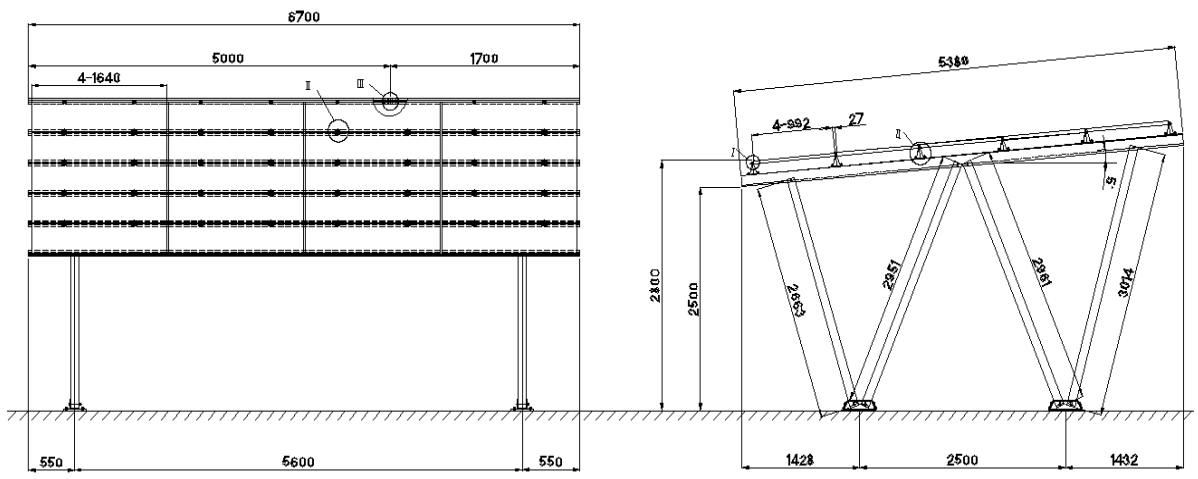
STRENGTH CALCULATION REPORT

ALUMINUM GROUND MOUNTING SYSTEM

Frist、Project Information

1、Module Dimension:	1640	×	992	×	40	mm
2、Array:	5	×	4			
3、Tilted Angle	5 °					
4、Wind Speed	45	m/s				
5、Snow Depth	40	cm				
6、Module Weight	20.5	Kg				
7、Surface Roughness Category	3					
8、Structure Span	5600	mm				
9、Total Length of Rail	6700	mm				

Design Drawing:



Second、Strength Reviews (four parts)

1、Rail Strength check;

2、Main Beam Strength;

3、Strength of Tilted Support Tube;

4、Pole Strength.

Third、Rail Strength

Rail Load Analysis

Two Parts of Rail Load: 1. Fixed Load: Weight of Module and Rail

2. External Load (wind, snow and etc.)

1、Fixed Load

Calculating Fixed Load by Reviewing One Row:

a) Module Weight:

Ga= 803.6 N

b)Rail Weight:

Gb= 139.9 N

Fixed Load G1=Ga+Gb= 943.5 N

2.Wind Pressure Load

Wp=Cw*Qp*Aw

Cw——Wind Pressure Coefficient

Tailwind, C1=0.65+0.009*5° = 0.7

Dead Wind,C2=0.71+0.016*5° = 0.79

Qp——Wind Pressure of Design(N/mˆ2)

Qp=0.6*Voˆ2*E*I

Vo——Wind Speed, 45 m/s

I——Function Coefficient, Value 1.0

E——Environment, E=Erˆ2*Gf

Er——Height Coefficient, Er=1.7*(Zb/Zg)ˆa

Gf——Gust Wind Influence Coefficient, Value 2.5

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Gust Wind Coefficient

Surface Roughness Category	Ground Clearance of Mounting System H (m)		
	(1)	(2)	(3)
	<10	>10 and <40	>40
I	2.0	The value of this blank is calculated by Linear Interpolation of Blank (1) and Blank (3).	1.8
II	2.2		2.0
III	2.5		2.1
IV	3.1		2.3

