PROJECT: STAVROS NIARCHOS FOUNDATION CULTURAL CENTER

DESIGN ANALYSIS

''RENZO PIANO SNFCC – CUSTOM MADE "GLASSCON FAÇADE SYSTEM''

SAMPLE – NOT FOR USE

CONTENTS

1. Technical Description - Assumptions

1.1 Technical Description

The subject of the present study is the structural design of the custom made glass facade system FT 03 in Stavros Niarchos Foundation Cultural Center (SNFCC). Facade system consists of glass panels (two panes of 2x6mm thick HS glass form a glass panel) supported by a grid of aluminium and steel profiles. Width and height of a typical glass panel equal to 1250mm and 3000mm respectively. Dimensions of the abovementioned structures are shown in detail in the submitted system drawings.

Glass panel analysis is carried out using software SAP2000, v.17.1.1. Discretisation follows a grid of 250x250mm. Different pane thickness is used for ULS and SLS analysis and checks, as it will be calculated in paragraph 1.4.2. Nevertheless, both sub-models (ULS and SLS) are presented independently in the same model (glass_facade.sdb). Only one pane of each panel is modeled, due to symmetric distribution of wind loads in each pane (see DIN 18008-2). Aluminium column analysis as well as all checks is conducted using analytical equations.

1.2 Design Standards and Norms

prEN 13474-3	Glass in building – Determination of the strength of glass panes – Part 3:General method of calculation and determination of strength of glass by testing
DIN 18008-1	Glass in Building - Design and construction rules: Terms and general bases
DIN 18008-2	Glass in Building - Design and construction rules: Linearly supported glazings

1.3 Loads - Load Combinations

- Wind loads according to wind tunnel test:

❖ Wind pressure at peak velocity

$q_p(z) = 1.760$ kN/m²

❖ External pressure coefficient $c_{p,e}$

$c_{p,e} = 1.20$

The following combinations are considered:

$1.35xG + 1.50xW$ (Ultimate Limit State - ULS)

$G + W$ (Serviceability Limit State - SLS)

Where "G" represents self weight loads and "W" represents wind loads.

More specifically, for each structure we obtain:

Glass pane:

G: Self weight

W = $c_{p,e}$ x $q_p(z)$ /2 = 1.20x1.76/2 = 1.056 kN/m^2

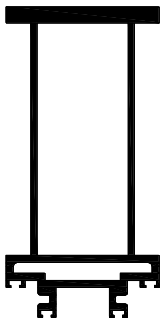
Aluminium Column:

G = $G_{,alum.members}$ + $G_{,glass}$ = 0.419+2.55 = 2.969 kN

W = $c_{p,e}$ x $q_p(z)$ x $s_{,infl.}$ = 1.20x1.76x1.25 = 2.64 kN/m

1.4 Frame and Area Sections

1.4.1 Aluminium column section



A= 21.26 cm^2
$W_{y,el}$= 86.22 cm^3
$W_{z,el}$= 29.72 cm^3
I_y= 700.61 cm^4
I_z= 114.42 cm^4
i_y= 5.74 cm
i_z= 2.32 cm

1.4.2 Laminated Glass Section

The laminated section comprises of 2 layers of heat strengthened glass of thickness **6.0 mm** each and 1 PVB interlayer of thickness **1.60 mm**.

The effective thickness, according to prEN 13474-3, § 9.2 is calculated as following:

$h_{ef,w} = \sqrt[3]{(1-\omega)\cdot\sum_i h_i{}^3 + \omega\cdot(\sum_i h_i)^3}$ for calculating bending deflection and

$$h_{ef,\sigma,j} = \sqrt{\frac{h_{ef,w}{}^3}{(h_j + 2\cdot\omega\cdot h_{m,j})}}$$

for calculating the stress of glass ply number j, where:

- ω = 0.25 (Table 12)

- $h_i = h_j = 6.0$ mm
- $h_{m,j} = 3.0$ mm, is the distance between mid-plane of each glass and mid-plane of laminated glass

We obtain:

$h_{ef,w}$ = 9.11 mm and

$h_{ef,\sigma,1} = h_{ef,\sigma,2}$ = 10.04 mm

1.5 Material Properties

	Modulus of Elasticity E (GPa)	Poisson Ratio ν (-)	Density ρ (kg/m³)
Steel S235	210.0	0.30	7850.0
Aluminium EN AW 6060-T66	70.0	0.30	2700.0
Glass	70.0	0.23	2500.0

2. <u>Checks</u>

2.1 Design of aluminium members according to ΕΛΟΤ EN 1999-1-1:2007

2.1.1 Main column design

LC :ULS

$M_{y,Ed}$= 4.46 kNm
$M_{z,Ed}$= 0.00 kNm
$V_{z,Ed}$= 5.94 kN
$V_{y,Ed}$= 0.00 kN
N_{Ed}= -4.01 kN

2.1.1.1 Compression

$N_{Ed}/N_{c,Rd} \leq 1.00$= [1.5%]
$N_{c,Rd} = \min\{N_{c,Rd}, N_{u,Rd}\}$= 265.77kN
$N_{u,Rd} = A_{net} \cdot f_u/\gamma_{M2}$ = 319.18kN
$N_{c,Rd} = A_{eff} \cdot f_o/\gamma_{M1}$ = 265.77kN

2.1.1.2 Bending Moment

$M_{Ed}/M_{Rd} \leq 1.00=$ [39.1%]
$M_{Rd} = \min\{M_{c,Rd}, M_{u,Rd}\}=$ 11.40kNm
$M_{u,Rd} = W_{net} \cdot f_u/\gamma_{M2} =$ 12.11kNm
$M_{c,Rd} = \alpha \cdot W_{el} \cdot f_o/\gamma_{M1} =$ 11.40kNm

2.1.1.3 Shear

$V_{Ed}/V_{Rd} \leq 1.00=$ [8.8%]

$V_{Rd} = A_V \cdot \frac{f_o}{\gamma_{M1} \cdot \sqrt{3}}=$ 67.60kN

2.1.1.4 Bending and Shear

$f_{o,V} = f_o \cdot (1 - (2 \cdot V_{Ed}/V_{Rd} - 1)^2)=$ 150.0MPa
$M_{V,Rd} = \alpha \cdot W_{el} \cdot f_{o,V}/\gamma_{M1}=$ 11.40kNm

2.1.1.5 Buckling of members in axial compression

$N_{Ed}/N_{b,Rd} \leq 1.00=$ [5.7%]
$N_{b,Rd} = \kappa \cdot \chi \cdot A_{eff} \cdot f_o/\gamma_{M1}=$ 69.90kN

2.1.1.6 Buckling of members in bending and axial compression

Hollow Sections and Solid cross-sections

$$\left(\frac{N_{Ed}}{\chi_{min} \cdot \omega_x \cdot N_{Rd}}\right)^{\psi_c} + \frac{1}{\omega_o} \cdot \left[\left(\frac{M_{y,Ed}}{M_{y,Rd}}\right)^{1,7} + \left(\frac{M_{z,Ed}}{M_{z,Rd}}\right)^{1,7}\right]^{0,6} \leq 1.00 = \text{ [48.8\%]}$$

2.1.2 Serviceability checks

LC: SLS → w = 0.0057m < L/250 = 3.00/250 = 0.0120m

2.1.3 Connection checks

Aluminium column connection to steel U-section

$F_{H,Ed}$ = 5.94 kN

$F_{V,Ed}$ = 4.01 kN

2 bolts M8 (8.8)

$F_{V,Rd}$ = 28.20 kN > $F_{V,Ed}$ O.K.

$F_{b,Rd}$ = 24.98 kN > $F_{V,Ed}$ O.K.

$F_{t,Rd}$ = 42.20 kN > $F_{H,Ed}$ O.K.

$B_{p,Rd}$ = 65.84 kN > $F_{H,Ed}$ O.K.

Steel U-section connection to steel frame

$F_{H,Ed}$ = 4.75 kN/m

$F_{V,Ed}$ = 3.21 kN/m

bolts M8 with spacing 40cm (M8/40) - (8.8)

$F_{V,Rd}$ = 35.25 kN/m > $F_{H,Ed}$ O.K.

