Engineering Manual No. 4

Update 09/2022

Formwork for concrete bridge

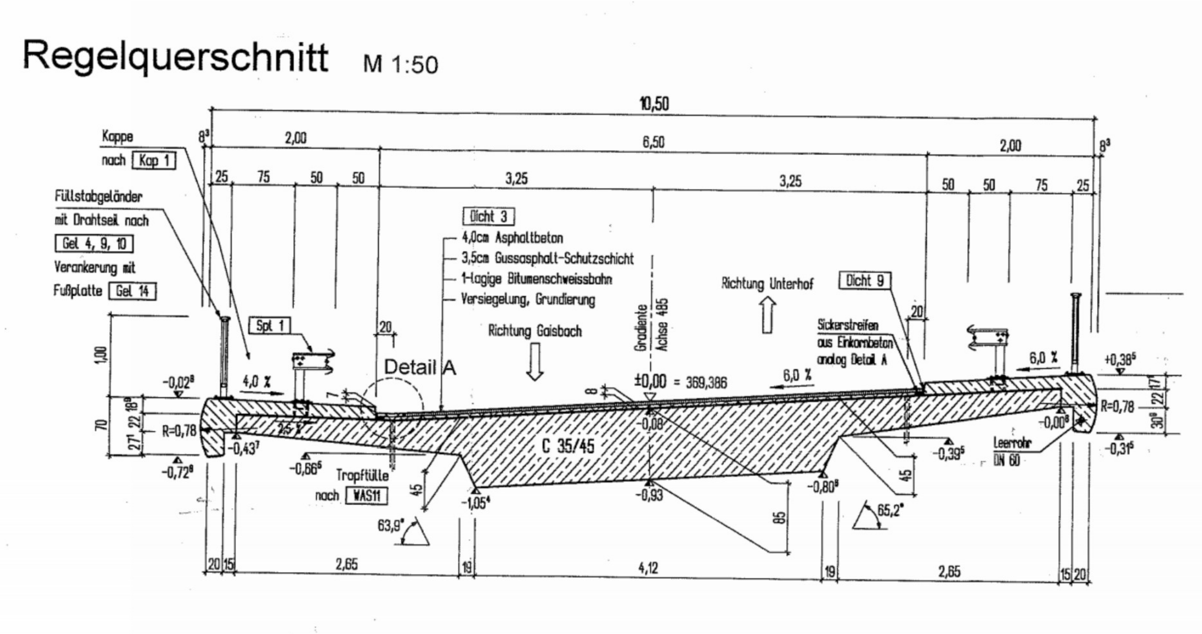
Project description

Program: Truss2D

File(s): FineTrial.trs

Formwork.dxf

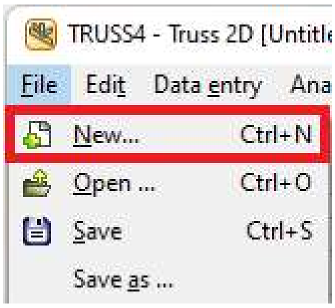
The target of this manual is a step-by-step input guide for a formwork truss. The example was taken from a real bridge project carried out in Germany.



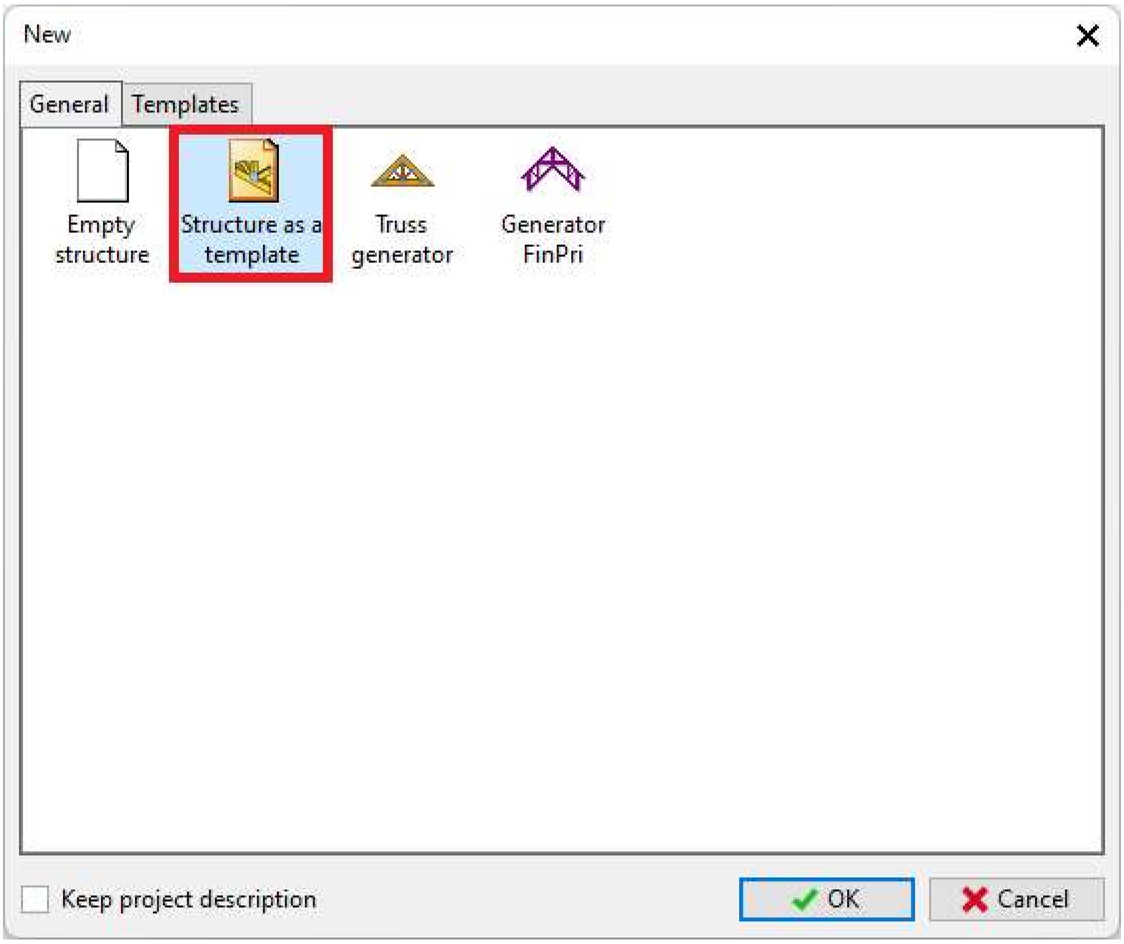
Starting new project

Start Truss2D

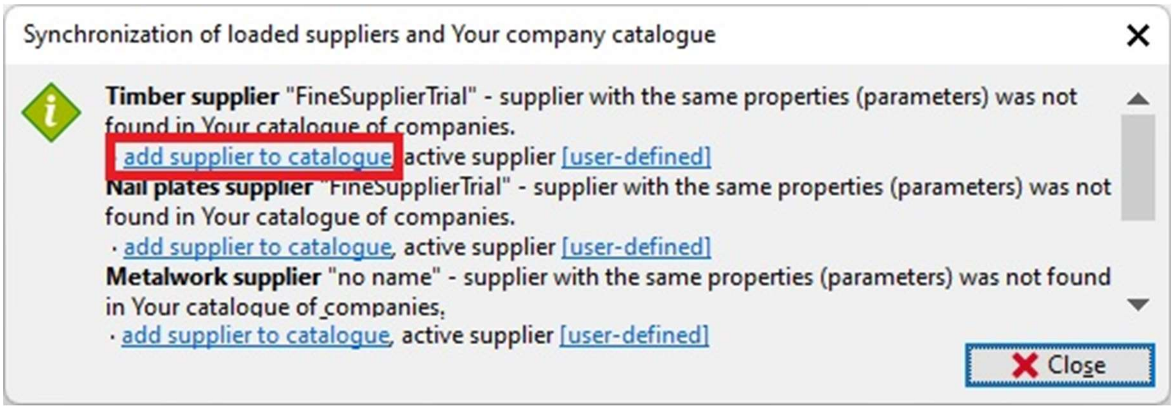
Create new project



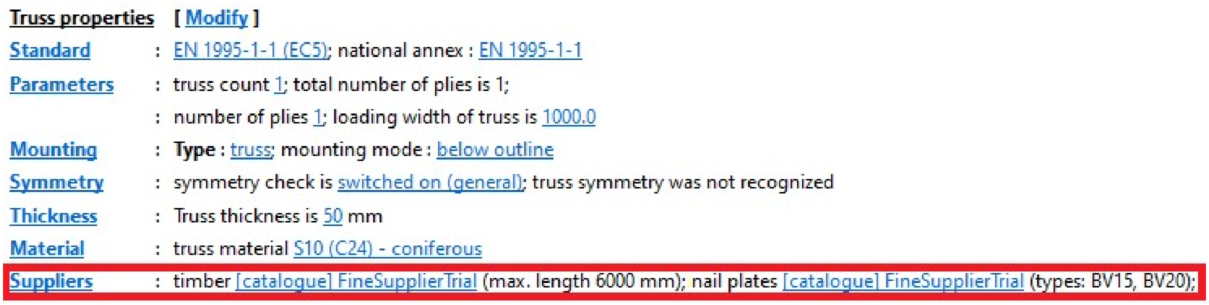
Use FineTrial.trs attached to this engineering manual as template



Add FineSupplierTrial catalogue to your catalogues and confirm by clicking “OK”



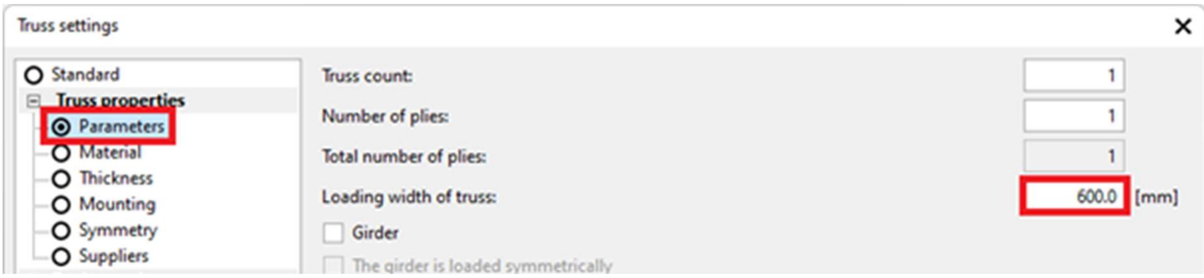
If the window does not appear, it means the catalogue was found, then just check if the timber and nail plates supplier is chosen correctly in “Truss properties”. If not click on the appropriate supplier and change it.



