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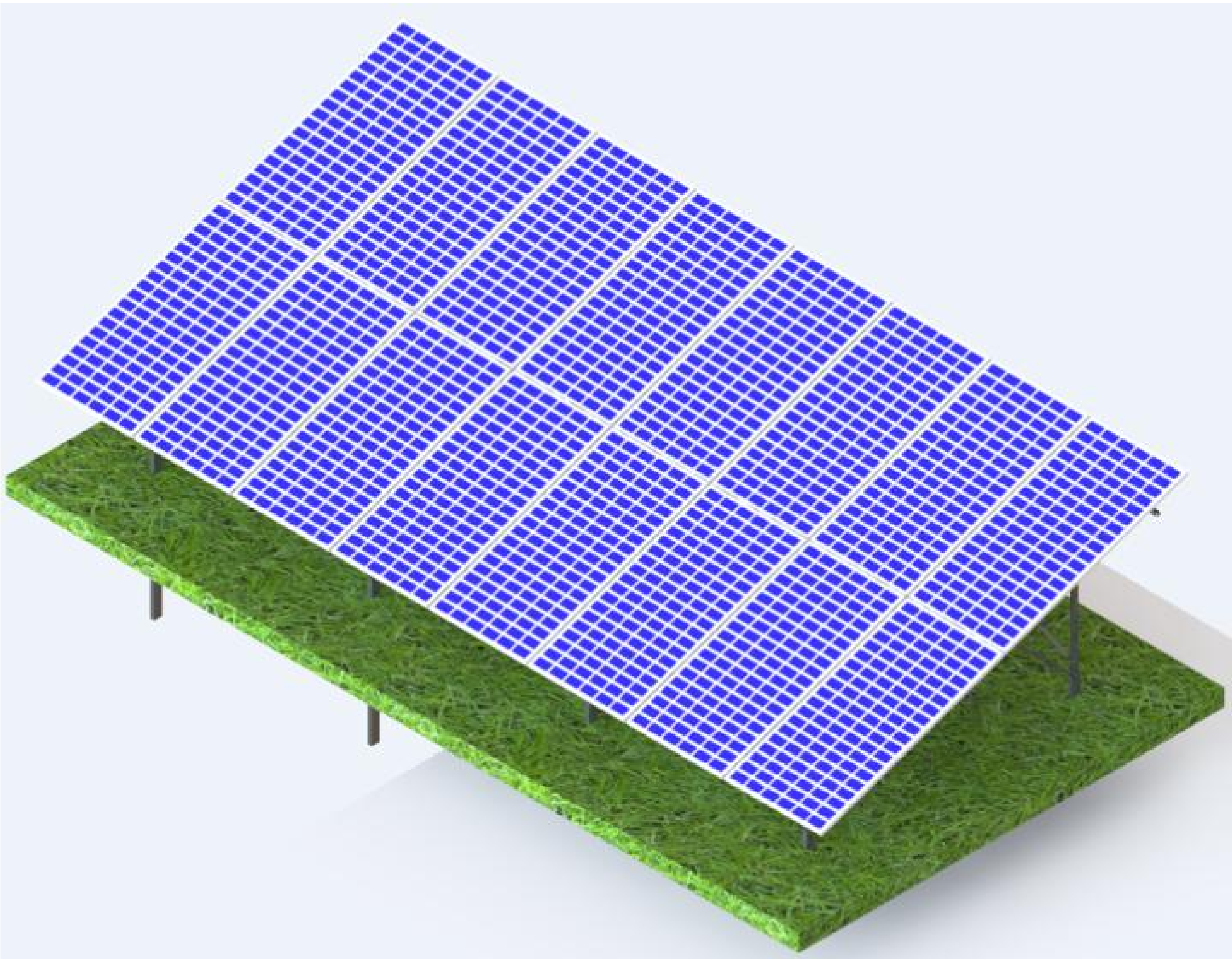
INSPIRED SOLAR TECHNOLOGY

Solar Mounting System Tech-report



Content

1.Design Considerations

1.1 Standard

Load Assumption	Name	Date
BS EN 1990	Eurocode - Basic of structural design	01.01.2005
BS EN 1990/NA	National Annex to Eurocode - Basis of structural design	04.06.2009
BS EN 1990/NA	Eurocode - Basic of structural design	30.06.2009
BS EN 1991-1-3	Eurocode 1- Actions on structures - Part 1-3: General actions, Snow loads	01.08.2005
BS EN 1991-1-3/NA	National Annex to Eurocode 1 – Actions on structures – 1-3: General actions, Snow loads	29.06.2007
BS EN 1991-1-4	Eurocode 1- Actions on structures - Part 1-4: General actions, Wind actions	15.05.2011
BS EN 1991-1-4/NA	National Annex to Eurocode 1- Actions on structures - Part 1-4:General actions, Wind actions	Nov 2008
Application:	Summary of wind test and simulation results	Jun 2009
	Zhongxinbo New Energy Technology (Suzhou) Co.,Ltd	17.04.2012
BS EN 1993-1-1	Eurocode 3: Design of steel structures - Part 1-1	01.10.2006
BS EN 1993-1-1/NA	National Annex to Eurocode 3: Design of steel structures - Part 1-1	01.12.2008
BS EN 1999-1-1	Eurocode 9 - Design of aluminium structures Part 1-1	01.08.2010
BS EN 1999-1-1/NA	National Annex to Eurocode 9 - Design of aluminium structures Part 1-1	01.05.2010