Surface Roughness Category

Surface Roughness Category		Z_b (m)	Z_G (m)	α
I	The area is out of city construction plan, and it is legally regulated by a certain administrative bureau. This area is very flat with no hurdles.	5	250	0.10
II	The area is out of city construction plan, and it does not belong to category I of Surface Roughness Category, which is not including the area under 13m of system ground clearance. Or, the area is in the city construction plan and does not belong to category IV of Surface Roughness Category, and is in the area with 500m distance from area to the coastline or lake line (It should be more than 1500m to the opposite bank. But it is not including the area under 13m of ground clearance, or the distance is more than 200m from area to the coastline or lake line, and the system's ground clearance is under 31m.	5	350	0.15
III	The area is out of the category Ⅰ, Ⅱ, and Ⅳ.	5	450	0.20
IV	The area is in the area of city construction plan, and legally regulated by a certain administrative bureau. And this area has a very clear indication of urbanization development.	10	550	0.27
Remark: The information above is quoted from No.1454 Construction Bulletin of Province (31/05/2000)				

Qp = 0.6*Voˆ2*Erˆ2*Gf*I = 1451N/mˆ2

Aw——Area of Wind Pressure

Aw= 6.51 ㎡

Calculation Result by Conditions above,

Tailwind:

W1=C1*Qp*Aw= 6563 N

Dead Wind:

W2=C2*Qp*Aw= 7460 N

3.Snow Load

Sk=Cs*P*Zs*As

Cs——Tilted Angle

$$Cs = \sqrt[2]{\cos(1.5 \times \theta)}$$

θ ——Tiled Angle of Snow on Module Surface

this project, Cs= 0.996

P——Snow Load per m2 with 1cm depth N/(mˆ2*cm)

Under the condition of 1m2 and 1cm depth snow, ordinary place is 20N,

and the place with frequent snow is 30N.

this project,20

Zs——The Biggest Value of Snow Depth

The Biggest Value of Snow Depth 40 cm

As——Area of Snow

As = Aw*cos(5°) = 6.5 ㎡

Calculation Result by the information above,

Sk= 5164.0 N

4.Earthquake Load

If the snow of installation area is ordinary,

$Kp=k_p*G$

Kp——Lateral Seismic Coefficient of Design 1

G——Fixed Load

Earhtquake Load of Rail

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Kp1= 1*1688.4= 943.5 N

5 Condition and Combination of Load

Referenc: JIS C 8955:2011

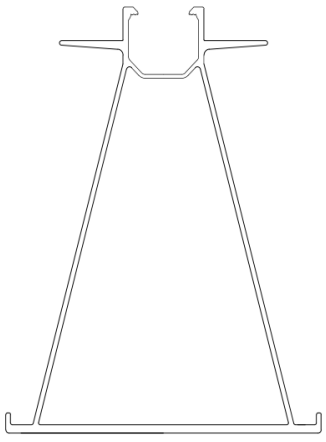
Condition and Combination of Load

Load Condition		Region	
		Ordinary	Frequent Snow
Long-Term	Usually	G	G
	Snowing		G+0.75S
Temporary	Snowing	G+S	G+S
	Storming	G+W	G+W
			G+0.35S+W
	Earthquake	G+K	G+0.35S+K

6 Material Character

Material: AL6005-T5 Yield Strength: σ p=215MPa

Safety Coefficient: 1.5 Section Modulus: Wx= 23418 mm^3



截面几何参数表

A	789.5691	Ip	2312872.4655
Ix	1757052.4925	Iy	555819.9730
ix	47.1734	iy	26.5321
Wx(上)	23418.5015	Wy(左)	11061.1658
Wx(下)	34004.7493	Wy(右)	11061.0222
绕X轴面积矩	17105.7554	绕Y轴面积矩	9379.4313
形心离左边缘距离	50.2497	形心离右边缘距离	50.2503
形心离上边缘距离	75.0284	形心离下边缘距离	51.6708
主矩I1	1757052.493	主矩1方向	(1.000,0.000)
主矩I2	555819.973	主矩2方向	(-0.000,1.000)

7 Strength

Structure Span: 5600 mm

Fixed Load G= 943.5 N

Load in Tailwind W1= 6563.2 N

Load in Dead Wind W2= 7460.4 N

Snow Load SK= 5164.0 N

Earthquake Load Kp= 943.5 N

If the installation area is ordinary:

Long-term Load

Long-term Load G1= 943.5 N

Temporary Load

Snowing G2= 6107.4 N

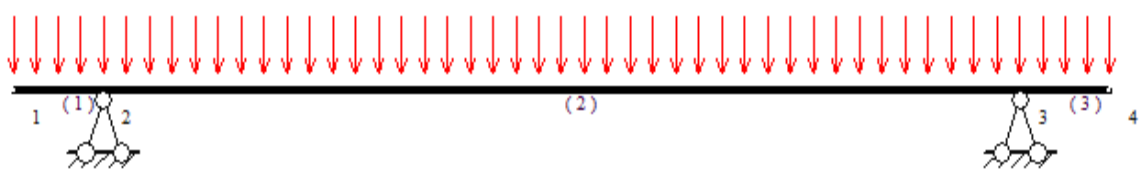
Tailwind G3= 7506.7 N

Dead Wind G4= 6516.9 N

Earthquake G5= 1886.9 N

The biggest load is the instant load in storm.

