TED SINGLETON & ASSOCIATES
CONSULTING ENGINEERS

Project: General Point Fixings	Contract: 1369-1
Subject: Glass Balustrade	Sheet No. 1
Date: 04/03/2020	By: R.F.

On Level Ltd.,

8, Alexandria Court
Ashton Commerce Park
Ashton-under-Lyne
Lancashire OL7 0QN
United Kingdom

General Point Fixings

1369-1 Glass Balustrade

Analysis By	Checked By
R.F.	T.S.

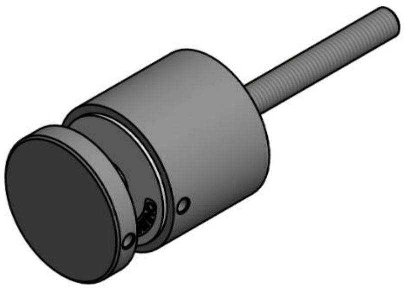
0	05/03/2020	T.S.	Issued
Revision	**Date**	**Issued By**	**Comment**

Contents

Introduction/Actions/Result Summary:

Introduction:

TSA was instructed by On Level to carry out calculations to be made with glass adaptor ø60mm thickness.



Actions:

Balustrade load = 0.74kN/m (Table NA.5 IS1991-1-1:2002)

Point load = 0.5kN (Table NA.4.2 IS 1991-1-1:2002)

Infill load = 1kN (Table NA.5 IS1991-1-1:2002)

Assumption:

Concrete Grade = C30/37

Result Summary:

Study	Size of the Glass (m)	Glass (mm)	Interlayer	Working Line Load for System (kN/m)	Glass Deflection (mm)
Case Study 01: Balustrade Railing Type	1.5 x 1.38	21.52	PVB	0.74	22.06
Case Study 02: Juliet Balcony Corner Type	2.0 x 1.1	17.52	PVB	0.74	4.579
Case Study 03: Juliet Balcony Inline Type	2.0 x 1.1	13.52	PVB	0.74	9.106

<u>NOTE:</u>

- All deflection < 25mm and therefore acceptable
- Glass thickness chosen determined by the material stress when subjected to 0.74kN/m Balustrade Load, 1.0kN/m2 Infill Load and 0.5kN Point Load

Glass Strength

Balustrade Loading:

< 5mins duration => $k_{mod} = 0.77$

$f_{gd} = (k_{mod})(k_{sp})(f_{gk})/\ \gamma_{ma} + k_v(f_{bk}\text{-}f_{gk})/\gamma_{mv}$

$f_{gd} = (0.77)(1.0)(45)/1.6 + 1.0(120\text{-}45)/1.2$

$\underline{f_{gd} = 84.2\text{N/mm}^2}$

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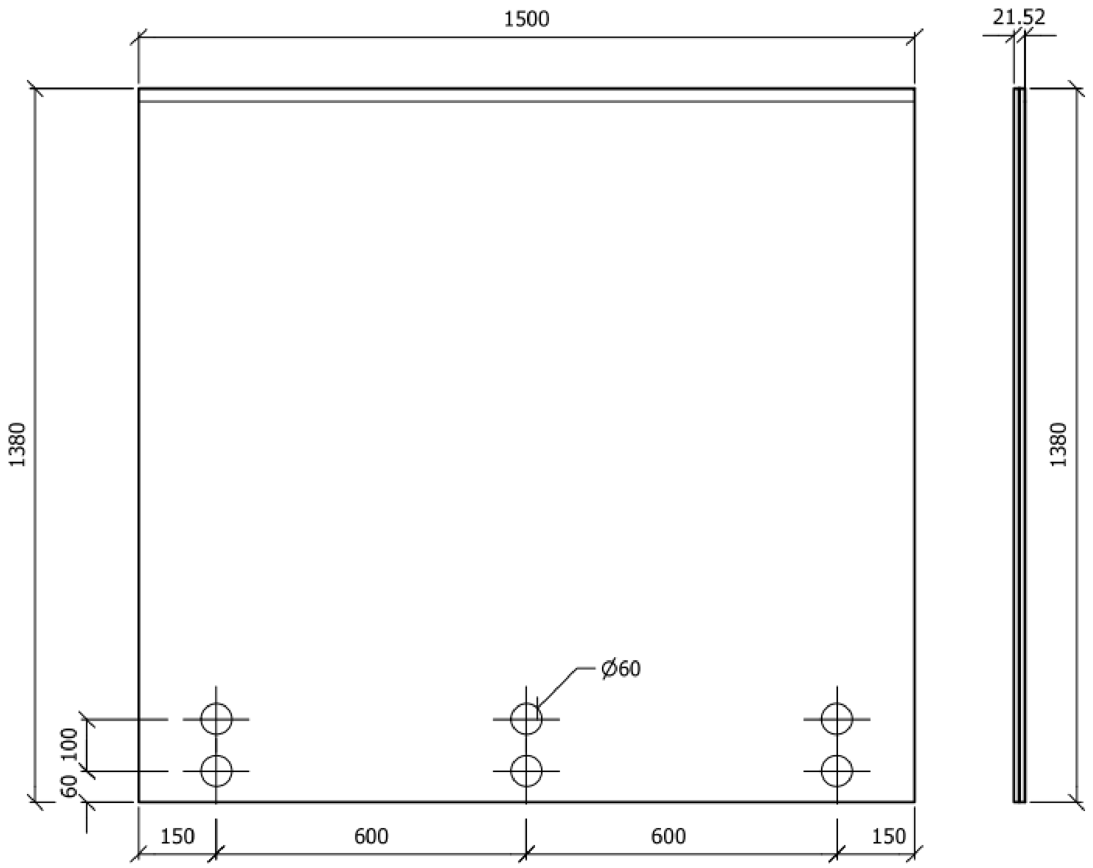
Project: General Point Fixings	Contract: 1369-1
Subject: Glass Balustrade	**Sheet No.** 6
Date: 04/03/2020	**By:** R.F.

Case Study 01 – Balustrade Railing Type:

Sketch - 21.52mm – 0.74kN/m PVB Interlayer:



NOTE:

- Deflection on the glass 22.06mm = **OK in deflection**

Glass Analysis:

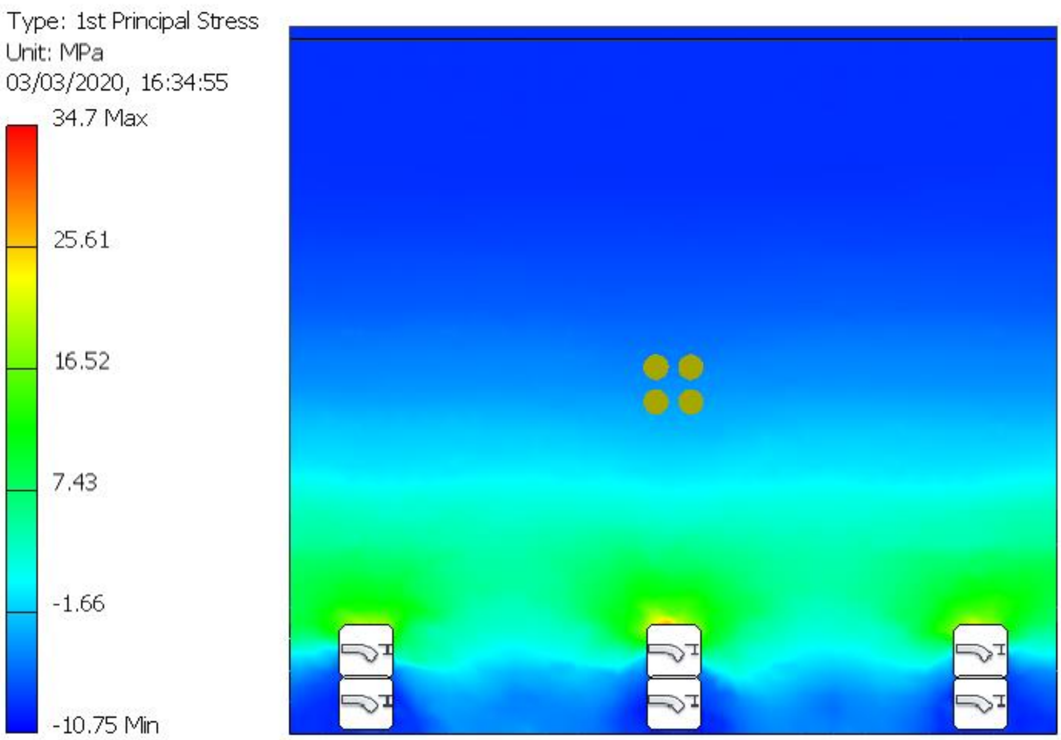
Glass Analysis - Bending Stress of Glass Panel due to 1.0kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.0N/m2 Infill Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 1.5m x 1.38m

Result:

Max. Bending Stress = 34.70N/mm^2 x1.5 = 52.05N/mm^2 < 84.2N/mm^2

OK in Bending



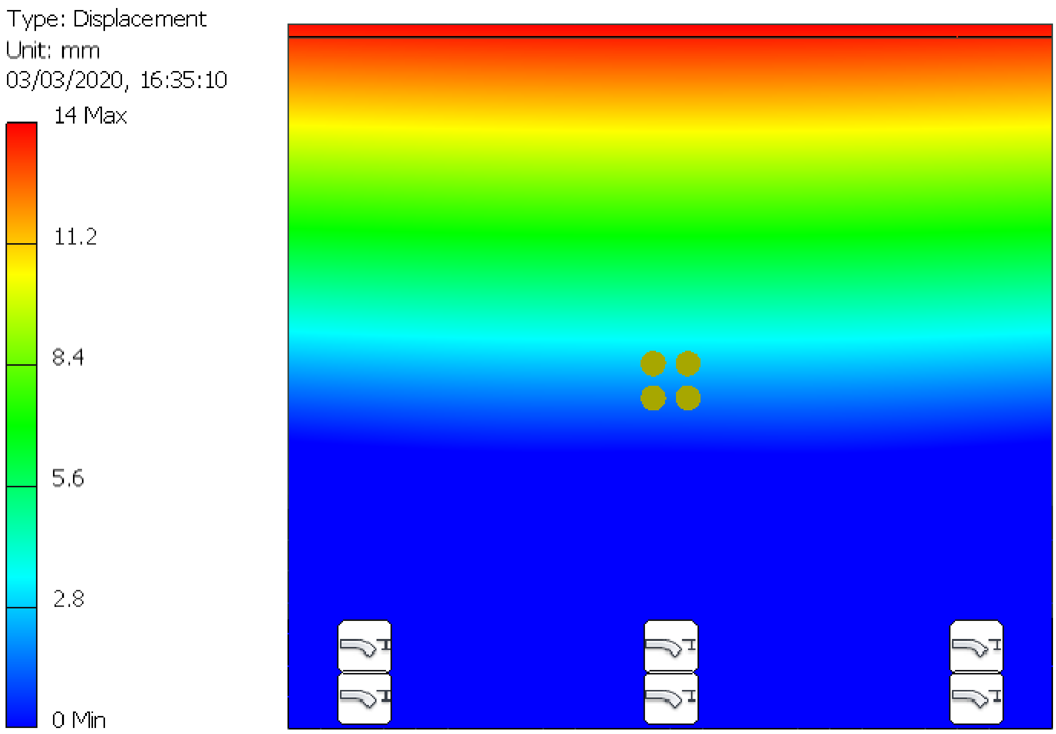
Glass Analysis - Deflection of Glass Panel due to 1.0kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.0N/m2 Infill Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 1.5m x 1.38m

Result:

Max. Deflection = 14.00mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



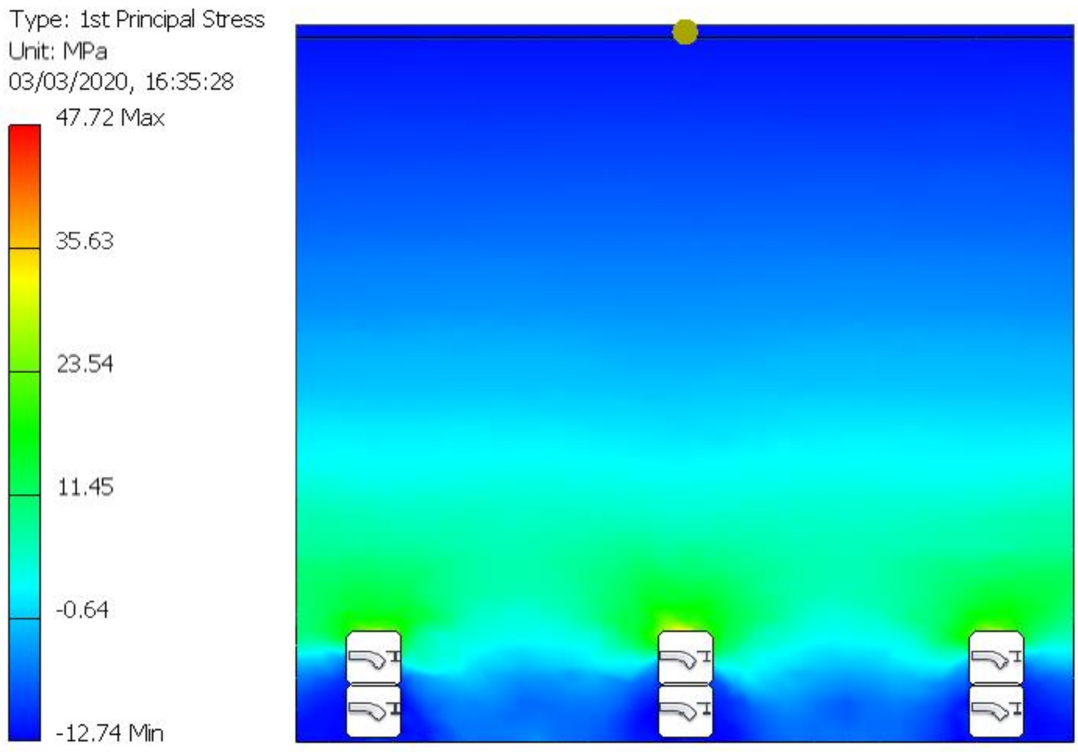
Glass Analysis - Bending Stress of Glass Panel due to 0.74kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.74kN/m Balustrade Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 1.5m x 1.38m

