

manual cross section editor


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The fastest way in Pre Design

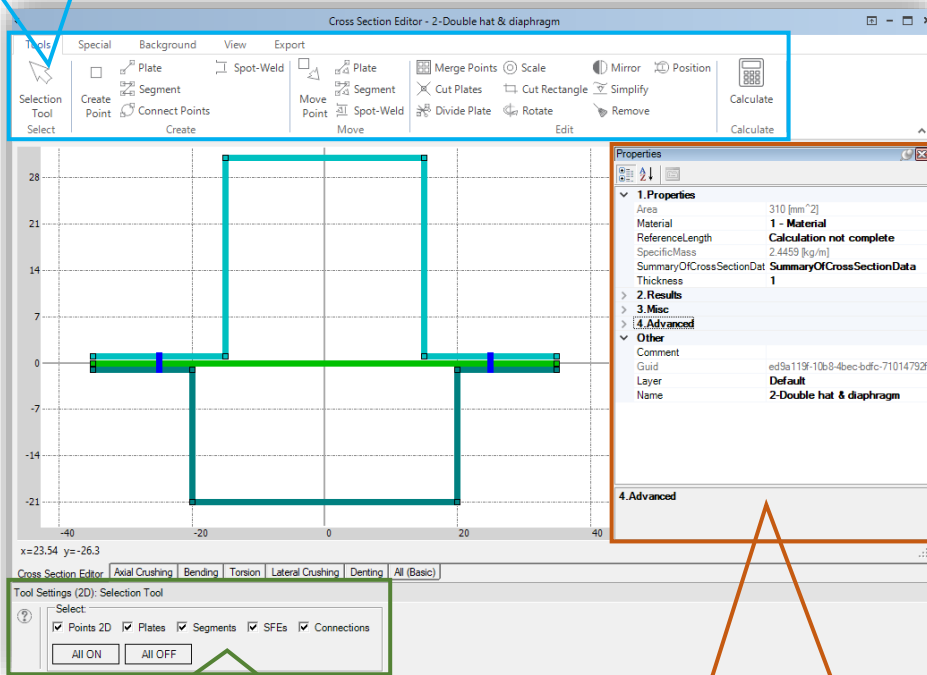
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THIN-WALLED CROSS SECTION EDITOR

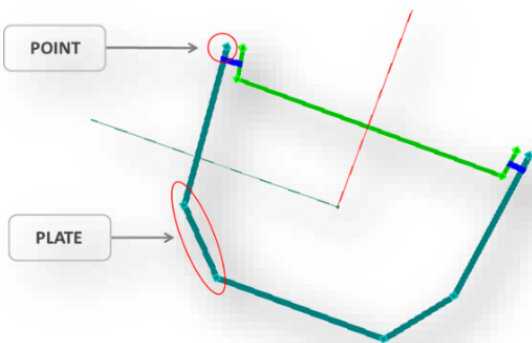
The **Cross Section Editor** is used to design, calculate and optimize thin-walled cross sections for best crash performances. Cross-Sections processed by the Cross Section Editor are then used to build 3D prismatic and tapered Super Beams.

MAIN TOOLBAR



TOOL SETTINGS WINDOW

PROPERTIES WINDOW



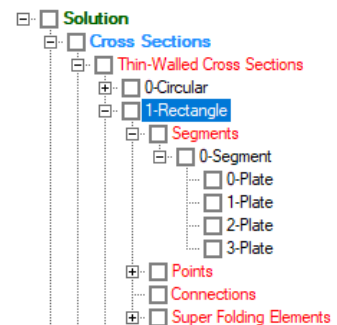
According to the Macro Element Method VCS software enables the creation of a simplified thin-walled cross section model build of Plates and Segments based on Points.

Each plate of across section can be defined with different material and thickness.

All Cross Sections created in VCS consist of :

- Points
- Plates – created by connecting two Points
- Segments – build of Plates
- Super Folding Elements and possibly
- Connections

All elements of the Cross Sections are automatically catalogued in appropriate folders in the Solution Explorer



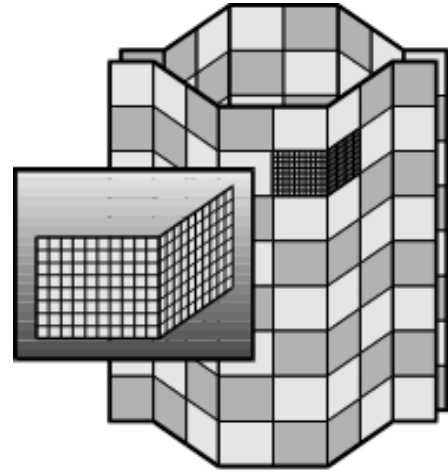
SUPER FOLDING ELEMENT – THEORETICAL BACKGROUND

The very core of the theoretical background of Cross Section Editor is the **Super Folding Element (SFE)**.

The SFE represents the segment of a corner line off a prismatic column. One SFE is cut off from a column by a set of two parallel horizontal planes.

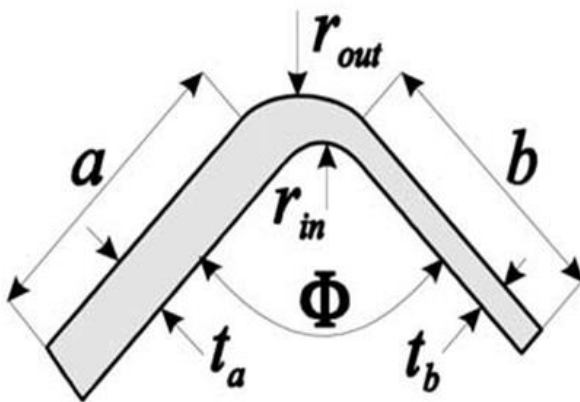
The distance between planes, $2H$, equals the length of the plastic folding wave of the column. The vertical boundaries of a SE are defined by a set of two vertical planes equally distanced from the neighboring corners and/or vertical edges of a column.

In the picture a checkerboard of Super Folding Elements in a spot welded hexagonal column is visualized. This illustrates the discretization procedure by using SFE's.



Please note the enlarged SFE which demonstrates the 'macro-size' of a SFE compared to the standard FE mesh.

A set of SFEs located between 2 horizontal plates defines a one deformable cell. A deformable cell creates a single layer of plastic folds in a progressively crushed prismatic column. The number of SFE in a Deformable Cell corresponds to the number of corners of the column.



The cross-sectional dimensions of a SE shown in picture on bottom of the slide. The initial geometry of a SE is defined by four parameters:

1. total length, C , of two arms of a SE, $C = a + b$,
2. central angle, Φ
3. wall thickness t_a of the arm of the length a
4. wall thickness t_b of the arm of the length b .

Those parameters are crucial especially in case of design of Cross Section for axial crushing.

More information about the Super Folding Element and the Macro Element theory can be found on www.impactdesign.pl

CROSS SECTION MODELLING – MACRO ELEMENT APPROACH

IMPORTANT NOTICE

When working in the Cross Section Editor it is important to follow the Macro Element Approach to fulfil the requirements of a proper, simplified VCS 2D modelling.

According to the Macro Element Method the VCS software enables the creation of a **simplified cross section model** build of plates and segments based on Points.

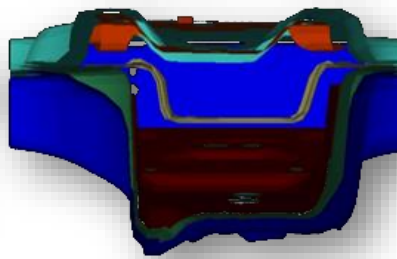
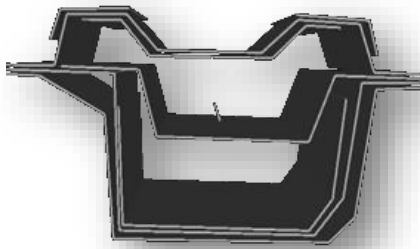
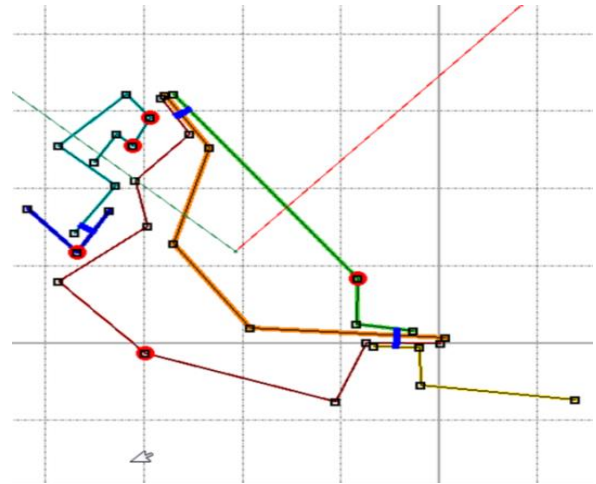


CROSS SECTION MODELLING – MACRO ELEMENT APPROACH

In the picture on the right, you can see an example of a Cross Section modelled in VCS.

Please note that each segment has been marked in different colors.

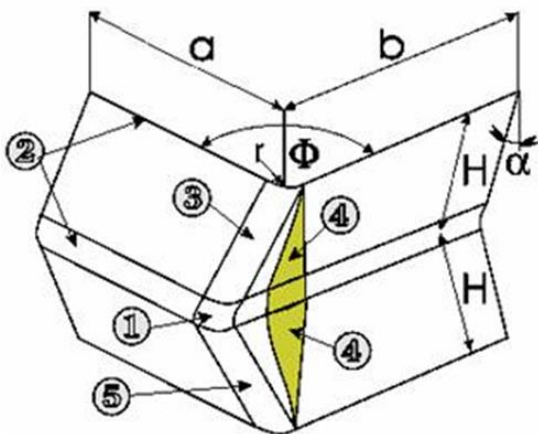
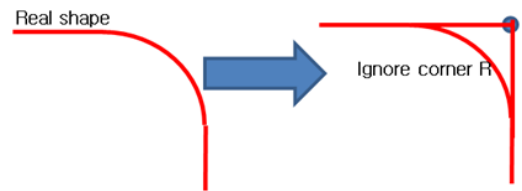
A Macro Element model is a **simplified model**, where details of the cross-sectional geometry should be neglected.



The simplicity of cross section modelling by means of macro elements (in comparison to a FE model) is illustrated in the picture on the left.

The problem of **radius modelling** at the Cross Section level is related to the definition of Super Folding Element (SFE) and corresponding modelling methodology (quite different then in FE programs).

R treatment



Please note that SFE models crushing behavior of the entire corner area in a prismatic member. Consequently, the cross-section details smaller than dimensions (a , b) of the SFE cannot be effectively modelled using this methodology.

In particular, the small corner radii, r , are found to have negligible impact onto energy absorption of the cross section and are neglected in Visual Crash Studio calculations.

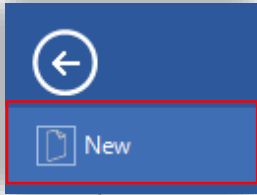
The energy absorption in corner area can be significantly increased only for radii that guarantee development of full plastic folds like in the case of circular or hexagonal column. In the case of very small Super Folding Elements – dense discretization at Cross Sectional level, CCC signals the modelling/design error.



A NEW THIN-WALLED CROSS SECTION

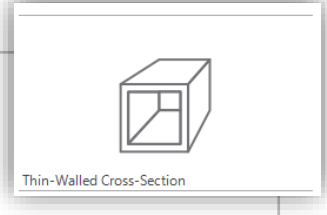
A new cross section can be defined in the **Cross Section Editor** window.

The user can also use one of the pre-defined cross-sectional templates which will be described in further sections of this Manual.



New cross sections are created in separate editor's window (Cross Section Editor).

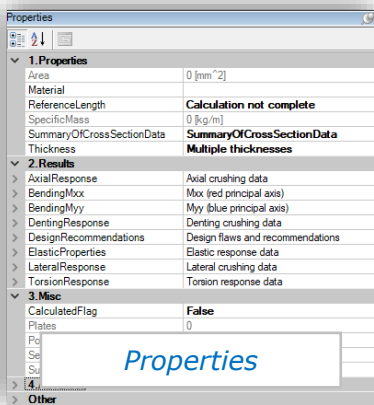
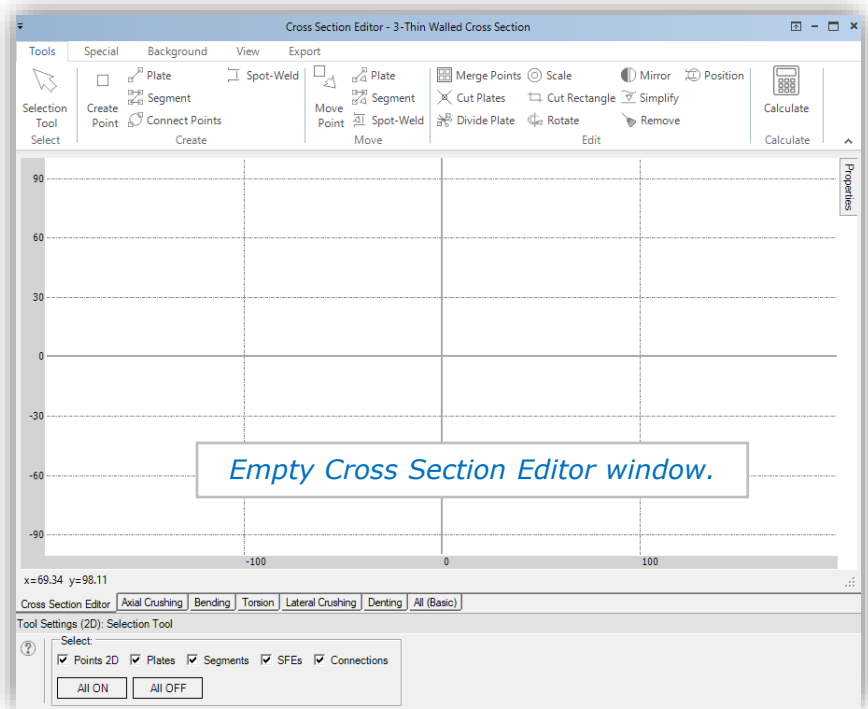
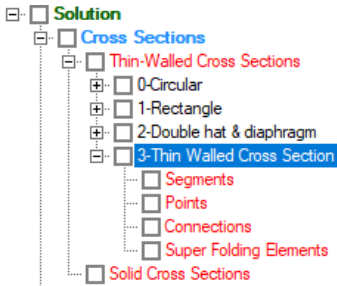
In order to open a new Editor window, select an appropriate option from the File menu



A new empty Cross Section Editor window will be now visible on the screen.

In the Solution Explorer tree separate folders are automatically created for each group of cross-sectional elements (Points, Plates, Segments, etc.).

The properties of the cross section are displayed in the Properties window.



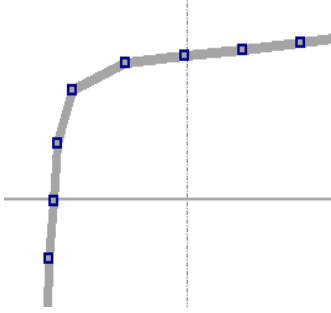
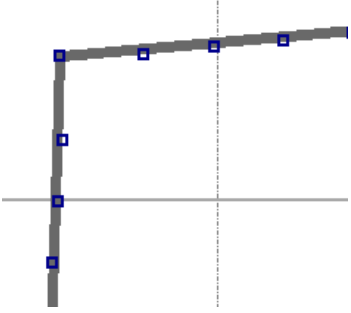
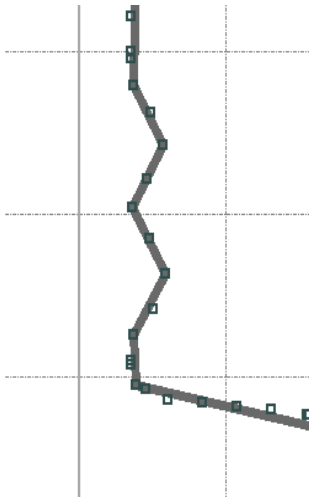
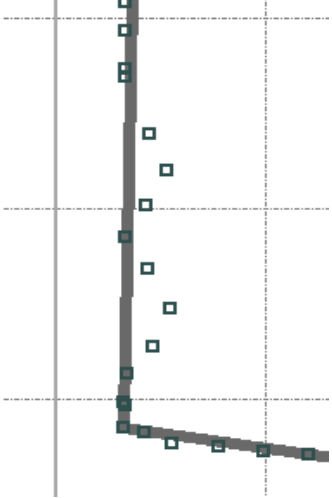
A thin-walled cross section is created by connecting 2D Points in the Cross Section Editor.

- Points are created in the Cross Section Editor as separate objects and catalogued in the corresponding Points folder in the Solution Explorer window.
- The points can be then connected into Plates (side faces of the cross section).
- A set of interconnected Plates defines a Segment.

There is no limit as to number of Plates that may originate from a single node. This allows for an easy definition of all types of the extruded sections.



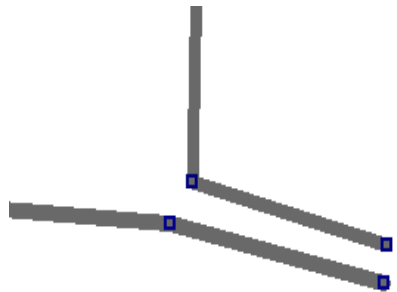
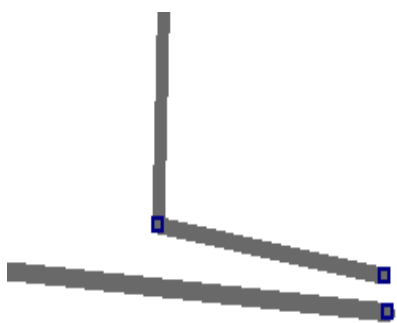
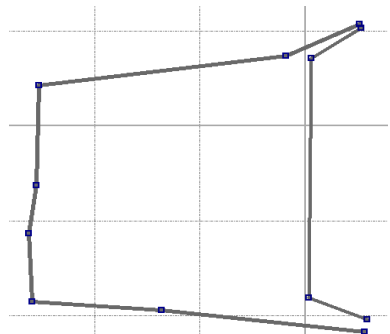
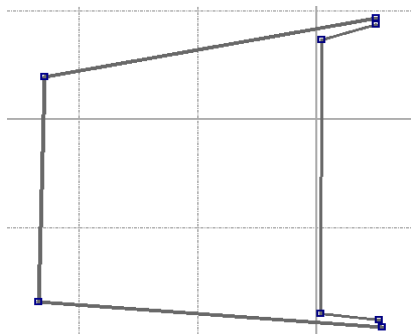
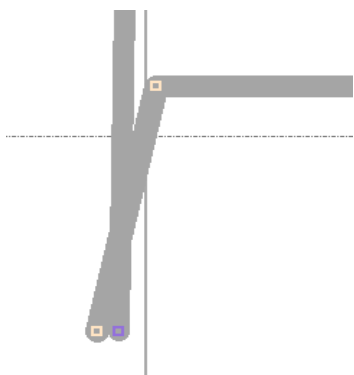
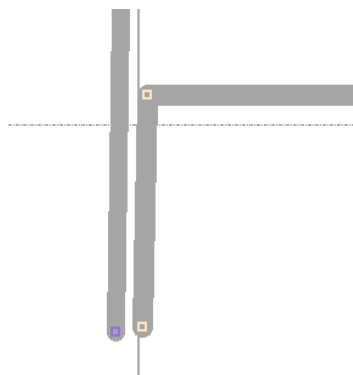
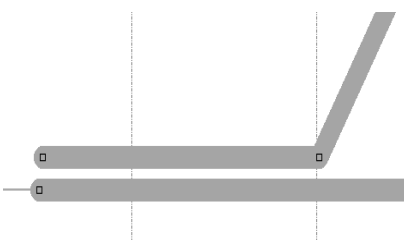
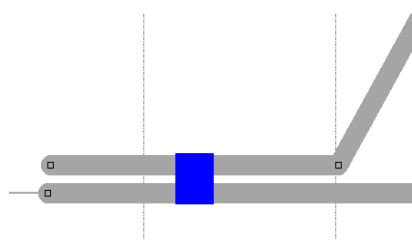


THIN-WALLED CROSS SECTION - TIPS

	Wrong X	Correct ✓																								
<p>- All plates must have assigned material</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="background-color: #cccccc;">1. Properties</th> </tr> </thead> <tbody> <tr> <td>CircularTube</td> <td style="text-align: center;">False</td> </tr> <tr style="border: 2px solid red;"> <td>Material</td> <td></td> </tr> <tr> <td>Thickness</td> <td style="text-align: center;">1</td> </tr> </tbody> </table>	1. Properties		CircularTube	False	Material		Thickness	1	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="background-color: #cccccc;">1. Properties</th> </tr> </thead> <tbody> <tr> <td>CircularTube</td> <td style="text-align: center;">False</td> </tr> <tr style="border: 2px solid green;"> <td>Material</td> <td style="text-align: center;">2000168 (LS_DYN)</td> </tr> <tr> <td>Thickness</td> <td style="text-align: center;">1.673</td> </tr> </tbody> </table>	1. Properties		CircularTube	False	Material	2000168 (LS_DYN)	Thickness	1.673								
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WidthEffective	0																									
<p>- Avoid reproducing corner radius</p>																										
<p>- Avoid creation of too many short plates (number of Super Folding Elements influences calculation results)</p>																										



THIN-WALLED CROSS SECTION - TIPS

	Wrong 	Correct 
<p>- Avoid creation of obtuse and acute angle between plates (refer to design recommendations)</p>		
<p>- Create possibly minimal number of plates</p>		
<p>- Avoid plates' intrusion</p>		
<p>- Create spot-weld connections if necessary</p>		



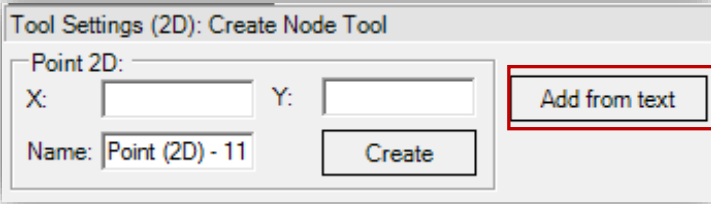
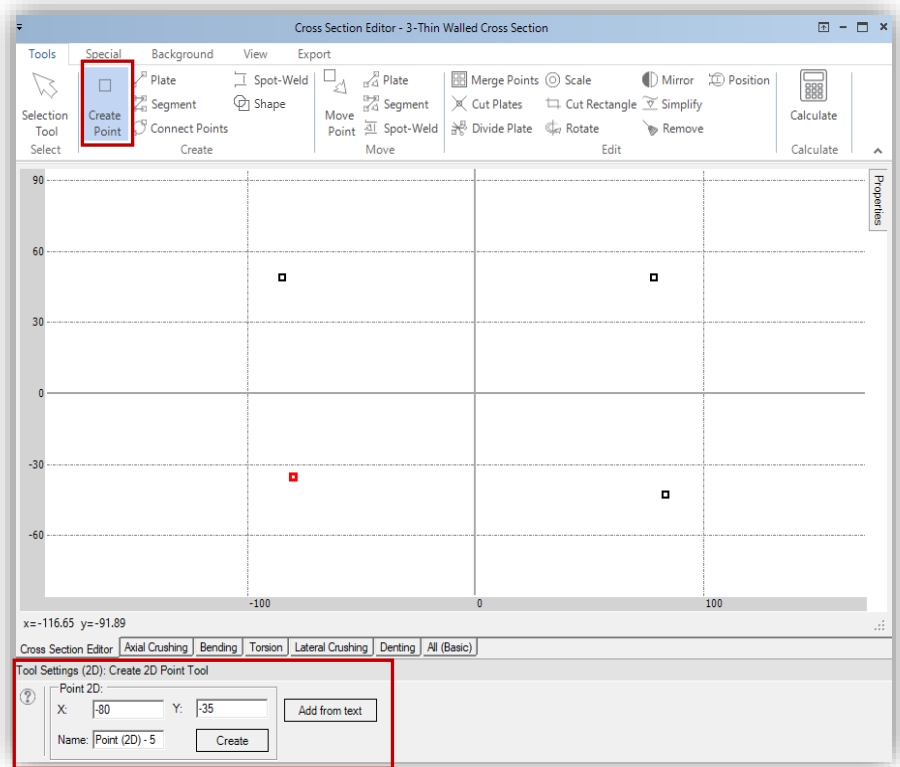
"Create Point" tool

After selecting the Create Point tool you can create points for a new cross section by clicking on the 2D view of the Cross Section Editor.

Each new node will be automatically catalogued in the Points folder in the Solution Explorer window.

After right click on the chosen Point in the Solution Explorer window you can rename the Point, remove it from the solution or zoom the 2D view to the selected object.

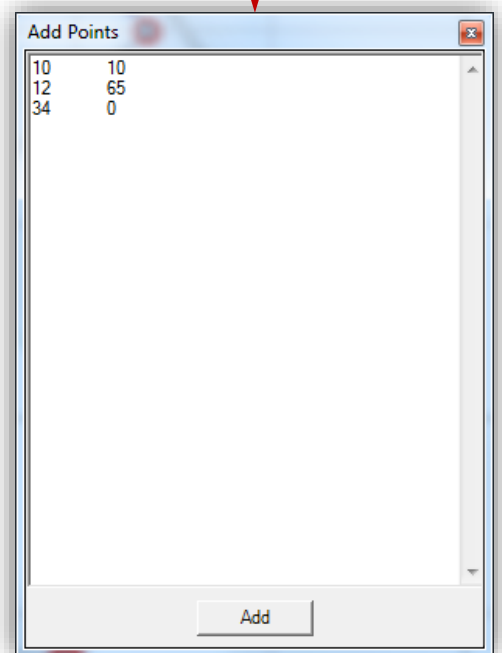
In the Properties window you can change the color of the Point, its visibility on the 2D view and its name. You can also edit the Point's coordinates.



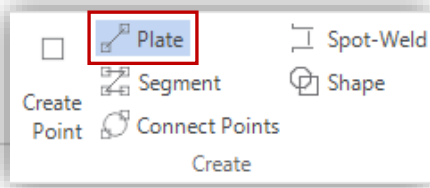
You can enter the coordinates of a newly created Point in the Tool Settings window. After clicking on the "Create" button the new point will be visible in the 2D view.

You can also define the coordinates of a group of Points in the Text editor. After clicking on the "Add Nodes From Text" option in the Tool Settings window a text editor will appear. In this window you can enter the required coordinates of new Points.

The syntax is: one Point per line, x and y coordinates separated by TAB. Next line – press 'Enter'

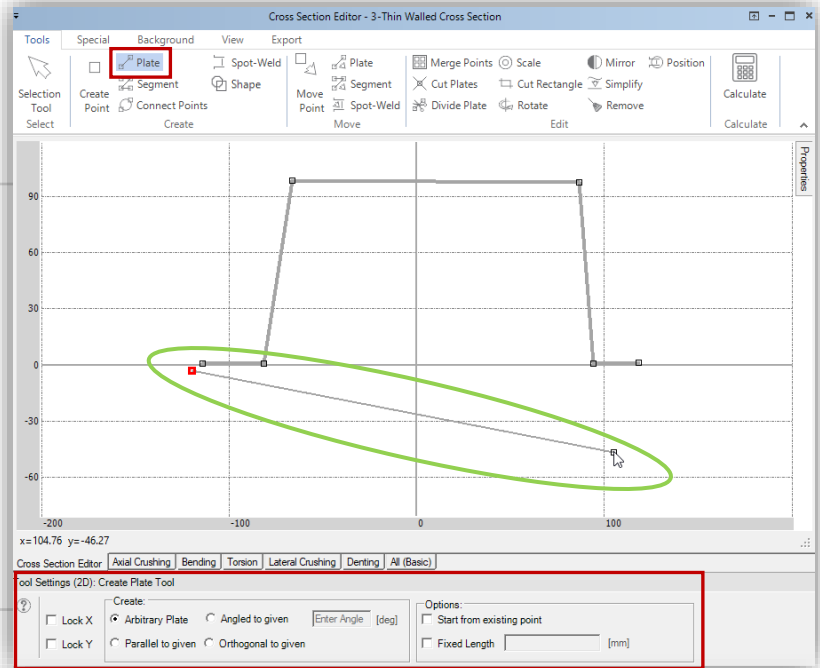


The Create Plate tool facilitates the procedure of creating new cross sections.



In its basic function the tool creates a new Plate after clicking in two locations in the Cross Section Editor 2D view.

Two Points defining the Plate will be automatically created and added to the Solution Explorer window.

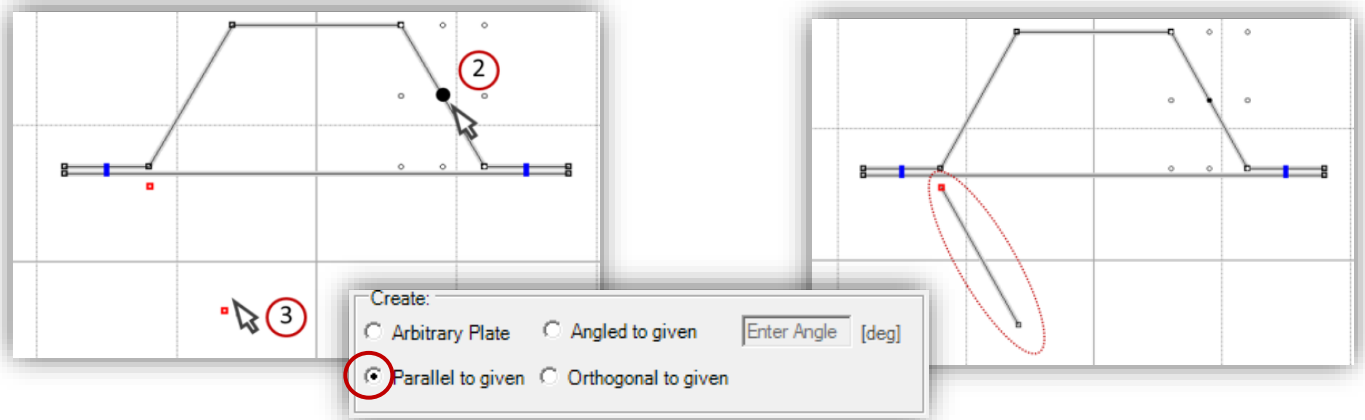


Tool Settings (2D): Create Plate Tool

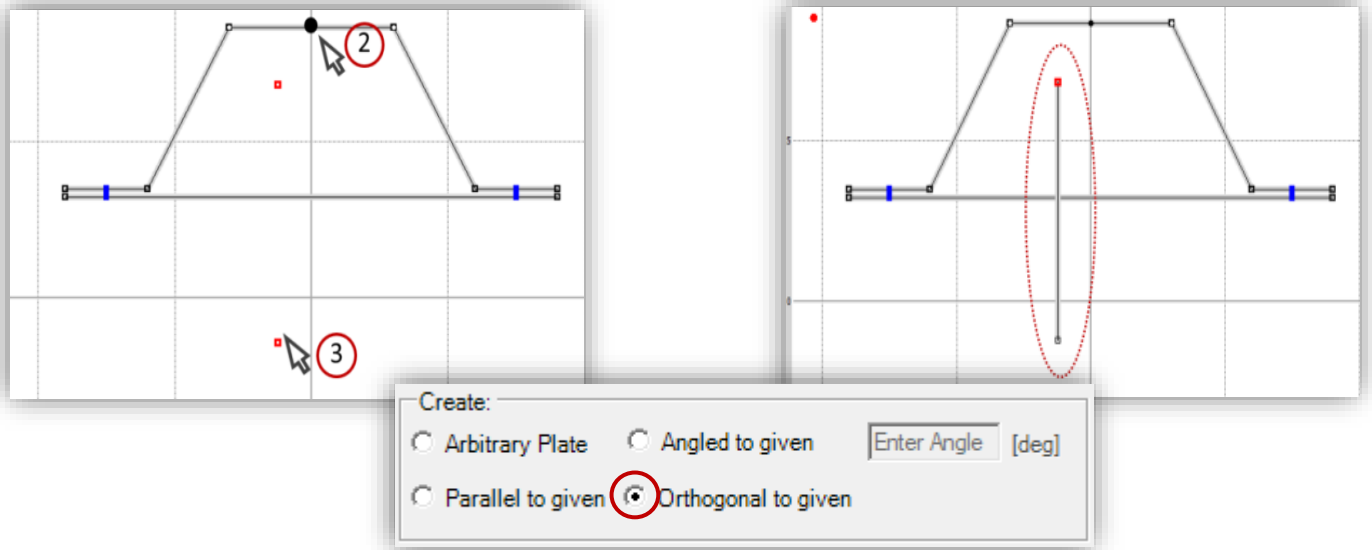


The Create Plate tool has several additional functionalities

CREATE PARALLEL AND ORTHOGONAL PLATES



- 1) After clicking on the Create Plate icon select the "Parallel Plate to given" option in the Tool Settings window.
- 2) Select one Plate from the already existing cross section. The chosen plate will be marked in the 2D view by a black dot located in its center.
- 3) Now click in a required location in the Cross Section Editor and define the coordinates of the first Point of the new Plate. After clicking in the second location a Plate parallel to the chosen one will be generated.



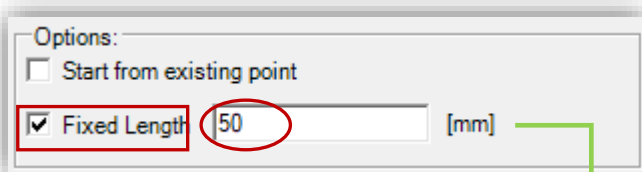
Similar procedure enables the User to easily define Plate orthogonal to a previously selected one.

In this case after selecting the Create Plate tool select the "Orthogonal Plate to given" option in the Tool Settings window.

Select one element of the Cross Section to which the newly created Plate will be orthogonal and then define coordinates of the new Plate.

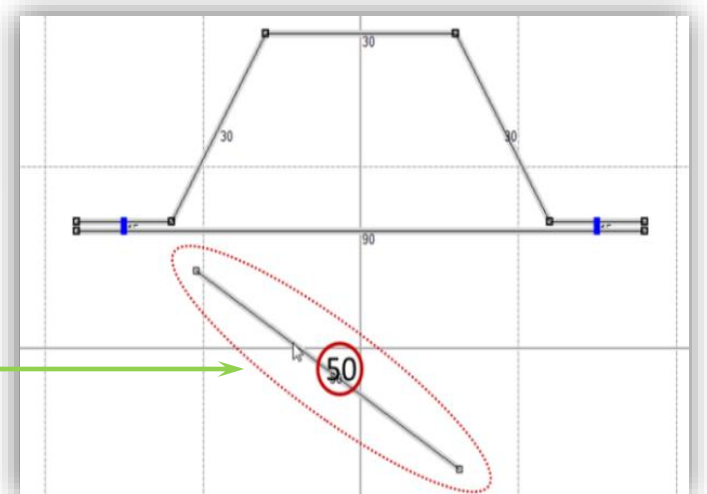
CREATE PLATE OF A DEFINED LENGTH

Using the Create Plate tool the User has the possibility to create a new Plate with a defined length.



After clicking on the Create Plate icon select the "Fixed Length" option in the Tool Settings window.

In the Fixed Length window define the requested length of the new Plate.

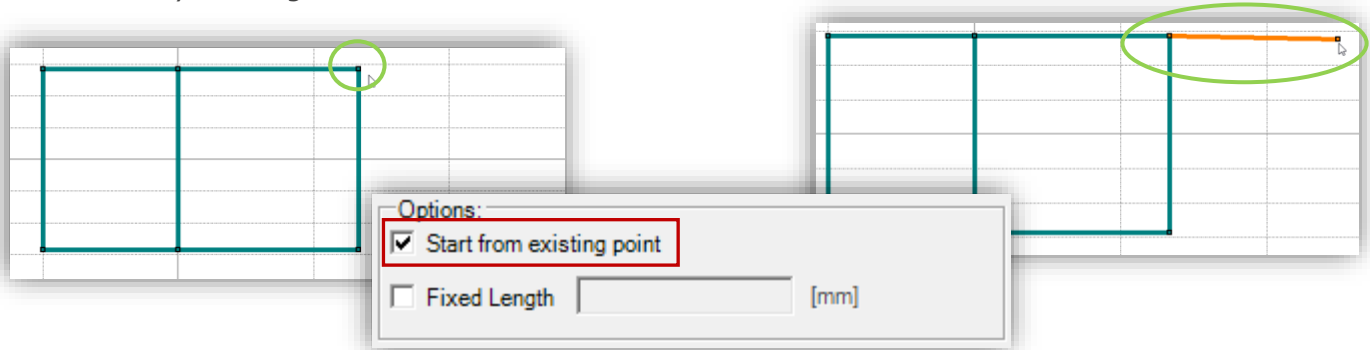


Now click in a required location in the Cross Section Editor and define the coordinates of the first Point of the new Plate.

After clicking in the second location a Plate of the previously defined length will be generated

CREATE PLATE FROM AN ALREADY EXISTING POINT

In the Cross Section Editor the User has the possibility to create a new Plate starting from a Point already existing in the 2D view.



After clicking on the Create Plate icon select the "Start from existing point" option in the Tool Settings window.

Select one Point on the 2D view or using the Solution Explorer window. The new Plate will be created basing on this chosen Point.

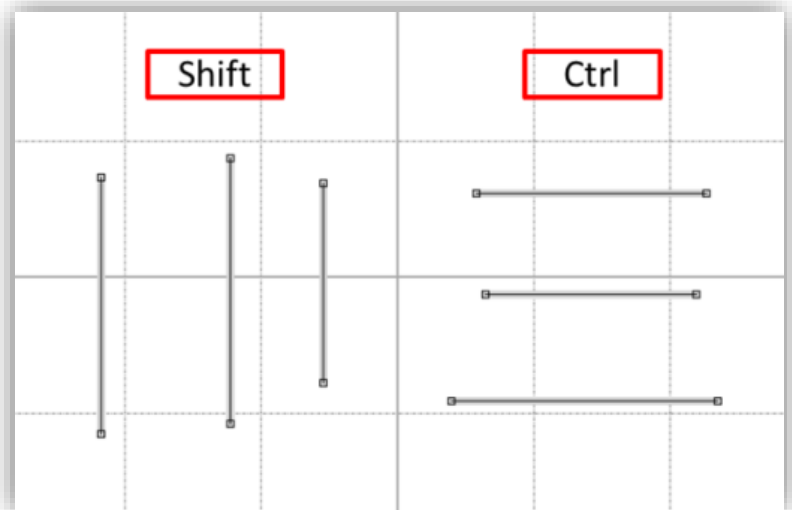
Now click in a required location in the Cross Section Editor and define the coordinates of the second Point of the new Plate

CREATE VERTICAL AND HORIZONTAL PLATES

After selecting the Create Plate tool click on the Cross Section Editor 2D view to determine the coordinates of the first Point of the new Plate.

Keeping the Shift button pressed choose the location of the second Point. A vertical new Plate will be automatically created.

Similarly, after clicking in the 2D view keeping the Ctrl button pressed you will automatically create a horizontal Plate.


 Lock X

 Lock Y

Additionally, you can create a Plate along the X or Y axis.

