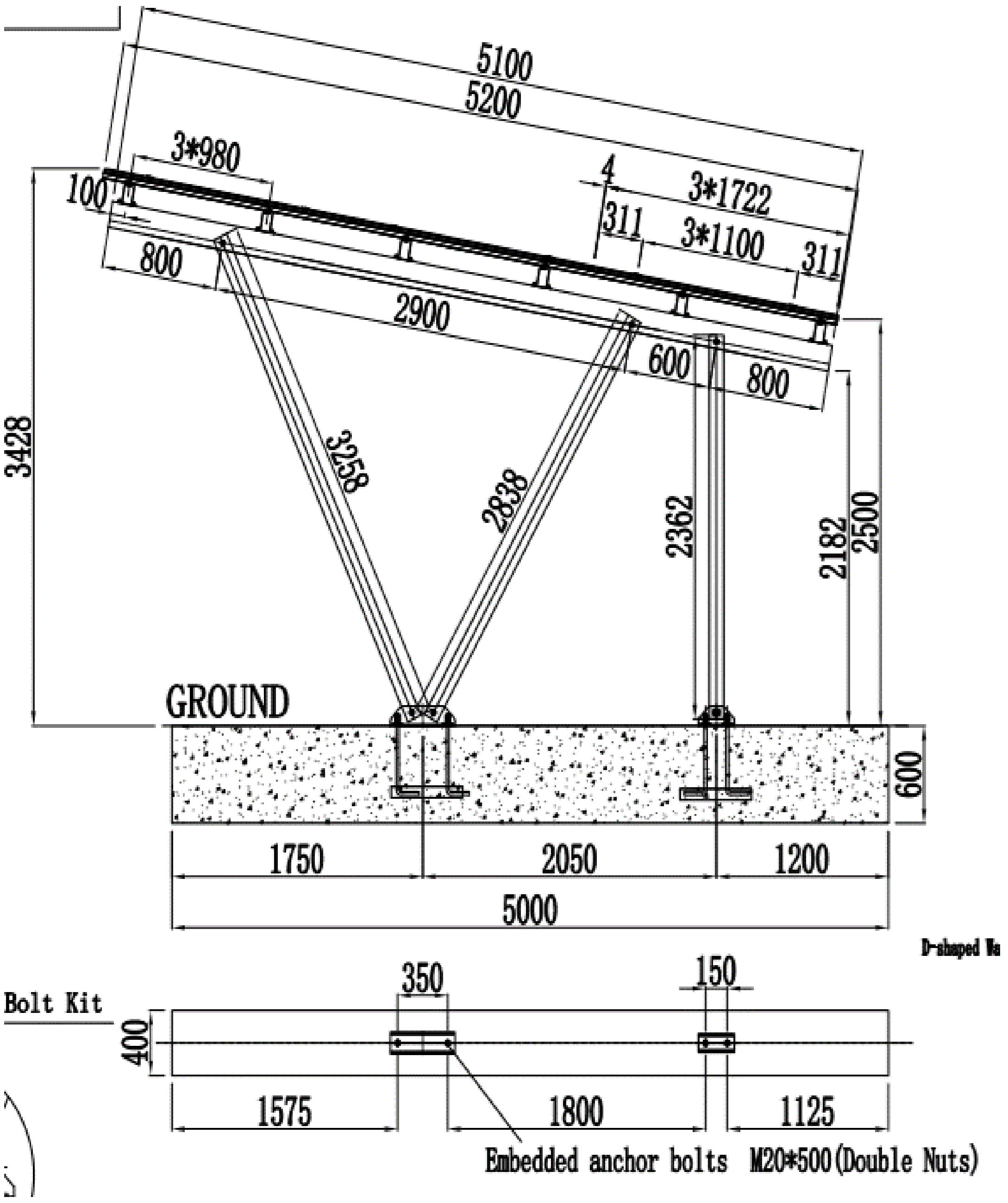
Mechanics calculation



Mibet(Xiamen)New Energy Co,.Ltd

15.05.2024

Contents

1. Introduction

1.1 System Review

- ●Solar Panel： L 1722 * W 1134 * H 30 24 Kg
- ●Layout: 3 * 6
- ●Angle: 10 °
- ●Span: 5400 mm
- ●Load of snow accumulation on the ground:

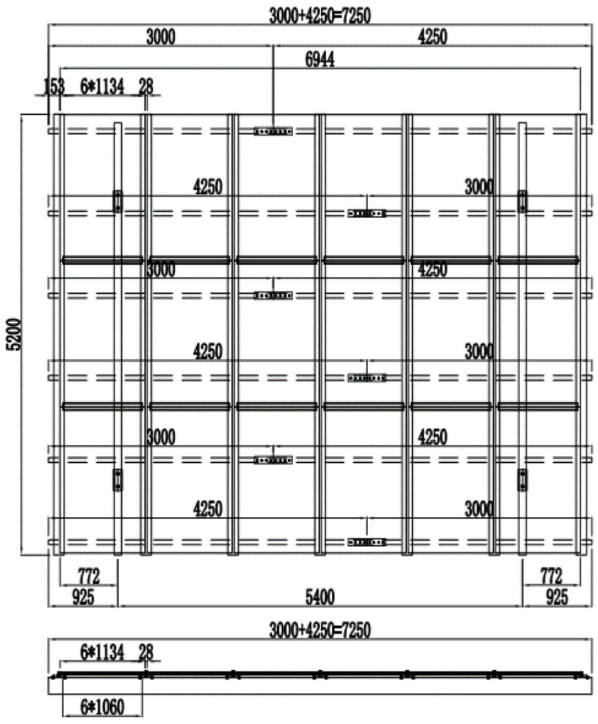
S_k = 0,9 kN/m²

- ●Load of wind accumulation on the ground:

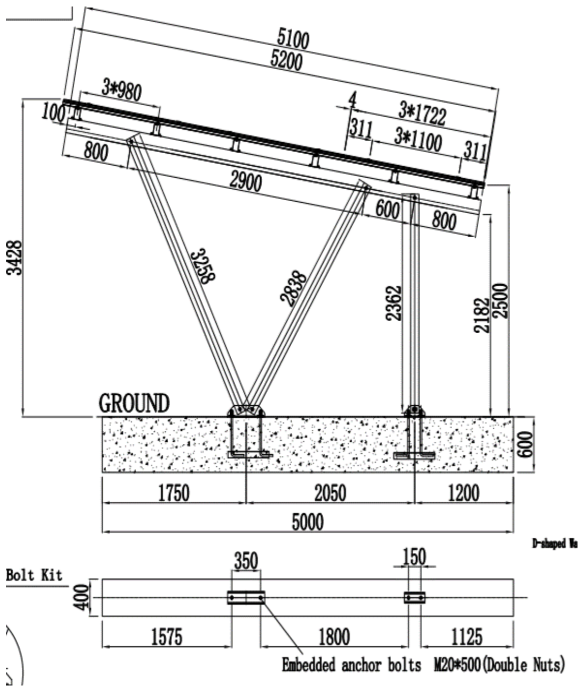
V = 40 m/s

Sketch of bracket：

- ● Front view



- ● Front view



2.Load calculation

2.1 Dead load

●Solar Panel:

Dead-weight of panel G1= 23,6 kg = 231,28 N

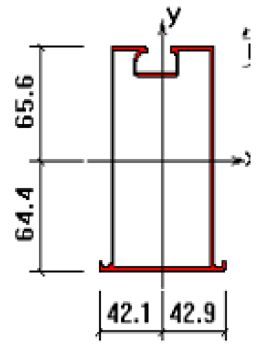
Standard load of panel：G1/m2 = 231,28 N / (1,722 x 1,134) = 118,4382 N/m^2

(Load for every square meter of solar module)

●Wide Rail 130 AL6005

Elasticity modulus $E=7\times10^6$ N/cm^2 (Elastic modulus of aluminum alloy)

Tensile/compressive/bending strength f= 24000 N/cm² (Yield strength of aluminum alloy)



A	905,4674525	Ip	2982085,977
Ix	2186112,591	Iy	795973,3866
ix	49,136	iy	29,64919
Wx(Top）	33332,1405	Wy(Left)	18891,32675
Wx(Down）	33938,3246	Wy(Right)	18569,0175
Area Moment Around X Axis	20250,96086	Area Moment Around Y Axis	12568,618
Distance from Centroid to Left Edge	42,134	Distance from Centroid to Right Edge	42,8656
Distance from Centroid to Top Edge	65,5857	Distance from Centroid to Bottom Edge	64,414
Principal Moment I1	2186320,168	Direction of Principal Moment 1	(1.000, 0.000)
Principal Moment I2	795765,81	Direction of Principal Moment 2	(0.000, 1.000)

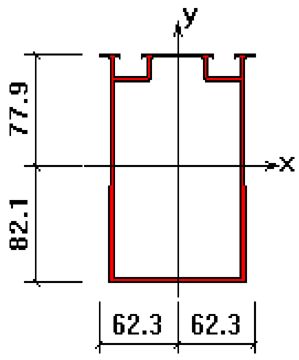
Dead-weight of Rail G2= 7,25 mm x 2,44476 kg/m= 17,7245 kg= 173,7003488 N

Standard load of Rail G2/m = 2,444762 kg/m= 23,9587 N/m

●Beam 160 AL6005

Elasticity modulus $E=7\times10^6$ N/cm^2 (Elastic modulus of aluminum alloy)

Tensile/compressive/bending strength f= 24000 N/cm² (Yield strength of aluminum alloy)



A	1668,984	Ip	2960362,639
Ix	5879739,594	Iy	3420737,664
ix	59,354	iy	45,272
Wx(Top）	75497,03354	Wy(Left)	54907,5066
Wx(Down）	71599,715	Wy(Right)	54907,5066
Area Moment Around X Axis	45298,90144	Area Moment Around Y Axis	35537,07587
Distance from Centroid to Left Edge	62,3	Distance from Centroid to Right Edge	62,3
Distance from Centroid to Top Edge	77,88	Distance from Centroid to Bottom Edge	82,11959
Principal Moment I1	5879739,594	Direction of Principal Moment 1	(1.000, 0.000)
Principal Moment I2	3420737,665	Direction of Principal Moment 2	(0.000, 1.000)

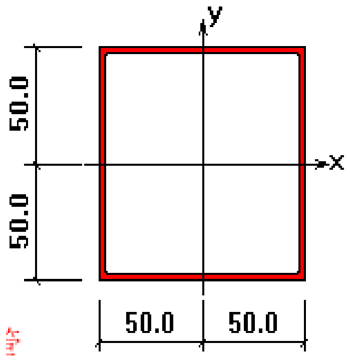
Dead-weight of Gider G3= 5,1 mm x 4,50626 kg/m= 22,98191 kg= 225,2227 N

Standard load of Rail G2/m = 4,506257 kg/m= 44,1613 N/m

●Post AL6005

Elasticity modulus E=20.6×10^6 N/cm^2 (Elastic modulus of aluminum alloy)

Tensile/compressive/bending strength f= 24000 N/cm² (Yield strength of aluminum alloy)



A	1161,42477	Ip	3641076,844
Ix	1820538,422	Iy	1820538,422
ix	39,5917	iy	39,5917
Wx(Top）	36410,768	Wy(Left)	36410,768
Wx(Down）	36410,768	Wy(Right)	36410,768
Area Moment Around X Axis	2774,898186	Area Moment Around Y Axis	3783,352283
Distance from Centroid to Left Edge	50	Distance from Centroid to Right Edge	50
Distance from Centroid to Top Edge	50	Distance from Centroid to Bottom Edge	50
Principal Moment I1	1820538,422	Direction of Principal Moment 1	(1.000,0.000)
Principal Moment I2	1820538,422	Direction of Principal Moment 2	(0.000,1.000)

3.Loads

3.1 Wind Load Calculation

Vb= 40 m/s

Terrain roughness factor calculation：

Terrain Ⅳ from design drawing Z= 3 m

$Cr(Z)= Kr*\ln(Z/Z_O) = 0,19 * (1 / 0,05)^{0.07}*\ln (10 / 1) = 0,54$

$Cr(Z)= Kr*\ln(Z/ZO)$ for $Zmin \leqslant Z \leqslant Zmax$

$Cr(Z)= Cr (Zmin)$ for $Z \leqslant Zmin$

Where:

$Kr=0.19*（Zo/ZO\,II）^{0.07}$

Zo = 1 m (is the roughness lenghth for terrain categoryⅢ taken form Table 4.1)

Zmin = 10 m (is minimum height for terrain categoryⅢ taken form Table 4.1)

ZO II = 0,05 m (terrain category II taken form Table 4.1)

Zmax is to be taken as 200m

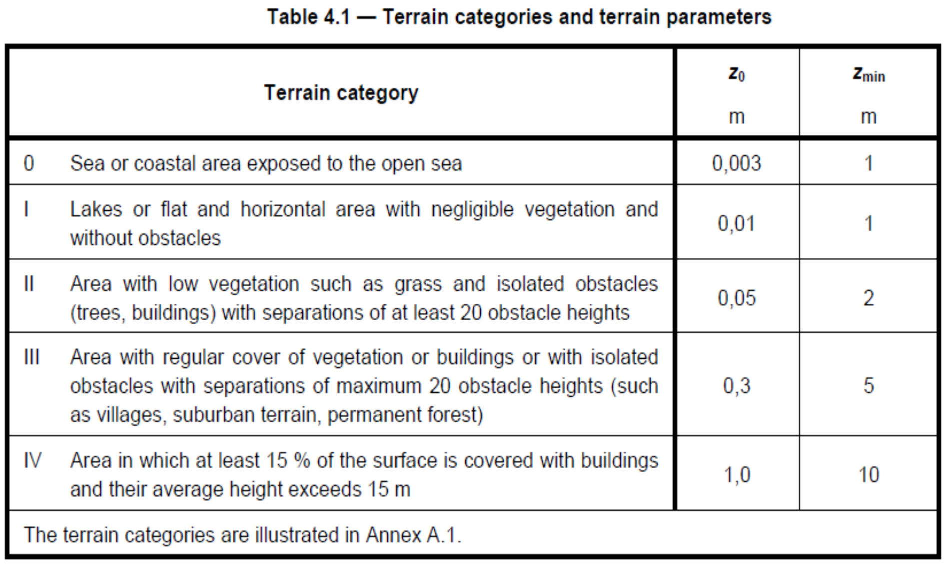


Table 4.1 — Terrain categories and terrain parameters

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 = 0,53956 * 1 * 40 = 21,5825 m/s