Result:

Max. Bending Stress = 47.72N/mm^2 x1.5 = 71.58N/mm^2 < 84.2N/mm^2

OK in Bending



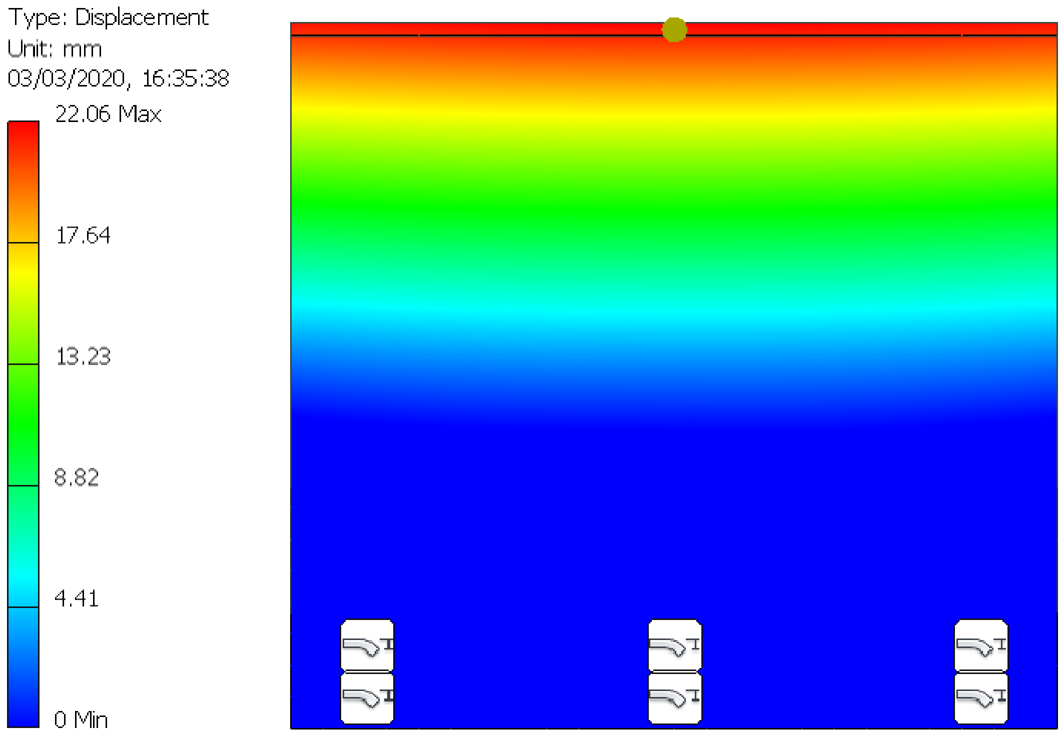
Glass Analysis - Deflection of Glass Panel due to 0.74kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.74kN/m Balustrade Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 1.5m x 1.38m

Result:

Max. Deflection = 22.06mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



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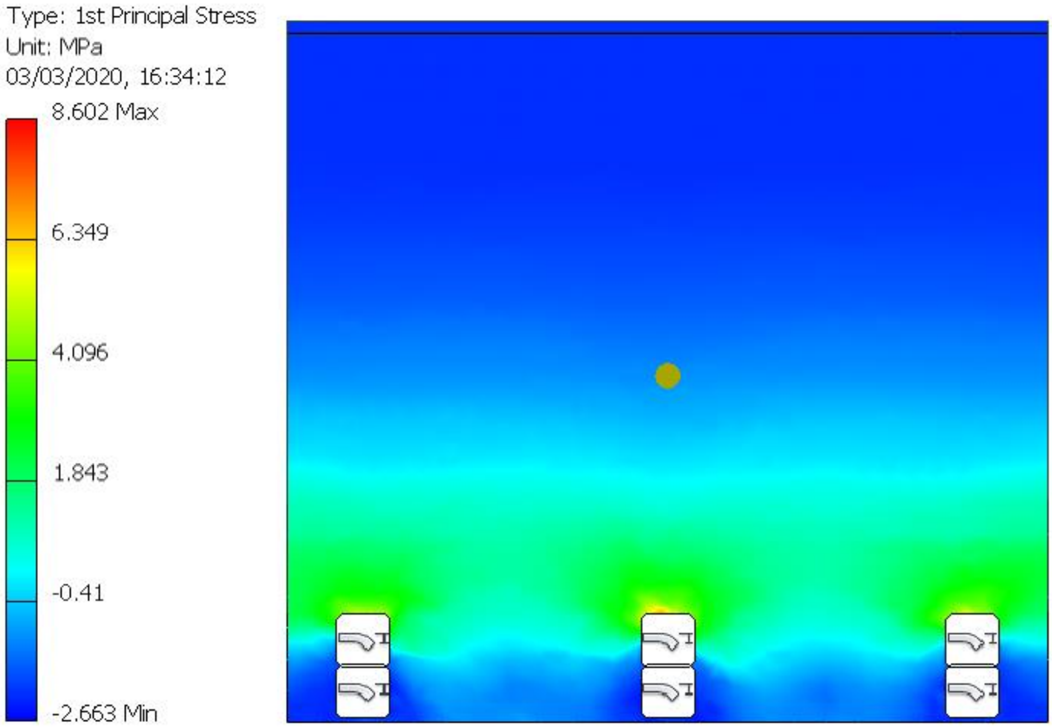
Glass Analysis - Bending Stress of Glass Panel due to 0.5kN/m Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN/m Point Load
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 1.5m x 1.38m

Result:

Max. Bending Stress = 8.602N/mm^2 x1.5 = 12.903N/mm^2 < 84.2N/mm^2

OK in Bending



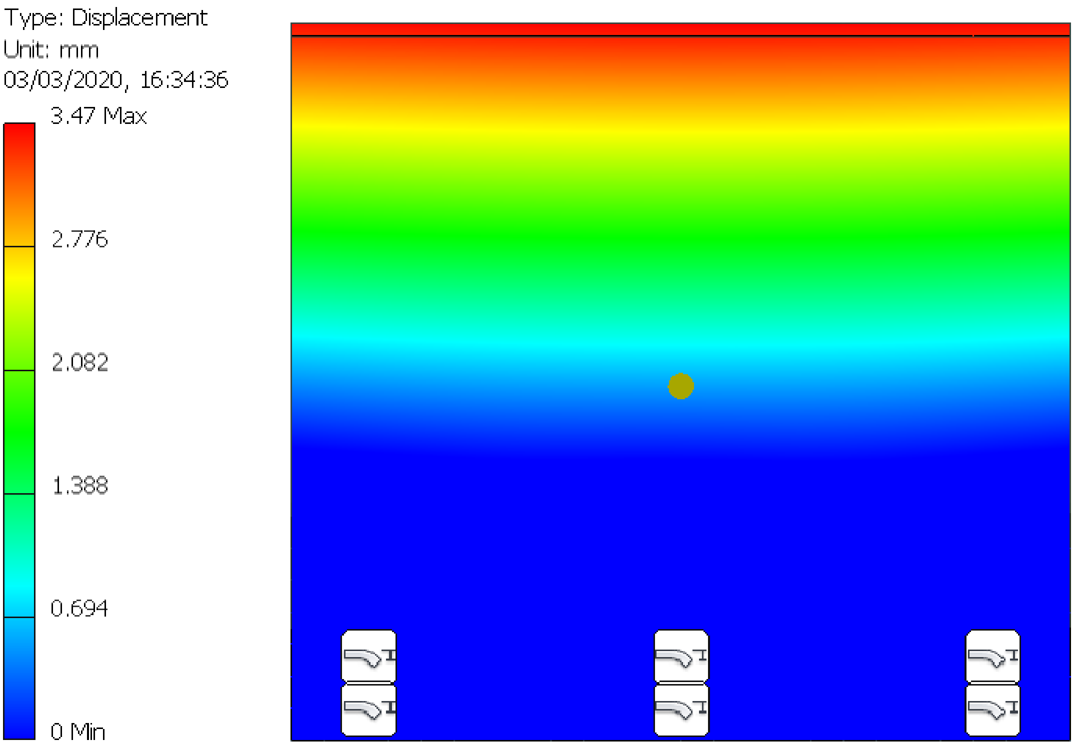
Glass Analysis - Deflection of Glass Panel due to 0.5kN/m Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN/m Point Load
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 1.5m x 1.38m

Result:

Max. Deflection = 3.47mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Reactions:

Case Study 01: Balustrade Railing Type			
	Reactions (N)		
	Balustrade	Pressure	Point
1	1797	1687	416
2	2720	2458	607
3	1797	1687	416
4	-1500	-1080	-270
5	-2204	-1602	-399
6	-1500	-1080	-270

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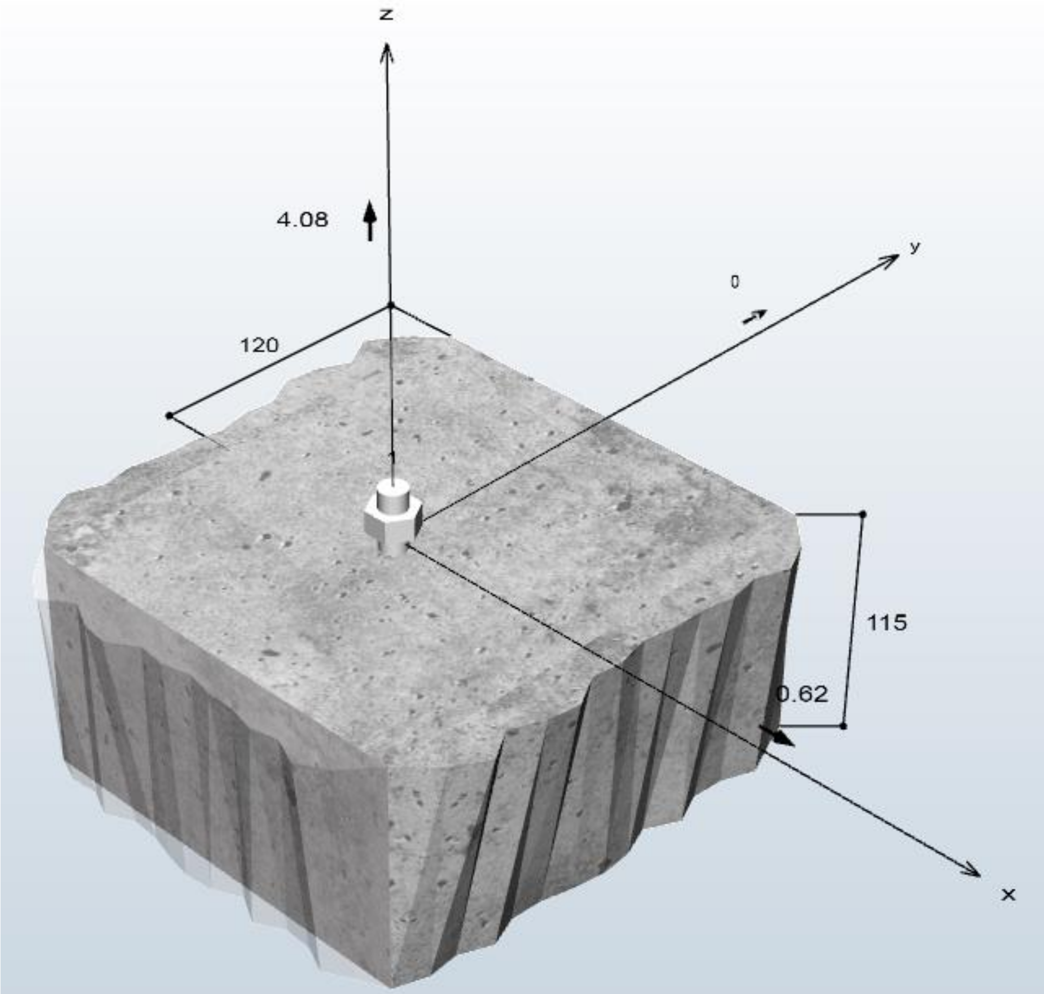
Connection Design:
Connection To Concrete:

$\text{Tensile Load} = 2.72\text{kN} \times 1.5 = 4.08\text{kN (ULS)}$

$\text{Shear Load} = 0.46\text{kN} \times 1.35 = 0.621\text{kN (ULS)}$

Therefore use FIS V 360 S Chemical Resin. See design in Appendix A.



