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July 2012

STRUCTURAL CALCULATIONS

FOR

BALUSTRADES

USING BALCONY 2 SYSTEM HANDRAIL
WITH INTERNAL REINFORCING BAR

BY

BALCONY SYSTEMS LIMITED

Balcony 2 System, posts in Royal Chrome

Prepared by : WRD Engineers Limited
Registered in England: No. 07977613 : The Stables, Rear of 60 The Avenue, SOUTHAMPTON, SO17 1XS
T D White CEng MICE MIHT MCIArb * M D Royall ACGI BSc CEng MICE MCIArb
* Philippa Dixon BSc CEng MICE

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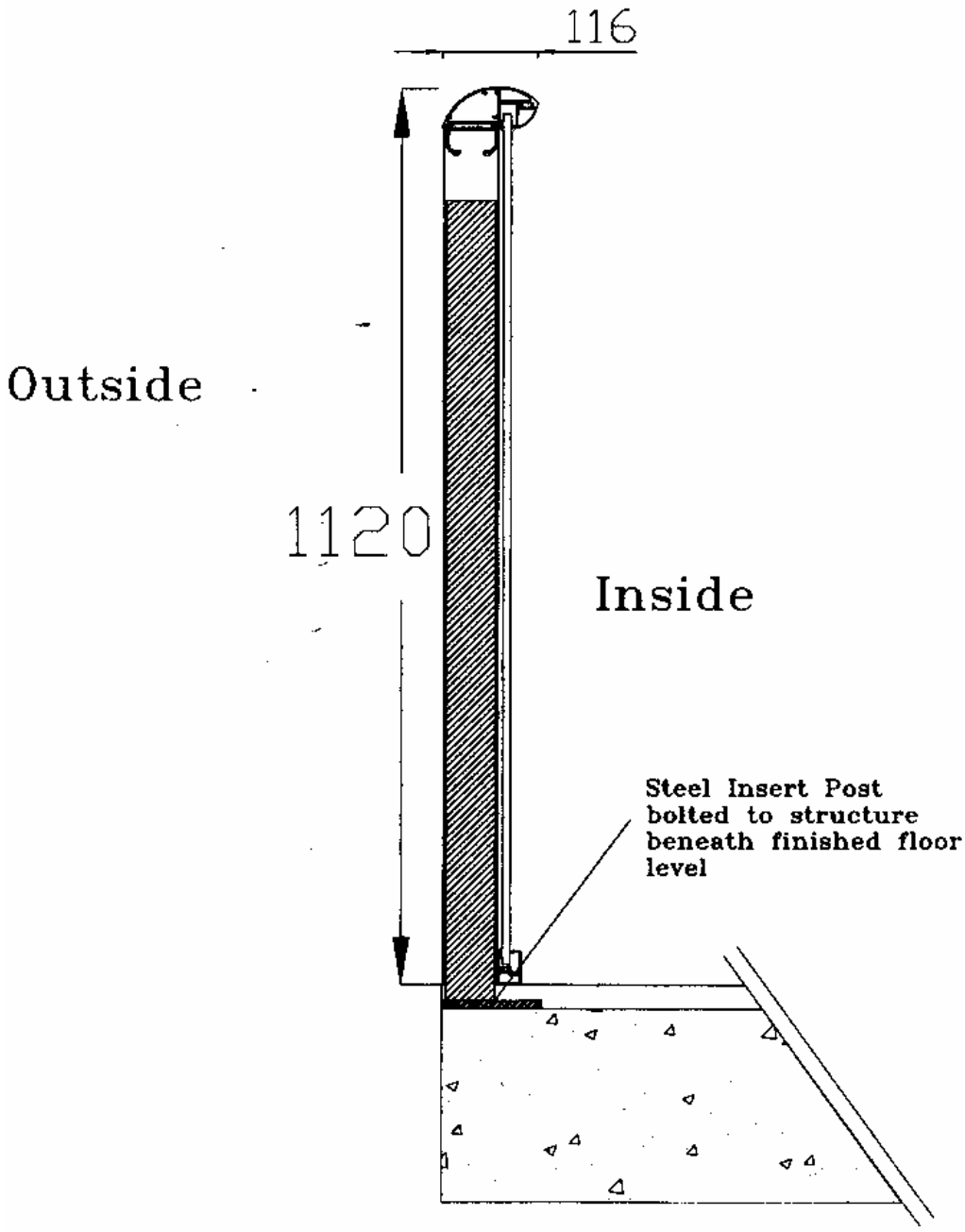
Balcony 2 system section



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BALUSTRADE LOADS:

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).**

Handrail: The handrail is designed for a uniformly distributed horizontal imposed line load of 0.74 kN/m (164 pounds per metre approximately).
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]				

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VERTICAL LOADS:
BS 6399-1:1996 also 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.

