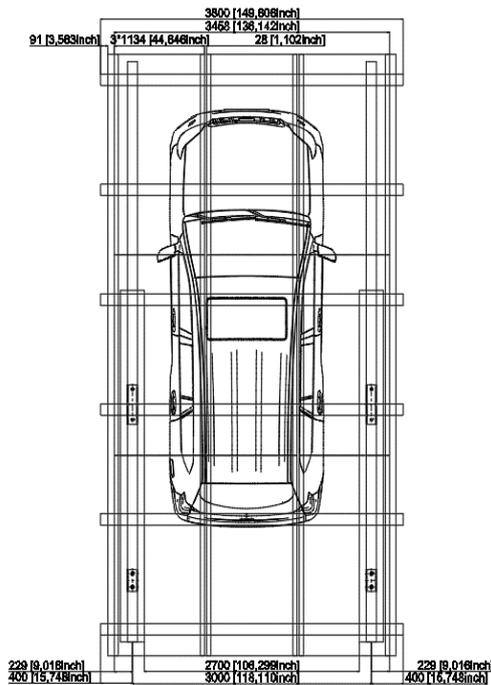
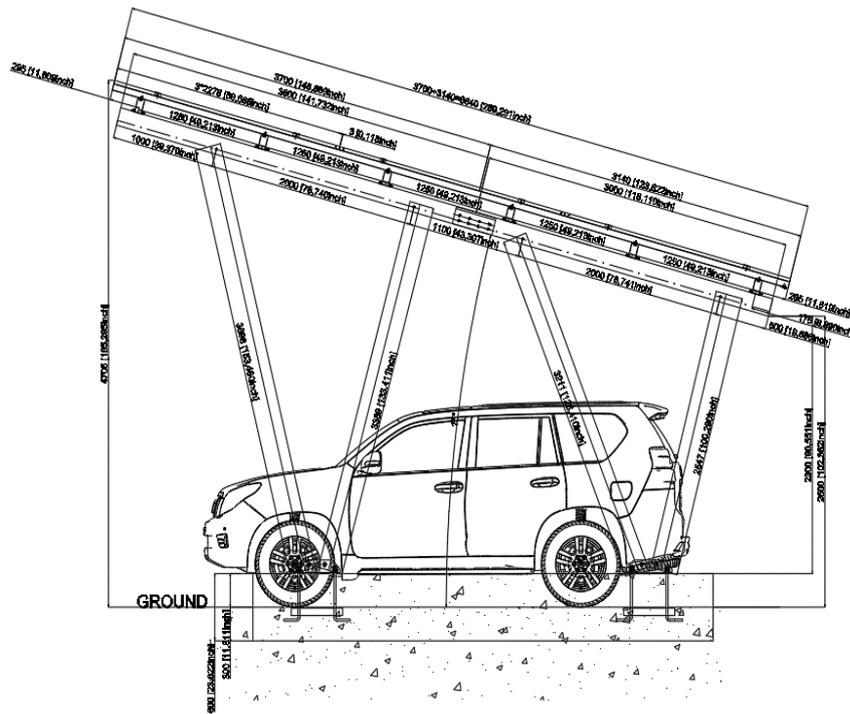




Elios Carport M9
3P*3 Carport Mounting Structure for 1 Car
Structural Load Calculation

Carport Mounting Structure (1 Car) Strength Calculation Report



1 Design Criteria

1.1 Design codes and references

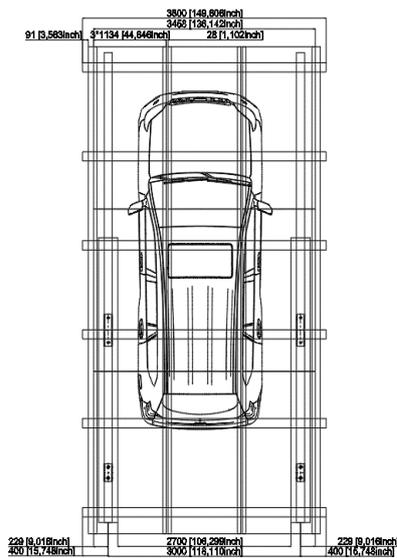
- a. American Society of Civil Engineers (ASCE 7-10) Minimum Design Loads for Buildings and Other Structures
- b. American Iron and Steel Institute (AISI)
- c. Uniform Building Code UBC - 1997

1.2 Design condition and technical parameters

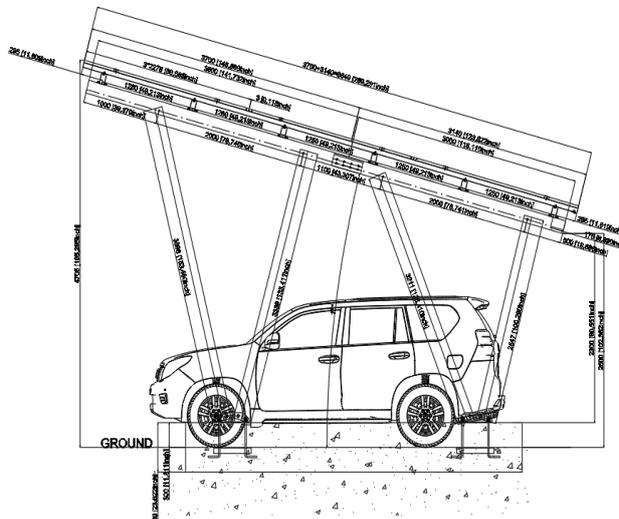
● Solar Panel:	2278 mm × 1134 mm × 30 mm	600 w
	29 kg	
● Layout	3 × 3	
● Span:	3000 mm	
● Rail:	3800 mm	
● BIPV Mounting Rail:	6840 mm	
● QTY:	2	
● Load of snow accumulation on the ground:	So= 2.87	KN/m ²
● Load of wind accumulation on the ground:	V _{b,0} = 55.00	m/s
● catagory terrain	III	

Sketch of bracket:

- Front view



- Side view



1.3 WIND DESIGN PARAMETERS:

DESIGN CODES AND REFERENCES

Location :

Exposure Category :

Mean roof height, h: 3.82 m

DESIGN WIND PRESSURE (P) CALCULATION

$P = q_h G C_{NP}$; design wind load for open buildings with monoslope, pitched, or troughed free module where:

q_z or $q_h = 0.613 K_z K_{zt} K_e V^2$ (N/m²) ; V in m/s ; velocity pressure evaluated at height z or h (kPa)

$p = q_h K_d G C_N$;

K_z or K_h velocity pressure exposure coefficient, see Section 26.10.1.