Connection To Stainless Steel:

1Nr M12 Bolt Grade 316 Stainless Steel

$f_y = 210\ MPa$ *(Grade 316 Stainless Steel, Table 2.1 EN 1993-1-4:2006)*

$f_{ub} = 520\ MPa$ *(Grade 316 Stainless Steel, Table 2.2 EN 1993-1-4:2006)*

$\alpha = 0.6$ *(6.2 EN 1993-1-4:2006)*

$A = 84.3mm^2$ *(For M12 Bolts)*

$K_2 = 0.9$ *(Table 3.4 EN 1993-1-8:2005)*

$\lambda_{m2} = 1.25$ *(Table 5.1 EN 1993-1-4:2006)*

Tensile Resistance Check: *(Table 3.4 EN 1993-1-8:2005)*

$F_{t,Ed}$: *is the design tensile force per bolt for the ultimate limit state.*

$F_{t,Rd}$: *is the design tension resistance per bolt.*

$\mathrm{F_{t,Ed}} = \mathrm{kN}$

$\mathrm{F_{t,Rd}} = \frac{\mathrm{K_2 F_{ub} A}}{\mathrm{\lambda m2}} = \frac{0.6\ x\ 520\ x\ 84.3}{1.25}\ x\ 10^{-3}$ = 21.04kN → $\mathrm{F_{t,Rd}} = 21.04\mathrm{kN} > 0.621\mathrm{kN}$ **Okay**

Shear Resistance Check: *(6.2 EN 1993-1-4: 2006)*

$F_{v,Ed}$: *is the design shear force per bolt for the ultimate limit state.*

$F_{v,Rd}$: *is the design shear resistance per bolt.*

$\mathrm{F_{V,Ed}} = \mathrm{kN}$

$\mathrm{F_{V,Rd}} = \frac{\mathrm{\alpha F_{ub} A}}{\mathrm{\lambda m2}} = \frac{0.9\ x\ 520\ x\ 57}{1.25}\ x\ 10^{-3} = 31.56kN$ → $\mathrm{F_{V,Rd}} = 31.56\mathrm{kN} > 4.08\mathrm{kN}$ **Okay**

Combined Shear & Tensile Resistance Check: *(Table 3.4 EN 1993-1-8:2005)*

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \leq 1 \rightarrow \frac{0.621}{21.04} + \frac{4.08}{31.56} = \leq 1$ **Okay**

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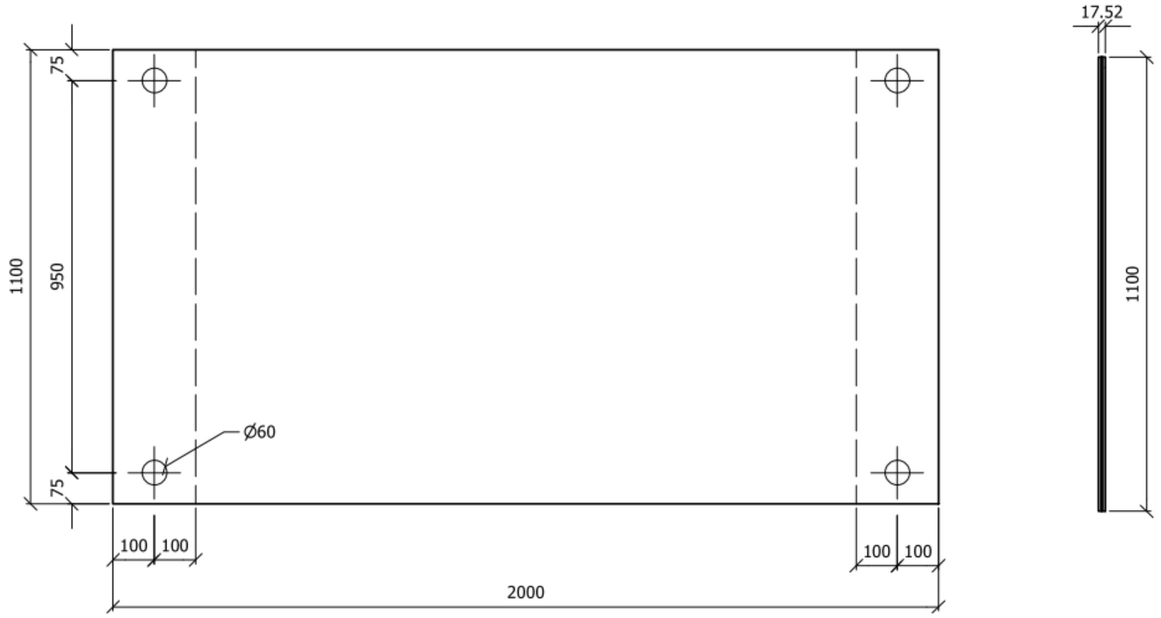
Case Study 02 – Juliet Balcony Corner Type:

Sketch - 17.52mm – 0.74kN/m (Glass) PVB Interlayer:



NOTE:

- Deflection on the glass 4.579mm = **OK in deflection**

Glass Analysis:

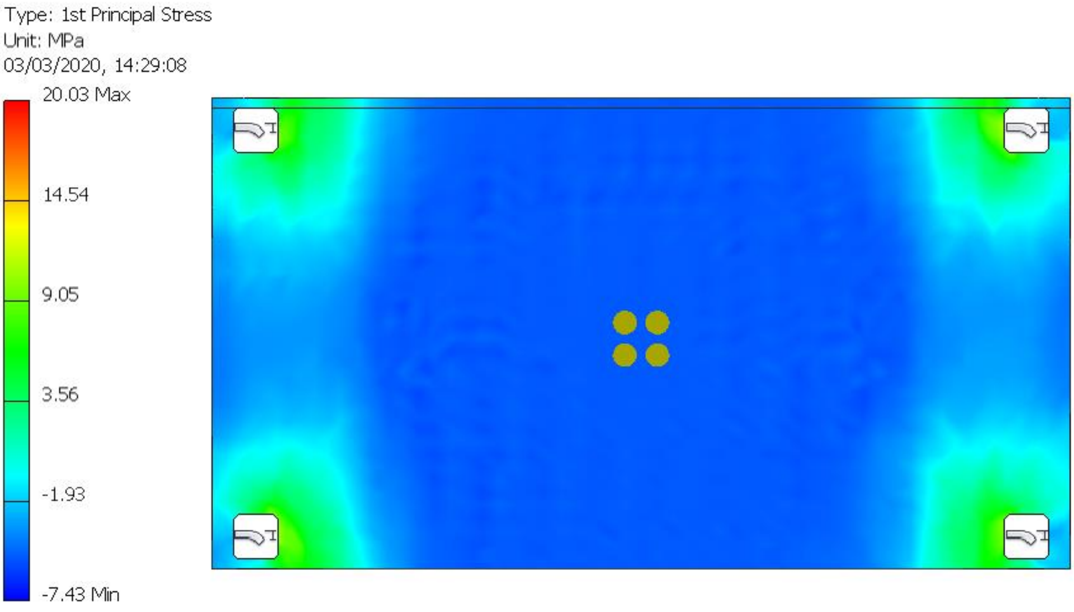
Glass Analysis - Bending Stress of Glass Panel due to 1.0kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.0N/m2 Infill Loading
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 20.03N/mm^2 x1.5 = 30.045N/mm^2 < 84.2N/mm^2

OK in Bending



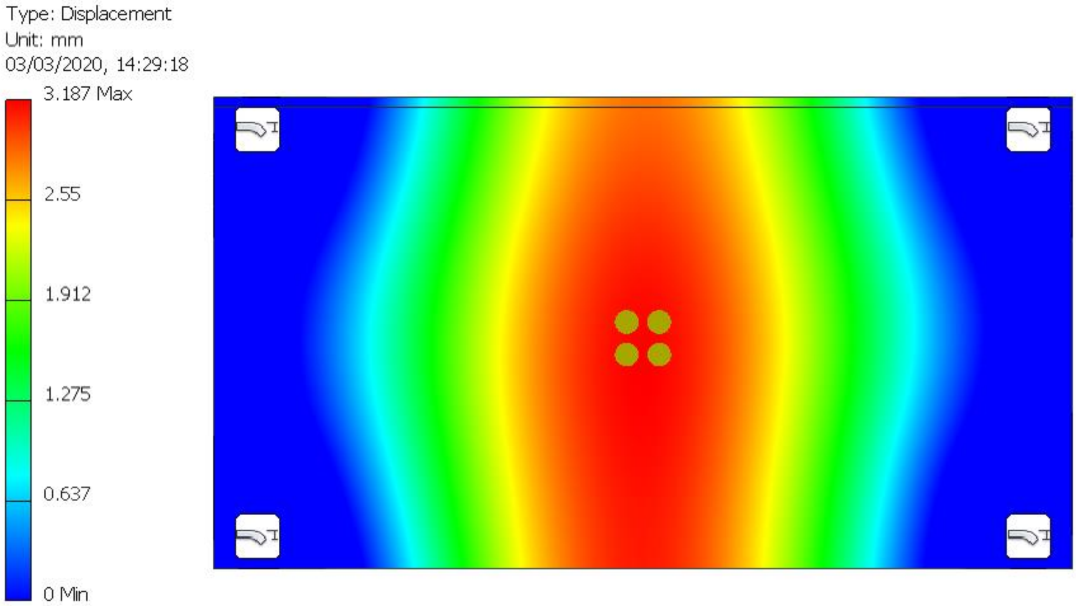
Glass Analysis - Deflection of Glass Panel due to 1.0kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.0N/m2 Infill Loading
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 3.187mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Project: General Point Fixings	Contract: 1369-1
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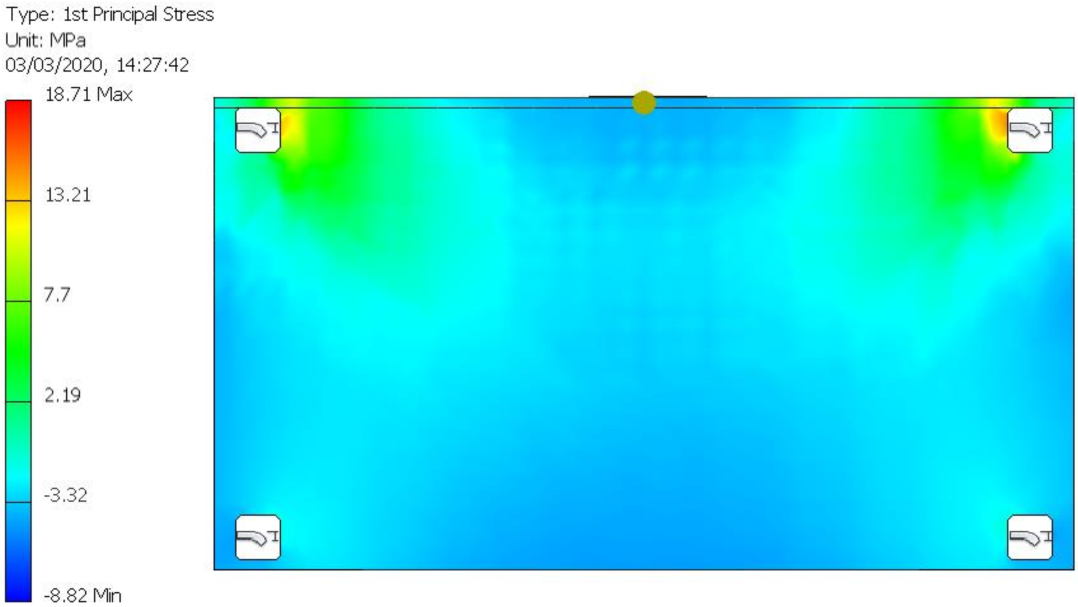
Glass Analysis - Bending Stress of Glass Panel due to 0.74kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.74kN/m Balustrade Loading
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 18.71N/mm^2 x1.5 = 28.065N/mm^2 < 84.2N/mm^2

OK in Bending



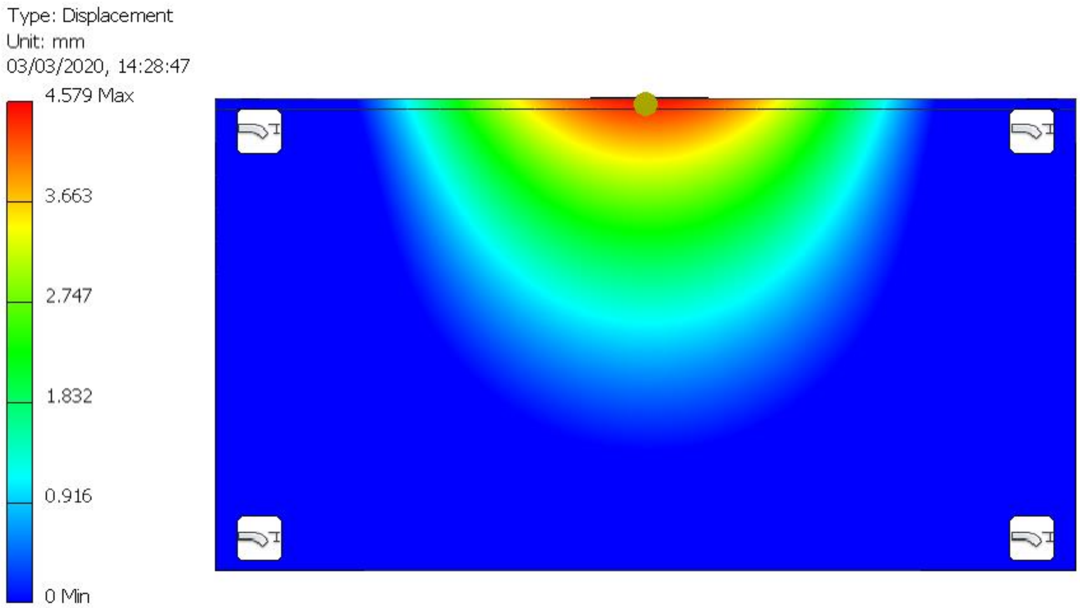
Glass Analysis - Deflection of Glass Panel due to 0.74kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.74kN/m Balustrade Loading
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 4.579mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