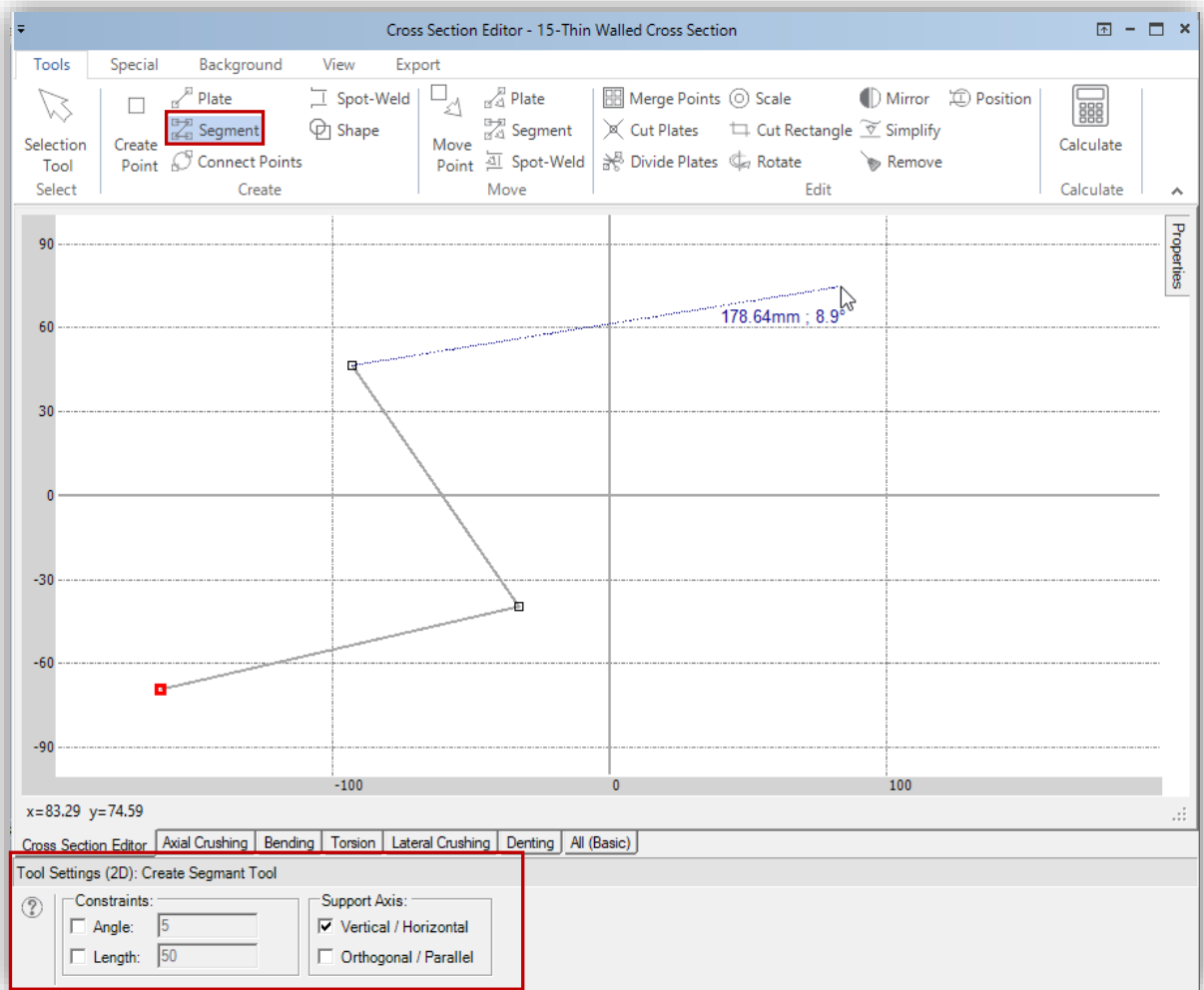
In order to block one of the axis of the Cross Section Editor select the "Lock X" or "Lock Y" option in the Tool Settings window



"Create Segment" tool

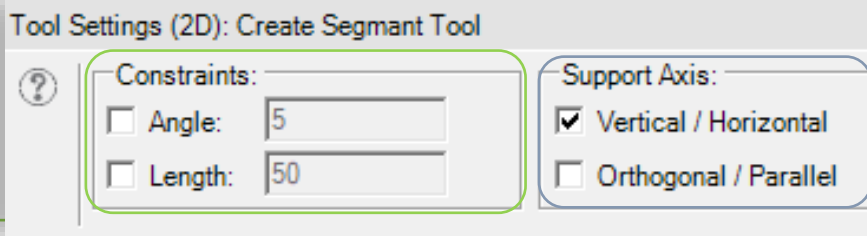
You can create Plates and Segments using the Create Segment tool.

After clicking on the editor 2D view you will create Points and Plates connecting them. In result you can easily create a Segment.



After creating new Point the auxiliary line is made and followed the cursor to show the future Plate. Also the length of Plate and the angle from the horizontal position are displayed as presented in the picture above.

To facilitate creating Segment, the constraint angle step and/or constrained length can be defined.



Additional support axis can be added. User can choose Vertical/Horizontal or Orthogonal/Parallel support axis.

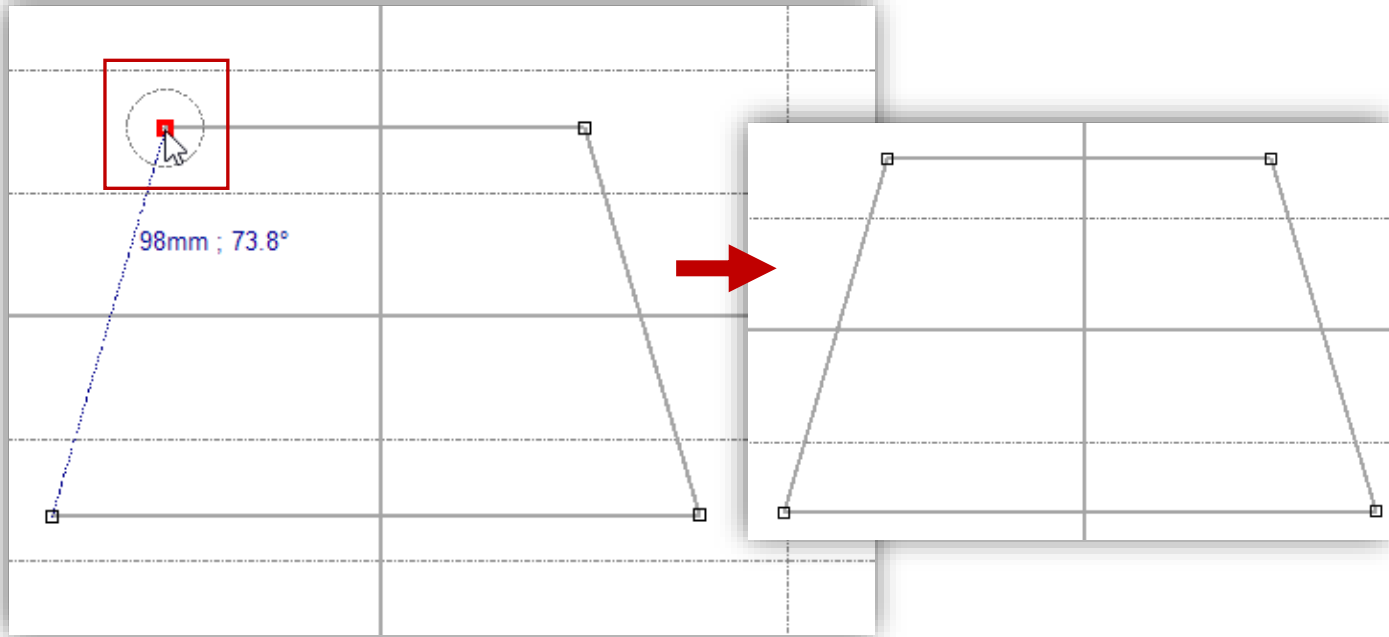
USEFUL TIPS

1. After moving the cursor over an existing point, when a circle appears, an existing point can be selected as the next point of the Segment. In this way closed cross-section can be made.
2. Double right mouse click or ESC button from keyboard enable to stop drawing the current Segment and start the new one.



"Create Segment" tool

After moving the cursor over an existing point, when a grey circle appears, an existing point can be selected as the next point of the cross-section.



Constraints

To facilitate creating Segment the constraints can be defined.

Select **Length** checkbox and enter the value into textbox to create Plates with requested length.

Select **Angle** checkbox and enter the value into textbox to create Plates with angle step rounded to requested one.

Constrained values are displayed in green color. Current cursor position is displayed in the gray color as presented in the pictures below.

Tool Settings (2D): Create Segment Tool



Constraints:

Angle: 90

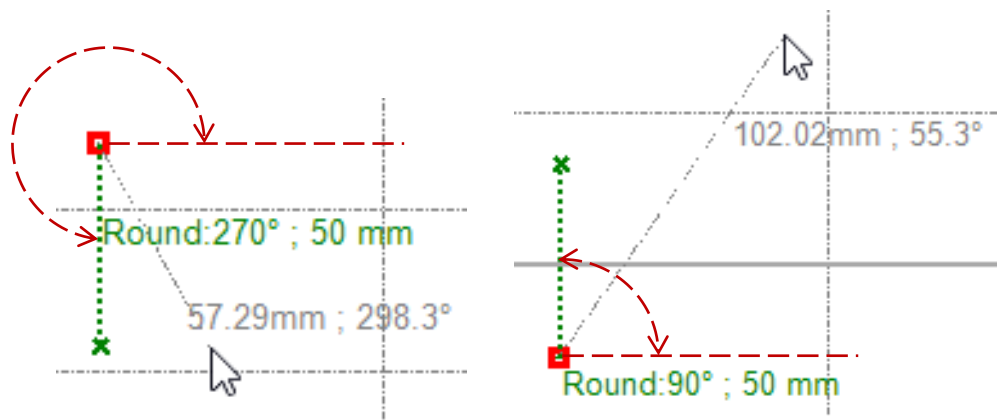
Length: 50

Support Axis:

Vertical / Horizontal

Orthogonal / Parallel

Please note that the rounding is always with respect to the horizontal position.

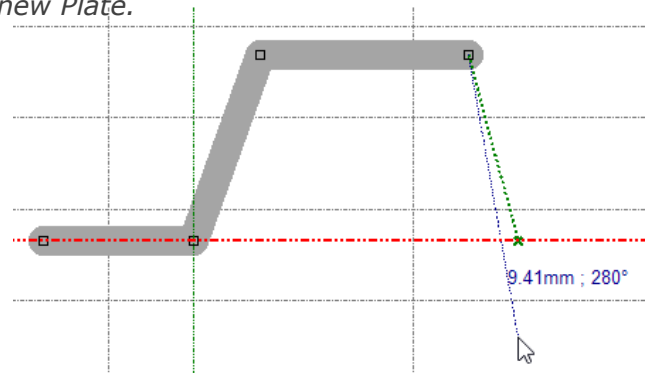
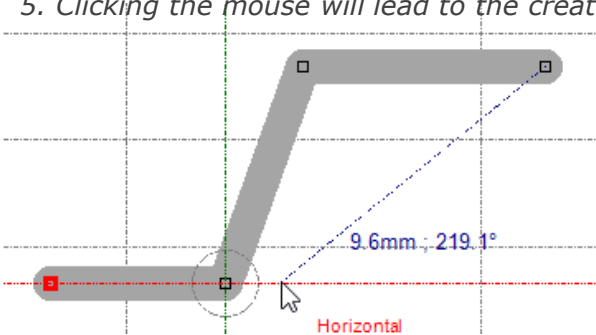
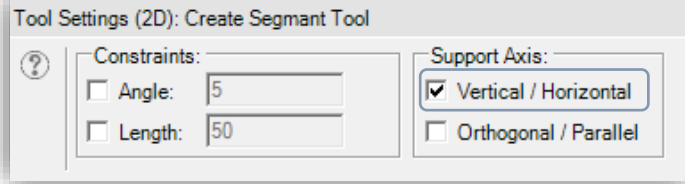


Support Axis – Vertical / Horizontal

The function enables creating a vertical or horizontal support axis from indicated Point and set the new Point on selected support axis.

To create vertical or horizontal support axis follow the steps:

1. Select Vertical / Horizontal axis checkbox
2. Indicate the point based on which the support axes will be created (hover over the point, don't click)
3. Select Horizontal or Vertical axis by mouse click. Please note that the Horizontal axis is marked in red and the Vertical axis is marked in green.
4. The new Point to be created, follows selected axis (during moving cursor its position is projected on the axis)
5. Clicking the mouse will lead to the creation of a new Plate.



Support Axis – Orthogonal / Parallel

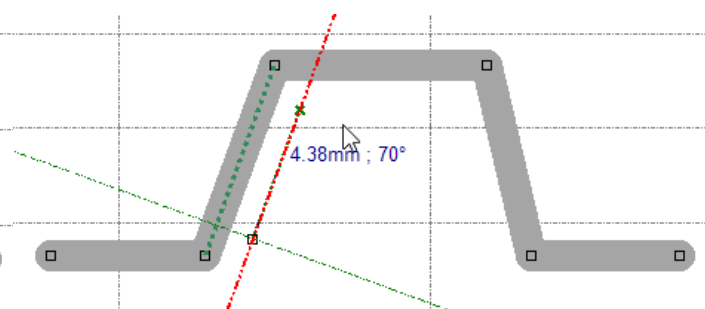
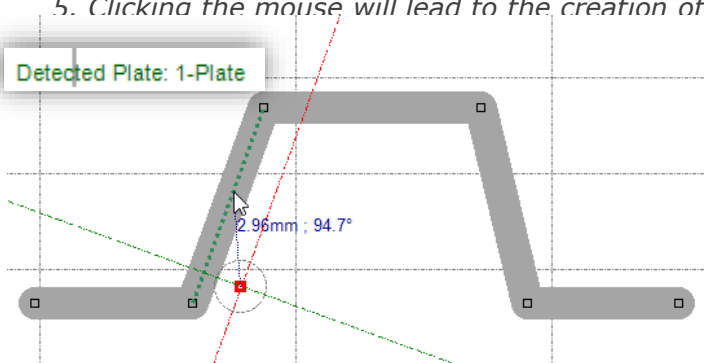
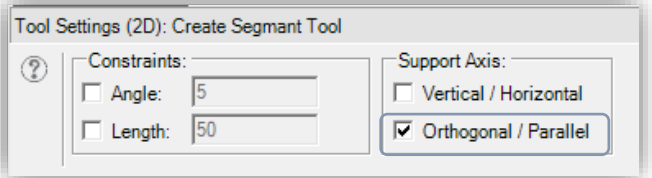
The function enables creating an orthogonal or parallel support axis based on an indicated Plate and setting a Point on a selected support axis.

To create orthogonal or parallel support axis follow the steps:

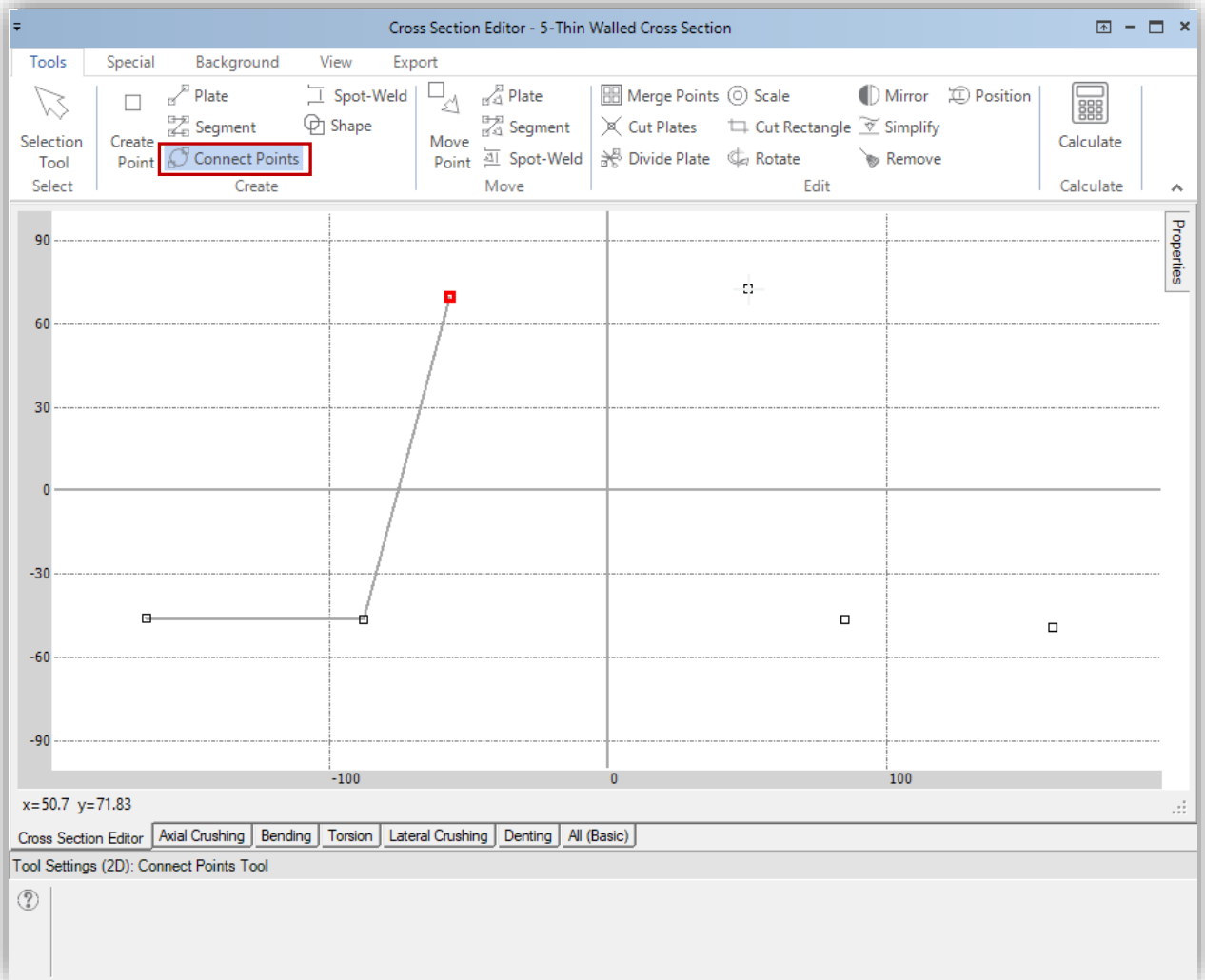
1. Select Orthogonal / Parallel axis checkbox
2. Indicate the Plate the basis of which the support axes will be created (hover over the plate, don't click).

The green dashed line and the text box with the name of detected Plate appears in the 2D window.

3. Select Orthogonal or Parallel axis. Please note that the Parallel axis is marked in red and the Orthogonal axis is marked in green.
4. The point to be created follow selected axis (during moving cursor its position is projected on the axis)
5. Clicking the mouse will lead to the creation of a new Plate



After selecting the Connect Points tool you can create a Plate between two selected Points.



You can connect number of Points and by doing so create a Segment.

Each Plate as well as number of connected Plates will be automatically catalogued in the Segments folder in the Solution Explorer window.



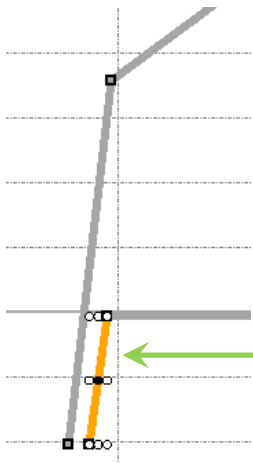
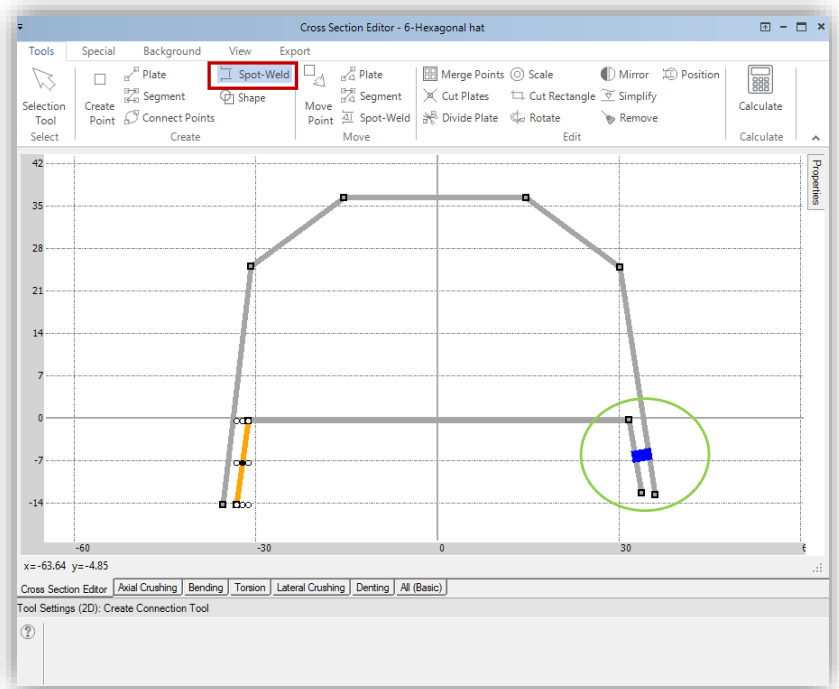
In order to guaranty the deformation transfer, connections need to be added to the cross-sectional model. Connections force connected element to fold in compatible manner regardless of the type of physical connection.

To create a Connection, select the „Spot-Weld“ tool.

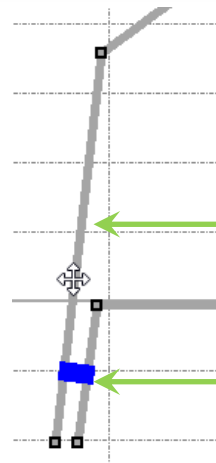
A spot weld is defined by clicking in turn on two Plates to be connected.

To create a Spot-Weld you need to select a master plate which corresponds to the first selected plate and a slave plate which is selected as a second plate.

A default position of a spot weld is automatically defined in the center of master plate (the first connection end). Second end position is perpendicular to the slave plate.



1) Select the MASTER plate

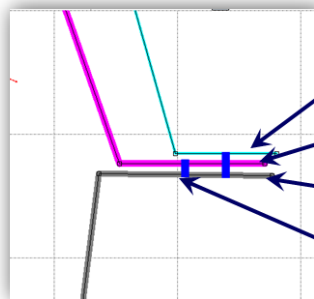


2) Select the SLAVE plate

3) NEW SPOT-WELD connection

Creation of a connection between three plates consists of two Spot Weld elements. In that case the selection order of master plate and slave plate is important.

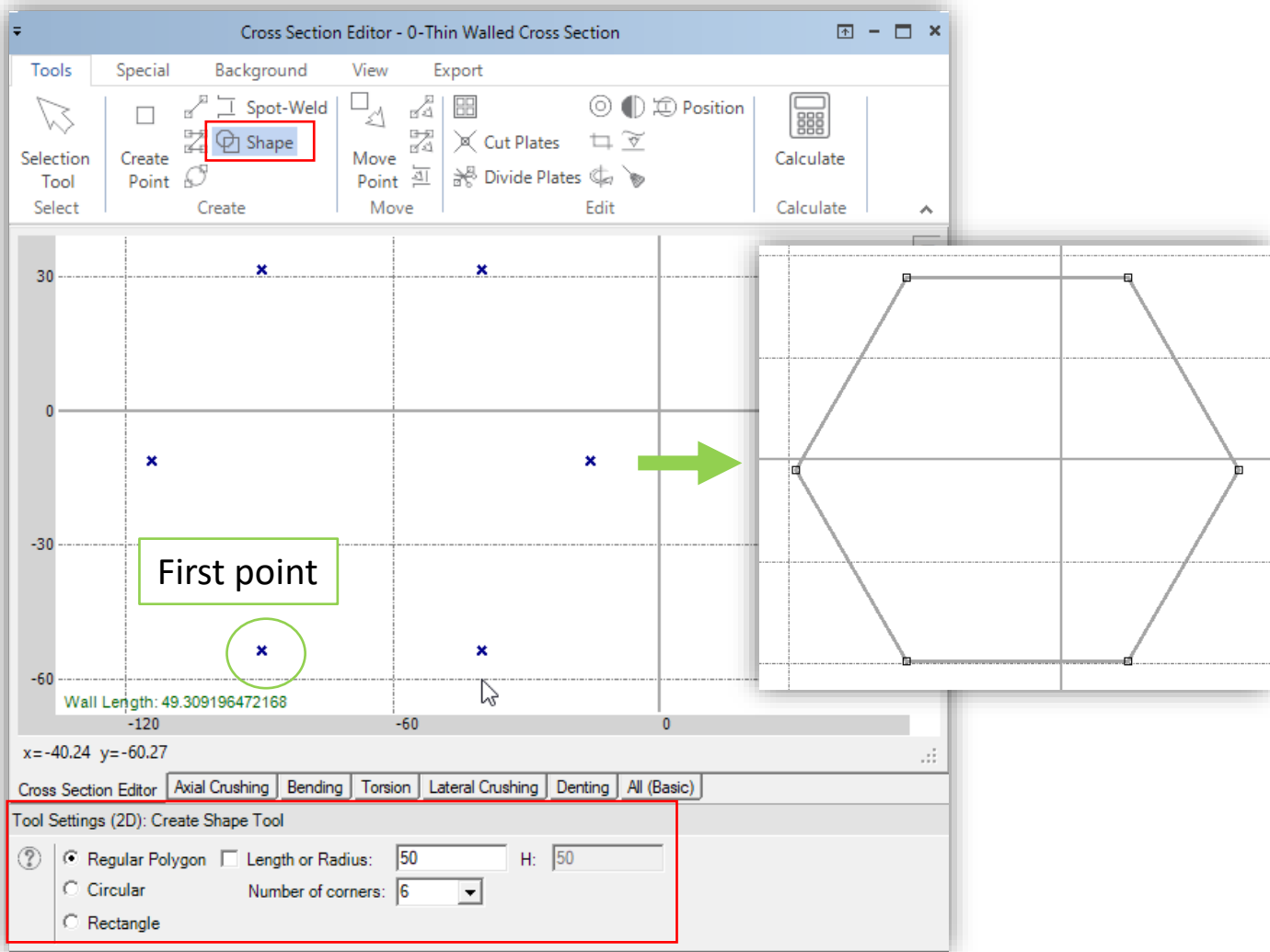
Select the outer plate, subsequently the plate lying in the middle. Do the same for second Spot Weld element.



- Master Plate
- Slave Plate
- Master Plate
- Leading Flange



Shape tool enables easy creation of new polygonal, rectangular or circular cross sections directly in the Cross Section Editor.



To create cross-section with specific shape, follow the steps:

1. Select shape (Regular Polygon / Circular / Rectangular)
2. Set the first point of the cross-section
3. Define the side length
4. Set second point to create the cross-section

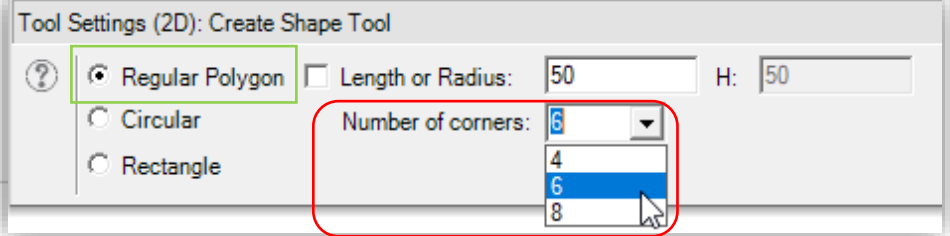
The side length can be defined by mouse move, or the specific value can be set in the Tool Settings Window.

The future Points are marked by blue X as it is illustrated in the picture above.

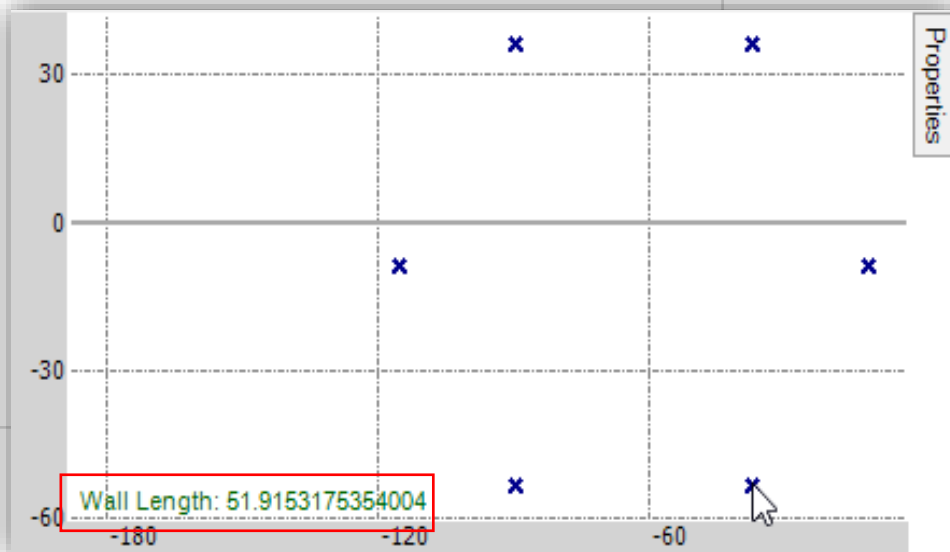
REGULAR POLYGON

This option enables to create regular polygon with selected number of corners: 4, 6, 8 corners.

Number of corners can be selected from drop-down list.

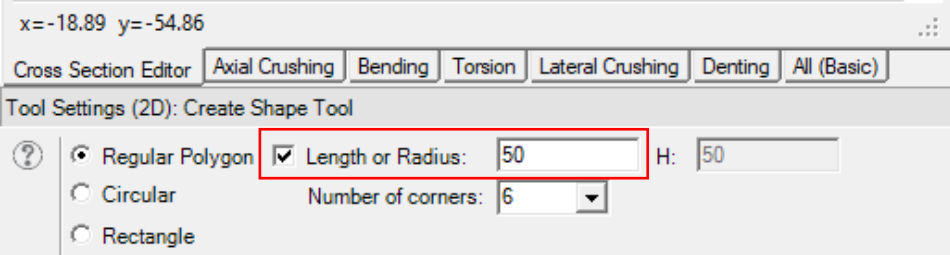
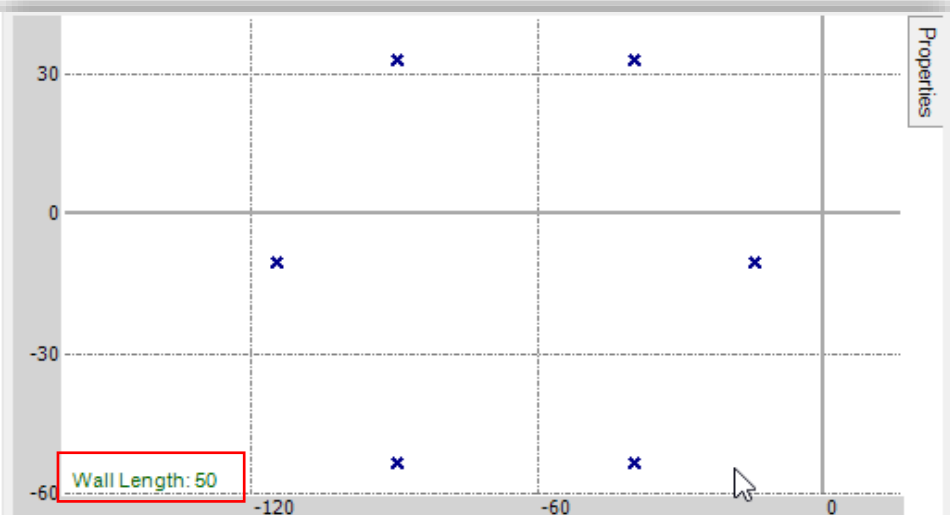


The **Wall Length** defined by following cursor movement can be previewed in the real time in the 2D view window.



The user has the possibility to set specific **Wall Length** by selecting check-box and entering value in the textbox.

After that, the polygon stops responding to the mouse move. To return, deselect "Length or Radius" check-box.



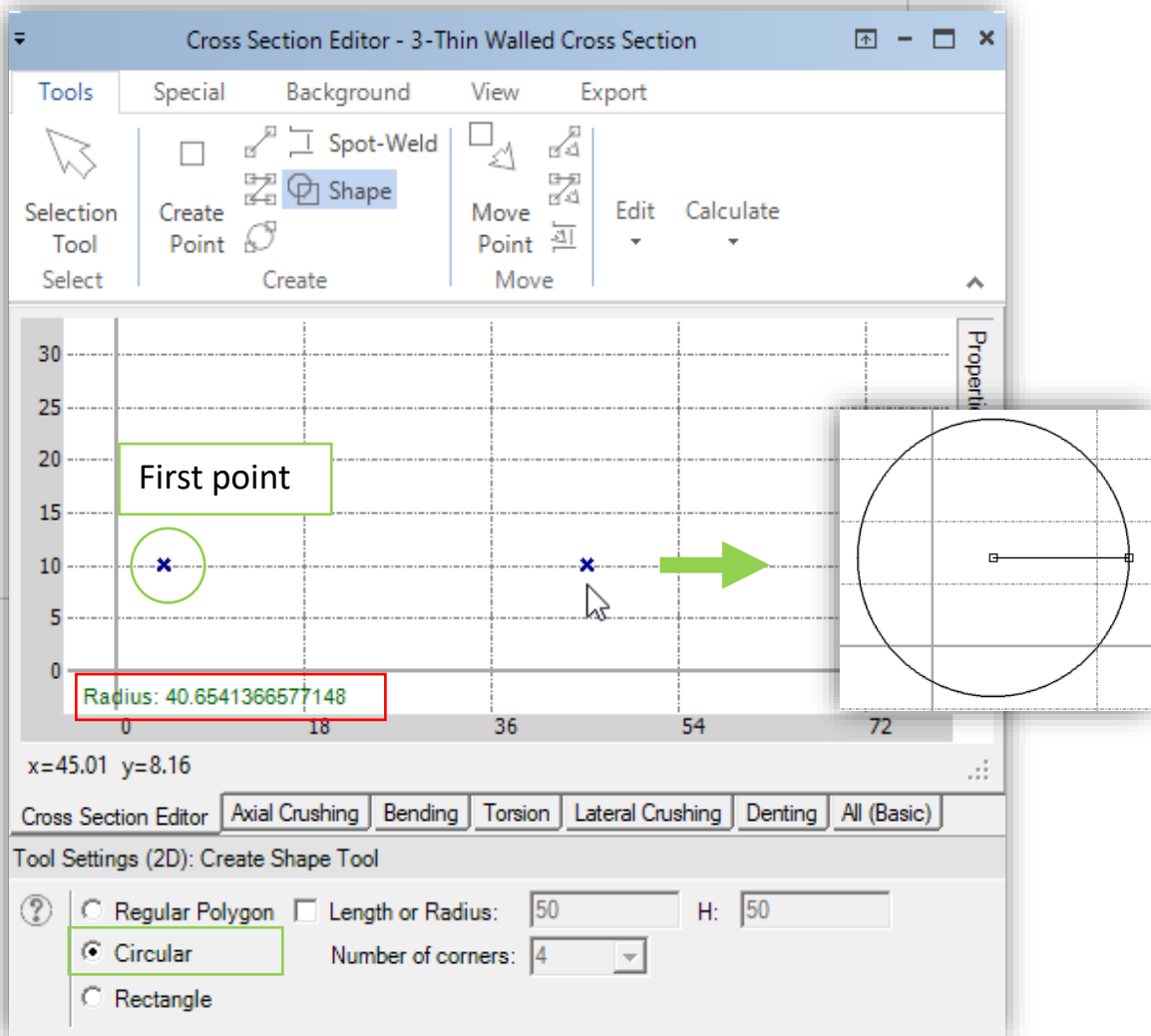
CIRCULAR SECTION

This option enables to create circular cross-section in easy way.

Important notice

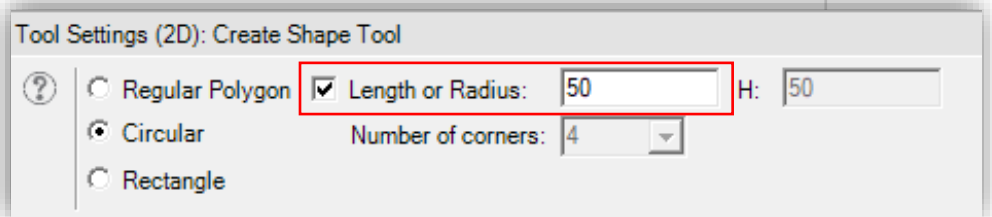
In VCS the circular cross-section must occur alone. It cannot contain any additional Plates.

The **Radius** defined by following cursor movement can be previewed in the 2D view window in the real time.



The user has the possibility to set specific **Radius** by selecting check-box and entering value in the textbox.

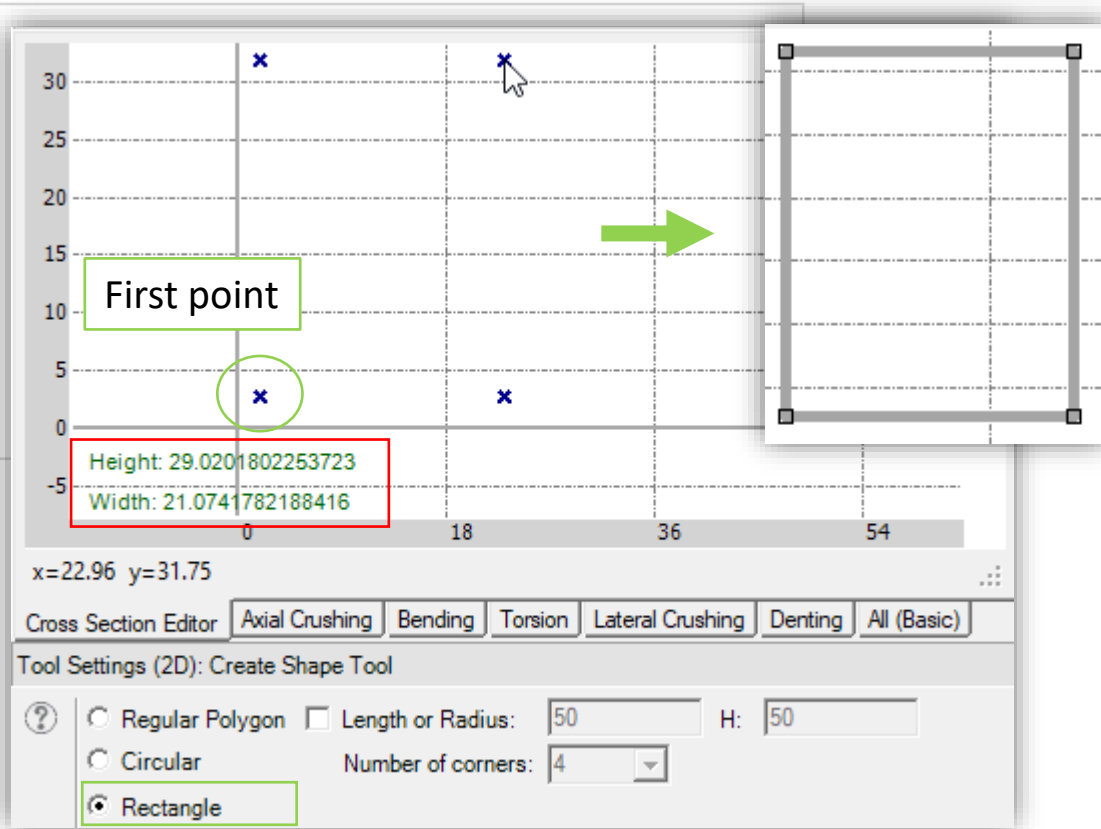
After that, the section stops responding to the mouse move. To return, deselect "Length or Radius" check-box.



