TECHNICAL NOTE
FRAME STRESS CALCULATION

Introduction

This document introduces the stress point locations of frame sections, and how the software calculates axial stress, shear-stress, principal stress, and Von Mises stress at each stress point. The frame sections addressed in this document include I section, Built-Up I section, Hybrid I section, T section, Channel section, Pipe section, Box section, Circular section and Rectangular section. For the section designer section, the users are allowed to define their own stress points simply following the procedure as shown in the figure below. For the frame sections that are not addressed here, only the axial stress will be available at the centroid location and the four corners of the bounding box of the section.

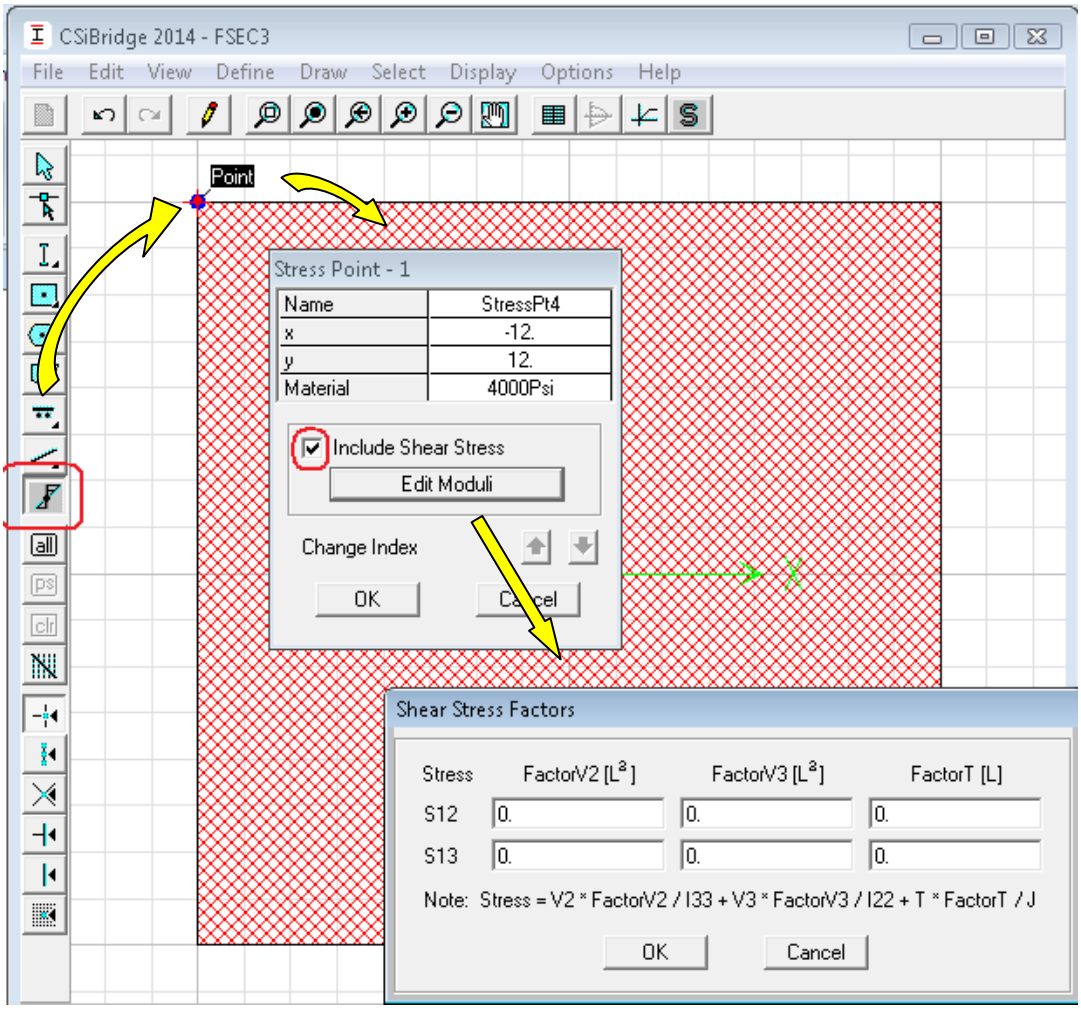


Figure 1 – User Defined Stress Point in Section Designer

Stress Formulas

- **Axial Stress S11**
  The axial stress S11 is parallel to the section local axis 1 on the plane 1 (the plane with normal direction parallel to the section local axis 1):

$$S_{11} = \frac{P}{A} - \frac{M_2(I_{33} \cdot a_3 - I_{23} \cdot a_2)}{(I_{22} \cdot I_{33} - I_{23} \cdot I_{23}) \cdot r} - \frac{M_3(I_{22} \cdot a_2 - I_{23} \cdot a_3)}{(I_{22} \cdot I_{33} - I_{23} \cdot I_{23}) \cdot r}$$

  In which a_2 and a_3 are the point coordinate in section local coordinate system $(x_2,\ x_3) = (a_2,\ a_3)$ and the *'r'* is the material *E* ratio

$$r = \frac{E_{Base\ material}}{E_{material\ at\ stress\ point}}$$

- **Shear Stresses S12 and S13**:
  The shear stress S12 is parallel to the section local axis 2 on the plane 1 and S13 is parallel to the section local axis 3 on the plane 1. The shear stress is contributed from shear forces V_2, V_3 and torsion T.

