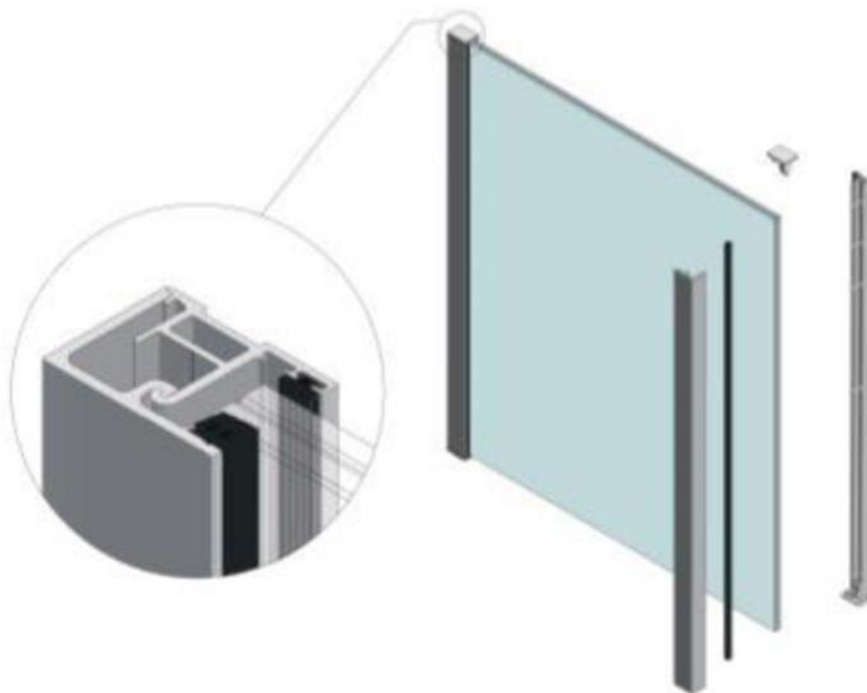


# TEST REPORT

## Juliet Balcony System - SKYFORCE

BS EN 6180:2011



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## 1. INTRODUCTION

Specialist Technical Services (U.K) Limited were commissioned to undertake a series of Balustrade Tests on multiple design combinations of their own product of balustrade systems - SkyFORCE. All testing was carried out by STS (U.K) in accordance with BS EN6180:2011. The purpose of the testing was to attain results and findings that could be analysed for deflection performance at multiple loadings. A visual inspection of each system was carried out before and after each test and photographic records taken for each test undertaken.

## 2. METHODOLOGY

In order to determine the adequacy of any installed balustrade, it is proposed that full scale load testing be undertaken and that this is done under the specification of the current British Standard. We loaded the area of the selected systems to replicate the imposed loads required under current British Standard BS 6180:2011, adhering to strict guidelines where referenced.

To accurately determine the deflection of each balustrade system tested, a 1250mm Drawstring Potentiometer was utilised. This was mounted on a freestanding tripod out of the zone of influence, of the test area. The load was monitored using a 4-20mA Pressure Sensor in-line with the hydraulic cylinder used to apply the force.

The electronic displacement potentiometer was mounted to the testing area directly in-line (if applicable) with each of the hydraulic jacks and attached to an independently free-standing tripod, positioned out of the zone of influence.

Displacements were plotted to a screen such that any non-elastic displacement will be instantly identified and the test will be aborted immediately and any load imposed, removed. The test was to be deemed a success if the system's (1) demonstrated they did not suffer non-elastic displacements and (2) displacements did not exceed 25mm. If non-elastic displacements do occur the test will be aborted and the system declared unfit for purpose.

Two methods of testing were carried-out, along with a third when applicable to the size of the glass infill panel being tested.

The first series of testing was a UDL (Uniformly Distributed Load) test along the top edge of the balustrade system at a height of 1100mm above FFL. This testing is carried out by applying a load along the entire span of the system, the load to be applied varies depending on the application of the balustrade. For most residential balustrades, the load is 0.74kN/m. However, this is subject to application and can also be 0.36kN/m. When testing balustrades for use in more commercial areas with a higher flow of traffic, the load is 1.5kN/m upto 3kN/m and 4.5kN/m.

The second type of testing carried out was a point load test. As with the UDL testing, the point load to be applied can vary depending on the application of the balustrade system to be tested. The load was applied over a 20mmx20mm area. For most uses, the point load is 1.5kN, when testing for areas at which people may congregate. For use within most residential areas, the load to be applied is 0.5kN. (All BS 6180:2011 reference values can be found in the table in Section 3 of this Report).

