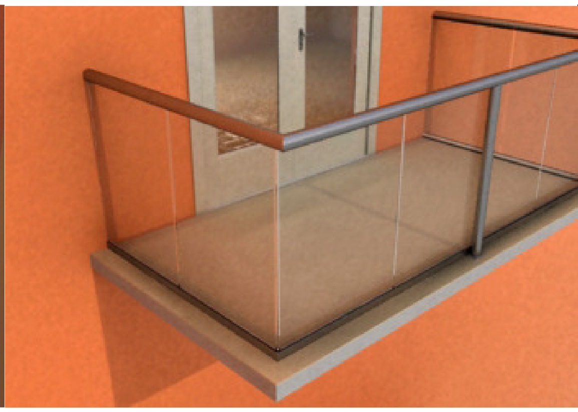
Balconette

Makes the most of yourview

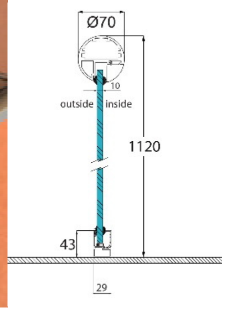
Structural Calculations for standard BALCONY 1 system handrail using 55mm diameter posts (48.3mm x 5mm CHS) & 150 x 150 x 15mm base plates

Our ref: B1NB55150150BP061016 **Date of issue: October 2016**

Balcony 1 Balustrade fixed between two walls



Balcony 1 Balustrade on a 3 sided balcony with a central post



Balcony 1 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 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

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.

<u>Deflection:</u>

- 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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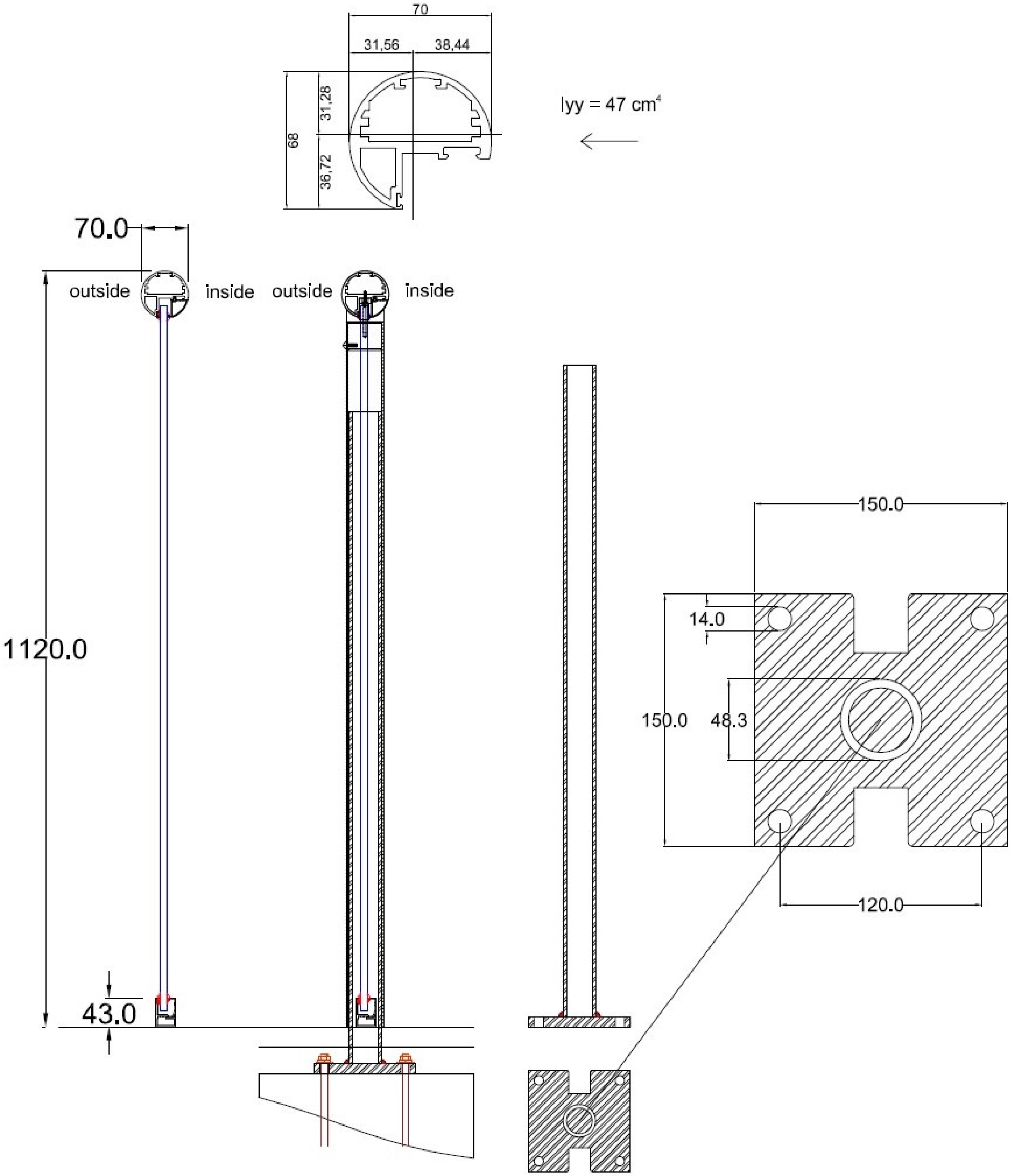


