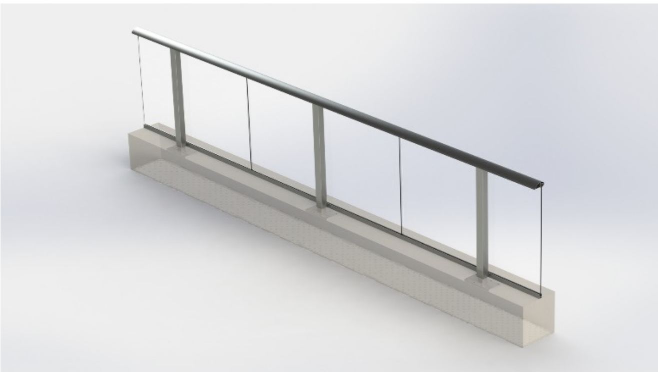
Makes the most of yourview

Structural Calculations for BALCONY 2 system handrail with and without 58 x 4mm internal steel reinforcing bar using 60 x 60 x 5 SHS posts & 300 x 150 x 15 base plates – For 1.5kN loading

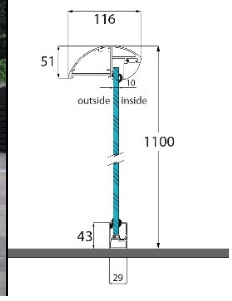
Our ref: B2NW6060300150BPR

Date of issue: August 2017
Revised January 2019



Balcony 2 Balustrade 3D mock up

Balcony 2 Balustrade on a public roof terrace



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 classes 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 – Classes (X), (Xi) & (Xii).
All retail areas – Class (Xiii).
Pedestrian areas in car parks – Class (xiv).

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 infill Qk1 = A uniformly distributed load of 1.50 kN/m^2

Point load on glass infill = 1.50 kN applied to any part of the glass infill panels

Balcony 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 2*** **(B2NW6060300150BPR)**

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

Table 2: BS6180:2011

Balcony 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 3*** **(B2NW6060300150BPR)**

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.

