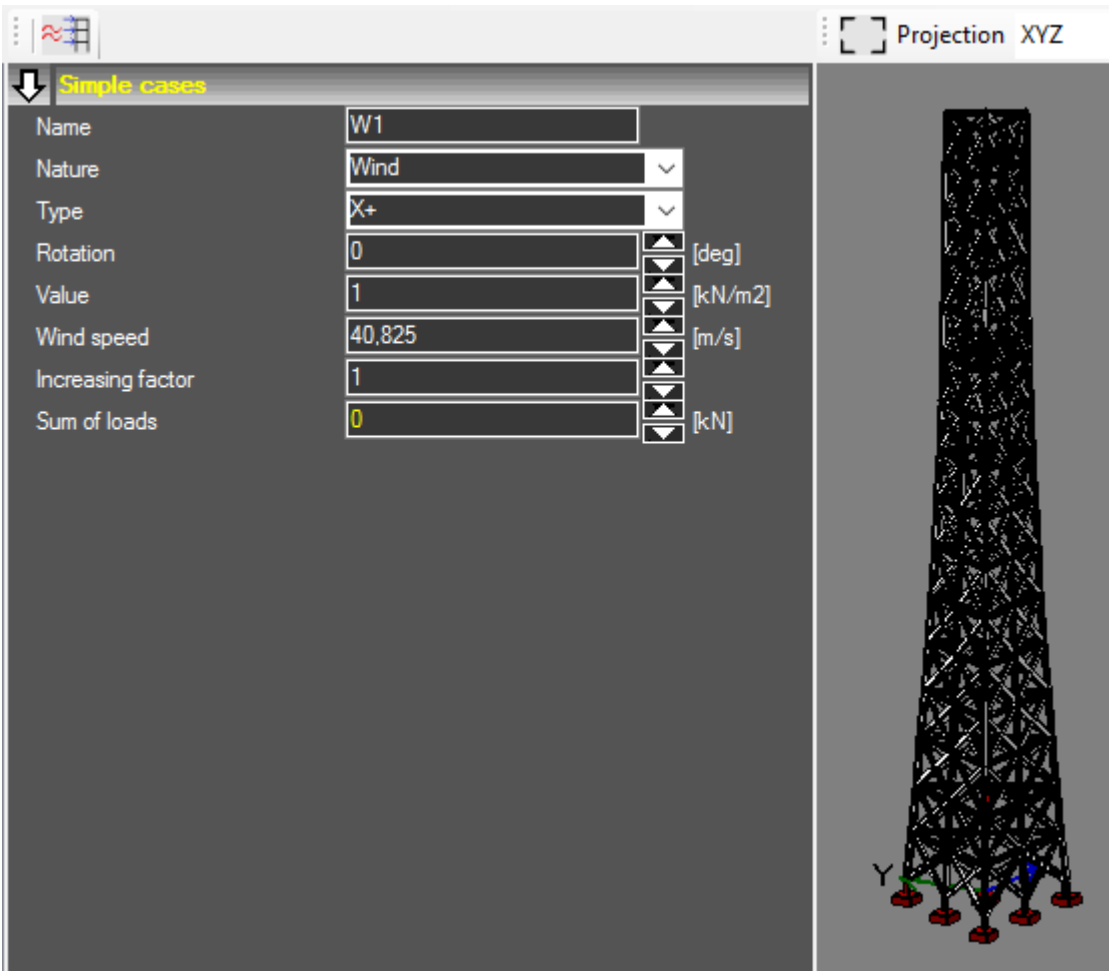


## Steel towers optimization

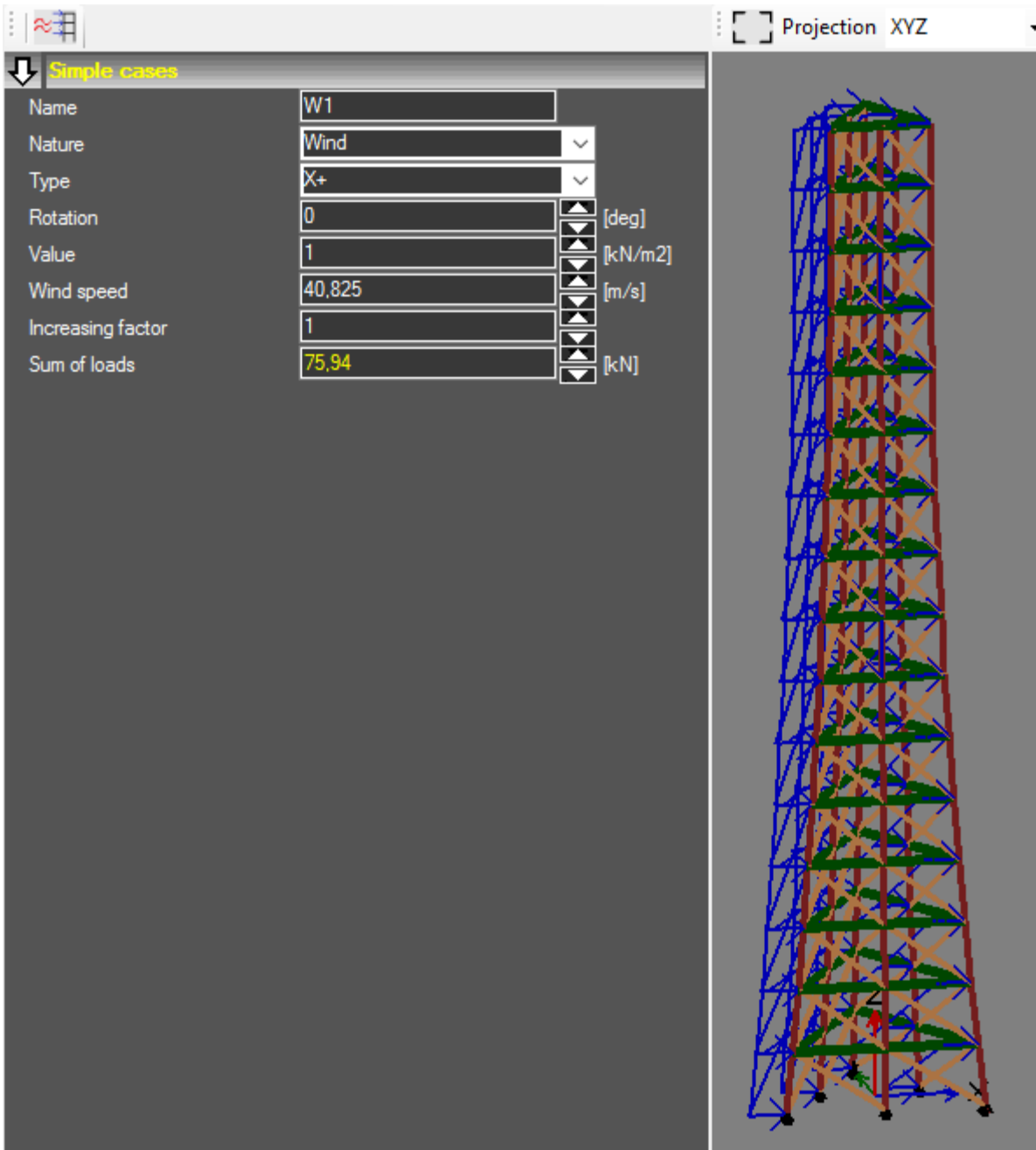
In the case of steel towers one of the most important elements is to determine wind loads. Generally, it is a complex issue because it involves the designation of the aerodynamic coefficient, which is influenced by many factors. One possibility is to use the module for automatic generation of wind loads in **Autodesk Robot Structural Analysis** program, which is based on simulations in the wind tunnel. However, due to a long generation time of wind loads, this method cannot be directly used in the optimization issues, but can serve as a reference.

