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		Prepared by	Y.S.Zhang
Project		Date	16.07.2020
Title	CHLOE @ SKY68	Revision	-

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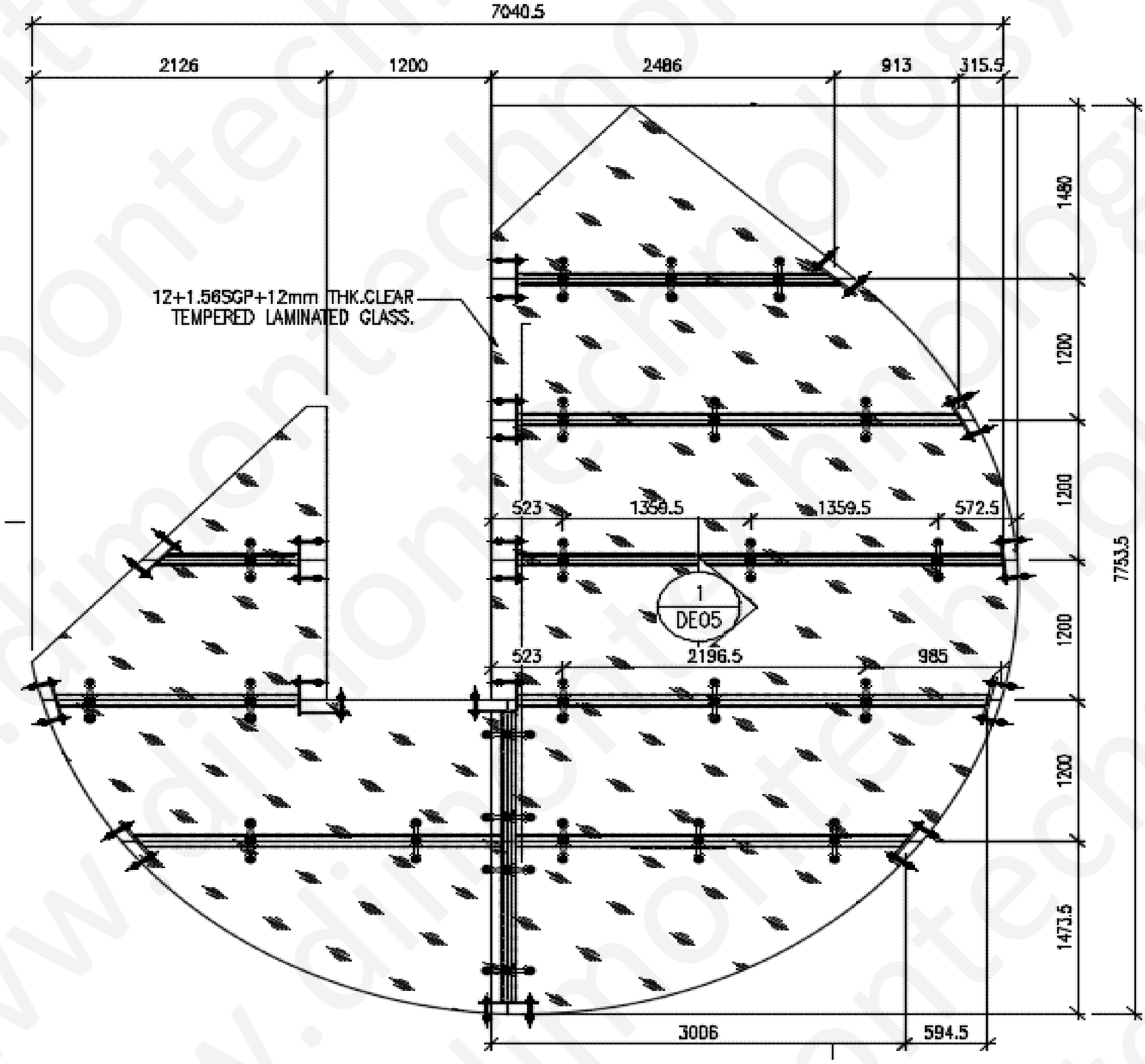
1. Introduction

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.

