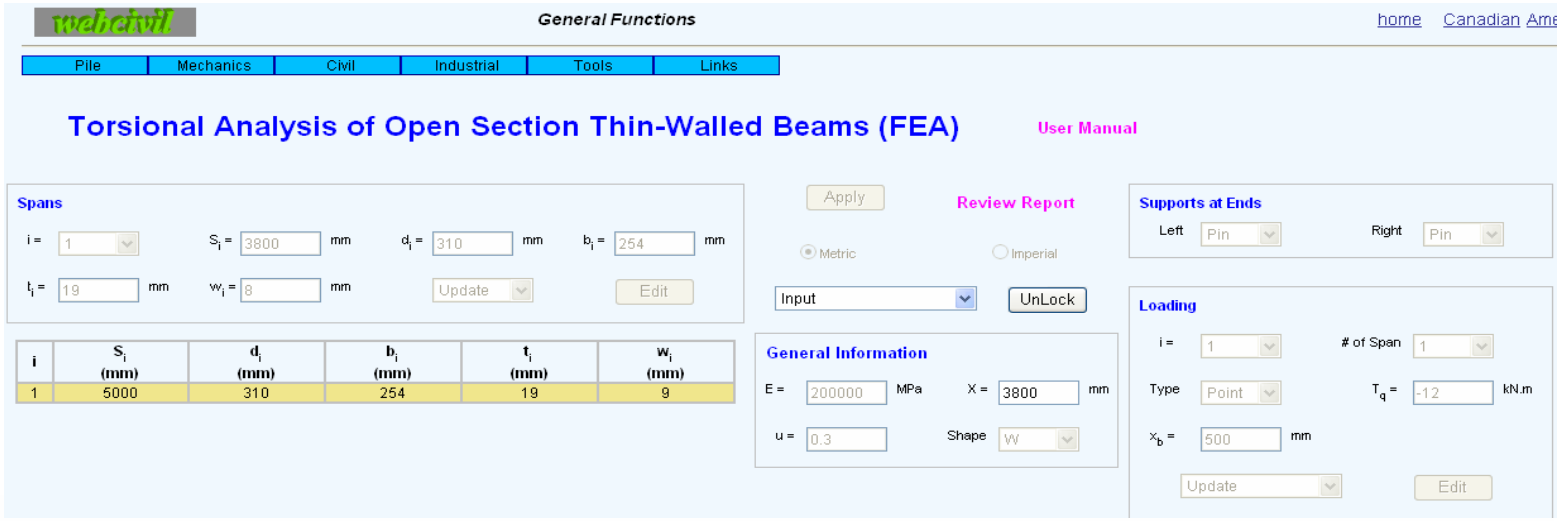
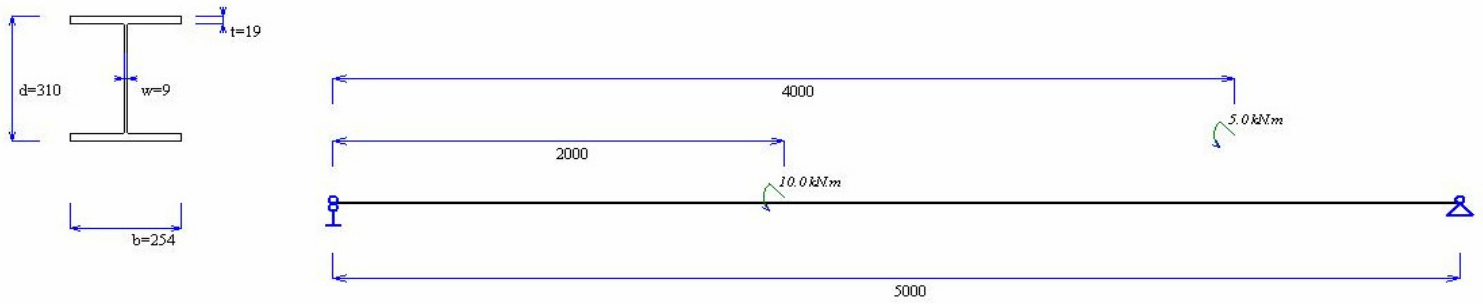
http://www.webcivil.com/CTBfea.aspx





Beam Input

Features

This software is for torsional analysis of open section thin-walled beams with finite element method

Considering spans, heights of beams, and loading locations, the software meshes beams to elements automatically

Provide results of twist angle, twist rate

Provide results of pure shear stress, warping shear stress, warping normal stress at specified location

Notes

Units: *torque and moment* kN.m (in. kips), *Bi-moment*: $kN.m^2$ ($in.^2$. kips)

Torque direction: with right hand rule, counter-clockwise is positive

References

Thin-Walled Elastic Beams, 2nd Edtion, *Vlasov V. Z.* Jerusalem: Israel Program for Scientific Translations, 1961

