On Level Ltd.,

8, Alexandria Court

Ashton Commerce Park

Ashton-under-Lyne

Lancashire OL7 0QN

United Kingdom

1311-1 Structural Glass Balustrade

Analysis By	Checked By
A.N	T.S.

0	17/10/2019	T.S	Issued
Revision	**Date**	**Issued By**	**Comment**

Project: 6020 Test	Contract: 1311-1
Subject: Glass Balustrade Design	Sheet No. 1
Date: 17/10/2019	By: A.N & T.S

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Actions/Assumptions/Result Summary:

Actions:

Type of occupancy for part of the building or structure	Examples of specific use	Horizontal uniformly distributed line load (kN/m)	Uniformly distributed load applied to the infill (kN/m^2)	A point load applied to part of the infill (kN)
Domestic and residential activities	(i) All areas within or serving exclusively one single family dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs	0.36	0.5	0.25
	(ii) Other residential, i.e. houses of multiple occupancy and balconies, including Juliette balconies and edges of roofs in single family dwellings	0.74	1.0	0.5

Assumptions:
Concrete Grade C30/37

Result Summary:
Glass: 1050×1000×12mm Toughened Laminated Glass panel.
Shoe: On Level Aluminium Shoe Model TL6020.

Test Number	Load	Glass	Handrail	Max. Deflection	OK
Test 1	0.74kN/m	12mm Toughened	Yes	24.72mm < 25mm	Yes
Test 2	0.36kN/m	12mm Toughened	No	12.03mm < 25mm	Yes
Test 3	0.36kN/m	13.52mm Toughened Laminated	No	8.4mm < 25mm	Yes

Option	Line Load	H1 Height FFL	Anchor Distance	Anchor Type	Grade	Concrete Edge Distance
1	0.74kN/m	1150mm	400mm	M10 FIS V 360	8.8	70mm
2	0.74kN/m	1150mm	200mm	M12 FAZ II	8.8	60mm
3	0.36kN/m	1150mm	600mm	M12 FAZ II	8.8	75mm
4	0.36kN/m	1150mm	600mm	M10 FIS V 360	8.8	70mm

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Glass Strength Calculation:

Balustrade Loading:

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

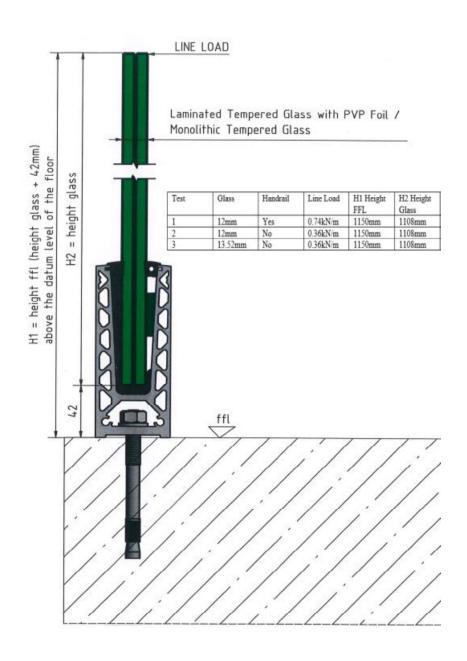$f_{gd} = (k_{mod})(k_{sp})(f_{gk})/\ \gamma_{ma} + k_v(f_{bk}-f_{gk})/\gamma_{mv}$

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

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

Sketch Of System:

LINE LOAD

Laminated Tempered Glass with PVP Foil / Monolithic Tempered Glass

H1 = height ffl (height glass + 42mm) above the datum level of the floor

H2 = height glass

42

ffl

Test	Glass	Handrail	Line Load	H1 Height FFL	H2 Height Glass
1	12mm	Yes	0.74kN/m	1150mm	1108mm
2	12mm	No	0.36kN/m	1150mm	1108mm
3	13.52mm	No	0.36kN/m	1150mm	1108mm

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Connection To Concrete Design:

Loading at Connection:

Option 1:

Shear Force = 0.74kN/m × 1.5 × 0.4m = 0.44kN (ULS)

Moment = 0.74kN/m × 1.5 × 1.150m × 0.4m = 0.51kNm (ULS)

Use 1 Nr M10×150 FIS V 360 Mild Steel bolts @400mm C/C.

