DIMON TECHNOLOGY		Sheet No.	1
		Prepared by	Y.S.Zhang
Project		Date	16.07.2020
Title	JOHSUA@HC 778	Revision	-

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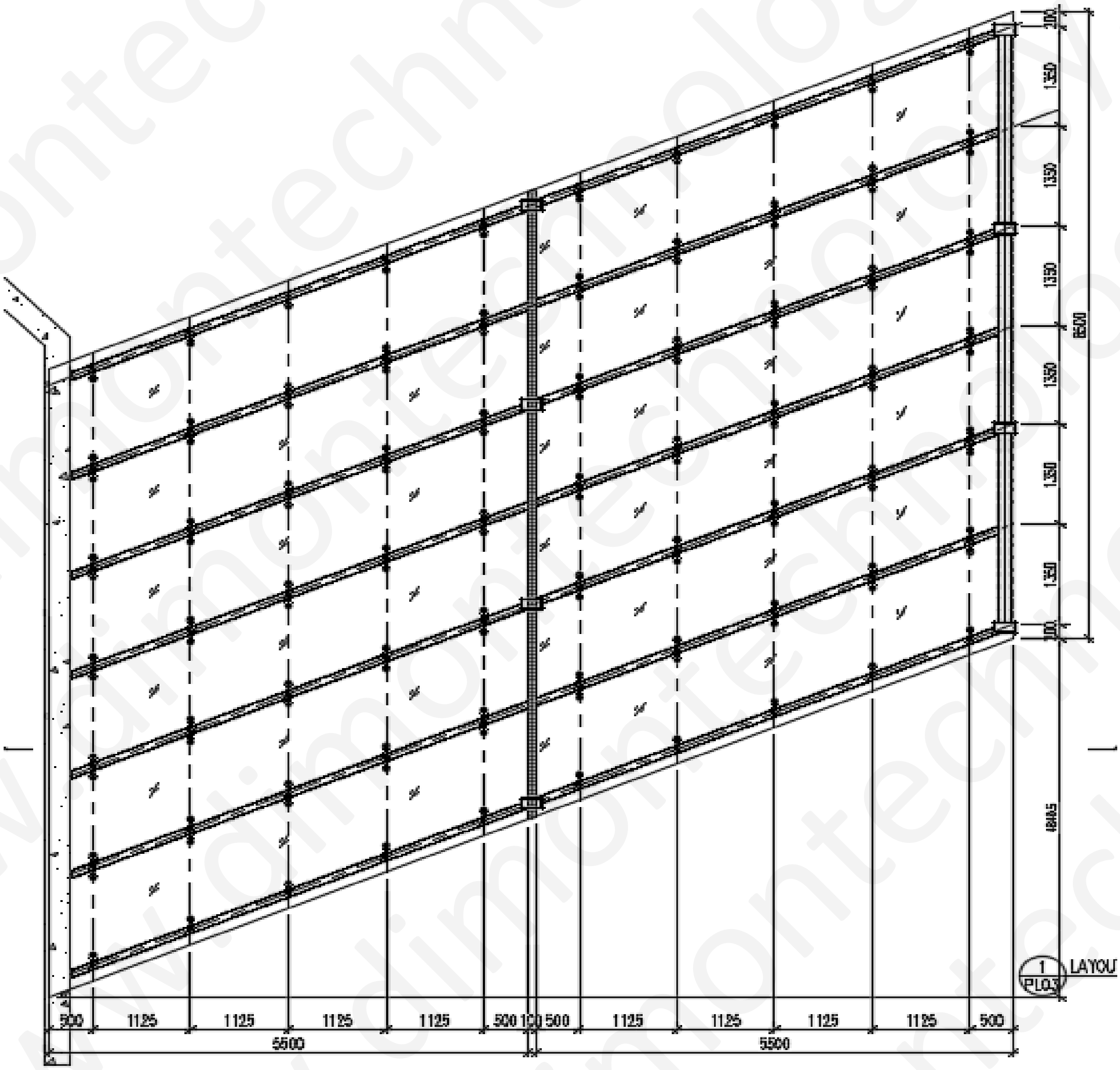
1. Introduction

The skylights are made of 12+12mm thick laminated tempered glass fixed to s.s. RHS by means of stainless steel spider system. The objective of this calculation is to check the design of skylight to be safe against the dead load, live load and wind load.

<u>Load path</u>

Wind load to skylight ➝ glass panels ➝ s.s. spiders ➝ steel RHS frame ➝ gms embeds ➝ r.c. structures



2. Design Code, Design Data

2.1 Design Code

a) Hong Kong Building (Construction) Regulation 1990 (Amendment 2011).
b) Code of Practice on Wind Effect 2008, Macau.
c) Code of Practice for the Structural Use of Steel 2011, Hong Kong
d) Code of Practice for the Structural Use of Concrete 2004, Hong Kong
e) Code of Practice for Dead and imposed Loads 2011, Hong Kong
f) Code of Practice for the Structural Use of Steel GB 50017-2003
g) Load Code of the design of buliding structure GB 50009-2012

2.2 Design Data

2.2.1 The design of steelwork to be complied with 'Code of Practice for the Structural Use of Steel 2011, Hong Kong' and 'Code of Practice for the Structural Use of Steel Macau The Steel sections to be grade Q345 complied to comply with GB/t 706-2008 and GB/t 3274-2007.

steel grade			Q345
thickness		(mm)	≤16
ultimate tensile strength,	U_s	(N/mm^2)	400
design strength,	p_y	(N/mm^2)	310
design shear strength,	v_c	(N/mm^2)	180
Modulus of Elasticity,	E_s	(N/mm^2)	206000

2.2.2 All welding to be complied with complied to GB50661-2011

steel grade		E50xx
design strength of filled weld	(N/mm^2)	200

2.2.3 ALL ordinary bolts to be complied with BS 4190

grade		8.8
ultimate tensile strength,	(N/mm^2)	800
design strength,	(N/mm^2)	450
design shear strength,	(N/mm^2)	375
design bearing strength,	(N/mm^2)	1000

2.2.4 Concrete

concrete strength,	f_{cu}	(N/mm^2)	45	
anchorage bond strength, (= $\beta f_{cu}^{0.5}$)	f_{bu}	(N/mm^2)	1.878	β = 0.28 for cast-in threaded rod
design concrete shear stress,	v_c	(N/mm^2)	0.4	
compressive strength, (= 0.6 f_{cu})		(N/mm^2)	27	

2.2.5 The date refer to SAP2000 program.

3. Design Load

3.1 Wind load

Wind pressure, q_z = 2.12 kPa (height above ground level ≤20m)

Pressure coefficient, = 2 (open frame)

Design wind load = 2.12 x 2.0
= 4.24 kPa

3.2 Live load

Live load = 0.75 kN/m^2

3.3 Dead Load

Weight of glass	= (12 + 12) x 26.5 / 1000	=	0.636	kPa
Others,	=	=	0.064	kPa
	Total	=	0.7	kPa

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4. Check for laminated tempered glass

