<u>Structural Calculations for SG12 system balustrades for 1.50 kN loading using 25.5mm laminated toughened glass without the need for a handrail</u>

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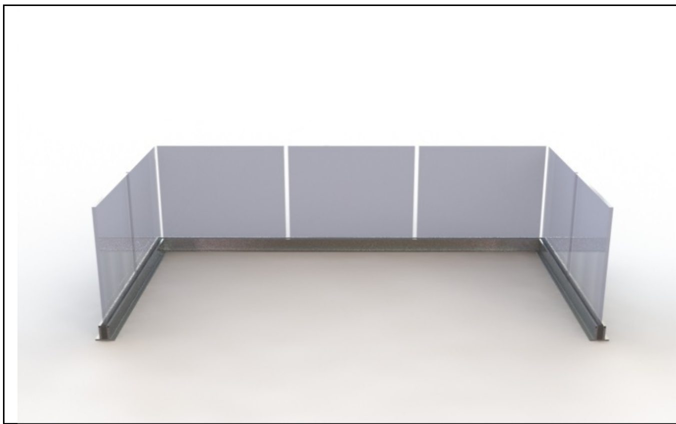
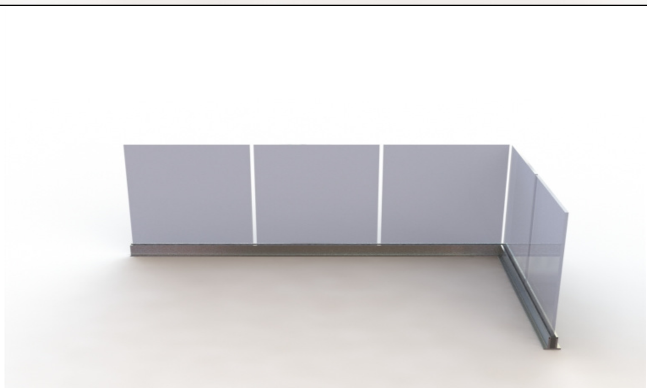
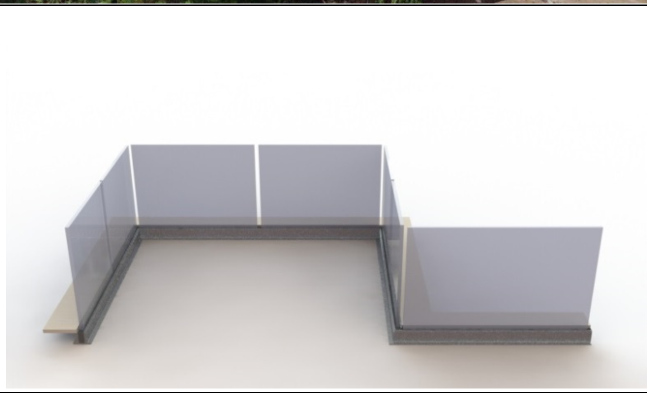


SG12 balustrade fixed above FFL **SG12 balustrade fixed below FFL**

DESIGN TO EUROCODES & CURRENT BRITISH STANDARDS

Design standards:

EN 1990	Eurocode 0:	Basis of structural design.
EN 1991	Eurocode 1:	Actions on structures.
EN 1991-1-4:2002 + A1 2010 + NA	Eurocode 1:	Actions on structures – wind actions.
EN 1993	Eurocode 3:	Design of steel structures.
EN 1999	Eurocode 9:	Design of aluminium structures.
BS EN 1990:2002 + A1:2005	Eurocode:	UK National annex for Eurocode
BS 6180:2011		British Standard: Barriers in and about buildings.

<u>Occupancy classes:</u>

Occupancy class/es for which this design applies (Table 2: BS6180:2011)	Areas where people may congregate – Class (vi). Areas with tables or fixed seating – Class (vii). Areas susceptible to overcrowding - (x), (xi) & (xii). All retail areas – Class (xiii). Pedestrian areas in car parks – Class (xiv).

SG12 Frameless Glass Balustrade system for 1.5kN using 25.5mm laminated glass: ***PAGE 2*** **(SG121.5KNFF030418R)**

Design loads:

Service load on handrail	Q_k	=	1.50 kN/m uniformly distributed line load acting 1100mm above finished floor level. (Table 2: BS6180:2011)
Service load applied to the glass	Qk1	=	A uniformly distributed load of 1.5 kN/m^2
Point load on glass infill		=	1.50 kN applied to any part of the glass infill panels

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/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
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

Table 2, BS 6180:2011

BS 6180:2011 BRITISH STANDARD

Table 2 Minimum horizontal imposed loads for parapets, barriers and balustrades *(continued)*

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)
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 [A]	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 (xv) Horizontal loads imposed by vehicles [B]	1.5	1.5	1.5

[A] See requirements of the appropriate certifying authority.