FIGURE 1-OPTION 1
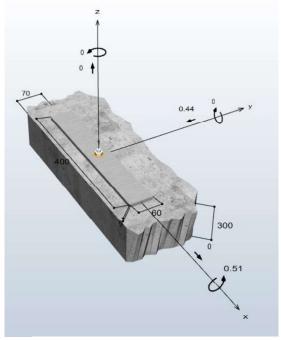
Option 2:

Shear Force = 0.74kN/m × 1.5 × 0.2m = 0.22kN (ULS)

Moment = 0.74kN/m × 1.5 × 1.150m × 0.2m = 0.25kNm (ULS)

Use 1 Nr M12 FAZ II Mild Steel bolts @200mm C/C.

FIGURE 2-OPTION 2
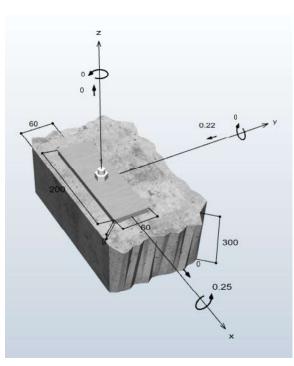
Option 3:

Shear Force = $0.36\text{kN/m} \times 1.5 \times 0.6\text{m} = 0.32\text{kN (ULS)}$

Moment = $0.36\text{kN/m} \times 1.5 \times 1.150\text{m} \times 0.6\text{m} = 0.37\text{kNm (ULS)}$

Use 1 Nr M12 FAZ II Mild Steel bolts @600mm C/C.

FIGURE 3-OPTION 3

Option 4:

Shear Force = $0.36\text{kN/m} \times 1.5 \times 0.6\text{m} = 0.32\text{kN (ULS)}$

Moment = $0.36\text{kN/m} \times 1.5 \times 1.150\text{m} \times 0.6\text{m} = 0.37\text{kNm (ULS)}$

Use 1 Nr M10×150 FIS V 360 Mild Steel bolts @600mm C/C.

FIGURE 4-OPTION 4

Option	Line Load	H1 Height FFL	Anchor Distance	Anchor Type	Grade	Concrete Edge Distance
1	0.74kN/m	1150mm	400mm	M10 FIS V 360	8.8	70mm
2	0.74kN/m	1150mm	200mm	M12 FAZ II	8.8	60mm
3	0.36kN/m	1150mm	600mm	M12 FAZ II	8.8	75mm
4	0.36kN/m	1150mm	600mm	M10 FIS V 360	8.8	70mm

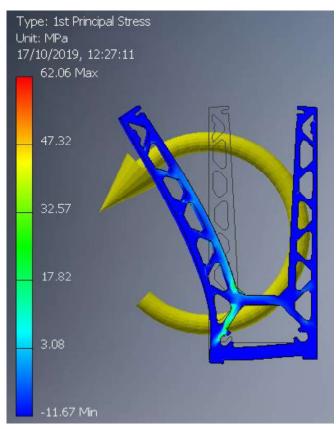| Project:		Contract:	
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Shoe Analysis:

Bending Stress of Shoe due to Maximum moment of 0.85kNm (SLS):

- Analysis Software was used to determine maximum bending stress of the shoe due to Maximum Moment of 0.85kNm (SLS)
- On Level Aluminium Shoe Model TL6020 restrained at base.

Result:
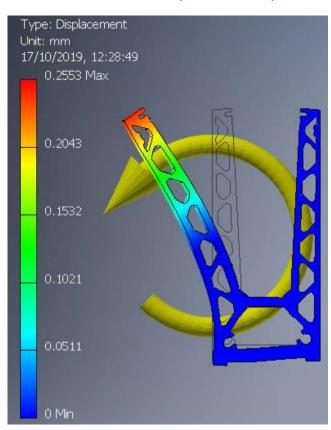
Max. Bending Stress = $\frac{93.09N}{mm^2} < 180N/mm^2$

Deflection of Shoe due to Maximum moment of 0.85kNm (SLS):

- Analysis Software was used to determine maximum Deflection of the shoe due to Maximum Moment of 0.85kNm (SLS)
- On Level Aluminium Shoe Model TL6020 restrained at base.

