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CONSULTING ENGINEERS

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 1
Date: 23/07/2020	**By:** R.F.

On Level Ltd.,

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

Glass Balustrade

1419-1 Glass Adaptor 1.5kN

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

Revision	Date	Issued By	Comment
0	23/07/2020	T.S.	Issued

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Project: Glass Adaptor 1.5kN	Contract: 1419-1
Subject: Glass Balustrade	Sheet No. 2
Date: 23/07/2020	By: R.F.

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Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 3
Date: 23/07/2020	**By:** R.F.

Introduction/Actions/Result Summary:

Introduction:

TSA was instructed by On Level to carry out calculations to be made with glass adaptor ø50mm thickness.

Actions:

Balustrade load = 1.5kN/m (Table NA.5 IS1991-1-1:2002)
Point load = 1.5kN (Table NA.4.2 IS 1991-1-1:2002)
Infill load = 1.5kN (Table NA.5 IS1991-1-1:2002)

Assumption:

Concrete Grade = C30/37

Result Summary:

Study	Size of the Glass (lxh) (m)	Glass (mm)	Interlayer	Working Line Load for System (kN/m)	Glass Deflection (mm)
Case Study 01	1.1 x 1.45	21.52	Sentry	1.5	15.19
Case Study 02	1.5 x 1.45	21.52	Sentry	1.5	14.42

NOTE:

- All deflection < 25mm and therefore acceptable
- Glass thickness chosen determined by the material stress when subjected to 1.5kN/m Balustrade Load, 1.5kN/m2 Infill Load and 1.5kN Point Load

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Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
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Glass Strength

Balustrade Loading:

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

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

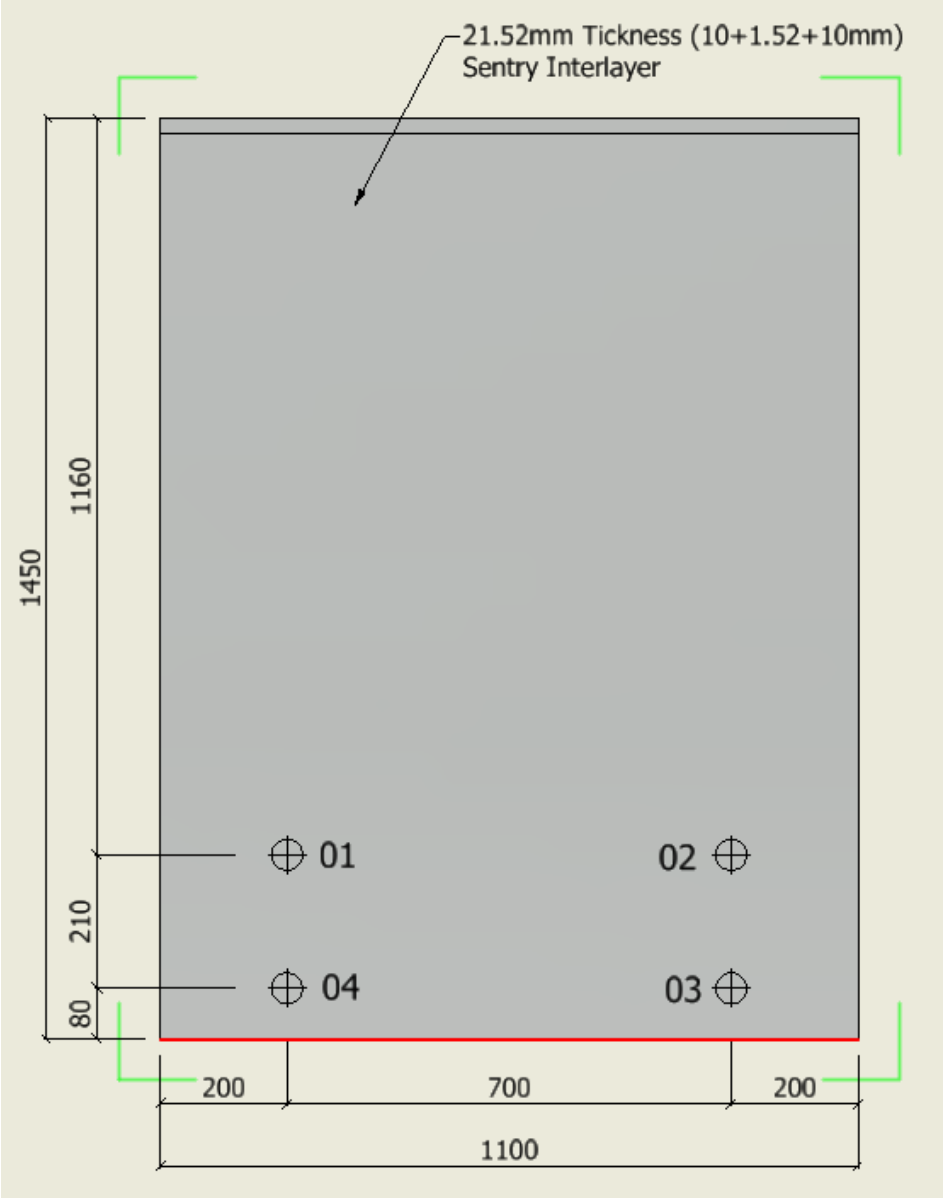
$f_{gd} = (0.77)(1.0)(45)/1.6 + 1.0(120-45)/1.2$

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

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 5
Date: 23/07/2020	**By:** R.F.

Case Study 01:

Sketch - 21.52mm thickness – 1.5kN/m - 1.1x1.45m – Sentry Interlayer:



NOTE:

- Deflection on the glass 15.19mm = **OK in deflection**

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 6
Date: 23/07/2020	**By:** R.F.

Glass Analysis – 21.52mm thickness – 1.5kN/m - 1.1x1.45m – Sentry Interlayer:

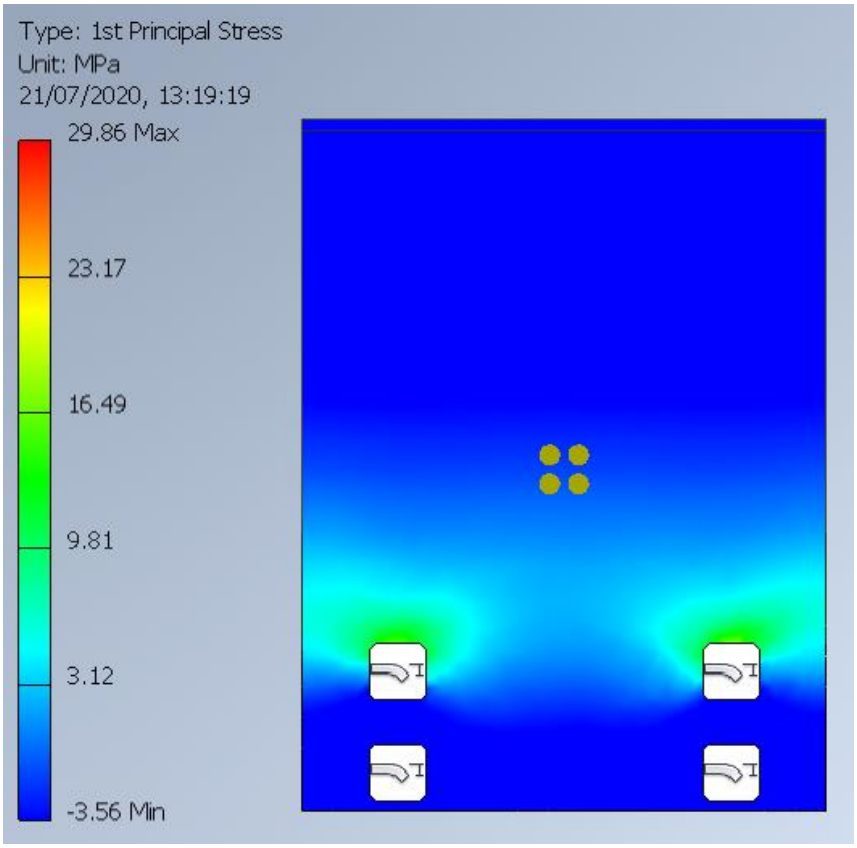
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5N/m2 Infill Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Bending Stress analysed based on glass panel of 1.1m x 1.45m

Result:

Max. Bending Stress = 29.86N/mm^2 x1.5 = 44.79N/mm^2 < 84.2N/mm^2

OK in Bending



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Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 7
Date: 23/07/2020	**By:** R.F.

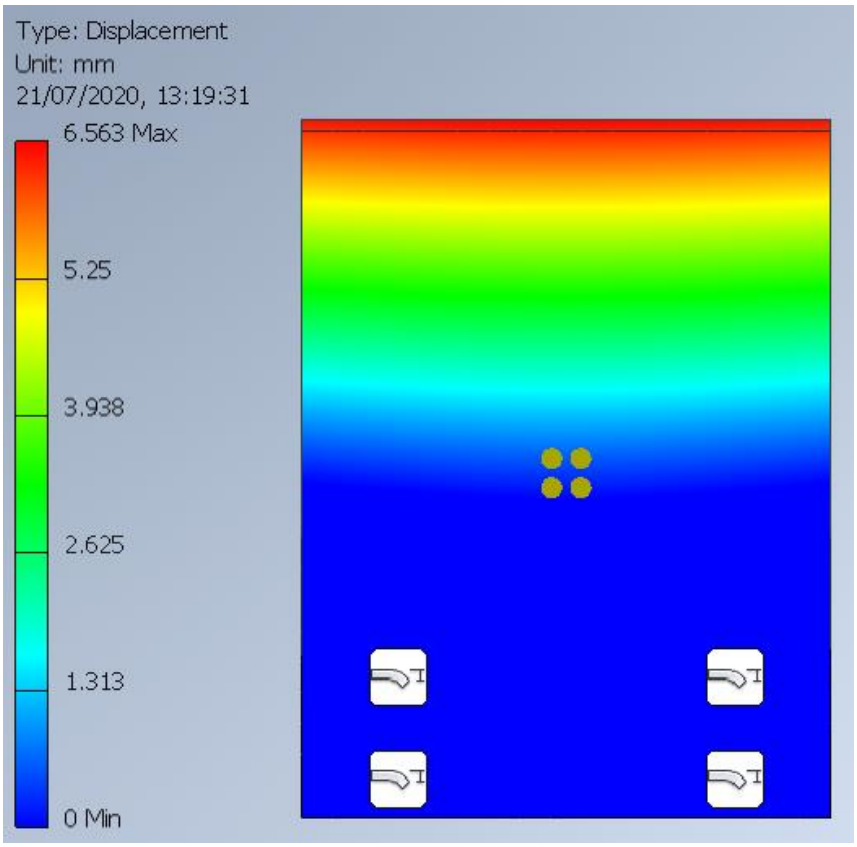
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5N/m2 Infill Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Deflection Stress analysed based on glass panel of 1.1m x 1.45m

Result:

Max. Deflection = 6.563mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 8
Date: 23/07/2020	**By:** R.F.

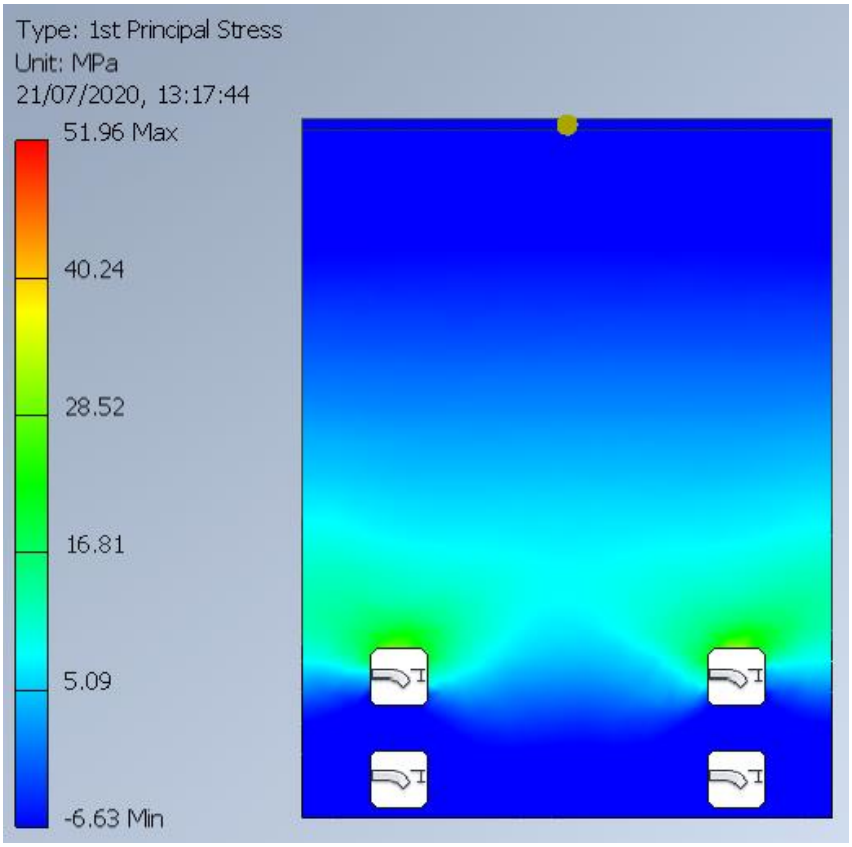
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Balustrade Loading
- Actual Balustrade Load applied to the glass is 1.65 kN/m (1.5x1.1m)
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Bending Stress analysed based on glass panel of 1.1m x 1.45m

Result:

Max. Bending Stress = 51.96N/mm^2 x1.5 = 77.94N/mm^2 < 84.2N/mm^2

OK in Bending



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 9
Date: 23/07/2020	**By:** R.F.