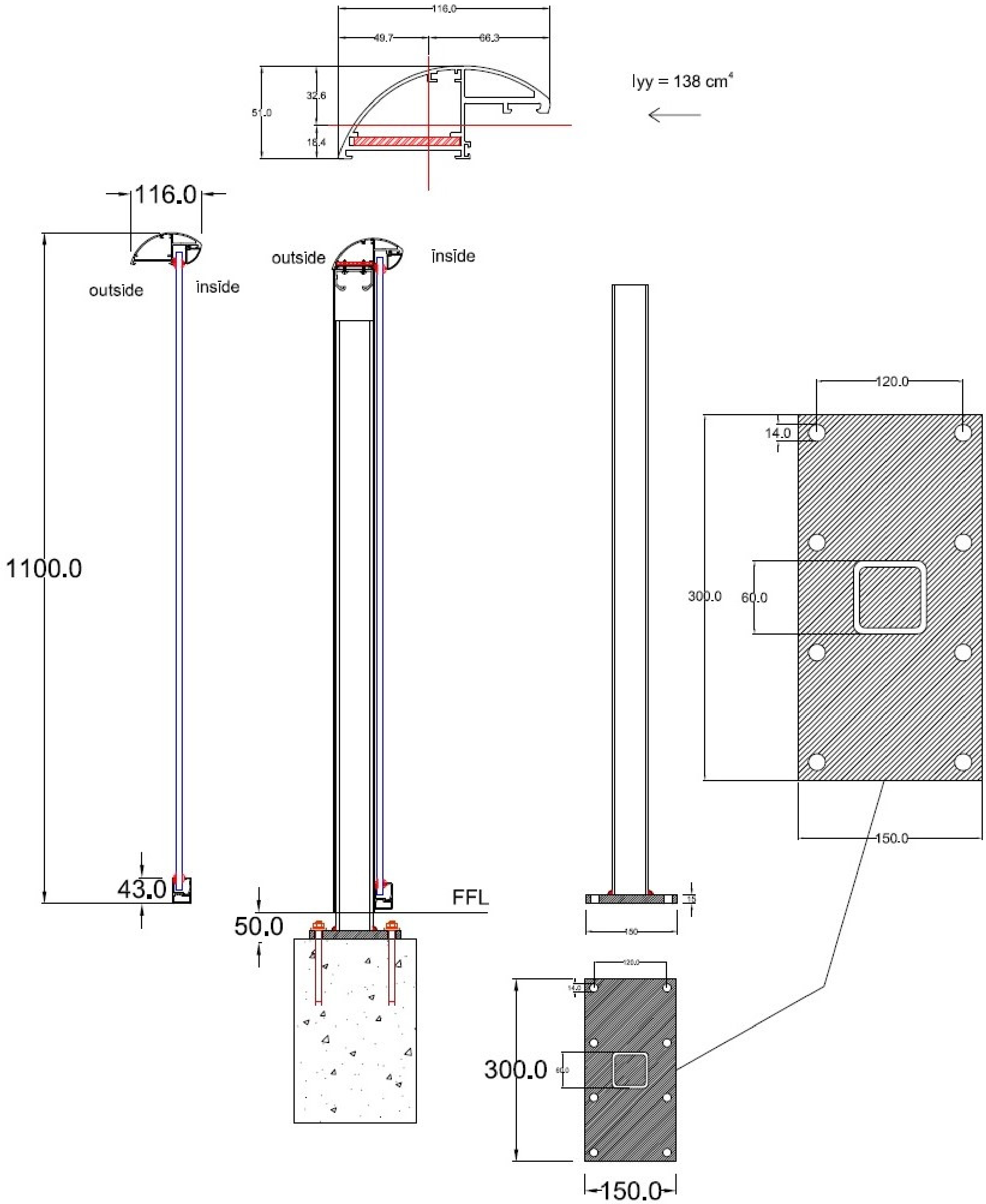
Table 2: BS6180:2011

- These loads are considered as three separate load cases. They are not combined.
- 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.
- Wind loading is considered as a separate design case. It is not considered in combination with imposed loads.

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 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 4*** **(B2NW6060300150BPR)**



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

Balcony 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 5*** **(B2NW6060300150BPR)**

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 severe 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 **2.675 kN/m^2** as determined below require separate calculation.

Site parameters selected for wind load calculation:

a) 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.

b) 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.

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

d) Site altitude **375m** maximum above sea level.

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

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 factor is 1.0. This is a slightly conservative approach.

Wind load design:

Basic wind speed	$V_{b\ map}$	=	27 m/sec	
Site altitude	A	=	375m above sea level	
Top of balustrade	z	=	50m above site level	
Altitude factor	C_{alt}	=	$1.0 + (0.001 \times A)\ (10/z)^{0.2}$	(Equation NA. 2b)
		=	1.0 + (0.375) (0.7248)	
		=	1.272	
Seasonal factor	C_{season}	=	1.0	
Directional factor	C_{dir}	=	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 1.272	
		=	34.34 m/sec	

Balcony 2 system (Aerofoil) handrail with (1.5 kN):

Wind load design (cont):

Site wind pressure	q_b	=	$0.613\ (V_b)^2$
		=	$0.613\ (34.34)^2$
		=	$722.87\ N/m^2$
Exposure factor	$C_e\ (z)$	=	3.7 (Figure NA7)
Peak velocity pressure	q_p	=	$q_b \times C_e\ (z)$
(**characteristic wind pressure)**		=	$0.723\ kN/m^2 \times 3.7$
		=	**$2.675\ kN/m^2$**
Wind load reaction on handrail		=	$2.675\ kN/m^2 \times 0.55$
		=	$1.47\ kN/m$
		= <	1.50 kN/m service line load

Summary: For sites that come within the parameters listed on page 5 of these calculations, the characteristic design wind load reaction on the handrail is slightly less than the specified imposed line load of 1.50 kN/m. Wind loading is therefore not the critical design case for the handrail and posts. The characteristic wind load of $2.675\ kN/m^2$ is however the critical design case in terms of glass design.

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 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}	=	$20.81\ cm^3$
Partial factor for material properties	=	γ_{M1}	=	1.10
Value of shape factor (conservative value)	=	α	=	1.2 say

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

$$= \frac{1.2 \times 20.81\ cm^3 \times 130\ N/mm^2 \times (10)^{-3}}{1.1}$$

= **2.95 kNm**

Design ultimate horizontal load on handrail F = 1.50 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 (with bar) = $L = \left[\frac{8 \times M_{Rd}}{F}\right]^{0.5} = \left[\frac{8 \times 2.95\ kNm}{2.25}\right]^{0.5} = 3.24m$

In terms of bending capacity the handrail (with bar) can span up to 3.24m 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.

Balcony 2 system (Aerofoil) handrail with (1.5 kN):

Handrail with bar:

Deflection (Δ) of a simply supported span (L) with an imposed UDL (F)

$$\Delta = \frac{5\,F\,L^4}{384\,E\,I}$$

For a handrail (with bar) span of 3.24m simply supported

$$\Delta = \frac{5\,(1500 \times 3.24)\,(3240)^3}{384 \times 70\,000 \times 138 \times (10)^4}$$

$$= 22.28\text{mm}$$

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

The handrail with strengthening bar is adequate to support the design imposed horizontal service load of 1.5 kN/m in terms of both ultimate bending strength and service load deflection for spans up to 3.24 metres.