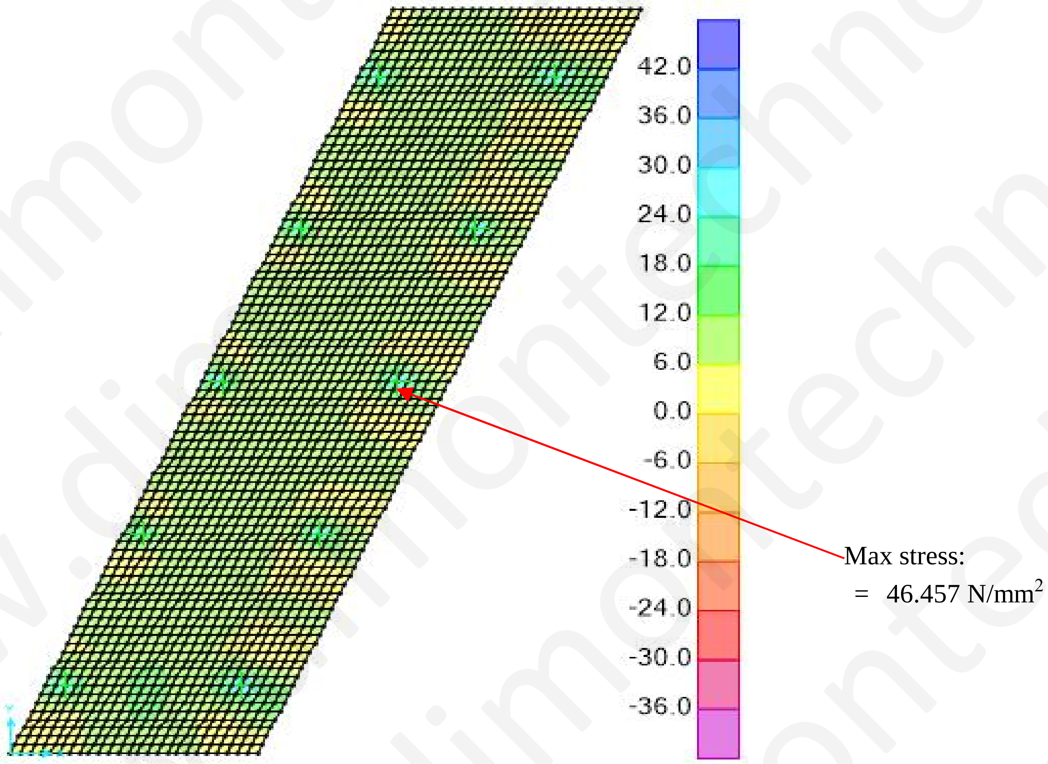
4.1 Check for 12mm+1.56PVB+12mm clear laminated tempered glass

Glass density,	ρ	=	2650	kg/m^3				
Nominal thickness of glass pane 1		=	12	mm	Min. thickness of glass pane 1,	t_1	= 11.91	mm
Nominal thickness of glass pane 2		=	12	mm	Min. thickness of glass pane 2,	t_2	= 11.91	mm

Glass type for pane 1 & 2	:	tempered	Ultimate design strength,	p_y	= 80	N/mm^2
Load duration	:	short term	Reduction factor,	γ_d	= 1	
Surface treatment	:	clear	Reduction factor,	γ_s	= 1	
			Material factor,	γ_m	= 1	

Ultimate resistance strength, $R_{ult} = p_y \gamma_d \gamma_s / \gamma_m$ = 80 N/mm^2

Comb 1: 1.3DL + 1.05LL + 0.9WL;



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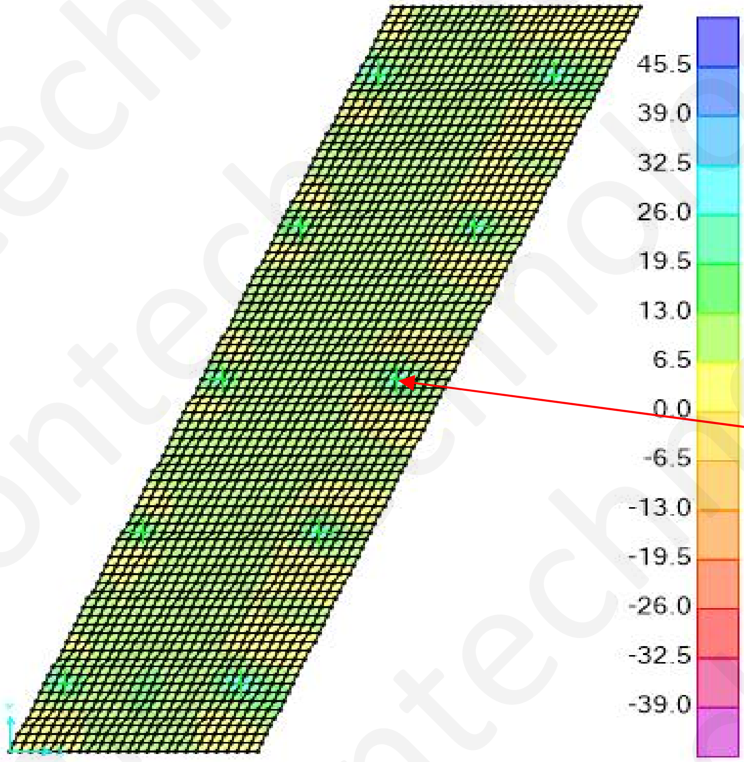
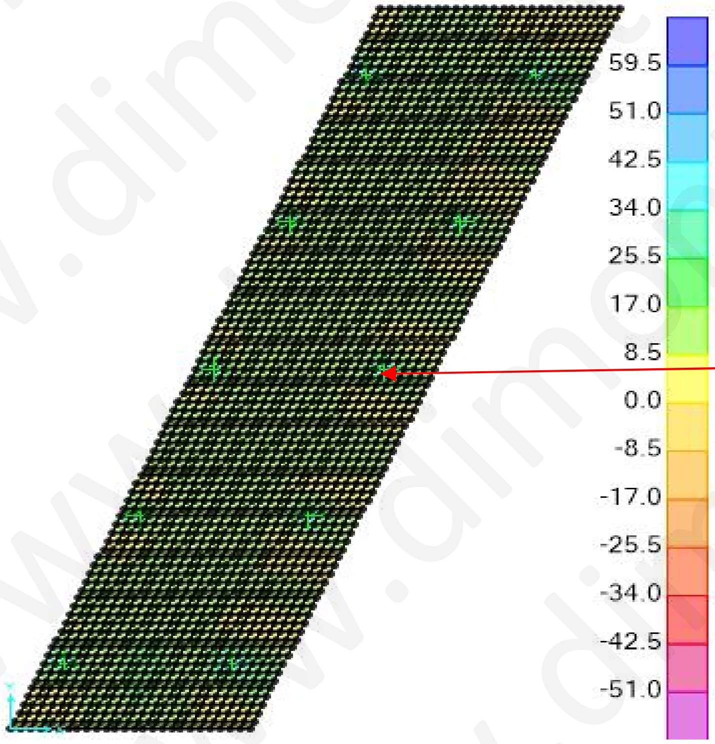
Comb 2: 1.2DL + 1.5LL + 0.9WL;



Max stress:
= 49.048N/mm^2

Comb 3: 1.2DL + 1.05LL + 1.5WL;