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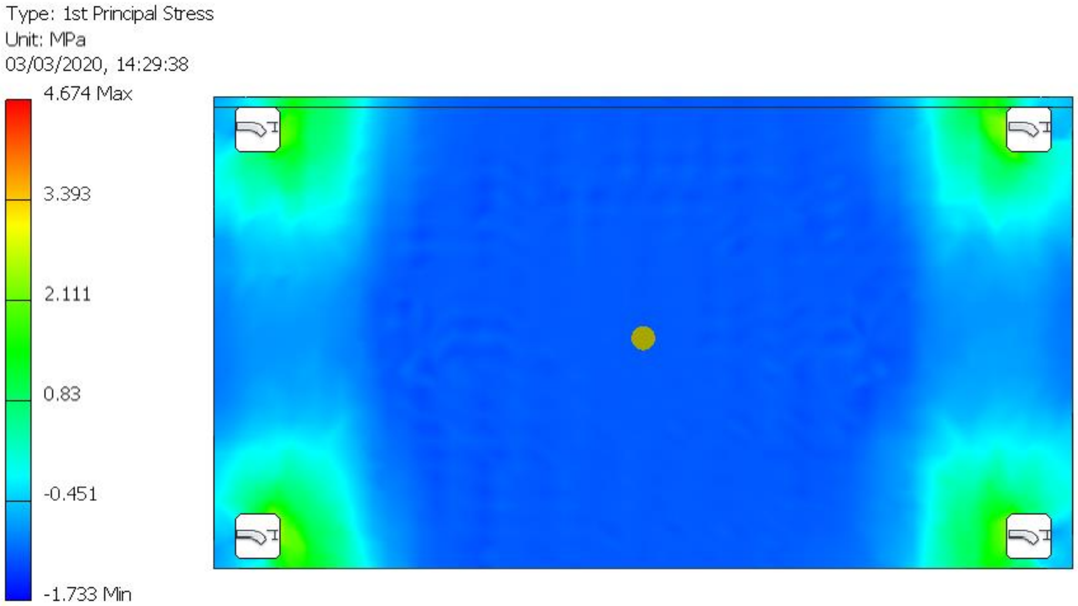
Glass Analysis - Bending Stress of Glass Panel due to 0.5kN/m Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN/m Point Load
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 4.674N/mm^2 x1.5 = 7.011N/mm^2 < 84.2N/mm^2

OK in Bending



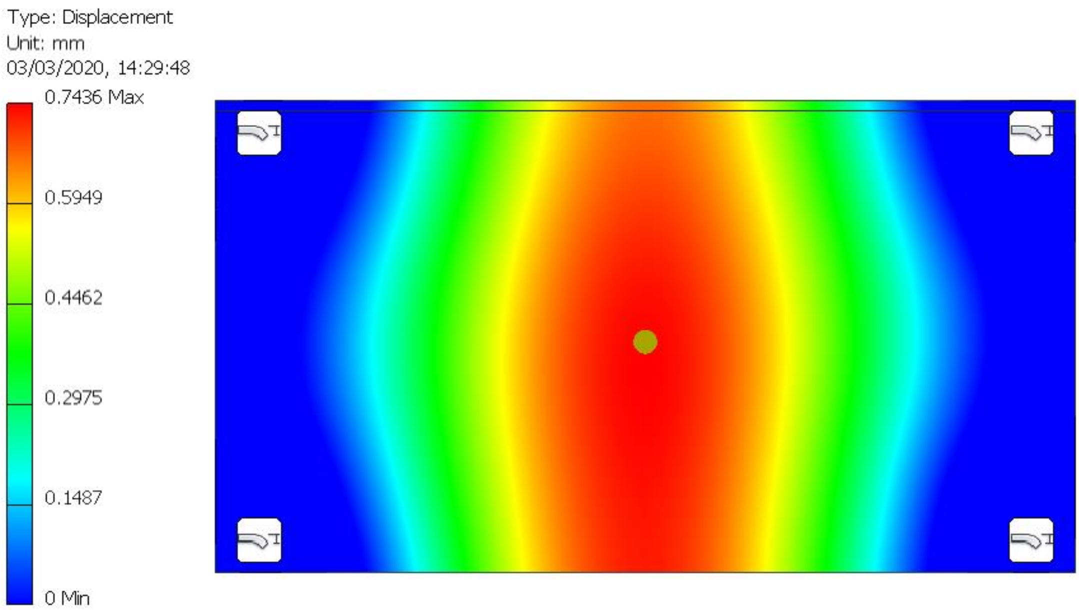
Glass Analysis - Deflection of Glass Panel due to 0.5kN/m Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN/m Point Load
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 0.7436mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



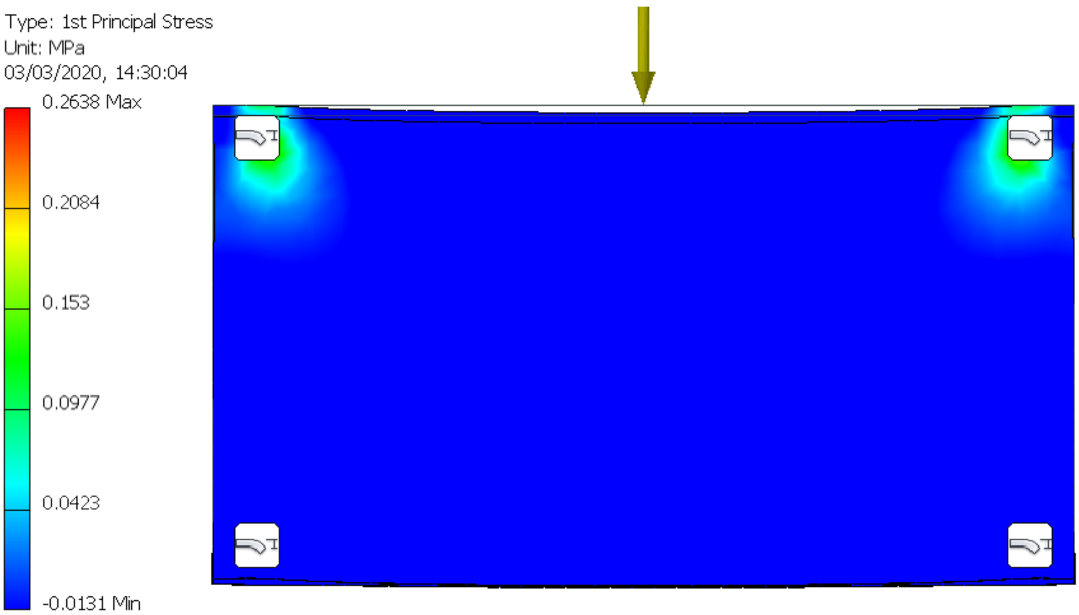
Glass Analysis - Bending Stress of Glass Panel due to Gravity Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN/m Point Load
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 0.2638N/mm^2 x1.5 = 0.3957N/mm^2 < 84.2N/mm^2

OK in Bending



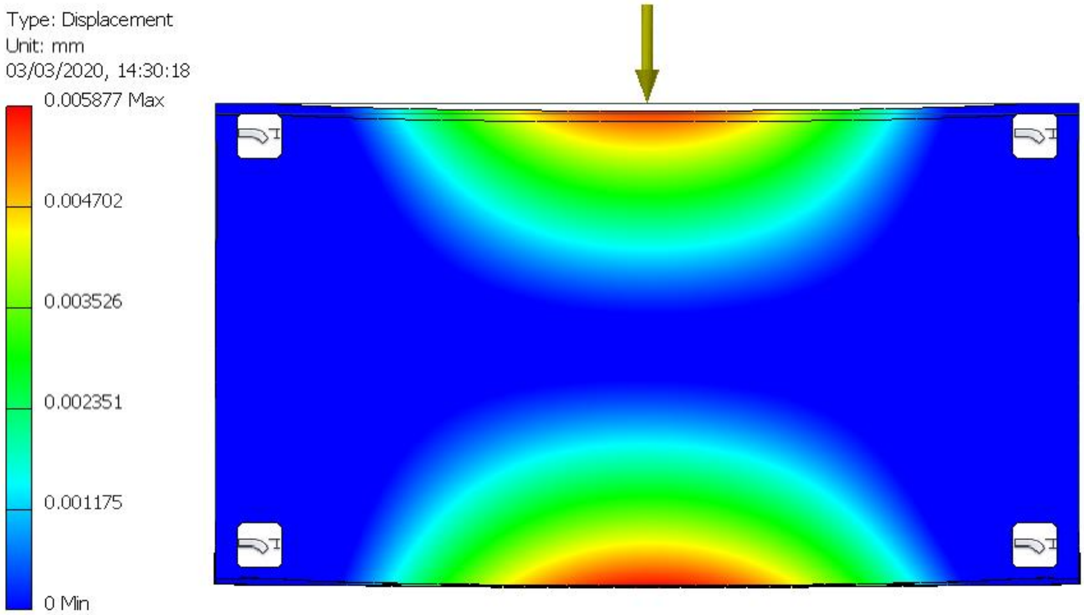
Glass Analysis - Deflection of Glass Panel due to Gravity Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN/m Point Load
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 0.005877mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Reactions:

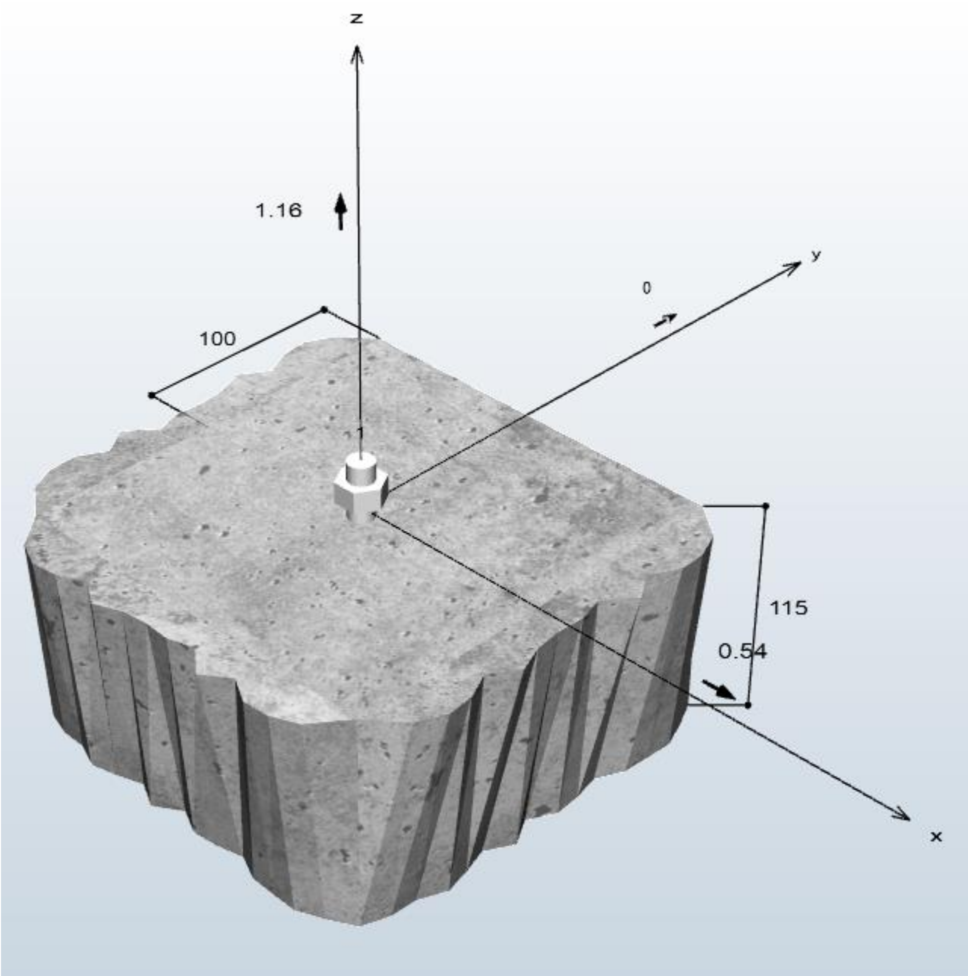
Case Study 02: Juliet Balcony Corner Type				
	Reactions (N)			
	Balustrade	Pressure	Point	Gravity
1	771	529	123	1
2	771	529	123	1
3	-32	557	128	-1
4	-32	557	128	-1

Connection Design:
Connection To Concrete:

$\text{Tensile Load} = 0.77\text{kN} \times 1.5 = 1.16\text{kN (ULS)}$

$\text{Shear Load} = 0.4\text{kN} \times 1.35 = 0.54\text{kN (ULS)}$

FIS V 360 S Chemical Resin. See design in Appendix A.