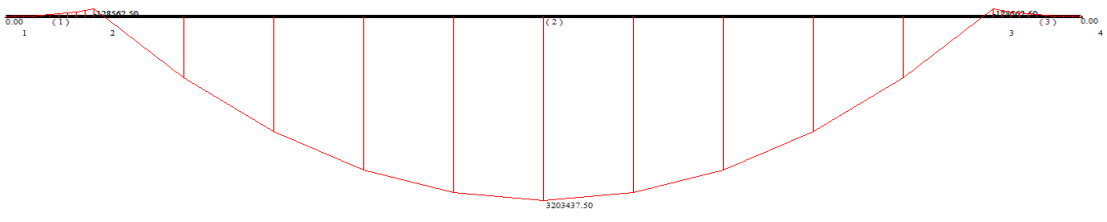
Gmax= 7506.7 N



Rail Pressure Figure

q=G/L= 1.12 N/mm

Bending Moment Figure:



Bending Moment Mmax=3203438 N*m

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The Biggest Normal Stress $\sigma = \frac{M_{max}}{W_x}$ = 137 MPa

Allowable Stress $\sigma_{st} = \frac{\sigma_p}{n} =$ 143.3 MPa

137 < 143.3

Result: Rail strength is in the range of safety.

Fourth、Main Beam Review

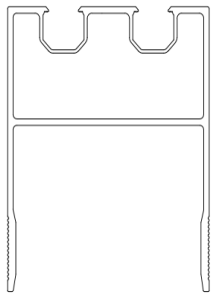
1、Load Analysis

Load of Main Beam=Rail Load + Main Beam Weight, Length of Main Beam 6350 mm

Weight of Main Beam= G1+ Beam G= 1207 N

2、The main beam's load of wind, snow and earthquake is the same as the rail's.

3、Mechanical Property of Main Beam:



截面几何参数表

A	1567.9883	Ip	5478797.1743
Ix	0.0000	Iy	0.0000
ix	38.9907	iy	44.4284
Wx(上)	46432.4628	Wy(左)	56231.9727
Wx(下)	29552.8003	Wy(右)	56317.7132
绕X轴面积矩	0.0000	绕Y轴面积矩	0.0000
形心离左边缘距离	55.0403	形心离右边缘距离	54.9565
形心离上边缘距离	51.3385	形心离下边缘距离	80.6615
主矩I1	2383767.273	主矩1方向	(1.000,-0.003)
主矩I2	3095029.901	主矩2方向	(0.003,1.000)

Material: AL6005-T5 Pulling Resistance: σ p=215MPa

Safety Coefficient: 1.5 Section Modulus: Wx= 29552 mm^3

4、Strength

Fixed Load G= 1206.7 N

Load in Tailwind W(Tailwind)= 6563.2 N

Load in Dead Wind W(Dead Wind)= 7460.4 N

Snow Load SK= 5164.0 N

Earthquake Load Kp= 1206.7 N

If the installation area is ordinary,

Long-term Load

Long-term Load G1= 1206.7 N

Temporary Load

Snowing G2= 6370.7 N

Tailwind G3= 7769.9 N

Dead Wind G4= 6253.7 N

Earthquake G5= 2413.4 N

The biggest load is the instant load in storm.

Gmax= 7769.9 N

Main Beam Pressure Figure:

2	0.00000000	3013.37500	0.00000000
3	0.00000000	7749.25000	0.00000000
4	0.00000000	3013.37500	-0.00000000