$K_{zt} = 1$ topographic factor wind

$K_e = 1$

$K_d = 0.85$ directionality factor

$K_z \& K_h = 0.85$

$G = 0.85$ exposure category C

Based on ASCE/SEI 7-10

Roof Angle θ°	Load Case	Wind Direction 0°		Wind Direction 180°	
		Clear Wind Flow		Clear Wind Flow	
		C_{NW}	C_{NL}	C_{NW}	C_{NL}
15	A	-0.90	-1.30	1.30	1.60
	B	-1.90	0.00	1.80	0.60

1.4 SNOW DESIGN PARAMETERS:

DESIGN CODES AND REFERENCES

The flat roof snow load, p_f , shall be calculated in lb/ft² (kN/m²) using the following formula $P_s =$

$C_s * P_f$

where:

$P_f = 0.7 * C_e * C_t * I_s * P_g$

$C_e = 0.9$; determined from Table 7-2

$C_t = 1.2$; determined from Table 7-3

$I_s = 0.8$; determined from Table 1.5-2

$C_s = 1$; determined from Table 7-2c

$P_s = 0.7 * 0.9 * 1.2 * 0.8 * 1.2 = 0.7$ KN/m²

$S = p_s * A = 0.73 * 23.25 = 16873.39$ N

$\cos 15^\circ = 0.97$

$\sin 15^\circ = 0.26$

1.5 LOAD DESCRIPTION Load effect under ultimate state: $D+0.75*0.6W+0.75S$ $D+0.6W$ $0.6D+0.6W$

LOAD DESCRIPTION	qh (kPa)	G	CN	P (kPa)	A(m ²)	W(N)	G(N)	F1(x)	F1(y)	F2(x)	F2(y)	
DIRECTION 180°: LOAD CASE "A " $D+0.75*0.6W+0.75S$												
WIND WARD	1.3397498	0.85	1.600	1.82	23.25	19062.70	16134.62	1.52	0.18	1.69	0.20	
LEEWARD	1.3397498	0.85	1.300	1.48	23.25	15488.44	16134.62	1.36	0.18	1.51	0.20	
DIRECTION 180°: LOAD CASE "B " $D+0.75*0.6W+0.75S$												
WIND WARD	1.3397498	0.85	0.600	0.68	23.25	7148.51	16134.62	1.00	0.18	1.11	0.20	
LEEWARD	1.3397498	0.85	1.800	2.05	23.25	21445.54	16134.62	1.62	0.18	1.80	0.20	
DIRECTION 180°: LOAD CASE "A " $D+0.6W$												
WIND WARD	1.3397498	0.85	1.600	1.82	23.25	25416.93	3479.58	1.26	0.04	1.40	0.04	
LEEWARD	1.3397498	0.85	1.300	1.48	23.25	20651.26	3479.58	1.05	0.04	1.17	0.04	
DIRECTION 180°: LOAD CASE "B " $D+0.6W$												
WIND WARD	1.3397498	0.85	0.600	0.68	23.25	9531.35	3479.58	0.57	0.04	0.63	0.04	
LEEWARD	1.3397498	0.85	1.800	2.05	23.25	28594.05	3479.58	1.40	0.04	1.56	0.04	
DIRECTION 0°: LOAD CASE "A " $0.6D+0.6W$												
WIND WARD	1.3397498	0.85	-0.900	-1.02	23.25	-14297.02	2087.75	-0.54	0.02	####	0.03	
LEEWARD	1.3397498	0.85	-1.300	-1.48	23.25	-20651.26	2087.75	-0.82	0.02	####	0.03	
DIRECTION 0°: LOAD CASE "B " $0.6D+0.6W$												
WIND WARD	1.3397498	0.85	-1.900	-2.16	23.25	-30182.61	2087.75	-1.24	0.02	####	0.03	
LEEWARD	1.3397498	0.85	0.000	0.00	23.25	0.00	2087.75	0.09	0.02	0.10	0.03	
Dead Loads								3479.579				

2.1 STRUCTURAL ANALYSIS

Load Combinations Allowable

Stress Design (ASD)

LOAD COMB 1 $D+0.75*0.6W+0.75S$ 180A

LOAD COMB 5 $0.6D+0.6W$ 0A

LOAD COMB 2 $D+0.75*0.6W+0.75S$ 180B

LOAD COMB 6 $0.6D+0.6W$ 0B

LOAD COMB 3 $D+0.6W$ 180A

LOAD COMB 4 $D+0.6W$ 180B

2.2 Load calculation

2.2.1 Dead load

●Solar Panel:

Dead-weight of panel G1= 29 kg = 284.2 N

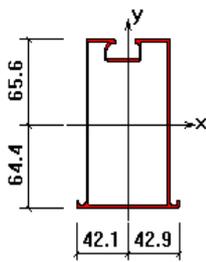
Standard load of panel: G1/m2 = 284.2 N / (2.278 x 1.134) = 110.0164 N/m²

(Load for every square meter of solar module)

●Wide Rail 130 AL6005-T5

Elasticity modulus E=7×10⁶ N/cm² (Elastic modulus of aluminum alloy)

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



A	905.467	Ip	2982085.977
Ix	2186112.590	Iy	795973.386
ix	49.136	iy	29.649
Wx(Top)	33332.140	Wy(Left)	18891.326
Wx(Bottom)	33332.140	Wy(Right)	18569.017
Area Moment Around X Axis	20250.960	Area Moment Around Y Axis	12568.618
Distance from Centroid to Left Edge	42.134	Distance from Centroid to Right Edge	42.865
Distance from Centroid to Top Edge	65.585	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	795765.810	Direction of Principal Moment 2	(0.000,1.000)

Dead-weight of Rail G2= 3.8 m x 2.44 kg/m= 9.29 kg= 91.04 N

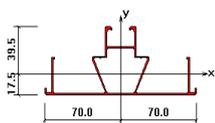
Standard load of Rail G2/m = 2.44 kg/m= 23.96 N/m

E*A= 70000 * 905.467 = 63382690 E*I= 70000 * 2186112.590 = 153027881300

●BIPV Mounting Rail AL6005-T5

Elasticity modulus E=7×10⁶ N/cm² (Elastic modulus of aluminum alloy)

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



A	518.715	Ip	971657.328
Ix	172699.206	Iy	798958.121
ix	18.246	iy	39.246
Wx(Top)	4370.343	Wy(Left)	11413.539
Wx(Bottom)	9866.991	Wy(Right)	11413.835
Area Moment Around X Axis	4177.308	Area Moment Around Y Axis	8400.165
Distance from Centroid to Left Edge	70.000	Distance from Centroid to Right Edge	69.999
Distance from Centroid to Top Edge	39.516	Distance from Centroid to Bottom Edge	17.502
Principal Moment I1	172699.206	Direction of Principal Moment 1	(1.000,0.000)
Principal Moment I2	798958.122	Direction of Principal Moment 2	(0.000,1.000)

Dead-weight of Rail G2= 6.84 m x 1.40 kg/m= 9.58 kg= 93.88 N

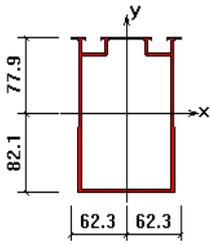
Standard load of Rail G2/m = 1.40 kg/m= 13.73 N/m

E*A= 70000 * 518.715 = 36310050 E*I= 70000 * 172699.206 = 12088944420

● Beam 160 AL6005-T5

Elasticity modulus $E=7 \times 10^6$ N/cm² (Elastic modulus of aluminum alloy)

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



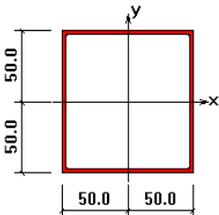
A	1668.984	I _p	9300477.258
I _x	5879739.593	I _y	3420737.664
i _x	59.354	i _y	45.272
W _x (Top)	75497.033	W _y (Left)	54907.506
W _x (Bottom)	71599.715	W _y (Right)	54907.506
Area Moment Around X Axis	45298.901	Area Moment Around Y Axis	35537.075
Distance from Centroid to Left Edge	62.300	Distance from Centroid to Right Edge	62.299
Distance from Centroid to Top Edge	77.880	Distance from Centroid to Bottom Edge	82.119
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)