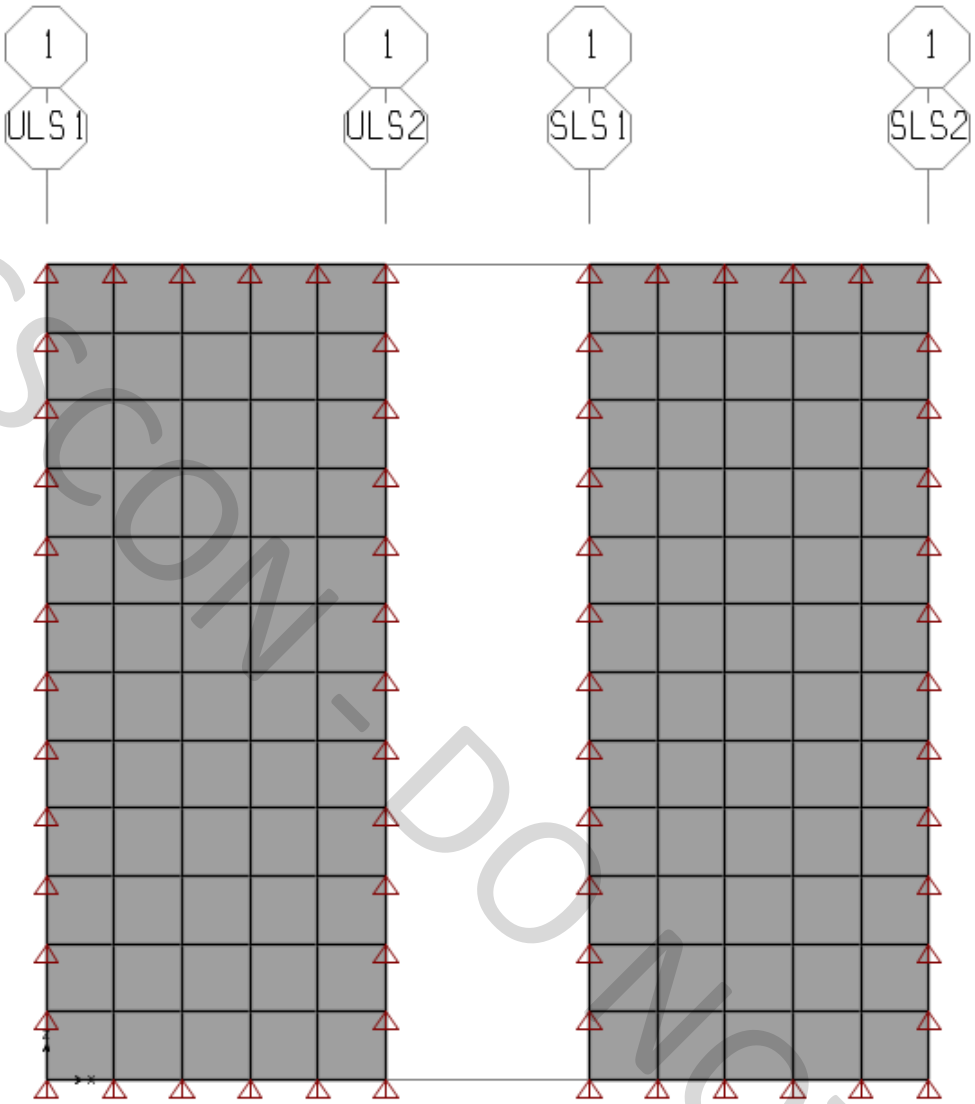
$F_{b,Rd}$ = 28.80 kN/m > $F_{H,Ed}$ O.K.

$F_{t,Rd}$ = 52.75 kN/m > $F_{V,Ed}$ O.K.

$B_{p,Rd}$ = 75.96 kN/m > $F_{V,Ed}$ O.K.

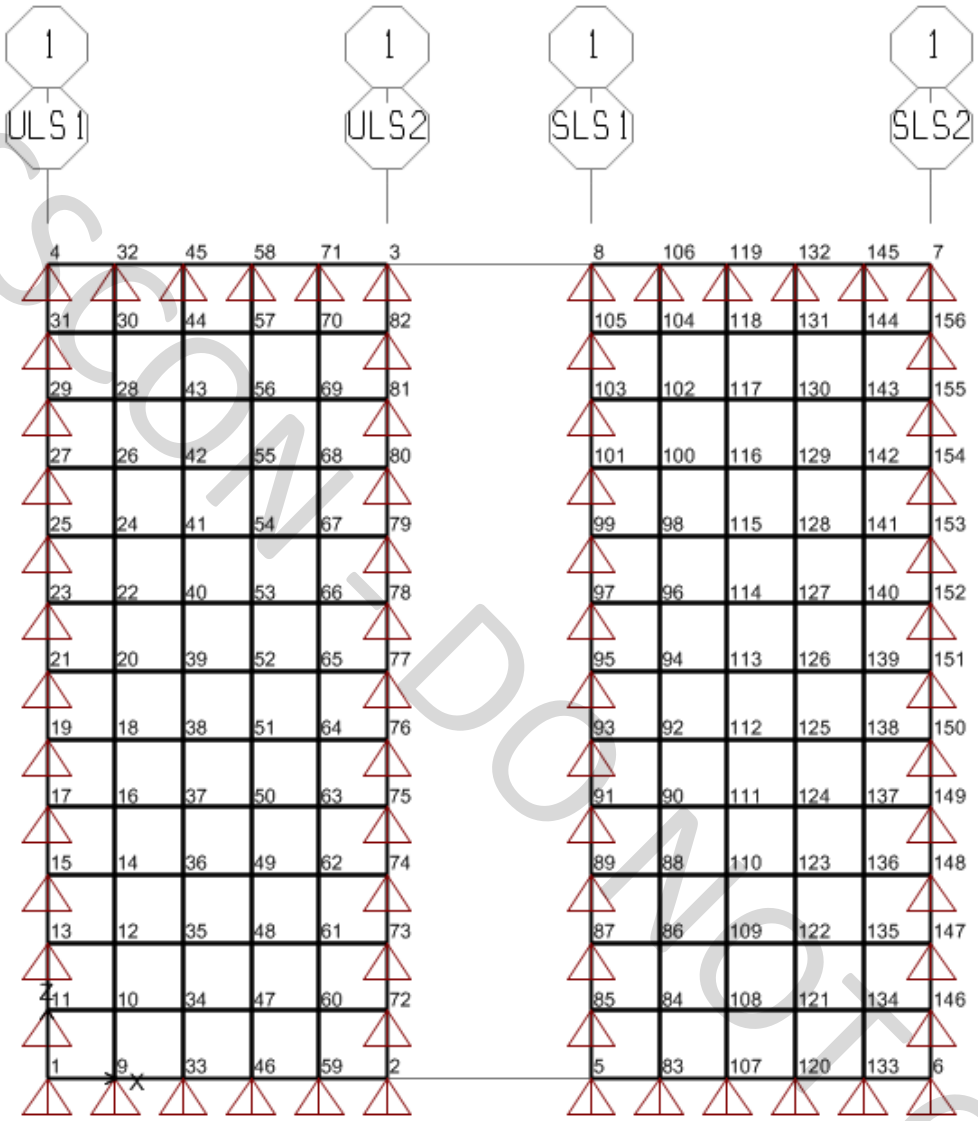
3. MODEL ANALYSIS IN SOFTWARE SAP2000 V.17.1.1