Connection To Stainless Steel:

1Nr M12 Bolt Grade 316 Stainless Steel

$f_y = 210\ MPa$ *(Grade 316 Stainless Steel, Table 2.1 EN 1993-1-4:2006)*

$f_{ub} = 520\ MPa$ *(Grade 316 Stainless Steel, Table 2.2 EN 1993-1-4:2006)*

$\alpha = 0.6$ *(6.2 EN 1993-1-4:2006)*

$A = 84.3mm^2$ *(For M12 Bolts)*

$K_2 = 0.9$ *(Table 3.4 EN 1993-1-8:2005)*

$\lambda_{m2} = 1.25$ *(Table 5.1 EN 1993-1-4:2006)*

Tensile Resistance Check: *(Table 3.4 EN 1993-1-8:2005)*

$F_{t,Ed}$: *is the design tensile force per bolt for the ultimate limit state.*

$F_{t,Rd}$: *is the design tension resistance per bolt.*

$\mathrm{F_{t,Ed}} = \mathrm{kN}$

$\mathrm{F_{t,Rd}} = \frac{\mathrm{K_2 F_{ub} A}}{\lambda m2} = \frac{0.6\ x\ 520\ x\ 84.3}{1.25} = 21.04\mathrm{kN} \rightarrow \mathrm{F_{t,Rd}} = 21.04\mathrm{kN} > 1.16\mathrm{kN}$ **Okay**

Shear Resistance Check: *(6.2 EN 1993-1-4: 2006)*

$F_{v,Ed}$: *is the design shear force per bolt for the ultimate limit state.*

$F_{v,Rd}$: *is the design shear resistance per bolt.*

$\mathrm{F_{V,Ed}} = \mathrm{kN}$

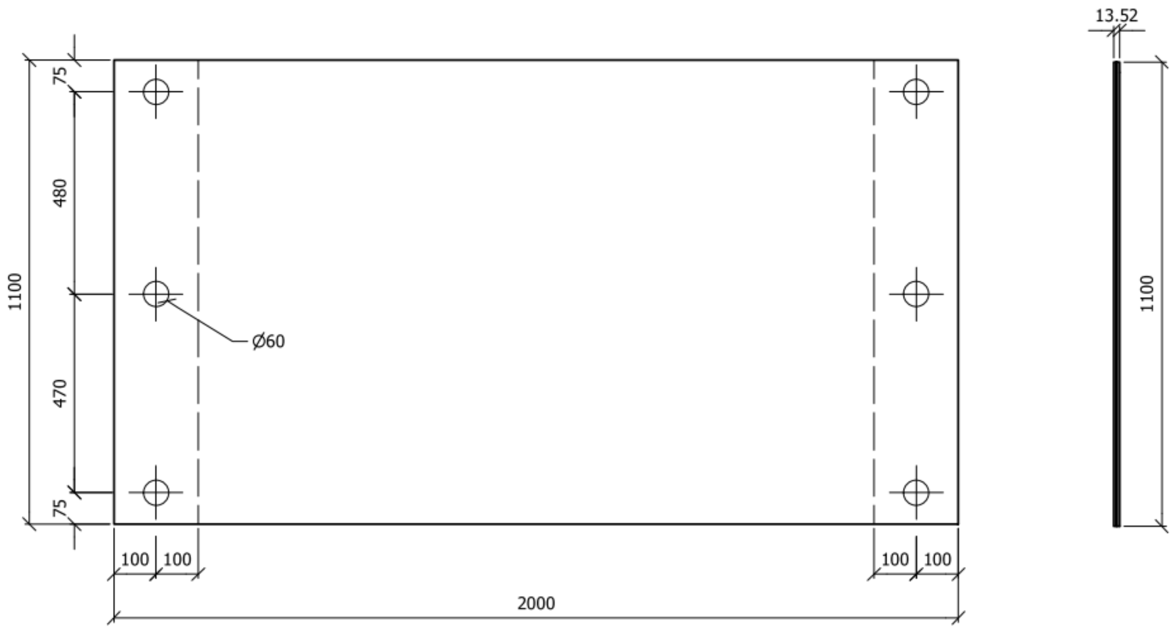
$\mathrm{F_{V,Rd}} = \frac{\alpha \mathrm{F_{ub} A}}{\lambda m2} = \frac{0.9\ x\ 520\ x\ 57}{1.25} = 31.56kN \rightarrow \mathrm{F_{V,Rd}} = 31.56\mathrm{kN} > 0.54\mathrm{kN}$ **Okay**

Combined Shear & Tensile Resistance Check: *(Table 3.4 EN 1993-1-8:2005)*

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \leq 1 \rightarrow \frac{1.16}{21.04} + \frac{0.54}{31.56} = \leq 1$ **Okay**

Case Study 03 – Juliet Balcony Inline Type:

Sketch - 13.52mm – 0.74kN/m (Glass) PVB Interlayer:



NOTE:

- Deflection on the glass 9.106mm = **OK in deflection**

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Glass Analysis:

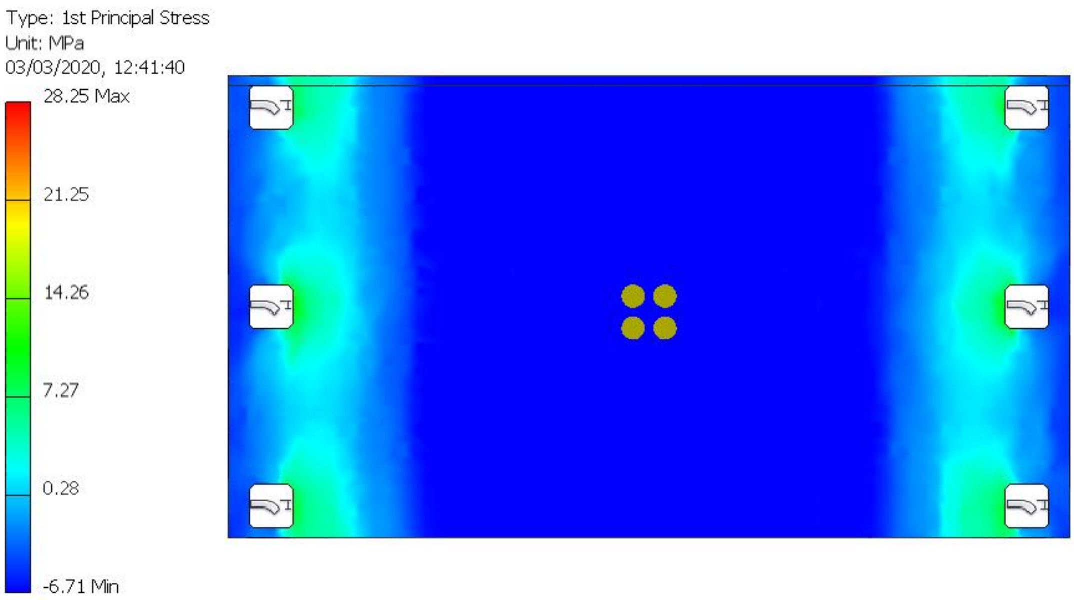
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5N/m2 Infill Loading
- 6/6/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 28.25N/mm^2 x1.5 = 42.375N/mm^2 < 84.2N/mm^2

OK in Bending



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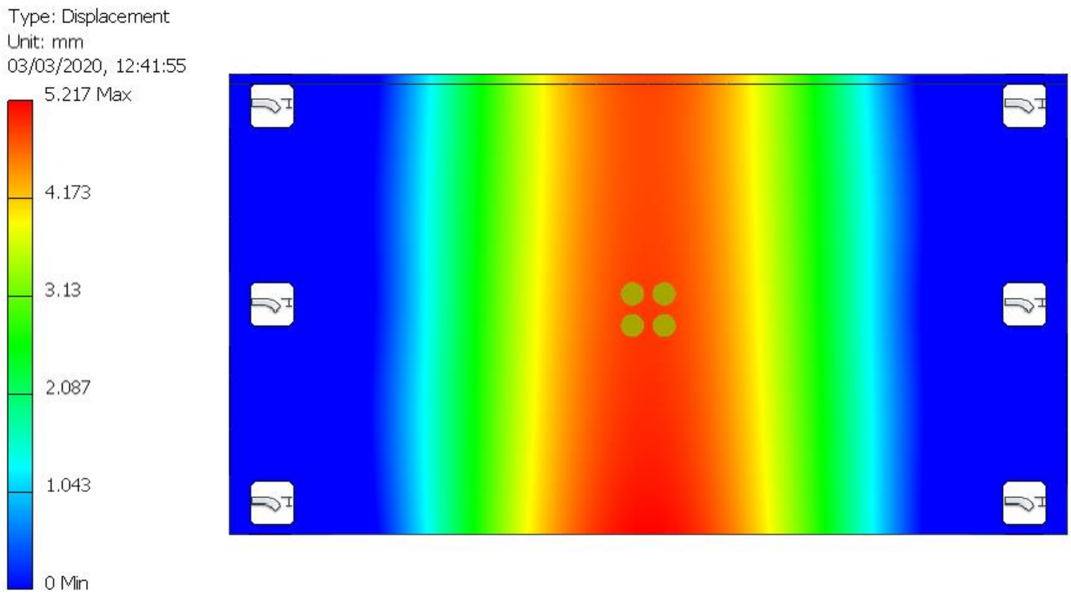
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5N/m2 Infill Loading
- 6/6/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 5.217mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



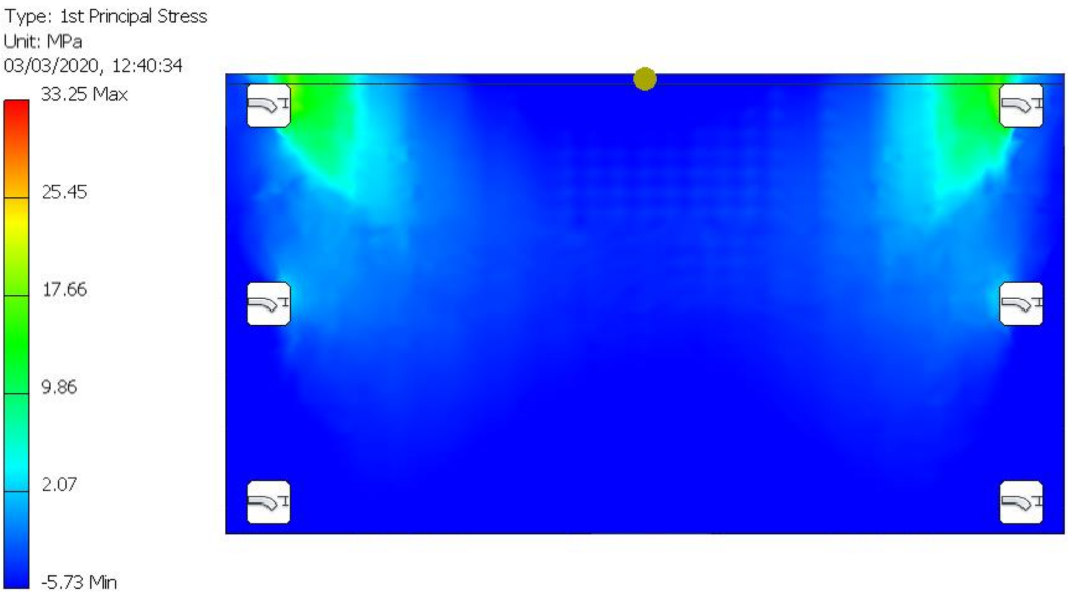
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Balustrade Loading
- 6/6/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 33.25N/mm^2 x1.5 = 49.875N/mm^2 < 84.2N/mm^2

OK in Bending



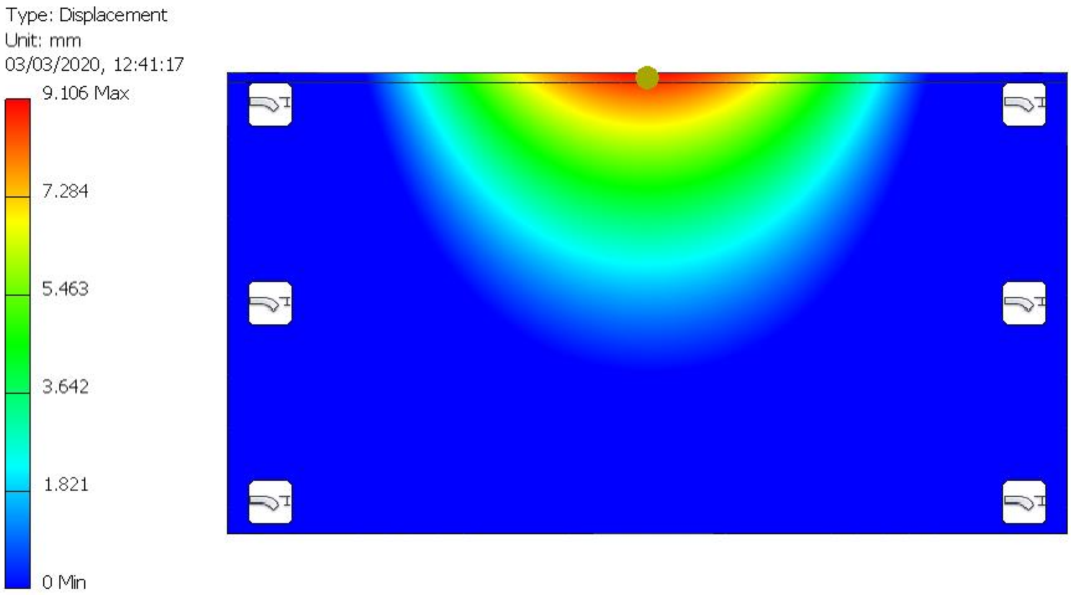
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Balustrade Loading
- 6/6/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 9.106mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



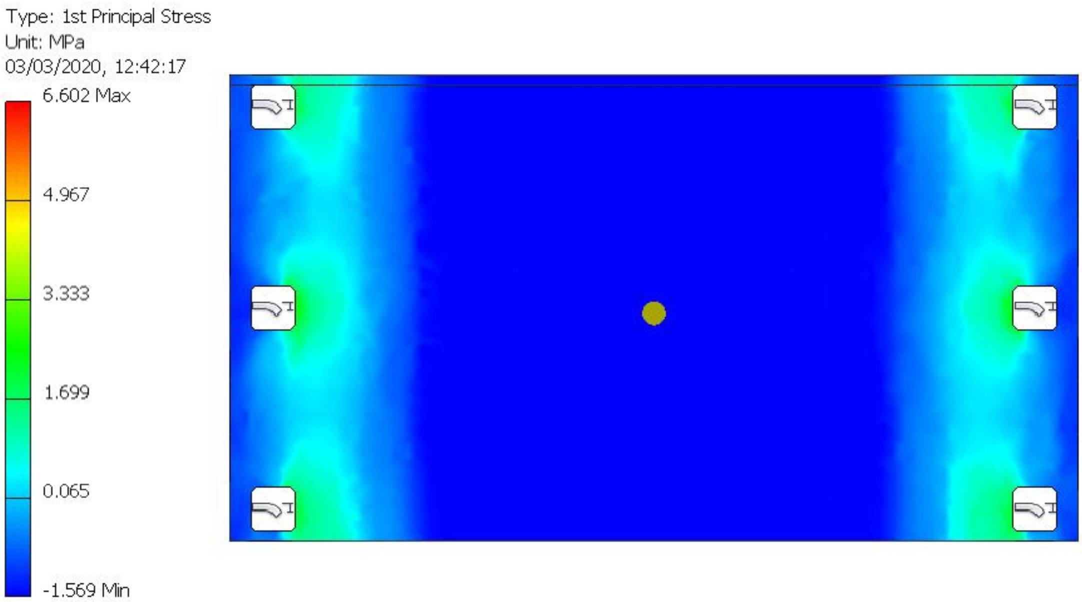
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Point Load
- 6/6/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 6.602N/mm^2 x1.5 = 9.903N/mm^2 < 84.2N/mm^2

OK in Bending



Project: General Point Fixings	Contract: 1369-1
Subject: Glass Balustrade	Sheet No. 34
Date: 04/03/2020	By: R.F.