Where:

C_O(Z) is orography factor,taken as 1.0

Cr(Z) is roughness factor

Wind turbulence calculation

From the design drwing Z= 3 m

lv(Z)=σv/ Vm(Z)= Kl /{C_O* ln(Z/Z_O)} = 1 / （ 1 * ln （ 10 / 1 ）） = 0,434

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

lv(Z)= lv(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 1 m, given in Table 4.1

Calculation of peak velocity pressure：

qp(Z)={1+7* lv(Z)}*0.5*ρ* Vm^2(Z) = （ 1 + 7 * 0,434 ）* 0,5 * 1,25 * 21,58 * 21,5825

= 1176,171743 N/m2

Where:

qp(Z) is the peak velocity pressure(N/m2)

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

lv(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/m2)

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

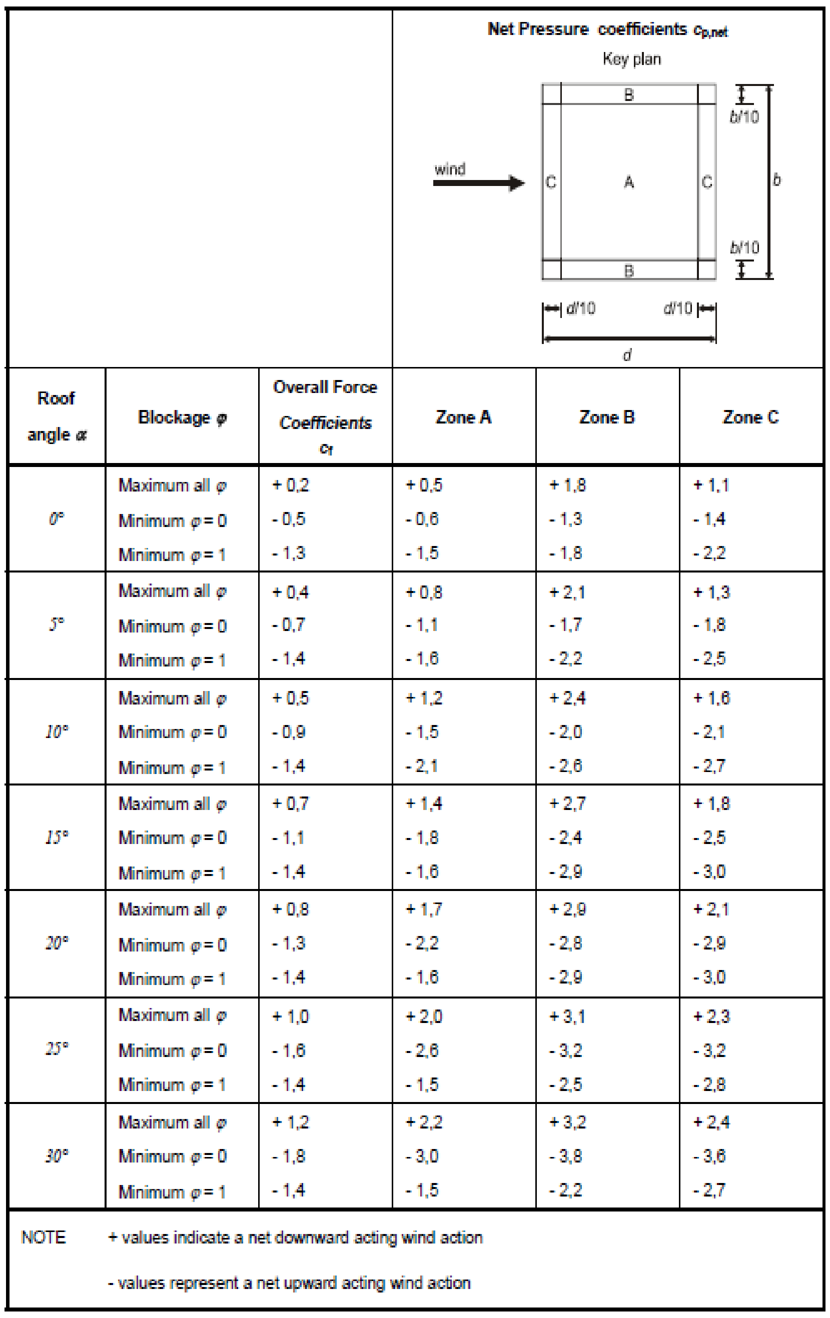
From sheet 7.4a, when tilt angle 10 ° positive pressure Cp.net= 1,2 ;

negative pressure Cp.net= -1,5

positive pressure： W1＝ 1176,17 * 1,2 ＝ 1411,41 N/m^2 ;

negative pressure： W2＝ 1176,17 * -1,5 ＝ -1764,3 N/m^2

Table 7.6 — $c_{p,net}$ and c_f values for monopitch canopies



			Net Pressure coefficients $c_{p,net}$		
Roof angle α	Blockage φ	Overall Force Coefficients c_f	Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum $\varphi = 0$	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum $\varphi = 1$	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum $\varphi = 0$	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum $\varphi = 0$	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum $\varphi = 1$	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum $\varphi = 0$	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum $\varphi = 0$	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum $\varphi = 0$	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum $\varphi = 1$	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum $\varphi = 0$	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum $\varphi = 1$	- 1,4	- 1,5	- 2,2	- 2,7

NOTE + values indicate a net downward acting wind action

- values represent a net upward acting wind action

3.2 Snow load calculation

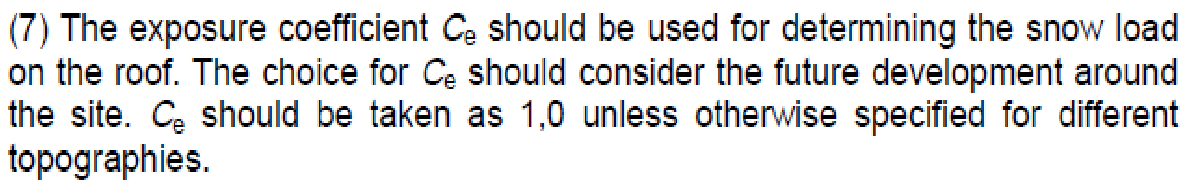
S= μi*Ce* Ct* Sk

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

Sk is the characteristic value of snow load on the ground

Ce is the exposure coefficient

Ct is the thermal coefficient



(7) The exposure coefficient C_e should be used for determining the snow load on the roof. The choice for C_e should consider the future development around the site. C_e should be taken as 1,0 unless otherwise specified for different topographies.