Shear stress due to shear force: $\tau_V = \frac{V\,Q}{I\,t} = \frac{V}{I} \cdot \mathrm{f1jV}$

Saint Venant Torsional stress: $\tau_T = \frac{T\,t}{J} = \frac{T}{J} \cdot \mathrm{f1jT}$

  For a point 'i' on the section, the shear stresses S12 and S13 can be represented as:

$$S_{12} = \frac{T}{J}\mathrm{f12T}(i) + \frac{V_2}{I_{33}}\mathrm{f12V2}(i) + \frac{V_3}{I_{22}}\mathrm{f12V3}(i)$$

$$S_{13} = \frac{T}{J}\mathrm{f13T}(i) + \frac{V_2}{I_{33}}\mathrm{f13V2}(i) + \frac{V_3}{I_{22}}\mathrm{f13V3}(i)$$

  In which $\mathrm{f1jV2}(i)$ and $\mathrm{f1jV3}(i)$ will be introduced later.

  Important Note: These shear stresses are calculated for the Built-Up I and Hybrid I sections assuming that the *E* ratio *r* = 1. Although the axial stress S11 accounts for different values of *E*, the shear stresses do not.

- **Principal Stresses Smax and Smin:**
  The principal stresses are calculated from Mohr's circle as:

$$S_{max} = \frac{S_{11}}{2} + S_V$$

$$S_{min} = \frac{S_{11}}{2} - S_V$$

  In which

$$S_V = \sqrt{\left(\frac{S_{11}}{2}\right)^2 + {S_{12}}^2 + {S_{13}}^2}$$

- **von Mises stress SVM**

  The general von Mises stress equation can be expressed as:

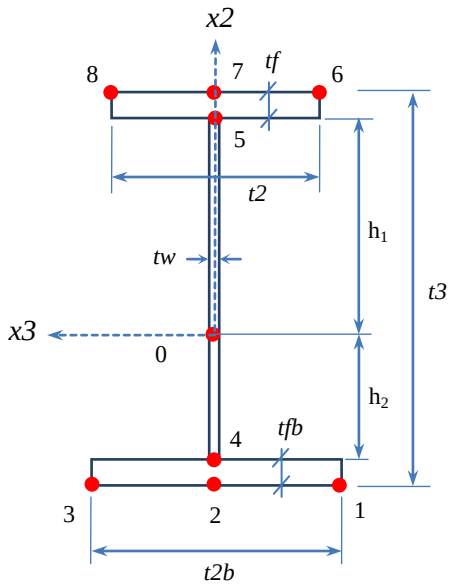
$$S_{VM} = \sqrt{\frac{1}{2}[(S_{11}-S_{22})^2+(S_{22}-S_{33})^2+(S_{33}-S_{11})^2+6\,(S_{12}^2+S_{23}^2+S_{31}^2)]}$$

  Considering only stresses S11, S12 and S13, the above equation can be simplified as:

$$S_{VM} = \sqrt{S_{11}^2+3\,(S_{12}^2+S_{13}^2)}$$

Stress Point Locations and Factors for Frame Sections

- **I Section / Hybrid I Section**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

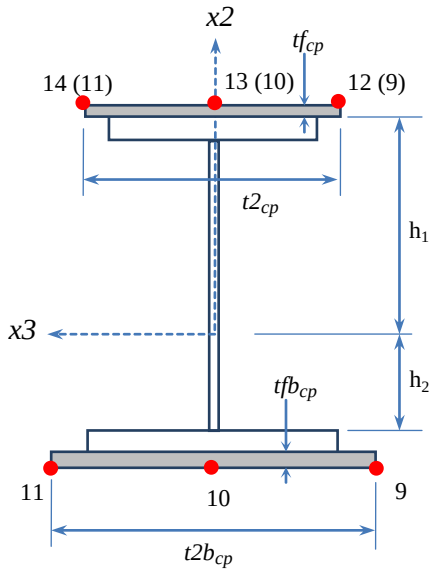
$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

Figure 2 - I Section/Hybrid I Section Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
0	S12 *(1)*	$\left[t2 \cdot tf \cdot \left(h_1 + \frac{1}{2}tf\right) + tw \cdot h_1 \cdot \frac{1}{2}h_1\right]$ / tw	*0*	tw
	S13 *(2)*	*0*	*0*	*0*
1	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	$-tfb$
2	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$t2b \cdot tfb \cdot \left(h_2 + \frac{1}{2}tfb\right)$ / $(2 \cdot tfb)$	$t2b \cdot t2b$ / 8	$-tfb$
3	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	$-tfb$
4	S12 *(1)*	$t2b \cdot tfb \cdot \left(h_2 + \frac{1}{2}tfb\right)$ / tw	*0*	tw
	S13 *(2)*	*0*	*0*	*0*
5	S12 *(1)*	$t2 \cdot tf \cdot \left(h_1 + \frac{1}{2}tf\right)$ / tw	*0*	tw
	S13 *(2)*	*0*	*0*	*0*
6	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	tf
7	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$t2 \cdot tf \cdot \left(h_1 + \frac{1}{2}tf\right)$ / $(2 \cdot tf)$	$t2 \cdot t2$ / 8	tf
8	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	tf

