WRDEL\E60839A
January 2013

STRUCTURAL CALCULATIONS

FOR

MIRRORED BALCONETTE SYSTEM

USING BALCONY 1 TYPE HANDRAIL

BY

BALCONY SYSTEMS LIMITED

Unit 6
Systems House
Eastbourne Road
Blindly Heath
Surrey
RH7 6JP

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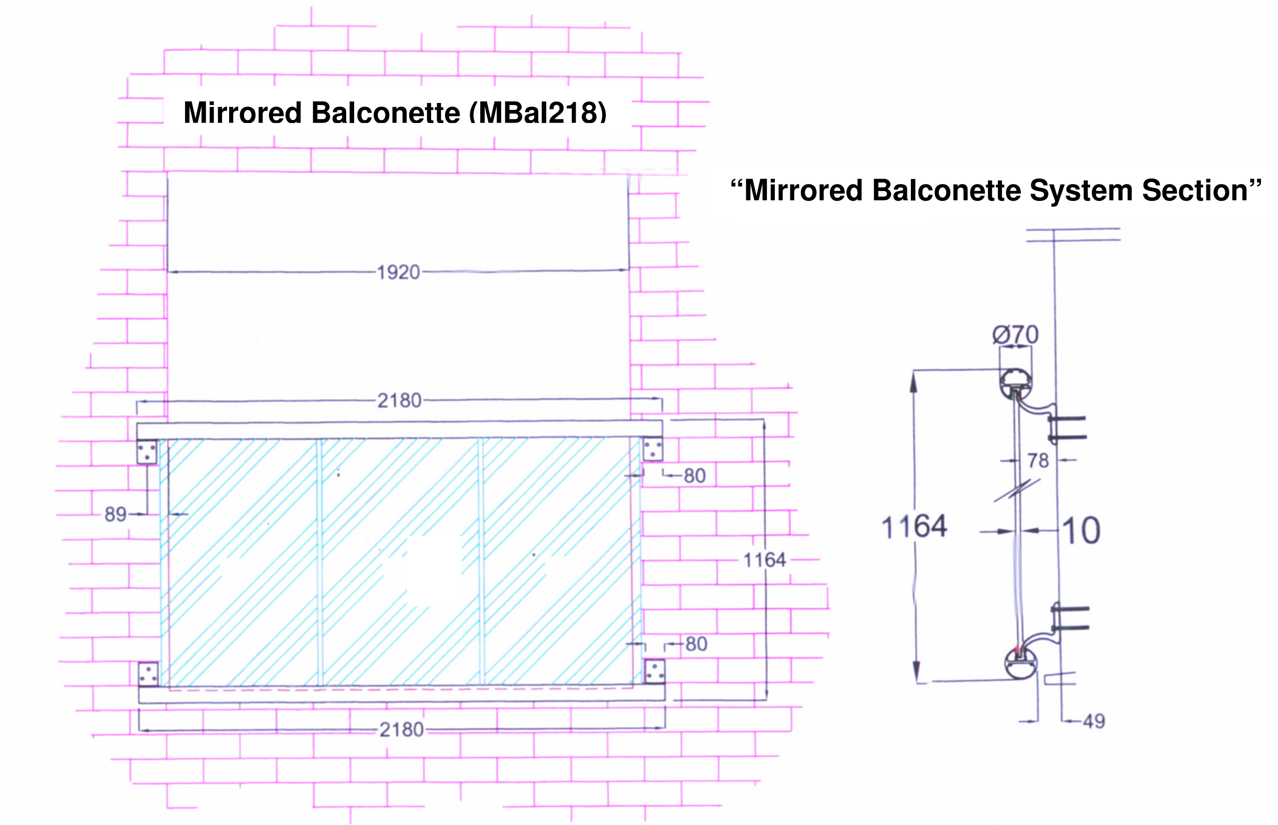

MIRRORED BALCONETTE SYSTEM

WRDEL\E60839A
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DESIGN LOADS ON BALUSTRADE:

The balustrade is designed to resist the horizontal imposed loads specified in **Table 4** of **BS 6399-1:1996** (see below), covering occupancy classes **A(i) and (ii), B(iii), (iv) and (v), C3(viii) and (ix), and (iii), (iv) and (iii).**

Glass infill: The glass infill is designed for a uniformly distributed load of 1.0 kN/m^2 (220 pounds per square metre approximately) plus a point load of 0.5 kN (110 pounds approximately).

Table 4

Minimum horizontal imposed loads for parapets, barriers and balustrades, etc.