Max stress:
= 66.71 N/mm^2

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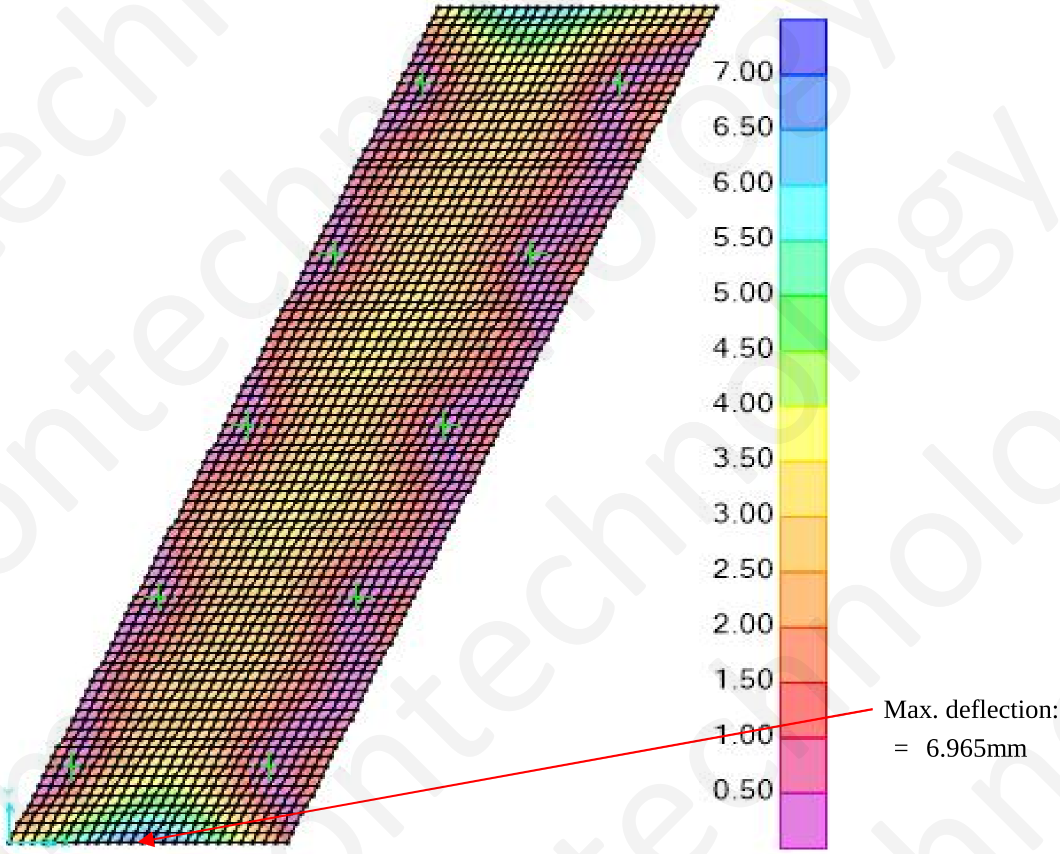
Comb 4: 1.0DL + 1.0WL; (for deflection checking)

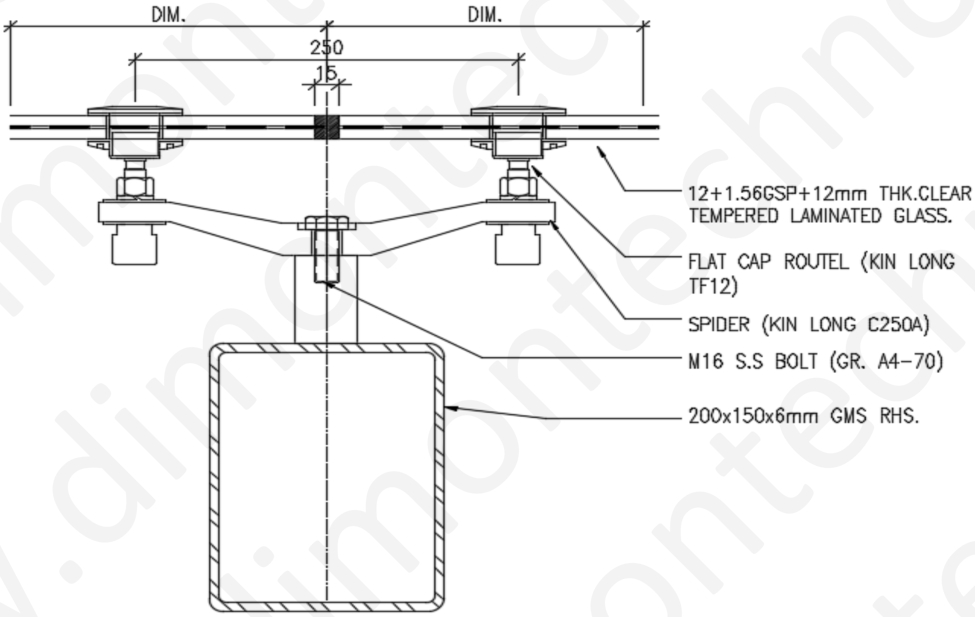


Max. bending stress of glass pane,	σ_{c1}	=	66.71	N/mm^2			
		≤	80	N/mm^2			O.K.
Max. deflection,	δ_c	=	6.965	mm			
		≤	1100 / 60		= 18.33	mm	O.K.

4.2 Check for flat cap routel (Kin Long TF12)

TABLE: Joint Reactions

Joint	OutputCase	CaseType	F1	F2	F3	M1	M2	M3
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
7	COMB1	Combination	0	0	1.619	0	0	0
7	COMB2	Combination	0	0	1.71	0	0	0
7	COMB3	Combination	0	0	2.325	0	0	0
7	COMB4	Combination	0	0	1.419	0	0	0
8	COMB1	Combination	0	0	2.573	0	0	0
8	COMB2	Combination	0	0	2.717	0	0	0
8	COMB3	Combination	0	0	3.695	0	0	0
8	COMB4	Combination	0	0	2.255	0	0	0
15	COMB1	Combination	0	0	1.805	0	0	0
15	COMB2	Combination	0	0	1.905	0	0	0
15	COMB3	Combination	0	0	2.592	0	0	0
15	COMB4	Combination	0	0	1.581	0	0	0
16	COMB1	Combination	0	0	2.386	0	0	0
16	COMB2	Combination	0	0	2.519	0	0	0
16	COMB3	Combination	0	0	3.426	0	0	0
16	COMB4	Combination	0	0	2.091	0	0	0



Vertcal load	= 3.695 kN		
Vertical load	= 0.7 + 0.75 + 3.68	(DL+LL + WL)	
	= 5.13 kN/m^2	(unfactored)	
	= 1.2 x 0.7 + 1.05 x 0.75 + 1.5 x 3.68	(1.2DL+1.05LL +1.5 WL)	
	= 7.15 kN/m^2	(factored)	
Vertical load on routel at centre	= 3.695 x 5.13 / 7.15		
	= 2.65 kN		

Reaction on each routel point tension/compresion	=	2.65	kN	(refer to Appendix)
	<	4.5	kN	O.K.

4.3 Check for spider (Kin Long C250A)

Vertical load on spider	=	2.65	kN	(refer to item 4.2)
Reaction on each spider tension/compresion	=	2.65	kN	(refer to Appendix)
	<	4	kN	O.K.

4.4 Check for M16 s.s. bolt, A4-70

Vertical load	=	2 x 3.695		
	=	7.39	kN	(refer to item 4.2)
Tensile area of M16 bolt	=	156	mm^2	
Tensile strength of M16 bolt	=	373	N/mm^2	
Shear strength of M16 bolt	=	280	N/mm^2	
Tensile capacity of bolt	=	156 x 373 / 1000		
	=	58.19	kN	
	>	7.39	kN	O.K.
Pull out capacity on connected part,	=	16 x 3.1416 x 10 / 2 x 127 / 1000		
	=	31.919	kN	
	>	7.39	kN	O.K.