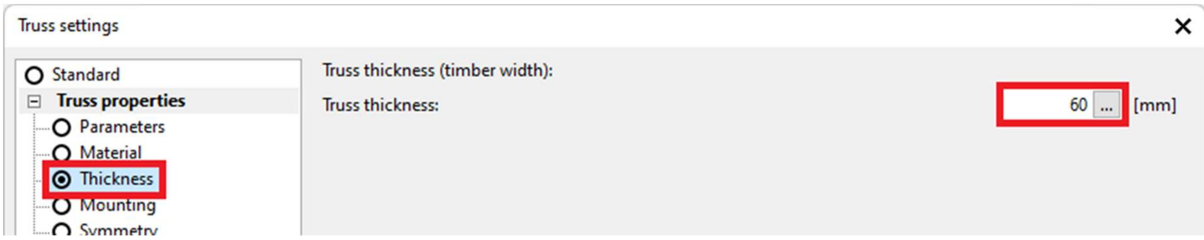
Truss settings

Open Truss settings

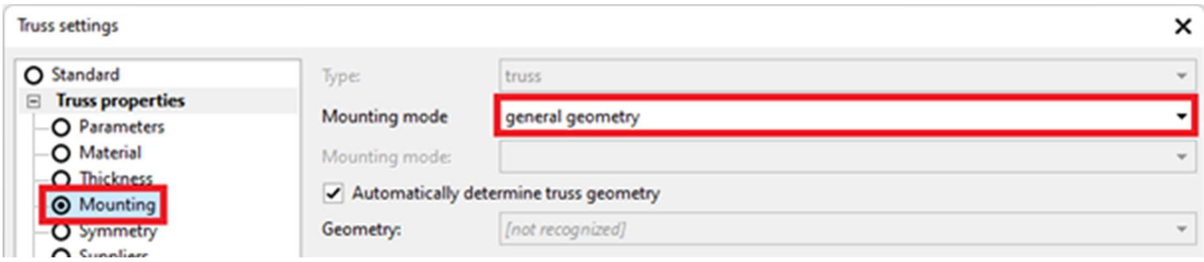
Set loading width to 600 mm



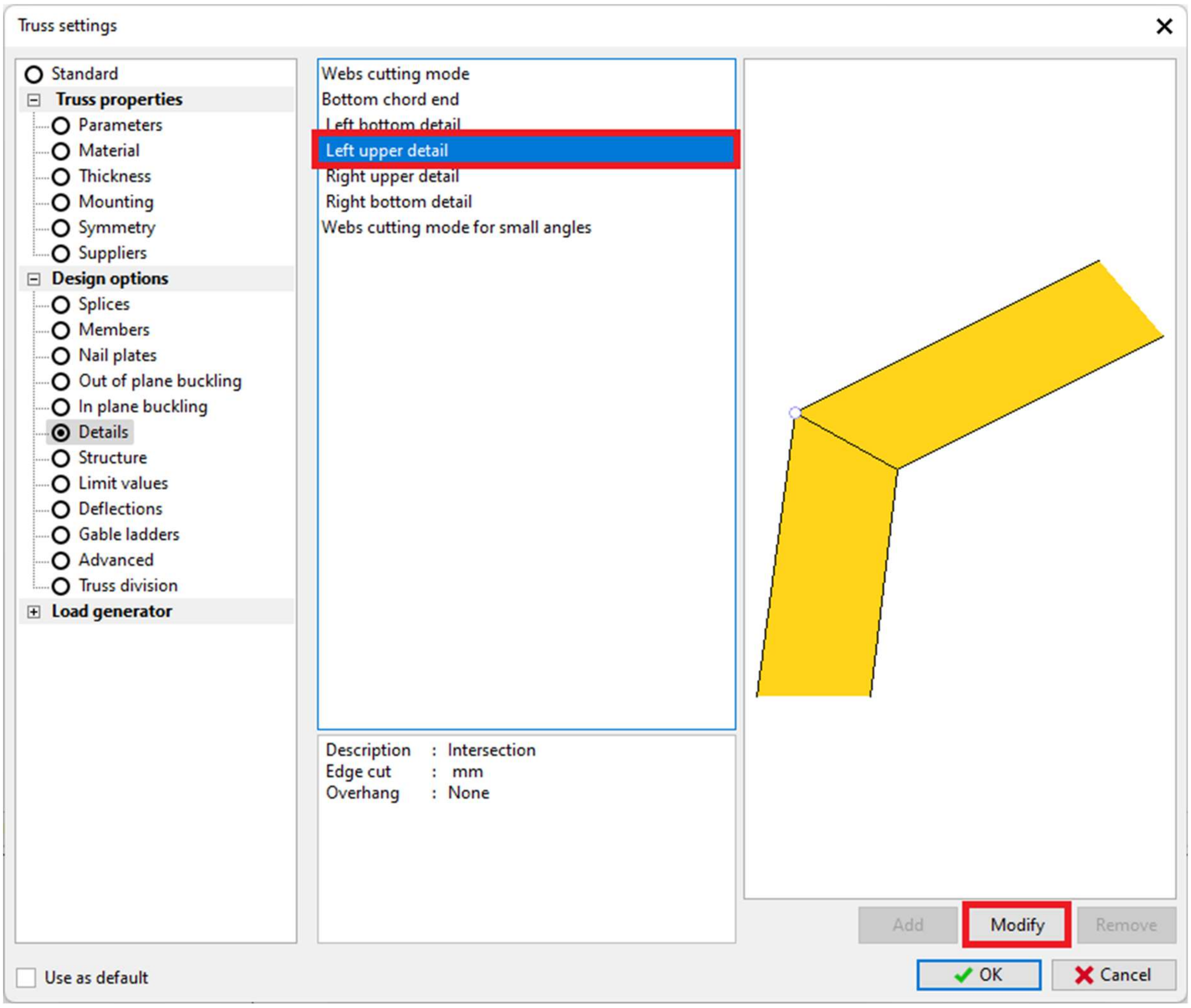
Set truss thickness to 60 mm



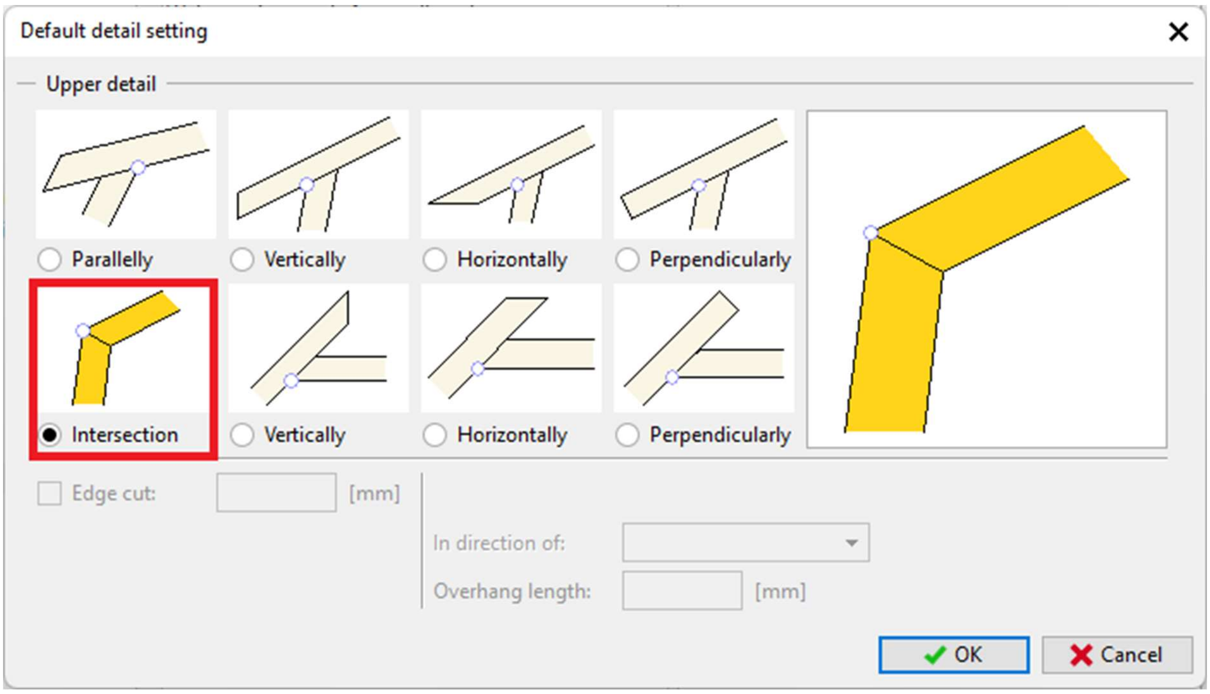
Change mounting to “General”



Choose left upper detail and click the button “Modify”

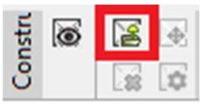


Choose the “Intersection” detail

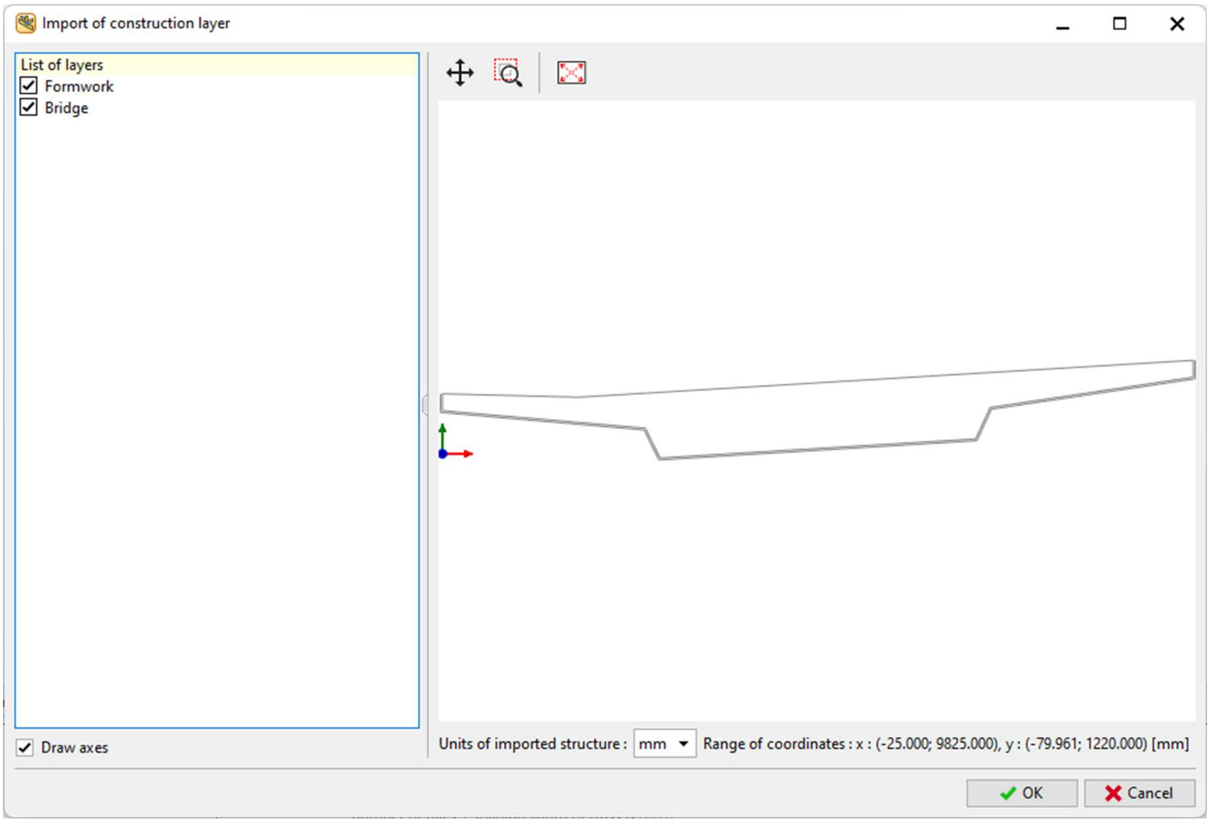


Project input

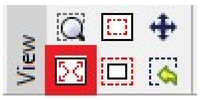
Import the drawing of the bridge´s cross-section by clicking on

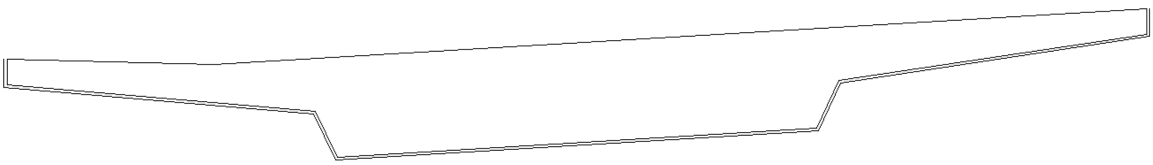


Use Formwork.dxf file attached to this EM. Import window pops up and should be accepted with “OK”. This drawing will be placed as a construction layer in the background of the main workspace window and provides snap points when creating the truss. Note that lines of the construction layer cannot interact with Truss 2D’s drawing functions, such as trim/extend, move, etc.



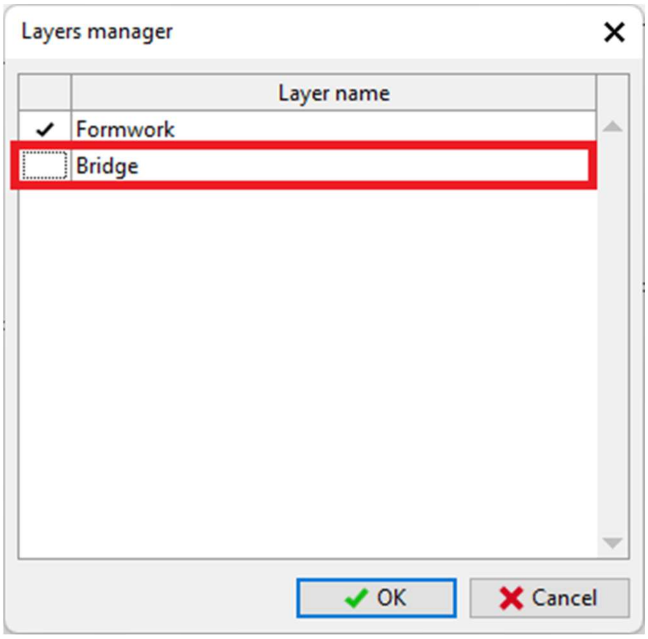
Adjust your view to maximum





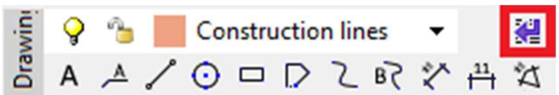
Turn off the bridge layer

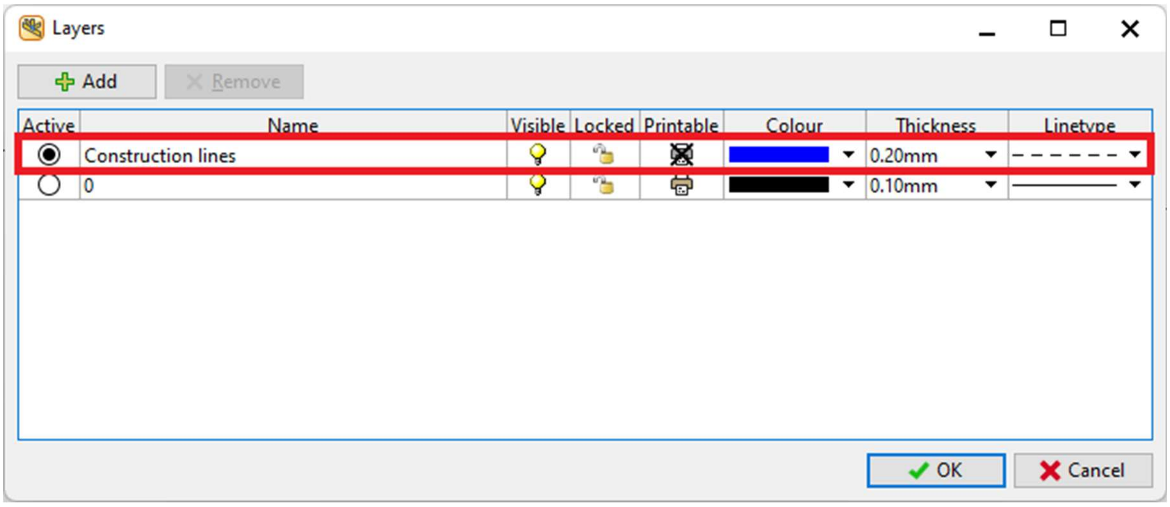
And leave only the “Formwork” layer turned on



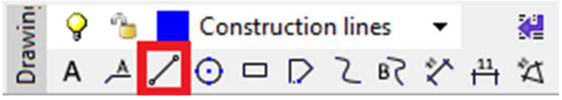
The formwork layer

Change the properties of the construction layer

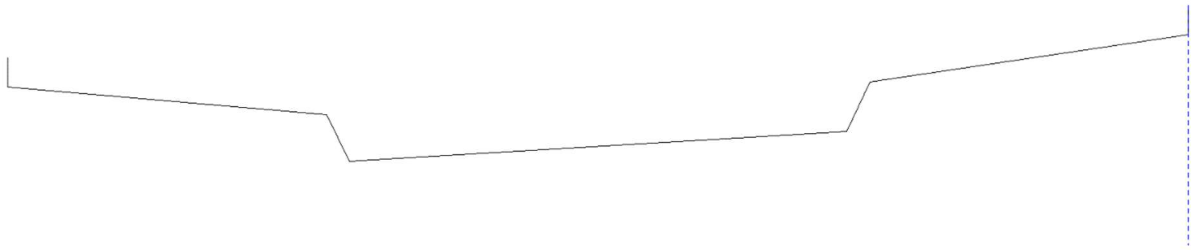




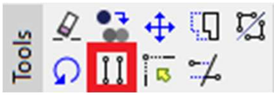
Now draw construction lines that will help us add joints and members. Select the line tool



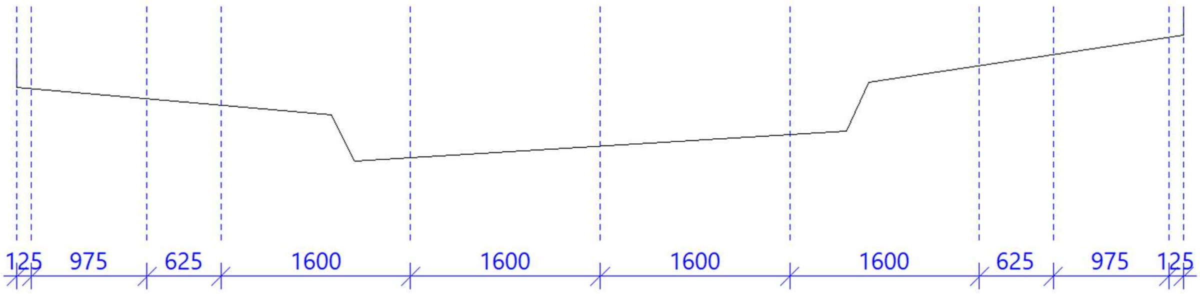
Draw the first line starting on the top right point of the formwork layer and with a length of 2000 mm.



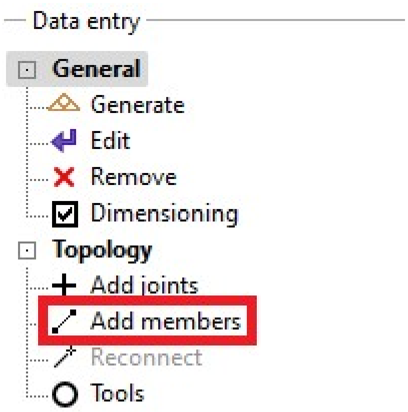
Copy the line by using “Equidistant”



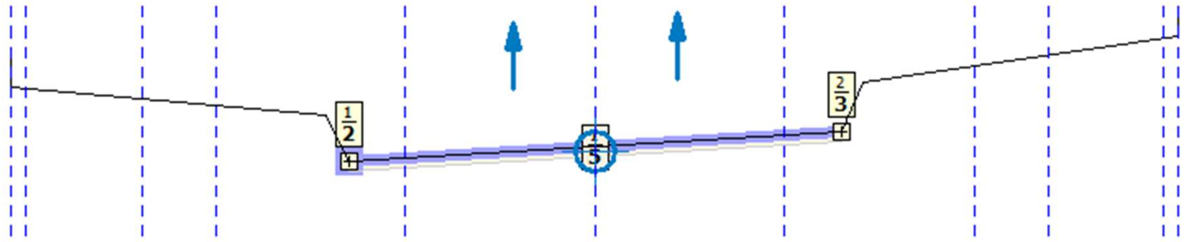
Enter the required length (See the picture below, e.g., 125, 975, 625, 1600...) and click on the line and towards the left direction. Now repeat with the newly created line. Click on it, place your mouse cursor to the left and click.



