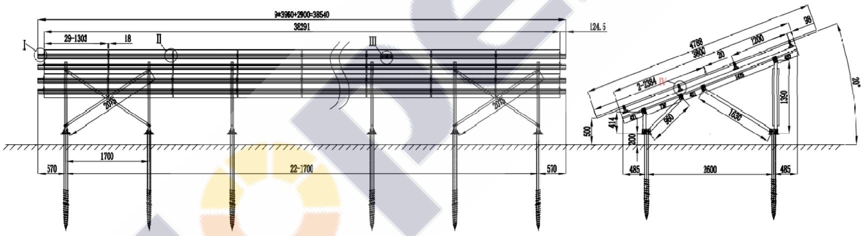
Design code: BS EN 1990&1991
Design guide on structures for Photovoltaic array



Project name: HP2301092

Designer: HOPERGY

Date 2023.11.7

Directory

1.Summary of Structural Design Criteria

1.1 Standards

1) EN 1990-2002 Eurocode -Basis of structural design

2) EN 1991-1-3-2003 Eurocode 1:Actions on structures - Part 1-3：General actions - Snow loa

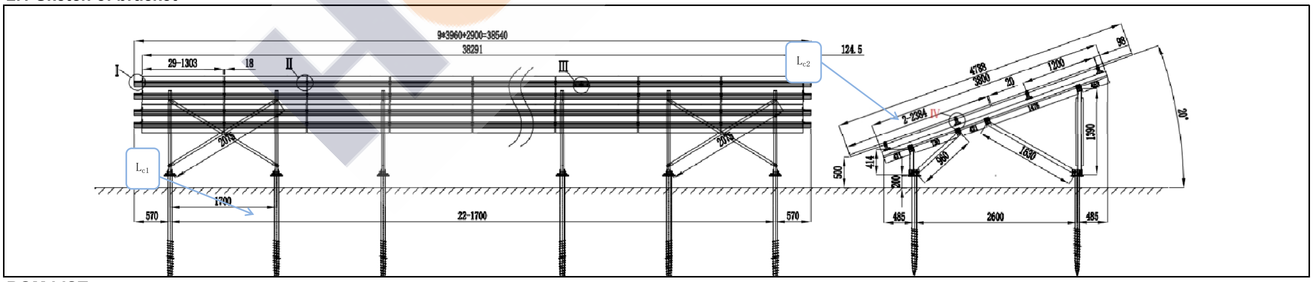
3) EN 1991-1-4-2005 Eurocode 1:Actions on structures - Part 1-4 General actions- Wind actior

1.2 Design condition and technical parameters

Module Specification（mm):			
System Type:	Ground		
Location:	Norway		
Length：	2384mm		
Width：	1303mm		
Heigth：	35mm		
Module Weight(kg):	40kg		
Layout:	2	×	29
Module area As：	180.17㎡		
Installation angle:	20.0°		
Panel ground clearance	500mm		
Buliding High(m):	0m		
Parapet height（m):	0.00m		
Exposure category:	II		
Wind speed in design(10min)	22.00m/s		
Tickness of snow accumulation on the ground S_k:			4.00KN/m²
Water speed:	2m/s	(Data source: 52205790 Enge - Flomvurdering 200-årsflom/ 52205790 Enge - Tilleggsvurderinger 200-årsflom J02)	
Span（mm):	1700mm		
total length of rail（mm)L_{c2}:	38540mm		
Number of rails used for calculation N:		4	

2.Load calculation

2.1 Sketch of bracket



BOM LIST:

NO.	Part Name	Size (mm)	Material	Quantity	Weight per	Single weight	Total weight
1	Module			58	/	40	2320
2	GDR Rail	L3960	AL6005-T5	36	1.147	4.54	163.52
3	GDR Rail	L2900	AL6005-T5	4	1.147	3.33	13.31
4	Inner Clamp Kit 35mm	L40	AL6005-T5	112	/	0.06	7.06
5	End Clamp Kit 35mm	L40	AL6005-T5	8	/	0.05	0.43
6	Select Rail Clamp	L38	AL6005-T5	184	/	0.05	9.75
7	Self-tapping screw	/	SUS304	0	/	0.01	0.00
7	Rail Connector	L300	AL6005-T5	36	/	0.89	31.90
8	Support-20°-Beam	L3800	AL6005-T5	23	1.771	6.73	154.80
9	Support-20°-Connector	L140	AL6005-T5	92	3.316	0.46	42.71
10	Support-20°Front Leg	L414	AL6005-T5	23	0.735	0.30	7.00
11	Support-20°Rear Leg	L1390	AL6005-T5	23	0.735	1.02	23.51
12	Support-20°-Bracing 1	L960	AL6005-T5	23	0.735	0.71	16.24
13	Support-20°-Bracing 2	L1630	AL6005-T5	23	0.735	1.20	27.57
15	Support-20°-Front base	L75	AL6005-T5	0	/	3.47	0.00
14	Support-20°-Rear base	L150	AL6005-T5	46	/	0.00	0.00
15	Support-20°-Back rod	L2075	AL6005-T5	4	0.491	1.02	4.07
16	Bolt Set	M8*20	SUS304	368	/	0.020	7.36
17	Bolt Set	M12*80	SUS304	92	/	0.130	11.96
18	Bolt Set	M12*90	SUS304	92	/	0.141	12.97
						Total	2854.15

2.2 Dead load

Dead-weight of Module G22.74KN

Dead-weight of Rail G 1.73KN

L_{c2}=	2384mm	=2.384m
N_b=	4	
L_{c1}=	1700mm	=1.700m
Fixed load of Rail Wi=:	24950.38N	
Mounting load G^{*}=:	27970.72N	

2.3 Snow load

（1） Calculate the snow area: Figure 1-1

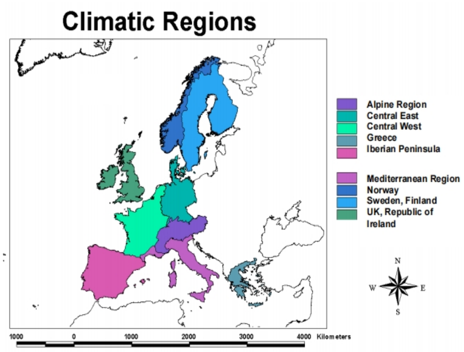


Figure 1-1 snow load area

The standard value Sk of the ground snow load in different areas is calculated according to the following formula:

Climatic Region	*Expression*
Alpine Region	$s_k=(0{,}642Z+0{,}009)\left[1+\left(\frac{A}{728}\right)^2\right]$
Central East	$s_k=(0{,}264Z-0{,}002)\left[1+\left(\frac{A}{256}\right)^2\right]$
Greece	$s_k=(0{,}420Z-0{,}030)\left[1+\left(\frac{A}{917}\right)^2\right]$
Iberian Peninsula	$s_k=(0{,}190Z-0{,}095)\left[1+\left(\frac{A}{524}\right)^2\right]$
Mediterranean Region	$s_k=(0{,}498Z-0{,}209)\left[1+\left(\frac{A}{452}\right)^2\right]$
Central West	$s_k=0{,}164Z-0{,}082+\frac{A}{966}$
Sweden, Finland	$s_k=0{,}790Z+0{,}375+\frac{A}{336}$
UK, Republic of Ireland	$s_k=0{,}140Z-0{,}1+\frac{A}{501}$

where: S_k is the characteristic snow load on the ground, kN/m2

A is the site altitude above Sea Level [m]

Z is the zone number given on the map.

