CALCULATIONS TO VERIFY THE STRUCTURAL STRENGTH AND STABILITY OF AN ARTIFICIAL CLIMBING WALL

SUBJECT OF THE STUDY:	Interactive artificial climbing wall with a height of 6.00 m according to product specifications
INVESTOR:	**ELCAP ROBOTICS Prosta Spółka Akcyjna** **ul. Fryderyka Chopina 41/2** **20-023 Lublin**
DESIGN UNIT:	Jacek Krzyśpiak ul. Darwina 9A/75 03-484 Warsaw

VERIFICATION CALCULATIONS
CONSTRUCTION

INDUSTRY DESIGN TEAM:	
AUTHOR:	DATE
Jacek Krzyśpiak, Eng. *Professional license in structural and building design without limitations* No. WAM/0082/POOK/11	SIGN inż. Jacek Krzyśpiak upr. bud. bez ograniczeń w specjalności konstrukcyjno-budowlanej do kierowania robotami budowlanymi nr WAM/0128/OWOK/07 oraz do projektowania nr WAM/0082/POOK/11

WARSAW, AUGUST 2025

1.0. Introduction

1.1. Subject of the study

The subject of the study is the static and strength calculations for the structural frame of a free-standing artificial climbing wall with a height of 6.00 m in the product specification. The scope of the study includes a technical description and static and strength calculations for the elements during operation and assembly.

1.2. Basis for the study

- Visual inspection of the structure
- Workshop drawings of the wall structure and its base
- Guidelines and agreements with the investor
- Applicable building standards and regulations, in particular:
  - **PN-EN 12572-1 – Artificial climbing walls**
  - PN-EN 1990 – Basis of structural design
  - PN-EN 1991 – Actions on structures
  - PN-EN 1992 – Design of concrete structures
  - PN-EN 1993 – Design of steel structures
  - PN-EN 1995 – Design of timber structures
  - PN-EN 1996 – Design of masonry structures
  - PN-EN 1997 – Geotechnical design

2.0. General characteristics of the climbing wall

The artificial climbing wall that is the subject of this study is an interactive wall designed for children and adults, combining elements of a computer game with physical activity involving climbing on the structure. The wall is designed for one user. It is equipped with one individual top belay point. The wall structure consists of four steel frames made of closed sections (square tubes RK80x80x4 and rectangular tubes RP80x40x4) stacked on top of each other. The lower frame has a total height of 33 cm and is positioned and bolted to the base structure with six M12 bolts. Three more frames, each 192 cm high, are positioned on the lower frame. The frames are bolted together with M16 bolts – six per connection. A structure made of RP100x80x6 rectangular tubes is bolted to the top of the upper frame for mounting the upper belay point. The reach of the support section allows the belay point to be mounted at a distance of 50 cm from the wall face. The stability of the entire structure is ensured by an individually designed base structure with a load distributed in such a way that the structure does not detach from the ground. The side and rear walls as well as the top of the structure are covered with a protective plate screwed to the structure. The upper cover on top of the structure also serves as a stiffener. The wall is designed for installation inside a building. The frame structure creates slots for the installation of hold modules. The modules are sets of mechanisms that allow the climbing holds to be moved using control software.

The photo below shows the upper part of the wall without side, top, and rear cladding.

3.0. Static calculations

3.1. Assumptions made for the calculations

Static calculations and dimensioning were performed based on the applicable PN-EN standards using the limit state method (load-bearing capacity and serviceability) applying loads and partial safety factors for static loads (1.35) and variable loads (1.50) as well as reduction factors in accordance with PN-EN 12572-1.

The following programs were used to perform the calculations:

- Autodesk Robot Structural Analysis by Autodesk
- Proprietary spreadsheets

The following assembly sequence was assumed in the calculations:

- Positioning, leveling, and loading of the base structure.
- Positioning and bolting the lower frame to the base structure using six M12 class 10.9 bolts.
- Assembly of subsequent frames; after assembling each subsequent frame, it should be bolted to the previously positioned frame using six M16 class 8.8 bolts.
- Assemble the upper frame with the support beam. Bolt the upper frame to the rest of the structure using six M16 class 8.8 bolts.
- Install subsequent modules starting from the lowest one. Installation using a winch and upper belay point.
- Make the cladding (side walls, rear wall, and top of the structure) with a cover plate screwed around the perimeter of the structure. The cladding installation may be carried out concurrently with module installation.

– Handover of the wall for use.

3.2. Loads

3.2.1. Permanent loads

3.2.1.1. Dead weight of the structure

The dead weight of the structure has been automatically included in the calculation program.

3.2.1.2. Weight of the cladding

3 mm thick plate - 0.04 kN/m2

The load was assumed to be surface load applied to the side walls, rear wall, and top of the structure.

3.2.1.3. Weight of modules

Weight of one module – 70 kg

Number of modules for the entire wall – 17 sets.

In the calculation model, the load of the modules was assumed to be concentrated forces of 35 kg applied to the horizontal beams of the structure at a distance of 18 cm from the front wall.

3.2.2. Variable loads during operation

The loads were assumed in accordance with Table A.1 of Annex A to PN-EN 12572-1.

Table A.1 — Loads

Dimensions in Kilonewton

	Proof test load	Characteristic load	Breaking load
Load of a climber	—	0,8	—
Load produced by falling climber on a protection point [a]	6,6	6,6	20,0
NOTE The proof testing only acts as a verification of good installation practice and cannot replace the calculations.			
[a] Based on experiments it is impossible to have two or more climbers create a peak impact force simultaneously due to a fall.			

The relevant load for static and strength calculations of the structure is the load from a falling climber with a value according to the above table:

Q_k= 6.60 kN

The load was applied at the fixed belay point at the top of the structure, as far away from the wall as possible.

In accordance with the above standard, it is assumed that this load may deviate from the vertical at an angle of 12.5 degrees in any direction.