Select “Add member” from the data entry window on the left

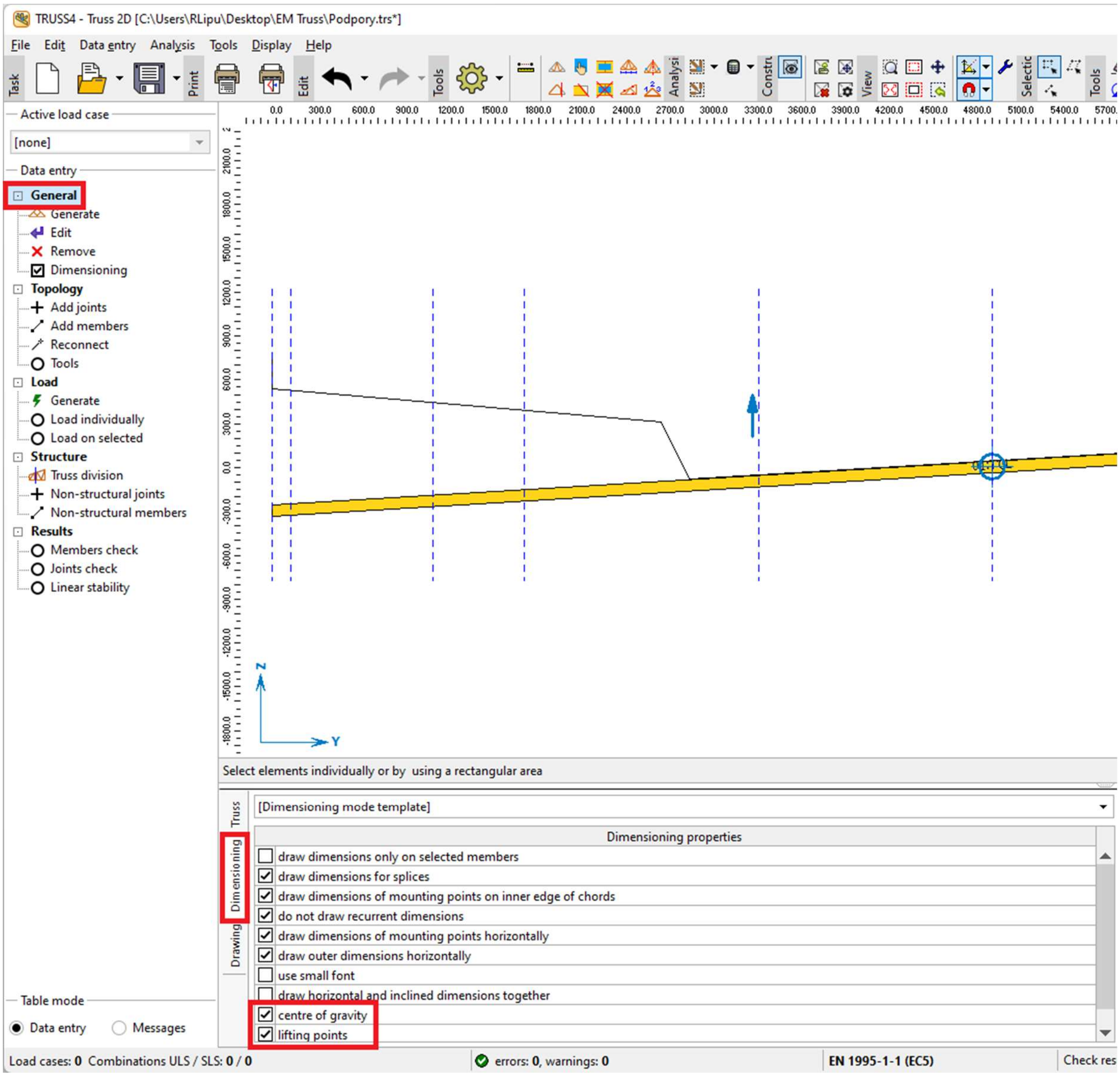


Click on the left end of the lower sloped line, then on the right end. This creates the bottom chord of the truss:

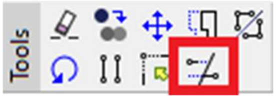


Boxed numbering of the joints and members will appear. There are always two numbers above each other for joints and members. An upper number is a serial number, the lower bold number indicates the type of joint and member, respectively. The joint numbers are placed close to the joints, and the location of the member numbers may vary.

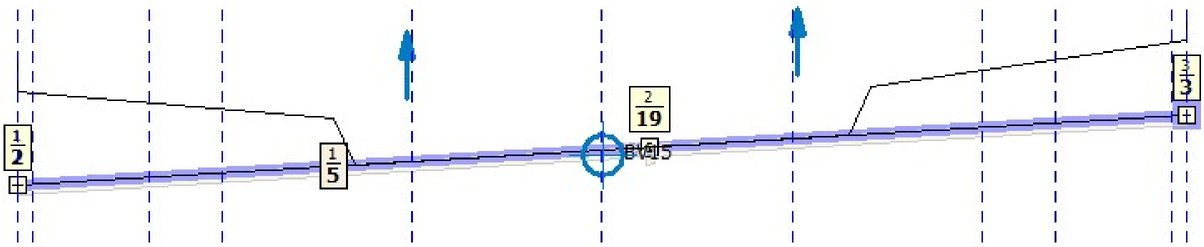
The two blue arrows show the lifting points for the "truss" and the blue circle with the cross indicates the centroid of gravity of the truss. If these shouldn't appear on your screen, tick the following checkboxes. Make sure that "General" is active in the Data entry window.



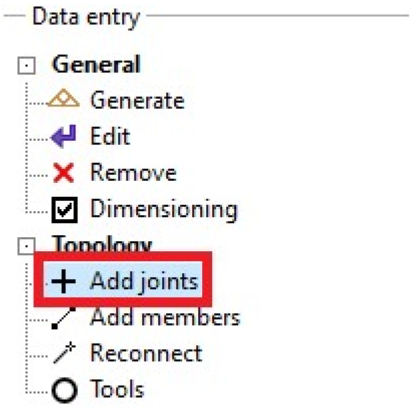
Use Extend/Trim from the CAD-tools menu to extend the bottom chord to the required length, which will be defined by the two vertical drawing lines.



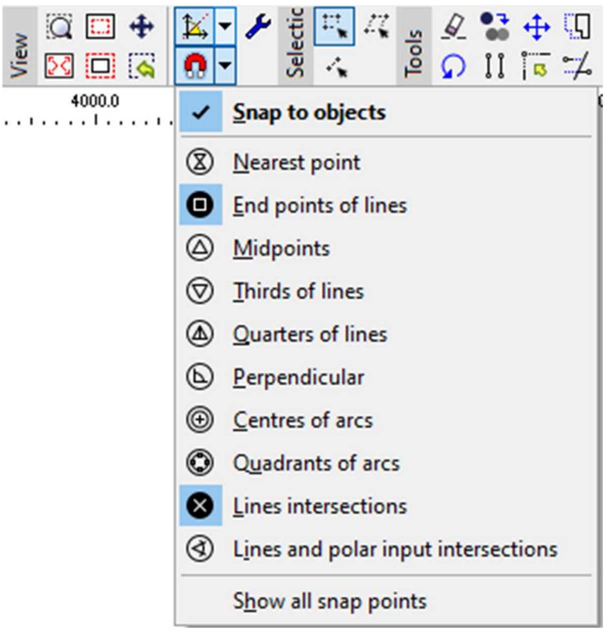
First click on the left vertical construction line to select to where the bottom chord shall be extended, then click on the bottom chord. Repeat for the other side, first click on the function Extend/Trim again, then on the right vertical construction line, and finally on the bottom chord.



Adding supports

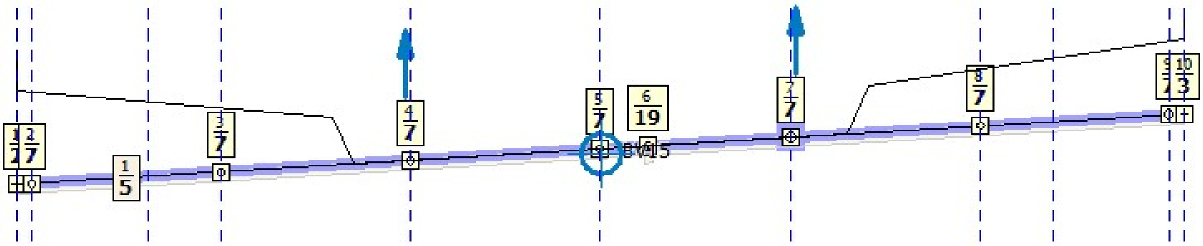


Change the snap points



TRUSS4

Zoom into the area where you want to place the joint by using the mouse wheel, click on the intersection point of the structural line and the upper edge of the bottom chord and repeat for the other points. Your joints should look like this:



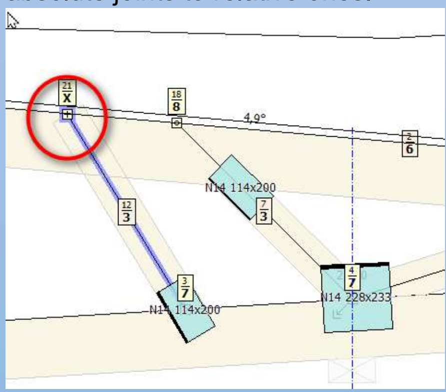
These joints will be turned into supports for the truss in a later step. It is easier to add them before the entire truss geometry has been created, as the drawing is clearer now. Joints can either be absolute or relative. Absolute joints have a fixed position in the coordinates system, relative joints can be moved in a simple way along members between two absolute joints. They also will move automatically if the coordinates of an absolute joint are changed.

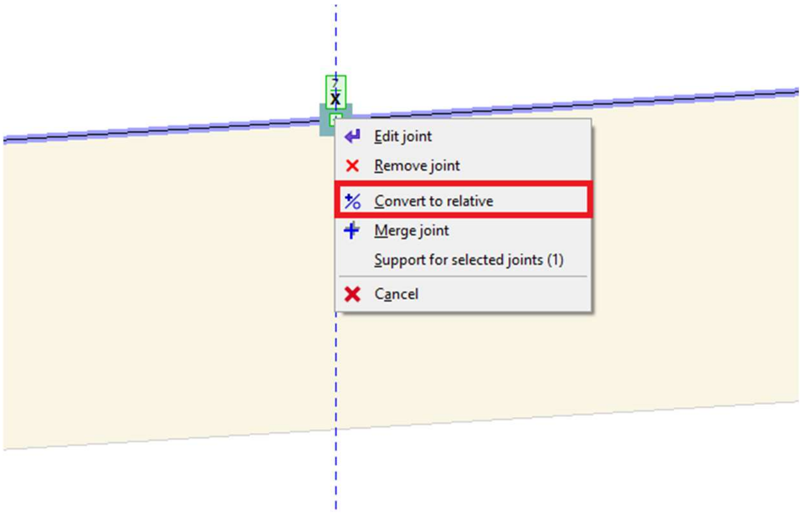
If any of the newly added joints turned out to be absolute, right-click on it and convert it to a relative.

If you miss a point that you want to click on, you can either cancel the function while it hasn't been finalized or click on "Undo" or use <CTRL+Z>. 

Note:

Webs must be connected through a relative joint to a chord (main member), otherwise no plate will be positioned automatically on such a joint. Change such unwanted absolute joints to relative ones.



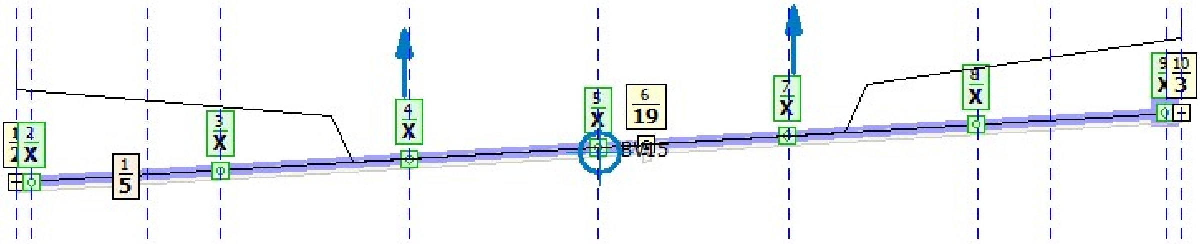


Your table of joints should look like this:

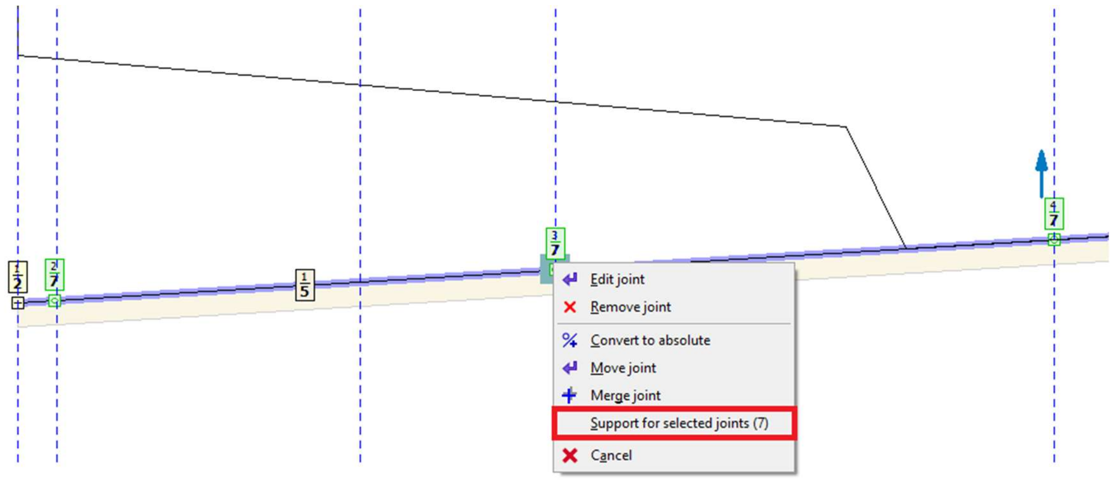
Number	Input style	Coordinates Y [mm]	Coordinates Z [mm]
1	abs.	-25,0	-252,2
2	rel. to 1; 125,2mm from prim.j., in axis 1	100,0	-244,7
3	rel. to 1; 1728,1mm from prim.j., in axis 1	1700,0	-148,0
4	rel. to 1; 3331,1mm from prim.j., in axis 1	3300,0	-51,3
5	rel. to 1; 4929,2mm from prim.j., in axis 1	4895,2	45,1
6	rel. to 1; 5334,7mm from prim.j., in axis 1	5300,0	69,6
7	rel. to 1; -3335,9mm from end j., in axis 1	6495,2	141,8
8	rel. to 1; -1733,0mm from end j., in axis 1	8095,2	238,5
9	rel. to 1; -130,1mm from end j., in axis 1	9695,2	335,2
10	abs.	9825,0	343,1

Make the intermediate joints special supports with vertical spring properties of 2,0 MN/m.

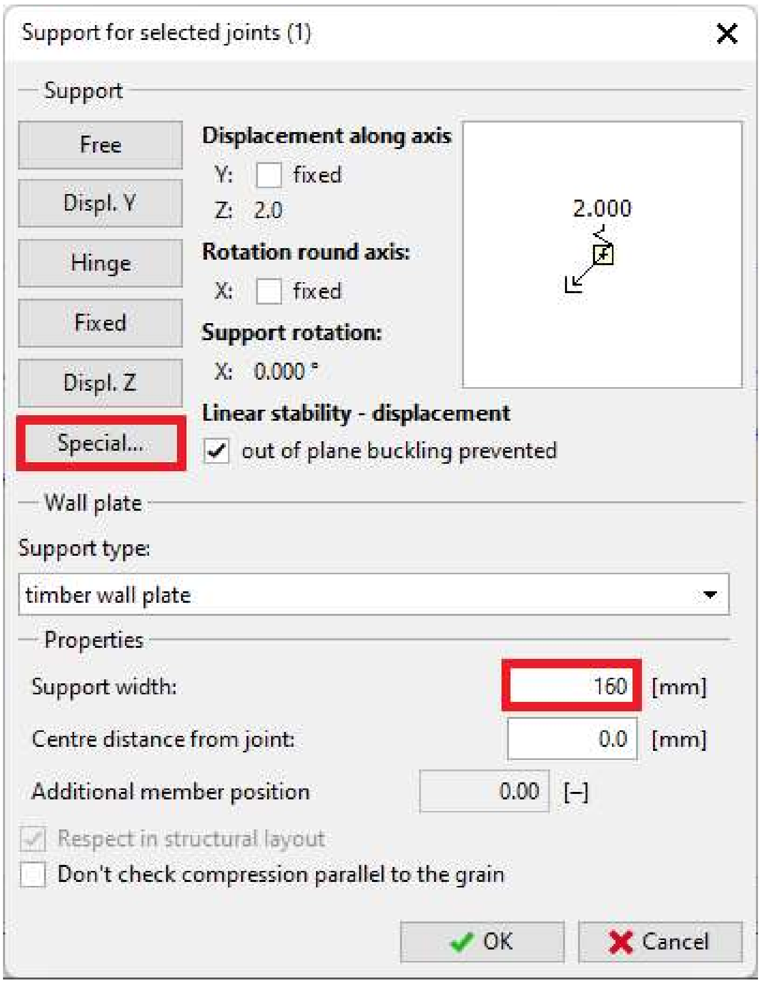
Hit the <ESC>-key to end any other functions. Select joints 2 to 5 and 7 to 9 within the table using Windows functionality (i.e. hold down the <Shift> key, klick on joint No.2, then on joint No. 5. Repeat the same procedure for joints No.7 and No.9). These relative joints should be selected and displayed in green colour.



