Structural Calculation Report SAP2000-EU EN-1991

2020

1. Considered Standard

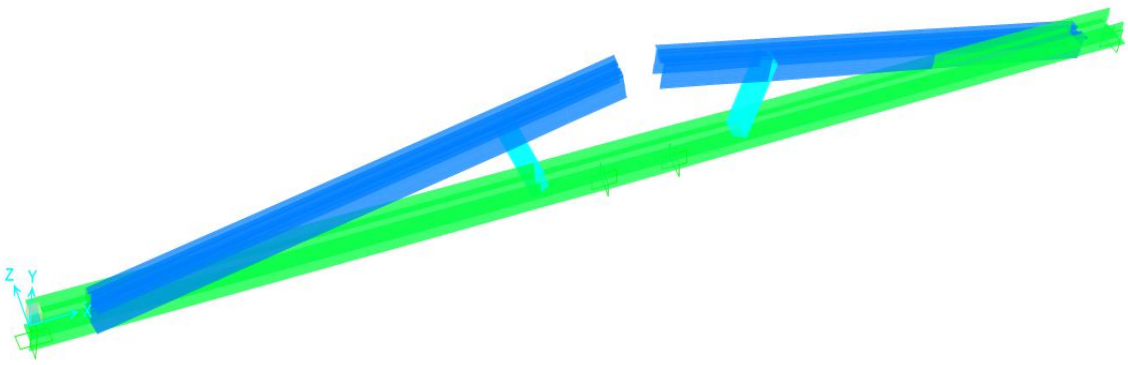
EN.1991.1.1.2002 General actions - Densities, self-weight, imposed loads for buildings
EN.1991.1.2.2002 General actions - Actions on structures exposed to fire
EN.1991.1.3.2003 General actions - Snow loads
EN.1991.1.4.2005 General actions - Wind actions
EN.1991.1.5.2003 General actions - Thermal actions
EN.1991.1.6.2005 General actions- Actions during execution
EN.1991.1.7.2006 General actions - Accidental actions
ENV1993-1-1:1992

2. Programme version

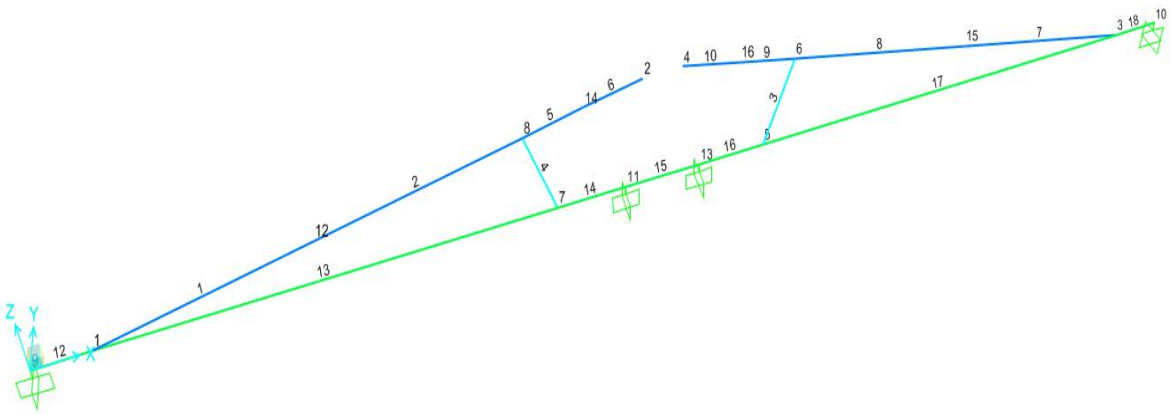
Table: Program Control

ProgramName	Version	ProgLevel	LicenseOS	LicenseSC	CurrUnits	SteelCode
SAP2000	15.1.1	Ultimate	Yes	Yes	N, mm, C	Chinese 2010