Type of occupancy for part of the building or structure	**Examples of specific use**	**Horizontal uniformly distributed line load (kN/m)**	**A uniformly distributed load applied to the infill (kN/m^2)**	**A point load applied to part of the infill (kN)**
A Domestic and residential activities	(i) All areas within or serving exclusively one **[A1]** single family **[A1]** dwelling including stairs, landings, etc but excluding external balconies and edges of roofs (see C3 ix)	0.36	0.5	0.25
	(ii) Other residential, (but also see C)	0.74	1.0	0.5
B and E Offices and work areas not included elsewhere including storage areas	(iii) Light access stairs and gangways not more than 600mm wide	0.22	N/A	N/A
	(iv) Light pedestrian traffic routes in industrial and storage buildings except designated escape routes	0.36	0.5	0.25
	(v) Areas not susceptible to overcrowding in office and institutional buildings also industrial and storage buildings except as given above	0.74	1.0	0.5
C Areas where people may congregate C1/C2 Areas with tables or fixed seating	(vi) Areas having fixed seating within 530 mm of the barrier, balustrade or parapet	1.5	1.5	1.5
	(vii) Restaurants and bars	1.5	1.5	1.5
C3 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 and edges of roofs. Footways and pavements within building curtilage adjacent to basement/sunken areas	0.74	1.0	0.5
C5 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	3.0	1.5	1.5
	(xii) **[A1]** Grandstands and stadia **[A1]**	See requirements of the appropriate certifying authority		
D Retail areas	(xiii) All retain areas including public areas of banks/building societies or betting shops. For areas where overcrowding may occur, see C5	1.5	1.5	1.5
F/G Vehicular	(xiv) Pedestrian areas in car parks including stairs, landings, ramps, edges or internal floors, footways, edges of roofs	1.5	1.5	1.5
	(xv) Horizontal loads imposed by vehicles	See clause 11		
[A1] Not deleted [A1]				

WRDEL\E60839A
January 2013

VERTICAL LOADS ON BALUSTRADES:
Amendment [A_1] of BS 6399-1:1996 specifies that handrails shall be designed for a vertical uniformly distributed imposed line 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.

ALUMINIUM PROPERTIES:

Design standard	=	BS 8118:Part 1:1991 '*The Structural use of aluminium'*.
Handrail material	=	Extruded aluminium type 6063 T5
Bracket material	=	Extruded aluminium type 6063 T6

Limiting stress for factored loads:

			Type T5	Type T6
Bending	P_o	=	110 N/mm^2	160 N/mm^2
Tension & compression	P_a	=	130 N/mm^2	175 N/mm^2
Shear	P_v	=	65 N/mm^2	95 N/mm^2

Factored resistance capacity of a member:

Member capacity	M_c	=	Calculated member capacity based upon the limiting stresses P_o, P_a and P_v divided by the material factor $\gamma_{m.}$
Material factor	γ_m	=	1.20

Factored loads:

Factored loads are used for checking the limit state of static strength of a member.

The imposed loads tabulated in BS 6988-1:1966 are known as 'service loads'. These loads are multiplied by a load factor γ_m of 1.33 (Table 3.1) to give 'limit state' design loads that are used in relation to the factored resistance capacity of a member. The load factor applied to dead loads (self weight of members) is 1.2.

Deflection:

All structural members deflect under load. For balustrade handrails the deflection is limited to 25mm under service load conditions.

Modules of elasticity:

Young's modulus of elasticity (aluminium)	Ea	=	70,000 N/mm^2

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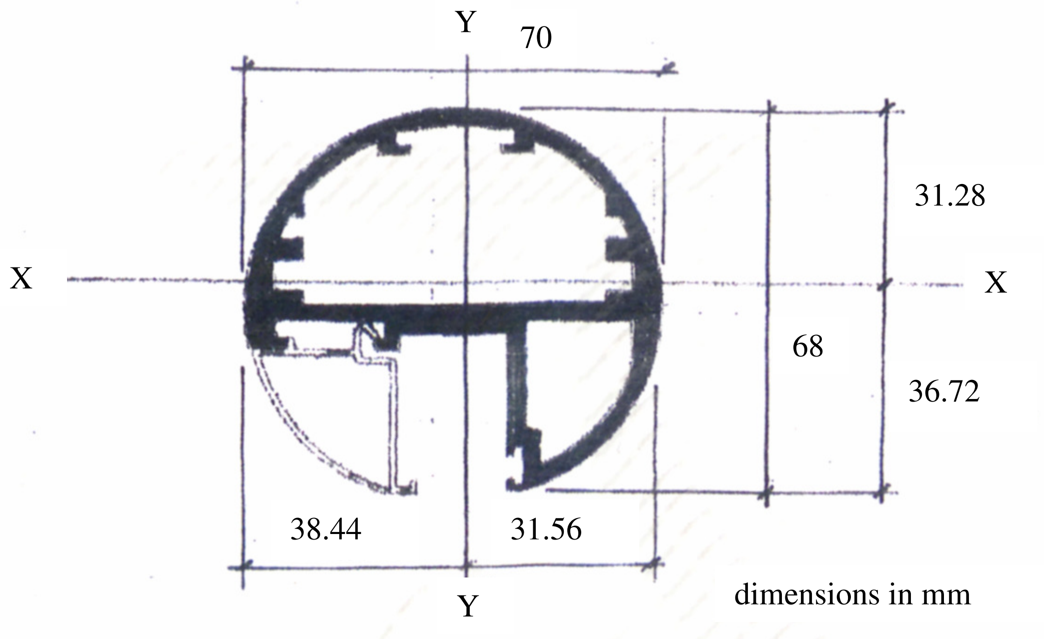
January 2013

BALCONY 1 SYSTEM HANDRAIL (without internal reinforcing bar)



Handrail Type 1

Section properties:

Moment of inertia about the y-y axis	=	I_{yy}	=	47 cm^4
Least section modulus About the y-y axis	=	Z_{yy}	=	12.227 cm^3
Moment of inertia about the x-x axis	=	I_{xx}	=	27.89 cm^4
Least section modulus About the y-y axis	=	Z_{xx}	=	7.595 cm^3

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January 2013

BALCONY 1 SYSTEM HANDRAIL (without internal reinforcing bar)

Moment capacity of the handrail:

Moment capacity for horizontal loads = $M_{rx} = \frac{(P_o) \times Z_{yy}}{(\gamma_m)}$

$= \frac{110\ N/mm^2 \times 12.227\ cm^3 \times (10)^{-3}}{1.2}$

$= 1.12\ kNm$

Moment capacity for vertical loads = $M_{ry} = \frac{(P_o) \times Z_{xx}}{(\gamma_m)}$

$= \frac{110\ N/mm^2 \times 7.595\ cm^3 \times (10)^{-3}}{1.2}$

$= 0.696\ kNm$

Factored design loads:

Factored horizontal UDL load on handrail = 0.74 kN/m x (1.33) = 0.984 kN/m

Factored vertical UDL load on handrail = 0.60 kN/m x (1.33) = 0.798 kN/m

Factored vertical point load on handrail = 1.00 kN x (1.33) = 1.33 kN

Factored dead load on bottom rail = weight of glass + aluminium elements x (1.2)
= 0.26 kN/m x 1.2 = 0.312 kN/m

Factored moments: (based upon a span of 2.1m between the centres of supporting brackets)

Horizontal moment on handrail $M_x = \frac{0.984\ kN/m \times (2.1)^2}{8} = 0.542\ kNm$

Vertical UDL moment $M_{y1} = \frac{0.798\ kN/m \times (2.1)^2}{8} = 0.440\ kNm$

Moment due to a central Vertical point load of 1.33 kN spread over a width of 650mm $M_{y2} = \left(\frac{1.33}{2} kN \times 1.05\right) - \left(2.046\ kN/m \times \frac{0.325^2}{2}\right)$
= 0.59 kNm (shared between the top & bottom rails)
> 0.44 kNm therefore point load governs

NOTE:
a) The horizontal imposed load is resisted by the handrail alone.
b) The vertical dead load is supported by the bottom rail alone.
c) The vertical imposed loads are transmitted through the glass and and are supported by the top and bottom rails in combination.

WRDEL\E60839A
January 2013

BALCONY 1 SYSTEM HANDRAIL (without internal reinforcing bar)

Factored horizontal load moment on handrail M_x = 0.542 kN/m

Moment capacity for horizontal loads M_{rx} = 1.12 kNm OK

Service load deflection for the horizontal imposed load of 0.74 kN/m on a simply supported span of 2.1m

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

$$= \frac{5\ (740 \times 2.1)\ (2100)^3}{384 \times 70000 \times 47 \times (10)^4}$$

$$= 5.70\text{mm} \qquad \text{OK}$$

Factored vertical load moment on handrail (page 6) $M_y = \frac{0.59\ \text{kNm}}{2}$

= 0.295 kNm

Moment capacity for vertical loads (page 6) M_{ry} = 0.696 kNm

Check handrail for biaxial bending:

$$= \frac{M_x}{M_{rx}} + \frac{M_y}{M_{ry}}$$

$$= \frac{0.542}{1.12} + \frac{0.295}{0.696}$$

$$= 0.908 < 1.00 \qquad \text{OK}$$

Bottom rail:

The factored concentration load of 1.33 kN applied at the centre of the handrail is spread through the central glass panel, applying a moment of 0.295 kNm to both the handrail and the bottom rail. In addition the bottom rail supports the self-weight of the glass and the self-weight of the top and bottom rails (0.312 kN/m factored load).