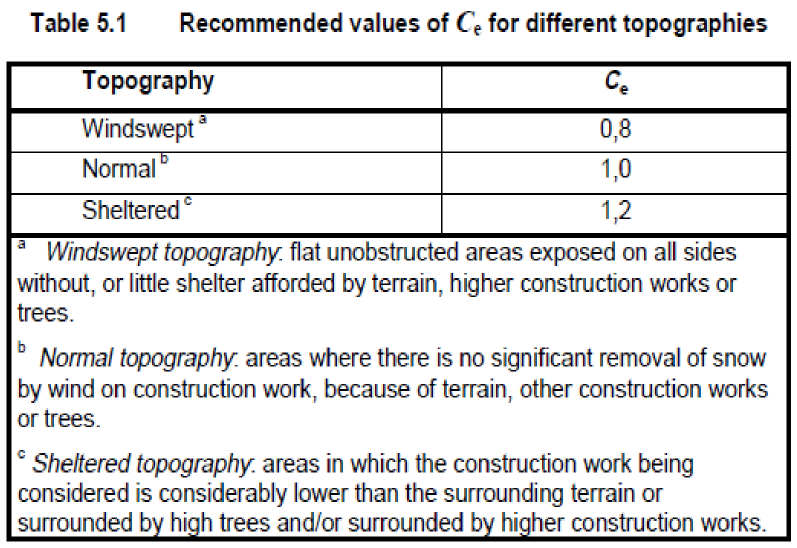


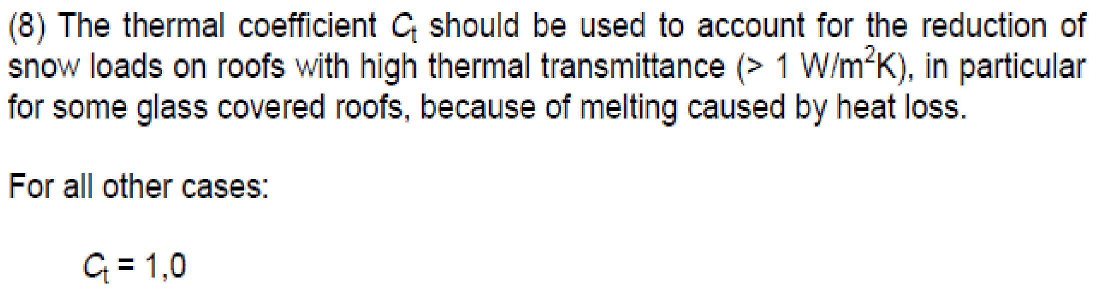
Table 5.1 Recommended values of C_e for different topographies

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.

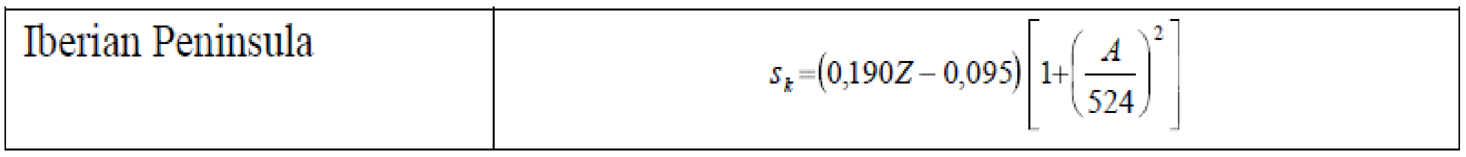
[c] *Sheltered topography*: areas in which the construction work being considered is considerably lower than the surrounding terrain or surrounded by high trees and/or surrounded by higher construction works.



(8) The thermal coefficient C_t should be used to account for the reduction of snow loads on roofs with high thermal transmittance (> 1 W/m^2K), in particular for some glass covered roofs, because of melting caused by heat loss.

For all other cases:

$C_t = 1{,}0$



Iberian Peninsula	$s_k = (0{,}190Z - 0{,}095)\left[1+\left(\frac{A}{524}\right)^2\right]$

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.

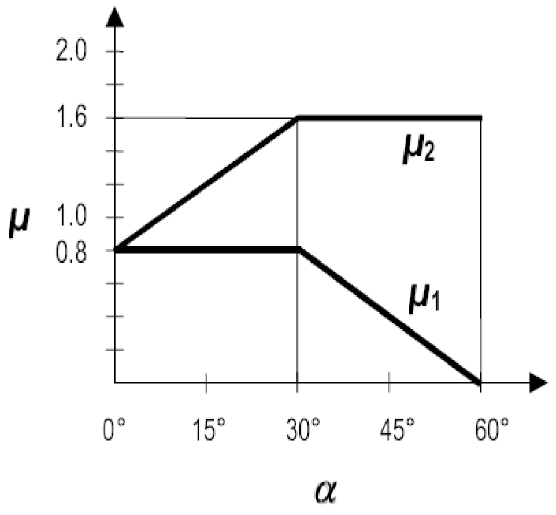


Figure 5.1: Snow load shape coefficients

(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	$0^\circ \leq \alpha \leq 30^\circ$	$30^\circ < \alpha < 60^\circ$	$\alpha \geq 60^\circ$
μ_1	0,8	0,8(60 - α)/30	0,0
μ_2	0,8 + 0,8 α/30	1,6	--

μi = 0,8

Sk = 0,85 kN/m^2

Ce = 1

Ct = 1

S1= μi*Ce* Ct* Sk= 0,8 * 1 * 1 * 0,85 = 0,68 kN/m^2

3.3 Load Combination

Combination second：0.9*D+1.5*Ws

Combination of load effects in limit states third:1.35*D+1.5*Wp+1.5*0.5*S

Combination Fourth：1.35*D+1.5*S+1.5*0.6*Wp

4. Strength Calculation

4.1 Applied load

D = 3 * 6 * G1 + 6 * G2
= 3 * 6 * 231,28 + 6 * 173,7003488 = 5205,242093 N
Ar = 3 * 6 * 1,722 * 1,134 = 35,149464 m2
Wp = W1 * Ar = 1411,41 * 35,1495 = 49610,16759 N
Ws = W2 * Ar = -1764,3 * 35,1495 = -62012,70949 N
S = S1 * Ar * COS 10 °= 0,68 * 35,149464 * COS 10 °* 1000 = 23538,516 N