3.2.3. Variable loads during the assembly phase

Loads from two assemblers were assumed in the form of two concentrated forces applied to the side horizontal beams with a value of Q_{M1} =1.50kN each.

In addition, a load of Q_{M2} =1.50 kN from the lifted modules was applied to the upper belay point.

3.3. Load combinations

3.3.1. Load combination under operating conditions

The load combination under operating conditions was assumed in accordance with the guidelines of Annex B of PN-EN 12572-1 based on the formula:

$$\gamma_G G_k + \gamma_Q Q_{k,1} + \sum_{i>1} \psi_i \gamma_Q Q_{k,i}$$

For permanent loads, the coefficient γ_G =1.35 or 1.0

For variable loads, the coefficient γ_Q= 1.50 or 0

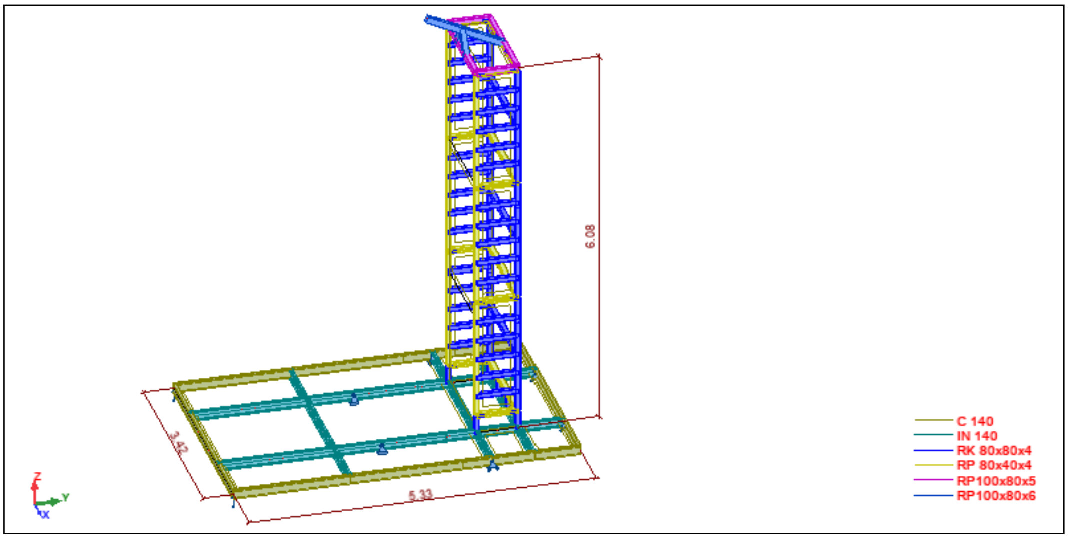
The combination factor ψ does not apply, as there is only one variable load.

3.3.2. Load combination under installation conditions

In the load combination, the coefficients were applied in accordance with section 3.3. It was assumed that the loads from the installers could occur independently of each other and independently of the load on the upper belay point, as well as independently of the load from the modules.

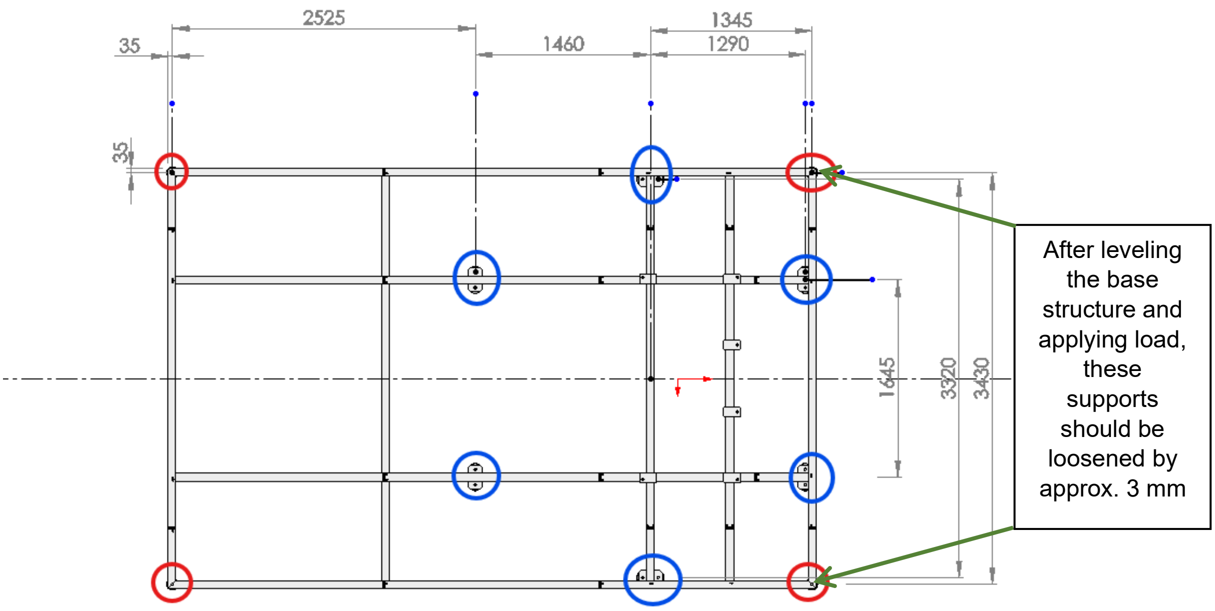
3.4. Dimensioning of the structure during the service life