RECTANGULAR SECTION

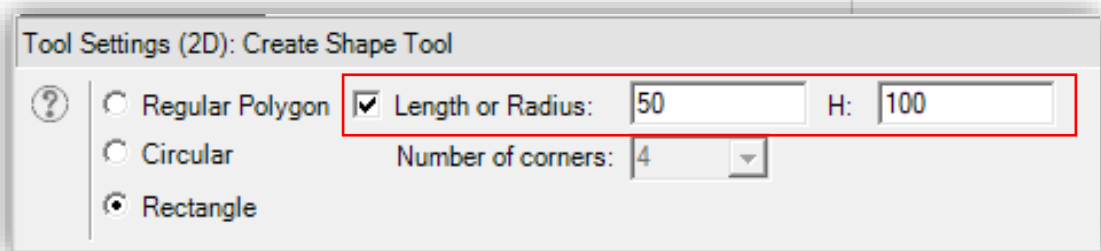
This option enables to create rectangular cross-section in easy way.

The **Height** and **Width** defined by following cursor movement can be previewed in the 2D view window in the real time



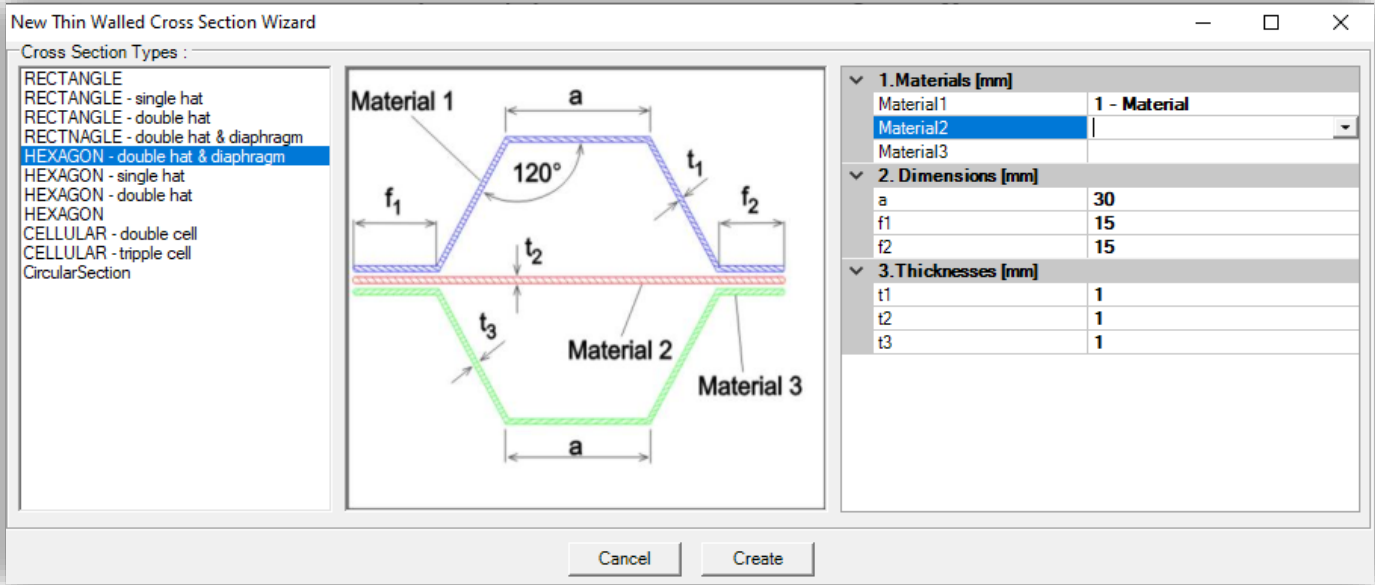
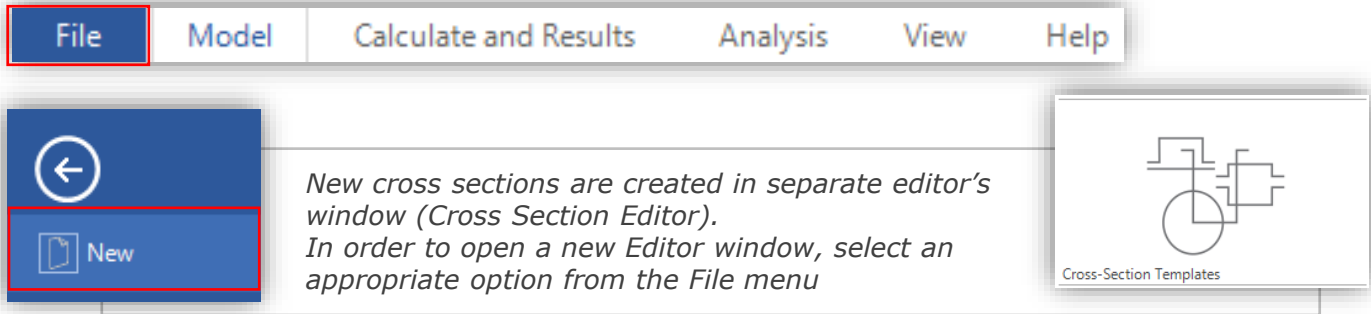
The user has the possibility to set specific **Height** and **Width** by selecting check-box and entering value in the textbox.

After that, the section stops responding to the mouse move. To return, deselect "Length or Radius" check-box.



THIN-WALLED CROSS SECTION TEMPLATES

After the commands sequence: File → New → Cross Section Templates a new window named **New Thin-Walled Cross Section Wizard** will appear on the screen.



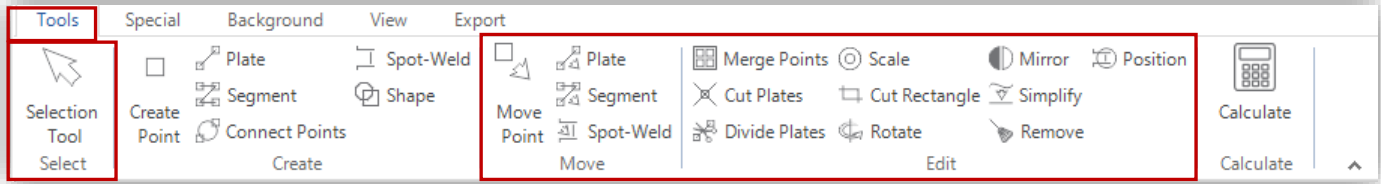
In this window you can select one of the 11 types of a modeled Cross Section:

- Rectangle Cross Sections
- Hexagon Cross Sections
- Cellular Cross Sections
- Circular Section

- In the middle section of the Wizard window you can see the drawing of the Cross Section you have selected.
- In the right section of the Wizard window you can find the Properties of the selected Cross Section.
- In the Properties Section you can edit the Dimensions and Thickness of each segment of the Cross Section.
- You can also select and assign a Material to each of the Cross Section's Segments.



EDITING TOOLS OF THE CROSS SECTION EDITOR



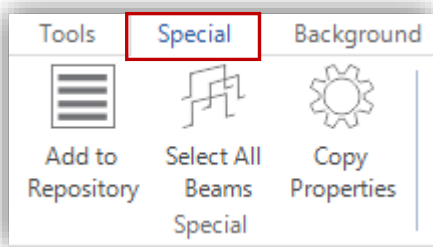
Every Cross Section can be modified at any time. Number of edit tools are available which will enable you to:

- Easily select objects – Selection tool
- Move elements of a Cross Section
- Merge Points
- Cut Plates
- Divide Plata
- Scale elements of a cross section
- Crop a cross section – Cut Rectangle tool
- Rotate Segments
- Mirror
- Optimize flat elements – Simplify tool
- Remove not connected points – Remove tool
- Optimize Spot-weld Position – Position tool

You can also change the position of each Cross Section's Element by entering the coordinates in the element's Properties window. You can select the element you wish to edit by clicking on it in the Solution Explorer tree or on the Cross Section Editor 2D view.

Note that in the Properties window you can assign a Material to each segment or Plate of the Cross Section.

Also note that in the Properties window you can edit the thickness of each Cross Section Plate.



In the "Special" section of the Cross Section Editor main toolbar you will find additional tools useful during the modeling process:

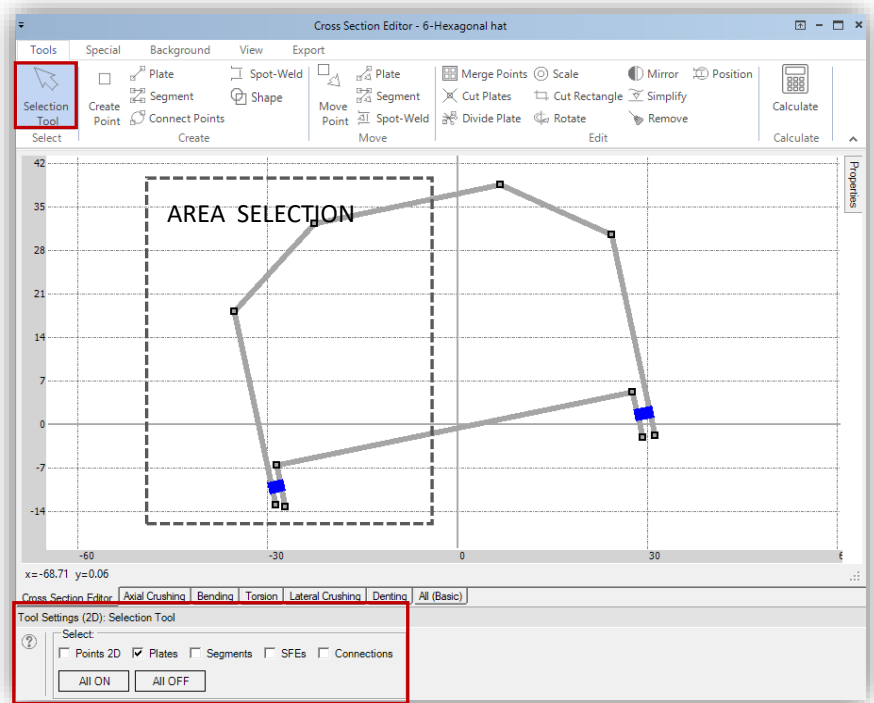
- Ass to Repository tool
- Select all beams with the currently opened cross section
- Copy Properties tool



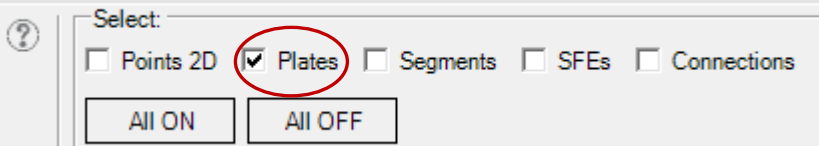
"Selection" tool allows you to select any part of the cross section visible in the 2D view. You can click on a chosen object or you can use the area selection option.

The Area Selection functionality facilitates the procedure of selecting several elements of a Cross Section simultaneously.

Please note that only elements which are located completely within the selected range will be marked using the Area Selection functionality.



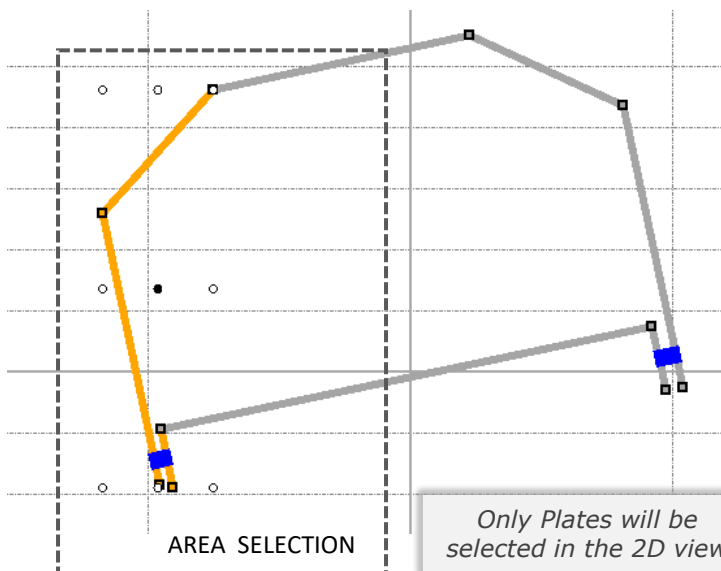
Tool Settings (2D): Selection Tool

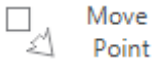


EXAMPLE: Select only Plates

- 1) Click on the "Plates" check box in the Tool Settings window
- 2) Use area selection option to select number of elements in the 2D view
- 3) Result: Only Plates will be selected (marked in orange color)

Please note that only elements which are located completely within the selected range will be marked

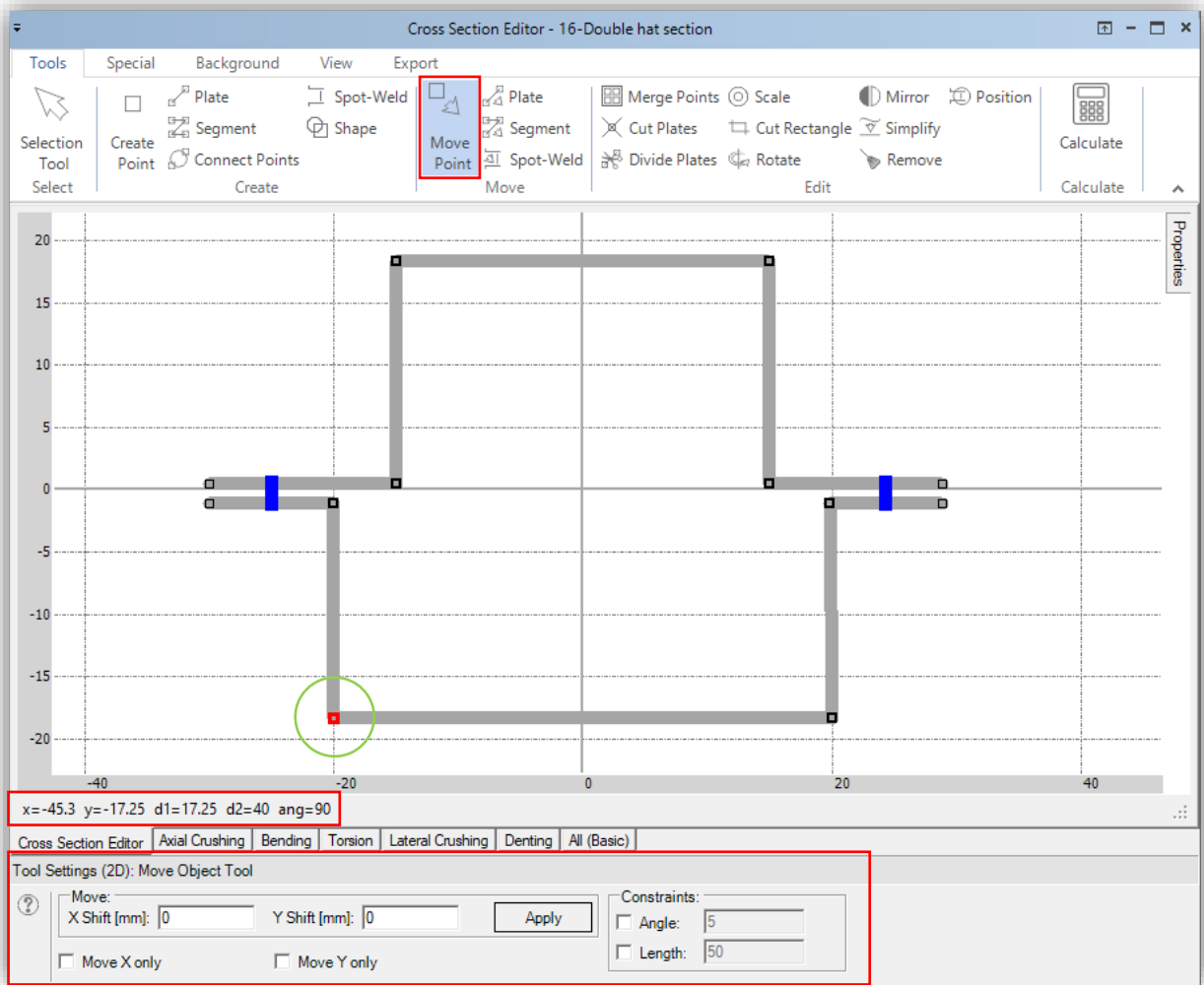




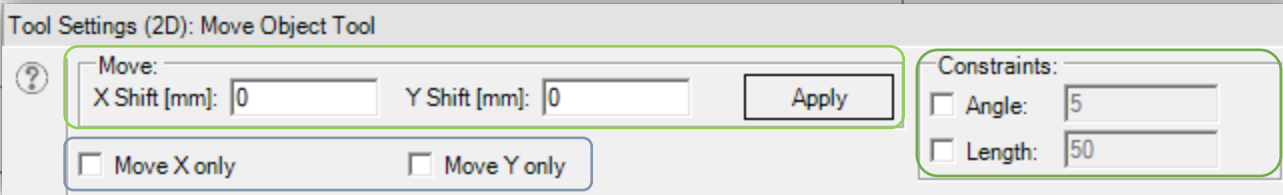
"Move Point" tool

Every Cross Section can be modified at any time.

The „Move Point“ tool enables the user to move any selected Point of the Cross Section in the Editor's 2D view ("click and drag" tool).



You can also change the position of each Cross Section's Point by entering its shift coordinates in Tool Settings window.

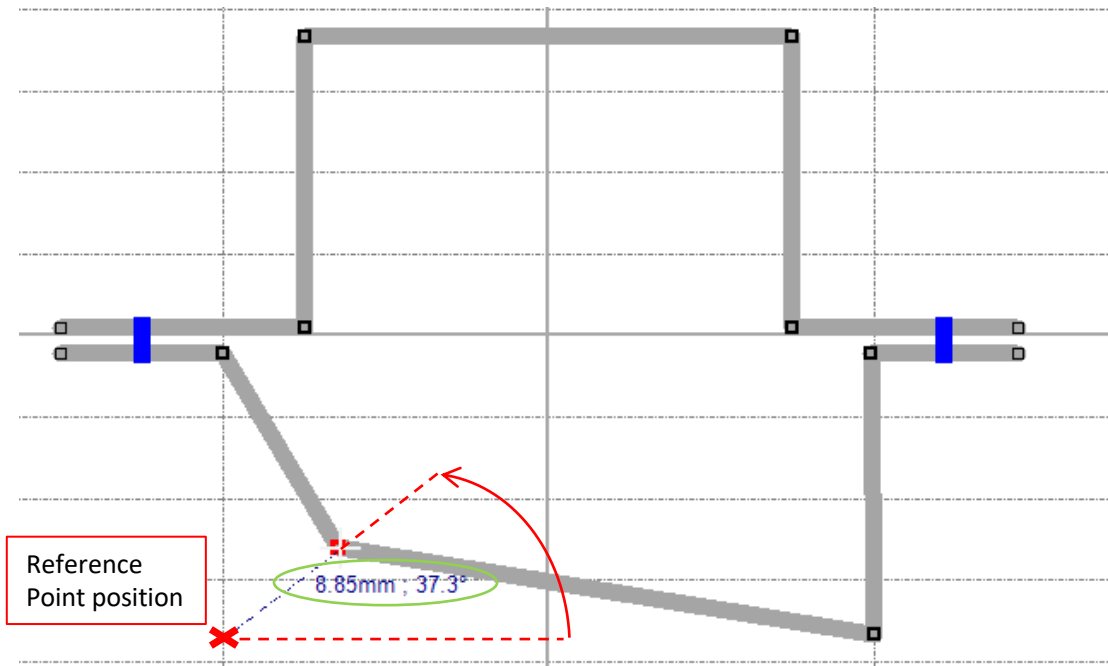


You can restrict the element's movement to one axis of the Cross Section Editor window ("Move X only" or "Move Y only" option).

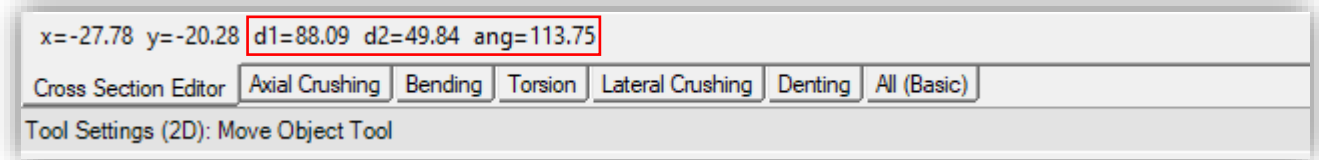
You can change the position of point with constraint angle's step and/or length from the reference location of the point.



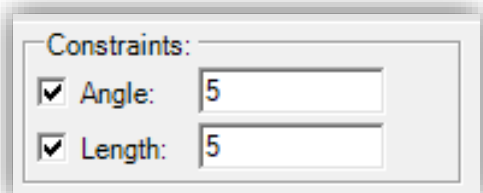
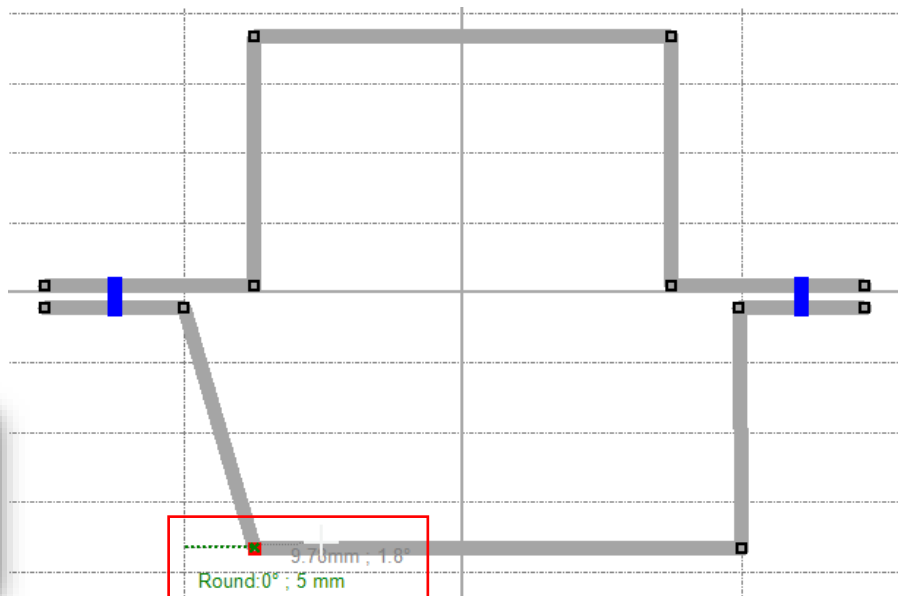
After dragging the Point, the auxiliary line with the information about the length and angle from reference Point position is displayed as shown on the picture below.
 * The angle value is measured with respect to the horizontal position.



Above the Tool Setting window there is also information about the length of the plates belonging to the selected point and the angle between them (picture below)

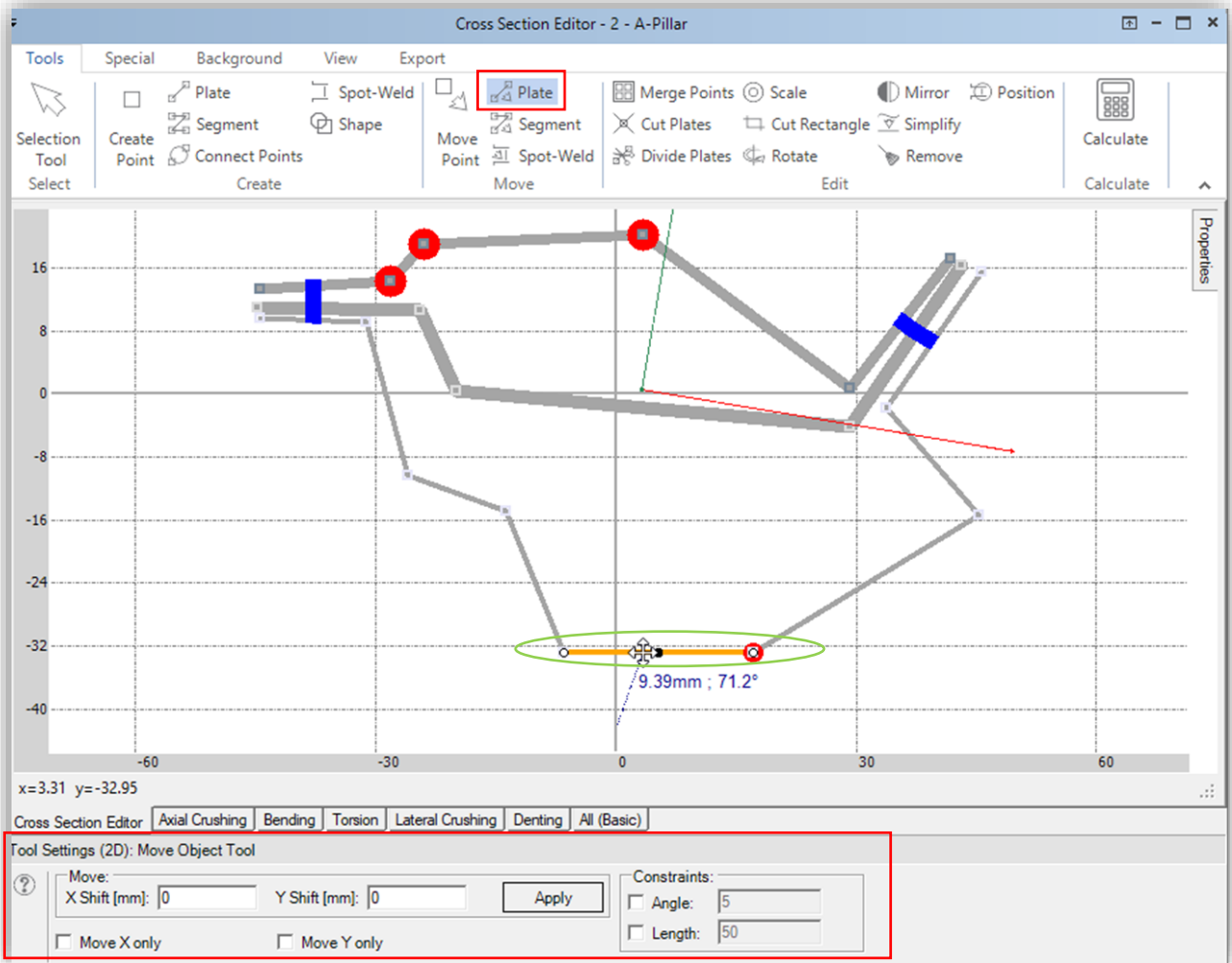


After defining constraints of the angle step and/or length, the auxiliary line and information about constrained length and rounded angle values are marked in green color as presented on the picture below.
 * The values resulting from the mouse position is highlighted in gray color.

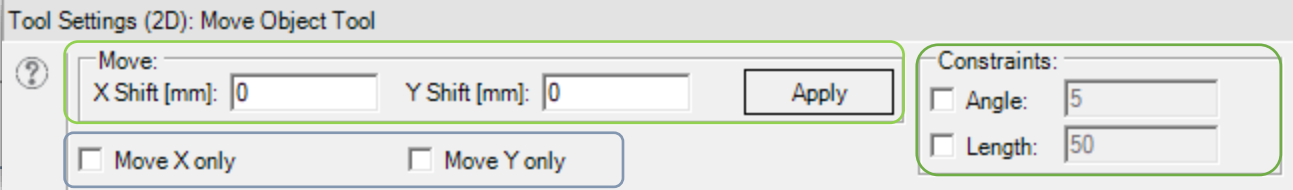


"Move Plate" tool

Every Cross Section can be modified at any time.
 The „Move Plate“ tool enables the user to move any selected Plate of the Cross Section in the Editor's 2D view ("click and drag" tool).



You can also change the position of each Cross Section's Plate by entering its shift coordinates in Tool Settings window.



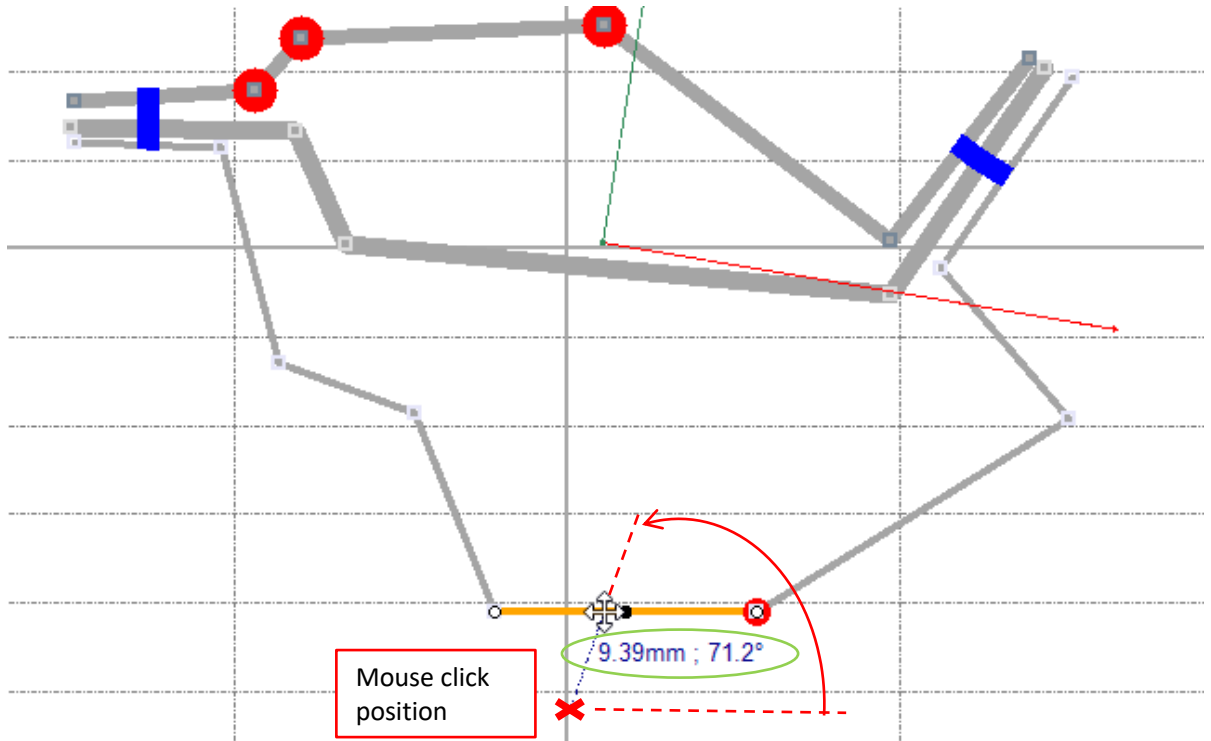
You can restrict the element's movement to one axis of the Cross Section Editor window ("Move X only" or "Move Y only" option).

You can change the position of plate with constraints angle step and/or length from the reference location of the plate.

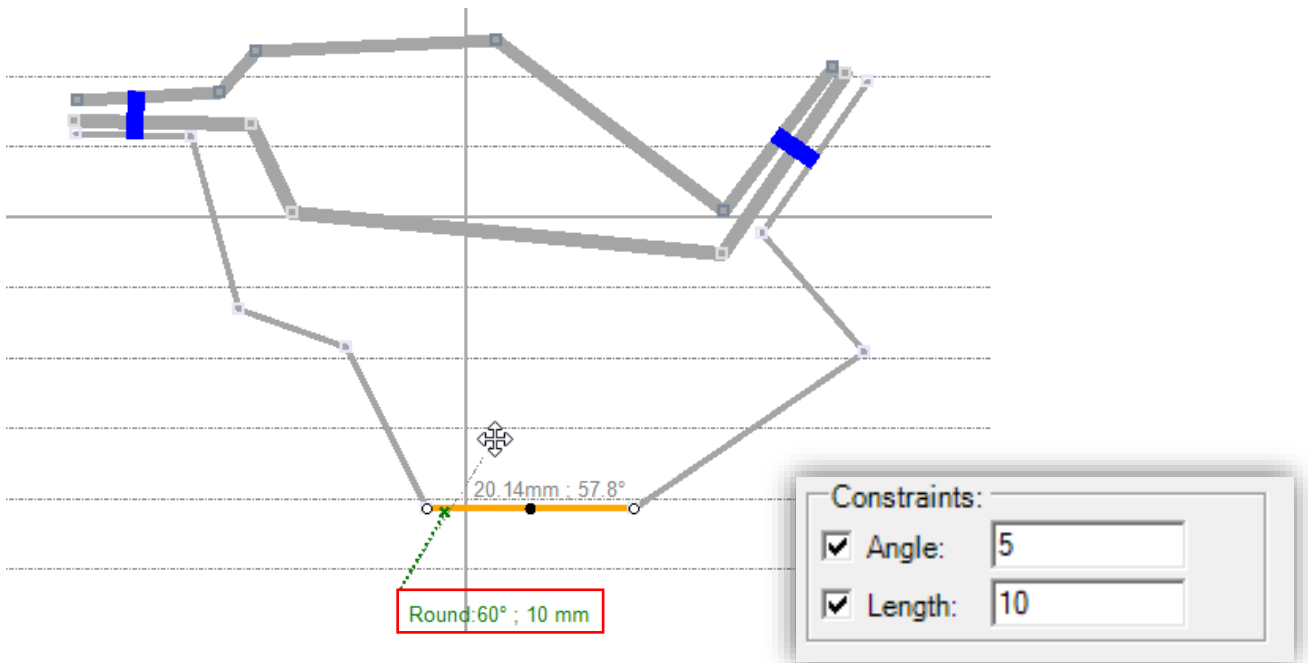


"Move Plate" tool

After dragging the Plate, the auxiliary line with the information about the length and angle from mouse click position is displayed as shown on the picture below.
 * The angle value is measured with respect to the horizontal position.

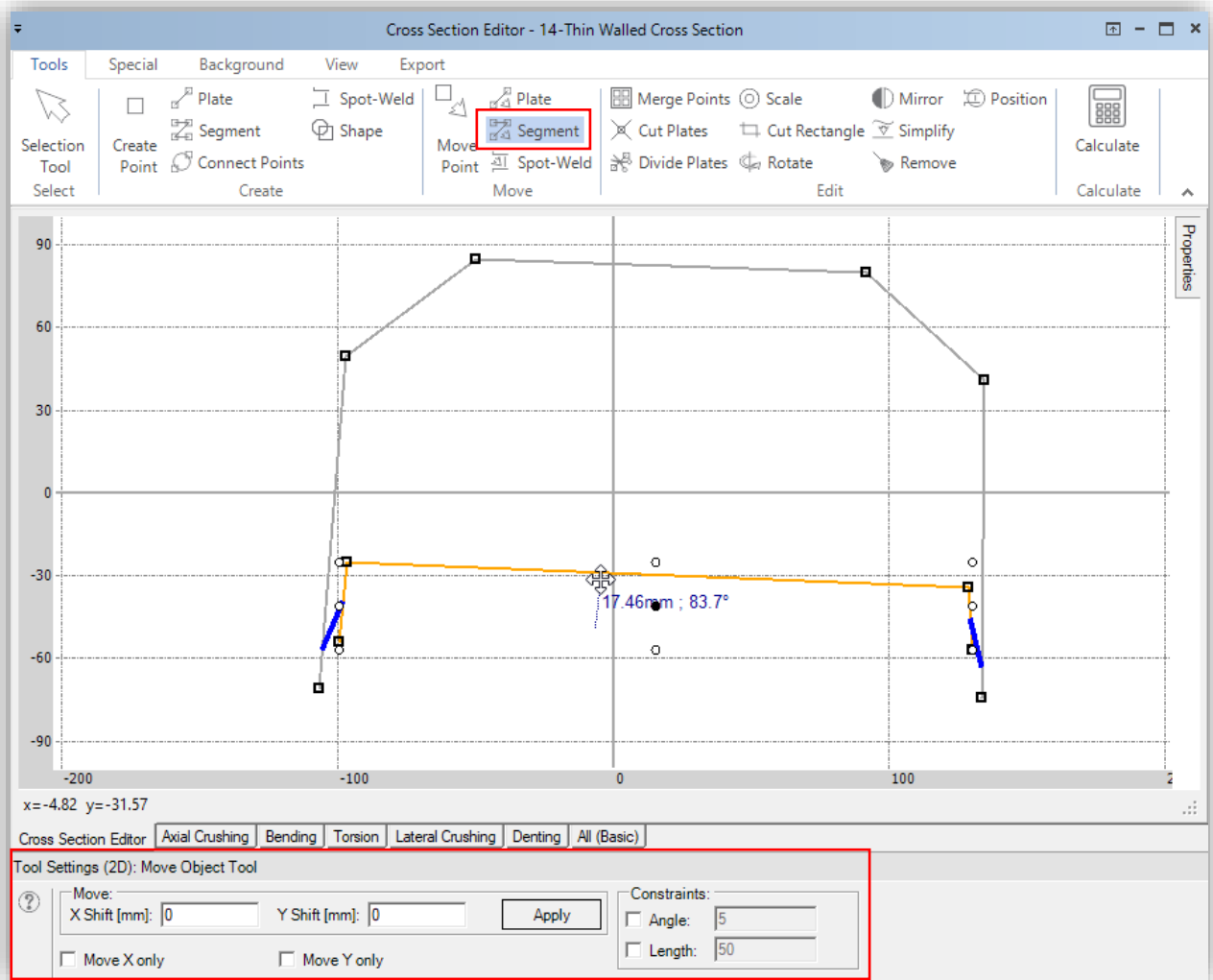


After defining constraints of the angle step and/or length the auxiliary line and information about constrained length and rounded angle values are mark in green color as presented on the picture below.
 * The values resulting from the mouse position is highlighted in gray color.

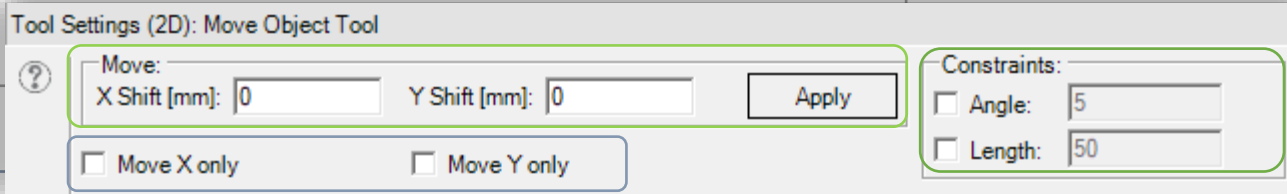


"Move Segment" tool

Every Cross Section can be modified at any time.
The „Move Segment“ tool enables the user to move any selected Segment of the Cross Section in the Editor's 2D view ("click and drag" tool).