（2）The exposure coefficient Ce should be used for determining the snow loadon the roof. The choice for Ce should consider the future development around the site. Ce should be taken as 1,0 unless otherwise specified for different to pographies.

Recommended values of Ce for different topographies

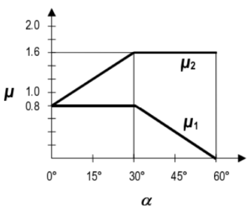
Topography	Ce
Windswept a	0.8
Normal b	1
Sheltered c	1.2

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.

(3) The snow load shape coefficient μ_1 that should be used for monopitch roofs isgiven in Table and shown in Figure .



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	--

(4)Snow load calculation

Tilt angle of support	α(°）	20.0°	
Snow load shape coefficient	No obstaclesμ1	0.80	Table 5.2, Figure 5.1 EN 1991-1-3:2003(E)
Snow load on the ground	$S_k(KN/m^2)$	4	EN 1991-1-3:2003 (E) Table C.1
Exposure coefficient	Ce(Windswept a)	0.8	Table 5.1EN 1991-1-3:2003(E)
Thermal coefficient	C_t	1	Expression 5.2-(8) EN 1991-1-3:2005
Snow load on roof (N/m2)	**$S'=\mu_i*C_e*C_t*S_k$**	2560	Expression 5.1 EN 1991-1-3:2005

Snow load on roof S= $S'*A_s$

= 398742.26N

2.4 Wind load

Calculate peak velocity pressure qp（z）

$(z) = [1 + 7 * lv(z)] * \frac{1}{2} * \rho * v^2{}_m(z)$ Based on formula（4.8) EN 1991-1-4:2005

In formula：

①.lv(z)：Turbulence intensity at height z

When $Z_{min} \leq Z \leq Z_{max}$ $(z) = \frac{k_1}{{}_0(z) * \ln(\frac{Z}{Z_0})}$

Based on formula(4.7) EN 1991-1-4:2005

When $Z \leq Z_{min}$ $l\ (z) = lv(zmin)$

z_0	Rough length
k_1	Turbulence coefficient
c_0	Mountain coefficient

②ρ:Air density

③.Vm(z):Average wind speed at height z above ground

$v_m(z)=c_r(z)\cdot c_o(z)\cdot v_b$ Based on 4.3, EN 1991-1-4:2005

$c_r(z)$	Roughness factor
c_0	Mountain coefficient

When $Z_{min} \leq Z \leq Z_{max}$ $c_r(z)=k_r\cdot\ln\left(\frac{z}{z_0}\right)$

根据EN 1991-1-4:2005公式（4.4）

When $Z \leq Z_{min}$ $c_r(z)=c_r(z_{min})$

z_0	Rough length
k_r	Terrain coefficient

$k_r=0.19\cdot\left(\frac{z_0}{z_{0,II}}\right)^{0.07}$ Based on formula 4.5 in EN 1991-1-4:2005

EN 1991-1-4:2005 Table 4.1 Terrain categories and terrain parameters

Terrain level	z_0 (m)	z_{min} (m)	Terrain category
0	0.003	1.00	Sea areas or coastal areas close to the open sea
I	0.01	1.00	Lakes with very small vegetation and no obstacles Or flat area
II	0.05	2.00	Areas with low vegetation (such as grass) and separate obstacles separated by at least 20 obstacle heights
III	0.3	5.00	Areas where vegetation or buildings are evenly covered, or there are separate obstacles separated by up to 20 obstacle heights (such as villages, suburban terrain, and permanent forests)
IV	1.00	10	At least 15% of the surface is covered with buildings and the average height of the buildings exceeds 15m

Determine the value of each parameter：

z_0 (m)	0.05
Turbulence coefficient k_1	1
Mountain coefficient c_0（z）	1
z_0, II (m)	0.05
z_{min} (m)	2
z_{max}(m)	200
z(m)	0.5
Air densityρ(kg/m^3)	1.25
Basic wind speed v_b(m/s)	22

In summary：

$L_v(z)$ =0.271

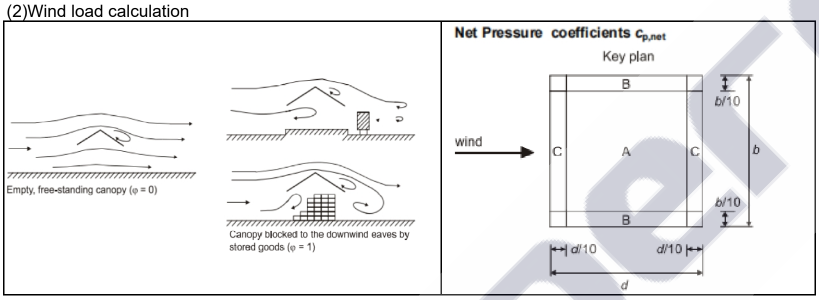
K_r =0.190

$C_r(z)$ =0.701

$V_m(z)$ =15.420m/s

$q_p(z)$ =430.585N/m2

(2)Wind load calculation



Zones for mono-pitch roof (Figure 7.7, EN 1991-1-4:2005)

Tilt angle	α(°）	20.0		Note
Building height	z(m)	0.0		
Wind area of the mudule	A(m^2)	3.1		
Peak velocity pressure at height z	q_p(z)(N/m^2)	430.6		
Wind direction	θ(°)	W+（θ=0°）	W-（θ=180°）	
External pressure coefficient that a building part with a bearing area of	C_f	0.80	-1.30	Zone A, Table 7.3a/7.2 EN 1991-1-4:2005
Unit wind pressure load（N/m^2)	$= qp(z) \times Cf$	344.47	559.76	Expression 5.1 EN 1991-1-4:2005

Unit wind pressure load W+= We*As

= 62062.30N

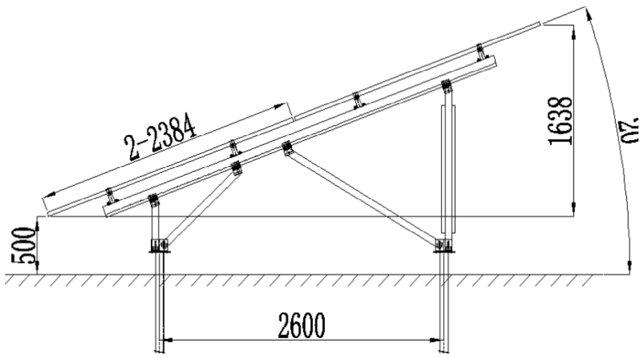
Unit wind pressure load W-= We*As

= 100851.24N

2.5. Hydraulic effect

The total horizontal force of water flow on a vertical surface Fwa(N)：

$$F_{wa}=\frac{1}{2}k\rho_{wa}hbv_{wa}^{2}$$ (BS EN 1991-1-7：2006-4.1)



In the formula:

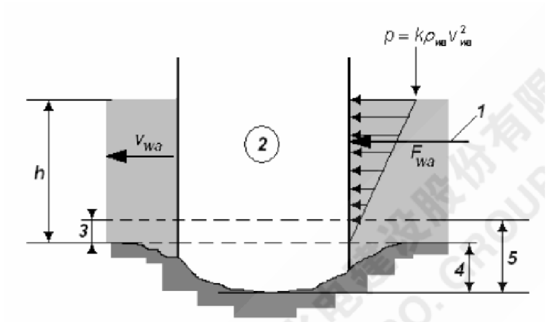
ρ_{wa}： 1 .1t/m³

h1： 1638mm

b1： 38540mm

v_{wa}： 2m/s

k： Rectangular section，k=1.44;Circular object，k=0.7.