**IntelForm** proposes an approach, in which the values of wind loads are taken in an approximate way, but fast generation allows to apply them for comparing different variants of the structure. Wind load is defined based on the following values:

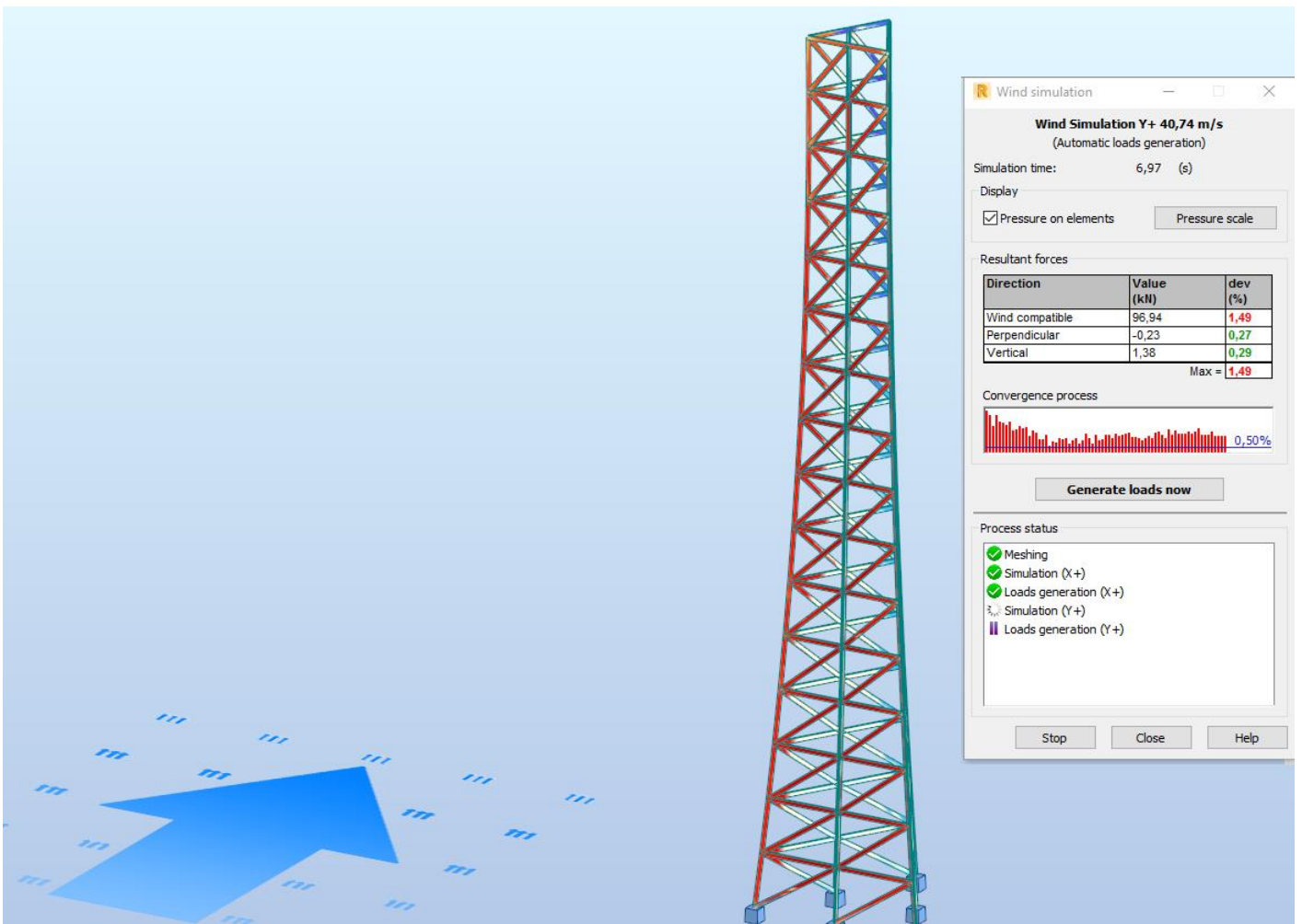


Normally there are 4 directions of wind (X +, X-, Y +, Y-) and by typing any angle in the **Rotation** field we can force any direction. The value of the load is specified directly by wind pressure or wind speed - these values are automatically calculated according to the formula  $q = 0.5 * \rho_0 * V * V$ ; where  $\rho_0$  is the density of the air taken as 1.2kg / m3. Ultimately, the program will be enriched with variable wind profile at altitude.

