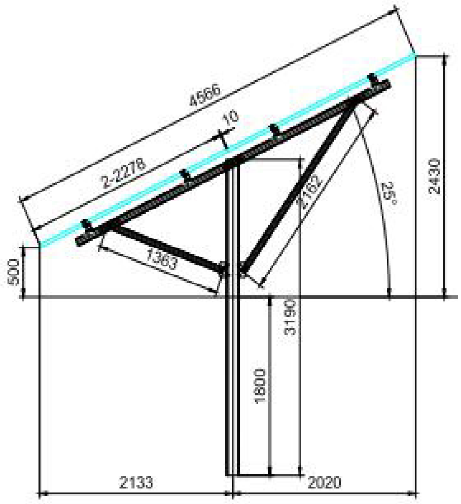
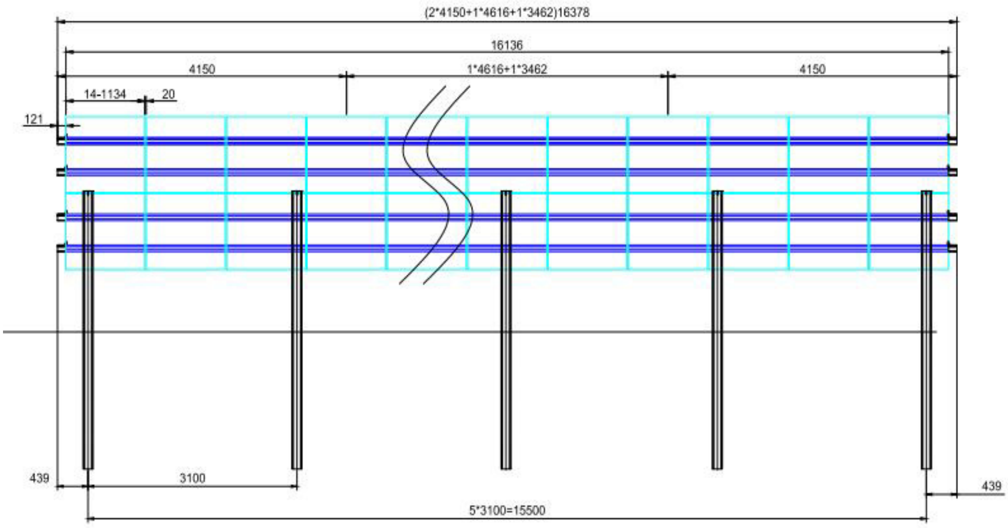


Side view



Positive view

1 Technical Regulations And Standards

BS-EN-1991-1-4:2005

Eurocode 1 Part1.4 (ENG) - prEN 1991-1-4 (2004 Jan)

Eurocode_1_Part_1_3_-_prEN_1991-1-3-2003

2 Design Conditions

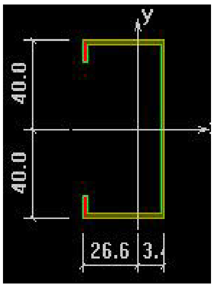
1	Solar Panel:	:	L 2278 * W 1134 * H 35	
2	Mounting Type:	:	GT4	
3	Layout:	:	2 * 14 = 28	
4	PV weight	:	32 kg	
5	Angle:	:	25 °	
6	Span:	:	3100 mm	
7	Load of snow accumulation on the ground:			
	S_k = 0.88 kN/m²		(Snow Zone 3 A= 0)	
8	Load of wind accumulation on the ground:			
	Vm = 33 m/s		(Wind Zone 3 inland)	
9	Maximum span on beam	:	500 mm	

3 Mounting

1	Rail Qty.	:	4	pcs
2	Rail length	:	16.378	m
3	Rail weight/m	:	2.7	kg/m
4	Beam Qty.	:	6	pcs
5	Beam length	:	3.8	m
6	Beam weight/m	:	2.7	kg/m
7	Pole length	:	3.19	m
9	Pole weight/m	:	6.31	kg/m
10	Diagonal brace 1 Qty.	:	6	pcs
11	Diagonal brace 1 length	:	1.363	m
12	Diagonal brace 1 weight/m	:	2.15	kg/m
13	Diagonal brace 2 Qty.	:	6	pcs
14	Diagonal brace 2 length	:	2.162	m
15	Diagonal brace 2 weight/m	:	2.15	kg/m
16	Mounting weight:	:	404.69	kg/m

4 Section size

4.1 Rail C80



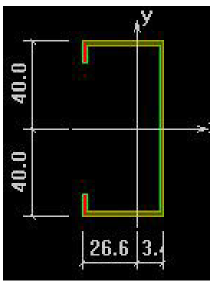
Section coefficient			
A	344.00	Ip	426445.71
Ix	353738.67	Iy	72707.04
ix	32.07	iy	14.54
Wx(up)	8843.47	Wy(left)	2730.48
Wx(down)	8843.47	Wy(right)	5437.22
Area Moment Around X-axis	5108.00	Area Moment Around Y Axis	2238.18
Distance of centroid from left edge	26.63	istance of centroid from right edg	13.37
Distance between centroid and upper edge	40.00	stance of centroid from lower ed	40.00
Principal moments I1	353738.67	Principal moments 1 direction	(1.000, 0.000)
Principal moments I2	72707.04	Principal moments 2 direction	(0.000,1.000)