Section of Balcony 1 system, post detail and base plate detail

<u>Balcony 1 system: Section properties of handrail:</u>

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}	=	47 cm^4
Least elastic modulus about the y-y axis	=	W_{el}	=	12.227 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Value of shape factor (conservative value)	=	α	=	W_{pl}/W_{el}
			=	1.2 say

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

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

$$= \frac{1.2 \times 12.227\ \text{cm}^3 \times 130\ \text{N/mm}^2 \times (10)^{-3}}{1.1}$$

$$= 1.734\ \text{kNm}$$

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

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

$$= \left[\frac{8 \times 1.734\ \text{kNm}}{1.11}\right]^{0.5}$$

$$= 3.54\text{m} \quad \text{say} = 3.50\text{m}$$

In terms of bending capacity the handrail can span up to 3.50m 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.

Deflection (Δ) of a simply supported span (L) with an imposed UDL load (F)	Δ	=	$\frac{5\,F\,L^4}{384\,E\,I}$
For a handrail span of 3.0m simply supported	Δ	=	$\frac{5\,(740 \times 3.0)\,(3000)^3}{384 \times 70\,000 \times 47 \times (10)^4}$
		=	23.72mm < 25mm OK

Therefore deflection limitations govern the allowable simply supported span of the handrail.

In order that calculated service load deflection shall not exceed 25mm the allowable simply supported span of the handrail is limited to **3.0m.**

Vertical posts

On longer balconies posts are installed to support the handrail.

To allow for deflection of the posts, deflection of the handrail has to be limited so that the overall combined displacement of the handrail + post at any point of the barrier from its original unloaded position does not exceed 25mm.

For a post spacing of 1.90m service load deflection of the handrail	Δ	=	$\frac{5\,F\,L^4}{384\,E\,I}$
		=	$\frac{5\,(740 \times 1.90)\,(1900)^3}{384 \times 70\,000 \times 47 \times (10)^4}$
		=	3.82mm