The program automatically retrieves the elements constituting the first obstacle on the direction of the wind and applies load to them, taking into account their actual cross-section and location. After starting the generation, which usually takes a few seconds, we get a visualization of the applied loads, and in the **Sum of loads** field the total value of wind loads is shown.

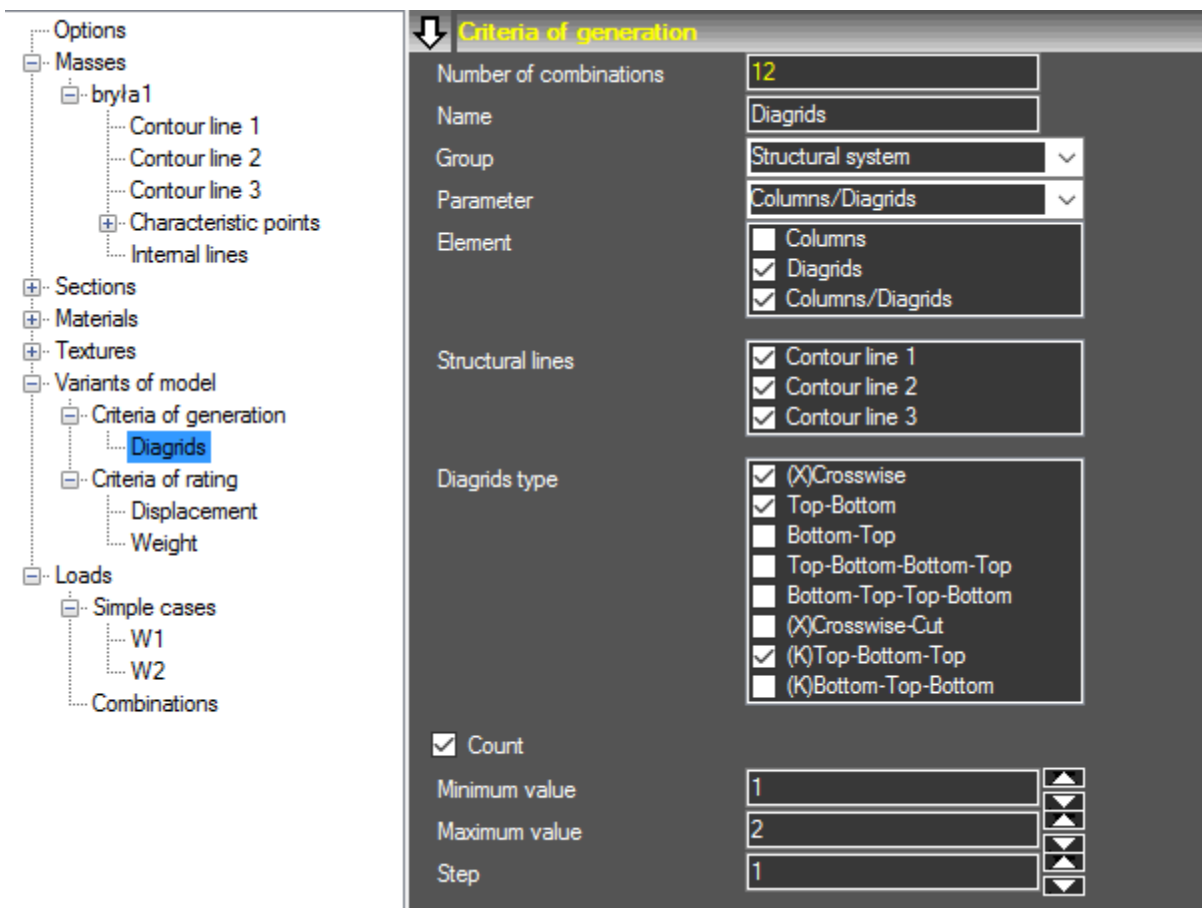
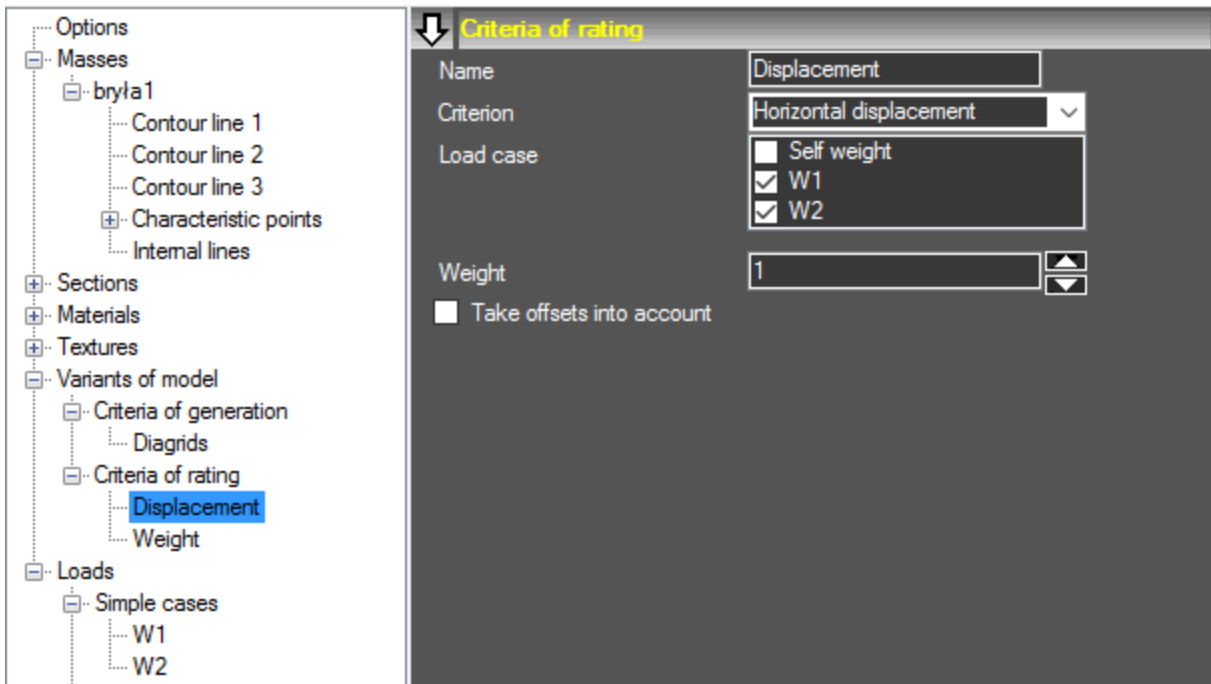


