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Torsional Analysis of Open Section Thin-Walled Beams (FEA) User Manual

Spans

i = $S_i =$ mm $d_i =$ mm $b_i =$ mm

$t_i =$ mm $w_i =$ mm

i	S_i (mm)	d_i (mm)	b_i (mm)	t_i (mm)	w_i (mm)
1	5000	310	254	19	8

Review Report

Metric Imperial

Input

General Information

E = MPa $X =$ mm

u = Shape

Supports at Ends

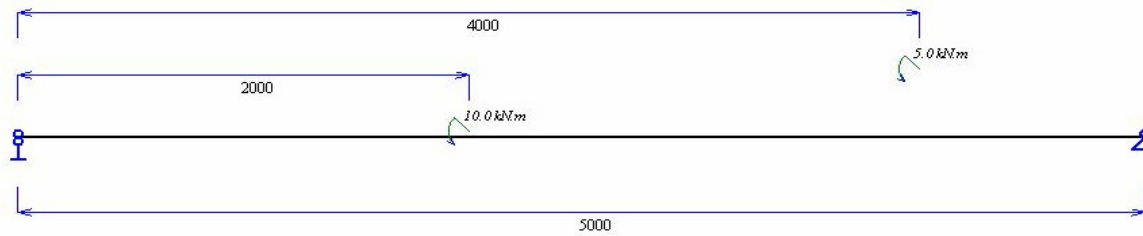
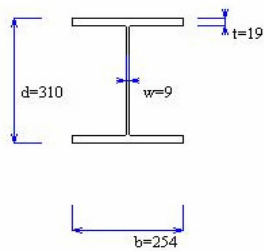
Left Right

Loading

i = # of Span

Type $T_q =$ kN.m

$x_b =$ mm



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.m² (in.² . kips)

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

References

Thin-Walled Elastic Beams, 2nd Edition, *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

General Information

E_0 = MPa X = mm

u = Shape

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

Shape

- W
- C**
- Z

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

Supports at Ends

Left Right

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*

Metric Imperial

All inputs can be transferred to other unit automatically

2. Input of Spans

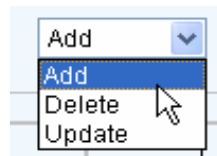
Spans

$i =$ $S_i =$ mm $d_i =$ mm $b_i =$ mm

$t_i =$ mm $w_i =$ mm

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

$i =$

$t_i =$

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

Spans

i =

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

Select **Delete** from the list

i = 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

Spans

$i =$
 $S_i =$ mm $d_i =$ mm $b_i =$ mm
 $t_i =$ mm $w_i =$ mm

i	S_i (mm)	d_i (mm)	b_i (mm)	t_i (mm)	w_i (mm)
1	3800	310	254	19	8
2	5000	310	254	19	9

Select **Update** from the list

$i =$ 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

Loading

i = # of Span

Type $T_q =$ kN.m

$x_b =$ mm

- Add
- Delete
- Update

Select **Add** from the list

i = Choose loading number as 3

of Span set loading on span 2

Type $T_q =$ kN.m/m

$x_b =$ mm $x_d =$ mm

Select loading as **Uniform**

Input T_q , x_b , x_d as required

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

Delete One Load

The screenshot shows a light blue rectangular panel with the title "Loading" in blue text at the top left. Below the title, there is a label "i =" followed by a dropdown menu containing the number "2". At the bottom left of the panel, there is another dropdown menu with a blue header "Delete" and a list of options: "Add", "Delete", and "Update". A mouse cursor is pointing at the "Delete" option in this list. To the right of this dropdown menu is a rectangular button with the text "Edit".

Select **Delete** from the list

i = 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

Loading

i = # of Span

Type $T_q =$ kN.m/m

$x_b =$ mm

- Add
- Delete
- Update**

Select **Update** from the list

i = 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 button **Apply**

Result for Twist Angle (θ)