For glass panels covering an area of at least 1sqm (Square Meter) or more, an infill test was undertaken. This was done by applying a Uniformly Distributed Load (depending on application, 0.5kN/m<sup>2</sup>, 1kN/m<sup>2</sup> or 1.5kN/m<sup>2</sup>), over a square meter to simulate and monitor the possible effects on the system caused by wind loadings.



At each panel of the balustrade, the load frame there will be a bespoke reaction frame bracket reaching a British Standard requirement supporting height of 1100mm. At this point a hydraulic jack was positioned pointing towards the balustrade. These components will enact the horizontal force onto the balustrade system via a hydraulic hand pump system, for controlled application.

Touching the top of the balustrade system, spanning the full length was a wooden plank (to protect the balustrade), strengthened by a steel angle bracket. This was utilised to distribute the load on the system in a uniform way over the (variable) required distance.

In order to measure any deflection of the system, potentiometer sensors with an accuracy of 0.1mm full stroke, were positioned on the balustrade close to the location of the hydraulic cylinder. These highly accurate sensors monitored any deflection throughout the test; in which was recorded onto a portable computer using bespoke software and data acquisition.

Once the reaction frame and instrumentation were fully installed as above, and all final checks were carried out; the test can be undertaken. This will begin by loading the balustrades at a steady rate up to the load value required for the individual balustrade system simultaneously across all hydraulic cylinder positions (if multiple positions were required due to overall length of the balustrade system).

If at any point the balustrade deflects more than 25mm, this is deemed a failure by the current British Standard BS6180:2011 and the test would be abandoned. Any permanent deflection will be measured to ensure this conforms to the testing standard as stated above.

Following the testing; the balustrade was visually inspected to ensure there was no permanent damage to the system as a result of the testing forces, the reaction frame and all associated testing equipment was then removed from the area and all housekeeping adhered too, in order to then setup for the next balustrade, where necessary.

The system area was monitored using displacement measuring devices known as drawstring displacement potentiometers. Generally, the potentiometer will be located at each hydraulic cylinder position longitudinally along the length of the system to be tested; this is where the most displacement shall occur, although it may be necessary to reposition depending on access restrictions.

The potentiometer was cabled back to the data logger, which was in turn connected to a laptop computer with a stand-alone power supply.

Initial monitoring of the system took place prior to any loading (zero load) and then continuously during all subsequent loading and unloading operations.

## **2.1 Initial Survey**

Prior to any testing being carried out, a detailed visual inspection was conducted before and after each test in order to avoid testing previously damaged or flawed systems, to maintain a high level of consistency.

### 3. RESULTS

All certificates can be found in Appendix A of this Report.