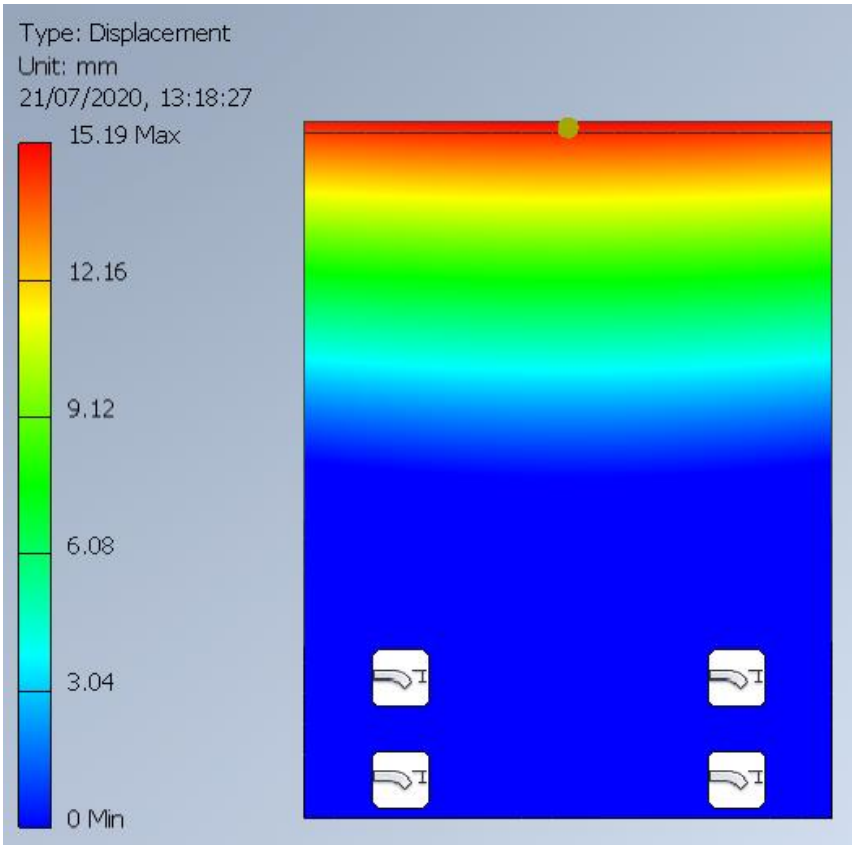
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Balustrade Loading
- Actual Balustrade Load applied to the glass is 1.65 kN/m (1.5x1.1m)
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Deflection analysed based on glass panel of 1.1m x 1.45m

Result:

Max. Deflection = 15.19mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 10
Date: 23/07/2020	**By:** R.F.

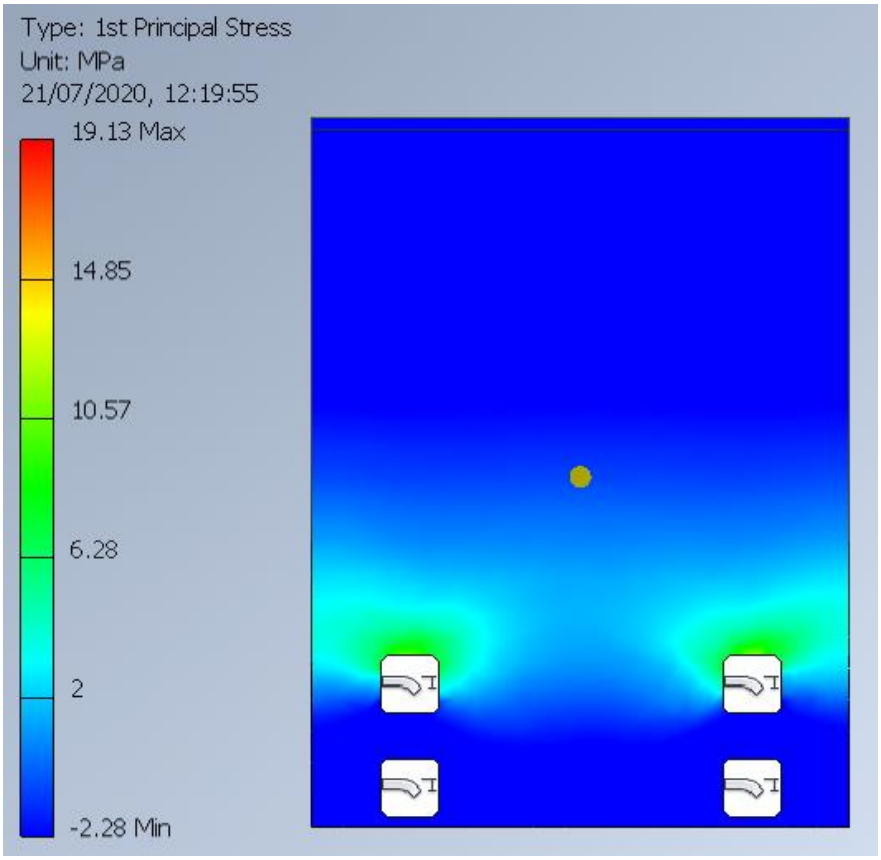
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Point Load
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Bending Stress analysed based on glass panel of 1.1m x 1.45m

Result:

Max. Bending Stress = 19.13N/mm^2 x1.5 = 28.70N/mm^2 < 84.2N/mm^2

OK in Bending



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 11
Date: 23/07/2020	**By:** R.F.

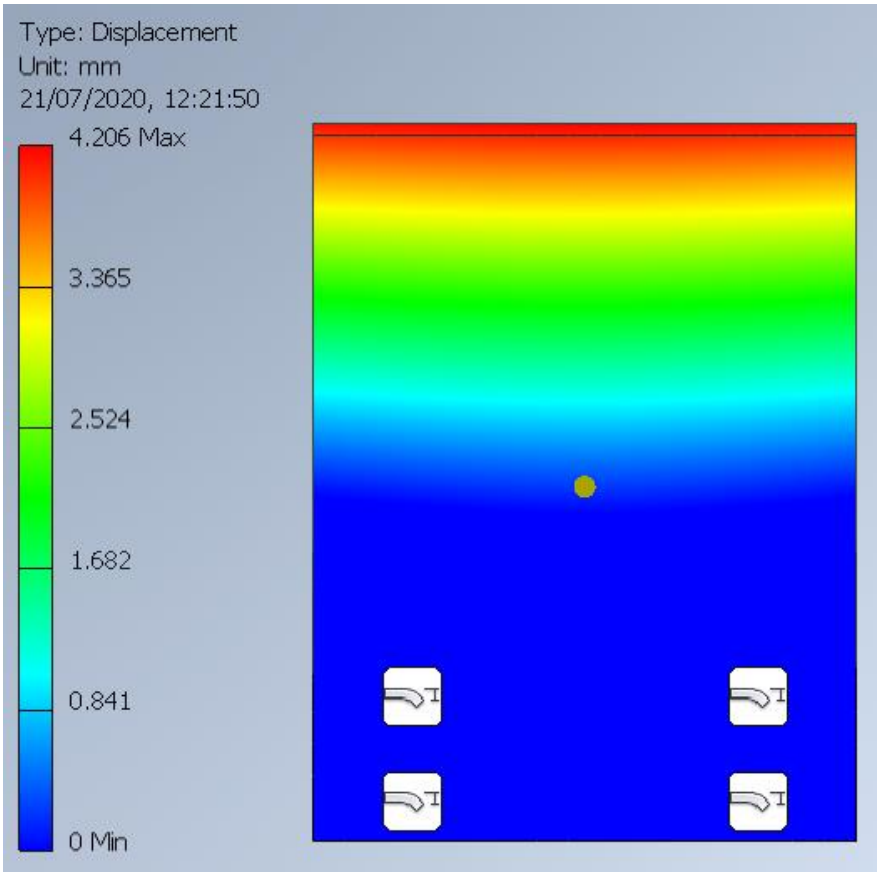
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 1.5kN/m Point Load
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Deflection analysed based on glass panel of 1.1m x 1.45m