Load path

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 Stainless steel to be grade X5CrNiMo17-12-2 complied with BS EN 10088

stainless steel grade		1.4401 (316 S31) X5CrNiMo17-12-2
0.2% proof stress	(N/mm^2)	220
ultimate tensile strength, min.	(N/mm^2)	510
Modulus of elasticity	(N/mm^2)	200000
Design strength	(N/mm^2)	220
Design stress of fillet weld	(N/mm^2)	220

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 stainless steel bolts or screws to be grade A4 complied to BS EN ISO 3506

class		70
0.2% proof stress	(N/mm^2)	450
ultimate tensile strength	(N/mm^2)	700
design tensile strength	(N/mm^2)	373
design shear strength	(N/mm^2)	280
design bearing strength	(N/mm^2)	805

stainless steel grade		A4 / 316
design bearing strength on connected part	(N/mm^2)	479

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 = 1.84 kPa (height above ground level ≤10m)

Pressure coefficient, = 2 (open frame)

Design wind load = 2.12 x 2.0
= 3.68 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

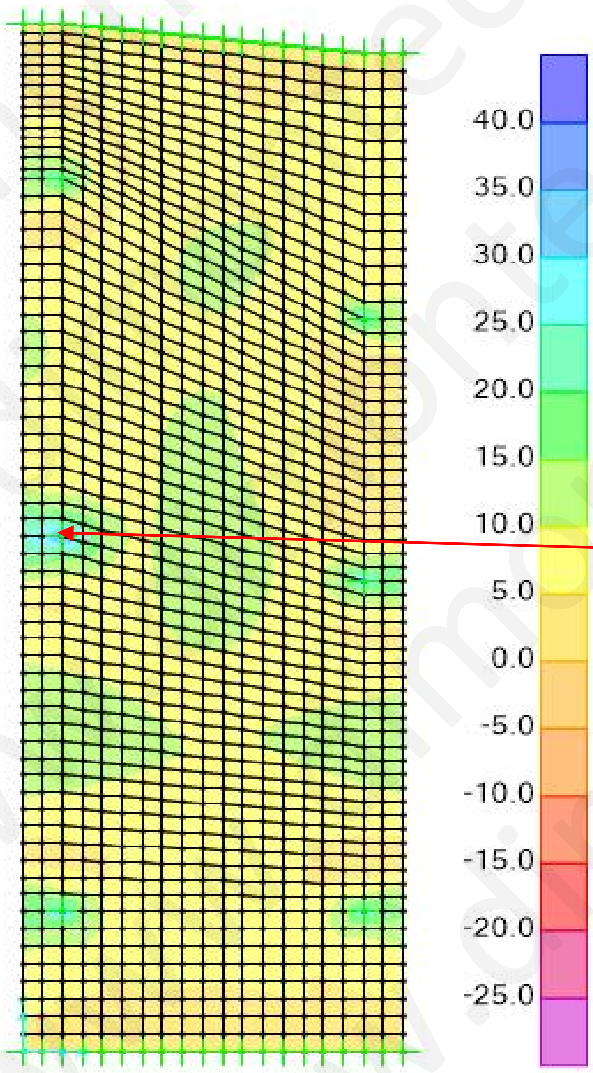
4.1 Check for 12mm+1.56PVB+12mm clear laminated tempered glass (6 point + 2 side supports)

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;



Max stress:
= 42.984 N/mm^2

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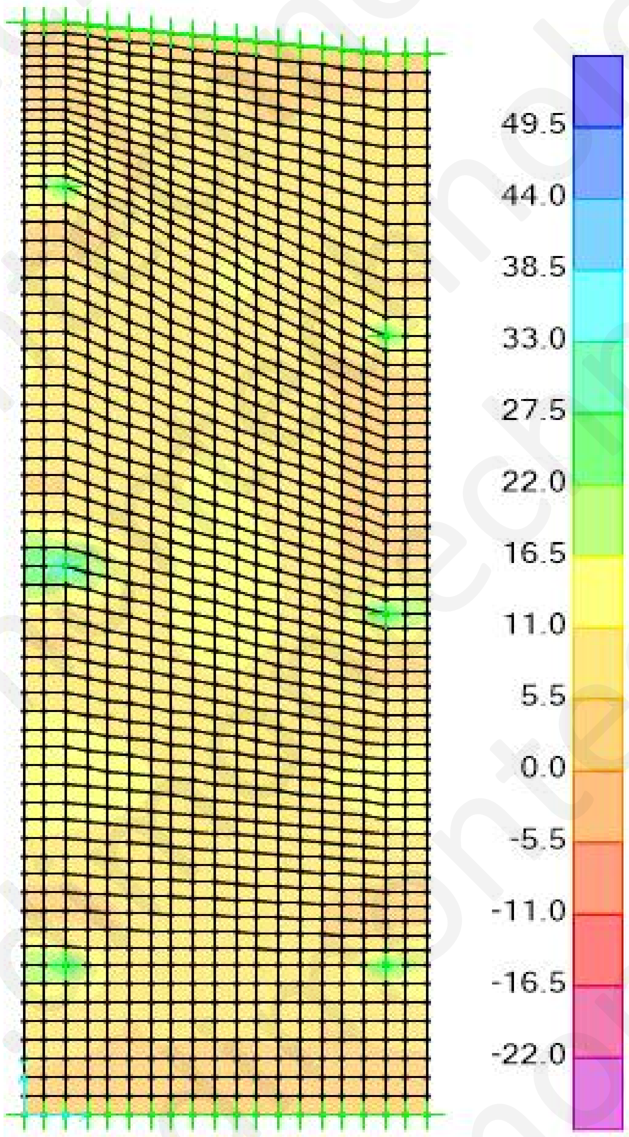
Comb 2: 1.2DL + 1.5LL + 0.9WL;



