# Form finding

One of the elements of the process design optimization can be finding the optimal form of solids, such, that the required design intent is fulfilled. Of course there are situations where, due to the different conditions the solid form is strictly enforced, and the task of the engineer is only a selection of the appropriate sections of load-bearing elements. However, there are situations where the strength requirements have a significant influence on the final shape of the structure form. For these tasks opens the field to search for the optimal form. Let's try to imagine the example of a simple design of hall defined as follows:
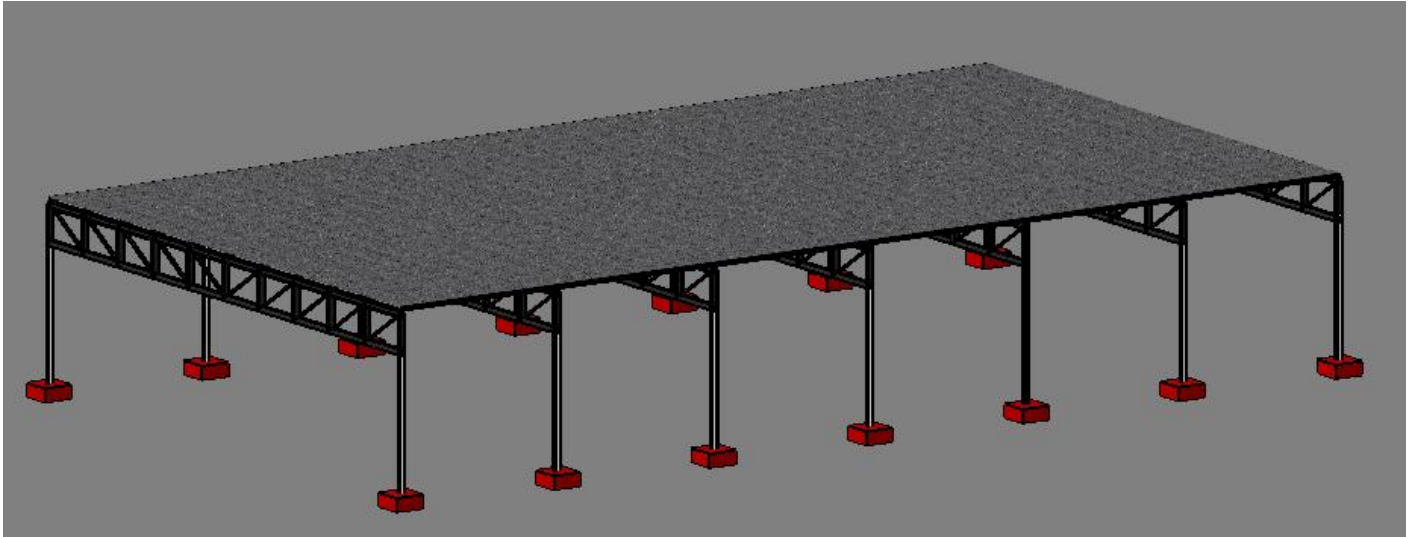
Generation criteria

1) Hall dimensions 20*36m, height 6m
2) Steel columns sections IPE 200
3) Carrying roof elements on Y axis in the form of truss, upper and lower edge as parabola with height range 0 – 2.5m with step 0.5m. **(6 variants)**
4) Truss chords section IPE 200, truss posts and diagonals section IPE 100
5) Carrying roof elements on X axis from section IPE 100, number of axes 9
6) Exploitation loads L1 on roof 2kN/m2
7) Truss height on side 1.25m
8) Number of internal trusses 5
9) Truss diagonals simple, symmetric

As it can be easily calculated, these criteria will generate 6 different variants.

Rating criteria

1) Admissible vertical displacement for SLS combination (self-weight + L1) is 40mm (1/500 hall span)

As can be seen from the accepted criteria for generation and evaluation, the aim is to find such a value of roof lift, that the criterion of the permissible vertical displacement is fulfilled.