Calculation used parameters:

Section Coefficient of Flexural Strength: (Min. W_V = 8843.47 [mm3] (Panel Vertical Direction)

W_H = 2730.48 [mm3] (Panel Parallel Direction)

4.2 Beam C80

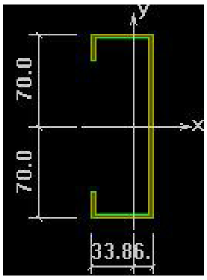


Section coefficient			
A	344.00	Ip	426445.71
Ix	353738.67	Iy	72707.04
ix	32.07	iy	14.54
Wx(up)	8843.47	Wy(left)	2730.48
Wx(down)	8843.47	Wy(right)	5437.22
Area Moment Around X-axis	5108.00	Area Moment Around Y Axis	2238.18
Distance of centroid from left edge	26.63	istance of centroid from right edg	13.37
Distance between centroid and upper edge	40.00	stance of centroid from lower ed	40.00
Principal moments I1	353738.67	Principal moments 1 direction	(1.000, 0.000)
Principal moments I2	72707.04	Principal moments 2 direction	(0.000,1.000)

Calculation used parameters:

Section Coefficient of Flexural Strength: (Min. W_V = 8843.47 [mm3] (Panel Vertical Direction)

4.3 Pole C140



Section coefficient			
A	804.00	Ip	2640345.00
Ix	2360952.00	Iy	279393.00
ix	54.19	iy	18.64
Wx(up）	33727.89	Wy(left）	8273.74
Wx(down）	33727.89	Wy(right）	17213.18
Area Moment Around X-axis	19992.00	Area Moment Around Y Axis	6712.37
Distance of centroid from left edge	33.77	istance of centroid from right edg	16.23
Distance between centroid and upper edge	70.00	stance of centroid from lower ed	70.00
Principal momentsI1	2360951.99	Principal moments 1 direction	（1.000，0.000）
Principal momentsI2	279392.97	Principal moments 2 direction	（0.000,1.000）

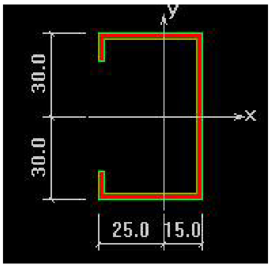
Calculation used parameters：

Section Coefficient of Flexural Strength: (Min. W_V = 33727.89 [mm3] （Panel Vertical Direction）

W_H = 8273.74 [mm3] （Panel Parallel Direction）

Sectional radius： i = 804.00 [mm]

4.4 Diagonal brace+Diagonal support C60



Section coefficient			
A	275.04	Ip	226365.45
Ix	166201.36	Iy	60164.08
ix	24.58	iy	14.71
Wx(up）	5540.05	Wy(left）	2406.56
Wx(down）	5540.05	Wy(right）	4010.94
Area Moment Around X-axis	3166.63	Area Moment Around Y Axis	1836.43
Distance of centroid from left edge	25.00	Distance of centroid from right edge	15.00
Distance between centroid and upper edge	30.00	Distance of centroid from lower edge	30.00
Principal momentsI1	182485.33	Principal moments 1 direction	（1.000，0.000）
Principal momentsI2	65765.34	Principal moments 2 direction	（0.000,1.000）

Calculation used parameters：

Section Coefficient of Flexural Strength: (Min. W_V = 5540.05 [mm3] （Panel Vertical Direction）

W_H = 2406.56 [mm3] （Panel Parallel Direction）

Sectional radius： i = 275.04 [mm]

5 Dead load

Total panel weight	G_1	:	32	×	28.00	×	9.80	=	8780.80	[N]
Mounting weight	G_2	:	404.69			×	9.80	=	3965.95	[N]
Panel area	A	:	28	×	2.278	×	1.13	=	72.33	[m^2]
Fixed Load	G	:	(8780.80	+	3965.95)	/	72.33	=	176.23	[N/m^2]
Calculating adoption value	G	:						=	180.00	[N/m^2]

5.1.Loads

5.1.1 Wind Load Calculation

Terrain roughness factor calculation：

Terrain　Ⅲ　from design drawing　Z=　0.5 m

$Cr(Z)= Kr*\ln(Z/Z_O)$　=　0.19　*　（　0.3　/　0.05　$)^{0.07}$*ln　（　5 /　0.3　）=　0.606

Cr(Z)= Kr*ln(Z/ZO)　for　Zmin≤Z≤Zmax

Cr(Z)= Cr (Zmin)　for　Z≤Zmin

Where:

$Kr=0.19*（Zo/ZOII）^{0.07}$

Zo　=　0.05　m　(is the roughness lenghth for terrain categoryⅢ taken form Table 4.1)

Zmin　=　2　m　(is minimum height for terrain categoryⅢ taken form Table 4.1)

ZOIII =　0.3　m　(terrain categoryⅢ taken form Table 4.1)

Zmax is to be taken as 200m

Table 4.1 — Terrain categories and terrain parameters

	Terrain category	z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
The terrain categories are illustrated in Annex A.1.			