Max stress:
= 45.381N/mm^2

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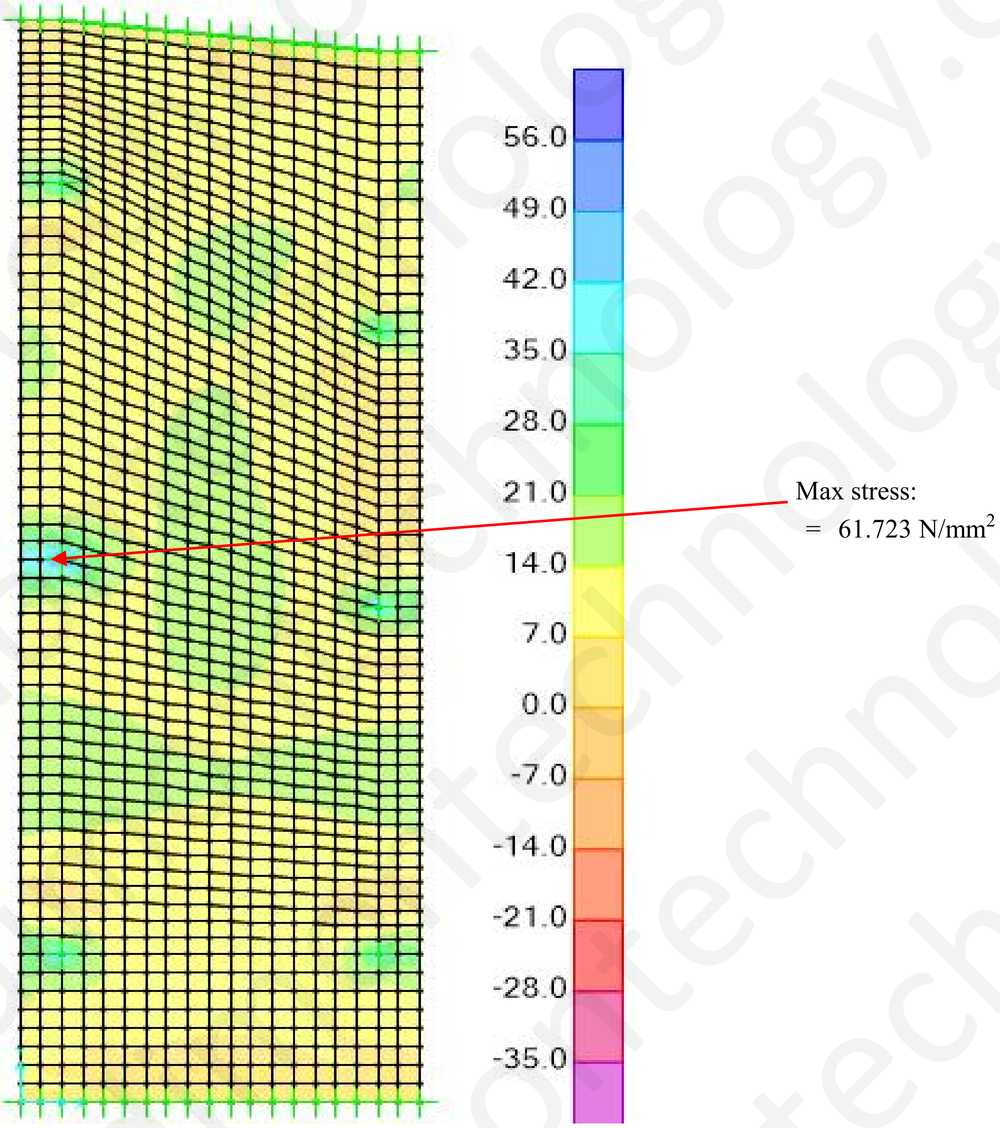
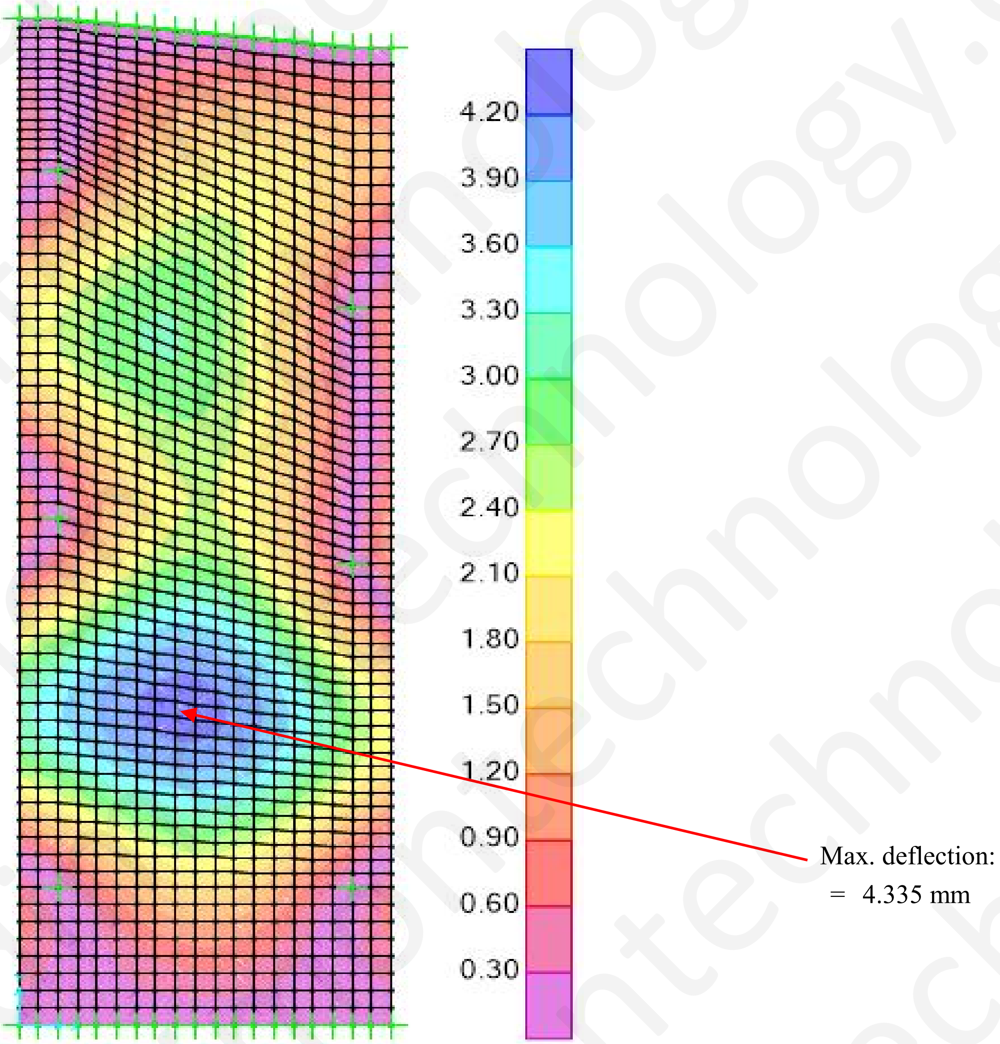
Comb 3: 1.2DL + 1.05LL + 1.5WL;



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



Max. bending stress of glass pane, σ_{c1} = 61.723 N/mm^2
≤ 80 N/mm^2 O.K.

Max. deflection, δ_c = 4.335 mm
≤ 950 / 60 = 15.83 mm O.K.