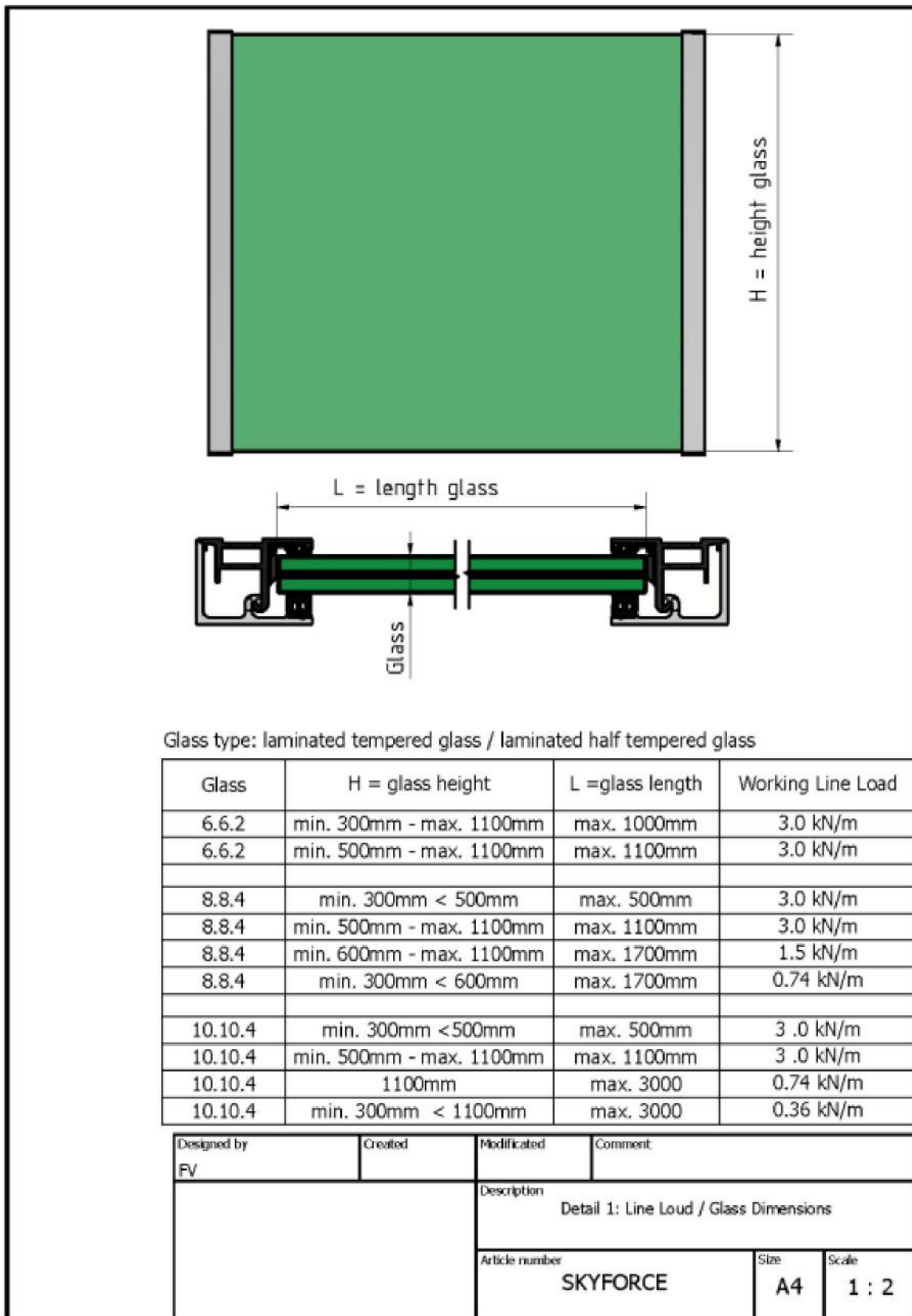
Below is a table showing the type of glass infill tested along with the maximum displacement recorded and the maximum load each of the glass sizes were tested to. The load is in (kN/m) for each of the UDL tests, (kN) for the point load tests and (kN/m<sup>2</sup>) for the infill tests.

TEST No.	PANEL TESTED (mm)	DISPLACEMENT (mm)	MAXIMUM LOAD (kN, kN/m, kN/m <sup>2</sup> )
1	UDL 6.6.2 300x500 TVG	9.92	3 kN/m
2	Point Load 6.6.2 300x500 TVG	5.13	1.5 kN
3	UDL 6.6.2 300x1000 TVG	23.05	3 kN/m
4	Point Load 6.6.2 300x1000 TVG	12.99	1.5 kN
5	UDL 6.6.2 300x1000 ESG	19.61	3 kN/m
6	Point Load 6.6.2 300x1000 ESG	13.73	1.5 kN
7	UDL 8.8.4 300x500 TVG	9.78	3 kN/m
8	Point Load 8.8.4 300x500 ESG	6.47	1.5 kN
9	UDL 8.8.4 300x1700 TVG	25	1.2 kN/m
10	Point Load 8.8.4 300x1700 TVG	19.73	1.5 kN
11	UDL 8.8.4 300x1700 ESG	25	1.3 kN/m
12	Point Load 6.6.2 300x1700 ESG	13.67	1.5 kN
13	UDL 6.6.2 300x500 ESG	7.13	3 kN/m
14	Point Load 6.6.2 300x500 ESG	5.06	1.5 kN
15	UDL 8.8.4 300x500 ESG	5.78	3 kN/m
16	Point Load 8.8.4 300x500 ESG	3.46	1.5 kN
17	UDL 10.10.4 300x500 TVG	5.40	3 kN/m
18	Point Load 10.10.4 300x500 TVG	3.19	1.5 kN
19	UDL 10.10.4 300x500 ESG	5.27	3 kN/m
20	Point Load 10.10.4 300x500 ESG	3.69	1.5 kN
21	UDL 6.6.2 500x1100 ESG	6.42	3 kN/m
22	Point Load 6.6.2 500x1100 ESG	3.18	1.5 kN
23	UDL 6.6.2 500x1100 TVG	6.48	3 kN/m
24	Point Load 6.6.2 500x1100 TVG	3.53	1.5 kN
25	UDL 8.8.4 500x1100 ESG	5.50	3 kN/m
26	Point Load 8.8.4 500x1100 ESG	2.13	1.5 kN
27	UDL 8.8.4 500x1100 TVG	5.35	3 kN/m
28	Point Load 8.8.4 500x1100 TVG	2.50	1.5 kN
29	UDL 10.10.4 500x1100 ESG	5.24	3 kN/m
30	Point Load 10.10.4 500x1100 ESG	2.42	1.5 kN