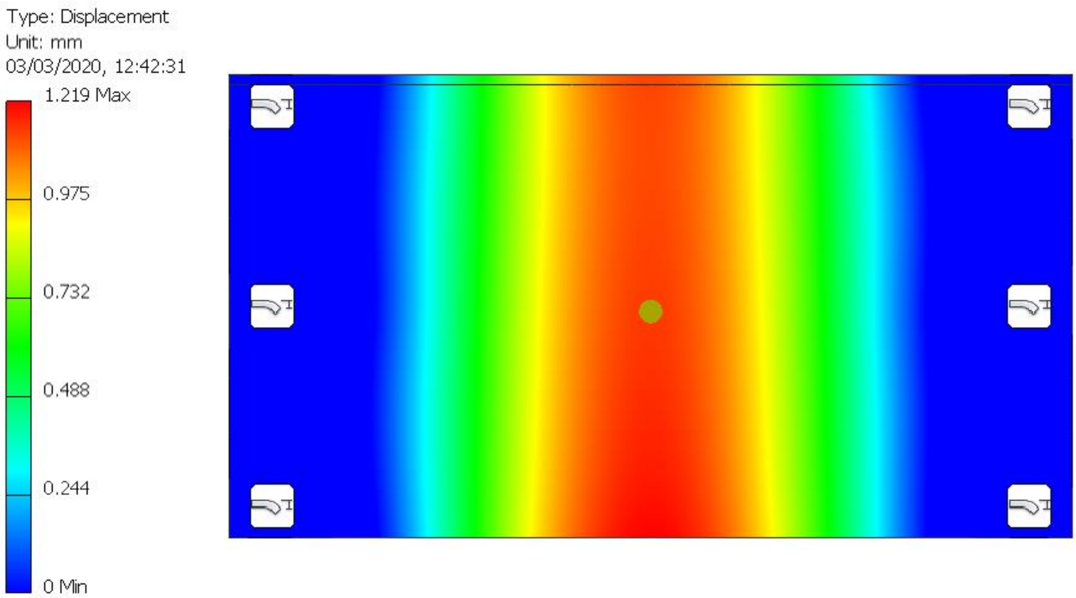
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 1.5kN/m Point Load
- 6/6/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 1.219mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



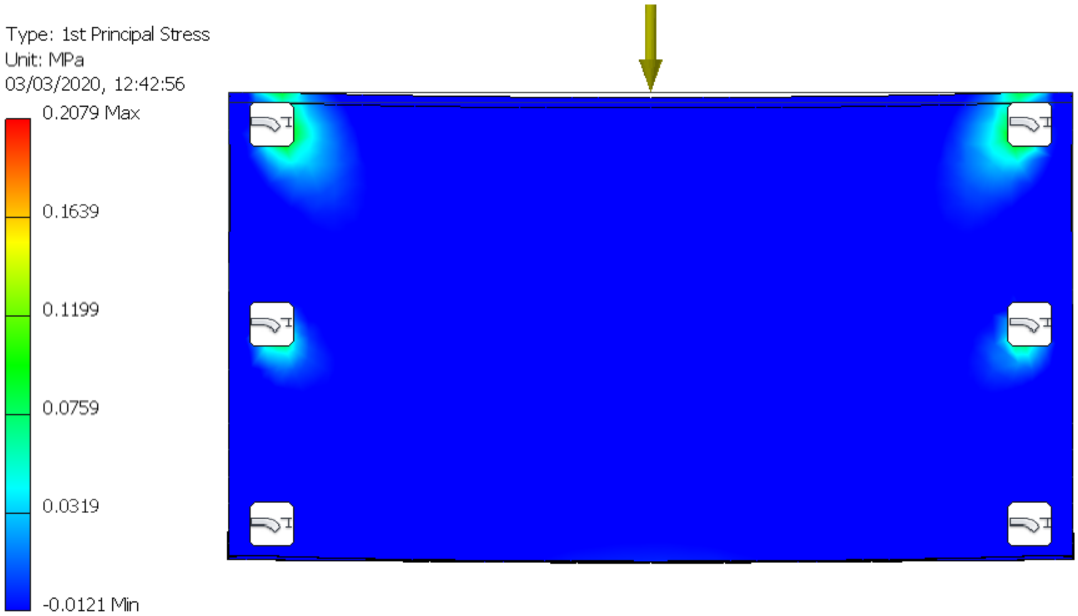
Glass Analysis - Bending Stress of Glass Panel due to Gravity Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN/m Point Load
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Bending Stress = 0.2079N/mm^2 x1.5 = 0.31185N/mm^2 < 84.2N/mm^2

OK in Bending



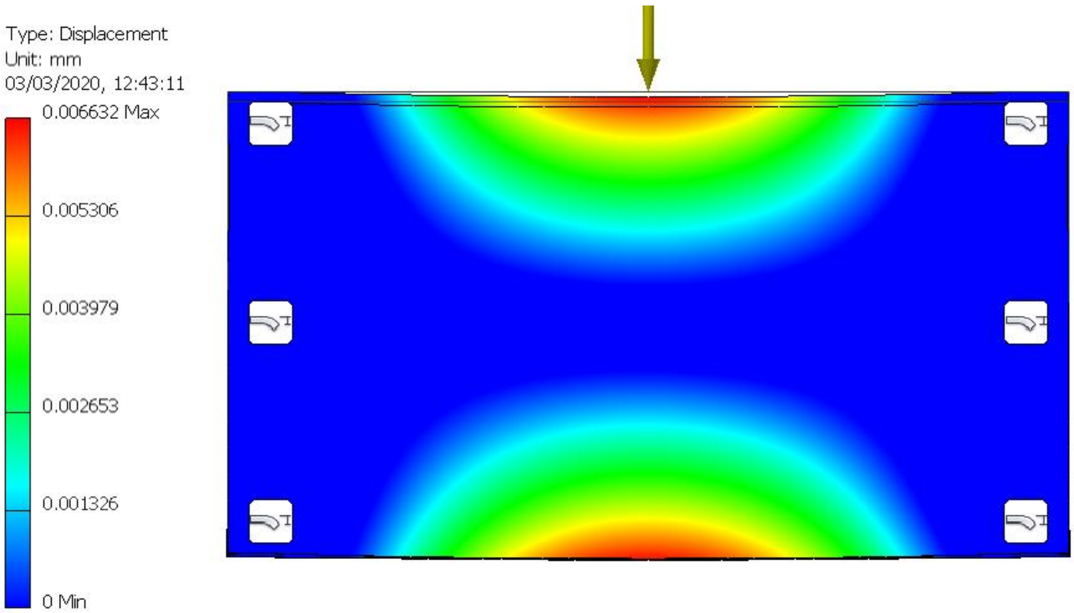
Glass Analysis - Deflection of Glass Panel due to Gravity Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN/m Point Load
- 8/8/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 3MPa, G = 1MPa
- Bending Stress analysed based on glass panel of 2.0m x 1.1m

Result:

Max. Deflection = 0.006632mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Reactions:

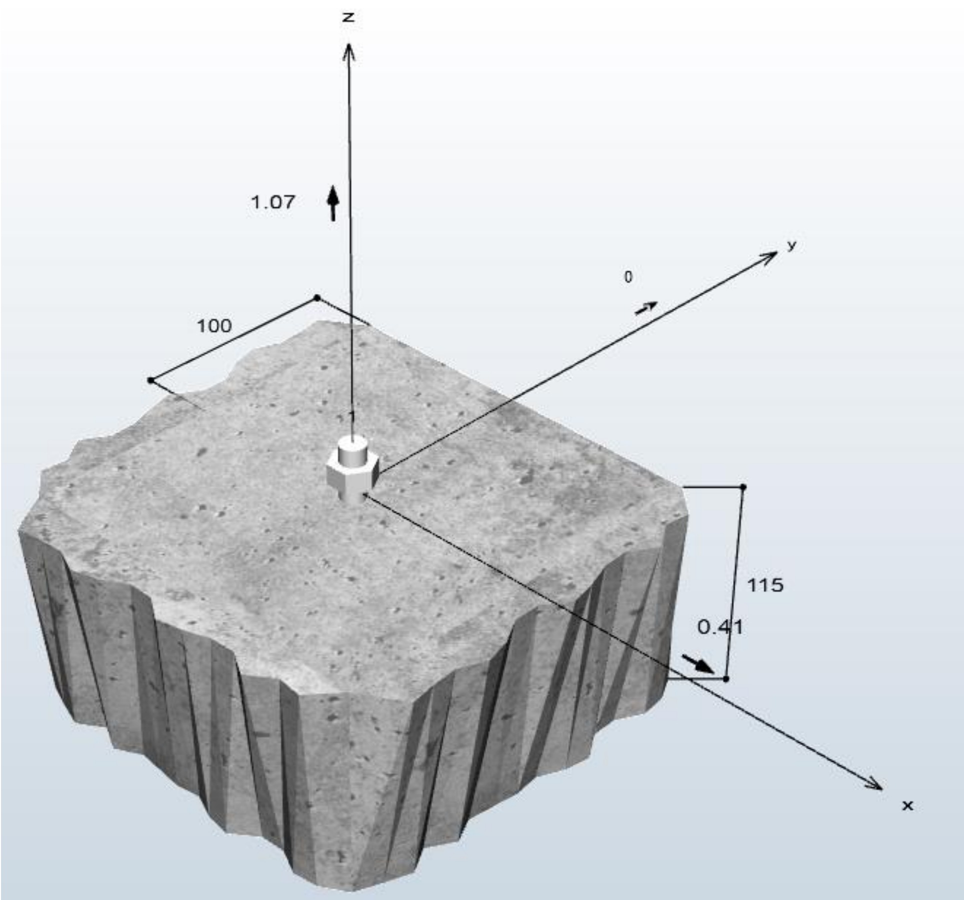
Case Study 03: Juliet Balcony Inline Type				
	Reactions (N)			
	Balustrade	Pressure	Point	Gravity
1	709	294	68	1
2	709	294	68	1
3	110	485	111	0
4	-79	316	72	-1
5	-79	316	72	-1
6	110	495	111	0

Connection Design:
Connection To Concrete:

$$\text{Tensile Load} = 0.71\text{kN} \times 1.5 = 1.065\text{kN (ULS)}$$

$$\text{Shear Load} = 0.30\text{kN} \times 1.35 = 0.405\text{kN (ULS)}$$

FIS V 360 S Chemical Resin. See design in Appendix A.



Connection To Stainless Steel:

1Nr M12 Bolt Grade 316 Stainless Steel

$f_y = 210\ MPa$ *(Grade 316 Stainless Steel, Table 2.1 EN 1993-1-4:2006)*

$f_{ub} = 520\ MPa$ *(Grade 316 Stainless Steel, Table 2.2 EN 1993-1-4:2006)*

$\alpha = 0.6$ *(6.2 EN 1993-1-4:2006)*

$A = 84.3mm^2$ *(For M12 Bolts)*

$K_2 = 0.9$ *(Table 3.4 EN 1993-1-8:2005)*

$\lambda_{m2} = 1.25$ *(Table 5.1 EN 1993-1-4:2006)*

Tensile Resistance Check: *(Table 3.4 EN 1993-1-8:2005)*

$F_{t,Ed}$: *is the design tensile force per bolt for the ultimate limit state.*

$F_{t,Rd}$: *is the design tension resistance per bolt.*

$F_{t,Ed} = kN$

$F_{t,Rd} = \frac{K_2 F_{ub} A}{\lambda m2} = \frac{0.6\ x\ 520\ x\ 84.3}{1.25} = 21.04kN \rightarrow F_{t,Rd} = 21.04kN > 1.065kN$ **Okay**

Shear Resistance Check: *(6.2 EN 1993-1-4: 2006)*

$F_{v,Ed}$: *is the design shear force per bolt for the ultimate limit state.*

$F_{v,Rd}$: *is the design shear resistance per bolt.*

$F_{V,Ed} = kN$

$F_{V,Rd} = \frac{\alpha F_{ub} A}{\lambda m2} = \frac{0.9\ x\ 520\ x\ 57}{1.25} = 31.56kN \rightarrow F_{V,Rd} = 31.56kN > 0.405kN$ **Okay**

Combined Shear & Tensile Resistance Check: *(Table 3.4 EN 1993-1-8:2005)*

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \leq 1 \rightarrow \frac{1.065}{21.04} + \frac{0.405}{31.56} = \leq 1$ **Okay**

Appendix A - Fiscer Reports

TSA is Both the Designer and the Specifier of the Fixings.

fischer
innovative solutions

MASONRY FIXINGS

Unit 83, Cherry Orchard Industrial Estate
Dublin 10
Phone: +353 1 642 6700
Fax: +353 1 626 2197
technical@masonryfixings.ie
www.masonryfixings.ie