glass_facade.sdb

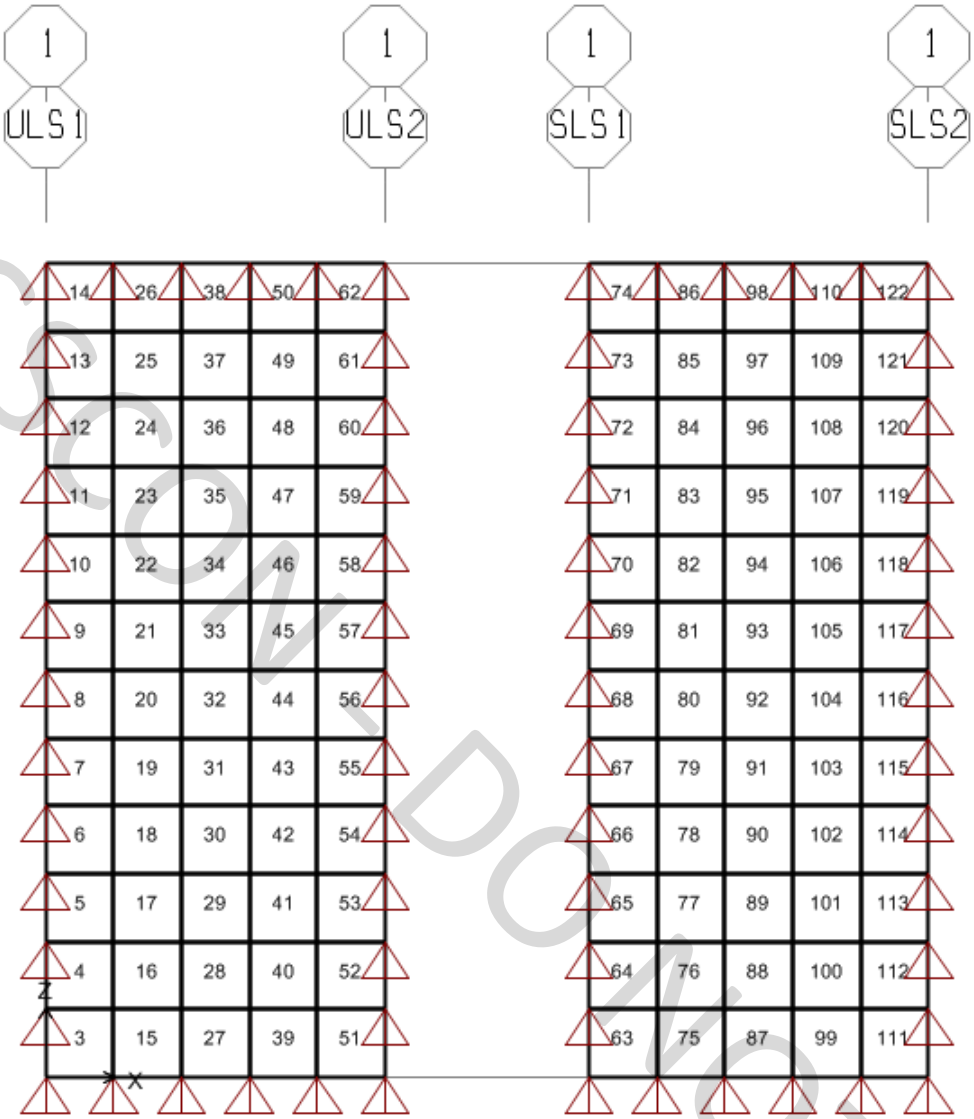


SAP17.1.1 2D View

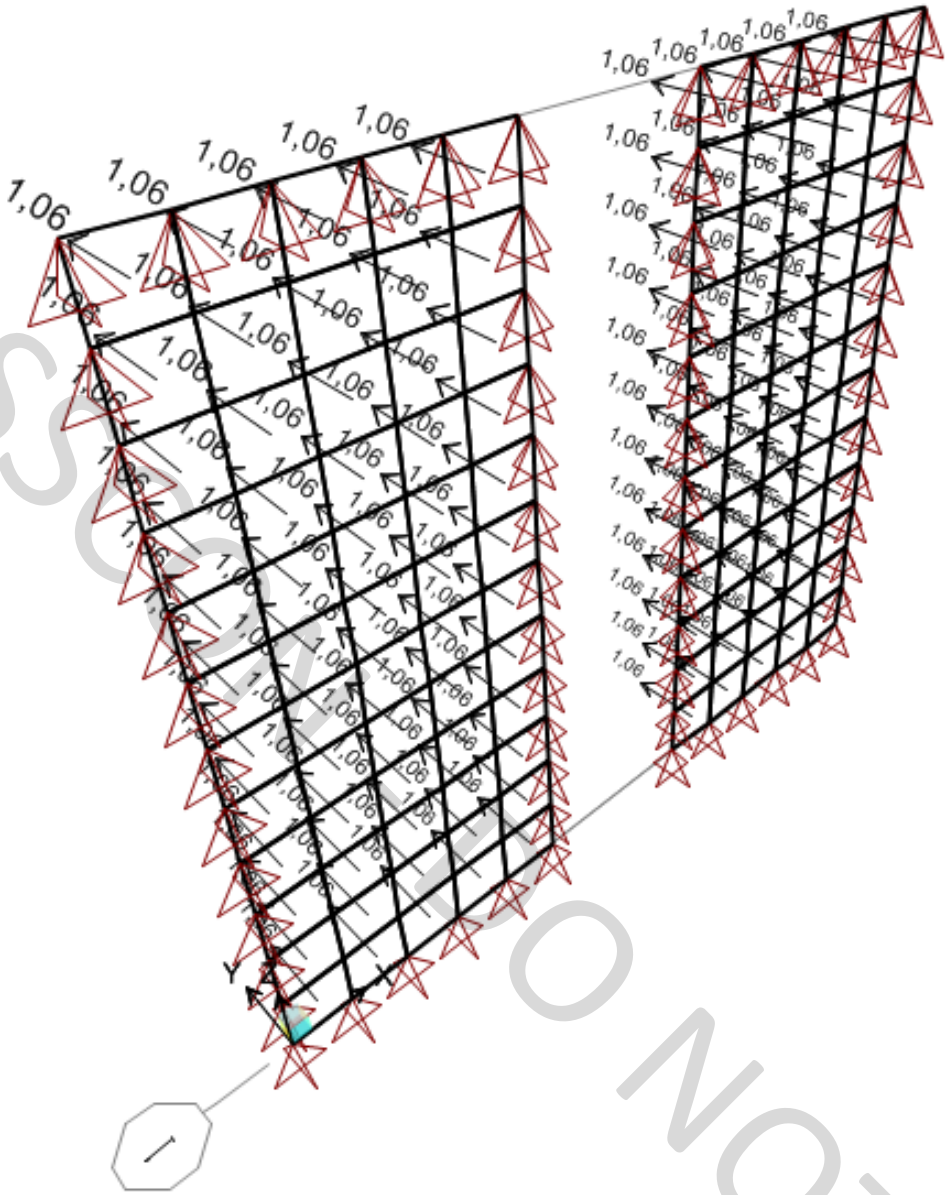
glass_facade.sdb



SAP17.1.1 Joint Labels

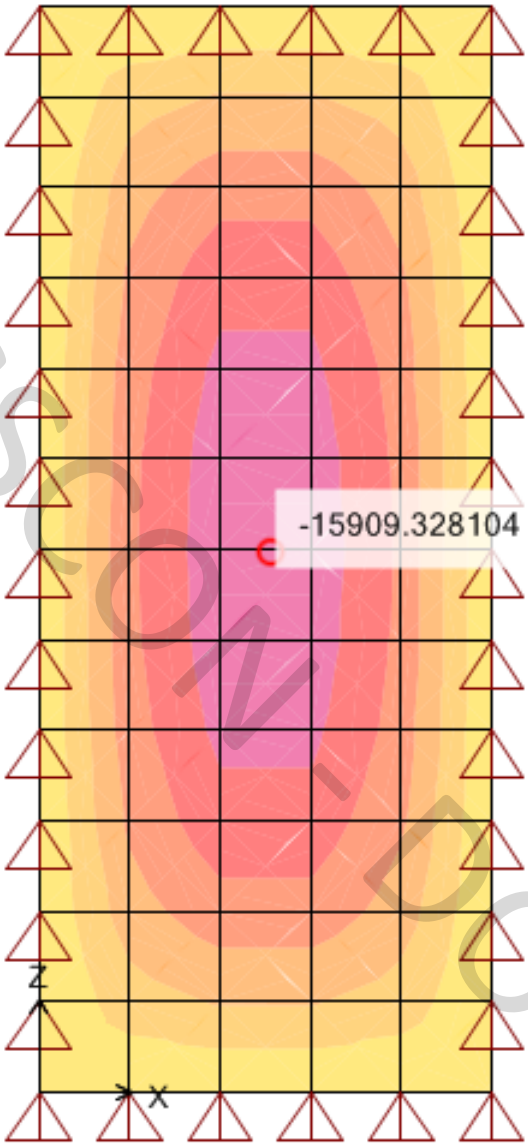


SAP17.1.1 Area Labels



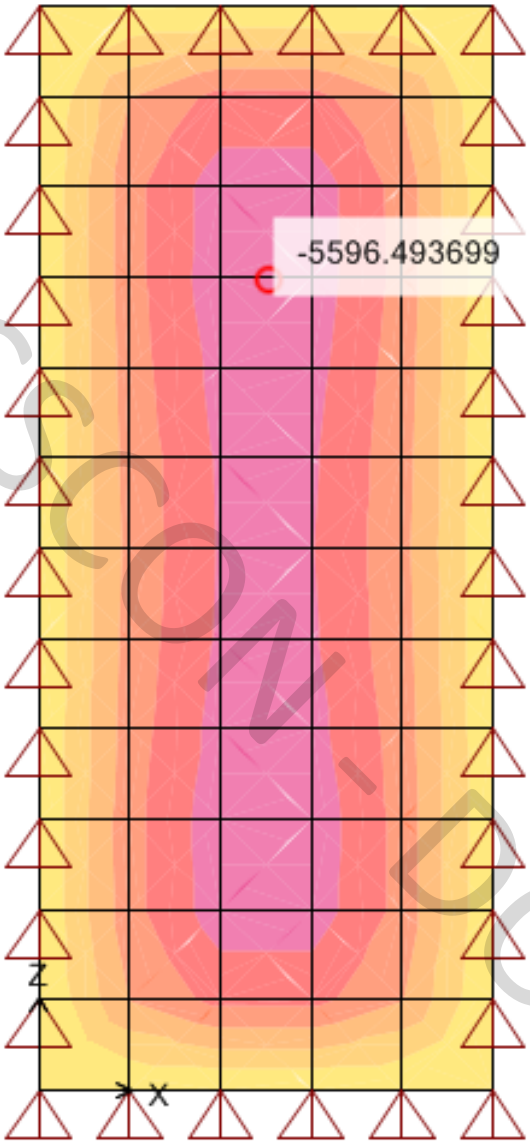
SAP17.1.1 Wind Loads

glass_facade.sdb



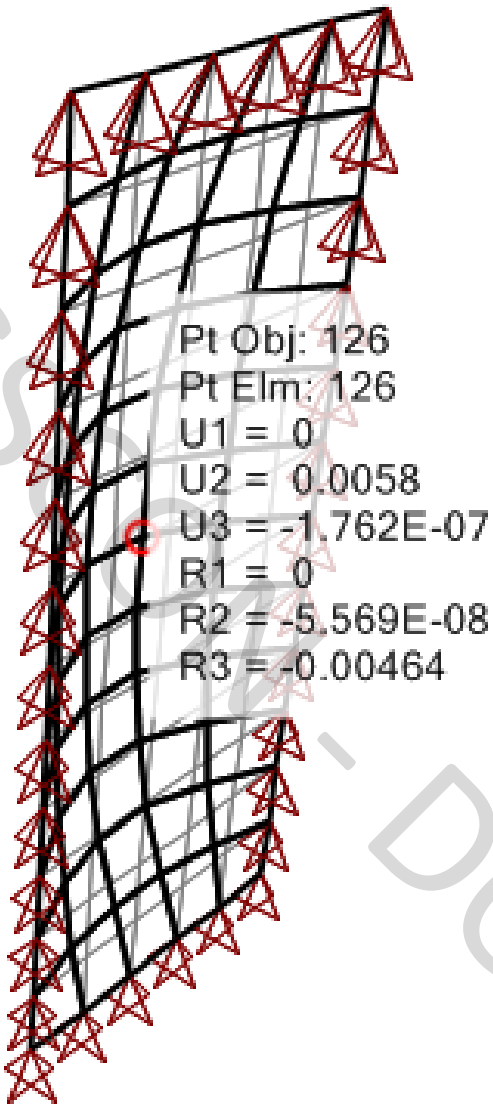
SAP17.1.1 Shell Stresses S11 (ULS)

glass_facade.sdb



SAP17.1.1 Shell Stresses S22 (ULS)

glass_facade.sdb



SAP17.1.1

Joint Displacements (SLS)

SAP2000 v17.1.1 5/19/15 2:53:52

Table: Material Properties 02 - Basic Mechanical Properties

Material	UnitWeight	UnitMass	E1	G12	U12	A1
	KN/m3	KN-s2/m4	KN/m2	KN/m2		1/C
Glass	2,4517E+01	2,5000E+00	70000000,00	28455284,55	0,230000	9,0000E-06

Table: Area Section Properties, Part 1 of 4

Section	Material	MatAngle	AreaType	Type	DrillDOF	Thickness	BendThick	Arc
		Degrees			m	m	Degrees	
SLS	Glass	0,000	Shell	Shell-Thin	Yes	0,009110	0,009110	
ULS	Glass	0,000	Shell	Shell-Thin	Yes	0,010000	0,010000	

Table: Area Section Properties, Part 2 of 4

Section	InComp	CoordSys	Color	TotalWt	TotalMass	F11Mod	F22Mod
				KN	KN-s2/m		
SLS			Magenta	1,103	8,541E-02	1,000000	1,000000
ULS			Magenta	1,099	9,375E-02	1,000000	1,000000

Table: Area Section Properties, Part 3 of 4

Section	F12Mod	M11Mod	M22Mod	M12Mod	V13Mod	V23Mod	MMod	WMod
SLS	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,317000
ULS	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,000000	1,195000

Table: Area Section Properties, Part 4 of 4

Section	GUID	Notes
SLS		Added 19/5/2015 1:04:54
ULS		Added 19/5/2015 1:04:19

Table: Joint Coordinates, Part 1 of 2

Joint	CoordSys	CoordType	XorR	Y	Z	SpecialJt	GlobalX
			m	m	m	m		
1	GLOBAL	Cartesian	0,00000	0,00000	0,00000	No	0,00000
2	GLOBAL	Cartesian	1,25000	0,00000	0,00000	No	1,25000
3	GLOBAL	Cartesian	1,25000	0,00000	3,00000	No	1,25000
4	GLOBAL	Cartesian	0,00000	0,00000	3,00000	No	0,00000
5	GLOBAL	Cartesian	2,00000	0,00000	0,00000	No	2,00000
6	GLOBAL	Cartesian	3,25000	0,00000	0,00000	No	3,25000
7	GLOBAL	Cartesian	3,25000	0,00000	3,00000	No	3,25000
8	GLOBAL	Cartesian	2,00000	0,00000	3,00000	No	2,00000
9	GLOBAL	Cartesian	0,25000	0,00000	0,00000	No	0,25000
10	GLOBAL	Cartesian	0,25000	0,00000	0,25000	No	0,25000
11	GLOBAL	Cartesian	0,00000	0,00000	0,25000	No	0,00000