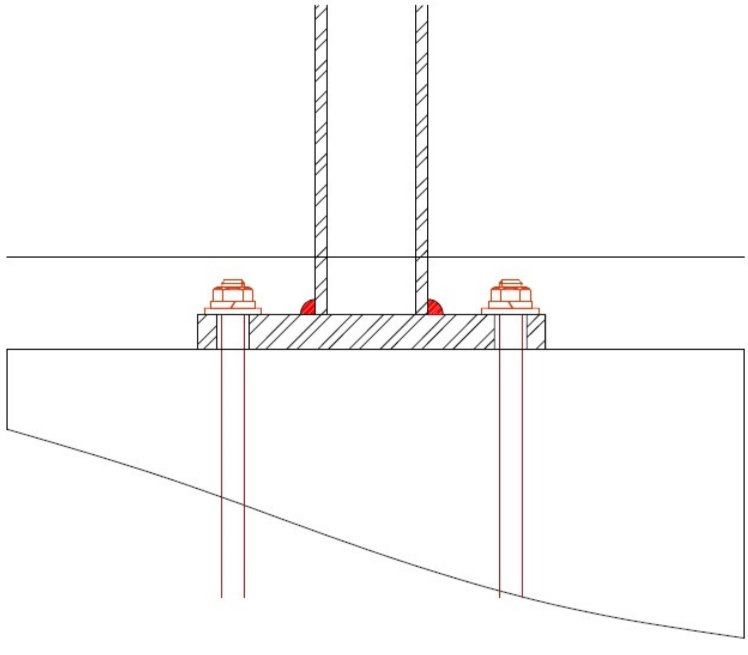
48.3mm diameter x 5mm thick CHS posts: properties of section:

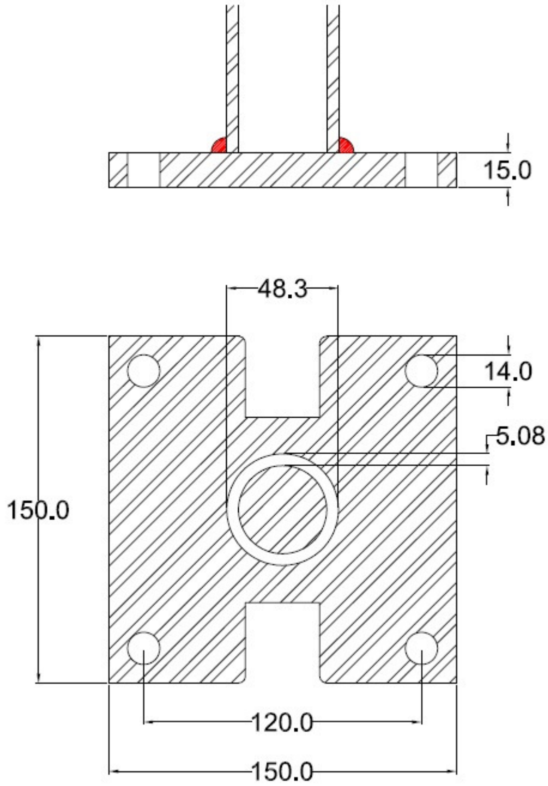
Steel grade	=	S 275 to EN 10025		
Nominal value of yield strength	=	f_y	=	275 N/mm^2
Nominal value of ultimate tensile strength	=	f_u	=	430 N/mm^2
Inertia of section	=	I_{xx}	=	16.2 cm^4
Elastic modulus of section	=	W_{el}	=	6.69 cm^3
Plastic modulus of section	=	W_{pl}	=	9.42 cm^3
Partial factor for material properties	=	γ_{M1}	=	1.10
Partial factor for class 1 sections	=	γ_{MO}	=	1.00
Modulus of elasticity	=	E	=	210 000 N/mm^2

Design ultimate resistance for bending	$M_{pl,Rd}$	=	$\frac{f_y \times W_{pl}}{\gamma_{Mo}}$
		=	$\frac{275\,N/mm^2 \times 9.42\,cm^3 \times (10)^{-3}}{1.0}$
		=	2.59 kNm
Ultimate moment from imposed load on handrail with posts at 1.9m centres	M_d	=	(0.74 x 1.90) x 1.10 x 1.5
		=	2.32 kNm < 2.59 kNm OK

Service load deflection of post supporting 1.9m of handrail	Δ	=	$\frac{P\,L^3}{3\,E\,I}$
		=	$\frac{(740 \times 1.90)\,(1100)^3}{3 \times 210\,000 \times 16.2 \times (10)^4}$
		=	18.34mm
Combined total displacement of handrail + post from the original unloaded position (service loads)	Δt	=	3.82mm + 18.34
		=	22.16mm < 25mm
		=	OK

The Balcony 1 handrail, in conjunction with 48.3mm diameter x 5mm thick CHS posts, is adequate to support the design loading on the handrail in terms of both strength and deflection limitations for posts spaced at up to 1.90 metre centres.