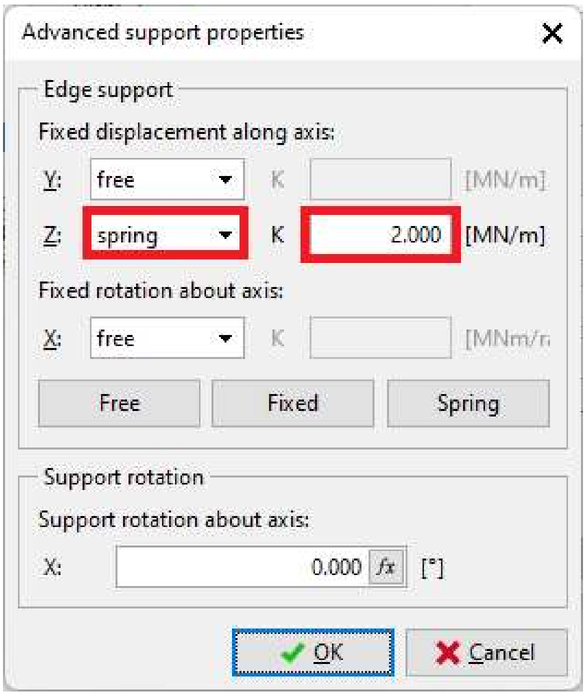
Right mouse click on any of the selected joints, select “Support for selected joints” from the context menu



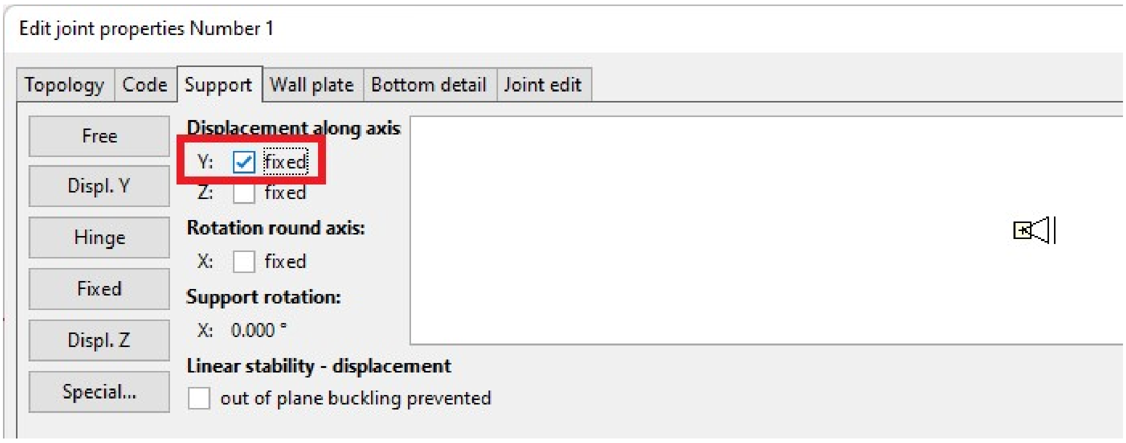
Change the support width to 160mm



Select “Special…” in the dialog and specify the spring properties as shown.



Edit joint no 1 and make it a horizontal support. Right mouse click on that joint, select “Edit joint” from the context menu, switch to the “Support” tab and check Y: fixed.



Hit <ESC> to deselect all objects.

Joint table with coordinates and support indicators

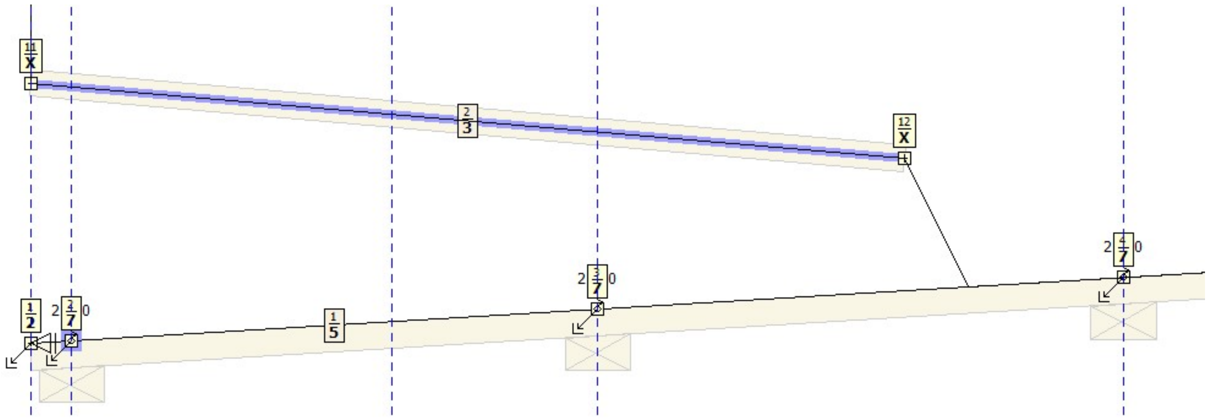
Joints | Members

Number	Input style	Coordinates Y [mm]	Z [mm]	Support P_Y	P_Z	O_X
1	abs.	-25.0	-252.2	✓		
2	rel. to 1; 125.2mm from prim.j., in axis 1	100.0	-244.7		✓	
3	rel. to 1; 1728.1mm from prim.j., in axis 1	1700.0	-148.0		✓	
4	rel. to 1; 3331.1mm from prim.j., in axis 1	3300.0	-51.3		✓	
5	rel. to 1; 4929.2mm from prim.j., in axis 1	4895.2	45.1		✓	
6	rel. to 1; 5334.7mm from prim.j., in axis 1	5300.0	69.6			
7	rel. to 1; -3335.9mm from end j., in axis 1	6495.2	141.8		✓	
8	rel. to 1; -1733.0mm from end j., in axis 1	8095.2	238.5		✓	
9	rel. to 1; -130.1mm from end j., in axis 1	9695.2	335.2		✓	
10	abs.	9825.0	343.1			

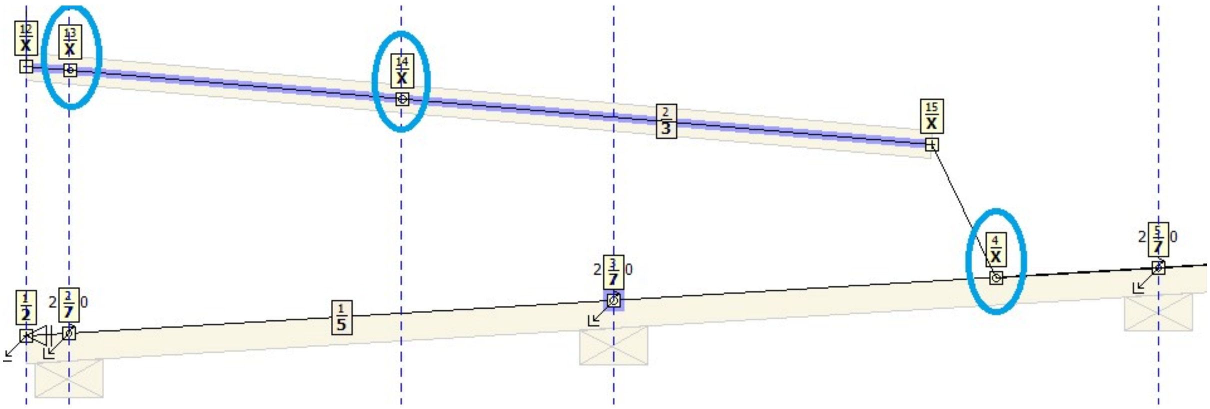
Adding the other members

We will add some more members (chords) which will describe the contour of the concrete cross-section and some diagonal and vertical webs to hold these chords and minimize their deflections.

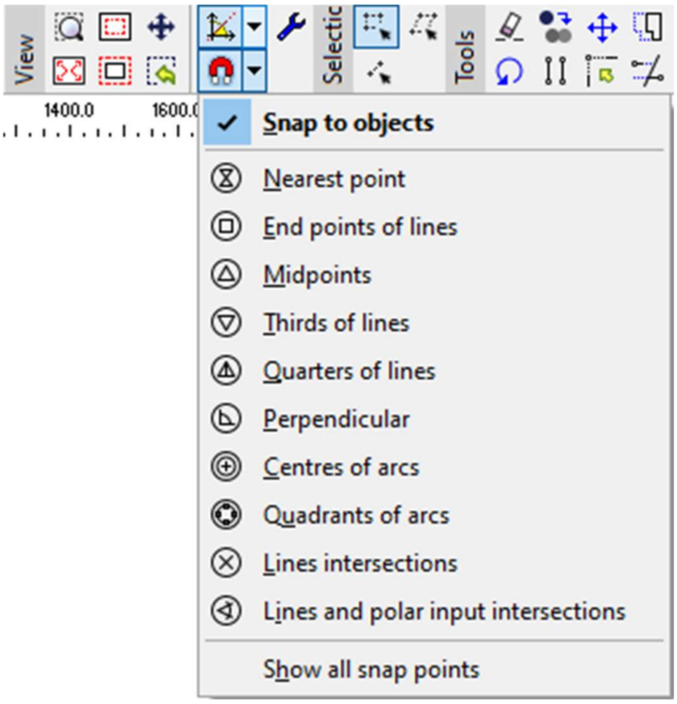
Zoom in the left part of the truss and add members that describe the contour of the cross-section. Use the lines that represent the framework, it will look like this



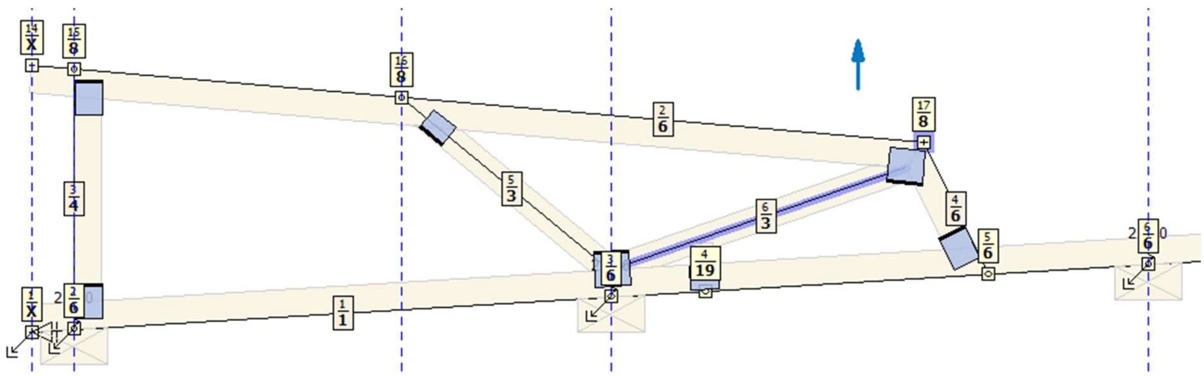
Continue by adding points that will connect top and bottom chords. All of these points have to be relative, in case they will turn absolute convert them to relative position.



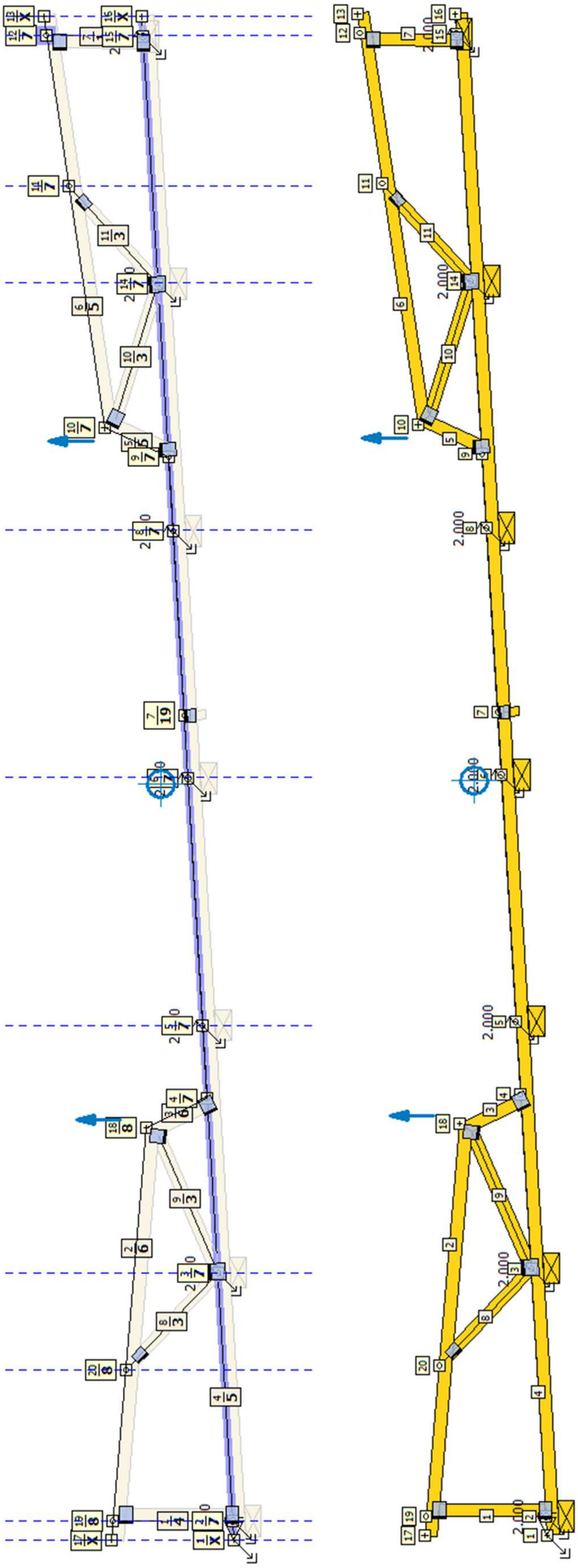
Before adding more members keep only snapping to objects which will ensure that you will click precisely on the required joint



Create members between joints 2-15, 17-5, 16-3, 3-17

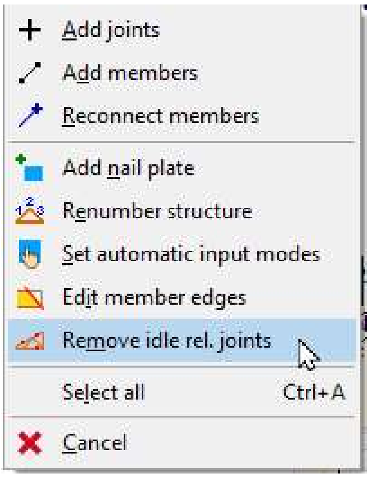


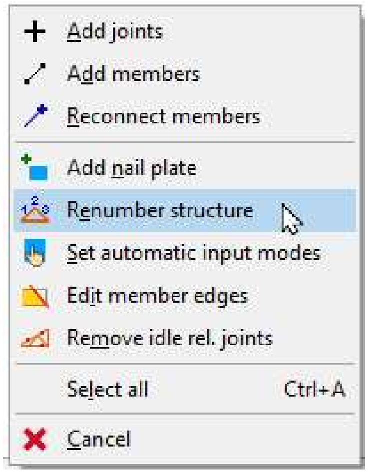
Your final structure should look like this



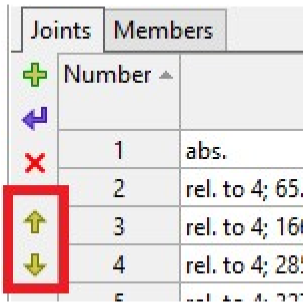
The entering of the truss geometry is completed.