Height Z, average wind speed：

$Vm(Z)= Cr(Z)* C_O(Z)* Vb$　=　0.606　*　1 *　33 =　19.9973　m/s

Where:

$C_O(Z)$ is orography factor,taken as 1.0

Cr(Z) is roughness factor

Wind turbulence calculation

From the design drawing　Z=　0.50　m

$Iv(Z)=\sigma v/ Vm(Z)= Kl /\{C_O* \ln(Z/Z_O)\}$　=　1 /（　1 *　ln（　5　/　0.3　））=　0.355

Iv(Z)=σv/ Vm(Z)= Kl /{CO(Z)* ln(Z/ZO)}　for　Zmin≤Z≤Zmax

Iv(Z)= Iv(Zmin)　for　Z≤Zmin

Where:

Kl　is turbulence factor,taken as　1

Co　is the orography factor,taken as　1

Zo　is roughness length ,taken as　0.3　m，　given in Table 4.1

Calculation of peak velocity pressure：

$qp(Z)=\{1+7* Iv(Z)\}*0.5*\rho* Vm^2(Z)$　=　（　1 +　7 *　0.355　）*　0.5　*　1.25　*　20　*　20.00

=　871.7849896　N/m^2

Where:

qp(Z)　is the peak velocity pressure(N/m^2)

ρ　is the air density,taken as 1.25kg/m3

Iv(Z)　is the turbulence intensity,

Vm(Z)　is the mean wing velocity,

wind load on solar panel：

W= qp(Z)* Cp.net

Where:

W　is the net wind pressure(N/m^2)

qp(Z)　is the peak velocity pressure at height h as show in Figure 7.16-BS EN1991-1-4:2005

Cp.net　is net pressure coefficient determined from Table 7.4a-BS EN1991-1-4:2005 as the below

From sheet 7.4a, when tilt angle　25 °　positive pressure Cp.net=　1.1

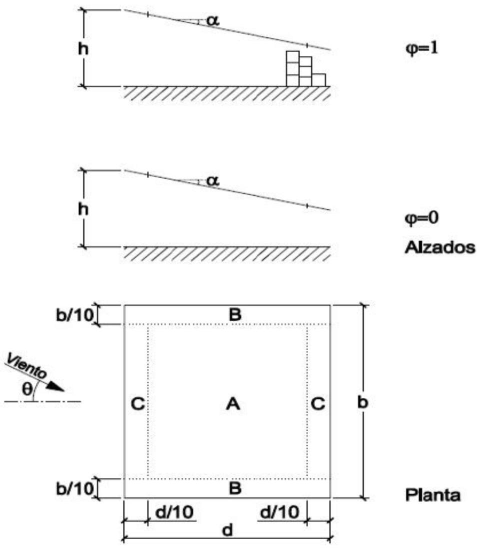
negative pressure Cp.net=　-1.6

positive pressure：　W1=　871.78 *　1.1　=　958.96　N/m^2　;

wind positive pressure on rail　Fw1 =　1.06　kn/m

negative pressure：　W2=　871.78 *　-1.6　=　-1394.86　N/m^2

wind negative pressure on ra　Fw1 =　-1.54　kn/m



Pendiente de la cubierta α	Efecto del viento hacia	Factor de obstrucción φ	Coeficientes de presión exterior $c_{p,10}$ Zona (según figura) A	B	C
0º	Abajo	0 ≤ φ ≤ 1	0,5	1,8	1,1
	Arriba	0	-0,6	-1,3	-1,4
	Arriba	1	-1,5	-1,8	-2,2
5º	Abajo	0 ≤ φ ≤ 1	0,8	2,1	1,3
	Arriba	0	-1,1	-1,7	-1,8
	Arriba	1	-1,6	-2,2	-2,5
10º	Abajo	0 ≤ φ ≤ 1	1,2	2,4	1,6
	Arriba	0	-1,5	-2,0	-2,1
	Arriba	1	-2,1	-2,6	-2,7
15º	Abajo	0 ≤ φ ≤ 1	1,4	2,7	1,8
	Arriba	0	-1,8	-2,4	-2,5
	Arriba	1	-1,6	-2,9	-3,0
20º	Abajo	0 ≤ φ ≤ 1	1,7	2,9	2,1
	Arriba	0	-2,2	-2,8	-2,9
	Arriba	1	-1,6	-2,9	-3,0
25º	Abajo	0 ≤ φ ≤ 1	2,0	3,1	2,3
	Arriba	0	-2,6	-3,2	-3,2
	Arriba	1	-1,5	-2,5	-2,8
30º	Abajo	0 ≤ φ ≤ 1	2,2	3,2	2,4
	Arriba	0	-3,0	-3,8	-3,6
	Arriba	1	-1,5	-2,2	-2,7

5.1.2 Snow load calculation

$S = \mu i * C_e * C_t * S_k$

μi is the snow load shape coefficient (from Table 5.2-EN1991-1-3:2003)

S_k is the characteristic value of snow load on the ground

C_e is the exposure coefficient

C_t is the thermal coefficient

The exprosure coefficient Ce should be used for determining the snow load on the roof. The choice for Ce should be cosider the future development around the site. Ce should be taken as 1.0 unless otherwise specified for different topographies

Table 5.1 Recommended values of C_e for different topographies

Topography	C_e
Windswept [a]	0,8
Normal [b]	1,0
Sheltered [c]	1,2

[a] *Windswept topography*: flat unobstructed areas exposed on all sides without, or little shelter afforded by terrain, higher construction works or trees.

