Makes the most of yourview

Balcony 1 system (with & without bar) 1.5 kN

<u>Structural Calculations for Orbit (Balcony 1) system handrail (with and without 58 x 4mm internal reinforcing bar) for 1.5 kN loading using 60 x 60 x 5mm SHS posts & 300 x 150mm x 15 base plates</u>

Our ref: B1WB6060300150BP090118R

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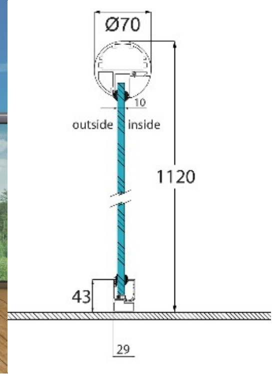
Balcony 1 Balustrade fixed between two walls

Balcony 1 Balustrade elevation with posts



Balcony 1 section Balcony 1

DESIGN TO EUROCODES & CURRENT BRITISH STANDARDS

Design standards:

EN 1990	Eurocode 0:	Basis of structural design.
EN 1991	Eurocode 1:	Actions on structures.
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>Design loads:</u>

Occupancy class/es for which this design applies (Table 2: BS6180:2011) =
Domestic and residential activities (i) & (ii)
Office and work areas not included elsewhere (iii), (iv) & (v)
Areas where people may congregate (vi)
Areas with tables or fixed seating (vii)
Areas not susceptible to overcrowding (viii) & (ix)

Service load on handrail = Q_k = 1.5 kN/m uniformly distributed line load acting 1100mm above finished floor level. (Table 2: BS6180:2011)

Service load applied to the glass infill = Qk1 = A uniformly distributed load of 1.5 kN/m^2

Point load on glass infill = point load = 1.5 kN applied to any part of the glass fill panels

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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

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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/m²)	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.

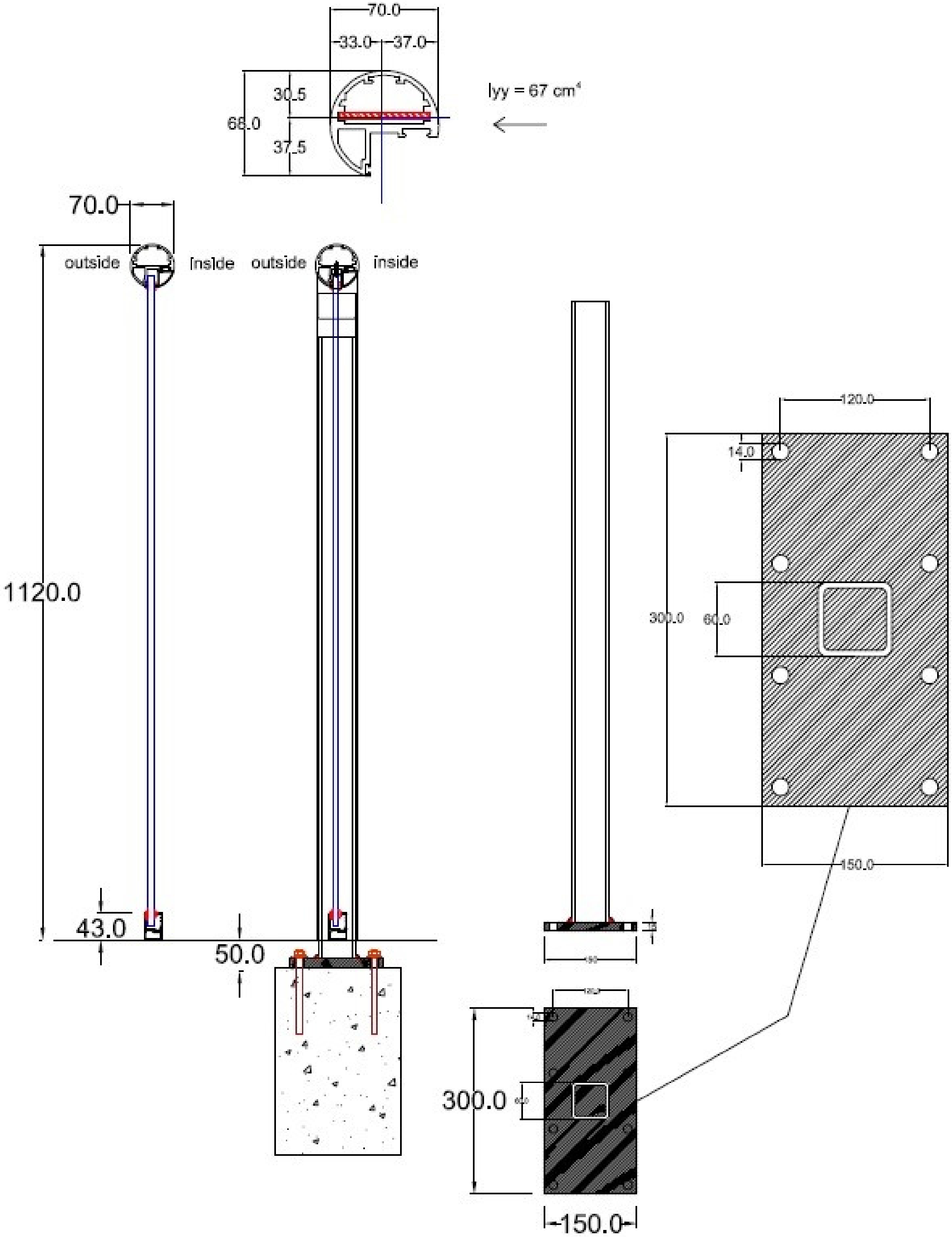
Table 2: BS6180:2011

- These loads are considered as three separate load cases. They are not combined.
- 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.