$E \cdot A = 70000 \cdot 1668.984 = 116828880$ $E \cdot I = 70000 \cdot 5879739.593 = 4.11582E+11$

● 100*100 Square Tube AL6005-T5

Elasticity modulus $E=7 \times 10^6$ N/cm² (Elastic modulus of aluminum alloy)

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



A	1161.424	I _p	3641076.884
I _x	1820538.422	I _y	1820538.422
i _x	39.591	i _y	39.591
W _x (Top)	36410.768	W _y (Left)	36410.768
W _x (Bottom)	36410.768	W _y (Right)	36410.768
Area Moment Around X Axis	21112.002	Area Moment Around Y Axis	21112.002
Distance from Centroid to Left Edge	50.000	Distance from Centroid to Right Edge	50.000
Distance from Centroid to Top Edge	50.000	Distance from Centroid to Bottom Edge	50.000
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)

$E \cdot A = 70000 \cdot 1161.424 = 81299680$ $E \cdot I = 70000 \cdot 1820538.422 = 1.27438E+11$

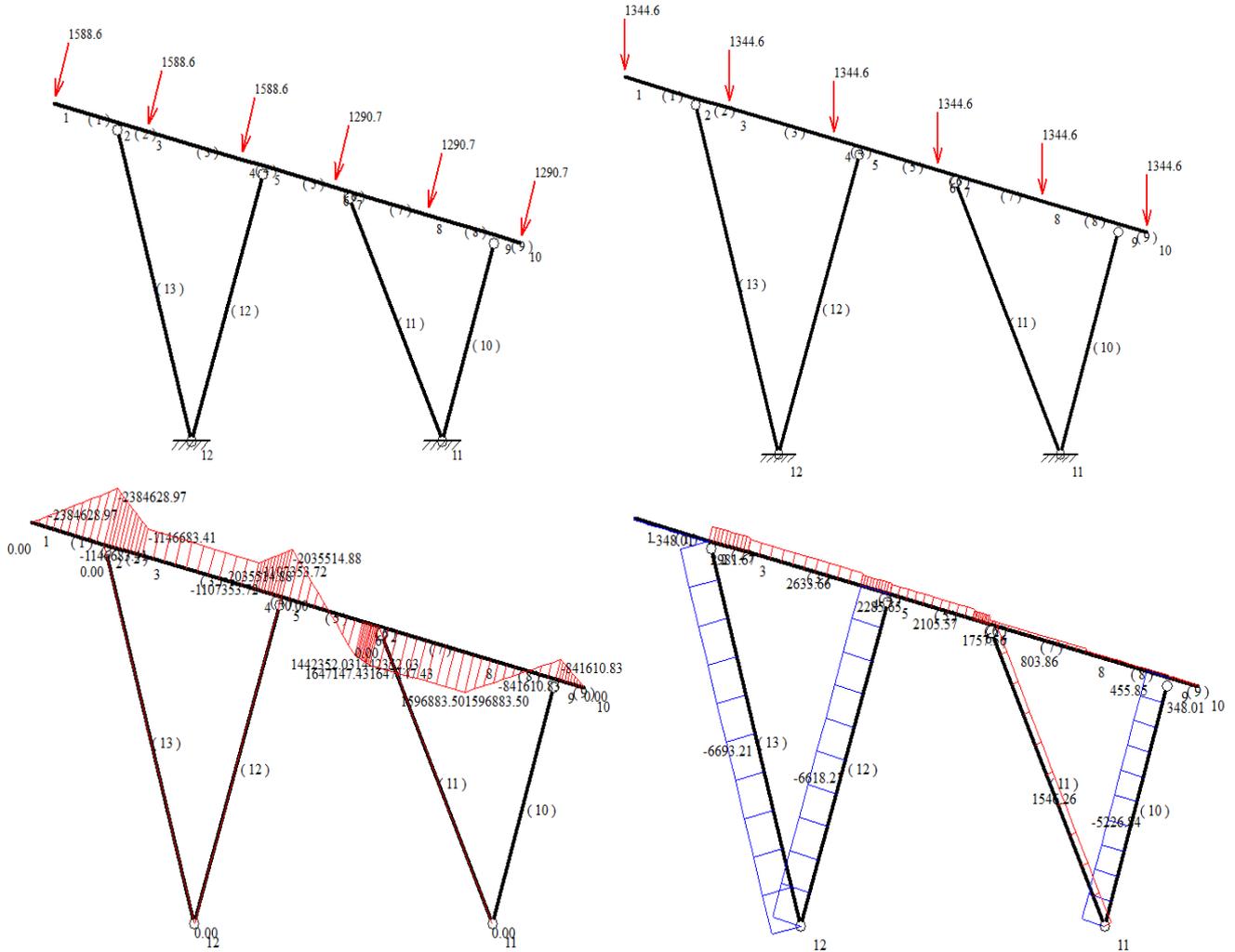
3.1 Wind blowing to the front of the modules:

$$W_{NL}=F1/ 6 / 2 = 19062.6999 / 6 / 2 = 1588.6 \text{ N}$$

$$W_{NW}=F1/ 6 / 2 = 15488.4437 / 6 / 2 = 1290.7 \text{ N}$$

$$G_{NL}=F1/ 6 / 2 = 16134.6204 / 6 / 2 = 1344.6 \text{ N}$$

$$G_{NW}=F1/ 6 / 2 = 16134.6204 / 6 / 2 = 1344.6 \text{ N}$$



(Stress value for Beam 160)

$$M_{max} = 2384628.97 \text{ N-mm}$$

$$\sigma_M = M_{max}/W_X = 2384628.97 / 75497.03 = 31.59$$

$$F_{max} = 2981.67 \text{ N}$$

$$\sigma_F = F_{max}/A = 2981.67 / 1668.98 = 1.79$$

$$\sigma_{all} = \sigma_M + \sigma_F = 33.372 < (240/1.67) = 143.71 \text{ N/mm}^2$$

(Stress value for 100*100 Square Tube)