[B] See Annex A.

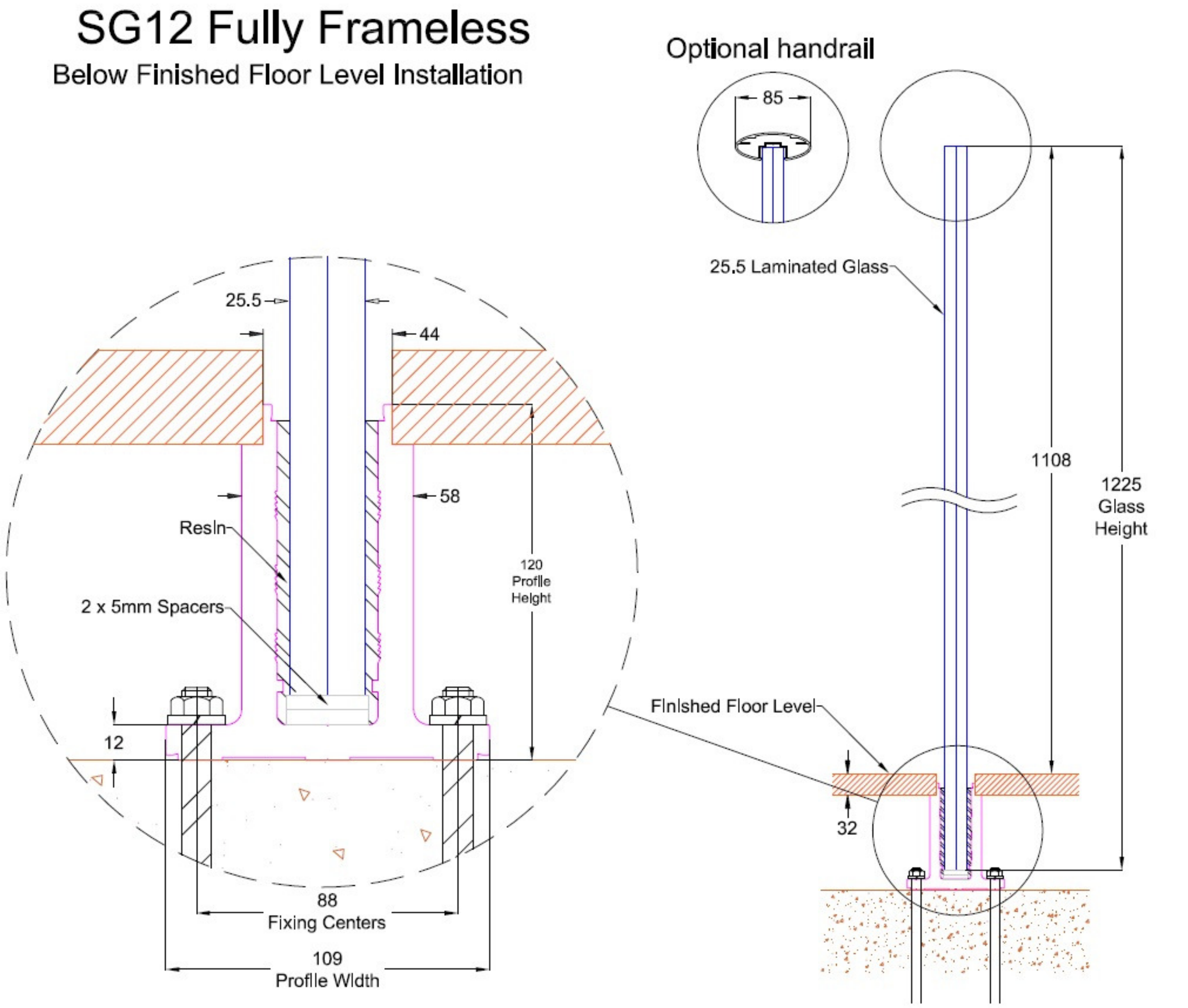
Table 2: BS6180:2011

- These loads are considered as three separate load cases. They are not combined. Wind loading is also considered as a separate design case.
- Factored loads are used for checking the limit state of static strength of a member.
- The service loads are multiplied by a partial factor for variable action $\gamma_{Q,1}$ of 1.5 to give the ultimate design load for leading variable action.