Table 1 – I Section, Hybrid I Section, Built-up I Section Stress Variables, by Point i

- **Built-up I Section – Cover plates**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

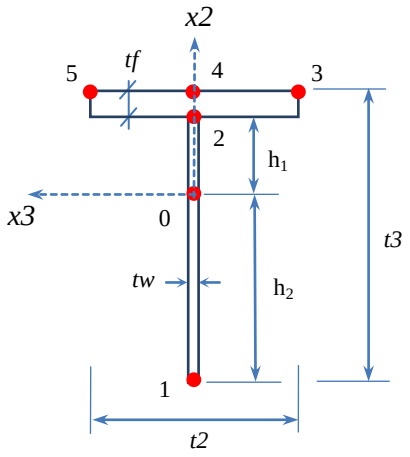
Figure 3 - Built-up I Section with Cover Plates, Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
9	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	$-tfb_{cp}$
10	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$t2b_{cp} \cdot tfb_{cp} \cdot \left(h_2 + tfb + \frac{1}{2}tfb_{cp}\right) / \left(2 \cdot tfb_{cp}\right)$	$t2b_{cp} \cdot t2b_{cp}$ /8	$-tfb_{cp}$
11	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	$-tfb_{cp}$
12 (9)*	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	tf_{cp}
13 (10)*	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$t2_{cp} \cdot tf_{cp} \cdot \left(h_1 + tf + \frac{1}{2}tf_{cp}\right) / \left(2 \cdot tf_{cp}\right)$	$t2_{cp} \cdot t2_{cp}$ /8	tf_{cp}
14 (11)*	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	tf_{cp}

* Note: In the case of no bottom cover plate, points 12-14 become points 9-11.

Table 1 (continued) – Built-up I Section (only) Stress Variables, by Point i

- **T Section**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

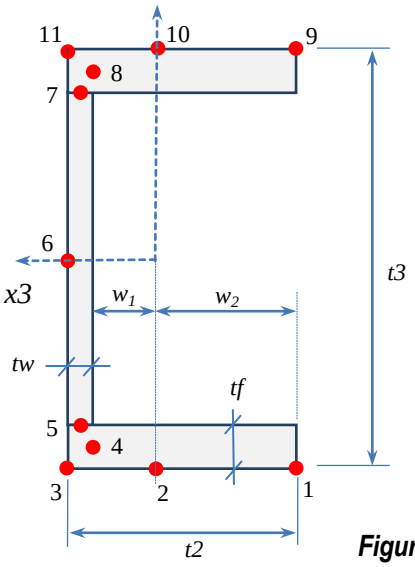
$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

Figure 4 - T Section Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
0	S12 *(1)*	$\left[t2 \cdot tf \cdot \left(h_1 + \frac{1}{2}tf\right) + tw \cdot h_1 \cdot \frac{1}{2}h_1\right] \,/\, tw$	*0*	tw
	S13 *(2)*	*0*	*0*	*0*
1	S12 *(1)*	*0*	*0*	tw
	S13 *(2)*	*0*	*0*	*0*
2	S12 *(1)*	$t2 \cdot tf \cdot \left(h_1 + \frac{1}{2}tf\right) \,/\, tw$	*0*	tw
	S13 *(2)*	*0*	*0*	*0*
3	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	tf
4	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$t2 \cdot tf \cdot \left(h_1 + \frac{1}{2}tf\right) / (2 \cdot tf)$	$t2 \cdot t2 \,/\, 8$	tf
5	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	tf

Table 2 – T Section Stress Variables, by Point i

- **Channel Section - 1**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

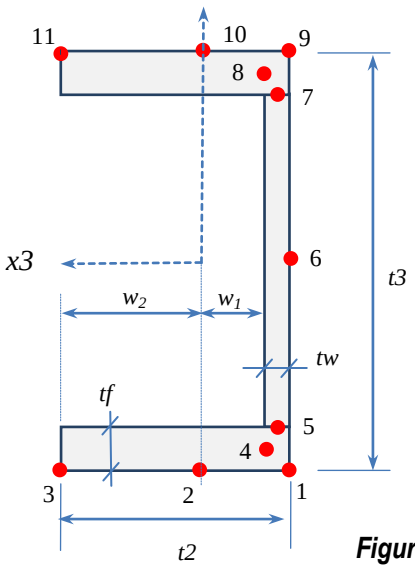
$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