[b] *Normal topography*: areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees.

[c] *Sheltered topography*: areas in which the construction work being considered is considerably lower than the surrounding terrain or surrounded by high trees and/or surrounded by higher construction works.

The thermal coefficient C_t should be used to account for the reduction of snnow loads on roofs with high thermal transmittance (>1W/m^{2}K), in particular for some glass covered roofs, because of meltiing caused by heat loss. For all other cases: C_t=1.0

According to DIN EN1991-1-3/NA2010-12, the characteristic value of snow load in snow zone: 2

can be determined by formula below:

S_k = 0.88 kN/m²

5.3.2. Monopitch roofs

(1) The snow load shape coefficient μ_1 that should be used for monopitch roofs is given in Table 5.2 and shown in Figure 5.1 and Figure 5.2.

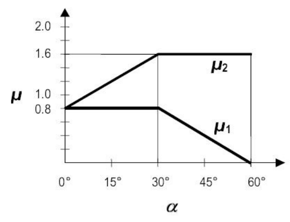


Figure 5.1: Snow load shape coefficients

(2) The values given in Table 5.2 apply when the snow is not prevented from sliding off the roof. Where snow fences or other obstructions exist or where the lower edge of the roof is terminated with a parapet, then the snow load shape coefficient should not be reduced below 0,8.

Table 5.2: Snow load shape coefficients

Angle of pitch of roof α	$0° \le \alpha \le 30°$	$30° < \alpha < 60°$	$\alpha \ge 60°$
μ_1	0,8	$0,8(60 - \alpha)/30$	0,0
μ_2	$0,8 + 0,8\ \alpha/30$	1,6	--

Z= 2 A= 500

μi = 0.8

Sk = 0.88

μi = 0.8

Ce = 1

Ct = 1

S1= μi*Ce* Ct* Sk= 0.8 * 1 * 1 * 0.880 = 0.70 kN/m²

wind positive pressure on ra Fw1 = 0.78 kn/m

6 Load Recombination and Load Direction

6.1 Load recombination

※G:Dead load ※S:Snow load ※W:Wind load ※K:Seism load

Load condition		General Area	Value（based pressure on rail）kN/M
Long term	regularly	G	0.18
	Snow cover	G	0.18
Short term	Snow cover	S	0.78
	Strong winds and downwind	W1	1.06
	Strong wind against the wind	W2	-1.54

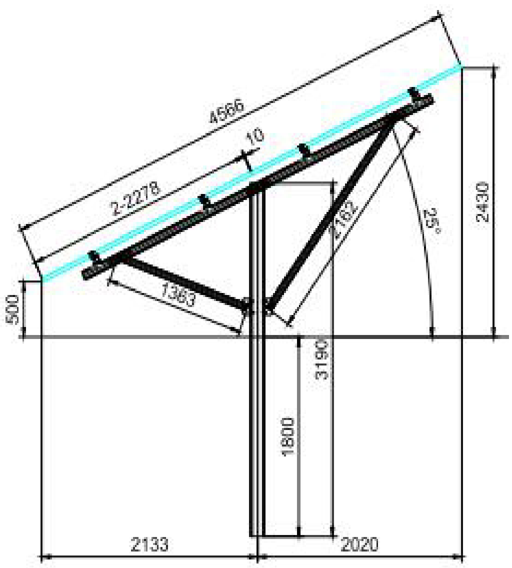
Note: Snowy areas refer to the following areas.

1、The area where the maximum vertical snow cover is more than 1 m.

2、reas with an average annual snow cover of more than 30 days (referring to days with snow cover area of more than 1/2 of the total area).

6.2 Direction of Load

The direction of each load is shown in the following schematic diagram (the direction of wind pressure load is vertical component, the direction of fixed load and snow load is vertical ground, and the direction of earthquake load is horizontal).



7 Materialcomponent allowable stress value

Elasticity coefficient E 201000 [MPa]

Allowable stress values are shown below

A. Material：S450GD Steel with ZAM coating

Yield point strength F σ_B= 398 [N/mm^2]

Min yield stress σ_y= 350 [N/mm^2]

(1)Allowable tensile stress

long-term load (the following is the minimum)

$\sigma_y/1.5$ ＝ 233.33 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ ＝ 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. ＝ 331.67 [N/mm^2]

(2)Allowable compressive stress

long-term load (the following is the minimum)

