Structural Calculations for Aerofoil Juliet balconies using BALCONY 2 (Aerofoil) system handrail with & without 58 x 4mm internal reinforcing bar

Our ref: JULB2NB080719 **Date of issue: July 2019**

Juliet balconies using BALCONY 2 System (Aerofoil) handrail

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.
BS EN 1991-1-1-4:2005 + A1 2010	Eurocode 1	Wind actions on structures

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	Q_{k1}	=	A uniformly distributed load of 1.0 kN/m^2
Point load on glass infill		=	0.50 kN applied to any part of the glass fill 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 imposed 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.

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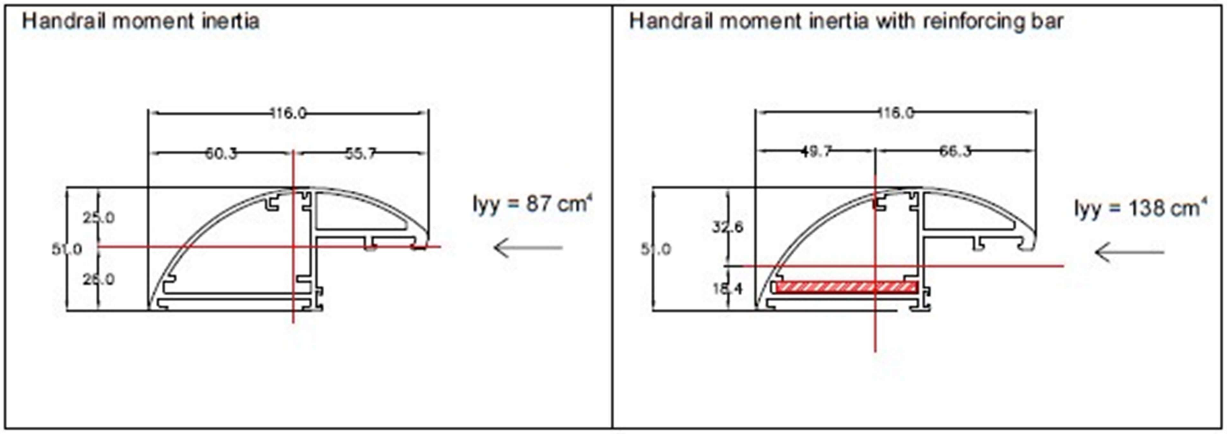
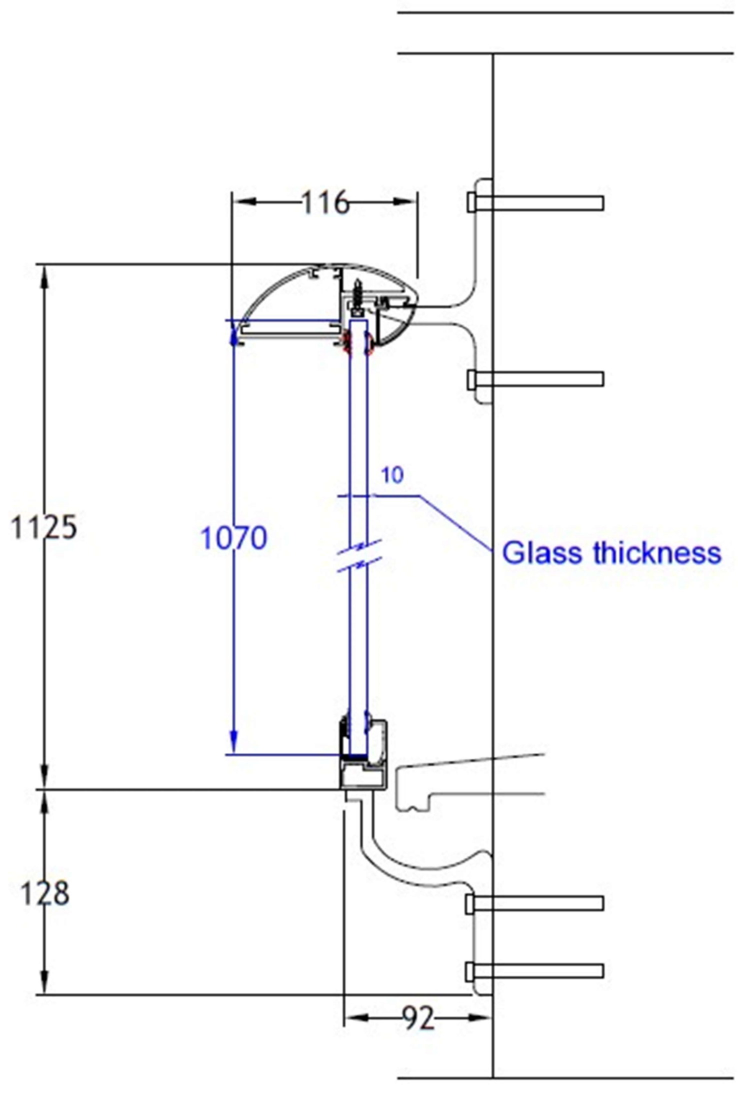