TEST No.	PANEL TESTED (mm)	DISPLACEMENT (mm)	MAXIMUM LOAD (kN, kN/m, kN/m <sup>2</sup> )
31	UDL 10.10.4 500x1100 TVG	5.36	3 kN/m
32	Point Load 10.10.4 500x1100 TVG	2.29	1.5 kN
33	UDL 6.6.2 1000x1100 TVG	15.97	3 kN/m
34	Point Load 6.6.2 1000x1100 TVG	5.86	1.5 kN
35	UDL 6.6.2 1000x1100 ESG	14.81	3 kN/m
36	Point Load 6.6.2 1000x1100 ESG	5.45	1.5 kN
37	UDL 8.8.4 1100x1700 TVG	25	2.69 kN/m
38	Point Load 8.8.4 1100x1700 TVG	7.02	1.5 kN
39	Infill 8.8.4 1100x1700 TVG	5.31	1.5 kN/m <sup>2</sup>
40	UDL 8.8.4 1100x1700 ESG	25	2.48 kN/m
41	Point Load 8.8.4 1100x1700 ESG	8.05	1.5 kN
42	Infill 8.8.4 1100x1700 ESG	5.33	1.5 kN/m <sup>2</sup>
43	UDL 8.8.4 300x1700 ESG	25	1.45 kN/m
44	UDL 8.8.4 300x1700 TVG	25	1.39 kN/m
45	UDL 8.8.4 600x1700 ESG	25	1.81 kN/m
46	Point Load 8.8.4 600x1700 ESG	9.19	1.5 kN
47	Point Load 8.8.4 600x1700 TVG	9.36	1.5 kN
48	UDL 8.8.4 600x1700 TVG	25	1.88 kN/m
49	UDL 10.10.4 1100x3000 ESG	25	0.77 kN/m
50	Point Load 10.10.4 1100x3000 ESG	17.28	1.5 kN
51	Infill 10.10.4 1100x3000 ESG	11.95	1.5 kN/m <sup>2</sup>
52	Infill 10.10.4 1100x3000 TVG	10.07	1.5 kN/m <sup>2</sup>
53	Point Load 10.10.4 1100x3000 TVG	16.45	1.5 kN
54	UDL 10.10.4 1100x3000 TVG	25	1.35 kN/m
55	UDL 10.10.4 300x3000 ESG	25	0.40 kN/m
56	Point Load 10.10.4 300x3000 ESG	25	1.07 kN
57	Point Load 10.10.4 300x3000 TVG	25	0.72 kN
58	UDL 10.10.4 300x3000 TVG	25	0.5 kN/m