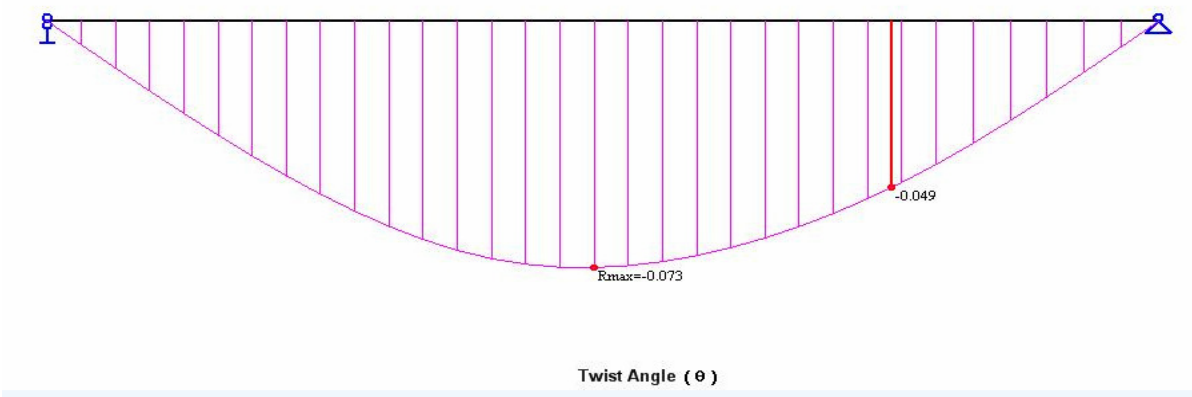
Apply **Review Report**

Metric Imperial

Twist Rate

Input
Twist Angle
Twist Rate
St. Venant Torsion Mv
Warping Torsion Mw = 3800
Total Torsion Mt
Bi-Moment Bw

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



Result for Twist Rate (θ')

Apply **Review Report**

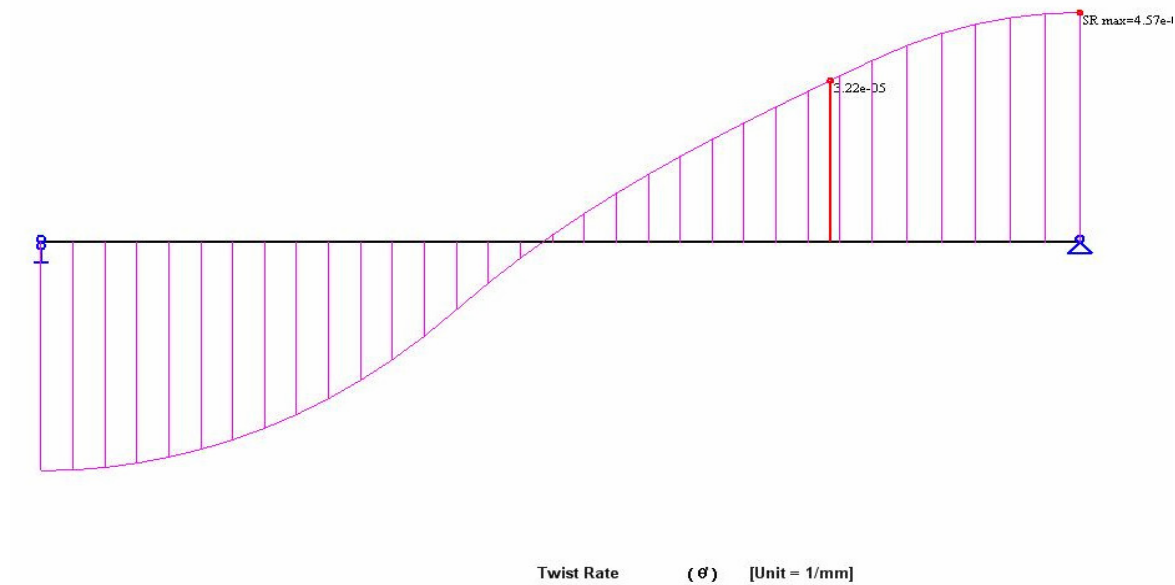
Metric Imperial

Twist Angle

- Input
- Twist Angle
- Twist Rate**
- St. Venant Torsion M_v
- Warping Torsion M_w
- Total Torsion M_t
- Bi-Moment B_w