Finite Element Procedures, *Bathe K. J*. Prentice Hall

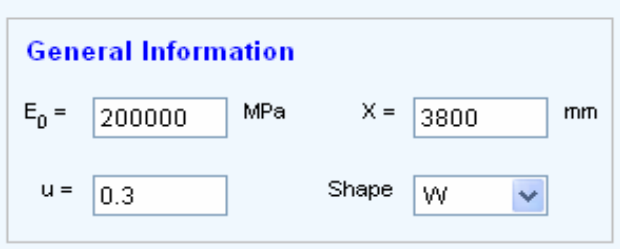
Structural Analysis for Thin-Walled Members, 4th Edition, *Shihua Bao, Jian Zhou*, China Architecture & Building Press

American Institute of Steel Construction (AISC) **Design Guide 9, Torsional Analysis of Structure Steel Members**

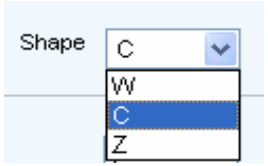
Salmon C. G., Johnson J. E. **Steel Structures : Design and Behavior**, 4th Edition, Prentice Hall, NJ

Instruction

1. General

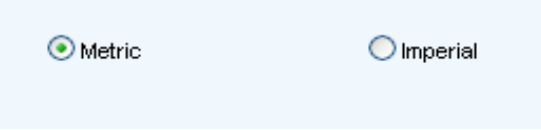


E_0 - Modulus of elasticity
u - Poisson ratio
X - Location from left support
After clicking button **Apply**, change X, then, click the screen, you can get the updated results



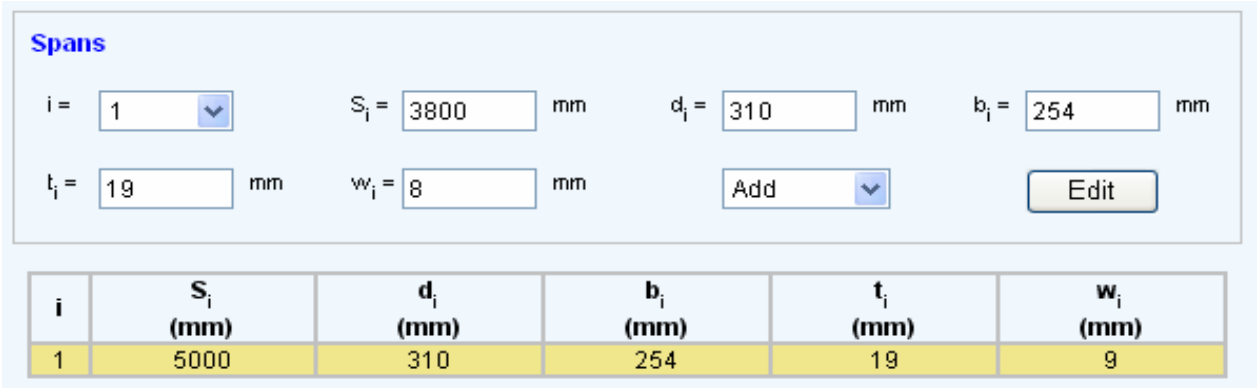
There are three shapes available (W, C, Z)

For left or right supports, **"free", "pin"**, and **"fix"** can be selected
For torsional pin support: no rotation,torsion fixed, warping free
For torsional fix support: no rotation,torsion fixed, warping fixed



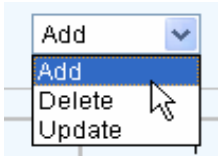
All inputs can be transferred to other unit automatically