Balcony 1 system (with bar) 1.5 kN ***PAGE 4*** **(B1WB6060300150BP090118R)**



Section of Balcony 1 system, post detail and base plate detail

To achieve the maximum span on single span and corner balconies, the handrail is provided with a 58 x 4mm steel internal reinforcing bar.

Section properties of handrail with bar:

Material type	=	Extruded aluminium type 6063 T5		
Characteristic 0.2% proof stress	=	f_o	=	130 N/mm^2
Characteristic UTS	=	f_u	=	175 N/mm^2
Modulus of elasticity	=	E	=	70 000 N/mm^2
Shear modulus	=	G	=	27 000 N/mm^2
Moment of inertia about the y-y axis	=	I_{yy}	=	67 cm^4
Least elastic modulus about the y-y axis	=	W_{el}	=	18.108 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Value of shape factor (assessment)	=	α	=	W_{pl}/W_{el}
			=	1.2 say

Design ultimate resistance to bending about the y-y axis = M_{Rd} = $M_{o,Rd}$

$$= \alpha W_{el} f_o / \gamma_{M1}$$

$$= \frac{1.2 \times 18.108\ \text{cm}^3 \times 130\ \text{N/mm}^2 \times (10)^{-3}}{1.1}$$

= **2.568 kNm**

Design ultimate horizontal load on handrail = F = 1.5 kN/m x 1.5
= 2.25 kN/m

Design horizontal moment on handrail between points of support, assuming simply supported spans (worst case) = M = $\frac{F L^2}{8}$

Allowable span L between points of support based upon the moment capacity of the handrail

$$= \left[\frac{8 \times M_{Rd}}{F}\right]^{0.5}$$

$$= \left[\frac{8 \times 2.568\ \text{kNm}}{2.25}\right]^{0.5}$$

= 3.02m **say 3.0m**

In terms of bending capacity the handrail can span up to 3.0m simply supported between points of support.

However, for a single span simply supported handrail, the service load deflection limit of 25mm restricts the allowable span to **2.8m** between points of support (ie. a handrail wall fixing, or a handrail corner joint).

Balcony 1 system (with bar) 1.5 kN

Service load deflection:

Deflection (Δ) of a simply supported span (L) with an imposed UDL load (F) $\Delta = \frac{5 F L^4}{384 E I}$

For a handrail span of 2.8m simply supported $\Delta = \frac{5 (1500 \times 2.8)(2800)^3}{384 \times 70\,000 \times 67 \times (10)^4}$

= 25.6mm slightly > 25mm but say = OK

Summary: The Balcony 1 system handrail (with bar) is adequate to support the specified design imposed loading in terms of ultimate moment capacity and service load deflection limitations on simply supported spans up to **2.8m** (ie. a wall fixing or a handrail corner joint).

Balcony 1 system (without bar)

Section properties of handrail without bar:

Material type	=	Extruded aluminium type 6063 T5		
Characteristic 0.2% proof stress	=	f_o	=	130 N/mm^2
Characteristic UTS	=	f_u	=	175 N/mm^2
Modulus of elasticity	=	E	=	70 000 N/mm^2
Moment of inertia about the y-y axis	=	I_{yy}	=	47 cm^3
Least elastic modulus about the y-y axis	=	W_{el}	=	12.227 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Value of shape factor (assessment)	=	α	=	1.2 say

Design ultimate resistance to bending about the y-y axis = $M_{RD} = \frac{\alpha \times W_{el} \times f_o}{\gamma_{M1}}$

$= \frac{1.2 \times 12.227\ \text{cm}^3 \times 130\ \text{N/mm2} \times (10)^{-3}}{1.1}$

= **1.734 kNm**

Design ultimate horizontal load on handrail = F = 1.5 kN/m x 1.5

= 2.25 kN/m

Design horizontal moment on handrail assuming a simply supported span = M = $\frac{F L^2}{8}$

Allowable span between points of support based upon the M_{RD} of the handrail = L = $\left[\frac{8 \times M_{RD}}{F}\right]^{0.5}$

$= \left[\frac{8 \times 1.734}{2.25}\right]^{0.5}$

= 2.48m say = **2.5m**

In terms of bending capacity the handrail without bar can span up to **2.5m** simply supported between points of support.