<u>Check for structural sealant</u>

Structural sealant bite required = 3.68 x 0.985 / 2 / 0.138
= 15.13 mm
≤ 26 mm O.K.

4.2 Check for flat cap routel (Kin Long TF12)

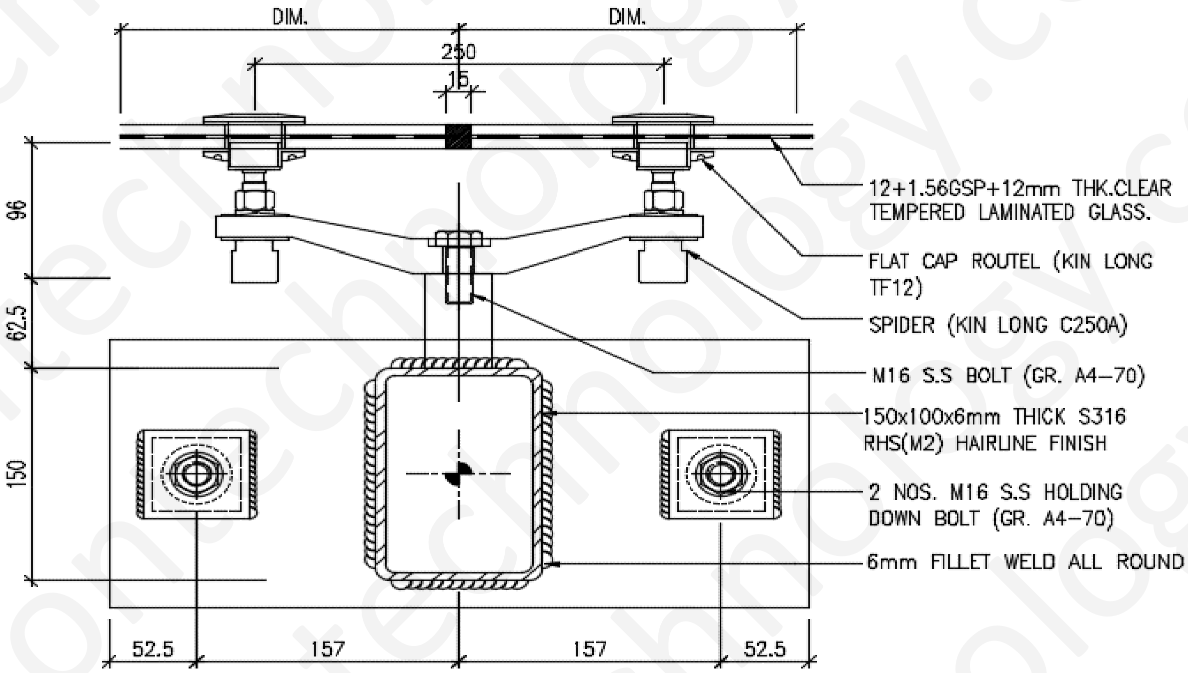
Table: Joint Reactions

Joint	Output Case	CaseType	F1	F2	F3	M1	M2	M3
			KN	KN	KN	KN-m	KN-m	KN-m
9	COMB1	Combination	0	0	1.652	0	0	0
9	COMB2	Combination	0	0	1.745	0	0	0
9	COMB3	Combination	0	0	2.373	0	0	0
9	COMB4	Combination	0	0	1.448	0	0	0
10	COMB1	Combination	0	0	1.542	0	0	0
10	COMB2	Combination	0	0	1.628	0	0	0
10	COMB3	Combination	0	0	2.215	0	0	0
10	COMB4	Combination	0	0	1.351	0	0	0
11	COMB1	Combination	0	0	1.514	0	0	0
11	COMB2	Combination	0	0	1.598	0	0	0
11	COMB3	Combination	0	0	2.174	0	0	0
11	COMB4	Combination	0	0	1.326	0	0	0
12	COMB1	Combination	0	0	1.559	0	0	0
12	COMB2	Combination	0	0	1.646	0	0	0
12	COMB3	Combination	0	0	2.238	0	0	0
12	COMB4	Combination	0	0	1.366	0	0	0
232	COMB1	Combination	0	0	2.115	0	0	0
232	COMB2	Combination	0	0	2.233	0	0	0
232	COMB3	Combination	0	0	3.037	0	0	0
232	COMB4	Combination	0	0	1.853	0	0	0
856	COMB1	Combination	0	0	1.681	0	0	0
856	COMB2	Combination	0	0	1.775	0	0	0
856	COMB3	Combination	0	0	2.414	0	0	0
856	COMB4	Combination	0	0	1.473	0	0	0