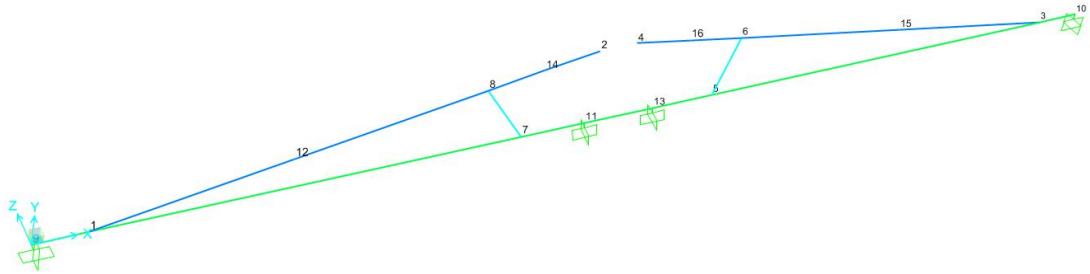
3. Model



4. Components#:



5. Nodes #:



6. Node constraint:

Table: Joint Restraint Assignments

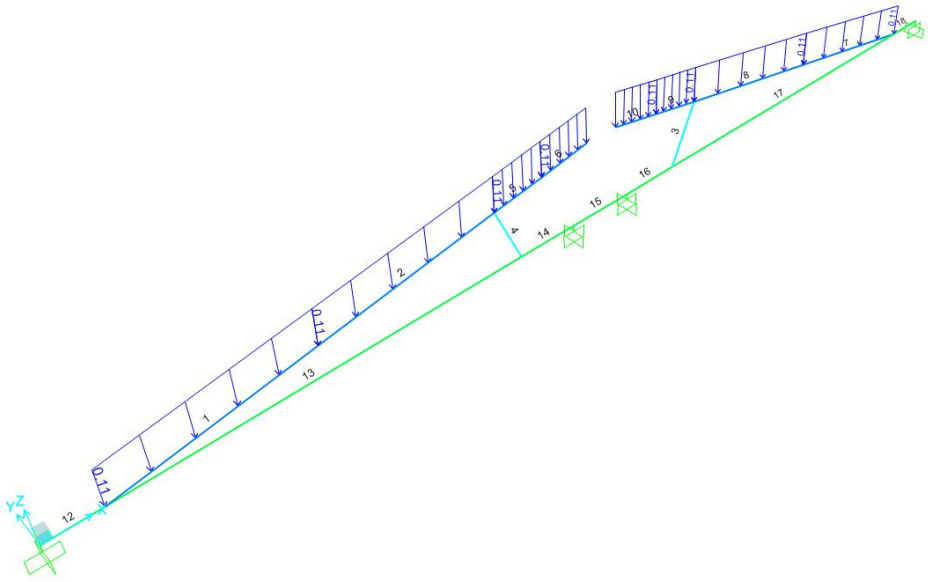
Joint	U1	U2	U3	R1	R2	R3
5	Yes	Yes	Yes	Yes	Yes	Yes
7	Yes	Yes	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes	Yes	Yes

7. Component Section:

8. Load Exertion：

1) Load（DEAD）：

Main Beam Dead Load(Linear distribution)：DEAD= $\frac{22*9.8}{2*1002}=0.11$ n/mm



2) Wind Load（Wind-36.2）：

According to EN.1991.1.4.2005 chapter 4.5“Peak velocity pressure”，Eq.（4.8）：

1) Structural design actions - Wind actions Calculated basic wind pressure：

$$q_p(z)=[1+7\cdot I_V(z)]\cdot\frac{1}{2}\cdot\rho\cdot V_m^2(z)$$ = (1+7*0.36)*0.5*1.25*20.77*20.77=949.06 N/m2

where：

ρ：Air Density，Suggested value1.25kg/m3;

$I_V(z)$：turbulence intensity；

湍流密度 $I_V(z)$	0.361
紊流因子 K_I	1
地形因子 $C_0(z)$	1
建筑高度（m）z	16
粗糙高度（m）z_0	1
最大高度（m）z_{max}	200
最小高度（m）z_{min}	10