Vertical loads on the handrail are transmitted direct to the balcony structure through the 10mm thick thermally toughened safety glass. The concentrated load is spread by the handrail. The maximum compressive stress on the glass is 600 / 10 x 1000 = 0.06 N/mm^2. This is a low value of compressive stress and well within the safe allowable stress recommended by Pilkington Glass Ltd, the glass manufacturer.

ALUMINIUM PROPERTIES:

Design standard	=	BS 8118:Part 1:1991 '*The Structural use of aluminium*'.
Material type	=	Extruded aluminium type 6063 T5
Limiting stress for bending and overall yielding	=	P_o = 110 N/mm^2 (Table 4.1)
Limiting stress for tension or compression	=	P_s = 130 N/mm^2 (Table 4.1)
Limiting stress for shear	=	P_v = 65 N/mm^2 (Table 4.1)
Factored resistance capacity of a member	=	Calculated member capacity based upon the limiting stresses P_o P_s & P_v divided by the material factor γ_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 on Page 3 are known as 'service loads'. These loads are multiplied by a load factor γ 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.

DEFLECTION:
All structural members deflect to some extent under load.

For balustrade handrails the displacement at any point from its original unloaded position is limited to 25mm under service load conditions.

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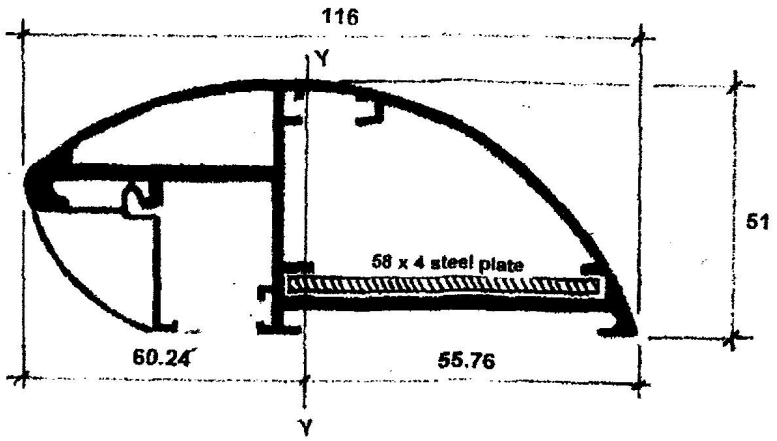
BALUSTRADES

Balcony 2 System handrail with 58 x 4mm internal reinforcing bar



dimensions in mm

Young's modulus of elasticity (aluminium)	=	E a	=	70000 N/mm^2
Young's modulus of elasticity (steel)	=	E s	=	20500 N/mm^2
Moment of inertia about the y-y axis in aluminium units	=	I_{yy}	=	138 cm^4
Least section modulus about the y-y axis	=	Z_{yy}		
	=	$\frac{138}{6.024}$	=	22.908 cm^3

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BALUSTRADES - Balcony 2 System handrail with internal bar

Moment capacity of handrail for horizontal loads

$$= \frac{(Po)\ X\ Zyy}{(\gamma_m)}$$

$$= \frac{110\ N/mm^2 \times 22.908\ cm^3 \times (10)^{-3}}{1.2}$$

$$= 2.10\ kNm$$

Applied design load (ultimate limit state)

$$= 0.74 \times 1.33$$

$$= 0.984\ kN/m$$

Horizontal moment on handrail

$$= \frac{w\ L^2}{8}$$

The handrail is restrained in the vertical direction by the toughened glass.

Allowable span L between posts based upon the moment of the handrail

$$= \frac{(\ 8 \times M\ )^{0.5}}{(\ \ w\ \ )}$$

$$L = \frac{(\ 8 \times 2.10\ )^{0.5}}{(\ \ 0.984\ \ )}$$

$$= 4.132\ m$$

say = 4.00 metres

Service load deflection:

Horizontal service load on handrail = 0.74 kN/m

Limiting service load deflection = 25 mm

Deflection of handrail based upon a simply supported span between points of support

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

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BALUSTRADES - Balcony 2 system handrail with internal reinforcing bar

Service load deflection (continued):