In order to have the same numbering for joints and members, we do the following:
Right mouse click in the free workspace and call the function “Remove idle rel. joints” from the context menu. Then right mouse click again and select “Renumber structure”.





If the renumbering didn’t give you the same results, adjust the numbering manually with the “Arrow” buttons in order to get the same result as the tables below. It is not necessary to have the same numbering, however in order to smoothly follow the tutorial it is strongly suggested to do so.



Joints – Numbers and coordinates

Number	Input style	Y [mm]	Z [mm]	P_Y	P_Z	O_X
1	abs.	-25.0	-252.2	✓		
2	rel. to 4; 125.2mm from prim.j., in axis 1	100.0	-244.7		✓	
3	rel. to 4; 1728.1mm from prim.j., in axis 1	1700.0	-148.0		✓	
4	rel. to 4; 2855.1mm from prim.j., in axis 1	2824.9	-80.0			
5	rel. to 4; 3331.1mm from prim.j., in axis 1	3300.0	-51.3		✓	
6	rel. to 4; 4929.2mm from prim.j., in axis 1	4895.2	45.1		✓	
7	rel. to 4; 5334.7mm from prim.j., in axis 1	5300.0	69.6			
8	rel. to 4; -3335.9mm from end j., in axis 1	6495.2	141.8		✓	
9	rel. to 4; 7014.2mm from prim.j., in axis 1	6976.4	170.9			
10	abs.	7167.0	582.3			
11	rel. to 6; 1575.2mm from prim.j., in axis 1	8725.0	814.5			
12	rel. to 6; 2561.0mm from prim.j., in axis 1	9700.0	959.9			
13	abs.	9825.0	978.5			
14	rel. to 4; -1733.0mm from end j., in axis 1	8095.2	238.5		✓	
15	rel. to 4; -130.1mm from end j., in axis 1	9695.2	335.2		✓	
16	abs.	9825.0	343.1			
17	abs.	-25.0	540.1			
18	abs.	2633.8	311.3			
19	rel. to 2; 125.5mm from prim.j., in axis 1	100.0	529.3			
20	rel. to 2; 1104.1mm from prim.j., in axis 1	1075.0	445.4			

TRUSS4

Members – primary and secondary joints, member lengths

Joints | Members

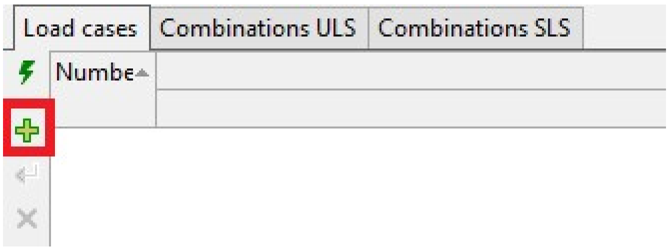
Number	Joint first	Joint primary	Joint secondary	Joint end	Length [mm]	Rotation [°]	Cross-section
1	2	2	19	19	774.0	90.000	60 x 80
2	17	17	18	18	2668.6	-4.918	60 x 80
3	18	18	4	4	435.5	-63.970	60 x 80
4	1	1	16	16	9868.0	3.459	60 x 80
5	9	9	10	10	453.4	65.142	60 x 80
6	10	10	13	13	2687.4	8.478	60 x 80
7	15	15	12	12	624.7	89.557	60 x 80
8	20	20	3	3	861.8	-43.516	60 x 80
9	3	3	18	18	961.6	23.503	60 x 80
10	10	10	14	14	914.8	-17.233	60 x 80
11	14	14	11	11	853.5	42.445	60 x 80

Creating load cases, load case combinations, and loads

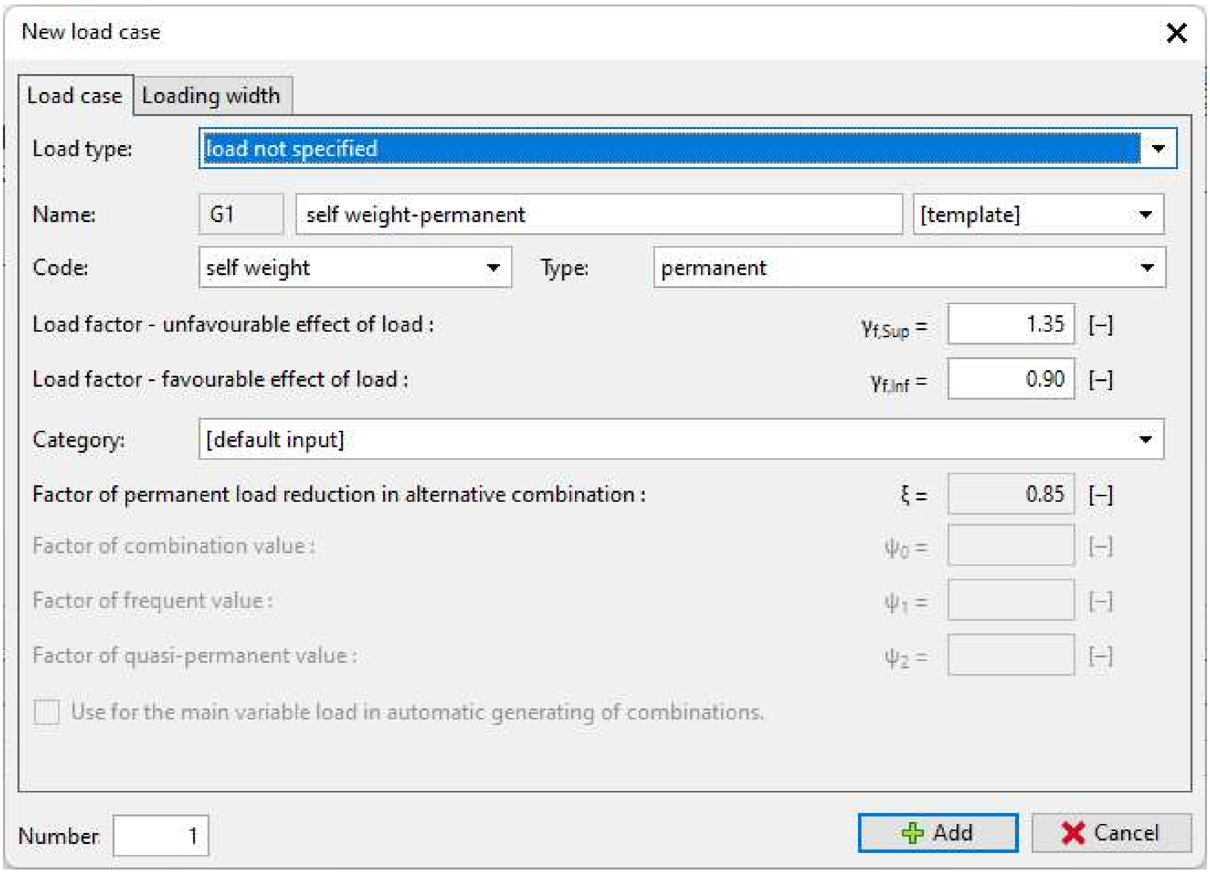
Generally, for creating loads, load cases, and load case combinations, the load's dialog can be used by clicking on the green flash "Generate" in the Data entry window Generate . This does not work for irregular shapes such as this formwork truss.

In the first step, we will create three load cases: self-weight, concrete load, and working load. Then we generate combinations for ULS (ultimate limit state) and SLS (serviceability limit state). Finally, we apply loads to different members.

Select "Load" from the Data entry window. Hit [+] in the table window with the Load cases" tab being active.

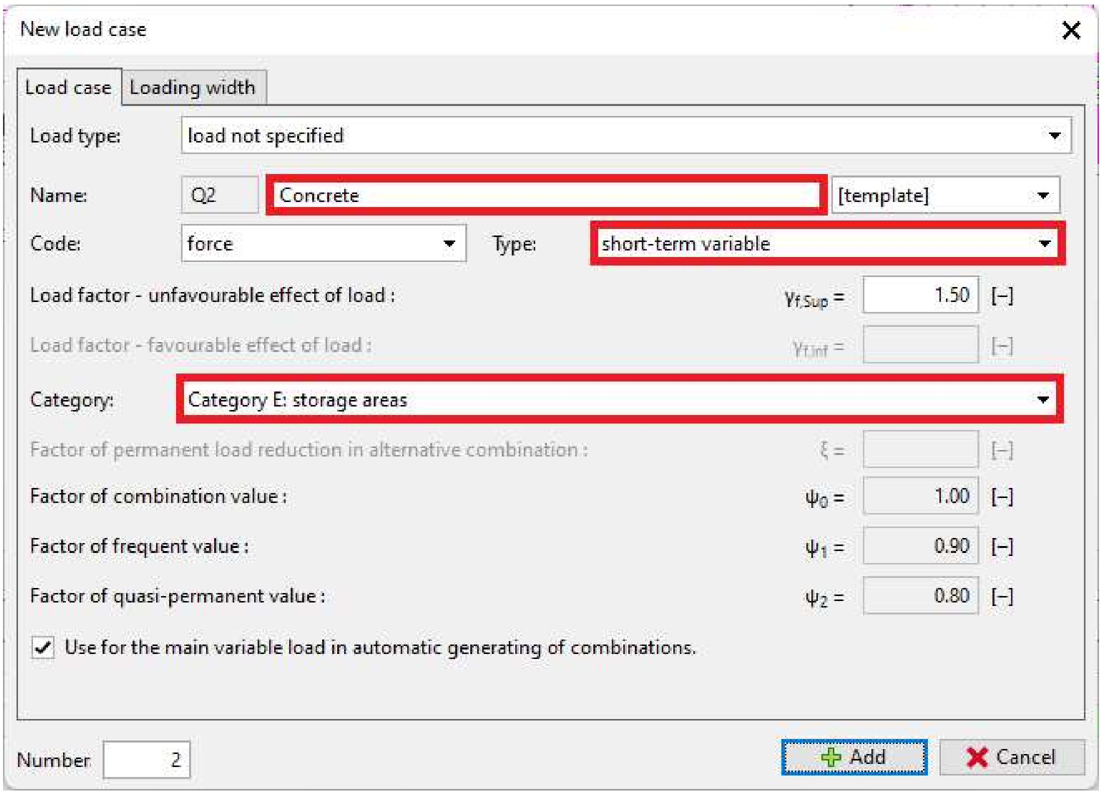


The first load case is self-weight.

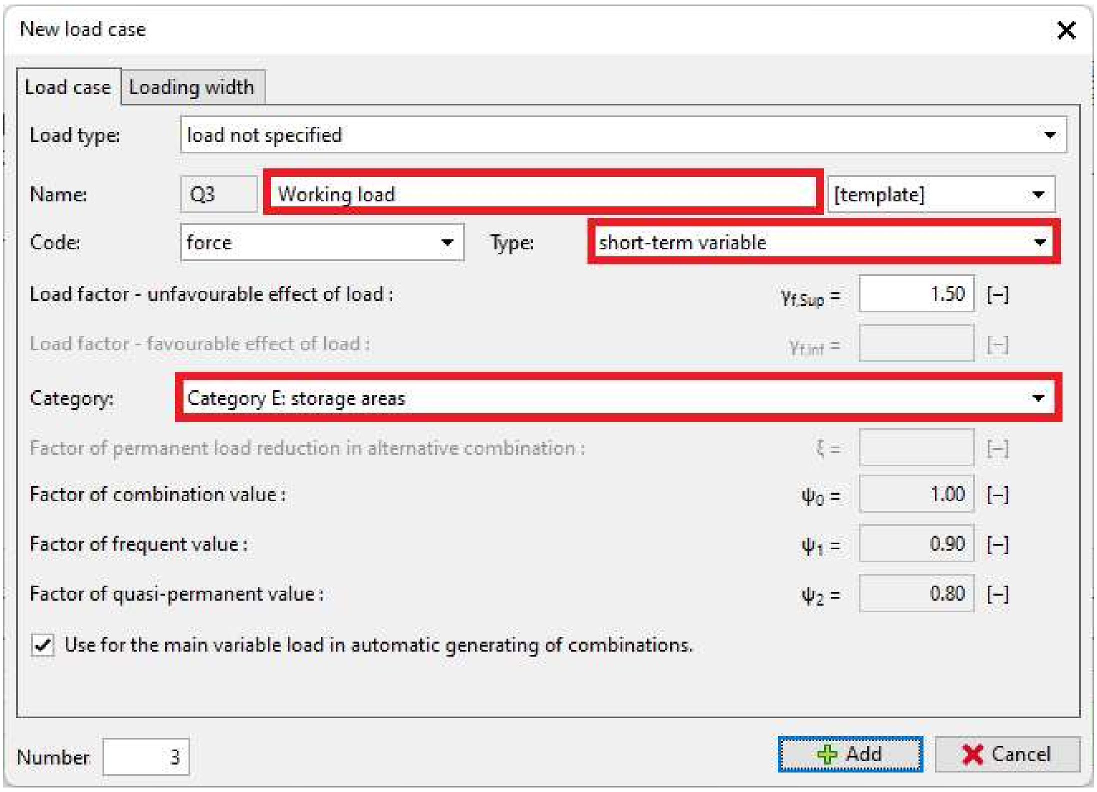


Click on Add, and continue defining two more load cases.

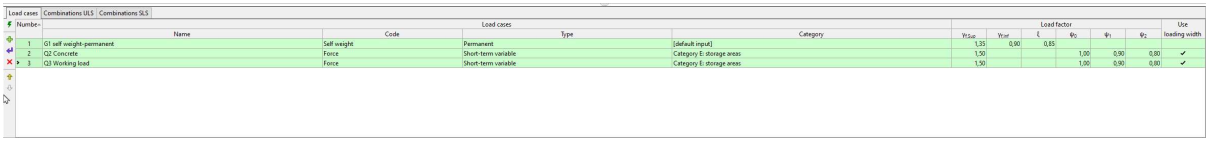
Type “Concrete” as the name of this load case Q2 and select short-term variable and Category E: storage areas.



Add a third load case Q3 called “Working load”, being the same type and category. Hit “Add” again then “Cancel” to close the dialog window.

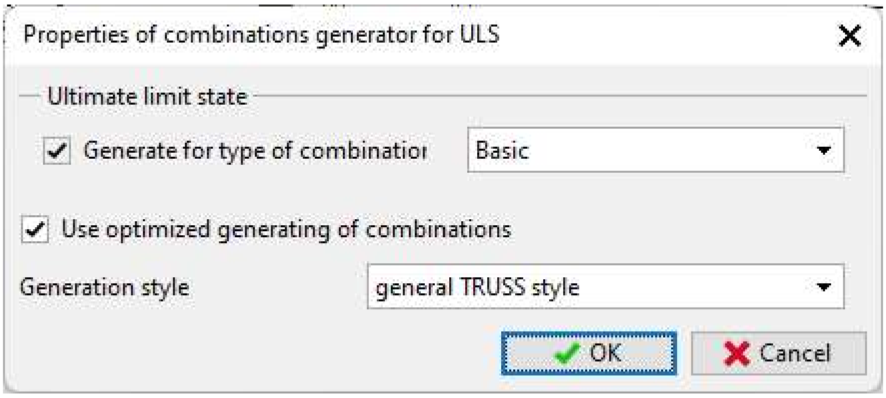


The table window shows 3 load cases, one permanent and two short-term.