Result:

Max. Deflection = 4.206mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



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Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 12
Date: 23/07/2020	**By:** R.F.

Reactions:

Case Study 01			
Size of the Glass – 1100 (l) x 1450 (h) mm			
	Reactions (N)		
	Balustrade	Pressure	Point
1	2161	3256	1496
2	2161	3256	1496
3	-1336	-2431	-746
4	-1336	-2431	-746

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 13
Date: 23/07/2020	**By:** R.F.

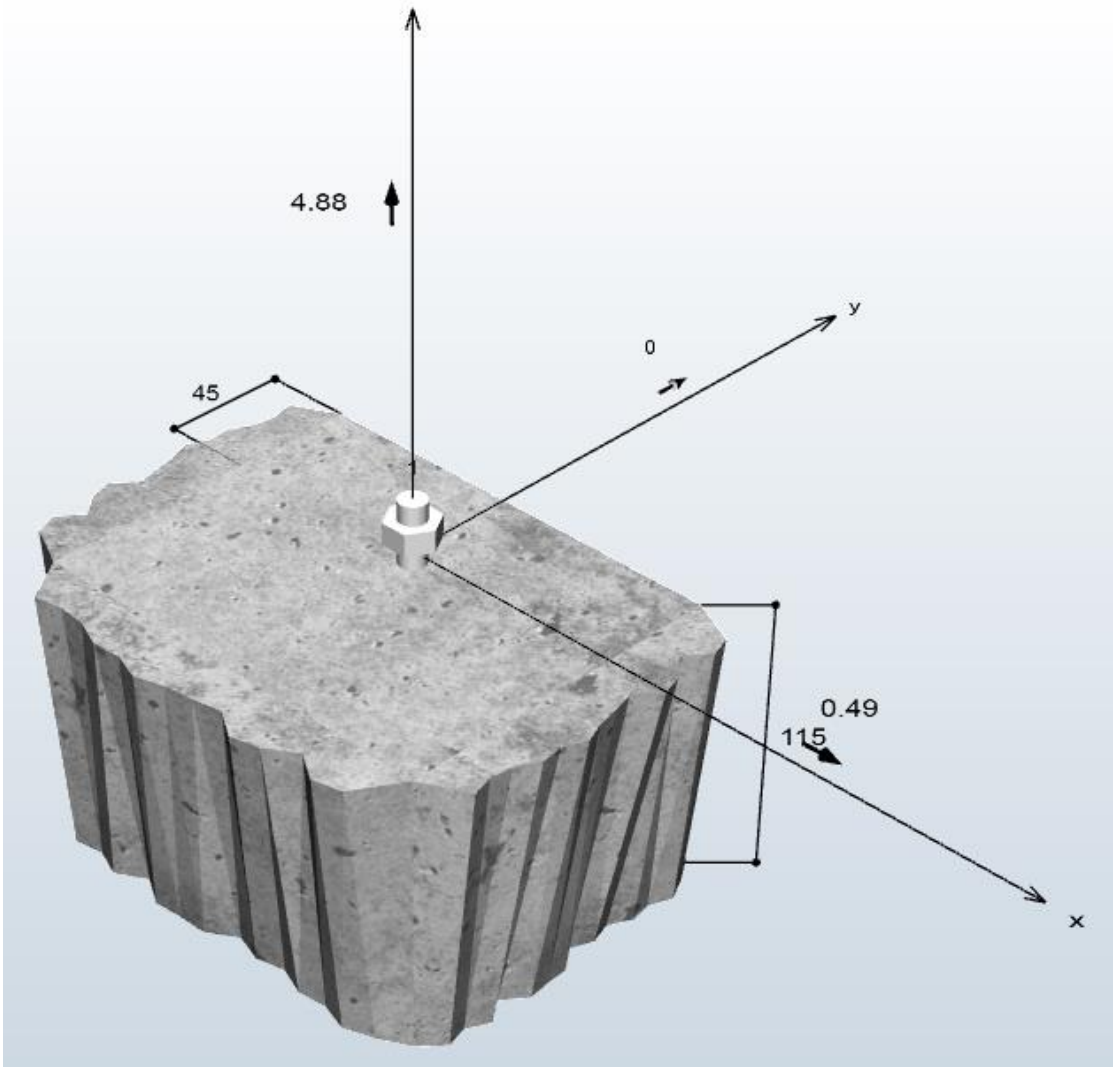
Connection Design:

Connection To Concrete:

Tensile Load $= 3.256\text{kN} \times 1.5 = 4.88\text{kN}$ (ULS)

Shear Load $= 0.36\text{kN} \times 1.35 = 0.49\text{kN}$ (ULS)

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



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 14
Date: 23/07/2020	**By:** R.F.

Connection To Stainless Steel:

1Nr M10 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)*

$A = 58.00mm^2$ *(For M10 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.*

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

$\mathrm{F_{t,Rd}} = \frac{\mathrm{K_2 F_{ub} A}}{\mathrm{\lambda m2}} = \frac{0.6\ x\ 520\ x\ 58}{1.25}\ x\ 10^{-3}$ = 14.48kN → $\mathrm{F_{t,Rd}} = 14.48\mathrm{kN} > 4.88\mathrm{kN}$ **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.*

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

$\mathrm{F_{V,Rd}} = \frac{\alpha \mathrm{F_{ub} A}}{\mathrm{\lambda m2}} = \frac{0.9\ \mathrm{x}\ 520\ \mathrm{x}\ 57}{1.25}\ x\ 10^{-3} = 31.56kN \rightarrow \mathrm{F_{V,Rd}} = 31.56\mathrm{kN} > 0.49\mathrm{kN}$ **Okay**

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

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \leq 1 \rightarrow \frac{4.88}{14.48} + \frac{0.49}{31.56} = \leq 1$ **Okay**

