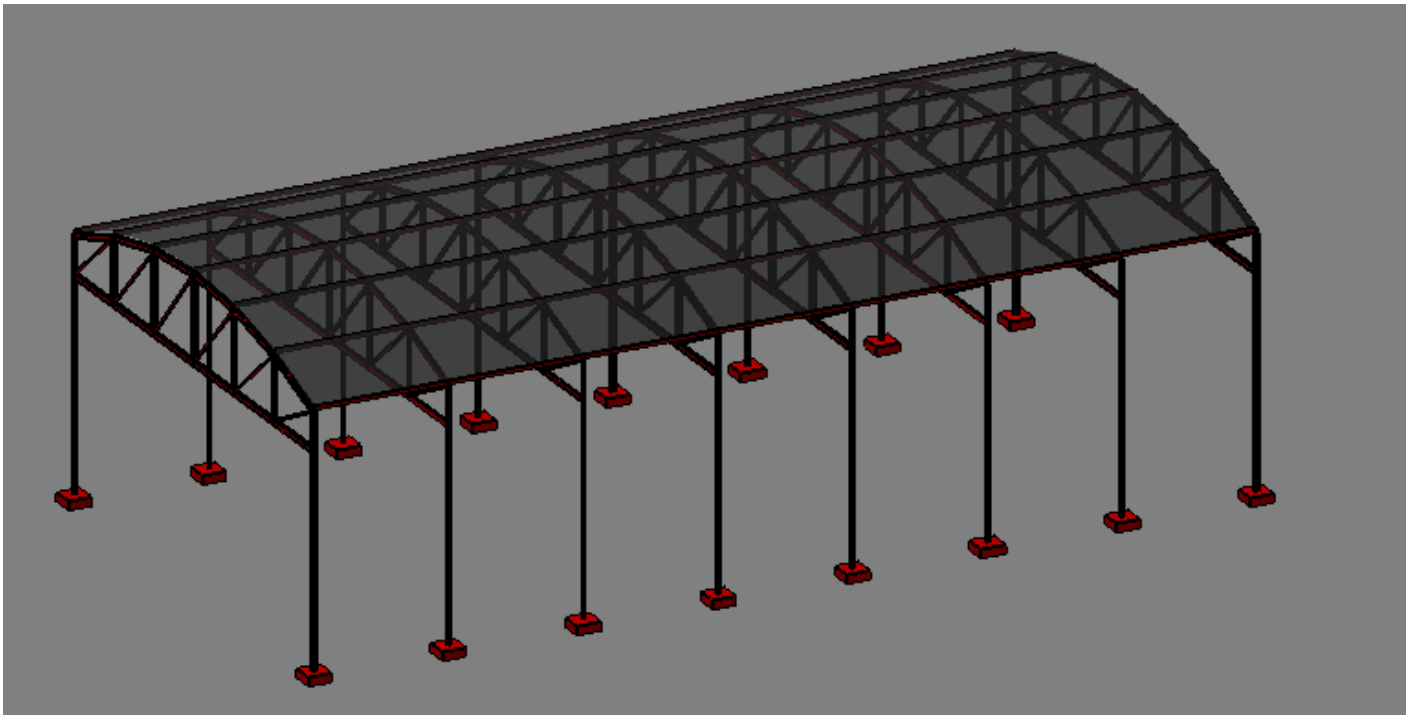
Structure optimisation

Structural optimization is a very important subject that has important practical significance. Standard design process uses optimization capabilities to a small extent. Typically, the project design is created by an architect who does not have the advanced tools in order to be able to generate a few dozen or several dozen variants of design, verify them, also in terms of strength and choose the most optimal solution according to preset criteria. Of course there are situations where, due to the different conditions, the skeleton of the structure is strictly enforced, and the task of the engineer is only a selection of the relevant sections of load-bearing elements. However, in many cases, the basic limitation is solid shape, but there is no rigid constraints on the structural system. In the case of such a task that opens the field to optimize the structure. Let's try to imagine this on the example of hall project defined as follows:



Generation criteria

1) Hall dimensions 20*40m, height 10m
2) Steel columns section IPE 200
3) Carrying roof elements on Y axis in the form of truss, upper edge as parabola with height 2m, lower edge as straight line.
4) Truss chords section IPE 200, posts and diagonal section IPE 100
5) Carrying roof elements on X axis in the form of IPE 120 profiles , axes number 5
6) Live load (L1) on roof 2kN/m2
7) Truss height on side in the range from 1.6m to 2m with step 0.2m **(3 variants)**
8) Number of internal trusses in the range from 4 to 7 with step 1 **(4 variants)**
9) Truss diagonals double or single **(2 variants)**

As it can be easily calculated, these criteria will generate 24 different variants.