2. Input of Spans

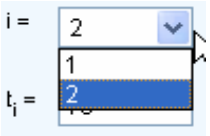


i	S_i (mm)	d_i (mm)	b_i (mm)	t_i (mm)	w_i (mm)
1	5000	310	254	19	9

Add One Span



Select **Add** from the list

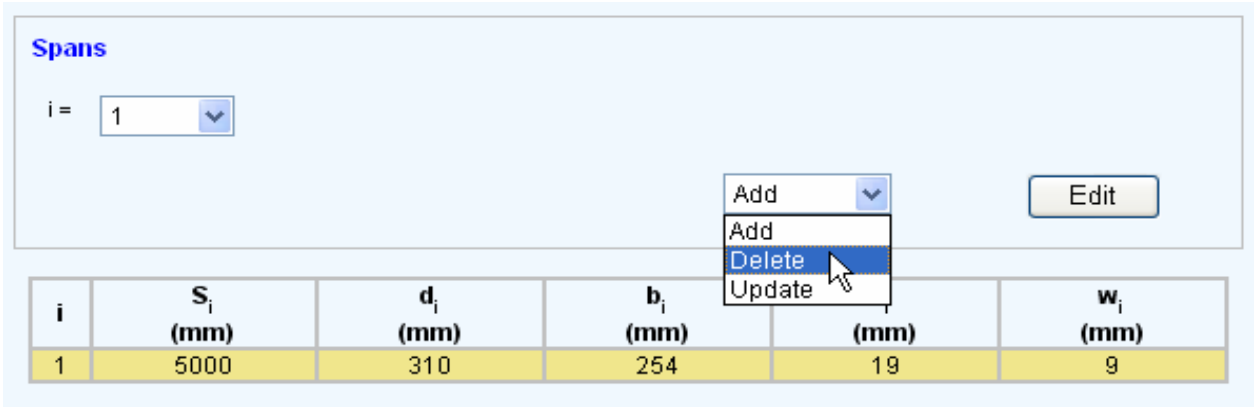


Choose new span **2**

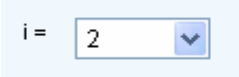
Input S_i, d_i, b_i, t_i, w_i as required

click button **Edit**, you can add new span 2

Delete One Span



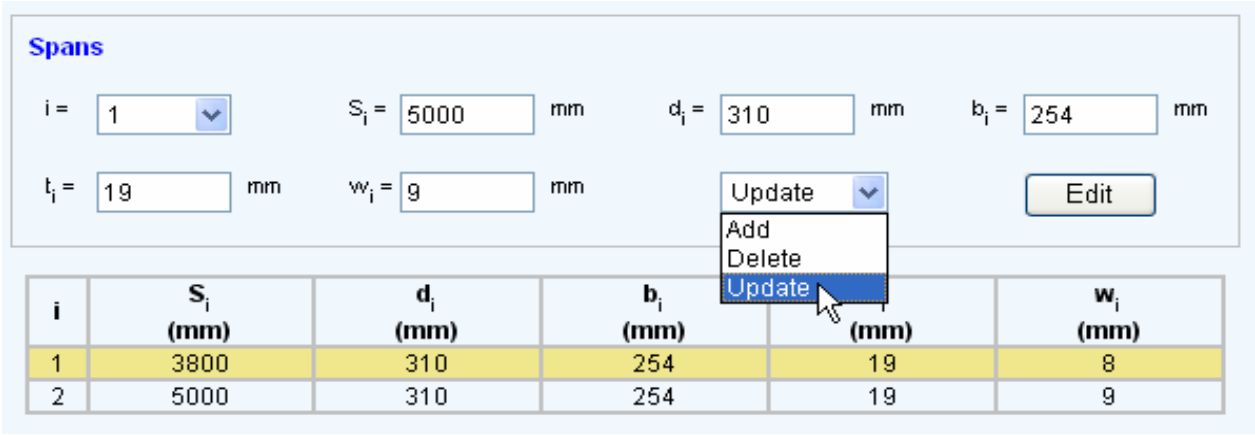
Select **Delete** from the list



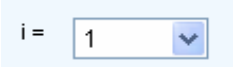
Select Span 2

Click button **Edit**, you can delete span 2,
You couldn't delete span 1, but you can update input for span 1

Update One Span



Select **Update** from the list



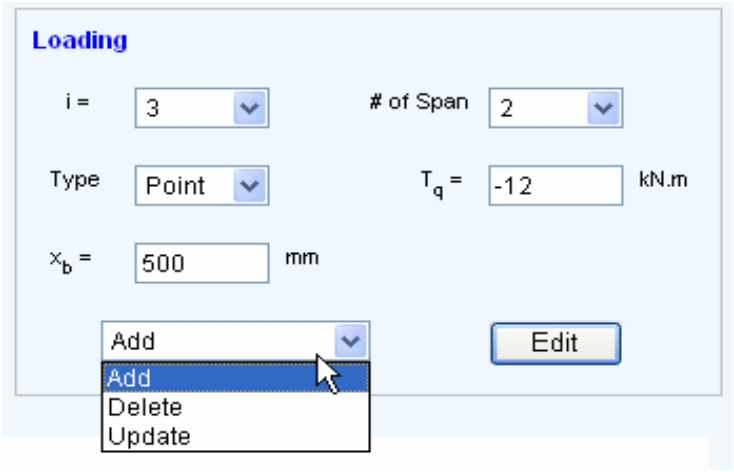
Select span 1

Input S_i, d_i, b_i, t_i, w_i as required

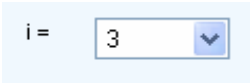
click button **Edit**, you can update input for span 1