Deflection:

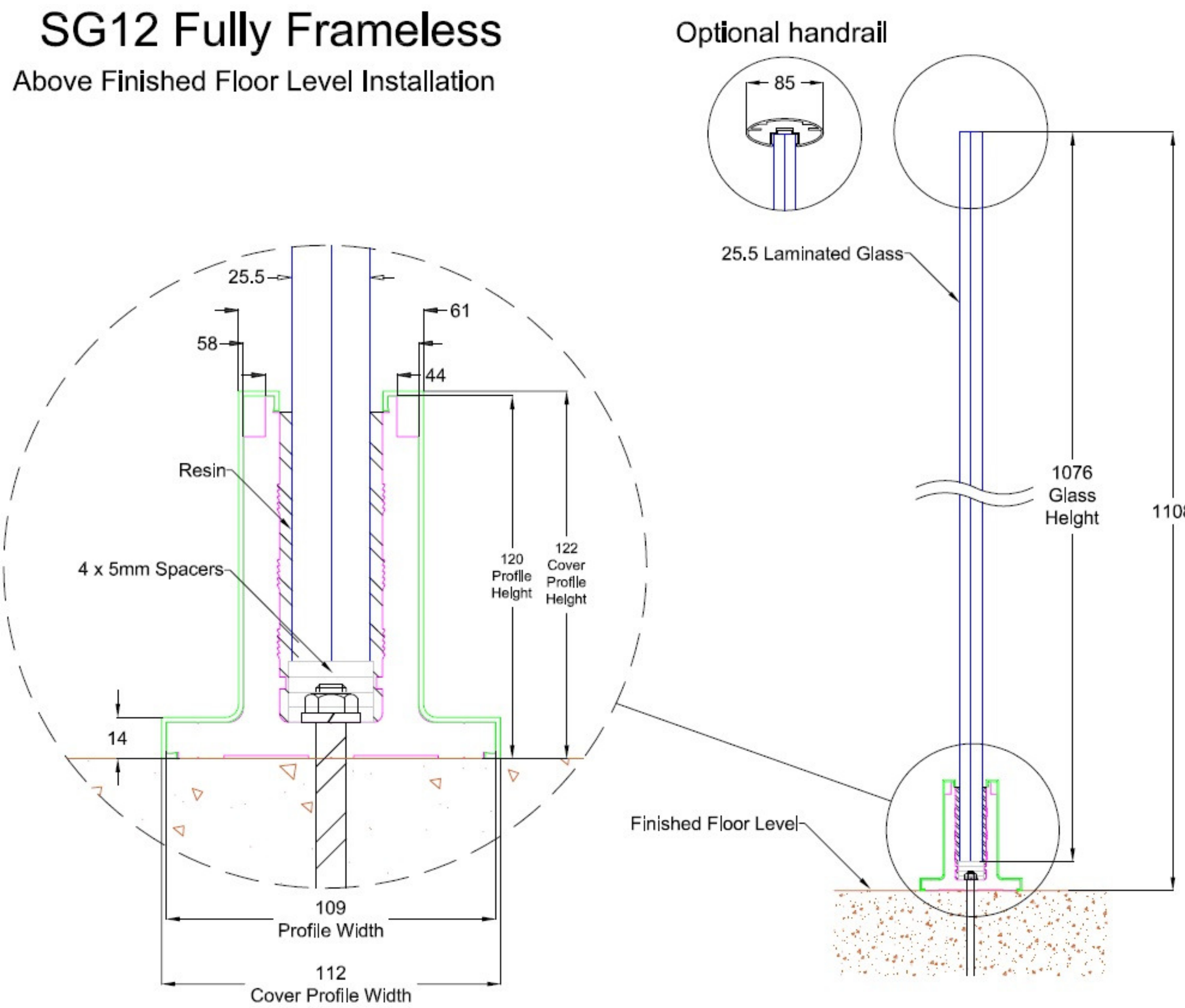
- All structural members deflect to some extent under load. Service loads are used to calculate deflections.
- The total displacement of any point of a barrier from its original unloaded position under the action of service loads is limited to 25mm.

