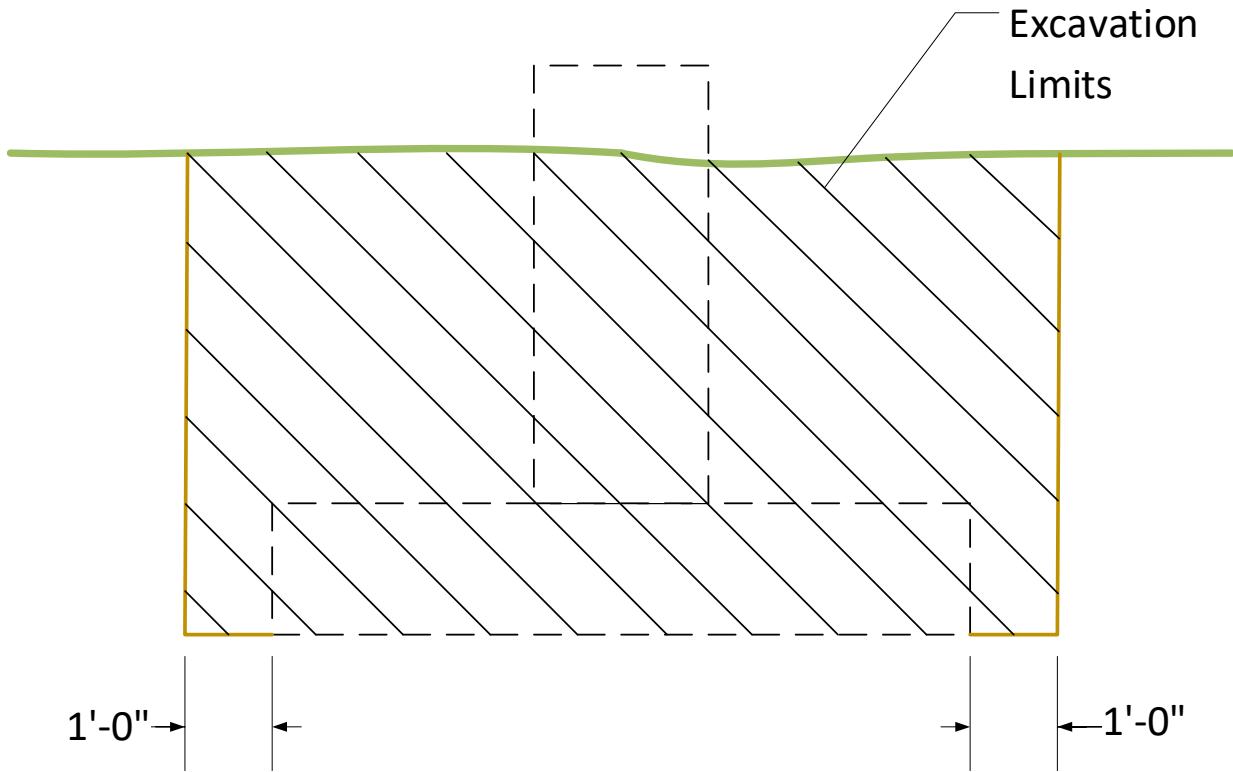
In addition to the loads applied to the footing at the top of the pedestal from the sign structure, the self-weight of the pedestal, the footing, and the soil cover are included in the analysis of the footing. The pedestal and footing are factored by the same DC load factors that are used for the sign structure. For the Strength Limit State, the DC load factor is 1.25 as specified by AASHTO Sign Specification in Table 3.4-1. For the Extreme Limit State, the DC load factor is 1.10 for maximum effects and 0.90 for minimum effects as specified by AASHTO Sign Specification in Table 3.4-1. For the Service Limit State, the DC load factor is 1.0.

The Load Combinations and Load Factors, Table 3.4-1 of LRFD Sign Specification, does not include EV load types; therefore, the EV load factors are based on Table 3.4.1-2 of LRFD Bridge Specification. The soil cover is factored by the EV load factors based on values given for Rigid Buried Structure in Table 3.4.1-2 of the AASHTO LRFD Bridge Specification. For the Strength Limit State, the EV load factor is 1.30. For the Extreme Limit State, the EV load factor is 1.30 for maximum effects and 0.90 for minimum effects. For the Service Limit State, the EV load factor is 1.0.

Refer to User Manual Section 3.4.8 for further details.

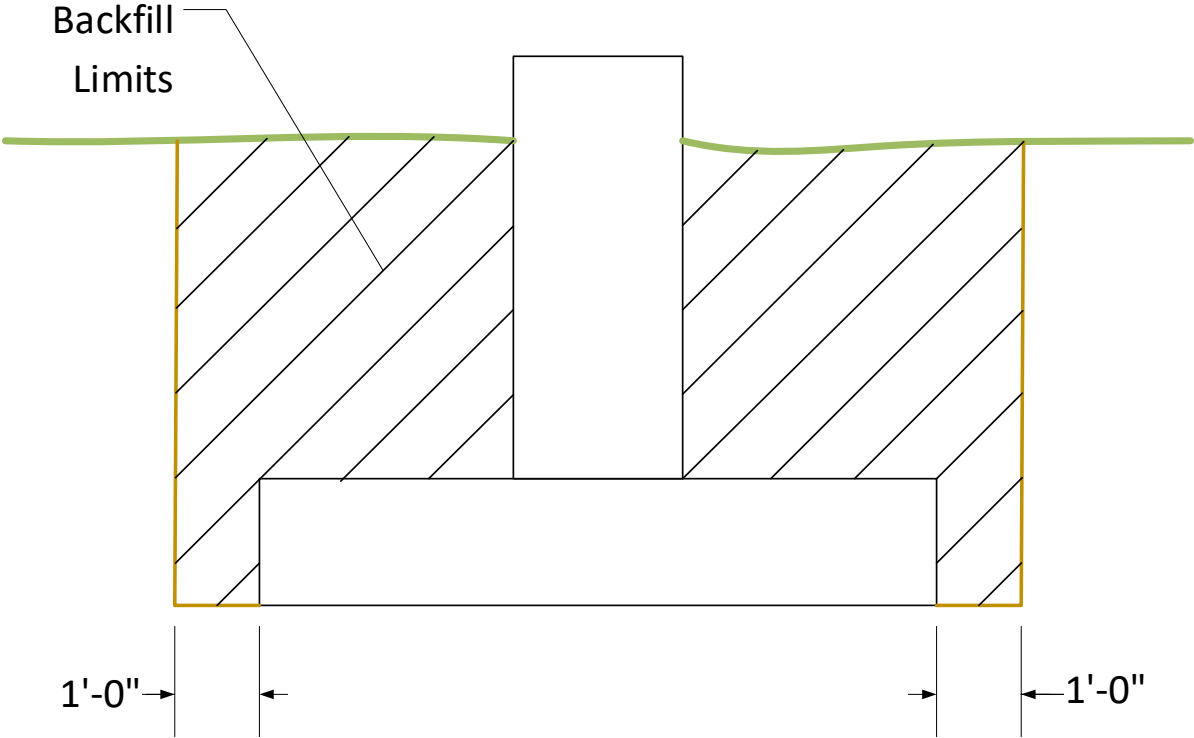
### 3.7.7 EXCAVATION AND BACKFILL QUANTITIES

The excavation quantity is based on a one-foot offset from the perimeter of the footing with a vertical slope. The depth of the excavation is the footing thickness plus the fill height.



**Figure 3.7-10 Excavation Quantity**

The backfill quantity is the excavation quantity minus the volume of the footing and minus the volume of the pedestal below the fill height.



**Figure 3.7-11 Backfill Quantity**

### 3.8 PROGRAM ASSUMPTIONS

The following assumptions are made by the Sign Structure Program:

- Default yield strength of all sign structure steel is 36 ksi.
- Bearing pressure distributions are assumed to vary linearly for the footing.
- Diagonals and verticals in tri-chord trusses are oriented as shown for tee sections on Sheet 7 of BC-744M, August 2017. This orientation allows the flange of the tee section to be connected to the connection plate for the top and bottom trusses. For channel cross-sections, this would imply one of the flanges of the channel is connected to the connection plate.
- Tee, channel, and angle sections are provided for the analysis of existing sign structures.

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# 4.0 *INPUT DATA REQUIREMENTS*

The input form shown on the following pages (Figure 4.0-1) has been provided to facilitate data preparation for execution of this program. All input fields are fixed format. The implied decimal point location for each data field is as shown on the input form. To override the fixed format, data can be entered with a decimal point as part of the data field. Examples of completed input files are shown in Appendix B. Refer to Figures 3.3-1 through 3.3-13 and the example problems in Appendix B for more information related to specific structure types. The units for dimensions and loads are documented for each input item. In general, dimensions and distances are in feet except as noted, and loads are in pounds except as noted.

## **PREPARING INPUT**

The program requires an ASCII input file. The input file consists of a series of data lines. Each data line consists of a number of fixed length data fields. The input can be created using Engineering Assistant, described below, or any text editor.

## **ENGINEERING ASSISTANT**

The Engineering Assistant (EngAsst) is a Windows application developed by the Pennsylvania Department of Transportation (PennDOT) to provide a graphical user interface (GUI) for PennDOT's engineering programs. The data for the input to the engineering program is presented in a user-friendly format, reflecting the implied structure of the data, showing each record type on a separate tab page in the display and showing each field on each record with a defining label.

With EngAsst the user can create a new input file, modify an existing input file, import input files, run the associated engineering program and view the output in a Windows environment. The help and documentation are provided, including text descriptions of each field, relevant images, and extended help text at both the record/tab level and the field level. Access to all parts of the Engineering Program User's Manual is also provided within EngAsst.

EngAsst is not included with this software. It requires a separate license that can be obtained through the Department's standard Engineering software licensing procedures. Order forms can be obtained from program support website at <http://penndot.engrprograms.com>.

## **RUNNING THE PROGRAM WITHOUT ENGINEERING ASSISTANT**

The engineering programs are FORTRAN console application programs. They may be run from a command window, by double-clicking on the program icon from Windows Explorer, by selecting the shortcut from the Start

menu under "PennDOT SNLRFD <version number>", or by double-clicking the shortcut icon on the desktop. To run the program in a command window, the user must specify the directory in which the program has been installed or change to the directory.

The program will first prompt for an input file name, and the user should then enter the appropriate input file name. The input file must be created before running the program. Next, the program will then prompt for whether the output should be reviewed on the screen. The user should enter "Y" if the output is to be reviewed on the screen after execution or "N" if the output is not to be reviewed on the screen. The program will then prompt for the name of the output file in which the output is to be stored, and the user should then enter the desired output file name. If a file with the specified output file name already exists, the program gives the option of overwriting the existing file or entering a new output file output file name. If no output file name is entered, a default output file will be used. The program will then execute.

To cancel the program during execution, press <Ctrl C> or <Ctrl Break>.

When the program completes execution, the user is prompted to "Press <ENTER> to exit program." This allows the user to view the last messages written to the screen when the program was started by double-clicking on the program icon from Windows Explorer.

The user can view the \*.out output file from within EngAsst or with a text editor, and the \*.PDF output file with Adobe Acrobat or any other PDF viewing program.





PROGRAM SNLRFD  
LRFD SIGN STRUCTURE ANALYSIS

BOLTED CONNECTIONS

BOLT DIAMETER	CONNECTION PLATE 1		CONNECTION PLATE 2		No. U BLTS		
	WIDTH	THICKNESS	WIDTH	THICKNESS			
1	6	7	13	19	20	26	32

CHORD  
SPLICE ONE

SPLICE NAME	PANEL No.
1	3

PIPE CONNECTION DETAILS

TYPE ORS	H. S. BOLTS			SPLICE PLATE			STIFFENERS			Fy
	NO.	BOLT DIAMETER	DISTANCE TO BOLT CIRCLE	THICKNESS	VENT HOLE DIAMETER	NO.	THICKNESS	WIDTH	HEIGHT	
1	2	4	8	12	16	20	22	26	30	34

LOADS

IF CATGY	MEAN WIND SPEED	VEHICLE DESIGN SPEED	BASIC WIND SPEED	SERVICE WIND SPEED
1	2	6	10	14

PREPARED BY .....

DATE ...../...../.....

SHEET .....OF .....

Figure 4.0-1 Input Form (continued)



PROGRAM SNLRFD  
LRFD SIGN STRUCTURE ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION  
BUREAU OF INFORMATION SYSTEMS  
JULY 2025

FOOTING

Q S C	INPUT FACTORED RESISTANCE	CONC F <sub>c</sub>	CONCRETE DENSITY	FILL DENSITY	COEFF FRICTION	FILL HEIGHT	PEDESTAL			FOOTING				
							HEIGHT	LENGTH	WIDTH	MIN THK	MAX THK	WIDTH	LENGTH	DESIGN MAX WIDTH
1	2	7	12	16	20	24	29	34	39	44	49	54	59	64

REBAR

REBAR GRADE	COVER TOP	COVER BOTTOM	TOP						BOTTOM						ULTIMATE TENSILE STRENGTH REBAR
			LONG BAR		TRANS BAR		LONG BAR		TRANS BAR		LONG BAR		TRANS BAR		
			SIZE	No.BARS	SIZE	No.BARS	SIZE	No.BARS	SIZE	No.BARS	SIZE	No.BARS	SIZE	No.BARS	
1	3	7	11	13	17	19	23	25	29	31	35				

PREPARED BY .....

DATE ...../...../.....

SHEET ..... OF .....

Figure 4.0-1 Input Form (continued)

#### 4.1 PROBLEM IDENTIFICATION

Any number of lines may be used to enter user comments for problem identification. The first column of each line must contain an asterisk (\*) to indicate that this is a user comment. These comment lines may be placed anywhere within the input data; up to three comment lines at the beginning of the input file will be printed on the output for identification.

4.2 CRITERIA

This input line defines the criteria required for modeling the sign structure.

MODEL TYPE (MODTYP)

A numeric value indicating the type of sign model to be run. The following is a description of the valid model types. (Refer to Figures 4.2-1 through 4.2-7 for an example of the model types).

- 1 - Two post tri-chord truss (Figure 4.2-1)
- 2 - Four post tri-chord truss (Figure 4.2-2)
- 3 - Four post four-chord truss (Figure 4.2-3)
- 4 - Cantilever structure (Figure 4.2-4)
- 5 - Centermount structure (Figure 4.2-5)
- 6 - Cantilever Monopipe (Figure 4.2-6)
- 7 - Monopipe Frame (Figure 4.2-7)

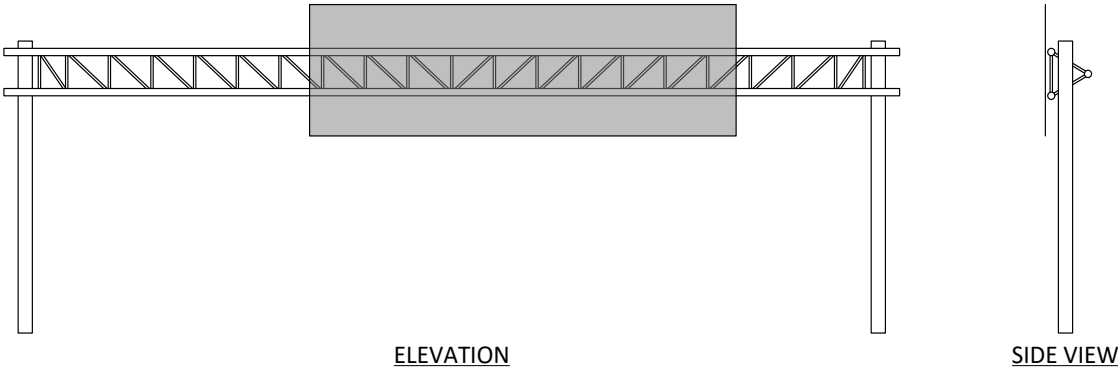


Figure 4.2-1 Two Post Tri-Chord Truss (Model Type 1)

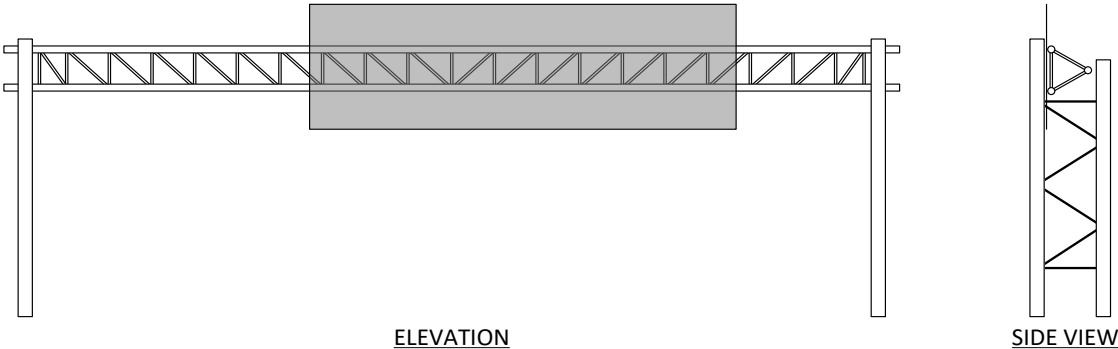
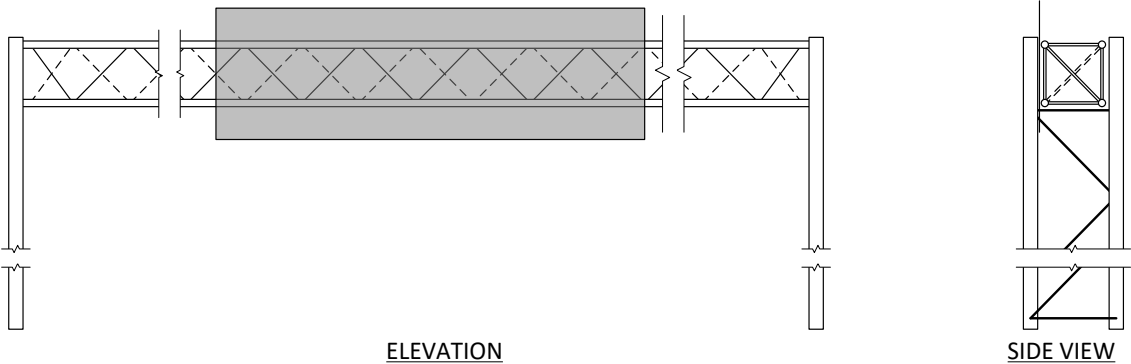
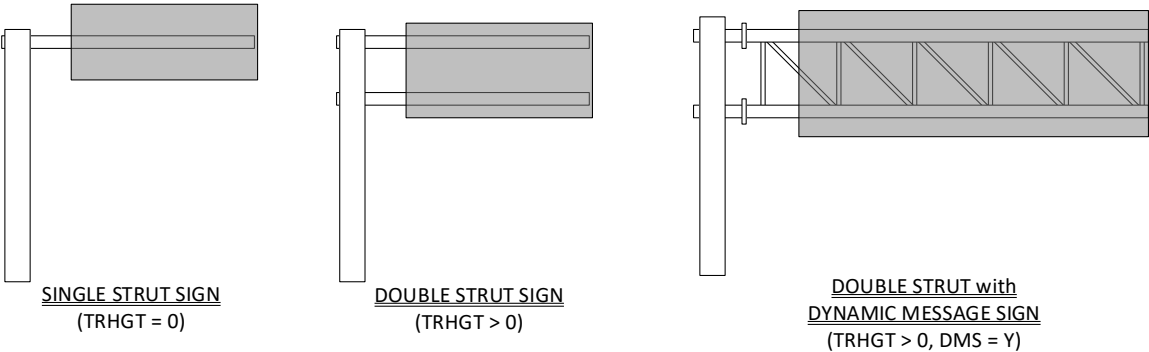


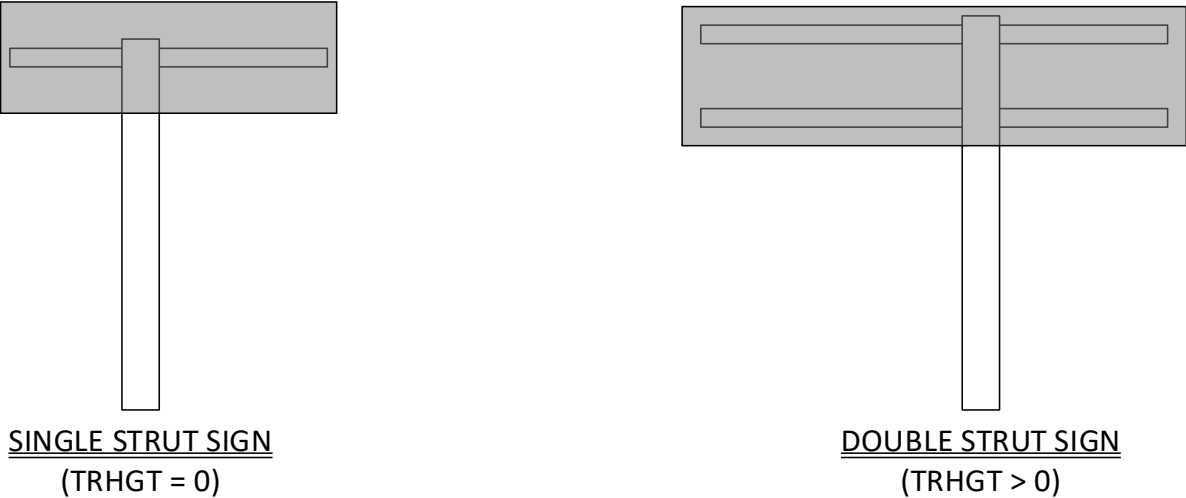
Figure 4.2-2 Four Post Tri-Chord Truss (Model Type 2)



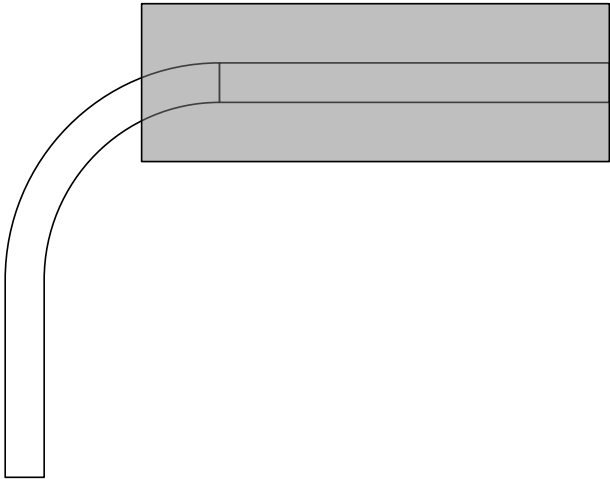
**Figure 4.2-3 Four Post Four-Chord Truss (Model Type 3)**



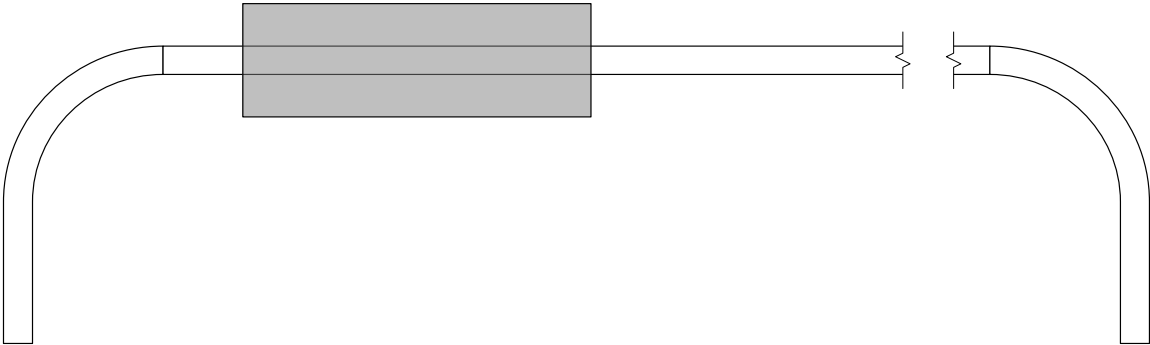
**Figure 4.2-4 Cantilever (Model Type 4)**



**Figure 4.2-5 Centermount (Model Type 5)**



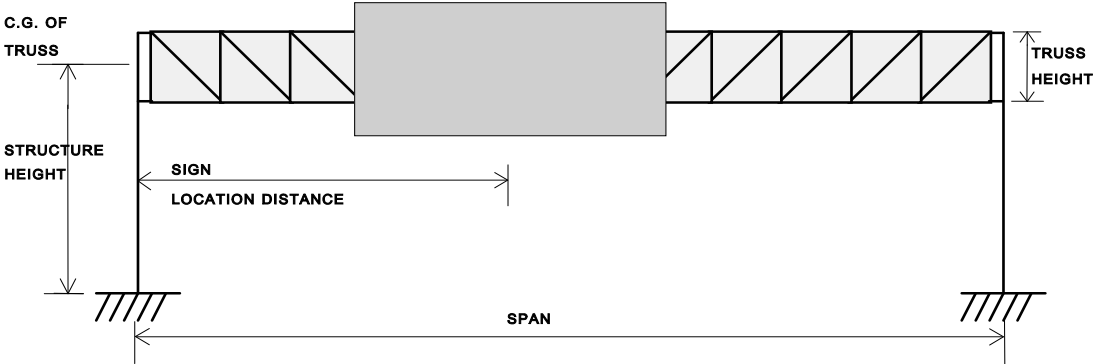
**Figure 4.2-6 Cantilever Monopipe (Model Type 6)**



**Figure 4.2-7 Monopipe Frame (Model Type 7)**

**STRUCT HEIGHT (STHGT)**

Enter the distance from the top of the post base plate to the center of gravity of the horizontal structure (truss or strut) in feet (see Figure 4.2-8). The valid range for this value is between 6 and 35 feet.



**Figure 4.2-8 Truss Sign Structure Geometry**

**SPAN / CANTILEVER LENGTH (STLEN)**

Enter the span length or the cantilever arm length in feet.

For Two post tri-chord, Four post tri-chord, Four post four-chord, and Monopipe frame models (i.e. models with end supports), the length is the distance between the centerlines of the supports (Figure 3.3-1 and Figure 3.3-13). The valid range for a two-post tri-chord truss is between 30 and 100 feet. The valid range for a four-post tri-chord or a four post four-chord truss is between 50 and 240 feet. The valid range for a monopipe frame is between 40 and 200 feet.

For Cantilever, Centermount, and Cantilever Monopipe models, the length represents the length of the cantilever measured from the centerline of the support (Figure 3.3-7, Figure 3.3-8, Figure 3.3-9 and Figure 3.3-12). The valid range for a cantilever structure is between 4 and 45 feet. The valid range for a centermount structure is between 1 and 40 feet. The valid range for a cantilever monopipe is between the bend radius + 2 feet, up to 38 feet.

Centermount structures may have different cantilever arm lengths on each side of the post. In that situation, enter one cantilever arm length here and enter the other cantilever arm length with the RIGHT STRUT (STLENR) input parameter, later on this command (Figure 3.3-10 and Figure 3.3-11).

**NUMBER SIGNS (NSIGN)**

Enter the number of signs to hang on the structure (minimum of 1 and a maximum of 3).

**NUMBER CATWALKS (NCATW)**

Enter the number of catwalks on the structure (minimum of 0 and a maximum of 2). Catwalk loads are not computed for cantilever, centermount (without DMS), or monopipe structures. Therefore, enter zero for these types of structures.

**NUMBER PANELS (NPANEL)**

Enter this value to define the number of truss panels. This value has a maximum of 100 and must be a multiple of 2. Leave blank for non-DMS cantilever, centermount and monopipe structures. For cantilevers structures supporting a DMS, an odd number is panels can be entered.

**TRUSS / STRUT HEIGHT (TRHGT)**

Enter the truss height in feet or enter the distance in feet between struts for a two strut centermount or cantilever structure. This value is used for all trusses, two-strut centermount structures, and two-strut cantilever structures. The valid range for trusses is between 2 and 20 feet. The valid range for struts is between 0 and 12 feet. Leave

blank for single strut and monopipe structures. The default for this value is based on the model type, shown in Table 4.2-1.

Table 4.2-1 Truss or Two Strut Default Heights

Model Type	Height
Tri-chord	$\frac{L}{23} *$
Four-chord	$L \leq 120'$ , 4'-0" $120' < L \leq 160'$ , 5'-0" $160' < L \leq 200'$ , 6'-0" $200' < L \leq 240'$ , 7'-0"
Two Strut Cantilever	NONE
Two Strut Centermount	NONE

\* Rounded to the next highest 3"

**TRUSS DEPTH (TRDPTH)**

Enter the truss depth in feet for tri-chord and four-chord trusses (see Figures 3.3-4 and 3.3-6). The valid range is between 2 and 20 feet. If no value is entered, the tri-chord truss default depth is based on the truss height and the assumption that the chords form an equilateral triangle. For the four-chord truss, the default depth is equal to the truss height.