1.2Material Mechanical Properties

1.2.1 Aluminium Alloy

Aluminium structures: AL6005-T5

Gravity Density ρ=27.1 kN/m^3

Elastic Modulus E=6.9×10^4 N/mm^2

Linear expansion coefficient α=2.32×10^{-5}

Poisson's ratio ν=0.33

Tensile / compression / bending strength fs=208 N/mm^2

1.2.2 Steel

Carbon structural steel: Q355B（S350GD-ZM）

Gravity Density ρ=78.5 kN/m^3

Elastic Modulus E=2.06×10^5 N/mm^2

Linear expansion coefficient α=1.2×10^{-5}

Poisson's ratio ν=0.3

Tensile / compression / bending strength fs=350 N/mm^2

Carbon structural steel: Q235B

Gravity Density ρ=78.5 kN/m^3

Elastic Modulus E=2.06×10^5 N/mm^2

Linear expansion coefficient α=1.2×10^{-5}

Poisson's ratio ν=0.3

Tensile / compression / bending strength fs=235 N/mm^2

1.3Load

1.3.1Dead Load

Aluminium Alloy Density ρ= 27.1 KN/m^3

Gravity Density ρ=78.5 KN/m^3

Solar module Size: 2279mm×1134mm×35mm

Solar module area per pcs: A=2.279×1.134=2.58m^2

Solar module self-weight per pcs: Dk=29.2kg=0.286KN

1.3.2Wind Load

Project location : Siegener StraBe 120, 57080 Siegen - Gosenbach

Basic Wind Load:

Wind Load & Snow Load Calculation

Basic wind speed: 22.5m/s（50n）

1.6.1
fundamental basic wind velocity
the 10 minute mean wind velocity with an annual risk of being exceeded of 0, 02, irrespective of wind direction, at a height of 10 m above flat open country terrain and accounting for altitude effects (if required)

1.6.2
basic wind velocity
the fundamental basic wind velocity modified to account for the direction of the wind being considered and the season (if required)

4.2 Basic values

(1)P The fundamental value of the basic wind velocity, $v_{b,0}$, is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open country terrain with low vegetation such as grass and isolated obstacles with separations of at least 20 obstacle heights.

NOTE 1 This terrain corresponds to terrain category II in Table 4.1.

NOTE 2 The fundamental value of the basic wind velocity, $v_{b,0}$, may be given in the National Annex.

(2)P The basic wind velocity shall be calculated from Expression (4.1).

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0} \qquad (4.1)$$

where:

v_b is the basic wind velocity, defined as a function of wind direction and time of year at 10 m above ground of terrain category II

$v_{b,0}$ is the fundamental value of the basic wind velocity, see (1)P

c_{dir} is the directional factor, see Note 2.

c_{season} is the season factor, see Note 3.

NOTE 1 Where the influence of altitude on the basic wind velocity v_b is not included in the specified fundamental value $v_{b,0}$ the National Annex may give a procedure to take it into account.

NOTE 2 The value of the directional factor, c_{dir}, for various wind directions may be found in the National Annex. The recommended value is 1,0.

NOTE 3 The value of the season factor, c_{season}, may be given in the National Annex. The recommended value is 1,0.

NOTE 4 The 10 minutes mean wind velocity having the probability p for an annual exceedence is determined by multiplying the basic wind velocity v_b in 4.2 (2)P by the probability factor, c_{prob} given by Expression (4.2). See also EN 1991-1-6.

4.3 Mean wind

4.3.1 Variation with height

(1) The mean wind velocity $v_m(z)$ at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity, v_b, and should be determined using Expression (4.3)

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b \qquad (4.3)$$

where:

$c_r(z)$ is the roughness factor, given in 4.3.2

$c_o(z)$ is the orography factor, taken as 1,0 unless otherwise specified in 4.3.3

NOTE 1 Information on c_O may be given in the National Annex. If the orography is accounted for in the basic wind velocity, the recommended value is 1,0.

NOTE 2 Design charts or tables for $v_m(z)$ may be given in the National Annex.

The influence of neighbouring structures on the wind velocity should be considered (see 4.3.4).

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4.3.2 Terrain roughness

(1) The roughness factor, $c_r(z)$, accounts for the variability of the mean wind velocity at the site of the structure due to:

the height above ground level

the ground roughness of the terrain upwind of the structure in the wind direction considered

NOTE The procedure for determining $c_r(z)$ may be given in the National Annex. The recommended procedure for the determination of the roughness factor at height z is given by Expression (4.4) and is based on a logarithmic velocity profile.

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \leq z \leq z_{max}$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \leq z_{min} \qquad (4.4)$$

Ground roughness category : II

where:

z_0 is the roughness length

k_r terrain factor depending on the roughness length z_0 calculated using

$$k_r = 0,19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0,07} \qquad (4.5)$$

where:

$z_{0,II}$ = 0,05 m (terrain category II, Table 4.1)

z_{min} is the minimum height defined in Table 4.1

z_{max} is to be taken as 200 m

z_0, z_{min} depend on the terrain category. Recommended values are given in Table 4.1 depending on five representative terrain categories.

Expression (4.4) is valid when the upstream distance with uniform terrain roughness is long enough to stabilise the profile sufficiently, see (2).

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
NOTE: The terrain categories are illustrated in A.1.			

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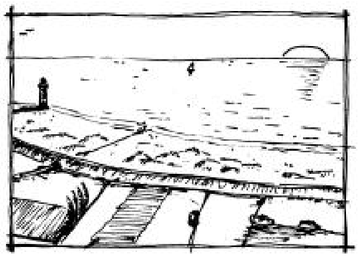
A.1 Illustrations of the upper roughness of each terrain category

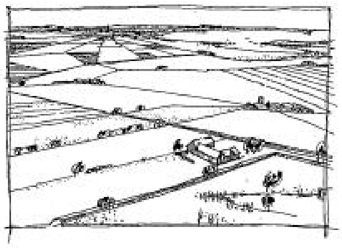
Terrain category 0

Sea, coastal area exposed to the open sea



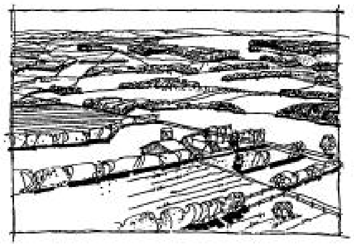
Terrain category I

Lakes or area with negligible vegetation and without obstacles



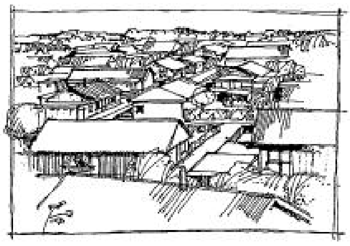
Terrain category II

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights



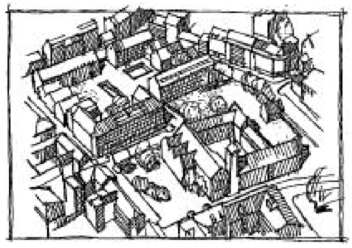
Terrain category III

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)