Rating criteria

1) Minimize the weight of the construction

2) Admissible vertical displacement for SLS combination (self-weight + L1) is 50mm

3) Admissible stress in bars for ULS combination (self-weight * 1.2 + L1*1.4) is 434MPa

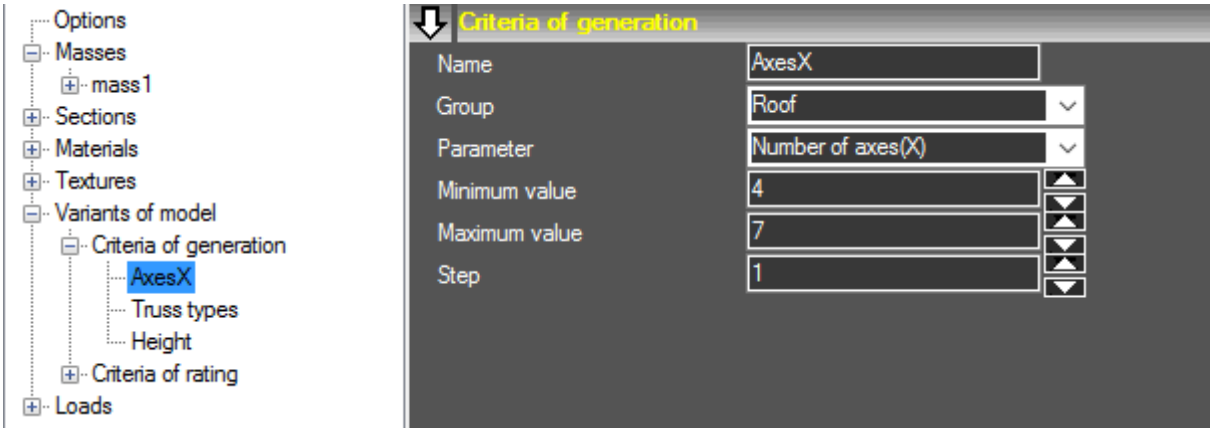
4) Each criterion has equal weight. For criteria with admissible value, the best solution is the solution with the value closest to admissible value from safe side.

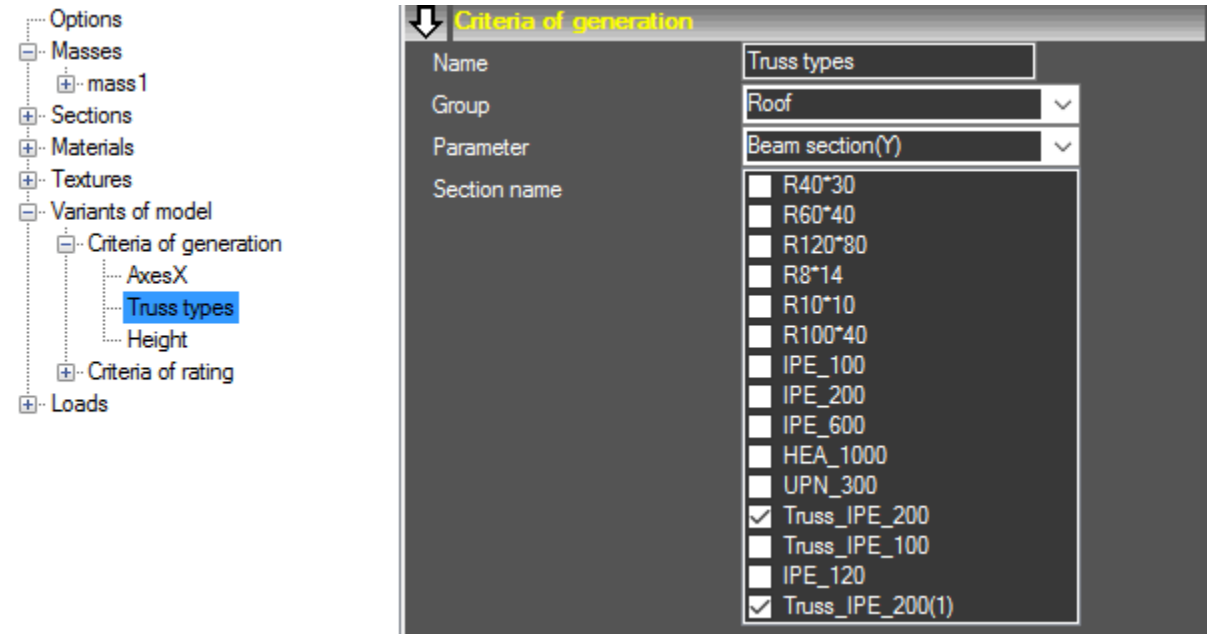
5) The assessment of a given variant of the construction is the resultant value of all criteria, including their weights.