Result:

Max. Deflection = 0.2553mm < 25mm

Okay in Deflection (Glass Deflection only)

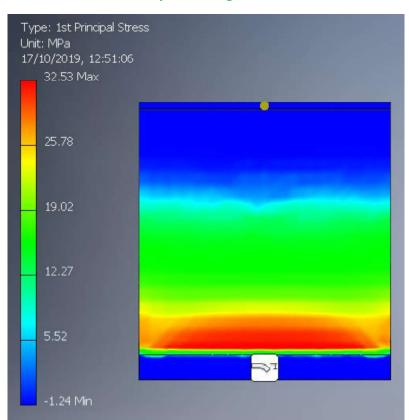| Project:		Contract:	
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Glass Analysis:

Test 1: Bending Stress of Glass Panel due to 0.74kN/m Balustrade Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.74kN/m Balustrade Load.
- 12mm Toughened Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 32.53N/mm^2 X 1.5 = 48.8N/mm^2 < 84.2 N/mm^2

Okay in Bending

Test 1: Deflection of Glass Panel due to 0.74kN/m Balustrade Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.74kN/m Balustrade load.
- 12mm Toughened Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Deflection (represents deflection of glass only) = 24.72mm < 25mm

Okay in Deflection

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Test 1: Bending Stress of Glass Panel due to 1.0kN/m^2 Infill Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 1.0kN/m^2 Infill Load.
- 12mm Toughened Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 19.53N/mm^2 X 1.5 = 29.3N/mm^2 < 84.2N/mm^2

Okay in Bending

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Test 1: Deflection of Glass Panel due to 1.0kN/m² Infill Load:

- Analysis Software was used to determine maximum deflection of the glass due to 1.0kN/m² Infill load.
- 12mm Toughened Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

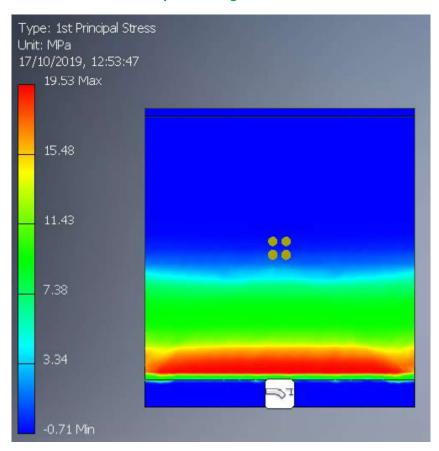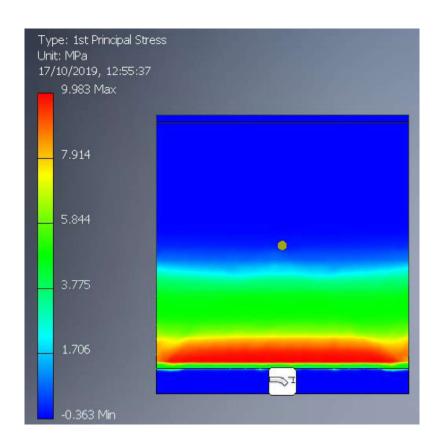Max. Deflection (represents deflection of glass only) = 11.85mm < 25mm

Okay in Deflection

Type: Displacement
Unit: mm
17/10/2019, 12:54:45

11.85 Max
9.48
7.11
4.74
2.37
0 Min

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Test 1: Bending Stress of Glass Panel due to 0.5kN Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN Point Load.
- 12mm Toughened Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = $9.983 N/mm^2$ X 1.5 = $15 N/mm^2$ < $84.2 \ N/mm^2$

Okay in Bending
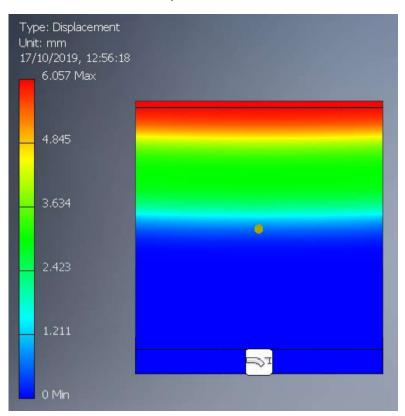
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Test 1: Deflection of Glass Panel due to 0.5kN Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN Point load.
- mm Toughened Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