<u>Check for 5mm fillet weld connector channel to steel frame</u>

Horizontal load,	=	7.39	kN	
Effective length of fillet weld,	=	2 x 3.14 x 23		
	=	144.44	mm	
Capacity of fillet weld	=	160 x144.44 x 5 x 0.7 / 1000		
	=	80.886	kN	
	>	7.39	kN	O.K.

5. Check for steel frame

5.1 Combination loads

Design wind load = 3.68 kN/m^2

Live load = 0.75 kN/m^2

Dead load = 0.7 kN/m^2

Load cases

Dead = Dead Load (gravity)
DL = Dead Load (gravity)
Live = Live load (gravity)
Wx = Wind load in x direction (horizontal)
Wy = Wind load in y direction (lateral)
Wz = Wind load in z direction (vertical)
EQ = Earth Quake
Tem = Tempurature

TABLE: Combination Definitions

ComboName	ComboType	CaseType	CaseName	ScaleFactor
Text	Text	Text	Text	Unitless
COMB1	Linear Add	Linear Static	DEAD	1.3
COMB1		Linear Static	DL	1.3
COMB1		Linear Static	LL	1.05
COMB1		Linear Static	Wz	0.9
COMB1		Linear Static	EQ	0.65
COMB1		Linear Static	Tem	0.72
COMB2	Linear Add	Linear Static	DEAD	1.3
COMB2		Linear Static	DL	1.3
COMB2		Linear Static	LL	1.05
COMB2		Linear Static	Wx	0.9
COMB2		Linear Static	EQ	0.65
COMB2		Linear Static	Tem	0.72
COMB3	Linear Add	Linear Static	DEAD	1.3
COMB3		Linear Static	DL	1.3
COMB3		Linear Static	LL	1.05
COMB3		Linear Static	Wy	0.9
COMB3		Linear Static	EQ	0.65
COMB3		Linear Static	Tem	0.72
COMB4	Linear Add	Linear Static	DEAD	1.2
COMB4		Linear Static	DL	1.2
COMB4		Linear Static	LL	1.5
COMB4		Linear Static	Wz	0.9
COMB4		Linear Static	EQ	0.65
COMB4		Linear Static	Tem	0.72

ComboName	ComboType	CaseType	CaseName	ScaleFactor
Text	Text	Text	Text	Unitless
COMB5	Linear Add	Linear Static	DEAD	1.2
COMB5		Linear Static	DL	1.2
COMB5		Linear Static	LL	1.5
COMB5		Linear Static	Wx	0.9
COMB5		Linear Static	EQ	0.65
COMB5		Linear Static	Tem	0.72
COMB6	Linear Add	Linear Static	DEAD	1.2
COMB6		Linear Static	DL	1.2
COMB6		Linear Static	LL	1.5
COMB6		Linear Static	Wy	0.9
COMB6		Linear Static	EQ	0.65
COMB6		Linear Static	Tem	0.72
COMB7	Linear Add	Linear Static	DEAD	1.2
COMB7		Linear Static	DL	1.2
COMB7		Linear Static	LL	1.05
COMB7		Linear Static	Wz	1.5
COMB7		Linear Static	Tem	0.72
COMB8	Linear Add	Linear Static	DEAD	1.2
COMB8		Linear Static	DL	1.2
COMB8		Linear Static	LL	1.05
COMB8		Linear Static	Wx	1.5
COMB8		Linear Static	Tem	0.72
COMB9	Linear Add	Linear Static	DEAD	1.2
COMB9		Linear Static	DL	1.2
COMB9		Linear Static	LL	1.05
COMB9		Linear Static	Wy	1.5
COMB9		Linear Static	Tem	0.72

ComboName	ComboType	CaseType	CaseName	ScaleFactor
Text	Text	Text	Text	Unitless
COMB10	Linear Add	Linear Static	DEAD	1.2
COMB10		Linear Static	DL	1.2
COMB10		Linear Static	LL	1.05
COMB10		Linear Static	EQ	1.3
COMB10		Linear Static	Tem	0.72
COMB11	Linear Add	Linear Static	DEAD	1
COMB11		Linear Static	DL	1
COMB11		Linear Static	LL	1
COMB11		Linear Static	Wz	0.6
COMB11		Linear Static	EQ	0.2
COMB11		Linear Static	Tem	0.2
COMB12	Linear Add	Linear Static	DEAD	1
COMB12		Linear Static	DL	1
COMB12		Linear Static	LL	1
COMB12		Linear Static	Wx	0.6
COMB12		Linear Static	EQ	0.2
COMB12		Linear Static	Tem	0.2
COMB13	Linear Add	Linear Static	DEAD	1
COMB13		Linear Static	DL	1
COMB13		Linear Static	LL	1
COMB13		Linear Static	Wy	0.6
COMB13		Linear Static	EQ	0.2
COMB13		Linear Static	Tem	0.2

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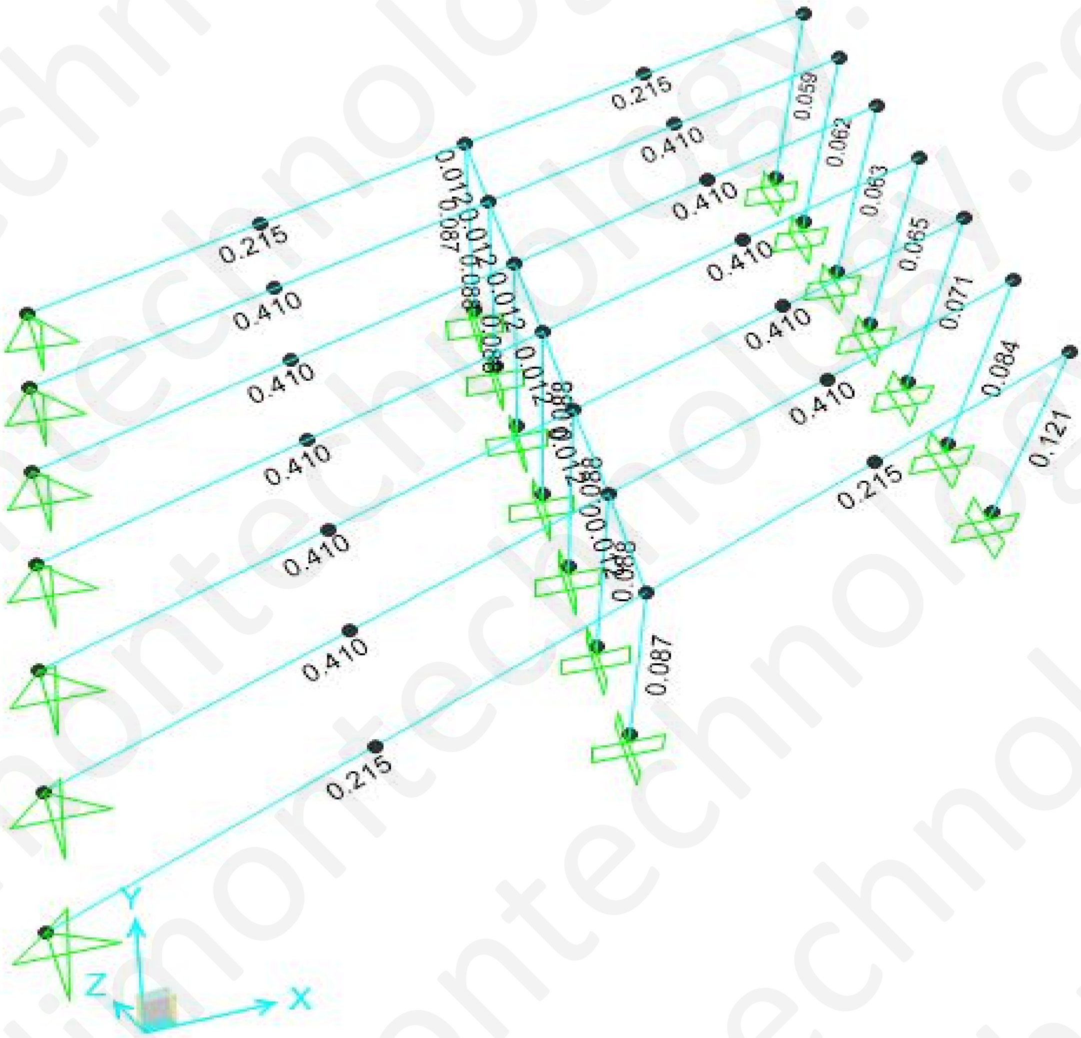