Typical section & handrail profile moment of inertia

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' &* UK National Annex to EN 1991-1-4:2002 + A1:2010. We have chosen to prepare a calculation based on certain conditions, resulting in specific coefficients.

The formula applied results in an overall ***characteristic wind pressure***. The design and calculation will be relevant not only to the conditions specified herein but to any combination of factors that result in a characteristic wind pressure that is equal to or less than the one specified in the calculation. The selected wind load coefficient will cover the majority of sites in England and Wales, and are appropriate for balustrades of any length with or without return corners.

a) Sites located geographically within the 23m/sec isopleth in Figure NA 1 off the UK National Annex.

b) Site altitude 100m maximum above sea level.

c) Top of balustrade located 35m maximum above ground level.

d) Site located in a coastal area exposed to the open sea, terrain category 0 of BS EN 1919 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 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	$V_{b, map}$	=	23m/sec	
Site altitude above sea level	A	=	100m	
Top of balustrade height above ground	z	=	35m	
Altitude factor	C_{alt}	=	$1.0 + (0.001 \times A)\ (10/z)^{0.2}$	
		=	$1.0 + (0.1)\ (10/35)^{0.2}$	
		=	1.0 + (0.1) (0.7783)	
		=	1.08 say	
Directional, seasonal & probability factors	C_{dir}, C_{season}, C_{prob}	=	1.0	
Site wind speed	V_b	=	$V_{b,map}\ (C_{dir} \times C_{season} \times C_{prob})\ (C_{alt})$	
		=	23m/sec x 1.08	
		=	24.84m/sec	
Site wind pressure	qb	=	$0.613\ (V_b)^2$	
		=	$0.613 \times (24.84)^2$	
		=	378 N/m^2	
Exposure factor	Ce(z)	=	3.50	(Figure NA 7)
Peak velocity pressure	qp	=	qb x Ce(z)	
(Characteristic wind pressure)		=	0.378 x 3.50	
		=	**1.323 kN/m^2**	
	say	**=**	**1.35 kN/m^2**	

Section properties of handrail (with internal reinforcing 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}	=	22.908 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Value of shape factor	=	α	=	W_{pl}/W_{el}
(conservative value)			=	1.2 say
Design ultimate resistance to bending about the y-y axis	=	M_{Rd}	=	$M_{o,Rd}$

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

$$= \frac{1.2 \times 22.908\ \text{cm}^3 \times 130\ \text{N/mm}^2 \times (10)^{-3}}{1.1}$$

= **3.249 kNm**

Section properties of handrail (without bar):

Properties as above except as follows:

Inertia about the y-y axis	=	I_{yy}	=	87.0 cm^4
Least elastic modulus about the y-y axis	=	W_{el}	=	14.448 cm^3
Design ultimate resistance to bending about the y-y axis	=	M_{Rd}	=	$\frac{\alpha \times W_{el} \times f_o}{\gamma_{M1}}$
			=	$\frac{1.2 \times 14.448 \times 130\ \text{N/mm}^2 \times (10)^{-3}}{1.1}$
			=	**2.049 kNm**
Design ultimate horizontal imposed line load on handrail	=	F_i	=	0.74 kN/m x 1.5
			=	1.11 kN/m
Design characteristic wind load on handrail	=	F_w	=	1.35 kN/m^2 x 0.55
			=	0.7425 kN/m
			=	virtually the same as the line load
Design horizontal moment on handrail between points of support.	=	M	=	$\frac{F L^2}{8}$