Service load deflection:

For a simply supported span of 2.5m service load deflection of the handrail without bar $\Delta = \frac{5 F L^4}{384 E I}$

$= \frac{5 (1500 \times 2.5)(2500)^3}{384 \times 70\,000 \times 47 \times (10)^4}$

= 23.19mm < 25mm = OK

Balcony 1 system (with bar) 1.5 kN ***PAGE 7*** **(B1WB6060300150BP090118R)**

Summary: The Balcony 1 system handrail (without internal reinforcing bar) is adequate to support the specified design imposed loading in terms of ultimate moment capacity and service load deflection limitations on simply supported spans up to **2.5m** between points of support (ie. a wall fixing or a handrail corner joint).

Longer spans: On longer spans exceeding 2.5m the Balcony 1 system handrail (without bar) is used in conjunction with 60 x 60 x 5mm structural hollow steel (SHS) vertical posts. A maximum post spacing of 2.0m is adopted. The combined service load displacement of the handrail + post at any position from its original unloaded position is limited to 25mm.

Vertical posts: 60 x 60 x 5mm SHS: properties of section:

Steel grade	=	S 275 H to EN 10025		
Nominal value of yield strength	=	f_y	=	275 N/mm^2
Nominal value of ultimate tensile strength	=	f_u	=	430 N/mm^2
Inertia of section	=	I_{xx}	=	50.50 cm^4
Elastic modulus of section	=	W_{el}	=	16.89 cm^3
Plastic modulus of section	=	W_{pl}	=	20.90 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Partial factor for class 1 sections	=	γ_{MO}	=	1.00
Modulus of elasticity	=	E	=	210 000 N/mm^2

Design ultimate resistance for bending

$$M_{pl,Rd} = \frac{f_y \times W_{pl}}{\gamma_{Mo}} = \frac{275\ N/mm^2 \times 20.90\ cm^3 \times (10)^{-3}}{1.0} = \mathbf{5.75\ kNm}$$

Ultimate moment on post 1.135m high above top of base to line of action of load. Posts at 2.0m c/c.

$$M_d = (1.50 \times 2.0) \times 1.135 \times 1.5\ (\gamma_{Q1})$$

$$= 5.1075\ kNm \quad < 5.75\ kNm \qquad \text{OK}$$

Service load deflection of post supporting 2.0m of handrail

$$\Delta_p = \frac{P\,L^3}{3\,E\,I} = \frac{(1500 \times 2.0)\ (1135)^3}{3 \times 210\,000 \times 50.5 \times (10)^4} = 13.79mm$$

Service load deflection of handrail (no bar) for a simply supported span of 2.0m

$$\Delta_h = \frac{5\ (1500 \times 2.0)\ \ (2000)^3}{384 \times 70000 \times 47 \times (10)^4} = 9.50mm$$

Combined total displacement of handrail + post from the original unloaded position (service loads)

$$\Delta t = 9.50mm + 13.79$$

$$= 23.29mm \quad < \quad 25mm \qquad \text{OK}$$

Summary: The Balcony 1 system handrail (without internal steel reinforcing bar) in conjunction with 60 x 60 x 5mm SHS posts in steel grade S275, is adequate to support the design imposed loading on the handrail for posts spaced at up to 2.0 metres centre to centre.

Wind load parameters:

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'* and UK National Annex to EN 1991-1-4:2002 + A1:2010. The formula applied results in an overall **characteristic wind pressure.**

The **characteristic wind pressure** on the glass infill that results in the same force on the handrail as the specified horizontal imposed line load of **1.50 kN/m** is **2.72 kN/m^2.**

We have therefore chosen to prepare a calculation based upon wind load coefficients that will result in a wind load reaction on the handrail equal to or less than 1.50 kN/m.

The design and calculations 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 calculations. Sites that have a characteristic wind pressure that exceeds **2.72 kN/m^2** as determined in these calculations require separate consideration.

The selected wind load coefficients will cover the majority of sites in the UK, and are appropriate for 1100mm high balustrades of any length with or without return corners.

a) Sites located geographically within the 27m/sec isopleth in Figure NA 1 of the UK National Annex. This covers the whole of England, Wales and Northern Ireland, and also most of Scotland.

b) Site altitude 250m 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) Site located in country terrain or less than 1.0 km inside town terrain.

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

g) Directional, seasonal, and probability factors are all taken as normal, for which the relevant coefficient is 1.0. This is a slightly conservative approach.

Wind load design:

Basic site wind speed	$V_{b\ map}$	=	27m/sec
Site altitude above sea level	A	=	250m
Handrail height above ground level	z	=	50m
Altitude factor	C_{alt}	=	$1.0 + (0.001 \times A)(10/z)^{0.2}$
		=	$1.0 + (0.25)(10/50)^{0.2}$
		=	$1.0 + (0.25)(0.7248)$
	say	=	1.181

Balcony 1 system (with bar) 1.5 kN *PAGE 9* (B1WB6060300150BP090118R)

Wind load design (cont):

Directional factor	C_{dir}	=	1.0	
Seasonal factor	C_{season}	=	1.0	
Probability factor	C_{prob}	=	1.0	
Site wind speed	V_b	=	$V_{b\,map}(C_{dir} \times C_{season} \times C_{prob})\ C_{alt})$	
		=	27m/sec x 1.181	
		=	31.887m/sec	
Site wind pressure	qb	=	$0.613\ (Vb)^2$	
		=	$0.613\ (31.887)^2$	
		=	623.29 N/m^2	
Exposure factor	Ce (z)	=	3.70	(Figure NA 7)
Peak velocity pressure	qp	=	qb x Ce (z)	
(characteristic wind pressure)		=	0.623 x 3.70	
		=	2.31 kN/m^2	
Wind load reaction on the handrail		=	2.31 kN/m^2 x 0.55	
		=	1.271 kN/m	
		= <	1.50 kN/m imposed service load	

Summary:

For sites that come within the parameters listed on page 9 of these calculations (ie. most sites within the UK) wind loading is not the dominant overall design condition for 1100mm high balustrades designed for 1.50 kN/m imposed service loading. However the characteristic wind pressure of 2.31 kN/m^2 is the dominant design condition for the glass infill.