F_{wa}= 199991.15N

Q_{wa}= 2173.82N

2.6 Load combination

Ultimate limit states	COMB1	G	ableA1.1 Table A1.2 (B) Table A1.4 EN 1990-2002
	COMB2	1.35G	
	COMB3	1.35G+1.5S	
	COMB4	1.35G+1.5W+1.5*0.7S	
	COMB5	1.35G+1.5S+1.5*0.6W	
	COMBa	1.35G+1.5Qwa+1.5*0.6W	
	COMB6	G+1.5W	
Serviceability limit states	COMB7	G+W+0.7S	

3. Strength Calculation

3.1 Material properties and allowable stress

Elasticity modulus E= 70000N/mm²

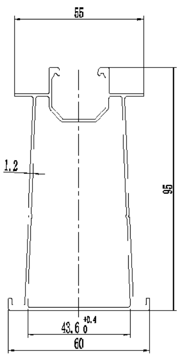
Tensile strength f= 245N/m²

Yield Strength= 205N/m²

Shearing strength fv= 118.36N/m²

3.2 Rail

Sectional parameter table of Rail: GDR

	Sectional area	A=424mm²	
	thickness	t=1.2mm	
	Moment of area	Sz=6705mm3	Sy=3746mm3
	Moment of inertia of section	Iz=504171mm4	Iy=150439mm4
	Section factor	Wz=10189mm3	Wy=5013mm3

3.3Rail strength check

Table.1--1

Load combination	Unit	Ultimate limit states	Ultimate limit states	Load combination in Serviceability limit states(θ=0°)	Load combination in Serviceability limit states(θ=180°)
		Gravity G	1.35G+1.5S	G+W+0.7S	G-W+0.7S
Axial force	N	0	0	0	0
Major axis uniform load a		W_d*COSβ	1.35W_d*COSβ+1.5S*COSβ	W_d*COSβ+W+0.7S*COSβ	W_d*COSβ-W+0.7S*COSβ
	N	23445.69	593694.43	347794.61	184881.07
Major axis load $Q_z=a/N/L_{c2}$	N/mm	0.15	3.85	2.26	1.20
Major axis bending moment $M_z=Q_z*L_{a1}^2/10$	N*mm	43953.07	1112984.49	652002.08	346592.04
Minor axis uniform load a'		W_d*Sinβ	1.35W_d*Sinβ+1.5S*Sinβ	W_d*Sinβ+0.7S*Sinβ	W_d*Sinβ+0.7S*Sinβ
	N	8533.53	216087.10	103998.05	103998.05
Minor axis load $Q_y=a'/N/L_{c2}$	N/mm	0.06	1.40	0.67	0.67
Minor axis bending moment $M_y=Q_y*L_{a1}^2/10$	N*mm	15997.61	405093.23	194962.62	194962.62
Axial stressσ_p=F/A	MPa	0.00	0.00	0.00	0.00
Major axial stress$\sigma_z=M_z/W$	MPa	4.31	109.24	63.99	34.02
Minor axial stress$\sigma_y=M_y/W$	MPa	3.19	80.81	38.89	38.89
Resultant stress $\sigma=\sigma_z+\sigma_y$	MPa	7.51	190.05	102.89	72.91
Rated strength value	MPa	205.00	205.00	205.00	205.00
Axial stress + bending stress ratio		0.04	0.93	0.50	0.36
Strength judgment（<1）		**OK**	**OK**	**OK**	**OK**
Major axial deflection δ_z $=0.521*Q_z*L_{a1}^4$ /	mm	0.19	4.75	2.78	1.48
Minor axial deflectionδ_y $=0.521*Q_y*L_{a1}^4$ /	mm	0.23	5.79	2.79	2.79
Joint deflectionδ_y	mm	0.30	7.49	3.94	3.16
Judgment(L/200)	mm	0.00017	0.00441	0.00232	0.00186
Deflection ratio		0.00500	0.00500	0.00500	0.00500
		0.03	**0.88**	**0.46**	**0.37**
Deflection judgment（<1）		**OK**	**OK**	**OK**	**OK**

Table.1--2

Load combination	Unit	Ultimate limit states(θ=0°）	Ultimate limit states(θ=180°）	Ultimate limit states(θ=0°）	Ultimate limit states(θ=180°）
		1.35G+1.5S+1.5*0.6W	1.35G+1.5S-1.5*0.6W	1.35G+1.5W+1.5*0.7S	1.35G-1.5W+1.5*0.7S
Axial force	N	0	0	0	0
Major axis uniform load a		1.35*W_d*COSβ +1.5*0.6W+1.5*S*COSβ	1.35*W_d*COSβ -1.5*0.6W+1.5*S*COSβ	1.35*W_d*COSβ +1.5*W+1.5*0.7*S*COSβ	1.35*W_d*COSβ -1.5*W+1.5*0.7*S*COSβ
	N	649550.50	502928.31	518175.05	273804.75
Major axis load Q_z=a/N/L_{c2}	N/mm	4.21	3.26	3.36	1.78
Major axis bending moment M_z=Q_z*L_{a1}^2/10	N*mm	1217696.51	942827.47	971410.16	513295.09
Minor axis uniform load a'		1.35*W_d*Sinβ +1.5*S*Sinβ	1.35*W_d*Sinβ +1.5*S*Sinβ	1.35*W_d*Sinβ +1.5*0.7*S*Sinβ	1.35*W_d*Sinβ +1.5*0.7*S*Sinβ
	N	216087.10	216087.10	154717.05	154717.05
Minor axis load Q_y=a'/N/L_{c2}	N/mm	1.40	1.40	1.00	1.00
Minor axis bending moment M_y=Q_y*L_{a1}^2/10	N*mm	405093.23	405093.23	290044.29	290044.29
Axial stressσ_p=F/A	MPa	0.00	0.00	0.00	0.00
Major axial stressσ_z=M_z/W	MPa	119.52	92.54	95.34	50.38
Minor axial stressσ_y=M_y/W	MPa	80.81	80.81	57.86	57.86
Resultant stress σ=σ_z+σ_y	MPa	200.33	173.35	153.21	108.24
Rated strength value	MPa	205.00	205.00	205.00	205.00
Axial stress + bending stress ratio		0.98	0.85	0.75	0.53
Strength judgment（<1）		**OK**	**OK**	**OK**	**OK**
Major axial deflection δ_z =0.521*Q_z*L_{a1}^4 /	mm	5.20	4.02	4.14	2.19
Minor axial deflectionδ_y =0.521*Q_y*L_{a1}^4 /	mm	5.79	5.79	4.15	4.15
Joint deflectionδ_y	mm	7.78	7.05	5.86	4.69
Judgment(L/200)	mm	0.00458	0.00415	0.00345	0.00276
Deflection ratio		0.00500	0.00500	0.00500	0.00500
		0.92	**0.83**	**0.69**	**0.55**
Deflection judgment（<1）		**OK**	**OK**	**OK**	**OK**