F1 = 1,35 * D * COS 10 °+ 1,5 * Wp + 1,5 * 0,5 * S * COS 10 °
= 1,35 * 5205,24 * 0,985 + 1,5 * 49610,2 + 1,5 * 0,5 * 23538,516 * 0,985
= 98721,256 N

F2 = 1,35 * D * SIN 10 °+ 1,5 * 0,5 * S * SIN 10 °
= 1,35 * 5205,24 * 0,174 + 1,5 * 0,5 * 23538,5 * 0,174
= 4285,8044 N

F3 = 1,35 * D * COS 10 °+ 1,5 * S * COS 10 ° + 1,5 * 0,6 * Wp
= 1,35 * 5205,24 * 0,985 + 1,5 * 23538,5 * 0,985 + 1,5 * 0,6 * 49610,2
= 86340,84 N

F4 = 1,35 * D * SIN 10 °+ 1,5 * S * SIN 10 °
= 1,35 * 5205,24 * 0,174 + 1,5 * 23538,5 * 0,174
= 7351,3697 N

F5 = 0,9 * D * COS 10 °+ 1,5 * Ws
= 0,9 * 5205,24 * 0,985 + 1,5 * -62012,7
= -88405,52 N

F6 = 0,9 * D * SIN 10 °
= 0,9 * 5205,24 * 0,174
= 813,49272 N

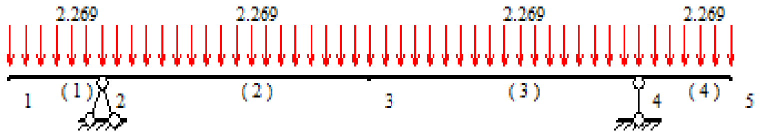
5 Membercheck

5.1 Calculation conclusion of Rail

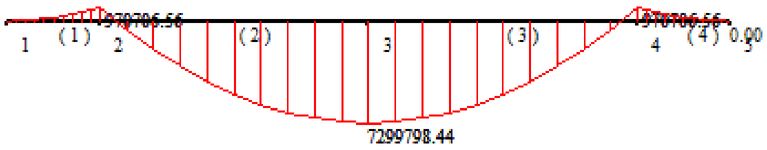
Combination first:

q1 =F1/(Rail length)/6= 98721,25589 / 7250 / 6 = 2,269 N （Vertical load combination on rail）

q2 =F2/(Rail length)/6= 4285,804387 / 7250 / 6 = 0,099 N （Horizontal load combination on rail）



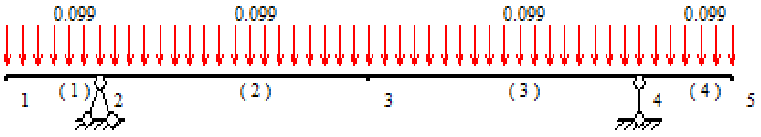
Model diagram



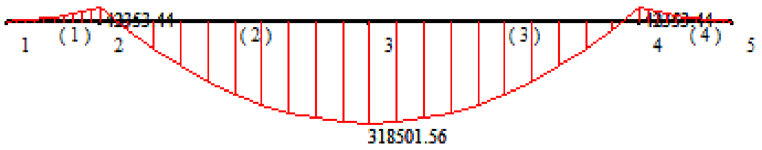
Bending moment diagram

Mmax= 7299798,4 N·mm

σv＝Mmax/WX = 7299798,43 / 33332,1405 = 219,002 N/mm²



Model diagram



Bending moment diagram

Mmax= 318501,56 N·mm

σh＝Mmax/WX = 318501,562 / 18891,32675 = 16,8597 N/mm²

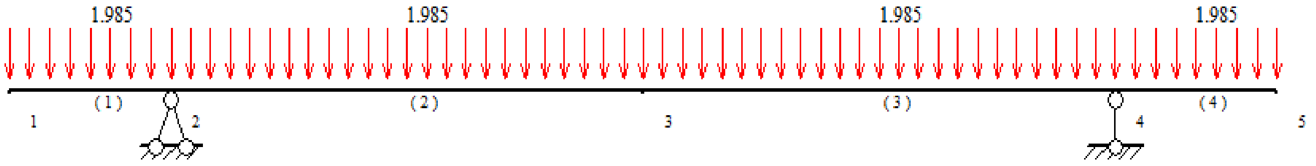
σ= $\sigma v+\sigma h$ = 235,861 N/mm²<240N/mm²

S = 240 / 235,86 = 1,01755

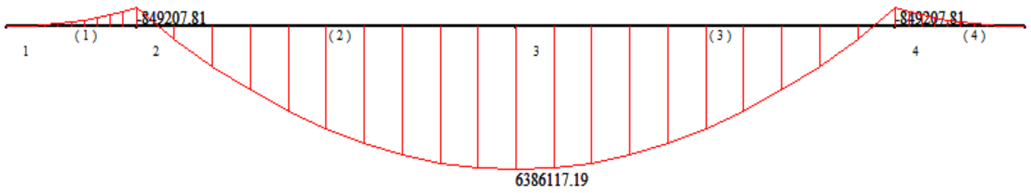
Combination second

q3 =F3/(Rail length)/6= 86340,8401 / 7250 / 6 = 1,985 N （Vertical load combination on rail）

q4 =F4/(Rail length)/6= 7351,36969 / 7250 / 6 = 0,169 N （Horizontal load combination on rail）