$$F_{max} = 6693.21 \text{ N}$$

$$\sigma_F = F_{max}/A = 6693.21 / 1161.424 = 5.76$$

$$\sigma_F = 5.76 < (240/1.67) = 143.71 \text{ N/mm}^2$$

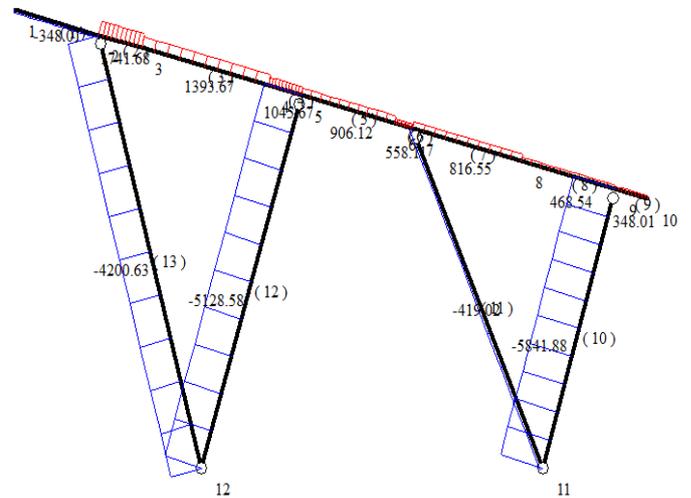
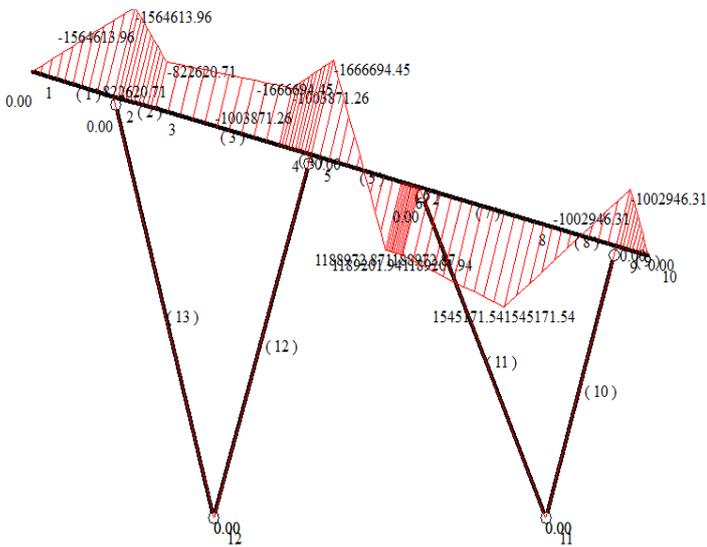
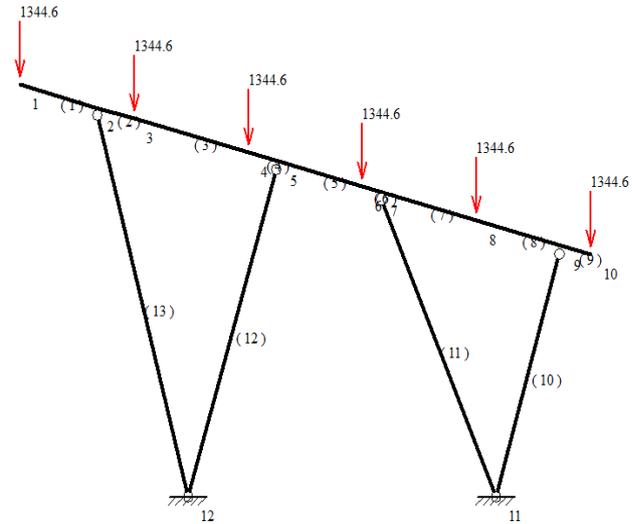
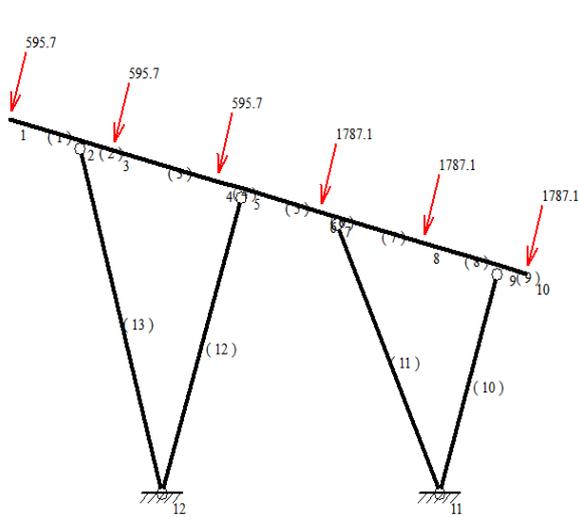
Wind blowing to the front of the modules:

$$W_{NL}=F1/ 6 / 2 = 7148.5125 / 6 / 2 = 595.7 \text{ N}$$

$$W_{NW}=F1/ 6 / 2 = 21445.5374 / 6 / 2 = 1787.1 \text{ N}$$

$$G_{NL}=F1/ 6 / 2 = 16134.6204 / 6 / 2 = 1344.6 \text{ N}$$

$$G_{NW}=F1/ 6 / 2 = 16134.6204 / 6 / 2 = 1344.6 \text{ N}$$



(Stress value for Beam 160)

Mmax= 1666694.45 N·mm

$$\sigma_M = M_{max} / W_X = 1666694.45 / 75497.03 = 22.08$$

Fmax= 1741.68 N

$$\sigma_F = F_{max} / A = 1741.68 / 1668.98 = 1.04$$

$$\sigma_{all} = \sigma_M + \sigma_F = 23.12 < (240/1.67) = 143.71 \text{ N/mm}^2$$

(Stress value for 100*100 Square Tube)

Fmax= 5841.88 N

$$\sigma_F = F_{max} / A = 5841.88 / 1161.424 = 5.03$$

$$\sigma_F = 5.03 < (240/1.67) = 143.71 \text{ N/mm}^2$$

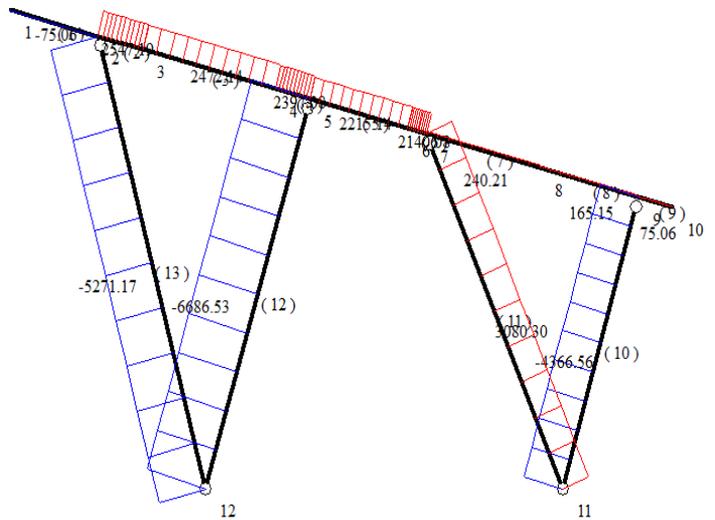
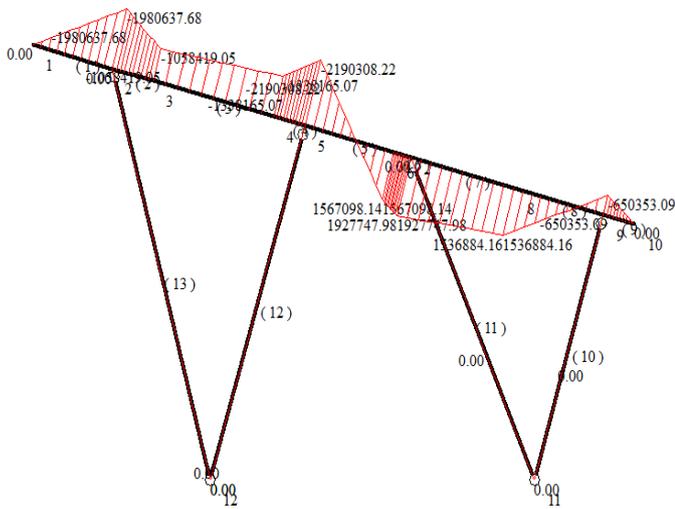
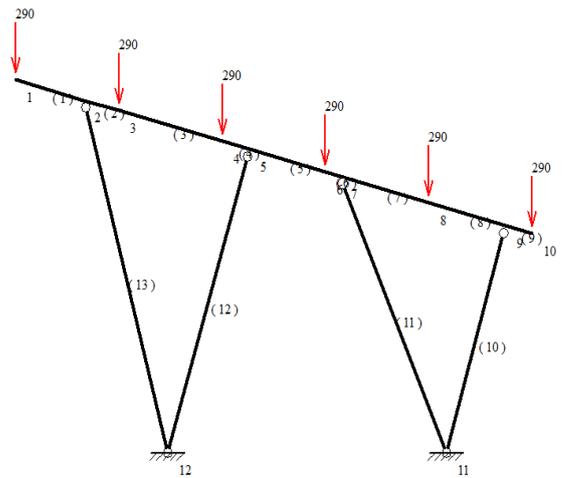
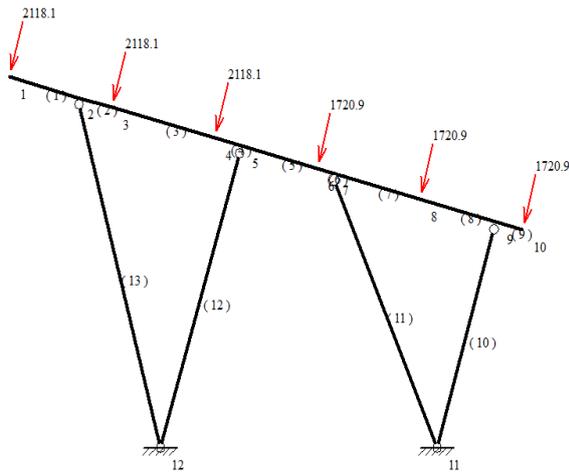
Wind blowing to the front of the modules:

$$W_{NL} = F1 / 6 / 2 = 25416.9332 / 6 / 2 = 2118.1 \text{ N}$$

$$W_{NW} = F1 / 6 / 2 = 20651.2582 / 6 / 2 = 1720.9 \text{ N}$$

$$G_{NL} = F1 / 6 / 2 = 3479.5788 / 6 / 2 = 290.0 \text{ N}$$

$$G_{NW} = F1 / 6 / 2 = 3479.5788 / 6 / 2 = 290.0 \text{ N}$$



(Stress value for Beam 160)

Mmax= 2190308.21 N-mm

$$\sigma_M = M_{max} / W_X = 2190308.21 / 75497.03 = 29.01$$

Fmax= 2547.19 N

$$\sigma_F = F_{max} / A = 2547.19 / 1668.98 = 1.53$$

$$\sigma_{all} = \sigma_M + \sigma_F = 30.538 < (240/1.67) = 143.71 \text{ N/mm}^2$$

(Stress value for 100*100 Square Tube)

Fmax= 6686.53 N

$$\sigma_F = F_{max} / A = 6686.53 / 1161.424 = 5.76$$

$$\sigma_F = 5.76 < (240/1.67) = 143.71 \text{ N/mm}^2$$

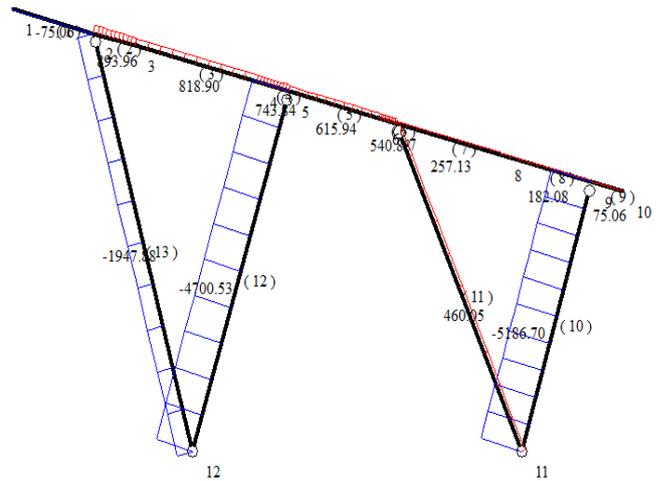
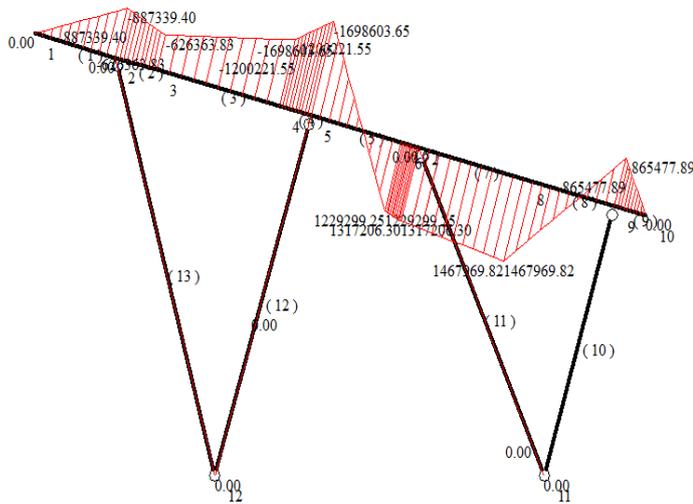
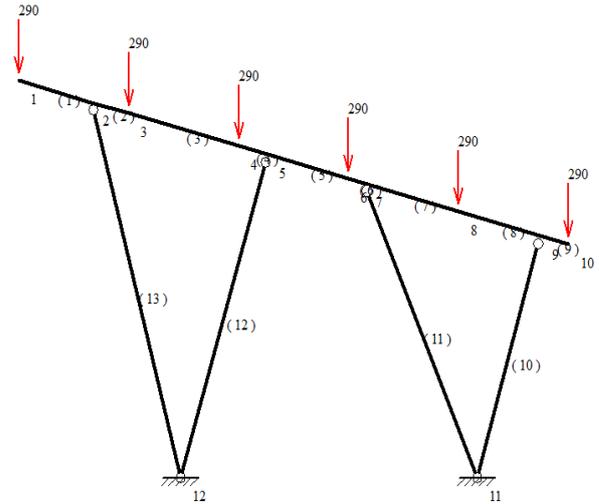
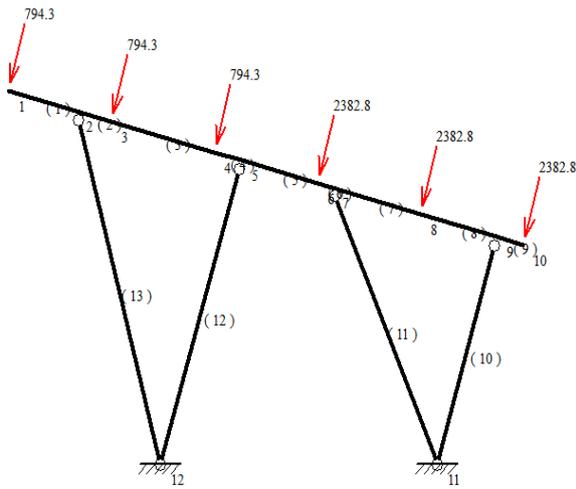
Wind blowing to the front of the modules:

$$W_{NL} = F1 / 6 / 2 = 9531.3499 / 6 / 2 = 794.3 \text{ N}$$

$$W_{Nw} = F1 / 6 / 2 = 28594.0498 / 6 / 2 = 2382.8 \text{ N}$$

$$G_{NL} = F1 / 6 / 2 = 3479.5788 / 6 / 2 = 290.0 \text{ N}$$

$$G_{Nw} = F1 / 6 / 2 = 3479.5788 / 6 / 2 = 290.0 \text{ N}$$



(Stress value for Beam 160)