Table.1--3

Load combination	Unit	Ultimate limit states	Ultimate limit states(θ=0°）	Ultimate limit states(θ=180°）
		1.35G	G+1.5W	G-1.5W
Axial force	N	0	0	0
Major axis uniform load a		1.35*W_d*COSβ	W_d*COSβ+1.5W	W_d*COSβ-1.5W
	N	31651.68	124745.13	119625.17
Major axis load Q_z=a/N/L_{c2}	N/mm	0.21	0.81	0.78
Major axis bending moment M_z=Q_z*L_{a1}^2/10	N*mm	59336.64	233856.67	224258.40
Minor axis uniform load a'		1.35W_d*Sinβ	W_d*Sinβ	W_d*Sinβ
	N	11520.27	8533.53	8533.53
Minor axis load Q_y=a'/N/L_{c2}	N/mm	0.07	0.06	0.06
Minor axis bending moment M_y=Q_y*L_{a1}^2/10	N*mm	21596.77	15997.61	15997.61
Axial stressσ_p=F/A	MPa	0.00	0.00	0.00
Major axial stressσ_z=M_z/W	MPa	5.82	22.95	22.01
Minor axial stressσ_y=M_y/W	MPa	4.31	3.19	3.19
Resultant stress σ=σ_z+σ_y	MPa	10.13	26.14	25.20
Rated strength value	MPa	205.00	205.00	205.00
Axial stress + bending stress ratio		0.05	0.13	0.12
Strength judgment（<1）		**OK**	**OK**	**OK**
Major axial deflection δ_z =0.521*Q_z*L_{a1}^4 /	mm	0.25	1.00	0.96
Minor axial deflectionδ_y =0.521*Q_y*L_{a1}^4 /	mm	0.31	0.23	0.23
Joint deflectionδ_y	mm	0.40	1.02	0.98
Judgment(L/200)	mm	0.00023	0.00060	0.00058
Deflection ratio		0.00500	0.00500	0.00500
		0.05	**0.12**	**0.12**
Deflection judgment（<1）		**OK**	**OK**	**OK**

4 .Bracket strength check

4.1Load Combinations for Check Calculation

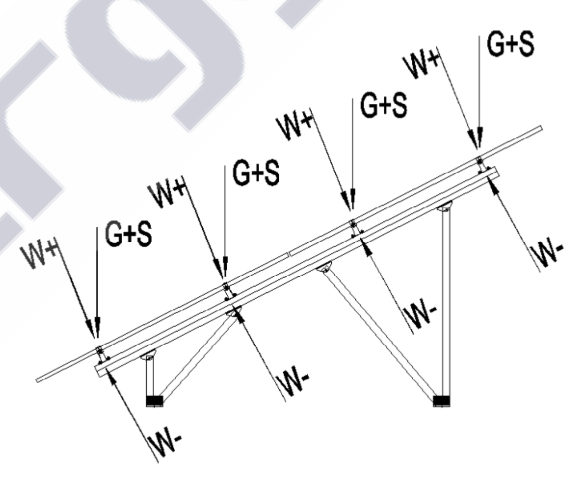
In summary, as described above for the check calculation of the guide rail,

the load combination that can be selected for the check calculation of the bracket is:

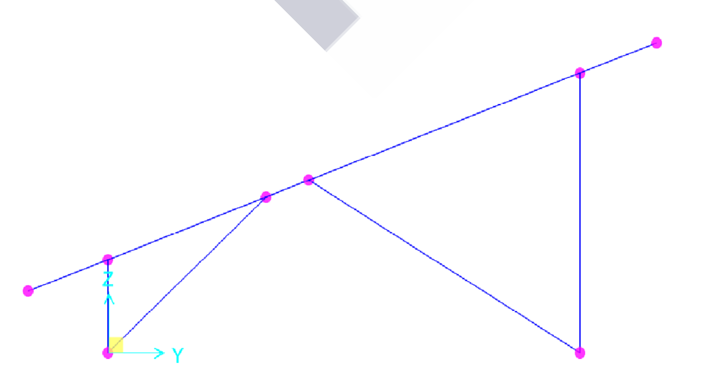
Ultimate limit states	COMB1	G	×
	COMB2	1.35G	×
	COMB3	1.35G+1.5S	×
	COMB4.1	1.35G+1.5W+1.5*0.7S（θ=0°）	×
	COMB4.2	1.35G-1.5W+1.5*0.7S（θ=180°）	×
	COMB5.1	1.35G+1.5S+1.5*0.6W（θ=0°）	√
	COMB5.2	1.35G+1.5S-1.5*0.6W（θ=180°）	×
	COMB6.1	G-1.5W（θ=180°）	×
	COMB6.2	G+1.5W（θ=0°）	√
	COMB a	1.35G+1.5Qwa+1.5*0.6W（θ=0°）	√
	COMB b	.35G-1.5Qwa-1.5*0.6W（θ=180°）	√
Serviceability limit states	COMB7.1	G+W+0.7S（θ=0°）	√
	COMB7.2	G-W+0.7S（θ=180°）	×

4.2 load application method

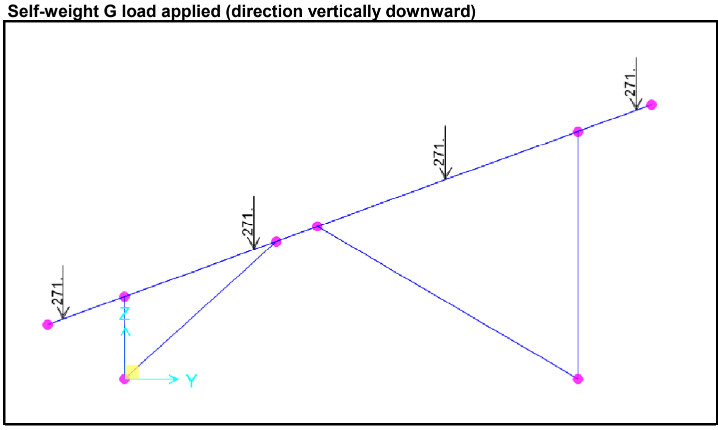
point	A	B	C	D
Gravity（N）(G)	271.20	271.20	271.20	271.20
following wind pressure load（N）(W+)	674.59	674.59	674.59	674.59
against wind pressure load（N）(W-)	1096.21	1096.21	1096.21	1096.21
against Snow pressure load（N）(S)	4334.16	4334.16	4334.16	4334.16
Hydraulic power Qwa+(N)	2173.82	2173.82	2173.82	2173.82
Hydraulic power Qwa-(N)	-2173.82	-2173.82	-2173.82	-2173.82