Properties of handrail (without bar):

Properties as for the handrail (with bar) except as follows:

Inertia about the y-y axis	I_{yy}	=	87.0 cm^3
Least elastic modulus about the y-y axis	W_{el}	=	14.45 cm^3
Design ultimate resistance to bending	M_{Rd}	=	2.049 kNm
Design ultimate horizontal load on handrail (without bar)	F	=	1.50 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

$$L = \left[\frac{8 \times M_{Rd}}{F}\right]^{0.5} = \left[\frac{8 \times 2.049\text{ kNm}}{2.25}\right]^{0.5} = 2.70\text{m}$$

In terms of bending capacity the handrail (without bar) can span up to 2.70m simply supported between points of support.

Service load deflection is limited to 25mm:

Service load deflection for a handrail (no bar) on a simply supported span of 2.7m

$$= \frac{5\,(1500 \times 2.7)\,(2700)^3}{384 \times 70\,000 \times 87 \times (10)^4}$$

$$= 17.04\text{mm}$$

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

Longer balconies with posts:

On longer balconies the handrail (without bar) is used in conjunction with vertical posts installed at 2.30m maximum centres to support the handrail.

The post comprise 60 x 60 x 5mm square hollow sections (SHS) in steel grade S 355 H.

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

Balcony 2 system (Aerofoil) handrail with (1.5 kN): **PAGE 8** (B2NW6060300150BPR)

Longer balconies with posts (cont):

For a post spacing of 2.30m service load deflection of the handrail (without bar)	Δ	=	$\frac{5\,F\,L^4}{384\,E\,I}$			
		=	$\frac{5\,(1500 \times 2.3)\,(2300)^3}{384 \times 70\,000 \times 87 \times (10)^4}$			
		=	8.97mm			

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

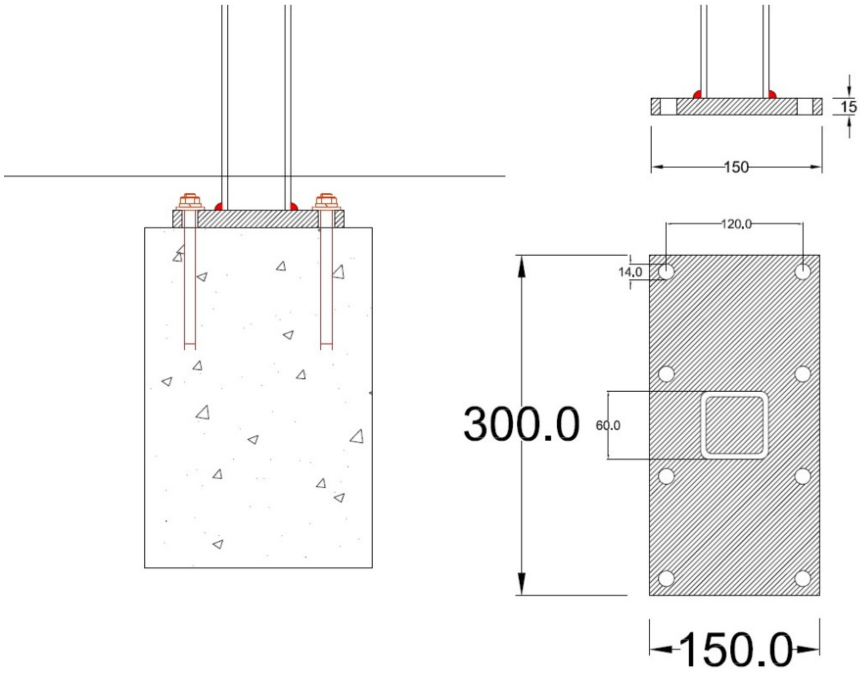
Steel grade	=	S 355 H to EN 10210-1			
Nominal value of yield strength	=	f_y	=	355 N/mm^2	
Nominal value of ultimate tensile strength	=	f_u	=	510 N/mm^2	
Inertia of section	=	I_{xx}	=	50.50 cm^4	
Elastic modulus of section	=	W_{el}	=	16.80 cm^3	
Plastic modulus of section	=	W_{pl}	=	20.90 cm^3	
Partial 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	$M_{pl,Rd}$	=		$\frac{f_y \times W_{pl}}{\gamma_{Mo}}$		
		=		$\frac{355\ N/mm^2 \times 20.90\ cm^3 \times (10)^{-3}}{1.0}$		
		=		**7.42 kNm**		
Ultimate moment on posts from the imposed line load on handrail with posts at 2.3m centres	M_d	=		(2.25 kN/m x 2.3) x 1.135		
		=		5.874 kNm		
		=	<	7.42 kNm	=	OK
Service load deflection of post supporting 2.3m of handrail	Δ	=		$\frac{P\,L^3}{3\,E\,I}$		
		=		$\frac{(1500 \times 2.3)\,(1135)^3}{3 \times 210\,000 \times 50.50 \times (10)^4}$		
		=		15.86mm		
For a post spacing of 2.3m the combined service load displacement of the handrail (no bar) + post from the original unloaded position	Δ	=		8.97mm + 15.86		
		=		24.83mm		
		=	<	25mm	=	OK