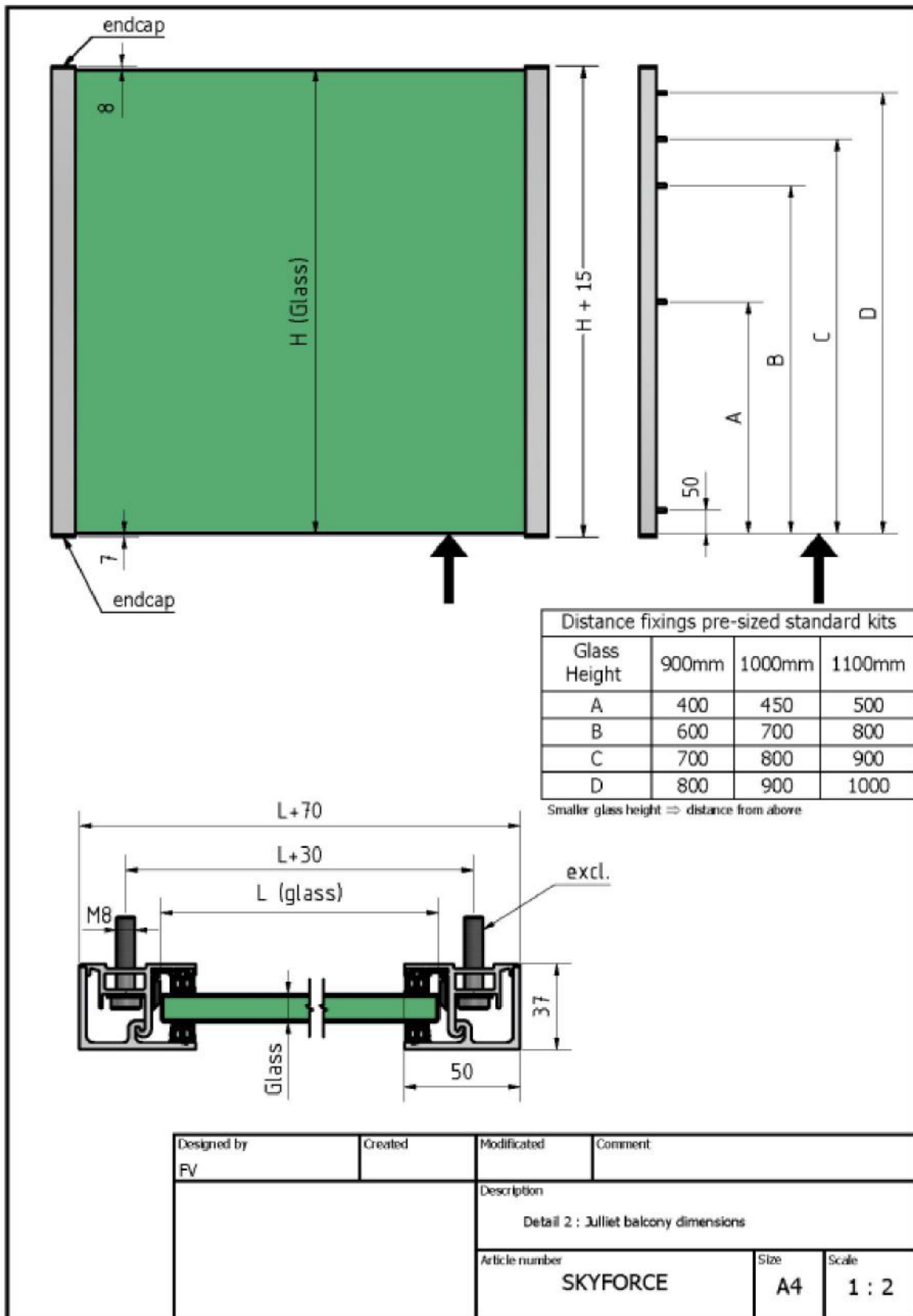
Table 1 – Test Results



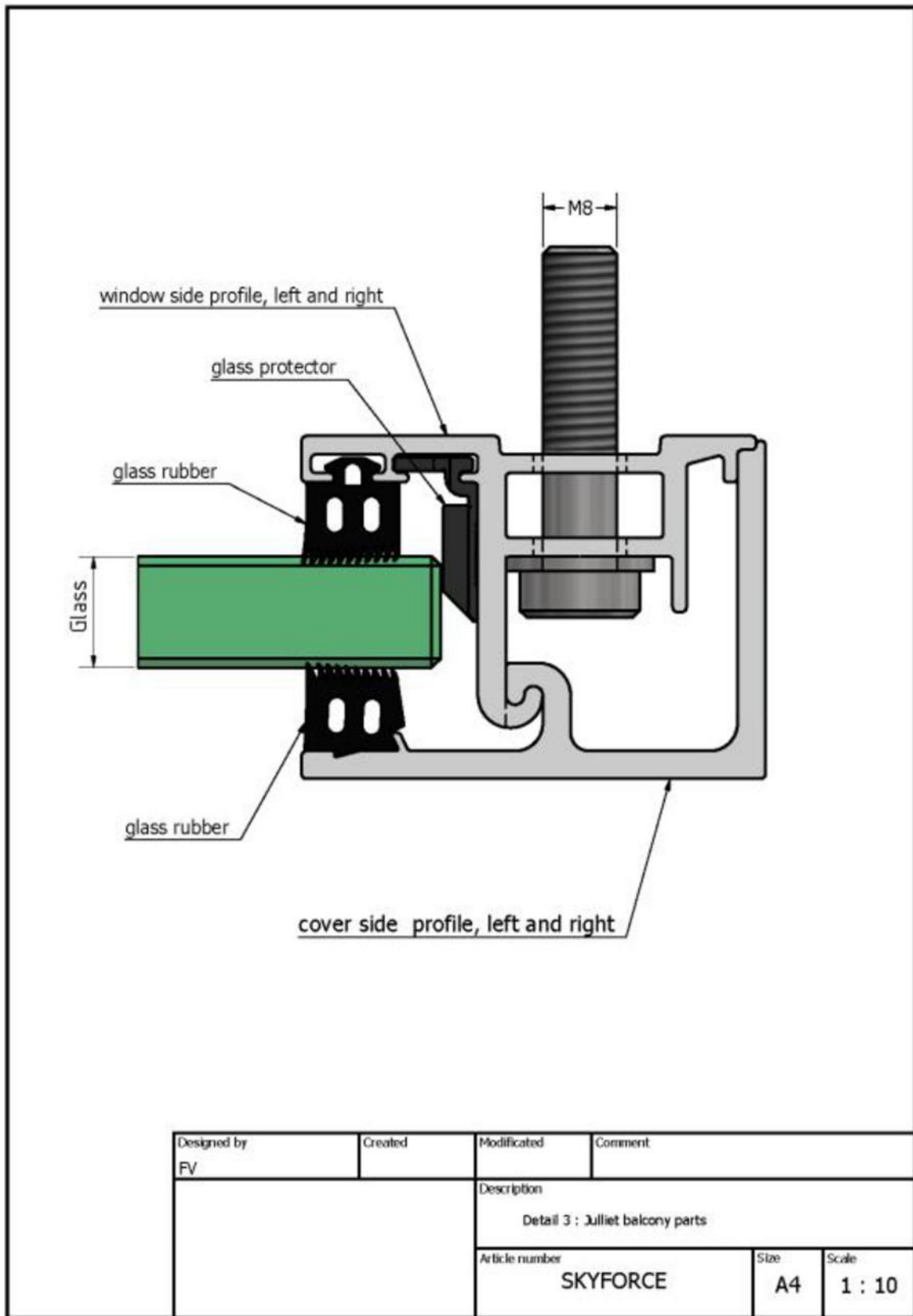


**Drawing 1 – SKYFORCE Barrier Specifications.**





**Drawing 1 – SKYFORCE Barrier Specifications.**



**Drawing 1 – SKYFORCE Barrier Specifications.**

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 <sup>2</sup> )	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 susceptible 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
Areas susceptible to overcrowding	(x) Footways or pavements less than 3 m wide adjacent to sunken areas	1.5	1.5	1.5
	(xi) Theatres, cinemas, discotheques, bars, auditoria, shopping malls, assembly areas, studio. Footways or pavements greater than 3 m wide adjacent to sunken areas. (xii) Grandstands and stadia <sup>A)</sup>	3.0	1.5	1.5
Retail areas	(xiii) All retail areas including public areas of banks/building societies or betting shops	1.5	1.5	1.5
Vehicular	(xiv) Pedestrian areas in car parks, including stairs, landings, ramps, edges or internal floors, footways, edges of roofs Horizontal loads imposed by vehicles	1.5	1.5	1.5

Table 2 – Minimum horizontal imposed loads for parapets, barriers and balustrades. Extracted from BS EN6180:2011.