Handrail (with bar):

Allowable span between points of support based upon the moment capacity of the handrail	L	=	$\left[\frac{8 \times M_{Rd}}{F}\right]^{0.5}$
		=	$\left[\frac{8 \times 3.249\ \text{kNm}}{1.11}\right]^{0.5}$
		=	4.82m

Handrail (without bar):

Design ultimate horizontal load on handrail = 1.11 kN/m

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

$$= \left[\frac{8 \times 2.049\ \text{kNm}}{1.11}\right]^{0.5}$$

$$= 3.84\text{m}$$

Summary: In terms of bending capacity the handrail (with bar) can resist the design service loads on spans up to 4.82m between points of support; the handrail (without bar) can resist the design service loads on spans up 3.84m between points of support. However, the allowable spans are limited to restrict service load deflection to 25mm.

Service load deflection of handrail (without bar) for a simply supported span of 3.5m

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

$$= \frac{5\ (740 \times 3.5)\ (3500)^3}{384 \times 70000 \times 87 \times (10)^4}$$

$$= 23.74\text{mm}$$

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

Handrail (with bar):

The maximum standard length of handrail used is 4.1m. The handrail support brackets at each end are 50mm wide, therefore the maximum span centre to centre of the support brackets is 4050mm.

Service load deflection of handrail (with bar) for a simply supported span of 4.05m

$$= \frac{5\ (740 \times 4.05)\ (4050)^3}{384 \times 70000 \times 138 \times (10)^4}$$

$$= 26.84\text{mm}$$

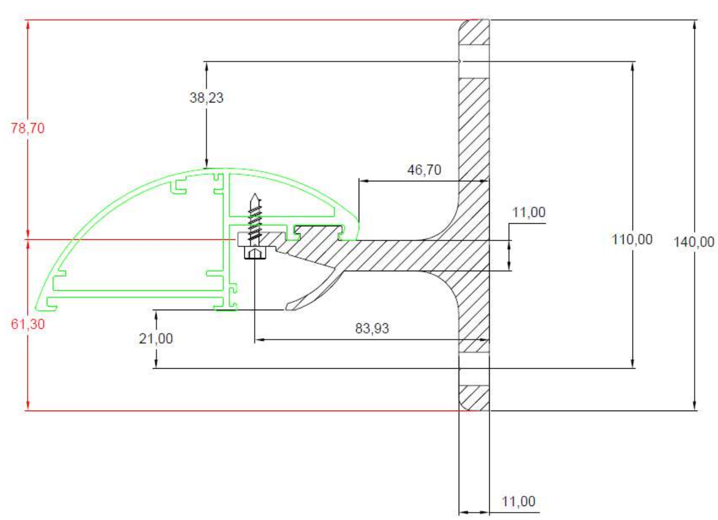
= slightly > 25mm but say OK

SUMMARY:

The **Balcony 2** (Aerofoil) system handrail (with 58 x 4mm internal steel reinforcing bar) is adequate to support the design ultimate loads on spans up to **4.05 metres** between the centres of the supporting brackets.

The **Balcony 2** (Aerofoil) system handrail (without the 58 x 4mm internal steel reinforcing bar) is adequate to support the design ultimate loads on spans up to **3.5 metres** between the centres of the supporting brackets.

Handrail brackets:



<u>Handrail brackets:</u>

The horizontal imposed design load on the handrail acts over the clear width of the opening. ie. 3840mm for a handrail 4100mm long overall. Wind loading can act over the full length of 4100mm.

