ETE Section Nonlinear Analysis and Design Program - User Manual

(**ETE-Section version 1.0**)

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Chapter 1 - Introduction

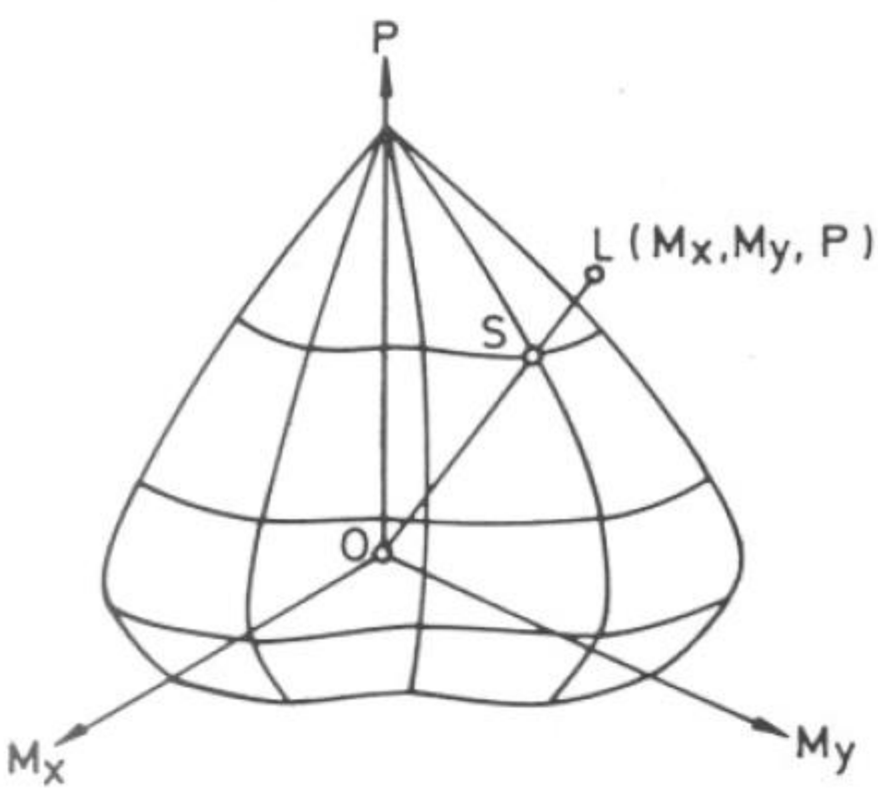
ETE section is a program for cross-section analysis based on the constitutive model with assumptions that the cross-sections of any member remain planar after deformation. The program can generate axial force – bending moment curve (P-M curve), and bi-directional bending moment curve (M-M curve). Based on the cross-sectional properties and loading condition, the program computes the combined stress state of the member, and the ratio to its ultimate structural capacity. The program follows the Code of Practice for Structural Use of Concrete 2013, and Code of Practice for Structural Use of Steel 2011.

Chapter 2 - Analysis Theory

Abstract of the Analysis Methodology of ETE Section

ETE section is a program for cross-section analysis with assumptions that the cross-sections of any member remain planar after deformation. The program can generate axial force – bending moment curve (P-M curve), and bi-directional bending moment curve (M-M curve) for given cross-sections defined by the user. The cross-section can be any combination of steel and concrete. ETE Section sub-divides the geometry of cross-section to a group of fibres. Each fibre records the stress and strain, so that can be summed up for the member's axial force and bending moments. The user could input the axial force P and bending moments Mx, My, then the program could compute the load fraction value. The program finds the P-M curve and M-M curve in an iterative approach until the load fraction value is 1.0.

Section Analysis Theory



Strength envelope (interaction surface) of RC sections subjected to axial compression and biaxial bending

Load fraction

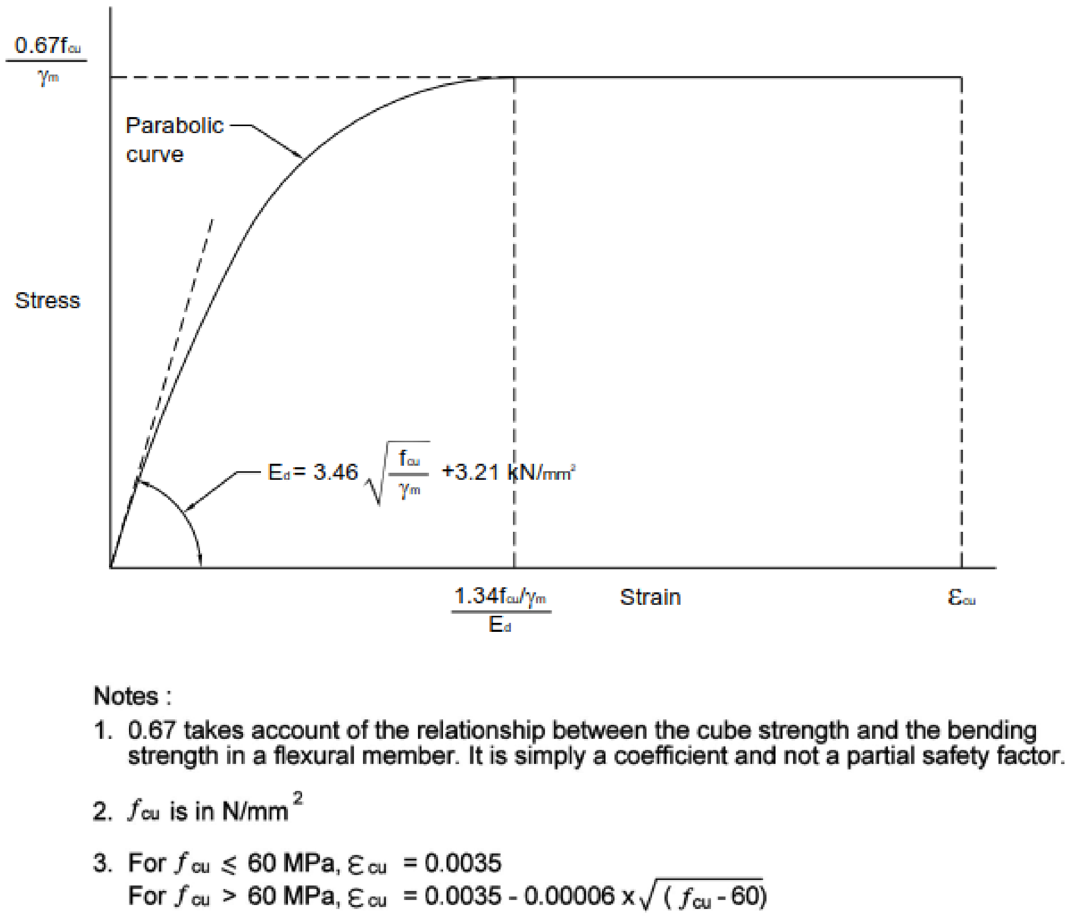
More specifically, the aim of ultimate strength analysis is to check that the design loads can be adequately withstood by the given section, i.e. that the point L which represents the design loads is within the strength envelope. Determination of the entire strength envelope is very exhaustive and in fact unnecessary, as will be shown. The present theory postulates that it is necessary only to find the point S on the strength envelope which would be intersected by the load vector OL. The ratio OS/OL is then the fraction of the design loads that can be adequately withstood by the given section. This ratio is called load fraction. It provides a quantitative measure of structural adequacy and determines whether the design loads can be safely taken. If the load fraction is greater than I -0, the strength provision is enough, otherwise the design is unsafe. Besides determining whether the strength provision is adequate, it also provides useful guidelines to necessary redesign at a later stage. It takes an important role in the automation and structural optimisation of the present design method.

Assumptions and material properties

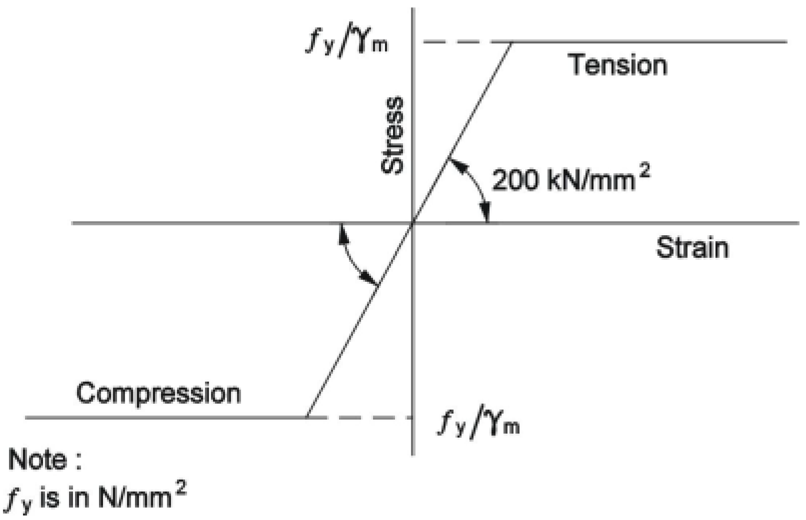
In the analysis, the following assumptions, which are the same as those codified in CP1101 and BS54002, are made.

(a) The strain distribution in the concrete in compression and the strain in the reinforcement, whether in tension or compression, are derived from the assumption that plane sections remain plane and that there is no bond-slip between the reinforcement and the concrete.
(b) The tensile strength of concrete is neglected.
(c) The stresses in the concrete in compression are derived from the stress-strain curve with $\gamma_m = 1.5$. The section will be at ultimate limit state of collapse when the maximum concrete strain reaches a specified value,ε_{cu} ,which is currently taken as 0.0035.
(d) The stresses in the reinforcement are derived from the stress-strain curve in Fig 3(b) with $\gamma_m = 1.5$.

Other than these assumptions, which are in strict accordance with the Codes, no other empirical assumptions have been made.



Short-term design stress-strain curve for normal weight concrete



Short-term design stress-strain curve for reinforcement

Mathematical formulation of ultimate strength analysis

Assumption (a) implies that the strain distribution is linear across the reinforced concrete section. Thus, the strain ε at any point with coordinates (x, y) is given by

$$\varepsilon = a + bx + cy \qquad \text{.... (1)}$$

where a, b, and c, are the parameters governing the strain distribution. Since the maximum compressive strain at ultimate limit state is ε_{cu}, therefore

$$max.(a + bx + cy) = \varepsilon_{cu} \qquad \text{.... (2)}$$

From the definition of load fraction and the conditions of equilibrium, it can be shown that

$$\lambda L = S \qquad \text{.... (3)}$$

where the load sector L is given by

$$L = \begin{bmatrix} P \\ Px_p + M_y \\ Py_p - M_x \end{bmatrix} \qquad \text{.... (4)}$$

and the strength vector S is given by

$$S = \begin{bmatrix} \int \sigma \, dA \\ \int \sigma \, x \, dA \\ \int \sigma \, y \, dA \end{bmatrix} \qquad \text{.... (5)}$$

in which σ is a function of t according to the stress-strain relations stated in assumptions (b), (c), and (d). Note that L is a vector representation of the load vector OL and that any S evaluated from a strain distribution satisfying eqn. (2) lies on the strength envelope.
The purpose of the above formulation is to pose the ultimate strength analysis mathematically as the determination of the parameters a, b and c, such that eqns. (1), (2) and (3), are satisfied. An iterative procedure to evaluate a, b, and c, and hence λ, is developed in the next section.

Initial estimates of a. b, and c

Initial estimates of the parameters a. b, and c, can be obtained by elastic analysis assuming that both concrete and steel have constant Young's moduli. Since Young's moduli are constant, therefore

$$\sigma = E(a + bx + cy) \qquad \text{.... (6)}$$

where E = Ec, for concrete and E = Es for steel. The conditions of equilibrium of axial force and bending moments about both axes give the following equations.

$$\begin{bmatrix} P \\ P \cdot x_p + M_y \\ P \cdot y_p - M_x \end{bmatrix} = k \begin{bmatrix} a \\ b \\ c \end{bmatrix} \qquad \text{.... (7)}$$

where the section stiffness matrix K is given by

$$K = \begin{bmatrix} \int E\, dA & \int Ex\, dA & \int Ey\, dA \\ \int Ex\, dA & \int Ex^2\, dA & \int Exy\, dA \\ \int Ey\, dA & \int Exy\, dA & \int Ey^2\, dA \end{bmatrix} \qquad .... (8)$$

Like stiffness matrices of all linear elastic structures, this matrix K is also symmetric and positive definite. It is first assumed that the whole reinforced concrete section is effective; thus, the integration for the section stiffness matrix is taken over the whole section. Having determined a, b, and c, from eqn. (7). the strain distribution is then evaluated using eqn. (1) and the concrete section is examined for tension. Since concrete in tension is actually ineffective in taking axial load and bending moment (assumption (b)), the section stiffness matrix is evaluated again with the tension zone of the concrete section neglected. The strain distribution is then re-examined, and the section stiffness matrix adjusted accordingly. After three to four iterations, a reasonably good estimate of the section stiffness matrix can be obtained. However, the initial estimates of a, b. and c, thus evaluated (i.e. a_o, b_o and c_o) do not necessarily give good agreement with that at ultimate limit state, since the latter is governed by eqn. (2). But the position of neutral axis thus obtained (given by a_o, b_o and c_o) generally agrees fairly closely with that at ultimate limit state.

Iterative procedure to evaluate load fraction

Before developing the iteration procedure, a convenient dimensionless error function, w, is defined in terms of vector norms by

$$w = \frac{||\ \lambda L - S\ ||}{||\ S\ ||} \qquad .... (9)$$

The definition of these vector norms is obvious from the following equation in which w is expressed in terms of matrices.

$$w = \frac{\sqrt{[(\lambda L - S)^1 K^{-1} (\lambda L - S)]}}{\sqrt{[S^1 K^{-1} S]}} \qquad .... (10)$$

The main advantage of employing these vector norms and error function is that their values are independent of the coordinates chosen.