Design Specifications

Anchor

Anchor system	fischer Injection system FIS V
Injection resin	FIS V 360 S
Fixing element	Threaded rod FIS A M 12 x 120 8.8, zinc plated steel, property class 8.8
Calculated anchorage depth	85 mm
Design Data	Anchor design in Concrete according European Technical Assessment ETA-02/0024, Option 1, Issued 02/01/2020

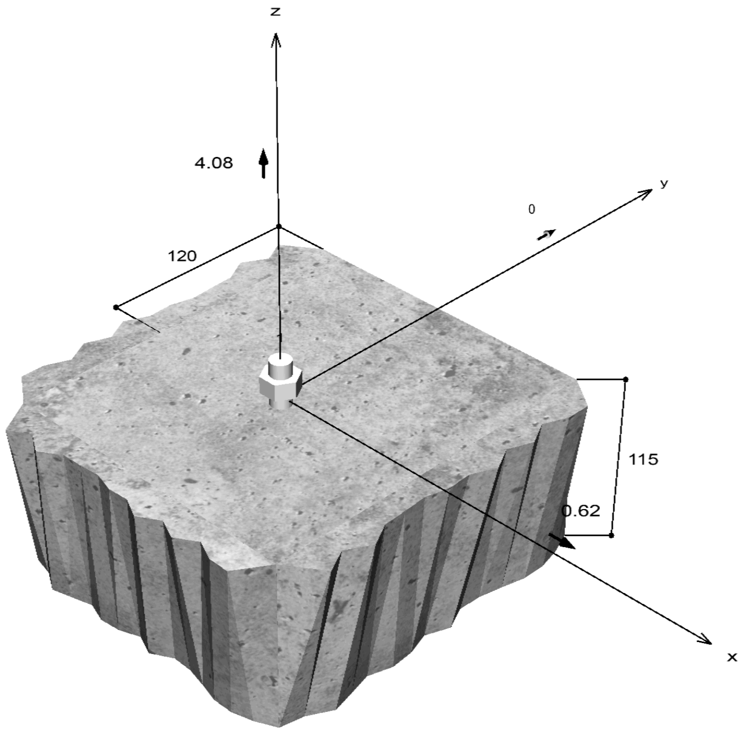
Geometry / Loads / Scale units

mm, kN, kNm

Value of design actions (including

partial safety factor for the load)

Static



Not drawn to scale

Input data

Design method	Design Method EN1992-4:2018 bonded fastener
Base material	Normal weight concrete, C30/37, EN 206
Concrete condition	Non-cracked, dry hole
Temperature range	24 °C long term temperature, 40 °C short term temperature
Reinforcement	Normal or no reinforcement. No edge reinforcement
Drilling method	hammer drilling
Installation type	Push-through installation
Type of loading	Static or quasi-static

Design actions *)

#	N_{Ed} kN	$V_{Ed,x}$ kN	$V_{Ed,y}$ kN	$M_{Ed,x}$ kNm	$M_{Ed,y}$ kNm	$M_{T,Ed}$ kNm	Type of loading
1	4.08	0.62	0.00	0.00	0.00	0.00	Static or quasi-static

*) The required partial safety factors for actions are included

Resulting anchor forces

Anchor no.	Tensile action kN	Shear Action kN	Shear Action x kN	Shear Action y kN
1	4.08	0.62	0.62	0.00

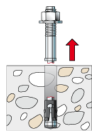
Resistance to tension loads

Proof	Action kN	Capacity kN	Utilisation β_N %
Steel failure *	4.08	45.33	9.0
Combined pull-out and concrete cone failure	4.08	24.65	16.6
Concrete cone failure	4.08	30.01	13.6
Splitting failure	4.08	19.13	**21.3**

* Most unfavourable anchor

Steel failure

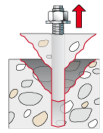
$$N_{Ed} \leq \frac{N_{Rk,s}}{\gamma_{Ms}} \quad (N_{Rd,s})$$



$N_{Rk,s}$ kN	γ_{Ms}	$N_{Rd,s}$ kN	N_{Ed} kN	$\beta_{N,s}$ %
68.00	1.50	45.33	4.08	9.0

Anchor no.	$\beta_{N,s}$ %	Group N°	Decisive Beta
1	9.0	1	$\beta_{N,s;1}$

Combined pull-out and concrete cone failure



$$N_{Ed} \leq \frac{N_{Rk,p}}{\gamma_{Mp}} \quad (N_{Rd,p})$$

$$N_{Rk,p} = N^0_{Rk,p} \cdot \frac{A_{p,N}}{A^0_{p,N}} \cdot \Psi_{s,Np} \cdot \Psi_{g,Np} \cdot \Psi_{ec,Np} \cdot \Psi_{re,Np}$$ Eq. (7.13)

$$N_{Rk,p} = 38.77kN \cdot \frac{63{,}113mm^2}{65{,}025mm^2} \cdot 0.982 \cdot 1.000 \cdot 1.000 \cdot 1.000 = 36.97kN$$

$$N^0_{Rk,p} = \Psi_{sus} \cdot \pi \cdot d \cdot h_{ef} \cdot \tau_{Rk} = 1.00 \cdot \pi \cdot 12mm \cdot 85mm \cdot 12.1N/mm^2 = 38.77kN$$ Eq. (7.14)

$$\Psi_{sus} = 1.00$$ Eq. (7.14a)

$$\alpha_{sus} = 0.00 \leq \Psi^0_{sus} = 0.74$$

$$s_{cr,Np} = min\left(7.3 \cdot d \cdot \left(\Psi_{sus} \cdot \tau_{Rk,ucr}\right)^{0.5}; 3 \cdot h_{ef}\right)$$ Eq. (7.15)

$$s_{cr,Np} = min\left(7.3 \cdot 12mm \cdot \left(1.00 \cdot 11.0N/mm^2\right)^{0.5}; 3 \cdot 85mm\right) = 255mm$$

$$c_{cr,Np} = \frac{S_{cr,Np}}{2} = \frac{255mm}{2} = 128mm$$ Eq. (7.16)

$$\Psi_{s,Np} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,Np}} = 0.7 + 0.3 \cdot \frac{120mm}{128mm} = 0.982 \leq 1$$ Eq. (7.20)

$$\Psi_{g,Np} = max\left(1; \Psi^0_{g,Np} - \sqrt{\frac{s}{s_{cr,Np}}} \cdot \left(\Psi^0_{g,Np} - 1\right)\right) = 1.000 - \sqrt{\frac{0mm}{255mm}} \cdot \left(1.000 - 1\right) = 1.000 \geq 1$$ Eq. (7.17)

$$\Psi^0_{g,Np} = max\left(1; \sqrt{n} - \left(\sqrt{n} - 1\right) \cdot \left(\frac{\tau_{Rk}}{\tau_{Rk,c}}\right)^{1.5}\right)$$ Eq. (7.18)

$$\Psi^0_{g,Np} = max\left(1; \sqrt{1} - \left(\sqrt{1} - 1\right) \cdot \left(\frac{12.1N/mm^2}{14.7N/mm^2}\right)^{1.5}\right) = 1.000 \geq 1$$

$$\tau_{Rk,c} = \frac{k_3}{\pi \cdot d}\sqrt{h_{ef} \cdot f_{ck}} = \frac{11}{3.14 \cdot 12mm}\sqrt{85mm \cdot 30.0N/mm^2} = 14.7N/mm^2$$ Eq. (7.19)

$$\Psi_{ec,Np} = \frac{1}{1 + \frac{2e_n}{s_{cr,Np}}} = \Psi_{ec,Npx} \cdot \Psi_{ec,Npy} = 1.000 \cdot 1.000 = 1.000 \leq 1$$ Eq. (7.21)

$$\Psi_{ec,Npx} = \frac{1}{1 + \frac{2 \cdot 0mm}{255mm}} = 1.000 \leq 1 \qquad \Psi_{ec,Npy} = \frac{1}{1 + \frac{2 \cdot 0mm}{255mm}} = 1.000 \leq 1$$

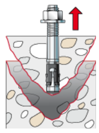
$$\Psi_{re,Np} = 1.000$$ Eq. (7.5)

$N_{Rk,p}$ kN	γ_{Mp}	$N_{Rd,p}$ kN	N_{Ed} kN	$\beta_{N,p}$ %
36.97	1.50	24.65	4.08	16.6

Anchor no.	$\beta_{N,p}$ %	Group N°	Decisive Beta
1	16.6	1	$\beta_{N,p;1}$

Concrete cone failure

$$N_{Ed} \leq \frac{N_{Rk,c}}{\gamma_{Mc}} \quad (\mathbf{N_{Rd,c}})$$



$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N} \cdot \Psi_{M,N}$$ Eq. (7.1)

$$N_{Rk,c} = 47.22kN \cdot \frac{63{,}113mm^2}{65{,}025mm^2} \cdot 0.982 \cdot 1.000 \cdot 1.000 \cdot 1.000 = 45.02kN$$

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h^{1.5}_{ef} = 11.0 \cdot \sqrt{30.0N/mm^2} \cdot \left(85mm\right)^{1.5} = 47.22kN$$ Eq. (7.2)

$$\Psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,N}} = 0.7 + 0.3 \cdot \frac{120mm}{128mm} = 0.982 \leq 1$$ Eq. (7.4)

$$\Psi_{re,N} = 1.000$$ Eq. (7.5)

$$\Psi_{ec,N} = \frac{1}{1 + \frac{2e_n}{s_{cr,N}}} \Longrightarrow \Psi_{ec,Nx} \cdot \Psi_{ec,Ny} = 1.000 \cdot 1.000 = 1.000 \leq 1$$ Eq. (7.6)

$$\Psi_{ec,Nx} = \frac{1}{1 + \frac{2 \cdot 0mm}{255mm}} = 1.000 \leq 1 \qquad \Psi_{ec,Ny} = \frac{1}{1 + \frac{2 \cdot 0mm}{255mm}} = 1.000 \leq 1$$

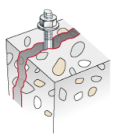
$$\Psi_{M,N} = 1.00 \geq 1$$ Eq. (7.7)

$N_{Rk,c}$ kN	γ_{Mc}	$N_{Rd,c}$ kN	N_{Ed} kN	$\beta_{N,c}$ %
45.02	1.50	30.01	4.08	13.6

Anchor no.	$\beta_{N,c}$ %	Group N°	Decisive Beta
1	13.6	1	$\beta_{N,c;1}$

Splitting failure due to loading

$$N_{Ed} \leq \frac{N_{Rk,sp}}{\gamma_{Msp}} \quad (\mathbf{N_{Rd,sp}})$$



$$N_{Rk,sp} = N^0_{Rk,sp} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N} \cdot \Psi_{h,sp}$$ Eq. (7.23)

$$N_{Rk,sp} = 38.77kN \cdot \frac{111{,}872mm^2}{135{,}424mm^2} \cdot 0.896 \cdot 1.000 \cdot 1.000 \cdot 1.000 = 28.69kN$$

$$\Psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,sp}} = 0.7 + 0.3 \cdot \frac{120mm}{184mm} = 0.896 \leq 1$$ Eq. (7.4)

$$\Psi_{re,N} = 1.000$$ Eq. (7.5)

$$\Psi_{ec,N} = \frac{1}{1 + \frac{2e_n}{s_{cr,sp}}} = \Psi_{ec,Nx} \cdot \Psi_{ec,Ny} = 1.000 \cdot 1.000 = 1.000 \leq 1$$ Eq. (7.6)

$$\Psi_{ec,Nx} = \frac{1}{1 + \frac{2 \cdot 0mm}{368mm}} = 1.000 \leq 1 \qquad \Psi_{ec,Ny} = \frac{1}{1 + \frac{2 \cdot 0mm}{368mm}} = 1.000 \leq 1$$

$$\Psi_{h,sp} = min\Bigg(\left(\frac{h}{h_{min}}\right)^{2/3};max\left(1;\left(\frac{h_{ef}+1.5\ c_1}{h_{min}}\right)^{2/3}\right);2\Bigg)$$ Eq. (7.24)

$$\Psi_{h,sp} = min\Bigg(\left(\frac{115mm}{115mm}\right)^{2/3};max\left(1;\left(\frac{85mm+1.5\cdot 120mm}{115mm}\right)^{2/3}\right);2\Bigg) = 1.000$$

$N_{Rk,sp}$ kN	γ_{Msp}	$N_{Rd,sp}$ kN	N_{Ed} kN	$\beta_{N,sp}$ %
28.69	1.50	19.13	4.08	21.3

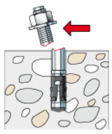
Anchor no.	$\beta_{N,sp}$ %	Group N°	Decisive Beta
1	21.3	1	$\beta_{N,sp;1}$

Resistance to shear loads

Proof	Action kN	Capacity kN	Utilisation β_V %
Steel failure without lever arm *	0.62	27.20	**2.3**
Concrete pry-out failure	0.62	49.29	1.3
Concrete edge failure	0.62	30.04	2.1

* Most unfavourable anchor

Steel failure without lever arm



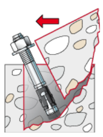
$$V_{Ed} \leq \frac{V_{Rk,s}}{\gamma_{Ms}} \quad (V_{Rd,s})$$

$$V_{Rk,s} = k_7 \cdot V^0_{Rk,s} = 1.00 \cdot 34.00kN = 34.00kN$$ Eq. (7.35)/ (7.36)