The Balcony 2 handrail (without bar) in conjunction with 60x60x5mm SHS posts in steel grade S 355 H, is adequate to support the design loading in terms of both strength and deflection limitations for posts spaced at up to 2.30 metre centres.

Balcony 2 system (Aerofoil) handrail with (1.5 kN): *PAGE 9* **(B2NW6060300150BPR)**

Baseplates and anchor bolts:



Baseplate size 300 x 150 x 15mm

Spacing of posts	=	2.30 m		
Design horizontal service load on handrail	=	1.50 kN/m (acts outwards)		
Ultimate design moment to u/side of base on posts at 2.30 m c/c	=	1.50 kN/m x 1.5 x 2.30 x 1.15	=	5.95 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	=	5.95 kNm / 4 No. x 0.12	=	12.40 kN/bolt
Working load bolt tension	=	12.40 kN / 1.50	=	8.27 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 bolt tension becomes 12.40 kN/bolt. A working load tension of **12.40 kN/bolt** is acceptable for M12 (8.8 grade) bolts when bolting direct to a substantial structural steel frame, or when drilling through and anchoring to the underside of a concrete slab.

Baseplates and anchor bolts: (cont):
Should drilled resin anchor bolts or similar fixings be proposed, the working load pull-out force on the bolts should be limited in accordance with the manufacturer's recommendations. For the purposes of these calculations a maximum working load pull-out force of 10.0 kN/bolt (including the BS 6180 50% increase) has been assumed when installing M12 bolts into sound concrete.

Working load BM/post based upon a	=	10.0 kN/bolt x 4 No. bolts x 0.12
limiting pull-out force of 10.0 kN/bolt	=	4.80 kNm/post
Allowable post spacing	=	$\frac{4.8 \text{ kNm}}{1.15 \times (1.5 \text{ kN/m} \times 1.5)}$
	=	1.86 m

The maximum post spacing is **1.86 metres** centre to centre when using drilled resin anchor bolts or similar and the design working load bolt tension force is limited to **10.0 kN/bolt**.

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

The installers should satisfy themselves that the bolts chosen are adequate to resist the specified loads, and also that the structure into which the bolts are installed is adequate to resist these loads.

Base plates: 300mm long x 150mm wide x 15mm thick.

Ultimate load bolt tension for posts at 2.6m max. spacing	T	=	12.40 kN/bolt	(excluding the BS 6180 50% increase, which applies only to fixings, not other structural elements)
Distance from centre of bolts to face of SHS	d	=	30mm	
Moment on base to face of SHS	M	=	12.40 kN/bolt x 4 No. x 0.03	
		=	1.488 kNm	

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 10mm fillet weld.

Elastic section modulus of post	W_{el}	=	16.8 cm^3		
Maximum ultimate elastic bending stress on posts at 2.6m spacing	$\frac{M_a}{W_{el}}$	=	$\frac{6.728 \times (10)^6}{16.80 \times (10)^3}$		
		=	383 N/mm^2		
		=	1.915 kN/mm on 5mm thick section		
Transverse capacity of 10mm fillet weld		=	1.925 kN/mm	=	OK

A continuous 10mm fillet weld around the perimeter of the post is adequate. A full strength butt weld, or a combination of welds that achieves a full strength connection, are also adequate.