**HEIGHT Z (HZ)**

Enter the height above ground at which the pressure is calculated for the sign structure. This value is used to compute the Height and Exposure Factor,  $K_z$ . If the value is not entered, the program will use the structure height as the default value. The minimum value for HZ is 16 ft. The value of  $K_z$  is based on Equation 3.8.4-1 of the LRFD Sign Specifications.

**POST FIXITY (FIXITY)**

Enter the fixity of the post for a four-post sign as 'F' for fixed supports. This is the only acceptable input for four-post sign structures.

**NUMBER X-SECT (NUMXSI)**

Enter the number of cross section definition cards that are supplied to define the structure. Cross section definition input lines are described in Section 4.5. Refer to Table 4.5-1 for the cross sections required for each model type. The minimum number of cross sections is two and the maximum number is 30.

**NEW OR EXISTING CHORD SPLICE (NORE)**

This variable must be entered as “E” to indicate the splice details will be entered and an analysis will be made using the entered values.

A future version of the program will allow “N” to be entered for a design of the splice.

Table 4.2-2 Number of Splices Criteria Table

MODEL TYPE	SPAN LENGTH	ANALYSIS OF A NEW STRUCTURE: (FUTURE OPTION) Allowable Number of Chord Splices	ANALYSIS OF AN EXISTING STRUCTURE: Allowable Number of Chord Splices
1 Two post tri-chord	All Span Lengths	2	1 or 2
2 Four post tri-chord	STLEN<=100'	2	1 or 2
	100'<STLEN<=160'	3	1 – 3
	160'<STLEN<=200'	4	1 - 4
	200'<STLEN	6	1 - 6
3 Four post four-chord	STLEN<=120'	2	1 or 2
	120'<STLEN	4	1 - 4
4 Cantilever	N/A	N/A	N/A
5 (Non-DMS) Centermount	N/A	N/A	N/A
5 (with DMS) Centermount	All Span Lengths	1	1
6 Cantilever Monopipe	All Span Lengths	0	0
7 Monopipe Frame	STLEN <= 60'	0 or 1	0 or 1
	60' < STLEN <= 100'	1 or 2	1 or 2
	100' < STLEN <= 140'	2 or 3	2 or 3
	140' < STLEN <= 180'	3 or 4	3 or 4
	180' < STLEN	4 or 5	4 or 5

**NUMBER OF CHORD SPLICES (NUMSPL)**

Enter the number of chord splices per chord. This represents the number of Chord Splice 1 input cards supplied for the program. If this input is left blank or if the user inputs a value of zero, then the program will assume that there are no chord splices and the user should not enter lines for the Chord Splice Input Cards (4.7 and 4.8). Instead, the user should input the Loads Card (4.9) directly after the Bolted Connections Card (4.6).

When NUMSPL > 0, the program assumes that each chord will contain the same number of splices and they will be at the same locations on each chord. The valid number of chord splices is based on model type and span length. Cantilever, Centermount and Cantilever Monopipe models (Model Types 4, 5 and 6, respectively) cannot have chord splices, so NUMSPL should be “0” or left blank. See Table 4.2-2 for the valid range for the other Model Types.

**NUMBER OF FATIGUE DETAILS (NUMDET)**

Enter the number of fatigue details. The program will automatically calculate certain fatigue details based on the Model Type of the structure. The number input for NUMDET represents the number of additional details that the user wants the program to calculate. These details can be details that the program does not normally calculate for a given model type or any of the optional details from Table 4.2-3. NUMDET represents the number of fatigue detail cards that will be supplied for the program to analyze. The maximum is 20. If this input is left blank or if the user inputs a value of zero, then the program will assume that the user doesn’t want the program to calculate any additional fatigue details. If this is the case, the user should not enter lines for the Fatigue Details Input Card (4.10).

Table 4.2-3 User-Input Fatigue Details

OPTIONAL FATIGUE DETAILS	DESCRIPTION
1.1	Plain Material with rolled or cleaned surface
2.1	High-Strength Bolted Connection, Net Section
3.1	Weep holes, Bottom of Columns
3.1	Unreinforced Hand Holes, Bottom of Columns
3.1	Wire Outlet Holes, Top of Columns
3.2	Reinforced Hand Holes, Bottom of Columns
4.1	Column and/or Chord/Strut Seam Welds
4.5	Chord splice, chord member
4.5	Column-to-base PL connection
5.3	Slotted tub-to-gusset connections without coped holes
5.5	Tube-to-Tube, Angle, or WT/ST Welded Connections
6.2	Column-to-Base PL Stiffener Connection

Table 4.2-4 Automatically Generated Fatigue Details, by Model Type

MODEL TYPE	DETAIL NUMBERS AND DESCRIPTIONS
Cantilever/Centermount	<p><b>4.4:</b> Column-to-base PL connection, Threshold 4.5 ksi</p>
Cantilever w/ DMS	<p><b>2.3:</b> Chord splice, bolts, Threshold 7.0 ksi</p> <p><b>4.4:</b> Column-to-base PL connection, Threshold 4.5 ksi</p> <p><b>5.5:</b> Mast-arm directly welded to chord, post members, Threshold 1.0 ksi</p> <p><b>5.5:</b> Mast-arm directly welded to chord, chord members, Threshold 1.2 ksi</p> <p><b>5.2:</b> Slotted tube-to-gusset connection, branching member, Threshold 4.5 ksi</p> <p><b>6.2:</b> Welds wrapped around termination of chord splice longitudinal stiffeners, Threshold 7.0 ksi</p> <p><b>7.1: (LRFD Bridge Specifications)</b> Base metal in a longitudinally loaded component, chord member, Threshold 4.5 ksi</p> <p>Note: Detail 5.5 follows note b of Table 11.9.3.1-1 of the AASHTO LRFD Sign Specification.</p>
2 Post Tri-Chord Truss 4 Post Tri-Chord Truss	<p><b>2.3:</b> Chord splice, bolts, Threshold 7.0 ksi</p> <p><b>4.4:</b> Chord splice, chord member, Threshold 4.5 ksi</p> <p><b>4.4:</b> Column-to-base PL connection, Threshold 4.5 ksi</p> <p><b>5.2:</b> Slotted tube-to-gusset or angle-to-gusset connection, branching member, Threshold 4.5 ksi</p> <p><b>7.1: (LRFD Bridge Specifications)</b> Base metal in a longitudinally loaded component, chord member of two and four post structures and post member of four post structures, Threshold 4.5 ksi</p>
4 Post 4-Chord Truss	<p><b>2.3:</b> Chord splice, bolts, Threshold 7.0 ksi</p> <p><b>4.4:</b> Chord splice, chord member, Threshold 4.5 ksi</p> <p><b>4.4:</b> Column-to-base PL connection, Threshold 4.5 ksi</p> <p><b>5.2:</b> Slotted tube-to-gusset or angle-to-gusset connection, branching member, Threshold 4.5 ksi</p> <p><b>7.1: (LRFD Bridge Specifications)</b> Base metal in a longitudinally loaded component, chord and post members, Threshold 4.5 ksi</p>
Cantilever Monopipe	<p><b>2.3:</b> End Connection splice, bolts, Threshold 7.0 ksi</p> <p><b>4.4:</b> End Connection splice, chord member, Threshold 4.5 ksi</p> <p><b>4.4:</b> End Connection splice, post member, Threshold 4.5 ksi</p> <p><b>4.4:</b> Column-to-base PL connection, Threshold 4.5 ksi</p>

(continued)

Table 4.2-4 Automatically Generated Fatigue Details, by Model Type (continued)

MODEL TYPE	DETAIL NUMBERS AND DESCRIPTIONS
Monopipe Frame	<p><b>2.3:</b> End Connection splice, bolts, Threshold 7.0 ksi</p> <p><b>2.3:</b> Mast Arm Splice Connection, bolts, Threshold 7.0 ksi</p> <p><b>4.4:</b> End Connection splice, chord member, Threshold 4.5 ksi</p> <p><b>4.4:</b> End Connection splice, post member, Threshold 4.5 ksi</p> <p><b>4.4:</b> Mast Arm splice, chord member, Threshold 4.5 ksi</p> <p><b>4.4:</b> Column-to-base PL connection, Threshold 4.5 ksi</p>

**OUTPUT (OUTPUT)**

Enter the level of output. A value from 0-2 can be entered to control the level of output.

- 0 = Worst combined stress ratio (CSR) for each type of cross section.
- 1 = Worst CSR for each finite element (worst i or j node).
- 2 = CSR values for all i and j nodes.

In addition to the worst combined stress ratios printed for each element, a geometry report listing all finite element node and element information will be printed for output levels 1 and 2.

**RIGHT STRUT (Centermount Only) (STLENR)**

The entry of this value in feet is optional and applies **ONLY** to centermount models (see Figure 3.3-10 and Figure 3.3-11). The value is entered for a structure with different strut lengths on either side of the post. The other strut length is entered with the SPAN / CANTILEVER LENGTH (STLEN) input parameter, earlier on this command. The valid range is between 1 and 40 feet. If this value is not entered, both strut lengths are assumed equal to the STLEN input parameter.

**DMS**

Dynamic Message Sign (DMS) indicator. Enter "Y" if the sign structure supports at least one DMS. Enter "N" or leave blank if there are no dynamic message signs or for monopipe structures. Dynamic Message Signs are prohibited on monopipe structures as per BD-647M, sheet 1.

**PANEL LENGTH (DMS Cantilever Only) (PNLLGTH)**

Enter the panel length in feet for the truss panels of a cantilever DMS structure. The Panel Length must be entered for cantilever structures with DMS. The typical maximum panel length is 6 feet. Leave blank for all other structure types and cantilever structures with flat signs.

**BEND RADIUS (Monopipes Only) (RBEND)**

Enter the bend radius in feet for the cantilever monopipe structure or the monopipe frame structure. The typical bend radius is 10 feet. The default value is 10 feet. Leave blank for all other structure types.

### 4.3 SIGN DESCRIPTION

The following input line(s) describes the signs that are attached to the structure.

One group of the following sign geometry entries should be entered for each sign (minimum of 1, maximum of 3). The number of signs is set by **NUMBER SIGNS** (Section 4.2 Criteria).

#### **SIGN (j) HEIGHT (SGNHGT(j))**

Enter the height of the sign in feet. The valid range for this value is between 1 and 25 feet. Also the sign height must be greater than or equal to the value entered for the **TRUSS / STRUT HEIGHT** (Section 4.2 Criteria).

#### **SIGN (j) AREA (SGNA(j))**

Enter the area of the sign in square feet (see Figure 3.4-4). Refer to PennDOT Standard Drawing BD-641M (Sheet 2 of 11) to compute the design sign area.

#### **SIGN (j) LOCAT (SGNX(j))**

Enter the distance from the center of the left column to the center of the sign in feet. For centermounts, enter the distance from the end of the left horizontal strut to the center of the sign in feet. The valid range for this value is between 1 foot and the value entered for **SPAN / CANT LENGTH** (Section 4.2 Criteria).

#### **SIGN (j) OFFSET (SGNY(j))**

Enter the distance from the center of gravity of the sign and its support beams to the centerline of the front chord or horizontal strut member in feet (see Figure 3.4-2). The valid range for this value is between -10 feet and 10 feet. A positive offset places the sign on the front side of the chord and a negative offset places the sign on the rear side of the chord. For 4-chord truss structures, a negative offset is measured from the centerline of the rear chord. A negative offset is not permitted for 3-chord truss structures.

#### **SIGN (j) HORIZONTAL PROJECTED AREA (HAREA(j))**

Enter the horizontal projected area for the sign in square feet. The horizontal projected area is defined as the exposed horizontal surface of the sign, in other words, the sign width times the sign thickness. Entering the horizontal projected area for a sign indicates that the sign is a dynamic message sign (DMS) and overrides the DMS parameter on the Criteria command resulting in a drag coefficient for DMS signs. The horizontal area is used to calculate fatigue loadings on the DMS. Enter a zero area to eliminate the fatigue loading. This field should be left blank for standard signs. Refer to Figure 3.4-10.

**SIGN (j) TRANSVERSE PROJECTED AREA (SAREAT(j))**

This input item is currently not used by the program and is for potential future use. This item is not used because the transverse loads are set equal to the normal loads.

**SIGN (j) SUPP BEAM WT (SUPWT(j))**

Enter the weight in lbs/ft of a one-foot section of the sign support beam. The sign support beams are attached vertically to the sign structure, at a spacing not to exceed 6'-0" (5'-0" for DMS), and the sign panels are attached to them. The sign support beam size will vary depending on the height of the sign. The valid range for this value is between 1 and 100 lbs/ft. If left blank, the program will use the following defaults shown in Table 4.3-1.

Table 4.3-1 Sign Support Beam Weight Table

Distance top chord to top of sign	Beam Size
0'-0" to 5'-6"	W6x15
5'-6"+ to 6'-6"	W6x20.0
6'-6"+ to 7'-6"	W6x25.0
7'-6"+ to 8'-6"	W8x28.0
8'-6"+ to 9'-6"	W8x31.0

See Section 3.4.1, Dead Load Attachments, for the description of the support weight calculation.

**SIGN (j) PANEL WT (PANWT(j))**

Enter the weight of the sign panel in pounds per square foot. The valid range for this value is between 1 and 40 psf.

For standard signs, if left blank the program will default to 2.848 psf, which is the weight of a 12" extruded aluminum channel sign panel.

For a DMS, enter the total sign weight divided by the area of the vertical face (Sign Height x Sign Width) of the DMS. There is no default value for a DMS.

**SIGN (j) NUMBER OF LUMINAIRES (NOLUM(j))**

Enter the number of luminaires attached to this sign panel. The number for each sign panel must be entered separately. Enter -1 to have the program compute the number of luminaires automatically at a maximum spacing of 12' along the width of this sign.

**SIGN (j) LUMINAIRE OFFSET (LUMOFF(j))**

Enter the distance from the center of gravity of the luminaire and its support members, to the centerline of the front chord/strut, in feet (See Figure 3.4-2). Always enter this as a positive value. If a sign has a negative offset then the luminaire offset will automatically be converted to a negative offset for that sign. For 4-chord truss structures, a negative offset is measured from the centerline of the rear chord. The valid range for this value is between 0 and 100 feet.

**SIGN (j) LUMINAIRE WEIGHT (LUMWT(j))**

Enter the weight of one luminaire and its support members in pounds. The value will be used for the luminaire weight for this sign panel. The valid range for this value is between 0 and 1000 lbs.

**SIGN (j) LUMINAIRE NORMAL AREA (LAREAN(j))**

Enter the cross-sectional area, in square feet, of one luminaire and its support members to be used in computing the wind load normal to the sign structure. The valid range for this value is between 0 and 10 ft<sup>2</sup>. Refer to Figure 3.4-4.

**SIGN (j) LUMINAIRE TRANSVERSE AREA (LAREAT(j))**

**This input item is currently not used by the program and is for potential future use.** This item is not used because the transverse loads are set equal to the normal loads.

**SIGN (j) LUMINAIRE TRUCK-GUST AREA (TGLAREA(j))**

Enter the truck-gust surface area, in square feet, of one luminaire and its support members to be used in computing the truck-gust load. The valid range for this value is between 0 and 10 ft<sup>2</sup>. Refer to Figure 3.4-10.

#### 4.4 CATWALK DESCRIPTION

The following input items describe the catwalks that are attached to the structure. Catwalk loads are not computed for cantilever, centermount (without DMS) or monopipe structures. Therefore, do not enter any of the following catwalk values for these types of structures.

One group of the following catwalk geometry entries should be entered for each catwalk (minimum of 0, maximum of 2). The number of catwalks is set by **NUMBER CATWALKS** (Section 4.2 Criteria).

##### **CATWALK (j) LOCATION (CATLOC(j))**

Enter the start location of the catwalk from the left post in feet. For centermounts (with DMS) enter the distance from the end of the left horizontal strut to the start location of the catwalk. The valid range for this value is between zero feet and the value entered for **SPAN / CANTILEVER LENGTH** (Section 4.2 Criteria). For centermounts (with DMS) the upper range limit is the sum of the values entered for **CANTILEVER LENGTH** and **RIGHT STRUT** (Section 4.2 Criteria).

##### **CATWALK (j) LENGTH (CATLEN(j))**

Enter the length of the catwalk in feet. The valid range for this value is between 5 feet and the value entered for **SPAN / CANTILEVER LENGTH** (Section 4.2 Criteria). For centermounts (with DMS) the upper range limit is the sum of the values entered for **CANTILEVER LENGTH** and **RIGHT STRUT** (Section 4.2 Criteria).

##### **CATWALK (j) OFFSET (CATOFF(j))**

Enter the distance from the center of gravity of the catwalk and its support members to the centerline of the front chord in feet. See Figure 3.4-3. The valid range for this value is between -10 feet and 10 feet. A positive offset places the catwalk on the front side of the chord and a negative offset places the catwalk on the rear side of the chord. For 4-chord truss structures, a negative offset is measured from the centerline of the rear chord. A negative offset is not permitted for 3-chord truss structures.

##### **CATWALK (j) WEIGHT (CATWT(j))**

Enter the dead load weight of the catwalk in pounds per linear foot. The valid range for this value is between 0 and 500 lbs/ft.

##### **CATWALK (j) NORMAL AREA (AREAN(j))**

Enter the cross-sectional area, in square feet per foot of catwalk, of the catwalk and its support members to be used in computing the wind load normal to the sign structure. The valid range for this value is between 0 and 10 ft<sup>2</sup>/ft. Refer to Figure 3.4-4.

**CATWALK (j) TRANSVERSE AREA (AREAT(j))**

**This input item is currently not used by the program and is for potential future use.** This item is not used because the transverse loads are set equal to the normal loads.

**CATWALK (j) TRUCK-GUST AREA (TGCAREA(j))**

Enter the truck-gust surface area, in square feet per foot of the catwalk and its support members. The valid range for this value is between 0 and 3 ft<sup>2</sup>/ft. Refer to Figure 3.4-10.

## 4.5 CROSS SECTION DEFINITION

This type of input line is used to fully define the cross section geometry of the structure. Each input line is separated into three groups: the first group is a descriptor to indicate the member type (e.g. FVERT for a front truss vertical member). The second group is a description of the cross section; this includes the **SECTION TYPE** of section and fields 1 through 3 to describe the physical dimensions. The third group represents the location of cross section transition by panel number for chord members only. There must be one and only one input line for each type of member in the sign structure, except for section transitions for chord members. Chords are the only members that can be transitioned by the user.

## 4.5.1 STRUCTURAL MEMBER TYPE

## SECTION LOCATION (IXSIID(i))

Enter one of the following identifiers to describe the structure location being defined. The entry can appear anywhere in the field (i.e. It does not have to be right or left justified).

Table 4.5-1 Cross Sections

<b>Cross Section</b>	<b>Model(s)</b>	<b>Description</b>	<b>Default (If applicable)</b>
POST	All Types	Sign post	
PXBRAC	4-Post Truss	Cross bracing between posts	
CHORD	All Trusses	Chord section	
CHORD	Cantilever, Centermount, Cantilever Monopipe, Monopipe Frame	Horizontal strut member or Mast Arm (Monopipe)	
RVERT	4-Chord Truss	Vert. member of the rear face	
FVERT	All Trusses, DMS Cantilever	Vert. member of the front face	
FDIAG	All Trusses, DMS Cantilever	Diag. member of the front face	
RDIAG	4-Chord Truss	Diag. member of the rear face	Same as FDIAG
TVERT	3, 4-Chord Truss	Vert. member of the top face	
TDIAG	3, 4-Chord Truss	Diag. member of the top face	
BVERT	3, 4-Chord Truss	Vert. member of the bottom face	Same as TVERT
BDIAG	3, 4-Chord Truss	Diag. member of the bottom face	Same as TDIAG
TXBRAC	4-Chord Truss	Truss cross bracing member	

#### 4.5.2 SECTION DESCRIPTION

( XSITYP(i), XSIDES(1-5,i) )

The input required following the section type differs for each section, with a maximum of five data fields required. The following sections describe the input for each cross section type. Enter one of the following section types for each section location. The entry can appear anywhere in the field (i.e. It does not have to be right or left justified).

##### SECTION TYPE (XSITYP(i))

Enter the type of section from the following list:

- P - Round pipe sections
- P8 - Octagonal pipe sections
- P12 - Dodecagonal pipe sections
- P16 - Hexadecagonal pipe sections
- C - Standard channel sections
- MC - Miscellaneous channels
- WT - WT sections
- ST - ST sections
- L - Angle sections

NOTE: Tee, channel, and angle sections are provided for the analysis of existing sign structures.

Table 4.5-2 shows the valid section types for each model.

Table 4.5-2 Valid Section Types

Cross Section	Two Post Tri-Chord	Four Post Tri-Chord	Four Post Four-Chord	Cantilever	Cantilever with DMS	Centermount	Monopipes (Frame or Cantilever)
POST	P	P	P	P	P	P	P**
PXBRAC	n/a	*	*	n/a	n/a	n/a	n/a
CHORD	P	P	L, P	P	P	P	P**
RVERT	n/a	n/a	*	n/a	n/a	n/a	n/a
FVERT	*	*	*	n/a	P	n/a	n/a
FDIAG	*	*	*	n/a	P	n/a	n/a
RDIAG	n/a	n/a	*	n/a	n/a	n/a	n/a
TVERT	n/a	*	*	n/a	n/a	n/a	n/a
TDIAG	n/a	*	*	n/a	n/a	n/a	n/a
BVERT	n/a	*	*	n/a	n/a	n/a	n/a
BDIAG	n/a	*	*	n/a	n/a	n/a	n/a
TXBRAC	n/a	n/a	*	n/a	n/a	n/a	n/a

\* Any section  
 \*\* Only round pipe shape  
 Where: P = any pipe shape

Table 4.5-3 Valid Nominal Pipe Diameters for Chord Section

Model Type	Valid Nominal Pipe Diameters for Chord Members
DMS Cantilever Two Post Tri-Chord Four Post Tri-Chord Four Post Four-Chord Cantilever (Non-DMS) Center Mount (Non-DMS)	4", 5", 6", 8", 10", 12', 14", 16", 18", 20", 24", 26"
Monopipes (Frame or Cantilever)	20", 22", 24", 26", 28", 30", 32", 34", 36"

**4.5.2.1 ROUND PIPE SECTION TYPE**

(Ex. P 12.0 0.375 0 0 0)

**FIELD 1 - ACTUAL OUTSIDE DIAM**

Enter the actual outside diameter of the pipe in inches. Value must be greater than 0.0. See Table 4.5-3 for valid nominal diameters (integer portion of actual outside diameter) for chord sections.

**FIELD 2 – THICKNESS**

Enter the actual wall thickness in inches. Value must be greater than 0.0 and cannot exceed the outside radius of the pipe.

No input is required in FIELDS 3, 4 and 5.

**4.5.2.2 POLYGONAL PIPE SECTION TYPES ( P8, P12, P16 )**

(Ex. P8 12.0 0.375 0.30 0 0)

**FIELD 1 – DEPTH**

Enter the distance between the outside surfaces of parallel faces of the pipe in inches as shown in Figure 4.5-1. Value must be greater than 0.0. See Table 4.5-3 for valid nominal diameters (integer portion of actual outside diameter) for chord sections.

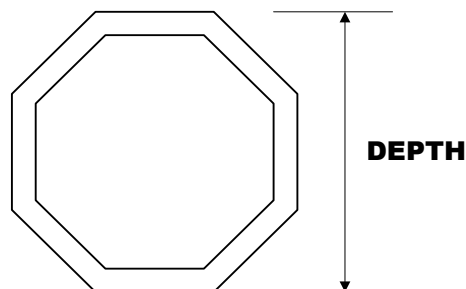
**FIELD 2 – THICKNESS**

Enter the actual wall thickness in inches. Value must be greater than 0.0 and cannot exceed the depth of the pipe.

**FIELD 3 - CORNER RADIUS RATIO**

Enter the ratio ( $r_c$ ) of the corner radius to the radius of an inscribed circle on the polygonal shape as described in LRFD Sign Specification Table 3.8.7-1 Note (e). The value of  $r_c$  must be greater than 0.0 and less than 1.0.

No input is required in FIELDS 4 and 5.



**Figure 4.5-1 Depth Dimension of Polygonal Pipe**

**4.5.2.3 CHANNEL SECTION TYPES ( C, MC )**

(Ex. C 8.0 11.5 1.0 0 0 or MC 12.0 50.0 1.1 0 0)

The channel sections must be valid standard (C) channels or valid miscellaneous (MC) channels from the "AISC Manual of Steel Construction."

**FIELD 1 – DEPTH**

Enter the nominal depth of the channel in inches.

**FIELD 2 – WEIGHT**

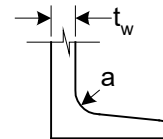
Enter the nominal weight of the channel in pounds/foot.

**FIELD 3 - STRESS CONCENTRATION FACTOR**

Enter the appropriate stress concentration factor ( $\delta$ ) for the channel section using the following equation (from page 2.10-8 of "Design of Welded Structures" by Omar W. Blodgett). The value must be greater than or equal to 1.0, but less than 1.5.

$$\delta = 1 + \frac{t_w}{4 a}$$

Where: a = Inside corner radius.  
 t<sub>w</sub> = Channel web thickness.



No input is required in FIELDS 4 and 5.

#### 4.5.2.4 WT SECTION TYPE

(Ex. WT 12.0 81.0 1.20 0 0)

The section entered must be a valid WT section from the "AISC Manual of Steel Construction."

##### FIELD 1 – DEPTH

Enter the nominal depth of the WT member in inches.

##### FIELD 2 – WEIGHT

Enter the nominal weight of the WT member in pounds/foot.

##### FIELD 3 - STRESS CONCENTRATION FACTOR

Enter the appropriate stress concentration factor ( $\delta$ ) from the figures in the "U.S. Steel Design Manual", pp. 161-162. See User Manual Figure 3.6-3. The value must be greater than or equal to 1.0, but less than 1.5.

No input is required in FIELDS 4 and 5.

#### 4.5.2.5 ST SECTION TYPE

(Ex. ST 10.0 33.0 1.20 0 0)

The section entered must be a valid ST section from the "AISC Manual of Steel Construction."

##### FIELD 1 – DEPTH

Enter the nominal depth of the ST member in inches.

##### FIELD 2 – WEIGHT

Enter the nominal weight of the ST member in pounds/foot.

##### FIELD 3 - STRESS CONCENTRATION FACTOR

Enter the appropriate stress concentration factor ( $\delta$ ) from the figures in the "U.S. Steel Design Manual", pp. 161-162. See Figure 3.6-4 and Table 4.5-4 for approximate stress concentration factors for ST shapes. The value must be greater than or equal to 0.9, but less than 1.4.

Table 4.5-4 Approximate Stress Concentration Factors for ST shapes

Designation	$t_w$	R	$t_f$	Thickness Ratio $t_w / t_f$	Ratio R / $t_f$	Approximate Stress Coefficient
ST 10 x 48	0.800	0.70	1.1875	0.6737	0.5895	1.12
ST 10 x 43	0.660	0.70	1.1875	0.5558	0.5895	1.09
ST 9 x 35	0.711	0.56	0.9375	0.7584	0.5973	1.15
ST 9 x 27.35	0.691	0.56	0.9375	0.7371	0.5973	1.15
ST 7.5 x 25	0.550	0.51	0.8125	0.6769	0.6277	1.13
ST 7.5 x 21.45	0.410	0.51	0.8125	0.5046	0.6277	1.08
ST 6 x 25	0.687	0.56	0.8750	0.7851	0.6400	1.17
ST 6 x 20.4	0.462	0.56	0.8750	0.5280	0.6400	1.09
ST 6 x 17.5	0.428	0.45	0.7500	0.5707	0.6000	1.10
ST 6 x 15.9	0.350	0.45	0.7500	0.4667	0.6000	1.07
ST 5 x 17.5	0.594	0.41	0.6875	0.8640	0.5964	1.18
ST 5 x 12.7	0.310	0.41	0.6875	0.4509	0.5964	1.06
ST 4 x 11.5	0.441	0.37	0.5625	0.7840	0.6578	1.17
ST 4 x 9.2	0.270	0.37	0.5625	0.4800	0.6578	1.08
ST 3 x 8.625	0.465	0.33	0.5000	0.9300	0.6600	1.23
ST 3 x 6.25	0.230	0.33	0.5000	0.4600	0.6600	1.07
ST 2.5 x 5	0.210	0.31	0.4375	0.4800	0.7086	1.09
ST 2 x 4.75	0.326	0.29	0.3750	0.8693	0.7733	1.22
ST 2 x 3.85	0.190	0.29	0.3750	0.5067	0.7733	1.10
ST 1.5 x 3.75	0.349	0.27	0.3750	0.9307	0.7200	1.24
ST 1.5 x 2.85	0.170	0.27	0.3750	0.4533	0.7200	1.08

Note: The term  $t_f$  in the "U.S. Steel Design Manual" is the thickness of the flange at the root of the fillet connecting the flange to the web. The values for R and  $t_f$  are taken from Catalog S-58, published by Bethlehem Steel Company, for "American Standard Beams".