Suppose the i^{th} estimate has been made of a, b, and c. where i = 0, 1, 2, … The estimate would not, in general, satisfy eqn. (2) and adjustment according to the following equation is necessary.

$$\begin{bmatrix} \overline{a_i} \\ \overline{b_i} \\ \overline{c_i} \end{bmatrix} = \frac{\varepsilon_{cu}}{max.(a_i + b_i x + c_i y)} \begin{bmatrix} a_i \\ b_i \\ c_i \end{bmatrix} \qquad .... (11)$$

Note that the position of the neutral axis is unchanged by this adjustment. After the adjustment, the strain and hence stress distributions at ultimate limit state can be evaluated according to eqn. (1) and the stress-strain relations stated in assumptions (b), (c), and (d). The i^{th} estimate of strength vector S can then be evaluated by

$$S = \begin{bmatrix} \int \sigma_i\, dA \\ \int \sigma_i\, x\, dA \\ \int \sigma_i\, y\, dA \end{bmatrix} \qquad .... (12)$$

where $\sigma_i = \sigma_i(x, y)$ is the ith estimate of stress distribution at ultimate limit state. This strength vector does not automatically satisfy eqn. (3), but an estimate of λ (the ith estimate) can be obtained by minimising the error function

$$\mathrm{w} = \frac{||\ \lambda L - S_i\ ||}{||\ S_i\ ||} \quad .... (13)$$

which gives

$$\lambda_i = \frac{S_i^t K^{-1} L}{L^1 K^{-1} L} \quad .... (14)$$

The approximations may be improved by the Newton-Raphson method for solutions of systems of non-linear equations, i.e.

$$\begin{bmatrix} a_{i+1} \\ b_{i+1} \\ c_{i+1} \end{bmatrix} = \begin{bmatrix} \overline{a_i} \\ \overline{b_i} \\ \overline{c_i} \end{bmatrix} \left[\frac{\partial S}{\partial(a,b,c)}\right]^{-1} (\lambda_i L - S_i) \quad .... (15)$$

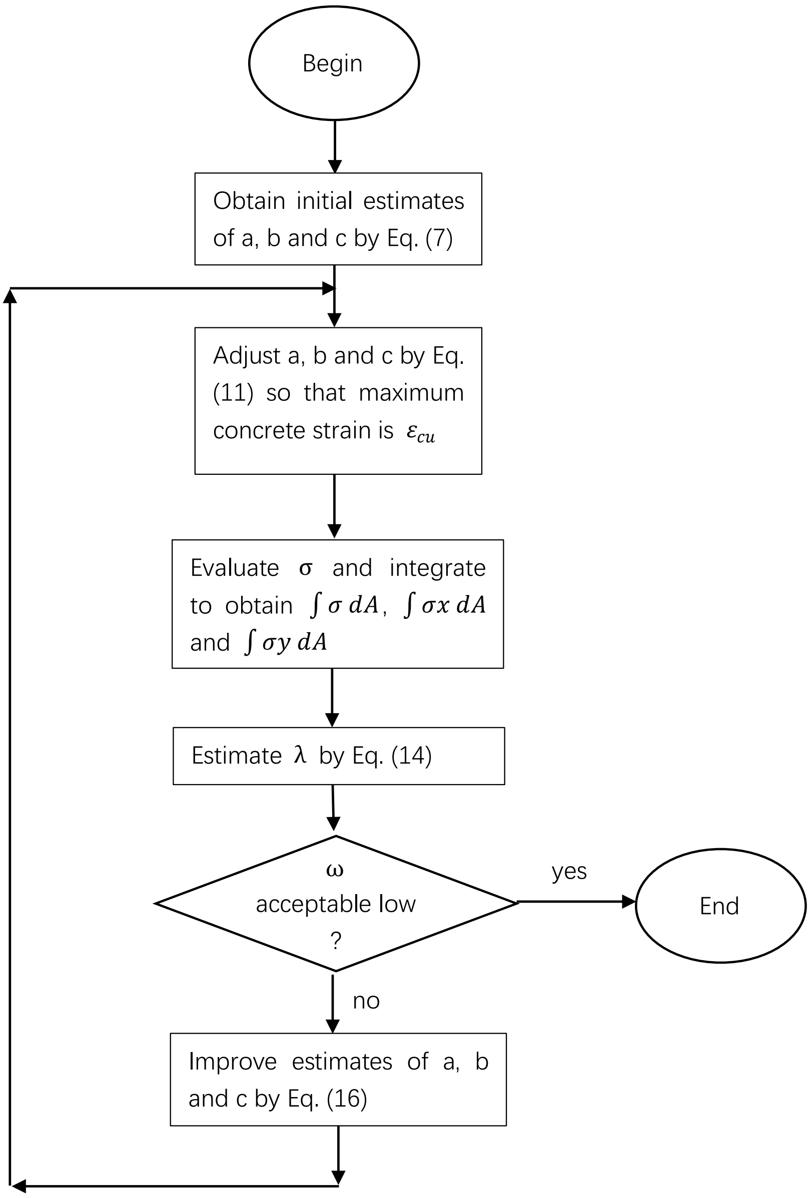
However, the evaluation of the Jacobian $\frac{\partial S}{\partial(a,b,c)}$ (analogous to derivatives) is a very arduous numerical exercise. Thus, in practice, an estimated derivative which is chosen to be the section stiffness matrix K is used. Therefore the iteration formula becomes

$$\begin{bmatrix} a_{i+1} \\ b_{i+1} \\ c_{i+1} \end{bmatrix} = \begin{bmatrix} \overline{a_i} \\ \overline{b_i} \\ \overline{c_i} \end{bmatrix} + K^{-1}(\lambda_i L - S_i) \quad .... (16)$$

The iterative procedures through eqns. (11), (14), and (16), can be repeated till the error function w_i, given by

$$\mathrm{w}_i = \frac{||\ \lambda_i L - S_i\ ||}{||\ S_i\ ||} \quad .... (17)$$

is acceptably small. The estimated derivative (matrix K) need not be recomputed at each iteration. Instead, the same value of derivative can be used until a new value is recomputed once every few iterations. A simplified flowchart of the iteration procedure is shown in the following figure. The convergence of the procedure will be studied later.



Flow chart 1 – Algorithm of load fraction evaluation

Chapter 3 - Limitations of ETE-Section

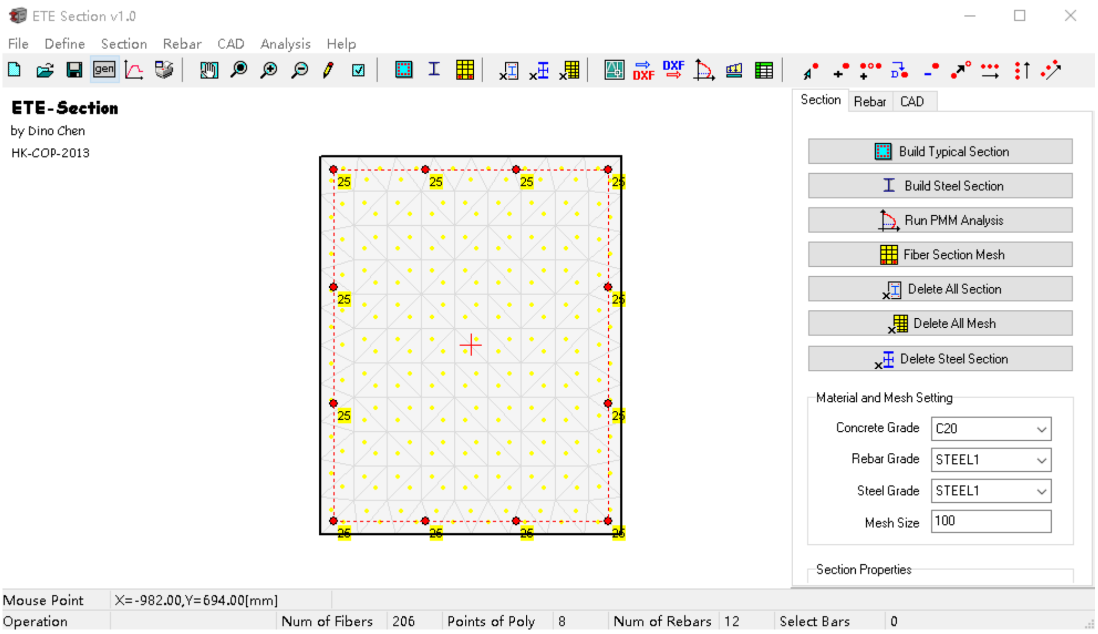
G	1.	Program can be used to analyse and design for reinforced concrete (RC) and steel reinforce concrete (SRC) only
A	2.	The program cannot take link reinforcement into consideration, hence cannot consider shear capacity of column and wall
G	3.	Maximum 5 types of steel materials are allowed for a model
G	4.	Concrete material input only allows within the range from C20 to C100
G	5.	Member’s internal forces (axial force and bending moments) should be imported from the analysis results computed by other software
A	6.	The program cannot take into consideration of the slenderness for column or wall members, therefore the additional moments cannot be included
A	7.	Tensile strength of concrete is assumed to be 0
G	8.	The program provides 16 types of concrete cross-sectional shape, and 10 types of steel cross-sectional shape. The program supports polygon shapes imported with no limitations on the number of edges for polygons
G	9.	Distance from reinforcement bar to the edge of concrete should be defined by the user manually
A	10.	The program computes the geometry centre of the concrete as the loading centre by default. If the loading centre is elsewhere, the user should calculate and input the additional moment manually
A	11.	The program does not check if the cross-section layout complies with max/min reinforcement ratio requirements

G-General A-Analysis

Chapter 4 - Operation Manual

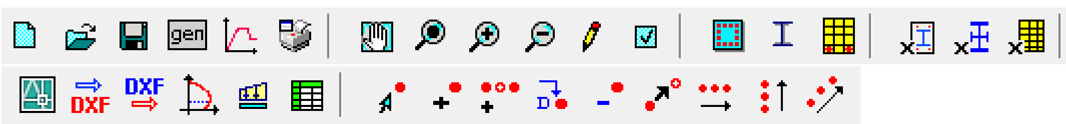
Main Window

The module's operation window is shown as in the image below:

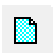


Main operation window of ETE Section

The module's main button bar contains following buttons.



The feature of each command button is shown below:

 Create a new ETE Section task

 Open an existing ETE Section model (*.sec)

 Save the ETE Section model (*.sec)

General Setting:
Parameter setting for analysis, such as number of envelope nodes for P-M and M-M analysis

Material Setting:
Modify the constitutive model of the material including concrete, reinforcement, and steel

Print

Pan view

Zoom to fit

Zoom in

Zoom out

Re-draw the section

Modify the display settings, such as show/hide outline of the section, or re-bars, etc.

Generate outline of the concrete section and layout of reinforcement bars based on input parameters

Generate outline of the steel section based on input parameters

Meshing the section

Delete all the concrete section, steel section, and reinforcement bars

Delete all the steel section

Delete all the mesh

Import AutoCAD file

Export model to .dxf file

Import section from .dxf file

Generate P-M or M-M curve

Import internal forces of member

Generate .csv file of the model

Select reinforcement bars

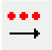
Add a single reinforcement bar

Add multiple reinforcement bars

Modify diameter of reinforcement bars

Delete selected reinforcement bar

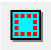
 Move/copy reinforcement bar

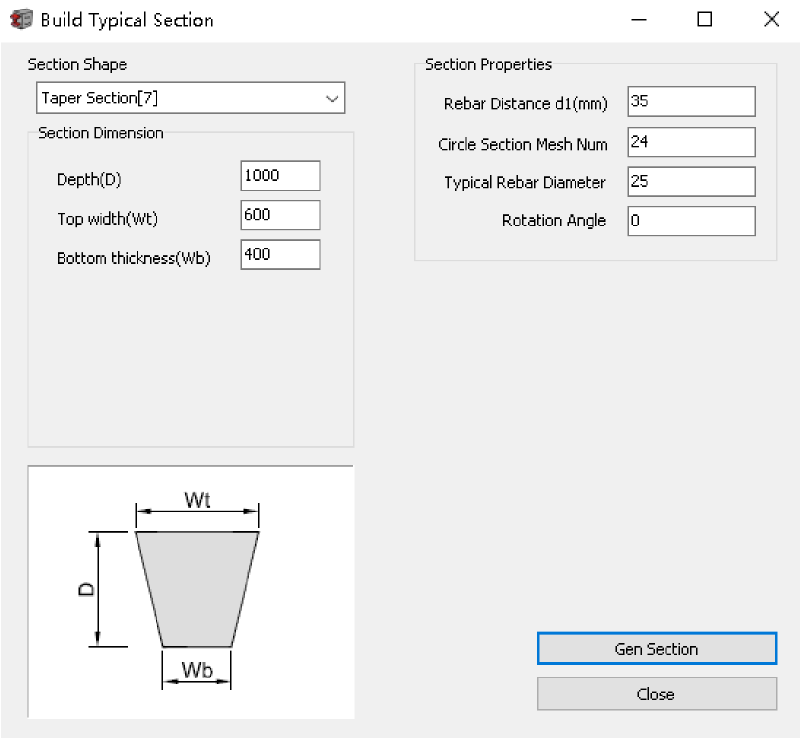
 Align reinforcement bars in X direction

 Align reinforcement bars in Y direction

 Align reinforcement bars in defined direction

Build Typical Section

Click the button **Build Typical Section** to create concrete section with pre-defined shapes. The window below will pop-up. Click the button **Gen Section** to generate the concrete section as the parameters input.