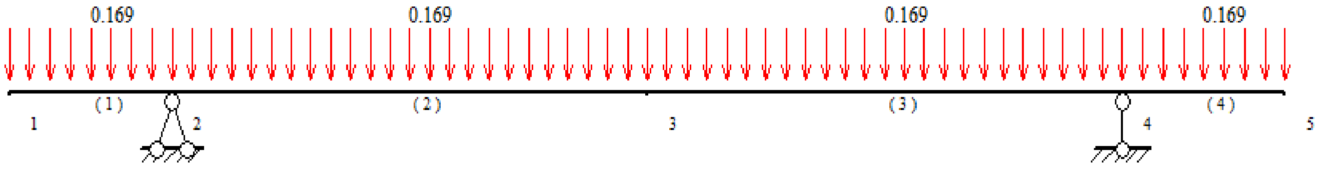
Model diagram



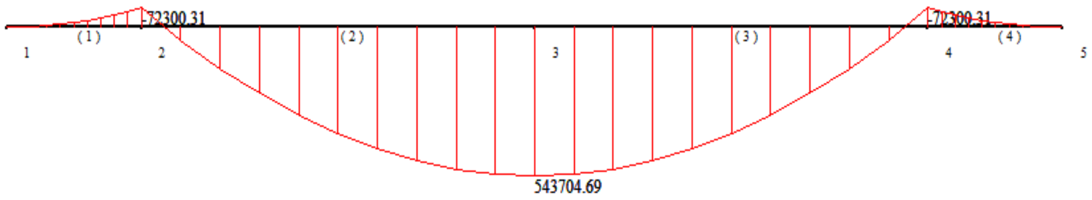
Bending moment diagram

Mmax= 6386117,2 N·mm

σv＝Mmax/WX = 6386117,18 / 33332,1405 = 191,59 N/mm²



Model diagram



Bending moment diagram

Mmax= 543704,69 N·mm

σh＝Mmax/WX = 543704,687 / 18891,32675 = 28,7807 N/mm²

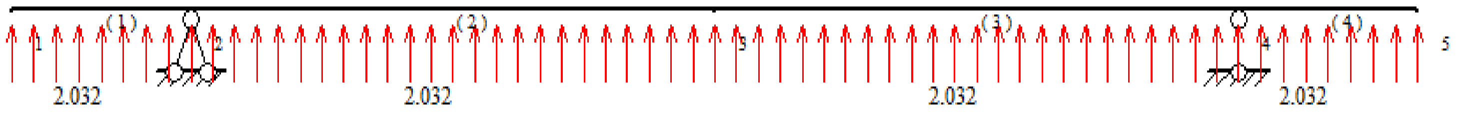
σ= σv+σh = 220,371 N/mm²<240N/mm²

S = 240 / 220,37 = 1,08907

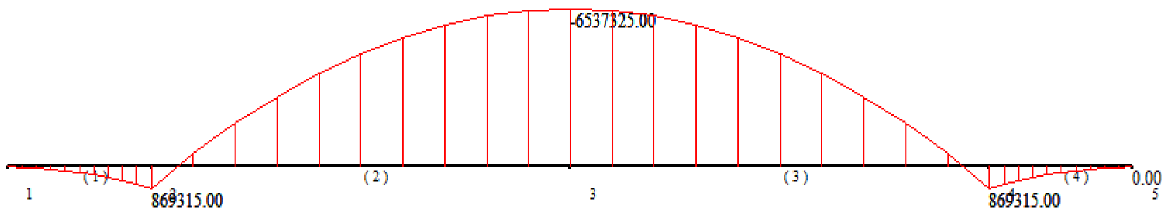
Combination third

q5=F5/(Rail length)/6= -88405,51774 / 7250 / 6 = -2,032 N （Vertical load combination on rail）

q6 =F6/(Rail length)/6= 813,4927233 / 7250 / 6 = 0,019 N （Horizontal load combination on rail）