Figure 5 - Channel Section – 1, Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
1	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*tf*
2	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$w_2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$\frac{1}{2} tf \cdot {w_2}^2 / tf$	*tf*
3	S12 *(1)*	$\frac{1}{2}[\text{f12V2}(4) + \text{f12V2}(5)]$	$\frac{1}{2}[\text{f12V3}(4) + \text{f12V3}(5)]$	$\frac{1}{2}[\text{f12T}(4) + \text{f12T}(5)]$
	S13 *(2)*	$\frac{1}{2}[\text{f13V2}(4) + \text{f13V2}(5)]$	$\frac{1}{2}[\text{f13V3}(4) + \text{f13V3}(5)]$	$\frac{1}{2}[\text{f13T}(4) + \text{f13T}(5)]$
4	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$(t2 - tw) \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$t3 \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tf)$	*tf*
5	S12 *(1)*	$t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tw$	$(t3 - 2 \cdot tf) \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tw)$	*tw*
	S13 *(2)*	*0*	*0*	*0*
6	S12 *(1)*	$\left[t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) + tw \cdot \left(\frac{t3-2 \cdot tf}{2}\right)^2\right] / tw$	*0*	*tw*
	S13 *(2)*	*0*	*0*	*0*
7	S12 *(1)*	$t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tw$	$-(t3 - 2 \cdot tf) \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right)/(2 \cdot tw)$	*tw*
	S13 *(2)*	*0*	*0*	*0*
8	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$(t2 - tw) \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$t3 \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tf)$	*tf*
9	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*tf*
10	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$w_2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$\frac{1}{2} tf \cdot {w_2}^2 / tf$	*tf*
11	S12 *(1)*	$\frac{1}{2}[\text{f12V2}(7) + \text{f12V2}(8)]$	$\frac{1}{2}[\text{f12V3}(7{,}1) + \text{f12V3}(8)]$	$\frac{1}{2}[\text{f12T}(7) + \text{f12T}(7)]$
	S13 *(2)*	$\frac{1}{2}[\text{f13V2}(7) + \text{f13V2}(8)]$	$\frac{1}{2}[\text{f13V3}(7) + \text{f13V3}(8)]$	$\frac{1}{2}[\text{f13T}(8) + \text{f13T}(8)]$

Table 3 – Channel Section - 1 Stress Variables, by Point i

- **Channel Section - 2**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

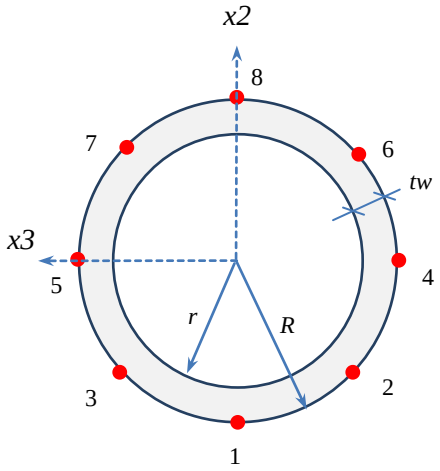
$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

Figure 6 - Channel Section – 2, Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
1	S12 *(1)*	$\frac{1}{2}$[f12V2(4) + f12V2(5)]	$\frac{1}{2}$[f12V3(4) + f12V3(5)]	$\frac{1}{2}$[f12T(4) + f12T(5)]
	S13 *(2)*	$\frac{1}{2}$[f13V2(4) + f13V2(5)]	$\frac{1}{2}$[f13V3(4) + f13V3(5)]	$\frac{1}{2}$[f13T(4) + f13T(5)]
2	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$w_2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$\frac{1}{2} tf \cdot {w_2}^2 / tf$	*tf*
3	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*tf*
4	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$(t2 - tw) \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$t3 \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tf)$	*tf*
5	S12 *(1)*	$t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tw$	$(t3 - 2 \cdot tf) \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tw)$	*tw*
	S13 *(2)*	*0*	*0*	*0*
6	S12 *(1)*	$\left[t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) + tw \cdot \left(\frac{t3-2 \cdot tf}{2}\right)^2\right] / tw$	*0*	*tw*
	S13 *(2)*	*0*	*0*	*0*
7	S12 *(1)*	$t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tw$	$-(t3 - 2 \cdot tf) \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tw)$	*tw*
	S13 *(2)*	*0*	*0*	*0*
8	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$(t2 - tw) \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$t3 \cdot tw \cdot \left(w_1 + \frac{1}{2}tw\right) / (2 \cdot tf)$	*tf*
9	S12 *(1)*	$\frac{1}{2}$[f12V2(7) + f12V2(8)]	$\frac{1}{2}$[f12V3(7) + f12V3(8)]	$\frac{1}{2}$[f12T(7) + f12T(7)]
	S13 *(2)*	$\frac{1}{2}$[f13V2(7) + f13V2(8)]	$\frac{1}{2}$[f13V3(7) + f13V3(8)]	$\frac{1}{2}$[f13T(8) + f13T(8)]
10	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$w_2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / tf$	$\frac{1}{2} tf \cdot {w_2}^2 / tf$	*tf*
11	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*tf*