5.1 Check for 200x150x6mm GM. RHS， Q345

The output data refer to sap2000 (Appendix)

Max. Axial load,	P	=	6.428	kN	(frame 23, COMB 10)
Shear load,	V_2	=	24.676	kN	(frame 27, COMB 7)
Shear load,	V_3	=	3.053	kN	(frame 21, COMB 9)
Max. torsion	T	=	0	kNm	
Max. moment,	M_2	=	4.5561	kNm	(frame 28, COMB 9)
Max. moment,	M_3	=	40.5305	kNm	(frame 27, COMB 7)

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TABLE: Element Forces - Frames

Frame	Station	Output Case	CaseType	P	V2	V3	T	M2	M3
Text	m	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
21	0	COMB9	Combination	3.808	-3.707	-3.053	0	0	0
21	2.98513	COMB9	Combination	2.519	-0.02	-4.7E-07	0	4.5561	6.123
21	2.98513	COMB9	Combination	2.519	-0.02	-4.7E-07	-8.8E-16	4.5561	6.123
21	5.97026	COMB9	Combination	1.23	3.933	3.053	-8.8E-16	-1.7E-15	7.69E-16
23	0	COMB10	Combination	6.428	-6.5	0.42	0	0	0
23	2.98513	COMB10	Combination	6.428	9.75E-06	0.42	0	-1.2532	10.5436
23	2.98513	COMB10	Combination	4.439	9.75E-06	-0.42	-1.6E-15	-1.2532	10.5436
23	5.97026	COMB10	Combination	4.439	6.5	-0.42	-1.6E-15	-2.6E-16	3.09E-15
27	0	COMB7	Combination	-1.2E-13	-24.676	0	0	0	0
27	2.98513	COMB7	Combination	-1.2E-13	-2.4E-06	0	0	0	40.5305
27	2.98513	COMB7	Combination	-1.2E-13	-2.4E-06	0	9.21E-17	0	40.5305
27	5.97026	COMB7	Combination	-1.2E-13	24.676	0	9.21E-17	0	-3.6E-14
28	0	COMB9	Combination	5.719	-3.707	-3.052	0	0	0
28	2.98513	COMB9	Combination	4.43	-0.02	-3.1E-07	0	4.5561	6.123
28	2.98513	COMB9	Combination	4.43	-0.02	-3.1E-07	-1.6E-15	4.5561	6.123
28	5.97026	COMB9	Combination	3.141	3.933	3.052	-1.6E-15	-2.2E-16	-5.1E-15

<u>Properties of200x150x6mm RHS</u>

Moment of inertia, I_x	= 2358	cm^4	Moment of inertia, I_y	= 1507	cm^4
Elastic modulus, Z_x	= 235	cm^3	Elastic modulus, Z_y	= 201	cm^3
Plastic modulus, S_x	= 280	cm^3	Plastic modulus, S_y	= 229	cm^3
Radius of gyration, r_x	= 7.63	cm	Radius of gyration, r_y	= 6.1	cm
Area	= 40.56	cm^2			

Shear stress = 24.676 x 1000 / (2 x 6 x 200) + 3.053 x 1000 / (2 x 6 x 150)
= 11.98 N/mm^2
< 0.6 x 180 = 108 N/mm^2 (low shear)

Moment capacity = $\min(1.2\ p_y\ Z_x,\ p_y\ S_x)$
= (1.2 x 310 x 235 /1000 , 310 x 280/ 1000)
= 86.8 kNm (factored)
> 40.5305 kNm O.K.

Moment capacity = $\min(1.2\ p_y\ Z_y,\ p_y\ S_y)$
= (1.2 x 310 x 148/1000 , 310 x 229 / 1000)
= 70.99 kNm (factored)
> 4.5561 kNm O.K.

Slenderness,λ L_e / r_y = 5970 / 61
= 97.87

Design compressive strength p_c = 150 MPa

Compression resistance P_c = 150 x 4056/ 1000
= 608.4 kN
> 6.428 kN O.K.

Combined loads = 6.428 / 608.4 + 4.5561 / 70.99 + 40.5305 / 86.8
= 0.542
< 1 O.K.

Deflection = 16.874 mm (Joint 44, COMB11)
< 5970 / 250 = 23.88 mm O.K.

Check for lateral torsional buckling

Design strength,	p_y	=	310	N/mm^2	Parameter,	$\varepsilon = (275 / p_y)^{0.5}$	=	0.9419		
Modulus of Elasticity,	E	=	206000	N/mm^2						
Overall width,	B	=	150	mm	Overall depth,	D	=	200	mm	
Wall thickness,	t	=	6	mm	Area,	A	=	40.56	cm^2	
Moment of inertia,	I_x	=	2358	cm^4	Moment of inertia,	I_y	=	1507	cm^4	
Section modulus,	Z_x	=	235	cm^3	Section modulus,	Z_y	=	201	cm^3	
Plastic modulus,	S_x	=	280	cm^3	Plastic modulus,	S_y	=	229	cm^3	
Torsional constant,	J	=	7.63	cm^4	Radius of gyration,	r_y	=	6.1	cm	
Effective length,	L_E	=	5970	mm						

Slenderness ratio,	λ	=	L_E / r_y	=	97.9	
	γ_b	=	$(1 - I_y / I_x)\,[1 - J / (2.6\,I_x)]$	=	0.3604	
Buckling index,	$\varnothing_b$	=	$[S_x^{\,2}\,\gamma_b / (A\,J)]^{0.5}$	=	9.5552	
Ratio,	β_w	=	1			for plastic section
Equivalent slenderness,	λ_{LT}	=	$2.25\,(\varnothing_b\,\lambda\,\beta_w)^{0.5}$	=	68.82	
	P_E	=	$\pi^2\,E / \lambda_{LT}^{\,2}$	=	429.28	
	α_{LT}	=	7			
	λ_{L0}	=	$0.4\,(\pi^2\,E / p_y)^{0.5}$	=	32.39	
Perry factor,	η_{LT}	=	$\alpha_{LT}\,(\lambda_{LT} - \lambda_{L0}) / 1000$	=	0.255	≥ 0 O.K.
	$\varnothing_{LT}$	=	$[p_y + (\eta_{LT} + 1)\,P_E] / 2$	=	424.37	

Bending buckling strength, p_b = $P_E\,p_y / (\varnothing_{LT} + (\varnothing_{LT}^{\,2} - P_E\,p_y)^{0.5})$
= 207.54 N/mm^2

Bending buckling resistanceh, = 207.54 x 280 /1000
= 58.111 kNm
> 40.5305 kNm O.K.