$M_{max} = 1698603.65 \text{ N}\cdot\text{mm}$

$\sigma_M = M_{max}/W_X = 1698603.65 / 75497.03 = 22.499$

$F_{max} = 893.96 \text{ N}$

$\sigma_F = F_{max}/A = 893.96 / 1668.98 = 0.536$

$\sigma_{all} = \sigma_M + \sigma_F = 23.035 < (240/1.67) = 143.71 \text{ N}/\text{mm}^2$

(Stress value for 100*100 Square Tube)

$F_{max} = 5186.70 \text{ N}$

$\sigma_F = F_{max}/A = 5186.70 / 1161.42 = 4.47$

$\sigma_F = 4.47 < (240/1.67) = 143.71 \text{ N}/\text{mm}^2$

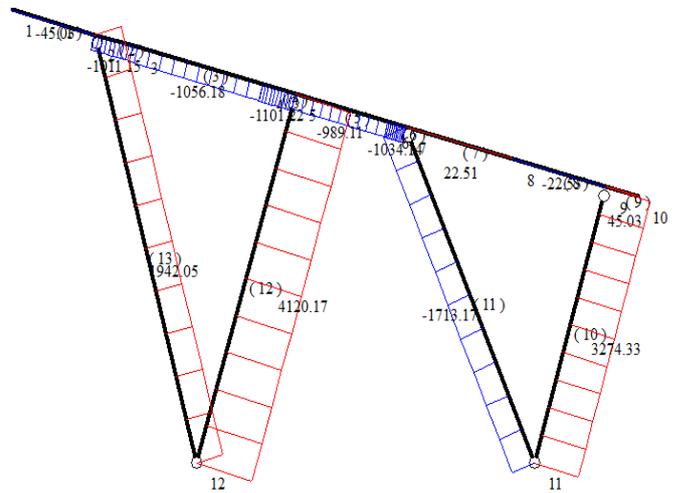
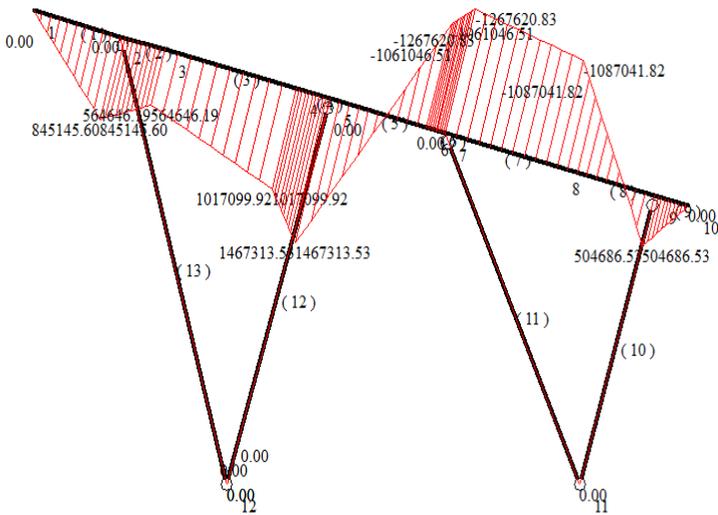
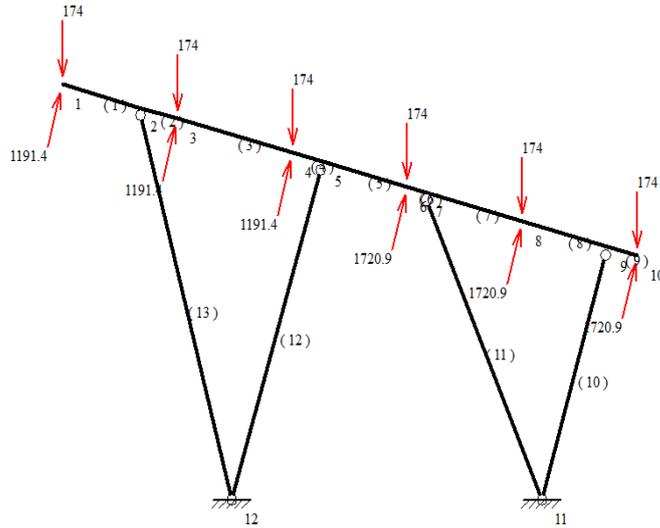
Wind blowing to the back of the modules:

$W_{NW} = F1 / 6 / 2 = -14297.0249 / 6 / 2 = -1191.4 \text{ N}$

$W_{NL} = F1 / 6 / 2 = -20651.2582 / 6 / 2 = -1720.9 \text{ N}$

$G_{NW} = F1 / 6 / 2 = 2087.7473 / 6 / 2 = 174.0 \text{ N}$

$G_{NL} = F1 / 6 / 2 = 2087.7473 / 6 / 2 = 174.0 \text{ N}$



(Stress value for Beam 160)

Mmax= 1467313.53 N·mm

$$\sigma_M = M_{max} / W_X = 1467313.53 / 75497.03 = 19.44$$

Fmax= 1101.22 N

$$\sigma_F = F_{max} / A = 1101.22 / 1668.98 = 0.66$$

$$\sigma_{all} = \sigma_M + \sigma_F = 20.095 < (240/1.67) = 143.71 \text{ N/mm}^2$$

(Stress value for 100*100 Square Tube)

Fmax= 4120.17 N

$$\sigma_F = F_{max} / A = 4120.17 / 1161.42 = 3.55$$

$$\sigma_F = 3.55 < (240/1.67) = 143.71 \text{ N/mm}^2$$

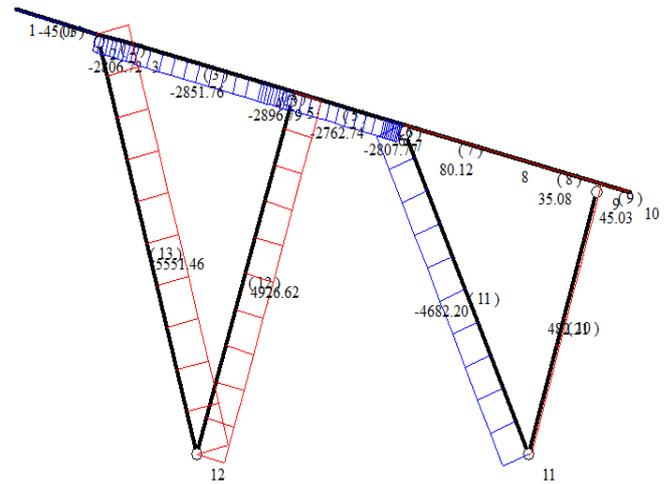
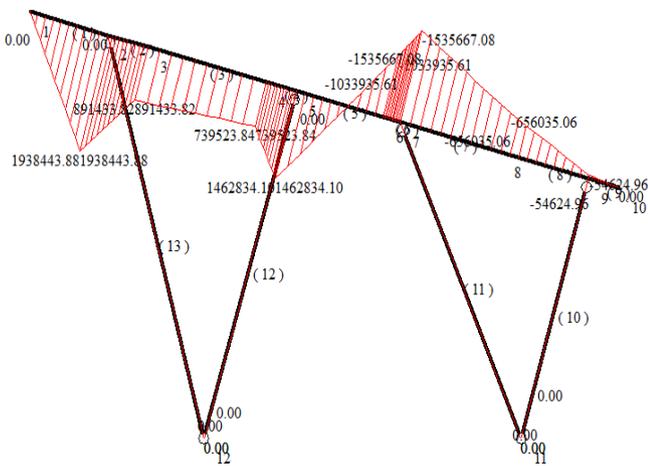
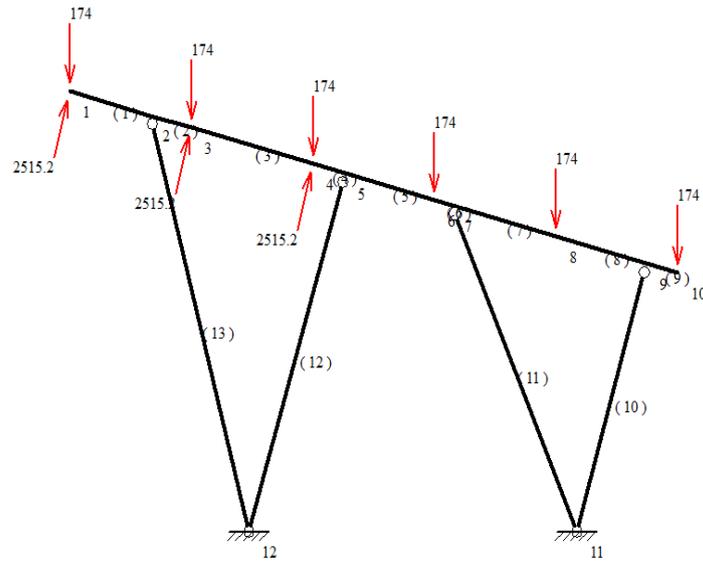
Wind blowing to the back of the modules:

$$W_{NW} = F1 / 6 / 2 = -30182.6082 / 6 / 2 = -2515.2 \text{ N}$$

$$W_{NL} = F1 / 6 / 2 = 0.0000 / 6 / 2 = 0.0 \text{ N}$$

$$G_{NW} = F1 / 6 / 2 = 2087.7473 / 6 / 2 = 174.0 \text{ N}$$

$$G_{NL} = F1 / 6 / 2 = 2087.7473 / 6 / 2 = 174.0 \text{ N}$$



(Stress value for Beam 160)

Mmax= 1938443.88 N·mm

$$\sigma_M = M_{max} / W_X = 1938443.88 / 75497.03 = 25.68$$

Fmax= 2896.79 N

$$\sigma_F = F_{max} / A = 2896.79 / 1668.98 = 1.74$$

$$\sigma_{all} = \sigma_M + \sigma_F = 27.411 < (240 / 1.67) = 143.71 \text{ N/mm}^2$$

(Stress value for 100*100 Square Tube)

Fmax= 5551.46 N

$$\sigma_F = F_{max} / A = 5551.46 / 1161.42 = 4.78$$

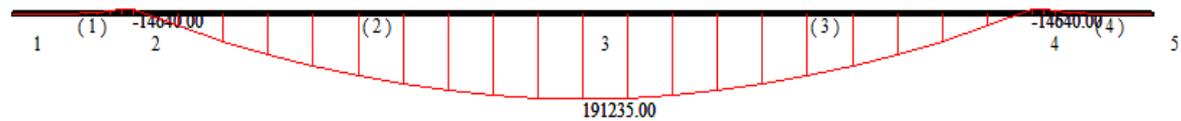
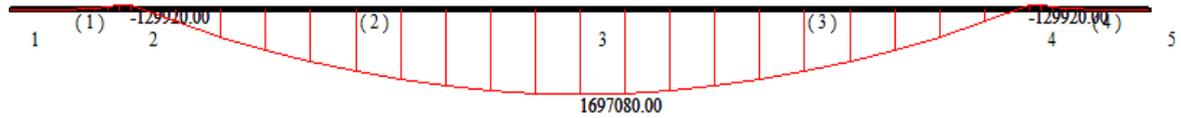
$$\sigma_F = 4.78 < (240 / 1.67) = 143.71 \text{ N/mm}^2$$

3.2 Calculation Conclusion of Wide Rail 130

$F1(x) = 1.62 \text{ N/mm}$

$F1(y) = 0.18 \text{ N/mm}$

(In downwind condition, the average load on beam)



$M_{max} = 1697080 \text{ N}\cdot\text{mm}$

$\sigma = M_{max}/WX = 1697080 / 33332.140 = 50.914$

$M_{max} = 191235 \text{ N}\cdot\text{mm}$

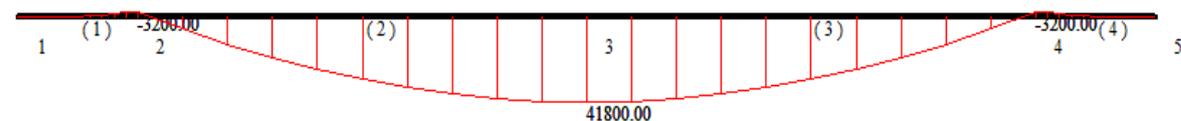
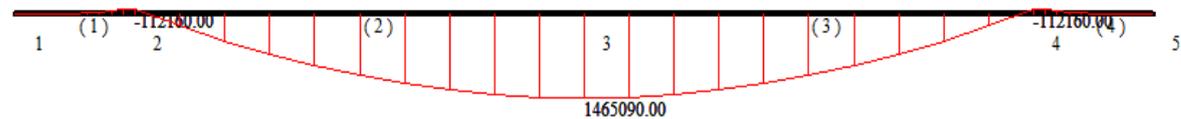
$\sigma = M_{max}/WX = 191235 / 18569.017 = 10.299$

$\sigma_{all} = \sigma_M + \sigma_F = 61.21 < (240/1.67) = 143.71 \text{ N/mm}$ (Stress value for Wide Rail 130)

$F1(x) = 1.4 \text{ N/mm}$

$F1(y) = 0.04 \text{ N/mm}$

(In downwind condition, the average load on beam)



$M_{max} = 1465090 \text{ N}\cdot\text{mm}$

$\sigma = M_{max}/WX = 1465090 / 33332.140 = 43.954$

$M_{max} = 41800 \text{ N}\cdot\text{mm}$

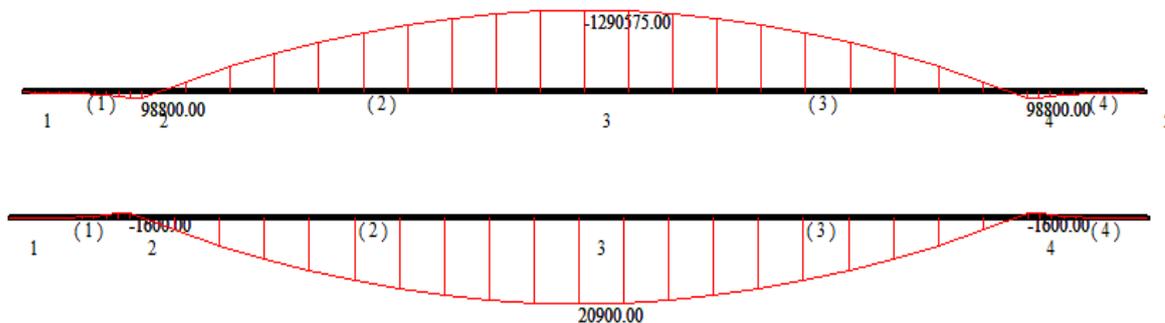
$\sigma = M_{max}/WX = 41800 / 18569.017 = 2.2511$

$\sigma_{all} = \sigma_M + \sigma_F = 46.21 < (240/1.67) = 143.71 \text{ N/mm}$ (Stress value for Wide Rail)

