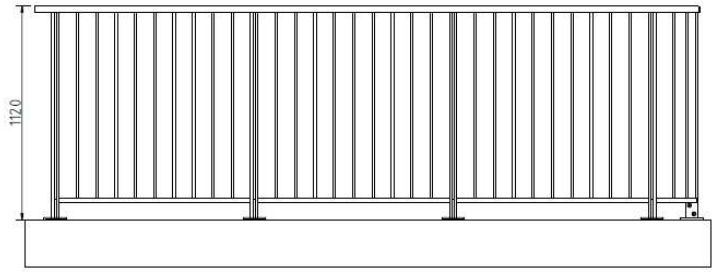
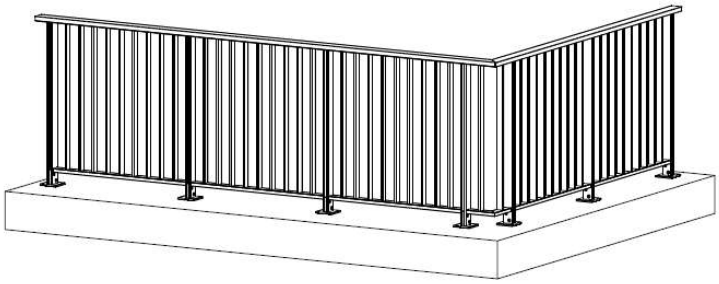
Milano System for 0.74 kN loading: ***PAGE 1*** **(MLNO230820)**

Structural Calculations for Milano System balustrades for 0.74 kN loading using surface mounted or side mounted systems

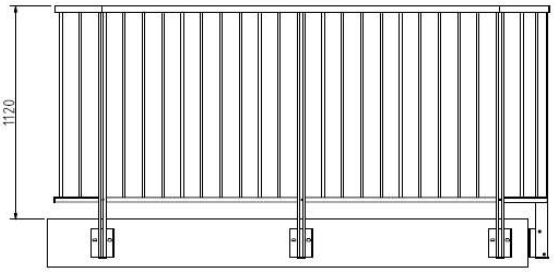
Our ref: MLNO230820 **Date of issue: August 2020**

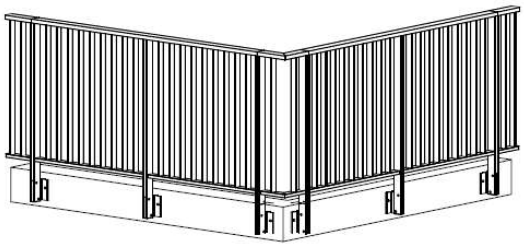
Surface mounted





Side mounted





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	=	0.74 kN/m horizontal uniformly distributed line load acting 1100mm above finished floor level. (Table 2: BS6180:2011)
Service load applied to the balusters	=	A uniformly distributed load of 1.0 kN/m^2
Service point load applied to the balusters	=	0.50 kN applied to each baluster in any position.

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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/m^2)	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