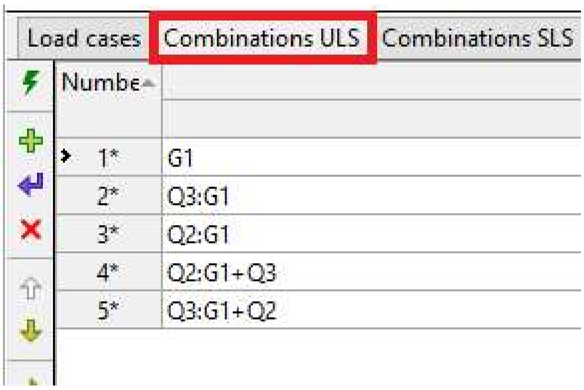


Number	Name	Code	Type	Category	$\gamma_{f,Sup}$	$\gamma_{f,inf}$	ξ	ψ_0	ψ_1	ψ_2	Use loading width
1	G1 self weight-permanent	Self weight	Permanent	[default input]	1,35	0,90	0,85				
2	Q2 Concrete	Force	Short-term variable	Category E: storage areas	1,50			1,00	0,90	0,80	✓
3	Q3 Working load	Force	Short-term variable	Category E: storage areas	1,50			1,00	0,90	0,80	✓

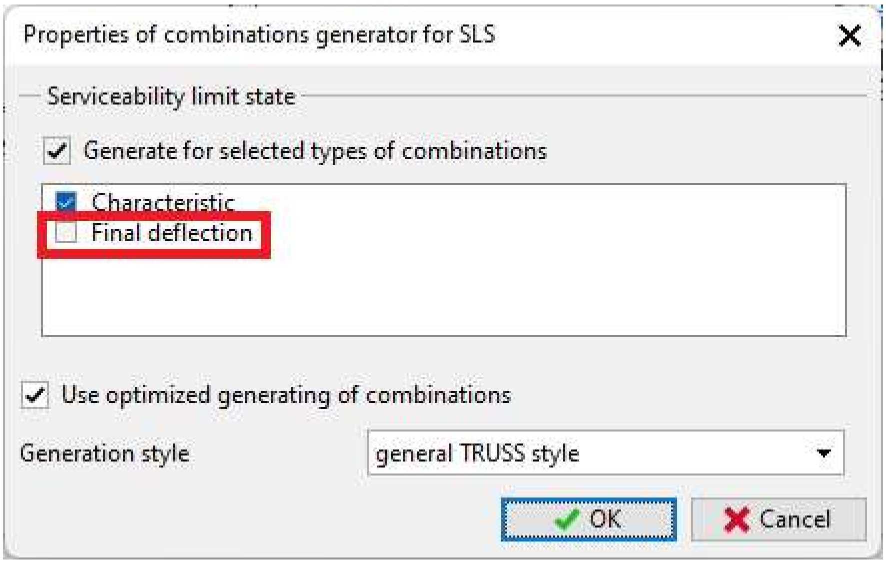
Click on the tab “Combinations ULS” next to the tab “Load cases”, then on the green flash  to create all load combinations for the ultimate limit state (strength). Confirm and close the dialog with “OK”.



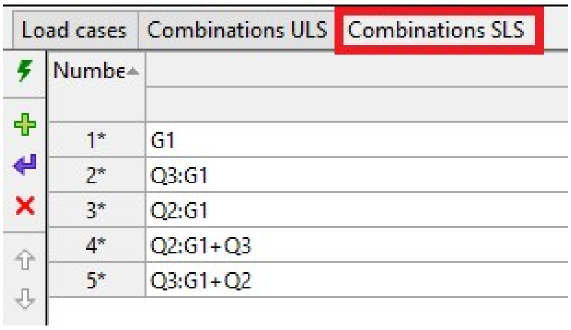
The program generated five load combinations, one with permanent load only, and the other four combinations of the permanent and short-term load cases.



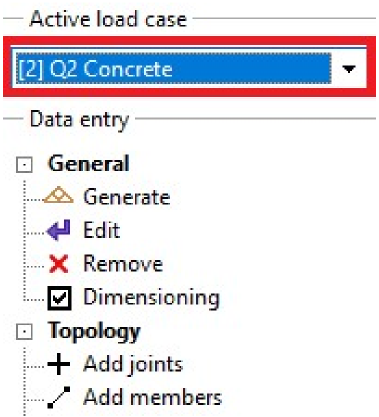
Switch to the tab “Combinations SLS” and click on the green flash again to generate all load combinations for the serviceability limit state (deflections). Remove the check from “Final deflection” as the load is not acting long enough upon the truss to cause any long-term deflection effects.



Five load combinations were generated by the program



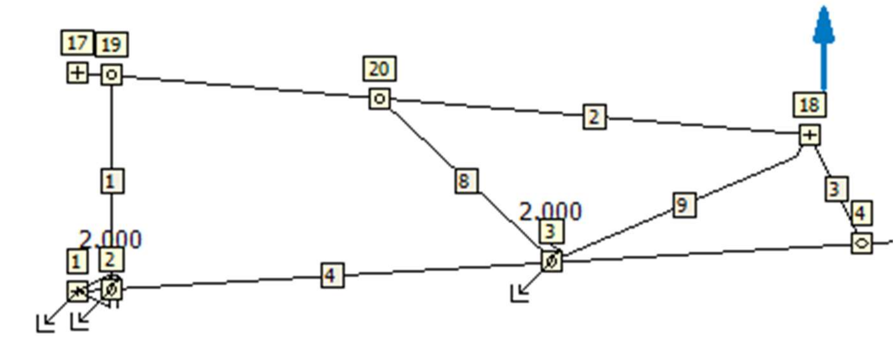
In the “Active load case window” select [2] Q2 Concrete as the active load case. That is the one for which we will now quantify the load values.

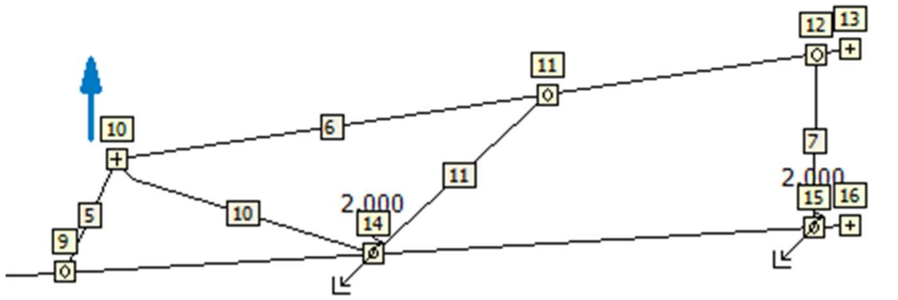


Applying loads to members

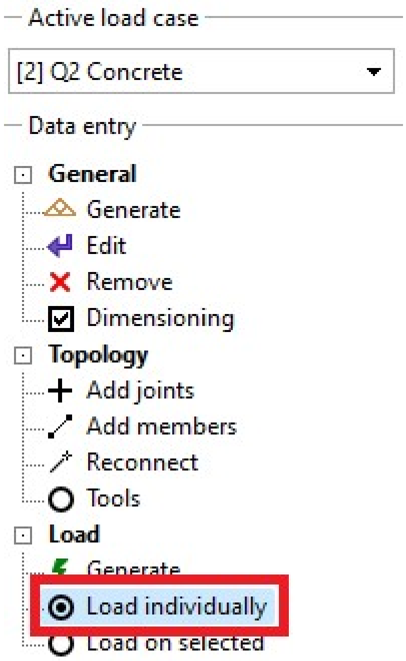
After having created load cases and combinations, the “real” loads must be connected with members. In the following table, the vertical loads are given

Member No	Joint Start - End.	Load Z-Dir. [kN/m²]	Load Y-Dir. [kN/m²]
2	17 – 18	-6,0 – (-12,0)	-
3	18 – 4	-12,0 – (-22,5)	-12,0 – (-22,5)
4	4 – 9	-22,5 – (-22,5)	-
5	9 – 10	-22,5 – (-12,0)	+22,5 – (+12,0)
6	10 - 13	-12,0 – (-6,0)	-

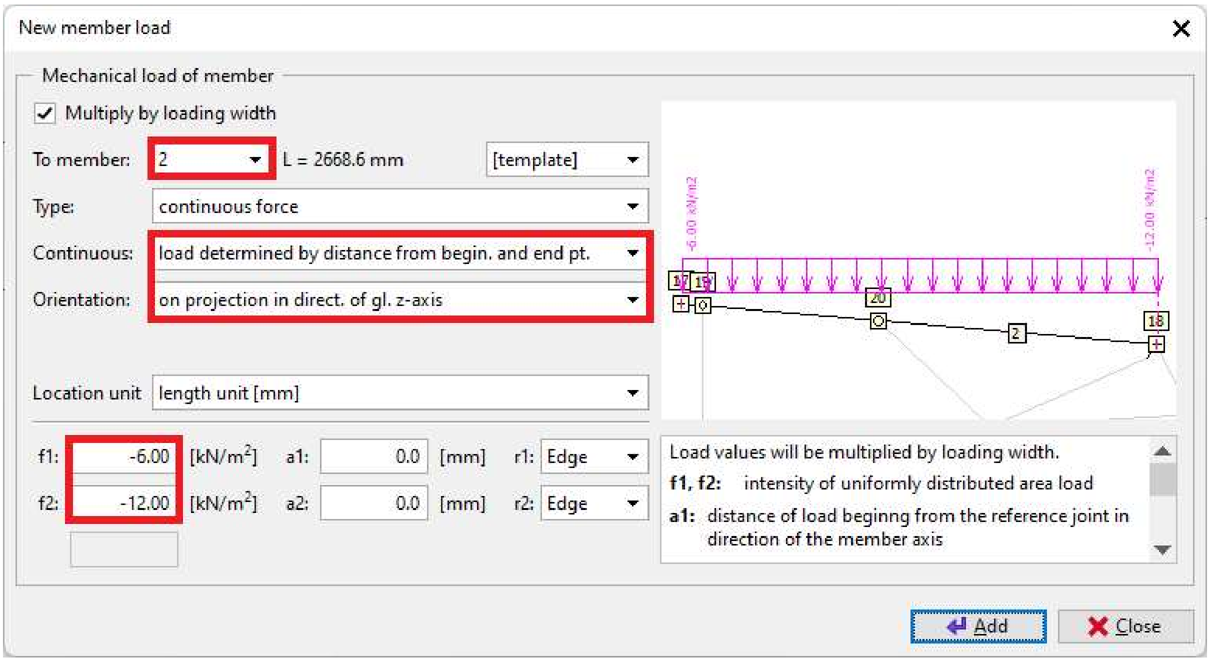




Select “Load individually” from the Data entry with the activated load case Q2.

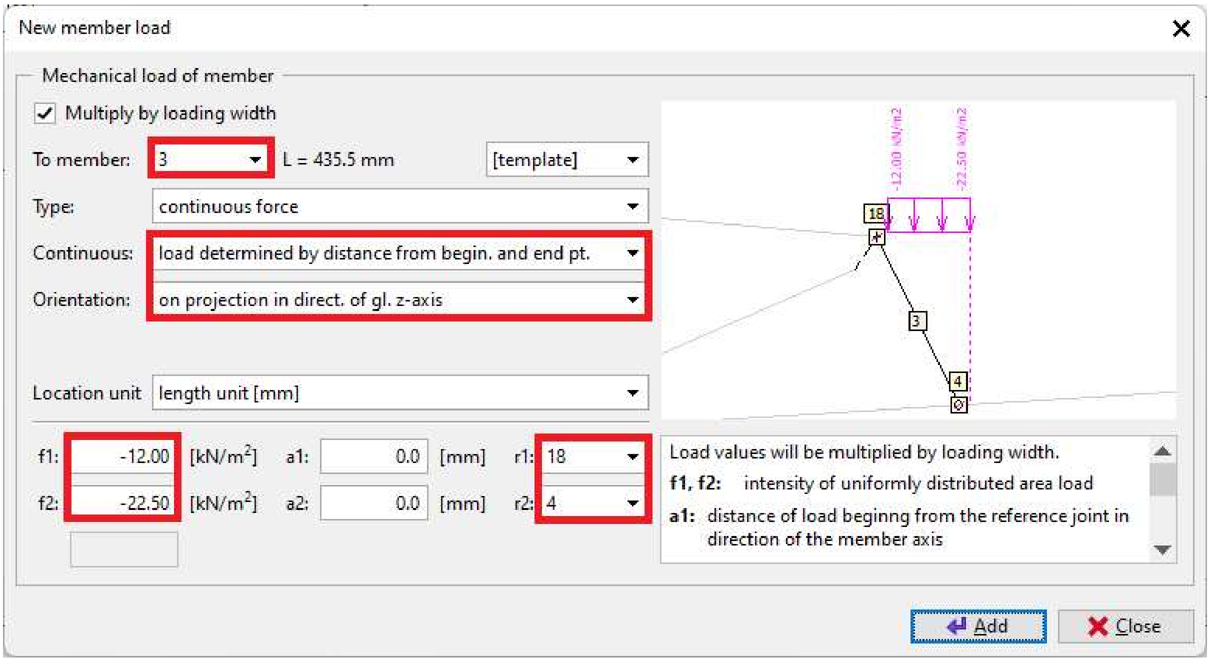


Click on [+] in the table window and make the following entries:



On member 2 apply a continuous load determined by distance from beginning and end point with the orientation on projection of global z-axis. Use the shown values for the load. Then hit “Add”.

Select member 3, look up the definition of the positive direction of the member by reviewing the order of the joint numbers at r1 and r2 (should be 18 for r1 and 4 for r2), change the load values to -12,0 for f1 and -22,5 for f2.

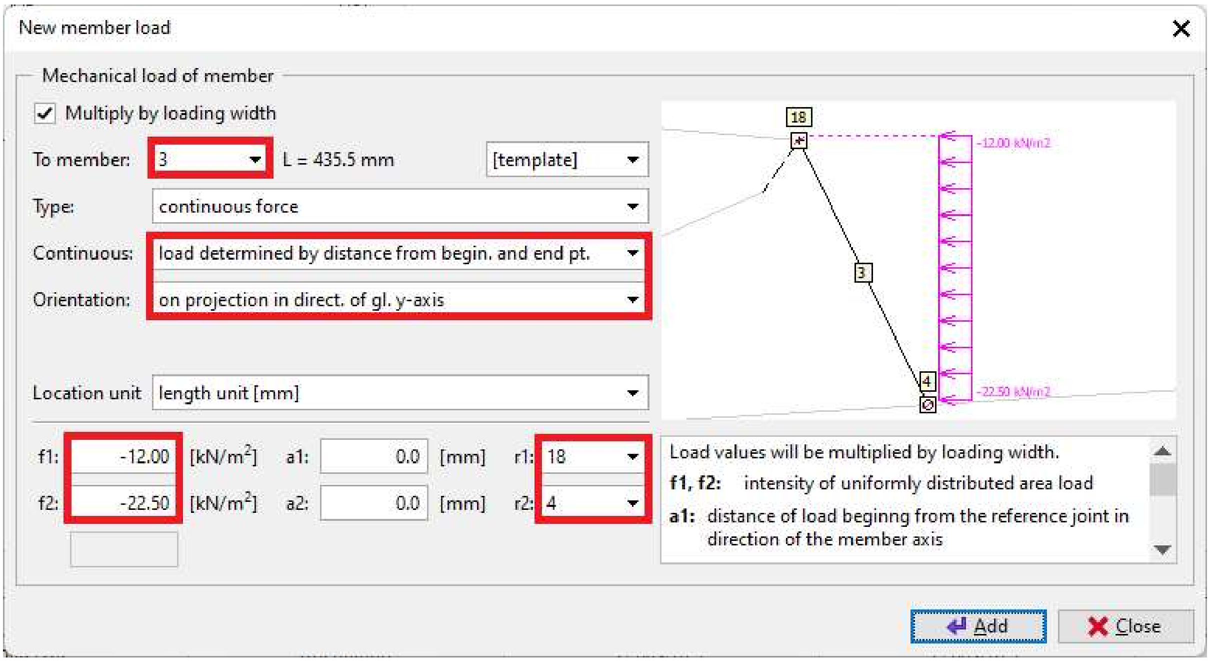


Hit “Add” and continue entry. Look at the table window, it now should contain two lines.