No input is required in FIELDS 4 and 5.

**4.5.2.6 ANGLE SECTION TYPE**

(Ex. L 3.5 0.25 0 0 0)

The section entered must be a valid equal leg angle section from the "AISC Manual of Steel Construction."

**FIELD 1 – LEG**

Enter the width of the equal leg angle in inches.

**FIELD 2 – THICKNESS**

Enter the thickness of the equal leg angle in inches.

No input is required in FIELDS 3, 4 and 5.

**4.5.3 CROSS SECTION YIELD STRENGTH**

This entry allows user to specify different yield strengths for different cross sections.

**SECTION Fy ( XSIDES(6,i) )**

Enter the section yield strength in ksi. Input value restrictions vary based on cross section type as follows:

Round and Multi-sided Pipes:	between 35 ksi to 70 ksi
Standard and Miscellaneous Channels:	either 36 ksi or 50 ksi
Tee Sections:	either 36 ksi or 50 ksi
Angle Sections:	either 36 ksi or 50 ksi

If the user leaves this input value blank, the program will default to 36 ksi for the yield strength of the current cross section.

**4.5.4 CHORD CROSS SECTION TRANSITION**

This entry applies only to chord members for truss type models. If this entry is left blank for chord members, the program will assume the chord cross section is prismatic.

**PANEL NUMBER (IXSIPN(i))**

Enter the last panel number from the left post that the cross-section is used as a chord member. Up to eight sections may be entered to fully define the chord cross-section. The section is stepped at the panel point. Only one chord is defined to represent all chords of the truss (i.e. all chords will have the same cross section transitions). If multiple sections are required to define a chord, the chord section commands should be

entered sequentially and should not be separated by other cross section commands. For a sample of a chord with a changing cross section, see Example 3 in Appendix B.

Please note that this input only specifies the location of the chord cross section transition. It does not designate the location of a chord splice. A chord splice location must be designated by SPLICE PANEL NUMBER parameter of the CHORD SPLICE 1 command (User's Manual Section 4.7). By extension, changing the chord size transition here will NOT change the location of the chord splice.

## 4.6 BOLTED CONNECTIONS

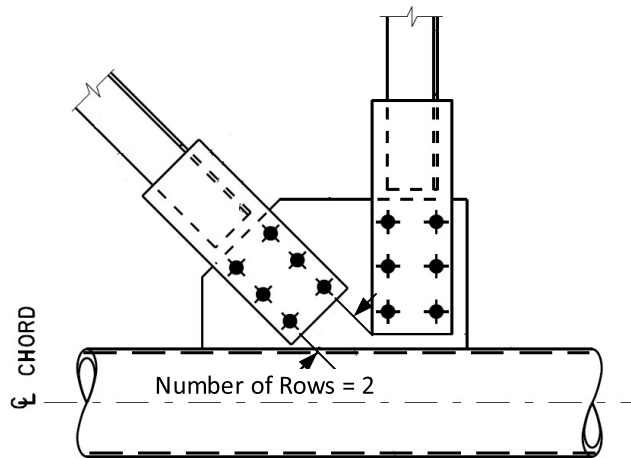
When the structure does not contain bolted connections, the bolted connections input card should be left blank.

### BOLT DIAMETER (BD)

If a bolt diameter is entered, the program will assume that the program has bolted, instead of welded, connections. Bolted connections are valid only for two post tri-chord, four post tri-chord, and four post four-chord model types. If no bolt diameter is entered, then the rest of the bolted connections card must be left blank and the program will assume welded connections. Valid bolt diameters are: 0.625", 0.750", 0.875", 1.000", 1.125", 1.250", and 1.375".

### NUMBER OF BOLT ROWS WEB (BRWC)

If a bolt diameter is entered, then the user must enter the number of bolt rows across the web depth (not along the member) for the web connection (See Figure 4.6-1). The program assumes that all bolted connections will contain the same number of bolt rows, regardless of the number of bolts required for each connection. Valid range for bolt rows is 1 – 6.



**Figure 4.6-1 Number of Bolt Rows**

**CONNECTION PLATE 1 WIDTH (CP1W)**

Connection Plate 1 is the front face/rear face connection plate, meaning that it is for members connected to the truss chord gusset plate via the web of the member (see Figure 4.6-1). Members with this type of connection are FVERT, FDIAG, RVERT, and RDIAG in two post tri-chord, four post tri-chord, and four post four-chord model types (See Table 3.6-4). Connection Plate 1 inputs cannot be used with cantilever, centermount, or monopipe model types.

If CP1W is entered, the program will assume that the bolted connections for members connected through the web in the program are connection plate connections, as opposed to member-to-member connections. If CP1W is not entered, the program assumes member-to-member connections. If CP1W is entered, then the next input item, CP1T, must also be entered.

**CONNECTION PLATE 1 THICKNESS (CP1T)**

If a CP1W is entered, then the user must enter the Connection Plate 1 Thickness (CP1T). This thickness cannot be less than 0.5”.

**NUMBER OF BOLT ROWS FLANGE (BRFC)**

If a bolt diameter is entered, then the user must enter the number of bolt rows across the flange (not along the member) for the flange connection (See Figure 4.6-1). The program assumes that all bolted connections will contain the same number of bolt rows, regardless of the number of bolts required for each connection. Valid range for bolt rows is 1 – 6.

**CONNECTION PLATE 2 WIDTH (CP2W)**

Connection Plate 2 Width (CP2W) is the top face/bottom face connection plate, meaning that it is for members connected to the truss chord gusset plate via the flange of the member. Members with flange connections are TVERT, TDIAG, BVERT, BDIAG, PXBRAC, and TXBRAC in two post tri-chord, four post tri-chord, and four post four-chord model types (See Table 3.6-4). Connection Plate 2 inputs cannot be used with cantilever, centermount, or monopipe model types.

If CP2W is entered, the program will assume that the bolted connections for members connected through the flange in the program are connection plate connections, as opposed to member-to-member connections. If CP2W is not entered, the program assumes member-to-member connections. If CP2W is entered, then the next input item, CP2T, must also be entered

**CONNECTION PLATE 2 THICKNESS (CP2T)**

If a CP2W is entered, then the user must enter the Connection Plate 2 (Top/Bottom Face) Thickness (CP2T). This thickness cannot be less than 0.5".

**NUMBER OF U-BOLTS (NUBOLTS)**

The number of U-bolts input by the user is used in the saddle detail module. The program assumes that U-bolts are A449 H.S. The minimum number of U-bolts required is one. The assumed bolt diameter is 1". If this value is left blank, it will default to two U-bolts for four post tri- and four-chord model types. It will default to one U-bolt for other model types.

## 4.7 CHORD SPLICE 1

The Chord Splice 1 input card contains a user-defined identifier for each chord splice and its corresponding distance along the chord.

This input card is valid only for Two post tri-chord, Four post tri-chord and Four post four-chord Model Types, and should be entered when the number of splices (from the Criteria Card) is greater than zero.

Cantilever Model Type (with DMS) structures also contain one chord splice located 1'-3" from the outside edge of the post in accordance with the ITS-1003M standards. Therefore, for the Cantilever Model Type (with DMS), the Chord Splice 1 input card is not needed and should not be entered.

It is assumed that for models with more than one chord, the splices will be located at the same point on each chord. Therefore, the user should not enter an input line for each chord splice on the model. Instead, the program will apply all of the splices entered to each chord.

The number of lines entered for the Chord Splice 1 input card should be the same as the number entered for NUMSPL in Section 4.2 (Criteria Card) and corresponds to Table 4.2-2.

For four-chord four post model types, the program places diagonal cross bracing at a maximum of every third panel, as described in Section 3.3.3 of this manual. If the user defines a chord splice at a cross bracing location, the program will generate a warning to inform the user to consider moving the splice so that it does not interfere with the cross bracing.

### **SPLICE(j) NAME (SPLICE(j))**

The Splice Name is a character input that will be used to identify each splice location. The user can input any combination of letters or numbers for this identifier.

### **SPLICE(j) PANEL NUMBER (PANNUM(j))**

The Splice Panel Number designates the panel number where the splice occurs. The splice is at the right edge of the panel. Please note that this input only specifies the location of the splice. It does not designate a change in chord dimensions. A chord size change must be designated by the CHORD CROSS SECTION TRANSITION parameter of the CROSS SECTION DEFINITION command (User's Manual Section 4.5.4). By extension, changing the splice location here will NOT change the location of the chord size change.

## 4.8 PIPE CONNECTION DETAILS (CHORD SPLICE 2)

The pipe connection detail input card is valid for the Two post tri-chord, Four post tri-chord, Four post four-chord, Cantilever (with DMS), Cantilever Monopipe and Monopipe Frame Model Types. For Model Types other than Cantilever Monopipe or Monopipe Frame, the input is a single line that will apply to all of the lines entered for the Chord Splice 1 input card. If the Chord Splice 1 input card is not needed, then the Pipe Connection Details input card should not be included (except for Cantilever Model Type (with DMS), Cantilever Monopipe Model Type, or Monopipe Frame Model Type, which always require a Pipe Connection Details input card). The pipe connection details input card is required for Cantilever Model Type (with DMS), Cantilever Monopipe Model Type and Monopipe Frame Model Type because these models always have splices. Cantilever Model Type (with DMS) always has a chord splice so a Type 'S' Pipe Connection input card must be entered. Cantilever Monopipe Model Type always has an End Connection so a Type 'E' Pipe Connection input card must be entered. Monopipe Frame Model Type has both End Connections and optionally can have a Splice Connection; therefore, input must be provided for 'E' and 'S' Type Connections. A Type 'S' Connection is required only when the Number of Chord Splices on the Criteria card is greater than zero. The number of bolts (SPLBLT) and the thickness of the splice plate (SPLTHK) must be entered since all runs are for an analysis of an existing structure (NORE from the Criteria Card = E).

### PIPE CONNECTION TYPE (SPLTYP(i))

Enter the Type of Pipe Connection. Valid entries are S for Splice Connection and E for End Connection.

### NUMBER OF BOLTS (SPLBLT(i))

Enter the Number of Bolts to be analyzed for the chord splice locations. The minimum allowed is four.

### CHORD SPLICE BOLT DIAMETER (SPLBD(i))

Enter the Bolt Diameter for Chord Splices in inches. Valid bolt diameters are: 0.625", 0.750", 0.875", 1.000", 1.125", 1.250", and 1.375". This parameter must always be entered for this card to be valid.

### DISTANCE TO BOLT CIRCLE (BCDIST(i))

Enter the Distance to the Bolt Circle in inches. This distance is measured from the outside face of the chord to the centerline of the bolt circle. The distance must be greater than 2.25". The default value is 2.5".

### SPLICE PLATE THICKNESS (SPLTHK(i))

Enter the Splice Plate Thickness in inches.

### VENT HOLE DIAMETER (SPLHOLE(i))

Enter the Vent Hole Diameter in inches. (This parameter is provided for future development and is not currently used by the program)

**NUMBER OF STIFFENERS (STFNO(i))**

Enter the number of stiffeners at the connection. (This parameter is provided for future development and is not currently used by the program)

**STIFFENER THICKNESS (STFTHK(i))**

Enter the stiffener plate thickness in inches. (This parameter is provided for future development and is not currently used by the program)

**STIFFENER WIDTH (STFWIDTH(i))**

Enter the stiffener plate width in inches. (This parameter is provided for future development and is not currently used by the program)

**STIFFENER HEIGHT (STFHEIGHT(i))**

Enter the stiffener plate height in inches. A node is placed at the top of the stiffener when the stiffener height is entered for monopipe structures.

**FY (SPLFY(i))**

Enter the splice plate and stiffener yield strength in ksi. The splice plate and stiffeners are assumed to have the same yield strength. If the user leaves this value blank, the program will default to 36 ksi for the yield strength of the current splice plate and stiffener.

## 4.9 LOADS

### IMPORTANCE FACTOR CATEGORY (IFCTOR)

The importance factor accounts for the degree of hazard to traffic and damage to property and is applied to the fatigue loadings to adjust the structural reliability. Enter the Importance Factor Category (from Table 4.9-1) number (1, 2, or 3). The program will then reference this number to apply the correct importance factor to the fatigue loadings. Importance Factor Category 1 is valid only for the Cantilever Model Type, Cantilever Monopipe Model Type, and structures with dynamic message signs (DMS). Importance Factor Categories 2 and 3 may be used for any Model Type.

Table 4.9-1 Importance Factor Categories

Importance Factor Category	Galloping Wind Gust	Natural Wind Gust	Truck-induced Gust
1	1.0	1.0	1.0
2	0.70	0.85	0.90
3	0.40	0.70	0.80

Importance Factor Category Descriptions:

- 1: Critical sign structures installed on major highways.
- 2: Other sign structures installed on major highways and all sign structures installed on secondary highways.
- 3: Sign structures installed at all other locations.

### YEARLY MEAN WIND SPEED (MWIND)

Enter the Yearly Mean Wind Speed in mph. This speed is used to calculate the fatigue due to natural wind gusts. The default value is 11.2 mph.

### VEHICLE DESIGN SPEED (VDESPD)

Enter the Vehicle Design Speed in mph. This speed is used to calculate the fatigue due to truck-induced gusts. The default value is 65.0 mph.

**BASIC WIND SPEED (DWIND)**

Enter the Basic Wind Speed in mph. This speed is used to calculate the wind loads acting on the supports, signs and attachments for the Extreme I Limit State. The default value is 120.0 mph which corresponds to a mean recurrence interval (MRI) of 1700 years within the state of Pennsylvania. The required MRI depends on the ADT and Risk Category as shown in Table 4.9-2. For the state of Pennsylvania the basic wind speed for MRI's of 300 years and 700 years is 105 mph and 115 mph, respectively.

Table 4.9-2 Mean Recurrence Interval

Traffic Volume	Risk Category		
	Typical	High	Low
ADT ≤ 100	300	1700	300
100 < ADT ≤ 1000	700	1700	300
1000 < ADT ≤ 10000	700	1700	300
ADT > 10000	1700	1700	300
Typical: Failure could cross travelway			
High: Support failure could stop a lifeline travelway			
Low: Support failure could not cross travelway			

**SERVICE WIND SPEED (SRVWIND)**

Enter the Service Wind Speed in mph. This speed is used to calculate the wind loads acting on the supports, signs and attachments for the Service I Limit State. The default value is 76.0 mph, corresponding to a Mean Recurrence Interval of 10 years, as stated in the LRFD Sign Specifications Article C3.8.2.

## 4.10 FATIGUE DETAILS

The Fatigue Details input card is needed only when the number of fatigue details (from the Criteria Card) is greater than zero. This card allows the user to input fatigue details that aren't automatically computed by the program. It also allows the user to enter fatigue details that the program automatically computes, but with a different allowable threshold stress. To change the default values, enter a full line on the Fatigue Details card for the detail that you want to change and include all the information that is needed for that detail. The program will use the line that the user inputs instead of the default values that it would normally use.

### DETAIL(j) NUMBER (DETNUM(j))

For each line of the Fatigue Details Input Card, enter a detail number for a detail that you want the program to analyze. Valid user-input details are listed in Table 4.2-3.

### FATIGUE THRESHOLD STRESS (CAFT(j))

Enter the Constant-Amplitude Fatigue Threshold (CAFT) that corresponds to the Detail Number. The CAFT is used to compute the Fatigue Combined Stress Ratio.

### WEEP HOLE AREA (AEWEEP(j))

When detail number 3.1 is entered, the user can input a weep hole area. Enter the cross-sectional area of the weep hole (the post wall thickness times the width of the opening) in square inches.

### WIRE OUTLET AREA (AEWIRE(j))

When detail number 3.1 is entered, the user can input a wire outlet area. Enter the cross-sectional area of the wire outlet (the post wall thickness times the width of the opening) in square inches.

### HAND HOLE AREA (AEWEEP(j))

When detail number 3.1 is entered, the user can input an unreinforced hand hole area. When detail number 3.2 is entered, the user must input a reinforced hand hole area. Enter the cross-sectional area of the hand hole (the post wall thickness times the width of the opening) in square inches.

### CHORD/POST/BRANCH (CPBTYP(j))

Enter "C", "P", or "B" to designate a chord, post, or branching member when a single detail can apply to more than one of these member types. CPBTYP needs to be input for Detail 4.1 (can apply to chords or posts). This variable will cause output level 0 to print out a separate line for each CPBTYP listed for each detail.

## 4.11 FOOTING

### A OR D (AORD)

Enter "A" for a footing analysis or "D" for a footing design problem. Refer to METHOD OF SOLUTION for what the program will do for a given type of problem. If left blank the program will run a footing design problem. The entry can appear anywhere in the field.

### INPUT FACTORED RESISTANCE (PRESS)

Enter the nominal bearing resistance multiplied by the bearing resistance factor for footings on soil in kips per square foot. The valid range for this value is between 0 and 50 ksf. If left blank, the program uses a value of 6.0 ksf.

### CONC F'C (FPC)

Enter the compressive strength of concrete for the foundation in psi. The valid range for this value is between 1000 and 9000 psi. If left blank, the program defaults to 3000 psi.

### CONCRETE DENSITY (CDENS)

Enter the density of concrete, in pcf. The valid range for this value is between 50 and 500 pcf. If left blank, the program will default to 150 pcf.

### FILL DENSITY (FDENS)

Enter the density of the fill material, in pcf. The valid range for this value is between 50 and 500 pcf. If left blank, the program will default to 100 pcf.

### COEFF FRICTION (FRICT)

Enter the coefficient of friction of the foundation material. The normal range for this data varies from 0.33 for silty clay, to 0.60 for gravel or sand, to 0.99 for rock. The value is used to compute the horizontal sliding resistance of the footing. The valid range for this value is between 0.1 and 1.0. If left blank, the program defaults to 0.25.

### FILL HEIGHT (FILLHT)

Enter the average height of fill material over the top of the footing in feet. The valid range for this value is between 1 and 30 feet.

**PEDESTAL HEIGHT (PEDHGT)**

Enter the height of the pedestal, in feet, as the distance from the top of the footing to the top of the base plate. This value must be entered for both footing analysis and design problems and cannot be zero. The valid range for this value is between 1 and 30 feet. (The actual pedestal height is to the bottom of the grout. Enter the pedestal height plus the grout thickness and base plate thickness.)

**PEDESTAL LENGTH (PEDWID)**

Enter the length of the pedestal, in feet. The pedestal length is that side of the pedestal measured parallel to the roadway. This value must be entered for both footing analysis and design problems, and cannot be zero. The valid range for this value is between 0.5 and 25 feet.

**PEDESTAL WIDTH (PEDLEN)**

Enter the width of the pedestal, in feet. The pedestal width is that side of the pedestal measured normal to the roadway. This value must be entered for both footing analysis and design problems, and cannot be zero. The valid range for this value is between 0.5 and 25 feet.

**FOOTING MIN THK (FMINTH)**

Enter the actual footing thickness for a footing analysis problem, or the minimum footing thickness for a footing design problem, in feet. The valid range for this value is between 2 and 20 feet. For a footing design problem, if this is left blank, the program will default to a 2.0 foot footing thickness.

**FOOTING MAX THK (FMAXTH)**

This item is ignored for a footing analysis problem. For a footing design problem, enter the maximum footing thickness in feet. This value must be greater than the value of the FOOTING MIN THK but less than or equal to 20 feet. If left blank, the program will default to a 5-foot footing thickness.

**FOOTING WIDTH (FTGWID)**

Enter the actual footing width for a footing analysis problem, or the minimum footing width for a footing design problem, in feet. The footing width is that side of the footing measured normal to the roadway. The valid range for this value is between 2.5 and 50 feet. For a footing design problem, if this value is left blank, the program will default to a value equal to the pedestal width plus 2.0 feet, rounded up to the nearest foot.

**FOOTING LENGTH (FTGLEN)**

Enter the actual footing length for a footing analysis problem, or the minimum footing length for a footing design problem, in feet. The footing length is that side of the footing measured parallel to the roadway. The valid range

for this value is between 2.5 and 50 feet. For a footing design problem, if this value is left blank, the program will default to a value equal to the pedestal depth plus 2.0 feet, rounded up to the nearest foot.

**FOOTING MAX WIDTH (FMAXWID)**

**This item is ignored for a footing analysis problem. For a footing design problem, enter the maximum footing width in feet. The footing width is that side of the footing measured normal to the roadway. The valid range for this value is between the FOOTING WIDTH and 50 feet. For a footing design problem, if this value is left blank, the program will default to 50 feet.**

## 4.12 REBAR

### REBAR GRADE (FY)

Enter the reinforcement grade. Enter "40", "50" or "60". If left blank, the program defaults to grade 60.

### COVER TOP (TLONG)

Enter the clear distance from the top of the footing to the first mat of reinforcement. The valid range for this value is between 1 and 9 inches. If left blank, the program defaults to 3.0 inches. The top cover is also used for the side cover when calculating bar spacing.

### COVER BOTTOM (BLONG)

Enter the clear distance from the bottom of the footing to the first mat of reinforcement. The valid range for this value is between 1 and 9 inches. If left blank, the program defaults to 4.0 inches.

### TOP LONG REBAR SIZE (TLSIZE)

For a footing analysis problem, enter the rebar size, as a number between 4 and 11, for the top longitudinal reinforcement. Leave blank for a footing design problem. The longitudinal bar is placed parallel to the centerline of roadway.

### TOP LONG REBAR COUNT (TLNBAR)

For a footing analysis problem, enter the number of rebars for the top longitudinal reinforcement. Valid counts are greater than zero. Leave blank for a footing design problem. The longitudinal bar is placed parallel to the centerline of roadway.

### TOP TRANS REBAR SIZE (TTSIZE)

For a footing analysis problem, enter the rebar size, as a number between 4 and 11, for the top transverse reinforcement. Leave blank for a footing design problem. The transverse bar is placed normal to the centerline of roadway.

### TOP TRANS REBAR COUNT (TTNBAR)

For a footing analysis problem, enter the number of rebars for the top transverse reinforcement. Valid counts are greater than zero. Leave blank for a footing design problem. The transverse bar is placed normal to the centerline of roadway.

**BOTTOM LONG REBAR SIZE (BLSIZE)**

For a footing analysis problem, enter the rebar size, as a number between 4 and 11, for the bottom longitudinal reinforcement. Leave blank for a footing design problem. The longitudinal bar is placed parallel to the centerline of roadway.

**BOTTOM LONG REBAR COUNT (BLNBAR)**

For a footing analysis problem, enter the number of rebars for the bottom longitudinal reinforcement. Valid counts are greater than zero. Leave blank for a footing design problem. The longitudinal bar is placed parallel to the centerline of roadway.

**BOTTOM TRANS REBAR SIZE (BTSIZE)**

For a footing analysis problem, enter the rebar size, as a number between 4 and 11, for the bottom transverse reinforcement. Leave blank for a footing design problem. The transverse bar is placed normal to the centerline of roadway.

**BOTTOM TRANS REBAR COUNT (BTNBAR)**

For a footing analysis problem, enter the number of rebars for the bottom transverse reinforcement. Valid counts are greater than zero. Leave blank for a footing design problem. The transverse bar is placed normal to the centerline of roadway.

**ULTIMATE TENSILE STRENGTH REBAR (FU)**

Enter the ultimate tensile strength for the reinforcement. If left blank, the program defaults to

90 for Grade 60

80 for Grade 50

70 for Grade 40

Valid range 55 to 100 ksi.

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## **5.0** *DESCRIPTION OF OUTPUT*

The level of output for the Sign Structure program can be controlled by the user by entering a different value for the 'level of output' variable on the input criteria card (see page 51). The printed output consists of a repeat of all the input values exactly as read by the program, error messages, default values used by the program and the following computed values. Only the output applicable to a given type of problem is printed.

## **5.1 INPUT ECHO**

An input echo section is provided for each input line provided by the user, namely the Criteria, Sign Description, Catwalk Description, Cross Section Definition, Bolted Connections, Chord Splice One, Pipe Connection Details, Loads, and Fatigue Details cards. Input items that are not entered by the user and have some default value assigned by the program are listed in the Default Values section of the output.

## 5.2 NODE OUTPUT

For output levels 1 and 2, a report indicating the model node geometry is provided. These coordinates are the values for the finite element model used by the analysis core of the program.

### **NODE NUMBER**

The node identification number.

### **COORDINATES X, Y, Z**

The location of the node in space in feet.

### 5.3 ELEMENT OUTPUT

For output levels 1 and 2, a report indicating the model element connectivity is provided. These coordinates are the values for the finite element model used by the analysis core of the program.

#### ELEMENT NUMBER

The member number.

#### TYPE

Describes the location within the sign structure as described in Table 5.3-1.

Table 5.3-1 Element Type

Type	Model(s)	Description
POST	All Types	Sign post Mast for monopipe models
PXBRAC	4-Post Truss	Cross bracing between posts
FUCORD	All Types	Front upper chord for all trusses and upper strut for centermount, and cantilever models
FLCORD	All Trusses, 2-strut cantilever, 2-strut centermount, Monopipes	Front lower chord for all trusses and lower strut for 2-strut centermount and 2-strut cantilever models. Mast Arm for monopipe models.
RUCORD	4-Chord Trusses	Rear upper chord for 4 chord trusses.
RLCORD	3, 4-Chord Trusses	Rear chord for 3 chord trusses and rear lower chord for 4 chord trusses.
RVERT	4-Chord Truss	Vertical member of the rear face
FVERT	All Trusses	Vertical member of the front face
FDIAG	All Trusses	Diagonal member of the front face
RDIAG	4-Chord Truss	Diagonal member of the rear face
TVERT	3, 4-Chord Truss	Vertical member of the top face
TDIAG	3, 4-Chord Truss	Diagonal member of the top face
BVERT	3, 4-Chord Truss	Vertical member of the bottom face
BDIAG	3, 4-Chord Truss	Diagonal member of the bottom face
TXBRAC	4-Chord Truss	Truss cross bracing member
CONNECT <sup>1</sup>	All Trusses	Connection elements between the post and trusses.

<sup>1</sup> Connection elements are rigid connections between the post and chords. Because they are used only to model the offset connection between the post and the chord, specification checking is not provided for these elements.

**INODE, JNODE**

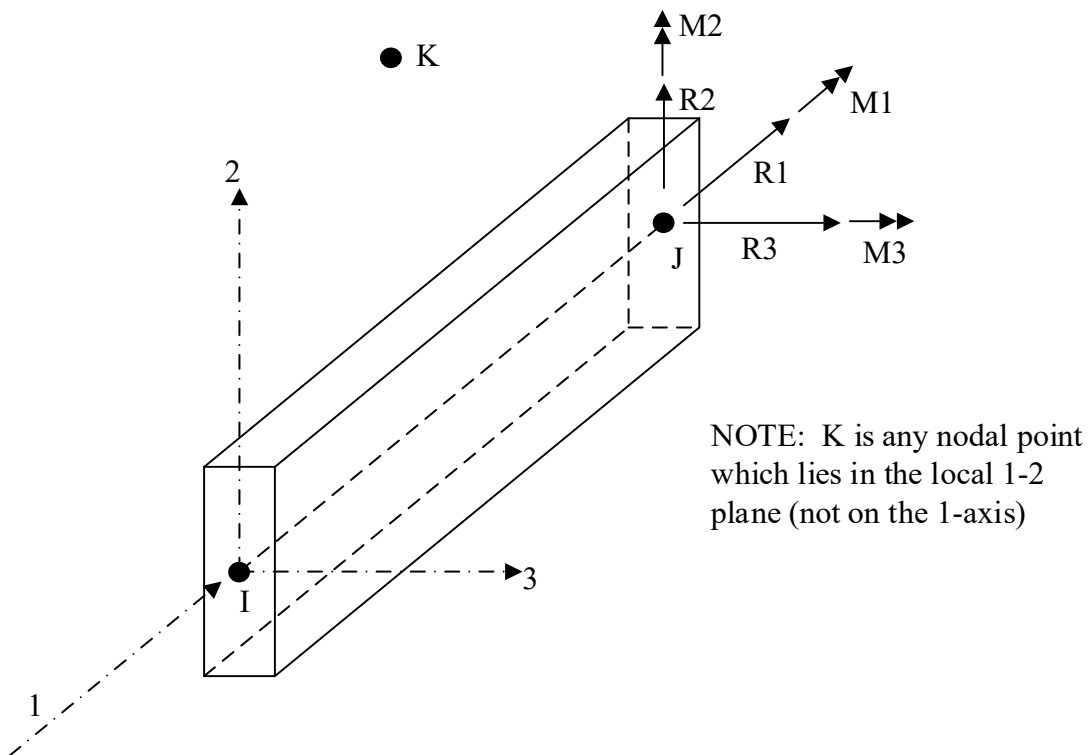
Indicates the node numbers representing the element connectivity (see Figure 5.3-1).