Terrain category IV

Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m



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Wind load calculate formula： Fw=CsCd×qp(z)×Aw

(2) The wind force F_w acting on a structure or a structural component may be determined directly by using Expression (5.3)

$$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref} \tag{5.3}$$

or by vectorial summation over the individual structural elements (as shown in 7.2.2) by using Expression (5.4)

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EN 1991-1-4:2005 (E)

$$F_w = c_s c_d \cdot \sum_{elements} c_f \cdot q_p(z_e) \cdot A_{ref} \tag{5.4}$$

where:

$c_s c_d$ is the structural factor as defined in Section 6

c_f is the force coefficient for the structure or structural element, given in Section 7 or Section 8

$q_p(z_e)$ is the peak velocity pressure (defined in 4.5) at reference height z_e (defined in Section 7 or Section 8)

A_{ref} is the reference area of the structure or structural element, given in Section 7 or Section 8

NOTE Section 7 gives c_f values for structures or structural elements such as prisms, cylinders, roofs, signboards, plates and lattice structures etc. These values include friction effects. Section 8 gives c_f values for bridges.

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qp(z)： wind pressure

4.5 Peak velocity pressure

(1) The peak velocity pressure $q_p(z)$ at height z, which includes mean and short-term velocity fluctuations, should be determined.

NOTE 1 The National Annex may give rules for the determination of $q_p(z)$. The recommended rule is given in Expression (4.8).

$$q_p(z) = \left[1 + 7 \cdot I_v(z)\right] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b \qquad (4.8)$$

where:

ρ is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms

$c_e(z)$ is the exposure factor given in Expression (4.9)

$$c_e(z) = \frac{q_p(z)}{q_b} \qquad (4.9)$$

q_b is the basic velocity pressure given in Expression (4.10)

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$$q_b = \tfrac{1}{2} \cdot \rho \cdot v_b^2 \qquad (4.10)$$

CsCd：the structure factor, taken as 1.0

National Annex.

6.2 Determination of $c_s c_d$

(1) $c_s c_d$ may be determined as follows:

a) For buildings with a height less than 15 m the value of $c_s c_d$ may be taken as 1.

b) For facade and roof elements having a natural frequency greater than 5 Hz, the value of $c_s c_d$ may be taken as 1.

c) For framed buildings which have structural walls and which are less than 100 m high and whose height is less than 4 times the in-wind depth, the value of $c_s c_d$ may be taken as 1.

d) For chimneys with circular cross-sections whose height is less than 60 m and 6,5 times the diameter, the value of $c_s c_d$ may be taken as 1.

e) Alternatively, for cases a), b), c) and d) above, values of $c_s c_d$ may be derived from 6.3.1.

f) For civil engineering works (other than bridges, which are considered in Section 8), and chimneys and buildings outside the limitations given in c) and d) above, $c_s c_d$ should be derived either from 6.3 or taken from Annex D.

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Aw： array pressure resistance acreage

Fw: the wind force

The wind pressure at project site：

qp(z)= [1+7×Iv(z)]×1/2×ρ×Vm(z)×Vm(z)

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z) \cdot \ln(z/z_0)} \quad \text{for} \quad z_{min} \le z \le z_{max} \qquad (4.7)$$

$$I_v(z) = I_v(z_{min}) \quad \text{for} \quad z < z_{min}$$

where:

k_I is the turbulence factor. The value of k_I may be given in the National Annex. The recommended value for k_I is 1,0.

c_o is the orography factor as described in 4.3.3

z_0 is the roughness length, given in Table 4.1

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
NOTE: The terrain categories are illustrated in A.1.			

$c_o(z)$ is the orography factor, taken as 1,0 unless otherwise specified in 4.3.3

NOTE 1 Information on c_o may be given in the National Annex. If the orography is accounted for in the basic wind velocity, the recommended value is 1,0.

NOTE 2 Design charts or tables for $v_m(z)$ may be given in the National Annex.

Iv(z)= Ki/(Coz×ln(H/Z0))=1/1×ln（3/0.01）=0.2442

ρ =1.25kg/m^3

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$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

where:

$c_r(z)$ is the roughness factor, given in 4.3.2

$c_o(z)$ is the orography factor, taken as 1,0 unless otherwise specified in 4.3.3

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \leq z \leq z_{max}$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \leq z_{min}$$

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07}$$

where:

$z_{0,II}$ = 0,05 m (terrain category II, Table 4.1)

z_{min} is the minimum height defined in Table 4.1

z_{max} is to be taken as 200 m

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
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IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
NOTE: The terrain categories are illustrated in A.1.			

