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1. Basis of development

Order of the Client EcoENERGY Artur Grzelak

Agreements with the Client

Applicable technical-building regulations and Polish standards (PN-EN)

2. Standards

[1] PN-EN 1990:2004 Eurocode 0:

Basis for the design of structures

[2] PN-EN 1991-1-1:2004 Eurocode 1: Actions on structures - Part 1-1: General actions - Dead loads, loads

own, service loads in buildings

[3] PN-EN 1991-1-3:2005 Eurocode 1: Actions on structures - Part 1-3: General actions - Snow load

[4] PN-EN 1991-1-4:2008 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions

[5] PN-EN 1992-1-2:2008 Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

[6] PN-EN 1993-1-1:2006 Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings

[7] PN-EN 1993-1-3:2008 Eurocode 3: Design of steel structures - Part 1-3: General rules Supplementary rules for members with cold-formed sections and profiled sheets

[8] PN-EN 1993-1-8:2006 Eurocode 3:

Design of steel structures - Part 1-8: Designing joints

3. Subject and scope of the study

The subject of the study is a typical design of a steel hall construction intended for a production or warehouse building. The study includes the technical design of the object's structure – steel construction and reinforced concrete foundations.

The typical project requires adaptation to local conditions in terms of compliance with adopted climatic loads and adopted foundation conditions. Adaptation should be carried out by an authorized designer in the structural-building specialty.

4. Assumptions adopted for design

4.1. Loads

- Load from roof covering
  Layered board with PUR or PIR core - 0.20 kN/m2

- Technological loads from suspensions to the roof structure
  Adopted characteristic load - 0.10 kN/m2

- Climatic loads [snow according to [3]

  Adopted snow load Zone II (sk=0.9 kN/m2, μ1=0.8)

- Climatic loads - wind according to [4]

  Adopted wind load Zone I (vb=22 m/s, terrain category II)

The designer of the adaptation of this project to local conditions will assess the conformity of the adopted load assumptions with the actual condition for the given location of the object.

4.2 Construction materials

- Concrete:

foundations structural concrete	C25/30 W-8

- Steel:

reinforcement steel in reinforced concrete structures structural steel of main frames cold-formed steel screw class	B500SP S355JR S350GD 8.8 (8)

4.3 Environmental aggressiveness classification

- Exposure class of concrete structures:

  XC2 – for underground elements

- Corrosion category for steel structures according to PN-EN ISO 12944-2:

  C2 – for internal elements

The designer of adapting this project to local conditions will assess the conformity of the adopted environmental classification assumptions with the actual state for the given location and intended use of the facility.

4.4 Classification of structure and contractor

Class of steel structure consequence: CC2 according to PN-EN 1990 [1] Class of steel structure execution: EXC2 according to PN-EN 1090-2 Tolerance class for steel structure: 2 according to PN-EN 1090-1+A1:2012 Class of concrete structure execution: 3 according to PN-EN 13670:2011 Tolerance class for concrete structure: 1 according to PN-EN 13670:2011

4.5 Fire resistance class of the structure

The designed structure does not require fire resistance specifications.

5. General concept of the object's construction

A one-story hall building with a steel – frame construction was designed. The frames with a transverse span of 14.00 m are arranged in 9 axes at 5.0 m. The hall consists of 8 bays, giving a total building length of 40.0 m. The height of the hall is: 5.00 m (at the eave), 7.00 m (at the ridge). The roof slope angle is 16°.

The main and ridge frames are designed from parallel-section I-beams (IPE) – struts and wide-flange (HEA) columns. Corner nodes of internal frames are connected with guy wires from Ø20 mm round bars. In the corners of the frames, sloped plates are designed to increase the structural height of the sections. Second-order elements (roof purlins) from cold-formed Z sections. The main and ridge frame columns will be supported on reinforced concrete foundation pads.

The hall structure will be braced in the two fore-edge bays using tie trusses tensioned – cross, from circular bars.

6. Geotechnical conditions of object foundation

6.1. Description of adopted assumptions

The project assumes the hall is founded on direct foundations – reinforced concrete pads. Foundations. It is assumed that the foundation will be placed on native mineral bearing soils – for calculations, the soil parameters are taken as for medium sand, medium-dense:

Nr	Name	φef [°]	cef [kPa]	γ [kN/m3]	γsu [kN/m3]	δ [°]
1	Medium sand, medium-dense	33.50	0.00	18.50	8.50	

Assessment of soil conditions and final decision regarding the method of foundation the designer will adapt this project to local conditions.

During foundation works, note that the foundation placement of the designed foundations must be carried out on native soil with an undisturbed structure. For this purpose, manually remove the last 30 cm of soil and immediately apply a leveling concrete layer C8/10. Any soil loss should be filled with concrete C8/10. Foundation excavations must be protected against groundwater and rainwater.

Assumed freezing-thawing zone Hz=1.00 m

6.5. Geotechnical category

The geotechnical category will be determined by the adaptation designer, in accordance with the Regulation of the Minister of Transport, Construction and Maritime Economy of April 25, 2012 on establishing geotechnical conditions for the foundation of building objects.

7. Foundation

Under the steel frame columns, monolithic rectangular footing foundations were designed, single-strap (one-slope) concrete C25/30, reinforced with B500SP grade steel. The footings are set at 1.00 m below ground level. In the foundation-soil contact zone a layer of a leveling layer made of concrete C8/10, thickness 10 cm. In the footings, anchoring bars will be installed using chemical anchors, e.g. FISCHER.

Under the light cladding of the external walls of the hall, foundation (sole) beams made of reinforced concrete were designed, prefabricated from concrete C25/30, reinforced with steel grade B500SP. The beam cross-section dimensions are 15x75 cm. The beams are founded at level -0.60 m below level “0” on the previously made footing bases. The foundation beams must be connected monolithically to the foundation footings, because they are an important bracing element of the main structure!

Reactions from the main columns to the foundations (axes A, D) (to be verified with the foundation layout design)

Node No.:	Rx:	Ry:	Rz:	Mx:	My:	Mz:	Loads:
15	-1,57	9,53	17,79	-0,36	0,00	0,00	CW+1,35·Ns+P+Pd
	-21,25	3,36	56,11	-0,03	0,00	0,00	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W1+W2)
	-9,66	9,97	19,41	-0,42	0,00	0,00	CW+1,35·Ns+P+Pd+1,5·W1
	-13,15	2,83	54,64	0,03	0,00	0,00	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W2)
	-7,31	3,82	10,02	0,01	0,00	0,00	CW+Ns+P+Pd+1,5·W2
	-21,13	5,91	56,31	-0,13	0,00	0,00	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1+W2)
	-20,54	3,48	50,12	-0,03	0,00	0,00	CW+Ns+P+Pd+1,5·(Sn+W1+W2)
	-10,04	9,91	22,90	-0,42	0,00	0,00	1,35·(CW+Ns)+P+1,35·Pd+1,5·W1
	-15,74	4,25	14,07	-0,05	0,00	0,00	CW+Ns+1,35·P+Pd+1,5·(W1+W2)
	-15,51	9,03	63,96	-0,40	0,00	0,00	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1) [Bx=1,5 By=0,9 Hz=1 Ex=0 Ey=0]
	-15,28	6,86	11,75	-0,15	0,00	0,00	CW+1,35·Ns+P+Pd+1,5·(W1+W2) [Bx=1,5 By=0,9 Hz=1 Ex=0 Ey=0]

Reactions from top columns to foundations (axes B,C) (to verify the foundation design)

