Balcony 2 system handrail with & without internal reinforcing bar: (0.74 kN) ***PAGE 1*** **(B2WB6060300150BPR)**

Structural Calculations for Aerofoil (BALCONY 2) system handrail (with & without) 58 x 4mm internal steel reinforcing bar using 60 x 60 x 5 SHS posts & 300 x 150 x 15 base plates

Our ref: B2WB6060300150BPR

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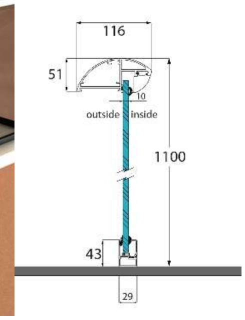
Balcony 2 Balustrade fixed between two walls

Balcony 2 Balustrade on a 3 sided balcony with a central post



Balcony 2 section

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.

Design loads:

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 without obstacles for moving people and not susceptible to overcrowding (viii) & (ix)

Service load on handrail = Q_k = 0.74 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 1.0 kN/m^2

Point load on glass infill = point load = 0.50 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/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

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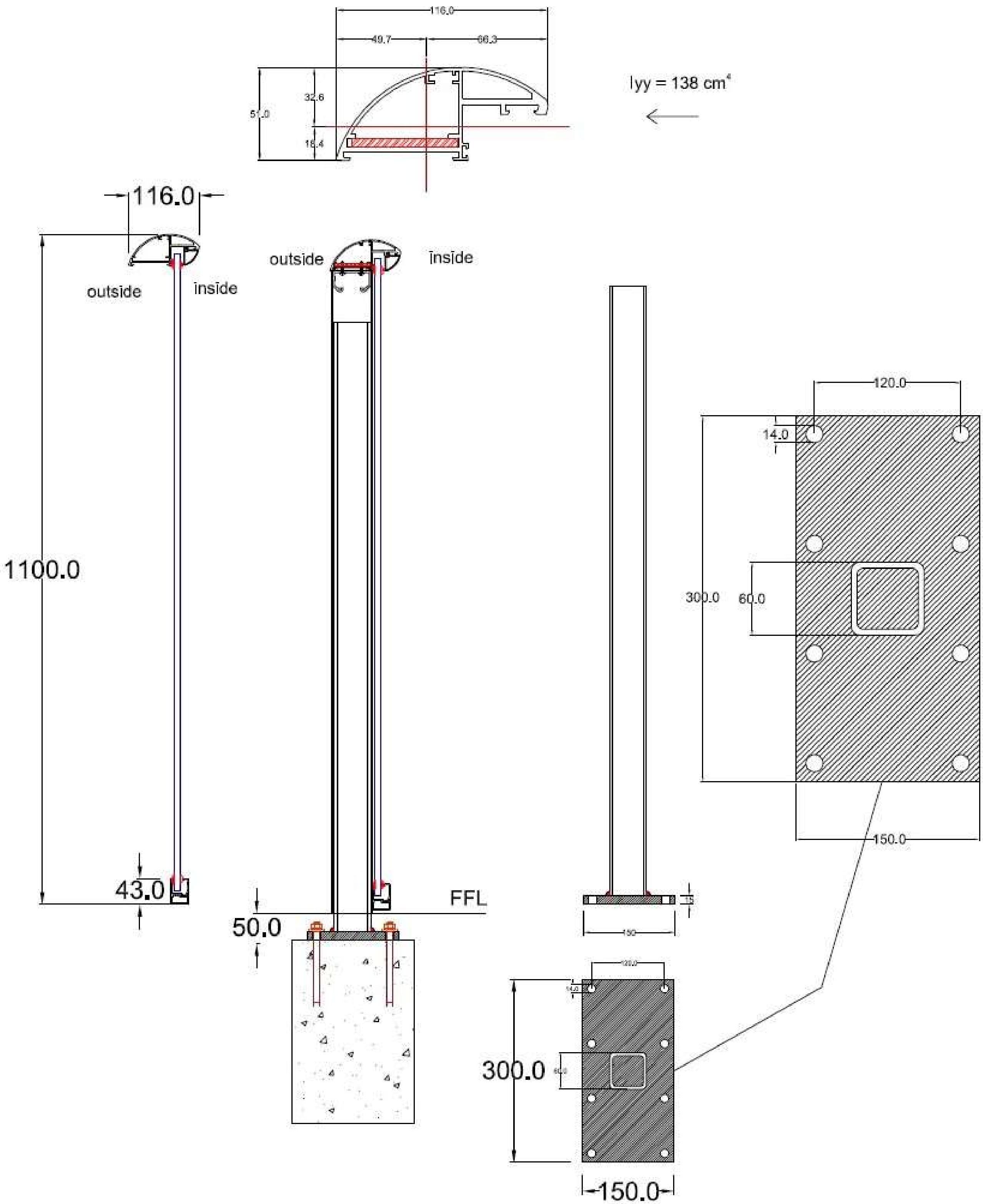
Table 2: BS6180:2011

- 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.