12	GLOBAL	Cartesian	0,25000	0,00000	0,50000	No	0,25000
13	GLOBAL	Cartesian	0,00000	0,00000	0,50000	No	0,00000
14	GLOBAL	Cartesian	0,25000	0,00000	0,75000	No	0,25000
15	GLOBAL	Cartesian	0,00000	0,00000	0,75000	No	0,00000
16	GLOBAL	Cartesian	0,25000	0,00000	1,00000	No	0,25000
17	GLOBAL	Cartesian	0,00000	0,00000	1,00000	No	0,00000
18	GLOBAL	Cartesian	0,25000	0,00000	1,25000	No	0,25000
19	GLOBAL	Cartesian	0,00000	0,00000	1,25000	No	0,00000
20	GLOBAL	Cartesian	0,25000	0,00000	1,50000	No	0,25000
21	GLOBAL	Cartesian	0,00000	0,00000	1,50000	No	0,00000
22	GLOBAL	Cartesian	0,25000	0,00000	1,75000	No	0,25000
23	GLOBAL	Cartesian	0,00000	0,00000	1,75000	No	0,00000
24	GLOBAL	Cartesian	0,25000	0,00000	2,00000	No	0,25000
25	GLOBAL	Cartesian	0,00000	0,00000	2,00000	No	0,00000
26	GLOBAL	Cartesian	0,25000	0,00000	2,25000	No	0,25000
27	GLOBAL	Cartesian	0,00000	0,00000	2,25000	No	0,00000
28	GLOBAL	Cartesian	0,25000	0,00000	2,50000	No	0,25000
29	GLOBAL	Cartesian	0,00000	0,00000	2,50000	No	0,00000
30	GLOBAL	Cartesian	0,25000	0,00000	2,75000	No	0,25000
31	GLOBAL	Cartesian	0,00000	0,00000	2,75000	No	0,00000
32	GLOBAL	Cartesian	0,25000	0,00000	3,00000	No	0,25000
33	GLOBAL	Cartesian	0,50000	0,00000	0,00000	No	0,50000
34	GLOBAL	Cartesian	0,50000	0,00000	0,25000	No	0,50000
35	GLOBAL	Cartesian	0,50000	0,00000	0,50000	No	0,50000
36	GLOBAL	Cartesian	0,50000	0,00000	0,75000	No	0,50000
37	GLOBAL	Cartesian	0,50000	0,00000	1,00000	No	0,50000
38	GLOBAL	Cartesian	0,50000	0,00000	1,25000	No	0,50000
39	GLOBAL	Cartesian	0,50000	0,00000	1,50000	No	0,50000
40	GLOBAL	Cartesian	0,50000	0,00000	1,75000	No	0,50000
41	GLOBAL	Cartesian	0,50000	0,00000	2,00000	No	0,50000
42	GLOBAL	Cartesian	0,50000	0,00000	2,25000	No	0,50000
43	GLOBAL	Cartesian	0,50000	0,00000	2,50000	No	0,50000
44	GLOBAL	Cartesian	0,50000	0,00000	2,75000	No	0,50000
45	GLOBAL	Cartesian	0,50000	0,00000	3,00000	No	0,50000
46	GLOBAL	Cartesian	0,75000	0,00000	0,00000	No	0,75000
47	GLOBAL	Cartesian	0,75000	0,00000	0,25000	No	0,75000
48	GLOBAL	Cartesian	0,75000	0,00000	0,50000	No	0,75000
49	GLOBAL	Cartesian	0,75000	0,00000	0,75000	No	0,75000
50	GLOBAL	Cartesian	0,75000	0,00000	1,00000	No	0,75000
51	GLOBAL	Cartesian	0,75000	0,00000	1,25000	No	0,75000
52	GLOBAL	Cartesian	0,75000	0,00000	1,50000	No	0,75000