Node No.:	Rx:	Ry:	Rz:	Mx:	My:	Mz:	Loads:
73	0,38	-6,32	20,68	0,00	-0,63	0,00	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W2)
	-1,39	9,87	17,95	0,00	-2,59	-0,01	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W1)
	0,14	-6,37	5,40	0,00	-1,00	0,00	CW+1,35·Ns+P+Pd+1,5·W2
	0,30	0,07	22,82	0,00	0,45	0,00	1,35·CW+Ns+1,35·(P+Pd)+1,5·Sn
	-1,54	3,42	0,52	0,00	-4,04	0,00	CW+1,35·Ns+P+Pd+1,5·(W1+W2)
	-1,39	9,86	17,54	0,00	-2,60	-0,01	1,35·CW+Ns+1,35·P+Pd+1,5·(Sn+W1)
	-1,40	9,86	17,13	0,00	-2,61	0,00	1,35·CW+Ns+P+1,35·Pd+1,5·(Sn+W1)
	-1,62	9,81	4,09	0,00	-2,95	0,00	1,35·CW+Ns+P+Pd+1,5·W1
	0,29	0,07	21,39	0,00	0,45	0,00	CW+Ns+1,35·(P+Pd)+1,5·Sn
	-1,39	9,86	17,93	0,00	-2,60	-0,01	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1) [Bx=1,5 By=0,9 Hz=1 Ex=0 Ey=0]
	-1,63	9,81	2,66	0,00	-2,96	0,00	CW+1,35·Ns+P+Pd+1,5·W1 [Bx=1,5 By=0,9 Hz=1 Ex=0 Ey=0]

8. Description of steel construction

8.1 Static schemes of structural elements

The following structural schemes were adopted for calculations:

- frame gBówne: ground-floor single- span frames with rigid joints and [chain, hinged on foundation feet,
- roof rafter: beams ci gBe, o[mioprz sBowe

- Supporta podciągane szczytowych: belka wolnopodparta z dodatkow□ si□B□ [ciskaj□c□.

8.2 Main frames (steel S355JR)

The main frames of the hall were designed from hot-formed I-beams – parallelepiped IPE 240 (bracings) and wide-flange HEA180 (columns). Bracing profiles in corner joint zones were expanded by welding plates to increase load capacity and stiffness of elements (in accordance with the bending moment distribution) and tied with tie rods. All rigid connections are designed as dead-end bolted category D pre-tensioned to 5% of capacity using M20 bolts of grade 8.8 (8). Stability of the system in the transverse direction is ensured by the frame with rigid corner nodes. In the longitudinal direction, transverse roof braces between bracing frames and vertical wall bracing between columns ensure stability.

8.3 Peak frame columns (steel S355JR)

Peak frame columns were designed from hot-rolled HEA140 profiles. Connections columns with bracing bolted connections Category D, pre-tensioned to 5% capacity using M20 bolts of grade 8.8 (8).

8.4 Roof purlins (steel S350GD)

Purlins designed as continuous, multi-span beams with bent members of height 180 mm and wall thickness 2.0 mm. Theoretical span of purlin bays is 5.0 m, with transverse spacings about 1.55 m. Tensioning of purlins will be achieved by overlaps in support zones of length 100 cm.

8.5 Roof bracing (steel S355JR)

Designed cross-roof bracing in an X arrangement from hollow circular rods pre-tensioned (pre-tensioned up to 10% of load capacity) with a diameter of 12 mm. Braces will be located in the pre-edge fields of the hall.

8.6 Wall bracing (steel S355JR)

Designed inter-column wall braces in an X arrangement from round bars pre-tensioned (up to 10% of capacity) with 20 mm diameter. Braces will be located in the pre-edge fields of the hall.

8.7 Guidelines for anti-corrosion protection of structural steel elements

Corrosion aggressiveness class for steel construction – C2 according to T1. PN-EN-ISO 12944-2 Surface preparation grade before painting Sa 2½ according to PN-ISO 12944-4. Expected durability: long-term H (over 15 years) according to T.A.1 PN-EN-ISO 12944-5. Top coat color as per individual agreements.

8.8 Conditions of execution and acceptance of steel structure

Steel construction elements must be manufactured to execution class EXC2

(according to PN EN 1090-2 table B.3)

The execution class was chosen based on the following assumptions:

- destruction class CC2
- usage category SC1
- production category PC2

Surface preparation grade of steel elements – P2 according to table 22 PN EN 1090-2, Functional tolerance class 1 according to annex D PN EN 1090-2, basic tolerances according to annex D PN-EN 1090-2.

Marking of elements required.

The installation of steel structures shall be carried out based on the assembly design prepared by the company installing the structure, in accordance with the guidelines contained in section 9 PN EN 1090-2. The assembly should be performed only by installation crews with the appropriate equipment and qualifications necessary to perform the installation in accordance with this description and cited standards. Before starting installation, the installation manager should check the completeness of the delivered structure and fasteners, report any damages for removal, and prepare prefabricates in an order convenient for installation.

Steel profiles, plates, and sections used for prefabrication of the structure, in relation to technical delivery conditions, dimensions, and tolerances, must meet the corresponding standards assigned in tables 2, 3, 4 PN-EN 1090-2.

Thickness tolerance of plates A according to 5.3.2 PN EN 1090-2.

Condition of flat plate surfaces class A2, condition of profiles surfaces class C1 according to 5.3.3 PN EN 1090-2.

Additional materials for welding shall meet EN 13479 and the relevant product standards listed in table 5.

For non-preloaded connections, bolts compliant with EN 15048-1 should be used (ISO 4014 bolts with partial thread + ISO 4032 nut from a single manufacturer). Bolt connections shall be checked for class markings on heads and tightening of nuts to the first stop for non-preloaded bolts.

Bolt thread must protrude from the nut by at least 2 turns. Each non-preloaded connection should be brought to a tight clamping condition according to section 8.3 PN EN 1090-2.

Hot-dip galvanized bolts, nuts, and washers.

Structural products should be transported and stored under conditions compliant with the manufacturers' guidelines. During transport and storage, appropriate protections should be used according to table 8 PN EN 1090-2. The contractor shall prepare a procedure for renewing elements damaged during transport.

Materials and products shall be stored and maintained in accordance with the standards and warranty conditions, in a way that allows easy and unambiguous identification of each delivery. Unmarked products should not be used on load-bearing structural elements.

Surface quality after cutting, defined in accordance with EN ISO 9013, should meet the requirements for EXC2 class per tab. 9 PN EN 1090-2.

Welding of the structure shall be performed in accordance with the requirements contained in PN EN ISO 3834-3. Before starting welding, a welding plan shall be prepared based on PN EN ISO 3834-3 and the guidelines for its content as specified in point 7.2.2 PN EN 1090-2.

Workshop contacts of components shall be agreed with the structural designer. Do not perform workshop butt joints in elements shorter than 6 m.

Qualification of the welding method and welding personnel together with welding supervision in point 7.4 PN EN 1090-2.

Welding nonconformity criteria are adopted according to EN ISO 5817 – quality level C. NDT inspection scope for the construction per Table 24 for the specified EXC2 class. Selection of inspection methods according to standards assigned to each method (RT – EN 1435, UT – EN 1714/EN 1713, MT – EN 1290, PT – EN 571-1). All welds are visually inspected according to EN 970.

Anti-corrosion protection of steel sections will be a paint coating selected based on parameters defined in point 4.3.

The steel structure contractor is obliged to prepare a quality plan in accordance with Appendix C PN EN 1090-2.

9. Structural handover

During assembly of the structure, the following inspections shall be performed:

- checking the elevations of the top of the foundations,
- checking the compliance and completeness of the assembled structure, checking assembly deviations,
- checking tensioned and non-tensioned connectors
- checking the dimensions of elements, reinforcement (diameter, spacing).

10. Final remarks

Any ambiguities regarding this project and any changes to applied solutions must be consulted and agreed on promptly, within the framework of the author's supervision, with the design unit and its authorized designers.