PAGE 3 **(B2WB6060300150BPR)**



Section of Balcony 2 system, post and base plate details.

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Balconette is a trading name of Balcony Systems Solutions Limited. Registration No. 6937600. VAT No. 975 6213 93

Balcony 2 system: Section properties of handrail:

Material type	=	Extruded aluminium type 6063 T5		
Characteristic 0.2% proof stress	=	f_o	=	130 N/mm^2
Characteristic ultimate tensile strength	=	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}	=	138 cm^4
Least elastic modulus about the y-y axis	=	W_{el}	=	22.81 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Shape factor (conservative value)	=	α	=	1.2 say
Design ultimate resistance to bending about the y-y axis	=	M_{Rd}	=	$M_{o, Rd}$
	=	$\alpha W_{el} f_o / \gamma_{M1}$		
	=	$\frac{1.2 \times 22.81 \text{ cm}^3 \times 130 \text{ N/mm}^2 \times (10)^{-3}}{1.1}$		
	=	**3.235 kNm**		

Section properties of handrail (no bar):

Properties as above except as follows:

Moment of inertia about the y-y axis	=	I_{yy}	=	87 cm^4
Least elastic modulus about the y-y axis	=	W_{el}	=	14.45 cm^3
Ultimate resistance to bending about y-y	=	M_{Rd}	=	**2.049 kNm**

Handrail (with bar): single span and corner system:

Ultimate horizontal load on handrail	=	F	=	1.11 kN/m
Horizontal BM on handrail between points of support for simply supported spans (worst case)	=	M	=	$\frac{F L^2}{8}$
Design ultimate horizontal load on handrail	=	F	=	0.74 kN/m x 1.5
			=	1.11 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 between points of support based upon the moment capacity of the handrail	=	$\left[\frac{8 \times M_{Rd}}{F}\right]^{0.5}$		
	=	$\left[\frac{8 \times 3.325 \text{ kNm}}{1.11}\right]^{0.5}$		
	=	4.895m	say =	4.80m

In terms of bending capacity the handrail can span up to 4.80m simply supported between points of support.

However for a single span simply supported handrail the service load deflection is limited to a maximum of 25mm.

Handrail (with bar): single span and corner system (cont):

Deflection (Δ) of a simply supported span (L) with an imposed UDL (F)	Δ	=	$\frac{5 F L^4}{384 E I}$
For a handrail span of 4.0m simply supported	Δ	=	$\frac{5 (740 \times 4.0) (4000)^3}{384 \times 70\,000 \times 138 \times (10)^4}$
		=	25.53mm = slightly > 25mm but say OK

Therefore deflection limits the allowable simply supported span of the handrail to **4.0m**.

Handrail (without bar): single span and corner system:

Design horizontal load on handrail	=	1.11 kN/m
Allowable simply supported span based upon the moment capacity	=	$\left[\frac{8 \times 2.049 \text{ kNm}}{1.11}\right]^{0.5}$
	=	3.84m

In terms of moment capacity the handrail (without bar) can span up to 3.84m simply supported between points of support. However the allowable span is reduced to 3.50m to keep service load deflection to less than 25mm.

Service load deflection of handrail (no bar) for a simply supported span of 3.50m	=	$\frac{5 (740 \times 3.5) (3500)^3}{384 \times 70000 \times 87 \times (10)^4}$	
	=	23.74mm	
	= <	25mm	OK

The allowable simply supported span of the handrail (no bar) is 3.50m.

Longer balconies with posts:

On longer balconies exceeding 4.0m in length the handrail (without bar) is used in conjunction with 60 x 60 x 5mm vertical steel posts (SHS) installed at 3.13m maximum spacing to support the handrail.

The overall combined displacement of the handrail + post at any point of the barrier from its original unloaded position is limited to 25mm.

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

Steel grade	=	S 275 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}	=	16.80 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	$M_{pl,Rd}$	=	$\frac{f_y \times W_{pl}}{\gamma_{Mo}}$	=	$\frac{275 \times 20.90 \times (10)^{-3}}{1.0}$
				=	**5.75 kNm**
Ultimate moment on posts to top of base with posts at 3.13m centres	M_d	=	(0.74 x 1.5 x 3.13) x 1.135		
		=	3.94 kNm		
		= <	5.75 kNm		OK

Service load deflection of post supporting 3.13m of handrail	Δ	=	$\frac{P\ L^3}{3\ E\ I}$		
		=	$\frac{(740 \times 3.13)\ (1135)^3}{3 \times 210\ 000 \times 50.50 \times (10)^4}$		
		=	10.644mm		
Service load deflection of handrail for a post spacing of 3.13m	Δ	=	$\frac{5\ (740 \times 3.13)\ (3130)^3}{384 \times 70000 \times 87 \times (10)^4}$		
		=	12.186mm		
Combined total displacement of handrail + post from the original unloaded position (service loads)	Δt	=	10.644mm + 15.186		
		=	25.83mm		
		=	Slightly > 25mm		but say OK

Summary: The Balcony 2 handrail (without bar), in conjunction with 60x60x5mm SHS posts, is adequate to support the design imposed loading on the handrail in terms of both strength and deflection limitations for posts spaced at up to 3.13 metre centres.