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$Kr = 0.19 \times (Z_0/Z_{0,II})^{0.07} = 0.19$

$Cr(z) = Kr \times \ln(H/Z_0) = 0.78$

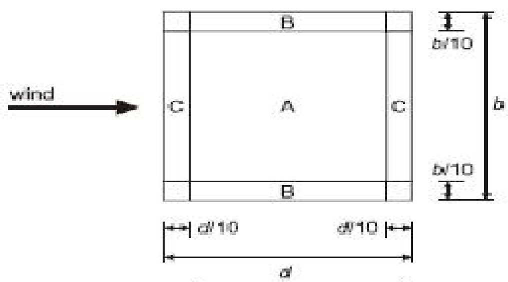
$Vm(z) = Crz \times Coz \times V = 0.78 \times 1 \times 22.5 = 17.5m/s$

$qP(z) = [1+7 \times Iv(z)] \times 1/2 \times \rho \times Vm(z) \times Vm(z)$

$= [1+0.2442 \times 7] \times 1/2 \times 1.25 \times 17.5 \times 17.5 = 0.518kN/m^2$

wind load of one module： $q_p = 0.518KN/m^2$

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

			Net Pressure coefficients $c_{p,net}$ Key plan 		
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 φ = 0	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum φ = 1	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum φ = 0	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum φ = 1	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum φ = 0	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum φ = 1	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum φ = 0	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum φ = 0	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum φ = 0	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum φ = 1	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum φ = 0	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum φ = 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				

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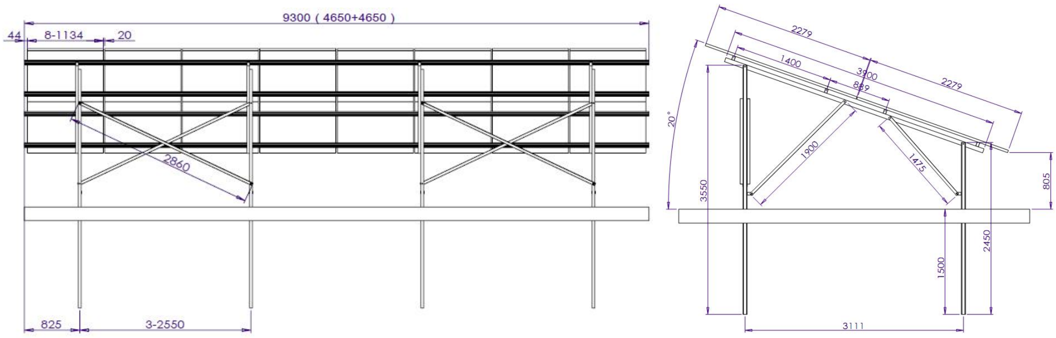


Angle	Blockage Φ	Overall Force Coefficients Cf
20°	maximum all Φ	0.8
	minimum Φ = 0	-1.3

W（90+）: 0.518 KN/m^2 ×0.8×1.140 = 0.472 N/mm

W（90-）: 0.518 KN/m^2 ×-1.3×1.140 = -0.768 N/mm

1.3.3Snow Load

<BS EN 1991-1-3-2003 General actions - Snow Loads>

Basic Snow Load：S_b=1.38KN/m^2

1.6.1
characteristic value of snow load on the ground
snow load on the ground based on an annual probability of exceedence of 0,02, excluding exceptional snow loads.

(3)P Snow loads on roofs shall be determined as follows:

a) for the persistent / transient design situations

$$s = \mu_i \; C_e \; C_t \; s_k \qquad (5.1)$$

μ_i is the snow load shape coefficient (see Section 5.3 and Annex B)

s_k is the characteristic value of snow load on the ground

C_e is the exposure coefficient

C_t 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.

NOTE: The National Annex may give the values of C_e for different topographies. The recommended values are given in Table 5.1 below.

EN 1991-1-3:2003 (E)

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^{2}K), in particular for some glass covered roofs, because of melting caused by heat loss.

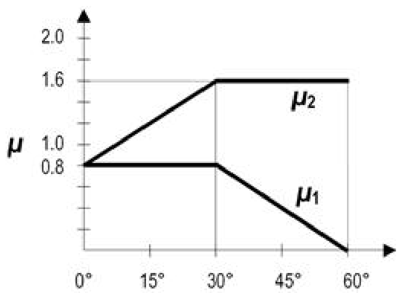
For all other cases:

$$C_t = 1,0$$

NOTE 1: Based on the thermal insulating properties of the material and the shape of the construction work, the use of a reduced C_t value may be permitted through the National Annex.

NOTE 2: Further guidance may be obtained from ISO 4355.

(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.



Snow Load Coefficient： μ_1=0.8

Snow Load：S= 1.38×1.0×1.0×cos20° ×0.8×1.140 = 1.18 N/mm

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1.3.4Standard Load

G=0.286/1134 = 0.252 N/mm

1.3.5Load Combinations

<BS EN 1990-2002 Basis of structural design>

6.4.3.2 Combinations of actions for persistent or transient design situations (fundamental combinations)

(1) The general format of effects of actions should be :

$$E_d = \gamma_{Sd} E\{\gamma_{g,j} G_{k,j} ; \gamma_p P ; \gamma_{q,1} Q_{k,1} ; \gamma_{q,i} \psi_{0,i} Q_{k,i}\} \quad j \geq 1 ; i > 1 \qquad (6.9a)$$

(2) The combination of effects of actions to be considered should be based on

– the design value of the leading variable action, and
– the design combination values of accompanying variable actions :

NOTE See also 6.4.3.2(4).

$$E_d = E\{\gamma_{G,j} G_{k,j} ; \gamma_P P ; \gamma_{Q,1} Q_{k,1} ; \gamma_{Q,i} \psi_{0,i} Q_{k,i}\} \quad j \geq 1 ; i > 1 \qquad (6.9b)$$

(3) The combination of actions in brackets { }, in (6.9b) may either be expressed as :

$$\sum_{j\geq1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \qquad (6.10)$$

or, alternatively for STR and GEO limit states, the less favourable of the two following expressions:

$$\begin{cases} \sum_{j\geq1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} \psi_{0,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} & (6.10a) \\ \sum_{j\geq1} \xi_j \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} & (6.10b) \end{cases}$$

Where :

"+ "	implies "to be combined with"
Σ	implies "the combined effect of"
ξ	is a reduction factor for unfavourable permanent actions G

NOTE Further information for this choice is given in Annex A.

(4) If the relationship between actions and their effects is not linear, expressions (6.9a) or (6.9b) should be applied directly, depending upon the relative increase of the effects of actions compared to the increase in the magnitude of actions (see also 6.3.2.(4)).