Baseplates and HD bolts:

Maximum spacing of posts	=	2.0 m	
Ultimate design moment to top of base	=	(1.50 kN/m x 1.5) x 2.0 x 1.135	
on posts at 2.0 m c/c	=	5,1075 kNm	
Lever arm between bolt centres	=	120mm	
Ultimate load pull-out force on 4 No. bolts	=	$\frac{(1.50 \times 1.5)\ kN/m \times 2.0 \times 1.15}{0.12 \times 4\ No.}$	
	=	**10.78 kN/bolt**	(ultimate load)
	=	**7.19 kN/bolt**	(working load)

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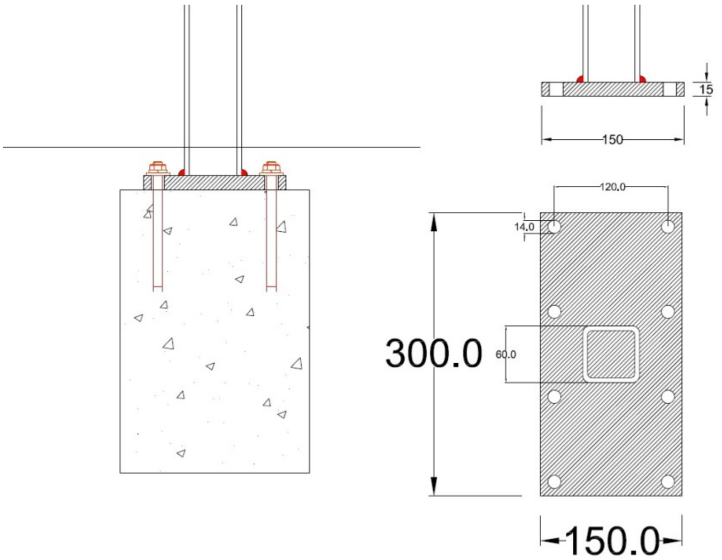
Baseplates & HD bolts:



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 this recommendation, the design **working load** bolt force = **10.78 kN/bolt**.

A working load pull-out force of **10.78 kN/bolt** should be achievable using M12 drilled resin anchor bolts or similar installed into a suitable thickness of good quality concrete.

However the installers should satisfy themselves that the fixings chosen are suitable to resist the specified working load pull-out force, and also that the structure into which they are to be installed is adequate to resist this force.

Nominal tension capacity of M12 (8.8 grade) bolts	=	37.80 kN/bolt
Nominal tension capacity of M12 stainless steel bolts grade A2 to BS EN ISO 3506	=	30.30 kN/bolt

Higher bolt forces can therefore be achieved by direct bolting to a substantial steel frame, or by drilling through and anchoring to the underside of a suitable concrete slab.

Base plates: 300 wide x 150 deep x 15mm thick: steel grade S275

Ultimate applied moment on posts at 2.0m maximum spacing	M_a	=	(1.50 x 1.5) x 2.0 x 1.135	=	5.1075 kNm
Plastic modulus of base	W_{pl}	=	$\frac{300 \times (15)^2}{4}$	=	16875 mm^3
Ultimate moment capacity of base	Mu	=	$\frac{f_y \times W_{pl}}{\gamma_{M1}}$		
		=	$\frac{275\ N/mm^2 \times 16875mm^3 \times (10)}{1.1}^{-6}$		
		=	4.22 kNm		

Base plates (cont)

Distance from centre of bolts to face of SHS	=	30mm		
Ultimate bolt pull-out load (not including BS 6180 50% increase, which applies only to fixings, not other elements)	=	10.78 kN/bolt		
Ultimate BM to face of SHS	=	10.78 kN x 4 No. x 0.03	=	1.294 kNm
	= <	4.22 kNm	=	OK

Welded connection between post & baseplate:
The SHS post is welded to the top of the base by means of a full strength butt weld, a continuous fillet weld, or a combination of welds that achieves a full strength connection.

Maximum ultimate elastic bending stress on post $= \frac{M}{W_{el}} = \frac{5.1075 \times (10)^6}{16.89 \times (10)^3}$ = 302 N/mm² = 1.51 kN/mm on 5mm section

Use continuous 8mm FW (transverse capacity 1.54 kN/mm).

Summary:
For a post spacing of up to 2.0 metres, 300mm wide x 150mm deep x 15mm thick steel base plates in steel grade S275 with 8 No. M12 HD bolts, are adequate to resist the specified design loading. A full strength butt weld, a continuous 8mm fillet weld, or a combination of welds that achieves a full strength connection, are adequate to connect the 60 x 60 x 5 SHS posts to the base plates.