= 3800

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



Result for St. Venant Torsion Mv

Apply **Review Report**

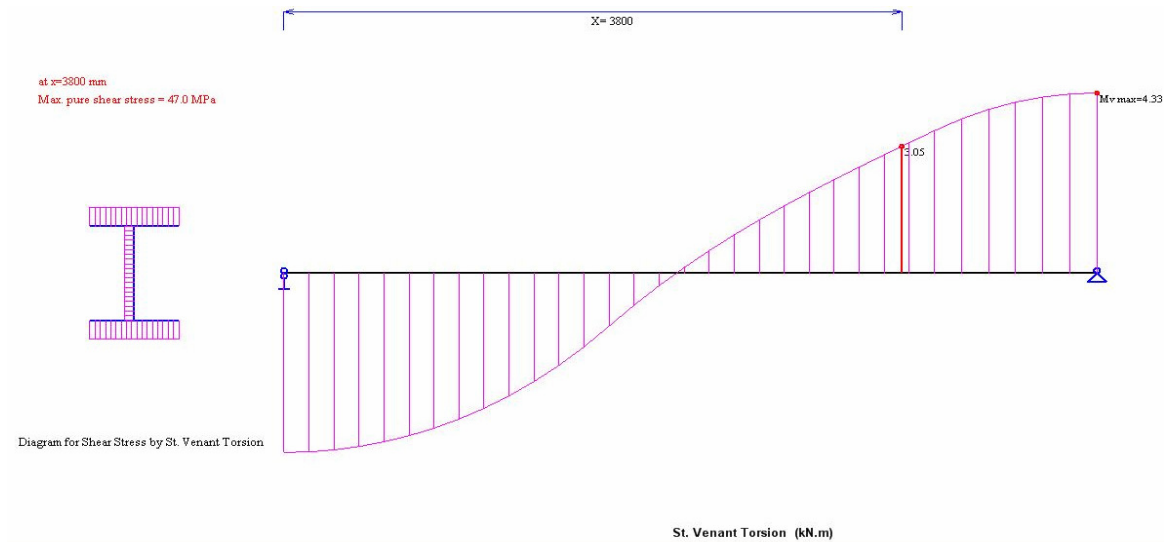
Metric Imperial

Twist Angle

Input
Twist Angle
Twist Rate
St. Venant Torsion Mv
Warping Torsion Mw
Total Torsion Mt
Bi-Moment Bw

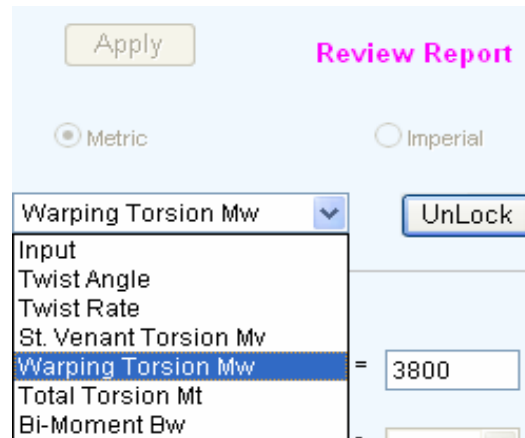
= 3800

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

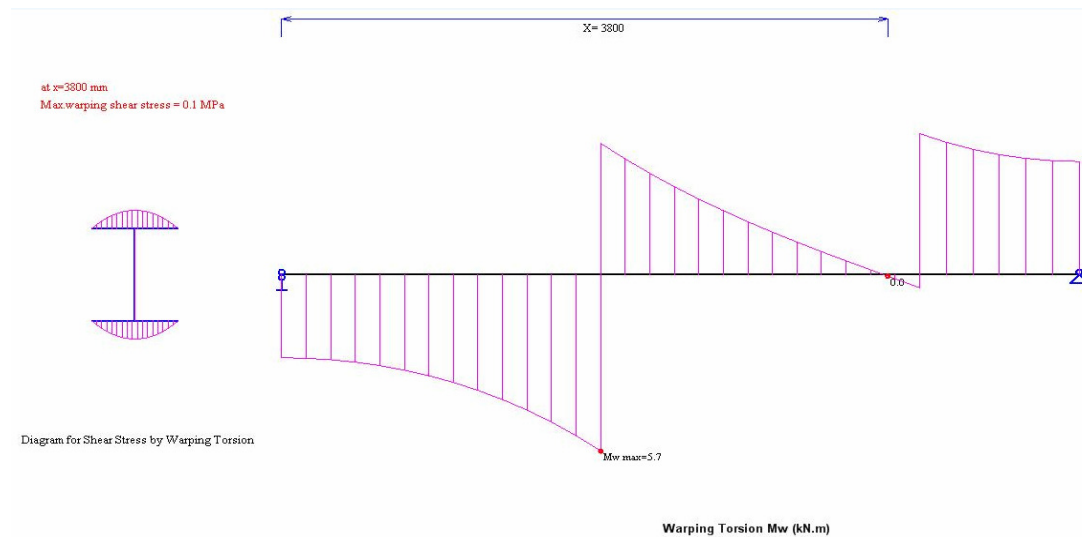


Click **Review Report**, you can see the detail report for maximum pure shear stress at X

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 [Review Report](#), you can see the detail report for maximum warping shear stress at X