Ultimate horizontal wind load H = (1.35 kN/m^2 x 1.5 x 0.55) x 2.05
on the brackets for a length of 4100mm. = 2.283 kN

The handrail is attached to the bracket by means of a slotted connection and two 4.8mm diameter stainless steel self - tapping screws. Ultimate shear force = 1.1415 kN/screw

<u>Properties of stainless steel self-tapping screws:</u>

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 capacity taken from the table on page 7 of Lindab's technical literature.

Nominal thickness of aluminium in the handrail = 5mm
and bracket at screw positions (Nom t mm)

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

For safety classes 2 and 3 this shear 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 a material having a tensile yield limit of 350 N/mm^2.

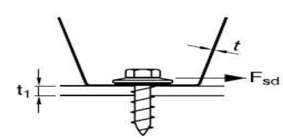
The ultimate shear capacity of 3.64 kN/screw has therefore been reduced by 290/350 and divided by 1.2 to represent safety class 3 and 290 N/mm^2 yield stress rather than 350 n/mm^2. The adjusted shear capacity is then 2.51 kN/screw.

As a worst possible case for shear force on the self-tapping screws, it is assumed that they resist the whole of the ultimate horizontal force on the brackets. ie. the resistance contribution of the slotted connection is ignored.

Ultimate shear force/screw = 1.1415 kN/screw = < 2.283 kN/screw

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/mm^2	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.

Except of the table at the foot of page 7 of Lindab's technical literature

Handrail brackets: Fixing bolts:
There are two M12 fixing bolts located 110mm apart vertically. The centre of the top bolt is approximately 70mm above the middle of the 11mm thick projecting part of the bracket. The centre of the lower bolt is approximately 40mm below this position.

Maximum handrail length (with bar)	=	4100mm			
Maximum opening width	=	3840mm			
Maximum horizontal wind load on bracket	=	2.283 kN	(ultimate)		
Maximum ultimate pull-out load on lower bolt	=	$2.283 \times \frac{70}{110}$		=	1.453 kN
			say	=	1.50 kN
Maximum ultimate pull-out load on upper bolt	=	2.283 - 1.453		=	0.83 kN

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 **working load** pull-out force on the lower bolt becomes **1.50 kN.**

For practical purposes a **working load** pull-out force of **1.50 kN**/bolt is specified for both the top and lower bolts.

For handrails shorter than 4100mm (clear width of openings less than 3840mm) the design working load pull-out forces on the anchor bolts is reduced pro-rata.

Brackets:

Limiting stress in bending	f_o	=	130 N/mm^2		
Plastic modulus of 11mm thick section x 50mm wide	W_{pl}	=	$\frac{50 \times (11)^2}{4}$	=	1512mm^3
Moment capacity of 11mm thick section x 50mm wide	M_{Rd}	=	$\frac{130 \text{ N/mm}^2 \times 1512\text{mm}^3 \times (10)^{-6}}{1.1}$		
		=	0.179 kNm		
Dimension from centre of lower bolt to root radius at middle section		=	20mm approximately		
Factored applied moment on lower part of bracket	M	=	1.50 kN x 0.02	=	0.03 kNm
		= <	0.179 kNm	=	OK
Dimension from centre of upper bolt to root radius at middle section		=	50mm approximately		
Factored applied moment on upper part of bracket	M	=	1.50 kN x 0.05	=	0.075 kNm
		= <	0.179 kNm	=	OK
Direct tensile stress on central 11mm thick x 50mm wide section		=	$\frac{2.283 \text{ kN} \times (10)^3}{11 \times 50}$	=	4.15 N/mm^2
				=	OK