Factored moment at centre span due to dead load

$$= 0.312 \times \frac{(2.10^2)}{8}$$

= 0.172 kNm

The top and bottom rails are similar and are connected together by the 10mm safety glass. They will therefore deflect equally under vertical imposed loads, which will be carried equally by both rails.

$\sum$ moment (dead + imposed loads) = 0.172 + 0.295

= 0.467 kNm = $< M_{ry}$ of 0.696 kNm
= OK

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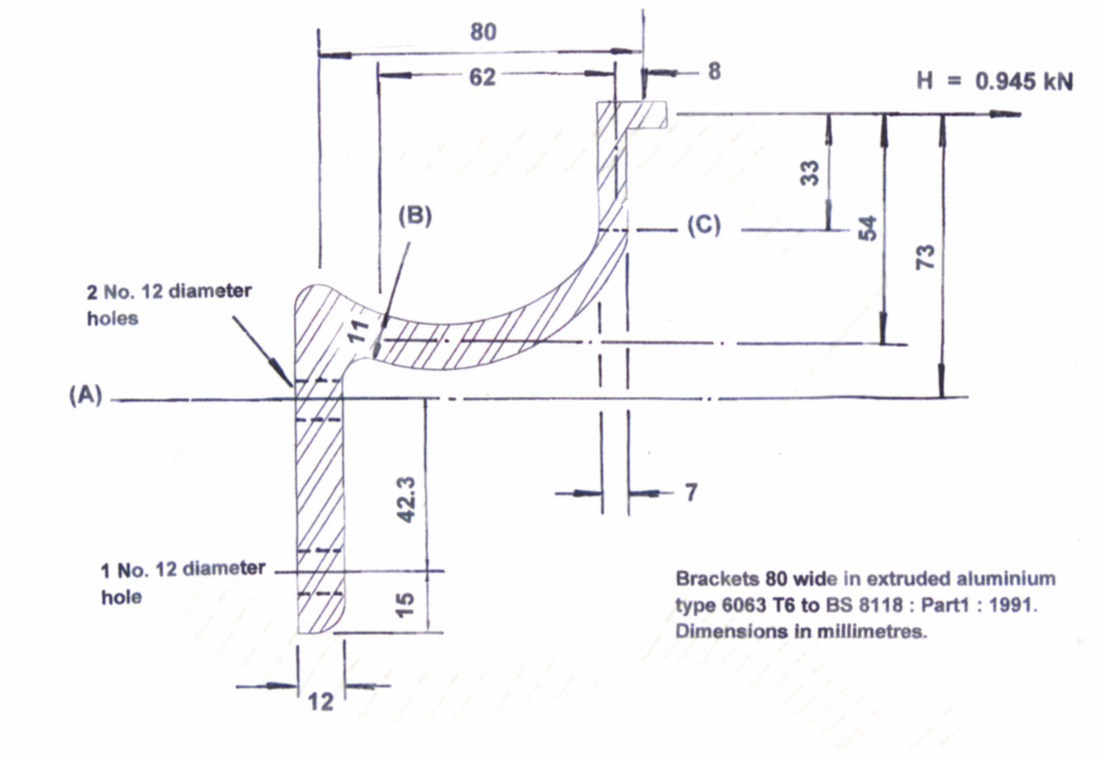
January 2013

TOP & BOTTOM RAIL BRACKETS



HANDRAIL BRACKET – FACTORED LOADS

Handrail brackets: The horizontal imposed design load on the handrail can only act over the clear width of the opening, ie 1.92m. Bracket design load H calculated on this basis.

Horizontal load H = $0.984 \text{ kN/m} \times \frac{1.92}{2}$ = 0.945 kN

Vertical load V = 1.33 kN which occurs when the point load is applied immediately above or close to the bracket.

Dimensions at section (A) = 80mm wide x 12mm thick overall, less 2 No 12mm diameter holes for 10mm diameter bolts. 56mm x 12mm effective section.