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 site 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 1991-11-4:2002 + A1:2010. We have chosen to prepare a calculation based upon certain conditions, resulting in specific coefficients.

The formula applied results in an overall **characteristic wind pressure.** The design and calculations will be relevant not only to the conditions specified herein but to any combination of factors that results 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 **1.33 kN/m²** as determined in these calculations require separate consideration.

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

a) Sites located geographically within the 23 m/sec isopleth in Figure NA.1 of the UK National Annex. This covers most of England and the Eastern half of Wales.

b) Site altitude 100m maximum above sea level.

c) Top of balustrade located 30m maximum above ground level.

d) Site located in a coastal area exposed to the open sea, terrain category 0 of BS 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) Site with no significant orography in relation to wind effects (ie. orography coefficient 1.0).

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

Wind load design: *PAGE 7* (B2WB6060300150BPR)

Basic wind speed	$V_{b\ map}$	=	23 m/sec	
Site altitude above sea level	A	=	100m	
Handrail height above ground level	z	=	30m	
Altitude factor	C_{alt}	=	$1 + (0.001 \times A)\ (10/z)^{0.2}$	(eqn. NA. 2b)
		=	$1 + (0.1)\ (10/30)^{0.2}$	
		=	1.08	
Directional factor	C_{dir}	=	1.0	
Probability factor	C_{prob}	=	1.0	
Seasonal factor	C_{season}	=	1.0	
Site wind speed	V_b	=	$V_{b\ map}\ (C_{dir} \times C_{prob} \times C_{season})\ (C_{alt})$	
		=	23m/sec x 1.08	
		=	24.84 m/sec	
Site wind pressure	qb	=	$0.613\ (24.84)^2$	
		=	$378\ N/m^2$	
Exposure factor	Ce (z)	=	3.42	(Figure NA.7)
Peak velocity pressure	qp	=	qb x Ce (z)	
(characteristic wind pressure)		=	0.378 x 3.42	
		=	$1.329\ kN/m^2$	
	say	**=**	**$1.33\ kN/m^2$**	
Wind load reaction on the handrail		=	$1.33\ kN/m^2 \times 0.55$	
		=	0.74 kN/m	

Summary: For sites that come within the parameters listed on page 6 of these calculations, the specified imposed service UDL on the handrail and the characteristic design wind load reaction on the handrail are the same

Wind pressure on the glass is greater than the specified overall design imposed UDL.

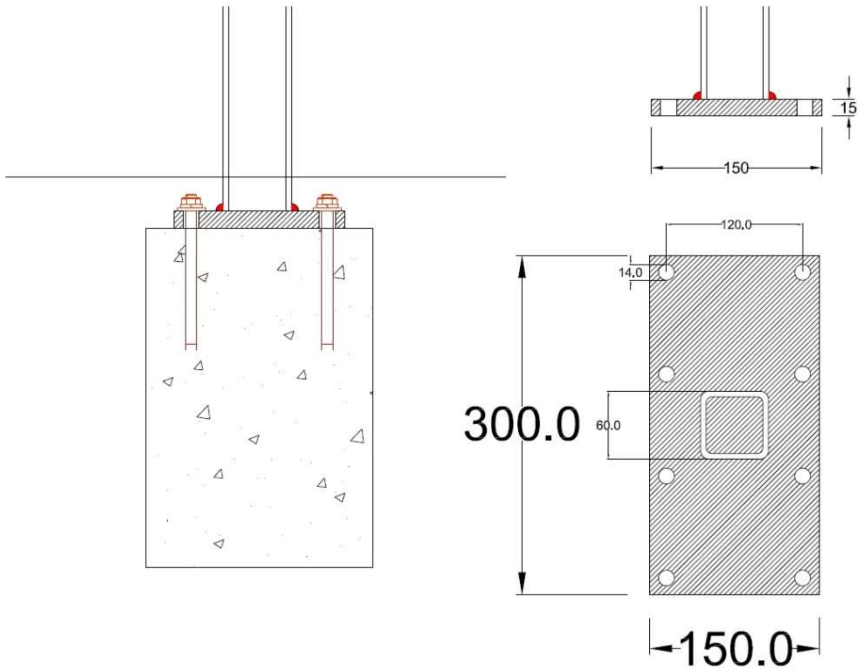
Wind loading is therefore the dominant condition in terms of glass design.