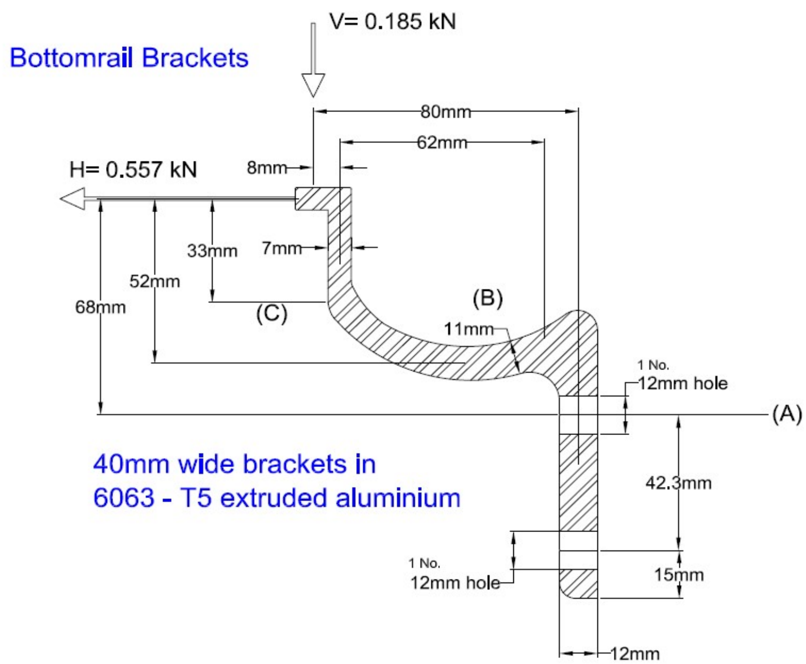
Summary: The handrail brackets are adequate to resist the ultimate load design forces.

<u>Handrail brackets:</u> design working loads on fixing bolts:

For standard length handrails shorter than 4100mm, the design pull-out forces on bracket fixing bolts are as noted below:

Handrail length	**opening size**	**working load tension on each bolt** (including the 50% increase recommended in BS 6180)
1280mm	1020mm	0.47 kN
1500mm	1240mm	0.55 kN
1680mm	1420mm	0.62 kN
1860mm	1600mm	0.68 kN
2180mm	1920mm	0.80 kN
2450mm	2190mm	0.90 kN
2840mm	2580mm	1.04 kN
3200mm	2940mm	1.17 kN
3400mm	3140mm	1.24 kN
3600mm	3340mm	1.32 kN
3800mm	3540mm	1.39 kN

Lower rail brackets:



The brackets are installed at 500mm nominal centres. The brackets support a vertical load V comprising the self weight of the glass and rails, plus a horizontal load H from wind on the glass acting inwards or outwards. One 12mm diameter holes is provided top and bottom for M10 bolts, making the effective width of the vertical leg 28mm. The partial safety factor (γ) for permanent dead loads is 1.35.

Factored dead load from glass + rails	V	=	0.275 kN/m x 1.35 (γ)	=	0.37 kN/m
				=	0.185 kN/bracket
Factored wind load	H	=	1.35 kN/m^2 x 0.55 x 1.5 (γ)	=	1.114 kN/m
				=	0.557 kN/bracket

<u>Lower rail brackets:</u>

<u>Section (A)</u> dimensions		=	40mm wide x 12mm thick, less 2 No. 12mm diameter holes for 10mm diameter bolts, making the effective section 16mm wide x 12mm thick.		
Plastic section modulus	W_{pl}	=	$\frac{16 \times (12)^2}{4}$	=	$576mm^3$
Limiting stress in bending	f_o	=	$130\ N/mm^2$		
Moment capacity of section	M_c	=	$\frac{130\ N/mm^2 \times 576mm^3 \times (10)^{-6}}{1.1}$	=	0.068 kNm
Factored applied moment	M	=	(0.185 kN x 0.08) + (0.557 kN x 0.068)		
		=	0.053 kNm		
		= <	0.068 kNm	=	OK
<u>Section (B)</u> dimensions		=	40mm wide x 11mm thick		
Plastic section modulus	W_{pl}	=	$\frac{40 \times (11)^2}{4}$	=	$1210mm^3$
Moment capacity of section	M_c	=	$\frac{130\ N/mm^2 \times 1210mm^3 \times (10)^{-6}}{1.1}$	=	0.143 kNm
Factored applied moment	M	=	(0.185 kN x 0.07) + (0.557 kN x 0.052)		
		=	0.042 kNm		
		= <	0.143 kNm	=	OK
<u>Section (C)</u> dimensions		=	40mm wide x 7mm thick		
Plastic section modulus	W_{pl}	=	$\frac{40 \times (7)^2}{4}$	=	$490\ mm^3$
Moment capacity of section	Mc	=	$\frac{130\ N/mm^2 \times 490mm^3 \times (10)^{-6}}{1.1}$	=	0.058 kNm
Factored applied moment	M	=	(0.185 kN x 0.008) + (0.557 kN x 0.033)		
		=	0.02 kNm		
		= <	0.058 kNm	=	OK
Design plastic shear resistance	$V_{pl,Rd}$	=	$\frac{A\ (f_y/\sqrt{3})}{\gamma_{MO}}$		
		=	$\frac{(40 \times 7)\ (190/1.732) \times (10)^{-3}}{1.0}$	=	30.71 kN
				=	OK