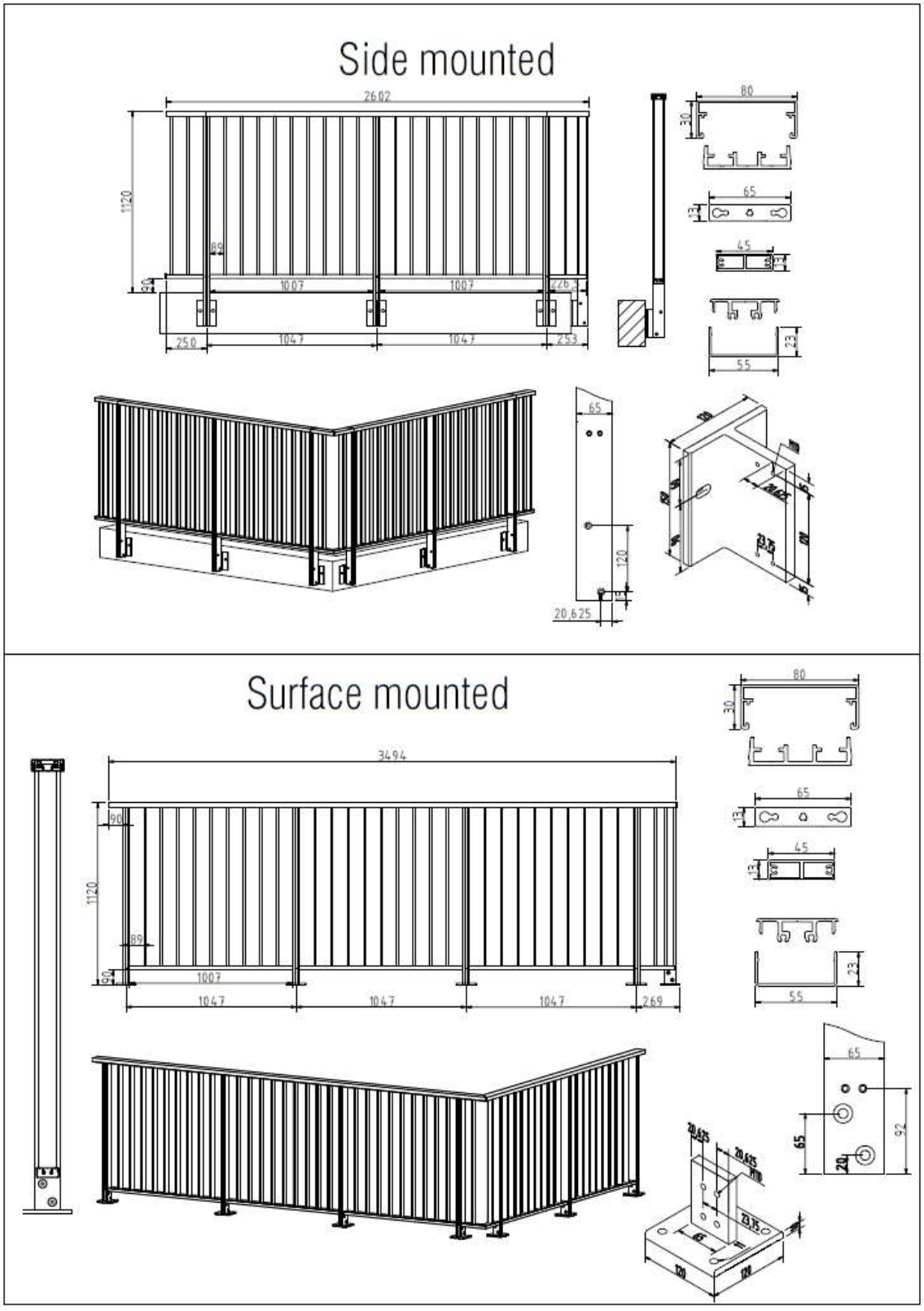
Table 2: BS6180:2011

- 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.

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.

Milano System for 0.74 kN loading:



Milano System for 0.74 kN loading:

Section properties of handrail: PN : FPK3

Overall width		=	69.6 mm
Overall height		=	18.5 mm
Material type		=	Extruded aluminium type 6063 T5
Characteristic 0.2% proof stress (t ≤ 3mm)	f_o	=	130 N/mm^2
Characteristic ultimate tensile strength (t ≤ 3mm)	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}	=	18.99 cm^4
Elastic modulus about the y-y axis	W_{el}	=	5.457 cm^3
Partial factor for material properties	γ_{M1}	=	1.10
Value of shape factor (conservative value)	α	=	1.2

Design ultimate resistance to bending about the y-y axis

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

$= \dfrac{1.2 \times 5.457\ cm^3 \times 130\ N/mm^2 \times (10)^{-3}}{1.1}$

$=$ **0.774 kNm**

Design ultimate horizontal load on handrail		=	0.74 kN/m x 1.5	=	1.11 kN/m
Span of handrail between points of support		=	1047mm		
Design horizontal moment on handrail between points of support (simply supported spans or 2 spans continuous over a central support)		=	$\dfrac{1.11\ kN/m \times (1.047)^2}{8}$	=	0.152 kNm
		=	< 0.774 kNm	=	OK

Service load deflection of handrail between points of support, simply supported. (worst case)

$= \dfrac{5\ W\ L^4}{384\ E\ I}$

$= \dfrac{5 \times (740 \times 1.047)\ (1047)^3}{384 \times 70000 \times 18.99 \times (10)^4}$

$=$ 0.871mm = OK

Design notes:

1. The handrail is laterally restrained in the x-x direction by the balusters.
2. The handrail cover, part reference FPK3A, will provide additional bending and deflection resistance.
3. However, since the cover is a clip-on component it has not been taken into account in the above calculation.
4. The handrail alone is adequate to resist the design loads.