Glass infill:

Design standard = Institution of Structural Engineers publication *'Structural use of glass in buildings (second edition) February 2014'.*

Glass type = 10mm thick thermally toughened soda silicate safety glass with smooth float 'as produced' finish with polished edges.

Characteristic design strength = 120 N/mm²

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

where:

K_{mod} = 30 second load duration factor
= 0.89 for a domestic 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/mm²

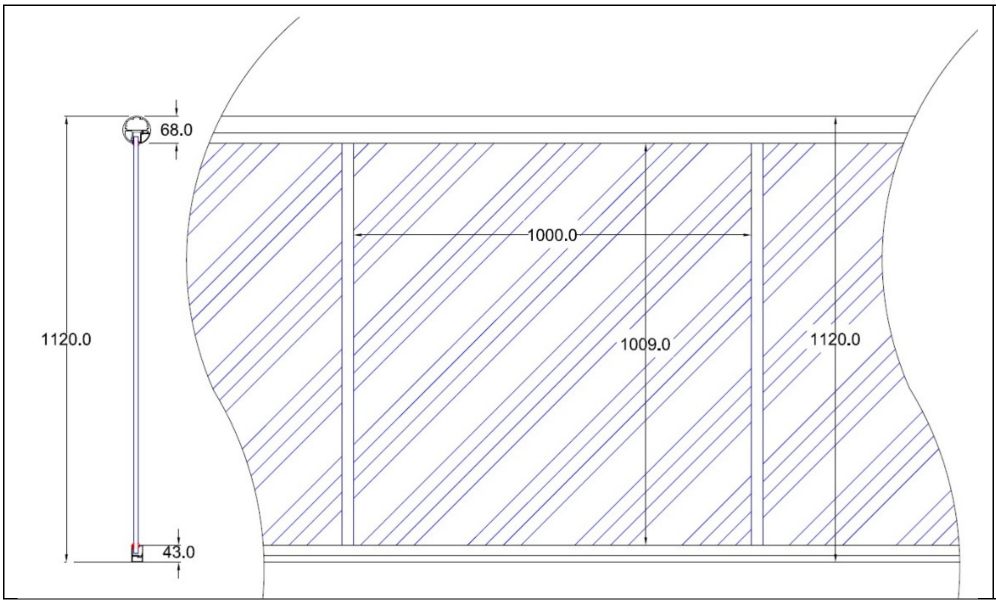
K_v = manufacturing process strengthening factor
= 1.0 for horizontal toughening

$f_{b;k}$ = characteristic bending strength of prestressed glass (120 N/mm²)

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

Glass infill panels (cont)

	$\gamma_{M;V}$	=	material partial factor		
		=	1.2 for surface prestressed (toughened) glass		
Ultimate design stress	$f_{g;d}$	=	$\frac{0.89 \times 1.0 \times 45}{1.6}$	+	$\frac{1.0\,(120 - 45)}{1.2}$
		=	**87.53 N/mm²**		
Section modulus of glass 1000mm wide x 10mm thick	Z	=	$\frac{1000 \times (10)^2}{6}$	=	16667 mm³/m
Ultimate moment capacity of glass 1000mm wide x 10mm thick	Mu	=	$f_{g;d} \times Z$		
		=	$87.53\ N/mm^2 \times 16667mm^3 \times (10)^{-6}$		
		=	**1.459 kNm/m**		



Glass panels can be any length.

For the purposes of design and checking a nominal glass panel width of 1000mm simply supported between the bottom rail and the handrail has been used.

Two separate design loading conditions are considered:

1. Uniformly distributed wind load on the infill of 2.31 kN/m²

Ultimate UDL on glass	w	=	$2.31kN/m^2 \times 1.5$	=	3.465 kN/m²
Ultimate moment on glass due to UDL on span of 1.0m	Mu	=	$\frac{3.465\ kN/m^2 \times (1.0)^2}{8}$	=	0.433 kNm/m
		=	< 1.459 kNm	=	OK

The reaction on the handrail from the UDL on the glass is less than the imposed horizontal UDL on the handrail. Therefore the imposed UDL on the glass is not a critical design case in terms of stresses and displacements of the barrier system as a whole.

Worst case for bending stress on the glass due to point load = point load applied at mid-height of glass

2. Service point load on the infill of 1.5 kN

Point load on the glass = 1.5 kN point load applied in any position

Ultimate moment on glass due to point load = $\frac{1.5 \text{ kN} \times 1.5 \times 1.0\text{m}}{4}$ = 0.5625kNm

Ultimate moment on glass due to point load = $\frac{1.5 \text{ kN} \times 1.5 \times 1.0\text{m}}{4}$ = 0.5625kNm

Conservatively it is assumed that the bending moment of 0.5625 kNm is carried by a 400mm wide vertical strip of glass.

Moment capacity of 400mm strip = 1.459 kNm x 0.4 = 0.5836 kNm
= > 0.5625 kNm = OK

In terms of moment capacity the glass is adequate to support the ultimate design loading.