You can also change the position of each Cross Section's Segment by entering its shift coordinates in Tool Settings window.



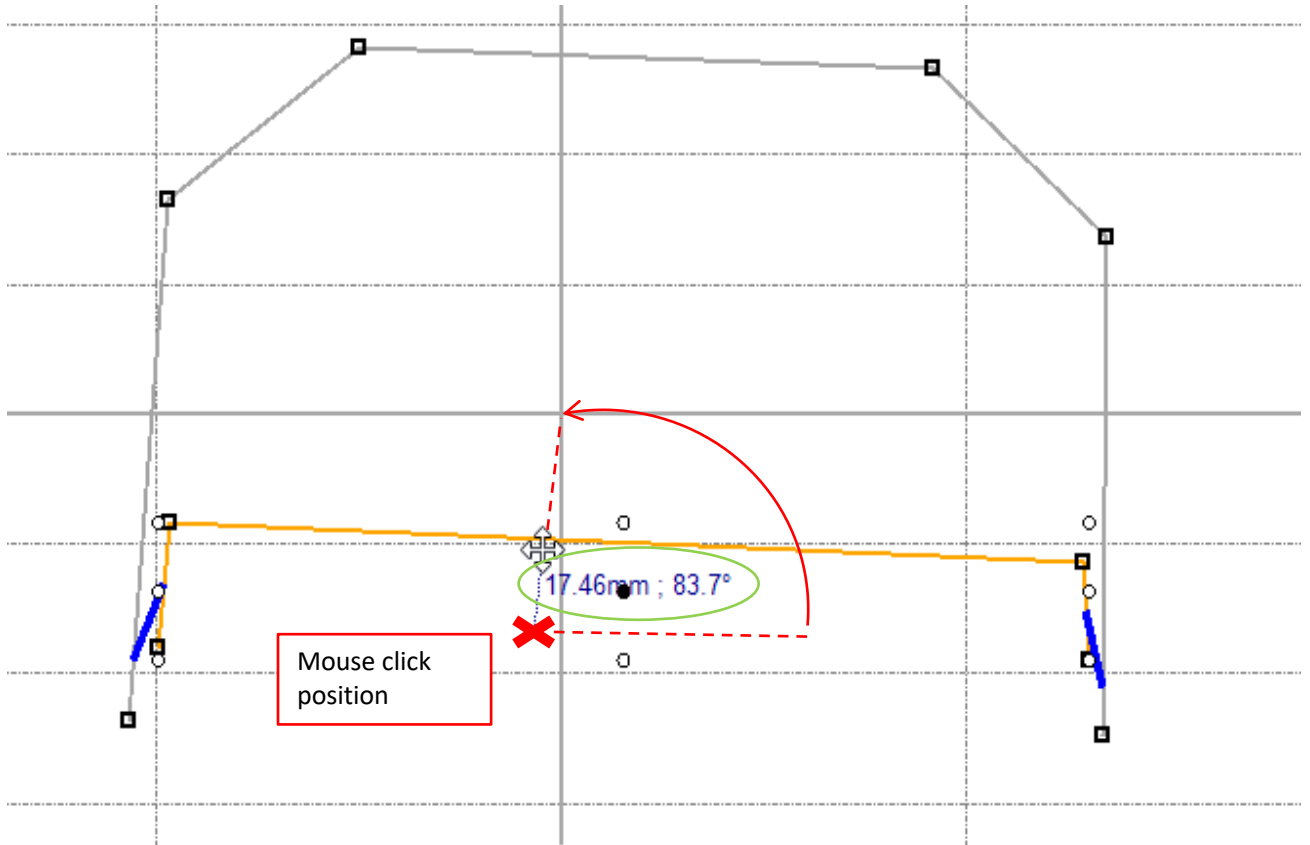
You can restrict the element's movement to one axis of the Cross Section Editor window ("Move X only" or "Move Y only" option).

You can change the position of segment with constraints angle step and/or length from the reference location of the segment.

"Move Segment" tool

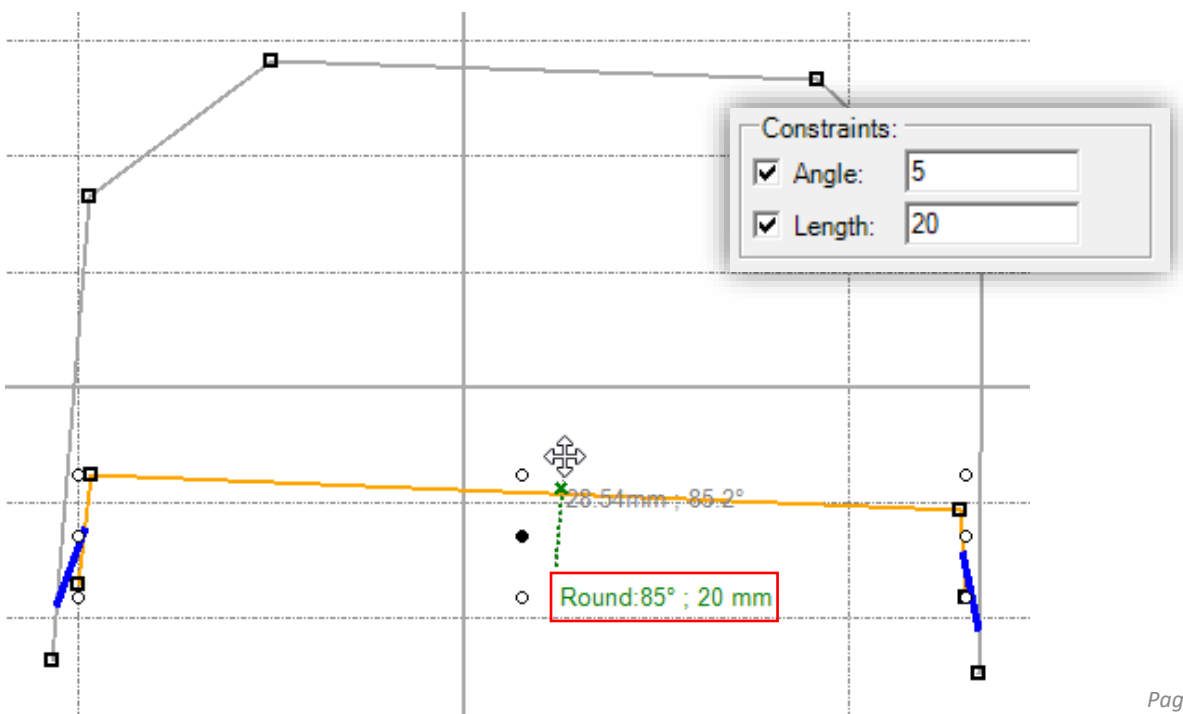
After dragging the Plate, the auxiliary line with the information about the length and angle from mouse click position is displayed as shown on the picture below.

* The angle value is measured with respect to the horizontal position.



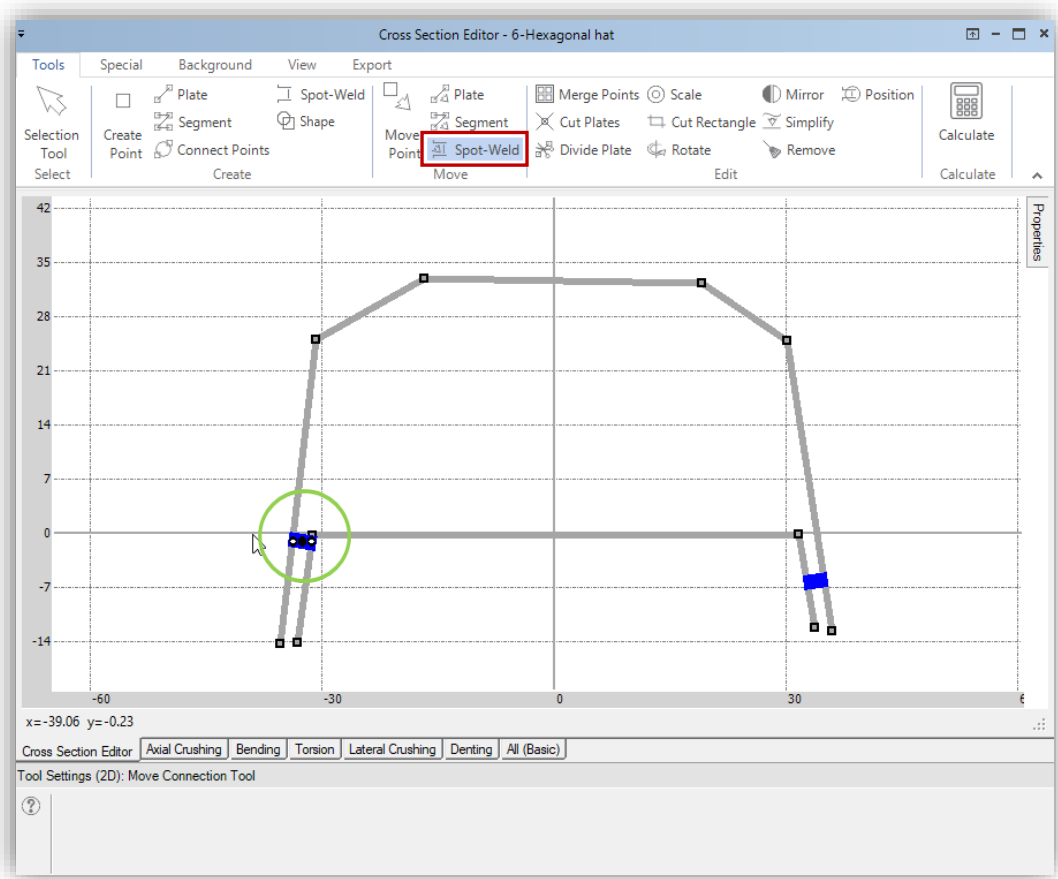
After defining constraints of the angle step and/or length the auxiliary line and information about constrained length and rounded angle values are mark in green color as presented on the picture below.

* The values resulting from the mouse position is highlighted in gray color.



Every Cross Section can be modified at any time.

The „Move Spot-Weld“ tool enables the user to move any selected connection between segments of the Cross Section in the Editor's 2D view ("click and drag" tool).



Please note that a Spot-Weld connection can be moved only along its master and slave plates

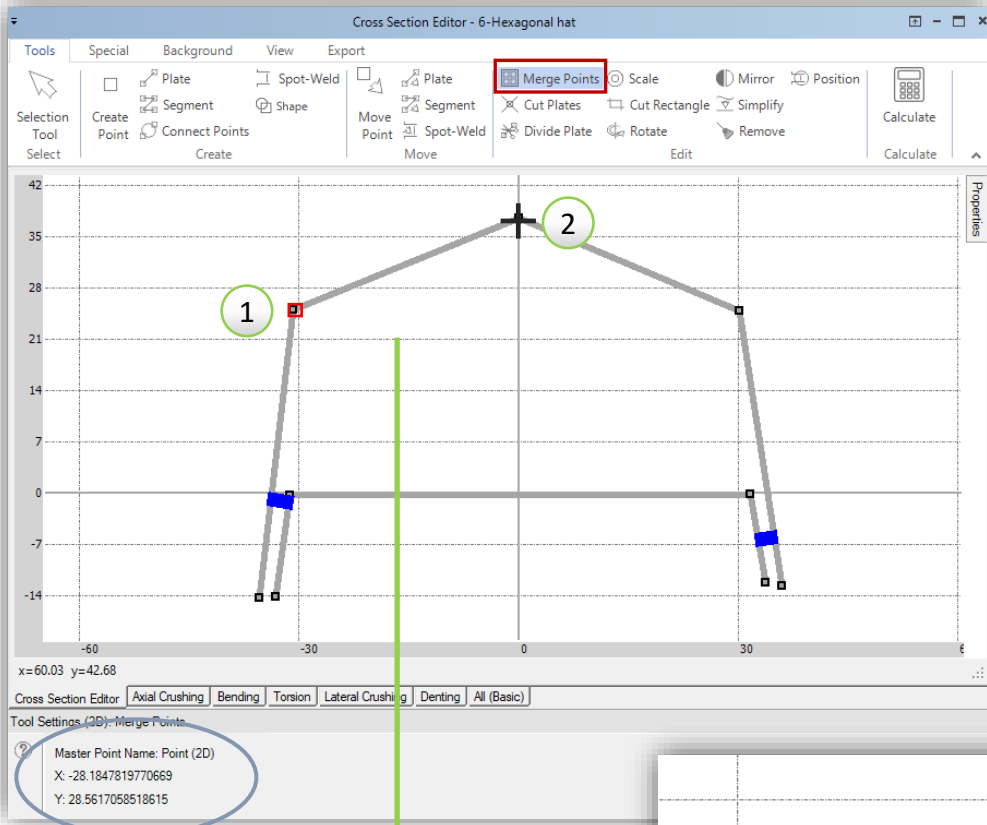


"Merge Points" tool

After selecting the Merge Points tool click on the Points to be merged.

The first selected Point will be the "master" point.
The second Point will be the "slave" point

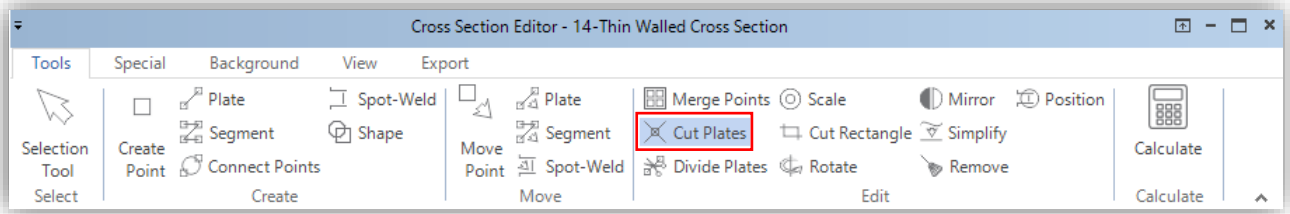
Notice that the second Point will be "moved" to the position of the first Point.



The information about Name and position of indicated Master Point can be found in the Tool Settings window.

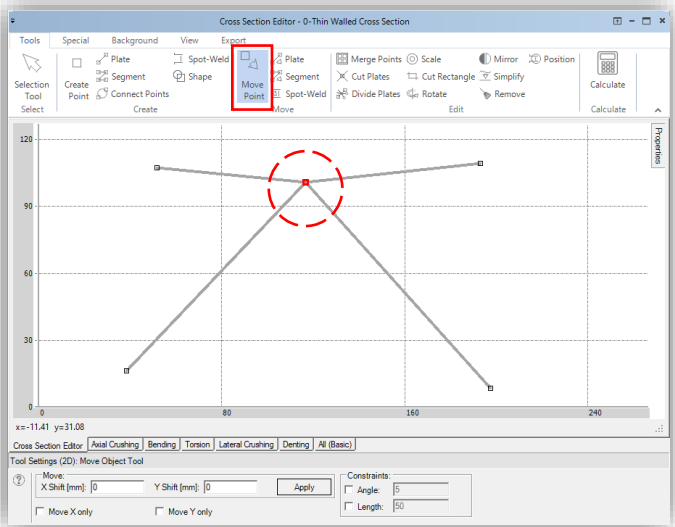
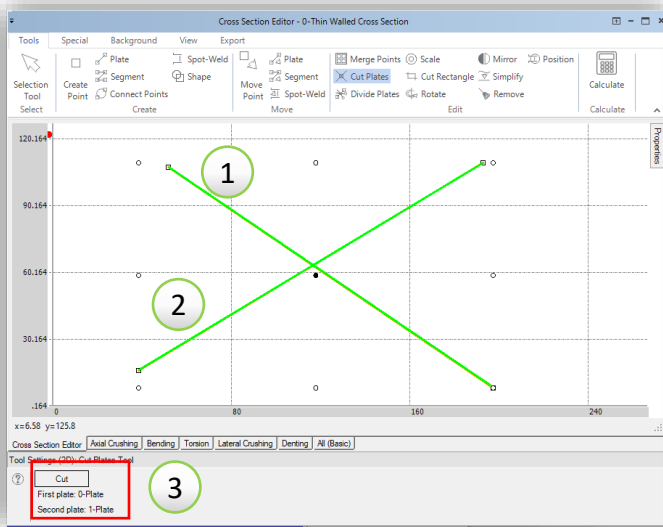


In the Cross Section Editor the user has the possibility to cut two Plates of an existing Cross Section.

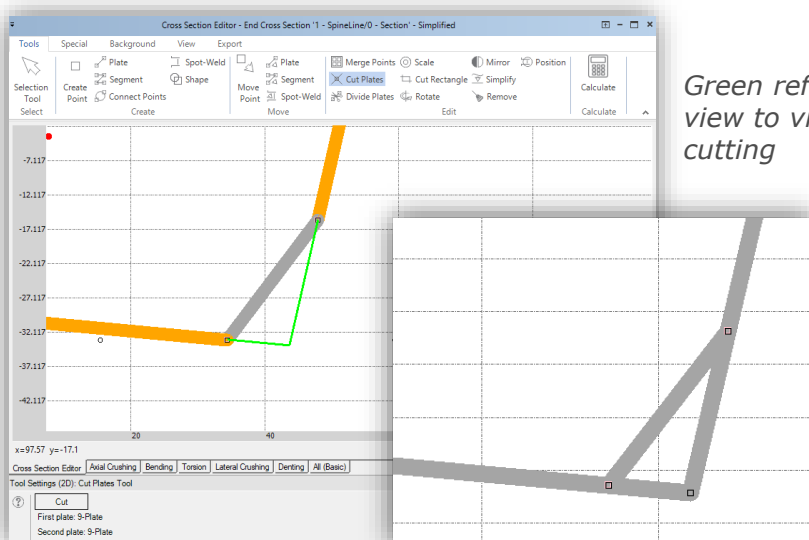


If you will select two intersecting Plates, you will receive as a result of the Cut Plate operation four new Plates, as it is illustrated in the pictures below. All four Plates will share a common Point, which will be positioned in the location of the intersection of initial Plates.

Use CTRL button from keyboard to select two Plates at once and confirm by Cut button to cut plates.



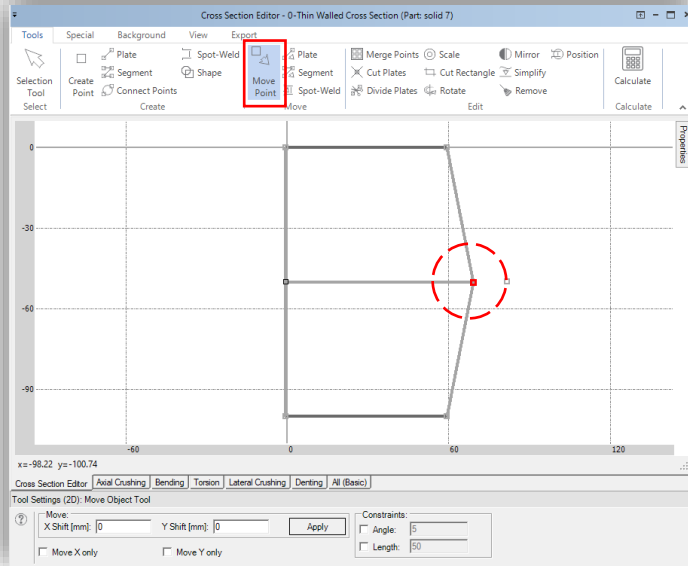
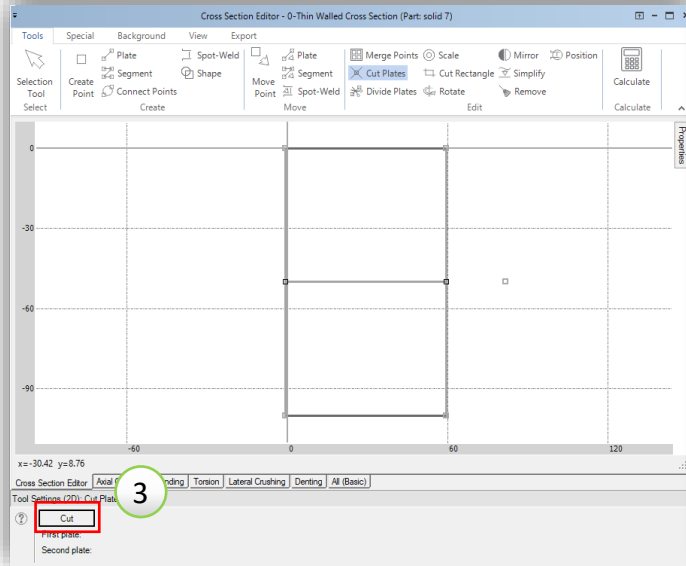
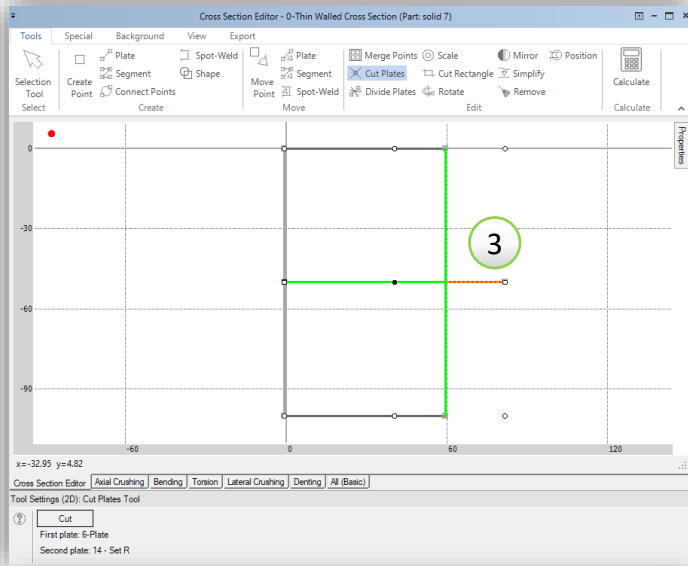
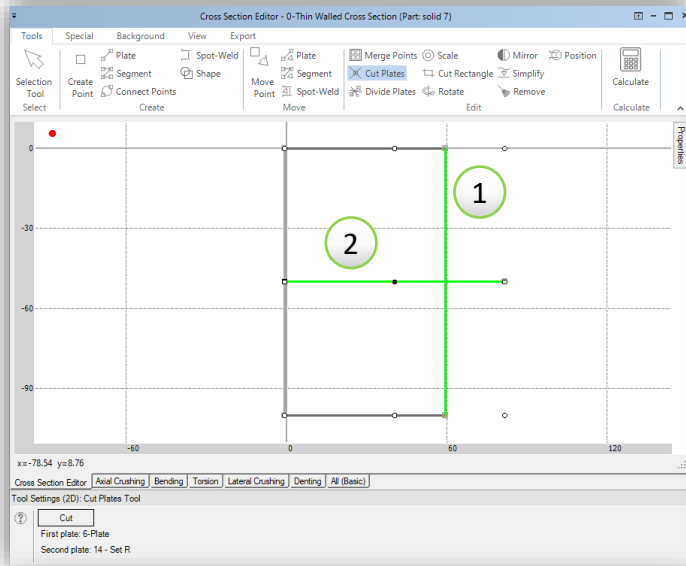
In case when two selected plates do not intersect, you will receive two new Plates as an outcome of the Cut Plate operation. In this case however two new Plates will be lengthened up to the point of their intersection. As a result, the two newly created Plates will share one common Point, as it is illustrated in the pictures below.



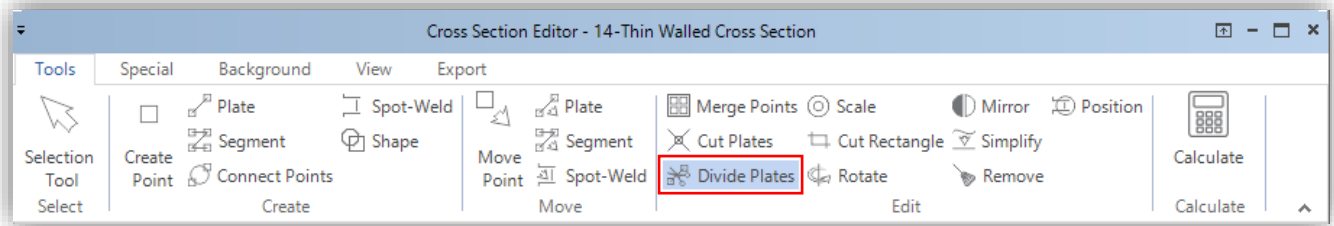
Green reference lines are displayed in the 2D view to visualize the future Plates after cutting

Any unnecessary Points and Plates that remain should be removed.

In the Cut Plates tool there is also possibility to delete plate directly during cutting action. In this case, select with CTRL button two Plates to be cutted and than click on the Plates that should be deleted during cutting. Plates to be removed are marked with a red dotted line.



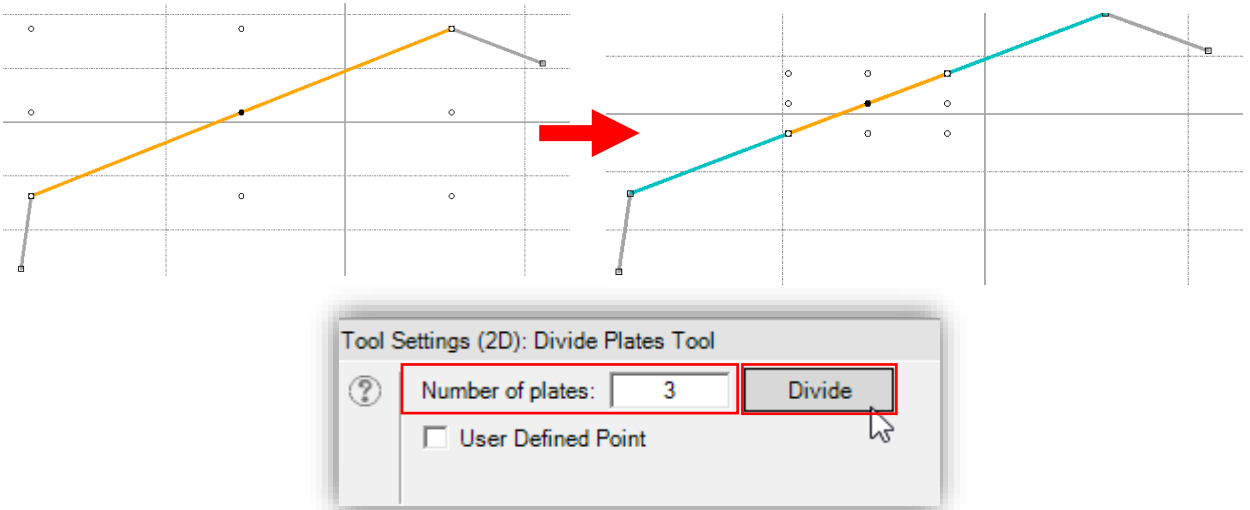
The user can divide the selected Plate into the requested number of equal Plates or into two Plates with the indicated location of a new Point to be created.



To divide plate into requested number of plates, enter the number of plates to division, click on the Plate to be divided. The selected Plate will be marked by orange color and a black dot as it illustrated in the below. Confirm by **Divide** button to make division.

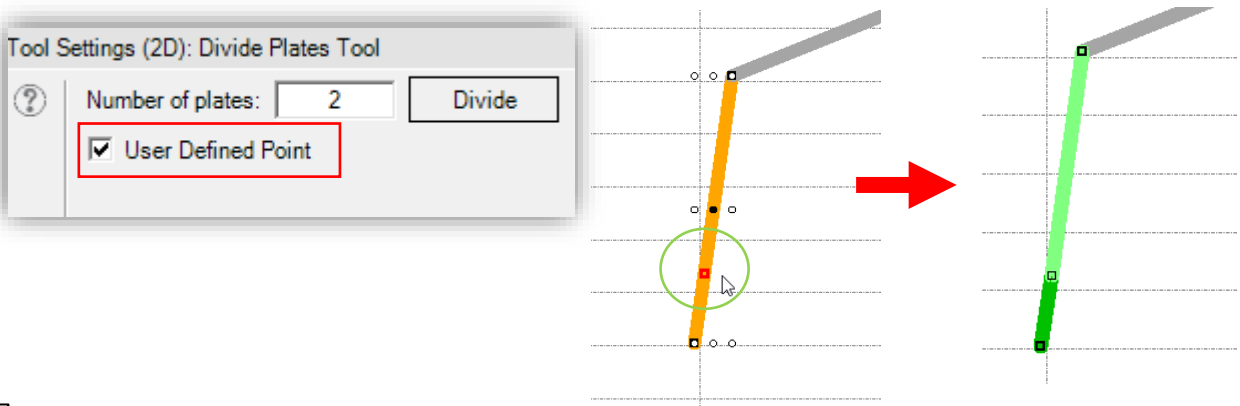
USEFUL TIP

The multiple number of Plates can be divided at once by selecting the plates with the CTRL button on the keyboard.



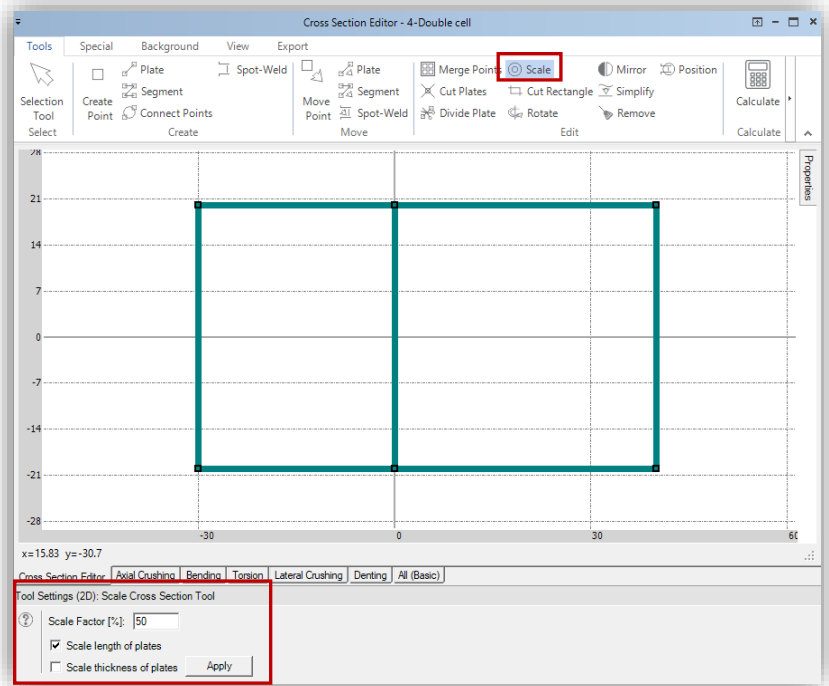
Click on the "User Defined Point" check box to divide Plate into two plates in user indicated position.

Select Plate to be divided. Red point follows the cursor along the selected Plate line and shows the division position. Mouse click lead to division selected Plate into two plates as indicated.



"Scale Cross Section" tool

"Scale Cross Section" tool allows you to modify the size of cross section.



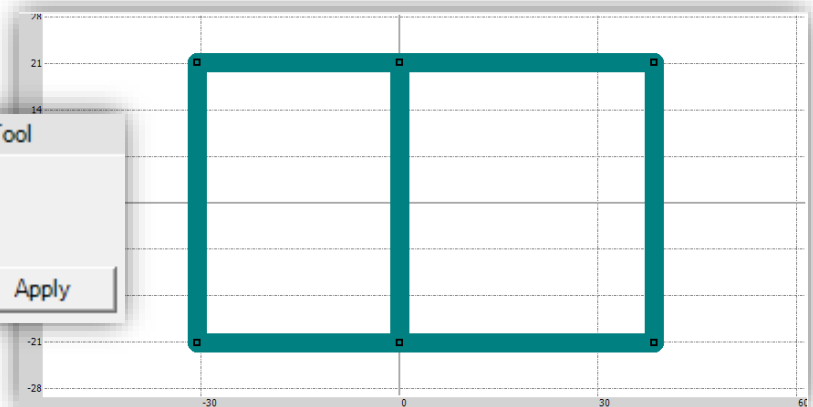
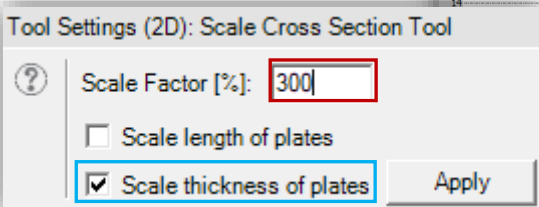
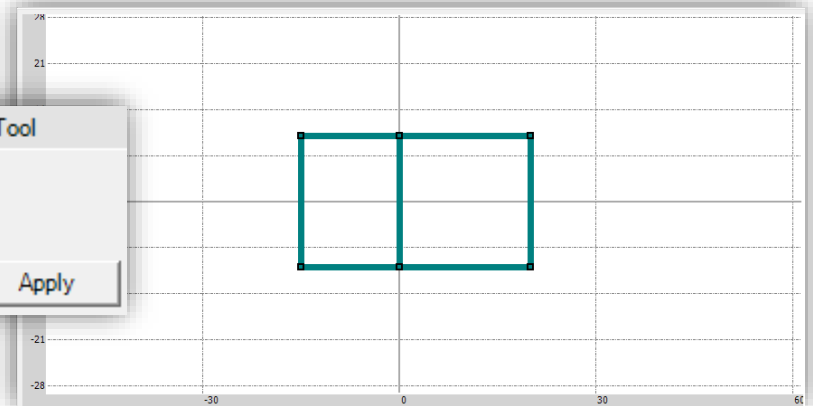
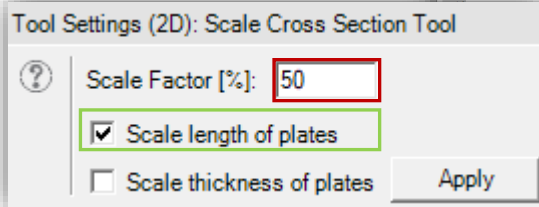
Scale Factor [%]:

The text box is used to define percentage size change of selected parameters. Actual size is multiplied by the factor.

Toggle Parameters to size:

Each check box allows to select exclusively one scale parameter type.

- **Scale length of plates** changes coordinates of cross-sectional points.
- **Scale thickness of plates** changes the thickness of all plates

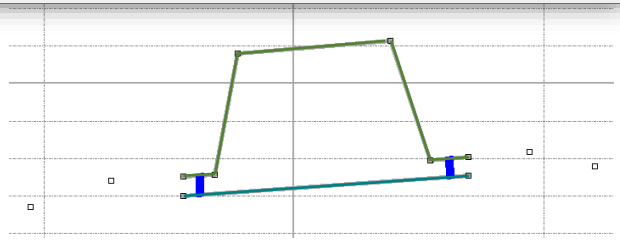
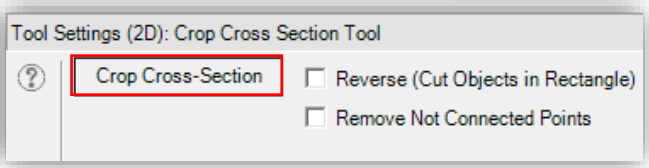
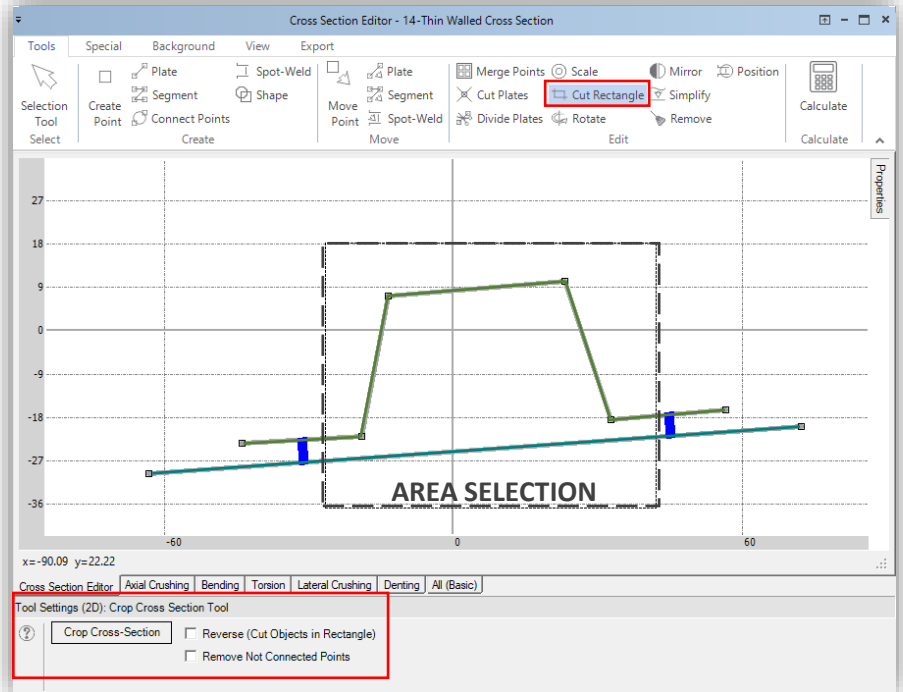


The „**Cut Rectangular**“ tool enables to cut any number of Plates of an existing Cross Section. The Cross Section is crop using a rectangular area.

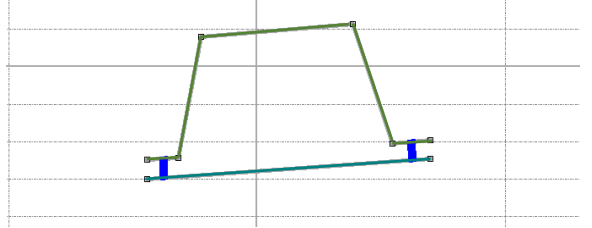
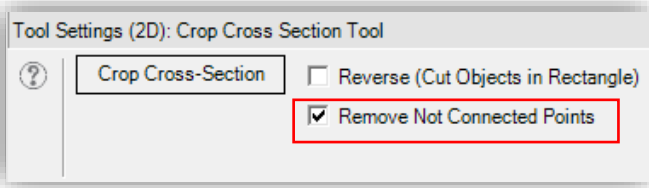
After selecting the "**Cut Rectangle**" tool you need to select the area. All parts of the Cross Section that are outside the rectangle area will be cropped and removed.

If the "**Reverse (Cut Objects in Rectangle)**" checkbox is selected, then the objects inside the rectangle will be removed.

Choose the "**Crop Cross Section**" button to confirm changes.

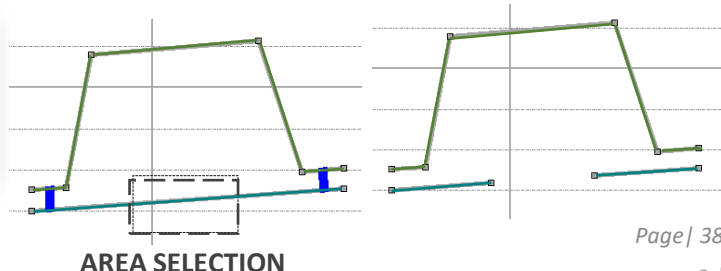
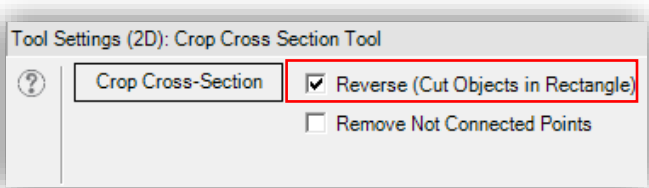


Click on the "**Remove Not Connected Points**" check box to automatically delete all Points which are not assigned to any Plate of a Cross Section after cutting operation.