3.4.1. Static diagram of the main structure and cross-sections used

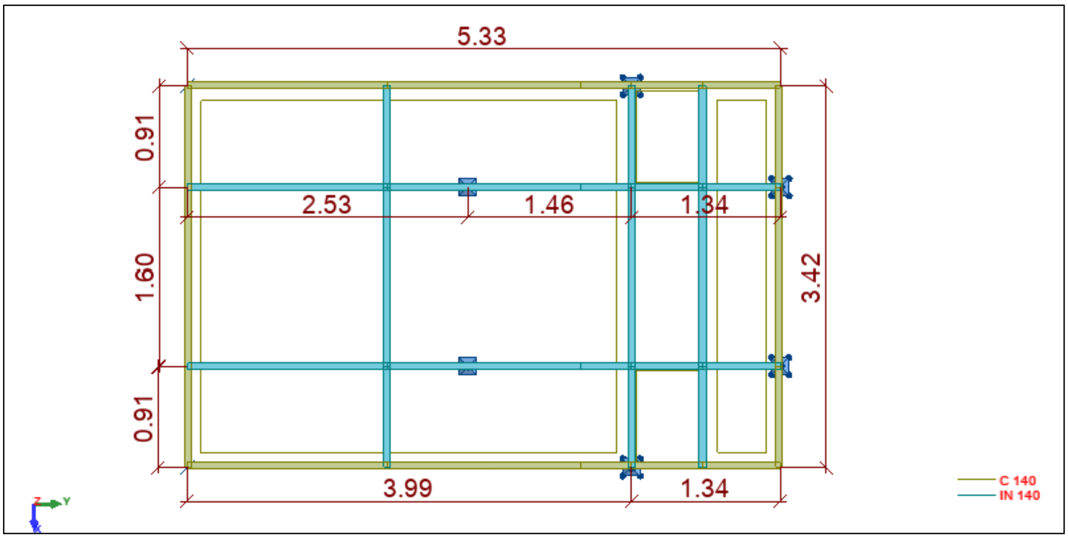


3.4.2. Base structure

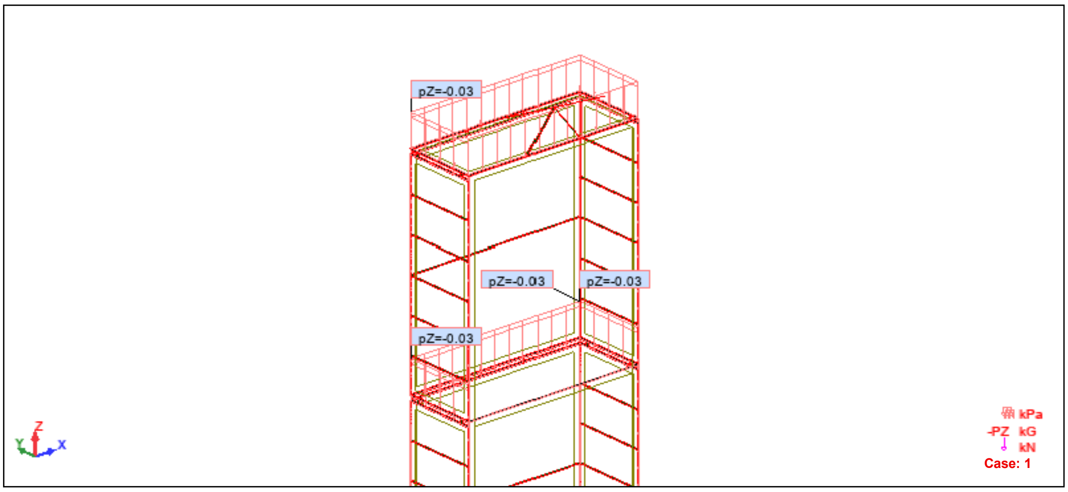
Actual dimensions



Assumed in the calculation model

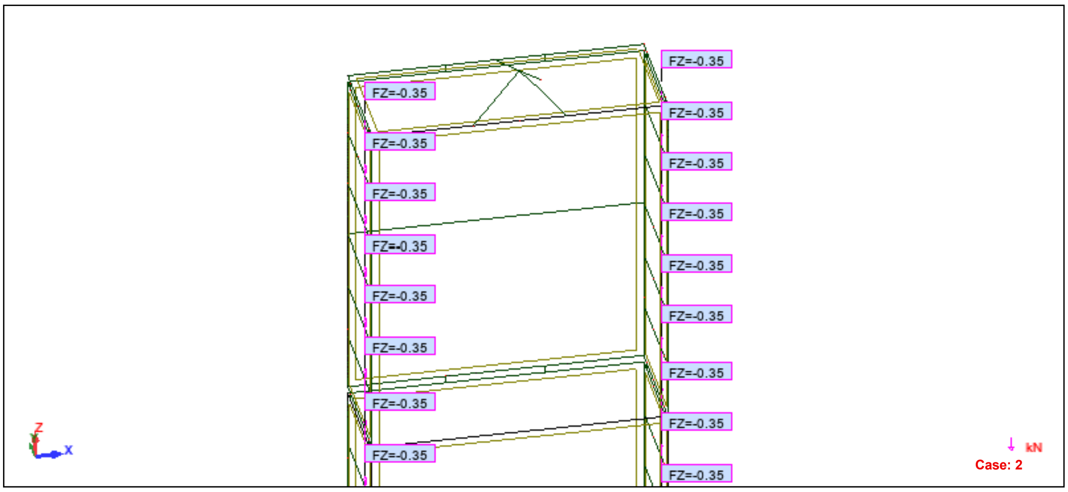


3.4.3. Load from the cladding



3.4.4. Loads from modules

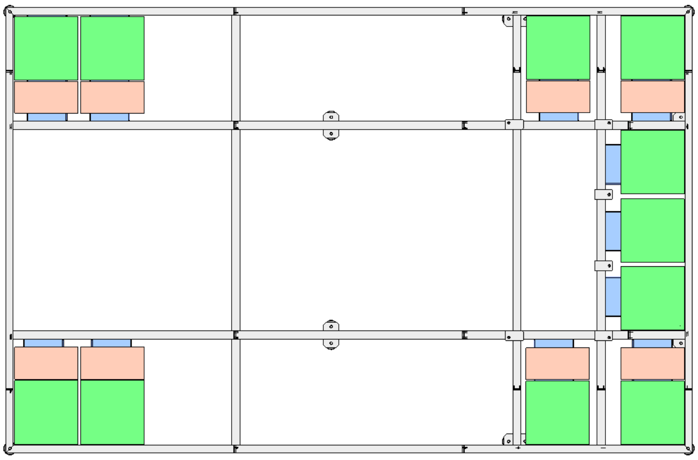
The illustration below shows a fragment of the structure with module loads. Similar loads are applied over the entire height of the structure