3. Input of Loading

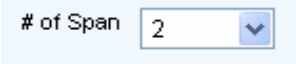
Add One Load



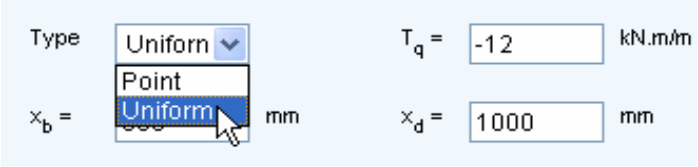
Select **Add** from the list



Choose loading number as 3



set loading on span 2

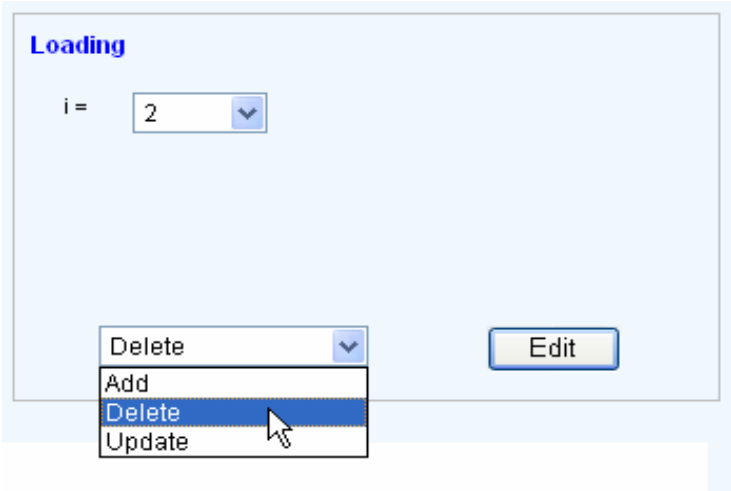


Select loading as **Uniform**

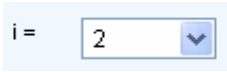
Input T_q, x_b, x_d as required

Click button **Edit**, you can add one load

Delete One Load



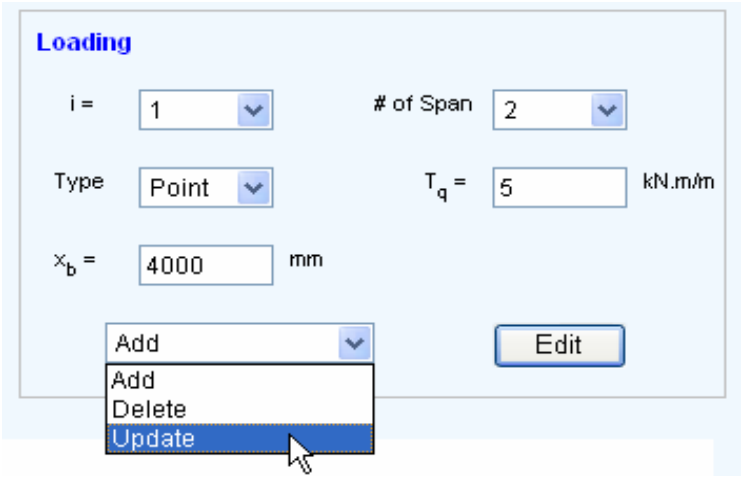
Select **Delete** from the list



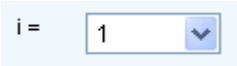
choose loading number of 2

click button **Edit,** you can delete loading number of 2
You couldn't delete loading number of 1, but you can update input for loading number of 1

Update One Load



Select **Update** from the list



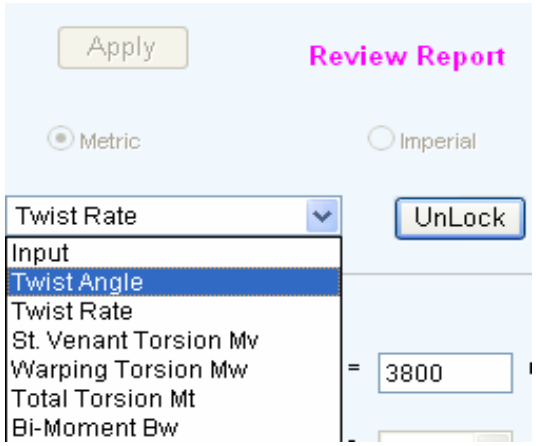
Choose loading number of 1

You can change information for # of span, Loading Type, T_q, x_b, x_d as required
Click button **Edit**, you can update input for the selected load