$\sigma_y/1.5$ ＝ 233.33 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ ＝ 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. ＝ 331.67 [N/mm^2]

a)Pole（the section above of the ground）

Compressive Stres: σ_c : 150.36 （long term） 225.55 （short term

length of pile Lt ＝ 3190 ＊ slender ratio λ ＝ L_t / i_c ＝ 58.87

$c\lambda = \lambda \times (331.67 / \pi^2 / 201000)$ ^0.5 = 0.7611631

$\lambda_p = 0.2$ $\lambda_e = 1.41$ $V = 2$

$c\lambda < \lambda_p$ $\sigma_b = F/V$

$\lambda_p < c\lambda < \lambda e$ $\sigma_b = (1.0 - 0.5 \times ((c\lambda - \lambda_p)/(\lambda_e - \lambda_p)) \times (F/V)$

$c\lambda > \lambda e$ $\sigma_b = F/V/c\lambda^2$

F = 331.67 [N/mm^2]

(3)Allowable bending moment

long-term load (the following is the minimum)

$\sigma_y/1.5$ = 233.33 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ = 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 331.67 [N/mm^2]

(4)Allowable shear stress values

long-term load (the following is the minimum)

$\sigma_y/(1.5\times\sqrt{3})$ = 134.72 [N/mm^2]

$5\sigma_B/6\times\{1/(1.5\times\sqrt{3})\}$ = 127.66 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 191.49 [N/mm^2]

(5)Allowable axial stress values

long-term load (the following is the minimum)

$\sigma_y/1.1$ = 318.18 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ = 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 331.67 [N/mm^2]

B. Material：S450GD Steel with ZAM coating

Yield point strength F σ_B= 398 [N/mm^2]

Min yield stress σ_y= 350 [N/mm^2]

(1)Allowable tensile stress

long-term load (the following is the minimum)

$\sigma_y/1.5$ = 233.33 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ = 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 331.67 [N/mm^2]

(2)Allowable compressive stress

long-term load (the following is the minimum)

$\sigma_y/1.5$ = 233.33 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ = 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 331.67 [N/mm^2]

a)Pole（the section above of the ground）

Compressive Stres σ_c : 150.36 （long term） 225.55 （short term

length of pile Lt = 3190 slender ratio $\lambda = L_t / i_c$ = 58.87

$c\lambda = \lambda \times (331.67 / \pi^2 / 201000)$ ^0.5 = 0.7611631

$\lambda_p = 0.2$ $\lambda_e = 1.41$ $V = 2$

$c\lambda < \lambda_p$ $\sigma_b = F/V$

$\lambda_p < c\lambda < \lambda e$ $\sigma_b = (1.0 - 0.5 \times ((c\lambda - \lambda_p)/(\lambda_e - \lambda_p)) \times (F/V)$

$c\lambda > \lambda e$ $\sigma_b = F/V/c\lambda^2$

F = 331.67 [N/mm^2]

(3)Allowable bending moment

long-term load (the following is the minimum)

$\sigma_y/1.5$ = 233.33 [N/mm^2]

$5\sigma_B/6\times(1/1.5)$ = 221.11 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 331.67 [N/mm^2]

(4)Allowable shear stress values

long-term load (the following is the minimum)

$\sigma_y/(1.5\times\sqrt{3})$ = 134.72 [N/mm^2]

$5\sigma_B/6\times\{1/(1.5\times\sqrt{3})\}$ = 127.66 [N/mm^2]

Short-term load is 1.5 times that of long-term load. = 191.49 [N/mm^2]

(5)Allowable axial stress values

long-term load (the following is the minimum)

$\sigma_y/1.1$ = 318.18 [N/mm^2]

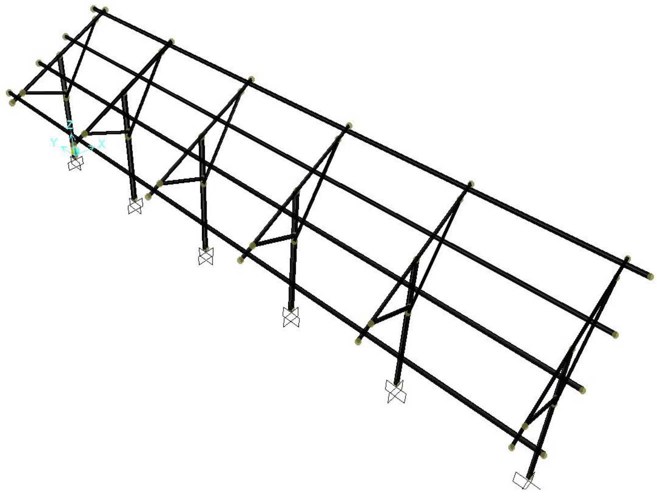
$5\sigma_B/6\times(1/1.5)$ = 221.11 [N/mm^2]

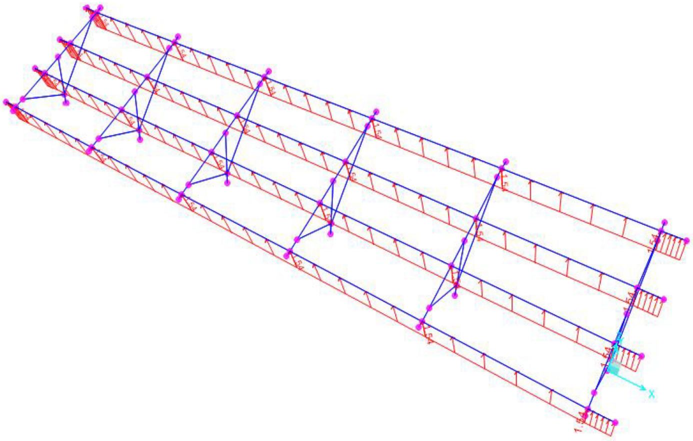
Short-term load is 1.5 times that of long-term load. = 331.67 [N/mm^2]