Type of Building or Structure	Examples of Specific Use	UDL (kN/m)	Infill Load (kN/m <sup>2</sup> )	Point Load (kN)	6.6.2		8.8.4				10.10.4			
					L = 1000 (mm)	L = 1100 (mm)	L = 500 (mm)	L = 1100 (mm)	L = 1700 (mm)	L = 1700 (mm)	L = Max 500 (mm)	L = Max 1100 (mm)	L = Max 3000mm	L = Max 3000mm
					H = Min – 300mm Max – 1100mm	H = Min - 500mm Max – 1000mm	H = Min - 300mm < 500mm	H = Min – 500mm Max - 1100mm	H = Min - 600mm Max - 1100mm	H = Min – 300mm < 600mm	H = Min – 300mm < 500mm	H = Min – 500mm Max – 1100mm	H = 1100mm	H = 300mm < 1100mm
Domestic and Residential Activities	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	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	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	Light access stairs and gangways not more than 600 mm wide	0.22	—	—	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Light pedestrian traffic routes in industrial and storage buildings except designated escape routes	0.36	0.5	0.25	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Areas not susceptible 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	Areas having fixed seating within 530 mm of the barrier, balustrade or parapet	1.5	1.5	1.5	✓	✓	✓	✓	✓	✗	✓	✓	✗	✗