Baseplate size 150 x 150 x 15mm

Spacing of posts	=	1.90 m		
Design horizontal service load on handrail	=	0.74 kN/m (acts outwards)		
Ultimate design moment	=	0.74 kN/m x 1.5 x 1.90 x 1.1	=	2.32 kNm

on posts at 1.90 m c/c

Base plates and fixing bolts:

Fixing bolts

Lever arm between bolt centres = 120mm

Ultimate load pull-out force on 2 No. bolts = $\frac{(0.74 \times 1.5)\ kN/m \times 1.9 \times 1.10}{0.12}$

= 19.33 kN

= 9.665 kN/bolt (ultimate load)

= 6.44 kN/bolt (working load)

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 ultimate bolt load becomes 9.665 x 1.5 = 14.50 kN/bolt. (9.66 kN/bolt working load). A working load capacity of 9.66 kN/bolt should be within the capacity of most 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

Bending stresses: At the critical section for bending the base plate is 80mm long x 15mm thick.

Ultimate applied moment on posts at 1.9m maximum spacing = M_a = (0.74 x 1.5) x 1.9 x 1.10

= 2.32 kNm

Ultimate load bolt pull-out force on HD bolts with posts at 1.9m spacing = T = 9.665 kN/bolt (not including the 50% increase noted above. This applies to bolt loads only, not other elements)

Distance from bolt centre to critical section = d = 44.0mm

Ultimate applied moment at the critical section = M = T x d

= 9.665 x 2 No. x 0.044

= 0.850 kNm

Plastic modulus of critical section = W_{pl} = $\frac{80 \times (15)^2}{4}$

= 4500 mm^3

Ultimate moment capacity of critical section = Mu = $\frac{f_y \times W_{pl}}{\gamma_{M1}}$

= $\frac{275\ N/mm^2 \times 4500mm^3 \times (10)^{-6}}{1.1}$

= 1.125 kNm

> 0.850 kNm = OK

<u>Shear</u>: Design plastic shear resistance of the critical section = $V_{pl,Rd}$ = $\frac{A_v (f_y / \sqrt{3})}{\gamma_{MO}}$

= $\frac{(80 \times 15)(275 / 1.732) \times (10)^{-3}}{1.0}$

= 190.53 kN

= > 19.33 kN = OK

<u>Welded connection between post & base plate</u>

The 48.3mm diameter CHS post is welded to the top of the base by means of a full strength butt and/or fillet weld.

ultimate moment applied to posts @ 1.9m c/c maximum spacing M = (0.74 x 1.50) kN/m x 1.9 x 1.1

= 2.32 kNm

section modulus of 48.3mm dia. x 5mm CHS Z = $6.69\ cm^3$

maximum ultimate elastic bending stress on CHS $\frac{M}{Z}$ = $\frac{2.32 \times (10)^6}{6.69 \times (10)^3}$

= $346.79\ N/mm^2$

= 1.734 kN/mm on 5mm thick section

Transverse capacity of a 10 FW Pt = 1.925 kN/mm = OK

Therefore a continuous 10mm fillet weld around the perimeter of the post provides an adequate post/base plate connection.

Balcony 1 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)