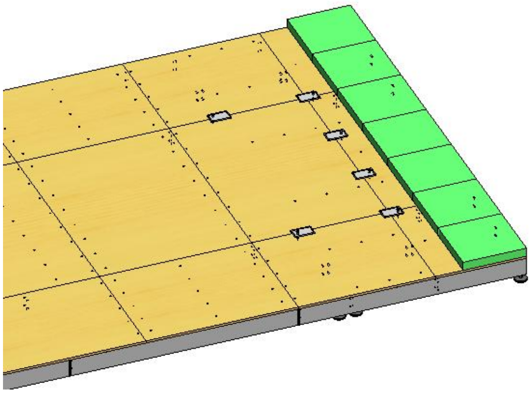


3.4.5. Ballasting of the base structure

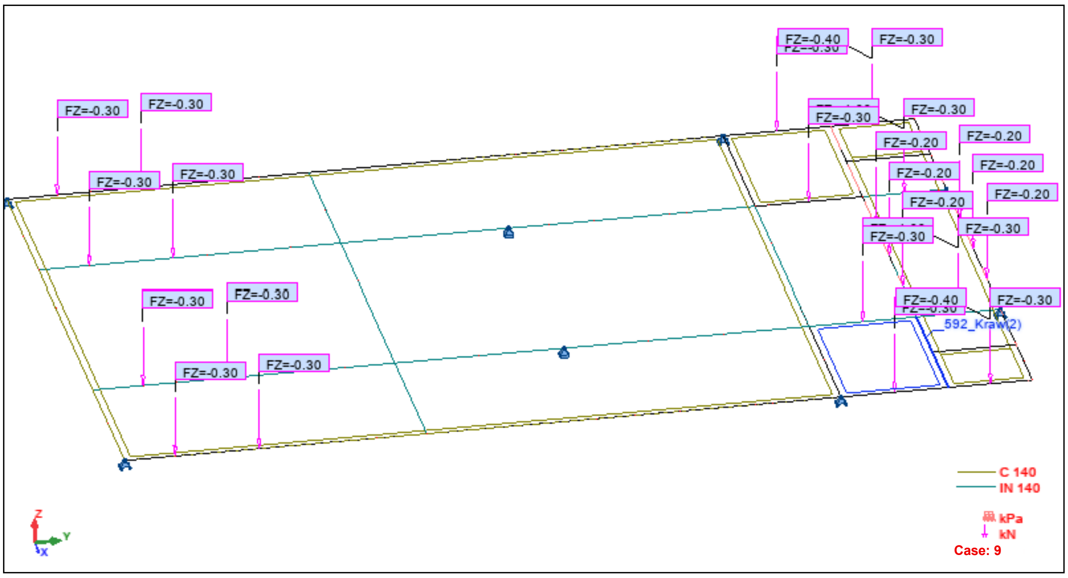
Distribution of ballast elements

- green color – 40 kg slabs
- orange – 20 kg plates



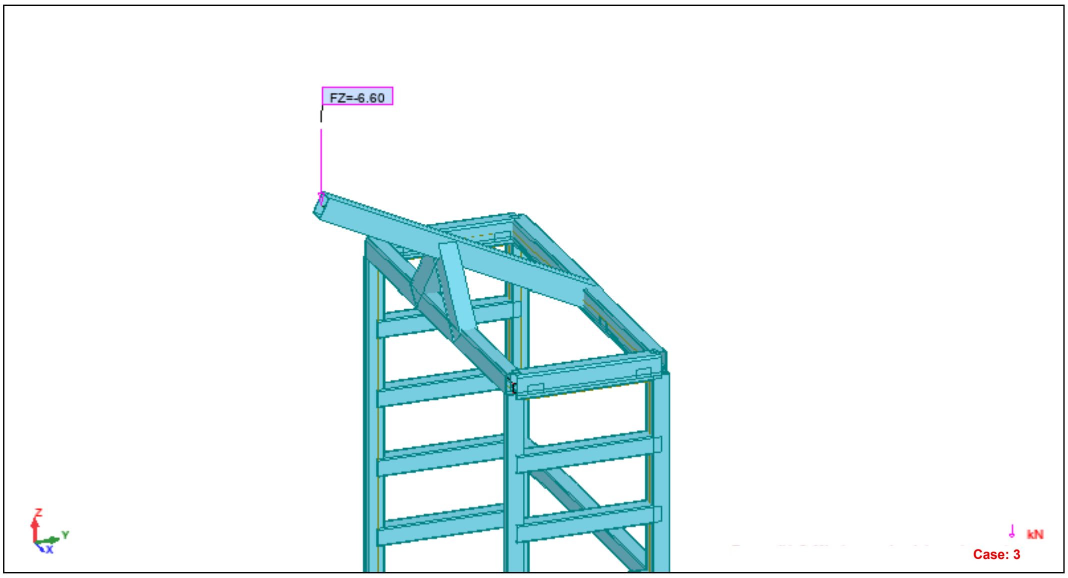


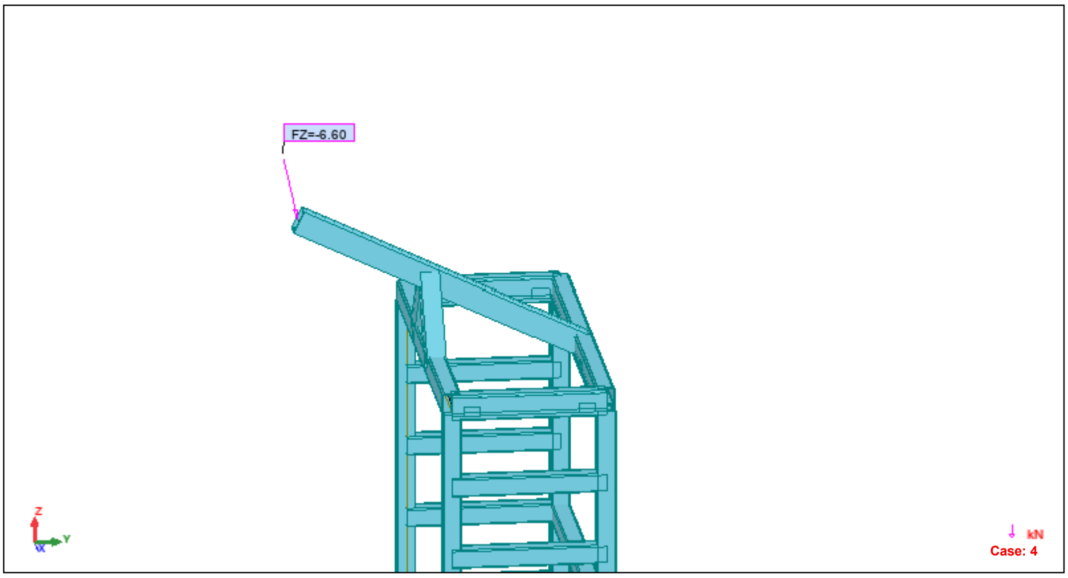