Summary: The lower rail brackets at 500mm nominal centres are adequate to resist the ultimate design bending and shear forces from the specified imposed and wind loads.

<u>Lower rail bracket fixing bolts:</u> (1 No. M10 bolt top and bottom of the bracket).

Moments taken about the lower bolt for the direct pull-out force on the top bolt. (max. handrail length 3400mm)

Factored moment on bracket	=	(0.185 kN x 0.08) + (0.557 kN x 0.1103)		
	=	0.076 kNm		
Tension on top bolt (ultimate)	=	$\frac{0.076\ kNm}{0.0423}$	=	1.80 kN

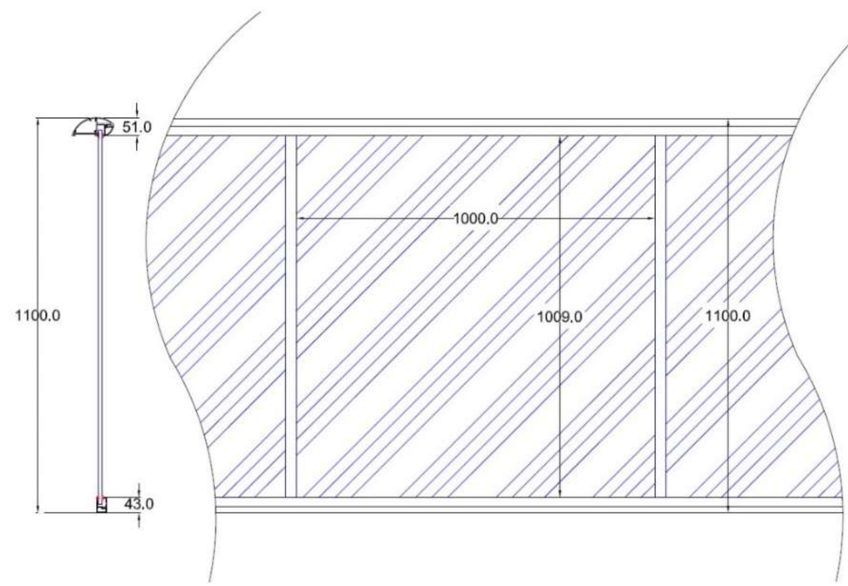
Applying the BS 6180 50% increase, this becomes the design **working load** bolt tension.

Glass infill:

Design standard		=	Institution of Structural Engineers publication *Structural use of glass in building (second edition) February 2014.*
Glass type		=	10mm thermally toughened soda silicate safety glass with smooth '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}	=	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 strength of processed 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	M_u	=	$f_{g;d} \times Z$
		=	87.53 N/mm^2 x 16667mm^3 x $(10)^{-6}$
		=	**1.459 kNm/m**

Aerofoil Juliet Balcony System

Glass infill:



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.

Glass panels are 1070mm high o/a say 1000mm between centres of supports.

Three separate design conditions are considered:

1) Uniformly distributed service load on the infill of $1.0\ kN/m^2$

Ultimate UDL on glass = $1.0\ kN/m^2 \times 1.5$ = $1.5\ kN/m^2$

Ultimate moment on glass due to UDL on 1.0m span = $\frac{1.5\ kN/m^2 \times (1.0)^2}{8}$ = $0.1875\ kNm/m$

= < 1.459 kNm/m = OK

The reaction on the handrail from the UDL on the glass is less than the design horizontal UDL on the handrail. Therefore the design load on the glass is not a critical design case in terms of the handrail.