Changes to the project are not allowed without the authors' consent of this document. All changes must receive written approval from the project authors.

All construction works in carrying out the structure must be performed solidly, in accordance with this project, PN standards and regulations, technical knowledge, under the proper supervision of an authorized person and in compliance with health and safety regulations.

For construction works, only materials and products with appropriate approvals and certificates enabling their use in Poland should be used.

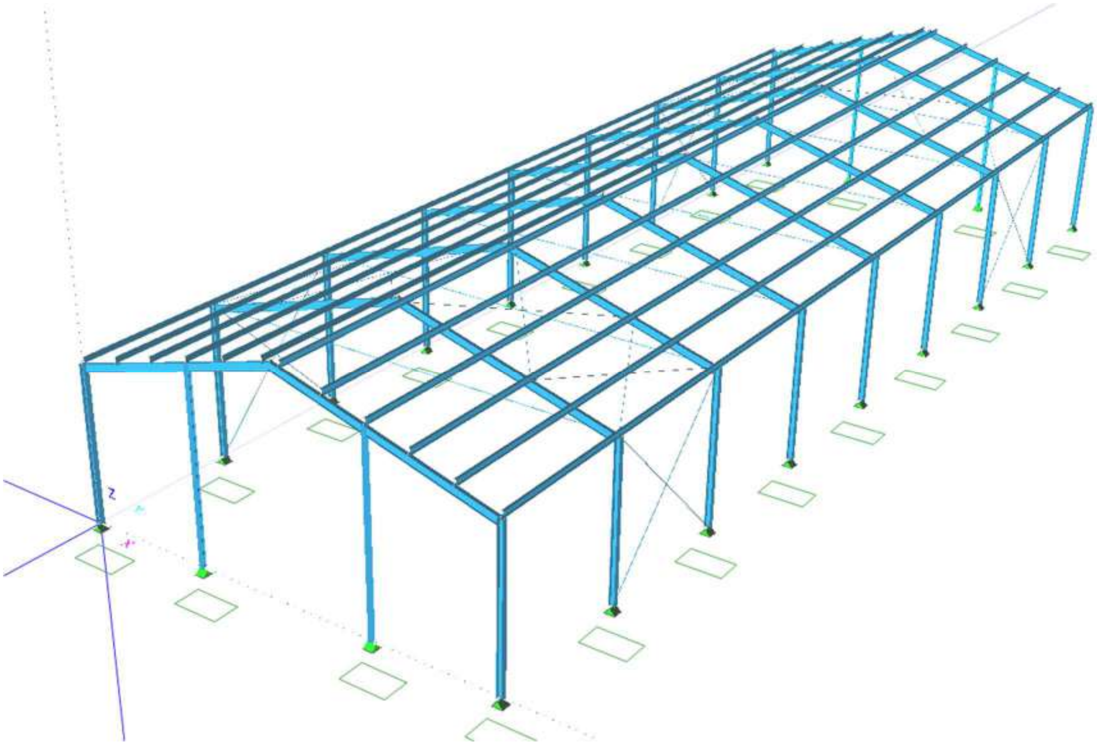
Before starting the implementation, the contractor is obliged to prepare a work organization project. The organization project must take into account maintaining the stability of the structure at every stage of its realization.

11. Static strength calculations

Static strength calculations of rod elements of the hall structure were carried out in a spatial model using RM_3d software v. 8.75 license no. 41191.

Foundation calculations were performed using GEO5 - Direct foundations, license no. 11155/1.

11.1 Static model



Sections:

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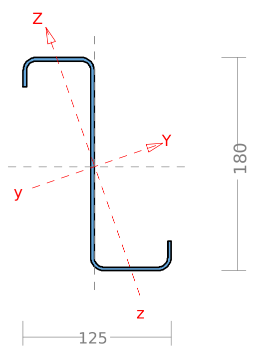		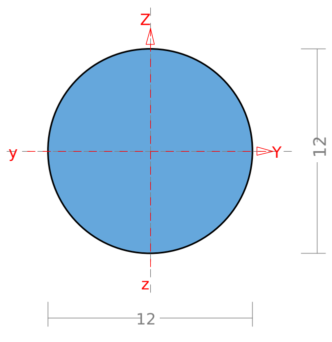		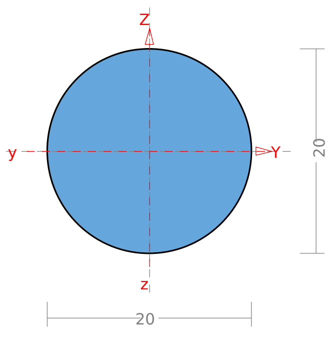	
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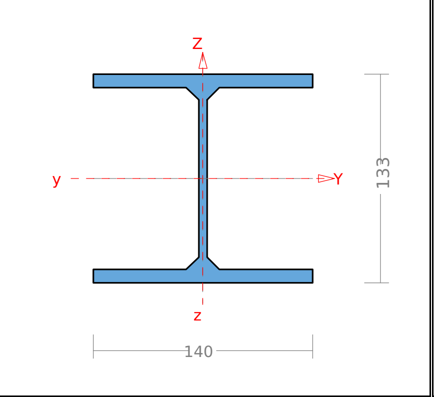
Jz [cm4]	88,81	Jz [cm4]	0,10	Jz [cm4]	0,79
Dyz [cm4]	-151,40	Dyz [cm4]	0,00	Dyz [cm4]	0,00
α[Deg]	19,27	α[Deg]	0,00	α[Deg]	0,00
Iy [cm4]	521,98	Iy [cm4]	0,10	Iy [cm4]	0,79
Iz [cm4]	35,89	Iz [cm4]	0,10	Iz [cm4]	0.79
Jt [cm4]	0.31	Jt [cm4]	0.10	Jt [cm4]	0.78
Jω [cm4]	5461.01	Jω [cm4]	0.00	Jω [cm4]	0.00

iy [cm]	7,26	iy [cm]	0,30	iy [cm]	0,50
iz [cm]	1,90	iz [cm]	0,30	iz [cm]	0,50
is [cm]	7,52	is [cm]	0,42	is [cm]	0,71
m [kg/m]	7,76	m [kg/m]	0,00	m [kg/m]	0,00

4 - I 140 HEA



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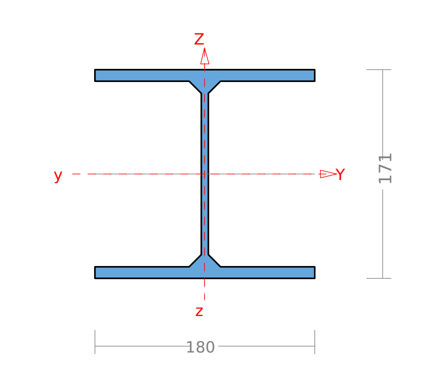
Jz [cm4]	389,00
Dyz [cm4]	0,00
α[Deg]	0,00
Iy [cm4]	1033.00
Iz [cm4]	389.00
Jt [cm4]	7.71
J□ [cm4]	15063.66
iy [cm]	5.74
iz [cm]	3.52
is [cm]	6.73
m [kg/m]	24.65

5 - I 180 HEA



Material:	S 355
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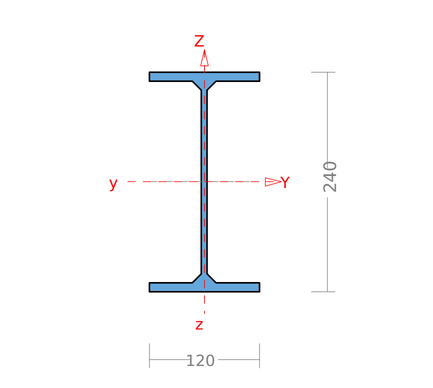
Jz [cm4]	925,00
Dyz [cm4]	0,00
α[Deg]	0.00
Iy [cm4]	2510.00
Iz [cm4]	925.00
Jt [cm4]	13.74
J□ [cm4]	60210.87
iy [cm]	7.44
iz [cm]	4.52
is [cm]	8.71
m [kg/m]	35.56