Summary:

The handrail is adequate to resist the specified design loads in terms of both bending strength & deflection limitations.

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Section properties of bottom rail: PN : FPR2

Overall width		=	54.96 mm		
Overall height		=	15.92 mm		
Length between points of support		=	1047 mm		
Material type		=	Extruded aluminium type 6063 T5		
Characteristic 0.2% proof stress (t ≤ 3mm)	f_o	=	130 N/mm^2		
Characteristic ultimate tensile strength (t ≤ 3mm)	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}	=	5.42 cm^4		
Elastic modulus about the y-y axis	W_{el}	=	1.972 cm^3		
Moment of inertia about the x-x axis	I_{xx}	=	0.58 cm^4		
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}	=	$\alpha W_{el} f_o / \gamma_{M1}$		
		=	$\frac{1.2 \times 1.972\ cm^3 \times 130\ N/mm^2 \times (10)^{-3}}{1.1}$		
		=	**0.283 kNm**		
Ultimate load from UDL on balusters		=	0.50 kN/m x 1.5	=	0.75 kN/m
Distance between points of support		=	1047 -13.8 – 13 – 13	=	1007.2mm
Design ultimate BM between points of support		=	$\frac{1.50 \times (1.007)^2}{8}$	=	0.190 kNm
		= <	0.283 kNm	=	OK
Service load deflection between points of support		=	$\frac{5\ W\ L^4}{384\ E\ I}$		
		=	$\frac{5\ (500 \times 1.007)\ (1007)^3}{384 \times 70000 \times 5.42 \times (10)^4}$		
		=	1.87 mm	=	OK

Design notes:

1. The bottom rail is laterally restrained in the x-x direction by the balusters.
2. The bottom rail cover, part reference FPR2A, will provide additional bending and deflection resistance.
3. However, since the cover is a clip-on component it has not been taken into account in the above calculation.
4. The bottom rail alone is adequate to resist the design loads.

Summary:

The bottom rail is adequate to resist the specified design loads in terms of both bending strength & deflection limitations.

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Section properties of balusters: PN : FPD 2

Overall width		=	13.0 mm
Overall depth		=	45.0 mm
Length between points of support		=	1000 mm
Material type		=	Extruded aluminium type 6063 T5
Characteristic 0.2% proof stress (t ≤ 3mm)	f_o	=	130 N/mm^2
Characteristic ultimate tensile strength (t ≤ 3mm)	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}	=	4.49 cm^4
Elastic modulus about the y-y axis	W_{el}	=	1.996 cm^3
Moment of inertia about the x-x axis	I_{xx}	=	0.48 cm^4
Partial factor for material properties	γ_{M1}	=	1.10
Value of shape factor (conservative value)	α	=	1.2

Design ultimate resistance to bending about the y-y axis

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

$= \dfrac{1.2 \times 1.996\ cm^3 \times 130\ N/mm^2 \times (10)^{-3}}{1.1}$

= **0.283 kNm**

Service point load applied at mid-height (worst case for bending) = 0.50 kN

Ultimate design point load = 0.50 kN x 1.5 = 0.75 kN

Ultimate design point load BM = $\dfrac{0.75\ kN \times 1.0}{4}$ = 0.188 kNm

Service load deflection due to 0.50 kN point load applied at mid-span

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

$= \dfrac{500 \times (1000)^3}{48 \times 70000 \times 4.49 \times (10)^4}$ = 3.31 mm OK

Summary:

The balusters are adequate to support the design loads in terms of bending strength and deflection.