Load diagram based on the above graphics included in the calculation program

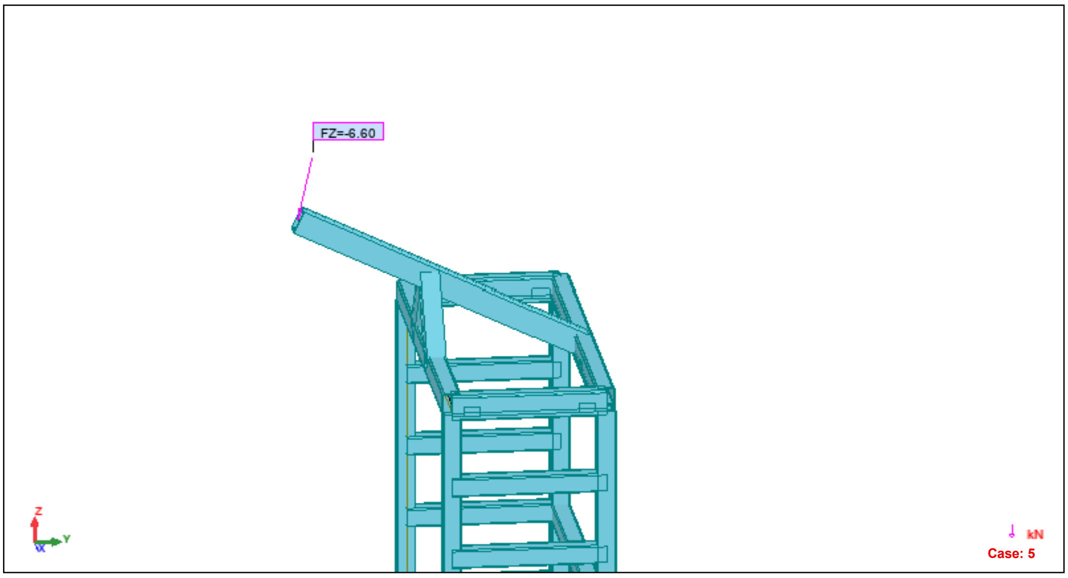

FZ=-0.30
FZ=-0.40
FZ=-0.20
592_Kraw(2)
C 140
IN 140
kPa
kN
Case: 9

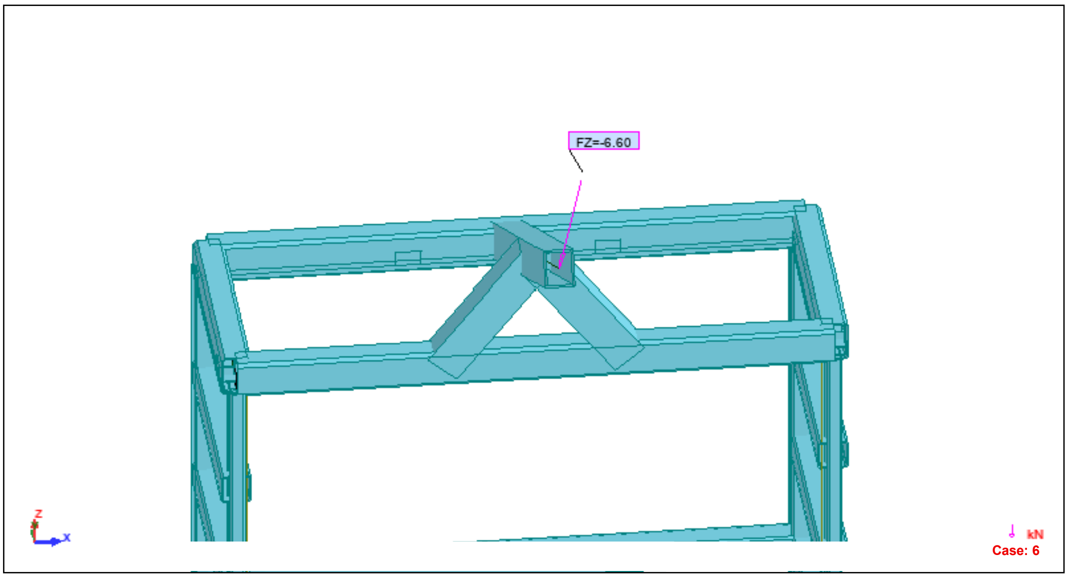
3.4.6. Loads caused by a falling climber