Service load deflection on a span of 4000mm

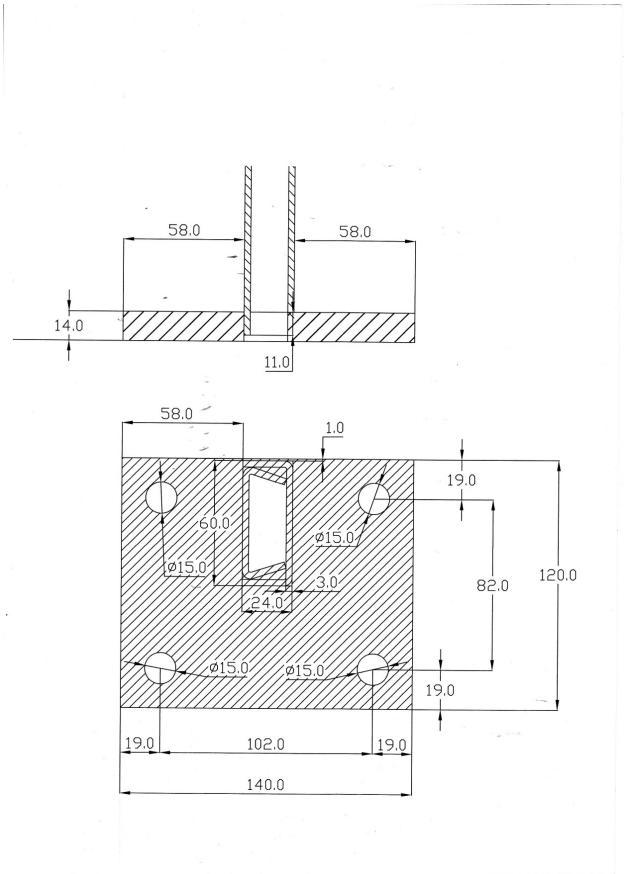
$$= \frac{5\ (740 \times 4.00)\ (4000)^3}{384 \times 70000 \times 138 \times (10)^4}$$

$$= 25.53 \text{ mm} = \text{slightly} > 25\text{mm but}$$

$$= \text{say OK}$$

Balcony 2 system posts:

The design horizontal load on the handrail is applied 1.1m above balcony floor level. The posts are installed at a maximum spacing of 2.1m.



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BALUSTRADES - Balcony 2 system posts (continued)

properties of post: To allow for the fact that the end flanges of the channels are not parallel, the post is assumed to be equivalent to a rectangular hollow section 60 x 24mm overall, with 3mm thick side walls and 5mm thick end walls.

second moment of area about the X – X axis = I xx
= 24.45 cm^4

section modulus about the X –X axis = 8.15 cm^3

steel grade = S 275

moment capacity about the X-X axis (ultimate)
= 1.2 x Py x Z
= 1.2 x 275 x 8.15 x $(10)^{-3}$
= 2.689 kNm

ultimate design horizontal load on the handrail = 0.984 kN/m

ultimate design moment on the posts
= 0.984 x 1.10
= 1.0824 kNm/m
= 2.273 kNm/post @ 2.10m centres
= < 2.689 kNm/post
= OK

service load deflection on a post supporting a 2.1m length of handrail
= $\frac{P L^3}{3 E I}$
= $\frac{(740 \times 2.1)\ (1100)^3}{3 \times 205000 \times 24.45 \times (10)^4}$
= 13.76 mm

service load deflection on the handrail based upon a simply supported span of 2.1m
= $\frac{5wL^4}{384\ EI}$
= $\frac{5\ (740 \times 2.1)(2100)^3}{384 \times 70000 \times 138 \times (10)^4}$
= 1.94 mm

combined total deflection of handrail and post
= 13.76 + 1.94
= 14.70 mm = < 25 mm = OK

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BALUSTRADES: Balcony 2 system post base plates and bolts:

Posts at 2.10m spacing:

base plate thickness	=	14mm	
plate width	=	140mm	
modulus of plate (Z)	=	$\frac{14 \times (1.4)^2}{6}$	
	=	4.5733 cm^4	
ultimate moment capacity of base plate (Mc)	=	Py x Z	
	=	275 N/mm^2 x 4.5733 x $(10)^{-3}$	
	=	1.2577 kNm	
lever arm between bolt centres in the direction of applied load	=	82mm	
ultimate load pull pull out force on 2 No. bolts	=	$\frac{1.0824 \times 2.1}{0.082}$	
	=	27.72 kN	
	=	13.86 kN/bolt	(ultimate load)
	=	10.42 kN/bolt	(working load)
distance from face of post to centre of bolts in tension	=	40mm	
moment on base plate (ultimate load)	=	tension force on 2 No. bolts x 40mm	
	=	27.72 kN x 0.04	
	=	1.109 kNm	
	=	$<$ 1.2577 kNm	
	=	OK	