Fmax = 7750 N

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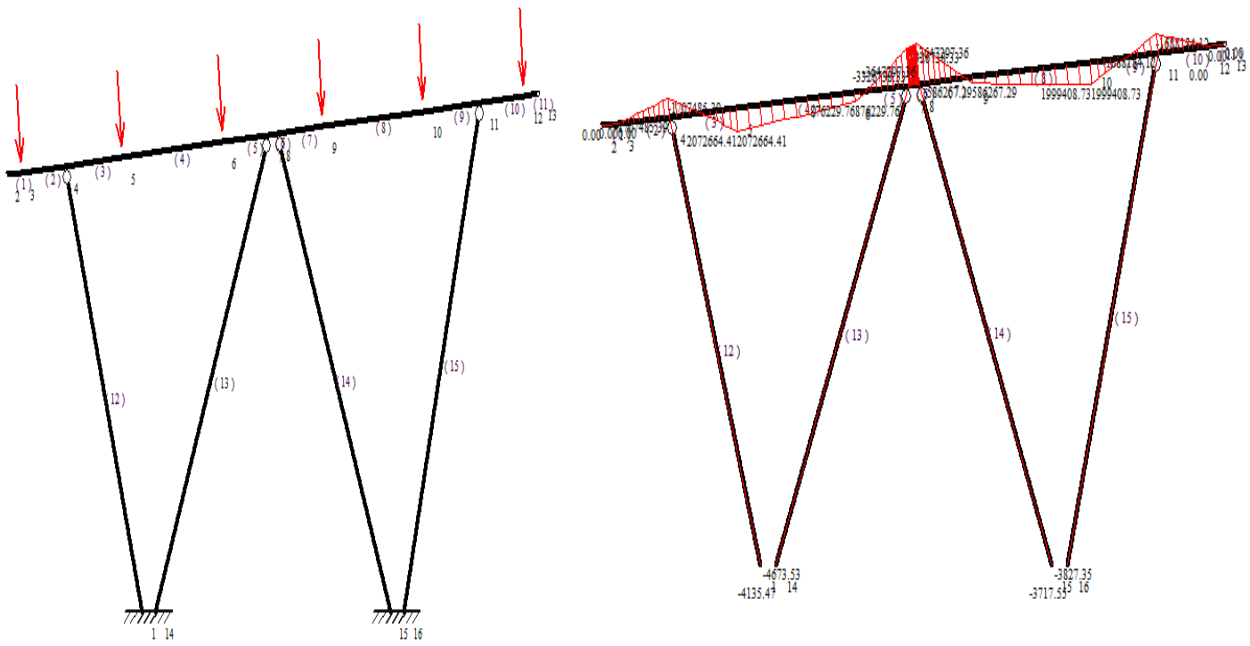
Bending Moment Figure:



Mmax= 3647298 N*m

The Biggest Normal Stress $\sigma = \frac{M_{max}}{W_x}$ = 123 MPa

Allowable Stress $\sigma_{st} = \frac{\sigma_p}{n} =$ 143.3 MPa

123 < 143.33

Result: The strength of Main Beam is in the range of safety.

Fifth、Tilted Support Tube

Figure of Tilted Support Tube Pressure:

1	-0.00000001	0.00000000	0.00000000	-0.00000001	0.00000000	0.00000001
2	-3.57012065	-3874.99835	0.00000002	-3.57012065	-3874.99835	-1707485.38
3	2201.17217	6572.14632	-1707485.38	2201.17217	6572.14632	2072664.40
4	2200.11211	-1176.54843	2072664.40	2200.11211	-1176.54843	876229.760
5	2199.07296	-8927.50418	876229.760	2199.07296	-8927.50418	-3326738.33
6	-441.160413	-3895.08976	-3326738.33	-441.160413	-3895.08976	-3647297.35
7	3677.92359	9147.33184	-3647297.35	3677.92359	9147.33184	586267.287
8	3691.91982	1389.77225	586267.287	3691.91982	1389.77225	1999408.73
9	3695.77643	-6355.22718	1999408.73	3695.77643	-6355.22718	-1688184.11
10	-0.26511226	3874.99999	-1688184.11	-0.26511226	3874.99999	-0.00000045
11	0.00000001	0.00000000	-0.00000047	0.00000001	0.00000000	0.00000001
12	-10676.6985	1.75104457	-4673.53140	-10676.6985	1.75104457	-0.00000000
13	-5678.48352	1.39610334	-4135.47302	-5678.48352	1.39610334	0.00000000
14	-13674.7285	1.28960582	-3827.35476	-13674.7285	1.28960582	-0.00000000
15	-10878.3049	1.23023949	-3717.54619	-10878.3049	1.23023949	0.00000000