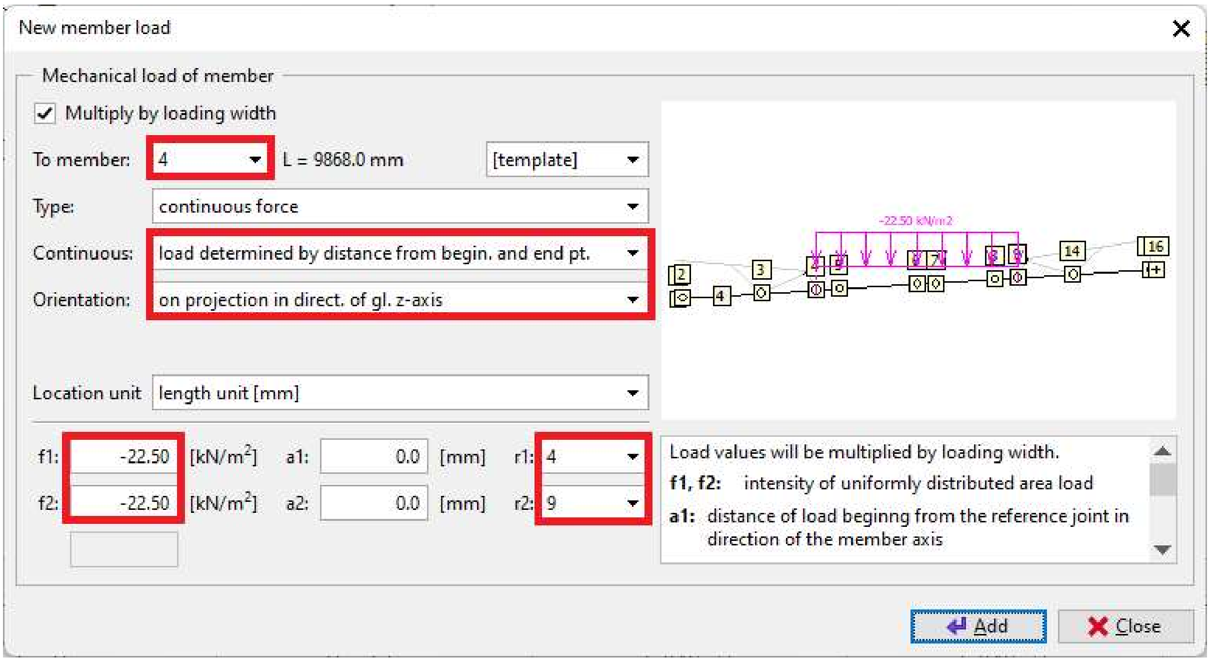
Joint load | Member loads

Number	Member	Load type
1	3	Continuous force
2	2	Continuous force

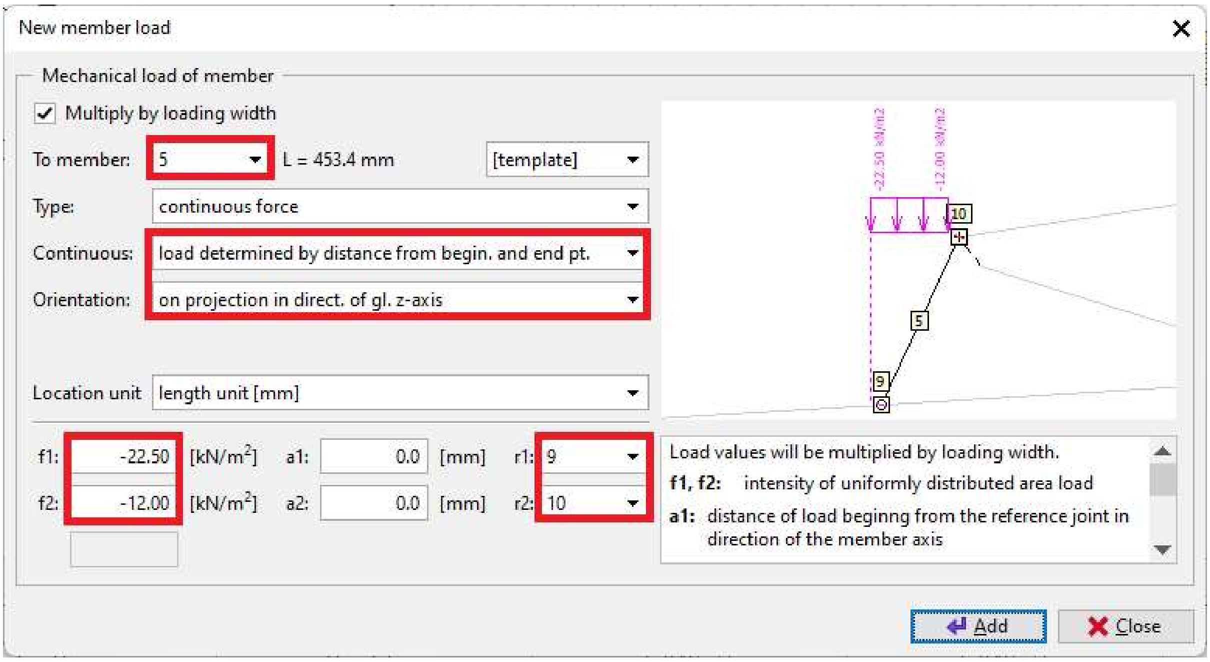
Simply change the orientation to “on projection in direction of gl. y-axis” and hit “Add”. This added the horizontal hydrostatically distributed concrete load to member 3.

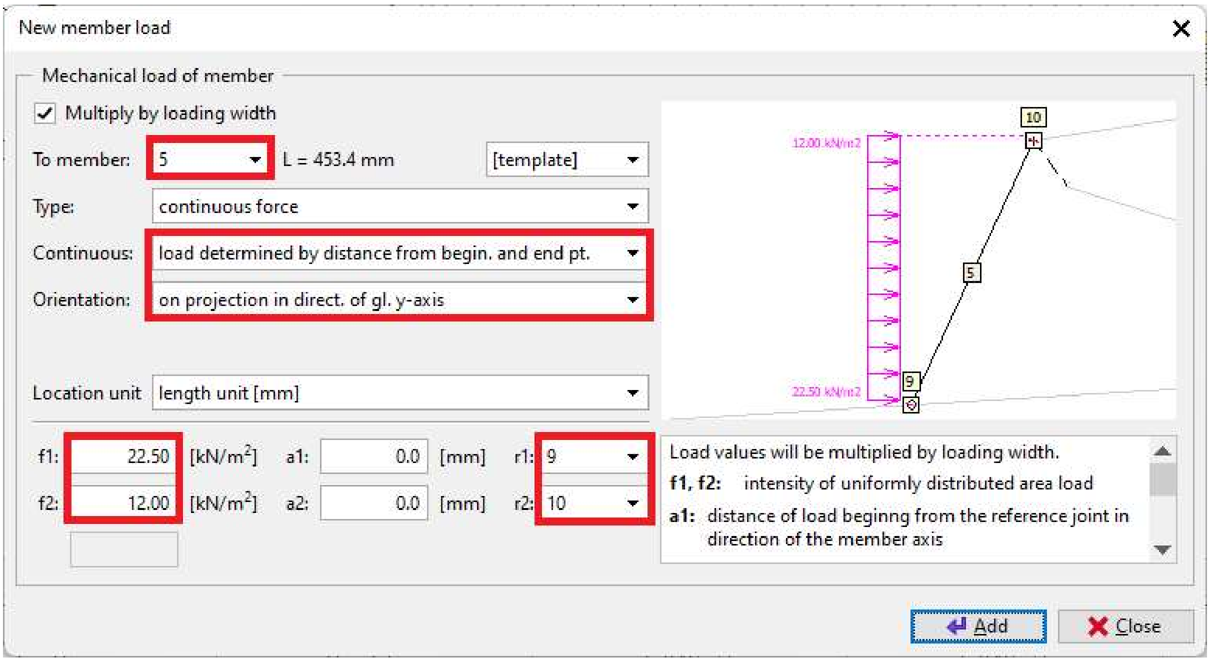


Continue with member 4 as shown:

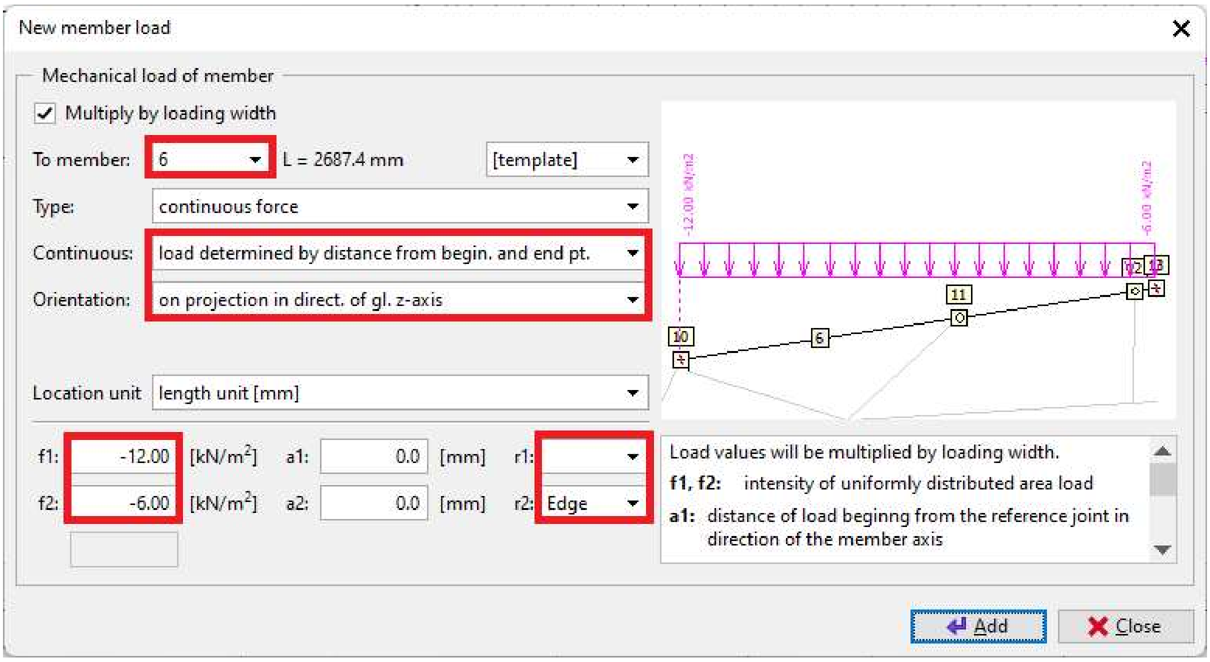


Add loads to member 5 with the vertical load and the horizontal load. Don't forget to change the sign for the horizontal load (positive when pointing to the right)

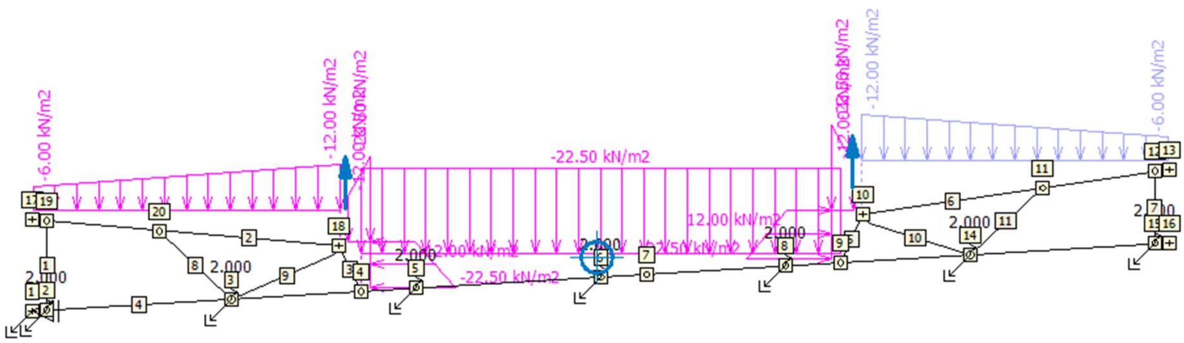




Last member 6 with concrete load

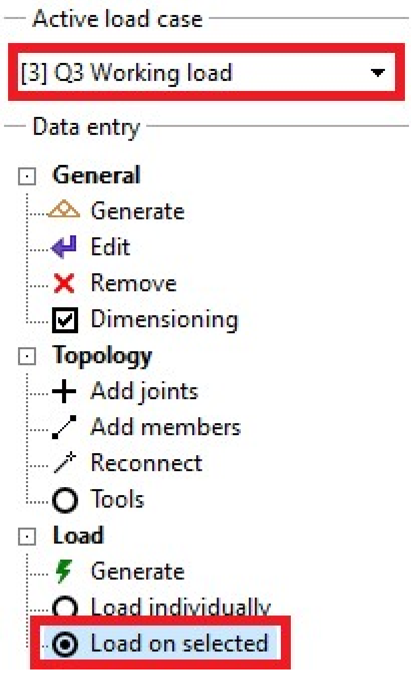


“Add” and “Close” the dialog

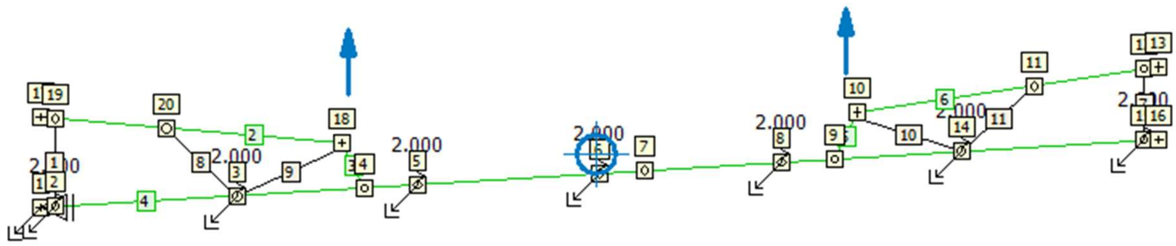


Switch the active load case to Q3 Working load.

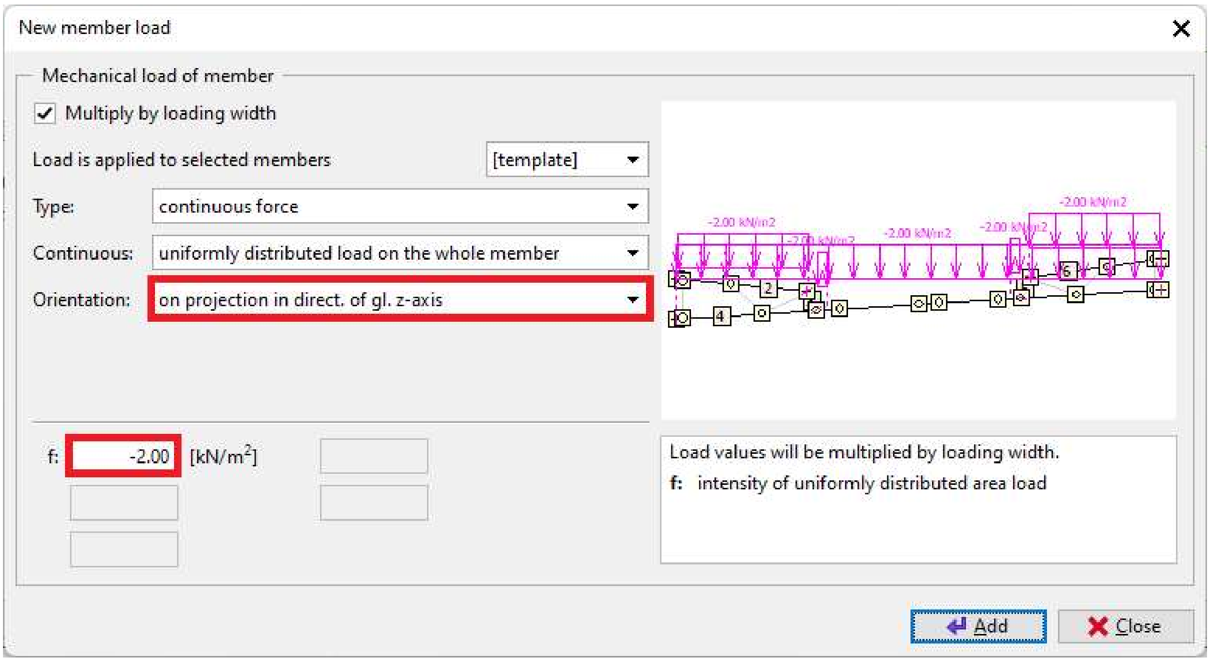
In Data entry select “Load on selected”.