6 - I 240 PE



Material:	S 355
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Jz [cm4]	284,00
Dyz [cm4]	0,00
α[Deg]	0.00
Iy [cm4]	3890.00
Iz [cm4]	284.00
Jt [cm4]	11.23
J□ [cm4]	37391.18
iy [cm]	9.97
iz [cm]	2.70
is [cm]	10.33
m [kg/m]	30.69

Materials:

No.:	Type:	Name:	E:	G:	:	α_T:	ρ:	Ro:
			[GPa]	[GPa]	[-]	[1/K]	[kg/m3]	[MPa]
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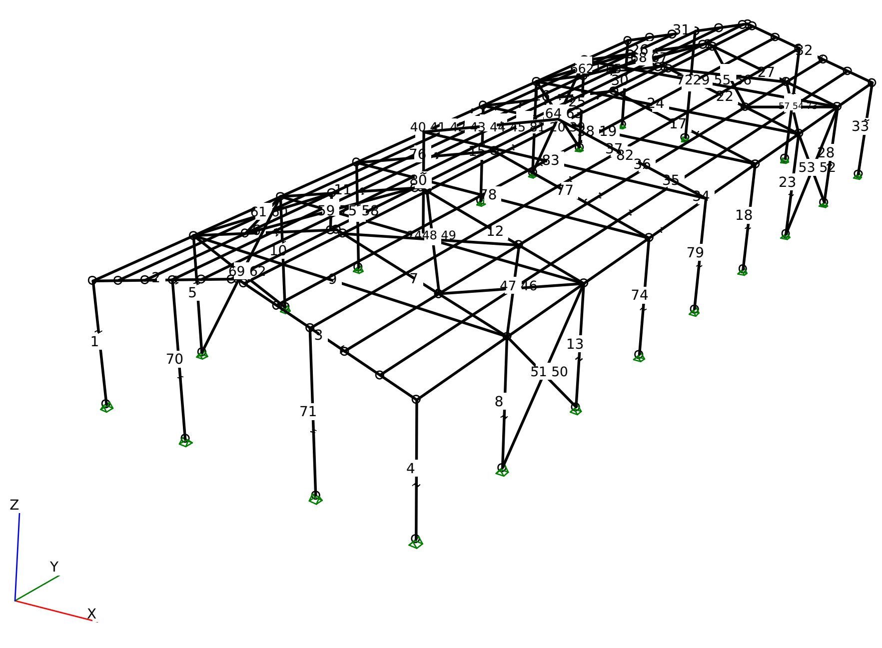
6	Steel 1993	S 355 weightless	210	81	0,3	0	0	355



Bars:

No.:	Nodes:		Orient. fixings		L[m]:	Section:
	A:	B:		[deg]		
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41 47 46 P.P.: Rigid 164,1 40,000						1 Angle section Gc 180x68x6
42	49	48 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
43	51	50 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
44	53	52 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
45	55	54 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
34 34 4 P.P.: Rigid 164,1 40,000						1 Angle section Gc 180x68x6
35	36	37 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
36	38	39 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
37	40	41 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
38	42	43 P.P.: Rigid 164,1 40,000				1 Angle section Gc 180x68x6
39 44 45 P.P.: Rigid 164,1 40,000						1 Angle section Gc 180x68x6
2	2	3 P.P.: Rigid		0,0	7,280	6 I 240 PE
3	3	4 P.P.: Rigid		0,0	7,280	6 I 240 PE
6	7	8 P.P.: Rigid		0,0	7,280	6 I 240 PE
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11 12 13 P.P.: Rigid 0.0					7,280	6 I 240 PE
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21	22	23 P.P.: Rigid		0.0	7,280	6 I 240 PE
22 23 24 P.P.: Rigid 0.0					7,280	6 I 240 PE
26	27	28 P.P.: Rigid		0.0	7,280	6 I 240 PE
27	28	29 P.P.: Rigid		0.0	7,280	6 I 240 PE
31	32	33 P.P.: Rigid		0.0	7,280	6 I 240 PE
32	33	34 P.P.: Rigid		0.0	7,280	6 I 240 PE
76	79	80 P.P.: Rigid		0.0	7,280	6 I 240 PE
77	80	76 P.P.: Rigid		0.0	7,280	6 I 240 PE
81	84	85 P.P.: Rigid		0.0	7,280	6 I 240 PE
82	85	81 P.P.: Rigid		0,0	7,280	6 I 240 PE
9	9	7	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
14	14	12	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
19	19	17	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
24	24	22	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
29	29	27	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
46 9 56 P.P.: None				0,0	5,731	2 R *12x6
47	14	57	P.P.: None	-6,6	5,731	2 R *12x6
48	57	58	P.P.: None	-1,4	6,530	2 R *12x6
49	56	59	P.P.: None	-7,3	6,530	2 R *12x6
50	10	14	P.P.: None	0,0	7,071	3 R *20x10
51 15 9 P.P.: None				0,0	7,071	3 R *20x10
52	30	24	P.P.: None	0,0	7,071	3 R *20x10
53	25	29	P.P.: None	0,0	7,071	3 R *20x10
54	24	60	P.P.: None	0,0	5,731	2 R *12x6
55	61	62	P.P.: None	-1.4	6,530	2 R *12x6
56 60 63 P.P.: None				-7.3	6,530	2 R *12x6
57	29	61	P.P.: None	-6.6	5,731	2 R *12x6
58	65	64	P.P.: None	-7.3	6,530	2 R *12x6
59	67	66	P.P.: None	-1.4	6,530	2 R *12x6
60	66	12	P.P.: None	-6.6	5,731	2 R *12x6
61 64 7 P.P.: None				0,0	5,731	2 R *12x6
62	7	11	P.P.: None	0,0	7,071	3 R *20x10
63	27	21	P.P.: None	0,0	7,071	3 R *20x10
64	22	26	P.P.: None	0,0	7,071	3 R *20x10
65	68	27	P.P.: None	-6,6	5,731	2 R *12x6
66 69 22 P.P.: None				0,0	5,731	2 R *12x6