**KNODE**

The location of the k-node orients the member in space (see Figure 5.3-1).

**IREL, JREL**

Indicates the local member releases at the end of each member for the force components  $R_1$ ,  $R_2$ ,  $R_3$ ,  $M_1$ ,  $M_2$ , and  $M_3$  (see Figure 5.3-1). A "0" indicates that the force is not released while a "1" indicates the force is released.



**Figure 5.3-1 Local Member Orientation**

## 5.4 SAPV FINITE ELEMENT OUTPUT

The detailed results from the SAPV finite element analysis are stored in an output file named “<input filename>\_SAPV.oui”. The information provided in the SAPV output is in a general finite element form. **For a description of the general SAPV finite element output, see Appendix A.**

## 5.5 CROSS SECTION OUTPUT

The cross section output lists all cross section information for the user input sections. The values for pipes are computed in the program. The values for all other cross sections are retrieved from a cross section table corresponding to the "AISC Manual of Steel Construction".

### LOCAT

The location (either member or attachment) that the load is applied.

### X-SECT NO.

Cross-section identification number. This number is assigned by the program and referenced in other output reports.

### Sect Type

Cross section type as defined by the user (see Section 4.4.2 Cross Section Description).

### D

Depth of the member in inches.

### T

Web thickness for WT, ST and channel sections, pipe wall thickness, or angle leg thickness in inches.

### B

Flange width or angle width in inches. Length of one side of a polygonal pipe in inches. Value is reported 0.0 for other sections.

### Tf

Thickness of the flange for WT, ST, channel, and angle sections in inches. Value is reported as 0.0 for other sections.

### Xsa

Cross sectional area in  $\text{inch}^2$ .

**Perim**

Outside perimeter of the cross section in inches (previously used for ice loading on members).

**J**

Torsional moment of inertia in  $\text{inch}^4$ .

**Rt/Rz**

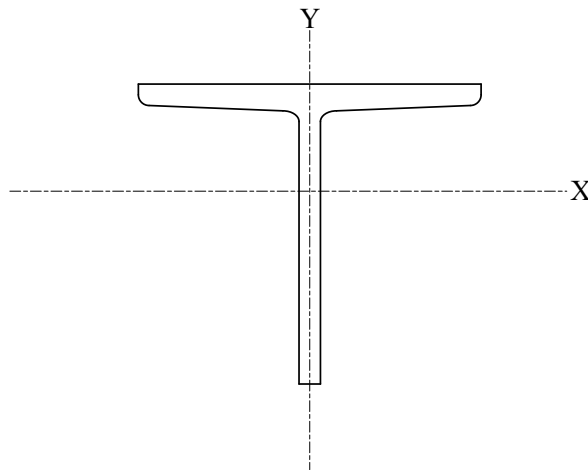
For WT, and ST sections, the value is  $R_t$ , which is defined as the radius of gyration of a section comprising the compression flange plus  $1/3$  of the compression web area, taken about an axis in the plane of the web. For angle sections, the value is  $R_z$ , which is defined as the radius of gyration about the principal axis. For all other sections, the value is set to 0.0.

**I<sub>x</sub>**

Moment of inertia about the X-X (see Figure 5.5-1) axis in  $\text{inch}^4$ .

**I<sub>y</sub>**

Moment of inertia about the Y-Y (see Figure 5.5-1) axis in  $\text{inch}^4$ .



**Figure 5.5-1 Member Axis**

**S<sub>x/top</sub>**

Section modulus to the top of the section about the X-X axis in  $\text{inch}^3$ .

**Sx/bot**

Section modulus to the bottom of the section about the X-X axis in inch<sup>3</sup>.

**Sy/Lt**

Section modulus to the bottom of the section about the Y-Y axis for the left part of the section in inch<sup>3</sup>.

**Sy/Rt**

Section modulus to the bottom of the section about the Y-Y axis for the right part of the section in inch<sup>3</sup>.

**Rx**

Radius of gyration about the X-X axis in inches.

**Ry**

Radius of gyration about the Y-Y axis in inches.

## 5.6 LOADS OUTPUT

The loads output consist of a section for Wind Pressures and a section for Loads applied to members.

### 5.6.1 WIND PRESSURES

The wind pressures are presented in two tables. The first table lists wind pressures applied to members. The second table lists wind pressures applied to attachments.

#### 5.6.1.1 WIND PRESSURES ON MEMBERS

The following values are listed in the Wind Pressures on Member output table.

**Location**

The location of the member.

**X-Sec No.**

The cross-section identification for the member. This number refers to the cross section identification number provided in the CROSS SECTION OUTPUT.

**Pz(Ext)**

The design wind pressure in pounds per square foot for the Extreme Limit State.

**Pz(Srv)**

The design wind pressure in pounds per square foot for the Service Limit State.

**P(NW)**

The natural wind gust pressure range in pounds per square foot for the Fatigue Limit State.

**P(TG)**

The truck gust pressure range in pounds per square foot for the Fatigue Limit State.

#### 5.6.1.2 WIND PRESSURES ON ATTACHMENTS

The following values are listed in the Wind Pressures on Attachments output table.

**Attachment**

The attachment type of either Sign, Luminaire or Catwalk.

**Pz(Ext)**

The design wind pressure in pounds per square foot in the normal and transverse wind directions for the Extreme Limit State.

**Pz(Srv)**

The design wind pressure in pounds per square foot in the normal and transverse wind directions for the Service Limit State.

**P(NW)**

The natural wind gust pressure range in pounds per square foot in the normal and transverse wind directions for the Fatigue Limit State.

**P(G)**

The galloping vertical shear pressure range in pounds per square foot for the Fatigue Limit State.

**P(TG)**

The truck gust pressure range in pounds per square foot for the Fatigue Limit State.

**5.6.2 LOAD TABLE**

The following values are listed in the Sign Structure LOAD TABLE. For a description of how these loads are computed, see Chapter 3. The loads are group by Loads applied to Members and Loads applied to Attachments. For each attachment a separate table lists the loads applied to the members from the attachments.

**LOCAT**

The location (either member or attachment) at which the load is applied.

**X-SECT NOS.**

Starting and ending cross-section identifications for the member. These numbers refer to the cross section identification numbers provided in the **CROSS SECTION OUTPUT**.

**Mbr No.**

**The member number being reported.**

**DL**

Self-weight load in pounds per foot of the member or attachment.

**Fatigue GVW**

Galloping wind load in pounds per foot on the sign.

**Fatigue NWGn**

Natural wind gust load normal to the sign panel in pounds per foot.

**Fatigue NWGt**

Natural wind gust load transverse to the sign panel in pounds per foot.

**Fatigue TrG**

Truck-induced gust load in pounds per foot.

**Ht. Reduc.**

The reduction applied to the Truck-Induced wind gust based on the height of the member above the travel lane.

**Extreme WIND**

Wind pressure in pounds per square foot on the member or attachment for the Extreme Limit State.

**Extreme Wn**

Wind load normal to the sign panel in pounds per foot for the Extreme Limit State.

**Extreme Wt**

Wind load transverse to sign structure panel in pounds per foot for the Extreme Limit State.

**Service WIND**

Wind pressure in pounds per square foot on the member or attachment for the Service Limit State.

**Service Wn**

Wind load normal to the sign panel in pounds per foot for the Service Limit State.

**Service Wt**

Wind load transverse to sign structure panel in pounds per foot for the Service Limit State.

### 5.6.3 SIGN N LOADS ON MEMBERS (CATWALK N LOADS ON MEMBERS)

The following values are listed for attachments, either signs or catwalks. The sign loads includes the sign panel, sign support beams, and the luminaires.

#### **LOCAT**

The location of the member that the attachment load is applied to.

#### **XS**

The cross-section identifications for the member. This number refers to the cross section identification numbers provided in the **CROSS SECTION OUTPUT**.

#### **Mbr**

The member number being reported.

#### **Begin %Len**

The location along the member where the load starts expressed as a percentage of the member length. These values only appear in the attachment load tables.

#### **End % Len**

The location along the member where the load stops expressed as a percentage of the member length. These values only appear in the attachment load tables.

#### **Attachment Self Weight (Fy, Fz)**

Self-weight load in pounds per foot for the attachment that is applied to the member. The Fy load is applied in the vertical direction. For model types with at least two chords/struts, the Fz load corresponds to a moment couple based on the eccentricity of the self-weight to the loaded member. For model types with a single chord/strut the load eccentricity is applied as uniform torque (foot-pounds per foot) along the axis of the chord/strut.

#### **Extreme WnExt (Fz)**

Wind normal to the attachment in pounds per foot for the Extreme Limit State applied to the member in the global Z-direction.

**Extreme WtExt (Fx)**

Wind transverse to the attachment in pounds per foot for the Extreme Limit State applied to the member in the global X-direction.

**Service WnSrv (Fz)**

Wind normal to the attachment in pounds per foot for the Service Limit State applied to the member in the global Z-direction.

**Service WtSrv (Fx)**

Wind transverse to the attachment in pounds per foot for the Service Limit State applied to the member in the global X-direction.

**Fatigue GVW (Fy)**

Galloping wind load on the attachment that is applied to the member in pounds per foot for the Fatigue Limit State applied to the member in the global Y-direction.

**Fatigue GVW (Fz)**

For model types with at least two chords/struts, the Fz load corresponds to a moment couple based on the eccentricity of the vertical galloping load. For model types with a single chord/strut the load eccentricity is applied as uniform torque (foot-pounds per foot) along the axis of the chord/strut.

**Fatigue NWGn (Fz)**

Natural wind gust normal to the attachment in pounds per foot for the Fatigue Limit State applied to the member in the global Z-direction.

**Fatigue NWGt (Fx)**

Natural wind gust transverse to the attachment in pounds per foot for the Fatigue Limit State applied to the member in the global X-direction.

**Fatigue TrG (Fy)**

Truck-Induced Gust load on the attachment that is applied to the member in pounds per foot for the Fatigue Limit State applied to the member in the global Y-direction.

**Fatigue TrG (Fz)**

For model types with at least two chords/struts, the Fz load corresponds to a moment couple based on the eccentricity of the vertical truck gust load. For model types with a single chord/strut the load eccentricity is applied as uniform torque (foot-pounds per foot) along the axis of the chord/strut.

**Centermount Torque**

For centermount structures the torque applied to the structure based on loading the signs, luminaires, and struts on one side of the structure and some of the intermediate values used to calculate the torque are listed. The torque reported here is unfactored. It is the torque applied to all post members for centermount structures and is included all load cases that include the wind load in the normal direction. The same load factors are applied to this torque as are applied to the wind load in the normal direction.

## 5.7 LOAD CASE TABLE

This table lists the AASHTO sign structure load combination table (see LRFD Sign Specifications Article 3.4 and LRFD Bridge Specifications Article 3.4).

### LOAD CASE

Load id number used as a reference in subsequent tables listing forces and moments.

### LIMIT STATE

AASHTO limit state (see LRFD Sign Specifications Table 3.4-1 and LRFD Bridge Specifications Article 3.4).

### DL, Wn, Wt, GVW, NWGn, NWGt, TrG

Load combinations for each type of loading on the sign structure where:

- DL = Dead Load
- Wn = Wind Load normal to sign panel
- Wt = Wind Load transverse to sign panel
- GVW = Galloping Induced Vibration Load
- NWGn = Natural Wind Gust Vibration Load Normal
- NWGt = Natural Wind Gust Vibration Load Transverse
- TrG = Truck Gust Load
- EV = Vertical Earth Pressure

## 5.8 COMPACT/NON-COMPACT CRITERIA TABLE

This table lists the compact/non-compact criteria for each cross section used in the model.

### LOCAT

The cross section member location.

### X-SEC NO.

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### MEM

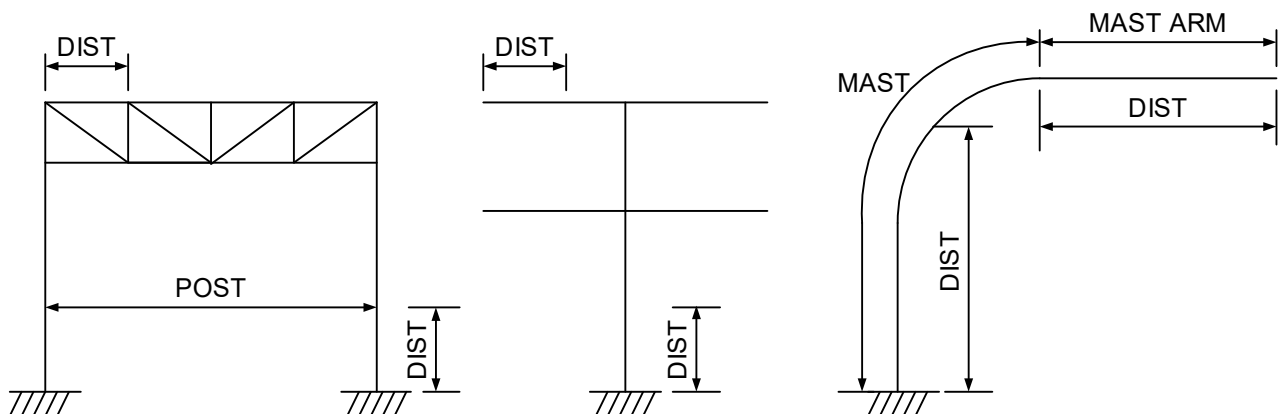
This value lists the finite element member number.

### NODE

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1 the worst result of the two element nodes is displayed. For output level 2 both node results are displayed.

### DIST

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.



**Figure 5.8-1 DIST Location**

**CATEGORY**

Lists whether the section is COMPACT or NON-COMPACT.

**SECT TYPE**

List the cross section type (see **Section 4.4.2 Cross Section Description**).

**CRITERIA**

Lists the equation used to compute the actual compactness ratio for this cross section. This value is compared with the allowable values to determine if the section is compact or non-compact. For a description of the equations, see **Section 3.6 Specification Checking**.

**ACTUAL VALUE**

Displays the compactness ratio for this cross section.

**ALLOW COMPACT VALUE**

The allowable compactness value. If the actual value is less than the allowable, the section is compact.

**ALLOW NON-COMPACT VALUE**

The allowable non-compactness value. If the actual value exceeds the allowable compactness value but is less than the allowable non-compactness value, the section is non-compact. If the actual value exceeds the allowable non-compactness value then the section is undefined and the allowable stress equations do not apply to this section.

**ALLOW SLENDER VALUE**

The allowable slenderness value (not related to 5.9 Slenderness Table). If the actual value exceeds the allowable non-compactness value but is less than the maximum allowable value, the section is slender. If the actual value exceeds the allowable slenderness value then the section is undefined and the allowable stress equations do not apply to this section.

## 5.9 SLENDERNESS TABLE

This table lists the slenderness values for each member type. For information about the computation of these values, see Chapter 3.

### LOCATION

The cross section member location.

### X-SEC NO

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### MEM

This value lists the finite element member number.

### NODE

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1, the worst result of the two element nodes is displayed. For output level 2, both node results are displayed.

### DIST

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

### K

The value for the ratio of effective column length to unbraced length (for members in which tension controls, this value will print as N/A).

### L

The length of the member in feet.

**R**

Radius of gyration of the member in inches.

**ACTUAL RATIO**

Computed slenderness ratio for the member ( $KL/r$  for members governed by compression,  $L/r$  for members governed by tension). If this exceeds the allowable ratio, the program will place an asterisk next to the value.

**ALLOWABLE RATIO**

Allowable slenderness ratio value for the member. The allowable slenderness ratio value is based on Articles 5.9.4 and 5.10.3 of the LRFD Sign Specifications and Articles 6.8.4 and 6.9.3 of the LRFD Bridge Specifications.

**MEMBER CATEGORY**

Describes whether the member is in tension, compression, or experiences stress reversal. If the member experiences reversal, the actual ratio and allowable ratio values reported here are those that result in the largest actual / allowable ratio.

## 5.10 BOLTED CONNECTIONS TABLE

This table lists the number of bolts required for each member with bolted connections. The table is only printed if the model contains bolted connections. Chords, posts, and round or multi-sided pipes cannot have bolted connections. Below the table, the program will always print the following error message:

“The value indicated does not account for an increased force due to the eccentricity of the bolt pattern relative to the neutral axis on the member. The user must either account for this increased force or detail the bolted connection so that the center of gravity (c.g.) of the bolt pattern and the neutral axis of the member coincide (produce no eccentricity).”

This message is printed because the bolt pattern is not known. Since the minimum number of bolts is two, it would be conservative to increase the shear/slip force assuming only two bolts resist the  $M_x$  moment for FVERT and FDIAG members. An additional increase in the shear/slip force occurs due to the eccentricity of the bolt group relative to the neutral axis of the member. This increase in force can only be determined with a known bolt pattern. Because each fabricator details this connection differently, the increase in force cannot be accounted for accurately. Therefore, this shear/slip force will not be calculated by the program. The designer/fabricator should however be required to verify that this increase in force will not overstress the bolts. The force is calculated as follows:

$$M_{(A_x)} = A_x * e$$

Where  $A_x$  is actual Axial Load in the member and  $e$  is the eccentricity of the bolt group relative to the neutral axis of the member.

$$V_{(A_x)} = M_{(A_x)} * \frac{d}{E * d^2}$$

Where  $d$  is the distance to the bolt under consideration and  $E * d^2$  is the summation of all distances squared.

The program does, however, consider some member eccentricity when determining the axial design force for members bolted through the flange. Tees and channels used in the top or bottom trusses are the only members connected through the flange. An axial load is found such that the interaction of the axial load and the moment induced by the axial load result in a combined force interaction ratio of 1.0:

$$\frac{P_{des}}{P_r} + \frac{P_{des} * y}{M_r} = 1.0$$

where:  $P_{des}$  = design axial load to solve for  
 $P_r$  = factored axial resistance of the member

- y = neutral axis to top of flange
- Mr = factored moment resistance of the member

This equation is solved for  $P_{des}$ , (the member bolt design resistance) which is then used in combination with the factored axial force in the member,  $P_u$ , to determine the number of bolts required for the connection.

For tees and channels connected through the web,  $P_{des}$  is equal to  $P_r$ .

Note that the results on this output report are based on the load combination leading to the largest number of bolts required. This load case is reported on the report. The program assumes A325 bolts, standard holes, Class C surface conditions, threads excluded from the shear plane, and only one shear plane. The assumed bolt tension is based on the bolt diameter and is shown in Table 1.

The bearing resistance of a single bolt hole is based on the LRFD Bridge Specifications, Article 6.13.2.9. Hole diameter is assumed to be equal to the bolt diameter + 1/16". The assumed bolt spacing and edge distances are based on bolt diameter and are shown in Table 1. For members with a yield strength of 36 ksi, an ultimate strength of 58 ksi is assumed, while for a yield strength of 50 ksi, an ultimate strength of 65 ksi is assumed.

Table 5.10-1 Assumed Bolt Design Values

Bolt Diameter (in)	Center-to-center Spacing (in)	Edge Distance (in) <sup>3</sup>	Minimum Required Bolt Tension (kips) <sup>4</sup>
0.625"	2-1/4 <sup>1</sup>	1-1/8	19.0
0.750"	2-1/2 <sup>1</sup>	1-1/4	28.0
0.875"	3 <sup>1</sup>	1-1/2	39.0
1.000"	3-1/2 <sup>1</sup>	1-3/4	51.0
1.125"	3-1/2 <sup>2</sup>	2	56.0
1.250"	3-3/4 <sup>2</sup>	2-1/4	71.0
1.375"	4-1/4 <sup>2</sup>	2-3/8	85.0

Notes:

- 1 DM-4 Preferred Spacing from DM-4 Table C6.13.2.6.1P-1
- 2 Center-to-center spacing equal to 3 \* Bolt Diameter, rounded up to the nearest 1/4" unless 3 \* Bolt diameter is already at a 1/4" interval
- 3 Edge distance from LRFD Bridge Specifications, Table 6.13.2.6.6-1, assuming sheared edges
- 4 Minimum required bolt tension from LRFD Bridge Specifications Table 6.13.2.8-1, assuming A325 bolts

**LOCATION**

The cross section member location.

**X-SEC NO**

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

**MEM**

This value lists the finite element member number.

**NODE**

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1, the worst result of the two element nodes is displayed. For output level 2, both node results are displayed.

**DIST**

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case. Slip resistance is checked only for Service limit states, while bearing and shear resistance are checked for Strength and Extreme limit states. Slip, bearing, and shear resistances are all checked for both tension and compression.

**Fu**

Ultimate strength of the connected material. The program calculates Ultimate strength based on the yield strength. Fu is 58 ksi for Fy = 36ksi. Fu is 65 ksi for Fy = 50 ksi.

**Pdes TYPE**

State for which the member bolt design resistance is calculated (Compression or Tension).

**Member Pu (kips)**

The actual factored load in kips for the bolt design. The program computes this value by assuming that there are at least two bolts. It computes the shear in the bolts by applying the factored moment in the member at this location to two bolts at the preferred minimum spacing (DM-4 Table C6.13.2.6.1P-1) to determine a shear force couple. The program then computes the resultant force from this shear couple and the shear force from the factored axial load in the member.

**Member Pdes (kips)**

The member bolt design resistance.

**Bolt Rr (kips)**

The governing resistance of a single bolt. The resistance can be based on slip (S), shear (V), or bearing resistance (B) as designated in the next column.

**Bolts Required for Pu**

Number of bolts required for the factored load in the member.

**Bolts Required for (Pu + Pdes)/2**

Number of bolts required for the average of the factored load in the member and the member bolt design resistance. When the number of bolts is governed by a Service limit state, this value will print as N/A because member bolt design resistance is not calculated for Service limit states.

**Bolts Required for 75% Pdes**

Number of Bolts Required for 75% of the member bolt design resistance. When the number of bolts is governed by a Service limit state, this value will print as N/A because member bolt design resistance is not calculated for Service limit states.

**Bolts Required for Three Per Row**

Number of bolts required assuming a minimum of three bolts per row along the member. For FDIAG, FVERT, RDIAG, and RVERT members, this value is based on multiplying the NUMBER OF BOLT ROWS WEB on the BOLTED CONNECTIONS input command by three. For TDIAG, TVERT, BDIAG, BVERT, PXDIAG, and TXDIAG,

this value is the NUMBER OF BOLT ROWS FLANGE on the BOLTED CONNECTIONS input command multiplied by three. The minimum of three bolts per row is used to decrease the effects of eccentricity on the connection.

## 5.11 CHORD SPLICE TABLES

**The program currently only analyzes existing chord splices. Design of new splices (designated by the NORE parameter on the CRITERIA input command) will be implemented in a future version of this program.**

The bending resistance of the plate is calculated according to Article 5.8.7.1 of the LRFD Sign Specifications, assuming a rectangular bar bent about its weak axis for two different loading conditions.:

$$M_r = \phi_f M_n$$

$$M_n = M_p = F_y Z \leq 1.6 M_y$$

where: $M_r$	= flexural resistance of the plate
$\phi_f$	= resistance factor for flexure
$M_n$	= nominal flexural capacity of the plate
$M_p$	= plastic moment
$F_y$	= yield strength of the splice plate
$Z$	= plastic modulus of the rectangular bar = $b * h^2 / 4$
$M_y$	= yield moment of the rectangular bar = $F_y * S$
$S$	= section modulus of the rectangular bar = $b * h^2 / 6$
$b$	= width of rectangular section, either L1 or ( BCDIST + Edge ), depending on the type of bending being checked
$h$	= required thickness solved for

Note that because of the geometry of the plate and the expressions for plastic and elastic section modulus,  $F_y * Z$  simplifies to  $0.25 * F_y * b * h^2$  and  $1.6 * M_y$  simplifies to  $0.267 * F_y * b * h^2$ , so  $F_y * Z$  will always govern.

To calculate the required splice plate thickness, the expression for flexural resistance given above is set equal to the applied moment calculated for the following two conditions, then solved for the plate thickness:

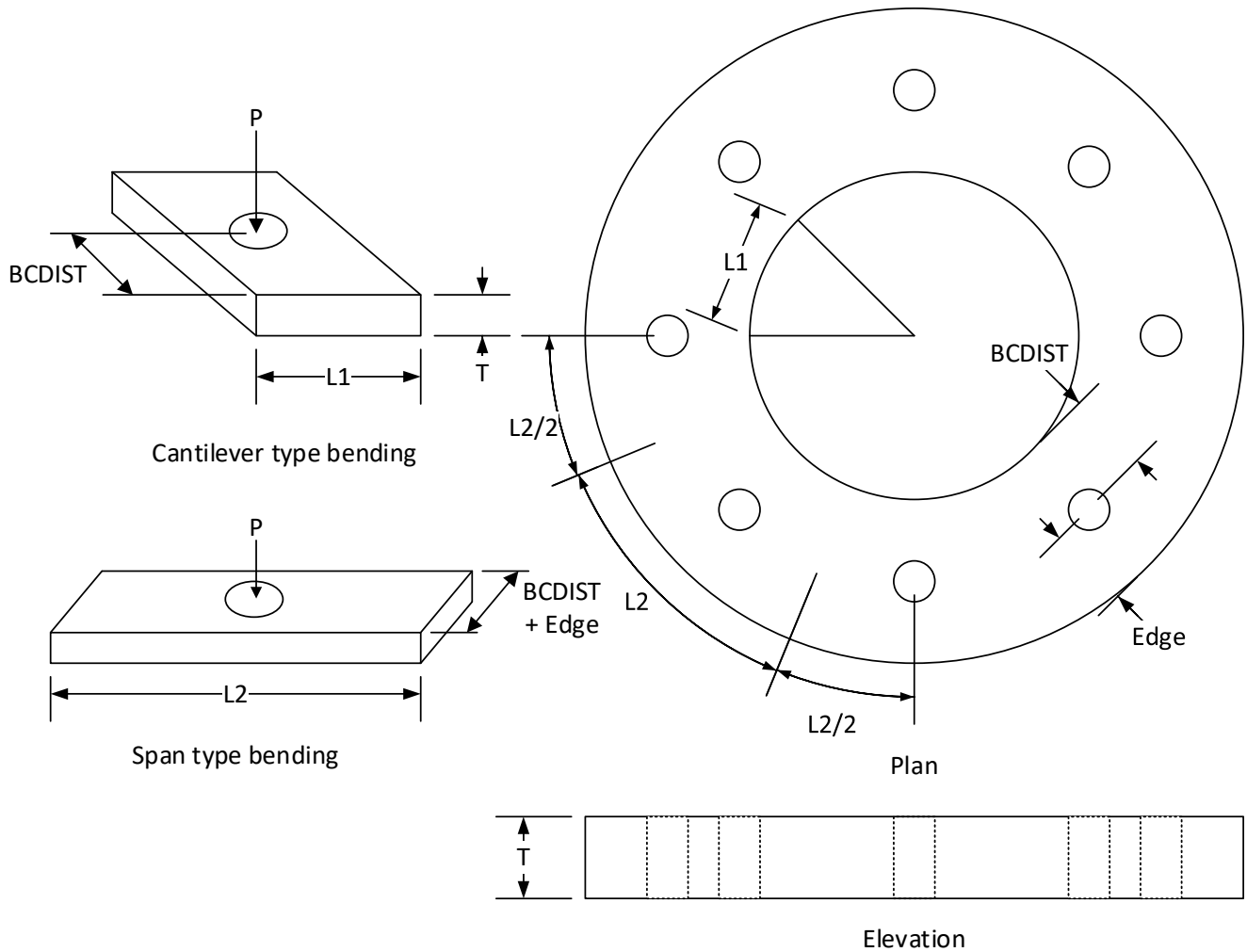
- 1) **“Cantilever” type bending:** It is assumed that the flange of the splice plate will act as a cantilever beam, subject to bending caused by a “P” force in the bolt. In this case, the splice plate is modelled as a cantilever beam, with the force P placed a distance BCDIST from the face of the chord and the plate fixed at the face of the chord. The plate is assumed to act as a rectangular section bending about its weak axis with a width equal to L1 (outer circumference of chord divided by the number of chord splice bolts, as shown in Figure 1). The required thickness, T, is then solved for.

$$M_u = \phi_f F_y Z$$

$$M_u = P * BCDIST$$

$$M_u = \phi_f F_y \frac{L1 * T^2}{4}$$

$$T = \sqrt{\frac{4 * P * BCDIST}{\phi_f F_y L1}}$$



**Figure 5.11-1 Bending of the Chord Splice Plate**

- 2) “Span” type bending: It is assumed that the splice plate will be subjected to bending moments resulting from simple span bending due to the “P” force in a single bolt. In this case, the splice plate is modelled as a rectangular section spanning a distance L2 (circumference to the chord splice bolts divided by the number of bolts, as shown in Figure 1) with a width equal to (BCDIST + Edge). The required thickness, T, is then solved for.

$$M_u = \phi_f F_y Z$$

$$M_u = \frac{P * L2}{4}$$

$$M_u = \phi_f F_y \frac{(BCDIST + Edge) * T^2}{4}$$

$$T = \sqrt{\frac{P * L2}{\phi_f F_y (BCDIST + Edge)}}$$

For each of these two bending conditions, the bolts in the connection plate are subjected to applied static tension as a result of direct axial tension and tension resulting from bending moments in the chords. Therefore, the required thickness of the splice plate is calculated using a “P” force equal to the actual force in the bolts for analysis of the splice plate.