Vertical load = 0.7 + 0.75 + 4.24 (DL+LL + WL)
= 5.69 kN/m^2 (unfactored)

= 1.2 x 0.7 + 1.05 x 0.75 + 1.5 x 4.24 (1.2DL+1.05LL +1.5 WL)
= 7.99 kN/m^2 (factored)

Vertical load on routel at centre = 3.037 x 5.69 / 7.99
= 2.16 kN



Reaction on each routel point				
tension/compresion	= 2.16	kN	(refer to Appendix)	
	< 4.5	kN		O.K.

4.3 Check for spider (Kin Long C250A)

Vertical load on spider	= 2.16	kN	(refer to item 4.2)

Reaction on each spider				
tension/compresion	= 2.16	kN	(refer to Appendix)	
	< 4	kN		O.K.

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

Vertical load	= 2 x 3.037		
	= 6.074	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	
	>	6.074	kN	O.K.
Pull out capacity on connected part,	=	16 x 3.1416 x 10 / 2 x 127 / 1000		
	=	31.919	kN	
	>	6.074	kN	O.K.

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

Horizontal load,	=	6.074	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	
	>	6.074	kN	O.K.

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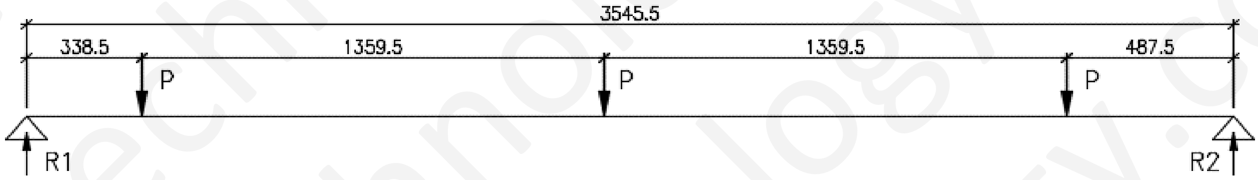
5. Check for steel frame

5.1 Check for 150x100x6mm s.s. RHS



Vertical load, P = 2 x 3.037 (refer to item 4.2)
= 6.074 kN (factored)

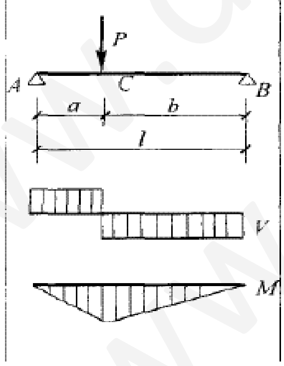
Reaction at support R1 = (3207 / 3545.5 + 1847 / 3545.5 + 487.5 / 3545.5) x 6.074
= 9.493 kN

R2 = 3 x 6.074 - 9.493
= 8.729 kN

Max bending moment = 9.493 x 1.698 - 6.074 x 1.3595
= 7.86 kNm

Shear stress = 9.493 x 1000 / (2 x 6 x 150)
= 5.27 N/mm^2
< 0.6 x 127 = 76.2 N/mm^2 (low shear)

Moment capacity = min(1.2 p_y Z_y, p_y S_y)
= (1.2 x 220 x 115/1000 , 220 x 141 / 1000)
= 30.36 kNm (factored)
> 7.86 kNm O.K.



$R_A = \frac{Pb}{l}$

$R_B = \frac{Pa}{l}$

A ~ C 段： $M_x = \frac{Pbx}{l}$

C ~ B 段： $M_x = Pa\left(1 - \frac{x}{l}\right)$

$M_{max} = M_C = \frac{Pab}{l}$

A ~ C 段：

$w_x = \frac{Pbx}{6EIl}(l^2 - b^2 - x^2)$

C ~ B 段：

$w_x = \frac{Pa(l-x)}{6EIl}(2lx - a^2 - x^2)$

$w_C = \frac{Pa^2b^2}{3EIl}$

若 $a > b$、当 $x = \sqrt{\frac{a}{3}(a+2b)}$：

$w_{max} = \frac{Pb}{9EIl}\sqrt{\left(\frac{a^2+2ab}{3}\right)^3}$

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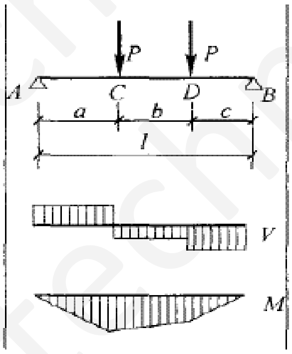