Table 4 – Channel Section - 2 Stress Variables, by Point i

- **Pipe Section**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

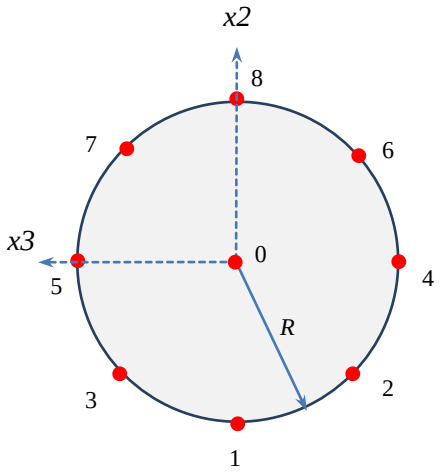
Figure 7 - Pipe Section Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
1	S12 *(1)*	0	0	0
	S13 *(2)*	0	$(R^2 + R \cdot r + r^2)/3$	$-R$
2*	S12 *(1)*	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	0	$R/\sqrt{2}$
	S13 *(2)*	0	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	$-R/\sqrt{2}$
3*	S12 *(1)*	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	0	$-R/\sqrt{2}$
	S13 *(2)*	0	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	$-R/\sqrt{2}$
4	S12 *(1)*	$(R^2 + R \cdot r + r^2)/3$	0	R
	S13 *(2)*	0	0	0
5	S12 *(1)*	$(R^2 + R \cdot r + r^2)/3$	0	$-R$
	S13 *(2)*	0	0	0
6*	S12 *(1)*	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	0	$R/\sqrt{2}$
	S13 *(2)*	0	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	$R/\sqrt{2}$
7*	S12 *(1)*	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	0	$-R/\sqrt{2}$
	S13 *(2)*	0	$(R\sqrt{2r^2 - R^2} + 2r^2)/6$	$R/\sqrt{2}$
8	S12 *(1)*	0	0	0
	S13 *(2)*	0	$(R^2 + R \cdot r + r^2)/3$	R

* The formulae are appropriate for the case of $r > R/\sqrt{2}$. For the case of $r \leq R/\sqrt{2}$., the formula $R^2/6$ should be used.

Table 5 – Pipe Section Stress Variables, by Point i

- **Circular Section**



$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

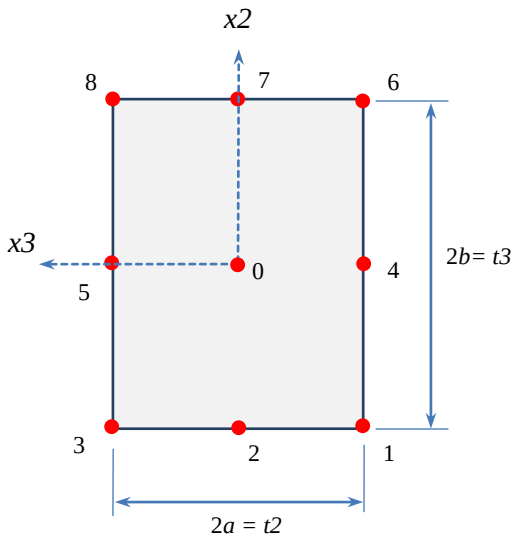
$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

Figure 8 - Circular Section Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
0	S12 *(1)*	$R^2/3$	0	0
	S13 *(2)*	0	$R^2/3$	0
1	S12 *(1)*	0	0	0
	S13 *(2)*	0	$R^2/3$	$-R$
2	S12 *(1)*	$R^2/6$	0	$R/\sqrt{2}$
	S13 *(2)*	0	$R^2/6$	$-R/\sqrt{2}$
3	S12 *(1)*	$R^2/6$	0	$-R/\sqrt{2}$
	S13 *(2)*	0	$R^2/6$	$-R/\sqrt{2}$
4	S12 *(1)*	$R^2/3$	0	R
	S13 *(2)*	0	0	0
5	S12 *(1)*	$R^2/3$	0	$-R$
	S13 *(2)*	0	0	0
6	S12 *(1)*	$R^2/6$	0	$R/\sqrt{2}$
	S13 *(2)*	0	$R^2/6$	$R/\sqrt{2}$
7	S12 *(1)*	$R^2/6$	0	$-R/\sqrt{2}$
	S13 *(2)*	0	$R^2/6$	$R/\sqrt{2}$
8	S12 *(1)*	0	0	0
	S13 *(2)*	0	$R^2/3$	R

Table 6 – Circular Section Stress Variables, by Point i

- **Rectangular Section**



For Saint Venant Torsional stress: $b \geq a$

$$\tau_{12}^{T} = G\theta \cdot 2a\left\{\frac{x}{a} - \frac{8}{\pi^2}\sum_{0}^{\infty}\frac{(-1)^n \sin\left(\frac{2n+1}{2}\pi \cdot \frac{x}{a}\right)\cdot \cosh\left(\frac{2n+1}{2}\pi \cdot \frac{y}{a}\right)}{(2n+1)^2 \cdot \cosh\left(\frac{2n+1}{2}\pi \cdot \frac{b}{a}\right)}\right\}$$