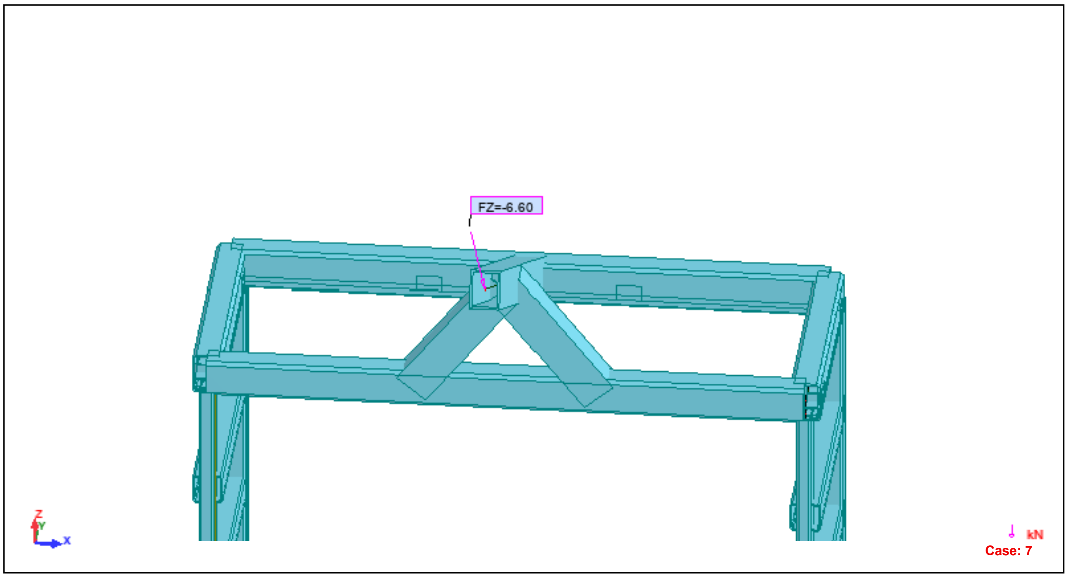
The loads shown below cannot occur simultaneously.











3.4.7. Load case numbers

Case	Label	Case name	Nature	Type of analysis
1	STA1	STA1	Structural	Linear statics
2	STA11	Modules	Structural	Linear statics
3	EKSP2	Climber falling vertically	constant	Linear statics
4	EKSP21	Climber falling 12.5 degrees	constant	Linear statics
5	EKSP3	Climber falling -12.5 degrees	constant	Linear statics
6	EKSP4	Climber falling 12.5 degrees left	constant	Linear statics
7	EKSP41	Climber falling 12.5 degrees to the right	constant	Linear statics
8	User	User	Category B	Linear statics
9	STA12	Ballasting	Structural	Linear statics
10		SGN		Linear statics
11		SGN+		Linear statics
12		SGN-		Linear statics
13		SGU		Linear statics
14		SGU+		Linear statics
15		SGU-		Linear statics
16		SGU:CHR		Linear statics
17		SGU:CHR+		Linear statics
18		SGU:CHR-		Linear statics
19		SGU:FRE		Linear statics
20		SGU:FRE+		Linear statics
21		SGU:FRE-		Linear statics
22		SGU:QPR		Linear statics
23		SGU:QPR+		Linear statics
24		SGU:QPR-		Linear statics
25		SPEC		Linear statics
26		SPEC+		Linear statics