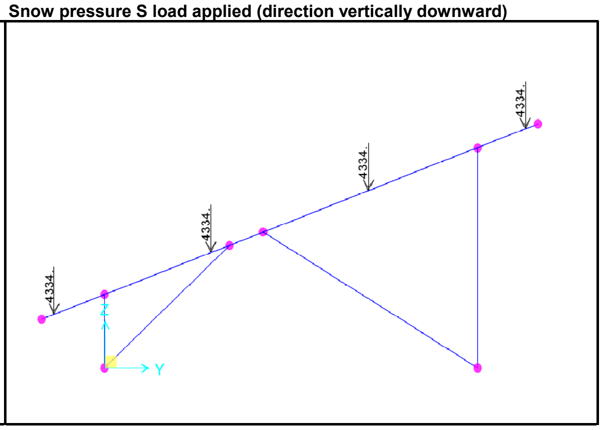
4.3SAP2000 2D bracket model



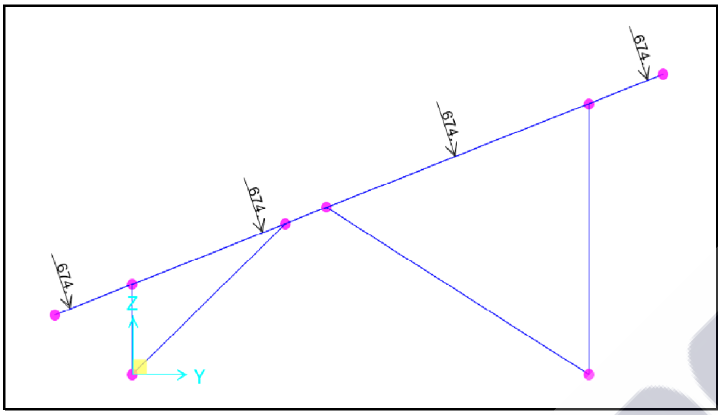
Self-weight G load applied (direction vertically downward)



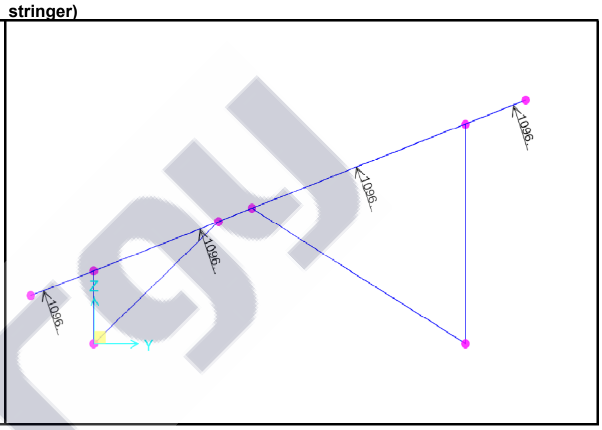
Snow pressure S load applied (direction vertically downward)



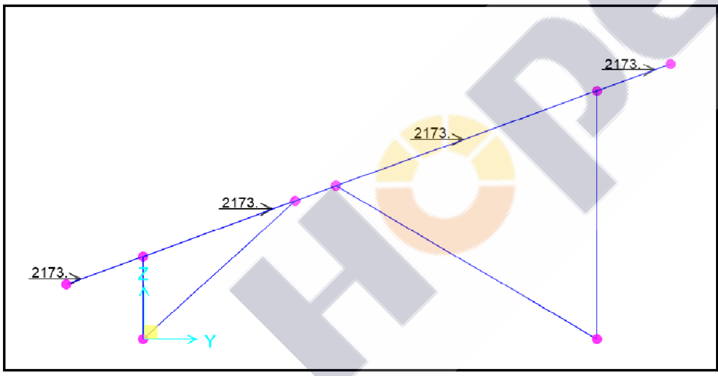
Positive wind pressure W+ load applied (direction perpendicular to the stringer)



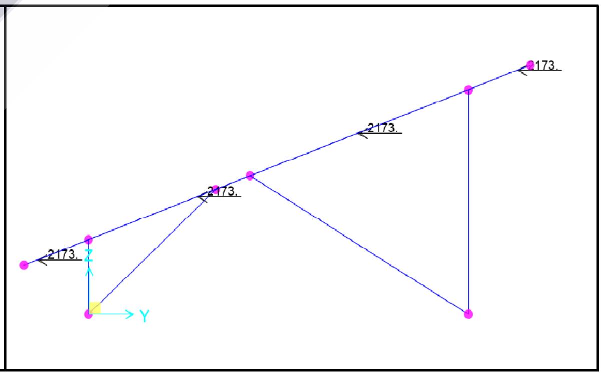
Upwind wind pressure W-load applied (direction perpendicular to the stringer)



Hydraulic action Qwa+

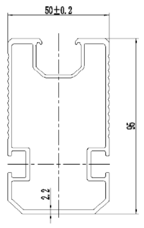


水力作用Qwa-



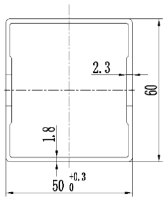
4.4Structural section parameter information

Beam

	Sectional area	A=656mm²	
	thickness	t=1.8mm	
	Moment of area	Sz=9942mm3	Sy=5896mm3
	Moment of inertia of section	Iz=732379mm4	Iy=240780mm4
	Section factor	Wz=15317mm3	Wy=9630mm3

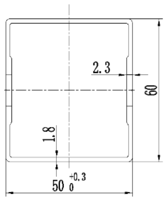
Material properties and allowable stress
Elasticity modulus E= 70000N/mm²
Tensile strength f= 245N/m²
Yield Strength= 205N/m²
Shearing strength f118.36N/m²

Front

	Sectional area	A=272mm²	
	thickness	t=1.3mm	
	Moment of area	Sz=2164mm3	Sy=1992mm3
	Moment of inertia of section	Iz=91958mm4	Iy=66088mm4
	Section factor	Wz=3344mm3	Wy=3304mm3

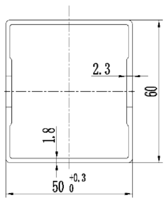
Material properties and allowable stress
Elasticity modulus E= 70000N/mm²
Tensile strength f= 245N/m²
Yield Strength= 205N/m²
Shearing strength f118.36N/m²

Rear

	Sectional area	A=272mm²	
	thickness	t=1.3mm	
	Moment of area	Sz=2164mm3	Sy=1992mm3
	Moment of inertia of section	Iz=91958mm4	Iy=66088mm4
	Section factor	Wz=3344mm3	Wy=3304mm3