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
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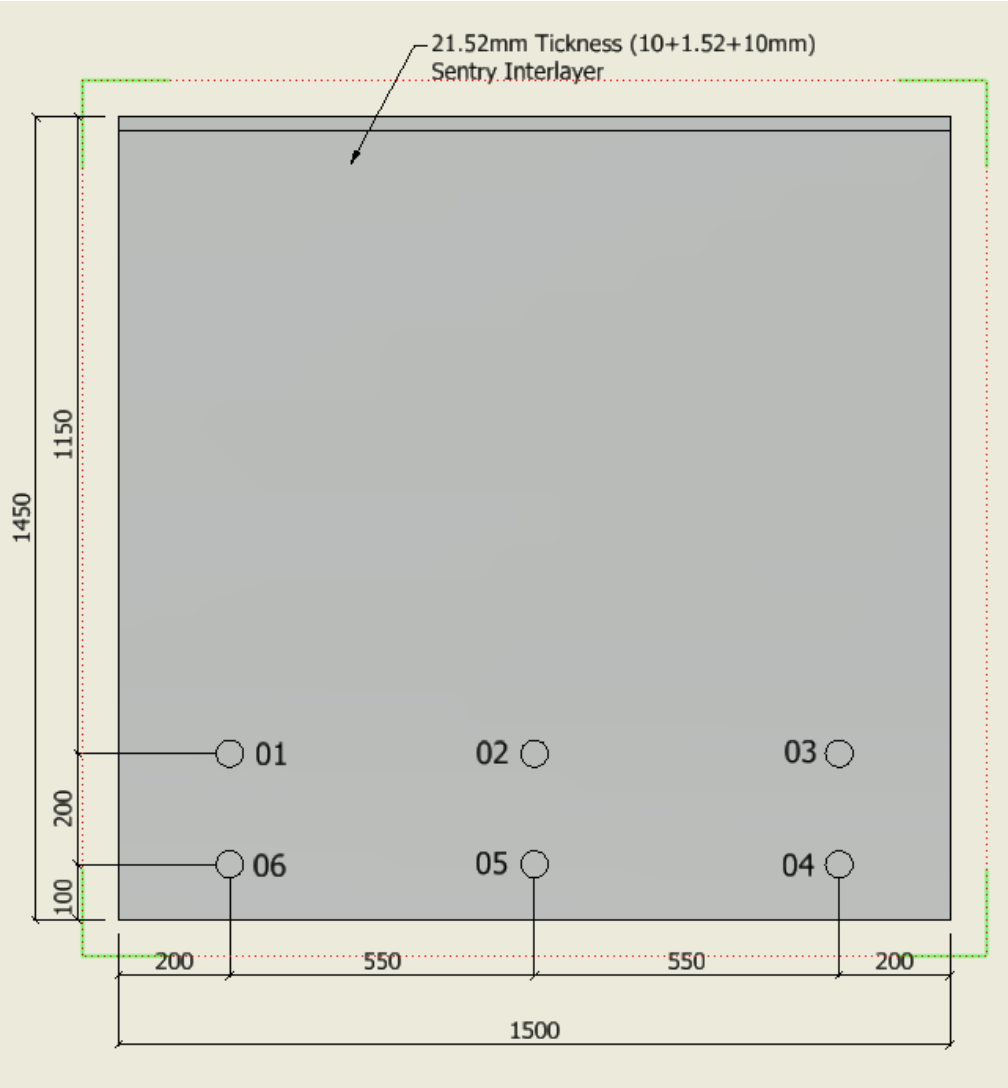
Date: 23/07/2020	**By:** R.F.

Case Study 02:

Sketch - 21.52mm thickness – 1.5kN/m - 1.5x1.45m – Sentry Interlayer:



NOTE:

- Deflection on the glass 14.42mm = **OK in deflection**

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 16
Date: 23/07/2020	**By:** R.F.

Glass Analysis – 21.52mm thickness – 1.5kN/m - 1.5x1.45m – Sentry Interlayer:

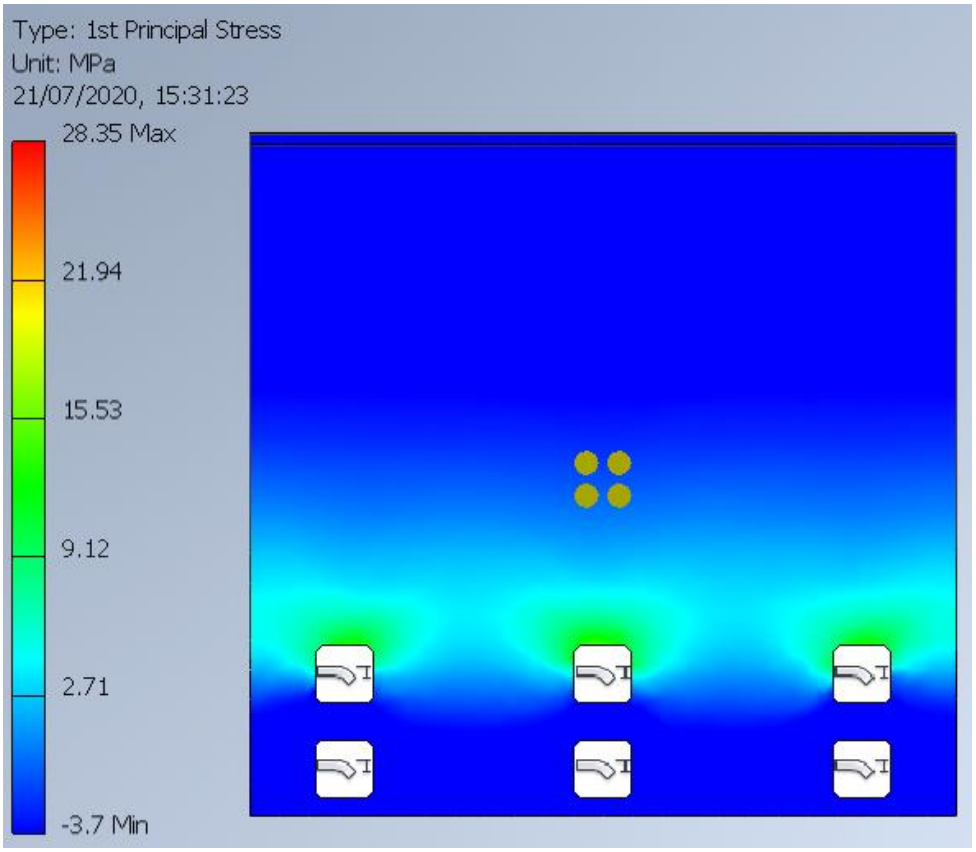
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5N/m2 Infill Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Bending Stress analysed based on glass panel of 1.5m x 1.45m

Result:

Max. Bending Stress = 28.35N/mm^2 x1.5 = 42.53N/mm^2 < 84.2N/mm^2

OK in Bending



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 17
Date: 23/07/2020	**By:** R.F.