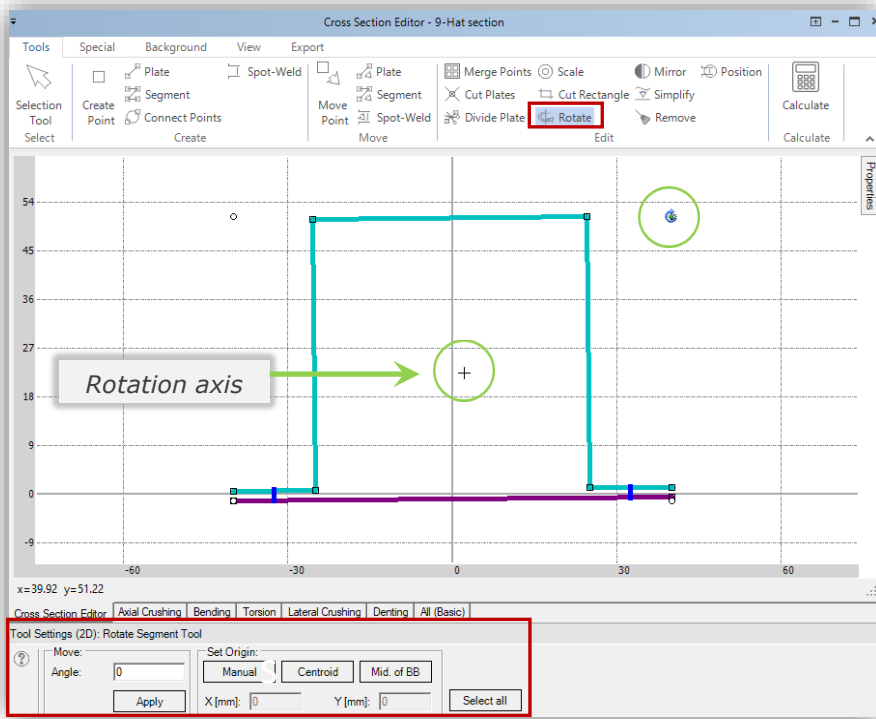
Click on the "**Reverse (Cut Objects in Rectangle)**" checkbox and to remove objects inside the rectangle.

Note that in case of reverse cut all existing connections (Spot-Welds) will be deleted.



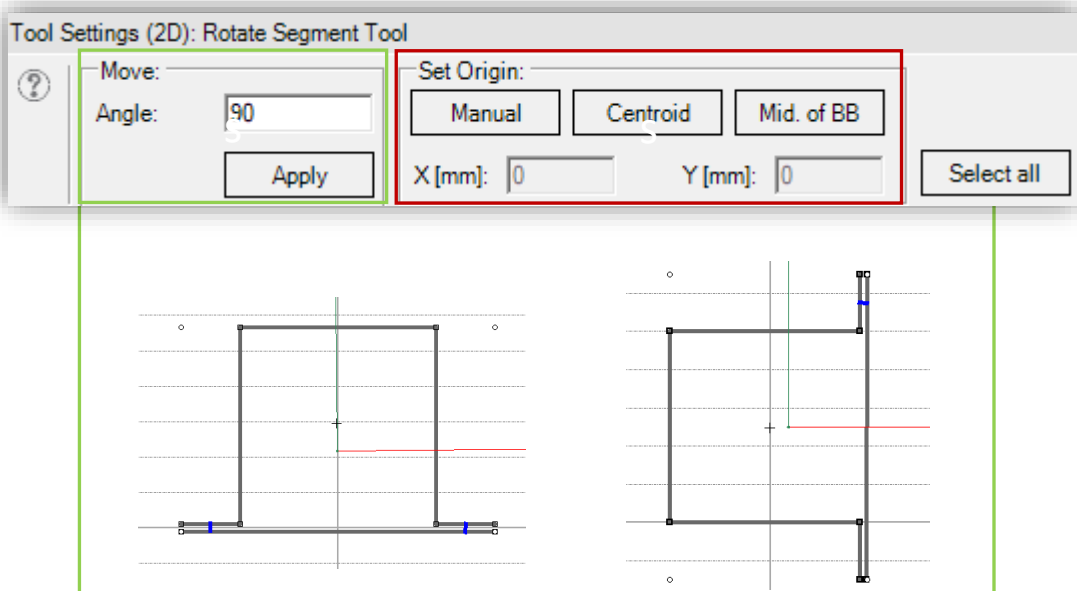
Every Segment of a Cross Section can be rotated.
In order to rotate an element of a Cross Section:

- 1) Select a Segment (or number of Segments) to be rotated; use the „**Select all**“ button in the tool settings window to select all segments of a cross section
- 2) Click on the **Rotate** tool
- 3) Drag around one of corners of bounding rectangle to rotate selected segments or set the precise rotation angle in the tool settings window

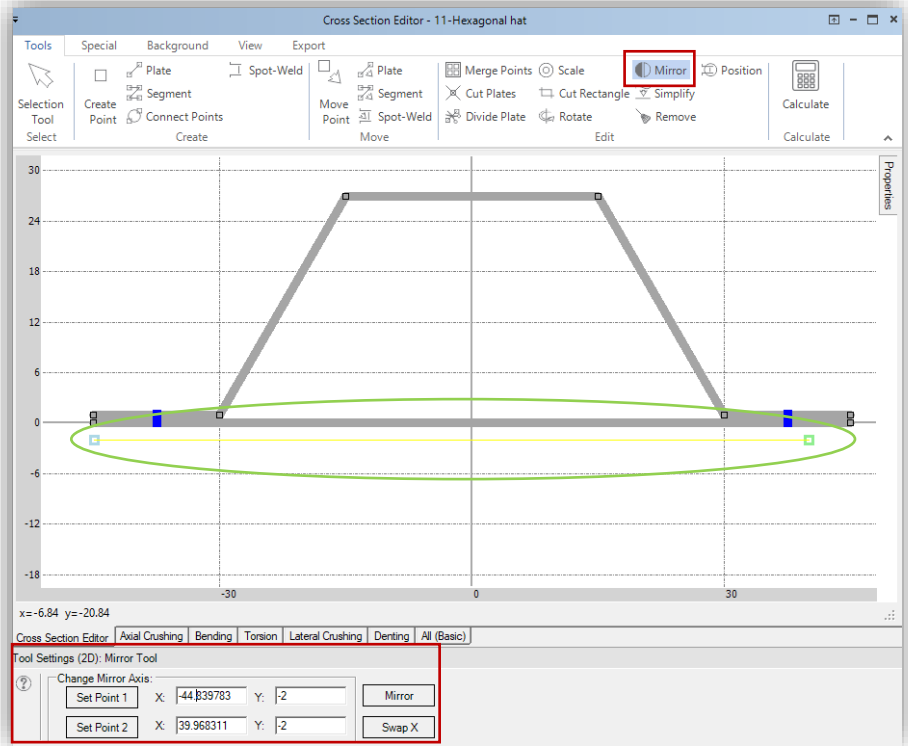


You can define the **rotation axis** in the Tool Settings window in the "Set Origin" section, by:

- entering its coordinates
- setting it manually
- setting it the cross section's centroid or middle of the bounding box (BB)



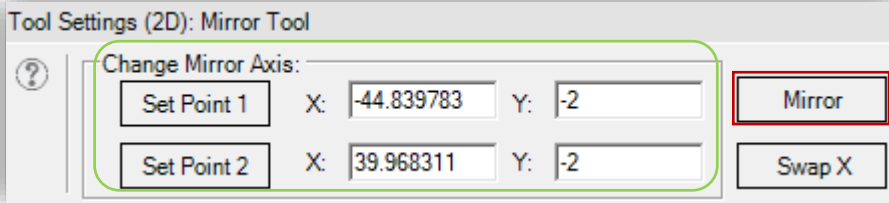
It is possible to mirror any selected element of a cross section with respect to the users defined axis.



After selecting the "Mirror" tool you need to define the mirror axis.

The mirror axis is defined by two points created in the 2D view.

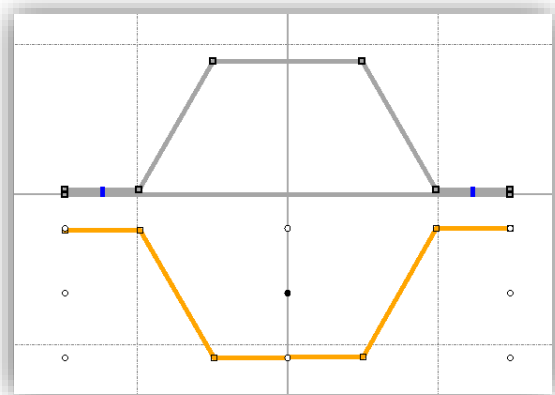
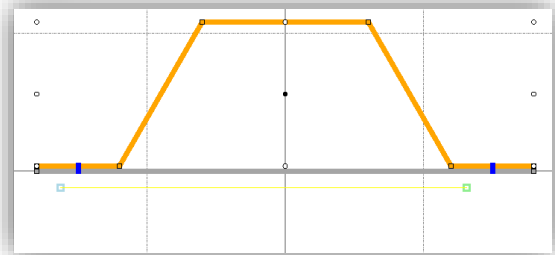
Coordinates of those point can be defined and changed in the Tool Settings window



Afterwards select the element of a cross section to be mirrored.

Note that the selected object will be marked by orange color in the 2D view.

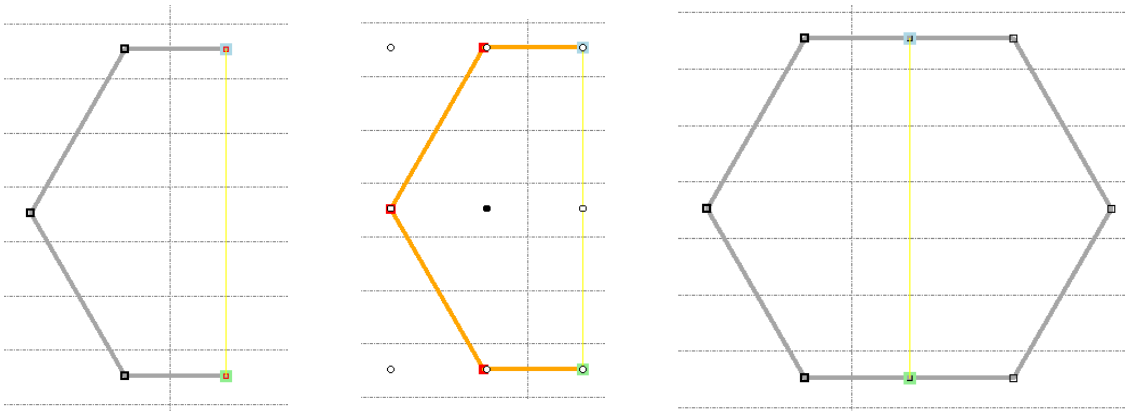
After clicking on the "Mirror" button in the Tool Settings window the selected element will be mirrored with respect to the previously defined axis



"Mirror" tool

USEFUL TIP

Currently existing cross-section Points can be used as points of mirror axis.

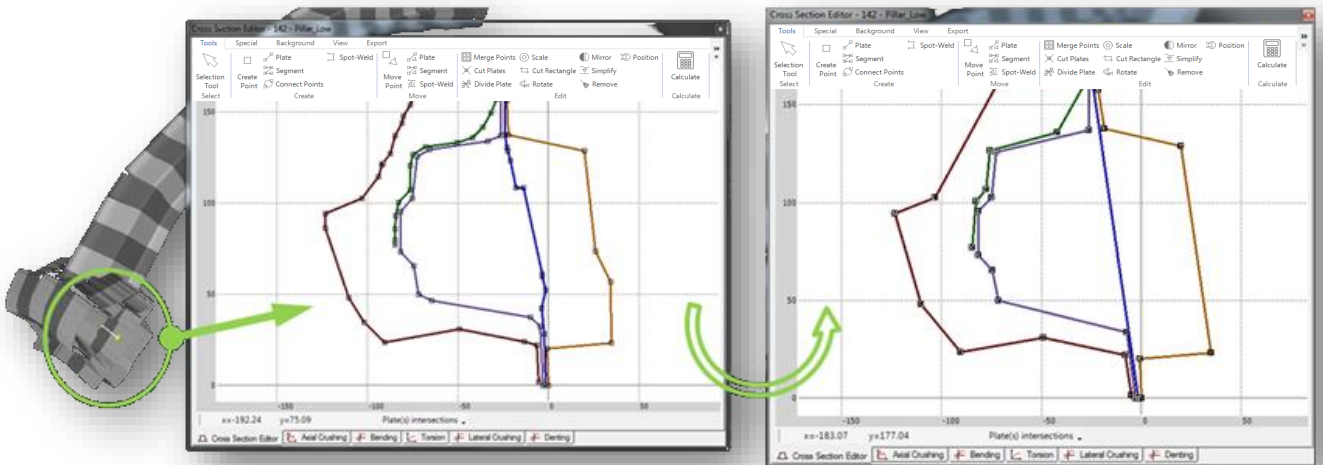


Important notice

Note that the points of mirror axis selected to mirror action, will be duplicated and need to be merged to achieve single Segment.

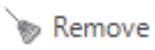
"Simplify" tool

The "Simplify" tool provides the possibility of automatic simplification of a cross sectional geometry with respect to Macro Element Method requirements.



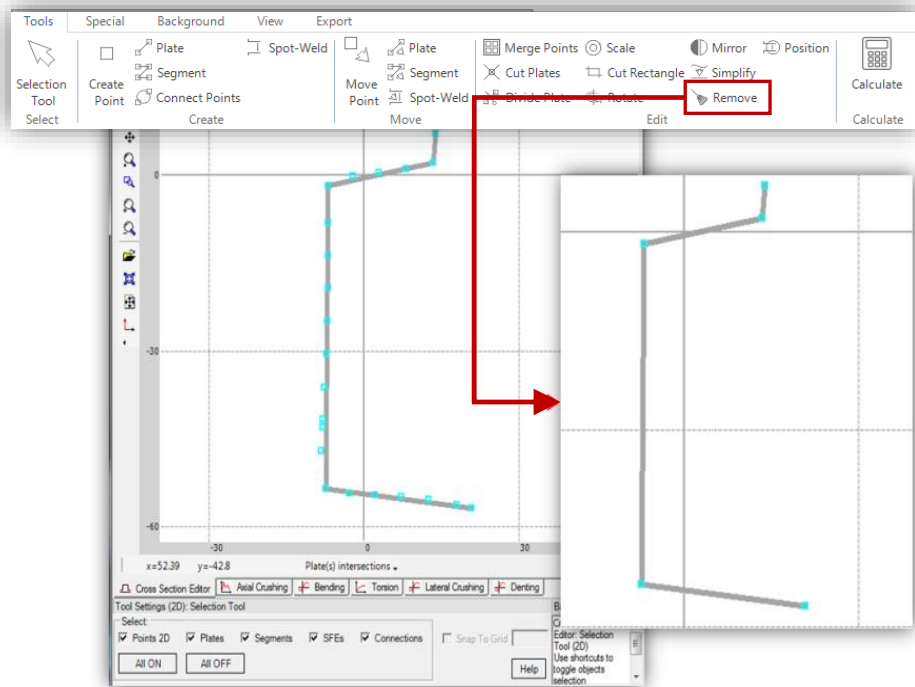
The tool is especially useful in case of cross sections of an imported FE model.

(* Please note that the optimized model represents the "best fit" to the expected final shape of the cross section calculated following the Macro Element Method rules. In case of more complex Cross Sections the user interaction is necessary to complete the cross section according to the VCS discretization requirements.



"Remove Not Connected Points" tool

The tool "Remove Not Connected Points" enables the user to automatically delete all Points present in the Cross Section Editor which are not assigned to any Plate of a cross section.



This functionality is especially useful when working on a cross section created from a FE part, where simplification of the geometry was made.

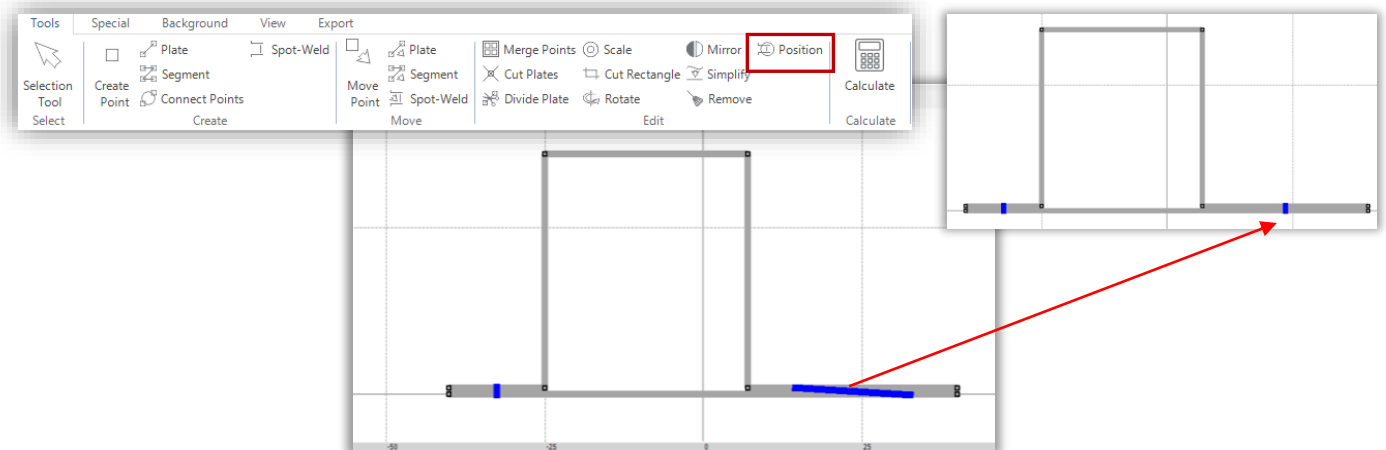
In order to delete all unneeded Point simply click on the "Remove Not Connected Points" icon available in the Cross Section Editor's main toolbar.



"Optimize Spotwelds Position" tool

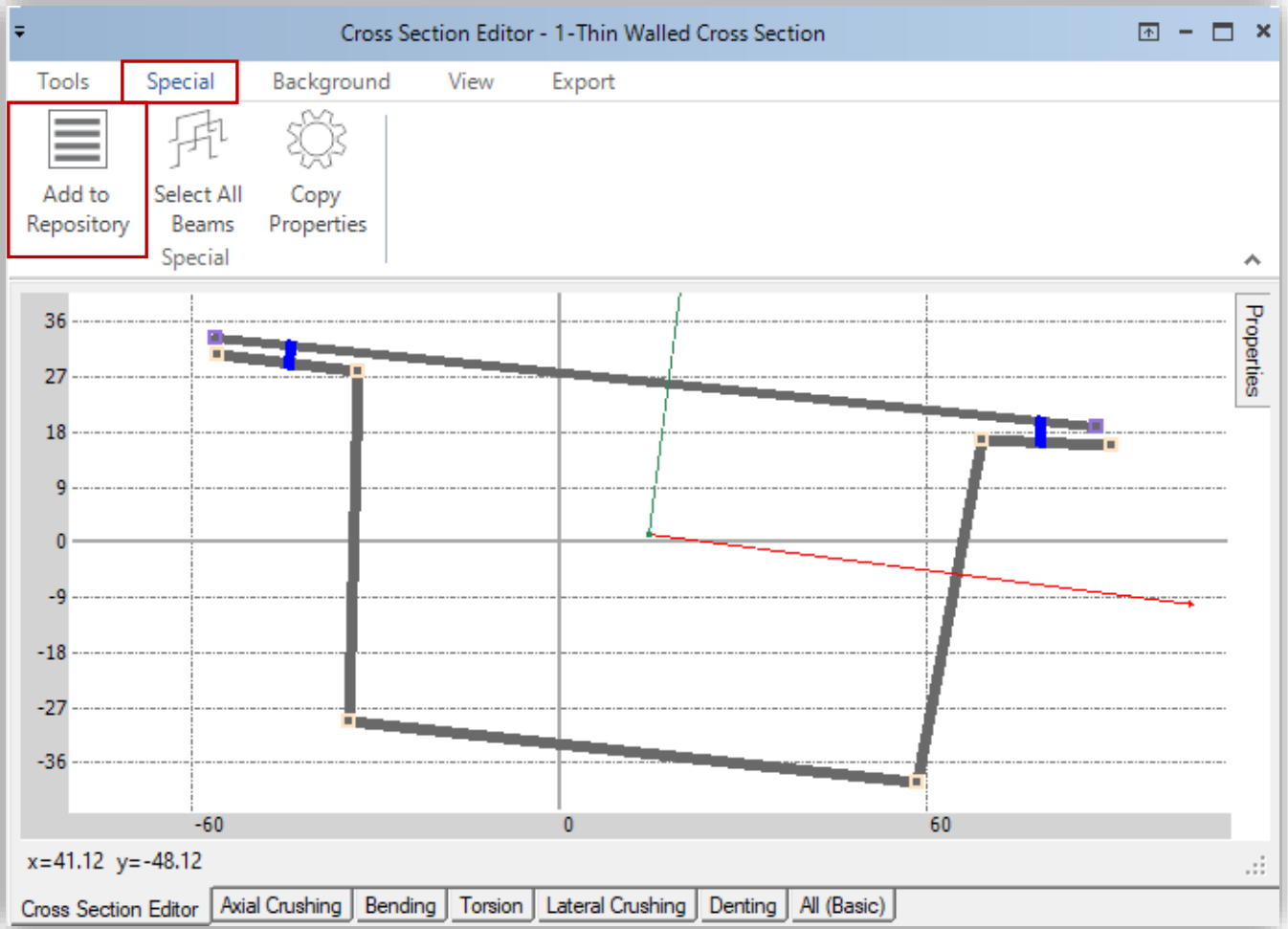
The "Optimize Flat Elements" tool provides the possibility of automatic correction of a connection position.

Modification of the Plate position causes simultaneously the change of the Spotweld position. Select „Optimize Spotwelds Position" to place them in the right place with just one click.



"Add to Repository" tool

In VCS there is a possibility to add a Cross Section's geometry to the local Repository.

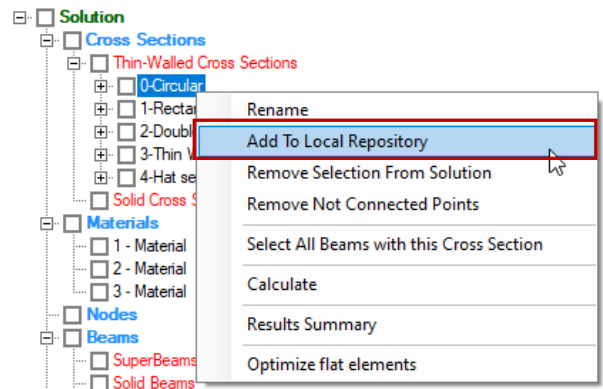


It is possible to create a personal archive of Cross Sections which can be opened and used whenever working on a new Solution.

In order to place a cross section in the Repository click on the "Add to Local Repository" icon available in the main toolbar of the Cross Section Editor ("Special" section).

Alternatively, you can select one or several cross sections in the Solution Explorer tree. Right click and choose the "Add to Local Repository" option.

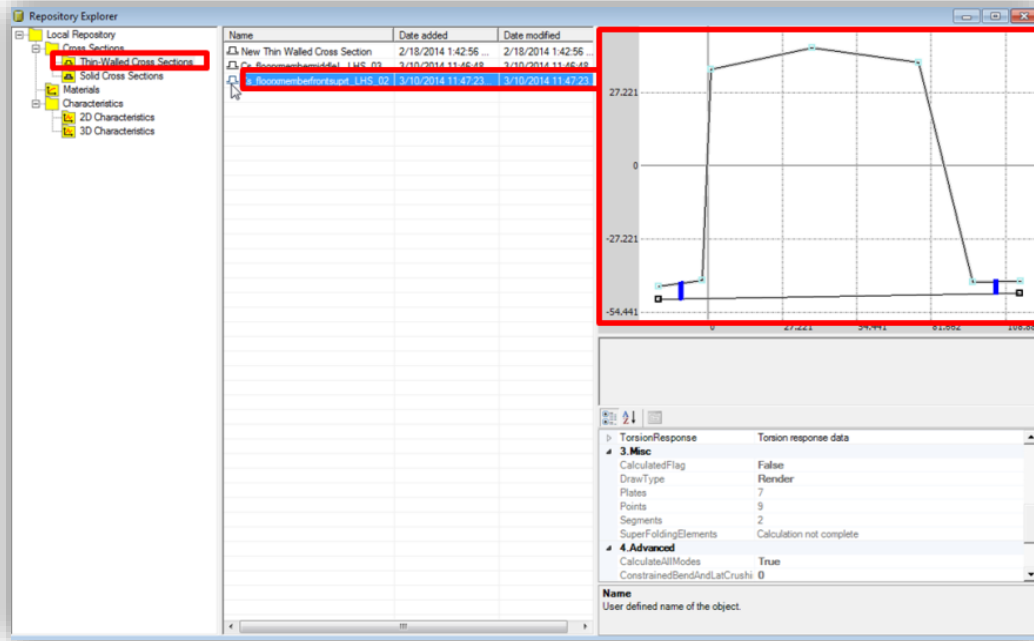
You can organize the saved Cross Sections by ascribing them to a selected folder (listed on the left side of the "Repository Explorer" window). You can also create new folders, transfer or copy objects from one folder to another and so on.





"Add to Repository" tool

This will enable you to create a personal, easy to use library of Cross Sections. In order to create or delete a folder right-click on one of the folders on the left column of Repository Explorer. You may then select the "Add folder" tool to create a new folder or "Delete folder" tool.



In the middle of the "Repository Explorer" window you will find a list of Cross Sections together with the date of addition to the repository and the date of the latest modification. You may sort the Cross Sections by name (alphabetically) by clicking on the "name" button, by the date of addition (click on "Date added") or by the date of last modification (click on "Date modified").

On the right-hand side of the Repository Explorer window the geometry of a selected Cross Section can be seen as well as a "read only" properties data.

In order to copy a Cross Section from the Solution into the Repository, left-click on the chosen Cross Section in the Solution Explorer window, and then right-click. After choosing the "Add to Local Repository" a window will appear, in which you may describe the selected Cross Section. The described Cross Section will be automatically added to the main folder in the Repository.

In order to import a Cross Section from the Repository into a Solution you need to right-click on the required Cross Section and choose the "Copy to current solution" option. The Cross Section will be automatically added to the Solution Explorer window.

All data gathered in the Repository Explorer will be automatically saved on your computer's drive in a separate folder. In order to find the Repository data, open the "Documents" folder, then find and open the "Visual Crash Studio" folder in which you will find the "Repository" folder with "repository.rvcs" file in it. You may easily copy the "repository.rvcs" file creating a backup of all of the Cross Sections (as well as Materials and Characteristics) gathered in the Repository Explorer.

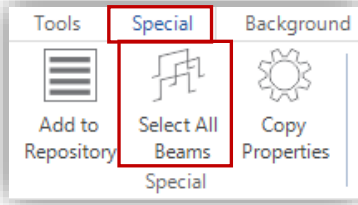
Note that it is also possible to create a personal "library" of Materials and Characteristics used in VCS Solutions. The detailed description of the Material and Characteristic part of the VCS Repository can be found in the Material Editor chapter of the VCS manual.





Select All Beams

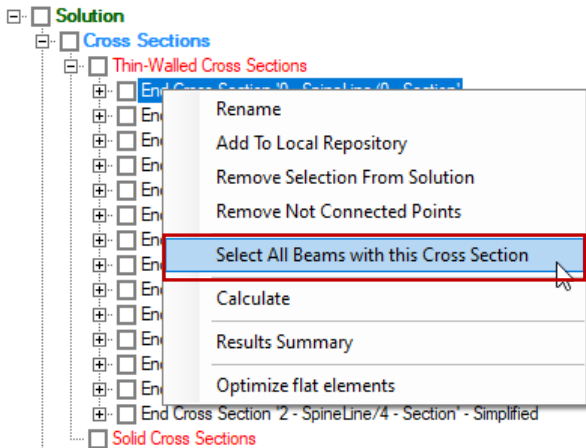
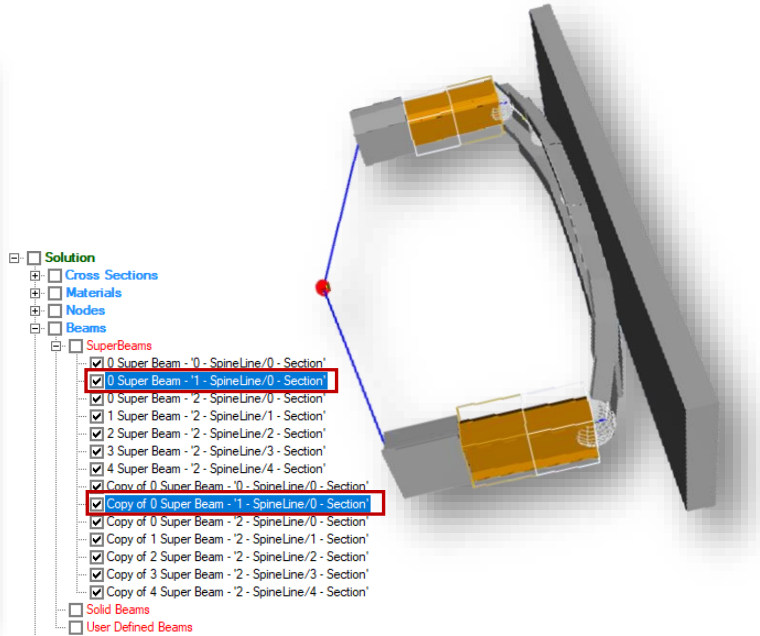
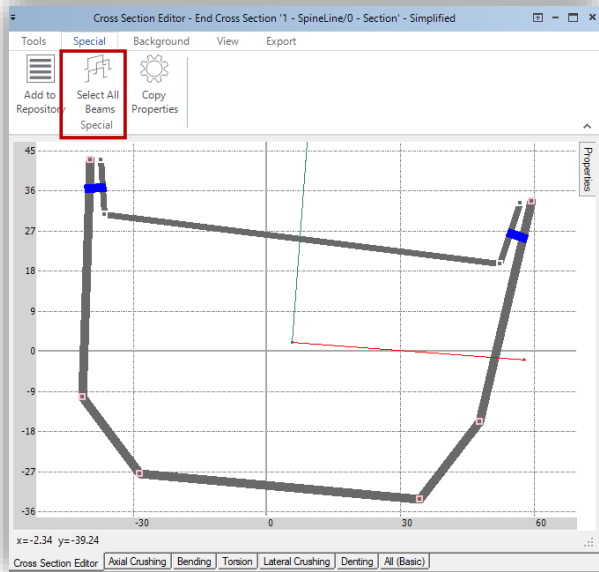
"Select All Beams" tool



The Cross Section Editor enables the User to automatically detect and mark all beams present in the VCS Solution which are defined by the currently opened cross section.

In the Cross Section Editor, in the "Special" section, you can find the "Select All Beams" icon.

All Beams defined with the use of this cross section will be automatically marked in the Solution Explorer window and in the 3D view.



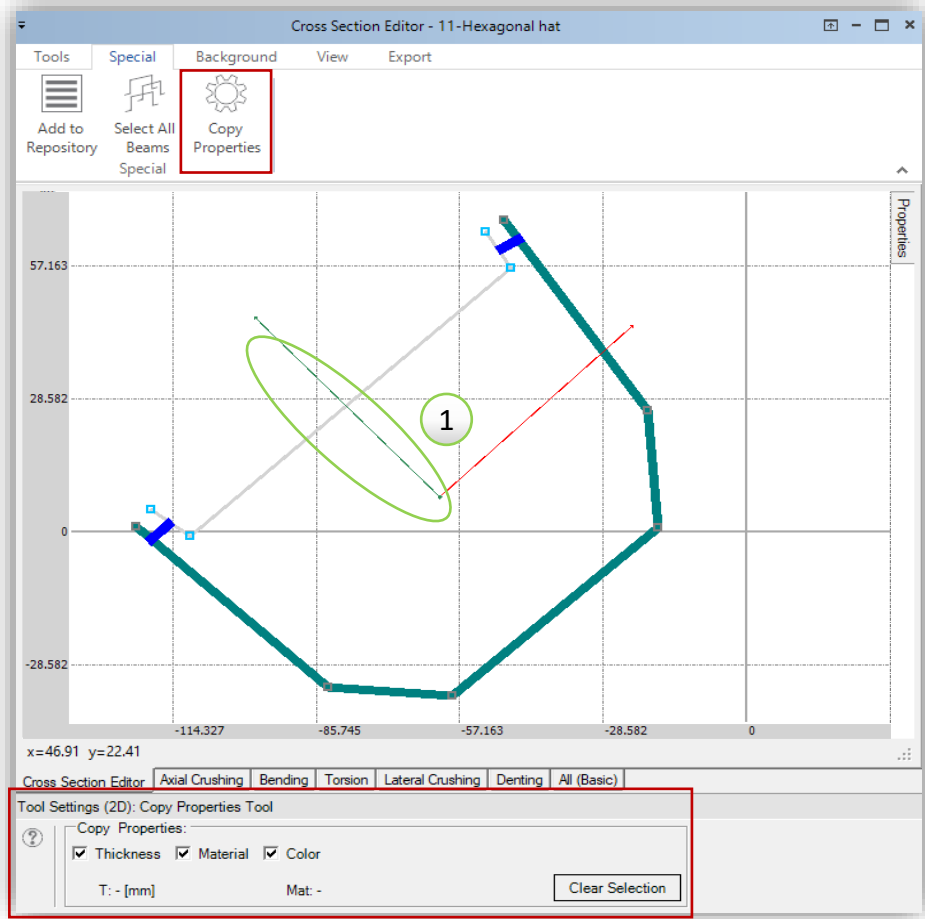
Alternatively, select the required cross section in the Solution Explorer window and right click.

From the drop-down list choose the "Select All Beams with this Cross Section" option.

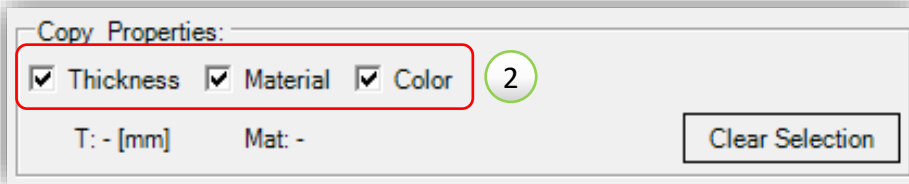


"Copy Properties" tool

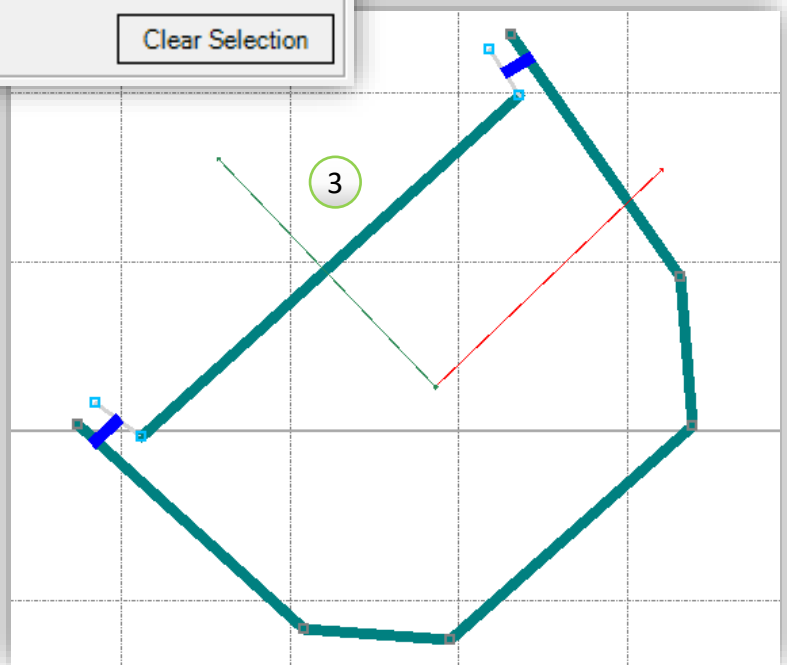
After selecting the Copy Properties tool choose the Plate from which you wish to copy properties.



Please note that in the Tool Settings window you can check which properties are to be copied. There is a possibility to copy plate's thickness, material and displayed color



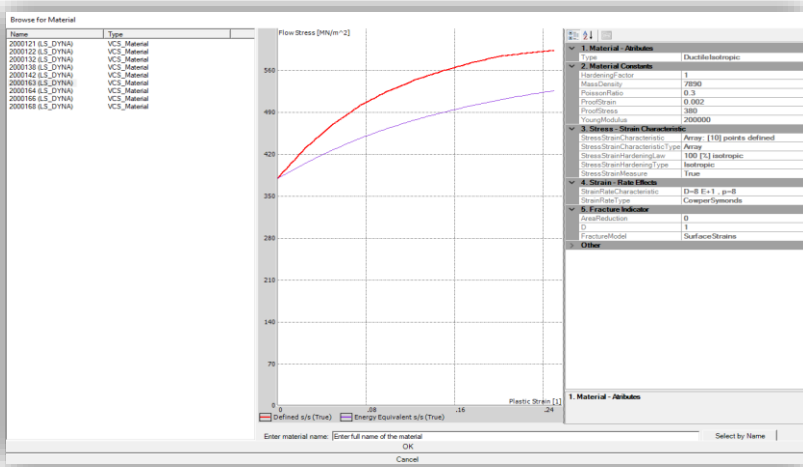
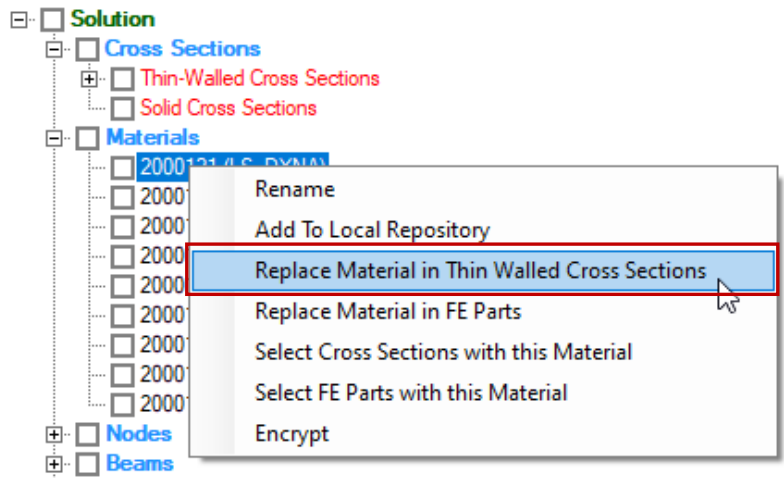
Afterwards click on the Plate to which you wish to copy properties. The result will be automatically displayed in the Cross Section Editor's view



REPLACE MATERIAL IN THIN-WALLED CROSS SECTIONS

The 'Replace Material in Thin-Walled Cross Sections' tool enables the user to replace one VCS Material assigned to Cross Sections with another.