Limiting stress in bending P_o = 160 N/mm^2

Section modulus Z = $\frac{56 \times (12)^2}{6}$ = 1344 mm^3

WRDEL\E60839A
January 2013

BRACKETS (continued)

Section (A)

Factored applied moment = (1.33 x 0.08) + (0.945 x 0.073)
= 0.175 kNm

Moment capacity of section = $\frac{(P_o) \times (Z)}{(\gamma_m)}$

= $\frac{160 \text{ N/mm}^2 \times 1344 \text{ mm}^3 \times (10)^{-6}}{1.2}$
= 0.178 kNm
> 0.175 kNm = OK

Section (B)

Factored applied moment = (1.33 x 0.07) + (0.945 x 0.054)
= 0.144 kNm

Section modulus Z = $\frac{80 \times (11)^2}{6}$
= 1613.33 mm^3

Moment capacity of section = $\frac{160 \text{ N/mm}^2 \times 1613.33 \text{ mm}^3 \times (10)^{-6}}{1.2}$
= 0.251 kNm
> 0.144 kNm = OK

Section (C)

Factored applied moment = (1.33 x 0.008) + (0.945 x 0.033)
= 0.042 kNm

Section modulus Z = $\frac{80 \times (7)^2}{6}$
= 653.33 mm^3

Moment capacity of section = $\frac{160 \text{ N/mm}^2 \times 653.33 \text{ mm}^3 \times (10)^{-6}}{1.2}$
= 0.087 kNm
> 0.042 kNm = OK

Shear force at Section (B) = 1.33 + 0.945
= 2.275 kN

Average shear stress = $\frac{2275}{80 \times 11}$ = 2.59 N/mm^2 which is OK

The brackets are adequate to resist the design bending and shear forces

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January 2013

Fixing bracket bolt forces:

Top rail brackets (2 No bolts top; 1 No bolt bottom of bracket)

Moments taken about the lower bolt for the direct pull-out force on the top 2 No bolts: Factored loads on the bracket are shown on Page 8.

Direct tension on top 2 bolts $= \frac{(0.945 \times 0.115) + (1.33 \times 0.086)}{0.042}$

= 5.31 kN

= 2.655 kN/bolt

say = 2.70 kN/bolt (factored load)

= 2.03 kN/bolt (working load)

Shear force on 3 No bolts = 1.33 kN (factored load)

= 0.443 kN/bolt

say = 0.50 kN/bolt (factored load)

= 0.38 kN/bolt (working load)

Bottom rail brackets (1 No bolt top; 2 No bolts bottom of bracket)

Vertical load on bracket V $= \frac{1.33}{2} + \frac{(0.312 \times 2.1)}{2}$

= 0.993 kN

Direct tension on top bolt $= \frac{(0.993 \times 0.086)}{0.042}$

= 2.033 kN ie, less than for top bracket. Use the higher forces for both top and bottom brackets

say = 2.70 kN (factored load)

= 2.03 kN (working load)

Shear force on 3 No bolts = 0.50 kN/bolt (factored load)

= 0.38 kN/bolt (working load)

These are relatively modest bolt forces that should be readily achievable with suitable drilled resin anchor bolts or similar into sound structure.

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SUMMARY

1. The Mirrored Balconette System, comprising Balcony 1 type handrails and bottom rails in extruded aluminium grade 6063 T5, is adequate to support the horizontal and vertical imposed loads specific in BS 6399-1:1996 in respect of the occupancy classes listed on page 3, for spans of up to 2.1 metres between the centres of supporting brackets.

2. The supporting brackets in extruded aluminium grade 6063 T6 are adequate to support the specified loads for spans up to 2.1 metres between bracket centres.

3. For the design loading, span and supporting bracket profile, the calculated working load direct pull-out force on each of the top 2 No bolts on the handrail brackets, and on the 1 No top bolt on the bottom rail bracket, is 2.03 kN.

4. The calculated working load shear force on each bolt on both the top and bottom brackets is 0.38 kN.

5. These are relatively modest bolt forces that should be readily achievable with suitable resin anchor bolts or similar into sound structure.

   However, the installers should satisfy themselves that the fixings chosen are suitable to resist these working load forces and also that the wall/structure into which the bolts are installed can safely support these loads.

6. The comprehensive stress on the 10mm thick toughened safety glass panels is low and well within the allowable stress recommended by the manufacturer, Pilkington Glass Limited.

   The toughened glass panels were also test loaded by an independent testing laboratory (Sandberg Consulting Engineers – report reference 26890/M) and found to be adequate to withstand the factored loads specified in relevant British Standards.

END