The task apparently seems very simple, but the given criteria resulting in a significant change in geometry of the structure for each variant makes that so defined task is practically unworkable in an 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 definition of given generation criterion:
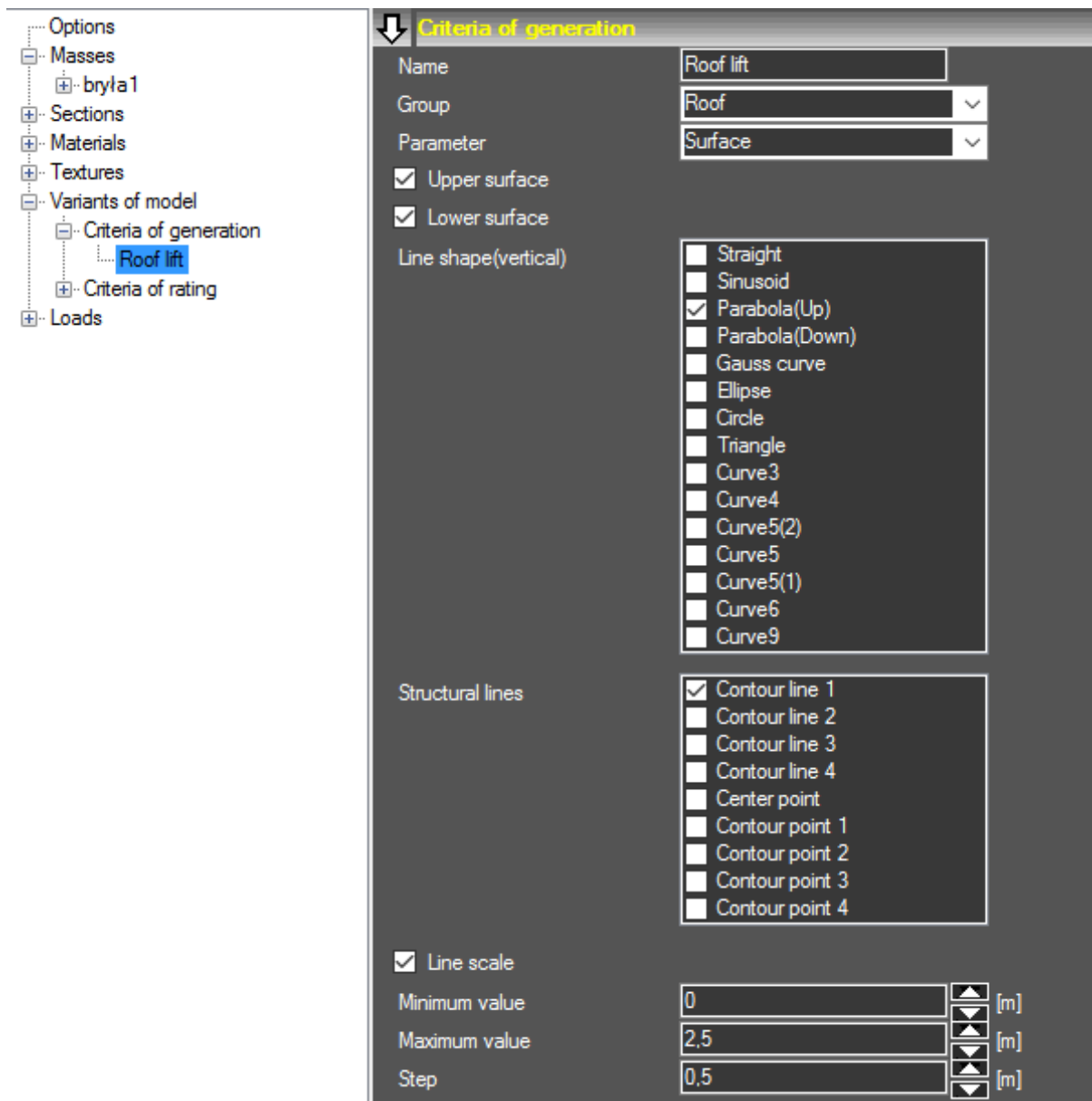
The same lift of upper and lower surfaces are achieved by switching on options "upper surface" and "lower surface", in "Line shape" option we select the curve, according to which the roof will be modified, in the "Structural lines" we select contour lines (or internal lines) which will be lifted by just defined curves, and the "Line scale" define the scope of the modifications.