Balcony 2 system (Aerofoil) handrail with (1.5 kN):

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

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 glass 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**

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

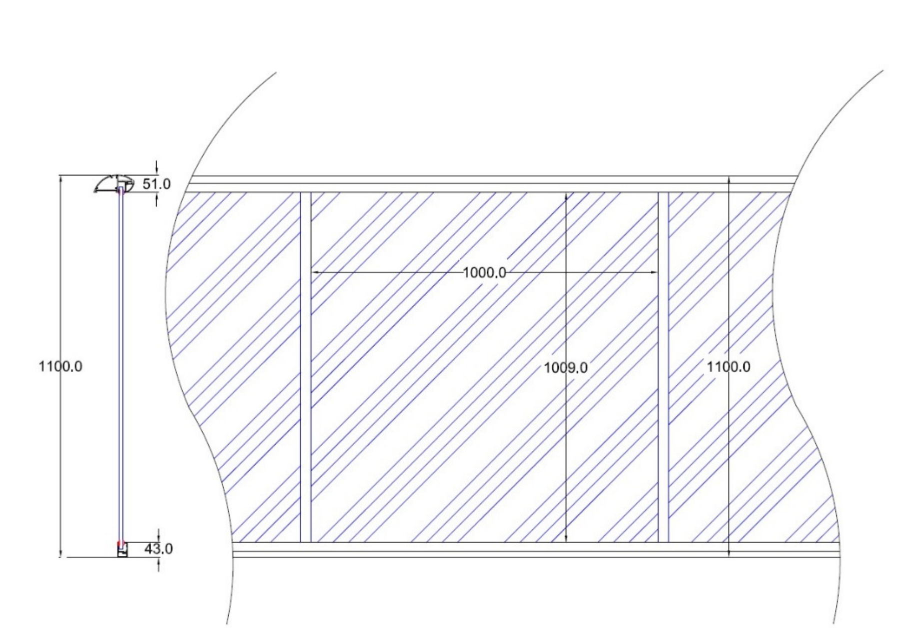
= 16667 mm^3/m

Ultimate moment capacity of glass 1000mm wide x 10mm thick Mu = $f_{g;d} \times Z$

= 84.16 N/mm^2 x 16667mm^3 x $(10)^{-6}$

1.403 kNm

Balcony 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 12*** **(B2NW6060300150BPR)**



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:

Uniformly distributed characteristic wind pressure on the glass of 2.675 kN/m^2

Ultimate UDL on glass	w	=	2.675 kN/m^2 x 1.5	=	4.01 kN/m^2
Ultimate moment on glass due to UDL on span of 1.0m	Mu	=	$\frac{4.01\ kN/m^2 \times (1.0)^2}{8}$	=	0.501 kNm/m
		= <	1.403 kNm	=	OK

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

The glass is adequate to support the ultimate design UDL.

Point load on the glass infill of 1.5 kN

Point load on the glass	=	1.5 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	=	$\frac{1.5\ kN \times 1.5 \times 1.0m}{4}$	=	0.5625kNm

It is assumed that the bending moment from the point load is carried by a 400mm wide vertical strip of glass.

Moment capacity of 400mm strip	=	1.403 kNm x 0.4	=	0.5612 kNm
	= >	0.5625kNm	=	OK

The glass has adequate moment capacity to support the ultimate design concentrated load.

Balcony 2 system (Aerofoil) handrail with (1.5 kN):

Glass deflection:

1) Uniformly distributed wind load of 2.675 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 2.675 kN/m^2 on a span of 1.0m simply supported

$$= \frac{5\ w\ L^4}{384\ E\ I}$$

$$= \frac{5 \times (2675 \times 1.0)\ (1000)^3}{384 \times 70\ 000 \times 83333}$$

$$= 5.97\ mm$$

$$= < \frac{span}{65} = OK$$

2) Service point load:

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 $= 0.4 \times 83333\ mm^4 = 33333\ mm^4$

Service load deflection due to a point load of 1.5 kN applied at mid-span

$$= \frac{P\ L^3}{48\ E\ I}$$

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

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

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 allowable simply supported span of the handrail between points of support is 3.24m.