SG12 Frameless Glass Balustrade system for 1.5kN using 25.5mm laminated glass: ***PAGE 4*** **(SG121.5KNFF030418R)**



Section of SG12 balustrade system using 25.5mm thick laminated glass fitted below FFL

SG12 Frameless Glass Balustrade system for 1.5kN using 25.5mm laminated glass: ***PAGE 5*** **(SG121.5KNFF030418R)**



Section of SG12 balustrade system using 25.5mm thick laminated glass fitted above FFL

Structural system:
The glass acts as a vertical cantilever from a continuous aluminium bottom channel to resist the imposed loads listed on pages 2 & 3 and also the design wind loading.

The channel may be located above finished floor level (case 1) or below finished floor level (case 2).

Design for imposed loads:

Case 1: Base **channel located above FFL:**

Design for service line load of 1.50 kN/m:

Design ultimate horizontal imposed line load on glass	F_L	=	1.50 kN/m x 1.5	=	2.25 kN/m

This load is applied 1100mm above FFL. The overall height of the base channel is 120mm. The glass extends approximately 80mm into the channel. The distance from the centre of the glass anchorage in the channel to the line of action of the horizontal imposed line load is 1100 - 32 - 40 = 1028mm.

Ultimate moment on glass from the imposed line load of 2.25 kN/m	M_g	=	2.25 kN/m x 1.028	=	2.313 kNm/m
Ultimate moment to underside of the base channel from the imposed line load of 2.25 kN/m	M_b	=	2.25 kN/m x 1.10	=	2.475 kNm/m

Design for uniform distributed service load of 1.50 kN/m^2:

Design ultimate UDL on glass	F_u	=	1.50 kN/m^2 x 1.5	=	2.25 kN/m^2
Ultimate moment on glass from UDL	Mg	=	$\frac{2.25\ kN/m^2 \times (1.028)^2}{2}$	=	1.189 kNm/m
Ultimate moment to underside of the base channel from the UDL	Mb	=	$\frac{2.25\ kN/m^2 \times (1.108)^2}{2}$	=	1.381 kNm/m

Wind load design:
Design wind loads are influenced by a number of variable factors. These include site location, site altitude above sea level, type of terrain, and height of balustrade above ground level.

These parameters and conditions are defined in BS EN 1991-1-4:2002 + A1: 2010 '*Actions on structures – wind actions' &* UK National Annex to EN 1991-1-4:2002 + A1:2010. We have chosen to prepare a calculation based on certain conditions, resulting in specific coefficients.

The formula applied results in an overall ***characteristic wind pressure***. The design and calculation will be relevant not only to the conditions specified herein but to any combination of factors that result in a characteristic wind pressure that is equal to or less than the one specified in the calculation. Sites that have a ***characteristic wind pressure*** that exceeds **2.45 kN/m^2** as determined on page 7 below require separate calculation.

Wind load parameters for more severe wind loading:

a) Sites located geographically within the **27m/sec** isopleth in Figure NA1 of the UK National Annex. This covers the whole of England, Wales and Northern Ireland, plus most of Scotland.

b) Site altitude **300m** maximum above sea level.

c) Top of balustrade located **50m** maximum above ground level.

d) Site located in a coastal area exposed to the open sea, terrain category 0 of BS EN 1991 Table 4.1. This is the most severe exposure category. Smaller wind load coefficients apply to less exposed inland sites, terrain categories 1 to 1V.

e) Sites with no significant orography in relation to wind effects. (ie. orography coefficient 1.0). Increased wind load factors apply to sites near the top of isolated hills, ridges, cliffs or escarpments.

f) Directional, seasonal, and probability factors are all taken as normal, for which the relevant factor is 1.0.

g) Sites located in country terrain or less than 1.0 km inside town terrain.

Wind load design:

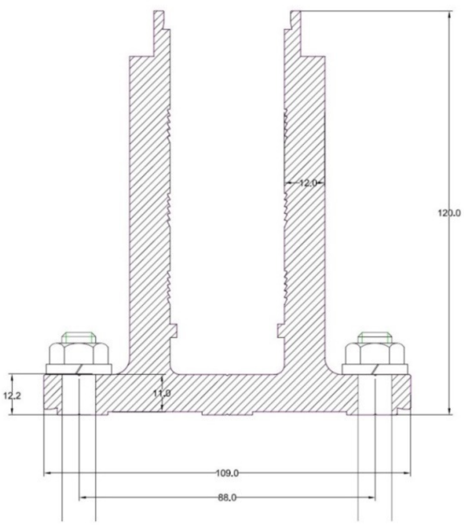
Basic wind speed	$V_{b\ map}$	=	27 m/sec	
Site altitude factor	C_{alt}	=	1.2174	(Equation NA 2b)
Directional factor	C_{dir}	=	1.0	
Seasonal factor	C_{season}	=	1.0	
Probability factor	C_{prob}	=	1.0	
Site wind speed	V_b	=	$V_{b\ map}(C_{dir} \times C_{season} \times C_{prob})(C_{alt})$	
		=	27 m/sec x 1.2174	
		=	32.87 m/sec	
Site wind pressure	q_b	=	$0.613\ (V_b)^2$	
		=	$0.613\ (32.87)^2$	
		=	662.3 N/m^2	
Exposure factor	$C_e\ (z)$	=	3.70	(Figure NA7)
Peak velocity pressure	q_p	=	$q_b \times C_e\ (z)$	
(Characteristic wind pressure)		=	0.662 x 3.70	
		=	**2.45 kN/m^2**	
Partial safety factor for leading variable action	γ_{Q1}	=	1.50	
Ultimate design wind pressure		=	2.45 kN/m^2 x 1.5	
		=	**3.675 kN/m^2**	

Summary of design loads:

Element	Service load	Ultimate load
Horizontal imposed line load applied 1100mm above FFL	1.50 kN/m	2.25 kN/m
Imposed UDL on the glass	1.50 kN/m^2	2.25 kN/m^2
Point load applied in any position	1.50 kN	2.25 kN
Wind loading	2.45 kN/m^2	3.675 kN/m^2

Case 2: Base channel fixed below FFL:

Glass height		=	1225mm		
Height to top of glass above FFL		=	1108mm		
Height to top of glass above underside of base channel		=	1247mm		
Depth of glass embedment in base channel		=	90mm approximately		
Height centre of embedment to top of glass		=	1180mm		
Ultimate wind BM to u/side base	M_{ub}	=	3.675 kN/m^2 x 1.108 x 0.693	=	**2.822 kNm/m**
Ultimate line load BM to u/side base	M_{ub}	=	2.25 kN/m x 1.239	=	2.788 kNm/m
Ultimate wind BM to centre of glass embedment in base channel	M_{uc}	=	3.675 kN/m^2 x 1.108 x 0.626	=	2.549 kNm/m
Ultimate line load BM to centre of glass embedment in base channel	M_{uc}	=	2.25 kN/m x 1.172	=	**2.637 kNm/m**



Base channel below FFL

Properties of glass:
Type: 25.5 mm thick laminated glass comprising 2 plies of 12mm thick thermally toughened safety glass with smooth float 'as produced' finish and polished edges, with a 1.5mm interlayer. Glass panels can be of any length. For design purposes a nominal glass panel width of 1000mm has been used.

Design standard: Institution of Structural Engineers publication 'Structural use of glass in building (second edition) February 2014.'

Characteristic design strength = 120 N/mm^2

Ultimate design stress $f_{g;d}$ = $\frac{K_{mod} \times K_{sp} \times K_{g;k}}{\gamma_{M;A}} + \frac{k_v (f_{b;k} - f_{g;k})}{\gamma_{M;V}}$

where K_{mod} = duration factor (Table C.5)
= 0.77 for workplace/public balustrade load

K_{sp} = glass surface profile factor
= 1.0 for float glass 'as produced'

$f_{g;k}$ = characteristic strength of basic annealed glass
= 45 N/mm^2

K_v = manufacturing process strengthening factor
= 1.0 for horizontal toughening

$f_{b;k}$ = characteristic bending strength of prestressed glass
= 120 N/mm^2

$\gamma_{M;A}$ = material partial factor
= 1.6 for basic annealed glass

$\gamma_{M;V}$ = material partial factor
= 1.2 for surface prestressed (toughened) glass

Ultimate design stress $f_{g;d}$ = $\frac{0.77 \times 1.0 \times 45}{1.6} + \frac{1.0 (120 - 45)}{1.2}$

= **84.16 N/mm^2**

Glass design:

The effective thickness of laminated glass $h_{ef;w}$ in terms of bending stress with respect to variable actions is defined in the Institution of Structural Engineers' publication *'The structural use of glass in building (second edition – February 2014)*.