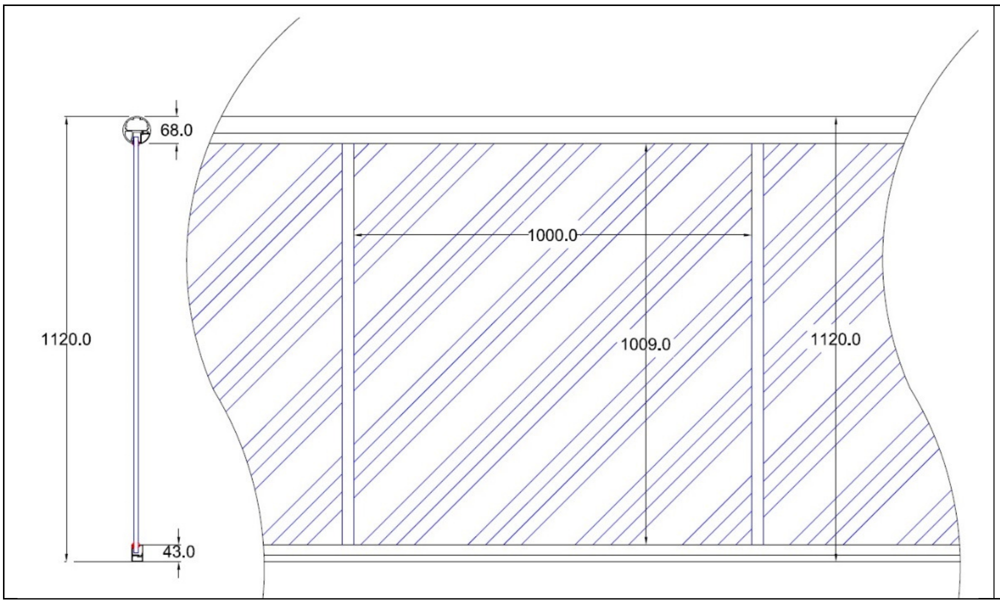
$\gamma_{M;A}$ = material partial factor
= 1.6 for basic annealed glass

$\gamma_{M;V}$ = 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.

Two separate design loading conditions are considered:

1. Uniformly distributed load on the infill of 1.0 kN/m²

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

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	=	$\frac{0.5\ kN \times 1.5 \times 1.0m}{4}$	=	0.1875kNm

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

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

The glass is adequate to support the ultimate design loading.

Glass deflection:

Consider service load deflection of the glass due to the design UDL:

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

Service load deflection due to a UDL of 1.0 kN/m^2 $= \dfrac{5\ w\ L^4}{384\ E\ I}$

on a simply supported span of 1.0m $= \dfrac{5 \times (1000 \times 1.0)\ (1000)^3}{384 \times 70\ 000 \times 83333}$

$= 2.232\ mm$

= OK

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

Inertia of glass 10mm thick x 300mm long $= 0.3 \times 83333\ mm^4 = 25\ 000\ mm^4$

Service load deflection due to a point load of 0.5 kN applied at mid-span $= \dfrac{P\ L^3}{48\ E\ I}$

$= \dfrac{500 \times (1000)^3}{48 \times 70\ 000 \times 25\ 000}$

$= 5.95mm < \dfrac{span}{65} =$ OK

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

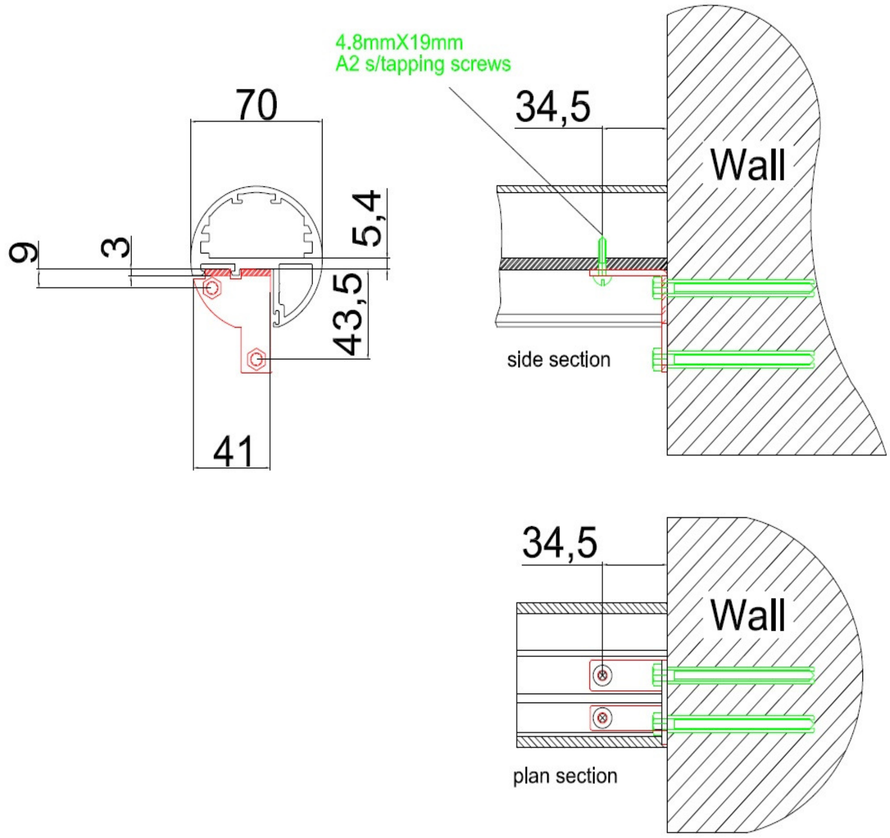
Wall fixings:

The handrail wall fixing consists of 3mm thick stainless steel angles bolted to the wall with 2 No. stainless steel resin anchors and secured to the handrail with 2 No. stainless steel Phillips self-tapping screws.

The allowable simply supported span of the handrail between points of support is 3.0m.

Horizontal service (working) load on the wall fixing for a span of 3.0m $= 0.74\ kN/m \times 1.5m = 1.11$ kN/fixing

The horizontal load on the handrail is applied to the fixing angles at the position of the Phillips screws located 34.5mm from the back of the angles. The wall fixing bolts are 24mm apart horizontally.



The allowable simply supported span of the handrail between points of support is 3.0m.

Horizontal service (working)	=	0.74 kN/m x 1.5m
load on the wall fixing for a	=	1.11 kN/fixing
span of 3.0m		

The horizontal load on the handrail is applied to the fixing angles at the position of the Phillips screws located 34.5mm from the back of the angles. The wall fixing bolts are 24mm apart horizontally.

Pull-out forces on wall fixing

Working load pull-out force on the anchor bolts = $1.11 \text{ kN} \times \frac{34.5}{24}$ = 1.60 kN/bolt

Applying the 50% increase on fixing design loads recommended in BS 6180:2011, this becomes 2.40 kN/bolt. The increase is considered to apply only to the bolt loads, not to other elements of the connection.

Shear forces on wall fixings

Working load shear force on the anchor bolts and the 4.8mm x 19mm stainless steel self-tapping screws = 1.11 kN/2 = 0.555 kN/bolt or screw

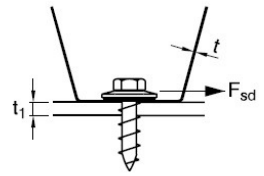
Ultimate load shear force on the anchor bolts and screws	=	0.555 kN/bolt x 1.5	=	0.833 kN/bolt or screw

Applying the 50% increase in design load on anchor bolts recommended in BS 6180:2011, this becomes 1.25 kN/bolt.

<u>Phillips stainless steel self-tapping screws</u>

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'

<u>Properties of stainless steel for angle brackets and self-tapping screws:</u>

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/mm^2. The values given in the table have been adjusted to allow for the yield stress of stainless steel type 304 (290 N/mm^2.)

The ultimate shear capacity of 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	=	1.25 kN		
Factor of safety against shear failure for a 4.8mm diam. screw	=	2.51/1.25		
	=	2.008	=	OK