Rating criteria are defined in a separate branch of the node "Variants of model"- below a definition for admissible vertical displacements. For strength criteria program allows to define the load by selecting the appropriate load combination.
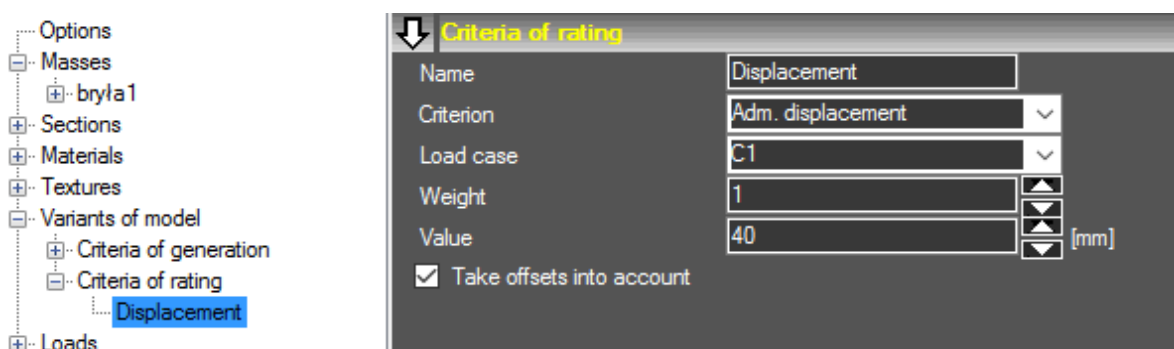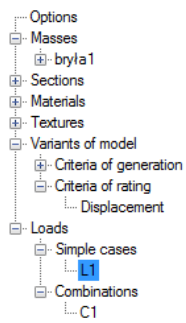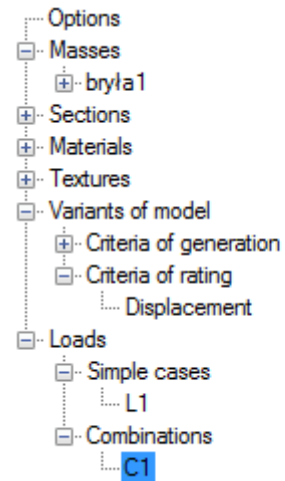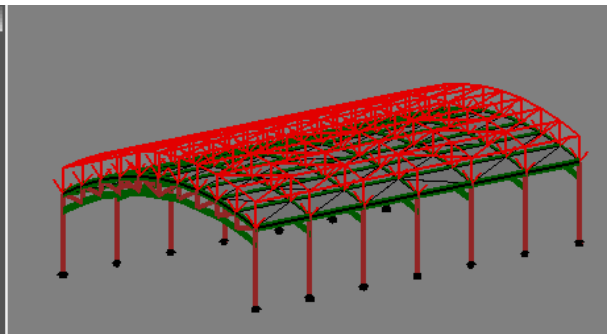
Some of the automatically generated variants are shown below. Visualization of subsequent variants in real time can be obtained by changing the number of the current variant.