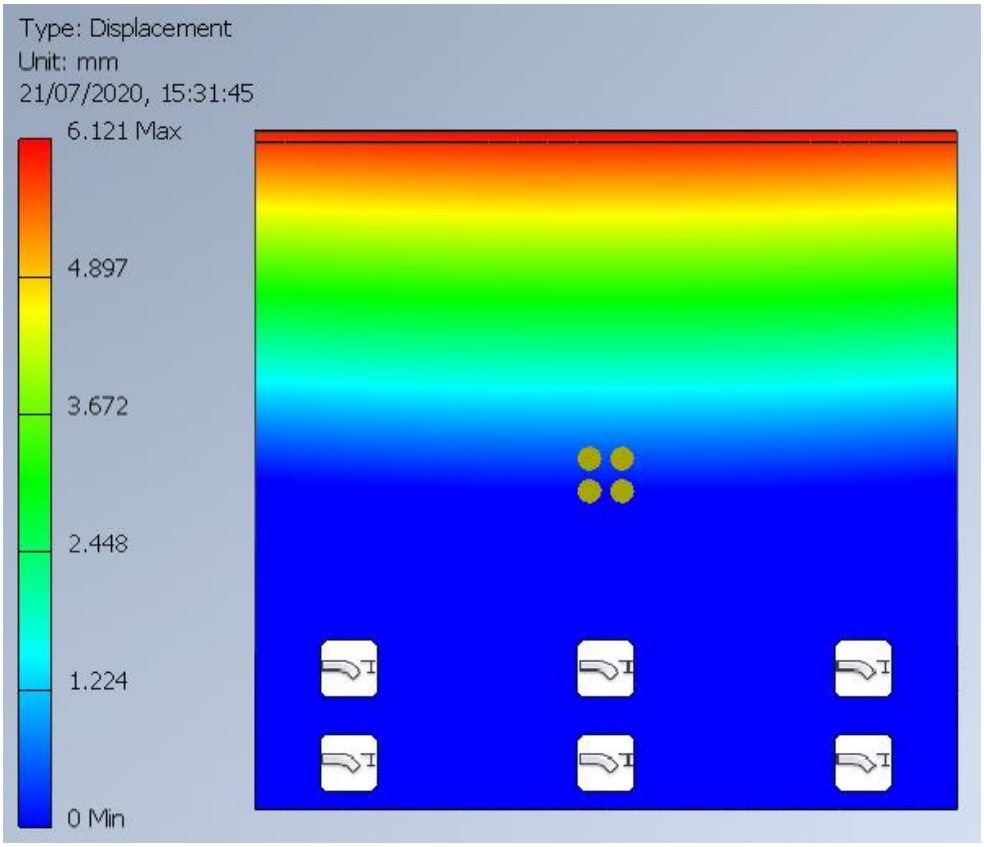
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m2 Infill Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5N/m2 Infill Loading
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Deflection analysed based on glass panel of 1.5m x 1.45m

Result:

Max. Deflection = 6.121mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 18
Date: 23/07/2020	**By:** R.F.

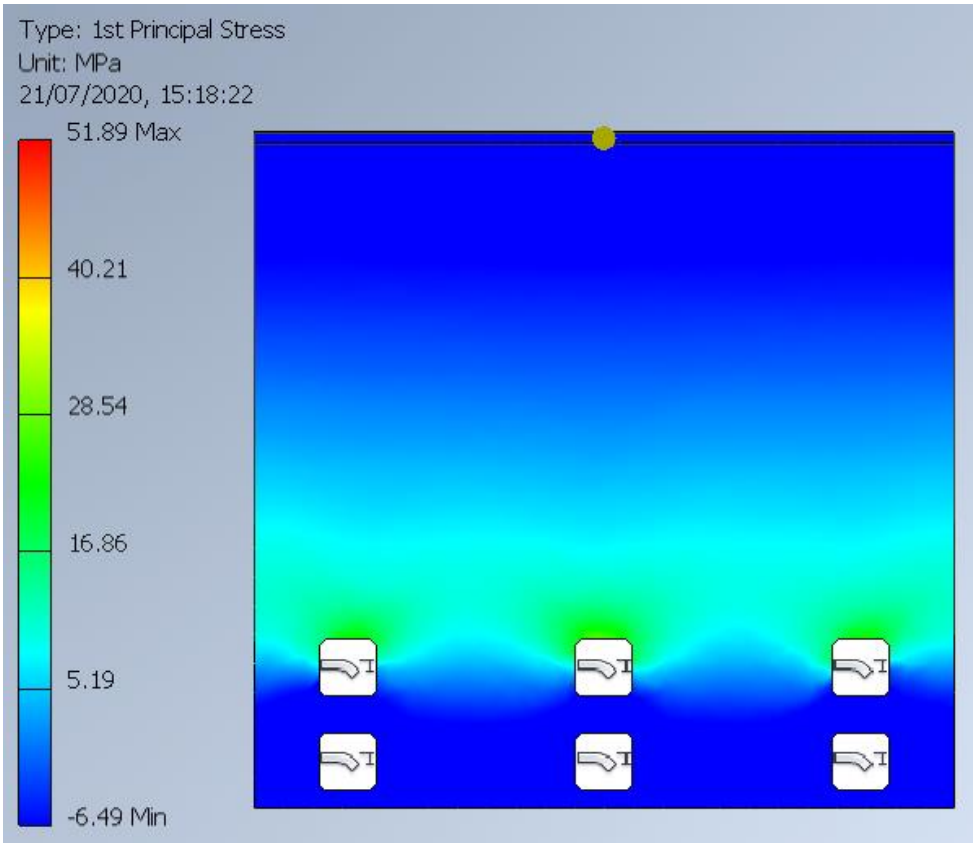
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Balustrade Loading
- Actual Balustrade Load applied to the glass is 2.25 kN/m (1.5x1.5m)
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Bending Stress analysed based on glass panel of 1.5m x 1.45m

Result:

Max. Bending Stress = 51.89N/mm^2 x1.5 = 77.84N/mm^2 < 84.2N/mm^2

OK in Bending



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Project: Glass Adaptor 1.5kN	Contract: 1419-1
Subject: Glass Balustrade	Sheet No. 19
Date: 23/07/2020	By: R.F.