After selecting (right click) a Material in the Solution Explorer window the "Replace Material in Thin-Walled Cross Sections" tool should be selected.



A new window 'Browse for Material' will be visible on the screen. In this window the user can select a previously defined Material by which the current Material is to be replaced.

This tool enables the user to quickly and easily replace a Material in all Cross Sections, Plates and Segments simultaneously.

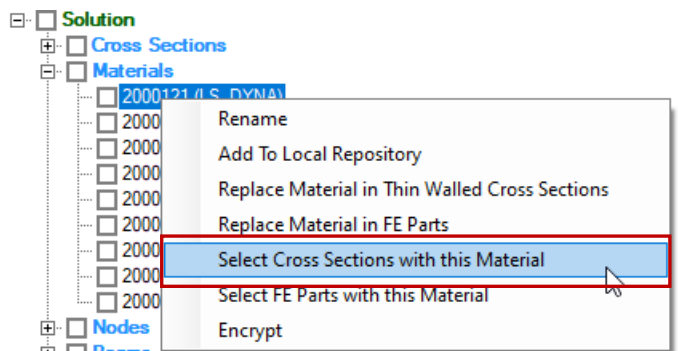
There is no need to look through all Cross Sections of the Solution. This saves time and reduces the probability of errors which could happen during such replacement procedure.

SELECT CROSS SECTIONS WITH A GIVEN MATERIAL

VCS provides the possibility to select all Cross Sections with a given Material assigned to them. This function enables the user to locate all Cross Sections which have a given Material without the necessity of time-consuming search.

In order to select all Cross Sections with the given Material right click on a chosen Material in the Solution Explorer window and select the **Select Cross Sections with this Material** option.

All Cross Sections having this Material assigned will be automatically marked in the Solution Explorer tree.



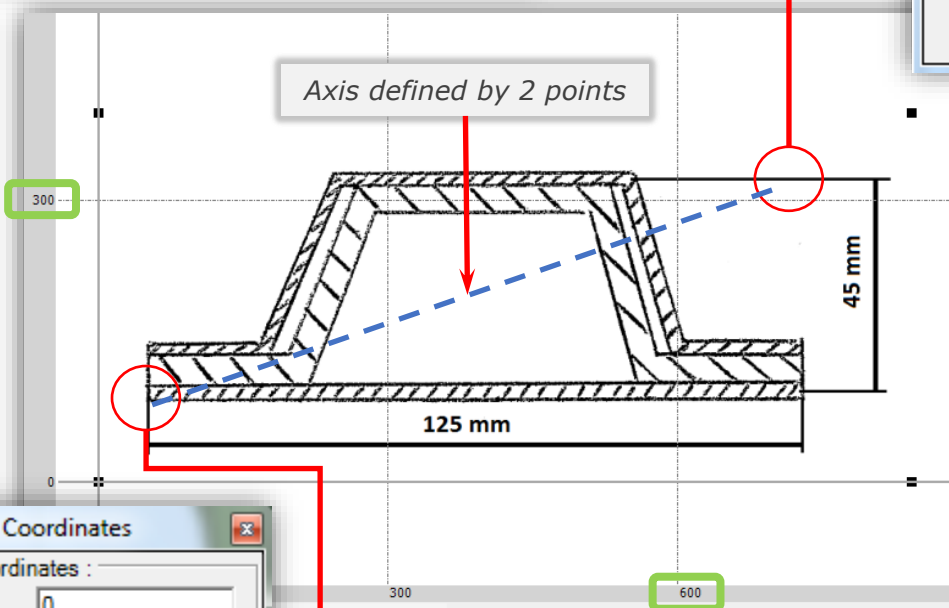
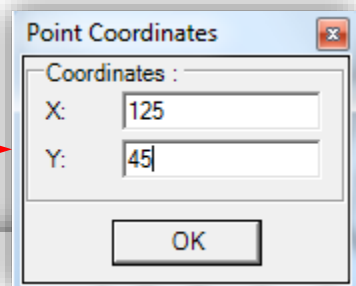
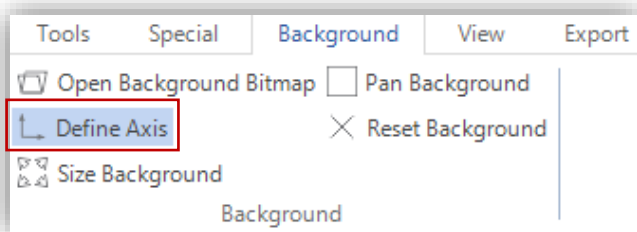
"Background" tools

Open Background Bitmap

With the usage of the **"Open Background Bitmap"** tool you can set any bitmap in the background of the Cross Section Creator to serve as reference for creation of a cross section model

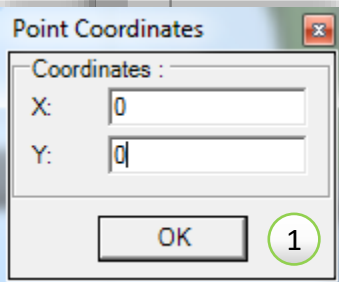
Define Axis

The **"Define Axis"** tool enables the user to scale the uploaded background bitmap by entering the coordinates of two points defining the diagonal line of the bitmap's bounding box.



Click in the second location in the 2D view.

Define coordinates of the second point of the axis.



Click in the 2D view. Define coordinates of the first point of the axis.

After definition of the axis the background bitmap will be automatically scaled with respect to the axis coordinates.

Please note that in the given example the bounding box of background bitmap is set to the dimensions corresponding to the coordinates of axis points.

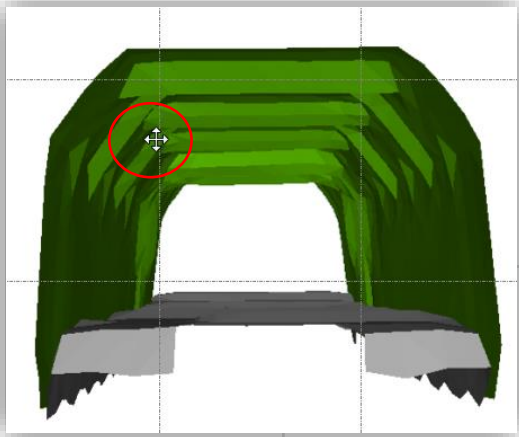
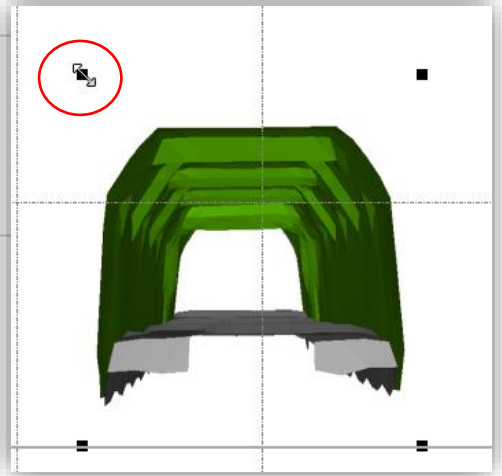


"Background" tool



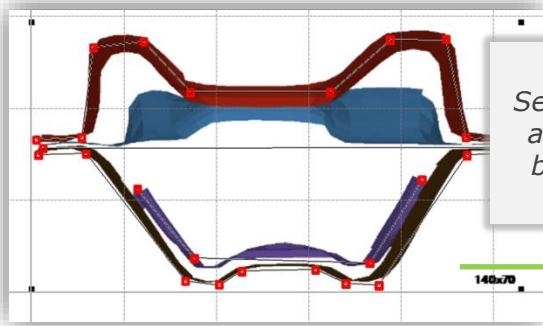
Size Background

The "**Size Background**" is a simple click and drag tool for setting the required dimensions of the background bitmap.

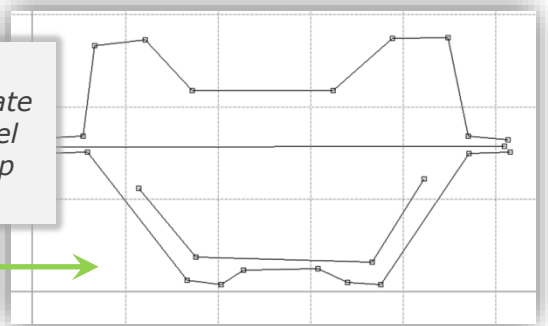


Pan Background

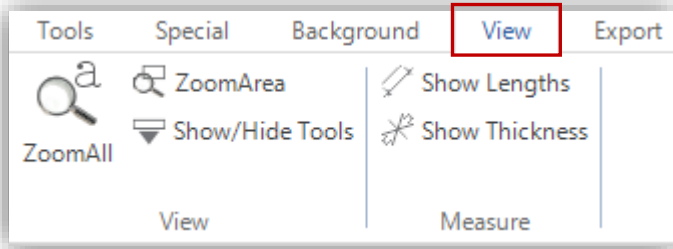
The "**Pan Background**" tool enables the user to move the bitmap background within the Cross Section Editor window.



Use the "Create Segment" tool to create a simplified ME model basing on the bitmap background



CROSS SECTION EDITOR – VIEW TOOLS

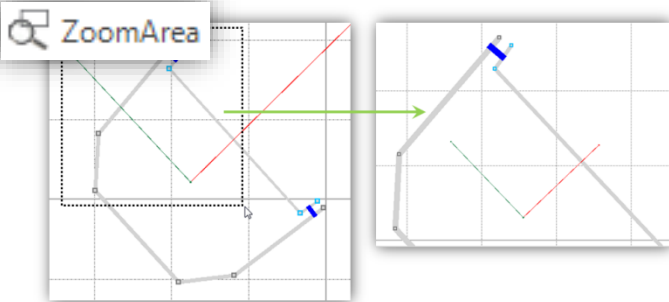


In the Cross Section Editor window you will find several tools for handling the 2D view. Below please find a short description of the 2D view tools:



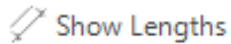
"Zoom to all" tool

After clicking on the "Zoom to all" icon the 2D view will automatically set to fit in the entire cross section modelled in the Cross Section Editor.

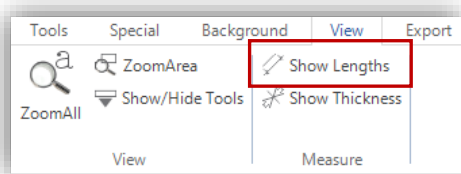


"Area Zoom" tool

The "Area Zoom" tool provides the possibility to view objects contained within the selected area.

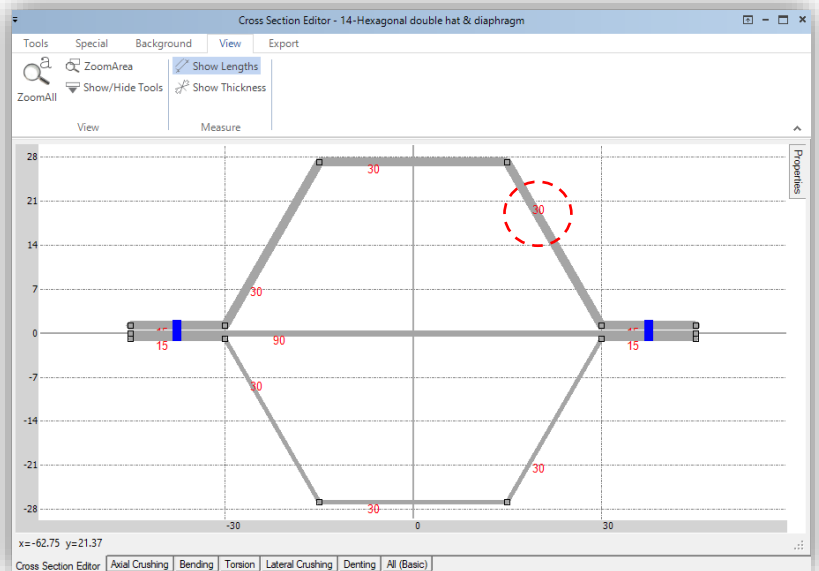


"Show Lengths" tool

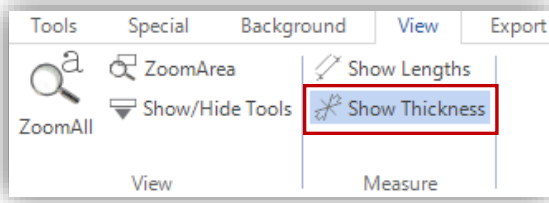


After clicking on the „**Show Lengths**“ icon in the Cross Section Editor window, the dimensions for each Plate of the Cross Section will be visible on the screen.

If the geometry of a Cross Section will be changed, by moving Points, Plates or Segments, the dimensions will change automatically accordingly to the modifications.

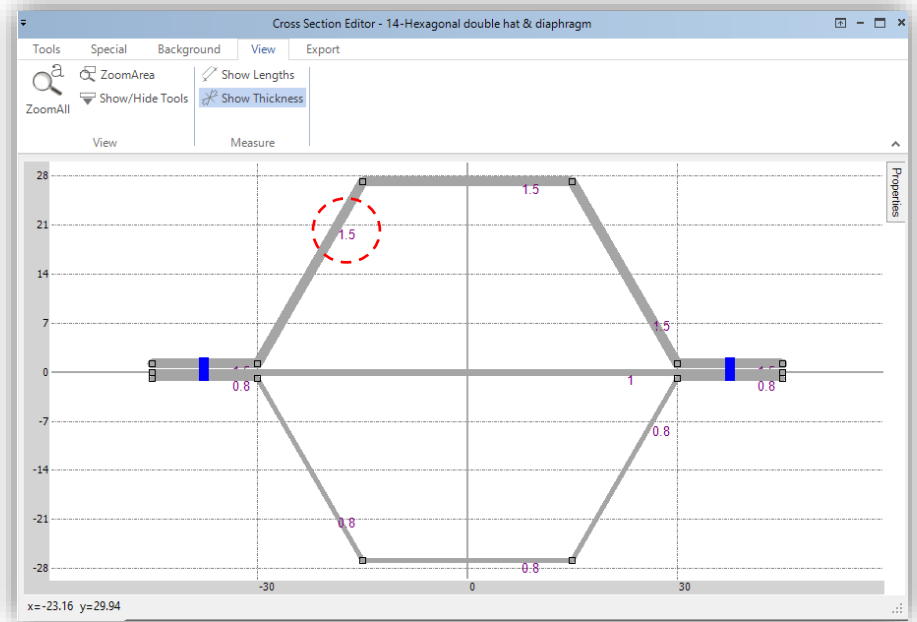


"Show Thickness" tool



After clicking on the „**Show Thickness**“ icon in the Cross Section Editor window, the thickness for each Plate of the Cross Section will be visible on the screen.

If the geometry of a Cross Section will be changed, the displayed values will change automatically accordingly to the modifications.

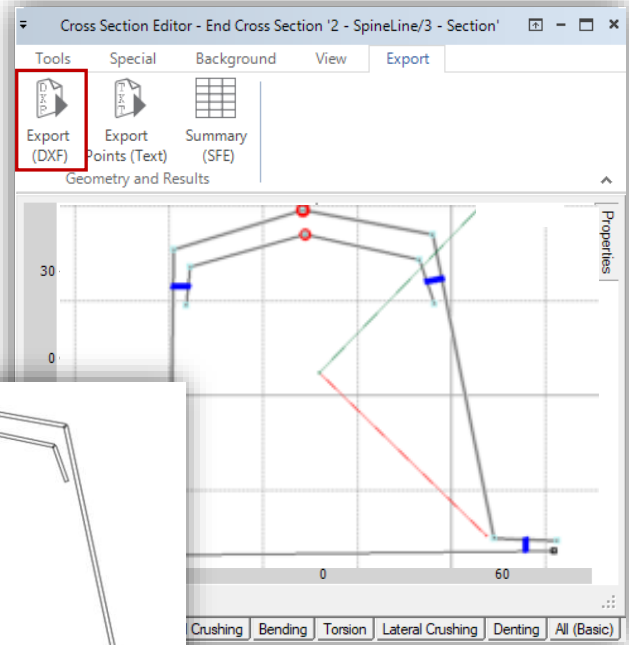
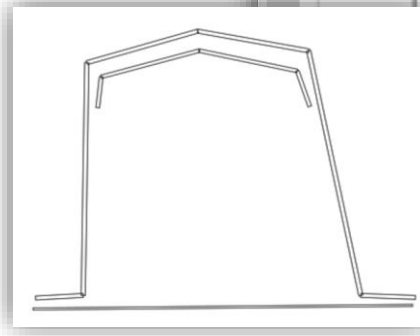


EXPORT CROSS SECTION'S GEOMETRY

VCS provides the possibility to export Cross Section geometry in a CAD-readable format DXF (.dxf).

The User has the possibility to export the geometry of any Cross Section created in the Solution. Cross Sections can be exported in .dxf format, readable for CAD programs.

The export procedure is very simple. In order to export a Cross-Section, the User need simply to click on the "**Export to DXF**" icon available in the main toolbar of the Cross Section Editor.

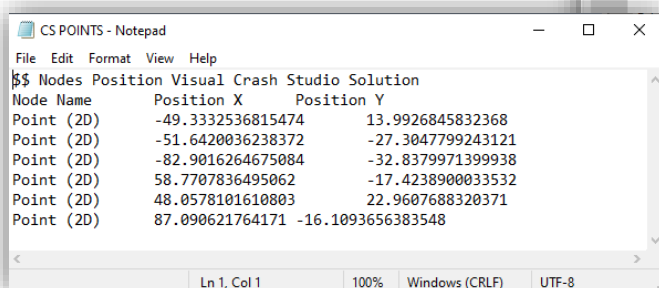
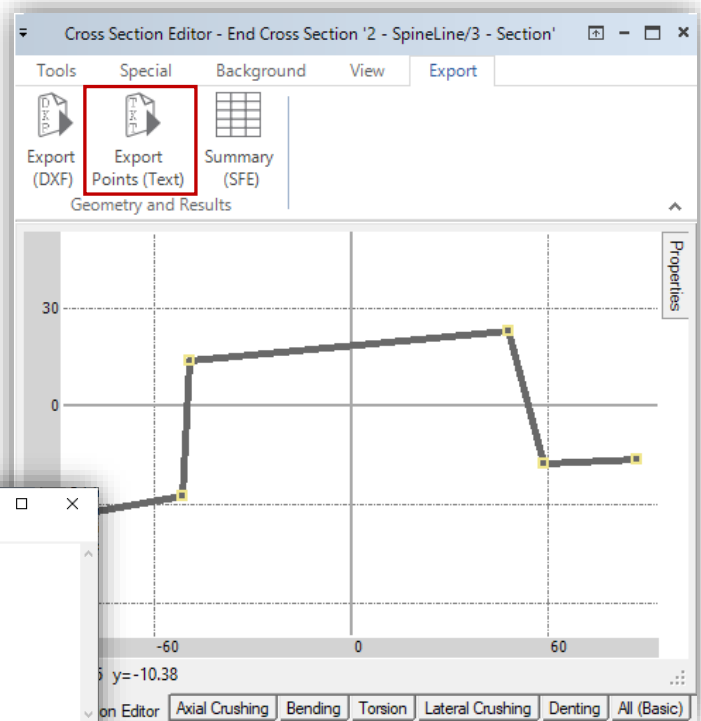


The result of the export procedure can be seen in the picture above. Please note that the dxf. format includes information about the thickness of each Plate of the Cross-Section. However it does not contain information about connections defined between Segments.

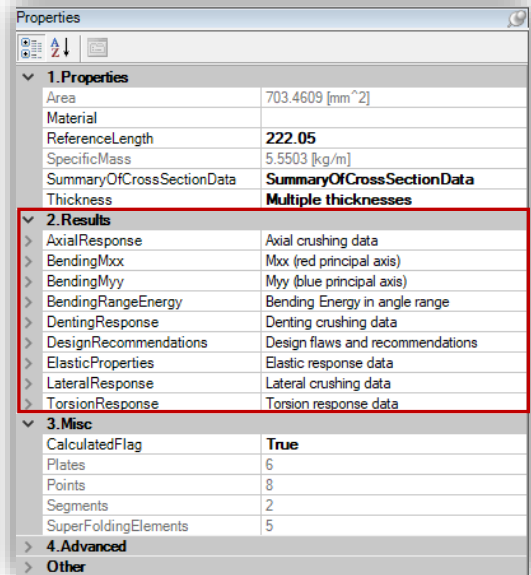
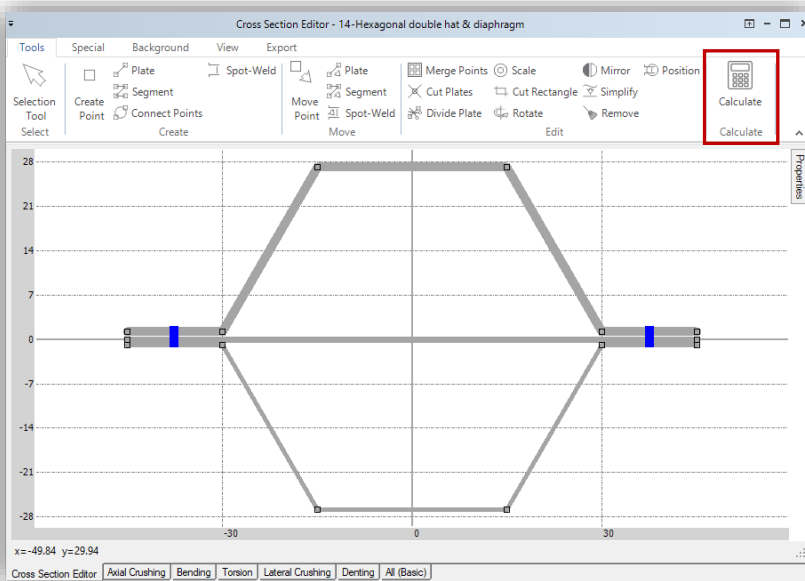
EXPORT POINTS (TEXT)

The User has the possibility to export coordinates of a cross section Points in plain text format

The export procedure is very simple. In order to export a Cross-Section, the User need simply to click on the "**Export Points (Text)**" icon available in the main toolbar of the Cross Section Editor.



THIN-WALLED CROSS SECTION – CALCULATIONS



Results of calculations for a cross section are grouped in expandable containers in the section Results of the properties window:

- Axial Response
- Design Recommendations
- Bending Mxx
- Bending Myy
- Bending Range Energy
- Denting Response
- Elastic Properties
- Lateral Response
- Torsion Response

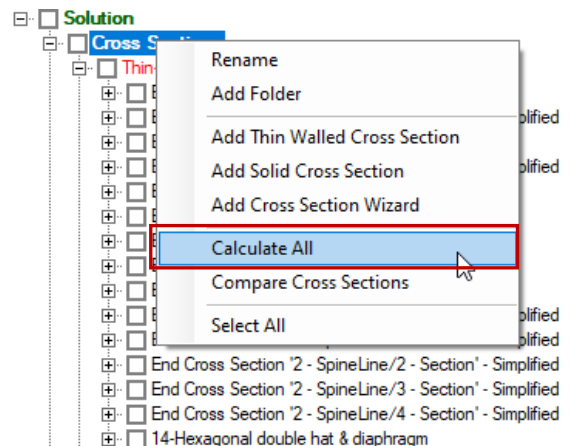
Each container lists characteristic parameters for a given crushing response mode such as maximal value of force or moment, energy absorption capacity, limiting value of a deformation such as total rotation in bending hinge or jamming rotation in torsion crushing.

Design recommendations contain basic information on the recommended corrections to the cross section and are the starting point of the design procedure for optimization of axial crushing response of the cross section.

In VCS the User can calculate all cross sections present in a Solution simultaneously.

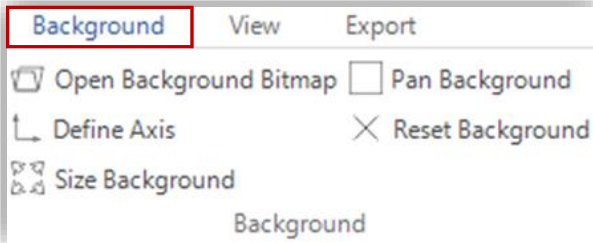
Right click on "Cross Sections" folder in the Solution Explorer tree.

From the drop-down list select the "Calculate All" option.




CALCULATIONS – CHARTS

CHARTS - BACKGROUND TOOLS





Charts BACKGROUND TOOLS


In the Chart Wizard window, you will find tools which will enable you to modify the chart's view.

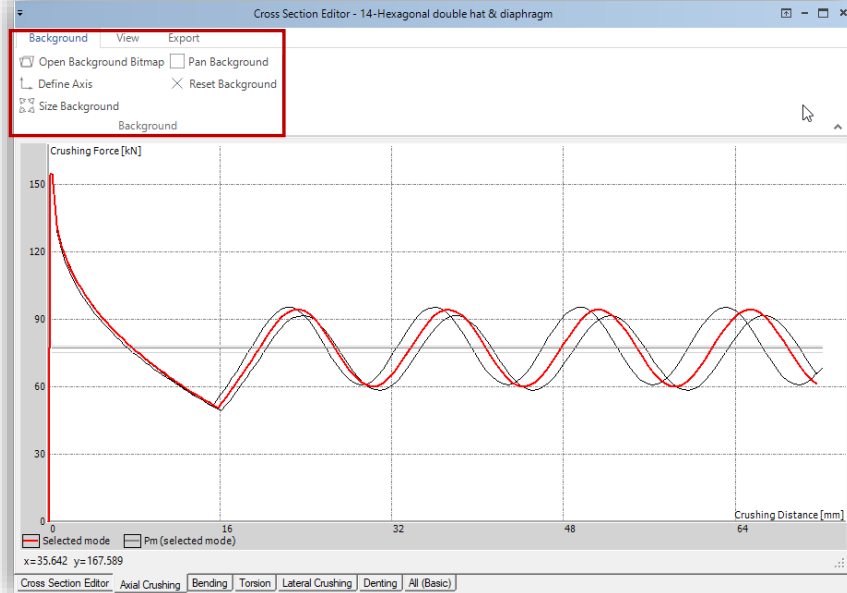
 **Open** – with the usage of this tool you can load an image into the chart window. This function allows easy comparison between simulation results and data collected in the past and imported as a picture.

 **Define Axis** – changes a chart scale

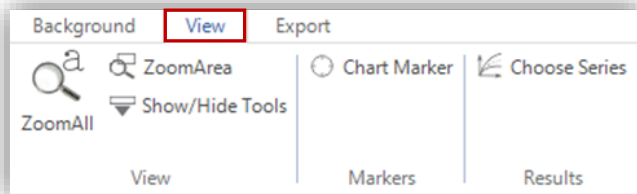
 **Size Background** – enables matching an imported chart to required scale.

 **Pan** – tool for translation of a loaded picture

 **Reset Background** – Resets background back to default settings. Any added background will be deleted from view




CHARTS - VIEW TOOLS



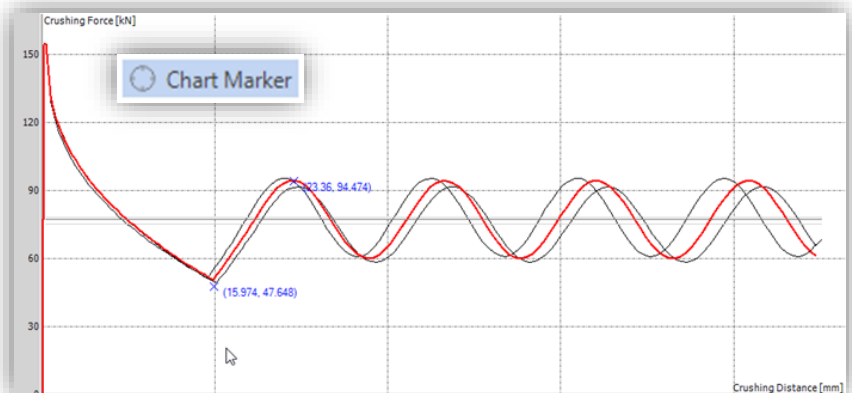
"Zoom to all" tool - automatically set to fit in the entire cross section modelled in the Cross Section Editor.

"Area Zoom" tool - provides the possibility to view objects contained within the selected area

 **Marker** – see exact coordinates of selected point on the chart

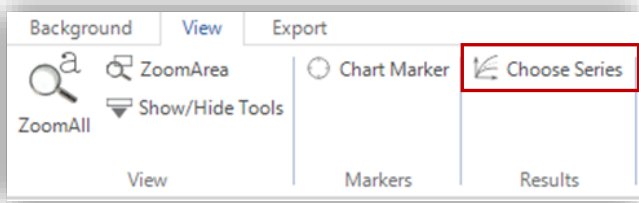
After selecting the "Marker" tool whenever you click in the function window the exact coordinates of the cursor's location will be displayed.

Right click in the function window in order to delete all marked locations



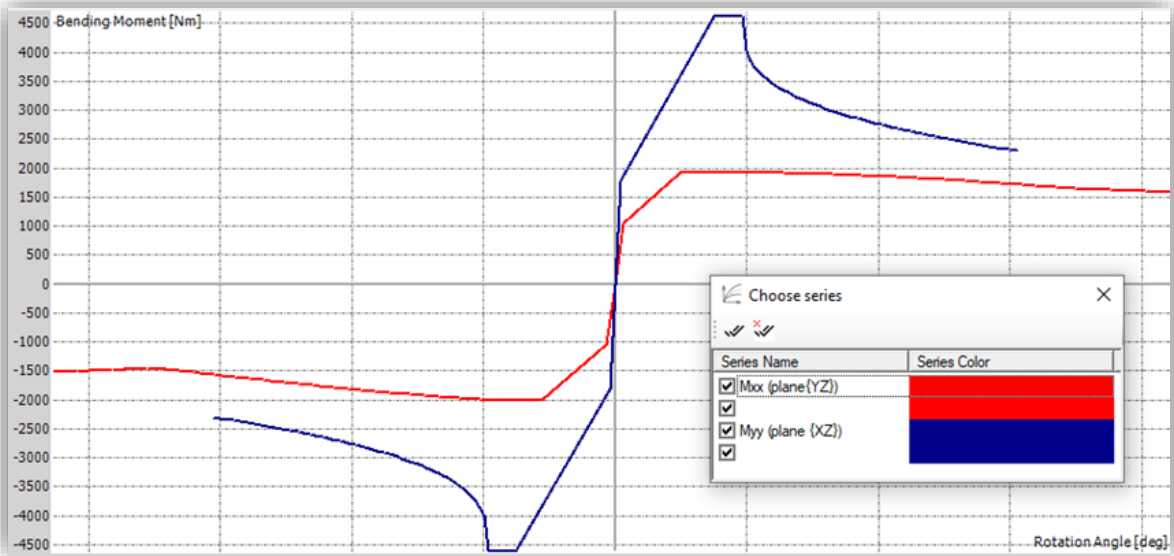
CALCULATIONS – CHARTS

CHARTS - VIEW TOOLS

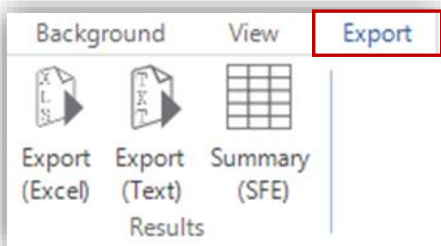


"Choose Series" tool - In the Choose Series window the user can find all series available for display in the currently opened Chart Wizard.

In order to show or hide a series click on its check box on the left side.



CHARTS - EXPORT TOOLS



"Export (Excel)" tool - enable to export selected chart to the excel file

"Export (Text)" tool - enable to export selected chart to the txt file

"Summary (SFE)" tool - enable to display properties summary of all Super Folding Elements, that belong to currently opened Cross Section

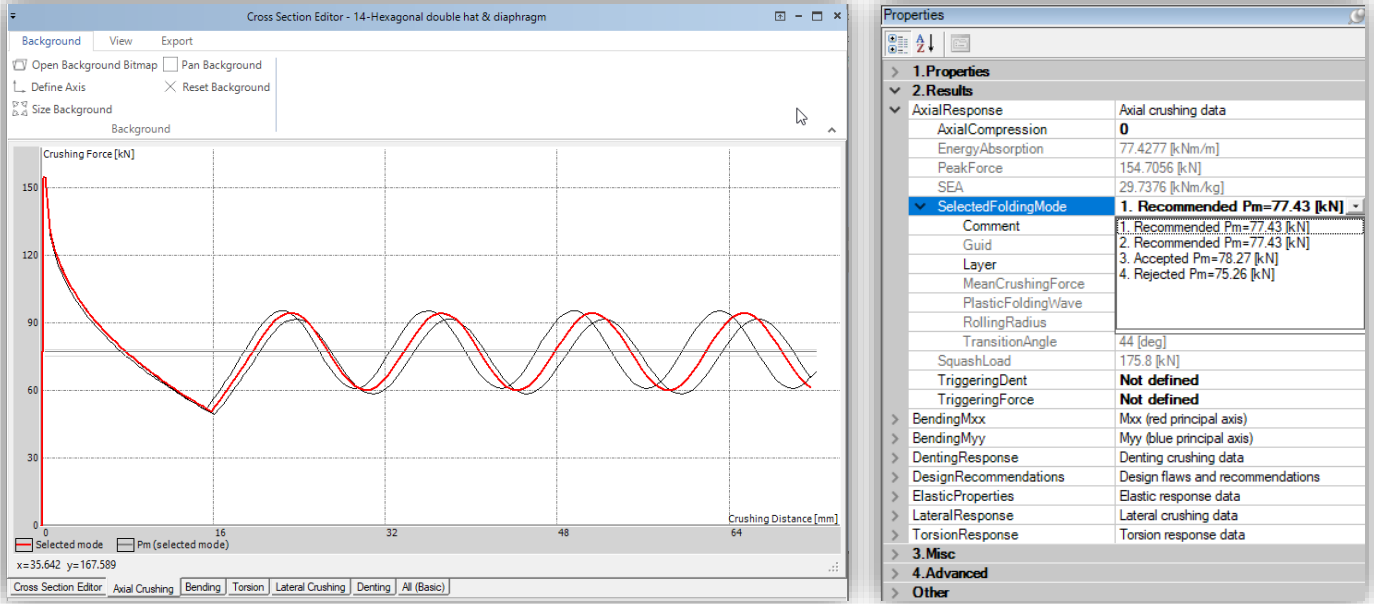
Report: 'Summary of SFE data'

	Pmax [N] or [kN]	Pm [N] or [kN]	2H [mm]	D [1]	eps max [1]	Def. Mode	Pmax [%]	Pm [%]	2H [%]	eps max [%]
Elem # 0	42.473 [kN]	9.2485 [kN]	144.96 [mm]	0.146 [1]	0.02 [1]	Symmetric	21.43 [%]	12.21 [%]	326.4 [%]	13.11 [%]
Elem # 1	43.4924 [kN]	19.7589 [kN]	40.06 [mm]	0.4597 [1]	0.1857 [1]	Asymmetric_A	21.94 [%]	26.09 [%]	90.2 [%]	121.72 [%]
▶ Elem # 2	43.4157 [kN]	19.7811 [kN]	41.13 [mm]	0.4597 [1]	0.1857 [1]	Asymmetric_B	21.9 [%]	26.12 [%]	92.62 [%]	121.72 [%]
Elem # 3	35.3992 [kN]	17.4721 [kN]	30.47 [mm]	0.4597 [1]	0.1857 [1]	Asymmetric_B	17.86 [%]	23.07 [%]	68.62 [%]	121.72 [%]
Elem # 4	33.4403 [kN]	17.237 [kN]	28.79 [mm]	0.4597 [1]	0.1857 [1]	Asymmetric_A	16.87 [%]	22.76 [%]	64.83 [%]	121.72 [%]



AXIAL RESPONSE

Axial response – summarizes axial crushing response of the Cross Section and facilitates basic design procedures.



The simple numeric entries like **Peak Force**, **Squash Load** or specific energy absorption (**SEA**) provide basic information on the strength and energy absorption capacity of the cross section.

The expanded **Selected Folding Mode** container shows data pertinent to the currently selected folding mode. This mode is marked in red on the **Axial Crushing** characteristic of the cross section.

The analyzed mode is selected from the drop-down list of all folding modes detected by the program. Recommended and accepted modes should be considered as a base for trigger design.

The deformation of the cross section in the plane perpendicular to the axis of prismatic column is displayed by selecting amount of axial deformation (crushing) of the active plastic fold (0 – 100%). The amount of axial compression is specified either numerically, by typing in a number in **Axial Compression** window or by moving the slider.

The **Axial Compression utility** is used for checking for internal contact and/or penetration of plastic lobes during axial crushing of the cross section.



AXIAL RESPONSE

In the Properties window you will find results for:

- **Axial Compression** – axial deformation of active plastic mode in [%]
- **Energy Absorption** – energy absorption (quasi – static) per unit crushing distance of the member in [kJ/m]
- **Peak Force** – peak force (quasi – static loading) in [N] or [kN]
- **SEA** – Specific Energy Absorption – energy absorbed per unit mass of the member in [kJ/kg] (quasi – static loading).
- **Squash Load** – squash load (fully plastic axial load) in [N] or [kN]

In the Selected Folding Mode field you will find a drop down list of folding modes

For a folding mode you will find results for:

- **Mean Crushing Force** – mean crushing force of the cross section in [N] or [kN]
- **Plastic Folding Wave** – length of Plastic Folding Wave (2H) in [mm]
- **Rolling Radius** – rolling radius in [mm]
- **Transition Angle** – rotation of the side wall corresponding to the mode transition (quasi – inextensional → extensional) in [deg]

Properties	
> 1. Properties	
> 2. Results	
AxialResponse	Axial crushing data
AxialCompression	0
EnergyAbsorption	77.4277 [kJ/m]
PeakForce	154.7056 [kN]
SEA	29.7376 [kJ/kg]
SelectedFoldingMode	1. Recommended Pm=77.43 [kJ]
Comment	
Guid	381698ed-8bcb-48b8-abeb-b42a4b138114
Layer	Default
MeanCrushingForce	77.4277 [kJ]
PlasticFoldingWave	19.2595 [mm]
RollingRadius	1.9811 [mm]
TransitionAngle	44 [deg]
SquashLoad	175.8 [kN]
TriggeringDent	Not defined
TriggeringForce	Not defined
> BendingMxx	Mxx (red principal axis)
> BendingMyy	Myy (blue principal axis)
> DentingResponse	Denting crushing data
> DesignRecommendations	Design flaws and recommendations
> ElasticProperties	Elastic response data
> LateralResponse	Lateral crushing data
> TorsionResponse	Torsion response data
> 3. Misc	
> 4. Advanced	
> Other	

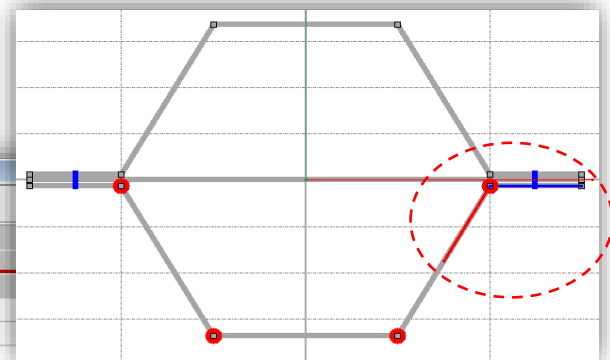
DESIGN RECOMMENDATIONS

The **Design Recommendations** section guides the user through the optimization process of the cross section for **effective axial crushing**.