Material properties and allowable stress
Elasticity modulus E= 70000N/mm²
Tensile strength f= 245N/m²
Yield Strength= 205N/m²
Shearing strength f118.36N/m²

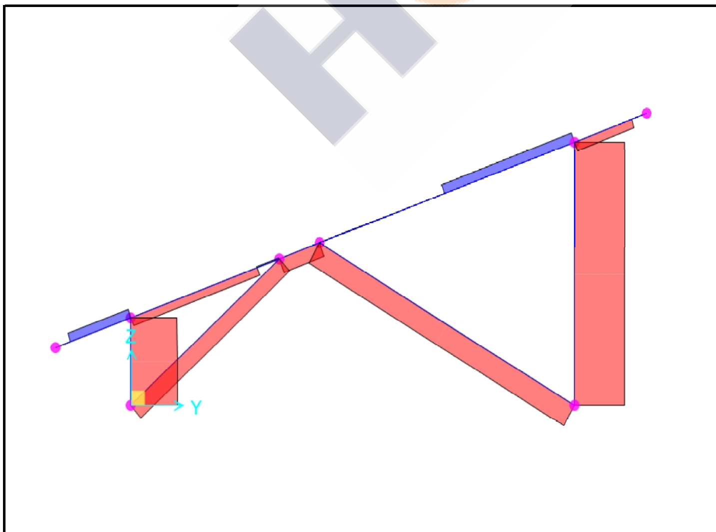
Diagonal brace

	Sectional area	A=272mm²	
	thickness	t=1.3mm	
	Moment of area	Sz=2164mm3	Sy=1992mm3
	Moment of inertia of section	Iz=91958mm4	Iy=66088mm4
	Section factor	Wz=3344mm3	Wy=3304mm3

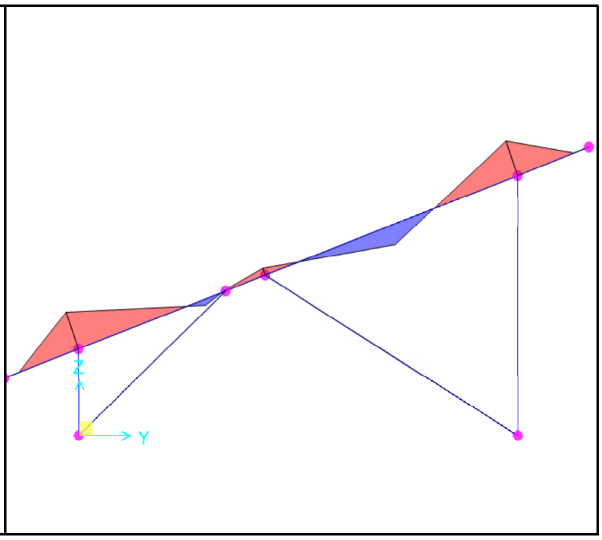
Material properties and allowable stress
Elasticity modulus E= 70000N/mm²
Tensile strength f= 245N/m²
Yield Strength= 205N/m²
Shearing strength f118.36N/m²

4.5 Example of longitudinal beam SAP2000 checking result diagram

Axis diagram



Bending moment diagram



4.6 Component SAP2000 Analysis Result Data Statistics

Beam	maximum bending moment（N/mm）	Maximum axial force(N)	maximum shear force(N)	Maximum deflection	Front	maximum bending moment（N/mm）	Maximum axial force(N)	maximum shear force(N)	Maximum deflection
COMB5.1	2739660.00	3611.00	7075.00	10.71	COMB5.1	41113.00	11662.00	/	/
COMB6.2	494383.00	669.00	1281.00	1.84	COMB6.2	8205.00	2169.00	/	/
COMB7.1	1468596.00	1826.00	3795.00	5.70	COMB7.1	16068.00	6279.00	/	/

Rear	maximum bending moment（N/mm）	Maximum axial force(N)	maximum shear force(N)	Maximum deflection	Diagonal brace1	maximum bending moment（N/mm）	Maximum axial force(N)	maximum shear force(N)	Maximum deflection
COMB5.1	1870.00	12625.00	/	/	COMB5.1	/	4606.00	/	/
COMB6.2	1678.00	2292.00	/	/	COMB6.2	/	174.00	/	/
COMB7.1	229.00	6798.00	/	/	COMB7.1	/	2089.00	/	/

Diagonal brace2	maximum bending moment（N/mm）	Maximum axial force(N)	maximum shear force(N)	Maximum deflection
COMB5.1	/	5017.00	/	/
COMB6.2	/	1435.00	/	/
COMB7.1	/	2902.00	/	/

4.7Component Strength Check

Strength Check Reference Formula

a)Axial stress calculation

$$\sigma = \frac{N}{A}$$

In the formula:

σ_A：stress transmitted from axial force，MPa；

A：Sectional area，mm^2；

N：axial force，N。

b) Bending moment stress calculation

$$\sigma = \frac{M_x}{W_x}$$

In the formula:

σ_W：Stress transmitted from bending moment，MPa；

Mx:bending moment，N*mm；

Wx：elastic section modulus，mm^3。

c)Shear stress calculation

$$\tau = \frac{V * S}{I * T}$$

In the formula:

τ：shear stress，MPa；

V：shear force，N；

S：cross-sectional area moment，mm^3；

I：Sectional moment of inertia，m^4；

T：thickness, mm；

Beam

project / load combination	bending moment stress σ	Bending moment stress (σ≤205Mpa）	axial stress σ_A	Shaft stress check (σA≤205Mpa）	shear stress τ	Shear Stress Check (τ≤79Mpa）	deflection check (S≤1/250）	Judgment ratio <1?
COMB5.1	178.86	OK	5.50	OK	53.35	OK	OK	OK
COMB6.2	32.28	OK	1.02	OK	9.66	OK	OK	OK
COMB7.1	95.88	OK	2.78	OK	28.62	OK	OK	OK

Front

project / load combination	bending moment stress σ	Bending moment stress (σ≤205Mpa）	axial stress σ_A	Shaft stress check (σA≤205Mpa）	shear stress τ	Shear Stress Check (τ≤79Mpa）	Judgment ratio <1?
COMB5.1	12.29	OK	42.81	OK	/	/	OK
COMB6.2	2.45	OK	7.96	OK	/	/	OK
COMB7.1	4.81	OK	23.05	OK	/	/	OK

Rear

project / load combination	bending moment stress σ	Bending moment stress (σ≤205Mpa）	axial stress σA	Shaft stress check (σA≤205Mpa）	shear stress τ	Shear Stress Check (τ≤79Mpa）	Judgment ratio <1?
COMB5.1	0.56	OK	46.35	OK	/	/	OK
COMB6.2	0.50	OK	8.41	OK	/	/	OK
COMB7.1	0.07	OK	24.96	OK	/	/	OK

Diagonal brace1

project / load combination	bending moment stress σ	Bending moment stress (σ≤205Mpa)	axial stress σA	Shaft stress check (σA≤205Mpa)	shear stress τ	Shear Stress Check (τ≤79Mpa)
COMB5.1	/	/	16.91	OK	/	/
COMB6.2	/	/	0.64	OK	/	/
COMB7.1	/	/	7.67	OK	/	/