8 Structure check

8.1 From 6.1 Load recombination, the structure is most stressed under the short-term Strong wind against the wind condiction

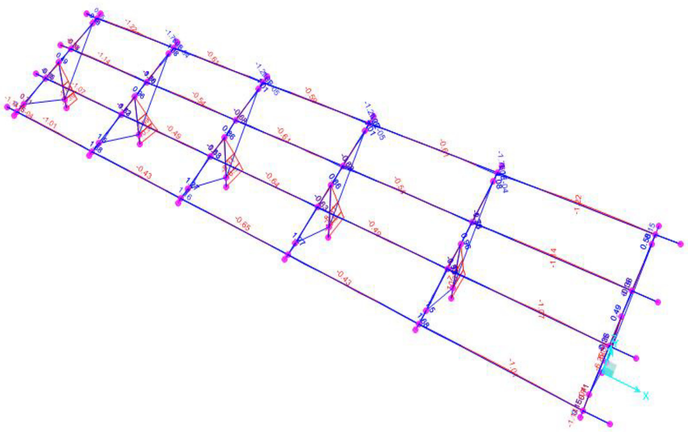
W2 = -1.54 KN/m

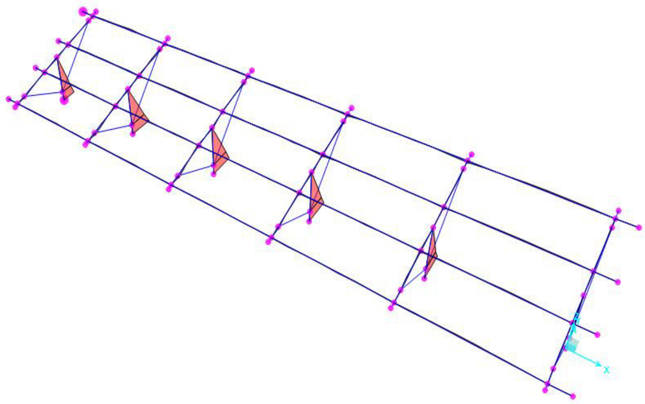


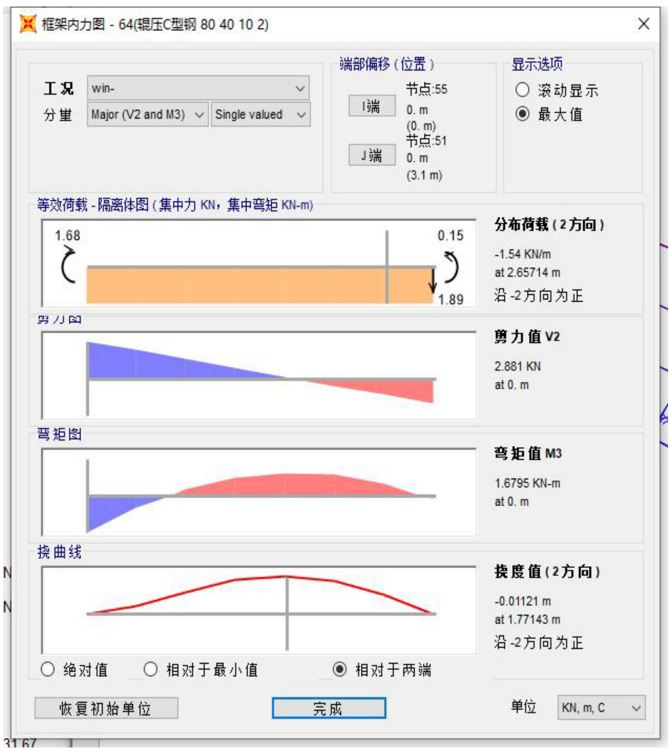


a. Rail Load

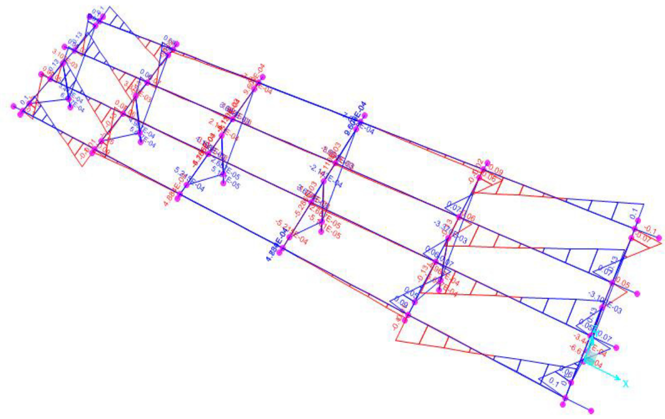
The longitudinal bending moment of the rail is shown in the figure