**CHORD SPLICE TABLE (BOLT TENSION CHECKS)**

**SPLICE NAME**

The user-defined splice identifier (from the Chord Splice One input card).

**CHORD LOCATION**

The chord type: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, and RLCORD = rear lower chord.

**INPUT NUMBER OF BOLTS**

This is the same value that was input into the Pipe Connection Details (Chord Splice 2) input command.

**BOLT DIAMETER**

The diameter of the splice bolts entered by the user.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**TENSION PER BOLT, ACTUAL**

This is the actual factored static tension per bolt.

**TENSION PER BOLT, RESISTANCE**

The tensile resistance of a single bolt.

**TENSION PER BOLT, CHECK**

When the factored tension force per bolt is less than or equal to the tensile resistance , this value is "OK". Otherwise, it is no good, "NG".

**CHORD SPLICE TABLE (BOLT SHEAR CHECKS)**

**SPLICE NAME**

The user-defined splice identifier (from the Chord Splice One input card).

**CHORD LOCATION**

The chord type: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, and RLCORD = rear lower chord.

**INPUT NUMBER OF BOLTS**

This is the same value that was input into the Pipe Connection Details (Chord Splice 2) input command.

**BOLT DIAMETER**

The diameter of the splice bolts entered by the user.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**SHEAR PER BOLT, ACTUAL**

The total factored shear force per bolt, including direct shear force and shear due to torsion.

**SHEAR PER BOLT, RESISTANCE**

The shear resistance of a single bolt.

**SHEAR PER BOLT, CHECK**

When the factored shear force per bolt is less than or equal to the bolt shear resistance, this value is "OK". Otherwise, it is no good, "NG".

**CHORD SPLICE TABLE (BOLT SLIP CHECKS)**

**SPLICE NAME**

The user-defined splice identifier (from the Chord Splice One input card).

**CHORD LOCATION**

The chord type: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, and RLCORD = rear lower chord.

**INPUT NUMBER OF BOLTS**

This is the same value that was input into the Pipe Connection Details (Chord Splice 2) input command.

**BOLT DIAMETER**

The diameter of the splice bolts entered by the user.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**ACTUAL SHEAR**

The total factored shear force per bolt, including direct shear force and shear due to torsion.

**SLIP RESISTANCE**

The slip resistance of a single bolt.

**SLIP RESISTANCE CHECK**

When the factored shear force per bolt is less than or equal to the bolt slip resistance, this value is "OK". Otherwise, it is no good, "NG".

**CHORD SPLICE TABLE (SPLICE PLATE THICKNESS CHECKS)**

**SPLICE NAME**

The user-defined splice identifier (from the Chord Splice One input card).

**CHORD LOCATION**

The chord type: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, and RLCORD = rear lower chord.

**INPUT NUMBER OF BOLTS**

This is the same value that was input into the Pipe Connection Details (Chord Splice 2) input command.

**BOLT DIAMETER**

The diameter of the splice bolts entered by the user.

**SPLICE YIELD STRENGTH**

The yield strength of the chord splice plate.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**PLATE THICKNESS, INPUT**

This is the user-input splice plate thickness from the PIPE CONNECTION DETAILS (CHORD SPLICE 2) input command.

**PLATE THICKNESS, MINIMUM REQUIRED**

The required splice plate thickness, based on span- and cantilever-type bending, in inches. The governing thickness calculation is also indicated here, C for cantilever type bending and S for span type bending.

**PLATE THICKNESS, CHECK**

This check indicates if the user-input splice plate thickness is greater than the required thickness of splice plate calculated by the program. If the user-input thickness is greater, the table will display "OK". Otherwise, the table will display "NG".

Table 5.11-1 Tension and Shear Check Equations

TENSION/STRESS PARAMETER NAME	FORMULA
Assumptions	<p>Bolts are ASTM A325 High Strength Bolts</p> <p>For bolts ≤ 1" in diameter, <math>F_{ub} = 120</math> ksi                      For bolts &gt; 1" and ≤ 1.5", <math>F_{ub} = 105</math> ksi.</p> <p>Splice plate yield strength is entered by the user.</p>
Actual Splice Bolt Shear	$V_u = \sqrt{V_x^2 + V_y^2} + \left  \frac{T_z}{r_{bc}} \right $ <p>where: <math>V_u</math> = shear force per bolt  <math>T_z</math> = torsion about the z-axis  <math>r_{bc}</math> = <b>radius of the bolt circle</b></p>
Splice Bolt Nominal Shear Resistance	<p>Minimum of:</p> <p>Bolt shear resistance:  <math>R_n = 0.48A_bF_{ub}N_s</math> (LRFD Bridge Specifications Equation 6.13.2.7-1)</p> <p>Assume threads excluded from the shear plane, and a single shear plane (<math>N_s</math>).</p> <p>Bolt slip resistance:  <math>R_n = K_hK_sN_sP_t</math> (LRFD Bridge Specifications Equation 6.13.2.8-1)</p> <p>where: <math>K_h</math> = hole size factor from LRFD Bridge Specifications Table 6.13.2.8-2                      (assume standard holes, <math>K_h = 1.00</math>)  <math>K_s</math> = surface condition factor from LRFD Bridge Specifications Table 6.13.2.8-3                      (assume Class C Surface, hot-dip galvanized, <math>K_s = 0.33</math>)  <math>P_t</math> = minimum required bolt tension from LRFD Bridge Specifications Table 6.13.2.8-1 (A325 bolts)</p>
Actual Tension Per Bolt	$P_u = \frac{P_T}{\# \text{ of bolts}} + \frac{d_{max}\sqrt{M_x^2 + M_y^2}}{I_{bolt \text{ group}}} A_b$ <p>where: <math>P_u</math> = actual static tension force per bolt  <math>P_T</math> = tensile force in chord (if force in chord is compressive, then ignore it and only count flexural tensile force)  <math>d_{max}</math> = distance from neutral axis of bolt group to furthest bolt  <math>A_b</math> = area of a single bolt</p>
Splice Bolt Nominal Tensile Resistance	<p>If <math>V_u / R_n \leq 0.33</math>  <math>T_n = 0.76A_bF_{ub}</math> (LRFD Bridge Specifications Equation 6.13.2.11-1)</p> <p>Otherwise:  <math>T_n = 0.76A_bF_{ub}\sqrt{1 - \left(\frac{V_u}{\phi_s R_n}\right)^2}</math> (LRFD Bridge Specifications Equation 6.13.2.11-2)</p>

## 5.12 MOMENT / TORSION TABLE

This table lists the moments and torsion values for each member. For output level 0 the case corresponding to the worst combined stress ratio (CSR) value for each member type is listed. For output level 1, the worst case for each element (i.e. the worst i or j node) in the model is listed. For output level 2, all values for each end of each element are listed.

### LOCATION

The cross section member location.

### X-SEC NO

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### MEM

This value lists the finite element member number.

### NODE

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1, the worst result of the two element nodes is displayed. For output level 2, both node results are displayed.

### DIST

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

### LOAD CASE

This number refers to the load case id listed in the load combination table. See section 5.7.

### LIMIT STATE

This gives the AASHTO Limit State for this load case.

**MX**

Moment about the member x-axis in kip-in (see Figure 5.12-1).

**MY**

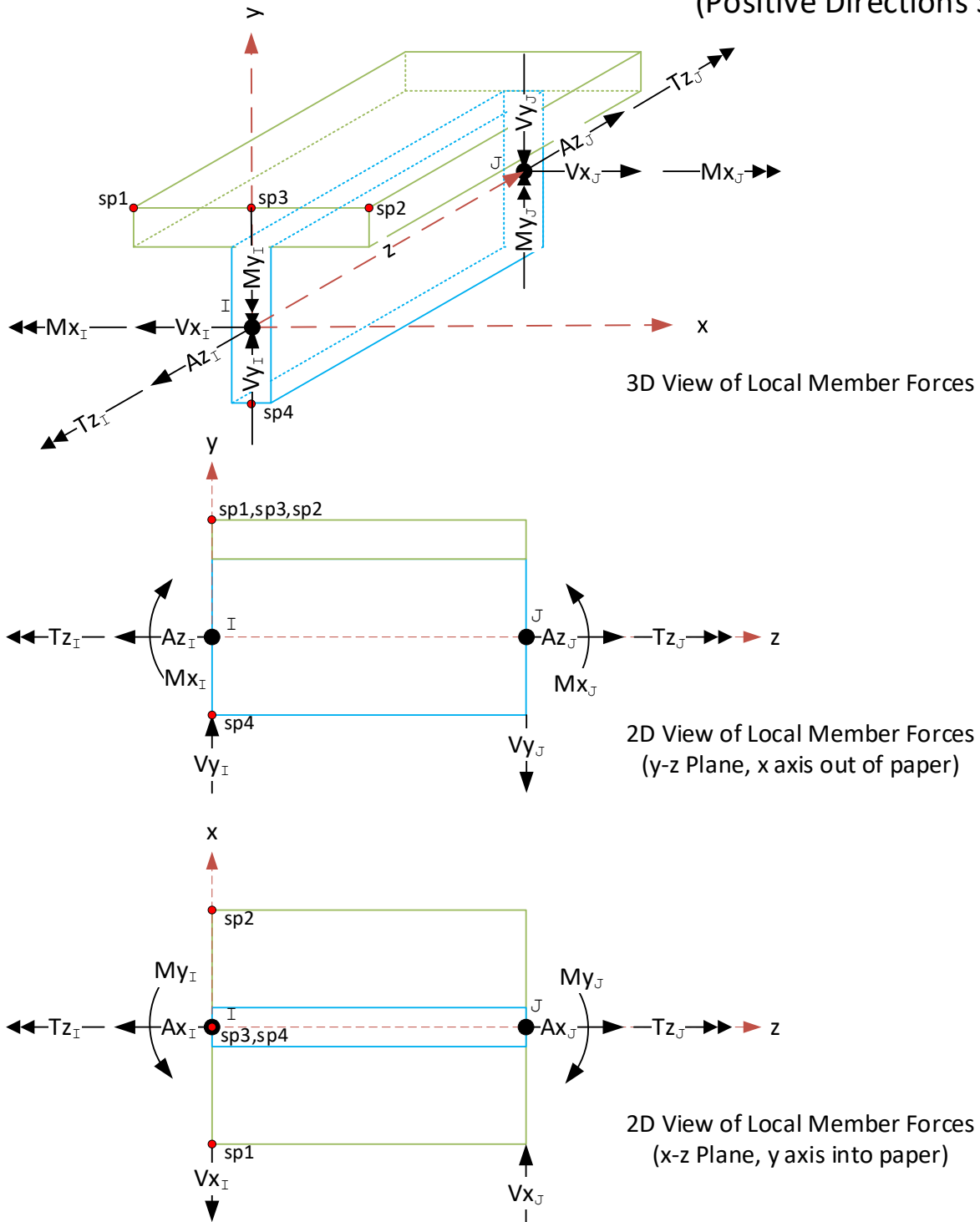
Moment about the member y-axis in kip-in (see Figure 5.12-1).

**TZ**

Torsion about the member z-axis in kip-in (see Figure 5.12-1).

## SNLRFD Local Member Forces

(Positive Directions Shown)



**Figure 5.12-1 Local Member Orientation**

### 5.13 SHEAR / AXIAL TABLE

This table lists the shear and axial values for each member. For output level 0, the case corresponding to the worst combined stress ratio (CSR) value for each member type is listed. For output level 1, the worst case for each element (i.e. the worst i or j node) in the model is listed. For output level 2, all values for each end of each element are listed.

#### LOCATION

The cross section member location.

#### X-SEC NO

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

#### MEM

This value lists the finite element member number.

#### NODE

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1, the worst result of the two element nodes is displayed. For output level 2, both node results are displayed.

#### DIST

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e., the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

#### LOAD CASE

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

#### LIMIT STATE

This gives the AASHTO Limit State for this load case.

**VY**

Shear on the member y-axis in kips (see Figure 5.13-1).

**VX**

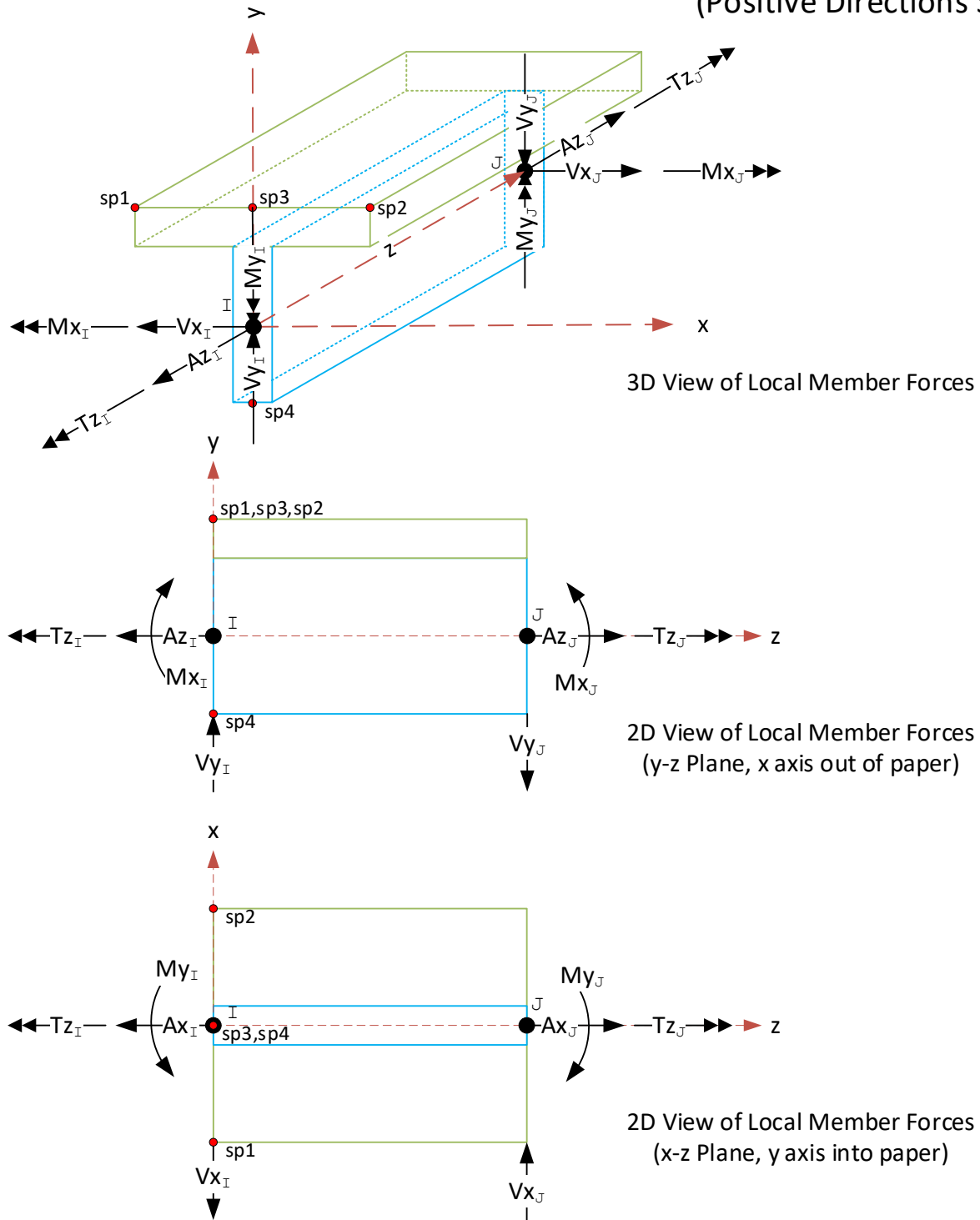
Shear on the member x-axis in kips (see Figure 5.13-1).

**AXIAL (AZ)**

Member axial load in kips (see Figure 5.13-1).

## SNLRFD Local Member Forces

(Positive Directions Shown)



**Figure 5.13-1 Local Member Orientation**

## 5.14 RESISTANCE TABLE

This table lists the factored resistance values for each member. For output level 0, the case corresponding to the worst combined force interaction ratio value for each member type is listed. For output level 1, the worst case for each element (i.e. the worst i or j node) in the model is listed. For output level 2, the resistances for the load case corresponding to the worst combined force interaction ratio for each end of each element are listed.

### LOCATION

The cross section member location.

### X-SEC NO

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### MEM

This value lists the finite element member number.

### NODE

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1, the worst result of the two element nodes is displayed. For output level 2, both node results are displayed.

### DIST

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

### LOAD CASE

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

### LIMIT STATE

This gives the AASHTO Limit State for this load case.

**Pr**

Factored resistance for members in axial compression or tension (kips). A positive value indicates tensile resistance while a negative value indicates compressive resistance, corresponding to the axial force in the member for the governing force interaction ratio.

**Mrx**

Factored flexural resistance about the x-axis of the member (kip-in). For tees and channels, this is the strong axis of the member. A positive value indicates that, for the governing force interaction ratio, the member is in positive bending.

**Mry**

Factored flexural resistance about the y-axis of the member (kip-in). For tees and channels, this is the weak axis of the member. A positive value indicates that, for the governing force interaction ratio, the member is in positive bending. For round and multi-sided pipes, this value prints as "n/a".

**Vr**

Factored shear resistance for each member (kips). An "X" after the shear resistance indicates that shear along the x-axis is used in the governing force interaction ratio and a "Y" indicates that shear along the vertical axis is used. For round and multi-sided pipes, the shear resistance is the same in all directions, so no directional indication is given.

**Tr**

Factored torsional resistance for each member (kip-in for round and multi-sided pipes, ksi for tees and channels).

## 5.15 COMBINED FORCE INTERACTION TABLE

This table lists the actual factored effects and the combined stress ratio (CSR) for each member. For output level 0, the case corresponding to the worst CSR value for each member type is listed. For output level 1, the worst case for each element (i.e., the worst i or j node) in the model is listed. For output level 2, all values for each end of each element are listed.

### LOCATION

The cross section member location.

### X-SEC NO

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### MEM

This value lists the finite element member number.

### NODE

This value lists the finite element node number that corresponds to this member. For output levels 0 and 1, the worst result of the two element nodes is displayed. For output level 2, both node results are displayed.

### DIST

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e., the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

### LOAD CASE

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

### LIMIT STATE

This gives the AASHTO Limit State for this load case.

**Pu**

Factored axial force for each member (kips).

**B**

**The moment magnification factor applied to the Mu/Mr ratio for calculation of the combined stress ratio.**

**Mux**

Factored bending moment. This value is taken about the member X-axis for tees and channels. For round and multi-sided pipes, this is the combined moment value, calculated as described in section 3.6.8 of this User's Manual (kip-in).

**Muy**

Factored bending stress about the member Y-axis for tees and channels. For round and multi-sided pipes, this value prints as "n/a" (kip-in).

**Vu**

Factored shear force for each member (kips).

**Tu**

Factored torsional effect for each member (kip-in for round and multi-sided pipes, ksi for tees and channels).

**CSR**

Combined stress ratio for each member.

## 5.16 FATIGUE MOMENT / AXIAL TABLE

This table lists the fatigue moments and axial force values for members whose fatigue loads are printed in the fatigue stress table (5.17). For output level 0 this table will print the controlling member for each fatigue detail automatically generated by the program and for each detail input by the user. Output level 1 is similar to level 0, the difference being that for level 1 the program will output each controlling member type (POST, FVERT, FUCHORD, etc.) for each detail automatically generated by the program and for each detail input by the user. For output level 2, the worst case for each node in the model applicable to each detail is listed for each fatigue load case that is applied to it for which the CSR is greater than 0.0.

### DETAIL NUMBER

The detail number from the fatigue details input card is printed.

### THRESHOLD (CAFT)

This echoes the Constant-Amplitude Fatigue Threshold (CAFT) from the fatigue details input card.

### CHORD/POST/BRANCH MEMBER

This echoes the member type from the fatigue details input card, where applicable.

### LOCATION

The cross section member location.

### X-SEC NO

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### MEMBER

The finite element member number.

### NODE

The finite element node number that corresponds to the current member.

**DIST**

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**AXIAL**

Member axial load in kips.

**MX**

Moment about the member x-axis in inch-kips.

**MY**

Moment about the member y-axis in inch-kips.

## 5.17 FATIGUE STRESS TABLE

This table lists the fatigue stress values and the fatigue combined stress ratio (CSR). For output level 0, the controlling member for each automatically generated fatigue detail and each user-input fatigue detail are printed out. For output 1, the case corresponding to the worst CSR value for each section type for both automatically generated and user-input fatigue details is printed. For output level 2, the worst case for each node in the model applicable to each detail and for each fatigue load case is listed.

### **DETAIL NUMBER**

The detail number from the fatigue details input card is printed.

### **THRESHOLD (CAFT)**

This echoes the Constant-Amplitude Fatigue Threshold (CAFT) from the fatigue details input card.

### **CHORD/POST/BRANCH MEMBER**

This echoes the member type from the fatigue details input card.

### **LOCATION**

The cross section member location.

### **X-SEC NO**

The cross section identification number. This number refers to the cross section identification number provided in the **CROSS SECTION OUTPUT**.

### **MEMBER**

This value lists the finite element member number.

### **NODE**

This value lists the finite element node number that corresponds to this member.

### **DIST**

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown

in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**fa**

Calculated axial compressive fatigue stress for each (ksi). For fatigue detail 2.3, fa includes the effects of moment and axial load on the member to determine the total axial tension stress in the bolt.

**fbx**

Calculated bending fatigue stress about the member X-axis (ksi).

**fbY**

Calculated bending fatigue stress about the member Y-axis (ksi).

**CSR**

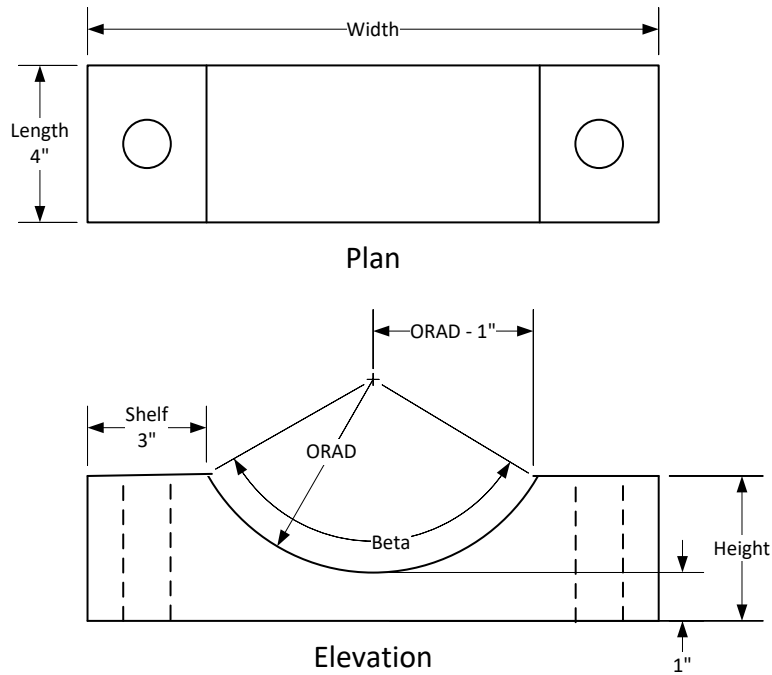
Combined fatigue stress ratio for each member. See Table 5 in Section 3.6 for the equations used to compute the CSR values.

## 5.18 SADDLE DETAIL DESIGN TABLES

This table lists the saddle detail load effects and stresses at both ends of the applicable chords. The purpose of this table is to determine if the “ideal height” of the saddle (determined by geometric constraints) is adequate for the reaction from the chord. Also, the shear and frictional resistance of the system due to U-bolt tension will be checked to determine if the input number of U-bolts will be adequate for a given bolt diameter.

The program makes several assumptions:

1. U-bolts are to be A449 H.S.
2. U-bolts are assumed to have a bolt diameter of 1”.
3. Length of the saddle plate (parallel to the chord) is 4” (See Figure 5.18-1).
4. Shelf (top flats) length is 3” (See Figure 5.18-1).
5. Saddle height at center is 1” (See Figure 5.18-1).
6. Minimum number of U-bolts required is one. (Two legs per saddle block)
7. Allowable bolt shear is determined assuming the threads are excluded from the shear plane.  $R_r = \phi_s * R_n$ ;  $R_n = 0.48 * A_b * F_{ub} * N$ , based on the LRFD Bridge Specifications, Equation 6.13.2.7-1. One shear plane (N) is assumed.
8. If more than one U-bolt is required, the number of saddle blocks required will be the same.
9. The bearing length of the pipe on the saddle used for the calculation of bearing capacity will be limited to  $0.33 * (\text{circumference of pipe})$ , which is the length of arc subtended by Beta Angle = 120 degrees (upper limit for optimum saddle angle), even if the bearing length based on geometry (see Figure 5.18-1) is greater than  $0.33 * \text{circumference}$ .
10. The force used to calculate bearing at the pipe/saddle interface will include the effects of the minimum required tension in the U-bolt, 51k from each leg of the U-bolt (102 kips total) (See the LRFD Bridge Specifications, Table 6.13.2.8-1).
11. No bending of the U-bolt is considered.
12. Saddle is made of A36 steel.
13. “Ideal Height” assumes U-bolt is centered on 3” shelf.



**Figure 5.18-1 Saddle Block Dimensions**

**CHORD CHECK AT SADDLE BLOCK**

**LOCATION**

The cross section member location. For this table, the member location will always be a chord location, because the saddle detail design is applicable only for chords. The program will specify which chord is analyzed on each line of the table: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, RLCORD = rear lower chord.

**MEMBER**

This value lists the finite element member number.

**NODE**

This value lists the finite element node number that corresponds to this member.

**DIST**

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown

in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**. This load case is the load case corresponding to the CSR value printed in the CSR column of the table.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**NUMBER OF U-BOLTS**

This is an echo of the NUBOLTS input value from the Bolted Connections Input Card.

**CHORD Pu**

Factored axial force, in kips, in the specified chord.

**CHORD fb**

Circumferential factored bending stress induced by the chord resting on the saddle block, in ksi, in the specified chord. This equation comes from an expression for localized bending stresses in a pipe resting on supports at intervals, given in Section 13.7 of Roark's Formulas for Stress and Strain (7th Edition, 2002).

$$f_b = k \frac{P}{t^2} \ln \frac{R}{t}$$

$$k = 0.02 - 0.00012(\beta - 90)$$

- where:  $f_b$  = circumferential bending stress
- $k$  = coefficient calculated from equation above
- $P$  = total saddle reaction
- $t$  = thickness of chord
- $R$  = pipe outer radius
- $\beta$  = beta angle (angle of contact between pipe and saddle)

The "total saddle reaction" in the equation above is the sum of the vertical shear at the node and the total clamping force (generally 102 kips) from the tension in the U-bolt. See the SADDLE DETAIL DESIGN TABLE (U-BOLTS) for the required minimum tension in each leg of the U-bolt.

**CHORD Vu**

Actual factored shear force, in kips, in the specified chord.

**CHORD Tu**

Actual factored torsional moment, in kip-inches, in the specified chord.

**CSR**

Combined stress ratio for each member at the saddle location. This CSR value is based on the load case listed in the Load Case column of this Saddle Table. See Section 3.6.9 for the calculation of the CSR values.

**U-BOLTS**

**LOCATION**

The cross section member location. For this table, the member location will always be a chord location, because the saddle detail design is applicable only for chords. The program will specify which chord is analyzed on each line of the table: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, RLCORD = rear lower chord.

**MEMBER**

This value lists the finite element member number.

**NODE**

This value lists the finite element node number that corresponds to this member.

**DIST**

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

**NUMBER OF U-BOLTS**

This is an echo of the NUBOLTS input value from the Bolted Connections Input Card.