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NOTE 2 The recommended rules for the determination of $I_v(z)$ are given in Expression (4.7)

$$I_v(z)=\frac{\sigma_v}{v_m(z)}=\frac{k_I}{c_0(z)\cdot\ln(z/z_0)} \quad \text{for} \quad z_{min}\le z\le z_{max} \qquad (4.7)$$

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

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_0 is the orography factor as described in 4.3.3

z_0 is the roughness length, given in Table 4.1

湍流密度（turbulence intensity）$I_V(z)$：

$$I_V(z)=\frac{\sigma_V}{V_m(z)}=\frac{k_I}{C_0(z)\cdot\ln(z/z_0)} \quad for\ z_{min}\le z\le z_{max}$$

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

式中：

$\sigma_V=K_r\cdot V_b\cdot K_I$ 标准偏差（standard deviation）；

K_I：紊流因子（turbulence factor），建议取值 1.0；

$$V_m(z)=C_r(z)\cdot C_0(z)\cdot V_b$$ =0.649*1*32=20.77 m/s

where：

$C_r(z)$：Roughness Factor，Sec. 4.3.2 -A；

According to EN.1991.1.4.2005 第 4.3.2 节：The roughness of the terrain is determined according to the height and roughness of the building.：

$$C_r(z)=K_r\cdot\ln(\frac{z}{z_0}) \quad for\ z_{min}\le z\le z_{max}$$ =0.234*ln(16/1)=0.649

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

式中：

z_0：roughness length）（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.			

K_r： terrain factor（Table 4.1）；

$$k_r = 0.19 \cdot (\frac{z_0}{z_{0,II}})^{0.07}$$ =0.19*((1.0/0.05)^ 0.07)=0.234

$z_{0,II}$： = 0.05 m (terrain category II, Table 4.1)；

z_{min}： minimum height（Table 4.1）； take 16m；

z_{max}： maximum height，take 200；

2) Calculate wind load：

$W_e = q_p(z_e) \cdot C_{pe}$ =0.85*949.06 =806.7 N/m2

式中：

$q_p(z_e)$： peak velocity pressure；

z_e：reference height；The ground height of a building at a general value；

C_{pe}： pressure coefficient；According to Section 7 The main parameters are shown in the figure below: this project tilts 10 degrees taken value of -0.85,

；

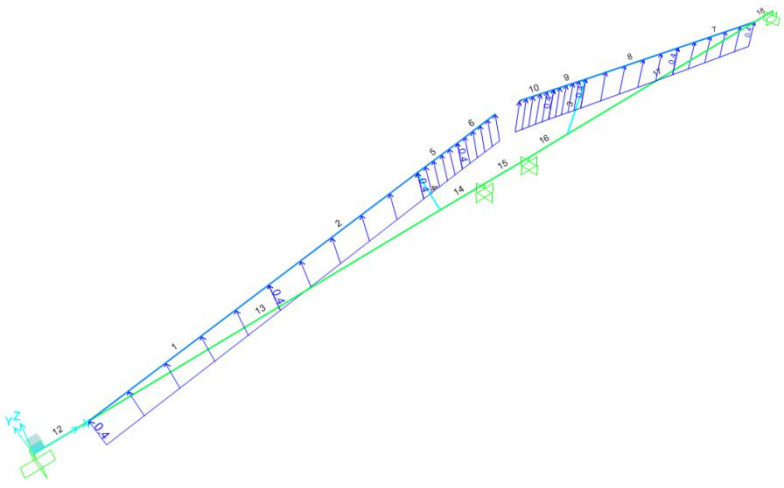
Table 7.3a — Recommended values of external pressure coefficients for monopitch roofs