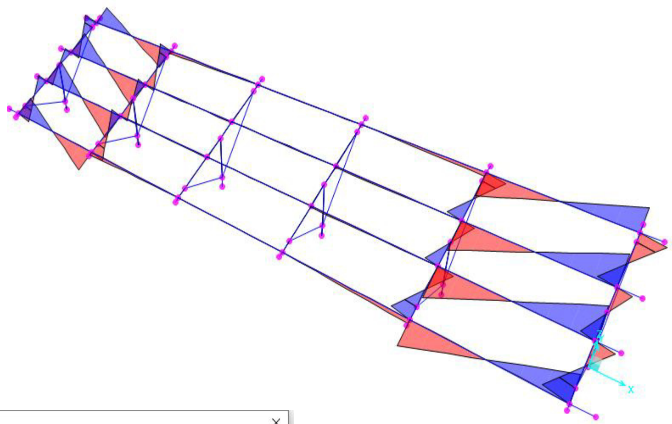


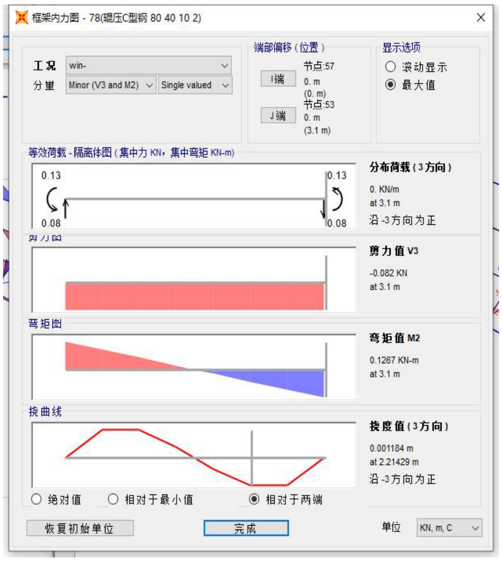




The horizontal bending moment of the rail is shown in the figure.







The maximum bending moments in both directions are as follows.

Mv(max)	=	1.6795	KN*m
MH(max)	=	0.1267	KN*m

Maximum combined stress

$$\sigma_{max} = \sigma_v + \sigma_H = Mv_{(max)}/W_v + MH_{(max)}/WH$$

$$= 189.91 + 23.30$$

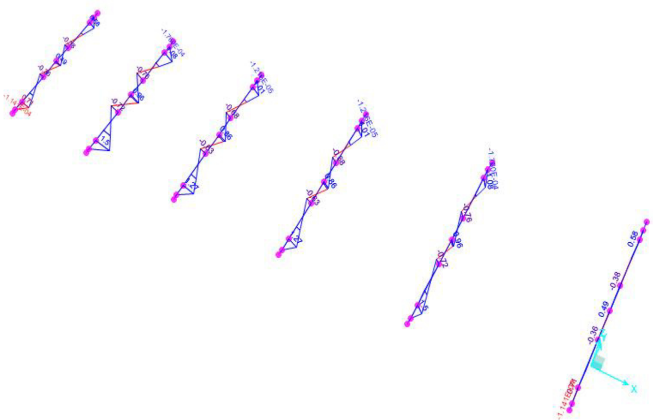
$$= 213.22 \text{ Mpa} < 331.67 \text{ Mpa}$$

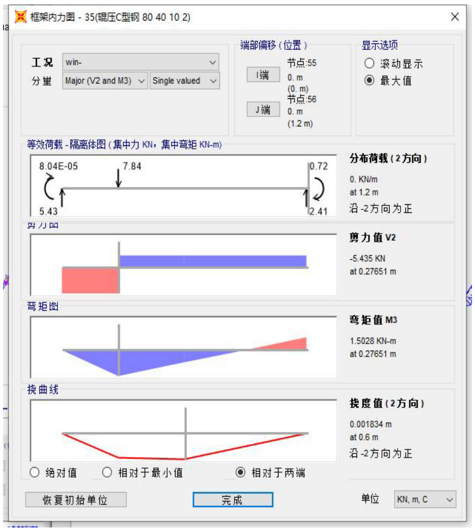
Bending strength OK

b. Beam Load

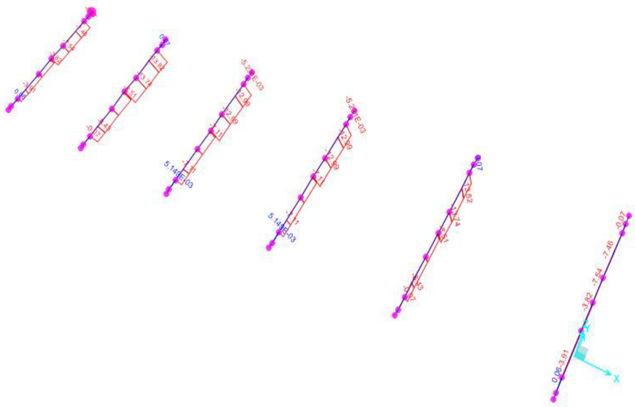
The stress of the two horizontal rails at outermost ends of the mounting rack is half of the middle rails, it is equal to only one horizontal rail. Therefore, the concentrated load acting on the vertical beam by the horizontal rails on both ends is F/2.