$R_A = \frac{P}{l}(2c+b)$

$R_B = \frac{P}{l}(2a+b)$

A ~ C 段: $M_x = \frac{P}{l}(2c+b)x$

C ~ D 段:

$M_x = \frac{P}{l}[(c-a)x + al]$

D ~ B 段:

$M_x = \frac{P}{l}(2a+b)(l-x)$

若 $a > c$

$M_C = M_{max} = \frac{Pa}{l}(2c+b)$

$w_C = \frac{Pa}{6EIl}[(2a+c)l^2 - 4a^2 l + 2a^3 - a^2 c - c^3]$

$w_D = \frac{PC}{6EIl}[(2c+a)l^2 - 4c^2 l + 2c^3 - ac^2 - a^3]$

Max .deflection $= 1/48\ P_k\ L^3\ (3\alpha - 4\ \alpha^3) / (E\ I) + P_k\ a\ [(2c+a)L^2 - 4c^2L + 2c^3 - ac^2 - a^3)] / (6E\ I)$

$= 8.38$ mm (unfactored)

$< 3545.5 / 250 = 14.18$ mm O.K.

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

Design strength, $p_y = 220$ N/mm^2 Parameter, $\varepsilon = (275 / p_y)^{0.5} = 1.118$

Modulus of Elasticity, $E = 200000$ N/mm^2

Overall width,	$B = 100$	mm		Overall depth,	$D = 150$	mm
Wall thickness,	$t = 6$	mm		Area,	$A = 28.2$	cm^2
Moment of inertia,	$I_x = 862$	cm^4		Moment of inertia,	$I_y = 456$	cm^4
Section modulus,	$Z_x = 115$	cm^3		Section modulus,	$Z_y = 91.2$	cm^3
Plastic modulus,	$S_x = 141$	cm^3		Plastic modulus,	$S_y = 106$	cm^3
Torsional constant,	$J = 946$	cm^4		Radius of gyration,	$r_y = 4.02$	cm
Effective length,	$L_E = 3545.5$	mm				

Slenderness ratio, $\lambda = L_E / r_y = 88.2$

$\gamma_b = (1 - I_y / I_x)\ [1 - J / (2.6\ I_x)] = 0.2722$

Buckling index, $\varnothing_b = [S_x^2\ \gamma_b / (A\ J)]^{0.5} = 0.4504$

Ratio, $\beta_w = 1$ for plastic section

Equivalent slenderness, $\lambda_{LT} = 2.25\ (\varnothing_b\ \lambda\ \beta_w)^{0.5} = 14.18$

$P_E = \pi^2\ E / \lambda_{LT}^2 = 9816.97$

$\alpha_{LT} = 7$

$\lambda_{L0} = 0.4\ (\pi^2\ E / p_y)^{0.5} = 37.89$

Perry factor, $\eta_{LT} = \alpha_{LT}\ (\lambda_{LT} - \lambda_{L0}) / 1000 = -0.166 < 0$

$\varnothing_{LT} = [p_y + (\eta_{LT} + 1)\ P_E] / 2 = 4203.68$

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

$= 265.25$ N/mm^2

> 220 N/mm^2

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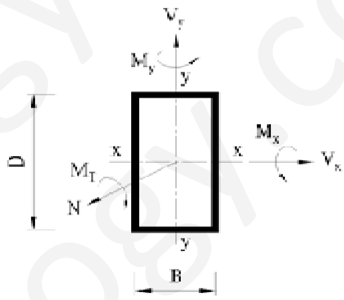
5.2 Check for 6mm fillet weld all round connection to base plate

Vertical load	=	9.493	kN	(refer to item 5.1)	