Table: Joint Coordinates, Part 2 of 2

Joint	GlobalY m	GlobalZ m	GUID
1	0,00000	0,00000	
2	0,00000	0,00000	
3	0,00000	3,00000	
4	0,00000	3,00000	
5	0,00000	0,00000	
6	0,00000	0,00000	
7	0,00000	3,00000	
8	0,00000	3,00000	
9	0,00000	0,00000	
10	0,00000	0,25000	
11	0,00000	0,25000	
12	0,00000	0,50000	
13	0,00000	0,50000	
14	0,00000	0,75000	
15	0,00000	0,75000	
16	0,00000	1,00000	
17	0,00000	1,00000	
18	0,00000	1,25000	
19	0,00000	1,25000	
20	0,00000	1,50000	
21	0,00000	1,50000	
22	0,00000	1,75000	
23	0,00000	1,75000	
24	0,00000	2,00000	
25	0,00000	2,00000	
26	0,00000	2,25000	
27	0,00000	2,25000	
28	0,00000	2,50000	
29	0,00000	2,50000	
30	0,00000	2,75000	
31	0,00000	2,75000	
32	0,00000	3,00000	
33	0,00000	0,00000	
34	0,00000	0,25000	
35	0,00000	0,50000	
36	0,00000	0,75000	
37	0,00000	1,00000	
38	0,00000	1,25000	
39	0,00000	1,50000	
40	0,00000	1,75000	
41	0,00000	2,00000	
42	0,00000	2,25000	
43	0,00000	2,50000	
44	0,00000	2,75000	
45	0,00000	3,00000	
46	0,00000	0,00000	
47	0,00000	0,25000	
48	0,00000	0,50000	

Table: Connectivity - Area, Part 1 of 2

Area	NumJoints	Joint1	Joint2	Joint3	Joint4	Perimeter	AreaArea
				m	m2		
3	4	1	9	10	11	1,000000	0,062500
4	4	11	10	12	13	1,000000	0,062500
5	4	13	12	14	15	1,000000	0,062500
6	4	15	14	16	17	1,000000	0,062500
7	4	17	16	18	19	1,000000	0,062500
8	4	19	18	20	21	1,000000	0,062500
9	4	21	20	22	23	1,000000	0,062500
10	4	23	22	24	25	1,000000	0,062500
11	4	25	24	26	27	1,000000	0,062500
12	4	27	26	28	29	1,000000	0,062500
13	4	29	28	30	31	1,000000	0,062500
14	4	31	30	32	4	1,000000	0,062500
15	4	9	33	34	10	1,000000	0,062500
16	4	10	34	35	12	1,000000	0,062500
17	4	12	35	36	14	1,000000	0,062500
18	4	14	36	37	16	1,000000	0,062500
19	4	16	37	38	18	1,000000	0,062500
20	4	18	38	39	20	1,000000	0,062500
21	4	20	39	40	22	1,000000	0,062500
22	4	22	40	41	24	1,000000	0,062500
23	4	24	41	42	26	1,000000	0,062500
24	4	26	42	43	28	1,000000	0,062500
25	4	28	43	44	30	1,000000	0,062500
26	4	30	44	45	32	1,000000	0,062500
27	4	33	46	47	34	1,000000	0,062500
28	4	34	47	48	35	1,000000	0,062500
29	4	35	48	49	36	1,000000	0,062500
30	4	36	49	50	37	1,000000	0,062500
31	4	37	50	51	38	1,000000	0,062500
32	4	38	51	52	39	1,000000	0,062500
33	4	39	52	53	40	1,000000	0,062500
34	4	40	53	54	41	1,000000	0,062500
35	4	41	54	55	42	1,000000	0,062500
36	4	42	55	56	43	1,000000	0,062500
37	4	43	56	57	44	1,000000	0,062500
38	4	44	57	58	45	1,000000	0,062500
39	4	46	59	60	47	1,000000	0,062500
40	4	47	60	61	48	1,000000	0,062500
41	4	48	61	62	49	1,000000	0,062500
42	4	49	62	63	50	1,000000	0,062500
43	4	50	63	64	51	1,000000	0,062500
44	4	51	64	65	52	1,000000	0,062500
45	4	52	65	66	53	1,000000	0,062500
46	4	53	66	67	54	1,000000	0,062500
47	4	54	67	68	55	1,000000	0,062500
48	4	55	68	69	56	1,000000	0,062500
49	4	56	69	70	57	1,000000	0,062500

Table: Connectivity - Area, Part 2 of 2

Area	Volume m3	CentroidX m	CentroidY m	CentroidZ	GUID
3	0,000625	0,12500	0,00000	0,12500	
4	0,000625	0,12500	0,00000	0,37500	
5	0,000625	0,12500	0,00000	0,62500	
6	0,000625	0,12500	0,00000	0,87500	
7	0,000625	0,12500	0,00000	1,12500	
8	0,000625	0,12500	0,00000	1,37500	
9	0,000625	0,12500	0,00000	1,62500	
10	0,000625	0,12500	0,00000	1,87500	
11	0,000625	0,12500	0,00000	2,12500	
12	0,000625	0,12500	0,00000	2,37500	
13	0,000625	0,12500	0,00000	2,62500	
14	0,000625	0,12500	0,00000	2,87500	
15	0,000625	0,37500	0,00000	0,12500	
16	0,000625	0,37500	0,00000	0,37500	
17	0,000625	0,37500	0,00000	0,62500	
18	0,000625	0,37500	0,00000	0,87500	
19	0,000625	0,37500	0,00000	1,12500	
20	0,000625	0,37500	0,00000	1,37500	
21	0,000625	0,37500	0,00000	1,62500	
22	0,000625	0,37500	0,00000	1,87500	
23	0,000625	0,37500	0,00000	2,12500	
24	0,000625	0,37500	0,00000	2,37500	
25	0,000625	0,37500	0,00000	2,62500	
26	0,000625	0,37500	0,00000	2,87500	
27	0,000625	0,62500	0,00000	0,12500	
28	0,000625	0,62500	0,00000	0,37500	
29	0,000625	0,62500	0,00000	0,62500	
30	0,000625	0,62500	0,00000	0,87500	
31	0,000625	0,62500	0,00000	1,12500	
32	0,000625	0,62500	0,00000	1,37500	
33	0,000625	0,62500	0,00000	1,62500	
34	0,000625	0,62500	0,00000	1,87500	
35	0,000625	0,62500	0,00000	2,12500	
36	0,000625	0,62500	0,00000	2,37500	
37	0,000625	0,62500	0,00000	2,62500	
38	0,000625	0,62500	0,00000	2,87500	
39	0,000625	0,87500	0,00000	0,12500	
40	0,000625	0,87500	0,00000	0,37500	
41	0,000625	0,87500	0,00000	0,62500	
42	0,000625	0,87500	0,00000	0,87500	
43	0,000625	0,87500	0,00000	1,12500	
44	0,000625	0,87500	0,00000	1,37500	
45	0,000625	0,87500	0,00000	1,62500	
46	0,000625	0,87500	0,00000	1,87500	
47	0,000625	0,87500	0,00000	2,12500	
48	0,000625	0,87500	0,00000	2,37500	
49	0,000625	0,87500	0,00000	2,62500	
50	0,000625	0,87500	0,00000	2,87500	

Table: Load Pattern Definitions

LoadPat	DesignType	SelfWtMult	AutoLoad	GUID	Notes
DEAD	DEAD	1,000000			
W	WIND	0,000000	None		

Table: Combination Definitions, Part 1 of 3

ComboName	ComboType	AutoDesign	CaseType	CaseName	ScaleFactor	SteelDesign
ULS	Linear Add	No	Linear Static	DEAD	1,350000	None
ULS			Linear Static	W	1,500000	
SLS	Linear Add	No	Linear Static	DEAD	1,000000	None
SLS			Linear Static	W	1,000000	

Table: Combination Definitions, Part 2 of 3

ComboName	CaseName	ConcDesign	AlumDesign	ColdDesign
ULS	DEAD	None	None	None
ULS	W			
SLS	DEAD	None	None	None
SLS	W			

Table: Combination Definitions, Part 3 of 3

ComboName	CaseName	GUID	Notes
ULS	DEAD		
ULS	W		
SLS	DEAD		
SLS	W		

4. ANNEX A

DESIGN OF L SECTIONS

Model

A typical part 1.25x3.00m is being examined. No other part for the designing of the L section needs to be checked.