Glass deflection:

Service load deflection of the glass due to the design wind UDL of 2.31 kN/m^2:

Inertia of glass 10mm thick x 1000mm long = $\frac{1000 \times (10)^3}{12}$ = 83333 mm^4

Service load deflection due to a UDL of 2.31 kN/m^2 on a simply supported span of 1.0m = $\frac{5 w L^4}{384 E I}$

= $\frac{5 \times (2310 \times 1.0) (1000)^3}{384 \times 70\,000 \times 83333}$ = 5.146mm
= OK

Point load of 1.50 kN:

For deflection calculation purposes consider that the design point load is carried by a 400mm wide vertical strip of glass:

Inertia of glass 10mm thick x 400mm long = 0.4 x 83333 mm^4 = 33333 mm^4

Service load deflection due to a point load of 1.5 kN applied at mid-span = $\frac{P L^3}{48 E I}$

= $\frac{1500 \times (1000)^3}{48 \times 70\,000 \times 33333}$

= 13.39mm < $\frac{\text{span}}{65}$ = OK

The glass is adequate in terms of both bending strength and deflection.

Wall fixings (1.5 kN):

The handrail wall fixing consists of a 107.4mm diameter x 4mm thick stainless steel plate bolted to the wall with 3 No. 10mm or 8mm diameter stainless steel resin anchors or similar and secured to the handrail with 2 No. 6.3mm diameter A2 grade stainless steel Phillips self-tapping screws.

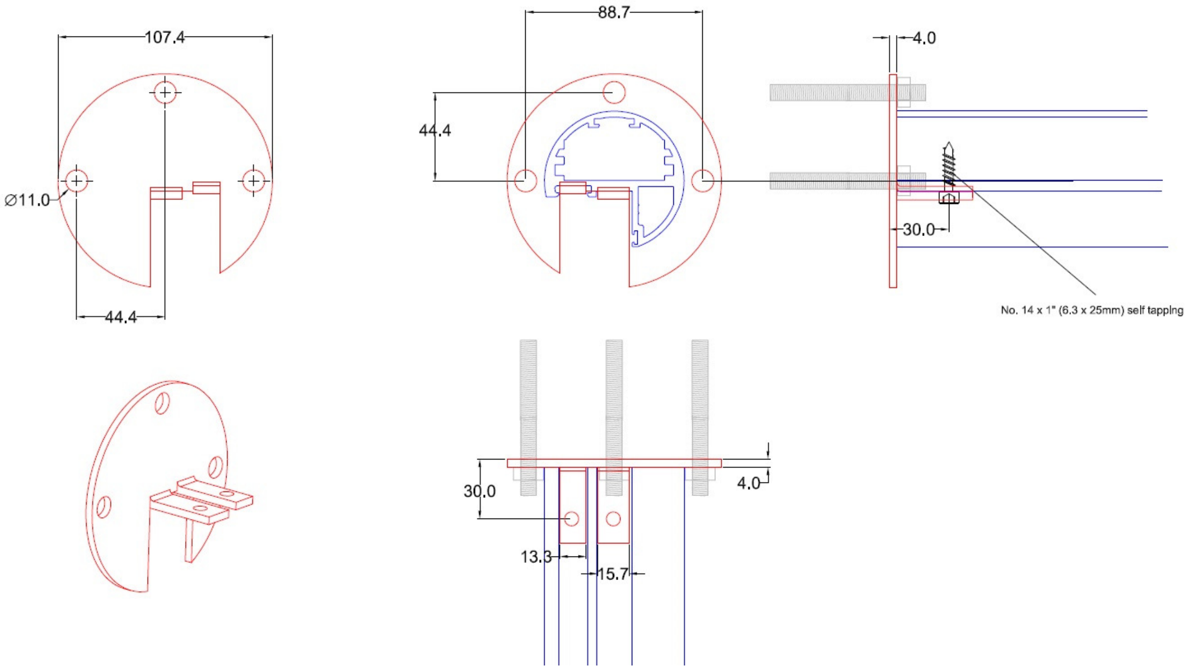
The horizontal load on the handrail is applied to the fixing angles at the position of the Phillips screws located 30mm from the back of the angles. The wall fixing bolts on each side of the plate are 88.7mm apart horizontally.

Balcony 1 system (1.5 kN):

Pull-out forces on wall fixing:
The allowable simply supported span of the handrail (with bar) between points of support is 2.8m.

Horizontal service load on the wall fixing for a span of 2.8m	=	1.50 kN/m x 1.40m	=	2.1 kN/m
Working load pull-out force on the side anchor bolts	=	2.1 kN x 30 / 88.7	=	0.71 kN/bolt

Applying the 50% increase on fixing design loads recommended in BS 6180:2011, this becomes **1.07 kN/bolt**.



Wall fixing detail

Shear forces on wall fixings

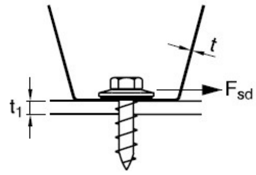
Working load shear force on the 3 No. anchor bolts	=	2.1 kN/3		=	0**.70 kN/bolt**
Ultimate load shear force on the anchor bolts and screws	=	0.70 kN/bolt x 1.5		=	1.065 kN/bolt
			say	=	**1.07 kN/bolt**

Applying the 50% increase in design loads on anchor bolts recommended in BS 6180:2011, the **working load** shear force becomes **1.07 kN/bolt**.