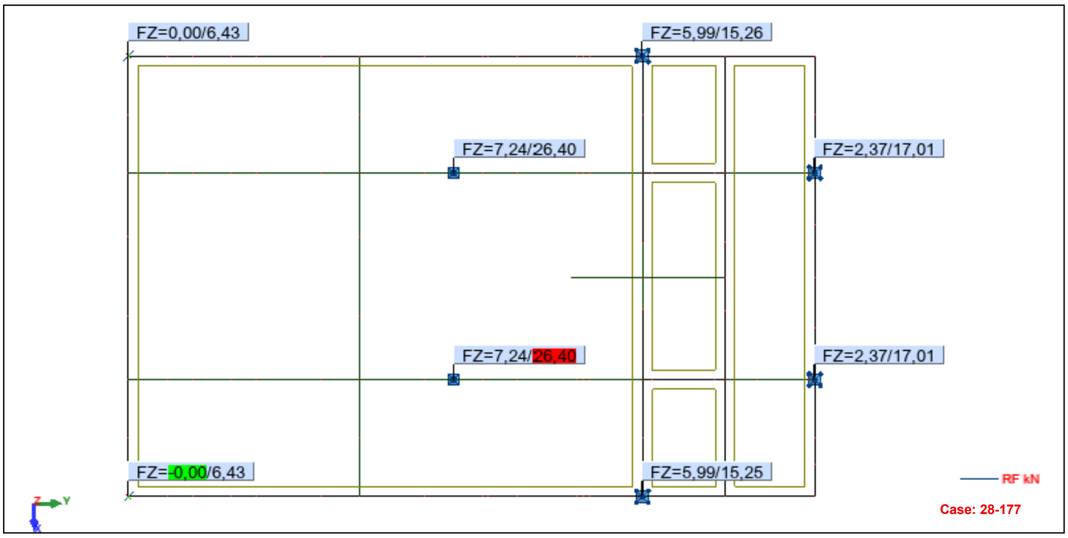
27		SPEC-		Linear statics

3.4.8. Load values

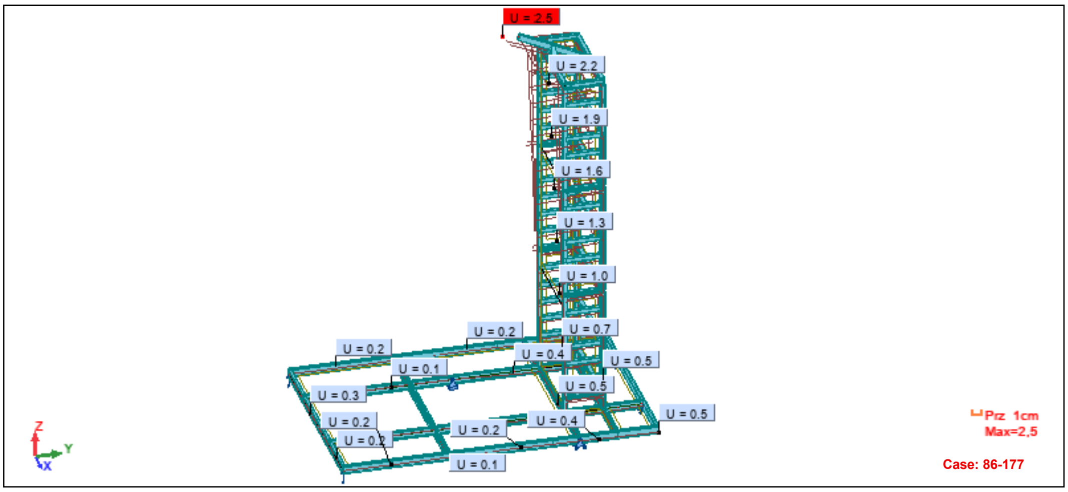
#	Case	Load type	List	Load value
1	1	dead weight	1 to 28 30 to 41 45 to 55 79 to 85 485 to 491 494 to 505 536 to 546 549 to 562 567 to 572 578 to 580 582 to 584 43 575 586 590 to 635	PZ Minus Wsp=1.00
62	1	(ES) homogeneous	567to572 575 578to580 621to623	PZ=-0.07(kN/m2)
135	1	(ES) homogeneous	591 to 594	PZ=-0.13(kN/m2)
243	1	node force	69	FZ=-0.60(kN)
33	2	bar force	485 540 600	FZ=-0.55(kN) X=0.46(m)
34	2	bar force	496 to 505 551 to 560 609 to 618	FZ=-0.55(kN) X=0.18(m)
35	2	bar force		FZ=-0.55(kN) X=0.46(m)
36	2	bar force		FZ=-0.55(kN) X=0.46(m)
37	2	bar force	487,542,602	FZ=-0.55(kN) X=0.46(m)
2	3	node force	805	FZ=-6.60(kN)
29	4	node force	805	FZ=-6.60(kN) Gamma=12.5(Deg)
30	5	node force	805	FZ=-6.60(kN) Gamma=-12.5(Deg)
31	6	node force	805	FZ=-6.60(kN) Beta=12.5(Deg)
32	7	node force	805	FZ=-6.60(kN) Beta=-12.5(Deg)
38	8	(ES) homogeneous	591	PZ=-2.00(kN/m2)
298	9	node force	806	
299	9	node force	808 809	
300	9	(ES) homogeneous	593	
307	9	bar force	37 38 40 45	FZ=-0.30(kN) X=0.50 relative
308	9	bar force	30 33 41 46	FZ=-0.30(kN) X=0.50 relative
309	9	node force	944 to 949	FZ=-0.20(kN)
310	9	node force	950to957	FZ=-0.30(kN)
333	9	bar force	46	FZ=-0.40(kN) X=0.50 relative
334	9	bar force	33	FZ=-0.40(kN) X=0.50 relative
335	9	bar force	40	FZ=-1.00(kN) X=0.50 relative
336	9	bar force	37	FZ=-1.00(kN) X=0.50 relative

3.4.9. Calculation results

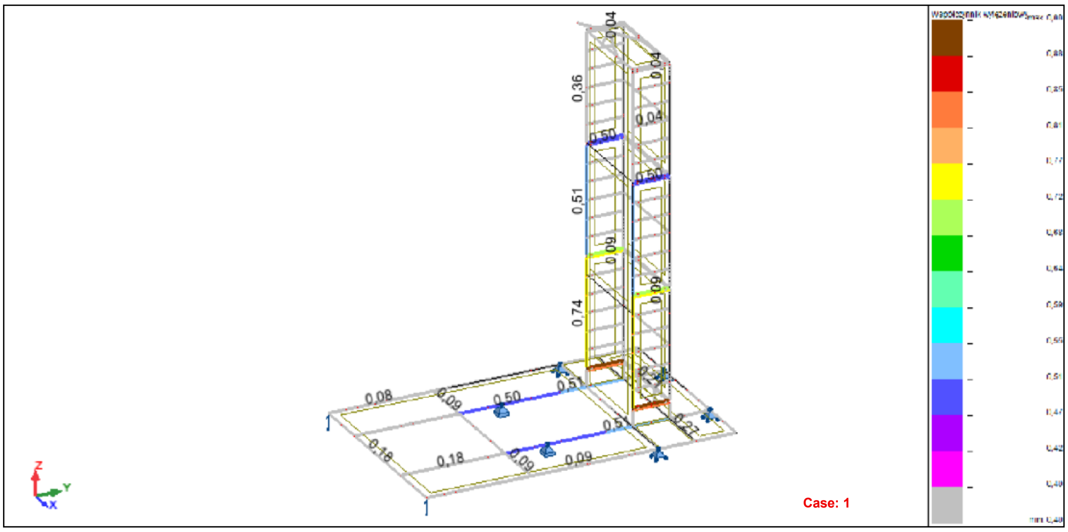
3.4.9.1. Envelope of support reactions



3.4.9.2. Displacement of structures in the SGU state



3.4.9.3. Stress on individual elements shown graphically



4.0. <u>Summary</u>

The above calculations confirmed that the structure meets the requirements of the standards specified in section 1.2 during operation and assembly and can therefore be safely used for its intended purpose.