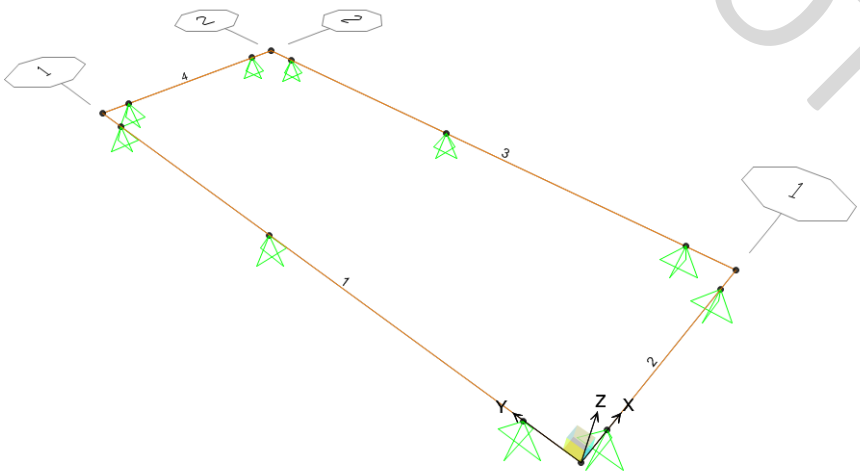


Figure Labels

Section L90/60/5

Material S235

<u>Dead loads</u>

1) Self weight
2) Glass weight

   24mm*2.5kg/mm = 0.60kN/m^2

Short side: Triangular distribution

Long side: Trapezoidal distribution

Maximum value:

0.60kN/m^2*0.59 = 0.35kN/m

3) Aluminum sections weight (0.07kN/m)

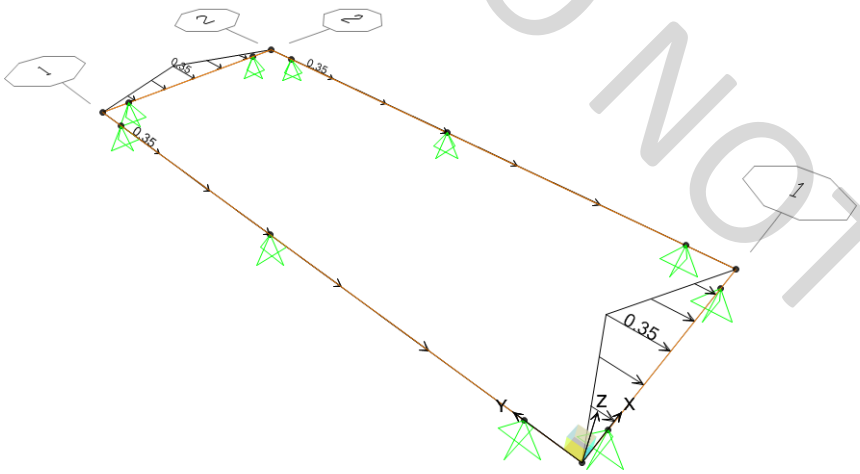


Figure Glass load

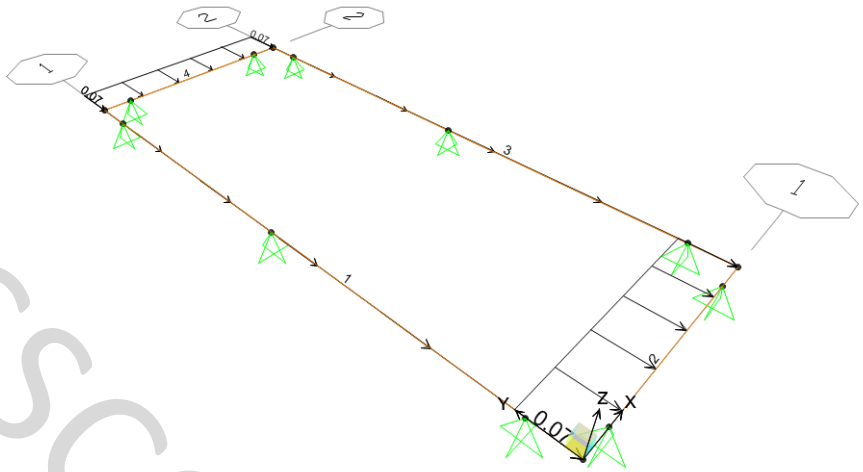


Figure Aluminum sections weight

<u>Wind load</u>

1.76kN/m^2*1.20 = 2.11kN/m^2

Short side: Triangular distribution

Long side: Trapezoidal distribution

Maximum value:

2.11kN/m^2*0.59 = 1.25kN/m

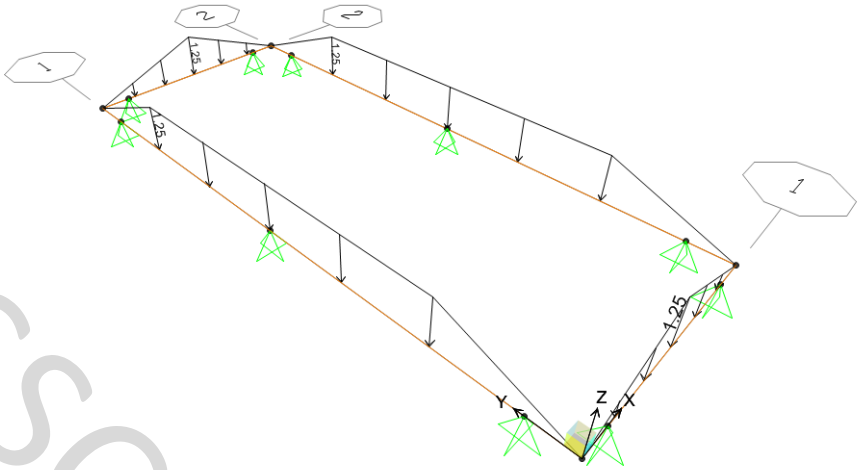


Figure Wind load

<u>Combination</u>

Ultimate limit state

1.35G + 1.5W

Serviceability limit state

1.00G + 1.00W

Analysis results

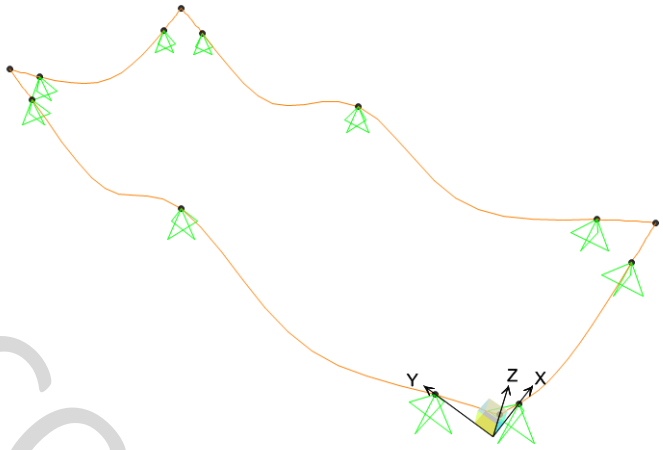


Figure Deform shape

Internal forces

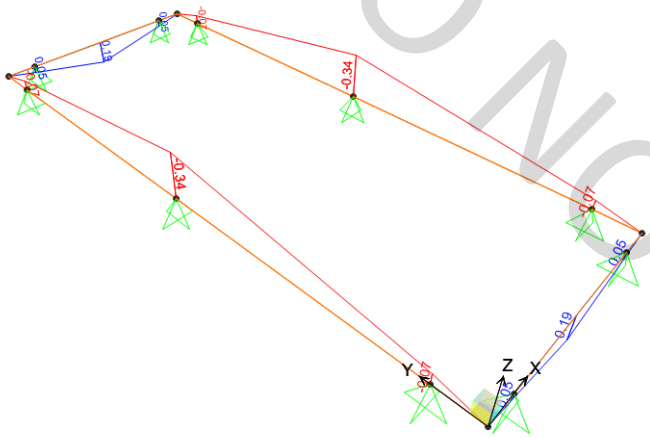


Figure Bending moment [kNm]

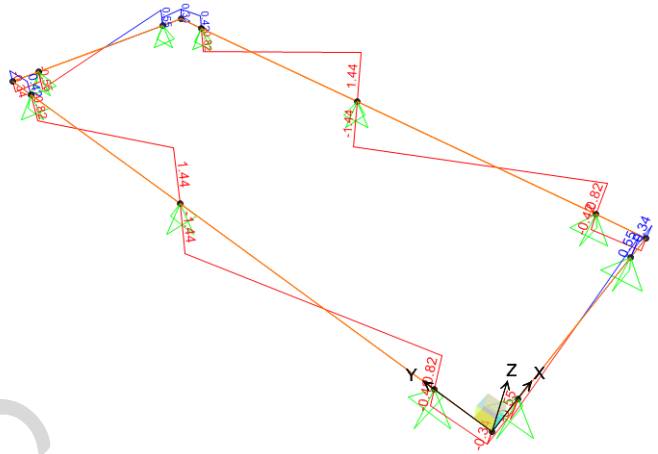


Figure Shear force [kN]