Pitch Angle α	Zone for wind direction θ = 0°						Zone for wind direction θ = 180°					
	F		G		H		F		G		H	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-2,3	-2,5	-1,3	-2,0	-0,8	-1,2
	+0,0		+0,0		+0,0							
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-2,5	-2,8	-1,3	-2,0	-0,9	-1,2
	+0,2		+0,2		+ 0,2							
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-1,1	-2,3	-0,8	-1,5	-0,8	
	+0,7		+0,7		+0,4							
45°	-0,0		-0,0		-0,0		-0,6	-1,3	-0,5		-0,7	
	+0,7		+0,7		+0,6							
60°	+0,7		+0,7		+0,7		-0,5	-1,0	-0,5		-0,5	
75°	+0,8		+0,8		+0,8		-0,5	-1,0	-0,5		-0,5	

3) Main Beam Wind Load（Linear Distribution）：

Wind= $\frac{806.7*1.002*1.684}{1.684*2*1000} = 0.404$ n/mm

The wind load is suction (the angle is small there for average suction force):



4) Snow Load(Snow-1.8)

According to Eurocode 1 - Actions on structures - Part 1-3: General actions -Snow loads： Section 5 “Snow load on roofs” we know：

$s = \mu_i C_e C_t s_k$ =0.8*0.9*1.0*2.3=1.66kN/m2

where：

μ_i：Shape coefficient；（Section5.3 和附录 B）Accord to EN.1991.1.3.2003 Chapter 5.3 节：“Roof shape coefficients”is0.8；C_e：exposure coefficient；According to EN.1991.1.3.2003table 5.1 taken，0.5×(1+0.8)=0.9；C_t：thermal coefficient；is 1.0；

Table 5.2: Snow load shape coefficients

Angle of pitch of roof α	$0° \le \alpha \le 30°$	$30° < \alpha < 60°$	$\alpha \ge 60°$
μ_1	0,8	0,8(60 - α)/30	0,0
μ_2	0,8 + 0,8 α/30	1,6	--

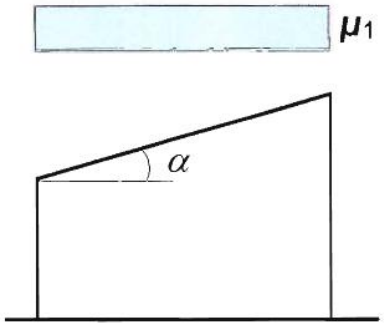


Table 5.1 Recommended values of C_e for different topographies

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.

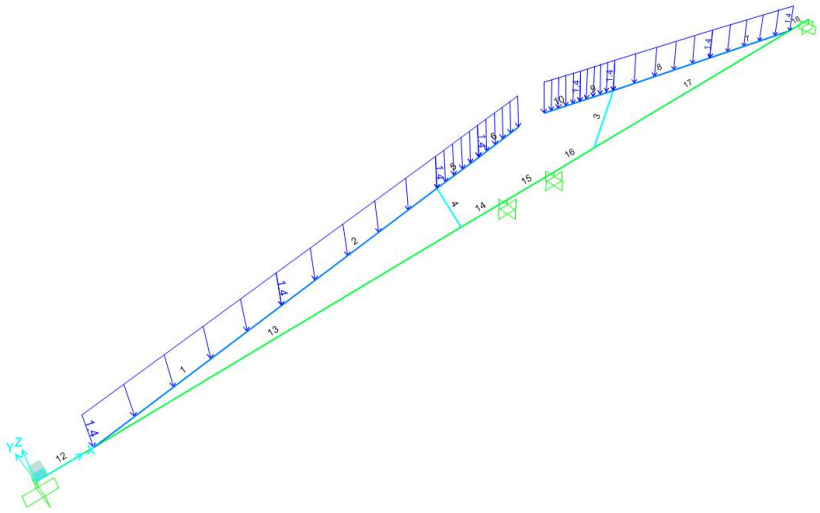
[b] *Normal topography*: areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees.

[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.