**LOAD CASE**

This number refers to the load case id listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**. This load case is the load case corresponding to the calculation of the minimum tension required for axial force.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**REQUIRED MINIMUM T**

This is the minimum required U-bolt tension per leg; the maximum of the tension required due to axial force and shear, or the minimum required tension from the LRFD Bridge Specifications Table 6.13.2.8-1.

U-bolt tension required due to axial force and shear:

$$T_{min} = \frac{\left(\frac{|A_x|}{0.3} - V_y\right)}{2n}$$

where:  $A_x$  = Factored axial force in the chord  
 $V_y$  = Factored shear along y-axis (vertical) from the chord  
 $n$  = Number of U-bolts

If the calculated value is greater than 51 kips (the required minimum tension in the U-bolt), a message will print stating that there is an insufficient number of U-bolts at this location.

**LOAD CASE**

This number refers to the load case ID listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**. This load case is the load case corresponding to the calculation of the shear in the U-bolts.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**U-BOLT  $V_u$**

Actual factored shear force, in kips, in the U-bolt.

$$V_u = \frac{\sqrt{V_x^2 + A_x^2}}{2n}$$

- where:  $V_u$  = actual factored shear force in one leg of a U-bolt  
 $V_x$  = actual factored shear in the chord  
 $A_x$  = actual factored axial force in the chord  
 $n$  = number of U-bolts

**U-BOLT  $V_r$**

Shear resistance, in kips, of the U-bolt. Threads are assumed excluded from the shear plane.

$$V_r = \phi_s V_n$$

$$V_n = 0.48 A_b F_{ub} N$$

- where;  $V_r$  = shear resistance  
 $\phi_s$  = resistance factor for shear in bolts  
 $V_n$  = nominal shear resistance  
 $A_b$  = bolt cross sectional area  
 $F_{ub}$  = ultimate strength of bolt (120 ksi for 1" U-bolt assumed)  
 $N$  = number of shear planes (1 assumed)

**SADDLE BLOCK**

**LOCATION**

The cross section member location. For this table, the member location will always be a chord location, because the saddle detail design is applicable only for chords. The program will specify which chord is analyzed on each line of the table: FUCORD = front upper chord, FLCORD = front lower chord, RUCORD = rear upper chord, RLCORD = rear lower chord.

**MEMBER**

This value lists the finite element member number.

**NODE**

This value lists the finite element node number that corresponds to this member.

**DIST**

Location of the member in feet. For chord members this is the distance along the chord from the centerline of the left post (see Figure 5.8-1). Truss vertical and diagonal member distances are measured by panel increments (i.e. the panel in which the member is contained). Distances for posts are measured from the support upward as shown in Figure 5.8-1. Distance for struts/chords on centermount sign structures is measured from the left most end of the strut (see Figure 5.8-1). Distances for masts (Post of Monopipe Types) are measured from the support vertically upward (not along the length of the mast) as shown in Figure 5.8-1.

**LOAD CASE**

This number refers to the load case ID listed in the load combination table. See **Section 5.7 LOAD CASE TABLE**. This load case is the load case corresponding to the bearing force in the saddle block.

**LIMIT STATE**

This gives the AASHTO Limit State for this load case.

**BETA ANGLE**

Angle, in degrees, between the saddle block and the center of the pipe (see Figure 5.18-1). The optimum saddle angle is between 90 and 120 degrees. This is applicable only for chords that have a diameter of 10" or greater.

**SADDLE HEIGHT**

Height, in inches, of the saddle block.

$$Height = 1" + ORAD \left( 1 - \cos \left( \frac{Beta\ Angle}{2.0} \right) \right)$$

where: ORAD = outside radius of the pipe (see Figure 5.18-1)

Beta Angle = contact angle between saddle block and pipe (see Figure 5.18-1)

**SADDLE WIDTH**

Width, in inches, of the saddle block.

$$Width = 2(ORAD - 1") + 6"$$

where: ORAD = outside radius of the pipe (see Figure 5.18-1)

**SADDLE LENGTH**

Length, in inches, of the saddle block. The length is 4" as per the Standards. (See Figure 5.18-1)

**BEARING FORCE,  $P_U$ :**

The bearing force applied to a single saddle block, in kips, equal to the factored shear in the y-direction plus the minimum tension in a single U-bolt (maximum of 102 kips or double the required minimum tension from the U-bolts output report).

**BEARING RESISTANCE,  $P_R$ :**

The bearing resistance of a single saddle block, in kips

## 5.19 CANTILEVER / CENTERMOUNT DEFLECTION TABLE

This table is provided for cantilever, centermount, and cantilever monopipe models. It lists the allowable and actual angular rotations as well as the allowable and actual horizontal deflections based on the LRFD Sign Specifications Article 10.4.2.

## 5.20 OVERHEAD TRUSS AND FRAME DEFLECTION CHECK

This table is provided for two post tri-chord, four post tri-chord, four post four-chord, and monopipe frame models. It lists the actual and allowable vertical chord deflections. This table is not printed for centermount, cantilever, or cantilever monopipe models.

## 5.21 VERTICAL CAMBER TABLE

This table lists deflections for the total vertical camber of the lower chord for truss type models, the chord for monopipe frame models, and the end of the strut for cantilever, centermount, and cantilever monopipe models.

## 5.22 QUANTITY TABLE

This table lists the total steel quantity in pounds for the structural steel.

## 5.23 FOOTING OUTPUT TABLE

### LOAD EFFECTS FOR FOOTING DESIGN/ANALYSIS

List of load effects applied at the top of the pedestal for each load case. The output includes the moments, shears and axial forces on the pedestal. Positive Pz pedestal force is downward. This is opposite of the sign convention for the Post element.

#### 5.23.1 LONG OUTPUT

Selecting output levels 1 and 2 produces additional pages in front of the standard output.

#### **BOTTOM FLEXURAL REINFORCEMENT FOR FOOTING (Footing Design Only)** **TOP FLEXURAL REINFORCEMENT FOR FOOTING (Footing Design Only)**

For the Footing Design Option, after the footing has been sized for the given load cases, the program checks every rebar size starting with a #5 bar for the bottom reinforcement and a #4 bar for the top reinforcement. Only bars with spacing of 3" or greater are included in the table. Also, when both the X and Y bars are controlled by the maximum spacing, larger bar sizes are not printed. The first bar size with spacing of at least 6" is selected as the design bar size. This feature gives the engineer the opportunity to change bar sizes and spacing within the footing.

#### **LOAD COMBINATIONS FOR FOOTING DESIGN (Part 1 of 2)**

This footing output table prints the respective factored load cases, the factored moments, factored axial loads, eccentricities, ratio of eccentricity limit to actual eccentricity, minimum and maximum soil pressures, the ratio of input factored resistance/maximum and the footing contact area percentage. When the percentage is less than 100%, coordinates of the zero-stress line are reported.

#### **LOAD COMBINATIONS FOR FOOTING DESIGN (Part 2 of 2)**

This footing output table prints the respective factored load cases, the horizontal forces applied to the footing, factored sliding resistance, factored sliding force and the ratio of the resistance to the sliding force. This output also includes the weights of the footing, overburden and pedestal along with a schematic of the footing and the corner pressures due to the governing load case.

#### **DESIGN OF BOTTOM FLEXURAL REINFORCEMENT FOR FOOTING WITH GIVEN BAR SIZES** **DESIGN OF TOP FLEXURAL REINFORCEMENT FOR FOOTING WITH GIVEN BAR SIZES**

These footing output tables print the results for the rebar analysis using the design bars. The results of the checking of minimum reinforcement are included with the governing analysis check printed at the bottoms.

### 5.23.2 STANDARD OUTPUT

The remainder of the output is always printed:

#### **FINAL RESULTS FOR FOOTING DESIGN**

Footing length, width and depth (as required by design or as per input if analysis checks are satisfied).

#### **SPREAD FOOTING PRESSURE/SLIDING/ECCENTRICITY RESULTS**

Governing soil pressures (maximum and minimum) and the governing ratios for sliding as well as eccentricity and footing contact area percentages.

#### **SHEAR RESULTS**

Each governing load case is listed for one-way shear in each direction and the load case, which governs punching shear (VP). The Shear capacities, the effective depths used to calculate the capacities, the actual shears, and the ratios of actual / allowable shears are listed.

#### **FLEXURE RESULTS**

Each bar (top x direction, top y direction, bottom x direction, and bottom y direction) is listed along with the governing load cases, the effective depths, applied governing moments, required bar spacing, total required steel area, and the total bars required for the design bar size.

NOTE: X direction is also referred to as the Longitudinal direction and Y direction is also referred to as the Transverse direction.

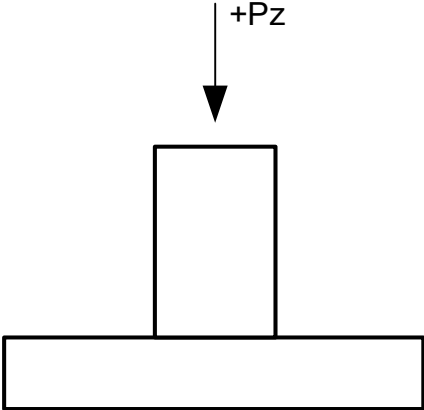
NOTE: Effective depths are calculated using the actual cover and the nominal diameters of the bar. The x bars are assumed to be placed closest to the outside edge with the y bars placed on top of the x bars.

#### **BAR REINFORCING STEEL (FOOTING ONLY)**

The total bar lengths for all bars and respective weights are given in this section.

#### **QUANTITIES**

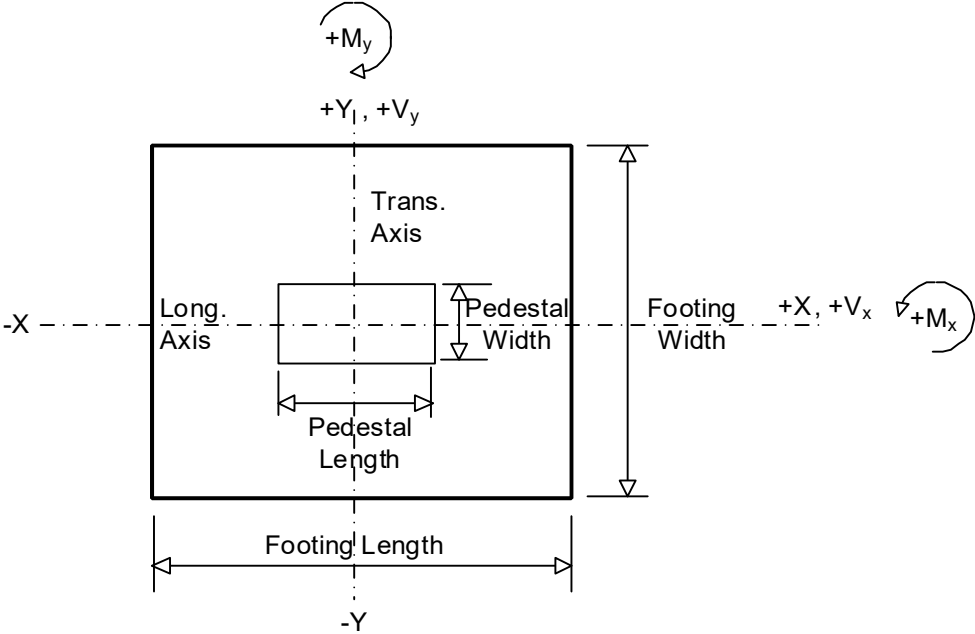
The required excavation for the input cover, the required backfill, and the total volume of concrete along with the total weight of the footing reinforcement are listed in this section. Refer to Section 3.7.7 for information on how the Excavation and Backfill quantities are computed.



Elevation View

Edge of Road

---



X-Axis is Parallel to the Centerline of Roadway

Plan View

**Figure 5.23-1 Footing Sign Convention**

## **6.0 ERROR MESSAGES**

The program prints an error message upon encountering a detectable input error. These messages are self-explanatory. The program checks all input values and lists all error messages for a single input line before terminating. The engineer should correct input errors and resubmit the job for execution.

For the model generation, the program will print an error message if the structure is found to be inadequate in any way. These messages are also self-explanatory. If an error is found during the model and load generation, the program will terminate before attempting to perform the finite element analysis.

If an error is found during the running of SAPV, a dialogue message is displayed with a brief description of the issue and both SNLRFD and EngAsst will exit without any other messages. The SAPV output file will contain information about the issue. Generally, errors during the running of SAPV are system errors that cannot be corrected by changing user input. Follow the instructions in Chapter 7 to submit the input and output files to PennDOT.

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# **7.0 TECHNICAL QUESTIONS AND REVISION REQUESTS**

This chapter contains a reply form to make it easier for users to convey their questions, problems or comments to the proper unit within the Department. General procedures for using these forms are given. Users should keep the form in the manual as a master copy, which can be reproduced as needed. It is also included as a Word template as part of the program installation.

Technical questions related to the interpretations of the design specifications as implemented in this program, why certain assumptions are made, applicability and limitations of this program, and other questions not related to the operation of this program can be directed to the appropriate person in PennDOT using this form or the information provided on the form. Please review the information provided in this User's Manual and the references given in Chapter 1 before submitting this form for processing or calling for assistance.

The form can also be used to report suspected program malfunctions that may require revisions to the program or to request revisions that may be required due to changes in specifications and for the enhancement of the program. Unexpected or incorrect output, rejection of input data, endless program cycling, and program abortion are examples of program malfunctions. Users are requested to review their input data and the program User's Manual before submitting the form for processing.

The form may also be used to submit suggestions for improving the User's Manual for this program. Suggestions might include typographical error correction, clarification of confusing sections, expansion of certain sections, changes in format, and the inclusion of additional information, diagrams, or examples.

The completed form should be sent to the Highway Applications Division via e-mail.

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# Appendix A: SAPV Output Description

This appendix is a description of the SAPV finite element output that accompanies each program runs. Each execution of the program creates a SAPV input file (*<input filename>\_SAPV.inp*) and a SAPV output file (*<input filename>\_SAPV.oui*). **NOTE: Some of the SAPV reports require 132 columns. When using model 5 always print the output using the appropriate 132 column printing option. This option varies dependent on the printer or operating system.**

## A1.1 NODAL POINT INPUT DATA

This section describes all of the node information. Nodes are generated internally within the program.

### NODE NUMBER

Node identification number.

### BOUNDARY CONDITION CODES (X, Y, Z, XX, YY, ZZ)

Fixity of the node for translation and rotation (X, Y, Z represent translation and XX, YY, ZZ represent rotation). If the value is "1", the node is fixed against movement in that global direction. If the value is "0", the node is free to move in that global direction.

### NODAL POINT COORDINATES (X, Y, Z)

The X, Y, Z nodal coordinates represent the global location of the node. The values shown are in inches. The origin for this model is located at the base of the front left post.

### T

This value is not used.

## A1.2 MATERIAL PROPERTIES

This section describes all of the material information. Only one material type is used by the sign structure program.

### **MATERIAL NUMBER**

Material identification number. This value is always "1".

### **YOUNG'S MODULUS**

Modulus of elasticity of the material. This value is set equal to 29000 ksi.

### **POISSON'S RATIO**

Poisson's ration of the material. This value is set equal to 0.3.

### **MASS DENSITY**

VALUES NOT USED BY THIS APPLICATION.

### **WEIGHT DENSITY**

VALUES NOT USED BY THIS APPLICATION. Self-weight of all members is entered as an applied uniform load.

### A1.3 BEAM GEOMETRIC PROPERTIES

This section describes all section property information for all members.

#### SECTION NUMBER

Cross-section identification number.

#### AXIAL AREA A(1)

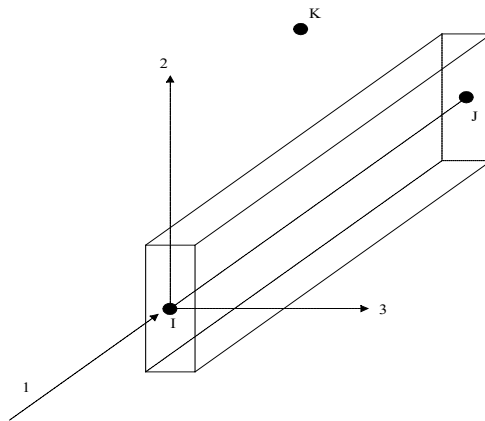
Cross sectional area in  $\text{inch}^2$ .

#### SHEAR AREA A(2)

Shear area associated with the forces in the local 2 direction in  $\text{inch}^2$  (see Figure A1.3-1). This area is for shear deformation effects. For pipes, this value is set to  $(\text{AXIAL AREA} / 2.0)$ . For other sections, this value is set to the  $(\text{DEPTH OF THE WEB} * \text{THICKNESS OF THE WEB})$ .

#### SHEAR AREA A(3)

Shear area associated with the forces in the local 3 direction in  $\text{inch}^2$  (see Figure A1.3-1). This area is for shear deformation effects. For pipes, this value is set to  $(\text{AXIAL AREA} / 2.0)$ . For other sections, this value is set to the  $(\text{DEPTH OF THE FLANGES} * \text{THICKNESS OF THE FLANGES})$ .



**Figure A1.3-1 Local Element Axis**

**TORSION J(1)**

Torsional moment in inch<sup>3</sup>.

**INERTIA I(2)**

Moment of inertia about the local 2 axis in inch<sup>4</sup>.

**INERTIA I(3)**

Moment of inertia about the local 3 axis in inch<sup>4</sup>.

**SECTION MODULUS S(2), S(3)**

These values represent the section moduli of the cross section. Since SAPV is not used to compute stresses, **these values are not entered and are thus always 0.0.**

## A1.4 MEMBER LOADS

This section describes the member load identifications. The loads described in this section are referenced by their **ID** in the **3D BEAM ELEMENT DATA** discussed in the next section.

### ID

Member load identification number.

### ORNT

Orientation of the member load:

0 - Load is in the global direction.

(NOTE: SNLRFD only defines member loads in the global direction. Refer to Figures 3.3-1 through 3.3-13 for the global orientation of each sign Model Type.)

1 - Load is in the local direction.

### DIR

This value represents the force or moment and its direction. See Figure A1.4-1.

1 - FX or F1 - Force in the x or 1 direction.

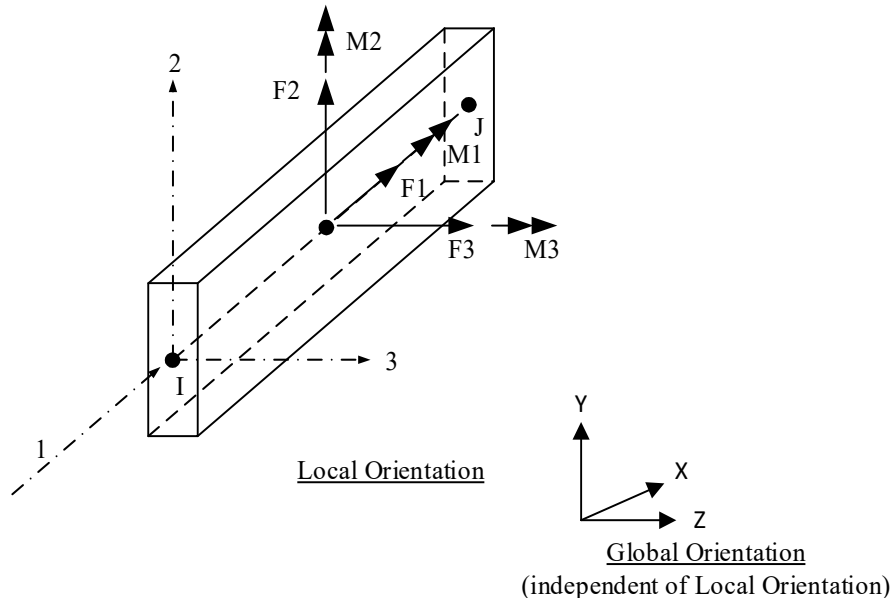
2 - FY or F2 - Force in the y or 2 direction.

3 - FZ or F3 - Force in the z or 3 direction.

4 - MX or M1 - moment in the x or 1 direction.

5 - MY or M2 - moment in the y or 2 direction.

6 - MZ or M3 - moment in the z or 3 direction.



**Figure A1.4-1 Force Orientation**

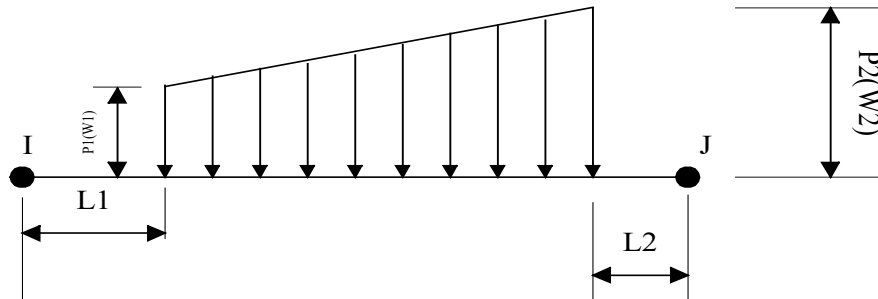
**TYPE**

This value represents the type of load. The following are the possible types:

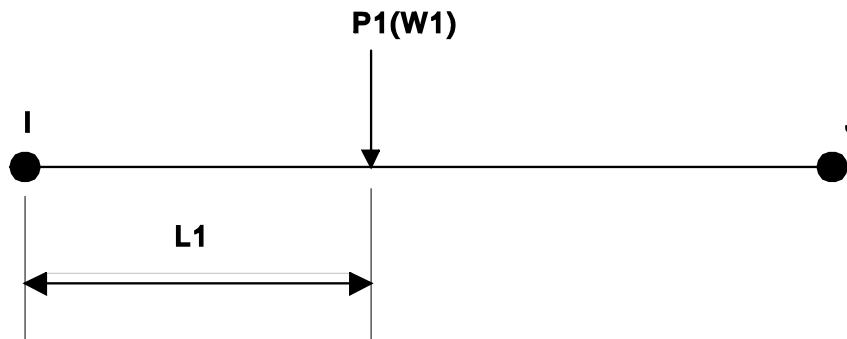
- 1 - Concentrated load.
- 2 - Uniform load.
- 3 - Linearly varying uniform load.

**P1 (W1)**

The magnitude of the load at the starting point for uniform and linearly varying uniform loads in kips/in. See Figure A1.4-2. For concentrated loads, the magnitude of the load in kips. See Figure A1.4-3.



**Figure A1.4-2 Member Load Location for Uniform/Linear Loads**



**Figure A1.4-3 Member Load Location for Concentrated Loads**

**P2 (W2)**

The magnitude of the load at the ending point for uniform and linearly varying uniform loads in kips/in. See Figure A1.4-2. For concentrated loads, this value is ignored.

**L1**

For uniform and linearly varying uniform loads, the starting point location of the load along the member measured from the I node as a ratio of the member length. See Figure A1.4-2. For concentrated loads this is the distance from the I node as a ratio of the member length to the concentrated load. See Figure A1.4-3.

**L2**

For uniform and linearly varying uniform loads, the ending point location of the load along the member measured from the J node as a ratio of the member length. See Figure A1.4-2. For concentrated loads, this value is ignored.

**DESCRIPTION**

Brief description of the type of load. Internally assigned by the program.

### A1.5 3/D BEAM ELEMENT DATA

This section describes the member connectivity and member load information.

#### BEAM NUMBER

Member identification number.

#### NODE I

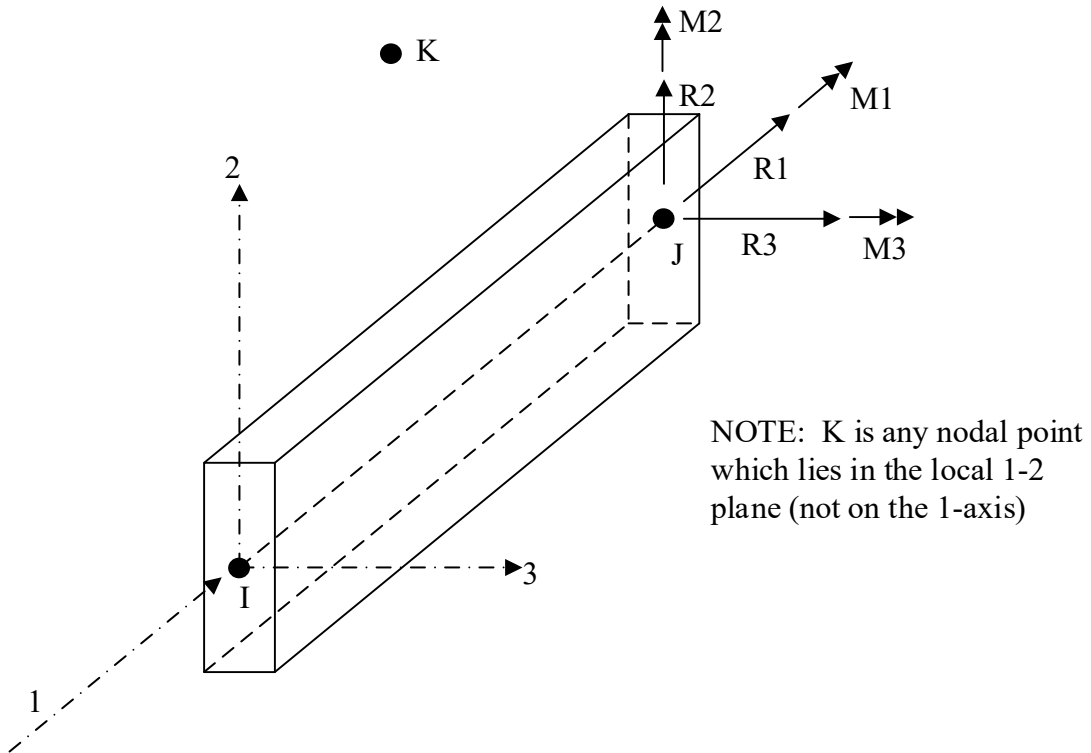
Starting node number of the member (see Figure A1.5-1).

#### NODE J

Ending node number of the member (see Figure A1.5-1).

#### NODE K

Node number defining the orientation of the member in space (see Figure A1.5-1).



**Figure A1.5-1 Local Member Axes**

**MATERIAL NUMBER**

Material identification number. Always equal to "1".

**SECTION NUMBER**

Section identification number.

**ELEMENT END LOADS**

NOT USED BY THIS APPLICATION.

**END CODES (I, J)**

Element end releases at the I and J nodes. Each end of the element is represented by a field width that is six digits wide representing local force components (see Figure A1.5-1), respectively (i.e., column 1 of the field represents R1, column 2 R2, column 3 R3, column 4 M1, column 5 M2, and column 6 M3). If any one of the above element end forces is known to be zero (hinge or roller), the digit corresponding to that component is a one.

**MEMB LOAD**

Number of member loads on this element.

**BAND**

NOT USED IN THIS APPLICATION.

**MEMBER LOAD CASE (line item output)**

The structure load case which to apply the given load id (see **Section A1.6 Structure Loads** for a definition of structure load case).

**LOAD ID (line item output)**

Load identification number. This number refers to **ID** defined in **Section A1.4 Member Loads**.

## A1.6 STRUCTURE LOADS

This section describes the structure load case multiplication factors. *Structure load cases* are load definitions that can be combined in part or in whole with other structure load cases to form a single *load case*. In other words, a *load case* is defined as a combination of *structure load cases*. The total number of *structure load cases* applied to any sign structure is 27 (For a full listing of the *structure load cases* used for the sign structure program, see Table 3.4-4).

### STRUCTURE LOAD CASE

Structure load case number from 1M to 27M.

### ELEMENT LOAD MULTIPLIERS

Load factor applied to each *structure load case* to form a *load case*. The load case identification number shown under the **ELEMENT LOAD MULTIPLIER** heading is the id number that is referenced in the **DISPLACEMENTS/ROTATIONS OF UNRESTAINED NODES** report (see Section A1.7) and in the **BEAM ELEMENTS FORCES AND MOMENTS** report (see Section A1.8). For a full listing of the load cases and their load factors, see the load equations in Table 3.4.-4.

## A1.7 DISPLACEMENT / ROTATIONS OF UNRESTRAINED NODES

This section describes the output for the global nodal displacements.

### LOAD CASE

At the beginning of each new set of displacements is a load case id number. The makeup of this load case is defined in **Section A1.6 STRUCTURE LOADS**.

### NODE NUMBER

Node identification number.