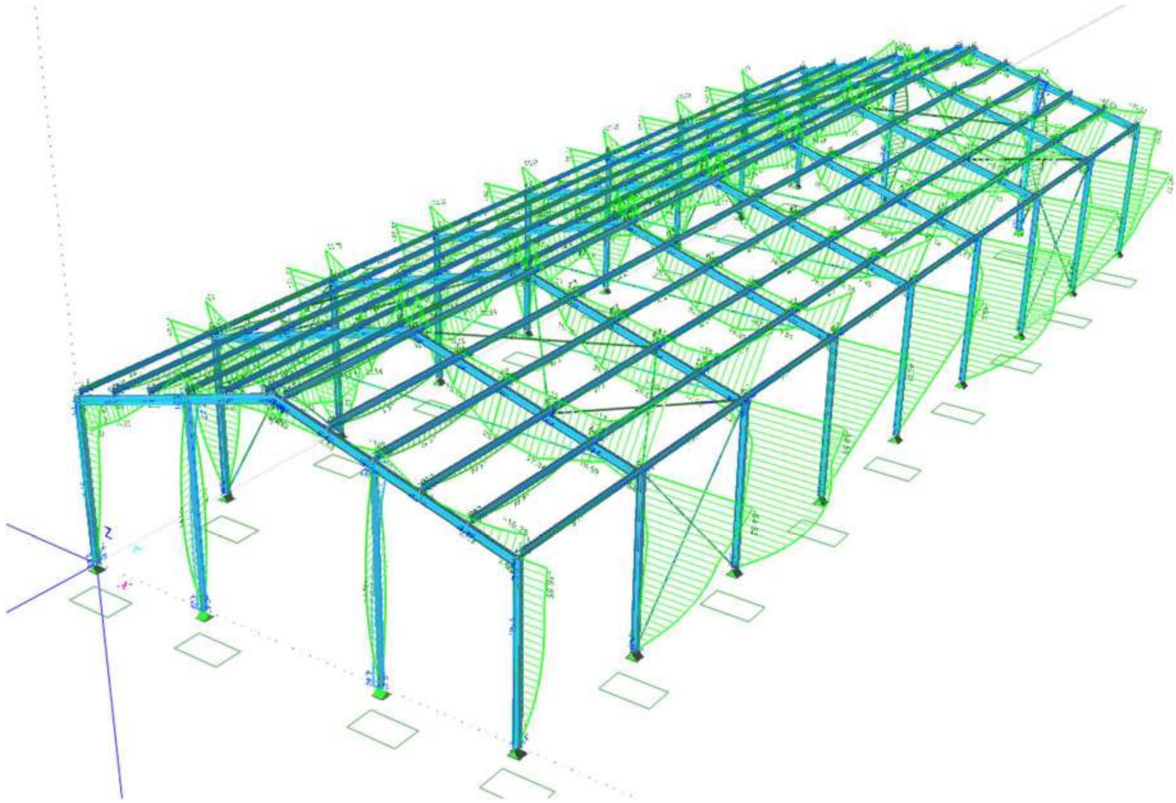
67	70	68	P.P.: None	-1,4	6,530	2 R *12x6
68	71	69	P.P.: None	-7,3	6,530	2 R *12x6
69	12	6	P.P.: None	0,0	7,071	3 R *20x10
78	76	79	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
83	81	84	A:y B:y	180,0 14,000		3 R *20x10
			P.P.: Rigid			
1	1	2 P.P.: Rigid 180,0			5,000	5 I 180 HEA
4	4	5 P.P.: Rigid		0,0	5,000	5 I 180 HEA
5	6	7 P.P.: Rigid 180,0			5,000	5 I 180 HEA
8	9	10 P.P.: Rigid		0,0	5,000	5 I 180 HEA
10	11	12 P.P.: Rigid 180,0			5,000	5 I 180 HEA
13	14	15 P.P.: Rigid		0,0	5,000	5 I 180 HEA
15	16	17 P.P.: Rigid 180,0			5,000	5 I 180 HEA
18	19	20 P.P.: Rigid		0,0	5,000	5 I 180 HEA
20	21	22 P.P.: Rigid 180,0			5,000	5 I 180 HEA
23	24	25 P.P.: Rigid		0,0	5,000	5 I 180 HEA
25 26 27 P.P.: Rigid 180,0					5,000	5 I 180 HEA
28	29	30 P.P.: Rigid		0,0	5,000	5 I 180 HEA
30	31	32 P.P.: Rigid 180,0			5,000	5 I 180 HEA
33	35	34 P.P.: Rigid 180,0			5,000	5 I 180 HEA
74	76	77 P.P.: Rigid		0,0	5,000	5 I 180 HEA
75 78 79 P.P.: Rigid 180,0					5,000	5 I 180 HEA
79	81	82 P.P.: Rigid		0,0	5,000	5 I 180 HEA
80	83	84 P.P.: Rigid 180,0			5,000	5 I 180 HEA
70	51	72	A:y	72,9	6,154	4 I 140 HEA
			P.P.: Rigid			
71 41 73			A:y	72,9	6,154	4 I 140 HEA
			P.P.: Rigid			
72	74	50	B:y	72,9	6,154	4 I 140 HEA
			P.P.: Rigid			
73	75	40	B:y	72.9	6,154	4 I 140 HEA
			P.P.: Rigid			

Loads:

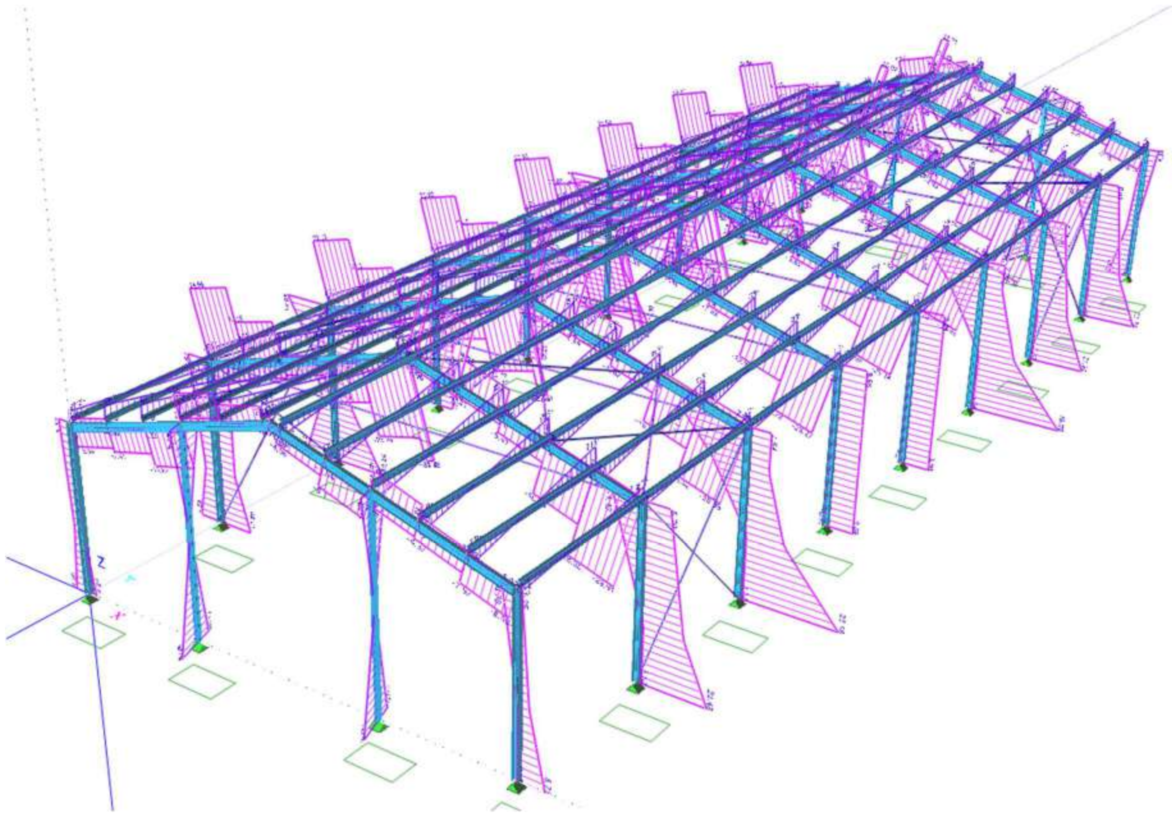
No. Bar/rod	Type:	Characteristic values Orientation coefficients: Position								Name:	
		Pa: Pb:		□G,sup(□Q):	□G,inf:	[deg] [deg] xa: xb:					
CW: Self-weight - Constant □G,sup=1.4 □G,inf=1											
P: Covering - Constant											
	Surface	0.20	0.20	1.35	1.00					Surface	
Pd: Suspensions - Constant											
	Surface	0.10	0.10	1.35	1.00					Surface	
Sn: Snow - Variable □0=0.5 □1=0.2 □2=0											
	Surface	0.72	0.72	1.50						Surface	
W1: Wind left - Variable □0=0.6 □1=0.2 □2=0											
	Surface	0.28	0.28	1.50						Surface	
	Surface	-0.22 -0.22 1.50								Surface	
	Surface	0.44	0.44	1.50						Surface	
	Surface	0.44	0.44	1.50						Surface	
W2: Wind peak - Variable □0=0.6 □1=0.2 □2=0											
	Surface	-0.44 -0.44		1.50						Surface	
	Surface	-0.44 -0.44		1.50						Surface	
	Surface	-0.28 -0.28 1.50								Surface	
	Surface	0.20	0.20	1,50						Surface	
	Surface area.	0,30	0,30	1,50						Surface	
	Surface area.	0,30	0,30	1,50						Surface	