Partial safety factor for wind load considered as a separate leading variable action	γ_{Q1}	=	1.50
Ultimate design wind pressure		=	$1.35\ kN/m^2 \times 1.5$
		=	$2.025\ kN/m^2$

Summary of design loads:

Element	**Service load**	**Ultimate load**
Horizontal imposed line load and wind applied to the handrail 1100mm above FFL. (ie. 1135mm above the top of the base)	0.74 kN/m	1.11 kN/m
Wind load on the glass	$1.35\ kN/m^2$	$2.025\ kN/m^2$
Point load applied in any position	0.50 kN	0.75 kN

Baseplate and HD bolts: ***PAGE 8*** **(B2WB6060300150BPR)**



Spacing of posts (maximum)	=	3.13 m		
Design horizontal service load on handrail	=	0.74 kN/m		
Ultimate design moment to underside of base with posts at 3.13m centres	=	(0.74 kN/m x 1.5 x 3.13) x 1.15	=	4.0 kNm
Nominal ultimate load tension capacity of M12 (8.8 grade) bolts	=	37.8 kN/bolt		
Lever arm between the centres of bolts in tension and compression	=	120 mm		
Ultimate load bolt tension on 4 No. bolts	=	4.0 kNm / 4 No. x 0.12	=	8.33 kN/bolt
Working load bolt tension on 4 No. bolts	=	8.33 kN / 1.50	=	5.55 kN/bolt

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 above recommendation, the design **working load bolt force** becomes **8.33 kN/bolt.**
A **working load** tension capacity of **8.33 kN/bolt** should be within the capacity of M12 drilled resin anchor bolts into good quality concrete, or by drilling through and anchoring to the underside of a concrete slab.

The nominal tension capacity of M12 (8.8 grade) bolts is 37.80 kN/bolt. Higher bolt forces can therefore be achieved by direct bolting to a substantial steel frame.

Separate consideration is required where it is proposed to use other types of fixings, or where fixings are to be inserted into weaker materials.

Base plates:

300 wide x 150 deep x 15mm thick.

Ultimate applied moment on posts at 3.13m maximum spacing	M_a	=	(0.74 x 1.5) x 3.13 x 1.135	=	3.94 kNm
Plastic modulus of base 300mm wide x 15mm thick	W_{pl}	=	$\frac{300 \times (15)^2}{4}$	=	$16875mm^3$
Ultimate moment capacity of base	Mu	=	$\frac{275\ N/mm^2 \times 16875mm^3 \times (10)^{-6}}{1.0}$	=	4.64 kNm
		= >	3.94 kNm	=	OK

Welded connection between post & base plate

The 60 x 60 x 5mm SHS post is welded to the top of the base by means of a full strength butt and/or fillet weld.

Elastic section modulus of post	W_{el}	=	$16.80\ cm^3$		
Maximum ultimate elastic bending stress on post	$\frac{M_a}{W_{el}}$	=	$\frac{3.94 \times (10)^6}{16.80 \times (10)^3}$	=	$234.52\ N/mm^2$
		=	1.173 kN/mm on 5mm thick section		
Transverse capacity of 6mm fillet weld		=	1.155 kN/mm	=	say OK

Summary: A full strength butt weld, or a continuous 6mm fillet weld around the perimeter of the post, are adequate. Also adequate are any combination of welds that achieves a full strength connection.

Balcony 2 system handrail:

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/mm^2

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

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/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)

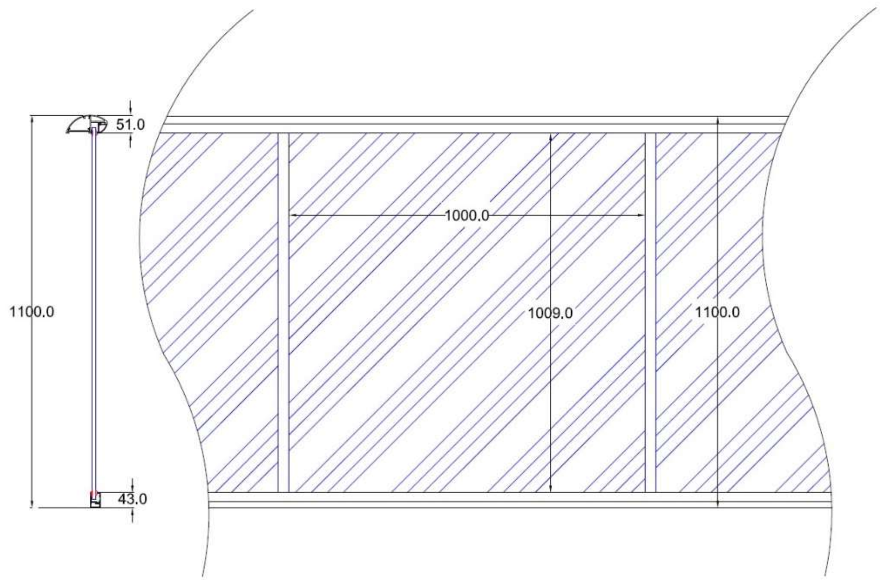
$\gamma_{M;A}$ = material partial factor
= 1.6 for basic annealed glass