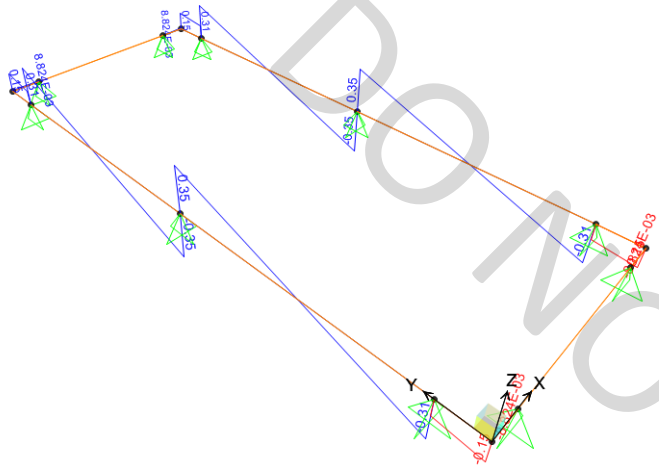


Figure Axial force [kN]

Design

According EN1993 Design of steel structures

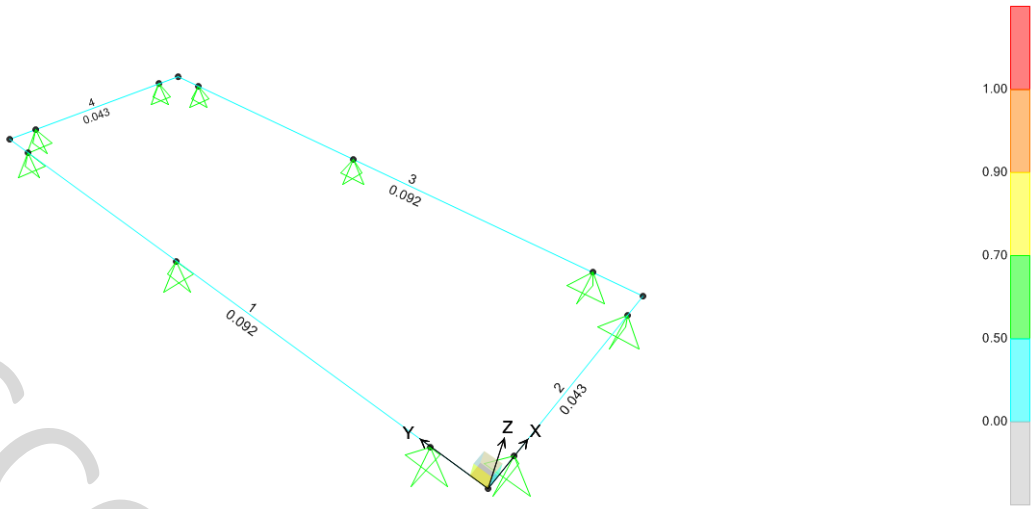


Figure Utility ratio

Table: Steel Design 1 - Summary Data - Eurocode 3-2005, Part 1 of 2

Table: Steel Design 1 - Summary Data - Eurocode 3-2005, Part 1 of 2

Frame	DesignSect	DesignType	Status	Ratio	RatioType
2	L90/60/6	Beam	No Messages	0.042989	PMM
1	L90/60/6	Beam	No Messages	0.128625	
3	L90/60/6	Beam	No Messages	0.128625	
4	L90/60/6	Beam	No Messages	0.043425	PMM

Table: Steel Design 1 - Summary Data - Eurocode 3-2005, Part 2 of 2

Table: Steel Design 1 - Summary Data - Eurocode 3-2005, Part 2 of 2

Frame	Combo	Location m	ErrMsg	WarnMsg
2	COMB1	0.15400	No Messages	No Messages
1	COMB2	1.47100	No Messages	No Messages
3	COMB2	1.47100	No Messages	No Messages
4	COMB1	0.15400	No Messages	No Messages

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 1 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 1 of 8

Frame	DesignSect	DesignType	Status	Combo	Location	Pu
					m	KN
2	L90/60/6	Beam	No Messages	COMB1	0.15400	-8.824E-03
1	L90/60/6	Beam	No Messages	COMB1	1.47100	-0.354
3	L90/60/6	Beam	No Messages	COMB1	1.47100	-0.354
4	L90/60/6	Beam	No Messages	COMB1	0.15400	8.824E-03

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 2 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 2 of 8

Frame	MuMajor	MuMinor	VuMajor	VuMinor	Tu	Equation	TotalRatio
	KN-m	KN-m	KN	KN	KN-m		
2	0.0487	0.0235	-0.284	-0.177	3.436E-19	6.3.3(4)-6.62	0.042989
1	-0.3433	-1.290E-17	1.437	0.000	-4.038E-19	6.3.3(4)-6.62	0.092030
3	-0.3433	1.290E-17	1.437	0.000	4.942E-19	6.3.3(4)-6.62	0.092007
4	0.0487	0.0235	-0.284	-0.177	-2.819E-17	6.3.3(4)-6.62	0.043425

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 3 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 3 of 8

Frame	PRatio	MMajRatio	MMinRatio	SRLimit	NsdDsgn	Ncrd	Ntrd
					KN	KN	KN
2	0.000000	0.037994	0.004940	0.950000	-8.824E-03	149.434	203.040
1	0.006719	0.085142	0.000168	0.950000	-0.354	51.117	203.040
3	0.006719	0.085142	0.000145	0.950000	-0.354	51.117	203.040
4	0.000000	0.037991	0.005434	0.950000	8.824E-03	152.701	203.040

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 4 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 4 of 8

Frame	NbrdMajor	NbrdMinor	MsdMajDsgn	McrdMajor	MvrdMajor	MbrdMajor	XKMajor
	KN	KN	KN-m	KN-m	KN-m	KN-m	
2	180.445	153.908	0.0487	5.8062	5.8062	4.9606	1.000000

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 4 of 8

Frame	NbrdMajor	NbrdMinor	MsdMajDsgn	McrdMajor	MvrdMajor	MbrdMajor	XKMajor
	KN	KN	KN-m	KN-m	KN-m	KN-m	
1	109.359	51.117	-0.3433	5.8062	5.8062	4.0219	1.000000
3	109.359	51.117	-0.3433	5.8062	5.8062	4.0219	1.000000
4	185.513	157.436	0.0487	5.8062	5.8062	4.9606	1.000000

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 5 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 5 of 8

Frame	XLMajor	kMajor	kzy	C1	MsdMinDsgn	McrdMinor	MvrdMinor
					KN-m	KN-m	KN-m
2	1.000000	0.900011	1.000000	1.000000	0.0235	4.3306	4.3306
1	1.000000	0.901696	1.000000	1.000000	0.0000	4.3306	4.3306
3	1.000000	0.901696	1.000000	1.000000	0.0000	4.3306	4.3306
4	1.000000	1.000000	1.000000	1.000000	0.0235	4.3306	4.3306

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 6 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 6 of 8

Frame	XKMinor	XLMinor	kMinor	kyz	Fy	E	Length
					KN/m2	KN/m2	m
2	1.000000	1.000000	0.909222	1.000000	235000.00	210000000.0	1.17000
1	1.000000	1.000000	0.401613	1.000000	235000.00	210000000.0	2.94200
3	1.000000	1.000000	0.401613	1.000000	235000.00	210000000.0	2.94200
4	1.000000	1.000000	1.000000	1.000000	235000.00	210000000.0	1.17000

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 7 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 7 of 8

Frame	MajAxisAng	RLLF	SectClass	FramingType	ErrMsg
	Degrees				
2		1.000000	Class 4	Ductility Class Low Moment Resisting Frame	No Messages
1		1.000000	Class 4	Ductility Class Low Moment Resisting Frame	No Messages

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 7 of 8

Frame	MajAxisAng Degrees	RLLF	SectClass	FramingType	ErrMsg
3		1.000000	Class 4	Ductility Class Low Moment Resisting Frame	No Messages
4		1.000000	Class 4	Ductility Class Low Moment Resisting Frame	No Messages

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 8 of 8

Table: Steel Design 2 - PMM Details - Eurocode 3-2005, Part 8 of 8

Frame	WarnMsg
2	No Messages
1	No Messages
3	No Messages
4	No Messages

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 1 of 4

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 1 of 4

Frame	DesignSect	DesignType	Status	VMajorCombo	VMajorLoc m	VMajorRatio
2	L90/60/6	Beam	No Messages	COMB1	1.01600	0.007495
1	L90/60/6	Beam	No Messages	COMB1	1.47100	0.019608
3	L90/60/6	Beam	No Messages	COMB1	1.47100	0.019608
4	L90/60/6	Beam	No Messages	COMB1	1.01600	0.007495

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 2 of 4

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 2 of 4

Frame	VsdMajDsgn KN	VrdMajor KN	TuMajor KN-m	VMinorCombo	VMinorLoc m	VMinorRatio	VsdMinDsgn KN
2	0.549	73.266	0.0000	COMB1	1.01600	0.003633	0.549
1	1.437	73.266	0.0000	COMB1	2.74200	0.000181	1.437
3	1.437	73.266	0.0000	COMB1	2.74200	0.000181	1.437
4	0.549	73.266	0.0000	COMB1	1.01600	0.003633	0.549