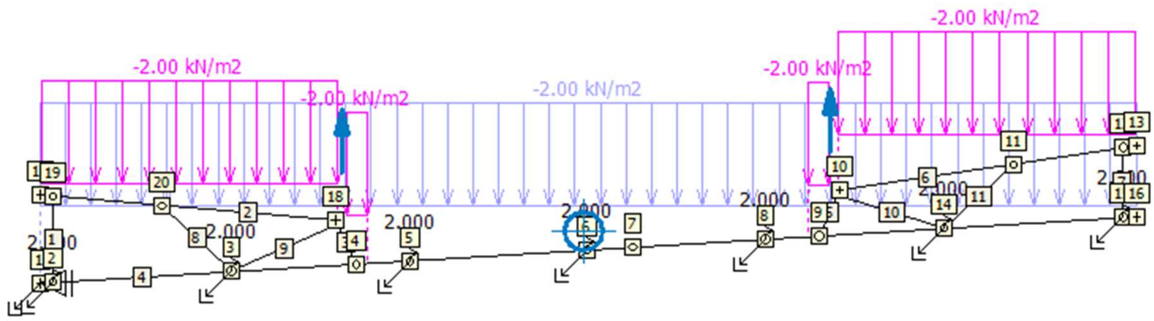
In the main workspace, window click on those members that should be loaded with Q3, i.e. members 2 through 6. Selected members and their numbers are highlighted in green colour.



In the table window click on the “plus” sign. In the dialog only specify the orientation of the load, i.e. global z-axis and enter a value of -2 kN/m² for f.

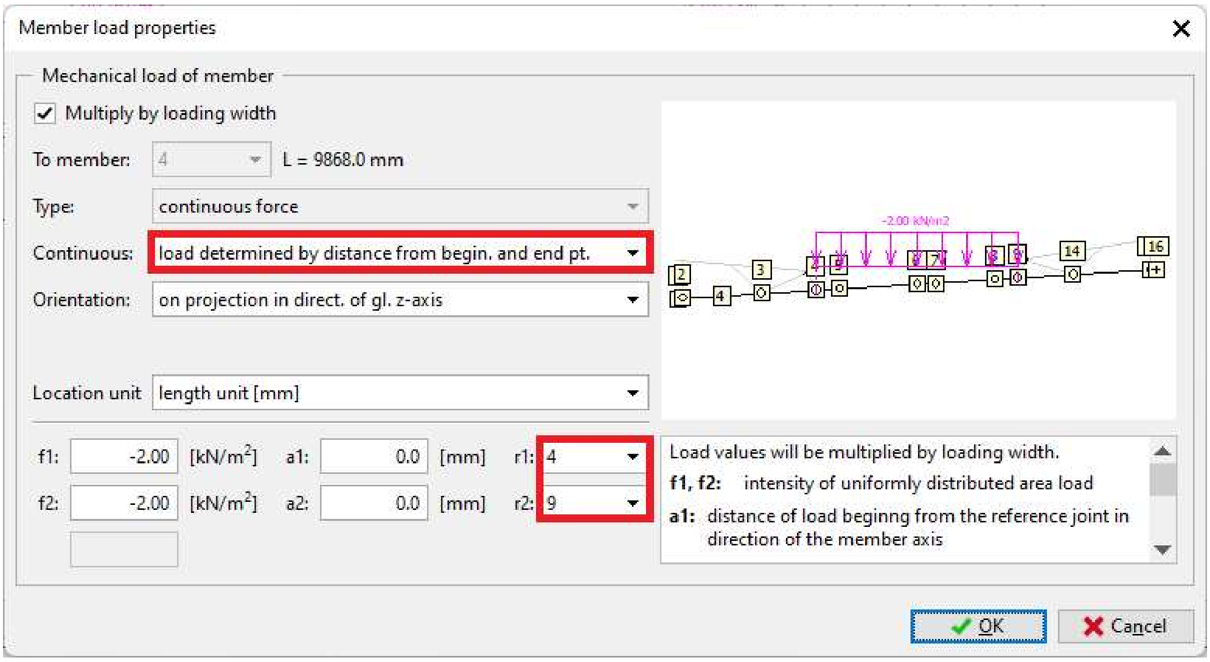


Hit “Add”, then “Close”.

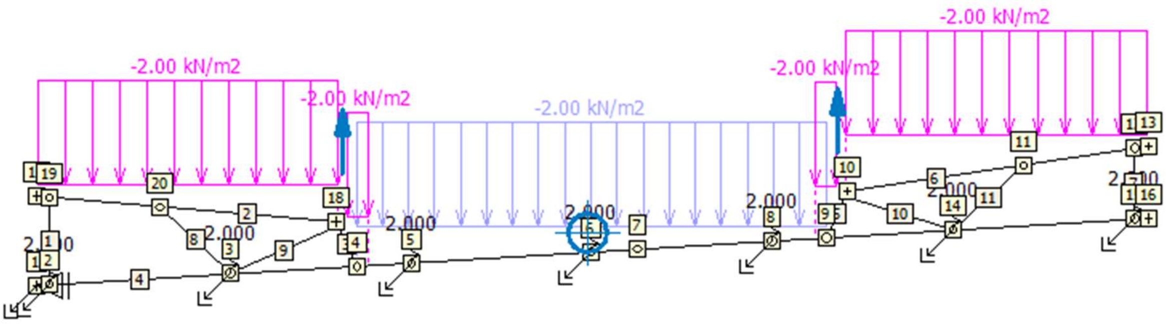


The working load is distributed along the entire bottom chord and needs to be adjusted to act only between joints 4 and 8. Switch back to “Load individually” in Data entry, pick the load in the table window that is related to member 4 (row 5) and either double click on the line or on the edit button  .click

Change “Continuous” in the dialog and specify joints 4 and 8 as r1 and r2, respectively. Close with “OK”.

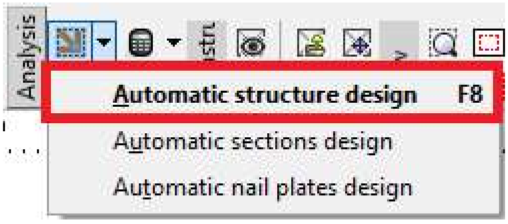


The input of loads is done and we can move on to the design.

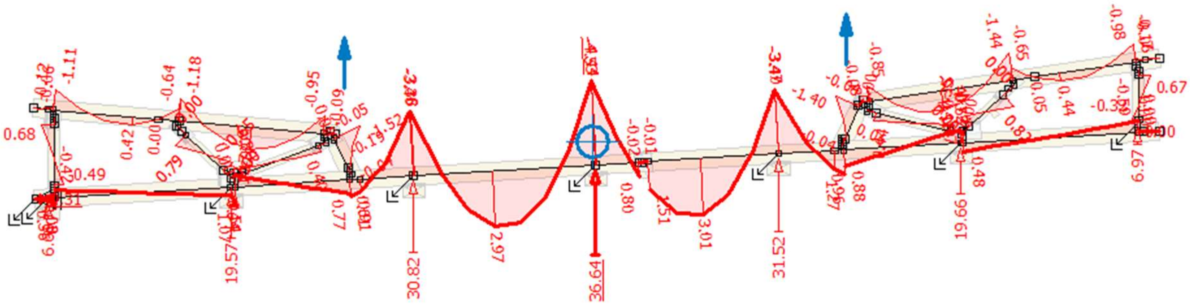


Design and analysis of the truss

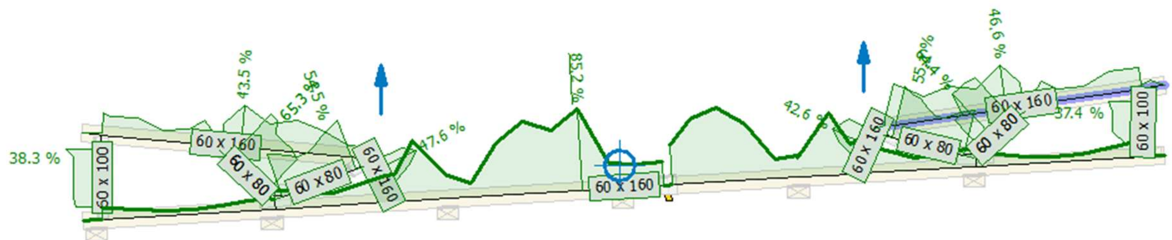
Analyse the truss <F8> or



Review the results, internal forces, reactions, and deflections.



Members check:

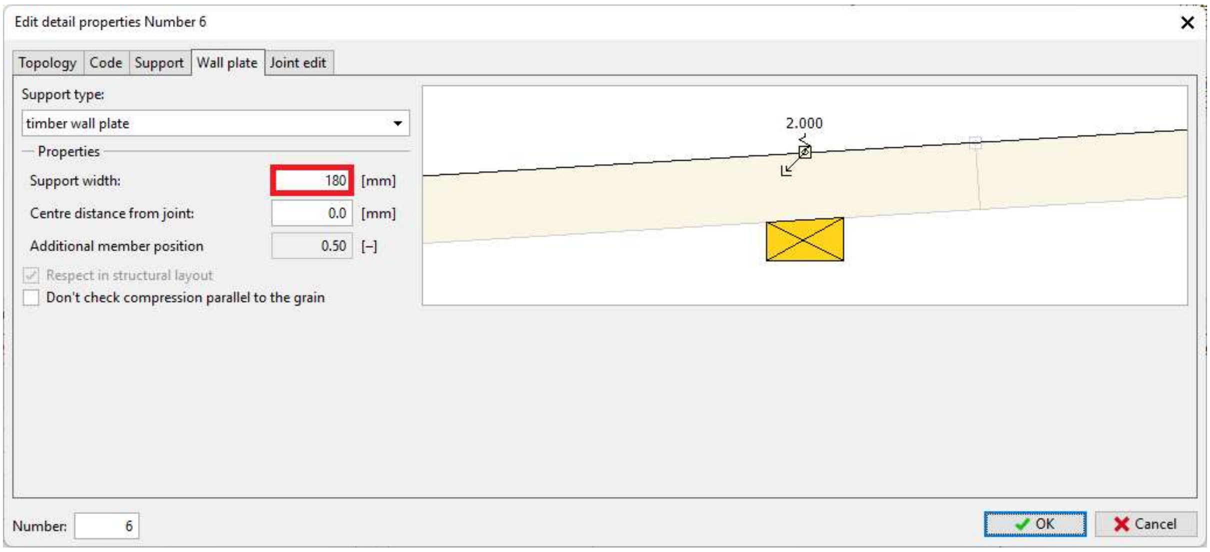


Joints check:

Overall verification of joints:	NOT SATISFIED		Edit
Number	Description	Verification - envelope	
		Max. utilization	Decisive combination
2	wall plate width: 160 mm	✓ [28.8 %]	
3	wall plate width: 160 mm	✓ [56.9 %]	
5	wall plate width: 160 mm	✓ [89.6 %]	
6	wall plate width: 160 mm	✗ [106.6 %]	
8	wall plate width: 160 mm	✓ [91.7 %]	
14	wall plate width: 160 mm	✓ [57.2 %]	
15	wall plate width: 160 mm	✓ [-10.0 %]	
2	nail plate BV15 1014 (105 x 147)	✓ [76.9 %]	[4] Q2:G1+Q3
3	nail plate BV20 2819 (280 x 198)	✓ [79.5 %]	[4] Q2:G1+Q3
4	nail plate BV15 0712 (70 x 126)	✓ [67.5 %]	[4] Q2:G1+Q3
7	nail plate BV15 1714 (175 x 147)	✓ [76.9 %]	[4] Q2:G1+Q3
9	nail plate BV15 0712 (70 x 126)	✓ [70.5 %]	[4] Q2:G1+Q3
10	nail plate BV15 2812 (280 x 126)	✓ [85.4 %]	[4] Q2:G1+Q3
11	nail plate BV15 2808 (280 x 84)	✓ [83.9 %]	[4] Q2:G1+Q3
12	nail plate BV15 1014 (105 x 147)	✓ [83.9 %]	[4] Q2:G1+Q3
14	nail plate BV20 1633 (160 x 330)	✓ [81.9 %]	[4] Q2:G1+Q3
15	nail plate BV15 1010 (105 x 105)	✓ [77.0 %]	[4] Q2:G1+Q3
18	nail plate BV15 2812 (280 x 126)	✓ [86.2 %]	[4] Q2:G1+Q3
19	nail plate BV15 1414 (140 x 147)	✓ [72.4 %]	[4] Q2:G1+Q3
20	nail plate BV15 1021 (105 x 210)	✓ [98.8 %]	[4] Q2:G1+Q3

In the table, we can see that Joint 6 does not satisfy. This is due to the high compression force in the joint, which means that we have to increase the width of the support.

Double click on the joint in the table and change the width to 180mm



Analyse the truss again by pressing <F8>

Overall verification of joints: SATISFIED | Edit

Number	Description	Max. utilization (Verification - envelope)	Decisive combination (Verification - envelope)
2	wall plate width: 160 mm	✔ [28.8 %]	
3	wall plate width: 160 mm	✔ [56.9 %]	
5	wall plate width: 160 mm	✔ [89.6 %]	
6	wall plate width: 180 mm	✔ [97.7 %]	
8	wall plate width: 160 mm	✔ [91.7 %]	
14	wall plate width: 160 mm	✔ [57.2 %]	
15	wall plate width: 160 mm	✔ [-10.0 %]	
2	nail plate BV15 1014 (105 x 147)	✔ [76.9 %]	[4] Q2:G1+Q3
3	nail plate BV20 2819 (280 x 198)	✔ [79.5 %]	[4] Q2:G1+Q3
4	nail plate BV15 0712 (70 x 126)	✔ [67.5 %]	[4] Q2:G1+Q3
7	nail plate BV15 1714 (175 x 147)	✔ [76.9 %]	[4] Q2:G1+Q3
9	nail plate BV15 0712 (70 x 126)	✔ [70.5 %]	[4] Q2:G1+Q3
10	nail plate BV15 2812 (280 x 126)	✔ [85.4 %]	[4] Q2:G1+Q3
11	nail plate BV15 2808 (280 x 84)	✔ [83.9 %]	[4] Q2:G1+Q3
12	nail plate BV15 1014 (105 x 147)	✔ [83.9 %]	[4] Q2:G1+Q3
14	nail plate BV20 1633 (160 x 330)	✔ [81.9 %]	[4] Q2:G1+Q3
15	nail plate BV15 1010 (105 x 105)	✔ [77.0 %]	[4] Q2:G1+Q3
18	nail plate BV15 2812 (280 x 126)	✔ [86.2 %]	[4] Q2:G1+Q3
19	nail plate BV15 1414 (140 x 147)	✔ [72.4 %]	[4] Q2:G1+Q3
20	nail plate BV15 1021 (105 x 210)	✔ [98.8 %]	[4] Q2:G1+Q3

All joints and supports are satisfied and we are done with this engineering example.

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