Taking into account the effect of wind on snow loads， C_e value is 0.5*(1+0.8)=0.9

Main beam snow load (linear distribution)：

Snow=$\dfrac{1.66*1.684*1.002}{2*1.002}=1.4$ N/MM



9. Load Combination

According to ENV1993-1-1:1992 The load combination is used as follows :

Table 2.2 Partial safety factors for actions on building structures for persistent and transient design situations

	Permanent actions (γ_G)	Variable actions (γ_Q)	
		Leading variable action	Accompanying variable actions
Favourable effect $\gamma_{F,inf}$	1,0 *)	-**)	-**)
Unfavourable effect $\gamma_{F,sup}$	1,35 *)	1,5	1,5

*) See also 2.3.3.1(3)
**) See Eurocode 1; in normal cases for building structures $\gamma_{Q,inf} = 0$.

(2) Three combinations of actions for serviceability limit states are defined by the following expressions:

Rare combination:

$$\sum_j G_{k,j} + Q_{k,1} + \sum_{i>1} \psi_{0,i} Q_{k,i} \qquad (2.14)$$

Frequent combination:

$$\sum_j G_{k,j} + \psi_{1,1} Q_{k,1} + \sum_{i>1} \psi_{2,i} Q_{k,i} \qquad (2.15)$$

Quasi-permanent combination:

$$\sum_j G_{k,j} + \sum_{i\geq 1} \psi_{2,i} Q_{k,i} \qquad (2.16)$$

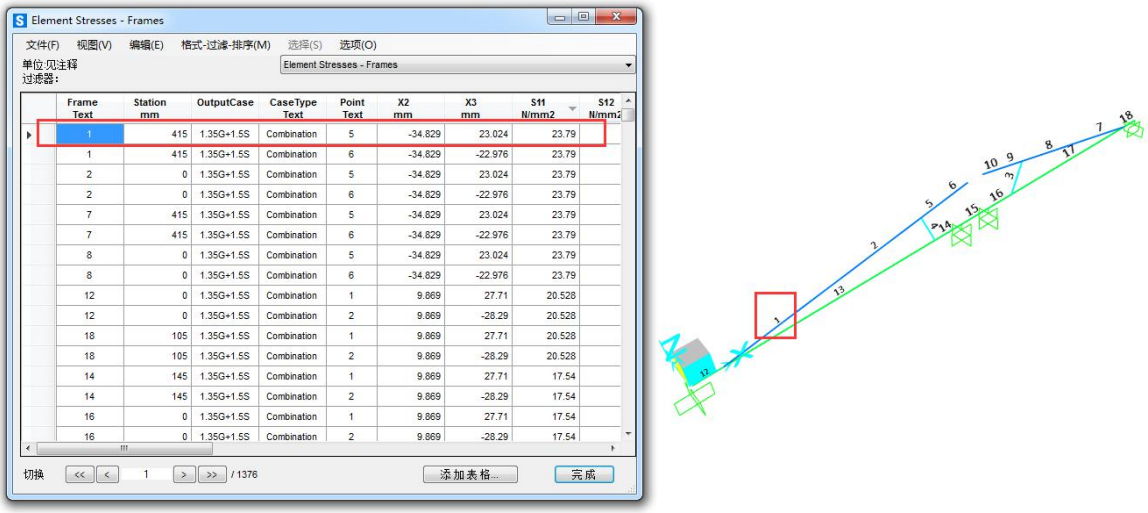
where the notation is defined in 2.3.2.2(2)