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Table A1.2(A) - Design values of actions (EQU) (Set A)

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The γ values may be set by the National annex. The recommended set of values for γ are :

$\gamma_{Gj,sup} = 1{,}10$

$\gamma_{Gj,inf} = 0{,}90$

$\gamma_{Q,1} = 1{,}50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1{,}50$ where unfavourable (0 where favourable)

NOTE 2 In cases where the verification of static equilibrium also involves the resistance of structural members, as an alternative to two separate verifications based on Tables A1.2(A) and A1.2(B), a combined verification, based on Table A1.2(A), may be adopted, if allowed by the National annex, with the following set of recommended values. The recommended values may be altered by the National annex.

$\gamma_{Gj,sup} = 1{,}35$

$\gamma_{Gj,inf} = 1{,}15$

$\gamma_{Q,1} = 1{,}50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1{,}50$ where unfavourable (0 where favourable)

provided that applying $\gamma_{Gj,inf} = 1{,}00$ both to the favourable part and to the unfavourable part of permanent actions does not give a more unfavourable effect.

Table A1.2(B) - Design values of actions (STR/GEO) (Set B)

Persistent and transient design situations	Permanent actions		Leading variable action	Accompanying variable actions (*)	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions (*)	
	Unfavourable	Favourable	Action	Main	Others
(Eq. 6.10a)	$\gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$		$\gamma_{Q,1} \psi_{0,1} Q_{k,1}$	$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$
(Eq. 6.10b)	$\xi \gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The choice between 6.10, or 6.10a and 6.10b will be in the National annex. In case of 6.10a and 6.10b, the National annex may in addition modify 6.10a to include permanent actions only.

NOTE 2 The γ and ξ values may be set by the National annex. The following values for γ and ξ are recommended when using expressions 6.10, or 6.10a and 6.10b.

$\gamma_{Gj,sup} = 1{,}35$

$\gamma_{Gj,inf} = 1{,}00$

$\gamma_{Q,1} = 1{,}50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1{,}50$ where unfavourable (0 where favourable)

$\xi = 0{,}85$ (so that $\xi \gamma_{Gj,sup} = 0{,}85 \times 1{,}35 \cong 1{,}15$).

See also EN 1991 to EN 1999 for γ values to be used for imposed deformations.

NOTE 3 The characteristic values of all permanent actions from one source are multiplied by $\gamma_{G,sup}$ if the total resulting action effect is unfavourable and $\gamma_{G,inf}$ if the total resulting action effect is favourable. For example, all actions originating from the self weight of the structure may be considered as coming from one source ; this also applies if different materials are involved.

NOTE 4 For particular verifications, the values for γ_G and γ_Q may be subdivided into γ_g and γ_q and the model uncertainty factor γ_{Sd}. A value of γ_{Sd} in the range 1,05 to 1,15 can be used in most common cases and can be modified in the National annex.

EN 1990:2002 (E)

Table A1.1 - Recommended values of ψ factors for buildings

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0
NOTE The ψ values may be set by the National annex. * For countries not mentioned below, see relevant local conditions.			