$F1(x) = -1.24 \text{ N/mm}$

$F1(y) = 0.02 \text{ N/mm}$

(In headwind condition, the average load on beam)



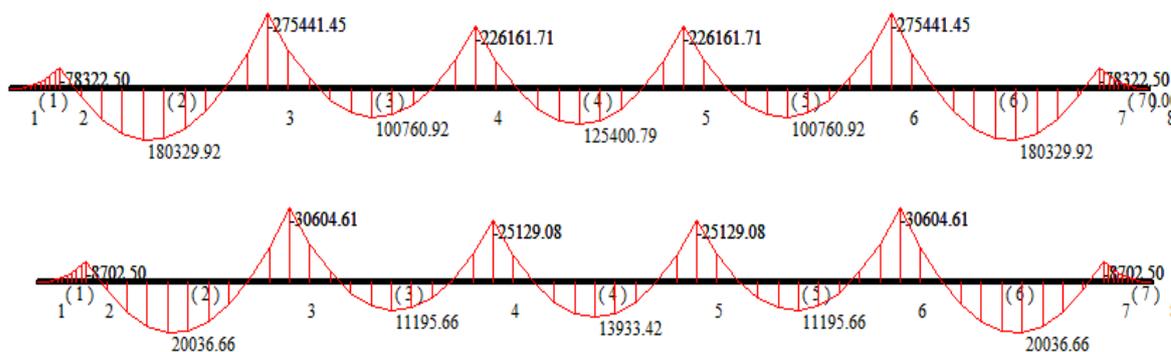
$$\begin{aligned}
 &M_{\max} = 1290575 \quad \text{N}\cdot\text{mm} \\
 &\sigma = M_{\max}/WX = 1290575 / 33332.140 = 38.719 \\
 &M_{\max} = 20900 \quad \text{N}\cdot\text{mm} \\
 &\sigma = M_{\max}/WX = 20900 / 18569.017 = 1.1255 \\
 &\sigma_{\text{all}} = \sigma_M + \sigma_F = 39.84 < (240/1.67) = 143.71\text{N/mm} \quad (\text{Stress value for Wide Rail 130})
 \end{aligned}$$

3.3 Calculation conclusion of BIPV Mounting Rail

$$F2(x) = 1.80 \text{ N/mm}$$

$$F2(y) = 0.20 \text{ N/mm}$$

(In downwind condition, the average load on beam)

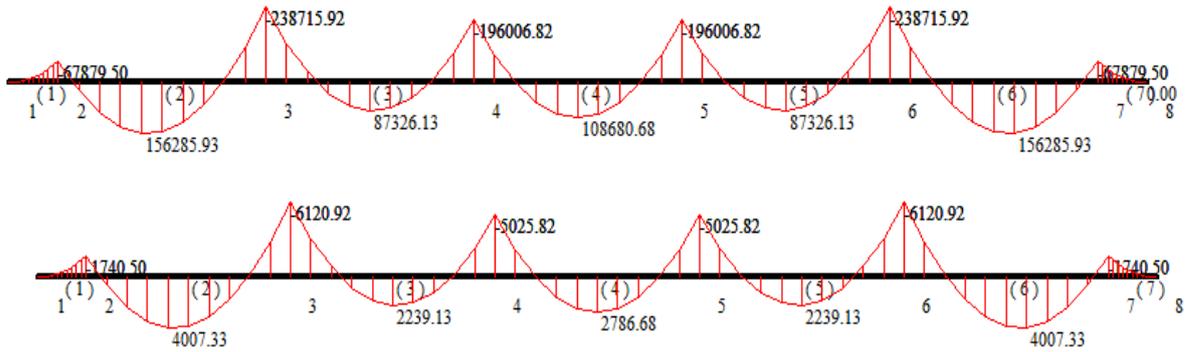


$$\begin{aligned}
 &M_{\max} = 275441.45 \quad \text{N}\cdot\text{mm} \\
 &\sigma = M_{\max}/WX = 275441.45 / 4370.343 = 63.025 \\
 &M_{\max} = 30604.61 \quad \text{N}\cdot\text{mm} \\
 &\sigma = M_{\max}/WX = 384016.718 / 11413.539 = 33.646 \\
 &\sigma_{\text{all}} = \sigma_M + \sigma_F = 96.67 < (240/1.67) = 143.71\text{N/mm} \quad (\text{Stress value for BIPV Mounting Rail})
 \end{aligned}$$

$$F2(x) = 1.56 \text{ N/mm}$$

$$F2(y) = 0.04 \text{ N/mm}$$

(In downwind condition, the average load on beam)

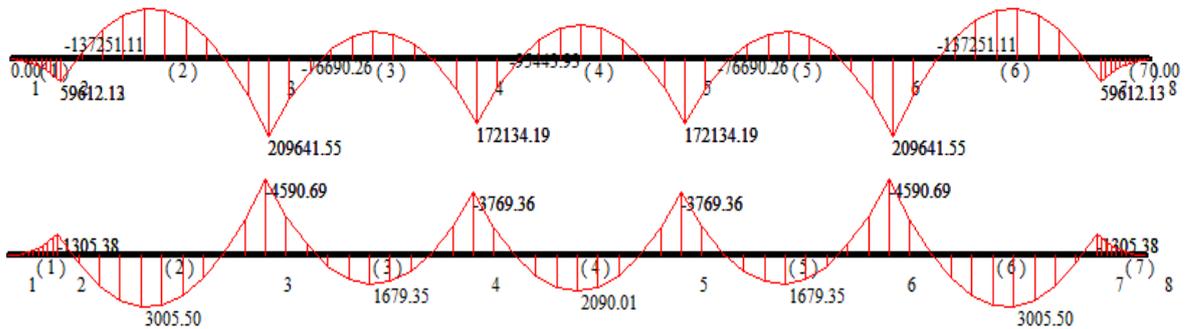


Mmax 238715.92 N-mm
 $\sigma = M_{max}/WX = 238715.92 / 4370.343 = 54.622$
 Mmax 6120.92 N-mm
 $\sigma = M_{max}/WX = 6120.92 / 11413.539 = 0.5363$
 $\sigma_{all} = \sigma_M + \sigma_F = 55.16 < (240/1.67) = 143.71 \text{ N/mm}$ (Stress value for BIPV Mounting Rail)

F2(x)= -1.37 N/mm

F2(y)= 0.03 N/mm

(In headwind condition, the average load on beam)



Mmax 209641.55 N-mm
 $\sigma = M_{max}/WX = 209641.55 / 4370.343 = 47.969$
 Mmax 4590.69 N-mm
 $\sigma = M_{max}/WX = 4590.69 / 11413.539 = 0.4022$
 $\sigma_{all} = \sigma_M + \sigma_F 4 = 48.37 < (240/1.67) = 143.71 \text{ N/mm}$ (Stress value for BIPV Mounting Rail)

Summary

(a) For tensile yielding in the gross section :

$$P_u = F_y A_g$$

$$\phi_t = 0.90 \text{ (LRFD)} \quad \Omega_t = 1.67 \text{ (ASD)}$$

$\Omega = 1.67$

Items	Calculated Permissible Strength			bending strength
Wide Rail 130	61.21	≤	143.71	240
BIPV Mounting Rail	96.67	≤	143.71	240
Beam 160	33.37	≤	143.71	240
Square Tube	5.76	≤	143.71	240