$$= G\theta \cdot F_{12}(x,y) = \frac{T}{J}F_{12}(x,y)$$

$$\tau_{13}^{T} = G\theta \cdot 2a\left\{-\frac{8}{\pi^2}\sum_{0}^{\infty}\frac{(-1)^n \cos\left(\frac{2n+1}{2}\pi \cdot \frac{x}{a}\right)\cdot \sinh\left(\frac{2n+1}{2}\pi \cdot \frac{y}{a}\right)}{(2n+1)^2 \cdot \cosh\left(\frac{2n+1}{2}\pi \cdot \frac{b}{a}\right)}\right\}$$

$$= G\theta \cdot F_{13}(x,y) = \frac{T}{J}F_{13}(x,y)$$

$$S_{12} = \frac{T}{J}\text{f12T}(i) + \frac{V_2}{I_{33}}\text{f12V2}(i) + \frac{V_3}{I_{22}}\text{f12V3}(i)$$

$$S_{13} = \frac{T}{J}\text{f13T}(i) + \frac{V_2}{I_{33}}\text{f13V2}(i) + \frac{V_3}{I_{22}}\text{f13V3}(i)$$

Figure 9 - Rectangular Section Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
0	S12 *(1)*	$t3 \cdot t3/8$	*0*	*0*
	S13 *(2)*	*0*	$t2 \cdot t2/8$	*0*
1	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*0*
2	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	$t2 \cdot t2/8$	$-\lvert F_{13}(0,b)\rvert$
3	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*0*
4	S12 *(1)*	$t3 \cdot t3/8$	*0*	$\lvert F_{12}(a,0)\rvert$
	S13 *(2)*	*0*	*0*	*0*
5	S12 *(1)*	$t3 \cdot t3/8$	*0*	$-\lvert F_{12}(a,0)\rvert$
	S13 *(2)*	*0*	*0*	*0*
6	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*0*
7	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	$t2 \cdot t2/8$	$\lvert F_{13}(0,b)\rvert$
8	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	*0*	*0*

Table 7 – Rectangular Section Stress Variables, by Point i

Values of $|F_{12}(a,0)/2a|$, in which $b > a$

b/a	$F_{12}(a,0)/2a$
1	0.675314
1.1	0.719777
1.2	0.758764
1.3	0.792722
1.4	0.822151
1.5	0.847562
1.6	0.869444
1.7	0.888248
1.8	0.904383
1.9	0.918214
2	0.930060
2.1	0.940200
2.2	0.948876
2.3	0.956297
2.4	0.962644
2.5	0.968070
2.6	0.972709
2.7	0.976674
2.8	0.980064
2.9	0.982961
3	0.985438
3.1	0.987554
3.2	0.989363
3.3	0.990910
3.4	0.992231
3.5	0.993360
3.6	0.994325
3.7	0.995150
3.8	0.995855
3.9	0.996458
4	0.996973

b/a	$F_{12}(a,0)/2a$
4	0.996973
4.1	0.997413
4.2	0.997789
4.3	0.998110
4.4	0.998385
4.5	0.998620
4.6	0.998820
4.7	0.998992
4.8	0.999138
4.9	0.999264
5	0.999371
5.1	0.999462
5.2	0.999540
5.3	0.999607
5.4	0.999664
5.5	0.999713
5.6	0.999755
5.7	0.999790
5.8	0.999821
5.9	0.999847
6	0.999869
6.1	0.999888
6.2	0.999904
6.3	0.999918
6.4	0.999930
6.5	0.999940
6.6	0.999949
6.7	0.999956
6.8	0.999963
6.9	0.999968
7	0.999973

b/a	$F_{12}(a,0)/2a$
7	0.999973
7.1	0.999977
7.2	0.999980
7.3	0.999983
7.4	0.999985
7.5	0.999988
7.6	0.999989
7.7	0.999991
7.8	0.999992
7.9	0.999993
8	0.999994
8.1	0.999995
8.2	0.999996
8.3	0.999996
8.4	0.999997
8.5	0.999997
8.6	0.999998
8.7	0.999998
8.8	0.999998
8.9	0.999999
9	0.999999
9.1	0.999999
9.2	0.999999
9.3	0.999999
9.4	0.999999
9.5	0.999999
9.6	1.000000
9.7	1.000000
9.8	1.000000
9.9	1.000000
10	1.000000