Milano System for 0.74 kN loading: ***PAGE 7*** **(MLNO230820)**

Section properties of posts: (posts in pairs at 1047mm centres)

Overall width of each post		=	13.0 mm
Overall depth of each post		=	65.0 mm
Material type		=	Extruded aluminium type 6063 T5
Characteristic 0.2% proof stress (t ≤ 25mm)	f_o	=	130 N/mm^2
Characteristic ultimate tensile strength (t ≤ 25mm)	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}	=	22.99 cm^4
Elastic modulus about the y-y axis	W_{el}	=	7.074 cm^3
Moment of inertia about the x-x axis	I_{xx}	=	1.15 cm^4
Partial factor for material properties	γ_{M1}	=	1.10
Value of shape factor (conservative value)	α	=	1.2
Design ultimate resistance to bending about the y-y axis	M_{Rd}	=	$\alpha W_{el} f_o / \gamma_{M1}$
		=	$\frac{1.2 \times 7.074\ cm^3 \times 130\ N/mm^2 \times (10)^{-3}}{1.1}$
		=	**1.003 kNm**

Surface fix system: posts:

Height from centre of anchorage in base bracket to line of action of the imposed UDL line load		=		1100 – 10 – 42.5	=	1047.5mm
Factored UDL line load		=		1.11 kN/m		
Span of handrail between posts centre to centre		=		1047 mm		
Maximum load occurs on central posts supporting a handrail continuous over 2 spans of 1047mm		=		1.11 (2 x 1.047 x 0.625)	=	1.45 kN
Factored BM on 2 No. posts to centre of post		=		1.45 kN x 1.048 /2 No.	=	0.76 kNm/post
anchorage at the base.		=	<	1.003 kNm/post	=	OK
Vertical spacing of post/bracket fixing studs		=		45mm		
Ultimate shear force on fixing studs		=		$\frac{0.76\ kNm}{0.045}$	=	16.9 kN/stud

Post deflection:

Service load deflection of posts supporting a point load at the top		=		$\frac{P L^3}{3 E I}$		
		=		$\frac{967 \times (1048)^3}{3 \times 70000 \times (2 \times 22.99) \times (10)^4}$		
		=		11.53mm		
		=	<	25mm	=	OK
Combined deflection handrail + post		=	<	25mm	=	OK

Summary:

The posts are adequate to support the design loading in terms of both bending strength & deflection limitations.

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Post/base plate connection:

Each post is connected to the base upstand by means of 2 No. M10 threaded stainless steel studs 45 mm apart centre to centre vertically.

Factored moment to be resisted	=	0.76 kNm/post		
Shear force on threaded stainless steel studs	=	$\frac{0.76 \text{ kNm}}{0.045}$	=	16.9 kN/stud

Stainless steel studs: surface fix system:

Stud diameter	Property class to BS EN ISO 350	Shear capacity	Tension capacity
M10	50	8.4 kN	8.8 kN
M10	70	18.0 kN	20.9 kN
M10	80	23.3 kN	26.0 kN

M10 threaded stainless steel studs property class 70 are adequate.

Baseplate brackets: surface fix system:

Dimensions of base		=	120 x 120 x 10mm thick
Dimensions of central upstand		=	95 high x 65 deep x 13.8 mm thick
HD bolts		=	4 M10 @ 90 mm c/c
Material type		=	extruded aluminium 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	=	70000 N/mm^2
Height from underside of base to line of action of the design imposed UDL		=	1100 mm
Imposed force from line load on 2 No. posts at the centre of 2 No continuous spans		=	1.45 kN (page 7)
Factored BM to underside of base		=	1.45 kN x 1.10 = 1.595 kNm
4 No. M10 HD bolts @ 90 mm c/c: bolt tension		=	$\frac{1.595 \text{ kNm}}{2 \text{ No. x } 0.090}$ = 8.86 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 50% increase in loads on fixings recommended in BS 6180:2011, the **ultimate load** bolt tension of **8.86 kN/bolt** calculated above becomes the design **working load bolt tension**.

Provision is made in the base plates for 4 No. M10 stainless steel HD bolts. The installers should ensure that if drilled resin anchor bolts or similar are selected, the bolts have a minimum working load pull-out capacity of **8.86 kN/bolt**. Alternatively it should be possible to achieve adequate fixings by drilling through and anchoring to the underside of a suitable slab.