Case1: 1.35G+1.5S

Case2: 0.9G+1.5W

Case3: 0.9G+1.5W-

Case4: 1.35G+1.5W+1.5×0.5S

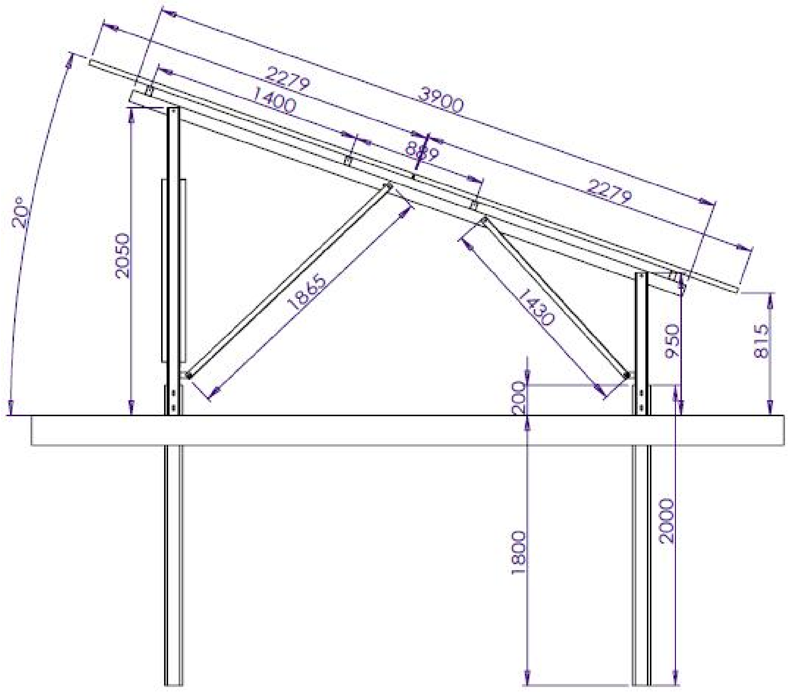
Case5: 1.35G+1.5W-+1.5×0.5S

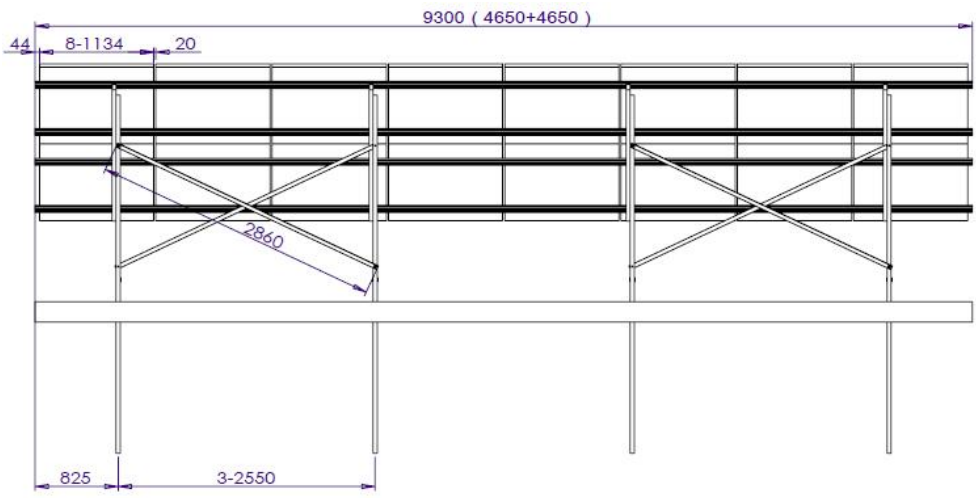
Case6: 1.35G+1.5S+1.5×0.6W

Case7: 1.35G+1.5S+1.5×0.6W-

Load combination distribution on purlins

1.4Deformation Control





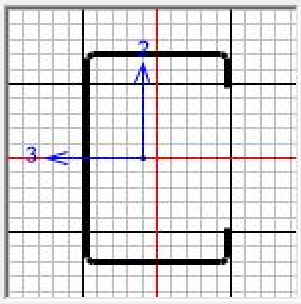
2.Aluminum Alloy /Steel calculation

2.1Material selection

Column：	C steel	C80×40×10×1.8	S350GD-ZM
Beam：	C steel	C80×40×10×1.8	S350GD-ZM
Rail：	U steel	U41×62×1.8	S350GD-ZM
Diagonal brace：	L steel	L40×40×3	S350GD-ZM

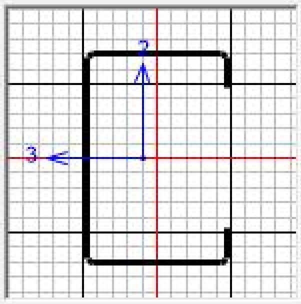
Column： C steel C80×40×10×1.8 S350GD-ZM

Outside Height (A)	60.
Outside Width (B)	40.
Thickness (t)	3.
Radius (R)	1.2
Lip Depth (d)	10.



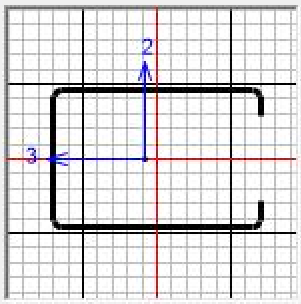
Beam： C steel C80×40×10×1.8 S350GD-ZM

Outside Height (A)	60.
Outside Width (B)	40.
Thickness (t)	1.8
Radius (R)	1.2
Lip Depth (d)	10.

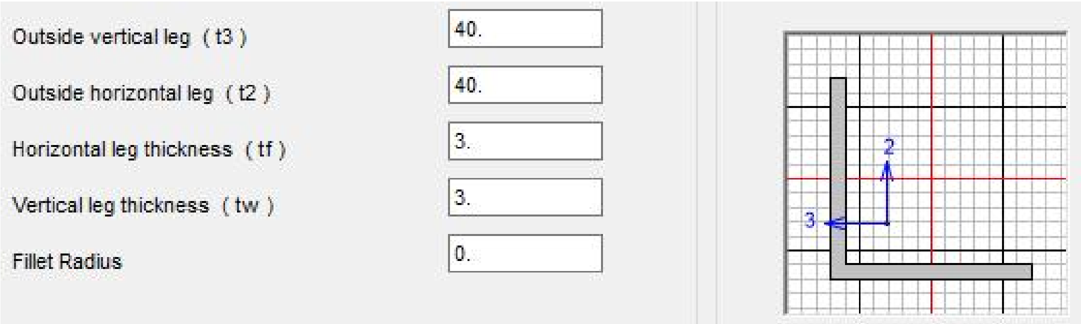


Rail： U steel U41×62×1.8 S350GD-ZM

Outside Height (A)	41.
Outside Width (B)	62.
Thickness (t)	1.8
Radius (R)	2.
Lip Depth (d)	8.