2) Service point load of 0.5 kN applied in any position on the glass

Worst case for bending stress occurs when the point load is applied at mid-height of the glass.

Ultimate moment on glass due to point load = $\frac{(0.50\ kN \times 1.5) \times 1.0m}{4}$ = $0.1875\ kNm$

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

Moment capacity of 300mm strip = $1.459\ kNm \times 0.30$ = $0.4377\ kNm$

= > 0.1875 kNm = OK

3) Wind loading:

Ultimate moment on glass due to wind = $\frac{(1.35\ kN/m^2 \times 1.5)\ (1.0)^2}{8}$ = $0.253\ kNm/m$

= > 1.459 kNm/m = OK

Glass deflection:

a) Service load deflection due to the maximum UDL:

Inertia of glass 1000 x 10mm	=	$1000 \times (10)^3 / 12$	=	$83333mm^4$
Service load deflection due to	=	$5 \times (1000 \times 1.35)\ (1000)^3$	=	3.0mm
a UDL of 1.35 kN/m^2		$384 \times 70\ 000 \times 83333$	=	OK

b) Glass deflection due to a service point load of 0.50 kN

The service point load of 0.50 kN is assumed to be carried by a 300mm wide vertical strip of glass.

Inertia of glass 300 x 10mm	=	$0.03 \times 83333mm^4$	=	$25\ 000\ mm^4$
Service load deflection due a	=	$500 \times (1000)^3$	=	5.95mm
point load of 0.5 kN at mid-span		$48 \times 70\ 000 \times 25\ 000$	=	OK

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

SUMMARY

Aerofoil Juliet balconies using BALCONY 2 (Aerofoil) system handrail with & without 58 x 4mm steel internal reinforcing bar

1. For the occupancy classes listed on pages 1 & 2 of these calculations, on sites that come within the wind load parameters listed on page 4 (and /or have a design characteristic wind pressure no greater than 1.35 kN/m^2) the Balcony 2 (Aerofoil) system handrail (with internal reinforcing bar) in conjunction with 10mm thick thermally toughened safety glass, is adequate to support the imposed & wind loads specified in relevant British and European Standards for spans up to **4.05 metres** between the centres of the handrail support brackets.

2. For similar occupancy classes and design wind loads, the Balcony 2 (Aerofoil) system handrail (without internal reinforcing bar) in conjunction with 10mm thick thermally toughened safety glass, is adequate to support the specified loads for spans up to **3.5 metres** between handrail bracket centres.

3. The handrail support brackets in extruded aluminium grade 6063 T5 are adequate to support the design loads for spans up to 4.05 metres between the centres of brackets. The bottom rail brackets in extruded aluminium grade 6063 T5 are adequate at up to **500mm** nominal centres between the brackets.

4. For the design loading and 3.35 maximum span between handrail bracket centres, the calculated working load direct pull-out force on each handrail bracket fixing bolt is **1.50 kN**. For smaller width openings the working load direct pull-out force on the handrail bracket fixing bolts are reduced, as listed below:

Handrail length	Opening size	Working load tension on each bolt (including 50% increase recommended in BS 6180)
1280mm	1020mm	0.47 kN
1500mm	1240mm	0.55 kN
1680mm	1420mm	0.62 kN
1860mm	1600mm	0.68 kN
2180mm	1920mm	0.80 kN
2450mm	2190mm	0.90 kN
2840mm	2580mm	1.04 kN
3200mm	2940mm	1.17 kN
3400mm	3140mm	1.24 kN
3600mm	3340mm	1.32 kN
3800mm	3540mm	1.39 kN

5. For bottom rail brackets installed at 500mm nominal centres, the calculated working load direct pull-out force on the fixing bolts is **1.8 kN**, including the 50% increase on calculated values recommended in BS 6180.

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

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

8. The 4.8mm diameter self-tapping stainless steel screws connecting the handrail to the aluminium wall brackets are adequate to support the design loads specified in relevant British and European Standards.

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