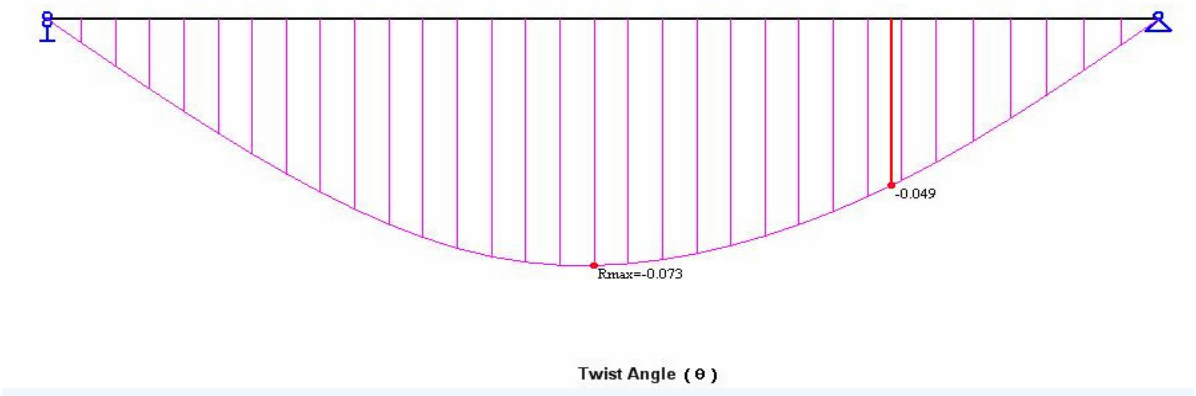
4. Review Results

Click botton **Apply**

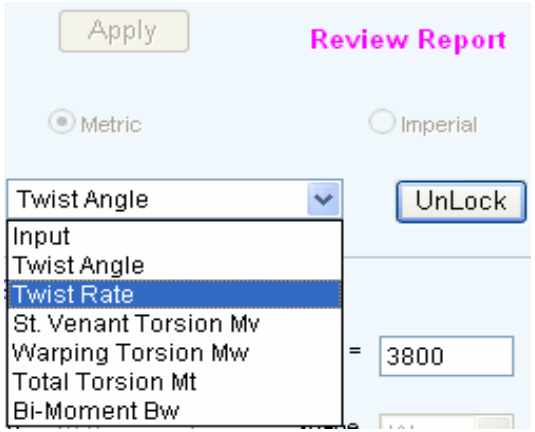
Result for Twist Angle (θ)



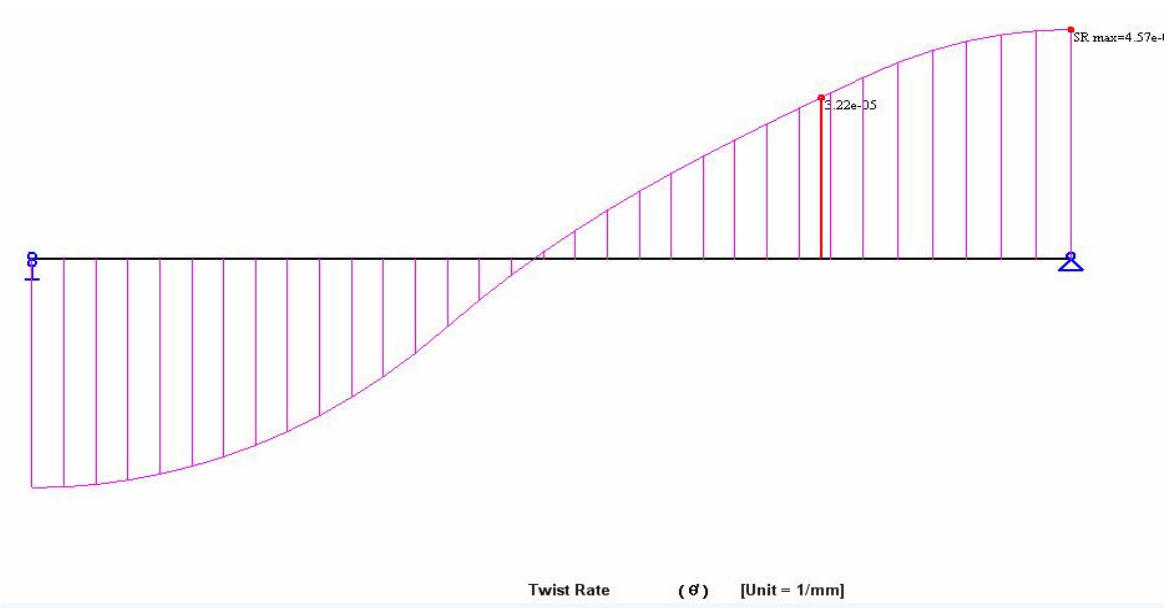
Select **Twist Angle** from the list
you can get envelope for rotation as following



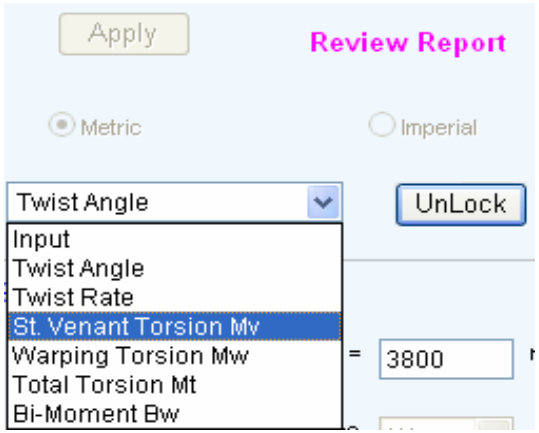
Result for Twist Rate (θ')