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 3 of 4

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 3 of 4

Frame	VrdMinor	TuMinor	SRLimit	RLLF	FramingType
	KN	KN-m			
2	48.844	0.0000	0.950000	1.000000	Ductility Class Low Moment Resisting Frame
1	48.844	0.0000	0.950000	1.000000	Ductility Class Low Moment Resisting Frame
3	48.844	0.0000	0.950000	1.000000	Ductility Class Low Moment Resisting Frame
4	48.844	0.0000	0.950000	1.000000	Ductility Class Low Moment Resisting Frame

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 4 of 4

Table: Steel Design 3 - Shear Details - Eurocode 3-2005, Part 4 of 4

Frame	ErrMsg	WarnMsg
2	No Messages	No Messages
1	No Messages	No Messages
3	No Messages	No Messages
4	No Messages	No Messages

Table: Steel Design 7 - Beam Shear Forces - Eurocode 3-2005

Table: Steel Design 7 - Beam Shear Forces - Eurocode 3-2005

Frame	DesignSect	ComboLeft	VMajorLeft	ComboRight	VMajorRight
			KN		KN
2	L90/60/6	COMB1	0.336	COMB1	0.336
1	L90/60/6	COMB1	0.336	COMB1	0.336
3	L90/60/6	COMB1	0.336	COMB1	0.336
4	L90/60/6	COMB1	0.336	COMB1	0.336

Connection checks

Check of 12 bolts M8 8.8

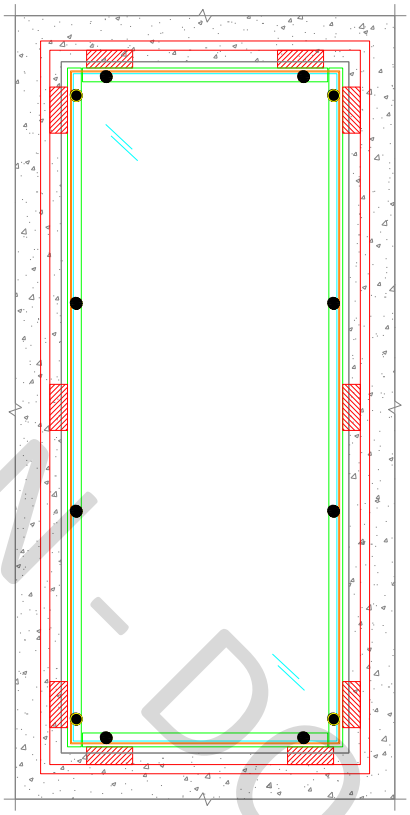


Figure Position of 12 bolts M8 8.8

<u>Loads</u>

Total weight

B = 0.60kN/m^2*(1.17*2.94) = 2.06kN

B = 0.07kN/m*(1.17 + 2.94)*2 = 0.58kN

B = 1.35*2.64kN = 3.56kN

Shear resistance

$$F_{v,Rd} = \frac{0.60 \cdot f_{ub} \cdot A}{\gamma_{Mb}} \Rightarrow F_{v,Rd} = \frac{0.60 \cdot 80 \cdot \frac{\pi \cdot (0.8cm)^2}{4}}{1.25} = 19.30kN > 3.56kN$$

Check is satisfied (one bolt is enough).

Bearing resistance

$$\alpha_b = \min\left\{\frac{e_1}{3 \cdot d_0}; \frac{f_{ub}}{f_u}; 1.0\right\} = \min\left\{\frac{120}{3 \cdot 10}; \frac{80}{36}; 1.0\right\} = 1.0$$

$$\alpha_b = \min\left\{\frac{p_1}{3 \cdot 10} - \frac{1}{4}; \frac{f_{ub}}{f_u}; 1.0\right\} = \min\left\{\frac{902}{3 \cdot 10} - \frac{1}{4}; \frac{80}{36}; 1.0\right\} = 1.000$$

$$k_1 = \min\left\{2.8 \cdot \frac{e_2}{d_0} - 1.7; 2.5\right\} = \min\left\{2.8 \cdot \frac{21.44}{10} - 1.7; 2.5\right\} = 2.5$$

$$V_{b,Rd} = n \cdot \frac{k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t}{\gamma_{M2}} = 1 \cdot \frac{2.5 \cdot 1.0 \cdot 36 \cdot 1.0 \cdot 0.5}{1.25} = V_{b,Rd} = 36.00kN > 3.56kN$$

Check is satisfied (one bolt is enough).

Check of holo bolts M8 8.8

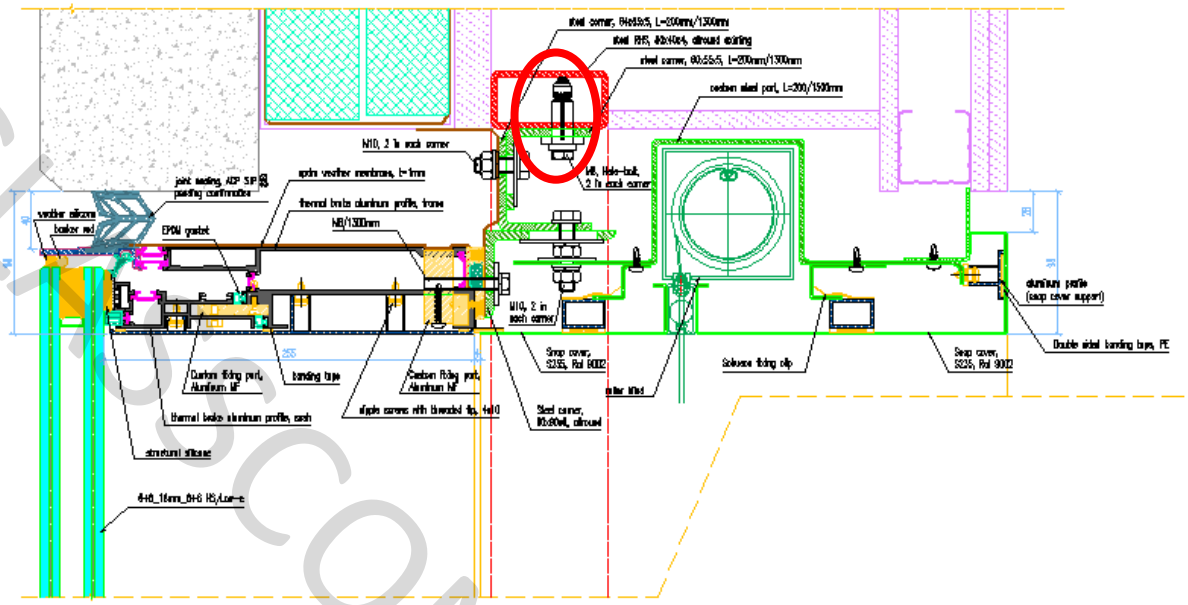


Figure Position of checking bolts

It is noted that bolts M10 are greater and thus need no t to be checked.

<u>Loads</u>

Weight B = 2.64kN

Wind load: W = 2.11kN/m^2*(1.17*2.94)m2 = 7.26kN

Vx = 1.35*2.64 = 3.56kN

Vy = 1.50*7.26 = 10.89kN

V = $(Vx^2 + Vy^2)^{0.5}$ = 11.46kN

Shear resistance

$$F_{v,Rd} = \frac{0.60 \cdot f_{ub} \cdot A}{\gamma_{Mb}} \Rightarrow F_{v,Rd} = \frac{0.60 \cdot 80 \cdot \frac{\pi \cdot (0.8cm)^2}{4}}{1.25} = 19.30kN > 11.46kN$$

Check is satisfied (one bolt is enough)

Bearing resistance

$$\alpha_b = \min\left\{\frac{e_1}{3 \cdot d_0}; \frac{f_{ub}}{f_u}; 1.0\right\} = \min\left\{\frac{25}{3 \cdot 10}; \frac{80}{36}; 1.0\right\} = 0.833$$

$$\alpha_b = \min\left\{\frac{p_1}{3 \cdot d_0} - \frac{1}{4}; \frac{f_{ub}}{f_u}; 1.0\right\} = \min\left\{\frac{150}{3 \cdot 10} - \frac{1}{4}; \frac{80}{36}; 1.0\right\} = 1.000 \quad k_1 = \min\left\{2.8 \cdot \frac{e_2}{d_0} - 1.7; 2.5\right\} = \min\left\{2.8 \cdot \frac{15}{10} - 1.7; 2.5\right\} = 2.5$$

$$V_{b,Rd} = n \cdot \frac{k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t}{\gamma_{M2}} = 1 \cdot \frac{2.5 \cdot 0.833 \cdot 36 \cdot 1.0 \cdot 0.5}{1.25} = V_{b,Rd} = 29.99kN > 11.46kN$$

Check is satisfied (one bolt is enough).