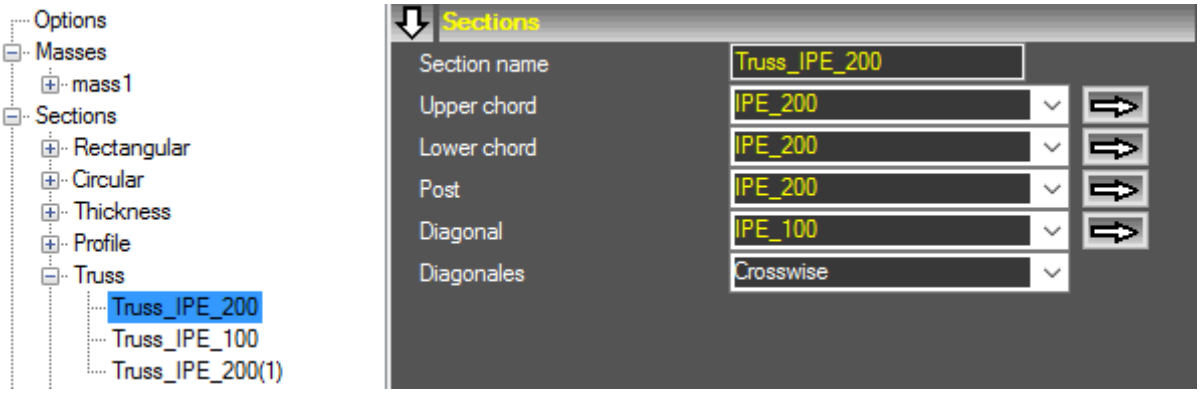
Task defined in such a way is practically unworkable in existing software due to time constraints. Each option would require manual generation of new 3D model, which would make this approach very inefficient.

To solve this task in a reasonable time we will need a program that is able to create models of the structure in parametric way. IntelForm is such a program, in which one can easily create so defined structures (as well as many other, more complex models).

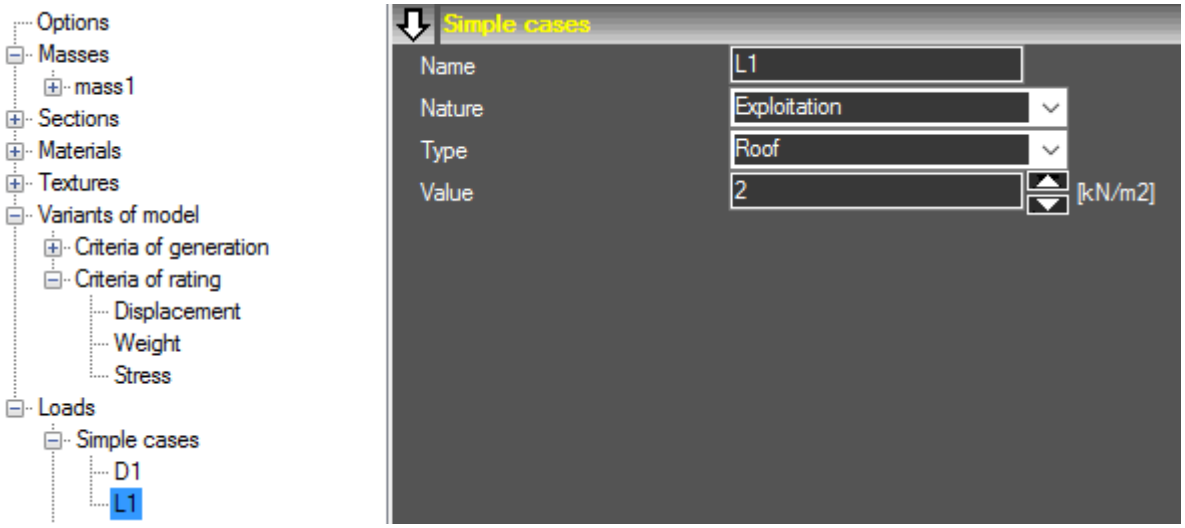
Generation criteria are defined in a separate branch of the node “Variants of model” - below a sample definition for the axes of the structure and the types of trusses:

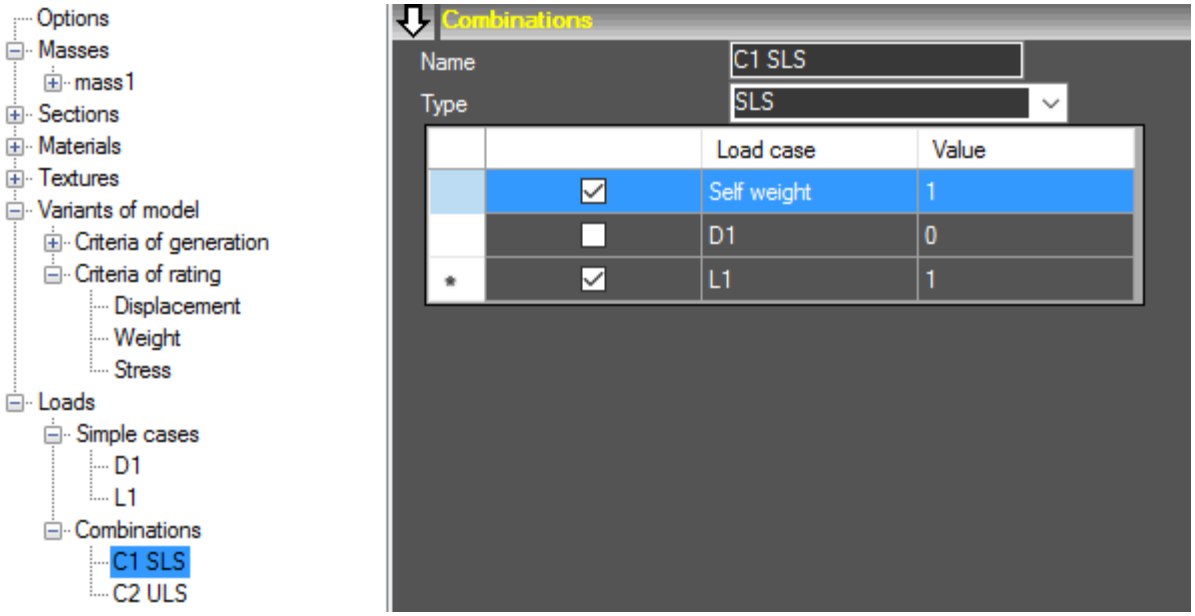




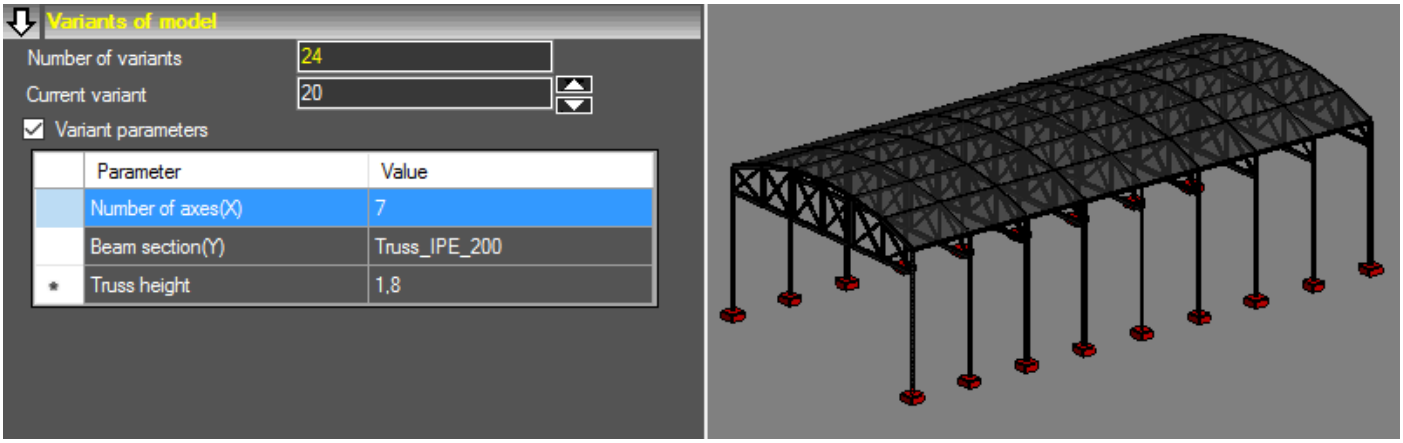


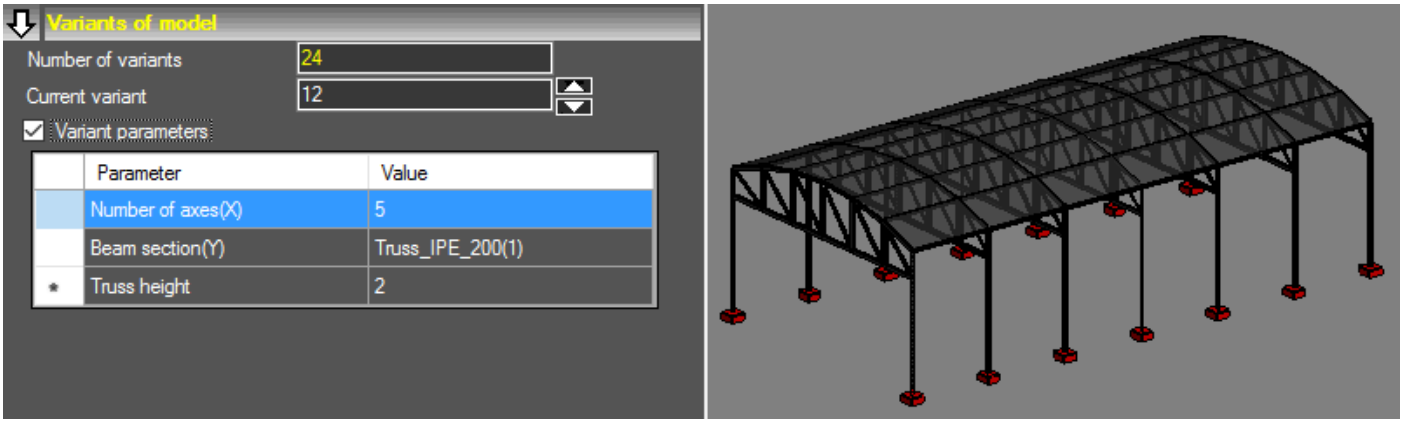
The rating criteria are defined in a separate branch of the node “Variants of model” - below a sample definition for admissible displacement values. For strength criteria program allows to define the load by selecting the appropriate load combination