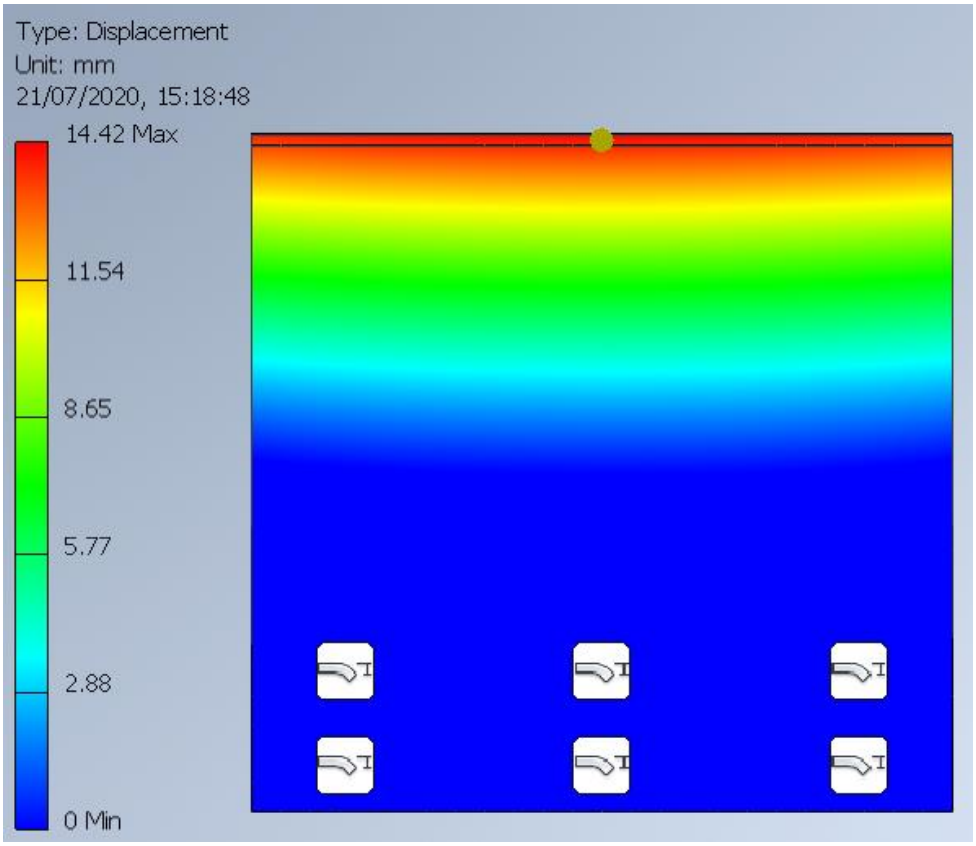
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m Balustrade Loading:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Balustrade Loading
- Actual Balustrade Load applied to the glass is 2.25 kN/m (1.5x1.5m)
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Deflection analysed based on glass panel of 1.5m x 1.45m

Result:

Max. Deflection = 14.42mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 20
Date: 23/07/2020	**By:** R.F.

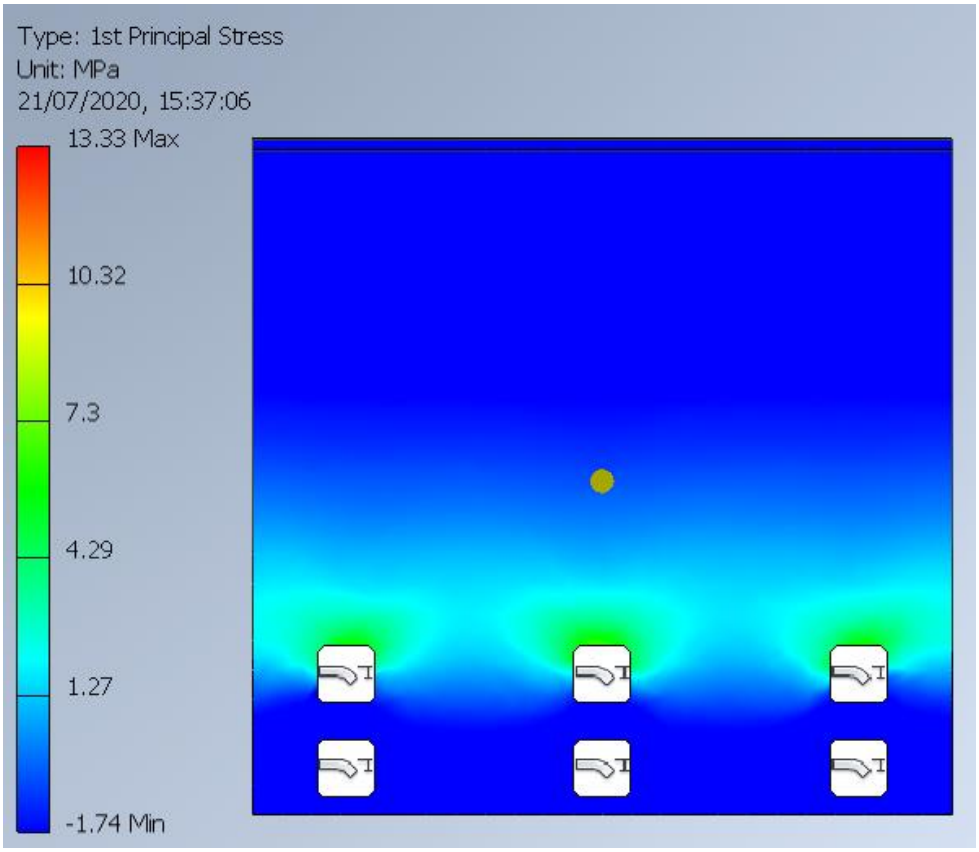
Glass Analysis - Bending Stress of Glass Panel due to 1.5kN/m Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.5kN/m Point Load
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Bending Stress analysed based on glass panel of 1.5m x 1.45m

Result:

Max. Bending Stress = 13.33N/mm^2 x1.5 = 20.00N/mm^2 < 84.2N/mm^2

OK in Bending



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 21
Date: 23/07/2020	**By:** R.F.

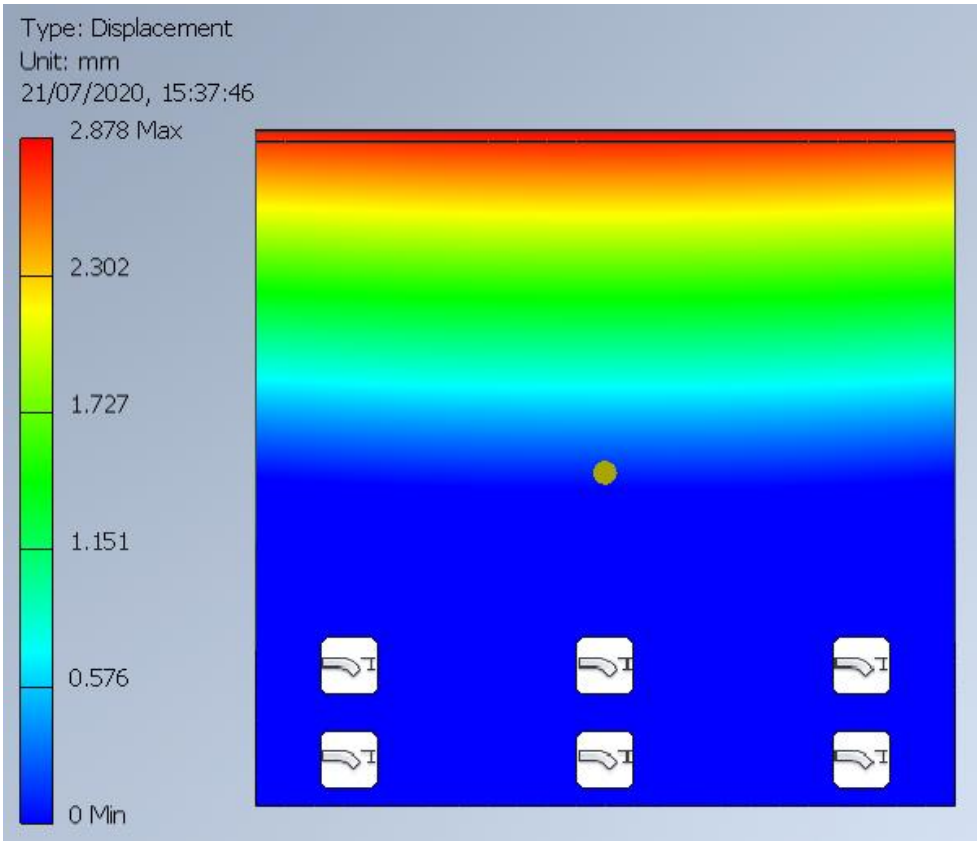
Glass Analysis - Deflection of Glass Panel due to 1.5kN/m Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 1.5kN/m Point Load
- 10/10/1.52mm T/L/T Glass analysed, horizontally toughened Laminated
- Interlayer Properties used for analysis, E= 606 MPa, G = 203.36MPa Sentry Glass SG5000
- Deflection analysed based on glass panel of 1.5m x 1.45m