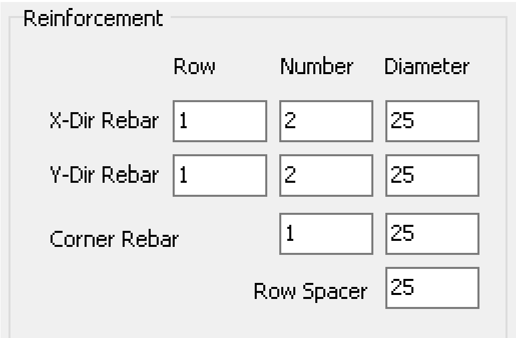


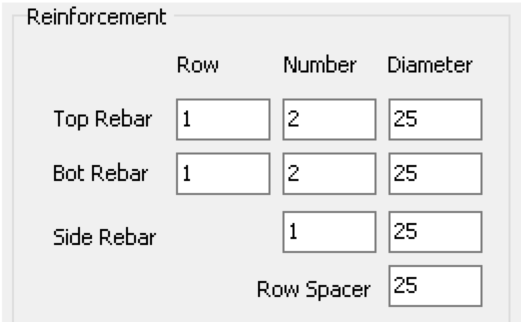
Build typical section operation window

ETE-Section provides several pre-defined section shapes. The key parameters to define a shape are explained in the table below:

Rebar Distance d1	Distance from reinforcement bars to the edge of concrete
Circle Section Mesh Num	Number of mesh cells for meshing circular section
Typical Rebar Diameter	Diameter of rebars
Rotation Angle	Rotational angle based on default orientation of the section

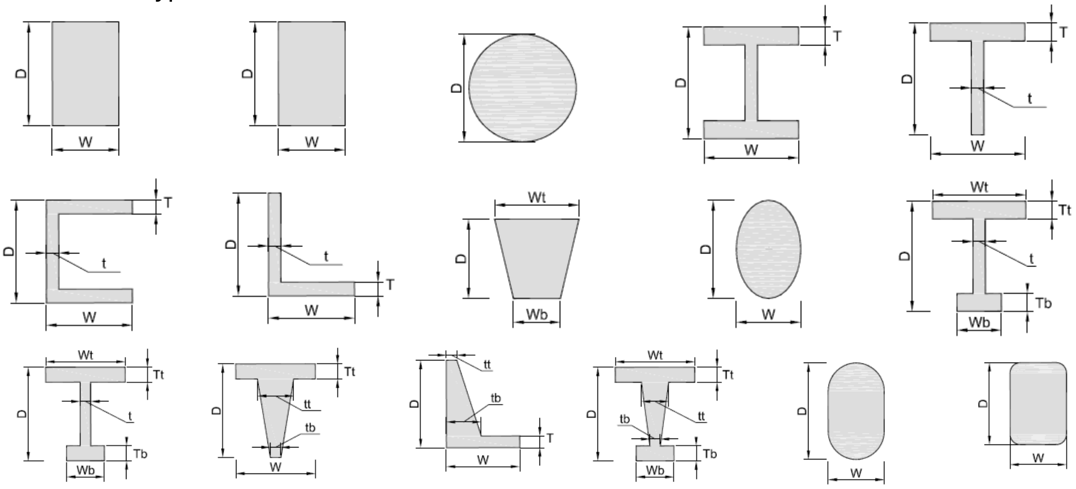
ETE-Section parameter setting examples to typical rectangular beam/column, or circular column is as following:



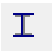


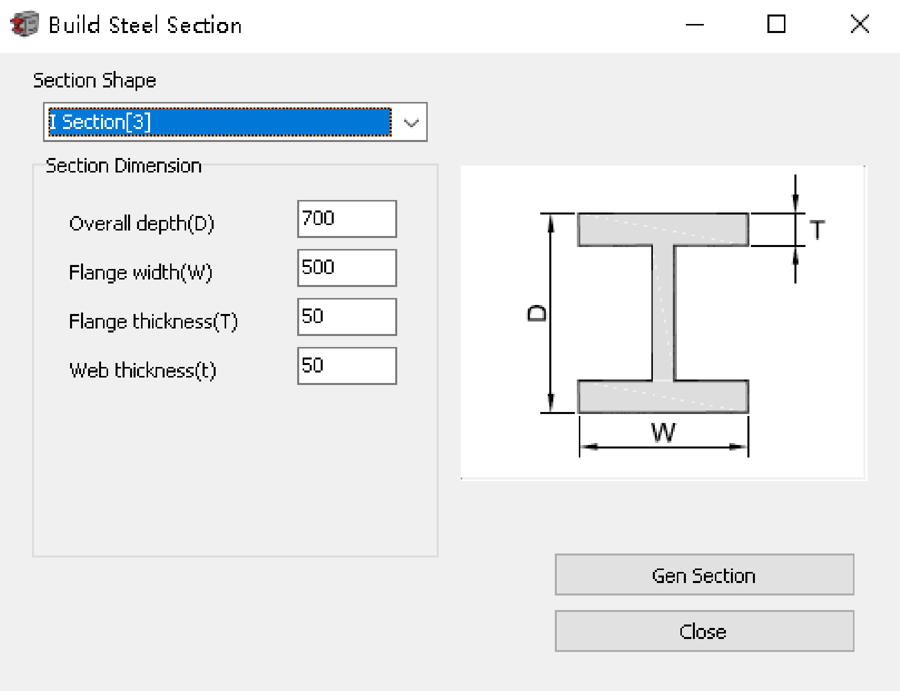
X-Dir Rebar	Number of layers, number of rebars per layer, and diameter for the rebars in global X direction
Y-Dir Rebar	Number of layers, number of rebars per layer, and diameter for the rebars in global Y direction
Top Rebar	Number of layers, number of rebars per layer, and diameter for the rebars at the top side
Bot Rebar	Number of layers, number of rebars per layer, and diameter for the rebars at the bottom side
Corner	Number of rebars and diameter for the rebars at the corner
Row Spacer	Distance between adjacent two layers of reinforcement

1-16 section types are listed below:



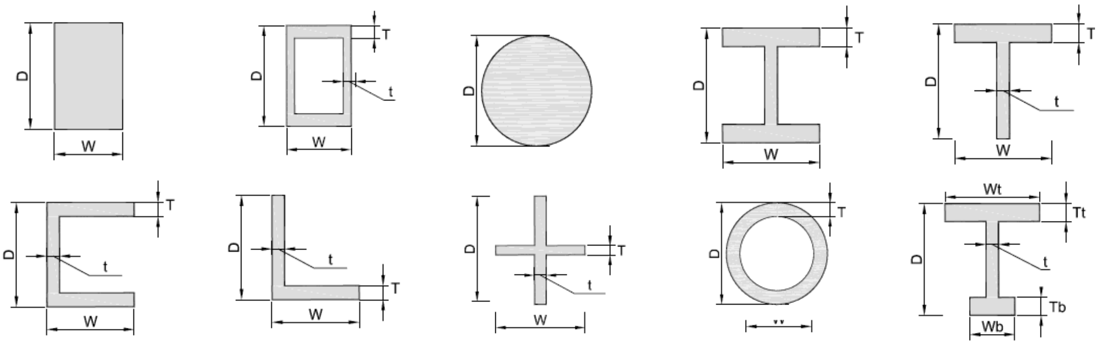
Build Steel Section

 Click the button **Build Steel Section** to create steel section. The following window will pop-up. Click the button **Gen Section** to generate the steel section as the parameters input.

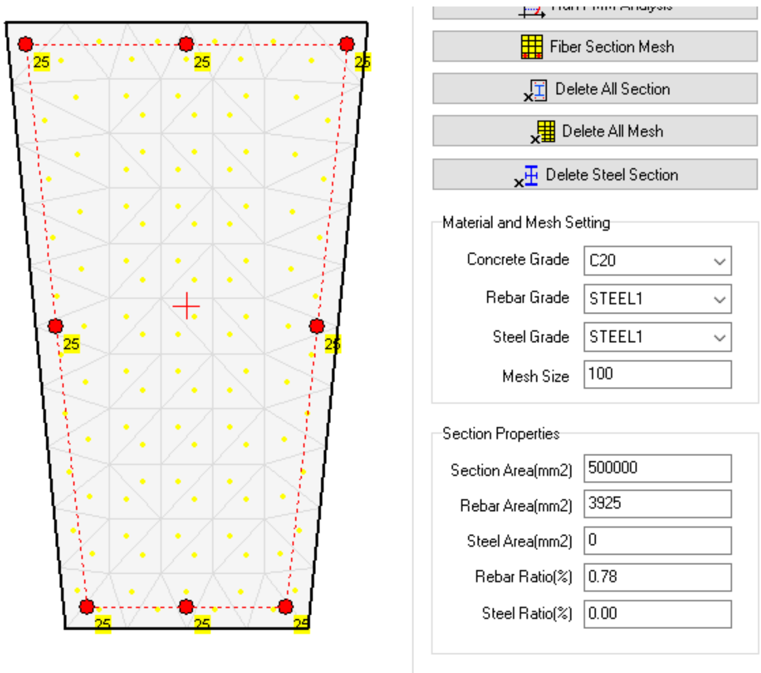


Build steel section operation window

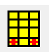
ETE-Section has 10 types of pre-defined steel section shape as shown in the figure below:



Section Mesh Operation



Meshing settings in the main operation window

 Click the button **Fibre Section Mesh** to create fibre meshing for the cross-section, so that the user can carry out P-M-M analysis.

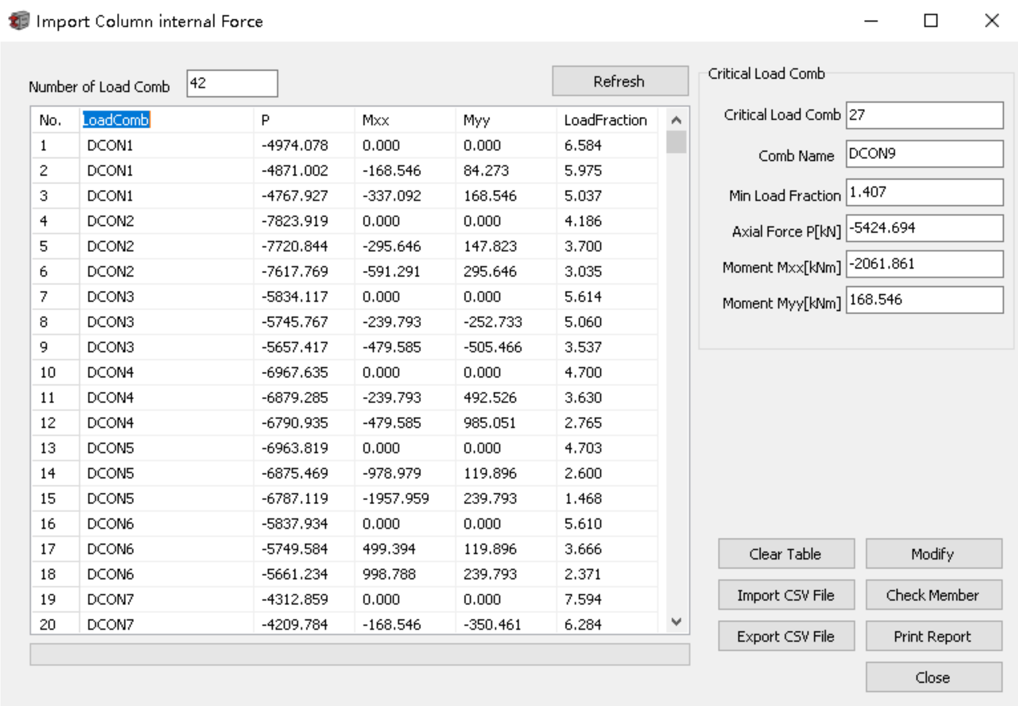
Concrete Grade	Material grade of concrete （C20~C100）
Rebar Grade	Material grade of reinforcement bars （Steel1~Steel5）
Steel Grade	Material grade of steel sections （Steel1~Steel5）
Mesh Size	Control size of mesh （default is 100mm）

After meshing, the program automatically computes the area by material type and reinforcement ratio

Section Area	Area of concrete cross-section (mm2)
Rebar Area	Total area of reinforcement in cross-section (mm2)
Steel Area	Total area of steel section in cross-section (mm2)
Rebar Ratio	Reinforcement ratio
Steel Ratio	Steel ratio

Import Member Internal Force

Click the button to import the internal forces of the element, including the information of load combination numbers and names, axial forces, x-x and y-y bending moments. The information imported should be saved as .csv format.