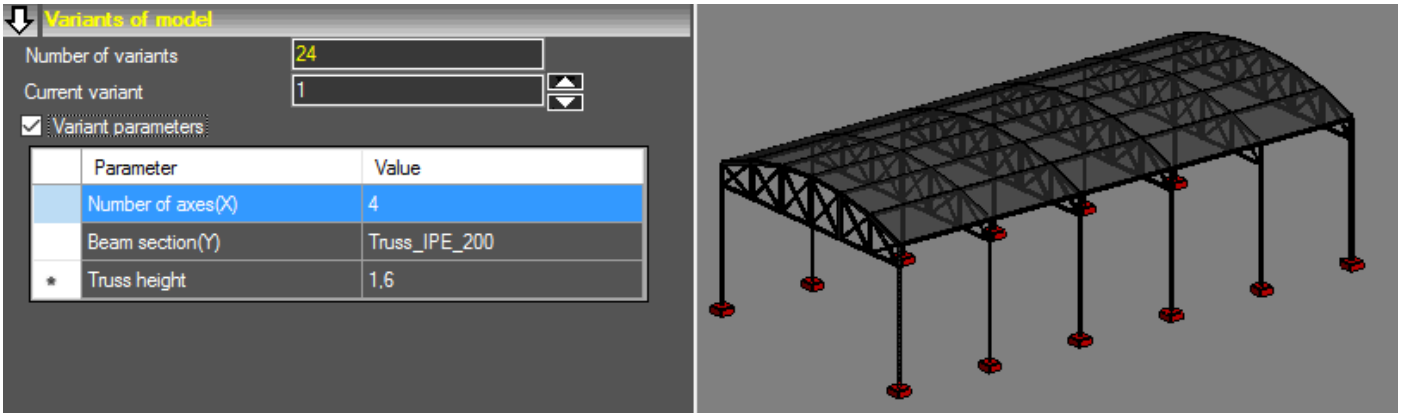




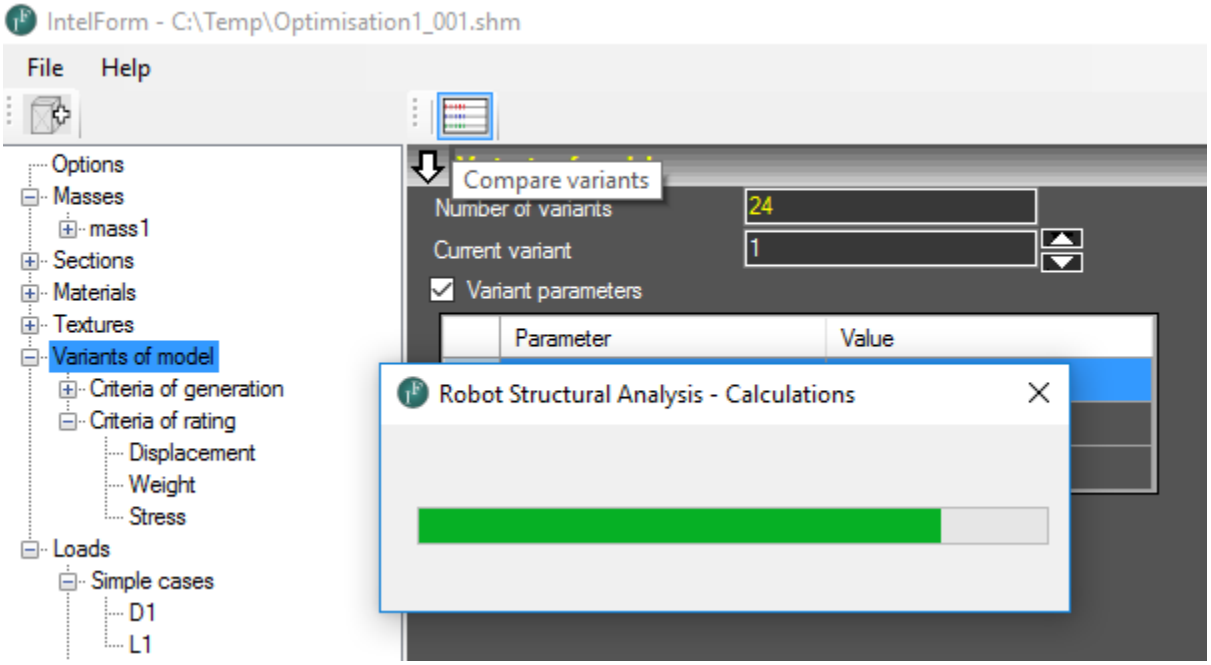
Some of the automatically generated variants are shown below. Visualization of subsequent variants in real time can be obtained by changing the number of the current variant.