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

Ultimate design stress $f_{g;d}$ = $\frac{0.89 \times 1.0 \times 45}{1.6} + \frac{1.0\,(120 - 45)}{1.2}$
= **87.53 N/mm^2**

Section modulus of glass 10mm thick Z = $\frac{1000 \times (10)^2}{6}$ = 16667 mm^3/m

Ultimate moment capacity of glass 1000mm wide x 10mm thick Mu = $f_{g;d} \times Z$
= 87.53 N/mm^2 x 16667mm^3 x $(10)^{-6}$
= **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.

Separate design loading conditions are considered:

1. Uniformly distributed load on the infill of 1.35 kN/m^2

Ultimate UDL on glass	w	=	1.35 kN/m^2 x 1.5	=	2.025 kN/m^2
Ultimate moment on glass due to UDL on span of 1.0m	Mu	=	$\frac{2.025 \text{ kN/m}^2 \times (1.0)^2}{8}$	=	0.253 kNm/m
		= <	1.459 kNm	=	OK

The reaction on the handrail from the uniformly distributed ultimate design load on the glass is less than the ultimate imposed 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.

2. Point load on the infill of 0.5 kN

Point load on the glass	=	0.5 kN point load applied in any position		
Worst case for bending stress on the glass due to point load	=	point load applied at mid-height of glass		
Ultimate moment on glass due to point load	=	$\frac{0.5 \text{ kN} \times 1.5 \times 1.0\text{m}}{4}$	=	0.1875kNm

Conservatively, it is assumed that this bending moment is carried by a 300mm wide vertical strip of glass.

Moment capacity of 300mm	=	1.459 kNm x 0.3	=	0.4377 kNm
strip	=	> 0.1875kNm	=	OK

The glass is adequate to support the ultimate design loading.

Glass deflection: *PAGE 12* (B2WB6060300150BPR)

1. Service load deflection due to the design UDL:

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 1.35 kN/m^2	=	$\frac{5\ w\ L^4}{384\ E\ I}$				
on a simply supported span of 1.0m	=	$\frac{5 \times (1350 \times 1.0)\ (1000)^3}{384 \times 70\ 000 \times 83333}$				
	=	3.01 mm	<	$\frac{span}{65}$	=	OK

2. Point load:
Conservatively, for deflection calculation purposes consider that the design point load of 0.50 kN is carried by a 300mm wide vertical strip of glass:

Inertia of glass 10mm thick x 300mm long	=	0.3 x 83333 mm^4			=	25 000 mm^4
Service load deflection due to a point load of 0.5 kN	=	$\frac{P\ L^3}{48\ E\ I}$				
applied at mid-span	=	$\frac{500 \times (1000)^3}{48 \times 70\ 000 \times 25\ 000}$				
	=	5.95mm	<	$\frac{span}{65}$	=	OK

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

Wall fixings:
The handrail wall fixing consists of 3mm thick stainless steel angles bolted to the wall with 2 No. M8 stainless steel resin anchors or similar and secured to the handrail with 2 No. 4.8mm diameter stainless steel Phillips self-tapping screws.

The maximum span of the handrail (with bar) between points of support is **4.0m**.