Equation C.3: $h_{ef;w} = \sqrt[3]{\Sigma h_k^3 + 12\dot{\omega} (\Sigma h_k h_{m,k}^2)}$

where $\dot{\omega}$ = coefficient of shear transfer of the interlayer
= 0.3 for standard grade PVB: family 2: for wind in non-Mediterranean locations; or ionoplast: family 3: for personal load – crowds (Table C.9).

h_k = 12mm thickness of plies

$h_{m,k}$ = 6.75mm distance from the mid plane of the glass plies to the centre of the interlayer

$h_{ef;w} = \sqrt[3]{\{ (12)^3 + (12)^3 + 12 \times 0.3 (2 [12 \times 6.75^2]) \}}$

$= \sqrt[3]{\{1728 + 1728 + 3.6 (1093.5) \}}$

$= \sqrt[3]{(7392.6)}$

= 19.45mm

This is defined this as the effective thickness of the laminated glass to be used for deflection calculations.

2nd moment of area of glass based upon an effective thickness of 19.45mm and a nominal length of 1000mm $= \dfrac{1000 \times (19.45)^3}{12} = 613165\text{mm}^4/\text{m}$

The effective thickness of laminated glass in terms of stress within a ply $h_{ef;\alpha;j}$ is defined in equation C.4.

Equation C.4: $h_{ef;\alpha;j} = \left\{ \dfrac{(h_{ef;w})^3}{(h_j + 2\dot{\omega} h_{mj})} \right\}^{0.5}$

where: $\dot{\omega}$ = coefficient of shear transfer of the interlayer.
= 0.3 as defined above.

h_j = 12mm thickness of plies.

h_{mj} = 6.75mm distance from the mid-plane of a ply to the centre of the interlayer.

$h_{ef;w}$ = 19.45mm as calculated above.

$h_{ef;\alpha;j} = \left\{ \dfrac{(19.45)^3}{(12 + 2 \times 0.3 \times 6.75)} \right\}^{0.5}$

$= \left\{ \dfrac{7358}{16.05} \right\}^{0.5}$

= 21.40 mm

This is defined as the effective thickness to be used for bending stress calculations.

Laminated glass (cont):

Modulus of glass 1000mm wide x 21.4mm effective thickness	W_{el}	=	$\frac{1000 \times (21.4)^2}{6}$	=	76327 mm^3/m
Moment capacity of glass 1000mm x 21.4mm effective thickness	M_u	=	84.16 $N/mm^2 \times 76327 \times (10)^{-6}$		
		=	**6.42 kNm/m**		
		= >	ultimate design moment of 2.637 kNm/m		
Service imposed line load	F	=	1.50 kN/m		
Height from centre of embedment in channel to line of action of line load	h	=	1172mm	(base channel located below FFL)	

Service load deflection of the glass is taken to the centre of the glass embedment in the base channel.

2nd moment of area of glass 1000mm wide x 19.45 mm effective thickness	I_{xx}	=	$\frac{1000 \times (19.45)^3}{12}$	=	613165 mm^4/m
Service load deflection due to line load	Δ	=	$\frac{F h^3}{3 E I_{xx}}$		
		=	$\frac{1500 \times (1172)^3}{3 \times 70000 \times 613165}$	=	18.75mm
		= >	25 mm	=	OK

For the case where the channel is located below FFL (worst case) the 25.5mm laminated glass comprising 2 x 12mm plies with a 1.5mm interlayer is adequate in terms of bending strength and deflection.

Post-failure condition:

Frameless laminated glass barriers are required to satisfy a condition where one ply in a panel is assumed to have failed. The remaining ply is designed to remain in place post-failure and withstand the full design service load for a short period pending replacement of the damaged panel. As a post-failure condition deflection limitations do not apply.

Inertia of glass pane 1000mm wide x 12mm thick	I_{xx}	=	$\frac{1000 \times (12)^3}{12}$	=	144000 mm^4
Modulus of glass pane 1000mm wide x 12mm thick	W_{el}	=	$\frac{1000 \times (12)^2}{6}$	=	24000 mm^3
Ultimate moment capacity of glass 1000mm wide x 12mm thick	Mu	=	84.16 $N/mm^2 \times 24000\ mm^3 \times (10)^{-6}$		
		=	**2.02 kNm**		
Service load BM on glass from line load (to centre of glass embedment)	M	=	1.50 kN/m x 1.172	=	1.758 kNm/m
		= <	2.02 kNm/m	=	OK
Service load BM on glass from imposed UDL (to centre of glass embedment)	M	=	$\frac{1.50\ kN/m^2 \times (1.172)^2}{2}$	=	1.03 kNm/m
		= <	2.02 kNm/m	=	OK

The 25.5mm laminated glass satisfies the requirement that should one ply in a panel fail, the remaining ply must be adequate to remain in place and support the design imposed loads pending replacement of the damaged panel.