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Base upstand: Surface Fix System:

Height of upstand		=	95 mm		
Length of upstand		=	65 mm		
Thickness of upstand		=	13.8 mm		
Moment of inertia about the x-x axis		=	$\frac{1.38 \times (6.5)^3}{12}$	=	31.58 cm^4
Plastic modulus about the x-x axis		=	$\frac{1.38 \times (6.5)^2}{4}$	=	14.576 cm^3
Design ultimate resistance to bending about the x-x axis		=	$\frac{14.576 \times 0.160}{1.1}$	=	2.12 kNm
Factored moment applied by 2 No. posts		=	1.52 kNm	=	OK

Side Fix System: posts:

Material type		=	extruded aluminium type 6063 T5		
Characteristic 0.2% proof stress	f_o	=	130 N/mm^2		
Characteristic UTS	f_u	=	175 N/mm^2		
Modulus of elasticity	E	=	70000 N/mm^2		
Moment capacity about the main axis		=	1.003 kNm/post		
Height from centre of anchorage in base bracket to line of action of the imposed UDL line load		=	1100 – 90 + 300 – 75	=	1235mm
Factored UDL line load		=	1.11 kN/m		
Span of handrail between posts centre to centre		=	1047 mm		
Maximum factored load applied to 2 No. posts		=	1.45 kN (page 7)		
Factored BM on 2 No. posts to centre of post anchorage		=	1.45 kN x 1.235	=	1.791 kNm/2 posts
		=	0.896 kNm/post < 1.003 kNm	=	OK
Vertical spacing of post/bracket fixing studs		=	120mm		
Ultimate shear force on post/bracket fixing studs		=	$\frac{1.791 \text{ kNm}}{0.120 \times 2 \text{ No.}}$	=	7.46 kN/stud
				=	OK

Side fix system: anchor bolts:

There are 2 No. anchor bolts located 90mm above the underside of the fixing bracket.

Assuming a triangular pressure distribution 45mm long between the bracket and the supporting structure:

Lever arm between the centres of compression and tension		=	90 – 15	=	75mm
Moment to be resisted by 2 No. bolts		=	1.791 kNm		
Factored bolt pull-out force		=	$\frac{1.791 \text{ kNm}}{2 \times 0.075}$	=	11.94 kN/bolt

Applying the BS 6180 50% increase in fixing loads, the **working load** bolt pull-out force becomes **11.94 kN/bolt, say 12.0 kN/bolt.**

Milano System for 0.74 kN loading: ***PAGE 10*** **(MLNO230820)**

SUMMARY

MILANO SYSTEM for 0.74 kN/m loading using surface fix or side fix systems

1) **The Milano Systems**, both surface fixed and side fixed, are adequate to support the design factored loads specified in the European and British Standards listed on page 1 of these calculations.

2) Both systems use 13 x 65mm posts in pairs at 1047mm centre to centre to support balustrades and bottom rails. 13 x 45mm balusters at approximately 100mm centres are installed to infill the space between balustrades and bottom rails.

3) **Surface fixed system:** The surface fixed system posts connect to 95 high x 65 wide x 13.8mm thick upstands on 120 x 120 x 10mm baseplates. The post/baseplate connection is made using 2 No. M10 stainless steel countersunk threaded studs grade 70 to BS EN ISO 350 per post.

4) Provision is made in the baseplates for 4 No. M10 holding down bolts. The design **working load** pull-out force on the HD bolts is **8.86 kN/bolt.** This load should be achievable using drilled resin anchor bolts or similar into good quality concrete, or by drilling through and anchoring to the underside of a suitable concrete slab.

5) **Side fixed system:** Similar components are used for the side fixed system, except for the baseplates. These are T shaped brackets comprising 120 wide x 150 high x 10mm thick backing plates with 120 x 150 high x 13.8mm outstands. Each post is connected to the outstand by means of 2 M10 stainless steel countersunk threaded studs.

6) There is provision in the backing plates for 2 No. M12 anchor bolts. The design **working load** pull-out force on the anchor bolts is **12.0 kN/bolt.**

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.

8) The Engineer for the main building structure should be advised that the structure supporting the balustrades should be designed to resist an outward overturning moment of **1.8 kNm** at each baseplate position without significant rotation. Any undue rotation at the supports could result in unacceptable displacement at handrail level.

Prepared for and on behalf of Balconette by
A. G. Bice CEng FICE FIStructE