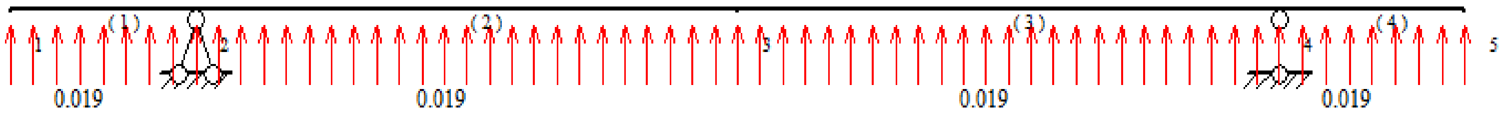
Model diagram



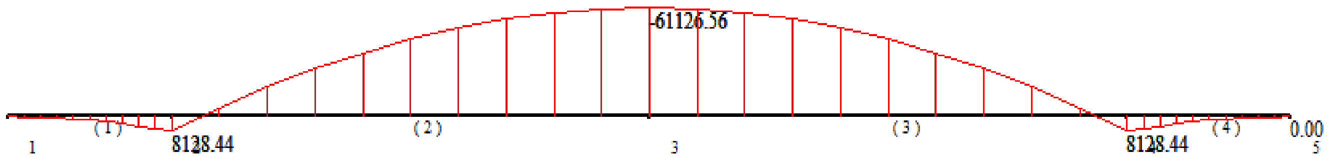
Bending moment diagram

Mmax= 6537325 N·mm

σv＝Mmax/WX = 6537325 / 33332,1405 = 196,127 N/mm²



Model diagram



Bending moment diagram

Mmax= 61126,563 N·mm

σh＝Mmax/WX = 61126,5625 / 18891,32675 = 3,23569 N/mm²

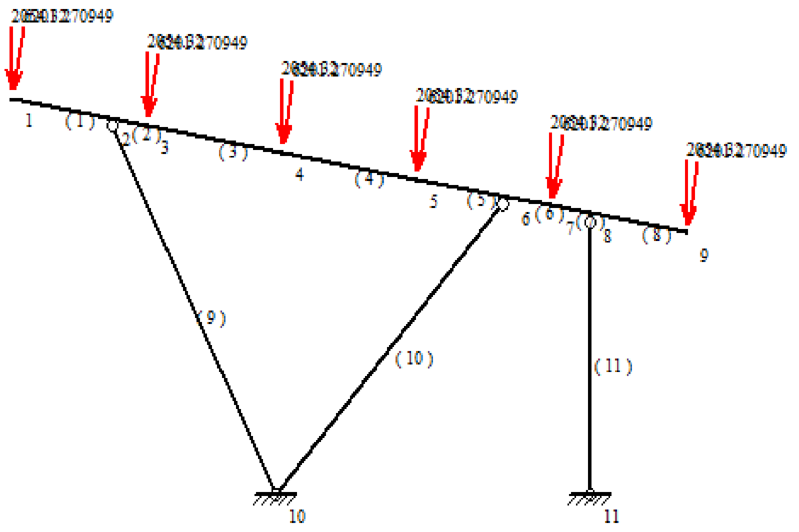
σ= σv+σh = 199,362 N/mm²<240N/mm²

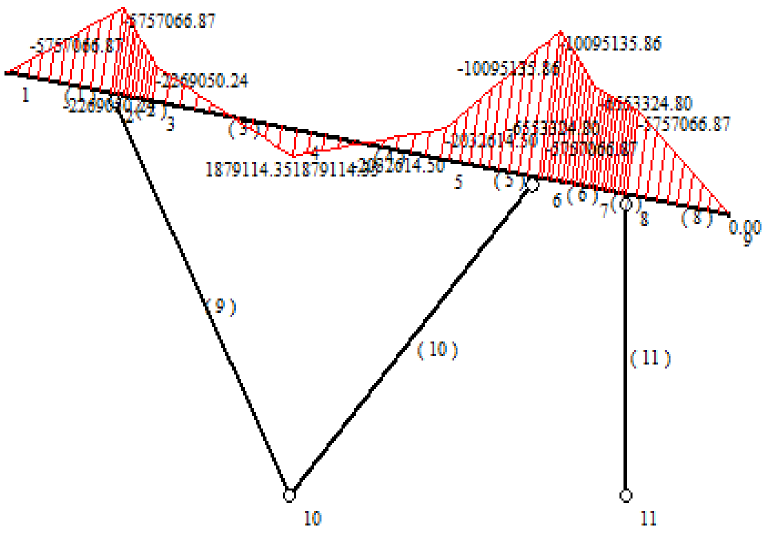
S = 240 / 199,36 = 1,20384

5.2 Calculation of Pre-assembled Support

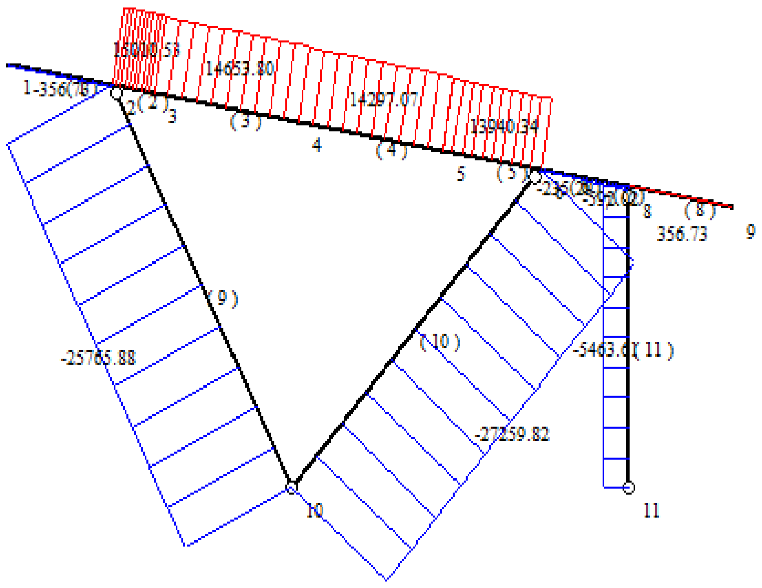
Wind blowing from the front of the modules:

F= 6201,270949 N Fh= 2056,746984 N





Bending moment diagram



Axial diagram

Mmax= 10095136 N·mm (Girder）

Fmax= 15010,531 N (Girder）

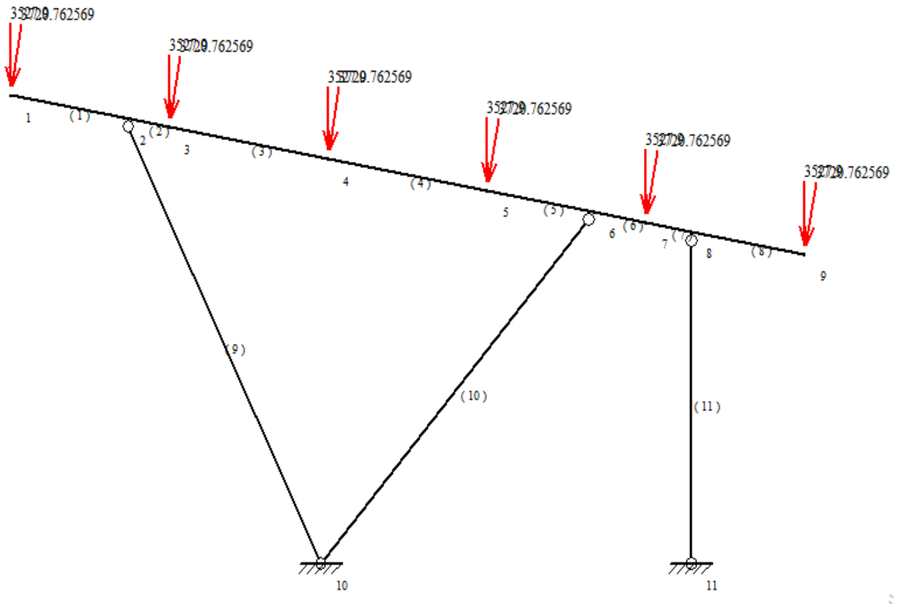
σv＝Mmax/WX+Fmax/A = 10095135,8 / 75497,03354 + 15010,53 / 1668,984 = 142,70948 N/mm²

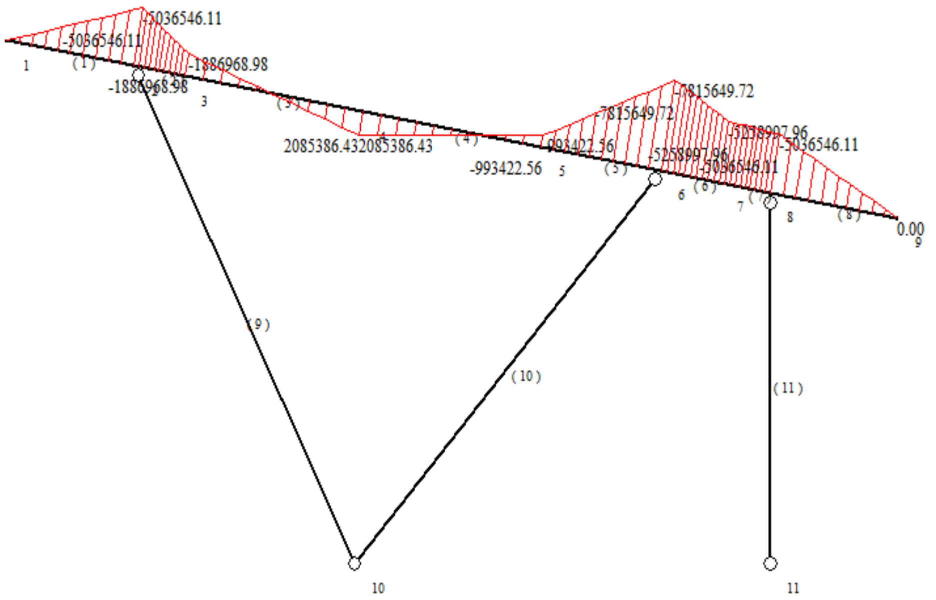
Fmax= 27259,822 N (Tube）

σv＝Fmax/A = 27259,822 / 1161,42477 = 23,471018 N/mm²

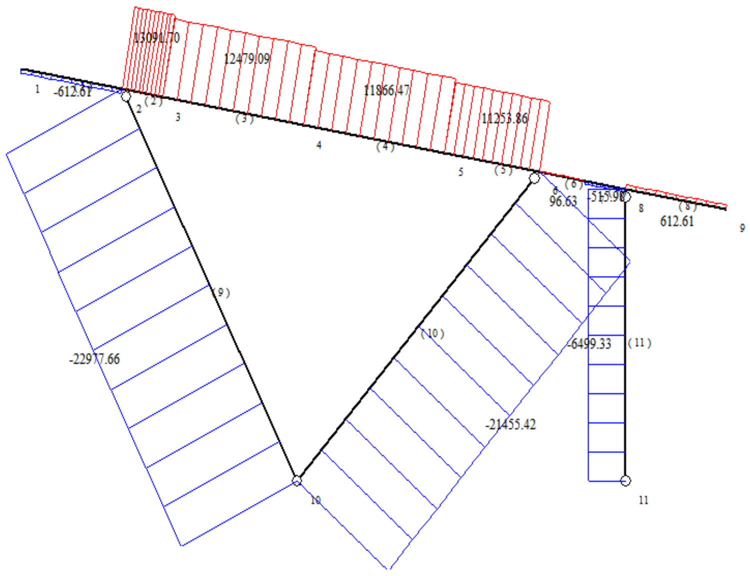
Wind blowing from the front of the modules:

F= 3720,762569 N Fh= 3527,904232 N





Bending moment diagram



Axial diagram

Mmax= 7815649,7 N·mm (Girder）

Fmax= 13091,701 N (Girder）

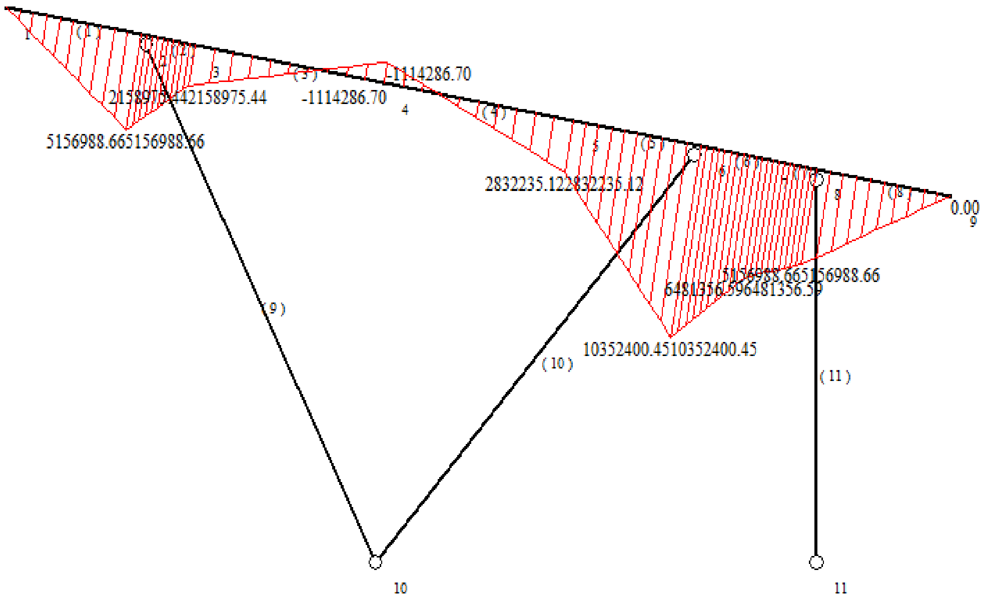
σv＝Mmax/WX+Fmax/A = 7815649,72 / 75497,03354 + 13091,70 / 1668,984 = 111,36672 N/mm²

Fmax= 22977,662 N (Tube）

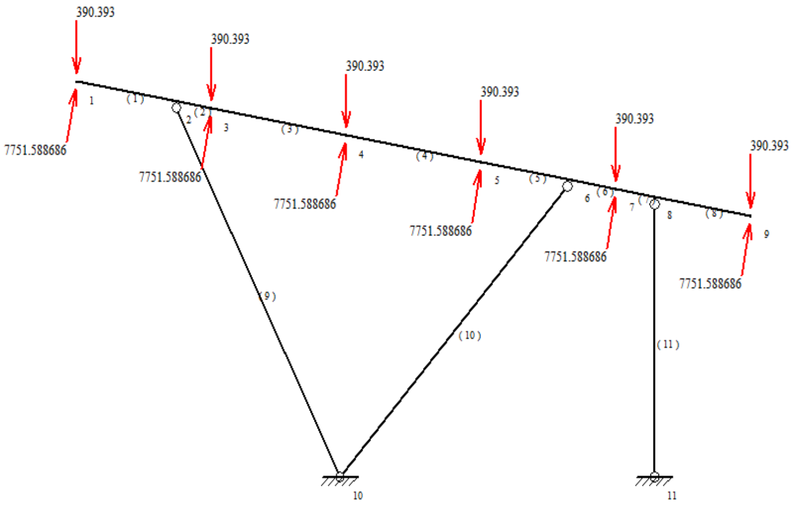
σv＝Fmax/A = 22977,6624 / 1161,42477 = 19,78403 N/mm²

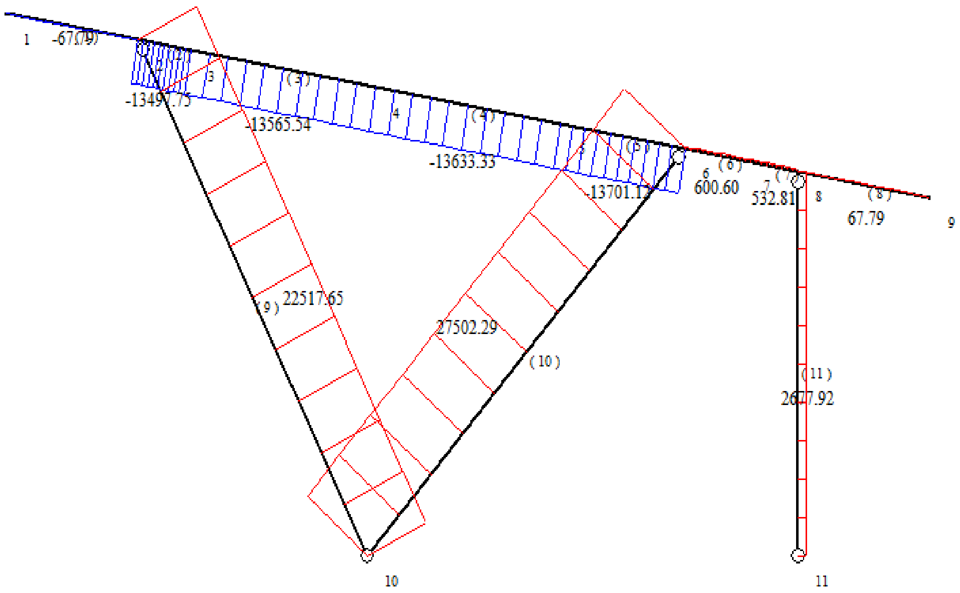
Wind blowing from the back of the modules:

F= -7751,588686 N   Fh= 390,3931569 N



Bending moment diagram





Axial diagram

Mmax= 10352400 N·mm (Girder)

Fmax= 13701,119 N (Girder)

σv＝Mmax/WX+Fmax/A = 10352400,4 / 75497,03354 + 13701,12 / 1668,984 = 145,33253 N/mm²

Fmax= 27502,285 N (Tube)

σv＝Fmax/A = 27502,2852 / 1161,42477 = 23,679782 N/mm²

6 summary

Items	Calculated [N/mm2]	Permissible strength（240 N/mm²）
Rail	235,861 N/mm²	240 N/mm²
Girder	145,333 N/mm²	240 N/mm²
Tube	23,680 N/mm²	240 N/mm²