$V_{Rk,s}$ kN	γ_{Ms}	$V_{Rd,s}$ kN	V_{Ed} kN	β_{Vs} %
34.00	1.25	27.20	0.62	2.3

Anchor no.	β_{Vs} %	Group N°	Decisive Beta
1	2.3	1	$\beta_{Vs;1}$

Concrete pry-out failure



$$V_{Ed} \leq \frac{V_{Rk,cp}}{\gamma_{Mc}} \quad (V_{Rd,cp})$$

$$V_{Rk,cp} = k_8 \cdot N_{Rk,p} = 2 \cdot 36.97kN = 73.94kN$$ Eq. (7.39c)

$$N_{Rk,p} = N^0_{Rk,p} \cdot \frac{A_{p,N}}{A^0_{p,N}} \cdot \Psi_{s,Np} \cdot \Psi_{g,Np} \cdot \Psi_{ec,Np} \cdot \Psi_{re,Np}$$ Eq. (7.13)

$$N_{Rk,p} = 38.77kN \cdot \frac{63{,}113mm^2}{65{,}025mm^2} \cdot 0.982 \cdot 1.000 \cdot 1.000 \cdot 1.000 = 36.97kN$$

$$N^0_{Rk,p} = \Psi_{sus} \cdot \pi \cdot d \cdot h_{ef} \cdot \tau_{Rk} = 1.00 \cdot \pi \cdot 12mm \cdot 85mm \cdot 12.1N/mm^2 = 38.77kN$$ Eq. (7.14)

$$\Psi_{sus} = 1.00$$ Eq. (7.14a)

$$\alpha_{sus} = 0.00 \leq \Psi^0_{sus} = 0.74$$

$$\Psi_{s,Np} = 0.7 + 0.3 \cdot \frac{c}{c_{cr,Np}} = 0.7 + 0.3 \cdot \frac{120mm}{128mm} = 0.982 \leq 1$$ Eq. (7.20)

$$\Psi_{g,Np} = max\left(1;\ \Psi^0_{g,Np} - \sqrt{\frac{s}{s_{cr,Np}}} \cdot \left(\Psi^0_{g,Np} - 1\right)\right)$$ Eq. (7.17)

$$\Psi_{g,Np} = max\left(1;\ 1.000 - \sqrt{\frac{0mm}{255mm}} \cdot \left(1.000 - 1\right)\right) = 1.000 \geq 1$$

$$\Psi^0_{g,Np} = max\left(1;\ \sqrt{n} - \left(\sqrt{n} - 1\right) \cdot \left(\frac{\tau_{Rk}}{\tau_{Rk,c}}\right)^{1.5}\right)$$ Eq. (7.18)

$$\Psi^0_{g,Np} = max\left(1;\ \sqrt{1} - \left(\sqrt{1} - 1\right) \cdot \left(\frac{12.1N/mm^2}{14.7N/mm^2}\right)^{1.5}\right) = 1.000 \geq 1$$

$$\tau_{Rk,c} = \frac{k_3}{\pi \cdot d}\sqrt{h_{ef} \cdot f_{ck}} = \frac{11}{3.14 \cdot 12mm}\sqrt{85mm \cdot 30.0N/mm^2} = 14.7N/mm^2$$ Eq. (7.19)

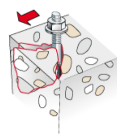
$$\Psi_{ec,Np} = \frac{1}{1 + \frac{2e_n}{s_{cr,Np}}} = \Psi_{ec,Npx} \cdot \Psi_{ec,Npy} = 1.000 \cdot 1.000 = 1.000 \leq 1$$ Eq. (7.21)

$$\Psi_{re,Np} = 1.000$$ Eq. (7.5)

$V_{Rk,cp}$ kN	γ_{Mcp}	$V_{Rd,cp}$ kN	V_{Ed} kN	$\beta_{V,cp}$ %
73.94	1.50	49.29	0.62	1.3

Anchor no.	$\beta_{V,cp}$ %	Group N°	Decisive Beta
1	1.3	1	$\beta_{V,cp;1}$

Concrete edge failure



$$V_{Ed} \leq \frac{V_{Rk,c}}{\gamma_{Mc}} \quad (V_{Rd,c})$$

$$V_{Rk,c} = V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \Psi_{s,V} \cdot \Psi_{h,V} \cdot \Psi_{\alpha,V} \cdot \Psi_{ec,V} \cdot \Psi_{re,V}$$ Eq. (7.40)

$$V_{Rk,c} = 28.19kN \cdot \frac{41{,}400mm^2}{64{,}800mm^2} \cdot 1.000 \cdot 1.251 \cdot 2.000 \cdot 1.000 \cdot 1.000 = 45.07kN$$

$$V^0_{Rk,c} = k_9 \cdot d^{\alpha} \cdot l_f^{\beta} \cdot \sqrt{f_{ck}} \cdot c_1^{1.5}$$ Eq. (7.41)

$$V^0_{Rk,c} = 2.4 \cdot \left(12mm\right)^{0.084} \cdot \left(85mm\right)^{0.063} \cdot \sqrt{30.0N/mm^2} \cdot \left(120mm\right)^{1.5} = 28.19kN$$

$$\alpha = 0.1 \cdot \sqrt{\frac{l_f}{c_1}} = 0.1 \cdot \sqrt{\frac{85mm}{120mm}} = 0.084 \qquad \beta = 0.1 \cdot \left(\frac{d}{c_1}\right)^{0.2} = 0.1 \cdot \left(\frac{12mm}{120mm}\right)^{0.2} = 0.063$$ Eq. (7.42/7.43)

$$\Psi_{s,V} = 0.7 + 0.3 \cdot \frac{c_2}{1.5c_1} = 0.7 + 0.3 \cdot \frac{180mm}{1.5 \cdot 120mm} = 1.000 \leq 1$$ Eq. (7.45)

$$\Psi_{h,V} = \sqrt{\frac{1.5c_1}{h}} = \sqrt{\frac{1.5 \cdot 120mm}{115mm}} = 1.251 \geq 1$$ Eq. (7.46)

$$\Psi_{\alpha,V} = \sqrt{\frac{1}{\left(cos\ \alpha_V\right)^2 + \left(0.5 \cdot sin\ \alpha_V\right)^2}} = \sqrt{\frac{1}{\left(cos\ 90.0\right)^2 + \left(0.5 \cdot sin\ 90.0\right)^2}} = 2.000 \geq 1$$ Eq. (7.48)

$$\Psi_{ec,V} = \frac{1}{1 + \frac{2}{3}\frac{e_v}{c_1}} = \frac{1}{1 + \frac{2 \cdot 0mm}{3 \cdot 120mm}} = 1.000 \leq 1$$ Eq. (7.47)

$$\Psi_{re,V} = 1.000$$

$V_{Rk,c}$ kN	γ_{Mc}	$V_{Rd,c}$ kN	V_{Ed} kN	$\beta_{V,c}$ %
45.07	1.50	30.04	0.62	2.1

Anchor no.	$\beta_{V,c}$ %	Group N°	Decisive Beta
1	2.1	1	$\beta_{V,c;1}$

Utilization of tension and shear loads

Tension loads	Utilisation β_N %
Steel failure *	9.0
Combined pull-out and concrete cone failure	16.6
Concrete cone failure	13.6
Splitting failure	**21.3**

Shear Loads	Utilisation β_V %
Steel failure without lever arm *	**2.3**
Concrete pry-out failure	1.3
Concrete edge failure	2.1

* Most unfavourable anchor

Resistance to combined tensile and shear loads

Utilisation steel

$$\beta_{N.s} = \beta_{N,s;1} = 0.09 \leq 1$$
$$\beta_{V.s} = \beta_{Vs;1} = 0.02 \leq 1$$
$$\beta_N^2 + \beta_V^2 = \beta_{N,s;1}^2 + \beta_{Vs;1}^2 = 0.01 \leq 1$$ Eq. (7.55)

Utilisation concrete

Proof successful

$$\beta_{N,sp} = \beta_{N,sp;1} = 0.21 \leq 1$$
$$\beta_{V.c} = \beta_{V,c;1} = 0.02 \leq 1$$
$$\beta_N^{1.5} + \beta_V^{1.5} = \beta_{N,sp;1}^{1.5} + \beta_{V,c;1}^{1.5} = 0.10 \leq 1$$ Eq. (7.56)

Information concerning the anchor plate

No plate

Technical remarks

The transmission of the anchor loads to the supports of the concrete member shall be shown for the ultimate limit state and the serviceability limit state; for this purpose, the normal verifications shall be carried out under due consideration of the actions introduced by the anchors. For these verifications the additional provisions given in the current design method shall be taken into account.
As a pre-condition the anchor plate is assumed to be flat when subjected to the actions. Therefore, the plate must be sufficiently stiff. The C-Fix anchor plate design is based on a proof of stresses and does not allow a statement about the stiffness of the plate. The proof of the necessary stiffness is not carried out by C-Fix.

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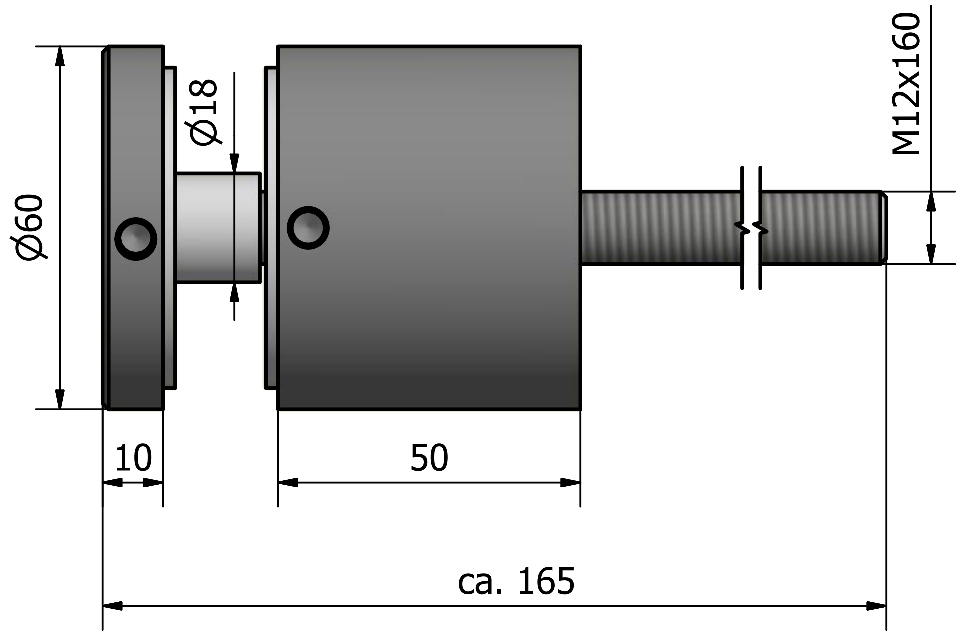
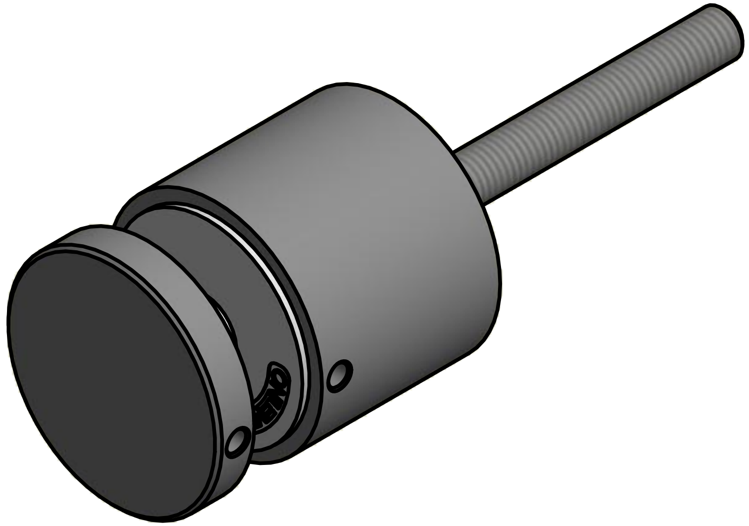
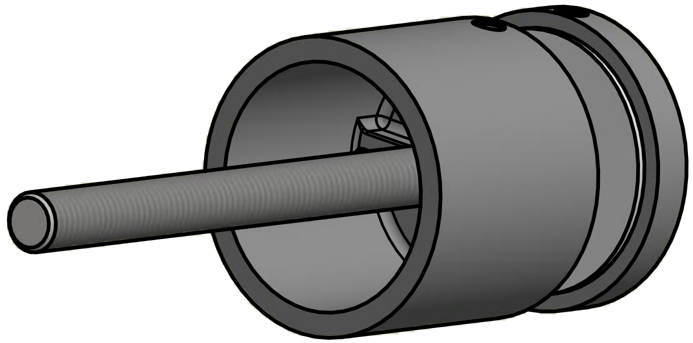
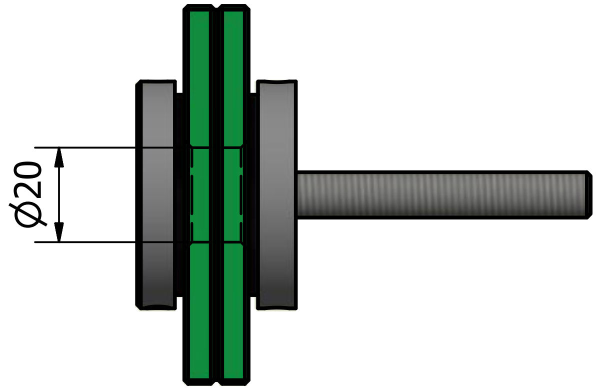
Appendix B – Glass Adaptor ø 60mm









Designed by	Created	Modificated	Comment
FV			

ONLEVEL

Description		
Glass adaptor Ø60mm thickness 50mm stainless steel AISI 316 satined		
Article number	Size	Scale
10206050031	A4	1 : 1.25