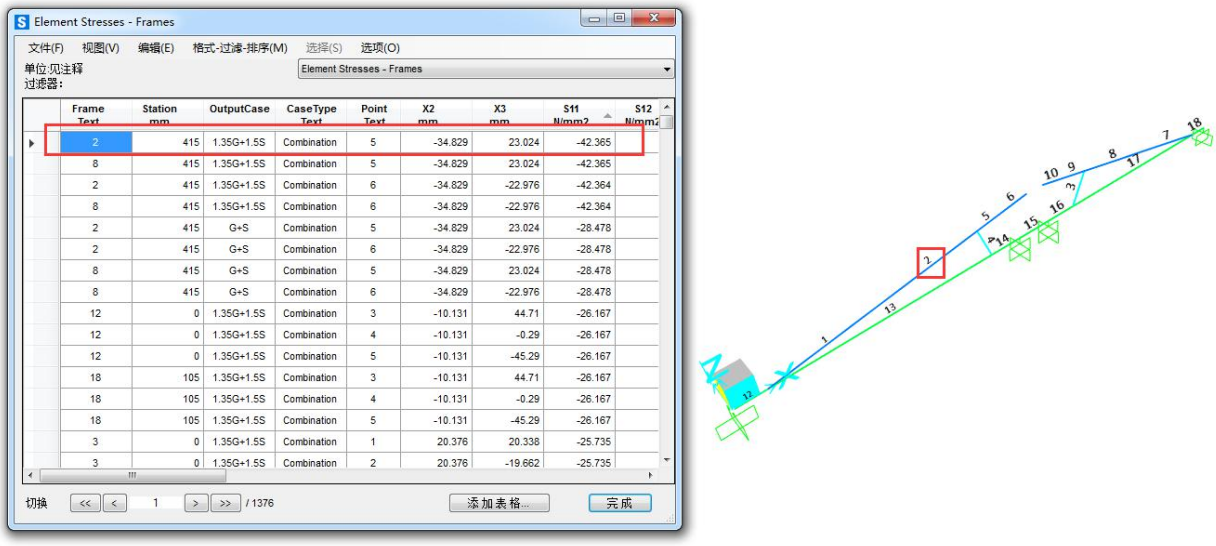
Table: Combination Definitions

ComboName	CaseName	ScaleFactor	remarks
COMB1	DEAD	1.000000	strength
COMB1	Wind	1.500000	
COMB2	DEAD	1.350000	
COMB2	Snow	1.500000	
COMB3	DEAD	1.000000	deformation
COMB3	Snow	1.000000	
COMB4	DEAD	1.000000	
COMB4	Wind	1.000000	

Calculation Result

1）Component Stress：





Maximum Stress on Main Beam 42.365 Mpa < 225

It can be seen by calculation: the structure stress in 2 operating conditions meet the requirements, the maximum stress on structure is mainly concentrated in the illustrated member：

2）Cross-medium deflection：

GenDispl	DisplType	OutputCase	Translation	GenDispl	DisplType	OutputCase	Translation
			mm				mm
9	Translation	COMB3	0	12	Translation	COMB4	0.092064
10	Translation	COMB3	0	15	Translation	COMB4	0.092064
11	Translation	COMB3	0	6	Translation	COMB4	0.020919
13	Translation	COMB3	0	8	Translation	COMB4	0.020919
1	Translation	COMB3	-0.106333	5	Translation	COMB4	0.018105
3	Translation	COMB3	-0.106333	7	Translation	COMB4	0.018105
2	Translation	COMB3	-0.108017	14	Translation	COMB4	0.016767
4	Translation	COMB3	-0.108017	16	Translation	COMB4	0.016767
14	Translation	COMB3	-0.114812	2	Translation	COMB4	0.016576
16	Translation	COMB3	-0.114812	4	Translation	COMB4	0.016576
5	Translation	COMB3	-0.123631	1	Translation	COMB4	0.015699
7	Translation	COMB3	-0.123631	3	Translation	COMB4	0.015699
6	Translation	COMB3	-0.143731	9	Translation	COMB4	0
8	Translation	COMB3	-0.143731	10	Translation	COMB4	0
12	Translation	COMB3	-0.565759	11	Translation	COMB4	0
15	Translation	COMB3	-0.565759	13	Translation	COMB4	0

The test point position is shown as shown, the displacement is not exceeded by the limit L/200;(Due to the interaction between the Main Beam and the PV panel in real situation, the trans-middle displacement tends to be reduced)

12.Conclusion：

1) Under the combined effect of component constant load and wind load, the deflection of the bracket by bending member is less than 1/200 over the span;Meet the conditions;

2) Components used: Bottom beam, Main beam, Support use 6005-T5 aluminum to meet the conditions;

3) The bottom beam, main beam, support and other cross-sections meet the conditions.