5.2 Check for 200x150x8mm GM. RHS， Q345

The output data refer to sap2000 (Appendix)

Max. Axial load,	P	=	-58.044	kN	(frame 9, COMB 7)
Shear load,	V_2	=	2.759	kN	(frame 7, COMB 8)
Shear load,	V_3	=	5.081	kN	(frame 1, COMB 9)
Max. torsion	T	=	0.14	kNm	(frame 9, COMB 9)
Max. moment,	M_2	=	10.9831	kNm	(frame 1, COMB 9)
Max. moment,	M_3	=	-6.0966	kNm	(frame 1, COMB 9)

TABLE: Element Forces - Frames

Frame	Station	Output Case	CaseType	P	V2	V3	T	M2	M3
Text	m	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
1	0	COMB9	Combination	-6.495	-1.742	5.081	-0.067	10.9831	-6.0966
1	1.75	COMB9	Combination	-5.407	-1.742	3.138	-0.067	3.7919	-3.0483
1	3.5	COMB9	Combination	-4.319	-1.742	1.196	-0.067	-1.5E-12	4.77E-15
7	0	COMB8	Combination	-6.181	2.759	-0.477	-0.00048	-1.6686	2.8565
7	1.75	COMB8	Combination	-5.093	0.816	-0.477	-0.00048	-0.8343	-0.2714
7	3.5	COMB8	Combination	-4.005	-1.126	-0.477	-0.00048	2.4E-13	3.59E-14
7	0	COMB9	Combination	-6.181	-0.738	3.551	-0.0122	5.6287	-2.5841
7	1.75	COMB9	Combination	-5.093	-0.738	1.608	-0.0122	1.1147	-1.292
7	3.5	COMB9	Combination	-4.005	-0.738	-0.334	-0.0122	4.84E-13	2.02E-13
7	0	COMB10	Combination	-6.181	0.393	-0.56	0.0148	-1.9604	1.3747
7	1.75	COMB10	Combination	-5.093	0.393	-0.56	0.0148	-0.9802	0.6873
7	3.5	COMB10	Combination	-4.005	0.393	-0.56	0.0148	-4E-13	2.56E-14
9	0	COMB7	Combination	-58.044	5.37E-14	-8.2E-15	-2.9E-16	-1.1E-14	6.17E-14
9	1.75	COMB7	Combination	-56.956	5.37E-14	-8.2E-15	-2.9E-16	3.54E-15	-3.2E-14
9	3.5	COMB7	Combination	-55.868	5.37E-14	-8.2E-15	-2.9E-16	1.79E-14	-1.3E-13
9	0	COMB9	Combination	-17.058	-1.178	4.205	0.14	7.9181	-4.1238
9	1.75	COMB9	Combination	-15.97	-1.178	2.262	0.14	2.2594	-2.0619
9	3.5	COMB9	Combination	-14.882	-1.178	0.32	0.14	-3.4E-12	1.63E-15

Properties of 200x150x8mm RHS

Moment of inertia, I_x	= 3043	cm^4	Moment of inertia, I_y	=	1935	cm^4
Elastic modulus, Z_x	= 304	cm^3	Elastic modulus, Z_y	=	258	cm^3
Plastic modulus, S_x	= 365	cm^3	Plastic modulus, S_y	=	299	cm^3
Radius of gyration, r_x	= 7.55	cm	Radius of gyration, r_y	=	6.02	cm
Torsional constant, J	= 3560	cm^4	Torsional constant,C	=	436	cm^3
Area	= 53	cm^2				

Shear stress = 5.081 x 1000 / (2 x 8 x 200) + 2.759 x 1000 / (2 x 8 x 150) + 0.14 x 10^6 / 436 / 1000

= 3.3 N/mm^2

< 0.6 x 180 = 108 N/mm^2 (low shear)

Moment capacity = min(1.2 p_y Z_x, p_y S_x)

= (1.2 x 310 x 304 /1000 , 310 x 365/ 1000)

= 113.15 kNm (factored)

> 6.0966 kNm O.K.

Moment capacity = min(1.2 p_y Z_y, p_y S_y)
= (1.2 x 310 x 258 /1000 , 310 x 299 / 1000)
= 92.69 kNm (factored)
> 10.9831 kNm O.K.

Slenderness,λ L_e / r_y = 3500 / 60.2
= 58.14

Design compressive strength p_c = 240 MPa

Compression resistance P_c = 240 x 53000 / 1000
= 1272 kN
> 58.044 kN O.K.

Combined loads = 58.044 / 1272 + 10.9831 / 92.69 + 6.0966 / 113.15
= 0.218
< 1 O.K.

Deflection = 2.96 mm (Joint 2, COMB131)
< 2 x 3500 / 250 = 28 mm O.K.

<u>Check for lateral torsional buckling</u>

Overall width,	B	= 150	mm	Overall depth,	D	=	200	mm
Wall thickness,	t	= 8	mm	Area,	A	=	53	cm^2
Moment of inertia,	I_x	= 3043	cm^4	Moment of inertia,	I_y	=	1935	cm^4
Section modulus,	Z_x	= 340	cm^3	Section modulus,	Z_y	=	258	cm^3
Plastic modulus,	S_x	= 365	cm^3	Plastic modulus,	S_y	=	299	cm^3
Torsional constant,	J	= 3560	cm^4	Radius of gyration,	r_y	=	6.02	cm
Effective length,	L_E	= 3500	mm					

Slenderness ratio,	λ	= L_E / r_y	= 58.1		
	γ_b	= $(1 - I_y / I_x) [1 - J / (2.6 I_x)]$	= 0.2003		
Buckling index,	$ø_b$	= $[S_x^2 \gamma_b / (A J)]^{0.5}$	= 0.3761		
Ratio,	β_w	= 1			for plastic section
Equivalent slenderness,	λ_{LT}	= $2.25 (ø_b \lambda \beta_w)^{0.5}$	= 10.52		
	P_E	= $\pi^2 E / \lambda_{LT}^2$	= 18371.11		
	α_{LT}	= 7			
	λ_{L0}	= $0.4 (\pi^2 E / p_y)^{0.5}$	= 32.39		
Perry factor,	η_{LT}	= $\alpha_{LT} (\lambda_{LT} - \lambda_{L0}) / 1000$	= -0.1531	< 0	
	$ø_{LT}$	= $[p_y + (\eta_{LT} + 1) P_E] / 2$	= 7934.25		

Bending buckling strength, $p_b = P_E\,p_y / (\phi_{LT} + (\phi_{LT}^2 - P_E\,p_y)^{0.5})$