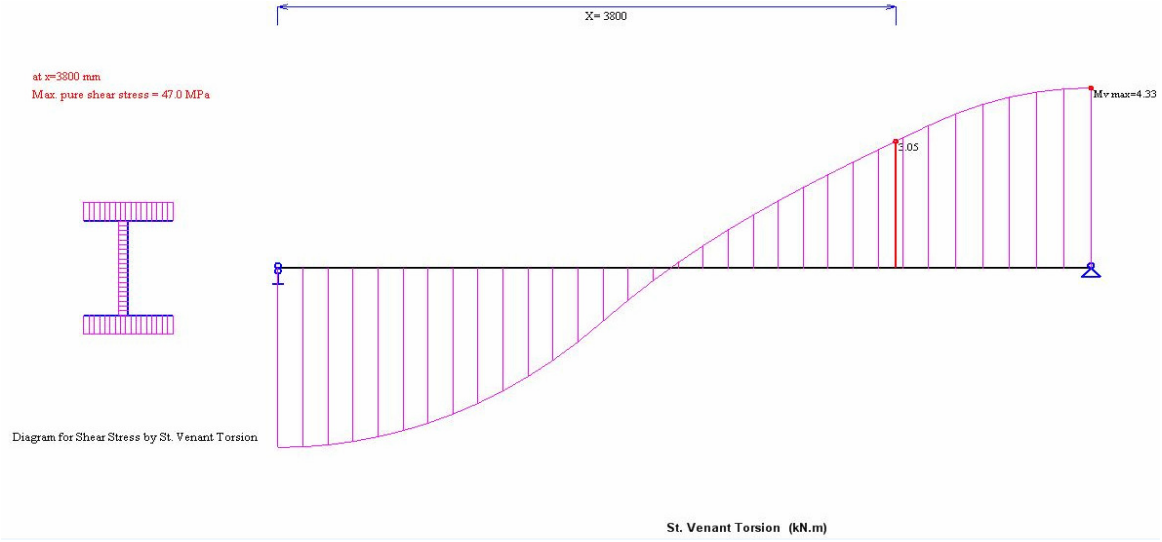
Select **Twist Rate** from the list
you can get envelope for slope of rotation as following



Result for St. Venant Torsion Mv

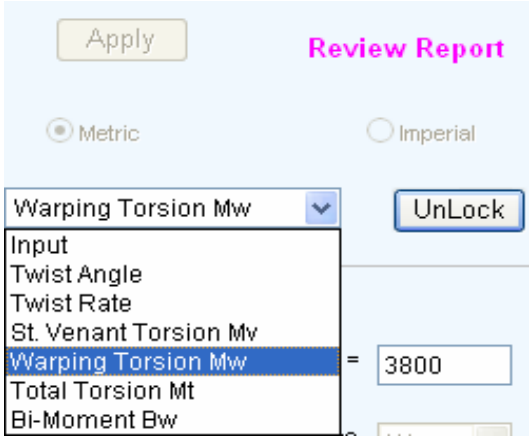


Select **St. Venant Torsion Mv** from the list
you can get envelope for St. Venant torsion and diagram for pure shear stress at location X