Base fixing channel and HD bolts: base channel located below FFL:

Ultimate design wind load BM to the underside of the base channel	M_u	=	2.822 kNm/m		(page 8)
Distance between the centres of bolts	d	=	88.0mm		
Ultimate load bolt tension	T_u	=	$\frac{2.822}{0.088}$	=	32.07 kN/m
Working load bolt tension	Tw	=	$\frac{32.07}{1.5}$	=	21.12 kN/m

BS 6180:2011, section 6.5, recommends that barrier fixings, attachments and anchorages should be designed to withstand a greater load than the design loading for the barrier generally. This is intended to ensure that under an extreme load condition, barriers show indications of distress by distortion, before there is any possibility of sudden collapse due to failure of the fixings. A 50% increase in the design load on fixings is recommended.

Applying the 50% increase in loads on fixings recommended in BS 6180:2011, the working load bolt tension becomes **32.07 kN/m.** Bolt forces vary depending upon the bolt spacing selected. eg:

Working load bolt tension:

Bolts installed @ 600mm centres	=	32.07 kN/m x 0.60	=	19.24 kN/bolt
Bolts installed @ 500mm centres	=	32.07 kN/m x 0.50	=	16.04 kN/bolt
Bolts installed @ 400mm centres	=	32.07 kN/m x 0.40	=	12.83 kN/bolt
Bolts installed @ 300mm centres	=	32.07 kN/m x 0.30	=	9.62 kN/bolt

The nominal tension capacity of M12 (8.8 grade) bolts is 37.80 kN/bolt. The higher bolt forces can therefore be achieved by direct bolting to a suitable steel frame, or by drilling through and anchoring to the underside of a suitable concrete slab.

The installers should satisfy themselves that the fixing bolts chosen are suitable to resist these loads, and also that the structure into which they are installed can support these loads.

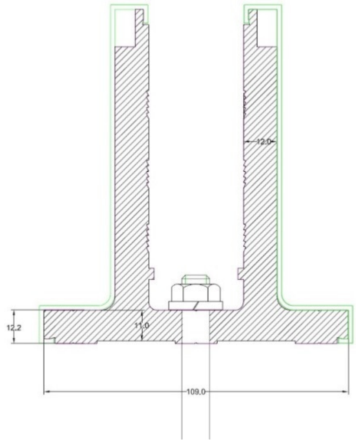
Base channel below FFL:

Properties of section:

Material type		=	Extruded aluminium type 6063 T6		
Limiting stress for bending	f_o	=	190 N/mm^2		
Limiting stress for tension/compression	f_u	=	220 N/mm^2		
Limiting stress for shear	P_v	=	65 N/mm^2		
Young's modulus of elasticity	E	=	70,000 N/mm^2		
Ultimate resistance capacity	M_c	=	Member capacity based upon *fo* *f*s and Pv divided by the material factor γ_{m1}	=	1.1
Thickness of sides of channel		=	12mm		
Elastic modulus of side of channel		=	$\frac{1000 \times (12)^2}{6}$	=	24000mm^3/m
Moment capacity of side of channel per metre	M_c	=	$\frac{190 \text{ N/mm}^2 \times 24000 \text{ mm}^3 \times (10)^{-6}}{1.1}$	=	4.15 kNm/m
Max. ultimate line load BM to centre of glass embedment in channel	Mu	=	2.637 kNm/m (page 8)	=	OK

The channels in extruded aluminium grade 6063 T6 are adequate to support the design imposed and wind loading.

Base channel located above FFL:



Base channel above FFL

Properties of section:

Material type		=	Extruded aluminium type 6063 T6
Limiting stress for bending	f_o	=	190 N/mm^2
Limiting stress for tension/compression	f_u	=	220 N/mm^2
Limiting stress for shear	P_v	=	65 N/mm^2
Young's modulus of elasticity	E	=	70,000 N/mm^2
Ultimate resistance capacity of side of channel per metre	M_c	=	Member capacity based upon *fo fs* and Pv divided by the material factor γ_{m1} = 1.1
		=	4.15 kNm/m (page 13)
Glass height		=	1076mm
Height underside of base to top of glass		=	1108mm
Depth of embedment of glass in base channel		=	80mm approximately
Ultimate line load BM to underside of base channel		=	2.25 kN/m x 1.10
		=	2.475 kNm/m
Ultimate wind load BM to underside of base channel		=	3.675 kN/m^2 x (1.108)^2/2
		=	2.223 kNm/m
Height from centre of glass embedment to line load		=	1100 – 12 – 20 – 40
		=	1028mm
Ultimate line load BM to centre of embedment		=	2.25 kN/m x 1.028
		=	2.313 kNm/m
Ultimate wind load BM to centre of embedment		=	3.675 kN/m^2 x (1.028)^2/2
		=	1.942 kNm/m

Base channel located above FFL:

Moment capacity of side of base channel in 6063 T6	=	4.15 kNm/m		=	OK
Width of base channel	=	109mm			
Distance centre of bolts to edge of base channel	=	54.5mm			
Assume a Δ stress block 27.25mm long under base:					
Distance centre of stress block to centre of bolts	=	45.42mm	say	=	45mm
Maximum ultimate BM to underside of base	=	2.475 kNm/m			
Ultimate load bolt tension	=	2.475 kNm/0.045			
	=	55.00 kN/m			
Applying the 50% BS 6180 increase on fixing loads:					
Design working load bolt tension	=	55.00 kN/m			
Bolt forces vary depending upon the spacing selected. eg.					
Bolts installed @ 400mm centres	=	55.00 x 0.40	=	22.00 kN/bolt	
Bolts installed @ 300mm centres	=	55.00 x 0.30	=	16.50 kN/bolt	
Bolts installed @ 250mm centres	=	55.00 x 0.25	=	13.75 kN/bolt	
Bolts installed @ 200mm centres	=	55.00 x 0.20	=	11.00 kN/bolt	

The installers should satisfy themselves that the fixing bolts chosen are suitable to resist these loads, and also that the structure into which they are installed can support these loads.

Maximum pressure under the base channel	=	55.00 kN/13.63	=	4.04 N/mm^2 OK

The base channels used above FFL in aluminium grade 6063 T6 are adequate to support the design imposed and wind loading.

SUMMARY

SG12 balustrade system using 25.5mm thick laminated glass without the need for a handrail

1) The SG12 balustrade system (1.5 kN) using 25.5mm thick laminated safety glass, is adequate to resist the imposed loads specified in BS 6180:2011 for the occupancy classes listed on pages 1 to 3 of these calculations, on sites that come within the wind load parameters listed on page 7, and/or have a characteristic wind pressure that does not exceed **2.45 kN/m^2**. Sites that do not come within these parameters require separate consideration.

2) The system comprises 2 plies of 12mm thick thermally toughened safety glass with a 1.5mm interlayer. A handrail can be provided as an option, but is not required for structural reasons.

3) The glass acts as a vertical cantilever from a continuous aluminium channel bolted to the balcony structure. These calculations demonstrate that the system is adequate to support the design imposed and wind loads in accordance with British and European Standards.

4) The base channels are made from extruded aluminium grade 6063 T6 and may be installed either above or below finished floor level (FFL). When fixed above FFL the channel is secured to the balcony structure by means of centrally located M12 anchor bolts. Pull-out forces on the bolts depends upon the spacing selected. Working load bolt pull-out forces for various spacing of bolts centre to centre are listed below.

Base channels fixed above FFL:	Bolt spacing	Working load pull-out force
	400 mm	22.00 kN/bolt
	300 mm	16.50 kN/bolt
	250 mm	13.75 kN/bolt
	200 mm	11.00 kN/bolt

5) Where the base channels are installed below FFL the channel profile is used with M12 holding down bolts located in the side projections of the base. Working load pull-out forces for various bolt spacing centre are listed below.

Base channels fixed below FFL:	Bolt spacing	Working load pull-out force
	600mm	19.24 kN/bolt
	500mm	16.04 kN/bolt
	400mm	12.83 kN/bolt
	300mm	9.62 kN/bolt

6) The installers should satisfy themselves that the fixing bolts chosen are suitable to resist the specified loads, and also that the structure into which they are installed can support these loads.

7) The higher bolt loads should be achievable where fixings are made direct to a substantial structural steel frame, or by drilling through and anchoring to the underside of a suitable concrete slab. Subject to manufacturers' recommended working load bolt forces, drilled resin anchor bolts or similar installed into good quality concrete might be adequate for the lower bolt forces.

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