$= 367.4$ N/mm^2

> 310 N/mm^2

5.3 Check for 8mm fillet weld all round connection to base plate

TABLE: Joint Reactions								
Joint	OutputCase	CaseType	F1	F2	F3	M1	M2	M3
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
1	COMB1	Combination	-0.23	0.331	13.376	-1.1578	-0.8061	-0.00092
1	COMB8	Combination	-2.755	0.473	6.495	-1.6554	-2.845	0.000594
1	COMB9	Combination	1.742	-5.081	6.495	10.9831	6.0966	0.067
1	COMB10	Combination	-0.461	0.662	6.495	-2.3155	-1.6123	-0.0018
13	COMB1	Combination	-0.196	0.28	12.408	-0.9802	-0.6873	-0.0074
13	COMB7	Combination	5.08E-14	2.42E-14	15.894	-1.4E-14	6.61E-14	-1.8E-16
13	COMB8	Combination	-2.759	0.477	6.181	-1.6686	-2.8565	0.000479
13	COMB9	Combination	0.738	-3.551	6.181	5.6287	2.5841	0.0122
13	COMB10	Combination	-0.393	0.56	6.181	-1.9604	-1.3747	-0.0148
17	COMB1	Combination	-0.391	0.57	42.584	-1.9946	-1.3687	0.009
17	COMB9	Combination	1.178	-4.205	17.058	7.9181	4.1238	-0.14
17	COMB10	Combination	-0.782	1.14	17.058	-3.9892	-2.7374	0.0179
25	COMB1	Combination	-0.391	0.57	42.584	-1.9951	-1.3693	0.0139
25	COMB6	Combination	0.312	-1.949	19.564	2.7415	1.0932	-0.0098
25	COMB7	Combination	-4.7E-14	-5.3E-14	58.044	5.92E-14	-5.4E-14	2.65E-17
25	COMB8	Combination	-2.736	0.45	17.058	-1.5761	-2.7757	0.0137
25	COMB9	Combination	1.173	-4.198	17.058	7.8943	4.1042	-0.0395
25	COMB10	Combination	-0.782	1.14	17.058	-3.9903	-2.7387	0.0279

The output data refer to sap2000 (Appendix)

Shear load,	$F_1 = -2.759$	kN	(joint 13, COMB8)
Shear load,	$F_2 = -5.081$	kN	(joint 1, COMB9)
Axial load,	$F_3 = 58.044$	kN	(joint 25, COMB 7)
Moment,	$M_1 = 10.9831$	kNm	(joint 1, COMB9)
Moment,	$M_2 = 6.0966$	kNm	(joint 1, COMB9)
Moment,	$M_3 = 0.14$	kNm	(joint 17, COMB 9)

Properties for unit throat thickness of fillet weld (effective length)

Breadth, $B = 150$ mm

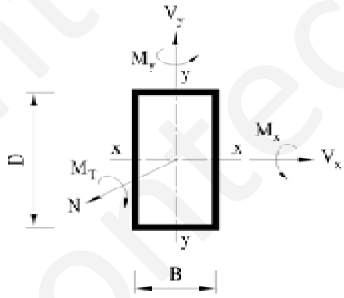
Height, $D = 200$ mm

Area, $A = 2\,(B + D) = 700$ mm^2

Moment of inertia, $I_x = B\,D^2 / 2 + D^3 / 6 = 4333333$ mm^4

Moment of inertia, $I_y = B^2\,D / 2 + B^3 / 6 = 2812500$ mm^4

Polar moment of inertia, $J = I_x + I_y = 7145833$ mm^4



Shear load,	$V_x = 2.759$	kN	Moment,	$M_x = 10.9831$	kNm
Shear load,	$V_y = 5.081$	kN	Moment,	$M_y = 6.0966$	kNm
Tensile load,	$N = 58.044$	kN	Torsional moment,	$M_T = 0.14$	kNm

Leg length of fillet weld,	t	= 8 mm			
Shear stress,	τ_x	$= V_x / (0.7\ t\ A) + M_T\ (D / 2) / (0.7\ t\ J)$	=	1.05	N/mm^2
Shear stress,	τ_y	$= V_y / (0.7\ t\ A) + M_T\ (B / 2) / (0.7\ t\ J)$	=	1.56	N/mm^2
Tensile stress,	σ	$= N / (0.7\ t\ A)$	=	14.81	N/mm^2
Tensile stress,	σ_x	$= M_x\ D / (2\ I_x) / (0.7\ t)$	=	45.26	N/mm^2
Tensile stress,	σ_y	$= M_y\ B / (2\ I_y) / (0.7\ t)$	=	29.03	N/mm^2

Resultant , $f_w = [\tau_x^2 + \tau_y^2 + (\sigma + \sigma_x + \sigma_y)^2]^{0.5}$

$= 89.12$ N/mm^2

≤ 200 N/mm^2 O.K.

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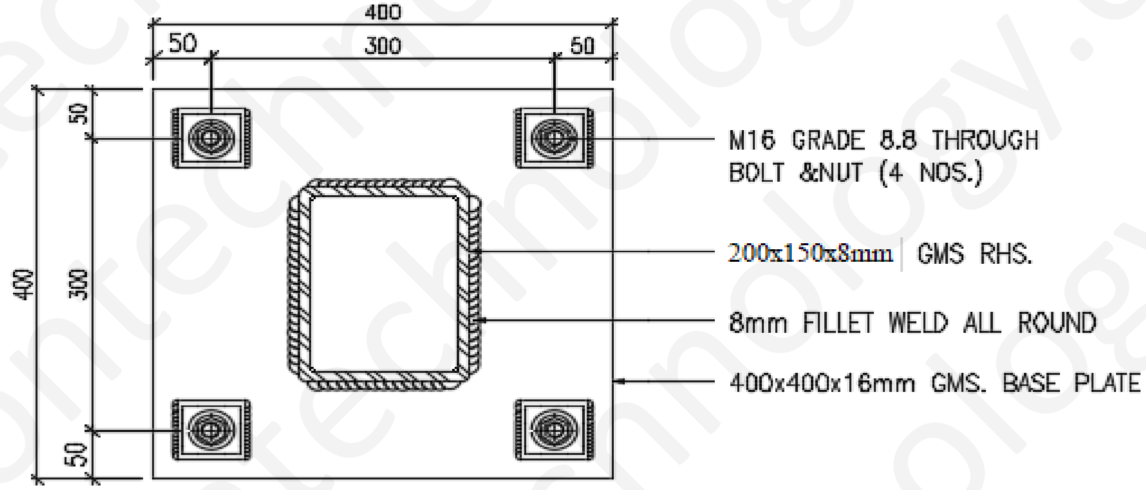
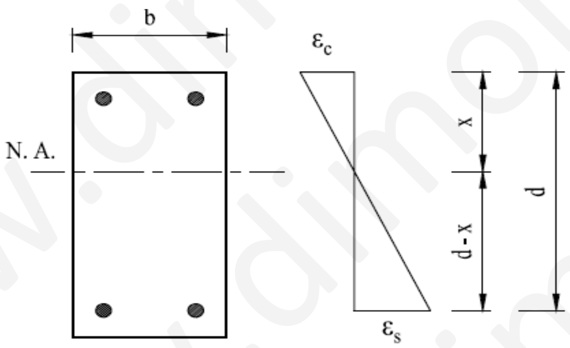
6. Check for embed

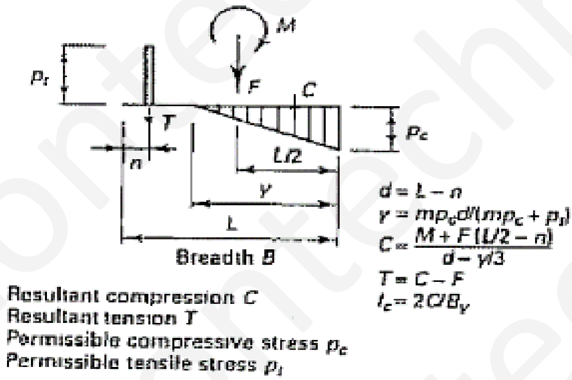
6.1 Check for ME1 M16 holding down bolt, Gr 8.8



The output data refer to sap2000 (Appendix)