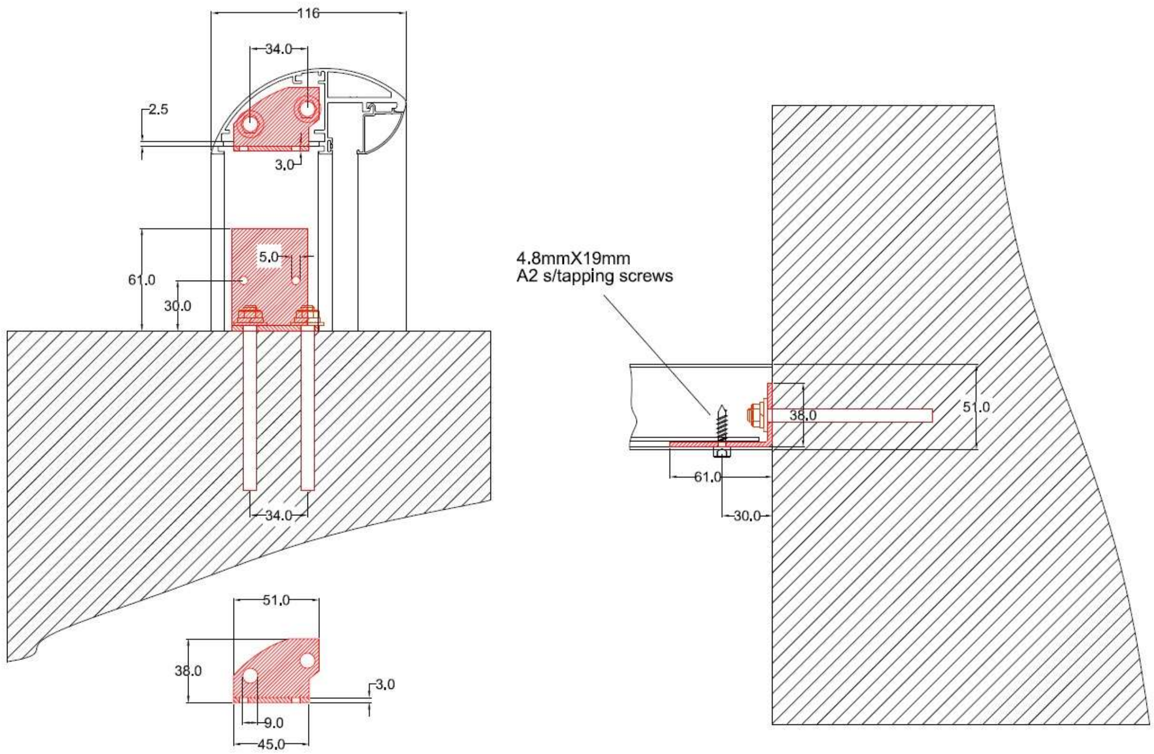
The maximum span of the handrail (without bar) between points of support is **3.5m**.

Horizontal service (working)	=	0.74 kN/m x 2.0m
load on the wall fixing for a	=	1.48 kN/fixing
span of 4.0m		

There are two options for wall brackets; the standard wall bracket and the larger wall bracket. The larger wall bracket has a greater distance between the fixings and so allows a smaller load in the two bolts.

Standard Balcony 2 wall fixings:

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 are 34mm apart horizontally.



Pull-out forces on wall fixing

Working load pull-out force on the anchor bolts	=	$1.48 \text{ kN} \times \frac{30}{34}$	=	1.305 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes 1.958 kN/bolt, **say 2.0 kN/bolt.**

Summary: For a handrail span of **4.0m** using the standard Balcony 2 wall bracket, the **working load** pull-out force on the wall fixing bolts is **2.0 kN/bolt,** including the 50% increase as per BS 6180.