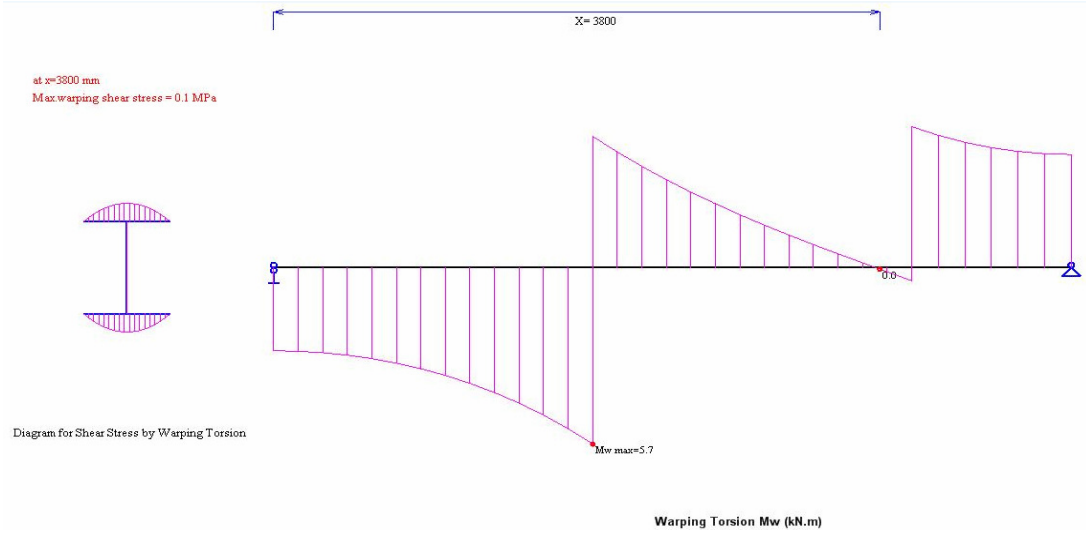


Click **Reivew Report**, you can see the detail report for maximum pure shear stress at X

Result for Warping Torsion Mw

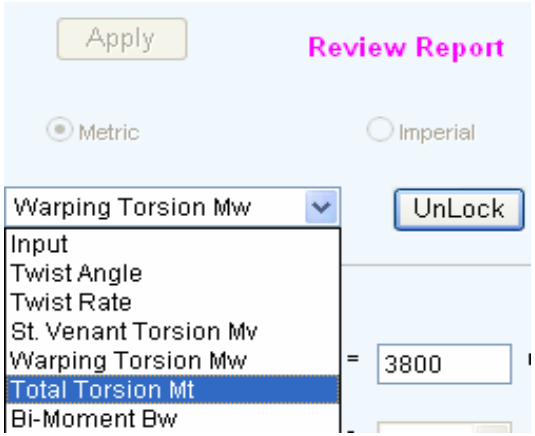


Select **Warping Torsion Mw** from the list
you can get envelope for warping torsion and diagram for warping shear stress at location X

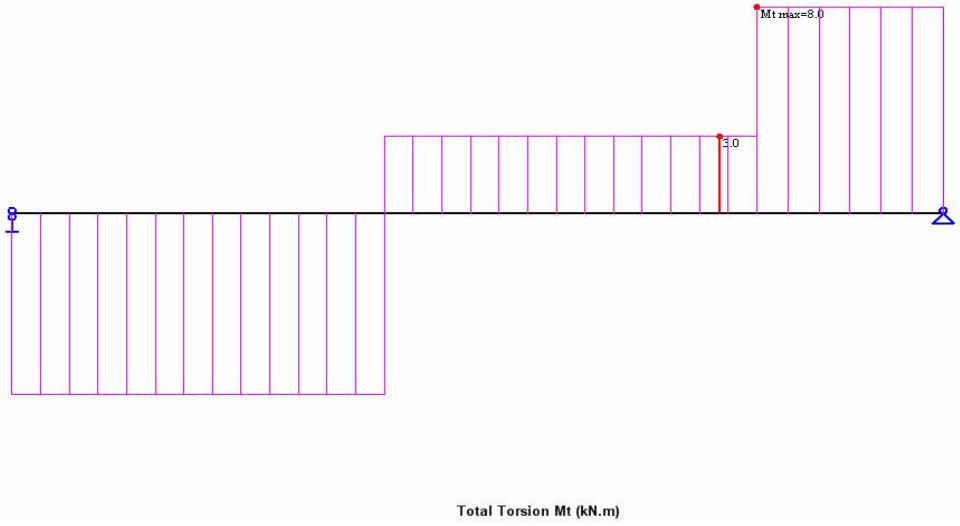


Click **Reivew Report**, you can see the detail report for maximum warping shear stress at X