### TRANSLATION (X, Y, Z)

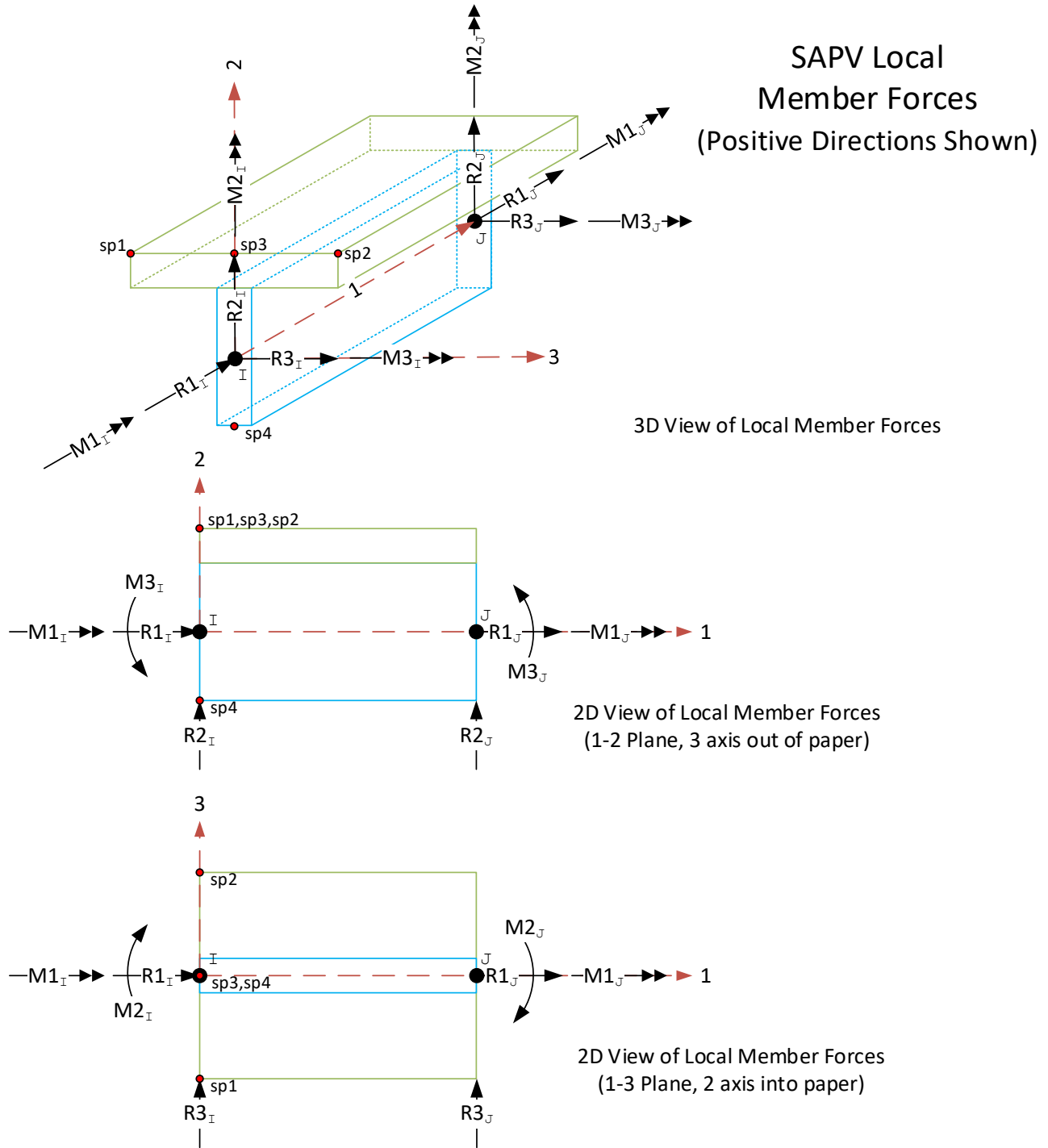
Translation of the node in the global direction measured from the original node location in inches.

### ROTATION (X, Y, Z)

Global rotation of the node measured in radians.

### A1.8 BEAM ELEMENT FORCES AND MOMENTS

This section describes the local member forces and moments. The forces described in the section are represented if Figure A1.8-1.



**Figure A1.8-1 Local Member Forces**

**BEAM NO.**

Member identification number.

**LOAD NO.**

Load case identification number. The makeup of this load case is defined in **Section A1.6 STRUCTURE LOADS**.

**AXIAL R1**

Member axial force in the 1-axis direction in kips. See Figure A1.8-1.

**SHEAR R2**

Shear force in the 2-axis direction in kips. See Figure A1.8-1.

**SHEAR R3**

Shear force in the 3-axis direction in kips. See Figure A1.8-1.

**TORSION M1**

Torsion about the 1-axis in kip-in. See Figure A1.8-1.

**BENDING M2**

Bending moment about the 2-axis in kip-in. See Figure A1.8-1.

**BENDING M3**

Bending moment about the 3-axis in kip-in. See Figure A1.8-1.

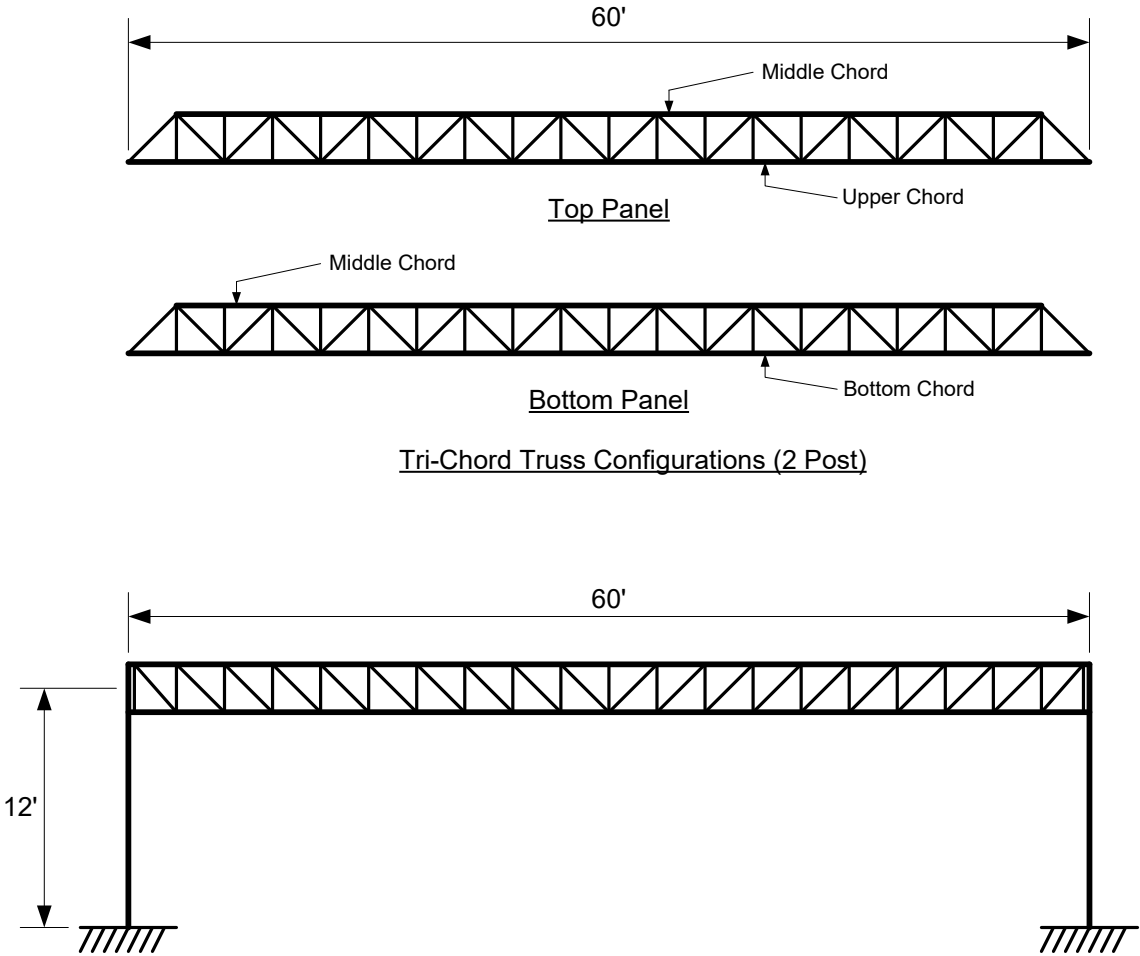
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# ***Appendix B: EXAMPLE PROBLEMS***

The following pages provide a description of the 8 example problems, one for each model type, along with prepared input forms. Prepared input files for each example are provided in the installation folder, and can be run to view output.

**B1.1 EXAMPLE 1**

Example 1 is a two-post tri-chord structure with a height of 12.0 feet and a span length of 60.0 feet as shown in Figure B1.1-1 below.



**Figure B1.1-1 Example 1 Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX1.dat

EXAMPLE 1 - 2-POST TRI-CHORD

60 FT SPAN LENGTH, SIGN HEIGHT 18.5 FT, SIGN AREA 125 SQ.FT.

12 FT STRUCTURE HEIGHT

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
1	12.00	60.00	1	1	20	0.00	0.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	NUMBER OUTPUT	RIGHT STRUT (FT)	PANEL LENGTH (FT)
10	E	2	0	0	0.00	0.000

BEND RADIUS (FT)  
0.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
18.50	125.0	34.80	1.23	0.0		31.0	0.00	-1

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
2.7	400.00	9.92		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CATWALK 1 DESCRIPTION -----

LOCAT (FT)	LENGTH (FT)	OFFSET (FT)	WEIGHT (LBS/FT)	NORMAL AREA (SF/FT)	TRANSVERSE* AREA (SF)	TRUCK-GUST AREA (SF/FT)
0.00	38.18	2.20	49.7	0.99		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION					SECTION Fy (KSI)	PANEL NUMBER
		FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5		
POST	P	10.750	0.500	0.000	0.000	0.000	36.	0
CHORD	P	5.563	0.258	0.000	0.000	0.000	36.	7
CHORD	P	5.563	0.258	0.000	0.000	0.000	36.	13
CHORD	P	5.563	0.258	0.000	0.000	0.000	36.	20
FVERT	ST	1.500	3.750	1.000	0.000	0.000	36.	0
TVERT	ST	1.500	3.750	1.000	0.000	0.000	36.	0
BVERT	ST	1.500	3.750	1.000	0.000	0.000	36.	0
FDIAG	ST	1.500	3.750	1.000	0.000	0.000	36.	0
TDIAG	ST	1.500	3.750	1.000	0.000	0.000	36.	0
BDIAG	ST	1.500	3.750	1.000	0.000	0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)	NUMBER OF BOLT ROWS TOP/BOTTOM FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0.000	0	0.000	0.000	0	0.000	0.000	0

----- CHORD SPLICE 1 -----

SPLICE NAME	PANEL NO.
1	7
2	13

----- PIPE CONNECTION DETAILS -----

CONN TYPE	NUM OF BOLTS	BOLT DIAM (IN)	DIST TO BLT CIR (IN)	SPLICE PL THK (IN)	VENT DIAM (IN)	NUM OF STIF	STIF THK (IN)	STIF WIDTH (IN)	STIF HGHT (IN)	FY (KSI)
S	4	0.875	2.50	2.000	0.00	0	0.000	0.00	0.00	0.

----- LOADS -----

IMP FACTOR	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
3	0.0	0.0	0.0	0.0

----- FOOTING -----

A OR D	INPUT RESISTANCE (KSF)	FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D		6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	2.17	2.17	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG REBAR SIZE	TOP LONG REBAR NO.BARS	TOP TRANS REBAR SIZE	TOP TRANS REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG REBAR SIZE	BOTTOM LONG REBAR NO.BARS	BOTTOM TRANS REBAR SIZE	BOTTOM TRANS REBAR NO.BARS	ULTIMATE TENSILE STRENGTH REBAR (KSI)
0.	0	0.	0	0.0

## Appendix B: Example Problems

```

----- DEFAULT VALUES -----
TRUSS/STRUT TRUSS HEIGHT POST RIGHT BEND
HEIGHT DEPTH Z FIXITY STRUT DMS RADIUS
(FT) (FT) (FT) (FT) (FT) (FT)
2.75 2.38 ----- -- ---- N ---

SIGN 1 SUPP SIGN 2 SUPP SIGN 3 SUPP SIGN 1 SIGN 2 SIGN 3
BEAM WT BEAM WT BEAM WT PANEL WT PANEL WT PANEL WT
(LBS/FT) (LBS/FT) (LBS/FT) (PSF) (PSF) (PSF)
---- ---- ---- 2.848 --- ---

NUMBER OF LUMINAIRES MEAN WIND VEHICLE BAS WIND SRV WIND NUMBER OF
SIGN 1 SIGN 2 SIGN 3 SPEED DES SPEED SPEED SPEED U-BOLTS
(MPH) (MPH) (MPH) (MPH)
1 --- --- 11.2 65.0 120.0 76.0 1

DIST TO CONNECTION YIELD INPUT FACTORED CONC CONCRETE FILL COEFF
BLT CIR SPLICE END A OR D RESISTANCE F'c DENSITY DENSITY FRICTION
(IN) (KSI) (KSI) (KSI) (PSI) (PCF) (PCF)
----- 36. --- --- --- 3000. 150. 100. ---

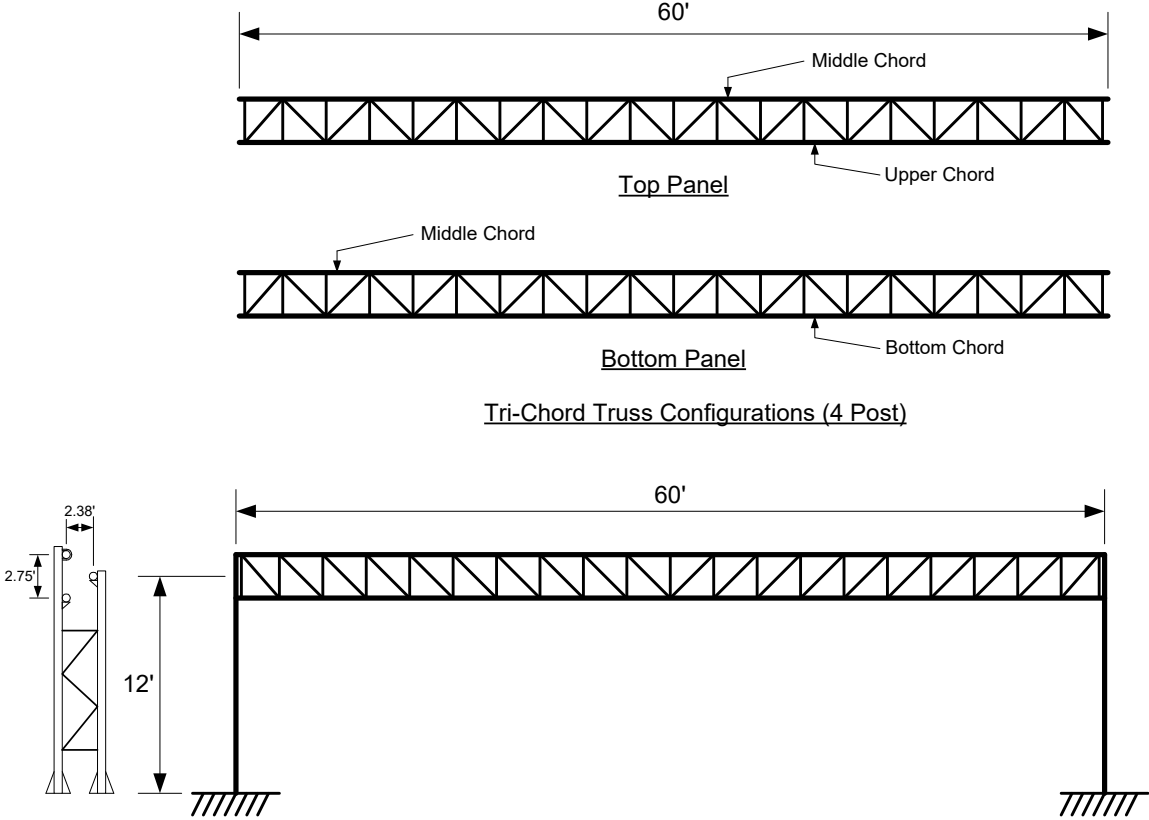
FOOTING FOOTING FOOTING FOOTING FOOTING
MIN THK MAX THK WIDTH LENGTH MAX WIDTH
(FT) (FT) (FT) (FT) (FT)
--- 5.00 5.00 5.00 50.00

REBAR COVER COVER ULTIMATE TENSILE
GRADE TOP BOTTOM STRENGTH REBAR
(KSI) (IN) (IN) (KSI)
60. 3.00 4.00 90.0

```

**B1.2 EXAMPLE 2**

Example 2 is a four-post tri-chord structure with a height of 12.0 feet and a span length of 60.0 feet as shown in Figure B1.2-1 below.



Tri-Chord Truss Configurations (4 Post)

**Figure B1.2-1 Example 2 Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX2.dat

EXAMPLE 2 - 4-POST TRI-CHORD  
 60 FT SPAN LENGTH, SIGN HEIGHT 18.5 FT, SIGN AREA 125 SQ.FT.  
 12 FT STRUCTURE HEIGHT

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
2	12.00	60.00	1	1	20	0.00	0.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	NUMBER OUTPUT	RIGHT STRUT (FT)	DMS	PANEL LENGTH (FT)
11	E	2	0	0	0.00		0.000

BEND RADIUS (FT)  
0.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
18.50	125.0	34.80	1.23	0.0		31.0	0.00	-1

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
2.7	400.00	9.92		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CATWALK 1 DESCRIPTION -----

LOCAT (FT)	LENGTH (FT)	OFFSET (FT)	WEIGHT (LBS/FT)	NORMAL AREA (SF/FT)	TRANSVERSE* AREA (SF)	TRUCK-GUST AREA (SF/FT)
0.00	38.18	2.20	49.7	0.99		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5	SECTION Fy (KSI)	PANEL NUMBER
POST	P	8.625	0.322	0.000	0.000	0.000	36.	0
CHORD	P	5.563	0.258	0.000	0.000	0.000	36.	7
CHORD	P	5.563	0.258	0.000	0.000	0.000	36.	13
CHORD	P	5.563	0.258	0.000	0.000	0.000	36.	20
PXBRAC	ST	2.000	4.750	1.000	0.000	0.000	36.	0
FVERT	ST	1.500	3.750	1.000	0.000	0.000	36.	0
TVERT	ST	1.500	2.850	1.000	0.000	0.000	36.	0
BVERT	ST	1.500	2.850	1.000	0.000	0.000	36.	0
FDIAG	ST	1.500	2.850	1.000	0.000	0.000	36.	0
TDIAG	ST	1.500	2.850	1.000	0.000	0.000	36.	0
BDIAG	ST	1.500	2.850	1.000	0.000	0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)	NUMBER OF BOLT ROWS TOP/BOTTOM FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0.000	0	0.000	0.000	0	0.000	0.000	0

----- CHORD SPLICE 1 -----

SPLICE NAME	PANEL NO.
1	7
2	13

----- PIPE CONNECTION DETAILS -----

CONN TYPE	NUM OF BOLTS	BOLT DIAM (IN)	DIST TO BLT CIR (IN)	SPLICE PL THK (IN)	VENT DIAM (IN)	NUM OF STIF	STIF THK (IN)	STIF WIDTH (IN)	STIF HGHT (IN)	FY (KSI)
S	4	0.875	2.50	2.000	0.00	0	0.000	0.00	0.00	0.

----- LOADS -----

IMP FACTOR CATGY	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
3	0.0	0.0	0.0	0.0

----- FOOTING -----

A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D	6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	7.67	2.50	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG REBAR SIZE	TOP LONG REBAR NO.BARS	TOP TRANS REBAR SIZE	TOP TRANS REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG REBAR SIZE	BOTTOM LONG REBAR NO.BARS	BOTTOM TRANS REBAR SIZE	BOTTOM TRANS REBAR NO.BARS	ULTIMATE TENSILE STRENGTH REBAR (KSI)
0.	0	0.	0	0.0

**Appendix B: Example Problems**

```

----- DEFAULT VALUES -----
TRUSS/STRUT TRUSS HEIGHT POST RIGHT BEND
HEIGHT DEPTH Z FIXITY STRUT DMS RADIUS
(FT) (FT) (FT) (FT) (FT) (FT)
2.75 2.38 ----- -- ---- N ---

SIGN 1 SUPP SIGN 2 SUPP SIGN 3 SUPP SIGN 1 SIGN 2 SIGN 3
BEAM WT BEAM WT BEAM WT PANEL WT PANEL WT PANEL WT
(LBS/FT) (LBS/FT) (LBS/FT) (PSF) (PSF) (PSF)
---- ---- ---- 2.848 --- ---

NUMBER OF LUMINAIRES MEAN WIND VEHICLE BAS WIND SRV WIND NUMBER OF
SIGN 1 SIGN 2 SIGN 3 SPEED DES SPEED SPEED SPEED U-BOLTS
(MPH) (MPH) (MPH) (MPH)
1 --- --- 11.2 65.0 120.0 76.0 2

DIST TO CONNECTION YIELD INPUT FACTORED CONC CONCRETE FILL COEFF
BLT CIR SPLICE END A OR D RESISTANCE F'c DENSITY DENSITY FRICTION
(IN) (KSI) (KSI) (KSI) (PSI) (PCF) (PCF)
----- 36. --- --- --- 3000. 150. 100. ---

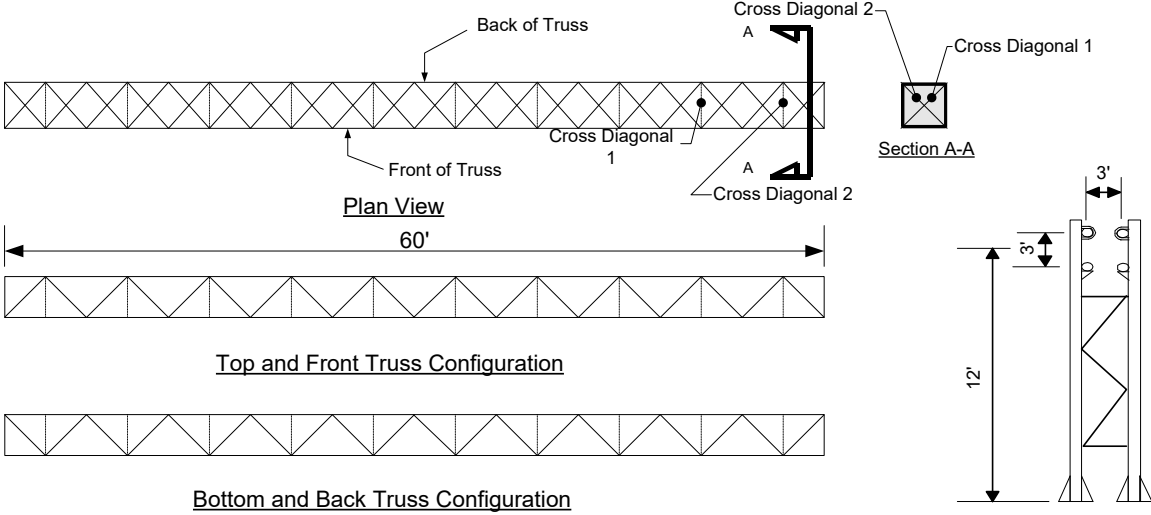
FOOTING FOOTING FOOTING FOOTING FOOTING
MIN THK MAX THK WIDTH LENGTH MAX WIDTH
(FT) (FT) (FT) (FT) (FT)
--- 5.00 5.00 10.00 50.00

REBAR COVER COVER ULTIMATE TENSILE
GRADE TOP BOTTOM STRENGTH REBAR
(KSI) (IN) (IN) (KSI)
60. 3.00 4.00 90.0

```

**B1.3 EXAMPLE 3**

Example 3 is a four post four-chord structure with a height of 12.0 feet and a span length of 100.0 feet as shown in Figure B1.3-1 below.



**Figure B1.3-1 Example 3 Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX3.dat

EXAMPLE 3 - 4-POST 4-CHORD

100 FT SPAN LENGTH, SIGN HEIGHT 18.5 FT, SIGN AREA 200 SQ.FT.

12 FT STRUCTURE HEIGHT

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
3	12.00	100.00	1	1	26	4.00	4.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	OUTPUT	RIGHT STRUT (FT)	DMS	PANEL LENGTH (FT)
14	E	2	0	1	0.00		0.000

BEND RADIUS (FT)  
0.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
18.50	200.0	58.00	1.14	0.0		25.0	0.00	-1

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
7.1	400.00	9.92		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CATWALK 1 DESCRIPTION -----

LOCAT (FT)	LENGTH (FT)	OFFSET (FT)	WEIGHT (LBS/FT)	NORMAL AREA (SF/FT)	TRANSVERSE* AREA (SF)	TRUCK-GUST AREA (SF/FT)
0.00	67.41	2.60	54.4	1.15		0.59

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

Appendix B: Example Problems

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION					SECTION Fy (KSI)	PANEL NUMBER
		FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5		
POST	P	10.750	0.365	0.000	0.000	0.000	36.	0
CHORD	P	6.625	0.280	0.000	0.000	0.000	36.	8
CHORD	P	6.625	0.280	0.000	0.000	0.000	36.	18
CHORD	P	6.625	0.280	0.000	0.000	0.000	36.	26
PXBRAC	ST	2.000	3.850	1.100	0.000	0.000	36.	0
FVERT	P	2.875	0.203	0.000	0.000	0.000	36.	0
TVERT	P	2.875	0.203	0.000	0.000	0.000	36.	0
BVERT	P	2.875	0.203	0.000	0.000	0.000	36.	0
RVERT	P	2.875	0.203	0.000	0.000	0.000	36.	0
FDIAG	P	2.875	0.203	0.000	0.000	0.000	36.	0
TDIAG	P	2.875	0.203	0.000	0.000	0.000	36.	0
BDIAG	P	2.875	0.203	0.000	0.000	0.000	36.	0
RDIAG	P	2.875	0.203	0.000	0.000	0.000	36.	0
TXBRAC	P	2.875	0.203	0.000	0.000	0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)	NUMBER OF BOLT ROWS TOP/BOTTOM FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0.000	0	0.000	0.000	0	0.000	0.000	0

----- CHORD SPLICE 1 -----

SPLICE NAME	PANEL NO.
1	8
2	18

----- PIPE CONNECTION DETAILS -----

CONN TYPE	NUM OF BOLTS	BOLT DIAM (IN)	DIST TO BLT CIR (IN)	SPLICE PL THK (IN)	VENT DIAM (IN)	NUM OF STIF	STIF THK (IN)	STIF WIDTH (IN)	STIF HGHT (IN)	FY (KSI)
S	4	0.875	2.50	2.000	0.00	0	0.000	0.00	0.00	0.

----- LOADS -----

IMP FACTOR CATGY	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
2	0.0	0.0	0.0	0.0

Appendix B: Example Problems

----- FOOTING -----

A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D	6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	9.75	2.75	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG REBAR SIZE	TOP LONG REBAR NO.BARS	TOP TRANS REBAR SIZE	TOP TRANS REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG REBAR SIZE	BOTTOM LONG REBAR NO.BARS	BOTTOM TRANS REBAR SIZE	BOTTOM TRANS REBAR NO.BARS	ULTIMATE TENSILE STRENGTH REBAR (KSI)
0.	0	0.	0	0.0

----- DEFAULT VALUES -----

TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY	RIGHT STRUT (FT)	DMS	BEND RADIUS (FT)
---	---	-----	--	----	N	---

SIGN 1 SUPP BEAM WT (LBS/FT)	SIGN 2 SUPP BEAM WT (LBS/FT)	SIGN 3 SUPP BEAM WT (LBS/FT)	SIGN 1 PANEL WT (PSF)	SIGN 2 PANEL WT (PSF)	SIGN 3 PANEL WT (PSF)
----	----	----	2.848	---	---

SIGN 1	SIGN 2	SIGN 3	MEAN WIND SPEED (MPH)	VEHICLE DES SPEED (MPH)	BAS WIND SPEED (MPH)	SRV WIND SPEED (MPH)	NUMBER OF U-BOLTS
1	---	---	11.2	65.0	120.0	76.0	2

DIST TO BLT CIR (IN)	CONNECTION SPLICE (KSI)	YIELD END (KSI)	A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION
-----	36.	---	---	---	3000.	150.	100.	---

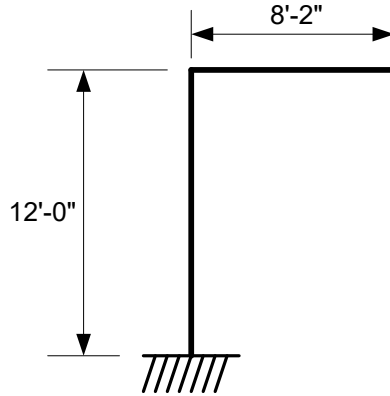
FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
---	5.00	5.00	12.00	50.00

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	ULTIMATE TENSILE STRENGTH REBAR (KSI)
60.	3.00	4.00	90.0

**B1.4 EXAMPLE 4**

Example 4 is a cantilever structure with a height of 12.0 feet and a cantilever length of 8'-2" as shown in Figure B1.4-1 below.