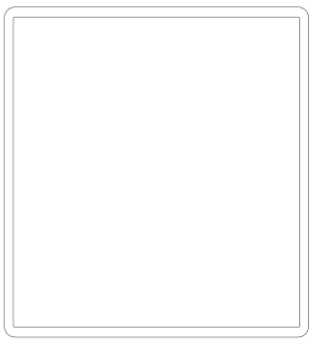
F1 = 10.677 KN

F2 = 5.679 KN

F3 = 13.675 KN

F4 = 10.879 KN

1、Mechanical Property of Main Beam



截面几何参数表

A	1153.6991	Ip	3604172.4287
Ix	1802086.2143	Iy	1802086.2144
ix	39.5222	iy	39.5222
Wx(上)	36041.7243	Wy(左)	36041.7243
Wx(下)	36041.7243	Wy(右)	36041.7243
绕X轴面积矩	20923.2544	绕Y轴面积矩	20923.2544
形心离左边缘距离	50.0000	形心离右边缘距离	50.0000
形心离上边缘距离	50.0000	形心离下边缘距离	50.0000
主矩I1	1802086.214	主矩1方向	(1.000,0.000)
主矩I2	1802086.214	主矩2方向	(0.000,1.000)

Material: AL6005-T5 Yield Strength: 215 MPa

Safety Coefficient: 1.5 Length of Tilted Support Tube: 2663 mm

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First Flexibility Character of Material $\lambda_1 = \sqrt{\frac{\pi^2 E}{\sigma_p}}$ = 56.28

Flexibility of Tilted Support Tube $\lambda_2 = \mu \frac{L}{i_{min}}$ = 68.28

68.3 > 56.28

This tube is a low flexibility tube. We mainly review its stability.

Allowable Loads $Fcr = \frac{\pi^2 \times E \times I}{\mu l^2} =$ 173054.15 N

Allowable Stress $\sigma_{cr} = \frac{F_{cr}}{A} =$ 150.09 MPa

Normal Stress $\sigma = \frac{F}{A} =$ 9.3

9.3 < 150.1

Result: The tilted support tube is sufficient for requirements.

2、Mechanical Property of Main Beam

Material: AL6005-T5 Yield Strength: 215 MPa

Safety Coefficient: 1.5 Length of Tilted Support Tube: 2951 mm

First Flexibility Character of Material $\lambda_1 = \sqrt{\frac{\pi^2 E}{\sigma_p}}$ = 56.28

Flexibility of Tilted Support Tube $\lambda_2 = \mu \frac{L}{i_{min}}$ = 74.71

74.7 > 56.28

This tube is a low flexibility tube. We mainly review its stability.

Allowable Loads $Fcr = \frac{\pi^2 \times E \times I}{\mu l^2} =$ 140924.3 N

Allowable Stress $\sigma_{cr} = \frac{F_{cr}}{A} =$ 122.2 MPa

Normal Stress $\sigma = \frac{F}{A} =$ 4.9

4.9 < 122.2

Result: The tilted support tube is sufficient for requirements.

2、Pole Strength Review

Pole Pressure Figure

F1 = 13.675 KN

F4 = 10.879 KN

a) Length of Rear Pole 2961 mm

First Flexibility Character of Material $\lambda_1 = \sqrt{\frac{\pi^2 E}{\sigma_p}}$ = 56.28

Flexibility of Pole $\lambda_2 = \mu \frac{L}{i_{min}}$ = 75

75 > 56.28

Result: This pole is a high flexibility pole. We mainly review its stability.

Allowable Load $Fcr = \frac{\pi^2 \times E \times I}{\mu l^2} =$ 139974.1 N

Allowable Stress $\sigma_{cr} = \frac{F_{cr}}{A} =$ 121.4 MPa

Normal Stress $\sigma = \frac{F}{A} =$ 11.9 MPa

< 121.4

Result: The stability of rear pole is sufficient for the requirements.

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b) Length of front pole 3014 mm

First Flexibility Character of Material $\lambda_1 = \sqrt{\frac{\pi^2 E}{\sigma_p}}$ = 56.28

Flexibility of Pole $\lambda_2 = \mu \frac{L}{i_{min}}$ = 76.3

76.3 > 56.28

Result: The front pole is short and thick. We mainly review its strength.

Allowable Load $Fcr = \frac{\pi^2 \times E \times I}{\mu l^2} =$ 135094.6 N

Allowable Stress $\sigma_{cr} = \frac{F_{cr}}{A} =$ 117.2 MPa

Normal Stress $\sigma = \frac{F}{A} =$ 9.4 MPa

9.4 < 117.2

Result: The strength of front pole is sufficient for requirements.

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