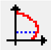


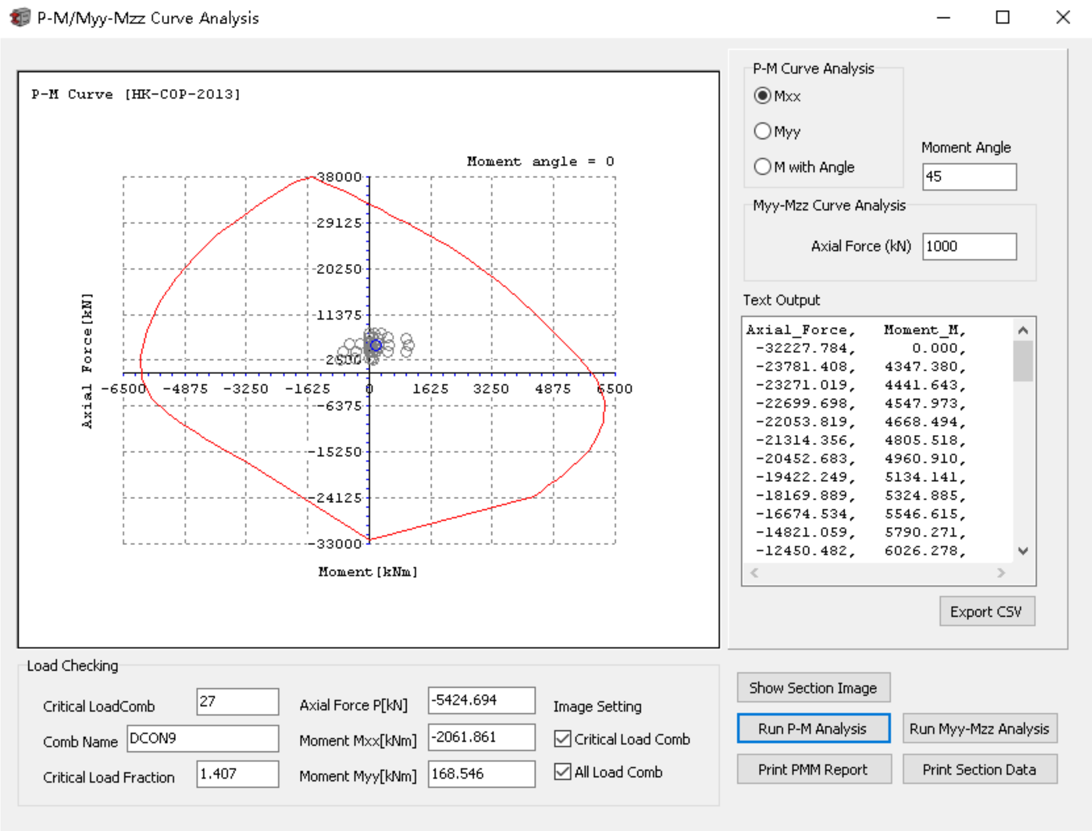
No.	LoadComb	P	Mxx	Myy	LoadFraction
1	DCON1	-4974.078	0.000	0.000	6.584
2	DCON1	-4871.002	-168.546	84.273	5.975
3	DCON1	-4767.927	-337.092	168.546	5.037
4	DCON2	-7823.919	0.000	0.000	4.186
5	DCON2	-7720.844	-295.646	147.823	3.700
6	DCON2	-7617.769	-591.291	295.646	3.035
7	DCON3	-5834.117	0.000	0.000	5.614
8	DCON3	-5745.767	-239.793	-252.733	5.060
9	DCON3	-5657.417	-479.585	-505.466	3.537
10	DCON4	-6967.635	0.000	0.000	4.700
11	DCON4	-6879.285	-239.793	492.526	3.630
12	DCON4	-6790.935	-479.585	985.051	2.765
13	DCON5	-6963.819	0.000	0.000	4.703
14	DCON5	-6875.469	-978.979	119.896	2.600
15	DCON5	-6787.119	-1957.959	239.793	1.468
16	DCON6	-5837.934	0.000	0.000	5.610
17	DCON6	-5749.584	499.394	119.896	3.666
18	DCON6	-5661.234	998.788	239.793	2.371
19	DCON7	-4312.859	0.000	0.000	7.594
20	DCON7	-4209.784	-168.546	-350.461	6.284

Import column internal force operation window

LoadComb - Load combination names
P - Axial force of the member (unit: kN, +ve as tension, -ve as compression)
Mxx - Bending moment about x-x axis (kNm)
Myy - Bending moment about y-y axis (kNm)
LoadFraction - The redundancy of the given cross-section under the load. If the load fraction is greater than 1.0, then the member is safe; if less than 1.0, the capacity of the cross-section is not enough.
Critical Load Comb - The most adverse load combination, which has the lowest value in load fraction
Check Member - Check the capacity of the section under imported load combinations, and computes the load fraction values
Clear Table - Clear the data in the table
Modify - Modify the value in the table
Import CSV File - Import .csv file
Export CSV File - Export .csv file
Print Report - Generate the calculation report file in .pdf format

P-M-M Section Analysis

 Click the button to carry out the section analysis. The window as below will pop-up. User can use this function to calculate and obtain the P-Mx, P-My. or P-Mx-My curves with load combination conditions overlaid on the diagram.

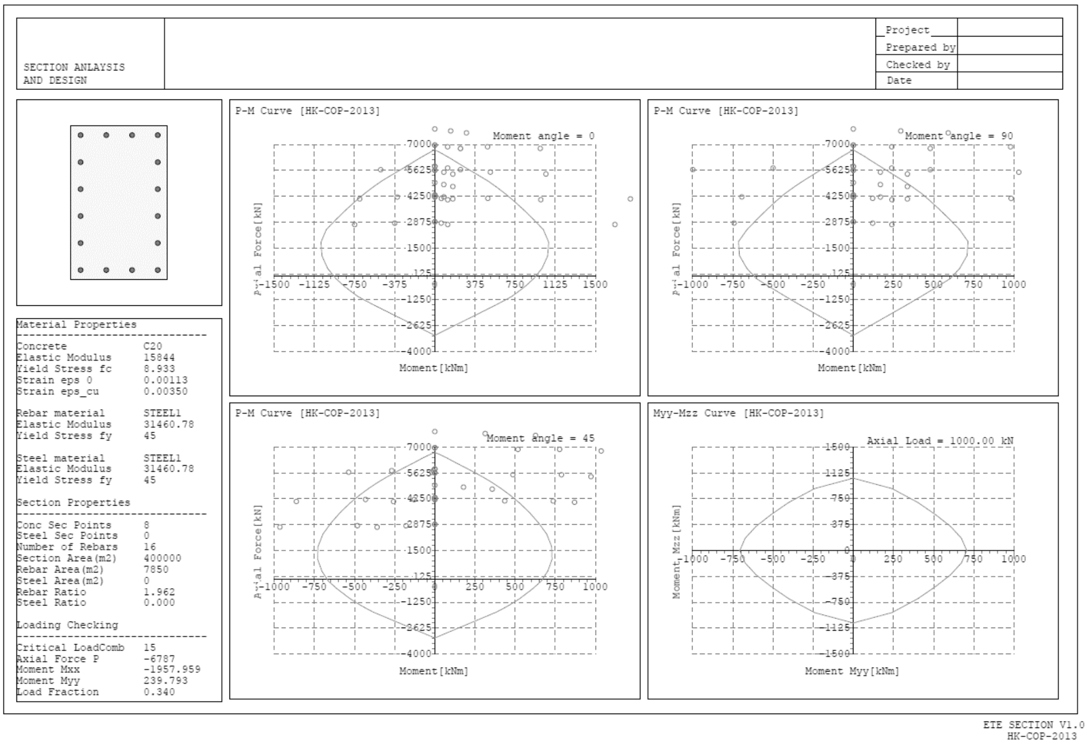


P-M-M analysis operation window

P-M Curve Analysis - Settings for P-M curve display. Select Mxx to display P-Mxx curve; Select Myy to display P-Myy curve; Select M with Angle to display rotated P-M curve; Moment Angle is the angle to rotate the axis
Myy-Mxx Curve Analysis - Parameter for M-M curve display. Axial Force(kN) is the level of axial force to trim the Mxx-Myy curve from P-M-M profile
Text Output - Display the data of the P-M curve or M-M curve
Show Section Image - Display the brief image of the cross-section
Run P-M Analysis - Calculate and display P-M curve
Run Mxx-Myy Analysis - Calculate and display Mxx-Myy curve
Print PMM Report - Generate P-M-M analysis report in .pdf format
CriticalLoadComb - The number of the most adverse load combination
CombName - The name of the most adverse load combination
Axial Force P[kN] - Axial force under the most adverse load combination

Moment Mxx[kNm] - Bending moment about x-x axis under the most adverse load combination
Moment Myy[kNm] - Bending moment about y-y axis under the most adverse load combination
Critical LoadComb - Display the point of the most adverse load combination overlaid to the P-M curve diagram
All LoadComb - Display the points of all the load combinations overlaid to the P-M curve diagram
Export CSV - The program output the content in “Text Ouput” to a .csv file

Click the button **Print PMM Report** to create the calculation report in .pdf format as the example below:



Typical report generated by ETE Section

Chapter 5 - Tutorial

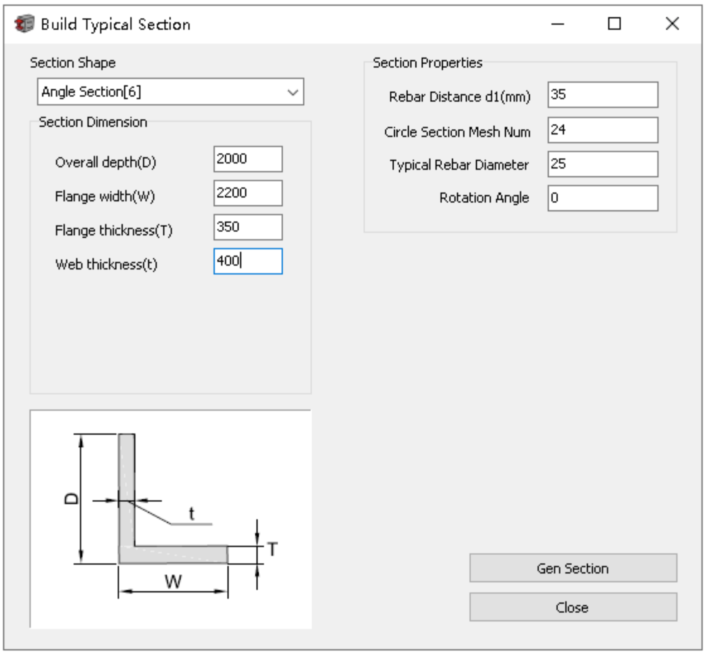
Example1: L Shape Shear Wall Section Analysis

Example Specification:

To create a L shape concrete section with control parameter of 2000(D)x2200(W)x350(T)x400(t)。Concrete material grade is C35, reinforcement strength is fy=500MPa, reinforcement layout is 26T32 as shown in the diagram below. And reinforcement ratio is 1.46%.

Step1 - Build Typical Section

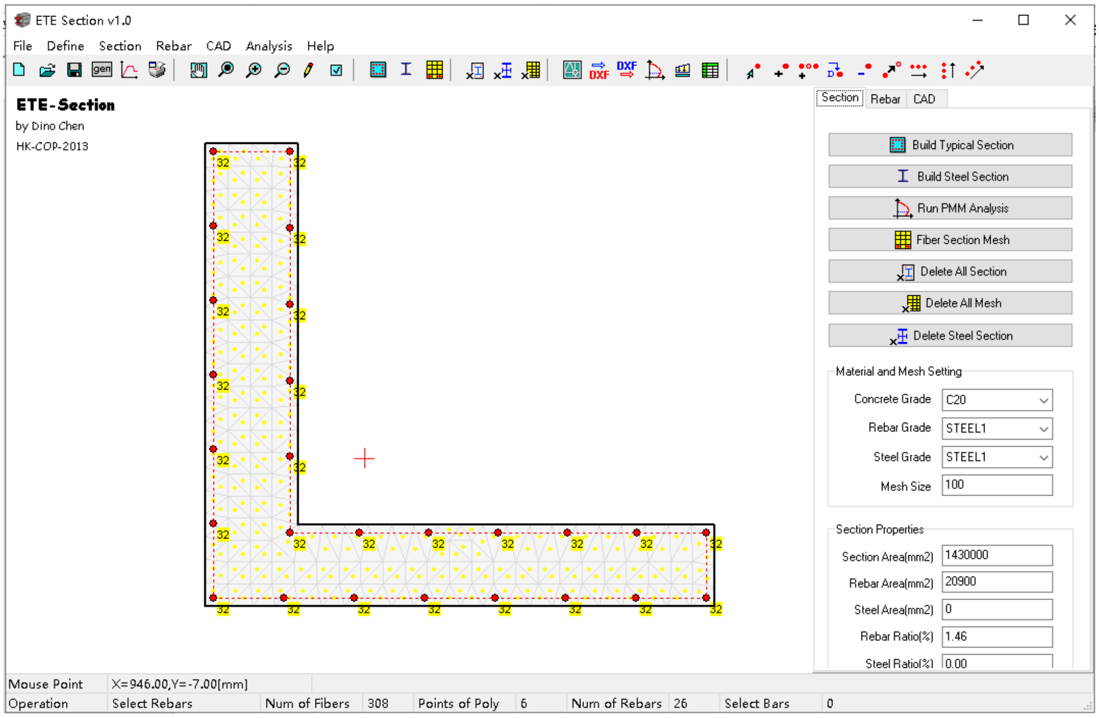
Click the button【Build Typical Section】, then select【Angle Section [6] 】as section shape. Input the section dimension 2000x2200x350x400， finally click the button【Gen Section】 to generate L shape concrete section.



Build typical section settings

Step2 - Build Reinforcement

Click the **Rebar** from the menu panel, use the tools in the sub-menu to draw the reinforcement arrangement as shown in the diagram below, 26T32.



The appearance of the built L-shape section

Step3 - Section Meshing

In the operation panel on the right, **Mesh Size** to be set as 100mm; Select Steel1 for **Rebar Grade**, which is the reinforcement property having strength fy=500MPa; Select C35 for **Concrete Grade**. Then click **Fiber Section Mesh** button to mesh the section.