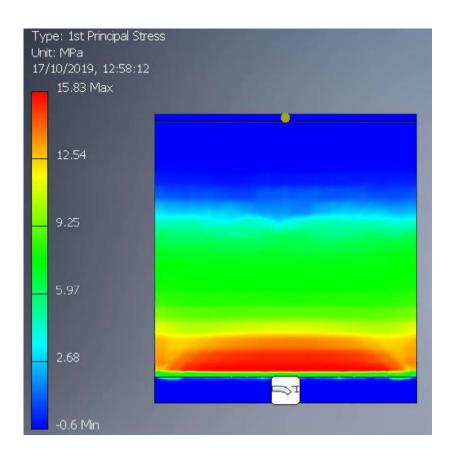Max. Deflection (represents deflection of glass only) = 6.057mm < 25mm

Okay in Deflection

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Test 2: Bending Stress of Glass Panel due to 0.36kN/m Balustrade Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.36kN/m Balustrade Load.
- 12mm Toughened Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 15.83N/mm^2 X 1.5 = 23.75N/mm^2 < 84.2 N/mm^2

Okay in Bending

Test 2: Deflection of Glass Panel due to 0.36kN/m Balustrade Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.36kN/m Balustrade load.
- 12mm Toughened Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

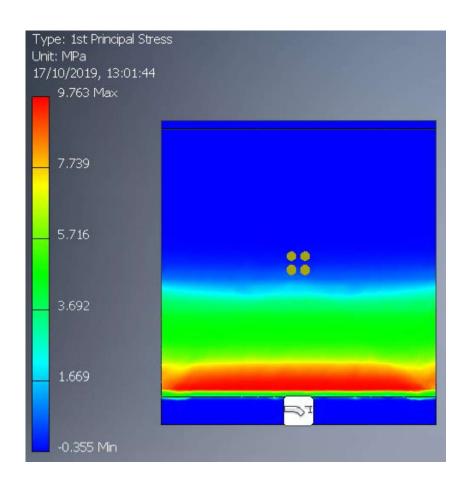Max. Deflection (represents deflection of glass only) = 12.03mm < 25mm

Okay in Deflection

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Test 2: Bending Stress of Glass Panel due to 0.5kN/m^2 Infill Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN/m^2 Infill Load.
- 12mm Toughened Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 9.763N/mm^2 X 1.5 = 14.65N/mm^2 < 84.2 N/mm^2

Okay in Bending

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Test 2: Deflection of Glass Panel due to 0.5kN/m^2 Infill Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN/m^2 Infill load.
- 12mm Toughened Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Deflection (represents deflection of glass only) = 5.923mm < 25mm

Okay in Deflection

Test 2: Bending Stress of Glass Panel due to 0.25kN Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.25kN Point Load.
- 12mm Toughened Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

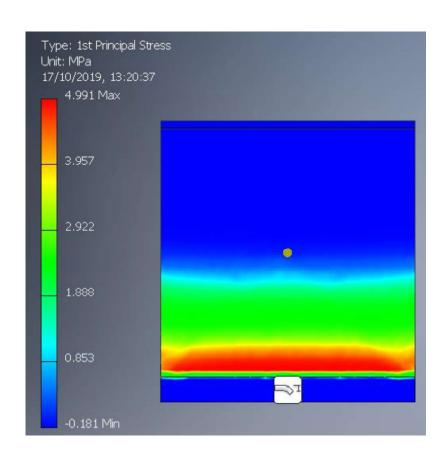Max. Bending Stress = $4.991 N/mm^2$ X 1.5 = $7.5 N/mm^2$ < $84.2 \ N/mm^2$

Okay in Bending

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Test 2: Deflection of Glass Panel due to 0.25kN Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.25kN Point load.
- 12mm Toughened Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Deflection (represents deflection of glass only) = 3.028mm < 25mm

Okay in Deflection

Type: Displacement
Unit: mm
17/10/2019, 13:21:19
3.028 Max
2.423
1.817
1.211
0.606
0 Min