The optimal cross section is obtained by **eliminating design flaws** detected by the program. It should be emphasized that flawed cross sections may not collapse progressively and, in most cases would collapse in global bending or irregular folding. In these cases, the energy absorption of the crushing process is much smaller than in the case of progressive crushing.

Design Recommendation
s can be found in
the Properties
window of a
selected Cross
Section and in the
Properties window
of each chosen
Super Folding
Element.

Properties	
> 1. Properties	
> 2. Crushing Response	
> 3. Design Recommendations	
Step1_CentralAngle	OK
Step2_WidthSideA	OK in this folding mode
Step2_WidthSideB	OK in this folding mode
Step3_FractureIndicator	EXTENSIVE FRACTURE D = 1.8976
Step4_ContactPenetrations	go to cross section level
> 4. Natural Folding Modes	
NaturalModes	Folding order: Asymmetric, Symmetric
> Misc	
Name	8-SFE:
> Other	



DESIGN RECOMMENDATIONS

The first step is done on the level of Cross Section.

- In the first step the acceptable folding mode is to be selected.

Steps 2 to 5 are done separately for each Super Folding Element of a Cross Section.
The steps for the level of a SFE are:

- Setting the central angle
- Elimination of narrow and wide faces
- Elimination of fracture flaw
- Elimination of contact events

STEP 1 – CROSS SECTION LEVEL

In the first optimization step the correct folding mode should be selected.

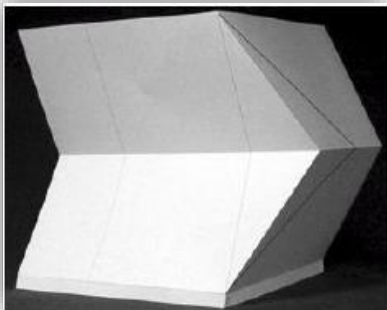
A standing alone Super Folding Element can create three basic NATURAL FOLDING MODES.
Asymmetric folding mode is the most wanted folding pattern for it results in progressive folding of the column during a head-on collision. Progressive folding absorbs most of the impact energy. At the same time, it is the most difficult to obtain in real-world design.

Symmetric modes involve large membrane stretching of the material and have good Specific Energy Absorption (SEA).

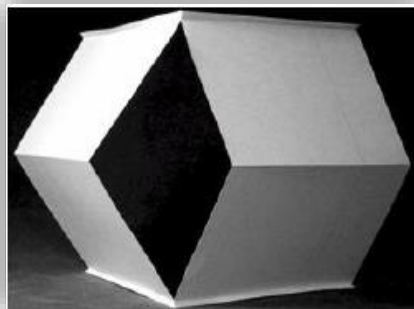
On the other hand, however, they frequently induce the so-called inverted mode(s).

Inverted folding mode has a very high axial stiffness in early stages of the folding process and therefore notoriously induces global bending of the entire column.

For the above reasons the **inverted folding modes must be eliminated** from cross-sections designed for axial crushing. This is done by corrections to the central angle and/or by reducing/increasing number of corners in the cross-section.



Asymmetric folding mode



Symmetric folding mode

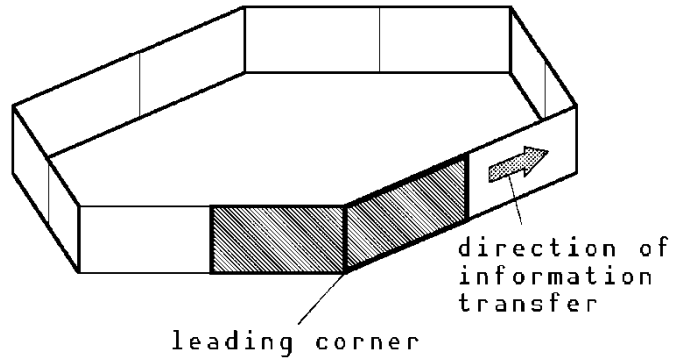


Inverted folding mode

DESIGN RECOMMENDATIONS

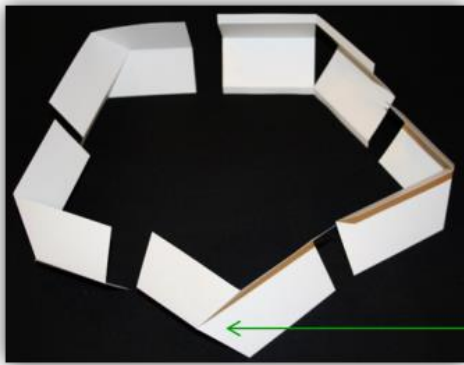
In reality a SFE is constrained by neighboring elements of a deformable cell.

The SFE is constrained by the nearest neighbor by imposing the deformation of 1 or 2 arms of the element in a pre-defined direction.

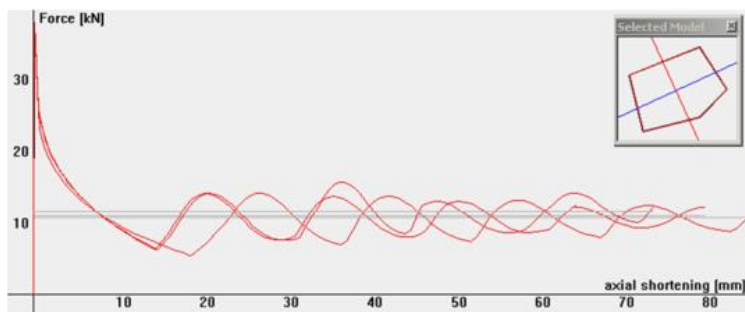
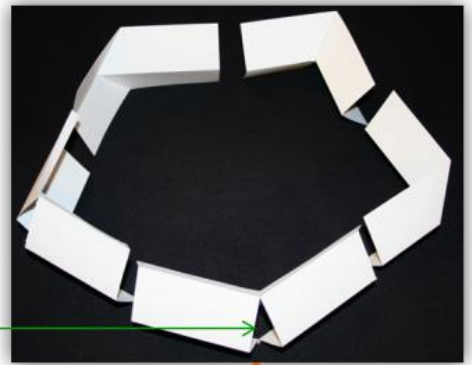
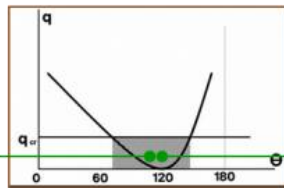


In other words, the deformation mode of the leading corner of the deformable cell will affect the mode of the remaining SFEs.

The requirement of the circumferential continuity of the deformation field may force an element to the deformation mode different than its natural folding mode.



Different folding modes initialize in leading SFE



Note that different folding modes of the Cross Section will give different characteristics visible in the diagram.

In the Cross Section Properties window you will find the **Design Recommendations** section.

The first necessary condition for a successful design of a Cross Section is the presence of at least one recommended folding mode.



DESIGN RECOMMENDATIONS

The recommended folding mode consists exclusively of **Super Folding Elements** deformed in asymmetric modes.

This type of folding is a necessary pre-requisite for trigger design and resulting progressive folding of the column. If the recommended mode is not detected by the Cross Section Editor the cross section requires major redesign.

Typically, number of corners and central angles in the cross section must be changed.

1. Properties	
Area	1064,9277 [mm ²]
Material	400 MPa v1
ReferenceLength	212,96
SpecificMass	8,4023 [kg/m]
SummaryOfCrossSectionData	SummaryOfCrossSectionData
Thickness	Multiple thicknesses
2. Results	
AxialResponse	Axial crushing data
BendingMxx	Mxx (red principal axis)
BendingMyy	Myy (blue principal axis)
DesignRecommendations	
CorrectFoldingModes	1 Recommended modes
SFE_BadMode	All modes are OK
SFE_CentralAngle	3
SFE_LobeCollision	2
SFE_Warnings	5
ShowMajorFlaws	True
ShowMinorFlaws	False
ElasticProperties	Elastic response data
TorsionResponse	Torsion response data
3. Misc	
CalculatedFlag	True
DrawType	Render
Plates	9
Points	11
Segments	2
SuperFoldingElements	7

DesignRecommendations
Results of calculations.

In the **Correct Folding Modes** field you will find the number of modes likely to promote progressive folding. These modes are recommended for Trigger design. Make sure that the recommended modes are detected in the designed Cross Section.

Below the Correct Folding Modes field you will find statistics of flaws in the Super Folding Elements (SFE) in the order of significance for energy absorption:

- **SFE Bad Mode** – number of Super Folding Elements with inverted folding mode (for more information see design recommendations in Properties window of SFE)
- **SFE Central Angle** – number of Super Folding Elements with bad central angle (for more information see design recommendations in Properties window of SFE)
- **SFE Lobe Collision** – plastic fold of neighboring elements collide in Cross Section SFE (for more information see design recommendations in Properties window of SFE)
- **SFE Warnings** – this warning may include: too wide or too short sides and/or fracture of SFE (for more information see design recommendations in Properties window of SFE)



DESIGN RECOMMENDATIONS

STEP 2-5 – THE SUPER FOLDING ELEMENT LEVEL

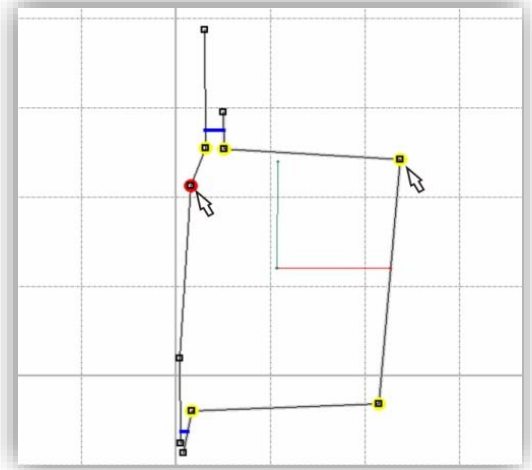
When a recommended mode is found, further design steps are done at **the level of Super Folding Elements**. For an easy identification flawed Super Folding Elements are marked on the cross section view by red (major flaws) and yellow (minor flaws) circles.

The major flaws include:

- **bad folding mode** (inverted)
- **bad central angles**
- **narrow side face** that leads to lobe collision (lobe collision).

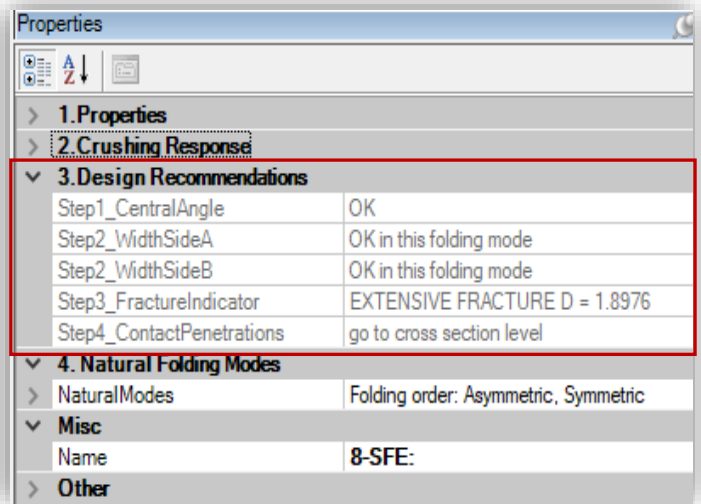
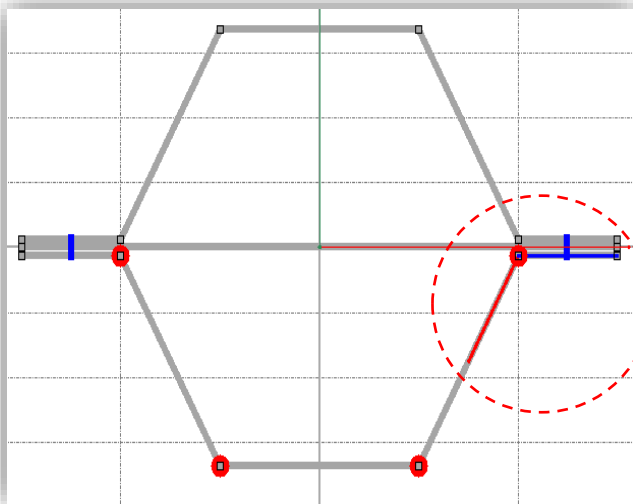
The minor flaws are:

- **wide faces** of the cross (may lead to irregular folding)
- **fracture** of material that occurs late in the folding process.



In the Solution Explorer window select one of the cross Section's Super Folding Element (SFE). The Properties window of the selected **SFE** lists consecutive steps of the design procedure in the Design Recommendations section.

In the Cross Section Editor window the selected SFE will be marked with blue and red line. Arm 'A' is drawn by a red line, arm 'B' is drawn by a blue line. You can find the length of each arm (A and B) and its thickness in the Properties section of the SFE Properties window.



DESIGN RECOMMENDATIONS

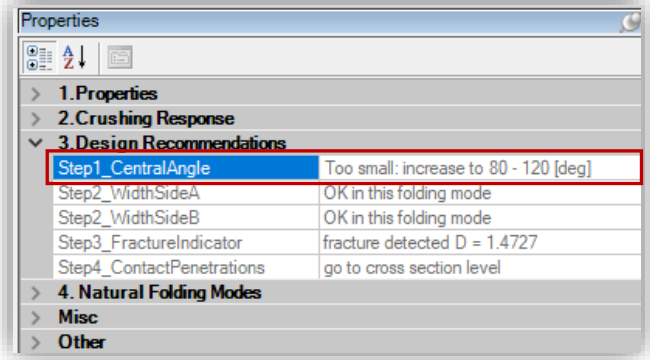
STEP 2 – CENTRAL ANGLE

In the second step the **Central Angles of all SFE** should be corrected. It follows from the mechanics of the Super Folding Element that the **central angle is a primary geometrical factor** responsible for energy absorption in a single SFE. Elements with too small central angle (acute elements) or too large angle (obtuse elements) do not develop progressive pattern.

In the SFE Properties window in the Step 1 - Central Angle field (Design Recommendations section) you will find the recommendation about the Central Angle of the selected SFE.

Note that the angle should be between **80 and 120 deg.**

Following the correction section must be recalculated in order to update design predictions.

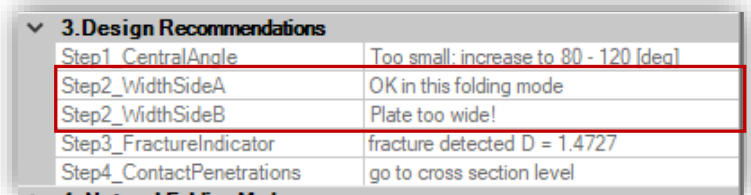


STEP 3 – ELIMINATION OF NARROW AND WIDE FACES

In the third step **narrow faces must be eliminated** by moving corresponding nodes. Care should be exercised during this procedure in order to prevent excessive changes to central angle.

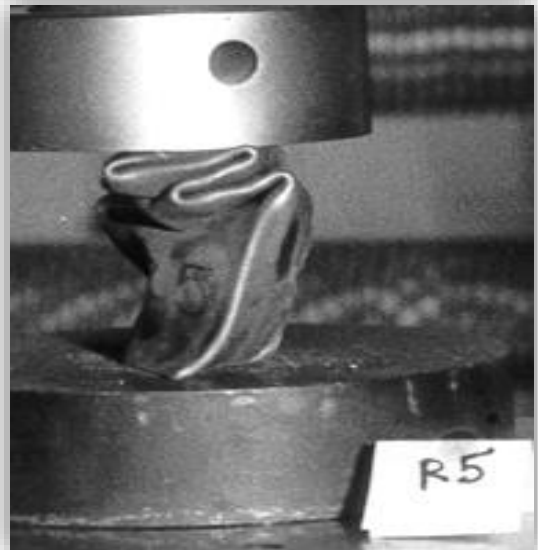
Note that properties window of corresponding plate element is very useful at this step.

In the SFE Properties window in the Step 2 - Width Side A and Width Side B fields (Design Recommendations section) you will find the recommendation about the length of each arm of the SFE.



When a side face of a cross section is **too narrow to accommodate propagating plastic lobes** the lobes may collide before plastic fold is completed.

Narrow face" phenomenon is closely related to the magnitude of central angle(s) in neighboring corner(s). This phenomenon is responsible for **local axial stiffening** of the column, which together with drastically **reduced bending stiffness** of the cross-section leads to the **overall bending** as it is visible in the picture on the right.



Irregular folding followed by overall bending induced by internal contact of neighboring walls



DESIGN RECOMMENDATIONS

The side face of a cross section must not be too narrow as shown in preceding section.
It cannot be too wide either!

When the plate is too wide (thickness too small) the **folding** of "wide" corner elements **becomes irregular**. This may lead to **irregular, non - progressive folding** as you can observe in the picture on the right, or **non-compact folding** when consecutive plastic folds are separated by unfolded segments of the column.

In both cases the **efficiency of energy absorption is dramatically decreased**. **Irregular/non compact folding** is typical for elements with large C/t ratio.

Once all corrections are introduced section must be recalculated.



Irregular folding mode of column with wide side faces (large width, C , to thickness, t , ratio C/t).

STEP 4 – FRACTURE FLAW

In the case of **fracture flaw** at this stage the only remedy is the change of material to more ductile or reduction of thickness (reduction of plastic strain – roughly inversely proportional). Modification of the cross-section geometry, in general, has a weak influence on induced plastic strains.

In the SFE Properties window in the Step 3 – Fracture Indicator field (Design Recommendations section) you will find the information about the ductility of the Material (Fracture Indicator D).

3.Design Recommendations	
Step1_CentralAngle	Too small: increase to 80 - 120 [deg]
Step2_WidthSideA	OK in this folding mode
Step2_WidthSideB	Plate too wide!
Step3_FractureIndicator	fracture detected $D = 1.4727$
Step4_ContactPenetrations	go to cross section level

Note that Fracture indicator D is calculated for selected Material fracture model. D larger than 1 indicates fracture of Material.

STEP 5 – CONTACT EVENTS

In the last design step contact and/or penetration events must be checked visually at the cross-section level (axial response property group).

In the SFE Properties window in the Step 4 – Contact Penetrations field (Design Recommendations section) you will find the information about contact events.

3.Design Recommendations	
Step1_CentralAngle	Too small: increase to 80 - 120 [deg]
Step2_WidthSideA	OK in this folding mode
Step2_WidthSideB	Plate too wide!
Step3_FractureIndicator	fracture detected $D = 1.4727$
Step4_ContactPenetrations	go to cross section level

Check for possible internal contacts and penetrations (see Properties window of the Cross Section).



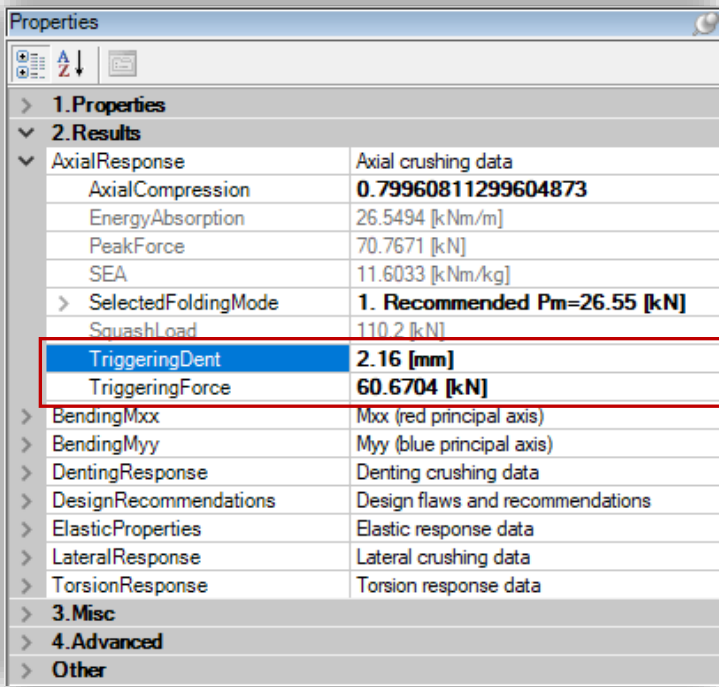
TRIGGER DESIGN

Triggering mechanism is designed in order **to promote a desired progressive folding pattern** and **reduce the peak force** below the level, which is likely to induce global buckling of a column. A triggering of columns is **especially important for complex cross - sections that develop large number of natural folding modes**.

Usually only few of these modes are likely to converge to the desired progressive folding pattern while other modes lead to a premature bending of a column.

Trigger is designed by specifying the level of quasi static peak load (in Newtons). Once this parameter is defined program shows a coupled parameter: i.e.: depth of dent corresponding to defined axial force.

Note that design of a trigger makes sense only for **Recommended** or **Accepted** folding mode.

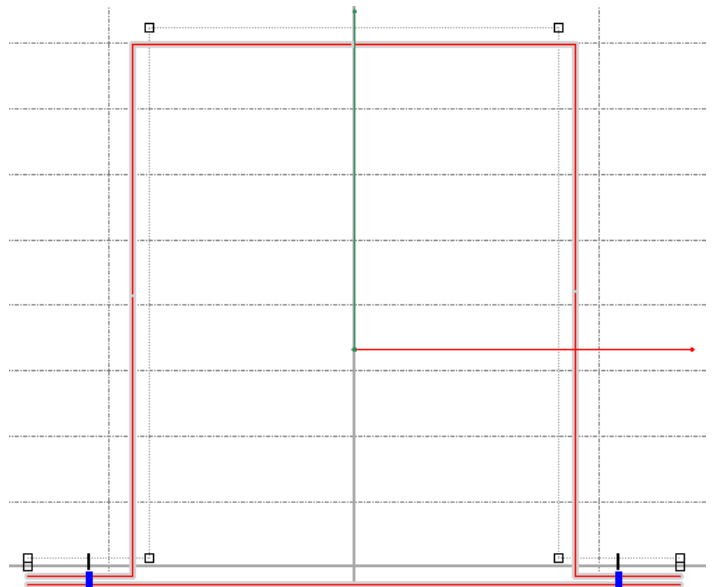


Properties	
1. Properties	
2. Results	
AxialResponse	Axial crushing data
AxialCompression	0.79960811299604873
EnergyAbsorption	26.5494 [kJ/m]
PeakForce	70.7671 [kN]
SEA	11.6033 [kJ/m/kg]
SelectedFoldingMode	1. Recommended Pm=26.55 [kN]
SquashLoad	110.2 [kN]
TriggeringDent	2.16 [mm]
TriggeringForce	60.6704 [kN]
BendingMxx	Mxx (red principal axis)
BendingMyy	Myy (blue principal axis)
DentingResponse	Denting crushing data
DesignRecommendations	Design flaws and recommendations
ElasticProperties	Elastic response data
LateralResponse	Lateral crushing data
TorsionResponse	Torsion response data
3. Misc	
4. Advanced	
Other	

In the Properties window you can enter the depth of the trigger dent (in millimeters) or the triggering force (in Newtons).

In the Cross Section Editor window you can see the shape of a trigger designed on the basis of Recommended folding mode (the black dotted line).

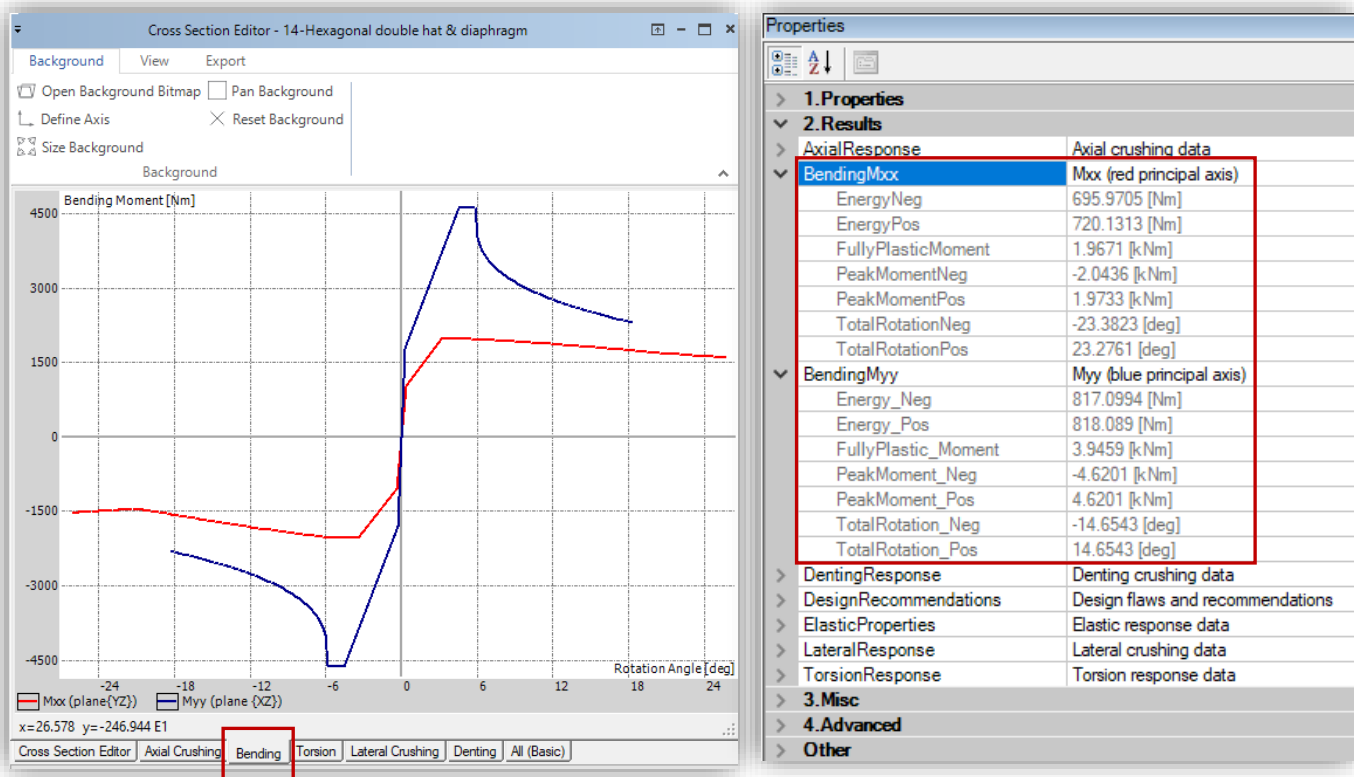
The value displayed in the Triggering Force cell in the Axial Response section of the Properties window, comes as a result of iteration routine and may slightly differ from starting value entered by the user.



BENDING RESPONSE

Bending crushing response of the cross section **is defined in two directions** corresponding to the orientation of principal axes (defined for elastic response of the cross section).

- **Bending Mxx** - red principal axis
- **Bending Myy** - blue principal axis



All three characteristics have similar structure. The crushing characteristic gives the variation of the moment versus angle (of bending or rotation) while the properties window shows numeric values of characteristic parameters such as maximal moment or energy absorption. In the Properties window you will find results for:

- **Energy Neg.** - energy absorbed in (Nm) or (kNm) - negative rotations for Mxx - red axis, principal plane parallel to {YZ} for Myy - blue axis, principal plane parallel to {XZ}
- **Energy Pos.** - energy absorbed in (Nm) or (kNm) - positive rotations for Mxx - red axis, principal plane parallel to {YZ} for Myy - blue axis, principal plane parallel to {XZ}
- **Fully Plastic Moment** - fully plastic bending moment in (Nm) or (kNm) for Mxx - red axis, principal plane parallel to {YZ} for Myy - blue axis, principal plane parallel to {XZ}
- **Peak Moment Neg.** - maximal bending moment in (Nm) or (kNm) - negative rotations for Mxx - red axis, principal plane parallel to {YZ} for Myy - blue axis, principal plane parallel to {XZ}
- **Peak Moment Pos.** - maximal bending moment in (Nm) or (kNm) - positive rotations for Mxx - red axis, principal plane parallel to {YZ} for Myy - blue axis, principal plane parallel to {XZ}

BENDING RESPONSE

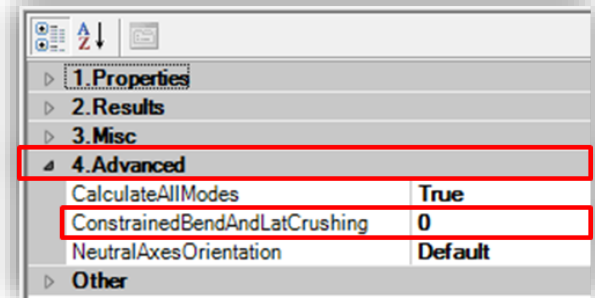
- **Total Rotation Neg.** – total rotation in (deg) – negative rotations for M_{xx} – red axis, principal plane parallel to $\{YZ\}$
for M_{yy} – blue axis, principal plane parallel to $\{XZ\}$
- **Total Rotation Pos.** – total rotation in (deg) – negative rotations for M_{xx} – red axis, principal plane parallel to $\{YZ\}$
for M_{yy} – blue axis, principal plane parallel to $\{XZ\}$

CONSTRAINED BENDING

This post-processing feature calculates **constrained** bending crushing response in a predefined bending plane.

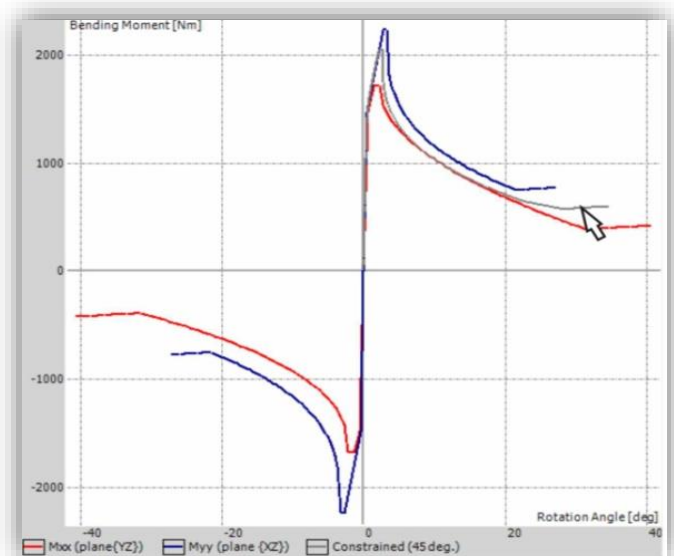
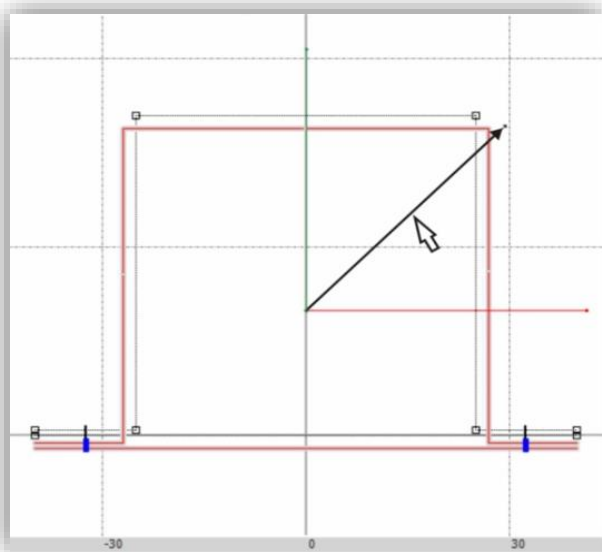
You can define the bending plane in the **Constrained Bending** field in the **Advanced** section of the Properties window.

In this field you should enter the angular position of user defined constrained bending plane and lateral crushing direction with respect to x (red) principal axis in degrees (0 to 360).



In general, this type of bending requires additional constraints to keep the cross section in assumed bending plane. Also, the direction of the velocity of rotation vector and resulting bending moment vector are, in general, not collinear. The plane of constrained rotation is defined by the positive angle measured from the x (red) neutral axis (0°-360°).

Plane of constrained bending is marked as black axis on the 2D Cross Section Editor view. The axis arrow points into direction of the compressed fiber. The bending crushing characteristic is displayed as dark grey curve on the Bending diagram. Typically, the constrained bending feature is used to determine bending crushing response of A pillars constrained by windshield.



BENDING RANGE ENERGY

This group of cross section results allows to count bending energy in the range of the rotation angles specified by the user in the Properties text box.

Counting is possible in any angle range of positive or negative Mxx and Myy moments separately. The results are displayed in the Properties Window.

The angles range can be changed at any time by entering the max and min values. The results of the bending energy in this range will be refreshed after clicking on its textbox, in the Properties Window. It is not necessary to recalculate the entire cross-section.

* Note that each "Energy in range" textbox must be refreshed separately to display proper value.

1. Properties

Area	530.0547 [mm ²]
Material	2000132 (LS_DYNA)
ReferenceLength	199.23
SpecificMass	4.1821 [kg/m]
SummaryOfCrossSectionData	SummaryOfCrossSectionData
Thickness	2.34

2. Results

- > AxialResponse Axial crushing data
- > BendingMxx Mxx (red principal axis)
- > BendingMyy Myy (blue principal axis)
- > BendingRangeEnergy Bending Energy in angle range
 - > BendingMxxRange Bending Mxx Energy in angle range

EnergyInRangeNeg_Mxx	0.6508
EnergyInRangePos_Mxx	0.6384
Neg_Max_Angle_Mxx	0
Neg_Min_Angle_Mxx	-3
Pos_Max_Angle_Mxx	3
Pos_Min_Angle_Mxx	0
 - > BendingMyyRange Bending Myy Energy in angle range

EnergyInRangeNeg_Myy	1.2581
EnergyInRangePos_Myy	1.4485
Neg_Max_Angle_Myy	0
Neg_Min_Angle_Myy	-15
Pos_Max_Angle_Myy	15
Pos_Min_Angle_Myy	0
- > DentingResponse Denting crushing data
- > DesignRecommendations Design flaws and recommendations
- > ElasticProperties Elastic response data
- > LateralResponse Lateral crushing data
- > TorsionResponse Torsion response data

3. Misc

4. Advanced

Other

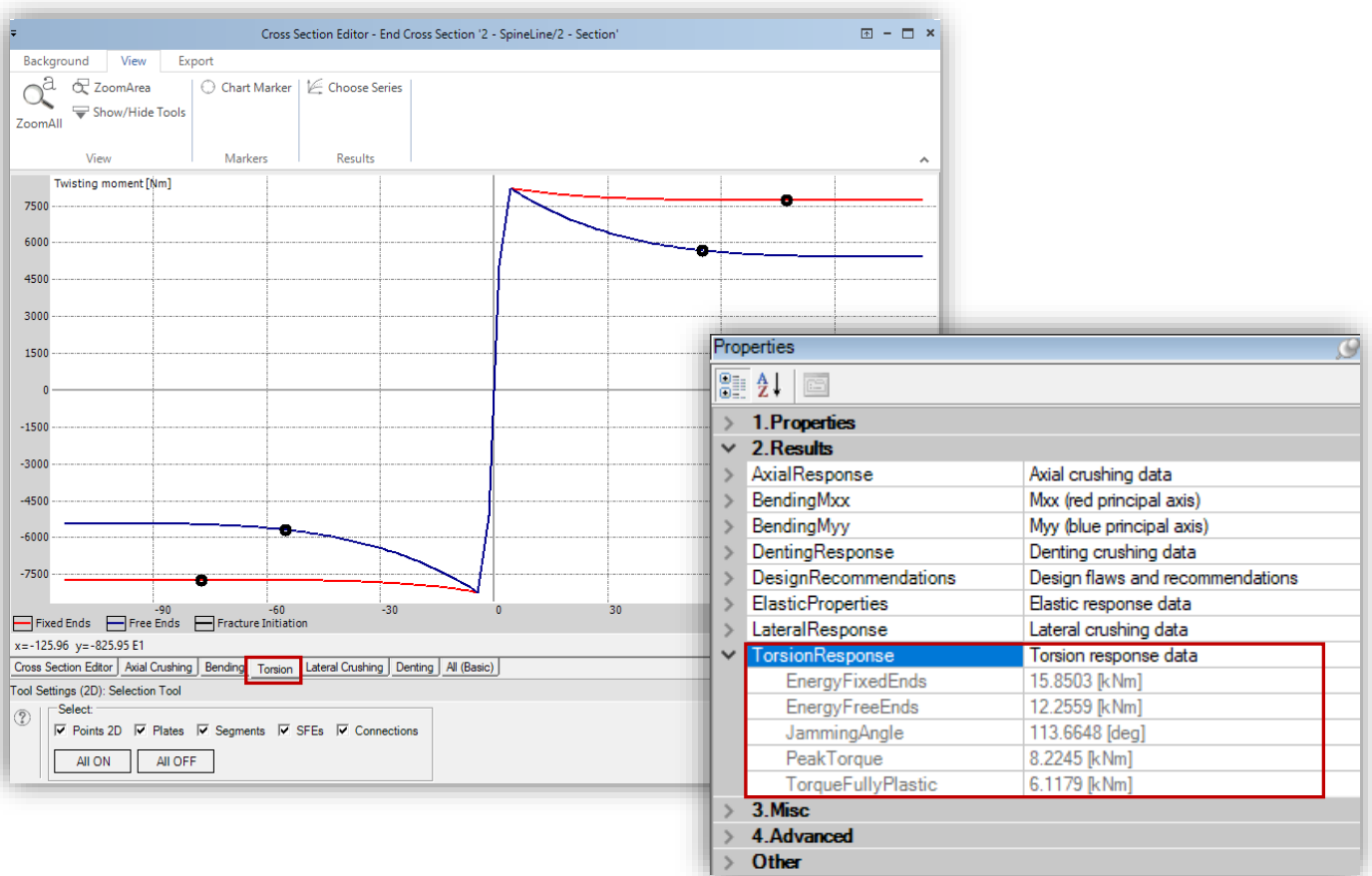
EnergyInRangeNeg_Myy
Energy Absorbed in [Nm] or [kJNm] - negative rotations, blue axis (principal plane parallel to {XZ})



TORSION RESPONSE

The **Torsion crushing characteristics** is calculated for two modes of torsion crushing. The **Fixed Ends** response corresponds to the fixed boundary condition that prevents **any axial deformation** of the column.

The **Free Ends** response corresponds to the **axial unconstrained motion** of one of the column ends. In both cases it is assumed that end cross sections remain parallel to each other and perpendicular to the column axis – **no warping deformation**.



In the Cross Section Editor window you can see the Torsion crushing characteristic for axially constrained (red – Fixed Ends) and unconstrained (blue – Free Ends) torsion crushing. The black circles show points of fracture initiation.