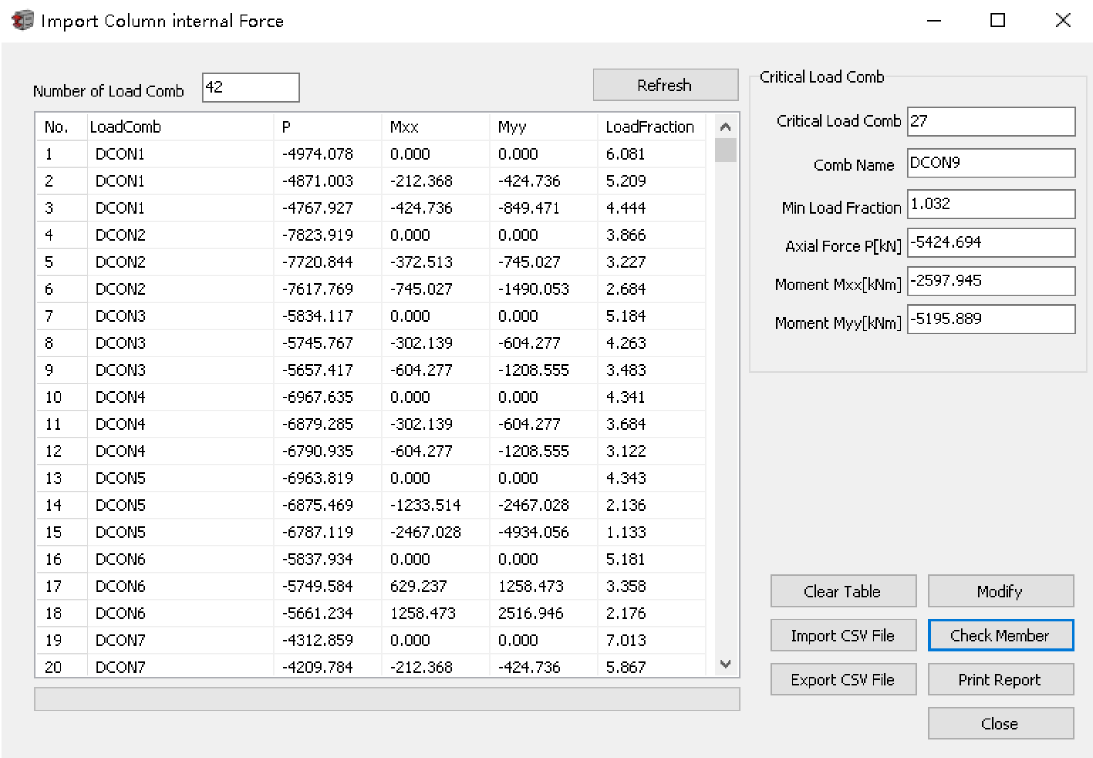
Step4 - Import Member Internal Force

Click **Import member internal force** button, to import the internal forces of multiple load combinations for the member.

Click **Import csv file** to load the .csv format of internal forces into the program. Below is an example of 42 load combinations being loaded.

Click **Check Member** to calculate the load fractions based on the internal forces for all the load combinations. In the example below, the program automatically found the most adverse load combination is the 27th, which has an axial force of -5424.694 kN, Mx of -2597.945 kNm, and My of -5195.889 kNm. The minimum load fraction value is 1.032, which is just slightly above 1.0 and the member is safe.

Click **Print Report** button, then the program will automatically generate the report of the load fraction calculation for all the load combinations.



Import column internal force operation window

Step5 - Generate P-Mx Curve and P-My Curve

Click the button **Run PMM Analysis**, the P-M-M analysis window will pop-up

Select Mx-x to carry out analysis for P-Mxx curve, the obtained curve is shown as below

Select My-y to carry out analysis for P-Myy curve

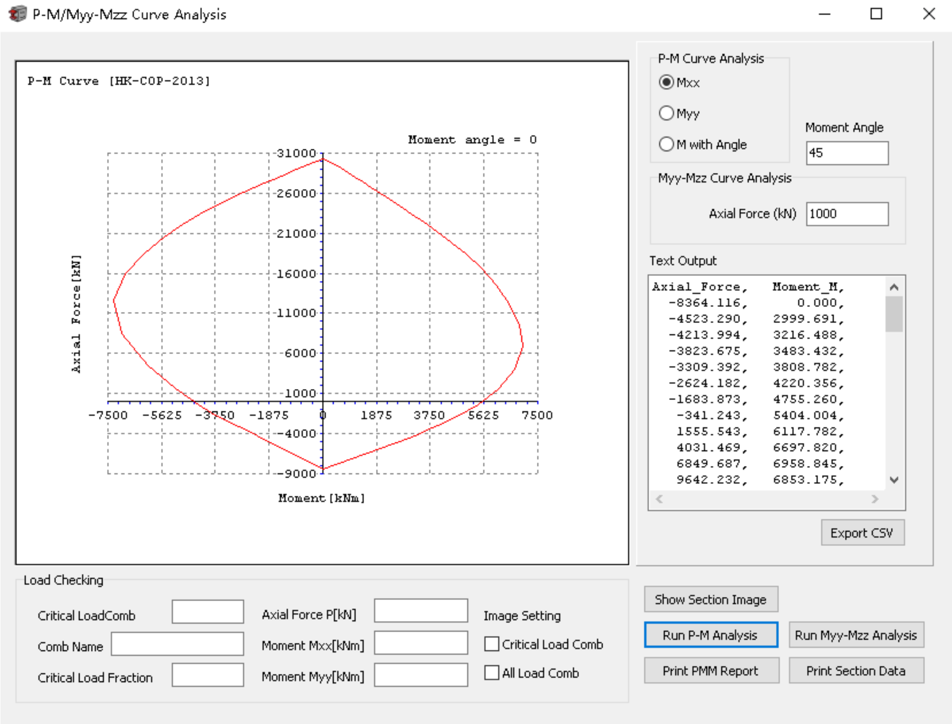
Select M with Angle, then input 45 for the **Moment Angle** which means that the program will generate the M-M curve by trimming the P-M-M envelope with the plane rotated about the axis of axial force P by the angle of input 45 degree

Step6 - Generate Mx-My Curve

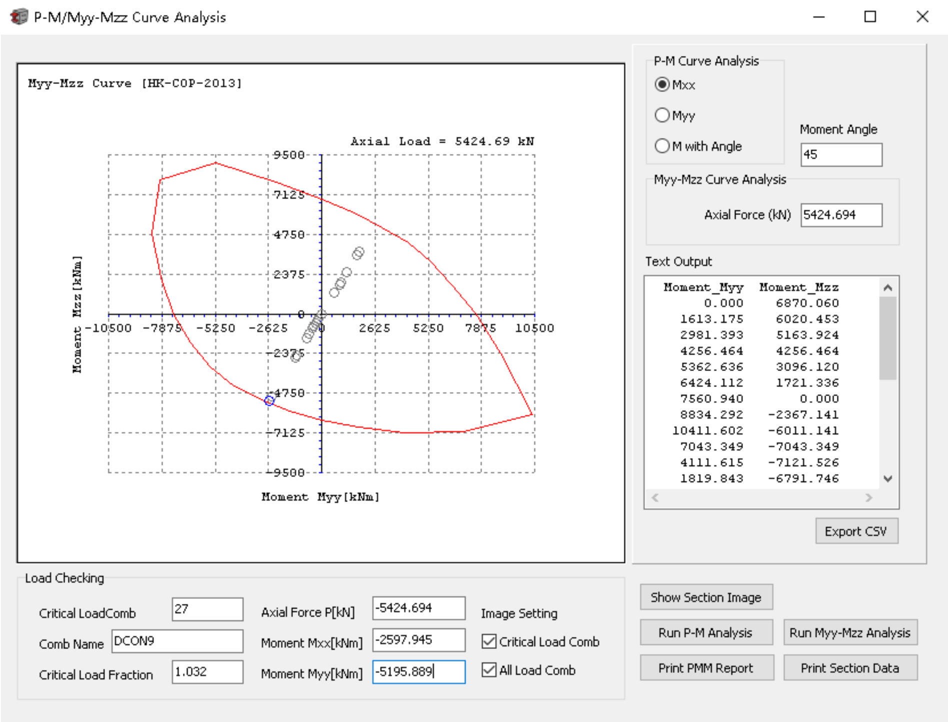
User could input axial force at **Axial Force[kN]**, for example 5424kN, to obtain the Mx-My curve when the axial force is 5424kN.

Step7 - Print PDF Report

Click the button **Print PMM Report** to generate the calculation report in .pdf format. The report includes the calculation of load fraction value, cross-sectional properties, P-M curve and/or M-M.



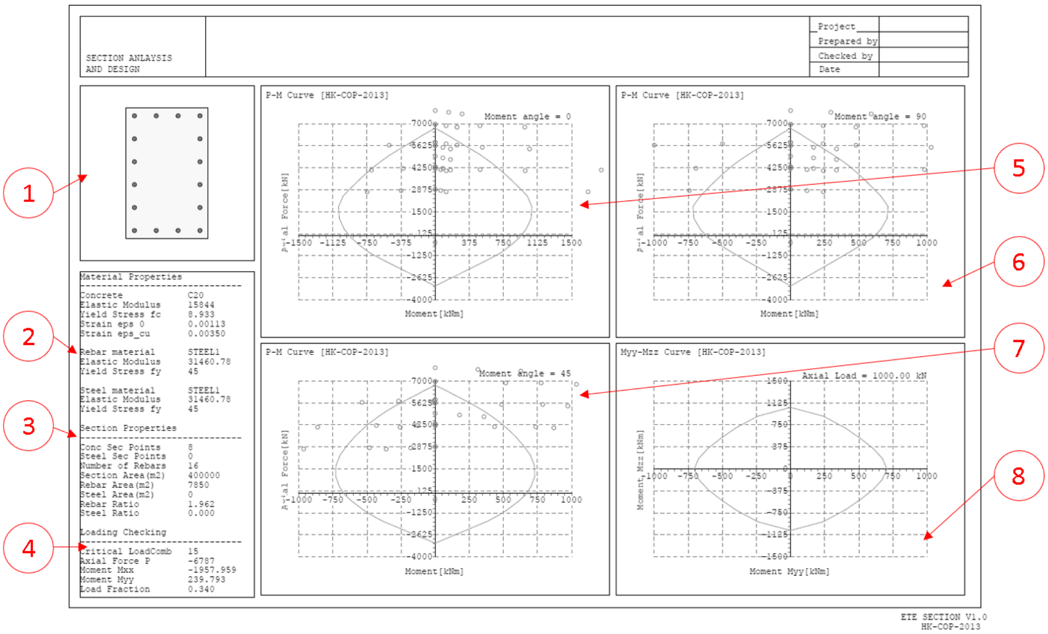
P-M-M analysis operation window of P-Mx analysis plot



P-M-M analysis operation window of P-Mx plot under user defined internal forces

Chapter 6 - Interpretation of Analysis and Design Results

Explanation of P-M, M-M Analysis Report



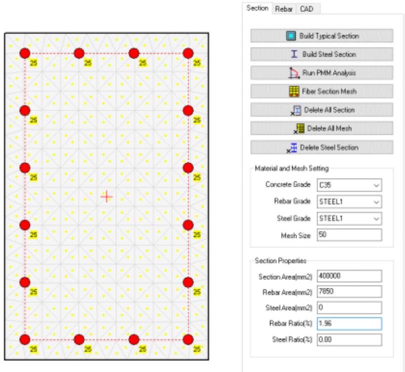
Typical analysis report from ETE Section

1. Brief diagram of cross-sectional geometry
2. Material properties used for the cross-section, such as concrete grade, reinforcement grade, steel grade
3. Cross-sectional properties, such as area of concrete, area of reinforcement, reinforcement ratio
4. Summarisation of capacity check shows the most adverse internal forces and the load fraction value
5. P-Mx curve (could overlay multiple points represent load combinations)
6. P-My curve (could overlay multiple points represent load combinations)
7. The P-M curve with user defined exerting angle (could overlay multiple points represent load combinations)
8. Mx-My curve under user defined axial force (could overlay multiple points represent load combinations)

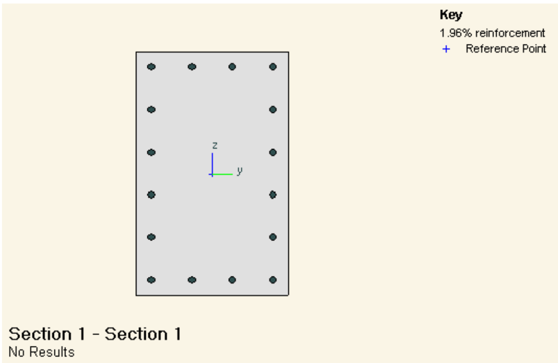
Chapter 7 - Program Verification

Example 1 P-M and M-M Curve Analysis for Rectangular Column

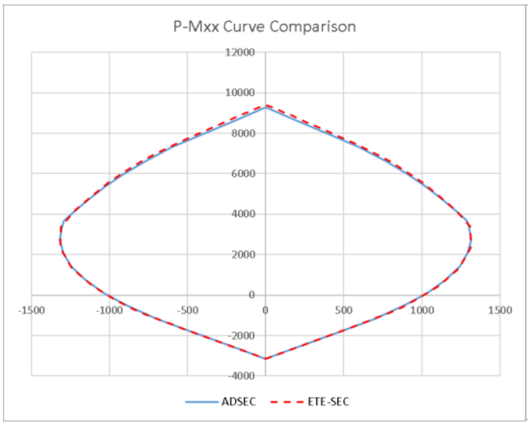
Task description:
Concrete grade is C35; Cross-sectional dimension is 500X800; Distance from the reinforcement bars to the edge of concrete is 50mm; material strength for reinforcement is 460MPa; Reinforcement bars are arranged as 16T25; Reinforcement ratio is 1.96%. The following charts are the comparison of the results between ETE Section and Oasys AdSec.