<u>Properties for unit throat thickness of fillet weld (effective length)</u>



Breadth,	B	=	100	mm		
Height,	D	=	150	mm		
Area,	A	=	$2\ (B + D)$	=	500	mm^2
Moment of inertia,	I_x	=	$B\ D^2 / 2 + D^3 / 6$	=	1687500	mm^4
Moment of inertia,	I_y	=	$B^2\ D / 2 + B^3 / 6$	=	916667	mm^4
Polar moment of inertia,	J	=	$I_x + I_y$	=	2604167	mm^4

Shear load,	V_x	=	0	kN	Moment,	M_x	=	0	kNm
Shear load,	V_y	=	9.493	kN	Moment,	M_y	=	0	kNm
Tensile load,	N	=	0	kN	Torsional moment,	M_T	=	0	kNm

Leg length of fillet weld,	t	=	6	mm

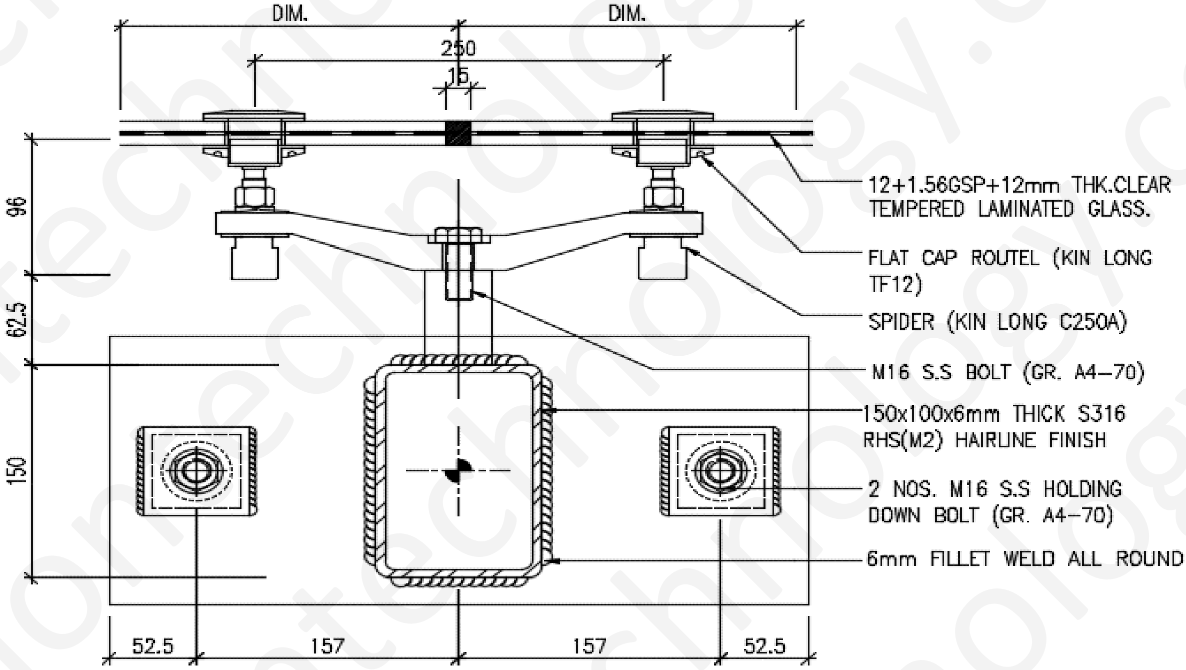
Shear stress,	τ_x	=	$V_x / (0.7\ t\ A) + M_T\ (D / 2) / (0.7\ t\ J)$	=	0	N/mm^2
Shear stress,	τ_y	=	$V_y / (0.7\ t\ A) + M_T\ (B / 2) / (0.7\ t\ J)$	=	4.52	N/mm^2
Tensile stress,	σ	=	$N / (0.7\ t\ A)$	=	0	N/mm^2
Tensile stress,	σ_x	=	$M_x\ D / (2\ I_x) / (0.7\ t)$	=	0	N/mm^2
Tensile stress,	σ_y	=	$M_y\ B / (2\ I_y) / (0.7\ t)$	=	0	N/mm^2

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

= 4.52 N/mm^2

$\leq$ 200 N/mm^2 O.K.

5.3 Check for M16 holding down bolt, A4-70



Vertical load	= 9.493	kN	(refer to item 5.1)	
Shear load on each bolt	= 9.493 / 2			
	= 4.75	kN		
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		
Shear capacity of bolt	= 156 x 280 / 1000			
	= 43.68	kN		
	> 4.75	kN		O.K.