In the Properties window you can find results for:

- **Energy Fixed Ends** – energy absorbed during twisting up to the jamming angle in (Nm) or (kJNm) (fixed ends)
- **Energy Free Ends** – energy absorbed during twisting up to the jamming angle in (Nm) or (kJNm) (free ends)
- **Jamming angle** – first contact of twisted side faces of the element in (deg)
- **Peak Torque** – maximal twisting moment in (Nm) or (kJNm)
- **Torque Fully Plastic** – fully plastic twisting moment in (Nm) or (kJNm)



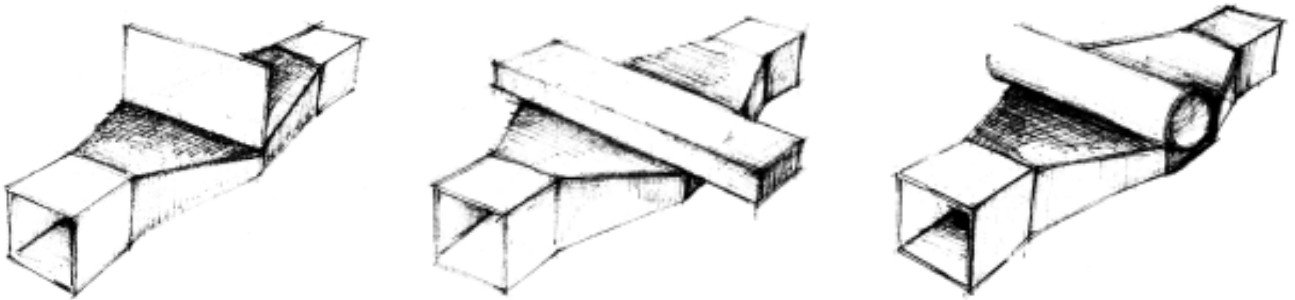
LATERAL RESPONSE & DENTING

The Denting / Lateral crushing module is intended to generalize the response of a classic beam by considering shell response of the walls of a thin walled beam. The denting/lateral crushing involves mostly bending deformations along stationary hinge lines and absorbs relatively little energy as compared to axial or bending crushing. However, lateral deformations are strongly coupled with axial and bending response of a beam (a flattened beam would not retain much bending and axial crushing resistance).

The beam dented by an edge loading collapses locally. At the same time the predominantly membrane deformation of the beam surface spreads over the span of the beam in the region referred to as a transition zone. Depending on the boundary conditions the transition zone reaches the physical ends of the beam or stops at certain distance from the denting region.

In general the denting/lateral crushing of a beam results in development of distinct deformation mechanisms:

The first mechanism is the denting of a cross section. The deformation in this region depends on the shape and extends of the penetrating object. In the case of edge loading the denting region is assumed to be of zero width in other cases extend of this region is finite.



In the transition region the cross section deformations results from boundary conditions, shape of original cross section of the beam and shape of the penetrating objects, and must be calculated separately for each cross section geometry and boundary conditions at the ends of a beam.

Finally, the extent of the transition zone depends on all the parameters listed above.



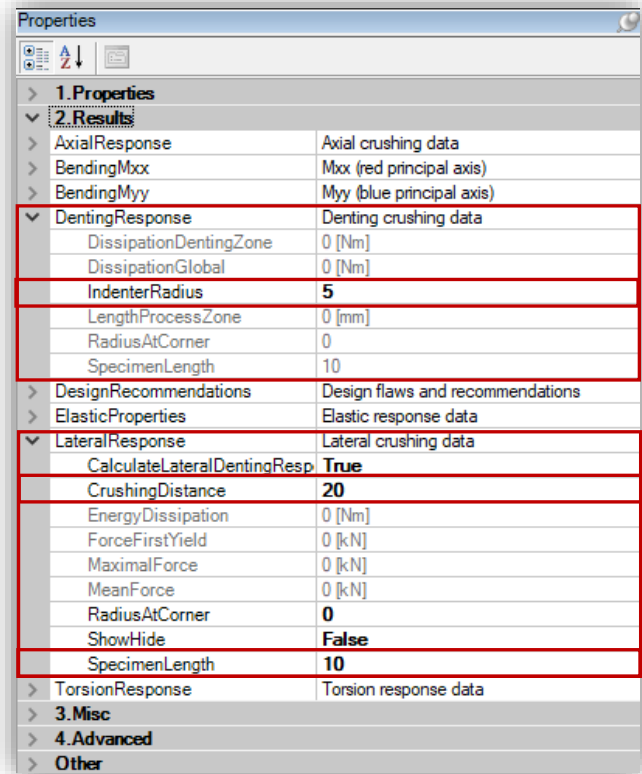
LATERAL RESPONSE & DENTING

In order to receive results for Lateral Crushing and Denting you need to set the Calculate Lateral Denting Response in the Lateral Response field of the Properties window to True.

It is also necessary to fill in the Specimen Length field which defines the length of the prismatic section subjected to lateral crushing [mm].

Moreover, the user is able to define:

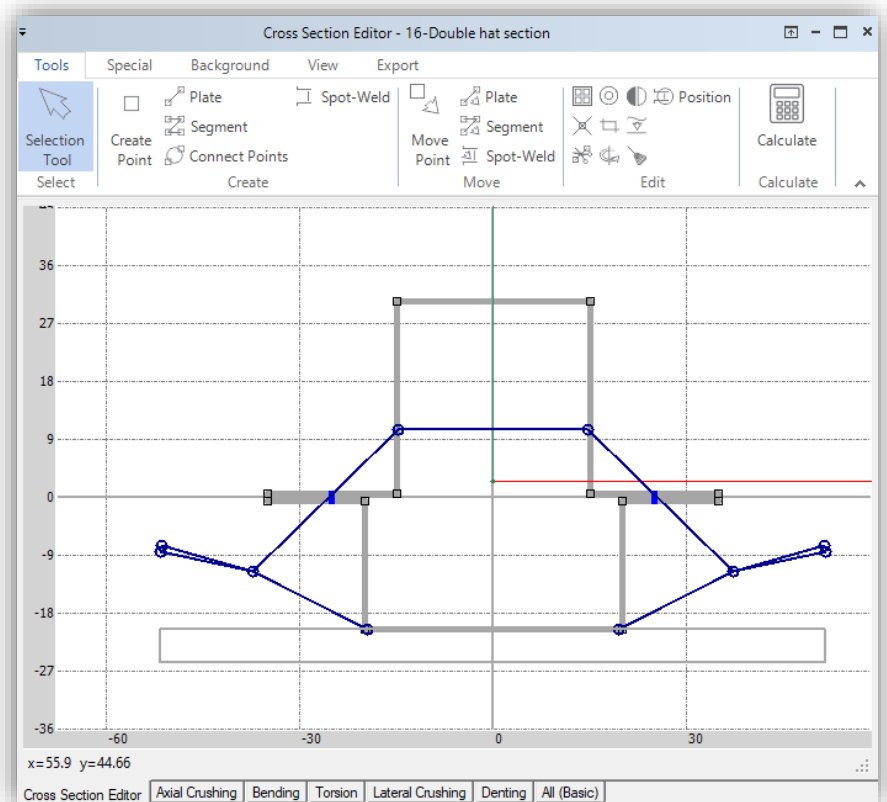
- **Crushing Distance [mm]** – the distance of specimen deformation in crushing direction. By default, Crushing distance is set to 80% of the specimen height (in crushing direction).
- **Radius at Corner** – the corner radius of the analyzed Cross Section
- **Indented Radius** – radius of a cylindrical penetrating object – in the Denting Response section of the Properties window



After the calculation of a Cross Section is completed, in the Cross Section Editor's main view additional blue – lined cross section will be visible. This blue cross section illustrates the deformation of the original Cross Section under the lateral crushing conditions.

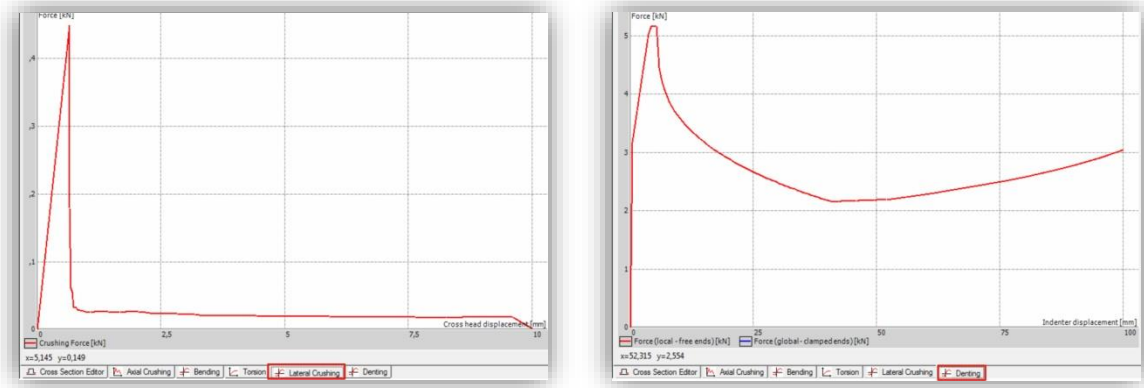
The height of the deformed cross section is determined by the Crushing Distance property defined by the user in the Properties window.

Note that the direction of lateral crushing load is determined by vertical axes of the Cross Section Editor.



LATERAL RESPONSE & DENTING

The Denting / Lateral crushing characteristic constitutes the fourth elementary characteristic that characterizes crashworthiness of prismatic member. This characteristic determined as part of the Cross Section Editor calculations is displayed in a separate tab of the Cross Section Editor window, as illustrated below.



In the Denting section of the Properties window you will find the results for:

- **Dissipation Denting Zone** – energy dissipated in local indentation (free ends) [Nm]
- **Dissipation global** – total energy dissipation: local denting + global beam response (clamped ends) [Nm]
- **Length Process Zone** – length of the process zone of denting mechanism (beam(s) span cannot be shorter than this length) [mm]

In the Lateral Response section of the Properties window you will find the results for:

- **Energy dissipation** – energy dissipated in the reference collapse range (default: 80% of the specimen height in crushing direction) [Nm]
- **Force First Yield** – force corresponding to the first plastic deformation(s) (end of elastic response) [kN]
- **Maximal Force** – maximal force of the lateral crushing response [kN]
- **Mean Force** – mean crushing force [kN] – in the plastic range



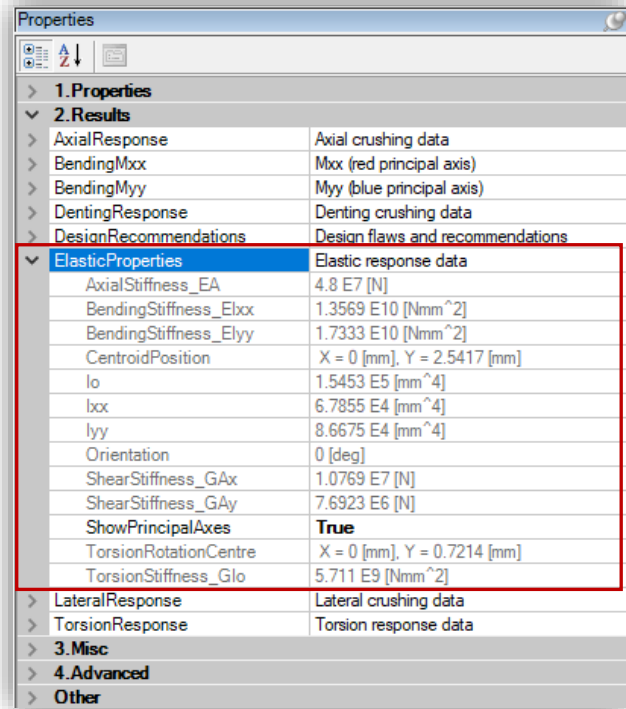
THE ELASTIC PROPERTIES OF THE CROSS SECTION

The **Elastic Properties** container on the Cross Section Properties window shows all the standard properties of thin-walled elastic cross section.

The Axial Stiffness EA , Bending Stiffness EI_{xx} and Bending Stiffness EI_{yy} are especially defined for cross sections with different elastic module of contributing plates.

In this case the reference Young modulus E is the module of the first plate in the cross section.

Note that in general the Centroid Position calculated for elastic bending response of cross section must not necessarily coincide with the position of free rotation center Torsion Rotation Centre.



The screenshot shows a software interface with a 'Properties' window. The 'ElasticProperties' section is expanded and highlighted with a red border. The data is as follows:

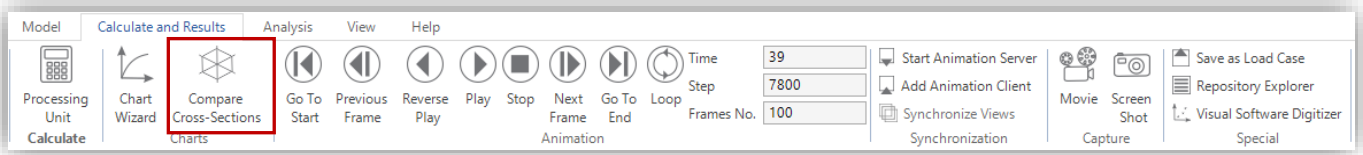
Property	Value
AxialStiffness_EA	4.8 E7 [N]
BendingStiffness_Elxx	1.3569 E10 [Nmm ²]
BendingStiffness_Elyy	1.7333 E10 [Nmm ²]
CentroidPosition	X = 0 [mm], Y = 2.5417 [mm]
lo	1.5453 E5 [mm ⁴]
lxx	6.7855 E4 [mm ⁴]
lyy	8.6675 E4 [mm ⁴]
Orientation	0 [deg]
ShearStiffness_GAx	1.0769 E7 [N]
ShearStiffness_GAy	7.6923 E6 [N]
ShowPrincipalAxes	True
TorsionRotationCentre	X = 0 [mm], Y = 0.7214 [mm]
TorsionStiffness_Glo	5.711 E9 [Nmm ²]

In the Properties window you will find results for:

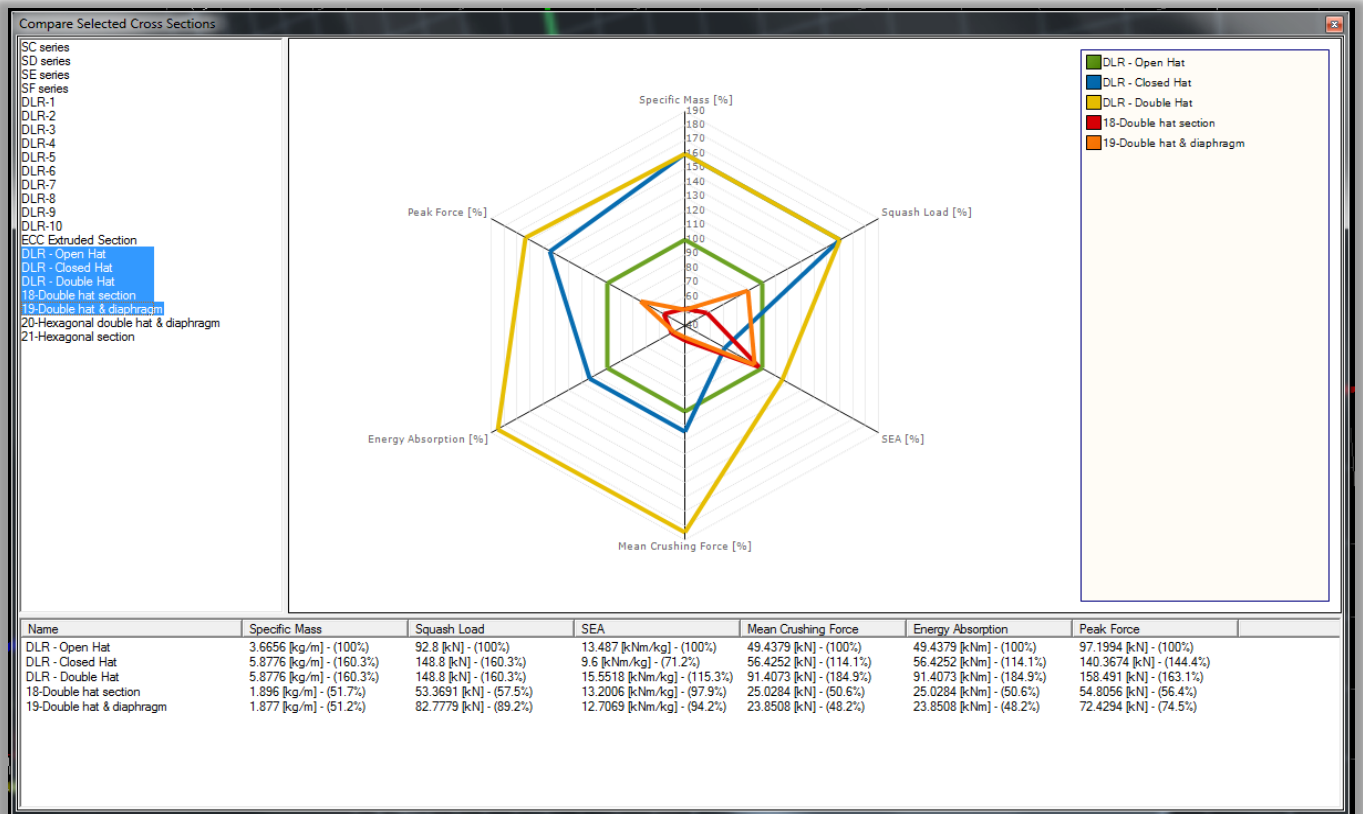
- **Axial Stiffness EA** – axial stiffness of the Cross Section EA in [N]
- **Bending Stiffness** – bending stiffness in [Nmm²]
For EI_{xx} – with respect to the principal axis x (red)
For EI_{yy} – with respect to the principal axis y (blue)
- **Centroid Position** – position of the centroid of the Cross Section in [mm]
- **lo** – second polar moment of area, lo [mm⁴]. Valid for sections with constant Kirchhoff modulus and parallel rigid end fixtures
- **lxx** – second moment of area, lxx [mm⁴], x principal axes (red). Valid for sections with constant Young modulus.
- **lyy** – second moment of area, lyy [mm⁴], y principal axes (blue). Valid for sections with constant Young modulus.
- **Orientation** – orientation of the principal axes (red and blue) with respect to the 2D view coordinate system [deg]
- **Shear Stiffness** – shear stiffness in [N]
For G_{Ax} – with respect to the principal x axis (red)
For G_{Ay} – with respect to the principal y axis (blue)
- **Torsion Rotation Centre** – position of the center of rotation in [mm] (for parallel rigid end fixtures)
- **Torsion Stiffness Glo** – torsional stiffness of the Cross Section Glo in [Nmm²] (for parallel rigid end fixtures)



The icon "Compare Selected Cross Sections" is located on the main toolbar in the "Calculate and Results" section



In order to open the Cross Section Comparison tool, click on the "Compare Cross Sections". Alternatively, select the Cross Sections branch on the Solution Explorer tree and right click on it. From the drop-down list select the Compare Cross Sections tool. A new window "Compare Selected Cross Sections" will be visible on the screen. In this window, in the left hand side column, you will find a list of all cross sections created in the Solution.



You can select as many Cross Sections as you wish to compare.

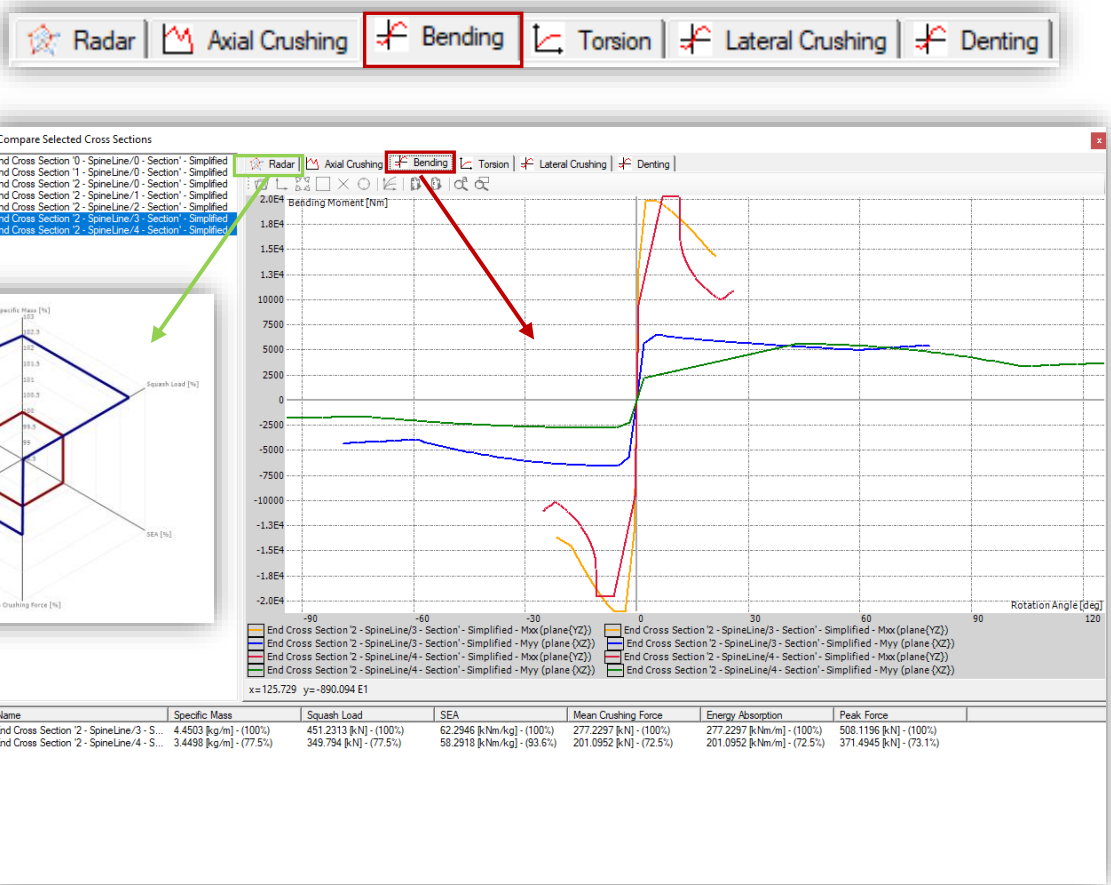
On the chart in the middle of the Compare Selected Cross Sections window you will see a diagram illustrating the results of selected Cross Sections. On this diagram you will see the comparison of results for Specific Mass, Squash Load, SEA, Mean Crushing Force, Energy Absorption and Peak Force.

Each Cross Sections results will be illustrated by a line of a different color. The list of selected Cross Sections and colors assigned to them is available in the column on the right-hand side. Below the chart you can find a list of selected Cross Sections and their results for Specific Mass, Squash Load, SEA, Mean Crushing Force, Energy Absorption and Peak Force.

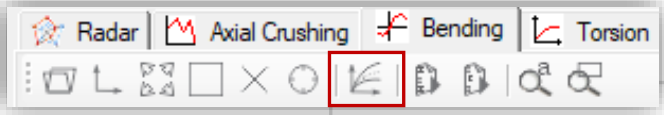


COMPARE CROSS SECTIONS – CURVE COMPARISON

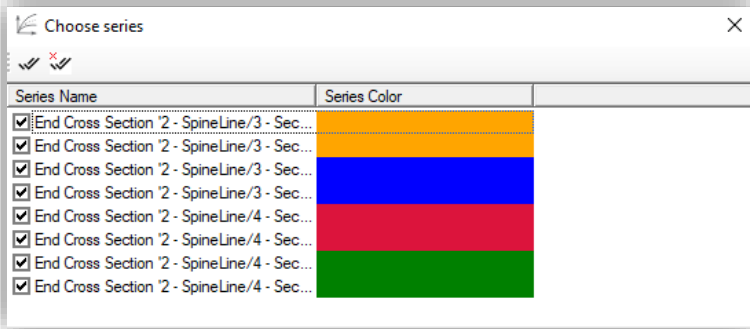
The "Compare Cross Sections" tool is enhanced with the functionality of curve comparison. The user can compare result charts of number of selected cross sections. The graphical comparison tool available in previous versions of VCS is accessible under the "Radar" bookmark.



Click on the "Choose series" icon in order to select the curves you wish to compare.



Choose series



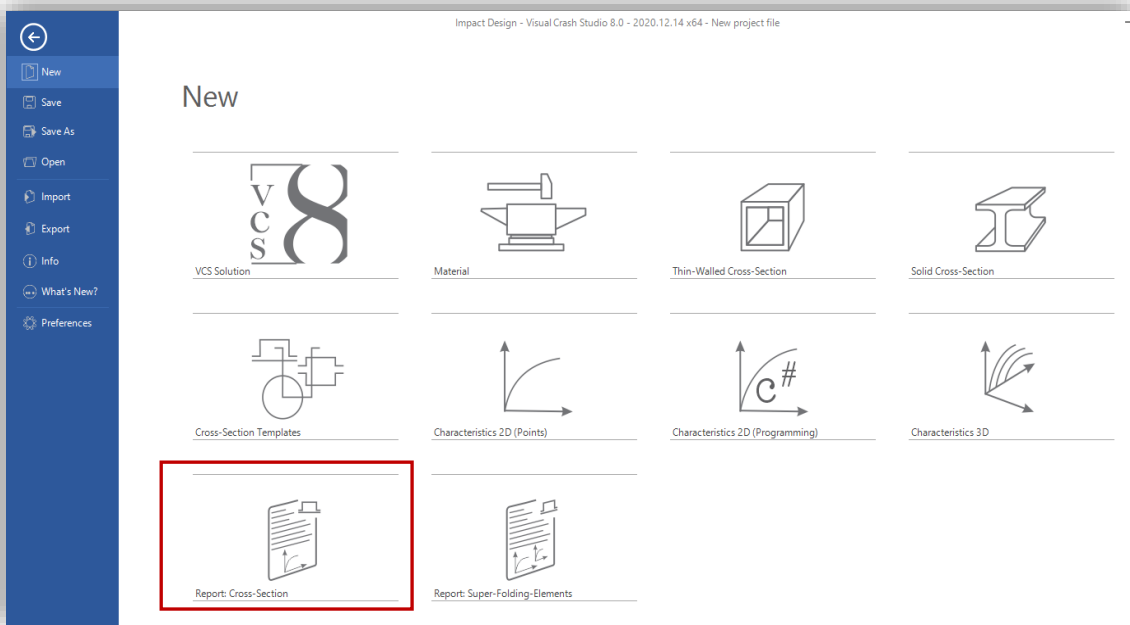
Check all results you wish to compare. Only the chosen series will be displayed in the comparison window. Double click on a selected series to change its color for more efficient comparison.



Results Report - Cross Sections

The command sequence :

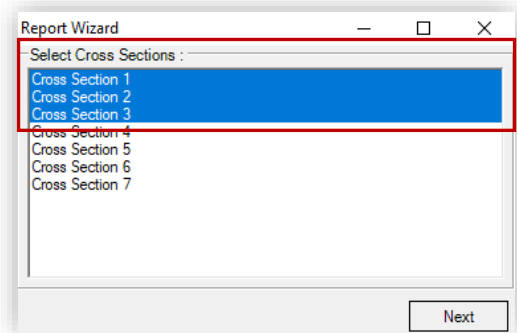
File -> New -> Report: Cross Section leads to opening the VCS Report Wizard which will enable you to automatically create a report of the selected Cross Sections and their results.



Below the procedure of creating a Cross Section Results Report is described (step-by-step).

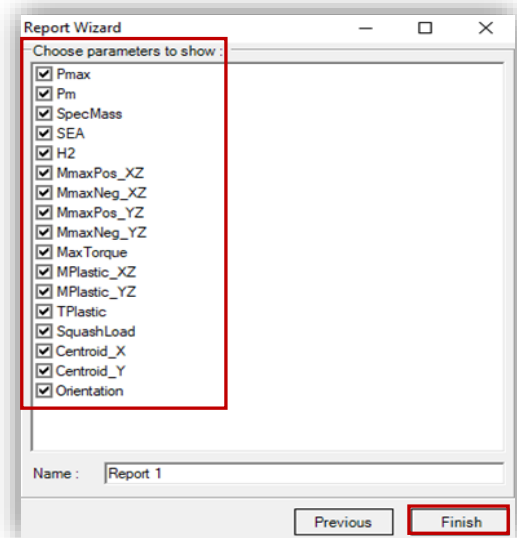
Step 1:

After selecting the "Report: Cross Section" tool a "Report Wizard" window will appear. Select the Cross Sections you wish to include into the report and confirm by Next button.



Step 2:

In the "Report Wizard" select the parameters from the list that will be included into the report. You can also name the created report.



Step 3:

After pressing the "Finish" button a table containing the report of the results of selected Cross Sections will be automatically created. This Report can be easily saved in an XLS format.



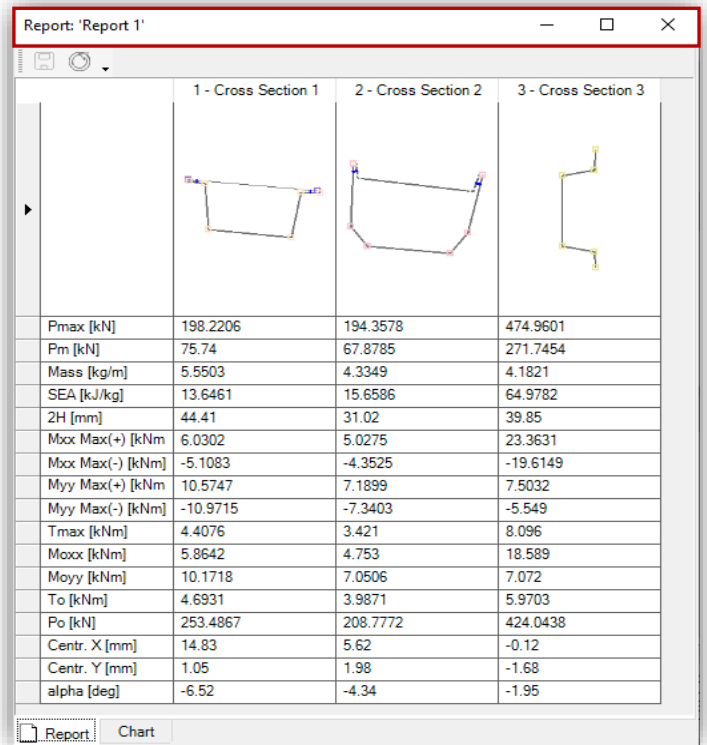
Results Report - Cross Sections

Report is generated in a new window and added to the Solution Explorer Tree.



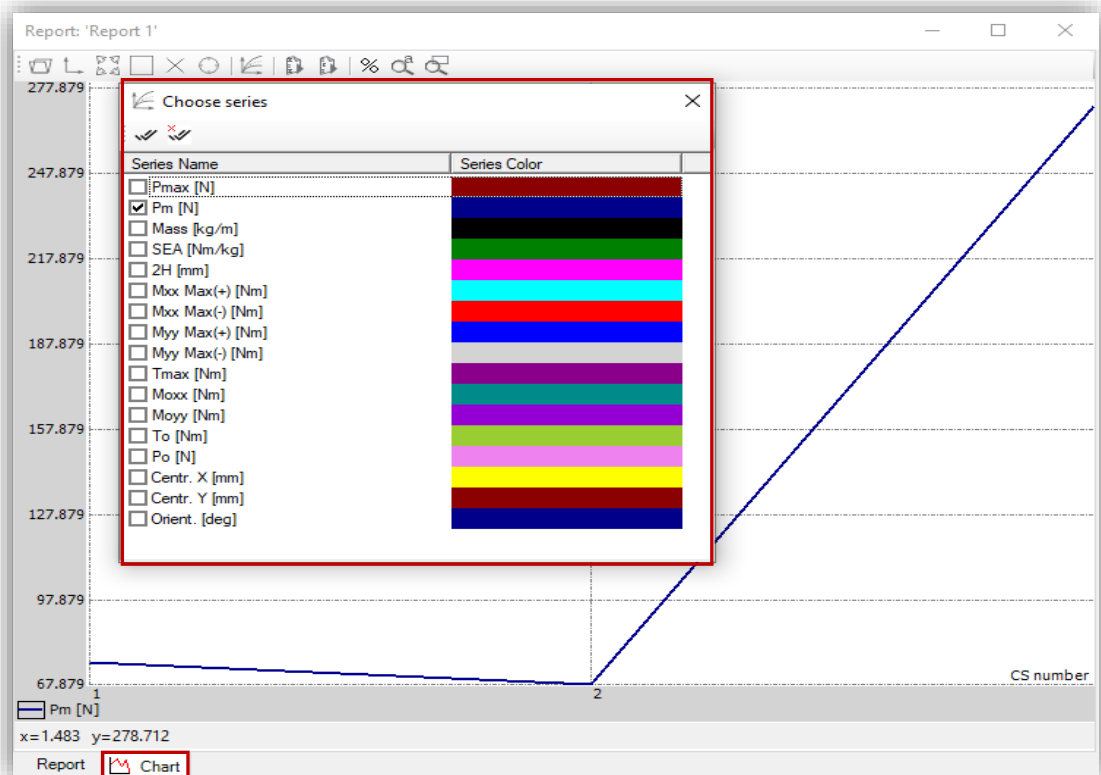
The Report can be easily saved in ".xls" format after clicking on the "Save" icon.

If changes are made to a cross section that belongs to the report, the data can be refreshed.



After clicking on the "Chart" bookmark you will be able to view a graph visualizing the comparison of cross sections (marked here as cross section 1, 2, 3 and so on).

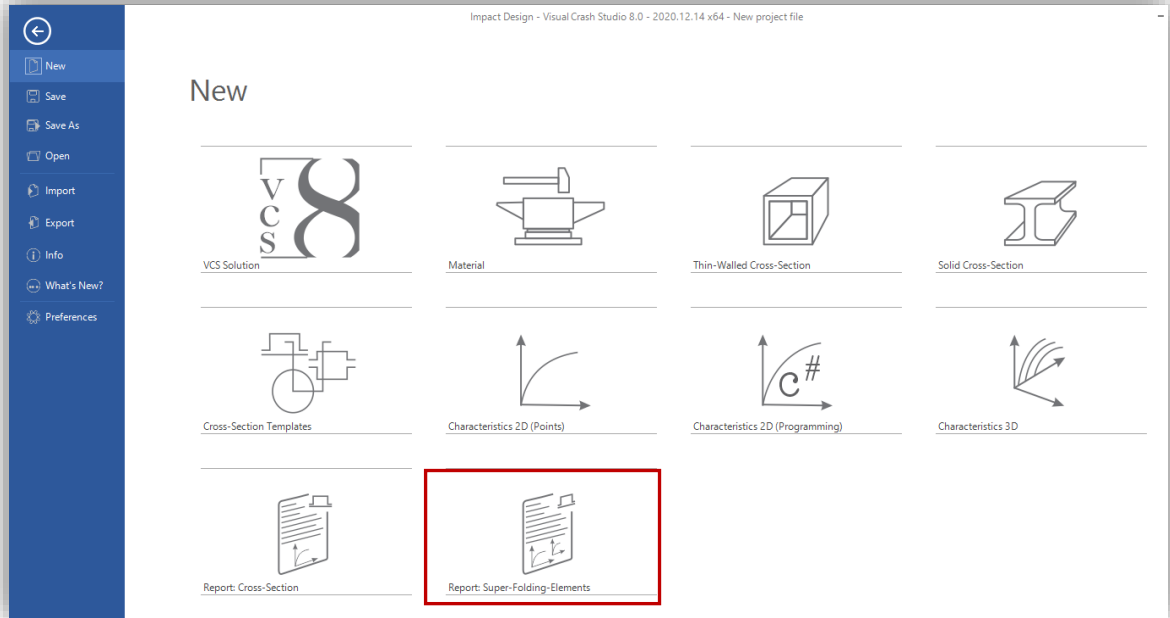
By default, the compared parameter is the Pm [N]. There is however a possibility to change the parameter after clicking on the "Choose series" icon. Note that in the Chart window you can compare several parameters simultaneously.



Results Report - Super Folding Elements

The command sequence :

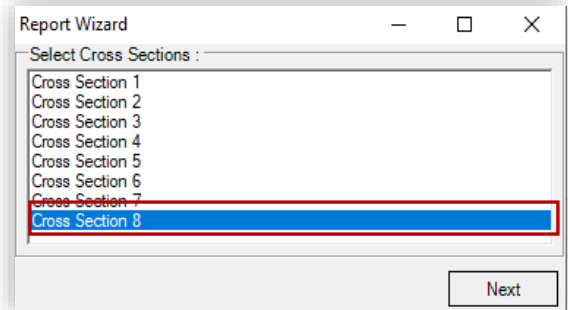
File -> New -> Report: Super-Folding-Elements leads to opening the VCS Report Wizard which will enable you to automatically create a **Summary of Super Folding Element data**.



Below the procedure of creating a Cross Section Results Report is described (step-by-step).

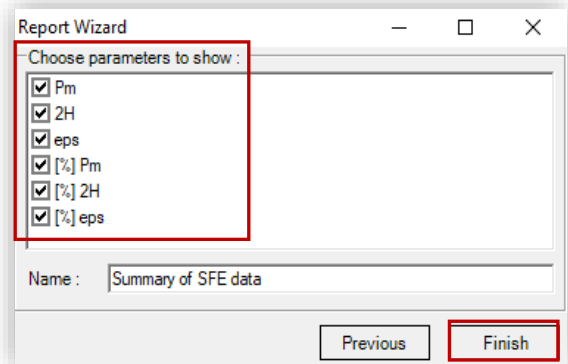
Step 1:

A new "Report Wizard" window will appear in which you can select the Cross Section that will be taken under consideration while creating the Report.



Step 2:

In the next step you are requested to choose which parameters of the Super Folding Elements are to be included in the final Report. You can also define the name of the new Report.



Step 3:

After Clicking on the "Finish" button a new Report - Summary of SFE data will be generated (as illustrated above).

The screenshot shows the 'Report: Summary of SFE data' window. The table contains the following data:

Elem #	Pmax [N] or [kN]	Pm [N] or [kN]	2H [mm]	D [1]	eps max [1]	Def. Mode	Pmax [%]	Pm [%]	2H [%]	eps max [%]
Elem # 0	22.027 [kN]	10.4293 [kN]	31.13 [mm]	0.5298 [1]	0.1789 [1]	Asymmetric_A	11.09 [%]	14.86 [%]	112.34 [%]	74.03 [%]
Elem # 1	17.5422 [kN]	9.7391 [kN]	27.12 [mm]	0.5298 [1]	0.1789 [1]	Asymmetric_A	8.83 [%]	13.87 [%]	97.85 [%]	74.03 [%]
Elem # 2	52.0654 [kN]	20.2131 [kN]	32.52 [mm]	0.7699 [1]	0.26 [1]	Asymmetric_A	26.22 [%]	28.8 [%]	117.36 [%]	107.59 [%]
Elem # 3	30.5433 [kN]	14.3804 [kN]	25.82 [mm]	0.8211 [1]	0.2773 [1]	Symmetric	15.38 [%]	20.49 [%]	93.16 [%]	114.74 [%]
Elem # 4	29.8108 [kN]	14.4251 [kN]	25.23 [mm]	0.8733 [1]	0.2949 [1]	Symmetric	15.01 [%]	20.55 [%]	91.05 [%]	122.03 [%]
Elem # 5	46.6094 [kN]	19.2951 [kN]	30.04 [mm]	0.7699 [1]	0.26 [1]	Asymmetric_B	23.47 [%]	27.49 [%]	108.42 [%]	107.59 [%]