11.2 Results – global model

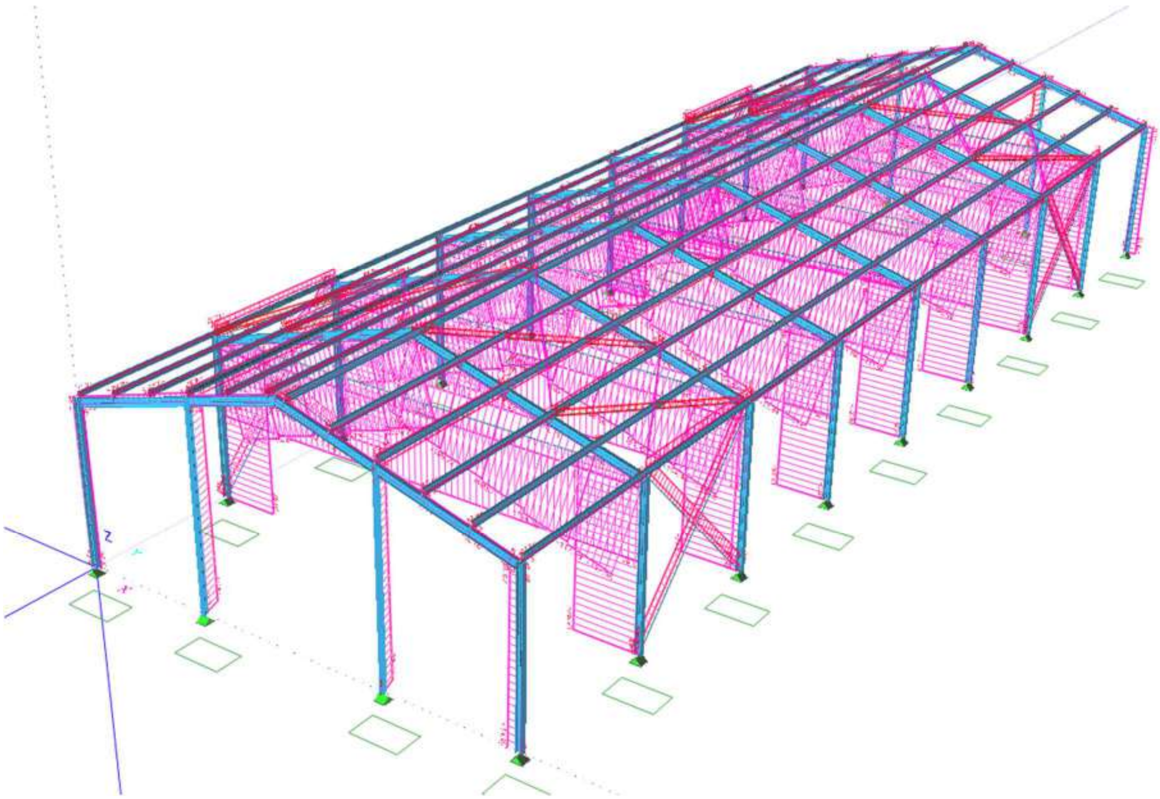
Bending moments My [kNm] (sections)



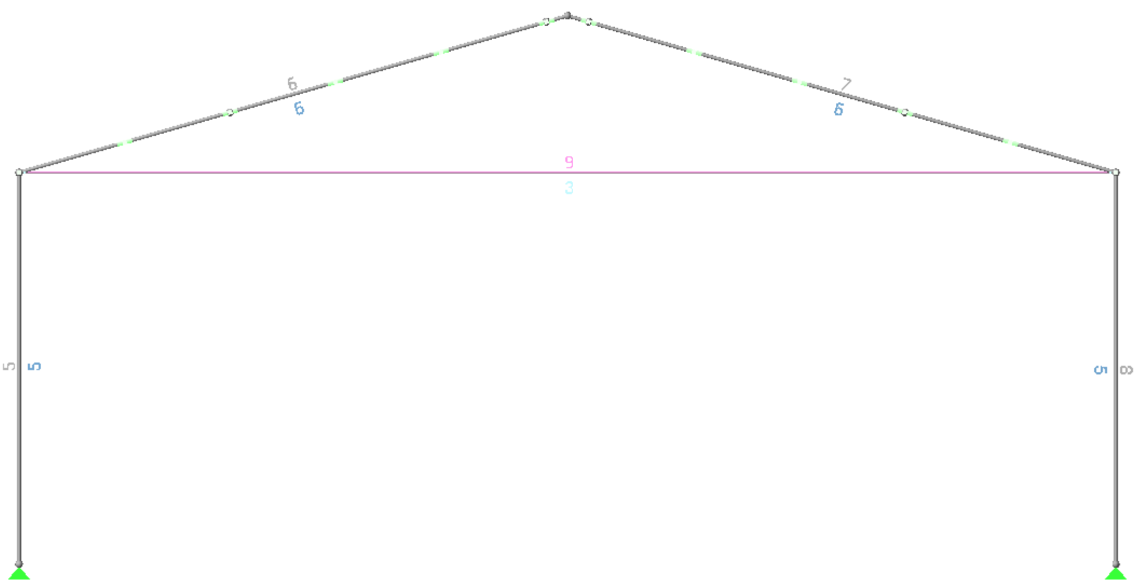
Shear forces Tz [kN] (sections)



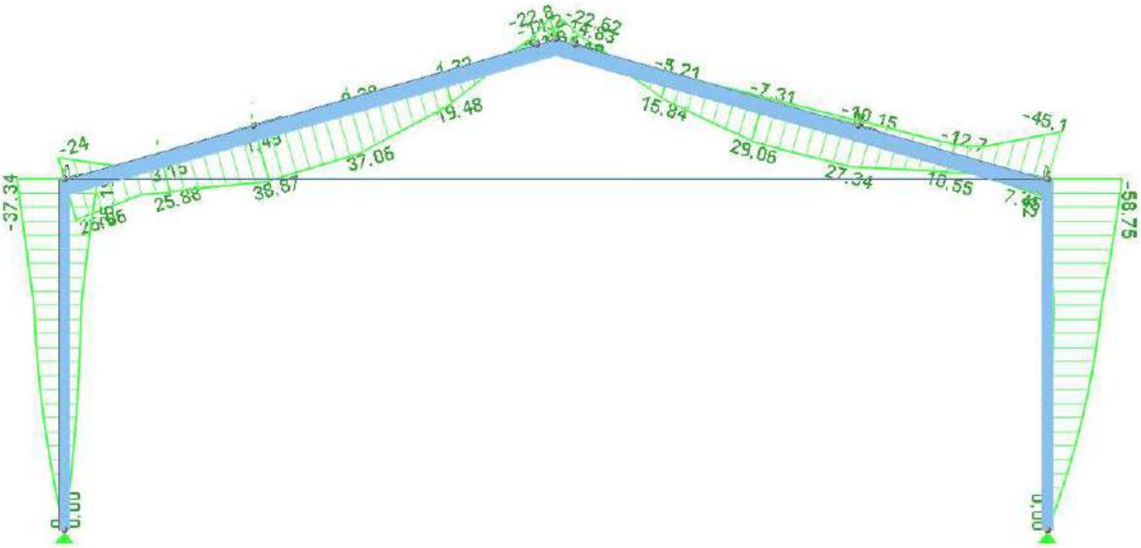
Normal forces N [kN] (perimeter)