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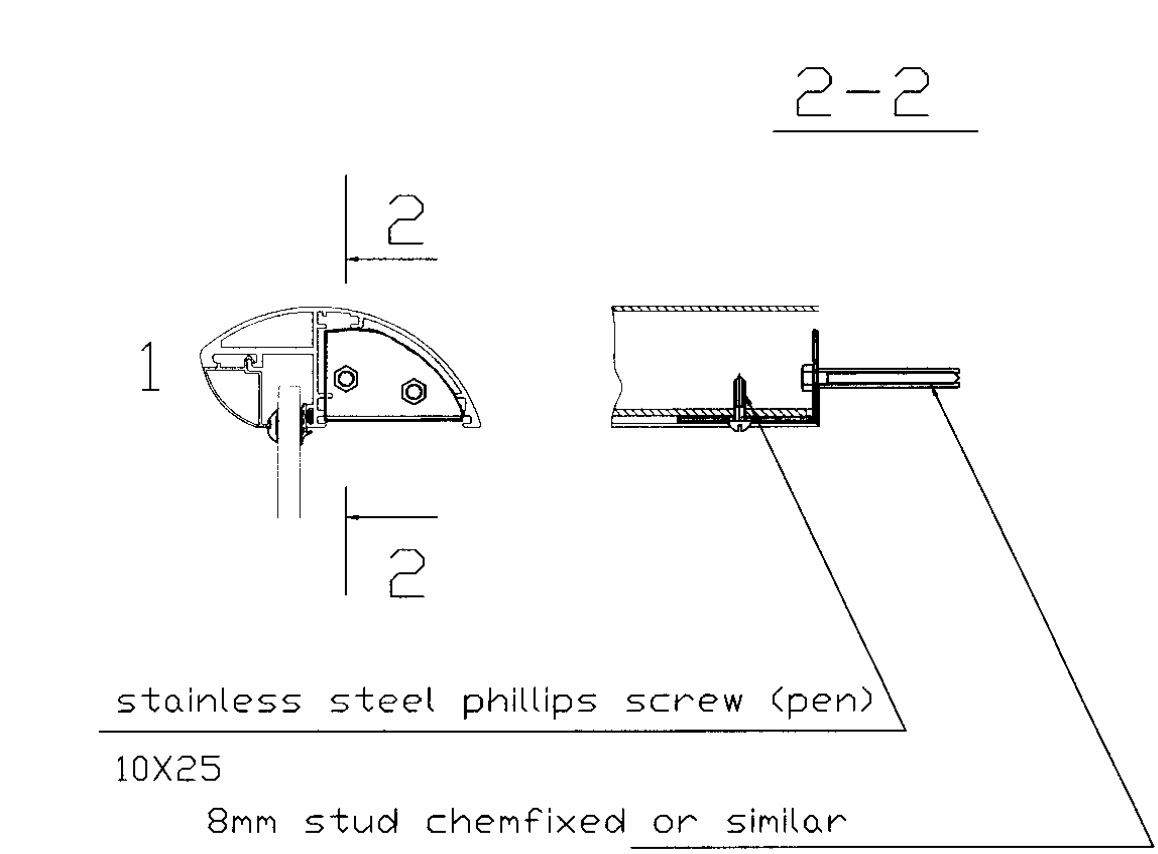
BALUSTRADES: Balcony 2 System wall fixings



The handrail wall fixing consists of 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 screws.

For the maximum allowable span of the handrail of 4.0m between points of support, the horizontal load on the wall fixings is as follows:

working load	=	0.74 kN/m x 2.0
	=	1.48 kN/fixing
	=	0.74 kN/bolt (0.984 kN/bolt factored load)

The horizontal load on the handrail is assumed to be applied to the fixing angles at the location of the Phillips screws 35mm from the back of the angle. The wall fixing bolts are 27.5mm apart. The resulting working load direct tension (pull-out) force on the bolts is 1.48 x 35/27.5 = 1.88 kN

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BALUSTRADES – Balcony 2 System handrail with internal steel reinforcing bar

SUMMARY

1 On single span and corner balconies, the handrail is capable of supporting the design factored loads over spans up to 4 metres between points of support. (ie. a handrail wall fixing, or a handrail corner joint).

2 On longer balconies where the length of the balustrade exceeds 4.0m, vertical posts are installed at a maximum spacing of 2.1 metres.

3. For the maximum spacing between the centres of posts of 2.1m, the working load pull-out force on each of the bolts on the post base plate is 10.42 kN.

4. For the maximum allowable span on single span and corner balconies, the horizontal working load shear force on each of the handrail wall fixing bolts is 0.74 kN. The co-existing working load pull-out force on the handrail wall fixing bolts is 1.88 kN.

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

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

END

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