Structure – designed by

Jacek Krzyśpiak, Eng.

building license no. WAM/0082/POOK/11

inż. Jacek Krzyśpiak
upr. bud. bez ograniczeń w specjalności
konstrukcyjno-budowlanej do kierowania
robotami budowlanymi nr WAM/0128/OWOK/07
oraz do projektowania nr WAM/0082/POOK/11

5.0. Designer's licenses and certificates

WARMIŃSKO-MAZURSKA
OKRĘGOWA IZBA INŻYNIERÓW BUDOWNICTWA
OKRĘGOWA KOMISJA KWALIFIKACYJNA
10-532 Olsztyn, Plac Konsulatu Polskiego 1

WAM/OKK/U/98/11

Olsztyn, dnia 12 grudnia 2011 r.

DECYZJA

Na podstawie art. 24 ust.1 pkt 2 ustawy z dnia 15 grudnia 2000 r. o samorządach zawodowych architektów, inżynierów budownictwa oraz urbanistów /Dz. U. z 2001 r. Nr 5 poz. 42, ze zm./, w związku z **art. 5 ustawy z dnia 28 lipca 2005 r.** o zmianie ustawy-Prawo budowlane oraz o zmianie niektórych innych ustaw /Dz. U. z 2005 r. Nr 163 poz. 1364/, art. 12 ust. 3, **art. 13 ust. 1 pkt 1, art. 14 ust. 1 pkt 2** ustawy z dnia 07 lipca 1994 r. Prawo budowlane /t.j. Dz. U. z 2003 r. Nr 207, poz. 2016 ze zm./, **§ 3 ust. 1, § 12 pkt 1** i **§ 17 ust. 1 pkt 1** rozporządzenia Ministra Infrastruktury z dnia 18 maja 2005 r. w sprawie samodzielnych funkcji technicznych w budownictwie /Dz. U. z 2005 r. Nr 96 poz. 817/ oraz art. 104 Kodeksu postępowania administracyjnego /t.j. Dz.U. z 2000 r. Nr 98, poz.1071 ze zm./

Okręgowa Komisja Kwalifikacyjna

nadaje

Panu JACKOWI HUBERTOWI KRZYŚPIAKOWI

inżynierowi budownictwa
ur. dnia 21 stycznia 1980 r. w Ostrołęce

UPRAWNIENIA BUDOWLANE

Nr ewid. WAM/ 0082 /POOK/11

DO PROJEKTOWANIA
BEZ OGRANICZEŃ
W SPECJALNOŚCI KONSTRUKCYJNO-BUDOWLANEJ

UZASADNIENIE

W związku z uwzględnieniem w całości żądania strony, na podstawie art. 107 § 4 K.p.a odstępuje się od uzasadnienia decyzji. Zakres nadanych uprawnień budowlanych wskazano na odwrocie decyzji.

Pouczenie :

1. Zgodnie z art. 12 ust. 7 w/w ustawy Prawo budowlane – podstawę do wykonywania samodzielnych funkcji technicznych w budownictwie stanowi wpis, w drodze decyzji, do centralnego rejestru Głównego Inspektora Nadzoru Budowlanego oraz wpis na listę członków właściwej izby samorządu zawodowego, potwierdzony zaświadczeniem wydanym przez tę izbę, z określonym w nim terminem ważności.
2. Od decyzji niniejszej służy odwołanie do Krajowej Komisji Kwalifikacyjnej Polskiej Izby Inżynierów Budownictwa w Warszawie, za pośrednictwem Okręgowej Komisji Kwalifikacyjnej Warmińsko-Mazurskiej Okręgowej Izby Inżynierów Budownictwa w Olsztynie, w terminie 14 dni od dnia jej doręczenia.

WARMIŃSKO-MAZURSKA OKRĘGOWA IZBA INŻYNIERÓW BUDOWNICTWA

Skład orzekający OKK:

1. mgr inż. Zdzisław Binerowski
2. inż. Janusz Palmowski
3. mgr inż. Elżbieta Lasmanowicz

POLSKA IZBA INŻYNIERÓW BUDOWNICTWA

Zaświadczenie

o numerze weryfikacyjnym:

WAM-522-1L6-NXM *

Pan Jacek Hubert Krzyśpiak o numerze ewidencyjnym WAM/BO/0031/08
adres zamieszkania ul. Karola Darwina 9 A / 75, 03-484 Warszawa
jest członkiem Warmińsko-Mazurskiej Okręgowej Izby Inżynierów Budownictwa i posiada wymagane ubezpieczenie od odpowiedzialności cywilnej.
Niniejsze zaświadczenie jest ważne od 2025-01-01 do 2025-12-31.

Zaświadczenie zostało wygenerowane elektronicznie i opatrzone bezpiecznym podpisem elektronicznym weryfikowanym przy pomocy ważnego kwalifikowanego certyfikatu w dniu 2024-12-16 roku przez:

Jarosław Kukliński, Przewodniczący Rady Warmińsko-Mazurskiej Okręgowej Izby Inżynierów Budownictwa.

Zgodnie z art. 78^1 K.c.
§ 1. Do zachowania elektronicznej formy czynności prawnej wystarcza złożenie oświadczenia woli w postaci elektronicznej i opatrzenie go kwalifikowanym podpisem elektronicznym.
§ 2. Oświadczenie woli złożone w formie elektronicznej jest równoważne z oświadczeniem woli złożonym w formie pisemnej.

* Weryfikację poprawności danych w niniejszym zaświadczeniu można sprawdzić za pomocą numeru weryfikacyjnego zaświadczenia na stronie Polskiej Izby Inżynierów Budownictwa www.piib.org.pl lub kontaktując się z biurem właściwej Okręgowej Izby Inżynierów Budownictwa.