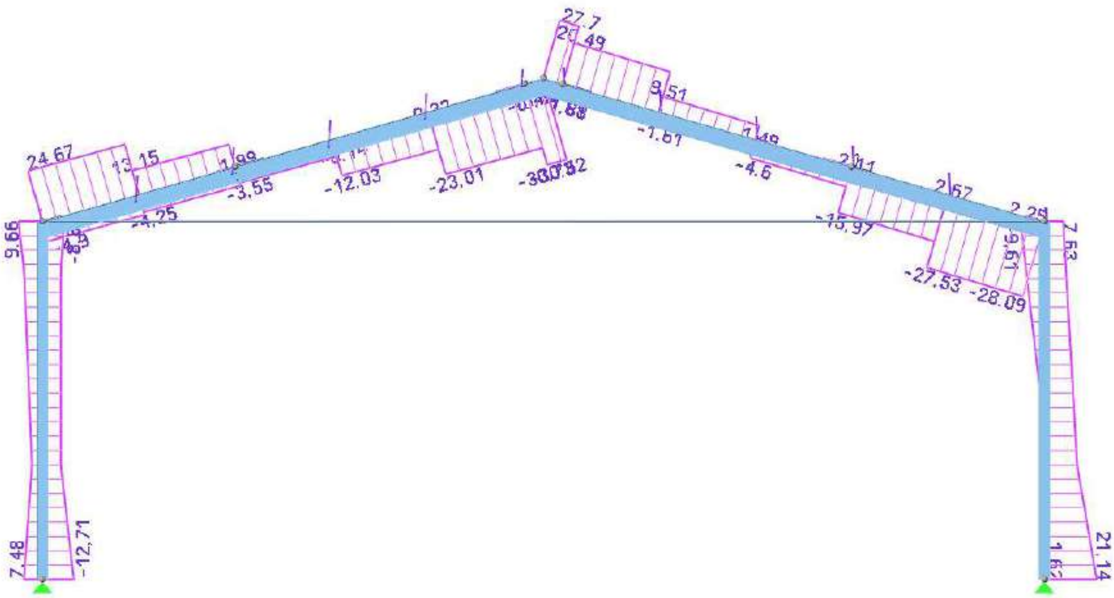
11.3 Results – pre-skid frame (axis 2)



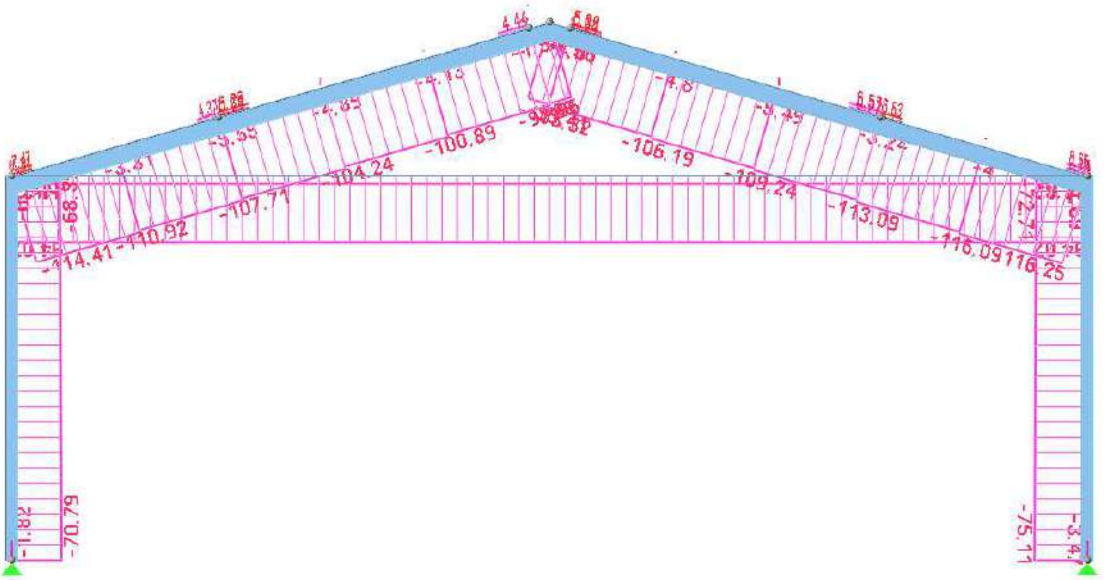
Bending moments My [kNm] (circumferential)



Shearing forces Tz [kN] (circumferential)



Normal forces N [kN] (circumferential)



Results: PN-EN design combination. First-order theory

Partial number	x / L: My		Tz	N	r	oc	Loads:
5	1,000	26.19	8.24	-2.65	100.13	-101.30	CW+1.35·Ns+P+Pd+1.5·(W1+W2)
	1,000	-37.34	-7.47	-65.88	118.34	-147.42	1.35·CW+Ns+1.35·(P+Pd)+1.5·Sn
	1,000	7.05	9.66	-4.26	30.33	-32.22	CW+1.35·Ns+P+Pd+1.5·W2
	0.000	0.00	-12.71	-47.64	-5.40	-15.63	1.35·CW+Ns+1.35·(P+Pd)+1.5·(Sn+W2)
	1,000	25.66	8.13	-0.04	97.52	-97.54	CW+Ns+P+Pd+1.5·(W1+W2)
	0.000	0.00	-7.37	-70.79	-11.28	-19.98	1.35·(CW+Ns+P+Pd)+1.5·Sn
	0.344	-0.16	-1.90	-68.35	-14.38	-15.79	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
	0.844	0.10	6.98	-1.97	3.76	-4.63	CW+Ns+P+Pd+1.5·W2
	1,000	-36.84	-7.37	-68.39	117.94	-148.13	1.35·(CW+Ns+P+Pd)+1.5·Sn
6	0.385	39.53	9.86	-110.76	101.31	-157.97	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
	0.000	-24.00	24.67	-112.40	53.68	-111.17	1.35·CW+Ns+1.35·(P+Pd)+1.5·Sn
	1.000	-22.80	-30.73	-97.96	46.45	-96.56	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
	1.000	-1.12	-0.45	-1.55	6.15	-6.95	CW+Ns+P+Pd+1.5·W2
	0.000	-4.14	21.84	-114.41	-12.59	-45.93	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
	0.132	0.02	24.06	-113.75	-28.12	-30.07	1.35·(CW+Ns+P+Pd)+1.5·Sn
	0.931	-0.05	-3.06	-4.03	-0.87	-1.19	CW+Ns+P+Pd+1.5·(W1+W2)
7	0.423	29.06	-1.54	-104.94	68.06	-121.73	1.35·CW+Ns+1.35·(P+Pd)+1.5·Sn
	1.000	-45.10	-28.09	-114.83	129.89	-188.62	1.35·CW+Ns+1.35·(P+Pd)+1.5·(Sn+W1)
	0.000	-21.95	27.70	-97.00	45.03	-94.65	1.35·(CW+Ns+P+Pd)+1.5·Sn
	0.000	-1.12	0.44	-1.56	6.10	-6.90	CW+Ns+P+Pd+1,5·W2
	1,000	-44,42	-27,87	-116,25	129,24	-188,71	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1)
	0,862	0,19	-24,37	-112,42	-28,06	-29,44	1,35·CW+Ns+1,35·(P+Pd)+1,5·Sn
	0,141	-0,68	-0,14	-4,08	1,14	-3,23	CW+Ns+P+Pd+1,5·W2
8	0,000	6,82	-9,61	-4,26	29,68	-31,56	CW+1,35·Ns+P+Pd+1,5·W2
	0,000	-58,75	7,63	-70,22	191,50	-222,50	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W1)
	1,000	0,00	21,14	-52,06	-6,10	-16,88	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W1+W2)
	0,000	6,32	-9,51	-1,69	26,80	-27,55	CW+Ns+P+Pd+1,5·W2
	1,000	0,00	15,77	-75,11	-11,85	-21,31	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1)
	1,000	0,00	15,88	-72,62	-12,43	-19,64	1,35·CW+Ns+1,35·(P+Pd)+1,5·(Sn+W1)
	0,156	-0,11	-6,93	-1,97	3,93	-4,80	CW+Ns+P+Pd+1,5·W2
	0,000	-58,24	7.52	-72.71	191.08	-223.18	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
9	1,000	0.00	0.00	79.52	253.36	252.87	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
	0,000	0.00	0.00	79.52	253.57	252.66	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1+W2)