Stainless steel brackets

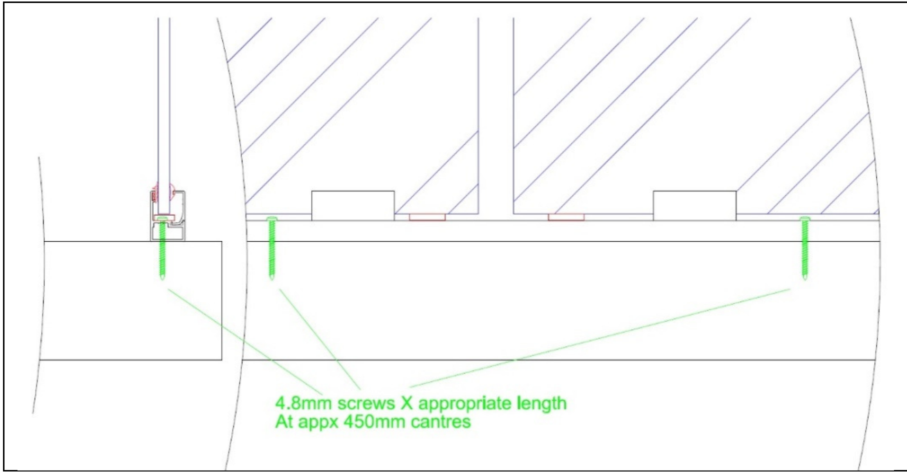
The top part of the bracket consists of two separate sections: one 15.5mm x 3mm and one 13mm x 3mm.

Plastic modulus of 15.5 x 3mm section for lateral loads	=	$\frac{3 \times (15.5)^2}{4}$	=	180.19 mm^3
Plastic modulus of 13 x 3mm section for lateral loads	=	$\frac{3 \times (13)^2}{4}$	=	126.75 mm^3
Σ plastic modulus	=	306.94 mm^3		
Σ resistance moment	=	290 N/mm^2 x 306.94 mm^3 x $(10)^{-6}$		
	=	0.089 kNm		
For a simply supported span of 3.0m: Ultimate load on end bracket	=	1.11 kN/m x 1.5	=	1.67 kN

This load is applied 32.5mm from the face of the bracket.

Moment applied horizontally to the top of the bracket	=	1.67 x 0.0325	=	0.054 kNm
			=	$<$ 0.089 kNm OK

Bottom rail fixing:

	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 load shear force of 0.50 kN.

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

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

VERTICAL LOADS:

As specified in Clause 10 of BS 6399-1:1996, the handrail is also designed for a vertical uniformly distributed load of 0.60 kN/m or a concentrated load of 1.0 kN, whichever gives the worst design condition in combination with the horizontal loading in Table 4.

Vertical loads are transmitted direct to the balcony structure through the 10mm thick thermally toughened safety glass. The concentrated load of 1.0 kN is spread by the handrail. The maximum compressive stress on the glass is 600 / 10 x 1000 = 0.06 N/mm^2 which is low and well within allowable values provided by the glass manufacturers.

SUMMARY ***PAGE 16*** ***(B1NB55150150BP061016)***

BALCONY 1 BALUSTRADE SYSTEM without internal reinforcing bar using 48.3mm diameter X 5mm thick CHS posts and 150 x 150 x 15mm base plates

1) On single span and corner balconies, the handrail is capable of supporting the design factored loads over spans up to 3.0 metres between points of support. (i.e. a handrail wall fixing, or a handrail corner joint.)

2) On longer balconies where the length of the balustrade exceeds 3.0 metres, vertical posts are installed at a maximum spacing of 1.9m between post centres. The posts comprise 48.3mm diameter x 5mm thick circular hollow steel sections (CHS) that are enclosed in 55mm diameter aluminium sleeves.

3) The CHS posts are full strength welded to the 150 x 150 x 15mm steel base plates using butt welds or 10mm fillet welds. 14mm diameter holes are provided at 120mm centres for 4 no. M12 (8.8 grade) holding down bolts.

4) For the maximum span of 3.0 metres on single span and corner balconies, the design horizontal working pull-out load on the wall fixing bolts is 2.40 kN/bolt. The horizontal working shear load on the wall fixing bolts is 0.833 kN/bolt. These loads should be achievable using drilled resin anchor bolts or similar into good quality concrete or brickwork.

5) On longer balconies, where posts are installed at a maximum spacing of 1.9m, the design working load pull-out force on the holding down bolts is 9.665 kN/bolt. 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. It should be appreciated that the manufacturer's recommended bolt load capacities will be reduced where fixings are made into timber or other materials having a lower strength than good quality concrete or brickwork.

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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