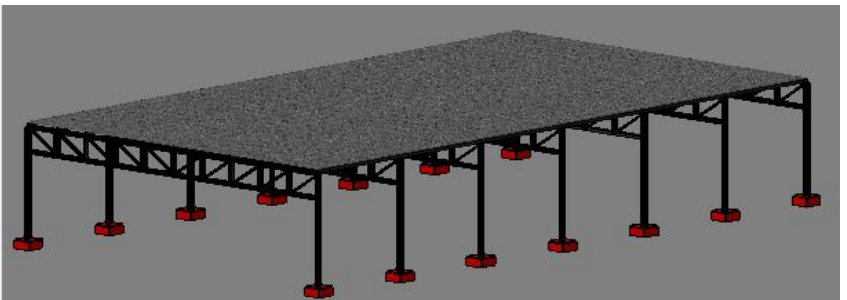
Before we start calculations let's verify the correctness of the assumptions. For this we use the option of direct export to Autodesk Robot Structural Analysis.
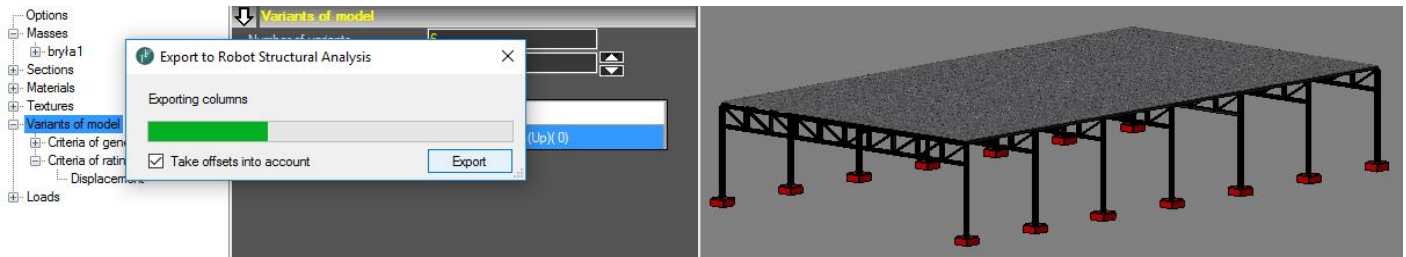
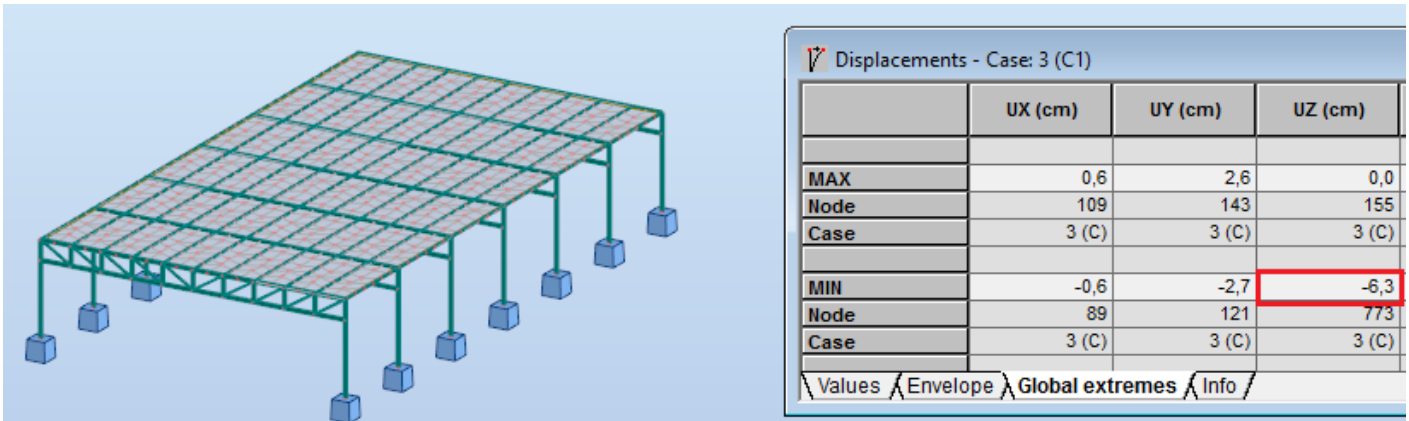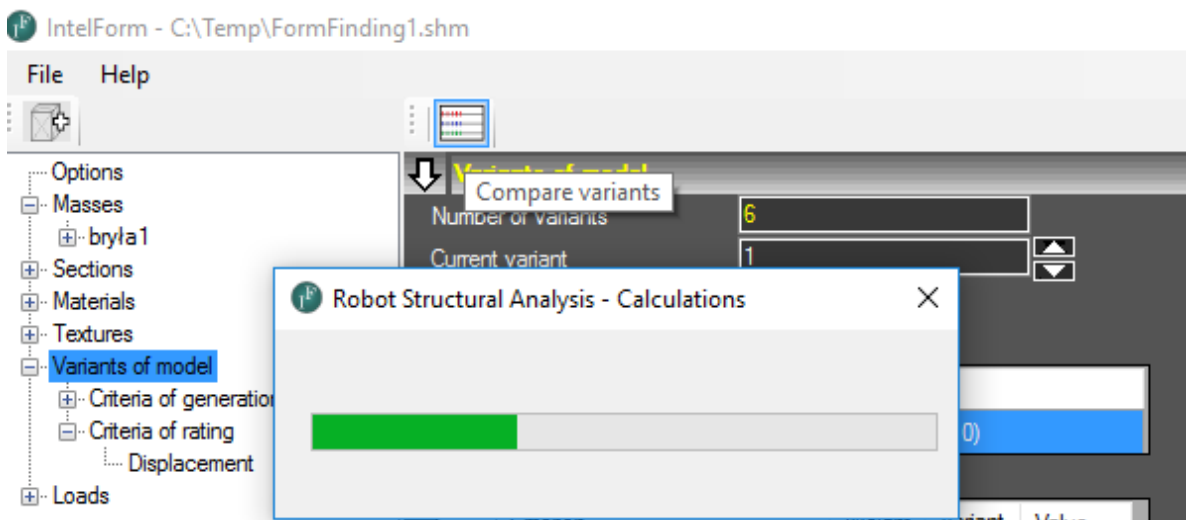After calculations we get the value of displacement exceeding the limit value, therefore, a shape optimization in this case is justified.