Areas with Tables or Fixed Seating's	Restaurants and bars	1.5	1.5	1.5	✓	✓	✓	✓	✓	✗	✓	✓	✗	✗
Areas without Obstacles for Moving People and not Susceptible to Overcrowding	Stairs, landings, corridors, ramps	0.74	1.0	0.5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
	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	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
Areas Susceptible to Overcrowding	Footways or pavements less than 3 m wide adjacent to sunken areas	1.5	1.5	1.5	✓	✓	✓	✓	✓	✗	✓	✓	✗	✗
	Footways or pavements greater than 3 m wide adjacent to sunken areas. (xii) Grandstands and stadia <sup>A)</sup>	3.0	1.5	1.5	✓	✓	✓	✓	✗	✗	✓	✓	✗	✗

Retail Areas	All retail areas including public areas of banks/building societies or betting shops	1.5	1.5	1.5	✓	✓	✓	✓	✓	✗	✓	✓	✗	✗
Vehicular	Pedestrian areas in car parks, including stairs, landings, ramps, edges or internal floors, footways, edges of roofs  Horizontal loads imposed by vehicles	1.5	1.5	1.5	✓	✓	✓	✓	✓	✗	✓	✓	✗	✗

Table 3 (Pages 12 - 15) – Table showing which glass can be used with each application with conformity to BS EN6180:2011. Where L = Length of Glass and H = Height of Glass as per Drawing 1 (Page 8 of this Report)

**Note (Table 3):**

As per Table 3 of this report showing the allowed applications of each system in accordance to BS 6180:2011. The glass systems of 10.10.4 and 8.8.4 are limited on applications and usage as not all size systems passed the criteria set out in BS EN6180:2011. For this reason, they have been marked as not applicable within Table 3.

However, some sized systems are applicable within these limitations. The systems that are not applicable are detailed in section 4 of this report (Pages 11-13).

All balustrade systems tested with the exception of the systems mentioned within section 4 of this report (8.8.4 300x1700 TVG, 8.8.4 300x1700 ESG, 8.8.4 300x1700 TVG, 8.8.4 300x1700 ESG, 10.10.4 1100x3000 ESG, 10.10.4 1100x3000 TVG, 10.10.4 300x3000 ESG, 10.10.4 300x3000 TVG), pass the criteria set out in BS EN6180:2011 for use within the forementioned areas. Table 1 details the maximum loadings achieved for each test conducted. This (along with tables 2 & 3) within this report detail the applications each system is suitable and compliant with the criteria layed out in BS EN6180:2011.



## 4. CONCLUSION

After analysis of the results found within Section 3 and Appendix A of this Report, it can be said that all infill tests passed the criteria set out by BS EN6180:2011. Two glass panels did not reach the higher point load at 1.5kN but attained the lower loading criteria of applications for domestic and residential activities, offices and work areas not included elsewhere, including storage areas and areas without obstacles for moving people and not susceptible to overcrowding. The maximum required point load for these applications as per Table 2 within BS EN6180:2011 is 0.5kN. The glass designs, 10.10.4 300x3000 ESG and 10.10.4 300x3000 TVG passed this loading (0.5kN) with a maximum recorded displacement of 13.62mm for the ESG design, and 17.62 for the TVG design.

All glass infill panels tested along with their respective setups passed the specified loading of 1.5kN/m<sup>2</sup> (Applied over 1sqm) for all applications laid out in BS EN6180:2011.

When testing the balustrade systems applying a UDL (Uniformly Distributed Load). The following glass did not reach the higher loading for application, however, may still be used for certain applications such as domestic and residential activities, Offices and work areas not included elsewhere, including storage areas, Areas without obstacles for moving people and not susceptible to overcrowding as these areas require a horizontal UDL of 0.22kN/m, 0.36kN/m and/or up to 0.74kN/m:




- 8.8.4 300x1700 TVG – This balustrade system achieved a maximum loading of 1.2kN/m when the recorded displacement reached 25mm. According to Table 2 within this Report (extracted from BS EN6180:2011), the balustrade system 8.8.4 300x1700 TVG conforms to the criteria set out in the standard for use in domestic and residential activities, Offices and work areas not included elsewhere, including storage areas, Areas without obstacles for moving people and not susceptible to overcrowding.
- 8.8.4 300x1700 ESG – When tested in accordance to BS EN6180:2011, this balustrade system achieved a maximum loading of 1.3kN/m before surpassing the permissible deflection limit of 25mm. The balustrade system 8.8.4 300x1700 ESG conforms to use within domestic and residential activities, Offices and work areas not included elsewhere, including storage areas, Areas without obstacles for moving people and not susceptible to overcrowding.
- 10.10.4 1100x3000 ESG – This balustrade system achieved a maximum loading of 0.77kN/m when deflecting 25mm. Because of this, the balustrade system 10.10.4 1100x3000 ESG is only compliant with BS EN6180:2011 for use in domestic and residential activities, Offices and work areas not included elsewhere, including storage areas, Areas without obstacles for moving people and not susceptible to overcrowding. The balustrade system 10.10.4 1100x3000 ESG is compliant with the requirements for both the Point Load test and Infill Test and as a result can be used within the mentioned areas.