Diagonal brace2

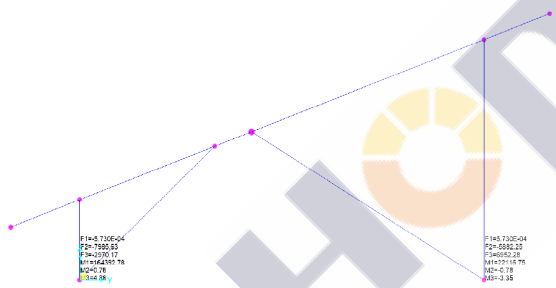
project / load combination	bending moment stress σ	Bending moment stress (σ≤205Mpa)	axial stress σA	Shaft stress check (σA≤205Mpa)	shear stress τ	Shear Stress Check (τ≤79Mpa)
COMB5.1	/	/	18.42	OK	/	/
COMB6.2	/	/	5.27	OK	/	/
COMB7.1	/	/	10.65	OK	/	/

4.8 Node reaction statistics

COMB a

Maximum down pressure Fv1= **6952.00N**

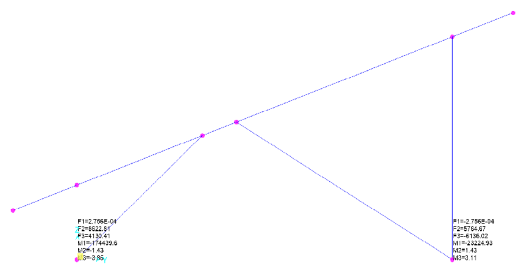
Maximum horizontal force FH1= **7985.00N**



COMB b

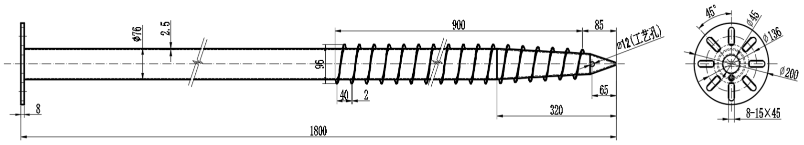
Maximum down pressure Fv1= **6136.00N**

Maximum horizontal force FH1= **8622.00N**



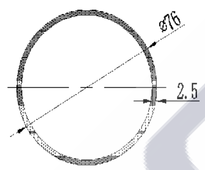
5.Calculation of screw piles

1) Basic information about screw piling



Specifications screw pile GS-A10-1800-T2.75

Material: Q235 Surface strength σ= 235 MPa



Sectional area	A=633mm²			
thickness	t=2.8mm			
thickness	Sz=7381	mm^3	Sy=7381	mm^3
Moment of inertia of section	Iz=425037	mm^4	Iy=425037	mm^4
Section factor	Wz=11185	mm^3	Wy=11185	mm^3

2) design load

d) Design horizontal force (north-south direction)： Fh1 = 8.622 [kN]

4) calculation of circumference and block cross section

The characteristics of a pile for support power are as follows.

- North-south span ： Sy = 2.600 [m]
- Pile diameter used for north-south direction study ： By = 0.076 [m]

5.1 examination of horizontal displacement

The standard ground reaction force coefficient Kh0 is obtained as follows.

$Kh_0 = \alpha \cdot \xi \cdot E_0 \cdot B_0^{-3/4}$

$= 80 \times 1.0 \times 4900 \times 7.6^{-3/4}$

$= 85640$ [kN/m^3]

α : The constant determined by the evaluation method: sandy soil α =80, viscous soil α=60 (1/ m)

(ground deformation coefficient estimated from the average N value of the target soil layer at E0 = 700 · N)

ξ : Coefficient considering the influence of pil = 1.0

Sy / Bx = 2.600 / 0.076 = 34.211 > 6.0

E_0 : Soft deformation coefficient

$= 700 \cdot N = 700 \times 7.0 = 4900$ [kN/m^2]

The range of ground that has a dominant influence on the horizontal resistance of the pile,

which is subjected to horizontal force on the pile head, is about 1 / beta from the ground surface.

In this case, the horizontal ground reaction force coefficient Kh is obtained as follows.

$Kh = 85640 \times 1.1 = 98235.6$ [kN/m^3] （南北方向）

The relative rigidity of the piles and the ground is determined by the formula.

$\beta = (Kh \cdot B / (4 E I))^{1/4}$

$= (98236 \times 0.076 / (4 \times 2.1E+08 \times 4.6E-07))^{1/4}$

$= 2.110$

Here E : Elastic coefficient of pile body = 2E+05 [N/mm^2] = 2.1E+08 [kN/m^2]

Iy : Cross section of the pile body used for the study of the strong axis secondary moment

= 459073 [mm^4] = 4.6E-07 [m^4]

$\beta \cdot EL_0 = 2.110 \times 1.800 = 3.799$

β · EL0 ≧ 2.25 Therefore, consider it as semi-infinite length.

$1 / \beta = 1 / 2.110 = 0.474$ [m]

β : And then you get more calculations.

B0 : Dimensional pile diameter = 7.6

The position of the maximum bending moment

$$\lambda m = \frac{1}{\beta} \cdot \tan^{-1}\left(\frac{1}{1+2\cdot\beta\cdot h}\right)$$

$$= \frac{1}{2.110} \times \tan^{-1}\left(\frac{1}{1+2\times 2.110\times 0.20}\right) = 0.235 \quad [m] \quad)$$

Here. h : The protrusion of the stake = 0.200 [m]

The maximum bending moment

$$Mm = \frac{Fh}{2\cdot\beta}\sqrt{(1+2\beta h)^2+1}$$

$$\exp\left(-\tan^{-1}\left(\frac{1}{1+2\cdot\beta\cdot h}\right)\right)$$

$$= 2.347 \quad [kN\cdot m] \quad = 2346636 \quad [N\cdot mm]$$

The test of bending stress is shown below.

$$\sigma bx = Mm / Z = 2346636 / 10270 = 228.489 \quad [N/mm^2]$$

$$\sigma c = Fv / Ap = 6136 / 633 = 9.70 \quad [N/mm^2]$$

$$\sigma bX/fbx + \sigma c/ft = 0.97 + 0.03 = 1$$ Results of discussion: OK

$$\leqq \sigma a = 235$$

Here. Z : Cross-section coefficient = 10270 [mm^3]

The surface displacement y0 is calculated as below.

$$y_0 = (1 + \beta h) \cdot Fh / (2 E I \beta^3)$$

$$= (1 + 2.110 \times 0.200) \times 8.622 / (2 \times 2.1E{+}08 \times 4.6E{-}07 \times 2.110^3) = 0.0069 \quad [m]$$

$$= 6.931 \quad [mm]$$

Here. h : The protrusion of the stake = 0.200 [m]

Fh : Horizontal force to be loaded onto a pile

As mentioned above, because the horizontal displacement y0 of the pile does not exceed the allowable horizontal displacement ya calculated as

It can be evaluated that the support ground does not exceed the elastic range.