The next step is to compare these effects with effects obtained in **Autodesk Robot Structural Analysis**. To do this, we export the structure to Robot, where we run wind loads simulation. After calculations, we compare the sum of the forces generated by both approaches - as it can be seen, in Robot for one direction there are also forces on the other direction, but in our task it does not matter, because we are interested in the extreme values, and they will be always the greatest from forces on the given direction. Finally, we will focus on a comparison of the maximum horizontal displacements - in this example the differences are small and are of the order of a few percent. In the case of structures, where deviations are bigger, the values of wind loads can be in **IntelForm** multiplied by the appropriate increase factor.



Node/Case	FX (kN)	FY (kN)	FZ (kN)	UX (mm)	UY (mm)	UZ (mm)
<b>Reactions:1 in the coordinate system: global - Cases: 1to5</b>						
<b>Displacements - Case: 2 (W1)</b>						
Case 2	W1					
Sum of val.	-75,95	-0,00	-0,00	MAX 40,52	2,64	
Sum of reac.	-75,95	-0,00	-0,00	Node 98	30	
Sum of forc.	75,95	-0,00	0,00	Case 2	2	
Check val.	0,00	-0,00	-0,00			
Precision	4,96237e-14	2,54984e-11		MIN 0,0	-3,23	
				Node 1	101	
				Case 2	2	
<b>Displacements - Case: 4 (Wind Simulation X+ 40,74 m/s)</b>						
Case 4	Wind Simulation X+ 40,74 m/s					
Sum of val.	-63,40	39,57	-0,67	MAX 4,23	52,07	2,54
Sum of reac.	-63,40	39,57	-0,67	Node 102	100	99
Sum of forc.	63,40	-39,57	0,67	Case 3	3	5
Check val.	0,00	-0,00	-0,00			
Precision	5,01795e-14	7,63553e-11		MIN -3,62	0,0	-3,85
				Node 26	1	97
				Case 3	3	5
<b>Displacements - Case: 3 (W2)</b>						
Case 3	W2					
Sum of val.	-0,00	-98,47	0,00	MAX 4,77	50,84	2,54
Sum of reac.	-0,00	-98,47	0,00	Node 102	100	99
Sum of forc.	0,00	98,47	0,00	Case 5	5	5
Check val.	-0,00	0,00	0,00			
Precision	3,44928e-14	6,09354e-11		MIN -4,78	0,0	-3,85
				Node 26	1	97
				Case 5	5	5
<b>Displacements - Case: 5 (Wind Simulation Y+ 40,74 m/s)</b>						
Case 5	Wind Simulation Y+ 40,74 m/s					
Sum of val.	0,52	-89,79	-1,10	11,49	3,90	-0,08
Sum of reac.	0,52	-89,79	-1,10	1810,90	-3,95	1,99
Sum of forc.	-0,52	89,79	1,10	-1810,89	3,95	-1,99
Check val.	-0,00	0,00	0,00	0,02	-0,00	0,00
Precision	3,10064e-14	6,98716e-11				

With approximately defined wind load, we can begin to try to optimize the design. As the evaluation criteria we choose the smallest horizontal displacement and the weight of the structure, and created variants of the structure will vary as far as diagrids type is concerned. To compare generated variants and find the best model, the approximate values of wind loads are sufficient. It is only important that the potential increase coefficient for each variant was virtually the same (program currently works with such assumption).