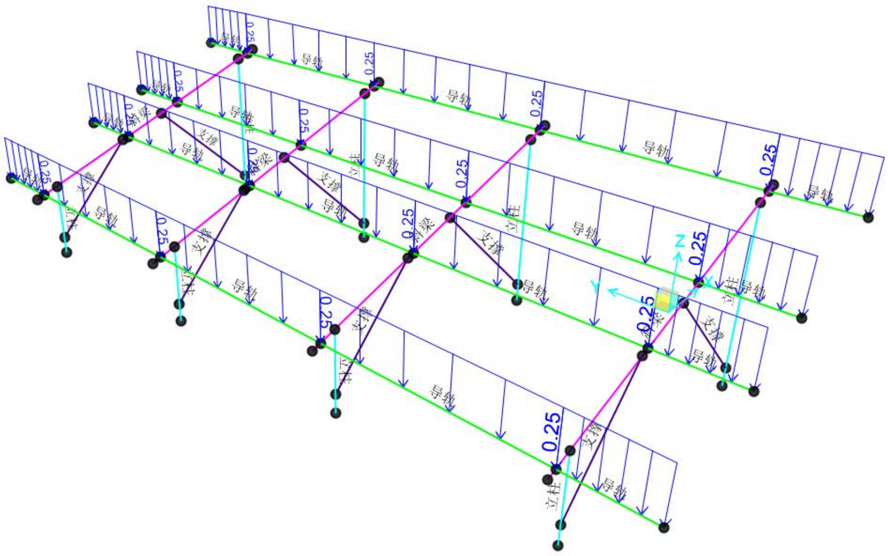


Diagonal brace： L steel L40×40×3 S350GD-ZM

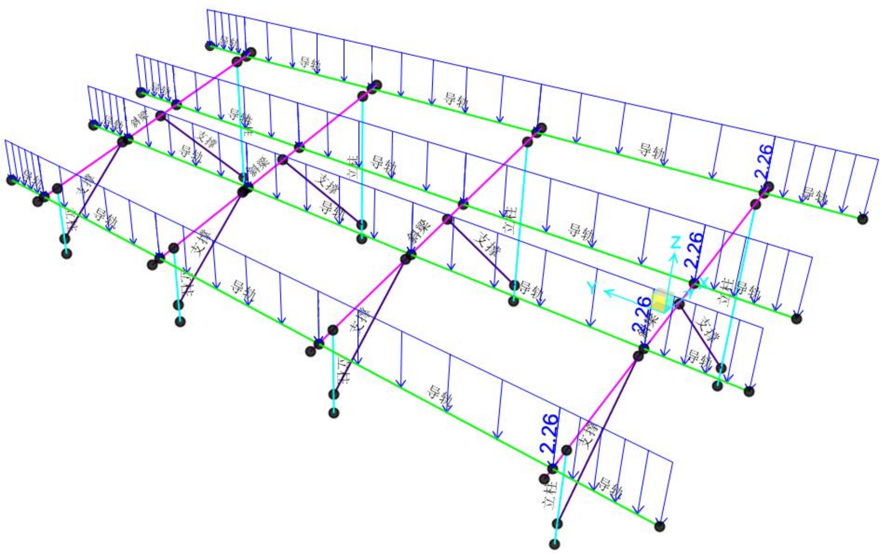


2.2Strength Calculation

Dead Load : G

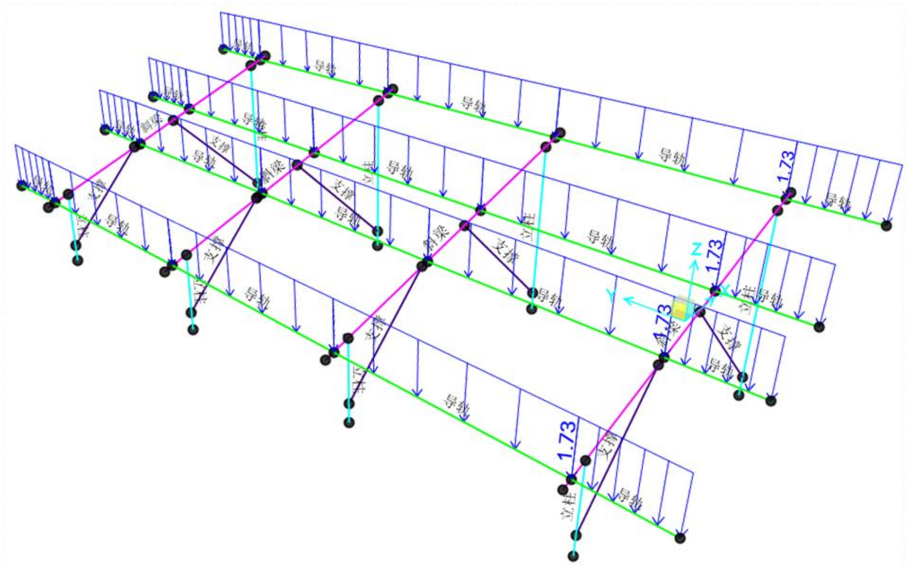


Snow Load : S

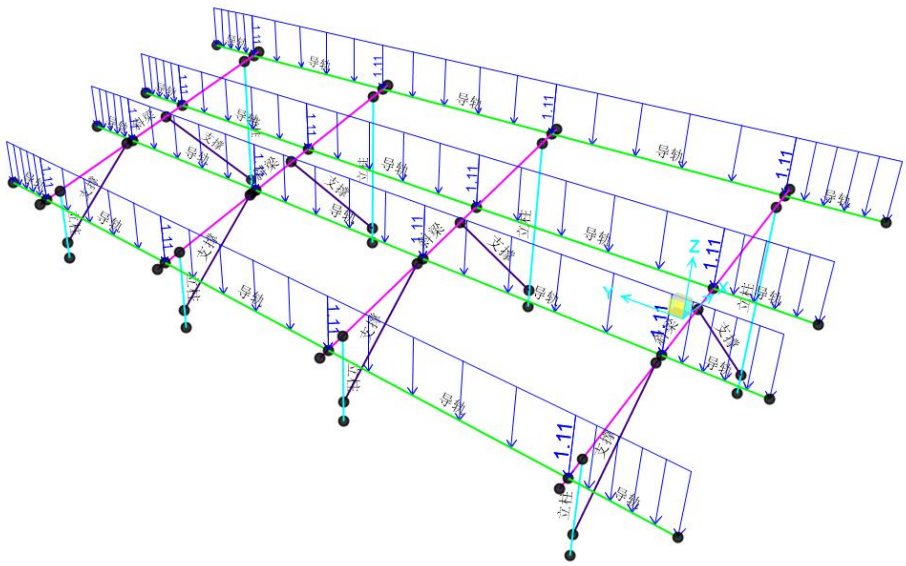


wind Load：

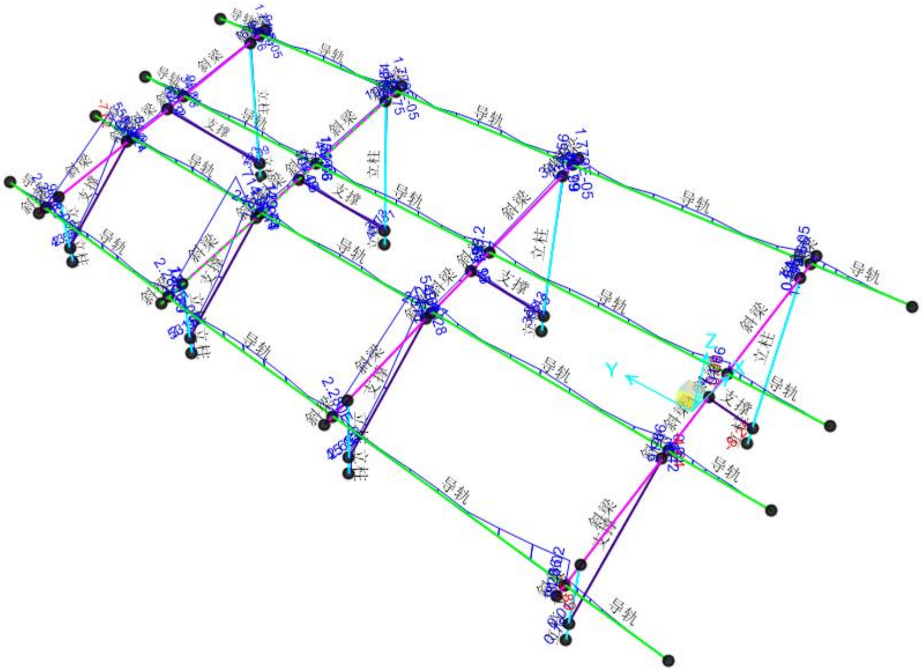
W+



W-



2.3 Parts Analysis



Rail:

	Axial force	Shear force	Bending moment	Axial force	Shear force	Bending moment
1	0.000	0.000	0.000	0.000	-1.650	-0.681
2	0.000	2.360	-0.681	0.000	-2.740	-1.164
3	0.000	2.550	-1.164	0.000	-2.550	-1.164
4	0.000	2.740	-1.164	0.000	-2.360	-0.681
5	0.000	1.650	-0.681	0.000	0.000	0.000

Beam:

	Axial force	Shear force	Bending moment	Axial force	Shear force	Bending moment
1	0.000	0.000	0.000	0.000	0.000	0.000
2	-0.044	-5.700	0.000	-0.044	-5.700	-1.107
3	-0.686	1.738	-1.107	-0.686	1.738	0.784
4	-1.621	2.227	0.784	-1.621	2.227	1.046
5	-1.679	-3.476	1.046	-1.679	-3.479	-0.977
6	2.482	4.458	-0.977	1.679	4.458	0.383
7	2.418	-1.236	0.383	2.418	-1.236	-1.107
8	0.044	5.700	-1.107	0.044	5.700	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000

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Column:

	Axial force	Shear force	Bending moment	Axial force	Shear force	Bending moment
1	-7.233	1.882	0.000	-7.223	1.822	1.374
2	-7.995	1.158	1.374	-7.995	1.158	1.629
3	-7.327	0.081	0.000	-7.327	0.081	0.149
4	-13.43	6.64	0.149	-13.43	6.64	1.61

Diagonal brace:

	Axial force	Shear force	Bending moment	Axial force	Shear force	Bending moment
1	-1.058	0.000	0.000	-1.058	0.000	0.000
2	-8.959	0.000	0.000	-8.959	0.000	0.000

2.3.1 Rail Load Analysis：

Purlin Calculation：