- 10.10.4 1100x3000 TVG – The balustrade barrier surpassed the permissible deflection limits of 25mm set out by BS EN6180:2011 at a loading of 1.35kN/m. The balustrade barrier passed both the Point Load test and Infill test. Due to this, the balustrade barrier 10.10.4 1100x3000 TVG can only be used in the following applications; domestic and residential activities, Offices and work areas not included elsewhere, including storage areas, Areas without obstacles for moving people and not susceptible to overcrowding.
- 10.10.4 300x3000 ESG – This balustrade system achieved a maximum loading of 0.40kN/m when the maximum deflection limit (25mm) was surpassed. The balustrade system also reached 1.07kN before reaching 25mm when undergoing the point load test. Due to these results from both the UDL and point load testing, the balustrade system 10.10.4 300x3000 ESG is only compliant with BS EN6180:2011 to be used within domestic and residential activities (All areas within or serving exclusively one single family dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs). Offices and work areas not included elsewhere, including storage areas (light access stairs and gangways not more than 600 mm wide, light pedestrian traffic routes in industrial and storage buildings except designated escape routes).
- 10.10.4 300x3000 TVG – When tested in accordance to BS EN6180:2011, this balustrade system achieved a maximum loading of 0.5kN/m when applying the UDL. However, the balustrade system 10.10.4 300x3000 TVG also achieved a maximum loading of 0.72kN during the point load test. Therefore this balustrade system is only compliant to BS EN6180:2011 when used in domestic and residential activities (All areas within or serving exclusively one single family dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs). Offices and work areas not included elsewhere, including storage areas (light access stairs and gangways not more than 600 mm wide, light pedestrian traffic routes in industrial and storage buildings except designated escape routes).



To conclude, all balustrade systems tested with the exception of the systems mentioned above (8.8.4 300x1700 TVG, 8.8.4 300x1700 ESG, 8.8.4 300x1700 TVG, 8.8.4 300x1700 ESG, 10.10.4 1100x3000 ESG, 10.10.4 1100x3000 TVG, 10.10.4 300x3000 ESG, 10.10.4 300x3000 TVG), pass the criteria set out in BS EN6180:2011 for use within the following areas:

- Domestic and residential activities. All areas within or serving exclusively one single family dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs. Other residential, i.e. houses of multiple occupancy and balconies, including Juliette balconies and edges of roofs in single family dwellings.
- Offices and work areas not included elsewhere, including storage areas. Light access stairs and gangways not more than 600 mm wide. Light pedestrian traffic routes in industrial and storage buildings except designated escape routes. Areas not susceptible to overcrowding in office and institutional buildings, also industrial and storage buildings except as given above.
- Areas where people might congregate. Areas having fixed seating within 530 mm of the barrier, balustrade or parapet.
- Areas with tables or fixed seating's, i.e. Restaurants and bars.
- Areas without obstacles for moving people and not susceptible to overcrowding (stairs, landings, corridors, ramps). External balconies including Juliette balconies and edges of roofs. Footways and pavements within building curtilage adjacent to basement/sunken areas.
- Areas susceptible to overcrowding. Footways or pavements less than 3m wide adjacent to sunken areas. When the UDL loading applied was 3kN/m or above, the balustrade systems can also be used in Theatres, cinemas, discotheques, bars, auditoria, shopping malls, assembly areas, studio. Footways or pavements greater than 3m wide adjacent to sunken areas, grandstands and stadia.
- Retail areas (all retail areas including public areas of banks/building societies or betting shops.
- Vehicular (pedestrian areas in car parks, including stairs, landings, ramps, edges or internal floors, footways, edges of roofs, Horizontal loads imposed by vehicles).

	Name	Signature	Date
<b>Created By:</b> Senior Technician	Andrew Mercer		02.06.2017
<b>Checked By:</b> Commercial Director	Ryan Kundi		06.07.2017
<b>Approved By:</b> Technical Director	Andrew Gore		07.07.2017

**FOR AND ON BEHALF OF SPECIALIST TECHNICAL SERVICES (U.K) LIMITED**



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**APPENDIX A**

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**TEST CERTIFICATES**





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## **APPENDIX B**

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### **PHOTOGRAPHIC RECORDS**