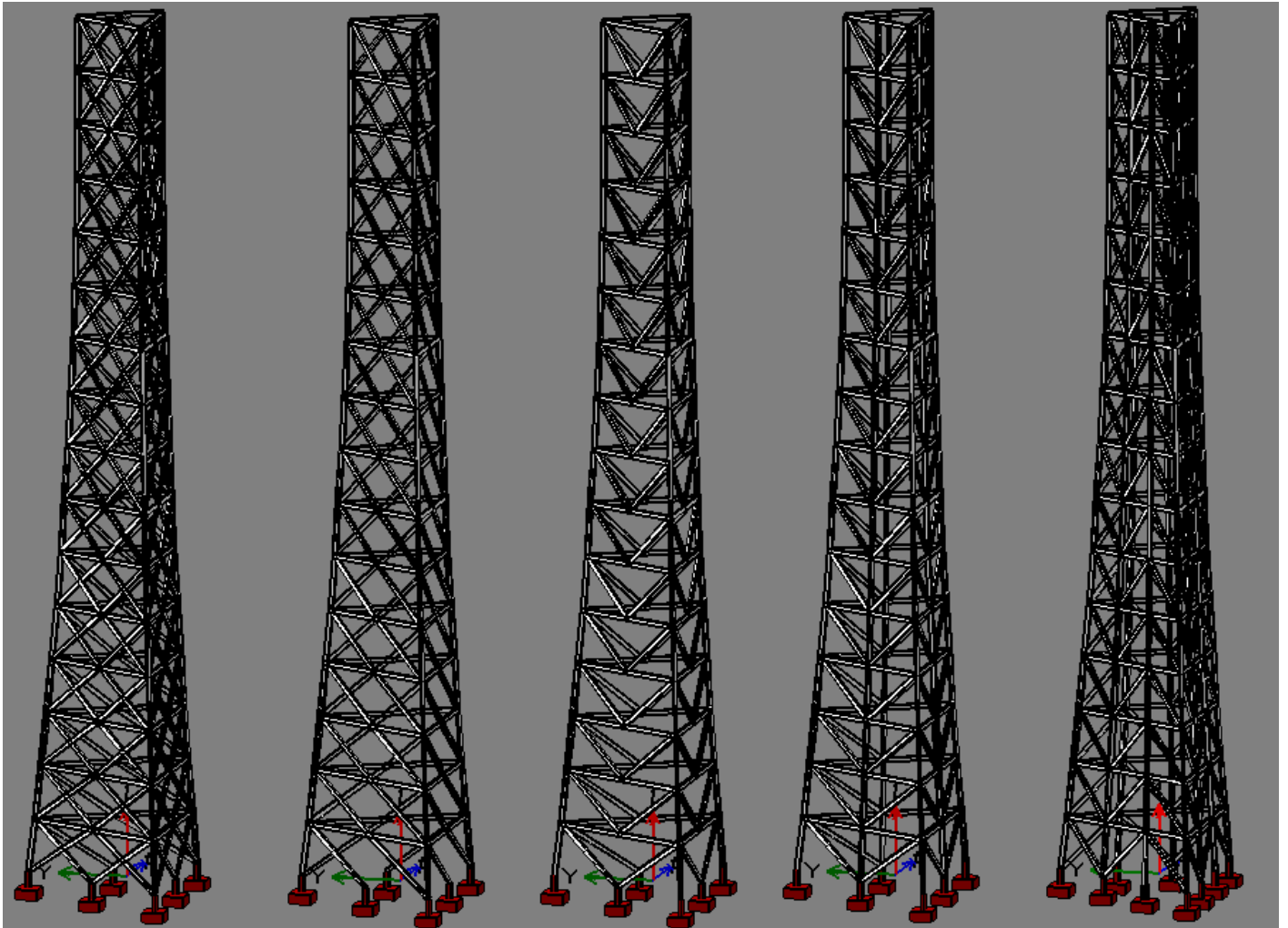


In **Element** field the generation of diagrids alone or diagrids with vertical columns has been chosen.

In **Diagrids type** 3 possibilities has been chosen. In **Count** field there is 1 or 2 columns, what gives 2 or 3 fields of diagrids.

These options in **Structural lines** field have been applied to all edges of the tower.

The above settings in generation criterion will create 12 different structure variants – a few of them are presented below.



The final step is variants comparing. Since displacement criterion has been defined, the calculation engine of Autodesk Robot Structural Analysis will be used in the background. For each variant there is a change in the geometry of the tower, so each time before the static calculations the wind loads are re-generated. Generally, it is difficult to predict the final result, as theoretically more rigid structure may have greater displacement due to the greater wind load value – for greater number of elements the wind resistance surface is also greater.

The whole process of comparing variants lasts at the present time for this example about 3min.40sek (i7-4790 processor), an average of approx. 18.5sec for one variant.