σ=1164/5.502=212

Maximum stress ratio: 212/350=0.61

2.3.2Beam Load Analysis:

Beam

Calculation：σ=1107/8.039=138

Maximum stress ratio: 138/350=0.39

2.3.3 Column Load Analysis：

Post Calculation：

σ=1629/8.039=203

Maximum stress ratio: 203/350=0.58

2.3.4 Diagonal brace Load Analysis:

Bracing Calculation:

σ=13430/231=58.14

Maximum stress ratio: 58.14/355=0.16

3 Conclusion

Stress showed on SAP 2000 are all less than 1.0, which means stress is OK for structure.

3 Pile calculation:

W（90-）:　　0.518 KN/m^2 ×-1.3×2.279×1.134 = -1740 N

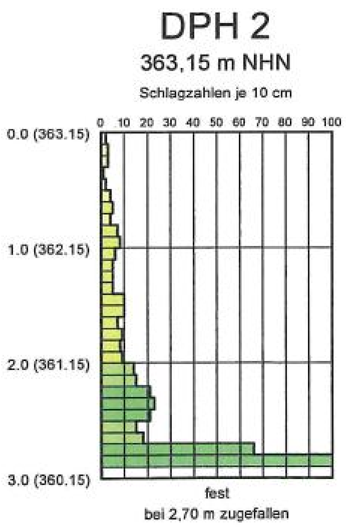
S:　　1.38×1.0×1.0×cos20° ×0.8×2.279×1.134 = 2681 N

F$^+$:　　1.35G+1.5S+1.5×0.6W=5025 N

F$^-$:　　0.9G+1.5×W$^-$=0.9×286+(-1740×1.5)=-2352 N

F Uplift:　　2×8×-2352/11×3/2=-5131 N

F Compression:　2×8×5025/11×3/2=10.96 N



Tiefe [m]	N_{10}	Tiefe [m]	N_{10}
0.10	2	1.60	10
0.20	3	1.70	7
0.30	3	1.80	9
0.40	1	1.90	8
0.50	2	2.00	9
0.60	4	2.10	14
0.70	5	2.20	15
0.80	4	2.30	21
0.90	7	2.40	23
1.00	8	2.50	21
1.10	6	2.60	15
1.20	5	2.70	18
1.30	5	2.80	66
1.40	5	2.90	100
1.50	10		

1.Pile self-weight w=	0.114	kN
2.Exposed height of pile h=	0.2	m
3.Pile driving depth L=	1.8	m
4.Wall thickness t=	3.00	mm
5.Pile area A=	0.00074	m^2
6.Pile perimeter φ=	0.26	m

Average N value： （2+3+3+1+2+4+5+4+7+8+6+5+5+5+10+10+7+9+8+9)/20=5.65

Circumferential friction force Rf = 1/2×qu×Lc× ϕ =0.5×12.25×5.65×1.8×0.26=16.2 kN

Frontend support qp = 150/3×N=150/3×5.65=282

Frontend supporting force Rp =Ap×qp=0.209 kN

Short term compressive force=2×Rp+2/3×Rf-w=11.104 kN ＞10.96 kN

Short term uplift force=8/15×Rf+w=8.76 kN ＞ 5.131 kN

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