Result for Total Torsion Mt

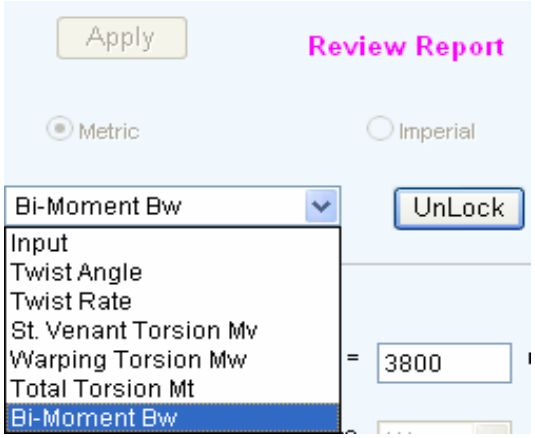


Select **Total Torsion Mt** from the list you can get envelope for total torsion

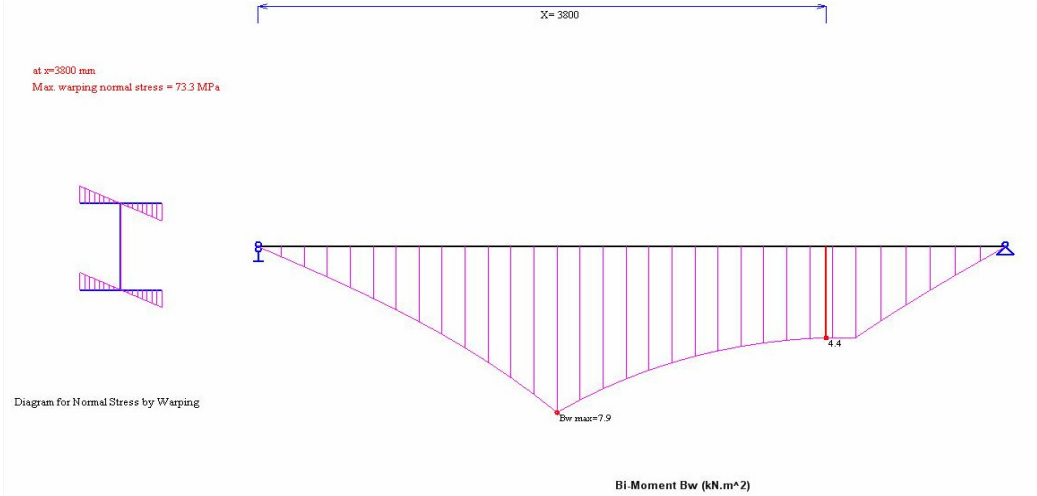


This torsion will apply for beam end connection design

Result for Bi-Moment Bw



Select **Bi-Moment Bw** from the list
you can get envelope for bi-moment and diagram for warping normal stress at location X



Click **Reivew Report**, you can see the detail report for maximum warping normal stress at X

click button **UnLock**, results are discarded, go back to input page

Theory for Torsional Analysis of Open Section Thin-Walled Members

Element Torsional Stiffness Matrix

$$\begin{pmatrix} M_{ti} \\ B_{\omega i} \\ M_{tj} \\ B_{\omega j} \end{pmatrix} .= \begin{pmatrix} 2\,i_\omega\,\gamma/L^2 & 2\,i_\omega\,(\alpha+\beta)/L & -2\,i_\omega\,\gamma/L^2 & 2\,i_\omega\,(\alpha+\beta)/L \\ 2\,i_\omega\,(\alpha+\beta)/L & 2\,i_\omega\,\alpha & -2\,i_\omega\,(\alpha+\beta)/L & 2\,i_\omega\,\beta \\ -2\,i_\omega\,\gamma/L^2 & -2\,i_\omega\,(\alpha+\beta)/L & 2\,i_\omega\,\gamma/L^2 & -2\,i_\omega\,(\alpha+\beta)/L \\ 2\,i_\omega\,(\alpha+\beta)/L & 2\,i_\omega\,\beta & -2\,i_\omega\,(\alpha+\beta)/L & 2\,i_\omega\,\alpha \end{pmatrix} \begin{pmatrix} \theta_i \\ \theta'_i \\ \theta_j \\ \theta'_j \end{pmatrix}$$

M_{ti}, M_{tj} = Total torsion at points i and j $M_t = M_v + M_\omega$

M_v = St. Venant (pure) torsion

M_ω = Warping torsion

$B_{\omega i}$, $B_{\omega j}$ = Bi-moment at points i and j

θ_i, θ_j = Twist angle at points i and j

θ'_i, θ'_j = Twist rate (or first derivative of twist angle) at points i and j

$$i_\omega = E_0 \,.\, J_\omega / L$$

$$\alpha = \kappa.\,(\,\kappa - th\kappa) \,/\, \{2\,th\kappa\,.\,[\kappa - 2\,th(\kappa/2)]\,\}$$

$$\beta = \kappa\,(sh\kappa - \kappa) \,/\, \{2\,sh\kappa\,.\,[\kappa - 2\,th(\kappa/2)]\,\}$$

$$\alpha + \beta = \kappa^2\,.th(\kappa/2) \;/\, \{2\,[\kappa - 2\,th(\kappa/2)]\,\}$$

$$\gamma = \kappa^3 \,/\, \{\,2\,[\kappa - 2\,th(\kappa/2)]\,\}$$

$\kappa = [\, G\, J_d\, L^2 / (E_1 \,.\, J_\omega)]^{0.5}$ $E_1 = E_0 / (1 - u^2)$ $G = E_0 / [2(1 + u)]$

J_d = St. Venant torsional constant

J_ω = Warping torsional constant

$M_v = G.\, J_d.\, \theta'$

$M_\omega = M_t - M_v$

Pure torsional shear stress $\tau = M_v \,.t / J_d$

Warping shear stress $\tau = M_\omega \,.S_\omega / (J_\omega \,.\, t)$

Warping normal stress $\sigma = B_\omega\, \omega / J_\omega$

for ω (sectorial area) and S_ω (sectorial moment), see detail report