Phillips stainless steel self-tapping screws

Shearing force, construction screws

Dimensioning value F_{sd} kN/screw. Attention is paid both to failure of the edge of the hole and shearing failure in the screw. Safety class 1.



Nom t mm	When calculating t mm	Tensile yield limit N/mm²	Screw diameter 4.2 mm		Screw diameter 4.8 mm		Screw diameter 5.5 mm		Screw diameter 6.3 mm	
			t_1 =t	t_1 = 2.5 t	t1 =t	t_1 = 2.5 t	t_1 =t	t_1 = 2.5 t	t_1 =t	t_1 = 2.5 t
0.4	0.32	250	0.26	0.54	0.28	0.61	0.30	0.70	0.32	0.81
0.5	0.41	250	0.38	0.69	0.40	0.79	0.43	0.90	0.46	1.03
0.6	0.52	250	0.52	0.86	0.56	0.98	0.60	1.12	0.64	1.29
0.7	0.60	350	0.93	1.41	1.00	1.61	1.07	1.85	1.14	2.12
0.8	0.73	350	1.25	1.72	1.34	1.96	1.43	2.25	1.53	2.58
1.0	0.93	250	1.29	1.56	1.38	1.79	1.47	2.05	1.58	2.34
1.0	0.93	350	1.80	2.19	1.93	2.50	2.06	2.86	2.21	3.28
1.2	1.13	350	2.41	2.66	2.58	3.04	2.76	3.48	2.95	3.99
1.5	1.42	250	2.39	2.39	2.60	2.73	2.78	3.12	2.97	3.58
1.5	1.42	350	3.03*	3.03*	3.63	3.82 3.64	3.89	4.37	4.16	5.01
2.0	1.91	350	3.03*	3.03*	4.16 3.64	4.16 3.64	5.72 5.20	5.72 5.20	6.49	6.74
2.5	2.40	350	3.03*	3.03*	4.16 3.64	4.16 3.64	5.72 5.20	5.72 5.20	7.80 6.76	7.80 6.76

In the area of number pairs in the table and marked *, shearing failure in the screw is decisive.
The value to the left in each number pair relates to carbon steel screws, while the number to the right relates to stainless steel screws.

Excerpt of the table at the foot of page 7 of Lindab's literature headed 'Shearing force, construction screws'

Properties of stainless steel for angle brackets and self-tapping screws:

Material type = stainless steel grade 304
Characteristic ultimate tensile strength = 621 N/mm^2
Characteristic 0.2% proof stress = 290 N/mm^2

Phillips self-tapping screws:

Ultimate shear loads taken from the table in Lindab's technical literature.

Thickness of aluminium in the handrail at screw positions = 5.4mm

Thickness of stainless steel angle brackets (Nom t mm) = 3.0mm

Ultimate shear capacity of 4.8mm diameter screws, safety class 1 for Nom t = 2.5mm = 3.64 kN/screw (from Lindab's table)

Balcony 1 system (1.5 kN) ***PAGE 16*** **(B1WB6060300150BP090118R)**

Phillips self-tapping screws: (cont)
For safety classes 2 and 3 this value is divided by 1.1 and 1.2 respectively. Safety class 3 is the highest safety class and has been assumed to apply to balustrades. The shear capacities given in Lindab's table are based upon material having a tensile yield limit of 350 N/mm^2. The values given in the table have been adjusted to allow for the yield stress of stainless steel type 304 (290 N/mm^2.)

The ultimate shear capacity of 6.76 kN/screw has therefore been reduced by 290/350 and divided by 1.2 to represent safety class 3 and 290 N/mm^2 yield stress rather than 350 N/mm^2. The adjusted ultimate shear capacity is then **4.67 kN/screw.**

Ultimate design shear force/screw	=	1.05 kN x 1.5	=	1.575 kN/screw
	= <	4.67 kN/screw	=	OK

Stainless steel brackets
The horizontal parts of the bracket measure 15.7 x 4.0mm and 13.3 x 4.0mm.

Plastic modulus of 15.7 x 4mm + 13.3 x 4mm sections for horizontal loads	=	$\frac{4 \times (15.7)^2}{4} + \frac{4 \times (13.3)^2}{4}$	=	423.36 mm^3
Ultimate resistance moment	=	290 N/mm^2 x 423 mm^3 x $(10)^{-6}$		
	=	0.123 kNm		