$y_0 <$ ya = 15.000 [mm] Results of discussion: OK

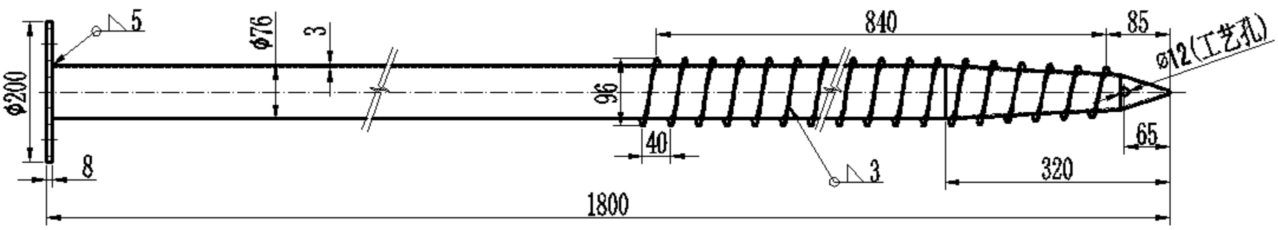
GS-76-1800A00

Fixed small blade ground screw

Structural Strength Calculation Report

Editor：
Time：
Check：
Version： V1.0

Ground screw structural strength calculation report



In this project, the soil is Soft clay, φ76*1800 non-adjustable small blade ground screw (GS-76-1800A00) are selected, and the driving depth is 1.6m. Under this condition, the ultimate bearing capacity and maximum pull-out resistance of the screw pile are calculated below.

1. Ultimate bearing capacity:

When determining the standard value of the vertical ultimate bearing capacity of a single pile according to the empirical relationship between the physical index of the soil and the bearing capacity parameters, it should be estimated as follows:

$$Q_{UK} = u_i \sum_{i=1}^{n} q_{sik}\, l_i + u_j \sum_{j=1}^{m} q_{lwsjk} l_j + q_{pk} A_P$$

Where：

q_{sik}——The standard value of the ultimate lateral resistance of the i-th layer of soil on the pile side, if there is no local experience, it can be taken according to the attached table 1;

q_{pk}——The standard value of the limit end resistance, if there is no local experience, can be taken according to the attached table 2;

q_{lwsjk} ——is the standard value of the equivalent limit side resistance of the i-th layer that the screw pile passes through, qlwsjk=β*qsik (β=1.3~2.0);

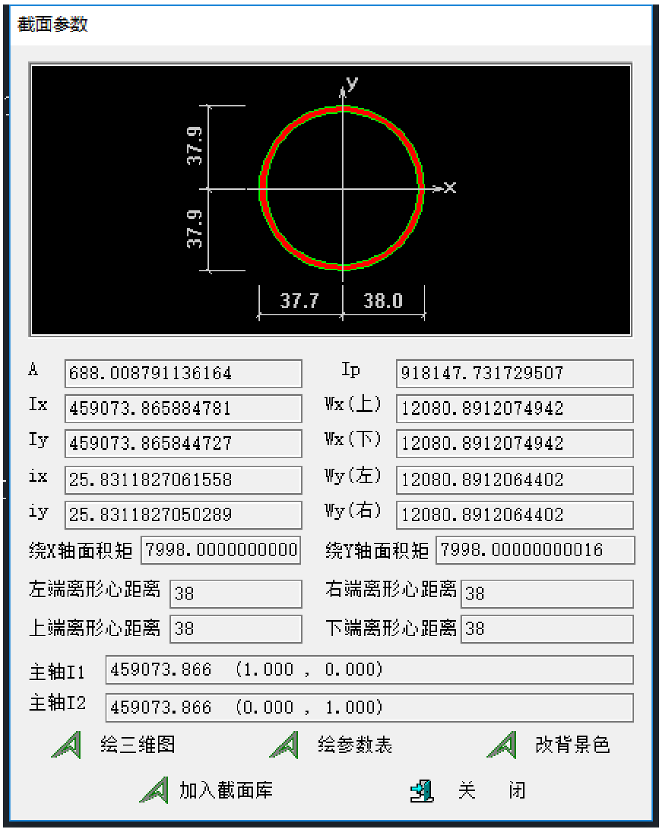
l_i ——The thickness of the pile body of the straight rod section on the i-th layer of rock and soil; lj — the thickness of the threaded section of the pile body on the i-th layer of rock and soil;

u_i——The circumference of the pile body of the straight rod section; the circumference of the pile body of the uj threaded section;

A_p——Pile end cross-sectional area (according to the screw pile section parameter table).

In this project, the diameter of the straight rod section of the ground screw is φ76, and ui=239mm; the diameter of the thread section is φ96, and uj=301mm;according chart 1, qsik=32~74kpa, equal 50kpa； qlwsjk= 1.5;Check attached table 2 to get qpk=850-1700kpa, take 120kpa; straight rod section driving depth li=1.6-0.84=0.76m; thread length lj=0.84m; pile end section area AP=688mm2.

Pile end section parameter table is as follows:



截面参数表

Substitute into the formula to get:

$$Q_{UK} = u_i \sum_{i=1}^{n} q_{sik} l_i + u_j \sum_{j=1}^{m} q_{lwsjk} l_j + q_{pk} A_P$$

=0.239*50000*0.76+0.301*1.6*50000*0.84+1200000*0.000688

=30134.8 N = 30.134 KN

2. Maximum pull-out resistance:

The pullout resistance of a single pile is determined by the empirical formula:

$$T_{u}=a\left(u_i\sum_{i=1}^{n} q_{sik}l_i + u_j\sum_{j=1}^{m} q_{lwsjk}l_j\right) + BG$$

Where:

Tu——T 阿 he ultimate bearing capacity of single pile uplift;

ui——The circumference of the pile body of the straight rod section; uj——the circumference of the pile body of the threaded section;

li ——The thickness of the pile body of the straight rod section on the i-th layer of rock and soil;

lj —— the thickness of the threaded section of the pile body on the i-th layer of rock and soil;

qsik——The i-th layer soil pile side compressive limit pile side resistance;

qlwsik ——is the standard value of the equivalent limit side resistance of the i-th layer that the screw pile passes through, qlwsik=βqsik (β=1.3~2.0);

G——The self-weight of the pile body, the effective gravity is taken underwater;

a——Uplift coefficient, sandy soil X = 0.50 ~ 0.70; cohesive soil, silt A = 0.70 ~ 0.80;

B——Reduction coefficient, generally 0.8~1.0;

Pile body weight G=10.25Kg=102.5N; B=0.8, a=0.8; other values are the same as before.

Substitute into the formula to find:

$$T_{u}=a\left(u_i\sum_{i=1}^{n} q_{sik}l_i + u_j\sum_{j=1}^{m} q_{lwsjk}l_j\right) + BG$$

=0.8*（0.239*50000*0.76+0.301*1.6*50000*0.84）+0.8*119.1

=23542.64 N = 23.542 KN