Result for Total Torsion Mt

Apply **Review Report**

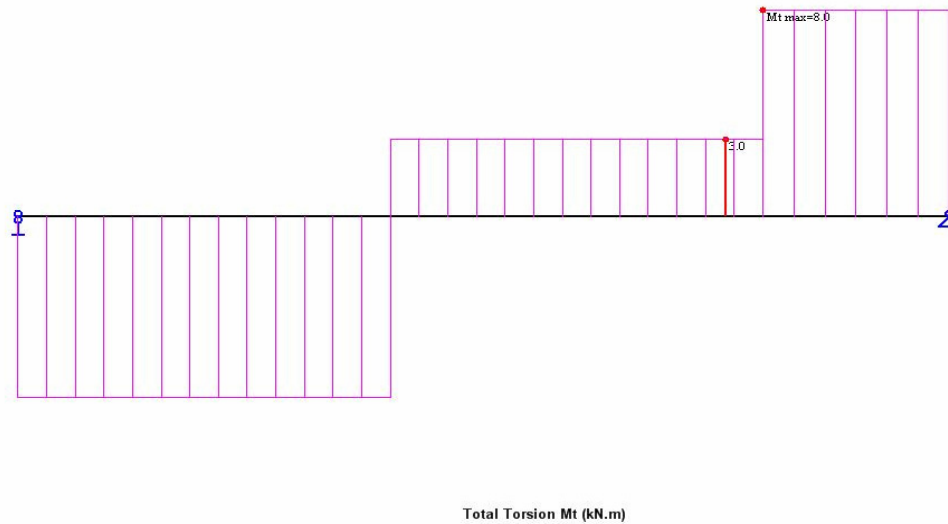
Metric Imperial

Warping Torsion Mw

Input
Twist Angle
Twist Rate
St. Venant Torsion Mv
Warping Torsion Mw
Total Torsion Mt
Bi-Moment Bw

= 3800

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

Apply **Review Report**

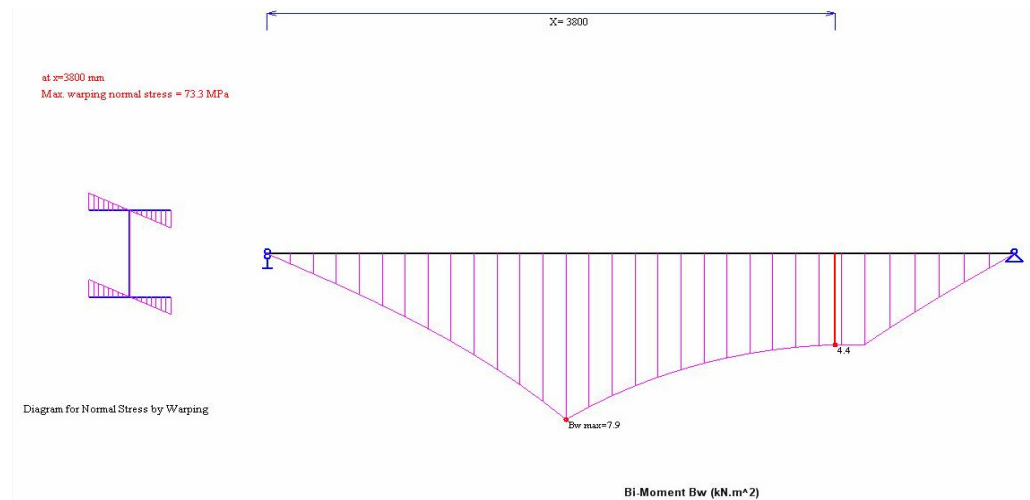
Metric Imperial

Bi-Moment Bw

Input
Twist Angle
Twist Rate
St. Venant Torsion Mv
Warping Torsion Mw
Total Torsion Mt
Bi-Moment Bw

= 3800

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



Click [Review 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

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

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

$$M_v = \text{St. Venant (pure) torsion}$$

$$M_{\omega} = \text{Warping torsion}$$

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

$$\theta_i, \theta_j = \text{Twist angle at points i and j}$$

$$\theta'_i, \theta'_j = \text{Twist rate (or first derivative of twist angle) at points i and j}$$

$$i_{\omega} = E_0 \cdot J_{\omega} / L$$

$$\alpha = \kappa \cdot (\kappa - \text{th}\kappa) / \{2 \text{th}\kappa \cdot [\kappa - 2 \text{th}(\kappa/2)]\}$$

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

$$\alpha + \beta = \kappa^2 \cdot \text{th}(\kappa/2) / \{2 [\kappa - 2 \text{th}(\kappa/2)]\}$$

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

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

J_d = St. Venant torsional constant
 J_ω = Warping torsional constant

$$M_v = G \cdot J_d \cdot \theta'$$

$$M_\omega = M_t - M_v$$

Pure torsional shear stress

$$\tau = M_v \cdot t / J_d$$

Warping shear stress

$$\tau = M_\omega \cdot S_\omega / (J_\omega \cdot t)$$

Warping normal stress

$$\sigma = B_\omega \cdot \omega / J_\omega$$

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

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