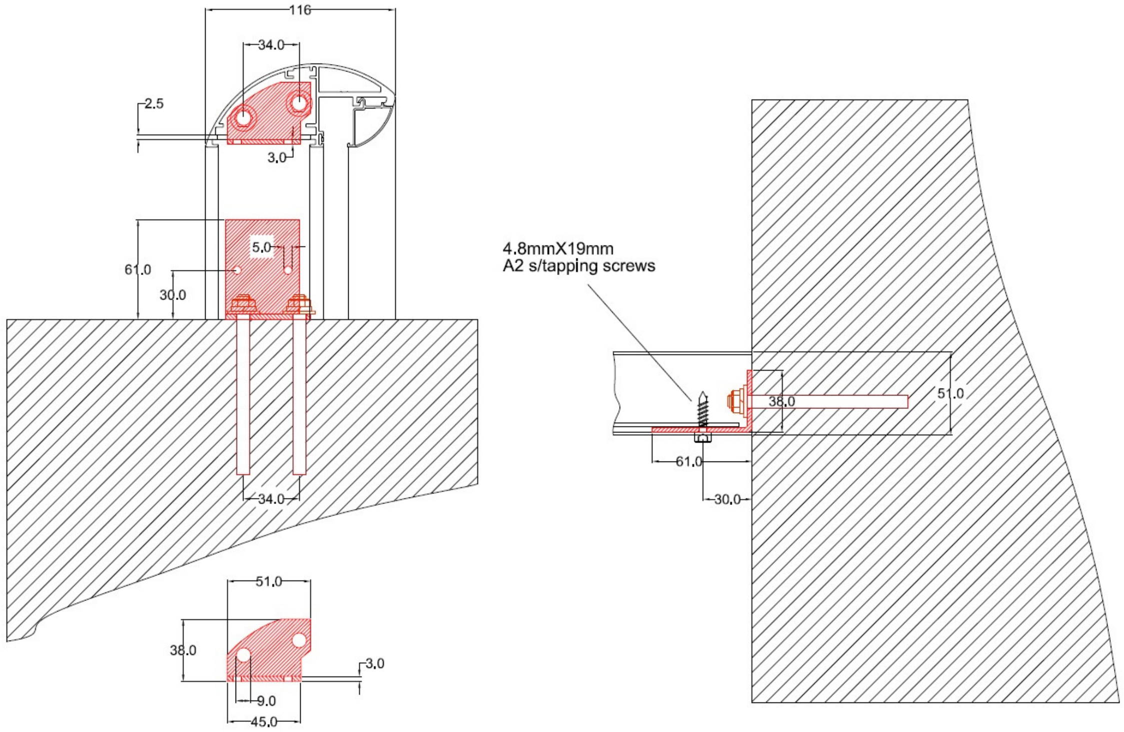
Horizontal service (working) load on the wall fixing for a span of 3.24m $= 1.5\ kN/m \times 1.62m = 2.43\ kN/fixing$

There are two options for wall fixing brackets; the standard bracket and the larger bracket. On the larger brackets the wall fixings bolts are further apart and so allows for smaller pull-out loads on the fixing bolts.

Standard wall fixing brackets:

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.

Balcony 2 system (Aerofoil) handrail with (1.5 kN): *PAGE 14* **(B2NW6060300150BPR)**



standard wall bracket

Pull-out forces on wall fixing

Working load pull-out force on the anchor bolts	=	$2.43\text{ kN} \times \frac{30}{34}$	=	2.14 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes **3.21 kN/bolt**.

For a handrail span of **3.24m** using the standard Balcony 2 wall bracket, the **working load** pull-out force on the wall fixing bolts is **3.21 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	=	2.43 kN/2	=	1.215 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes 1.82 kN/bolt.