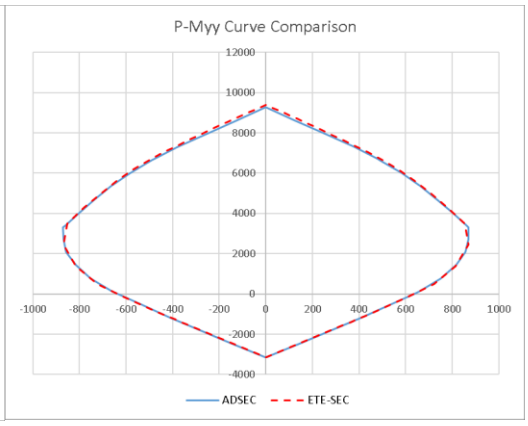
ETE Section



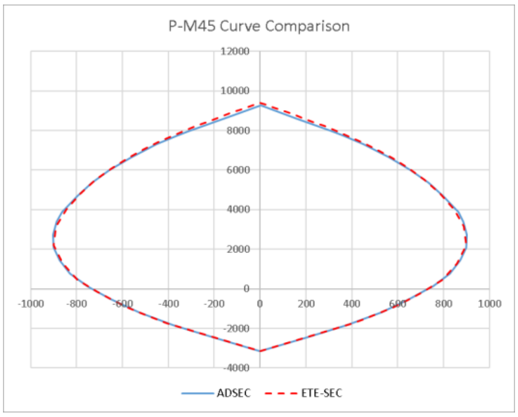
Oasys AdSec



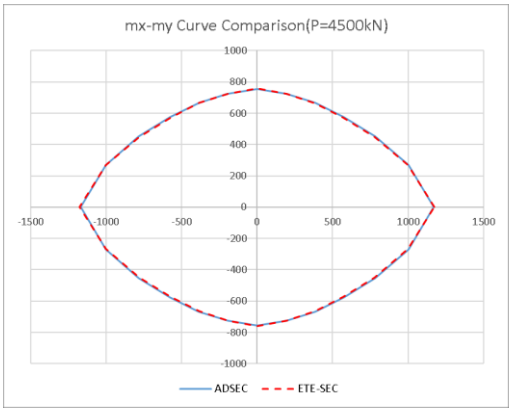
a) P-Mx curve



b) P-My curve



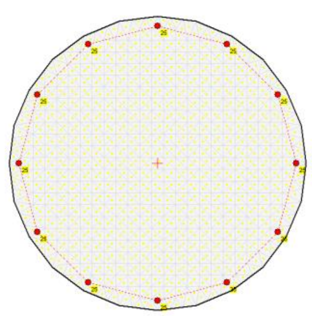
c) P-M curve (with 45 degree angle)



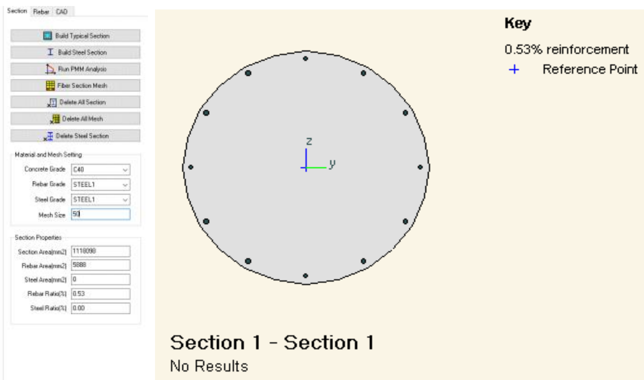
d) P-M curve (with axial force 4500kN)

Example 2 P-M and M-M Curve Analysis for Circular Column

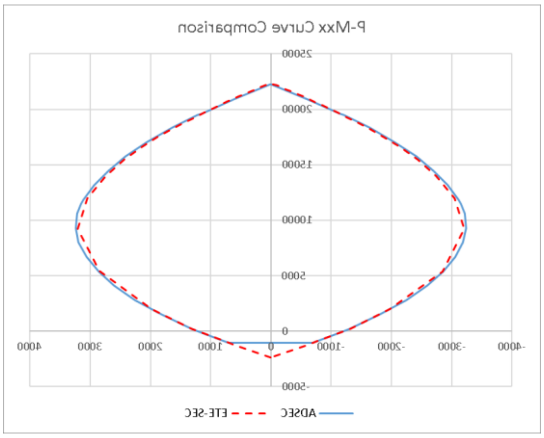
Task description:
Concrete grade is C40; Cross-sectional dimension is 1200mm diameter; Distance from the reinforcement bars to the edge of concrete is 40mm; material strength for reinforcement is 460MPa; Reinforcement bars are arranged as 12T25; Reinforcement ratio is 0.53%. The following charts are the comparison of the results between ETE Section and Oasys AdSec.



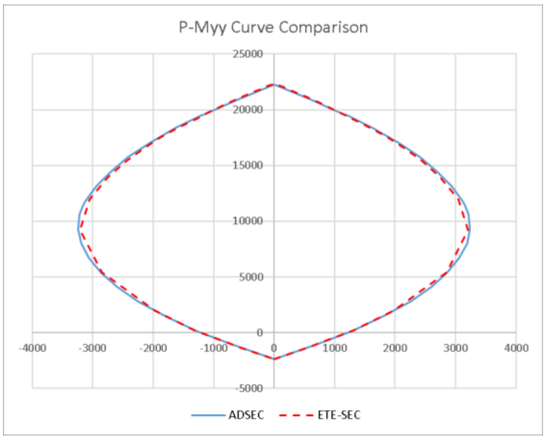
ETE Section



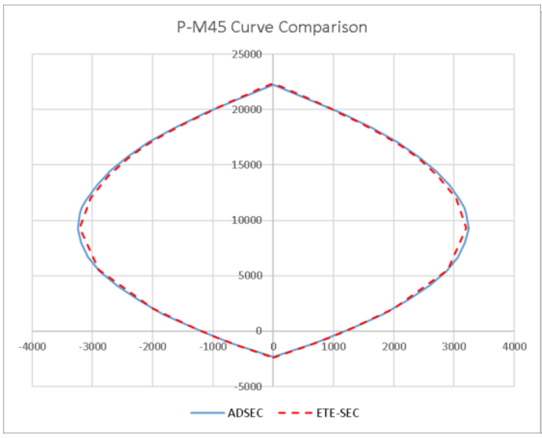
Oasys AdSec



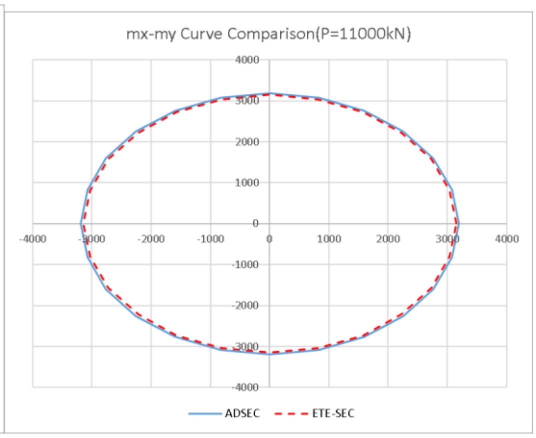
a) P-Mx curve



b) P-My curve



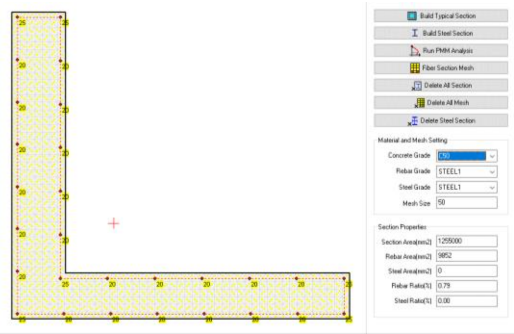
c) P-M curve (with 45 degree angle)



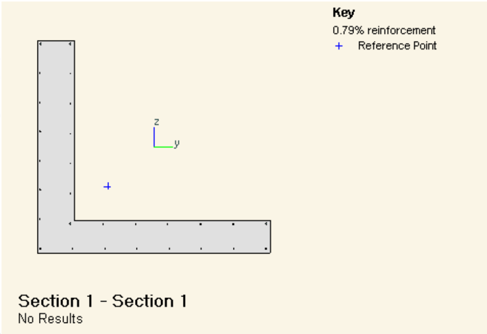
d) P-M curve (with axial force 11000kN)

Example 3 P-M and M-M Curve Analysis for L-shape Wall

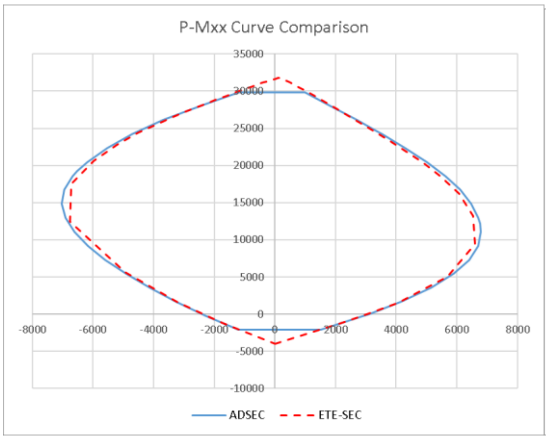
Task description:
Concrete grade is C50; Cross-sectional dimension is 2000x2200x300x350; Distance from the reinforcement bars to the edge of concrete is 35mm; Material strength for reinforcement is 460MPa; Reinforcement bars are arranged as 6T25 + 22T20; Reinforcement ratio is 0.79%. The following charts are the comparison of the results between ETE Section and Oasys AdSec.



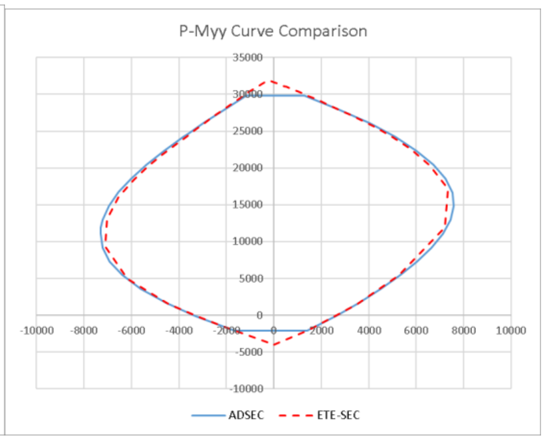
ETE Section



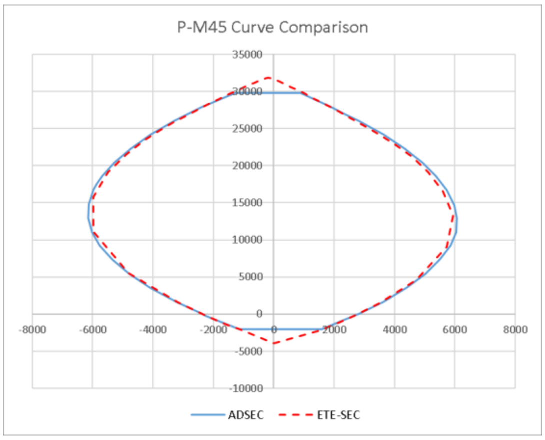
Oasys AdSec



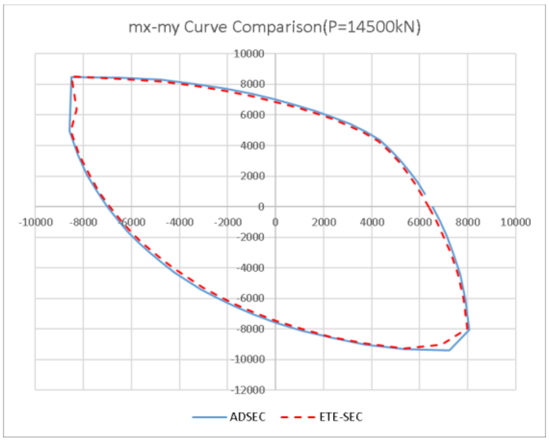
a) P-Mx curve



b) P-My curve



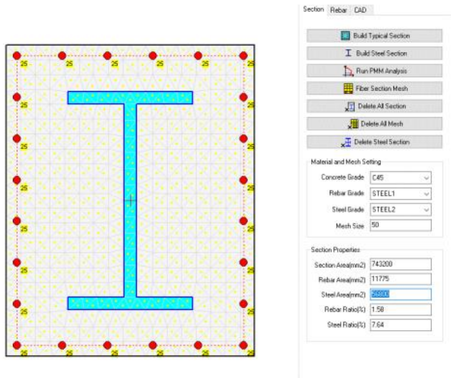
c) P-M curve (with 45 degree angle)



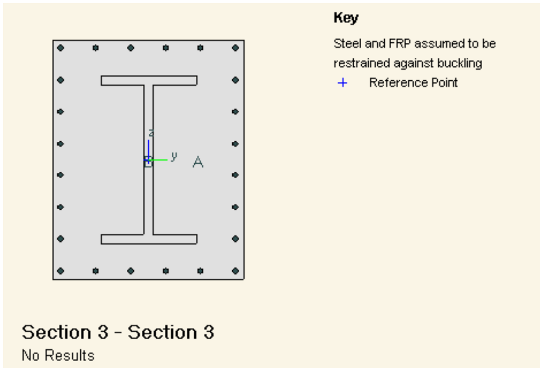
d) Mx-My curve (with axial force 14500kN)

Example 4 P-M and M-M Curve Analysis for Rectangular Steel Reinforced Concrete

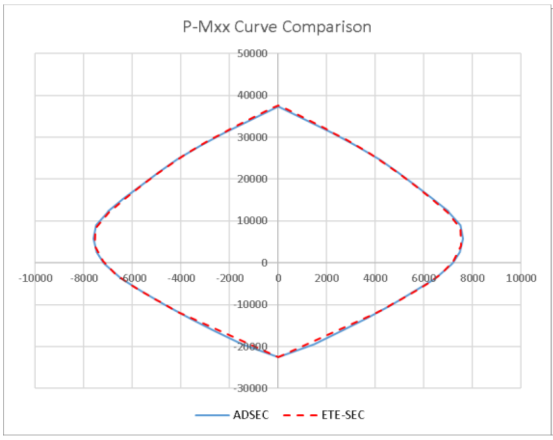
Task description:
Concrete grade is C45; Cross-sectional dimension is 800x1000; Distance from the reinforcement bars to the edge of concrete is 35mm; Material strength for reinforcement is 460MPa and for steel section is Q345; Reinforcement bars are arranged as 24T25; Steel section is 700x400x40x40 I-section; Reinforcement ratio is 1.58%. The following charts are the comparison of the results between ETE Section and Oasys AdSec.