Test 3: Bending Stress of Glass Panel due to 0.36kN/m Balustrade Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.36kN/m Balustrade Load.
- 13.52mm Toughened Laminated Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 12.46N/mm^2 X 1.5 = 18.7N/mm^2 < 84.2 N/mm^2
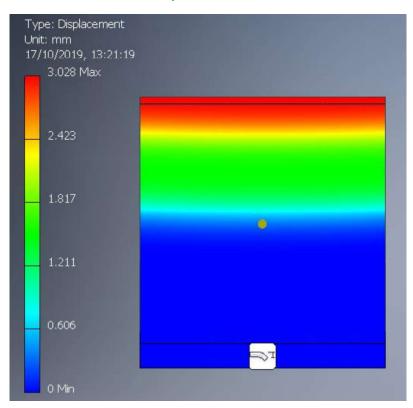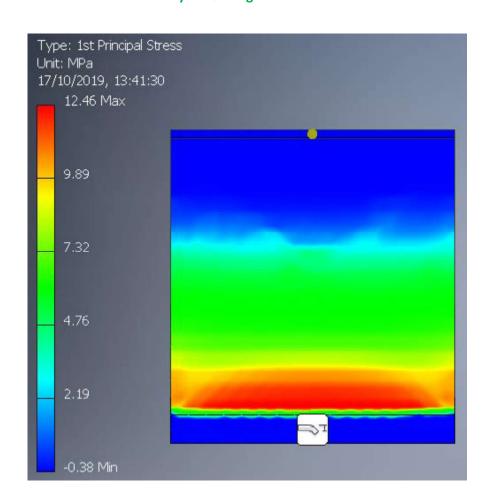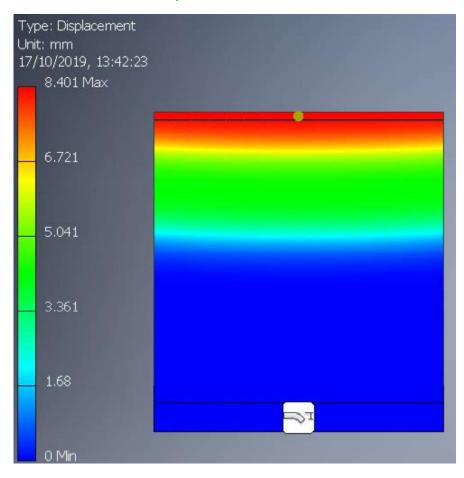
Okay in Bending

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Test 3: Deflection of Glass Panel due to 0.36kN/m Balustrade Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.36kN/m Balustrade load.
- 13.52mm Toughened Laminated Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

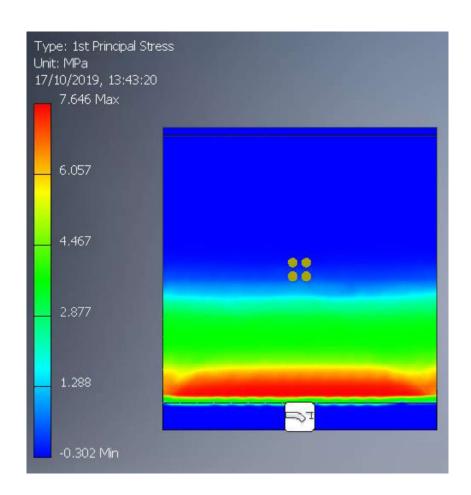Max. Deflection (represents deflection of glass only) = 8.401mm < 25mm

Okay in Deflection

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Test 3: Bending Stress of Glass Panel due to 0.5kN/m^2 Infill Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.5kN/m^2 Infill Load.
- 13.52mm Toughened Laminated Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 7.65N/mm^2 X 1.5 = 11.5N/mm^2 < 84.2N/mm^2

Okay in Bending

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Test 3: Deflection of Glass Panel due to 0.5kN/m² Infill Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.5kN/m² Infill load.
- 13.52mm Toughened Laminated Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Deflection (represents deflection of glass only) = 4.142mm < 25mm

Okay in Deflection

Test 3: Bending Stress of Glass Panel due to 0.25kN Point Load:

- Analysis Software was used to determine maximum bending stress of the glass due to 0.25kN Point Load.
- 13.52mm Toughened Laminated Glass Panel.
- Bending stress analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Bending Stress = 3.909N/mm^2 X 1.5 = $5.9 \text{N/mm}^2 < 84.2 \text{ N/mm}^2$