Shear forces on wall fixings

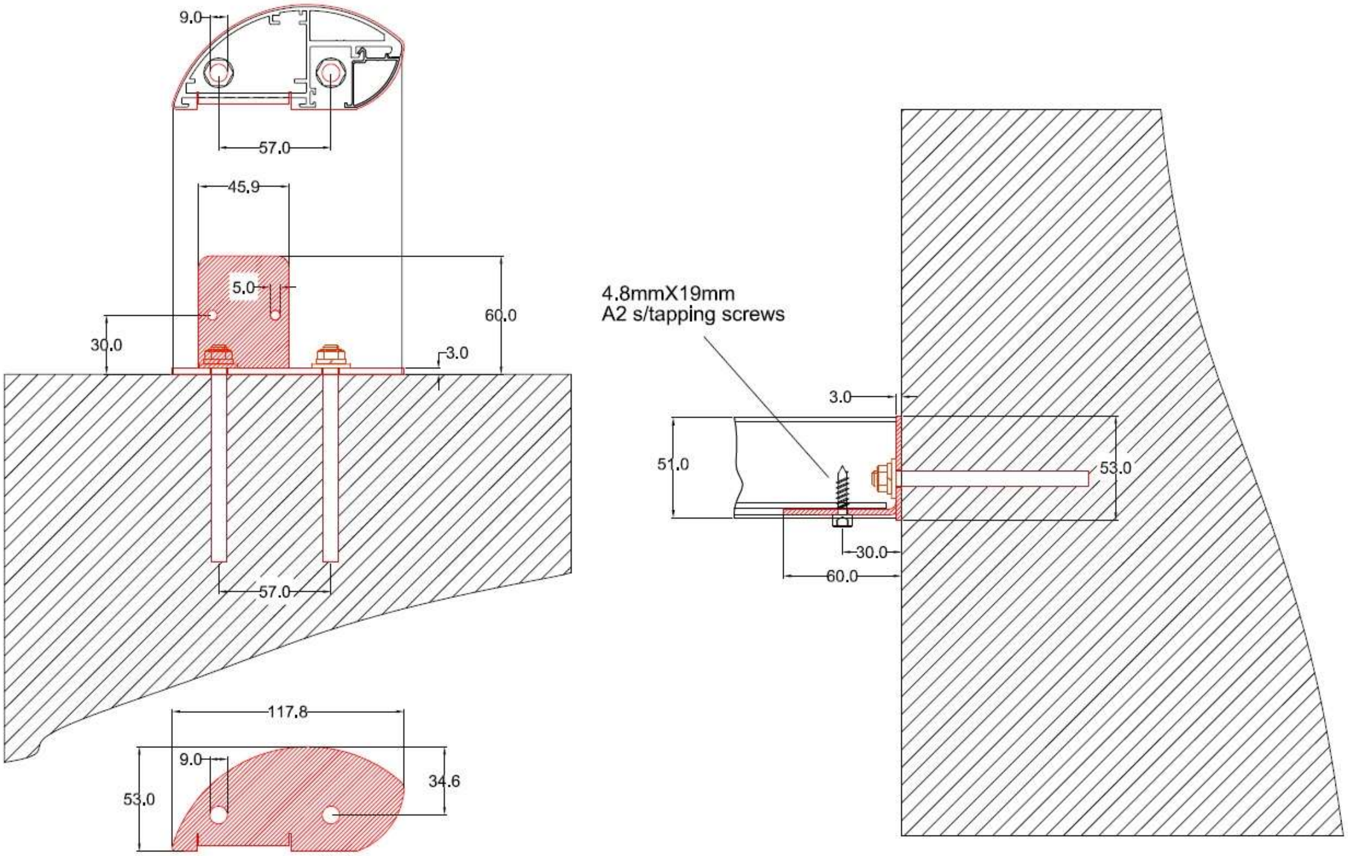
Working load shear force on the anchor bolts and the 4.8mm x 19mm stainless steel self-tapping screws	=	1.48 kN/2	=	0.74 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes **1.11 kN/bolt**.

Summary: For a handrail span of **4.0m** using the standard Balcony 2 wall bracket, the **working load** shear force on the wall fixing bolts is **1.11 kN/bolt**, including the 50% increase as per BS 6180.

<u>Larger Balcony 2 wall fixings:</u>

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 are 57mm apart horizontally.



<u>Pull-out forces on wall fixing</u>

Working load pull-out force on the anchor bolts for a maximum handrail (with bar) span of 4.0m = $1.48 \text{ kN} \times \frac{30}{57}$ = 0.779 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes **1.169 kN/bolt.**

Summary: For a handrail span of **4.0m** using the **larger** Balcony 2 wall bracket, the **working load** pull-out force on the wall fixing bolts is 1.169 kN/bolt, **say 1.2 kN/bolt,** including the 50% increase as per BS 6180.

<u>Shear forces on wall fixings</u>

Working load shear force on the anchor bolts and the 4.8mm x 19mm stainless steel self-tapping screws = 1.48 kN/2 = 0.74 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes **1.11 kN/bolt**.

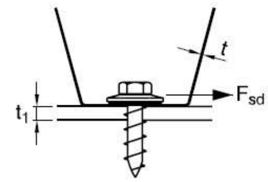
Summary: For the maximum span of **4.0m** for the handrail (with bar), the design **working load** shear force on the wall fixing bolts is **1.11 kN/bolt** for both the **standard** and the **larger** wall brackets, including the 50% increase as per BS 6180.

For the handrail (without bar) the maximum span is 3.5m. Loads on fixing bolts are therefore reduced in the ratio of 3.5/4.0.
For the standard wall fixing bracket: Bolt pull-out force is **1.75 kN/bolt**, shear force is 0.97 kN/bolt, say **1.0 kN/bolt**.
For the larger wall fixing bracket: Bolt pull-out force is **1.05 kN/bolt**; shear force is 0.97 kN/bolt, say **1.0 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'

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)

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.)

Phillips self-tapping screws (cont)

The ultimate shear capacity of 3.64 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 2.51 kN/screw.