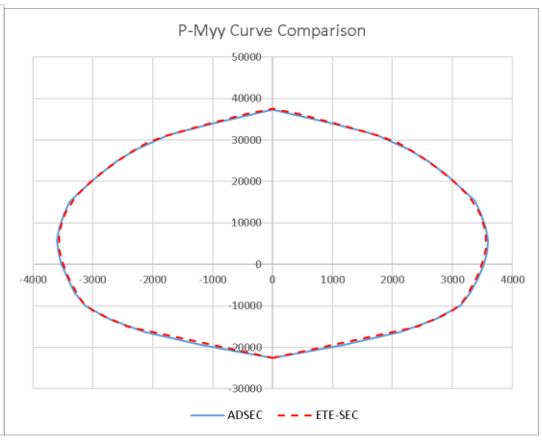
ETE Section



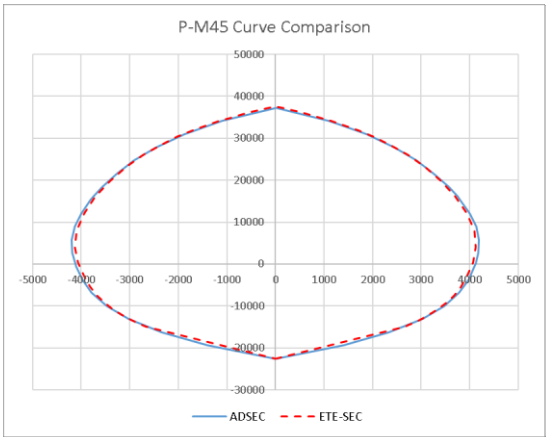
Oasys AdSec



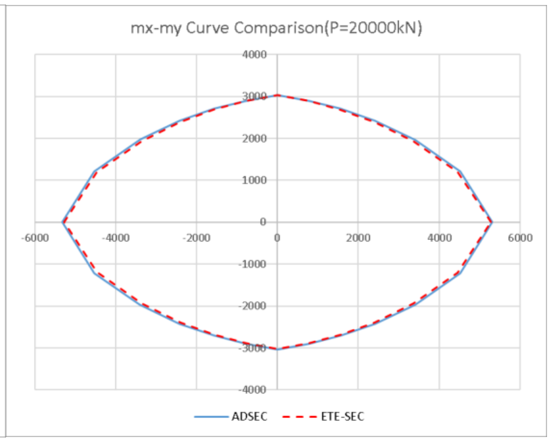
a) P-Mx curve



b) P-My curve



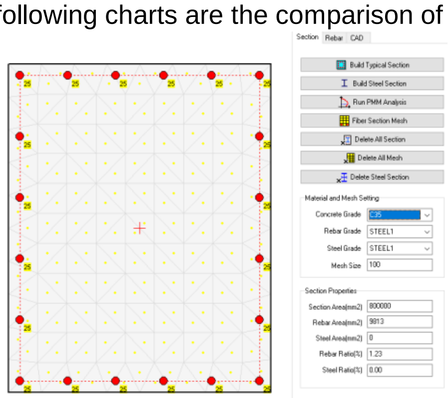
c) P-M curve (with 45 degree angle)



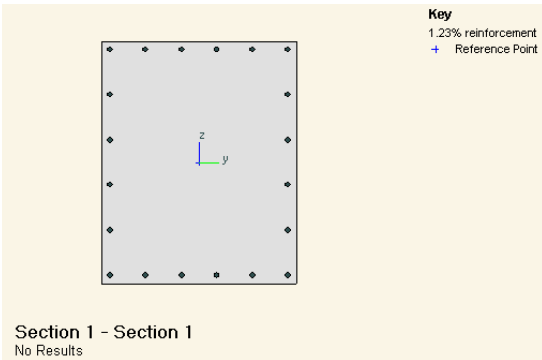
d) Mx-My curve (with axial force 14500kN)

Example 5 Load Fraction Calculation

Task description:
Concrete grade is C35; Cross-sectional dimension is 800x1000; Distance from the reinforcement bars to the edge of concrete is 35mm; Material strength for reinforcement is 460MPa; Reinforcement bars are arranged as 20T25; Reinforcement ratio is 1.23%. The following charts are the comparison of the results between ETE Section and Oasys AdSec.



ETE Section



Oasys AdSec

(1) Case 1: Concrete grade is C35; Reinforcement arrangement is 20T25; Reinforcement ration is 1.23%

ADSEC Result						ETE-SEC result				
Comb	P	M	Mu	M/Mu	Check	P	Mxx	Myy	Load_Fraction	Check
1	4871	347.5	2628	0.132		-4871.0	-84.3	337.1	2.857	
2	4768	694.9	2624	0.265		-4767.9	-168.5	674.2	2.450	
3	7721	609.5	2497	0.244		-7720.8	-147.8	591.3	1.771	
4	7618	1219	2509	0.486		-7617.8	-295.6	1182.6	1.482	
5	5746	542.1	2398	0.226		-5745.8	252.7	479.6	2.280	
6	5657	1084	2399	0.452		-5657.4	505.5	959.2	1.784	
7	6879	687.4	2179	0.316		-6879.3	-492.5	479.6	1.841	
8	6791	1375	2184	0.629		-6790.9	-985.1	959.2	1.381	
9	6875	1962	2766	0.709		-6875.5	-119.9	1958.0	1.260	
10	6787	3923	2774	1.414	Not OK	-6787.1	-239.8	3915.9	0.709	Not OK
11	5750	1006	2775	0.362		-5749.6	-119.9	-998.8	1.917	
12	5661	2012	2777	0.725		-5661.2	-239.8	-1997.6	1.308	
13	4210	486.3	2184	0.223		-4209.8	350.5	337.1	2.878	
14	4107	972.5	2178	0.447		-4106.7	700.9	674.2	2.065	
15	5532	618.9	2176	0.284		-5532.2	-519.0	337.1	2.185	
16	5429	1238	2175	0.569		-5429.1	-1038.0	674.2	1.579	
17	5528	2064	2821	0.732		-5527.8	-84.3	2061.9	1.319	
18	5425	4127	2819	1.464	Not OK	-5424.7	-168.5	4123.7	0.643	Not OK
19	4214	1390	2731	0.509		-4214.2	-84.3	-1387.7	1.874	
20	4111	2780	2720	1.022	Not OK	-4111.2	-168.5	-2775.4	0.975	Not OK
21	2818	445.3	2020	0.221		-2818.1	374.5	240.8	3.741	
22	2744	890.5	2011	0.443		-2744.4	749.1	481.6	2.392	
23	4141	550.4	2136	0.258		-4140.5	-494.9	240.8	2.728	
24	4067	1101	2131	0.517		-4066.9	-989.9	481.6	1.866	
25	4136	1966	2732	0.720		-4136.1	-60.2	1965.5	1.437	
26	4062	3933	2724	1.444	Not OK	-4062.4	-120.4	3931.1	0.634	Not OK
27	2823	1485	2538	0.585		-2822.5	-60.2	-1484.0	1.898	
28	2749	2970	2524	1.177	Not OK	-2748.9	-120.4	-2968.0	0.814	Not OK

(2) Case 2: Concrete grade is C35, Reinforcement arrangement is 20T32; Reinforcement ratio is 2.01%

ADSEC Result						ETE-SEC result				
Comb	P	M	Mu	M/Mu	Check	P	Mxx	Myy	Load_Fraction	Check
1	4871	347.5	3389	0.1025		-4871.0	-84.3	337.1	3.3	
2	4768	694.9	3387	0.2052		-4767.9	-168.5	674.2	2.848	
3	7721	609.5	3224	0.189		-7720.8	-147.8	591.3	2.046	

4	7618	1219	3238	0.3765		-7617.8	-295.6	1182.6	1.725	
5	5746	542.1	3059	0.1772		-5745.8	252.7	479.6	2.637	
6	5657	1084	3061	0.3542		-5657.4	505.5	959.2	2.097	
7	6879	687.4	2783	0.247		-6879.3	-492.5	479.6	2.132	
8	6791	1375	2788	0.4931		-6790.9	-985.1	959.2	1.632	
9	6875	1962	3572	0.5492		-6875.5	-119.9	1958.0	1.494	
10	6787	3923	3580	1.096	Not OK	-6787.1	-239.8	3915.9	0.924	Not OK
11	5750	1006	3576	0.2813		-5749.6	-119.9	-998.8	2.235	
12	5661	2012	3579	0.5621		-5661.2	-239.8	-1997.6	1.573	
13	4210	486.3	2820	0.1725		-4209.8	350.5	337.1	3.341	
14	4107	972.5	2815	0.3455		-4106.7	700.9	674.2	2.465	
15	5532	618.9	2780	0.2227		-5532.2	-519.0	337.1	2.536	
16	5429	1238	2780	0.4453		-5429.1	-1038.0	674.2	1.881	
17	5528	2064	3644	0.5663		-5527.8	-84.3	2061.9	1.587	
18	5425	4127	3645	1.132	Not OK	-5424.7	-168.5	4123.7	0.882	Not OK
19	4214	1390	3575	0.3889		-4214.2	-84.3	-1387.7	2.241	
20	4111	2780	3566	0.7797		-4111.2	-168.5	-2775.4	1.31	
21	2818	445.3	2682	0.166		-2818.1	374.5	240.8	4.379	
22	2744	890.5	2675	0.3329		-2744.4	749.1	481.6	2.936	
23	4141	550.4	2767	0.1989		-4140.5	-494.9	240.8	3.175	
24	4067	1101	2765	0.3981		-4066.9	-989.9	481.6	2.247	
25	4136	1966	3581	0.5492		-4136.1	-60.2	1965.5	1.805	
26	4062	3933	3574	1.1	Not OK	-4062.4	-120.4	3931.1	0.903	Not OK
27	2823	1485	3427	0.4334		-2822.5	-60.2	-1484.0	2.433	
28	2749	2970	3416	0.8696		-2748.9	-120.4	-2968.0	1.178	

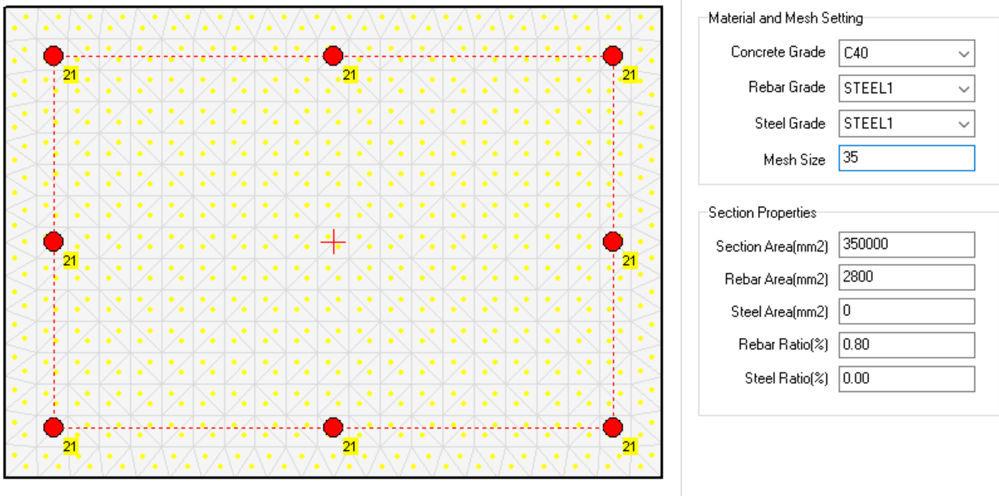
(3) Case 3: Concrete grade is C60; Reinforcement arrangement is 20T32; Reinforcement ratio is 2.01%

ADSEC Result						ETE-SEC result				
Comb	P	M	Mu	M/Mu	Check	P	Mxx	Myy	Load_Fraction	Check
1	4871	347.5	4008	0.08669		-4871.0	-84.3	337.1	4.794	
2	4768	694.9	3991	0.1741		-4767.9	-168.5	674.2	4.071	
3	7721	609.5	4316	0.1412		-7720.8	-147.8	591.3	2.967	
4	7618	1219	4311	0.2827		-7617.8	-295.6	1182.6	2.458	
5	5746	542.1	3794	0.1429		-5745.8	252.7	479.6	3.795	
6	5657	1084	3785	0.2865		-5657.4	505.5	959.2	2.932	
7	6879	687.4	3590	0.1915		-6879.3	-492.5	479.6	3.057	
8	6791	1375	3584	0.3836		-6790.9	-985.1	959.2	2.261	
9	6875	1962	4500	0.436		-6875.5	-119.9	1958.0	2.085	
10	6787	3923	4490	0.8738		-6787.1	-239.8	3915.9	1.17	
11	5750	1006	4312	0.2333		-5749.6	-119.9	-998.8	3.189	
12	5661	2012	4297	0.4682		-5661.2	-239.8	-1997.6	2.151	

13	4210	486.3	3345	0.1454		-4209.8	350.5	337.1	4.766	
14	4107	972.5	3332	0.2919		-4106.7	700.9	674.2	3.372	
15	5532	618.9	3415	0.1812		-5532.2	-519.0	337.1	3.628	
16	5429	1238	3404	0.3636		-5429.1	-1038.0	674.2	2.586	
17	5528	2064	4335	0.476		-5527.8	-84.3	2061.9	2.176	
18	5425	4127	4318	0.9557		-5424.7	-168.5	4123.7	1.059	
19	4214	1390	4084	0.3404		-4214.2	-84.3	-1387.7	3.095	
20	4111	2780	4062	0.6845		-4111.2	-168.5	-2775.4	1.607	
21	2818	445.3	3038	0.1466		-2818.1	374.5	240.8	6.173	
22	2744	890.5	3024	0.2944		-2744.4	749.1	481.6	3.899	
23	4141	550.4	3220	0.1709		-4140.5	-494.9	240.8	4.523	
24	4067	1101	3209	0.343		-4066.9	-989.9	481.6	3.053	
25	4136	1966	4077	0.4824		-4136.1	-60.2	1965.5	2.379	
26	4062	3933	4061	0.9685		-4062.4	-120.4	3931.1	1.044	
27	2823	1485	3774	0.3935		-2822.5	-60.2	-1484.0	3.135	
28	2749	2970	3754	0.7913		-2748.9	-120.4	-2968.0	1.339	

Example 6 Load Fraction Calculation for Rectangular Column

Task description:
Concrete grade is C40; Cross-sectional dimension is 500x700; Distance from the reinforcement bars to the edge of concrete is 52.5mm; Material strength for reinforcement is 500MPa; Reinforcement bars are arranged as 8T21; Reinforcement ratio is 0.8%. The following charts are the comparison of the results between ETE Section and SADS.