Table 8 – Rectangular Section F_{12} Values

Values of $|F_{13}(0,b)/2a|$, in which $b > a$

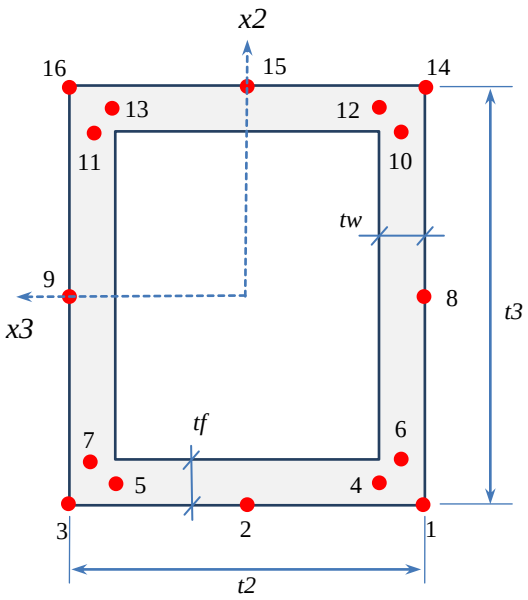
b/a	$F_{13}(0,b)/2a$
1	0.675318
1.1	0.692860
1.2	0.705928
1.3	0.715613
1.4	0.722762
1.5	0.728024
1.6	0.731890
1.7	0.734725
1.8	0.736803
1.9	0.738323
2	0.739436
2.1	0.740249
2.2	0.740844
2.3	0.741279
2.4	0.741596
2.5	0.741829
2.6	0.741998
2.7	0.742122
2.8	0.742212
2.9	0.742279
3	0.742327
3.1	0.742362
3.2	0.742388
3.3	0.742407
3.4	0.742420
3.5	0.742430
3.6	0.742438
3.7	0.742443
3.8	0.742447
3.9	0.742450
4	0.742452

b/a	$F_{13}(0,b)/2a$
4	0.742452
4.1	0.742454
4.2	0.742455
4.3	0.742455
4.4	0.742456
4.5	0.742456
4.6	0.742457
4.7	0.742457
4.8	0.742457
4.9	0.742457
5	0.742457
5.1	0.742457
5.2	0.742458
5.3	0.742458
5.4	0.742458
5.5	0.742458
5.6	0.742458
5.7	0.742458
5.8	0.742458
5.9	0.742458
6	0.742458
6.1	0.742458
6.2	0.742458
6.3	0.742458
6.4	0.742458
6.5	0.742458
6.6	0.742458
6.7	0.742458
6.8	0.742458
6.9	0.742458
7	0.742458

b/a	$F_{13}(0,b)/2a$
7	0.742458
7.1	0.742458
7.2	0.742458
7.3	0.742458
7.4	0.742458
7.5	0.742458
7.6	0.742458
7.7	0.742458
7.8	0.742458
7.9	0.742458
8	0.742458
8.1	0.742458
8.2	0.742458
8.3	0.742458
8.4	0.742458
8.5	0.742458
8.6	0.742458
8.7	0.742458
8.8	0.742458
8.9	0.742458
9	0.742458
9.1	0.742458
9.2	0.742458
9.3	0.742458
9.4	0.742458
9.5	0.742458
9.6	0.742458
9.7	0.742458
9.8	0.742458
9.9	0.742458
10	0.742458

Table 9 – Rectangular Section F_{13} Values

- **Box Section**



For Saint Venant Torsional stress:

$$\tau = \frac{T}{2\,t\,A_m} = \frac{T}{J}\cdot \mathrm{fT}\,, \quad \mathrm{fT} = \frac{J}{2\,t\,A_m}$$

Where $A_m = (t2 - tw)\cdot(t3 - tf)$

$$S_{12} = \frac{T}{J}\mathrm{f12T}(i) + \frac{V_2}{I_{33}}\mathrm{f12V2}(i) + \frac{V_3}{I_{22}}\mathrm{f12V3}(i)$$

$$S_{13} = \frac{T}{J}\mathrm{f13T}(i) + \frac{V_2}{I_{33}}\mathrm{f13V2}(i) + \frac{V_3}{I_{22}}\mathrm{f13V3}(i)$$