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 over a dozen seconds (structure generation in Robot, the calculations, results download), thus the final result of optimization at the present time is obtained after about 1.5 minute. (processor i7-4790).

After calculations we can check obtained displacements values for each variant
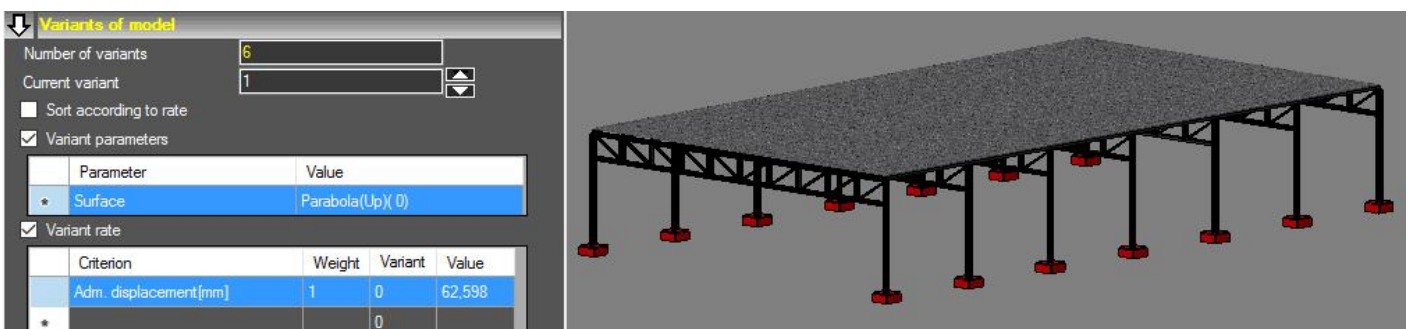
Variants of model

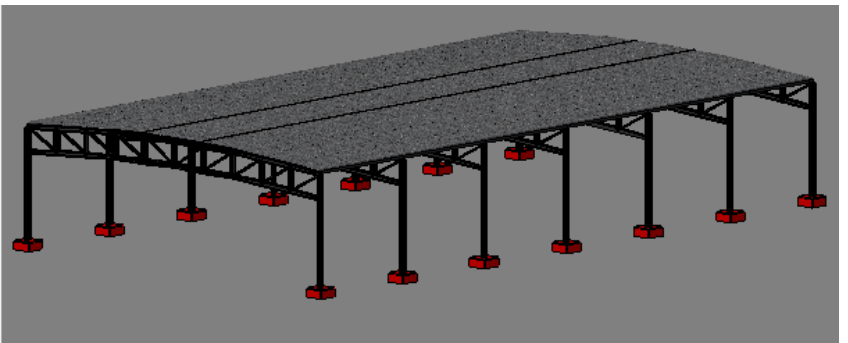|	Parameter	Value
Number of variants		6
Current variant		2
☐ Sort according to rate		
☑ Variant parameters		
*	Surface	Parabola(Up)(0.5)

	Criterion	Weight	Variant	Value
☑ Variant rate				
	Adm. displacement[mm]	1	0	46,744
*			0	

Variants of model

	Parameter	Value
Number of variants		6
Current variant		3
☐ Sort according to rate		
☑ Variant parameters		
*	Surface	Parabola(Up)(1)

	Criterion	Weight	Variant	Value
☑ Variant rate				
	Adm. displacement[mm]	1	0	41,735
*			0	
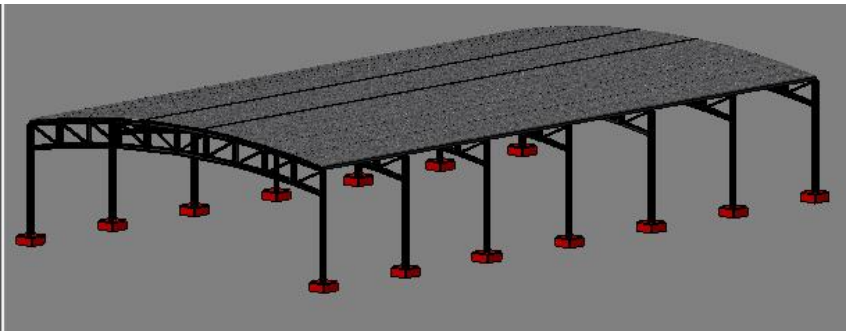
Variants of model