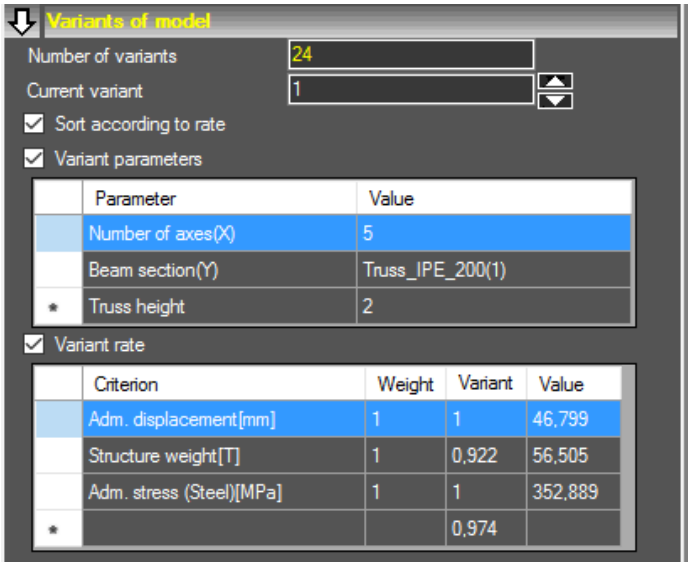


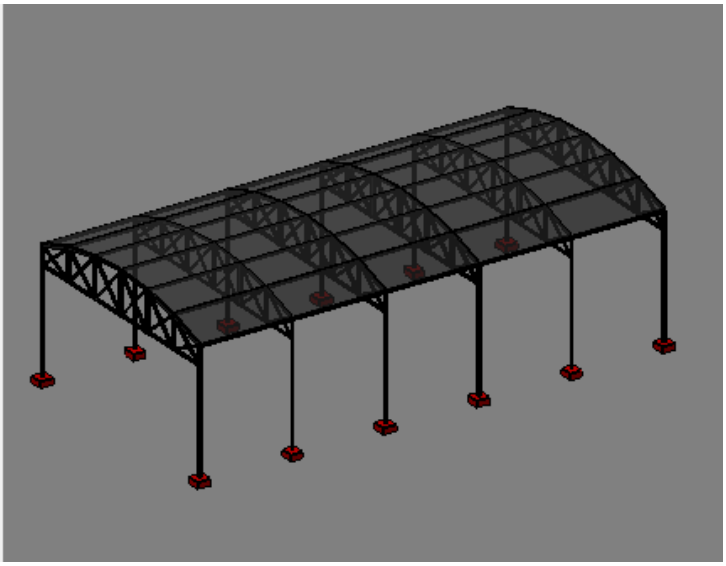




The last step is to run the option of variants comparing and display the results. For strength criteria in the background calculation engine of Autodesk Robot Structural Analysis is started. In the present example, evaluation of a single variant lasts a few seconds (structure generation in Robot, the calculations, results download), thus the final result of optimization at the present time is obtained after about 4 minutes. (processor i7-4790).







Thanks to "Sort according to rate" option variants can be automatically rank from best to worst solution. As the most optimal is chosen the variant with 5 internal trusses with single diagonals and truss height of 2m. The difference between the best and the worst acceptable solution is approx. 45% as far as final evaluation index is concerned with weight difference approx. 9 tons. Lighter structures were rejected due to failure to meet the strength conditions.

Variants of model

Number of variants: 24

Current variant: 18

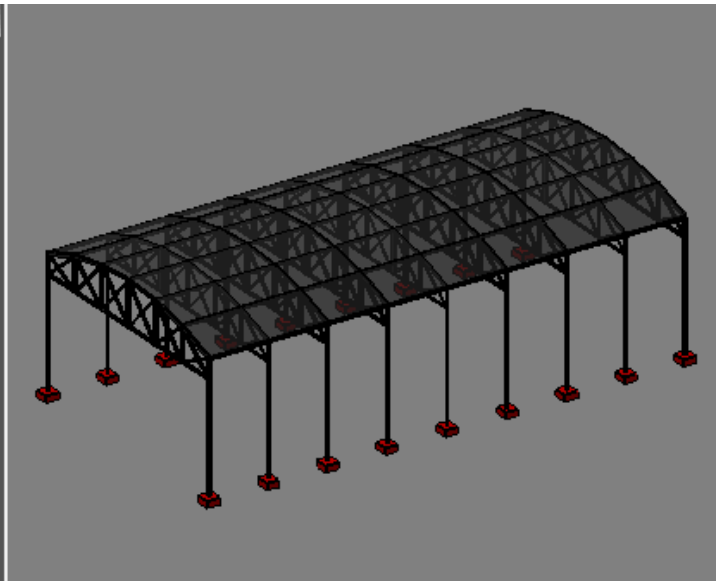
☑ Sort according to rate

☑ Variant parameters

	Parameter	Value
	Number of axes(X)	7
	Beam section(Y)	Truss_IPE_200
*	Truss height	1,6

☑ Variant rate

	Criterion	Weight	Variant	Value
	Adm. displacement[mm]	1	0,687	32,151
	Structure weight[T]	1	0,793	65,702
	Adm. stress (Steel)[MPa]	1	0,539	190,332
*			0,673	



Variants of model

Number of variants: 24

Current variant: 19

☑ Sort according to rate

☑ Variant parameters

	Parameter	Value
	Number of axes(X)	4
	Beam section(Y)	Truss_IPE_200
*	Truss height	1,6

☑ Variant rate

	Criterion	Weight	Variant	Value
	Adm. displacement[mm]	1	0	65,754
	Structure weight[T]	1	0,977	53,324
	Adm. stress (Steel)[MPa]	1	0	521,749
*			0