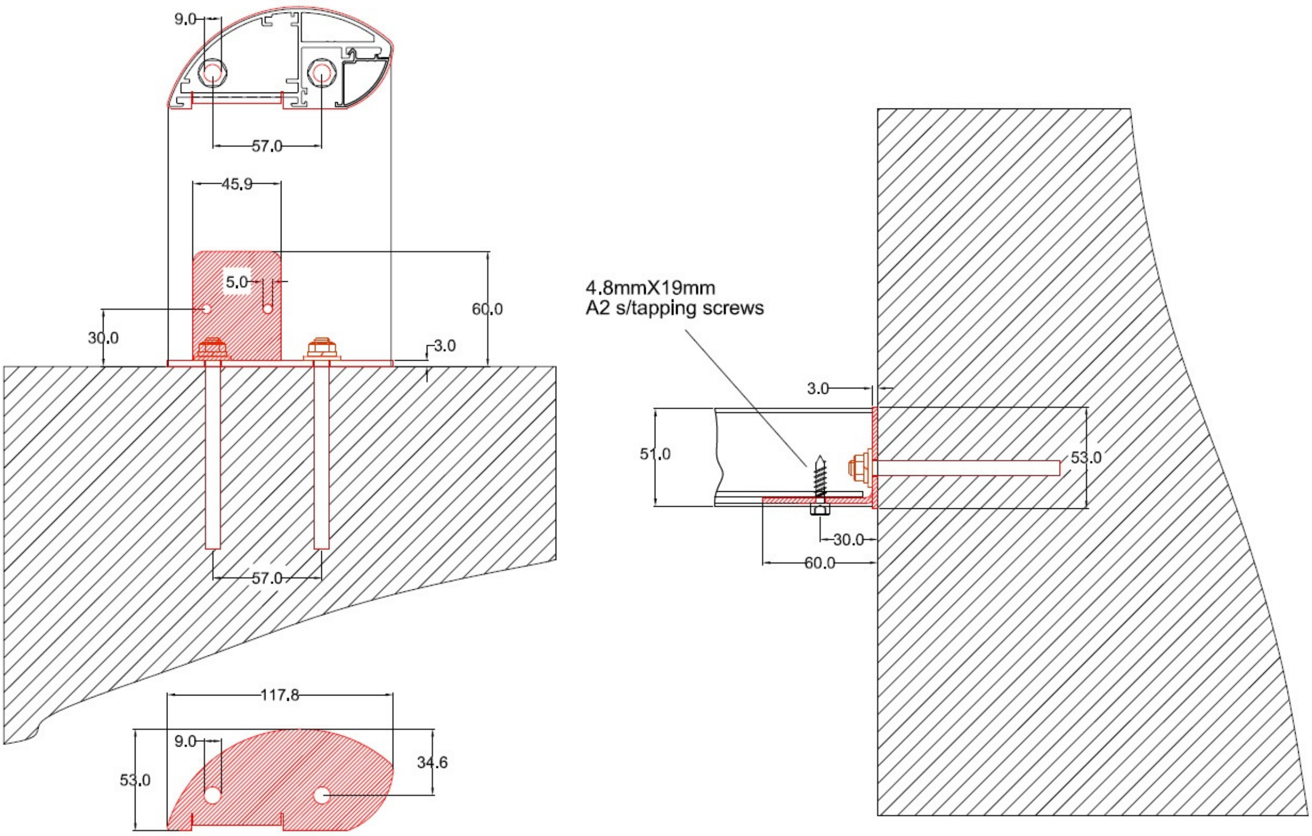
For a handrail span of **3.24m** using the standard Balcony 2 wall bracket, the **working load** shear force on the wall fixing bolts is **1.82 kN/bolt**, including the 50% increase as per BS 6180.

Ultimate load shear force on the anchor bolts and screws	=	1.82 kN/bolt x 1.5	=	2.73 kN/bolt or screw

Larger 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 57mm apart horizontally.

Balcony 2 system (Aerofoil) handrail with (1.5 kN): *PAGE 15* (B2NW6060300150BPR)



Larger wall bracket

Pull-out forces on wall fixing

Working load pull-out force on the anchor bolts	=	2.43 kN x 30/57	=	1.28 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes 1.92 kN/bolt.

For a handrail span of **3.24m** using the larger Balcony 2 wall bracket, the **working load** pull-out force on the wall fixing bolts is **1.92 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	=	2.43 kN/2	=	1.215 kN/bolt

Applying a 50% increase on fixing loads as recommended in BS 6180:2011, this becomes 1.82 kN/bolt.

For a handrail span of **3.24m** using the standard Balcony 2 wall bracket, the **working load** shear force on the wall fixing bolts is **1.82 kN/bolt**, including the 50% increase as per BS 6180.

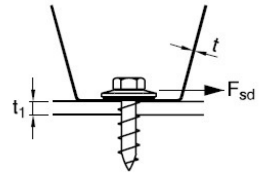
Ultimate load shear force on the anchor bolts and screws	=	1.82 kN/bolt x 1.5	=	2.73 kN/bolt or screw

Balcony 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 16*** **(B2NW6060300150BPR)**

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/mm²
Characteristic 0.2% proof stress = 290 N/mm²

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/mm². The values given in the table have been adjusted to allow for the yield stress of stainless steel type 304 (290 N/mm².)

<u>**Balcony 2 system (Aerofoil) handrail with (1.5 kN):**</u> ***PAGE 17*** **(B2NW6060300150BPR)**

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 3.24m	=		1.82 kN				
Factor of safety against shear failure for a 4.8mm diam. screw	=		2.51/1.11	=	2.26	=	OK