Result:

Max. Deflection = 2.878mm < 25mm {BS6180:2011 cl. 6.4.1}

OK in Deflection (Glass Only)



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Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 22
Date: 23/07/2020	**By:** R.F.

Reactions:

Case Study 02			
Size of the Glass – 1500 (l) x 1450 (h) mm			
	Reactions (N)		
	Pressure	Balustrade	Point
1	1951	2647	911
2	2505	3726	1171
3	1951	2647	911
4	-981	-2103	-467
5	-1182	-2566	-560
6	-981	-2103	-467

Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 23
Date: 23/07/2020	**By:** R.F.

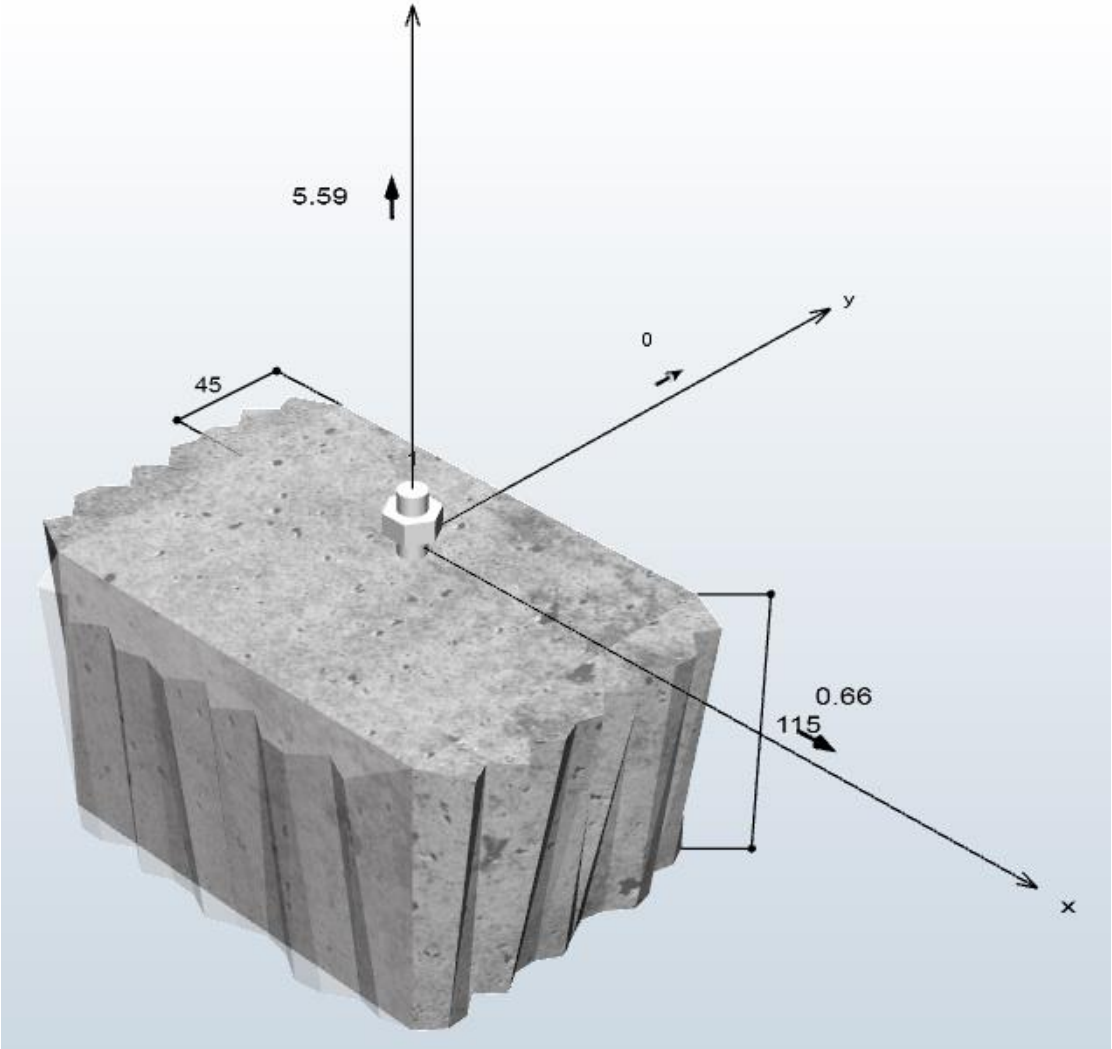
Connection Design:

Connection To Concrete:

Tensile Load $= 3.726\text{kN} \times 1.5 = 5.59\text{kN}$ (ULS)

Shear Load $= 0.49\text{kN} \times 1.35 = 0.66\text{kN}$ (ULS)

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



Project: Glass Adaptor 1.5kN	**Contract:** 1419-1
Subject: Glass Balustrade	**Sheet No.** 24
Date: 23/07/2020	**By:** R.F.

Connection To Stainless Steel:

1Nr M10 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)*

$A = 58.00mm^2$ *(For M10 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.*

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

$\mathrm{F_{t,Rd}} = \frac{\mathrm{K_2 F_{ub} A}}{\mathrm{\lambda m2}} = \frac{0.6\ x\ 520\ x\ 58}{1.25}\ x\ 10^{-3}$ = 14.48kN → $\mathrm{F_{t,Rd}} = 14.48\mathrm{kN} > 5.59\mathrm{kN}$ **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.*

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

$\mathrm{F_{V,Rd}} = \frac{\alpha \mathrm{F_{ub} A}}{\mathrm{\lambda m2}} = \frac{0.9\ \mathrm{x}\ 520\ \mathrm{x}\ 57}{1.25}\ x\ 10^{-3} = 31.56kN \rightarrow \mathrm{F_{V,Rd}} = 31.56\mathrm{kN} > 0.66\mathrm{kN}$ **Okay**

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

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \leq 1 \rightarrow \frac{5.59}{14.48} + \frac{0.66}{31.56} = \leq 1$ **Okay**

Appendix A - Fiscer Reports

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

Appendix B – Glass Adaptor ø 50mm