Ultimate shear force/screw on a simply supported span of 4.0m	=	1.11 kN				
Factor of safety against shear failure for a 4.8mm diam. screw	=	2.51/1.11	=	2.26	=	OK

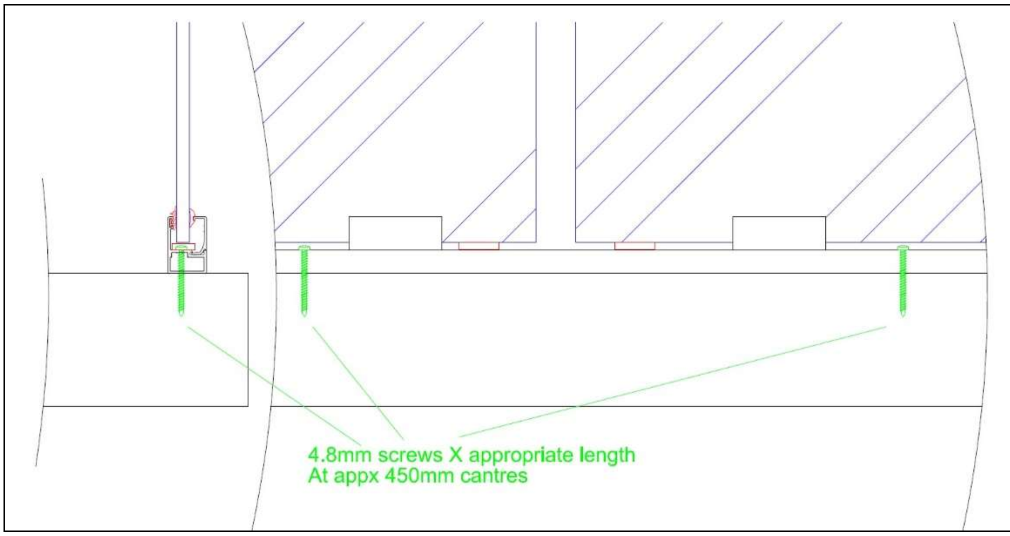
Stainless steel brackets
The horizontal part of the bracket measures 45mm wide x 3mm thick.

Plastic modulus of 45 x 3mm section for horizontal loads	=	$\frac{3 \times (45)^2}{4}$	=	1519 mm^3	
Resistance moment of section	=	290 N/mm^2 x 1519 mm^3 x $(10)^{-6}$			
for horizontal loads	=	0.44 kNm			
For a simply supported span of 4.0m: ultimate load on end bracket	=	1.48 x 1.5	=	2.22 kN	

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

Ultimate horizontal moment applied to the bracket on the maximum simply supported span of 4.0m	=	2.22 x 0.03	=	0.067 kNm	
			=	< 0.44 kNm	OK

<u>Bottom rail fixing:</u>



The standard bottom rail fixing consists of 4.8mm diameter screws at 450mm centres.

The worst case for design loading on the fixings is when the design service point load of 0.50 kN on the glass acts at the position of a fixing. The fixing screw is then subjected to a working load shear force of 0.50 kN/screw.

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 shear load 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.

SUMMARY ***PAGE 18*** **(B2WB6060300150BPR)**

Aerofoil (BALCONY 2) system handrail with & without 58 x 4mm steel internal reinforcing bar using 60 x 60 x 5mm SHS posts fitted to 300 x 150 x 15 base plates:

1) On single span and corner balconies, the **handrail (with bar)** is capable of supporting the design factored loads over spans up to **4.0 metres** between points of support. (i.e. a handrail wall fixing, or a handrail corner joint.) The **handrail (without bar)** is capable of supporting the design factored loads over spans up to **3.5m** between points of support.

2) On longer balconies where the length of the balustrade exceeds **4.0 metres**, vertical posts are installed at a maximum spacing of **3.13 metres** between post centres. The posts comprise **60 x 60 x 5mm** square hollow steel sections (SHS) with aluminium sleeves.

3) The SHS posts are welded (full strength butt welds, continuous 6mm fillet welds, or any combination of welds that achieves aa full strength connection) to **300 x 150 x 15mm** steel base plates. 14mm diameter holes are provided for **8 No. M12** holding down bolts.

4) For the maximum span of **4.0 metres** on single span and corner balconies, the horizontal working pull-out load on the wall fixing bolts is **2.0 kN/bolt** for the **standard** wall bracket, or **1.2 kN/bolt** for the **larger** wall bracket. The horizontal working shear force on the wall fixing bolts is **1.11 kN/bolt** for both types of bracket. 9mm diameter holes are provided in wall fixing brackets for M8 drilled anchor bolts.

5) On longer balconies, where posts are installed at a maximum spacing of **3.13m**, the design **working load** pull-out force on the holding down bolts is **8.33 kN/bolt**, including the 50% increase on calculated values recommended in BS 6180:2011. This load should be achievable using most M12 drilled resin anchor bolts into good quality concrete, or by drilling through and anchoring to the underside of a concrete slab. Higher loads are achievable using M12 (8.8 grade) bolts connected direct to a substantial steel frame.

6) Separate designs should be considered when fixing into weaker materials.

7) 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.

8) 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.

9) The standard bottom rail fixing comprises 4.8mm diameter screws inserted into the balcony deck at 450mm 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.

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

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