Figure 10 - Box Section Points, i

Point *i*	Stress (*j*)	f1jV2(*i*)	f1jV3(*i*)	f1jT(*i*)
1	S12 *(1)*	$\frac{1}{2}[\mathrm{f12V2}(4) + \mathrm{f12V2}(6)]$	$\frac{1}{2}[\mathrm{f12V3}(4) + \mathrm{f12V3}(6)]$	$\frac{1}{2}[\mathrm{f12T}(4) + \mathrm{f12T}(6)]$
	S13 *(2)*	$\frac{1}{2}[\mathrm{f13V2}(4) + \mathrm{f13V2}(6)]$	$\frac{1}{2}[\mathrm{f13V3}(4) + \mathrm{f13V3}(6)]$	$\frac{1}{2}[\mathrm{f13T}(4) + \mathrm{f13T}(6)]$
2	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	*0*	$\left[t3\cdot tw\cdot\left(\frac{t2-tw}{2}\right) + tf\cdot\left(\frac{t2-2\cdot tw}{2}\right)^2\right] / (2\cdot tf)$	$-J\,/\,(2\,tf\cdot A_m)$
3	S12 *(1)*	$\frac{1}{2}[\mathrm{f12V2}(5) + \mathrm{f12V2}(7)]$	$\frac{1}{2}[\mathrm{f12V3}(5) + \mathrm{f12V3}(7)]$	$\frac{1}{2}[\mathrm{f12T}(5) + \mathrm{f12T}(7)]$
	S13 *(2)*	$\frac{1}{2}[\mathrm{f13V2}(5) + \mathrm{f13V2}(7)]$	$\frac{1}{2}[\mathrm{f13V3}(5) + \mathrm{f13V3}(7)]$	$\frac{1}{2}[\mathrm{f13T}(5) + \mathrm{f13T}(7)]$
4	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$-(t2 - 2\cdot tw)\cdot tf\cdot\left(\frac{t3-tf}{2}\right) / (2\cdot tf)$	$t3\cdot tw\cdot\left(\frac{t2-tw}{2}\right) / (2\cdot tf)$	$-J\,/\,(2\,tf\cdot A_m)$
5	S12 *(1)*	*0*	*0*	*0*
	S13 *(2)*	$(t2 - 2\cdot tw)\cdot tf\cdot\left(\frac{t3-tf}{2}\right) / (2\cdot tf)$	$t3\cdot tw\cdot\left(\frac{t2-tw}{2}\right) / (2\cdot tf)$	$J\,/\,(2\,tf\cdot A_m)$
6	S12 *(1)*	$t2\cdot tf\cdot\left(\frac{t3-tf}{2}\right) / (2\cdot tw)$	$-(t3 - 2\cdot tf)\cdot tw\cdot\left(\frac{t3-tw}{2}\right) / (2\cdot tw)$	$-J\,/\,(2\,tw\cdot A_m)$
	S13 *(2)*	*0*	*0*	*0*
7	S12 *(1)*	$t2\cdot tf\cdot\left(\frac{t3-tf}{2}\right) / (2\cdot tw)$	$(t3 - 2\cdot tf)\cdot tw\cdot\left(\frac{t2-tw}{2}\right) / (2\cdot tw)$	$J\,/\,(2\,tw\cdot A_m)$
	S13 *(2)*	*0*	*0*	*0*
8	S12 *(1)*	$\left[t2\cdot tf\cdot\left(\frac{t3-tf}{2}\right) + tw\cdot\left(\frac{t3-2\cdot tf}{2}\right)^2\right] / (2\cdot tw)$	*0*	$J\,/\,(2\,tw\cdot A_m)$
	S13 *(2)*	*0*	*0*	*0*

9	S12 *(1)*	$\left[t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) + tw \cdot \left(\frac{t3-2 \cdot tf}{2}\right)^2\right] / (2 \cdot tw)$	0	$-J / (2\ tw \cdot A_m)$
	S13 *(2)*	0	0	0
10	S12 *(1)*	$t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / (2 \cdot tw)$	$(t_3 - 2 \cdot tf) \cdot tw \cdot \left(\frac{t2-tw}{2}\right) / (2 \cdot tw)$	$J / (2\ tw \cdot A_m)$
	S13 *(2)*	0	0	0
11	S12 *(1)*	$t2 \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / (2 \cdot tw)$	$-(t3 - 2 \cdot tf) \cdot tw \cdot \left(\frac{t2-tw}{2}\right) / (2 \cdot tw)$	$-J / (2\ tw \cdot A_m)$
	S13 *(2)*	0	0	0
12	S12 *(1)*	0	0	0
	S13 *(2)*	$(t2 - 2 \cdot tw) \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / (2 \cdot tf)$	$t3 \cdot tw \cdot \left(\frac{t2-tw}{2}\right) / (2 \cdot tf)$	$J / (2\ tf \cdot A_m)$
13	S12 *(1)*	0	0	0
	S13 *(2)*	$-(t2 - 2 \cdot tw) \cdot tf \cdot \left(\frac{t3-tf}{2}\right) / (2 \cdot tf)$	$t3 \cdot tw \cdot \left(\frac{t2-tw}{2}\right) / (2 \cdot tf)$	$-J / (2\ tf \cdot A_m)$
14	S12 *(1)*	$\frac{1}{2}[\text{f12V2(10)} + \text{f12V2(12)}]$	$\frac{1}{2}[\text{f12V3(10)} + \text{f12V3(12)}]$	$\frac{1}{2}[\text{f12T(10)} + \text{f12T(12)}]$
	S13 *(2)*	$\frac{1}{2}[\text{f13V2(10)} + \text{f13V2(12)}]$	$\frac{1}{2}[\text{f13V3(10)} + \text{f13V3(12)}]$	$\frac{1}{2}[\text{f13T(10)} + \text{f13T(12)}]$
15	S12 *(1)*	0	0	0
	S13 *(2)*	0	$\left[t3 \cdot tw \cdot \left(\frac{t2-tw}{2}\right) + tf \cdot \left(\frac{t2-2 \cdot tw}{2}\right)^2\right] / (2 \cdot tf)$	$J / (2\ tf \cdot A_m)$
16	S12 *(1)*	$\frac{1}{2}[\text{f12V2(11)} + \text{f12V2(13)}]$	$\frac{1}{2}[\text{f12V3(11)} + \text{f12V3(13)}]$	$\frac{1}{2}[\text{f12T(11)} + \text{f12T(13)}]$
	S13 *(2)*	$\frac{1}{2}[\text{f13V2(11)} + \text{f13V2(13)}]$	$\frac{1}{2}[\text{f13V3(11)} + \text{f13V3(13)}]$	$\frac{1}{2}[\text{f13T(11)} + \text{f13T(13)}]$

Table 10 –Box Section Stress Variables, by Point i