**Figure B1.4-1 Example 4 Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX4.dat

EXAMPLE 4 - CANTILEVER

SPAN LENGTH 8 FT 2 IN, SIGN HEIGHT 12 FT, SIGN AREA 100 SQ.FT  
STRUCTURE HEIGHT 12 FT

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
4	12.00	8.17	1	0	0	0.00	0.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	NUMBER OUTPUT	RIGHT STRUT (FT)	PANEL LENGTH (FT)
2		0	0	0	0.00	0.000

BEND RADIUS (FT)  
0.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
12.00	100.0	4.00	1.36	0.0		31.0	0.00	-1

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
2.9	400.00	9.92		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION	SECTION Fy (KSI)	PANEL NUMBER
POST	P	FIELD 1: 10.750 FIELD 2: 0.365 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0
CHORD	P	FIELD 1: 6.625 FIELD 2: 0.365 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)
0.000	0	0.000	0.000

NUMBER OF BOLT ROWS FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0	0.000	0.000	0

Appendix B: Example Problems

----- LOADS -----

IMP FACTOR CATGY	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
2	0.0	0.0	0.0	0.0

----- FOOTING -----

A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D	6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	2.17	2.17	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG SIZE	REBAR NO.BARS	TOP TRANS SIZE	REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG SIZE	REBAR NO.BARS	BOTTOM TRANS SIZE	REBAR NO.BARS	ULTIMATE TENSILE STRENGTH (KSI)
0.	0	0.	0	0.0

----- DEFAULT VALUES -----

TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY	RIGHT STRUT (FT)	DMS	BEND RADIUS (FT)
---	---	-----	--	----	N	---

SIGN 1 SUPP BEAM WT (LBS/FT)	SIGN 2 SUPP BEAM WT (LBS/FT)	SIGN 3 SUPP BEAM WT (LBS/FT)	SIGN 1 PANEL WT (PSF)	SIGN 2 PANEL WT (PSF)	SIGN 3 PANEL WT (PSF)
----	----	----	2.848	---	---

NUMBER OF SIGN 1	LUMINAIRES SIGN 2	SIGN 3	MEAN WIND SPEED (MPH)	VEHICLE DES SPEED (MPH)	BAS WIND SPEED (MPH)	SRV WIND SPEED (MPH)	NUMBER OF U-BOLTS
1	---	---	11.2	65.0	120.0	76.0	1

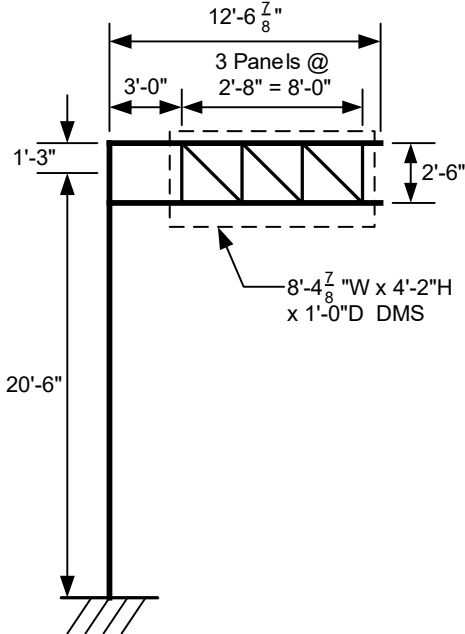
DIST TO BLT CIR (IN)	CONNECTION SPLICE (KSI)	YIELD END (KSI)	A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION
-----	---	---	---	---	3000.	150.	100.	---

FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
---	5.00	5.00	5.00	50.00

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	ULTIMATE TENSILE STRENGTH (KSI)
60.	3.00	4.00	90.0

**B1.4A EXAMPLE 4A**

Example 4a is a cantilever structure supporting a dynamic message sign (DMS). The structure height is 20'-6" with a cantilever length of 8'-2" as shown in Figure B1.4a-1 below.



**Figure B1.4a-1 Example 4a Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX4A.dat

EXAMPLE 4A - DMS CANTILEVER

STRUCTURE HEIGHT: 20'-6", SIGN HEIGHT: 4'-2", SIGN AREA: 35.03 FT^2

SPAN LENGTH: 12'-6 7/8"

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
4	20.50	12.57	1	0	3	2.50	0.00	0.0	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	OUTPUT	RIGHT STRUT (FT)	DMS	PANEL LENGTH (FT)
4	E	0	1	0	0.00	Y	2.667

BEND RADIUS (FT)  
0.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
4.17	35.0	7.67	1.51	8.4		15.0	31.40	0

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
0.0	0.00	0.00		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION	SECTION Fy (KSI)	PANEL NUMBER
POST	P	FIELD 1: 16.000, FIELD 2: 0.375, FIELD 3: 0.000, FIELD 4: 0.000, FIELD 5: 0.000	36.	0
CHORD	P	FIELD 1: 6.625, FIELD 2: 0.280, FIELD 3: 0.000, FIELD 4: 0.000, FIELD 5: 0.000	36.	0
FVERT	P	FIELD 1: 2.375, FIELD 2: 0.218, FIELD 3: 0.000, FIELD 4: 0.000, FIELD 5: 0.000	36.	0
FDIAG	P	FIELD 1: 2.375, FIELD 2: 0.154, FIELD 3: 0.000, FIELD 4: 0.000, FIELD 5: 0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)
0.000	0	0.000	0.000

NUMBER OF BOLT ROWS	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0	0.000	0.000	0

----- PIPE CONNECTION DETAILS -----

CONN TYPE	NUM OF BOLTS	BOLT DIAM (IN)	DIST TO BLT CIR (IN)	SPLICE PL THK (IN)	VENT DIAM (IN)	NUM OF STIF STIF	STIF THK (IN)	STIF WIDTH (IN)	STIF HGHT (IN)	FY (KSI)
S	8	0.875	2.69	2.000	0.00	0	0.000	0.00	0.00	0.

----- LOADS -----

IMP FACTOR CATGY	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
1	0.0	0.0	0.0	0.0

----- FATIGUE DETAIL -----

DETAIL NUMBER	Threshold (CAFT) (KSI)	WEEPHOLE NET AREA (SI)	WIRE OUT NET AREA (SI)	HANDHOLE NET AREA (SI)	CHORD/POST /BRANCH
3.2	4.50	0.00	0.00	1.12	P

----- FOOTING -----

A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D	0.00	0.	0.0	0.0	0.00	3.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
2.00	2.50	2.50	0.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG REBAR SIZE	TOP LONG REBAR NO.BARS	TOP TRANS REBAR SIZE	TOP TRANS REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG REBAR SIZE	BOTTOM LONG REBAR NO.BARS	BOTTOM TRANS REBAR SIZE	BOTTOM TRANS REBAR NO.BARS	ULTIMATE TENSILE STRENGTH REBAR (KSI)
0.	0	0.	0	0.0

**Appendix B: Example Problems**

```

----- DEFAULT VALUES -----
TRUSS/STRUT TRUSS HEIGHT POST RIGHT BEND
HEIGHT DEPTH Z FIXITY STRUT DMS RADIUS
(FT) (FT) (FT) (FT) (FT) (FT)
--- --- 20.5 -- ---- - ---

SIGN 1 SUPP SIGN 2 SUPP SIGN 3 SUPP SIGN 1 SIGN 2 SIGN 3
BEAM WT BEAM WT BEAM WT PANEL WT PANEL WT PANEL WT
(LBS/FT) (LBS/FT) (LBS/FT) (PSF) (PSF) (PSF)
---- ---- ---- --- --- ---

NUMBER OF LUMINAIRES MEAN WIND VEHICLE BAS WIND SRV WIND NUMBER OF
SIGN 1 SIGN 2 SIGN 3 SPEED DES SPEED SPEED SPEED U-BOLTS
(MPH) (MPH) (MPH) (MPH)
--- --- --- 11.2 65.0 120.0 76.0 1

DIST TO CONNECTION YIELD INPUT FACTORED CONC CONCRETE FILL COEFF
BLT CIR SPLICE END A OR D RESISTANCE F'c DENSITY DENSITY FRICTION
(IN) (KSI) (KSI) (KSI) (KSI) (PSI) (PCF) (PCF)
----- 36. --- --- 6.0 3000. 150. 100. 0.25

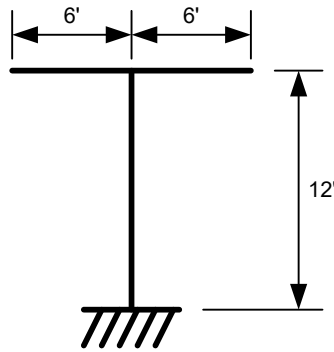
FOOTING FOOTING FOOTING FOOTING FOOTING
MIN THK MAX THK WIDTH LENGTH MAX WIDTH
(FT) (FT) (FT) (FT) (FT)
2.00 5.00 5.00 5.00 50.00

REBAR COVER COVER ULTIMATE TENSILE
GRADE TOP BOTTOM STRENGTH REBAR
(KSI) (IN) (IN) (KSI)
60. 3.00 4.00 90.0

```

**B1.5 EXAMPLE 5**

Example 5 is a centermount structure with a height of 12.0 feet and a cantilever length of 6.0 feet on each side as shown in Figure B1.5-1 below.



**Figure B1.5-1 Example 5 Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX5.dat

EXAMPLE 5 - CENTERMOUNT

STRUCTURE HEIGHT: 12'-0", SIGN HEIGHT: 8'-4", SIGN AREA: 100 SQFT  
 CANTILEVER LENGTH: 6'-0" (LEFT AND RIGHT)

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
5	12.00	6.00	1	0	0	0.00	0.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	NUMBER OUTPUT	RIGHT STRUT (FT)	DMS	PANEL LENGTH (FT)
2		0	0	1	6.00		0.000

BEND RADIUS (FT)  
0.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
8.33	100.0	6.00	1.27	0.0		31.0	0.00	-1

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
6.0	200.00	1.10		3.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION	SECTION Fy (KSI)	PANEL NUMBER
POST	P	FIELD 1: 10.750 FIELD 2: 0.365 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0
CHORD	P	FIELD 1: 4.500 FIELD 2: 0.237 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)
0.000	0	0.000	0.000

NUMBER OF BOLT ROWS FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0	0.000	0.000	0

Appendix B: Example Problems

----- LOADS -----

IMP FACTOR	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
2	0.0	0.0	0.0	0.0

----- FOOTING -----

A OR D	INPUT RESISTANCE (KSF)	FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D		6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	2.17	2.17	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP SIZE	LONG NO.BARS	REBAR NO.	TOP SIZE	TRANS NO.BARS	REBAR NO.
0.	0.00	0.00	0.	0		0.	0	

BOTTOM SIZE	LONG NO.BARS	BOTTOM SIZE	TRANS NO.BARS	REBAR NO.	ULTIMATE TENSILE STRENGTH (KSI)
0.	0	0.	0		0.0

----- DEFAULT VALUES -----

TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY	RIGHT STRUT (FT)	DMS	BEND RADIUS (FT)
---	---	-----	--	----	N	---

SIGN 1 BEAM WT (LBS/FT)	SUPP BEAM WT (LBS/FT)	SIGN 2 BEAM WT (LBS/FT)	SUPP BEAM WT (LBS/FT)	SIGN 3 BEAM WT (LBS/FT)	SIGN 1 PANEL WT (PSF)	SIGN 2 PANEL WT (PSF)	SIGN 3 PANEL WT (PSF)
----	----	----	----	----	2.848	---	---

SIGN 1	SIGN 2	SIGN 3	MEAN WIND SPEED (MPH)	VEHICLE DES SPEED (MPH)	BAS WIND SPEED (MPH)	SRV WIND SPEED (MPH)	NUMBER OF U-BOLTS
1	---	---	11.2	65.0	120.0	76.0	1

DIST TO BLT CIR (IN)	CONNECTION SPLICE (KSI)	YIELD END (KSI)	A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION
-----	---	---	---	---	3000.	150.	100.	---

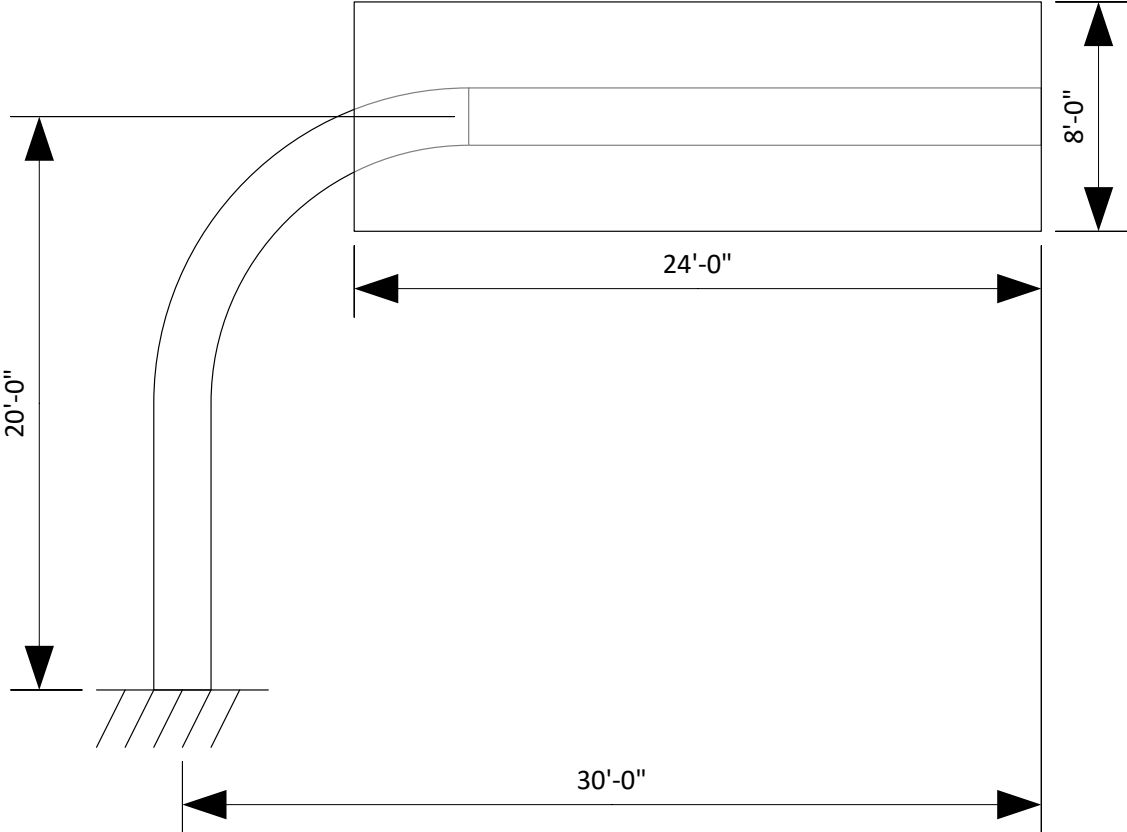
FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
---	5.00	5.00	5.00	50.00

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	ULTIMATE TENSILE STRENGTH (KSI)
60.	3.00	4.00	90.0

**B1.6 EXAMPLE 6**

Example 6 is a cantilever monopipe structure with a height of 20.0 feet and a cantilever length of 30.0 feet as shown in Figure B1.6-1 below.



**Figure B1.6-1 Example 6 Sketch**

Complete input for this example is shown on the following pages.

**Appendix B: Example Problems**

INPUT: EX6.dat

EXAMPLE 6 - CANTILEVER MONOPIPE  
 STRUCTURE HEIGHT: 20 FT, SPAN LENGTH 30 FT  
 SIGN HEIGHT: 8 FT, SIGN AREA: 192 FT^2

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
6	20.00	30.00	1	0	0	0.00	0.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	NUMBER OUTPUT	RIGHT STRUT (FT)	DMS	PANEL LENGTH (FT)
2	E	0	0	0	0.00	N	0.000

BEND RADIUS (FT)  
10.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
8.00	192.0	18.00	3.00	0.0		1.0	26.04	0

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
2.9	400.00	9.92		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION	SECTION Fy (KSI)	PANEL NUMBER
POST	P	FIELD 1: 24.000 FIELD 2: 0.688 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0
CHORD	P	FIELD 1: 24.000 FIELD 2: 0.375 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)	NUMBER OF BOLT ROWS TOP/BOTTOM FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0.000	0	0.000	0.000	0	0.000	0.000	0

----- PIPE CONNECTION DETAILS -----

CONN TYPE	NUM OF BOLTS	BOLT DIAM (IN)	DIST TO BLT CIR (IN)	SPLICE PL THK (IN)	VENT DIAM (IN)	NUM OF STIF	STIF THK (IN)	STIF WIDTH (IN)	STIF HGHT (IN)	FY (KSI)
E	16	1.375	3.75	2.000	18.00	8	0.375	8.50	24.50	0.

----- LOADS -----

IMP FACTOR CATGY	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
2	0.0	0.0	0.0	0.0

----- FOOTING -----

A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D	6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	2.17	2.17	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG REBAR SIZE	TOP LONG REBAR NO.BARS	TOP TRANS REBAR SIZE	TOP TRANS REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG REBAR SIZE	BOTTOM LONG REBAR NO.BARS	BOTTOM TRANS REBAR SIZE	BOTTOM TRANS REBAR NO.BARS	ULTIMATE TENSILE STRENGTH REBAR (KSI)
0.	0	0.	0	0.0

**Appendix B: Example Problems**

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----- DEFAULT VALUES -----
TRUSS/STRUT TRUSS HEIGHT POST RIGHT BEND
HEIGHT DEPTH Z FIXITY STRUT DMS RADIUS
(FT) (FT) (FT) -- (FT) - (FT)
---

SIGN 1 SUPP SIGN 2 SUPP SIGN 3 SUPP SIGN 1 SIGN 2 SIGN 3
BEAM WT BEAM WT BEAM WT PANEL WT PANEL WT PANEL WT
(LBS/FT) (LBS/FT) (LBS/FT) (PSF) (PSF) (PSF)
----

NUMBER OF LUMINAIRES MEAN WIND VEHICLE BAS WIND SRV WIND NUMBER OF
SIGN 1 SIGN 2 SIGN 3 SPEED DES SPEED SPEED SPEED U-BOLTS
(MPH) (MPH) (MPH) (MPH)
--- --- --- 11.2 65.0 120.0 76.0 1

DIST TO CONNECTION YIELD INPUT FACTORED CONC CONCRETE FILL COEFF
BLT CIR SPLICE END A OR D RESISTANCE F'c DENSITY DENSITY FRICTION
(IN) (KSI) (KSI) --- (KSF) (PSI) (PCF) (PCF) ---
----- 36. --- --- 3000. 150. 100. ---

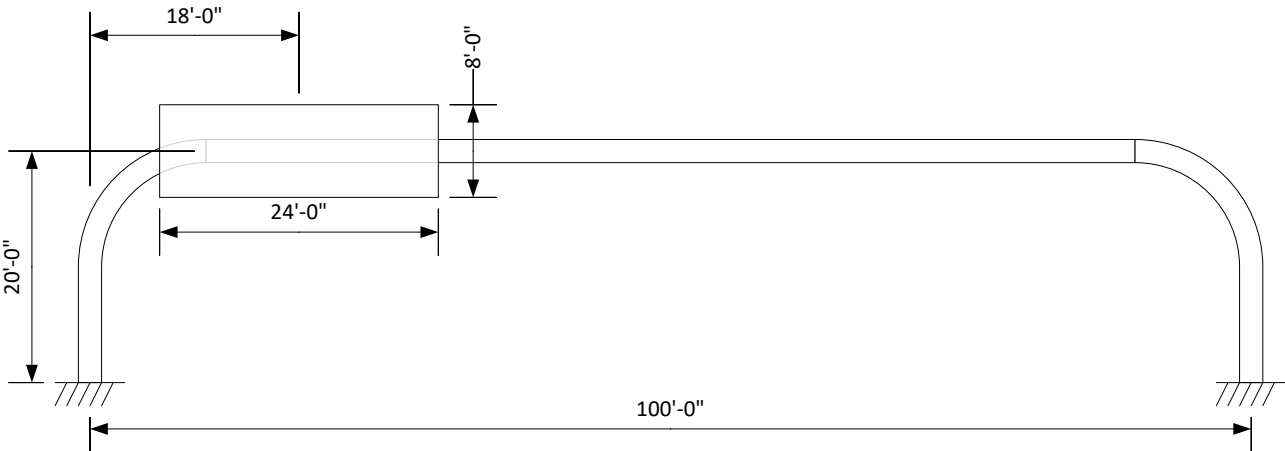
FOOTING FOOTING FOOTING FOOTING FOOTING
MIN THK MAX THK WIDTH LENGTH MAX WIDTH
(FT) (FT) (FT) (FT) (FT)
--- 5.00 5.00 5.00 50.00

REBAR COVER COVER ULTIMATE TENSILE
GRADE TOP BOTTOM STRENGTH REBAR
(KSI) (IN) (IN) (KSI)
60. 3.00 4.00 90.0

```

**B1.7 EXAMPLE 7**

Example 7 is a monopipe frame structure with a height of 20.0 feet and a span length of 100.0 feet as shown in Figure B1.7-1 below.



**Figure B1.7-1 Example 7 Sketch**

Complete input for this example is shown on the following pages.

Appendix B: Example Problems

INPUT: EX7.dat

EXAMPLE 7 - MONOPIPE FRAME

STRUCTURE HEIGHT: 20 FT, SPAN LENGTH: 100 FT

SIGN HEIGHT: 8 FT, SIGN AREA: 192 FT^2

----- CRITERIA -----

MODEL TYPE	STRUCT HEIGHT (FT)	SPAN/CANT LENGTH (FT)	NUMBER SIGNS	NUMBER CATWLK	NUMBER PANELS	TRUSS/STRUT HEIGHT (FT)	TRUSS DEPTH (FT)	HEIGHT Z (FT)	POST FIXITY
7	20.00	100.00	1	0	0	0.00	0.00	44.5	F

NUMBER X-SECT	NEW OR EXISTING CHORD SPLICE	NUM CHD SPLICE	NUMBER OF DET	NUMBER OUTPUT	RIGHT STRUT (FT)	DMS	PANEL LENGTH (FT)
2	E	2	4	2	0.00	N	0.000

BEND RADIUS (FT)  
10.000

----- SIGN 1 DESCRIPTION -----

HEIGHT (FT)	AREA (SF)	LOCAT (FT)	OFFSET (FT)	HORIZONTAL PROJ. AREA (SF)	TRANSVERSE* PROJ. AREA (SF)	SUPPORT BEAM WT (LBS/FT)	PANEL WT (PSF)	NUM OF LUMIN.
8.00	192.0	18.00	3.00	0.0		1.0	26.04	0

LUMINAIRE OFFSET (FT)	LUMINAIRE WEIGHT (LBS)	LUMIN NORMAL AREA (SF)	LUMIN* TRANSV. AREA (SF)	TRUCK-GUST ON LUMIN AREA (SF)
2.9	400.00	9.92		0.00

\* INPUT ITEM CURRENTLY NOT USED BY THE PROGRAM

----- CROSS SECTION DEFINITION -----

SECTION LOCATION	SECTION TYPE	SECTION DESCRIPTION	SECTION Fy (KSI)	PANEL NUMBER
POST	P	FIELD 1: 24.000 FIELD 2: 0.688 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0
CHORD	P	FIELD 1: 24.000 FIELD 2: 0.375 FIELD 3: 0.000 FIELD 4: 0.000 FIELD 5: 0.000	36.	0

----- BOLTED CONNECTIONS -----

BOLT DIAMETER (IN)	NUMBER OF BOLT ROWS WEB	CON PL WID FRONT/REAR (IN)	CON PL THK FRONT/REAR (IN)	NUMBER OF BOLT ROWS TOP/BOTTOM FLANGE	CON PL WID TOP/BOTTOM (IN)	CON PL THK TOP/BOTTOM (IN)	NUM OF U-BLTS
0.000	0	0.000	0.000	0	0.000	0.000	0

----- PIPE CONNECTION DETAILS -----

CONN TYPE	NUM OF BOLTS	BOLT DIAM (IN)	DIST TO BLT CIR (IN)	SPLICE PL THK (IN)	VENT DIAM (IN)	NUM OF STIF	STIF THK (IN)	STIF WIDTH (IN)	STIF HGHT (IN)	FY (KSI)
S	24	1.125	2.50	2.000	0.00	0	0.000	0.00	0.00	0.
E	20	1.125	2.25	2.000	0.00	0	0.000	0.00	0.00	0.

----- LOADS -----

IMP FACTOR CATGY	MEAN WIND SPEED (MPH)	VEHICLE DESIGN SPEED (MPH)	BASIC WIND SPEED (MPH)	SERVICE WIND SPEED (MPH)
2	0.0	0.0	0.0	0.0

----- FATIGUE DETAIL -----

DETAIL NUMBER	Threshold (CAFT) (KSI)	WEEPHOLE NET AREA (SI)	WIRE OUT NET AREA (SI)	HANDHOLE NET AREA (SI)	CHORD/POST /BRANCH
3.1	24.00	5.00	0.00	10.00	-
3.1	24.00	0.00	2.00	0.00	-
3.1	24.00	0.00	0.00	20.00	-
3.2	7.00	0.00	0.00	20.00	-

----- FOOTING -----

A OR D	INPUT FACTORED RESISTANCE (KSF)	CONC F'c (PSI)	CONCRETE DENSITY (PCF)	FILL DENSITY (PCF)	COEFF FRICTION	FILL HEIGHT (FT)
D	6.00	0.	0.0	0.0	0.25	10.00

PEDESTAL HEIGHT (FT)	PEDESTAL LENGTH (FT)	PEDESTAL WIDTH (FT)	FOOTING MIN THK (FT)	FOOTING MAX THK (FT)	FOOTING WIDTH (FT)	FOOTING LENGTH (FT)	FOOTING MAX WIDTH (FT)
11.00	2.17	2.17	2.00	0.00	0.00	0.00	0.00

----- REBAR -----

REBAR GRADE (KSI)	COVER TOP (IN)	COVER BOTTOM (IN)	TOP LONG REBAR SIZE	TOP LONG REBAR NO.BARS	TOP TRANS REBAR SIZE	TOP TRANS REBAR NO.BARS
0.	0.00	0.00	0.	0	0.	0

BOTTOM LONG REBAR SIZE	BOTTOM LONG REBAR NO.BARS	BOTTOM TRANS REBAR SIZE	BOTTOM TRANS REBAR NO.BARS	ULTIMATE TENSILE STRENGTH REBAR (KSI)
0.	0	0.	0	0.0

Appendix B: Example Problems

----- DEFAULT VALUES -----									
TRUSS/STRUT HEIGHT (FT) ---	TRUSS DEPTH (FT) ---	HEIGHT Z (FT) -----	POST FIXITY --	RIGHT STRUT (FT) -----	DMS -	BEND RADIUS (FT) ---			
SIGN 1 SUPP BEAM WT (LBS/FT) -----	SIGN 2 SUPP BEAM WT (LBS/FT) -----	SIGN 3 SUPP BEAM WT (LBS/FT) -----	SIGN 1 PANEL WT (PSF) ---	SIGN 2 PANEL WT (PSF) ---	SIGN 3 PANEL WT (PSF) ---				
NUMBER OF SIGN 1	NUMBER OF SIGN 2	NUMBER OF SIGN 3	MEAN WIND SPEED (MPH) 11.2	VEHICLE DES SPEED (MPH) 65.0	BAS WIND SPEED (MPH) 120.0	SRV WIND SPEED (MPH) 76.0	NUMBER OF U-BOLTS 1		
DIST TO BLT CIR (IN) -----	CONNECTION SPLICE (KSI) 36.	YIELD END (KSI) 36.	A OR D ---	INPUT FACTORED RESISTANCE (KSF) ---	CONC F'c (PSI) 3000.	CONCRETE DENSITY (PCF) 150.	FILL DENSITY (PCF) 100.	COEFF FRICTION ---	
FOOTING MIN THK (FT) ---	FOOTING MAX THK (FT) 5.00	FOOTING WIDTH (FT) 5.00	FOOTING LENGTH (FT) 5.00	FOOTING MAX WIDTH (FT) 50.00					
REBAR GRADE (KSI) 60.	COVER TOP (IN) 3.00	COVER BOTTOM (IN) 4.00	ULTIMATE TENSILE STRENGTH (KSI) 90.0	REBAR					

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