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

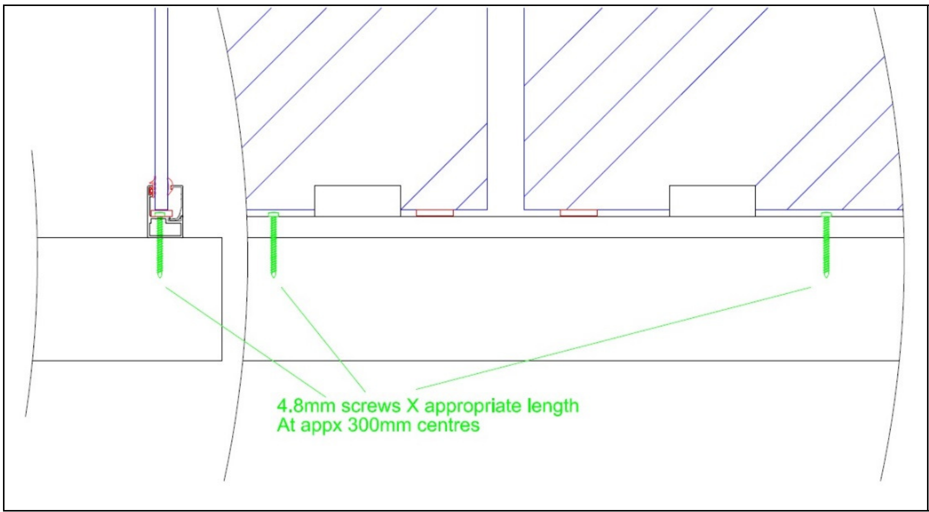
Plastic modulus of 45 x 3mm section for horizontal loads	=		$\frac{3 \times (45)^2}{4}$	=	1519 mm^3
Resistance moment of section	=		290 N/mm^2 x 1519 mm^3 x $(10)^{-6}$		
for horizontal loads	=		0.44 kNm		
For a simply supported span of 3.24m: ultimate load on end bracket	=		1.62 x 1.5 kN/m x 1.5	=	3.645 kN

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

Ultimate horizontal moment applied to	=		3.645 x 0.03	=	0.109 kNm
the bracket on a simply supported span of 3.24m	=	<	0.44 kNm	=	OK

The brackets are adequate.

<u>**Bottom rail fixing:**</u>



The standard bottom rail fixing consists of 4.8mm diameter screws at approx. 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 of the glass. The point load will be spread laterally by the glass, so the BS 6180 increase on individual fixings is assumed not to apply. The point load is considered to be resisted equally by a minimum of 3 No. fixing screws, giving a design working load shear force of 0.50 kN/screw.

Bottom rail fixing

Bottom rail fixings:

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.

Unit 6 Systems House, Eastbourne Road, Blindley Heath, Surrey, RH7 6JP - Tel 01342 410411
Balconette is a trading name of Balcony Systems Solutions Limited. Registration No. 6937600. VAT No. 975 6213 93

Balcony 2 system (Aerofoil) handrail with (1.5 kN): ***PAGE 19*** **(B2NW6060300150BPR)**

SUMMARY

BALCONY 2 system handrail with and without 58 x 4mm steel internal reinforcing bar, using 60 x 60 x 5mm SHS posts in steel grade S 355 H, fitted to 300 x 150 x 15 base plates: 1.50 kN basic design loading:

1) On single span and corner balconies, the handrail (with bar) is capable of supporting the design factored loads over spans up to 3.24 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 factor loads on spans up to 2.7 metres between points of support.

2) On longer balconies where the length of the balustrade exceeds 3.24 metres, the handrail (without bar) is used in conjunction with vertical posts installed to support the handrail at a maximum spacing of 2.3m between post centres. The posts are made from 60 x 60 x 5mm square hollow steel sections (SHS) in steel grade S 355 H enclosed in aluminium sleeves.

3) The SHS posts are welded (full strength butt welds, 10mm fillet welds, or a combination of welds that achieves a 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) On longer balconies, where posts are installed at a maximum spacing of 2.3m, the design working load pull-out force on the holding down bolts is 12.40 kN/bolt. This load would be achievable using M12 (8.8 grade) anchor bolts connected direct to a substantial structural steel frame, or by drilling through and anchoring to the underside of a suitable concrete slab. Should it be proposed to use drilled resin anchor bolts or similar, the manufacturer should be consulted regarding their recommended bolt safe working loads. If less than 12.40 kN/bolt the post spacing should be reduced accordingly. (eg. if the working bolt load is limited to 10.0 kN/bolt, the maximum post spacing is 1.86m).

5) For the maximum span of 3.24 metres on single span and corner balconies, the horizontal working pull-out load on the wall fixing bolts is **3.21 kN/bolt** for the standard wall bracket, or **1.92 kN/bolt** for the larger wall bracket. The horizontal working shear load on the wall fixing bolts is **1.82 kN/bolt**. 9mm diameter holes are provided in wall fixing brackets for M8 drilled anchor bolts.

7) The design working loads specified above include a 50 % increase on calculated loads, as recommended in BS 6180:2011.

8) 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.

9) 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.

10) The standard bottom rail fixing comprises 4.8mm diameter screws inserted into the balcony deck at 300mm nominal 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.

11) 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.