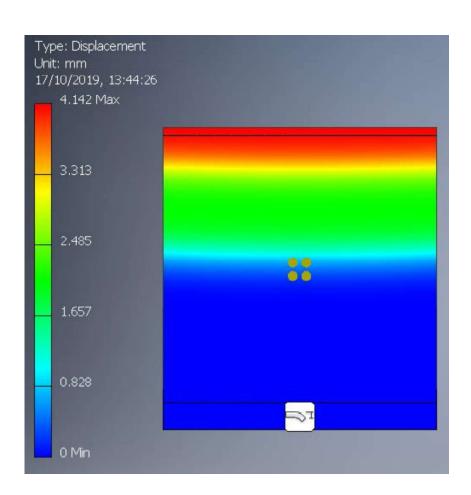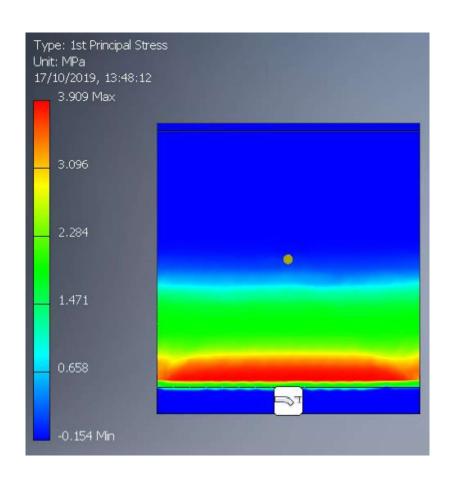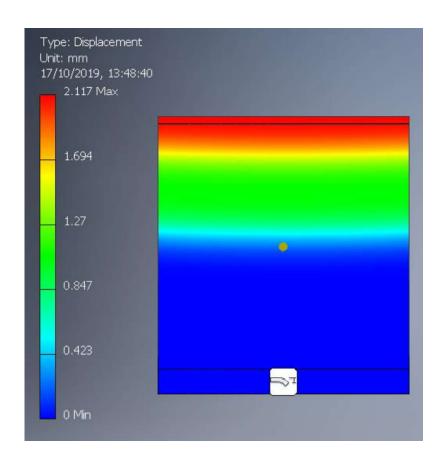**Okay in Bending**

Test 3: Deflection of Glass Panel due to 0.25kN Point Load:

- Analysis Software was used to determine maximum deflection of the glass due to 0.25kN Point load.
- 13.52mm Toughened Laminated Glass Panel.
- Deflection analysed based on glass panel 1000mm X 1108mm.

Result:

Max. Deflection (represents deflection of glass only) = 2.117mm < 25mm

Okay in Deflection

Appendix A

Table 2   Minimum horizontal imposed loads for parapets, barriers and balustrades

Type of occupancy for part of the building or structure	Examples of specific use	Horizontal uniformly distributed line load (kN/m)	Uniformly distributed load applied to the infill (kN/m²)	A point load applied to part of the infill (kN)
Domestic and residential activities	(i) All areas within or serving exclusively one single family dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs	0.36	0.5	0.25
	(ii) Other residential, i.e. houses of multiple occupancy and balconies, including Juliette balconies and edges of roofs in single family dwellings	0.74	1.0	0.5
Offices and work areas not included elsewhere, including storage areas	(iii) Light access stairs and gangways not more than 600 mm wide	0.22	—	—
	(iv) Light pedestrian traffic routes in industrial and storage buildings except designated escape routes	0.36	0.5	0.25
	(v) Areas not susceptile to overcrowding in office and institutional buildings, also industrial and storage buildings except as given above	0.74	1.0	0.5
Areas where people might congregate	(vi) Areas having fixed seating within 530 mm of the barrier, balustrade or parapet	1.5	1.5	1.5
Areas with tables or fixed seatings	(vii) Restaurants and bars	1.5	1.5	1.5
Areas without obstacles for moving people and not susceptible to overcrowding	(viii) Stairs, landings, corridors, ramps	0.74	1.0	0.5
	(ix) External balconies including Juliette balconies and edges of roofs. Footways and pavements within building curtilage adjacent to basement/sunken areas	0.74	1.0	0.5