	Parameter	Value
Number of variants		6
Current variant		4
☐ Sort according to rate		
☑ Variant parameters		
*	Surface	Parabola(Up)(1.5)

	Criterion	Weight	Variant	Value
☑ Variant rate				
	Adm. displacement[mm]	1	1	38,954
*			1	
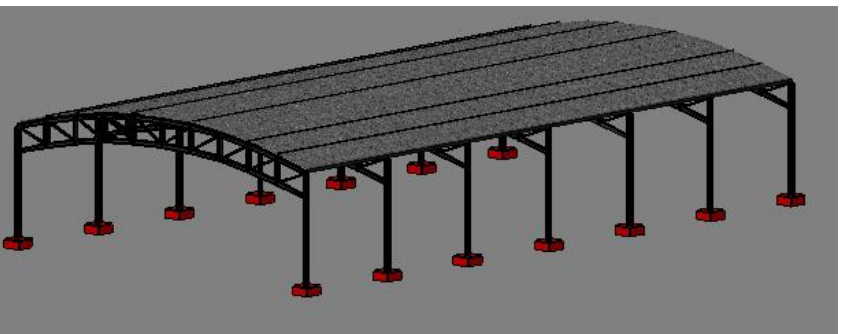
Variants of model

	Parameter	Value
Number of variants		6
Current variant		5
☐ Sort according to rate		
☑ Variant parameters		
*	Surface	Parabola(Up)(2)

	Criterion	Weight	Variant	Value
☑ Variant rate				
	Adm. displacement[mm]	1	0,99	38,55
*			0,99	
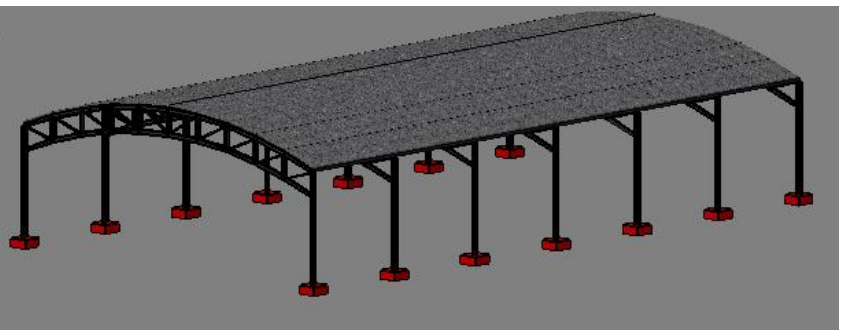
Variants of model

	Parameter	Value
Number of variants		6
Current variant		6
☐ Sort according to rate		
☑ Variant parameters		
*	Surface	Parabola(Up)(2.5)

	Criterion	Weight	Variant	Value
☑ Variant rate				
	Adm. displacement[mm]	1	0,987	38,429
*			0,987	
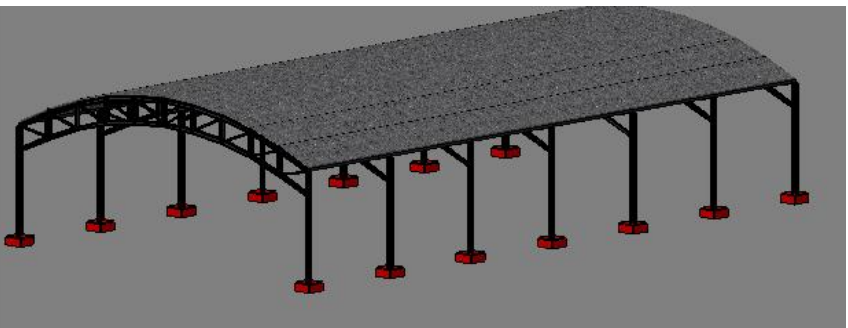
As the most optimal is chosen a variant with roof lift equals to 1.5m. It should also be noted that in this case the further lift of the roof is ineffective, because practically no change in the displacement values is observed, with increase in the cost of construction. Solutions with roof lift smaller than 1.5m were rejected due to failure to meet the given criteria.