Shear load,	F_1	=	-2.759	kN	(joint 13, COMB8)
Shear load,	F_2	=	-5.081	kN	(joint 1, COMB9)
Axial load,	F_3	=	58.044	kN	(joint 25, COMB 7)
Moment,	M_1	=	10.9831	kNm	(joint 1, COMB9)
Moment,	M_2	=	6.0966	kNm	(joint 1, COMB9)
Moment,	M_3	=	0.14	kNm	(joint 17, COMB 9)





$$\varepsilon_c / \varepsilon_s = x / (d - x)$$

$$\varepsilon_c / \varepsilon_s = (f_c / E_c) / (f_s / E_s)$$
$$= m f_c / f_s$$

$$m f_c / f_s = x / (d - x)$$

Thus, $$x = m f_c d / (m f_c + f_s)$$

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Breadth of plate,	b	=	400	mm	Concrete strength,	f_{cu}	= 45	N/n
Distance,	d	=	350	mm				
Conc/Grout Comp strength,	f_c	=	27	N/mm^2	(for $f_c = 0.6\ f_{cu}$)			
Holding down bolt strength,	f_s	=	450	N/mm^2				
Modulus of Elasticity, steel,	E_s	=	205	kN/mm^2				
Modulus of Elasticity, conc,	E_c		26.42	kN/mm^2	(for $E_c = 3.46\ f_{cu}^{0.5} + 3.21$)			
Modular ratio,	$m = E_s / E_c$	=	7.76					
Moment,	M	=	10.9831	kNm				

$x = m\ f_c\ d / (m\ f_c + f_s)$

$= 111.19$ mm

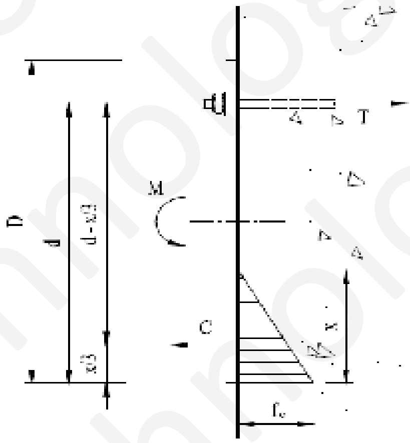
$d - x / 3 = 312.94$ mm

Taking moment at C, $T = M / (d - x / 3)$

$= 35.1$ kN

Bearing pressure on concrete $= 2\ C / (b\ x)$

$= 1.58$ N/mm^2



Similarly for M_y

Breadth of plate,	b	=	400	mm	Concrete strength,	f_{cu}	= 45	N/n
Distance,	d	=	350	mm				
Conc/Grout Comp strength,	f_c	=	27	N/mm^2	(for $f_c = 0.6\ f_{cu}$)			
Holding down bolt strength,	f_s	=	450	N/mm^2				
Modulus of Elasticity, steel,	E_s	=	205	kN/mm^2				
Modulus of Elasticity, conc,	E_c		26.42	kN/mm^2	(for $E_c = 3.46\ f_{cu}^{0.5} + 3.21$)			
Modular ratio,	$m = E_s / E_c$	=	7.76					
Moment,	M	=	6.0966	kNm				

$x = m\ f_c\ d / (m\ f_c + f_s)$

$= 111.19$ mm

$d - x / 3 = 312.94$ mm

Taking moment at C, $T = M / (d - x / 3)$

$= 19.48$ kN

Bearing pressure on concrete $= 2\ C / (b\ x)$

$= 0.88$ N/mm^2

Total bearing pressure on concrete	=	1.58 + 0.88		
	=	1.86	N/mm^2	
	<	27	N/mm^2	O.K.
Tensile load on each bolt	=	58.044 / 4 + 35.1 / 2 + 19.48 / 2		
	=	41.801	kN	
Shear load on each bolt	=	$[(2.759 / 4)^2 + (5.081 / 4 + 0.14 / 0.424)^2]^{0.5}$		
	=	1.166	kN	
Tensile area of M16bolt	=	156	mm^2	
Shar strength of M16 bolt	=	375	N/mm^2	
Tensile strength of M16 bolt	=	450	N/mm^2	
Tensile capacity of M16 bolt	=	156 x 450 / 1000		
	=	70.2	kN	
	>	41.801	kN	O.K.
Shear capacity of M16 bolt	=	450 x 375/ 1000		
	=	58.5	kN	
	>	1.166	kN	O.K.
Combined tensile & shear loads	=	$(41.801 / 70.2)^2 + (1.166 / 58.5)^2$		
	=	0.355		
	<	1		O.K.

<u>Check for 16mm thick gms base plate</u>

Distance between edge of gms SHS & cg of compression,	=	50	mm	
Bending moment at edge of gms SHS	=	2 x 41.801 x 50		
	=	4180.1	kNmm	
Moment resistance of gms plate	=	$1.2 \times 310 \times 400 \times 16^2 / 6 / 1000$		
	=	6348.8	kNmm	
	>	0	kNmm =	O.K.

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6.2 Check for ME2 M16 holding down bolt, Gr 8.8

TABLE: Joint Reactions								
Joint	OutputCase	CaseType	F1	F2	F3	M1	M2	M3
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
30	COMB1	Combination	-3.427	-1.02	19.834	0	0	0
30	COMB6	Combination	-4.587	-1.613	8.436	0	0	0
30	COMB7	Combination	9.09E-14	3.86E-14	27.676	0	0	0
30	COMB8	Combination	-2.279	-0.918	7.183	0	0	0
30	COMB9	Combination	-1.934	-0.989	7.183	0	0	0
30	COMB10	Combination	-6.853	-2.04	7.183	0	0	0
34	COMB1	Combination	-3.407	-1.013	19.834	0	0	0
34	COMB6	Combination	-4.425	-1.543	8.436	0	0	0
34	COMB7	Combination	1.08E-13	4.61E-14	27.676	0	0	0
34	COMB8	Combination	-2.278	-0.918	7.183	0	0	0
34	COMB9	Combination	-1.696	-0.883	7.183	0	0	0
34	COMB10	Combination	-6.815	-2.026	7.183	0	0	0
35	COMB1	Combination	-2.012	-0.701	10.051	0	0	0
35	COMB8	Combination	-2.105	-0.953	4.005	0	0	0
35	COMB9	Combination	-4.359	-4.907	4.005	0	0	0
35	COMB10	Combination	-4.024	-1.403	4.005	0	0	0

The output data refer to sap2000 (Appendix)

Shear load,	F_1	=	-6.853	kN	(joint 30, COMB10)
Shear load,	F_2	=	-4.907	kN	(joint 35, COMB 9)
Axial load,	F_3	=	27.676	kN	(joint 34, COMB 7)

Tensile load on each bolt = 6.853 / 6
= 1.142 kN

Shear load on each bolt = $[(4.907 / 6)^2 + (27.676/ 6)^2]^{0.5}$
= 4.685 kN

Tensile area of M16bolt = 156 mm^2
Shar strength of M16 bolt = 375 N/mm^2
Tensile strength of M16 bolt = 450 N/mm^2

Tensile capacity of M16 bolt = 156 x 450 / 1000
= 70.2 kN
> 1.142 kN O.K.

Shear capacity of M16 bolt = 450 x 375/ 1000
= 58.5 kN
> 4.685 kN O.K.

Combined tensile & shear loads = $(1.142 / 70.2)^2 + (4.685 / 58.5)^2$
= 0.007
< 1 O.K.