Appearance of the section and settings in main operation window

SADS Report

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* C10 *            F4 TO F3                                    X-X : Unbraced
                                                               Y-Y : Unbraced
               Mark      Type  Span  Section     Ang        F.E.M.
     Top Beam : 4B1        1   8.000  300x700    90.0    64.245(  14.224)
                4B9        1   8.000  300x700     0.0   137.477(  30.282)
     Bot.Beam : 3B1        1   8.000  300x700    90.0    64.245(  14.224)
                3B9        1   8.000  300x700     0.0   137.477(  30.282)

     Colm.Pro.:  Hux   Huy   Section   Hcx   Hcy   Section   Hlx   Hly   Section
                      None           3.000 3.000   700x500 3.000 3.000   700x500

     Slender  : Lex= 2.760   Lamx= 3.94 < 10  Ley= 2.760   Lamy= 5.52 < 10

     Vert.Load: DL.= 124.899(25.725)          LL.= 26.413
          Top :+Mdx= 123.575  -Mdx= 0.000    +Mdy= 52.638   -Mdy= 0.000
               +Mlx= 27.220   -Mlx= 0.000    +Mly= 11.654   -Mly= 0.000
          Bot.:+Mdx= -0.000   -Mdx= -65.078  +Mdy= -0.000   -Mdy= -28.932
               +Mlx= -0.000   -Mlx= -14.335  +Mly= -0.000   -Mly= -6.406

     Wind Load:        Mwtx       Mwty         Pw       Mwbx       Mwby
           X-X      -17.191      0.134     -4.624     -9.709      0.019
           Y-Y       -1.841    -13.233     -4.300     -0.703     -1.434
           U-U      -20.458    -12.295     -9.054    -11.657     -1.274
           V-V       16.815    -12.450      0.951     10.233     -1.304

     Concrete : C40           Fcu= 40        Ec = 25100     Cover = 40
     Steel    : GRADE 500     Fy = 500.0     Es = 200000

     Assume   : Asx= 1400     Asy= 1400       r = 0.800%
     Nu = 0.35*Fcu*(Ac-Asc)+0.67*Fy*Asc = 5798.800 > 253.135 O.K.
     Vxmax =   42.286  Vs = 0.131  Vc = 0.478  O.K.
     Vymax =   17.907  Vs = 0.057  Vc = 0.470  O.K.
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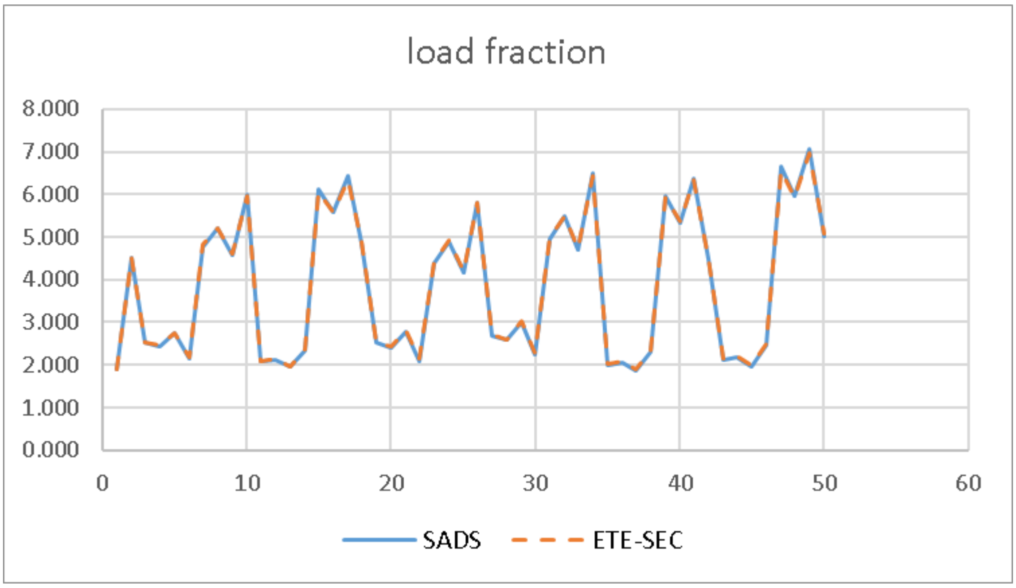
1.2D+1.2L+1.2Wu(B)	201.580	109.283	43.935	4.57376990431
1.2D+1.2L+1.2Wv(B)	213.586	83.015	43.971	5.99317652696
1.2D+1.2L-1.2Wx(T)	187.124	201.582	76.990	2.07175192695
1.2D+1.2L-1.2Wy(T)	186.735	183.162	93.030	2.12145597297
1.2D+1.2L-1.2Wu(T)	192.440	205.503	91.905	1.94553266879
1.2D+1.2L-1.2Wv(T)	180.434	160.775	92.091	2.34023309681
1.2D+1.2L-1.2Wx(B)	217.994	83.644	42.429	6.10515007749
1.2D+1.2L-1.2Wy(B)	217.605	94.451	40.685	5.58047220508
1.2D+1.2L-1.2Wu(B)	223.310	81.306	40.877	6.41773347955
1.2D+1.2L-1.2Wv(B)	211.304	107.574	40.841	4.84593137952
1.0D+1.4Wx(T)	118.426	148.937	73.881	2.51524415867
1.0D+1.4Wy(T)	118.879	170.427	55.167	2.40322986455
1.0D+1.4Wu(T)	112.224	144.363	56.480	2.77750436109
1.0D+1.4Wv(T)	126.231	196.545	56.263	2.09575171541
1.0D+1.4Wx(B)	144.151	104.701	40.479	4.39458905169
1.0D+1.4Wy(B)	144.604	92.093	42.513	4.88878095495
1.0D+1.4Wu(B)	137.949	107.429	42.289	4.17529735869
1.0D+1.4Wv(B)	151.956	76.783	42.331	5.81610256752
1.4D+1.4Wx(T)	168.385	148.937	73.881	2.69288108701
1.4D+1.4Wy(T)	168.839	170.427	55.167	2.58155130645
1.4D+1.4Wu(T)	162.183	144.363	56.480	3.00374191241
1.4D+1.4Wv(T)	176.190	196.545	56.263	2.23543245544
1.4D+1.4Wx(B)	204.400	104.701	40.479	4.93749221734
1.4D+1.4Wy(B)	204.854	92.093	42.513	5.49016174778
1.4D+1.4Wu(B)	198.198	107.429	42.289	4.68727890569
1.4D+1.4Wv(B)	212.205	76.783	42.331	6.49379287339
1.0D-1.4Wx(T)	131.373	197.072	73.506	2.00576790358
1.0D-1.4Wy(T)	130.919	175.582	92.219	2.06758105490
1.0D-1.4Wu(T)	137.575	201.646	90.906	1.87233282986
1.0D-1.4Wv(T)	123.568	149.463	91.123	2.31231394496
1.0D-1.4Wx(B)	157.098	77.516	40.532	5.96363045055
1.0D-1.4Wy(B)	156.644	90.125	38.498	5.31682137546
1.0D-1.4Wu(B)	163.300	74.789	38.722	6.36762807415
1.0D-1.4Wv(B)	149.293	105.435	38.680	4.46921395182
1.4D-1.4Wx(T)	181.332	197.072	73.506	2.12764811120
1.4D-1.4Wy(T)	180.879	175.582	92.219	2.18786203013
1.4D-1.4Wu(T)	187.534	201.646	90.906	1.97481749108
1.4D-1.4Wv(T)	173.527	149.463	91.123	2.45848116363
1.4D-1.4Wx(B)	217.347	77.516	40.532	6.64415372528
1.4D-1.4Wy(B)	216.894	90.125	38.498	5.95827884583
1.4D-1.4Wu(B)	223.549	74.789	38.722	7.05970922142
1.4D-1.4Wv(B)	209.542	105.435	38.680	5.02138316333

Num	Load Comb	P(kN)	Mx	My	SADS Load Fraction	ETE-SEC Load Fraction
1	1.4D+1.6L(T)	217.12	216.56	92.34	1.901	1.909
2	1.4D+1.6L(B)	253.14	114.04	50.76	4.500	4.502
3	1.2D+1.2L+1.2Wx(T)	176.03	160.32	77.31	2.512	2.525
4	1.2D+1.2L+1.2Wy(T)	176.42	178.74	61.27	2.430	2.448
5	1.2D+1.2L+1.2Wu(T)	170.71	156.40	62.40	2.738	2.75
6	1.2D+1.2L+1.2Wv(T)	182.72	201.13	62.21	2.162	2.187
7	1.2D+1.2L+1.2Wx(B)	206.90	106.95	42.38	4.777	4.827
8	1.2D+1.2L+1.2Wy(B)	207.29	96.14	44.13	5.215	5.216
9	1.2D+1.2L+1.2Wu(B)	201.58	109.28	43.94	4.574	4.616

10	1.2D+1.2L+1.2Wv(B)	213.59	83.02	43.97	5.993	5.955
11	1.2D+1.2L-1.2Wx(T)	187.12	201.58	76.99	2.072	2.084
12	1.2D+1.2L-1.2Wy(T)	186.74	183.16	93.03	2.121	2.134
13	1.2D+1.2L-1.2Wu(T)	192.44	205.50	91.91	1.946	1.954
14	1.2D+1.2L-1.2Wv(T)	180.43	160.78	92.09	2.340	2.363
15	1.2D+1.2L-1.2Wx(B)	217.99	83.64	42.43	6.105	6.064
16	1.2D+1.2L-1.2Wy(B)	217.61	94.45	40.69	5.580	5.584
17	1.2D+1.2L-1.2Wu(B)	223.31	81.31	40.88	6.418	6.348
18	1.2D+1.2L-1.2Wv(B)	211.30	107.57	40.84	4.846	4.899
19	1.0D+1.4Wx(T)	118.43	148.94	73.88	2.515	2.531
20	1.0D+1.4Wy(T)	118.88	170.43	55.17	2.403	2.438
21	1.0D+1.4Wu(T)	112.22	144.36	56.48	2.778	2.797
22	1.0D+1.4Wv(T)	126.23	196.55	56.26	2.096	2.14
23	1.0D+1.4Wx(B)	144.15	104.70	40.48	4.395	4.415
24	1.0D+1.4Wy(B)	144.60	92.09	42.51	4.889	4.921
25	1.0D+1.4Wu(B)	137.95	107.43	42.29	4.175	4.193
26	1.0D+1.4Wv(B)	151.96	76.78	42.33	5.816	5.791
27	1.4D+1.4Wx(T)	168.39	148.94	73.88	2.693	2.707
28	1.4D+1.4Wy(T)	168.84	170.43	55.17	2.582	2.604
29	1.4D+1.4Wu(T)	162.18	144.36	56.48	3.004	3.017
30	1.4D+1.4Wv(T)	176.19	196.55	56.26	2.235	2.268
31	1.4D+1.4Wx(B)	204.40	104.70	40.48	4.937	4.991
32	1.4D+1.4Wy(B)	204.85	92.09	42.51	5.490	5.485
33	1.4D+1.4Wu(B)	198.20	107.43	42.29	4.687	4.73
34	1.4D+1.4Wv(B)	212.21	76.78	42.33	6.494	6.44
35	1.0D-1.4Wx(T)	131.37	197.07	73.51	2.006	2.026
36	1.0D-1.4Wy(T)	130.92	175.58	92.22	2.068	2.084
37	1.0D-1.4Wu(T)	137.58	201.65	90.91	**1.872**	**1.885**
38	1.0D-1.4Wv(T)	123.57	149.46	91.12	2.312	2.345
39	1.0D-1.4Wx(B)	157.10	77.52	40.53	5.964	5.944
40	1.0D-1.4Wy(B)	156.64	90.13	38.50	5.317	5.359
41	1.0D-1.4Wu(B)	163.30	74.79	38.72	6.368	6.338
42	1.0D-1.4Wv(B)	149.29	105.44	38.68	4.469	4.492
43	1.4D-1.4Wx(T)	181.33	197.07	73.51	2.128	2.141
44	1.4D-1.4Wy(T)	180.88	175.58	92.22	2.188	2.203
45	1.4D-1.4Wu(T)	187.53	201.65	90.91	1.975	1.984
46	1.4D-1.4Wv(T)	173.53	149.46	91.12	2.458	2.49
47	1.4D-1.4Wx(B)	217.35	77.52	40.53	6.644	6.571
48	1.4D-1.4Wy(B)	216.89	90.13	38.50	5.958	5.943
49	1.4D-1.4Wu(B)	223.55	74.79	38.72	7.060	6.956
50	1.4D-1.4Wv(B)	209.54	105.44	38.68	5.021	5.078



From example 1-6, it illustrates that ETE Section performs with good accuracy in calculating the P-M curve, M-M curve and sectional capacity, and could be employed in engineering design projects for cross-sectional check.

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