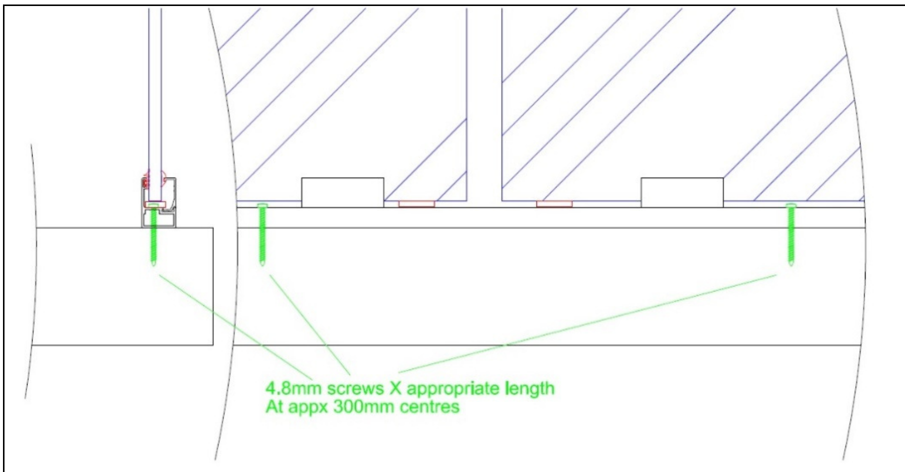
For a simply supported span of 2.8m:

Ultimate load on end bracket	=	(1.5 kN/m x 1.5) x 1.4	=	3.15 kN

This load is applied 30 mm from the face of the bracket.

Ultimate applied moment	=	3.15 x 0.03	=	0.095 kNm
on bracket	= <	0.123 kNm	=	OK

Bottom rail fixings:



The standard bottom rail fixing consists of 4.8mm diameter screws at 300mm centres.

The worst case for design loading on the fixings is when the design service point load of 1.50 kN acts close to the bottom edge of the glass. The load is assumed to be spread by the glass and resisted equally by 3 No. fixings. The fixing screws are then subjected to a working load shear force of 0.50 kN/screw.

Bottom rail fixings: (cont)

The allowable load on the fixing screws varies depending upon the type and thickness of the material into which the screws are inserted.

As an example, fixing to a balcony deck comprising 15mm thick plywood strength class C16, group 1, the basic allowable working load single shear value given in BS 5268 : Part 2 : 1996 for a No. 10 (4.88mm) screw 45mm long is 0.519 kN.

Where a pre-drilled steel component of adequate strength is screwed to a timber member, the basic lateral load of 0.519 kN is multiplied by a modification factor of 1.25, making an allowable shear value of 0.648 kN, which is adequate in relation to the design working load shear force of 0.50 kN.

Other values of allowable shear loads on fixings will apply where the deck material is of different strength and/or thickness.

The installers should satisfy themselves that the fixings chosen are adequate to resist the design loads in relation to the fixing material in each individual installation.

Orbit (Balcony 1) system (with and without 58 x 4mm steel internal reinforcing bar)

using 60 x 60 x 5mm SHS posts and 300 x 150 x 15mm base plates

1) On single span and corner balconies, the handrail (with 58 x 4mm internal steel reinforcing bar) is capable of supporting the design ultimate loads on spans up to **2.8 metres** between points of support. (i.e. a handrail wall fixing, or a handrail corner joint.) The handrail (without internal reinforcing bar) is capable of supporting the design ultimate loads over single spans and corner balconies up to **2.5 metres** between points of support.

2) On longer balconies where the length of the balustrade exceeds **2.8 metres**, the handrail (without internal reinforcing bar) is used in conjunction vertical posts installed at up to **2.0m** between post centres. The posts comprise **60 x 60 x 5mm** square hollow steel sections (SHS) in steel grade S 275 H.

3) The SHS posts are welded to **300 x 150 x 15mm** base plates (steel grade S 275) by means of full strength butt welds, or continuous 8mm fillet welds **(8 FW)**. 13mm diameter holes are provided for **8 no. M12** holding down bolts.

4) The 107.4mm diameter x 4mm wall fixing is used with the Balcony 1 system handrail (with and without bar). On single span and corner balconies, the design **working load** pull-out force on the wall fixing bolts is **1.07 kN/bolt**. The horizontal design **working load** shear force on the wall fixing bolts is also **1.07 kN/bolt**.

5) On longer balconies, where posts are installed at a maximum spacing of **2.0m**, the design **working load** pull-out force on the holding down bolts is **10.78 kN/bolt**. This load should be achievable using M12 drilled resin anchor bolts or similar installed into good quality concrete, or by drilling through and anchoring to the underside of a suitable concrete slab. Higher bolt forces can be achieved by direct bolting to a substantial steel frame.

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 4.8mm diameter self-tapping stainless steel screws connecting the handrail to the stainless steel angle brackets at wall and post fixings are adequate to support the design loads specified in relevant British and European Standards. The 3mm thick stainless steel brackets are also adequate to support these loads.

8) The standard bottom rail fixing comprises 4.8mm diameter screws inserted into the balcony deck at 300mm centres. At this spacing the fixings are required to have a working load shear capacity of 0.50 kN/screw. The installers should satisfy themselves that the screws chosen are suitable to resist this load when inserted into the particular deck material present on a specific project. Where the deck material is of reduced strength and/or thickness the spacing of the screws should be reduced accordingly.

9) The 10mm thick thermally toughened safety glass infill panels are adequate to support the design loads specified in the relevant British and European Standards.

Prepared for and on behalf of Balconette by
A. G. Bice CEng, FICE, FIStructE.