σ

	0,000	0,00	0,00	15,62	50,13	49,30	CW+Ns+1,35·P+Pd+1,5·(W1+W2)
	0,000	0,00	0,00	94,07	299,89	298,95	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1)
	0,000	0,00	0,00	11,37	36,20	36,17	CW+Ns+P+Pd+1,5·W2
	0,625	0,00	0,00	94,07	299,42	299,42	1,35·(CW+Ns+P+Pd)+1,5·(Sn+W1)
	1,000	0,00	0,00	11,37	36,23	36,14	CW+Ns+P+Pd+1,5·W2

Section dimensions of steel according to PN-EN 1993 (Stal1993_3d v. 1.91 license no. 41191)

Bar number	Group:	Cross-section:	Determining condition:	Capacity:	Interaction of external loads.
9	Stresses	3 - R *20x10	Tension	0.843	1.35·(CW+Ns+P+Pd)+1.5·(Sn+W1)
8	Main columns	5 - I 180 HEA	SGU	0.702	CW+Ns+P+Pd+Sn+W1+W2
6	Main crosspieces	6 - I 240 PE	SGU	0.568	CW+Ns+P+Pd+Sn+W1
5	Main columns	5 - I 180 HEA	SGU	0.401	CW+Ns+P+Pd+Sn+W2
7	Main crosspieces	6 - I 240 PE	Bending	0.396	1.35·CW+Ns+1.35·(P+Pd)+1,5·(Sn+W1)

11.4 Direct foundation analysis

Input data

Project

Date : 2021-08-16

Settings

Poland - EN 1997

Materials and standards

Concrete structures: EN 1992-1-1 (EC2)
EN 1992-1-1 coefficients: default

Reinforced foundations.

Calculations under discharge conditions: EC 7-1 (EN 1997-1:2003)
Analysis of tensile foundations: standard procedure

Allowance for eccentricity:	0.333
Calculation methodology:	calculations according to EN 1997
Computational approach:	2 - reduction of effects and resistances

Partial coefficients for actions (A)			
Long-term (permanent) design condition			
		Unfavorable	Favorable
Constant actions :	γ_G =	1.35 [–]	1.00 [–]

Partial factors for resistances or bearing capacity (R)		
Long-term design condition		
Vertical bearing capacity reduction factor :	γ_{Rvs} =	1.40 [–]
Partial factor for horizontal bearing capacity :	γ_{Rhs} =	1.10 [–]

Soil basic parameters

No.	Name	Shaftura	φef [°]	cef [kPa]	γ [kN/m3]	γsu [kN/m3]	δ [°]
1	Medium sand, moderately compacted		33.50	0.00	18.50	8.50	

In the calculations of the static thrust, all soils were assumed to be nonsolids.

Soil parameters

Medium sand, medium-dense

Unit weight :	γ = 18.50 kN/m3
Internal friction angle :	φ_{ef} = 33.50 °
Soil cohesion :	c_{ef} = 0.00 kPa
Edometric modulus :	E_{oed} = 32.00 MPa
Saturated soil unit weight :	γ_{sat} = 18.50 kN/m3

Foundation

Foundation type: axial foot foundation, stepped

Depth from the original ground surface hz	= 1.00 m
Bearing depth	d = 1.00 m
Height of the upper step	tv = 0.75 m
Foundation height	t = 0.40 m
Gradient of modified terrain	s1 = 0.00 °
Slope of the base of the foundation	s2 = 0.00 °

Overburden

Type: define unit weight

Unit weight of soil above the foundation = 20.00 kN/m3

Structure geometry

Foundation type: axial foot foundation, stepped

Length of foundation foot x = 2.40 m

Width of the foundation footing y = 1.20 m

Length of the upper step	avx = 0.60 m
Width of the upper step	avy = 0.61 m

Column width in the x direction cx = 0.30 m

Column width in the y direction cy = 0.15 m

Foundation footing volume = 1.43 m3

Excavation volume	= 2.88 m3
Embankment volume	= 1.51 m3

Construction material

Unit weight γ = 23.00 kN/m3

Concrete structure calculations were carried out using EN 1992-1-1 (EC2).

Concrete: C 20/25

Compressive strength	fck = 20.00 MPa
Tensile strength	fctm = 2.20 MPa
Elastic modulus	Ecm = 30000.00 MPa

Reinforcement longitudinal: B500B

Yield strength	fyk = 500.00 MPa

Transverse reinforcement: B500B

Yield strength	fyk = 500.00 MPa

Geological profile and assigned soils

No	Thickness of the layer t [m]	Depth z [m]	Assigned soil	Shaftbauer
1	-	0,00 ..	Medium sand, medium-dense	

Load

Nr	Load		Name	Type	N	Mx	My	Hx	Hy
	new	change			[kN]	[kNm]	[kNm]	[kN]	[kN]
1	Yes		Force No. 1	Computational	63.96	0.00	0.00	15.51	9.03
2	Yes		Force No. 2	Computational	11.75	0.00	0.00	15.28	6.86

Global calculation settings

Calculation method: calculations under with discharge conditions

Phase calculation settings

Calculation situation: permanent

Analysis No. 1

Analysis of load states

Name	Weight of soil beneficial	ex [m]	ey [m]	σ [kPa]	Rd [kPa]	Utilization [%]	Meets requirements
Force No. 2	Yes	0,24	-0,11	39,16	436,34	8,97	Yes
Force No. 2	No	0,18	-0,08	45,82	490,26	9,35	Yes

Calculations were carried out for load case No. 2. (Force No. 2)

Determined own weight of the foundation foot G = 44.29 kN

Determined overburden weight of the soil Z = 40.73 kN

Checking vertical bearing capacity

Contact stress shape: rectangular

Parameters of the sliding surface under the foundation:

Embedding of the sliding surface zsp = 2.16 m

Extent of the sliding surface lsp = 6.93 m

Calculated bearing capacity of the foundation soil Rd = 490.26 kPa

Maximum contact stress Vertical bearing capacity MEETS REQUIREMENTS σ = 45.82 kPa

Eccentricity analysis of loading

Max. eccentricity along the length of the foundation ex = 0.098 < 0.333

Max. eccentricity along the width of the foundation ey = 0.088 < 0.333

Spatial eccentricity et = 0.132 < 0.333

Foundation load eccentricity MEETS REQUIREMENTS

Horizontal bearing capacity check

Soil reaction: passive (resting)

Calculated soil resistance Spd = 3.18 kN

Horizontal bearing capacity of the foundation Rdh = 47.86 kN

Maximum horizontal force H = 16.75 kN

Horizontal bearing capacity MEETS REQUIREMENTS

Foundation bearing capacity MEETS REQUIREMENTS

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