The smallest displacement has been obtained for variant with diagrids of type X in 3 fields with columns in the middle(40.8mm). At the same time this variant was the heaviest (40.8T)

**↓ Variants of model**

Number of variants:

Current variant:

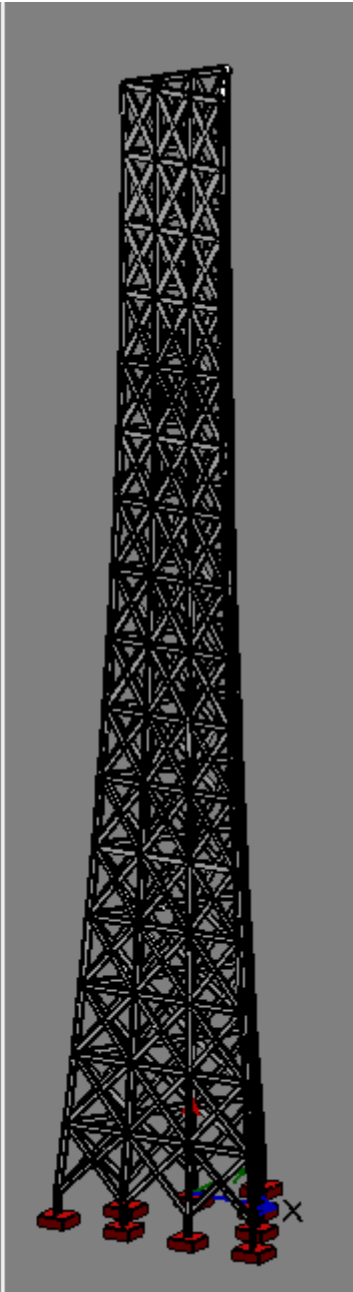
Sort according to rate

Variant parameters

	Parameter	Value
★	Columns/Diagrids	(X)Crosswise(2)

Variant rate

	Criterion	Weight	Variant	Value
	Horizontal displacement[mm]	1	1	40,874
	Structure weight[T]	1	0,519	40,833
★			0,76	



The biggest displacement has been obtained for variant with diagrids of type Top-Bottom in 3 fields without middle columns. (65.5mm).

↓ Variants of model

Number of variants: 12

Current variant: 9

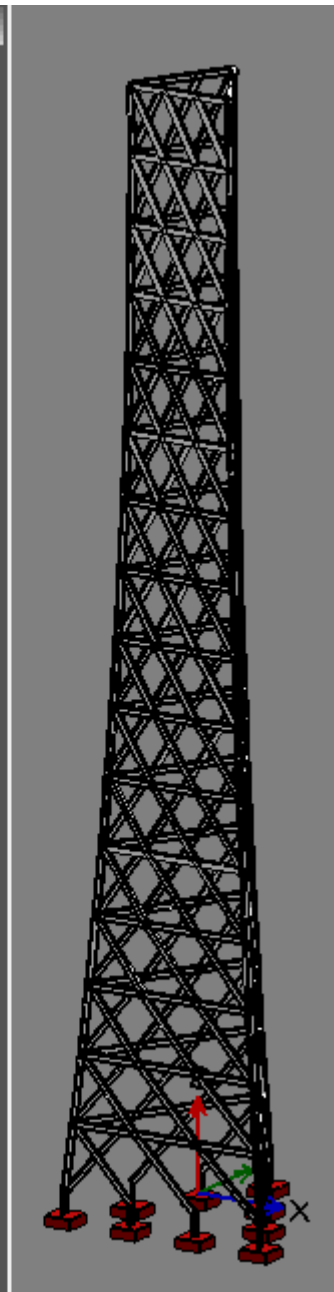
Sort according to rate

Variant parameters

Parameter	Value
Columns/Diagrids	Top-Bottom(2)

Variant rate

Criterion	Weight	Variant	Value
Horizontal displacement[mm]	1	0,624	65,485
Structure weight[T]	1	0,806	26,266
*		0,715	



As optimal the variant with diagrids of type Top-Bottom in 2 fields without middle columns has been chosen- displacement 57.3mm, structure weight 21.3T.

### ↓ Variants of model

Number of variants   
Current variant

Sort according to rate  
 Variant parameters

	Parameter	Value
*	Columns/Diagrids	Top-Bottom(1)

Variant rate

	Criterion	Weight	Variant	Value
	Horizontal displacement[mm]	1	0,713	57,312
	Structure weight[T]	1	0,995	21,277
*			0,854	