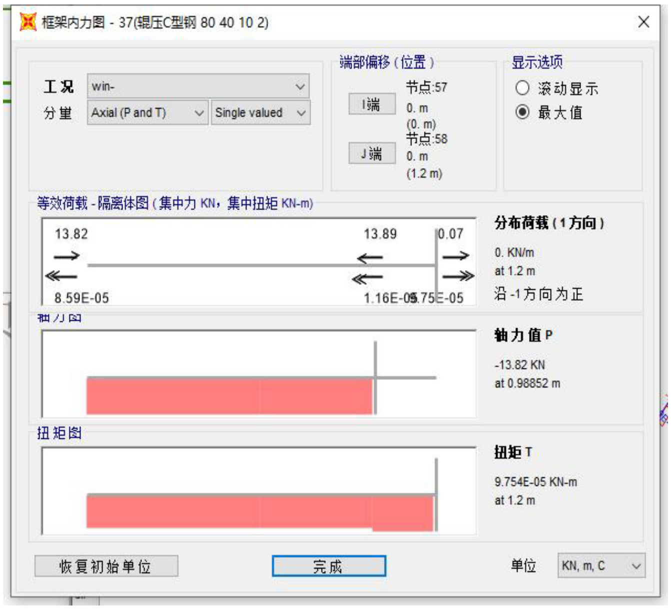
The bending moment diagram of the vertical longitudinal beam in F_V direction is as follows:





The longitudinal beam axial force is shown in the figure:





The maximum bending moment position and the maximum axial force position of the longitudinal beam may become the dangerous joints, but because the axial force is very small compared with the bending moment, only the combined stress of the maximum bending moment position of the beam is considered.

Maximum bending moment in F_V direction:

$Mv_{(max)}$ = 1.5028 KN*m

Maximum stress from F_V:

$\sigma_{v(max)}$= $Mv_{(max)}/Wv$ = 169.93 Mpa

Maximum axis force corresponding to FH direction:

F_H= 13.82 KN

Maximum stresst in F_H direction:

$\sigma_{H(max)}$= F/A = 40.174 Mpa

Maximum combined stress:

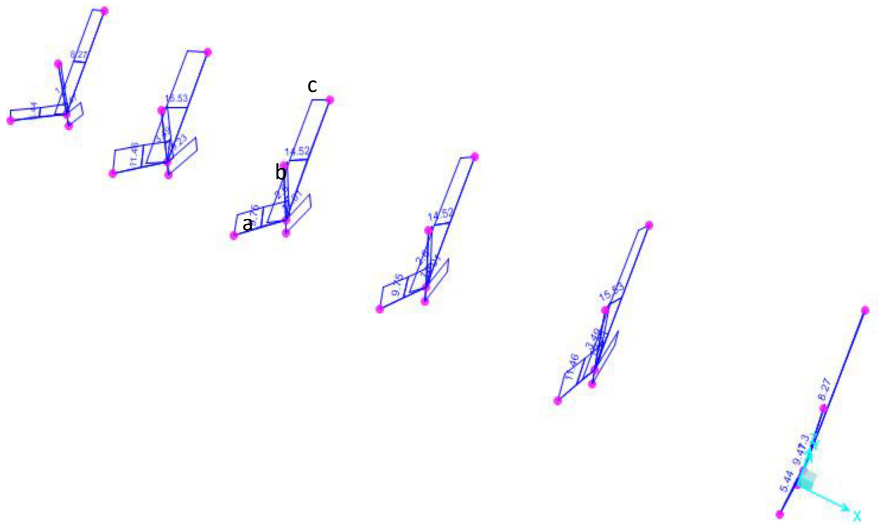
σ_{max}= $\sigma v_{(max)}$ + $\sigma_{H(max)}$ = 169.93 + 40.174

= 210.108 Mpa < 331.67 Mpa

Bending strength OK

c. Post and bracing

The axial force diagram of the vertical post and the bracing



Fa=	11.463	KN	Fb=	19.23	KN
Fc=	15.532	KN			

Compressive strength and axial tensile force checking：

σ_a=	Fa/A=	41.68	Mpa	<	225.55	Mpa	tensile force OK
σ_b=	Fb/A=	23.92	Mpa	<	225.55	Mpa	tensile force OK
σ_c=	Fc/A=	56.47	Mpa	<	225.55	Mpa	tensile force OK

Post b stability checking：

Both ends of the Post b are connected by bolts(hinged at both ends), Length coefficient μ=1

λ = $\mu * L / i_{min}$ = 1* 3190 / 24.5821

= 129.77 < λ_p = 150

Since the post b is a highly flexible rod, the critical stress is calculated by an empirical formula:

$\sigma_{cr}=\pi^2*E/\lambda^2=$ 3.14²*201000 / 129.77 ² = 120.61 Mpa

σ_b= 23.92 Mpa < 120.61 Mpa stability OK

Conclusion: According to the above data, this structure design meets the requirements.