MiScion Pty Ltd
STRUCTURAL DESIGN
PO Box 164
MAITLAND, SA 5573
email:sch@miscion.com.au

REF.:	**TN/300**
PAGE:	
DATE:	3/12/2016
Author:	SCH

Technical Notes: Barrier Design

Barriers versus: Partitions, Walls, Doors, Windows, Balustrades, Guard Rails, Hand rails, Grab Rails

Codes provide no real guidance regarding classification of a structure as a barrier or a wall.
AS1170.1 specifies barrier loadings to the top edge of the barrier: this doesn't always make sense.

{NB: AS1170.1 does not identify imposed loads for vertical surfaces or plate elements. AS1170.0 identifies a need for robustness, and gives requirements for minimum lateral resistance, but this is based on gravity loads bearing on the structural element. No consideration of a direct lateral load to face of vertical element.}

A1 When does a full height glass panel become a wall of light weight construction ? {BCA: Specification C1.8: LL=0.25kPa}
A2 When does a plasterboard on stud wall framing become a barrier ? {BCA: Specification C1.8: LL=0.25kPa}
A3 When does a cantilever brick wall become a barrier?

B1 A barrier has to have a minimum height to minimise chances of a person toppling over the barrier. {This would be related to the centre of gravity (COG) of a human body, this varies with position (standing, sitting, leaning etc...). When standing, COG approximately 55% of height, so for 95th percentile height of 1846mm, about 1015mm above ground.}
B2 A guardrail has to have a maximum height so that people cannot pass under it.
B3 A barrier that is not a simple rail, does not need a maximum limit on its functional height, only a lower limit.
B4 Guardrails and handrails may or may not be one and the same component of a barrier system.
B5 People may be pushing against a barrier at either shoulder or waist height. Such height maybe lower than the top edge of a barrier.
B6 People can only pull horizontally against a barrier, which is within reach of their arms. The higher the reach to the barrier top edge, the lower the lateral pull which can be exerted.
B7 People can typically push with more force than they can pull.
B8 A barrier guarding a floor edge cannot be loaded from either direction with equal loading, compared to barrier accessible from both directions used to control flow of traffic.

∴ Applying barrier loads to top edge of barrier is not sensible in all cases. Such position does not always match the location where load is likely to be experienced by the barrier: irrespective of whether the barrier is cantilevered framing or a plate, or a simply supported panel.

MiScion Pty Ltd
STRUCTURAL DESIGN
PO Box 164
MAITLAND, SA 5573
email:sch@miscion.com.au

REF.:	**TN/300**
PAGE:	
DATE:	3/12/2016
Author:	SCH

Technical Notes: Barrier Design

BARRIERS {philosophy adopted for height of applied load}

A barrier is taken to be an obstacle or hindrance to the flow of traffic, or otherwise prevents access and egress, and includes protecting the free edge of a floor where there is a change in level, and may otherwise be considered a flow control device creating channels for traffic. A barrier typically forms a vertical obstruction between horizontally adjacent spaces and includes doors, windows and walls, it excludes horizontal barriers, between vertically adjacent spaces, such as floors ceilings and roofs.

The BCA does not clearly define nor distinguish between walls, partitions, balustrades, guard rails, hand rails and barriers. AS1170.1 assumes that a barrier has a free edge at its top, which is at the minimum height necessary to experience and thus restrain the applied load. Below the top edge is optional infill, which if provided needs to be robust enough to resist tampering, and otherwise resist the lower magnitude loads likely to be experienced below the primary restraining mechanism.

	Male	Female
Standing	1846	1742
Shoulder Height	1528	1440
Hand (knuckle) height	837	787
knee height (sitting)	598	571

Tutt and Adler, 1997, New Metric Handbook: Planning and Design Data, Architectural Press
Table 1: 95th percentile anthropometric data, millimetres

	Male	Female
COG	1052.2	958.1

The centre of gravity (COG) moves with body position, when standing it lies somewhere between 50% and 60% of the height of a person, as measured from the feet. With some sources quoting 55% for females and 57% for males.
Table 2: Centre of Gravity

If a barrier is too low, that is if a force is applied above a persons centre of gravity and the restraint is below, then they will topple over the barrier. If a barrier is a simple horizontal rail and is too high, then a person can fold at the waist or knees and fall under the barrier. A barrier suitable for adults would be too high to be suitable for children. Similarly a handrail comfortable and reachable by adults would be unsuitable for children. Vertical infill rails below a horizontal rail barrier, can act as restraint for movement of children and also provide an alternative to a handrail. Vertical infill rails are preferable to horizontal infill rails, as horizontal rails pose a climbing hazard not just to children but also to careless workers and those otherwise having intent to cause personal injury.

Whilst the anthropometric data above may not be representative of the Australian population and 50th percentile values may be preferable for economic reasons, the data does suggest that the minimum height for a barrier should be 1000mm. In recent years architects have been specifying higher barriers with heights of 1200mm or 1800mm, and in existing buildings "code compliant" barriers have been removed in favour of installing such higher barriers. Such higher barriers prevent people leaning over, and also avoid hazards which may be associated with people standing on chairs or tables.

Unfortunately higher barriers are penalised by the loading requirements of AS1170.1, as the assumption of the code is that the primary restraint is provided by a top edge, with secondary restraint provided by optional infill. When a barrier is higher than the minimum necessary height, it functions differently and experiences loading differently.

MiScion Pty Ltd
STRUCTURAL DESIGN
PO Box 164
MAITLAND, SA 5573
email:sch@miscion.com.au

Some suppliers of glass balustrades have got around this issue by installing handrails where handrails are not required. Whilst referred to as handrails, they are actually guardrails, and it is important to refer to them as such, as handrails can be required to be lower than is suitable for function of a guardrail. These guardrails provide the primary restraint at a height no greater than 1100mm whilst the glass panel behind is treated as infill and only resists infill loads.

AS1288 Glass in Buildings, provides lookup tables for balustrades where the glass is the primary restraint and where glass is just infill and a frame provides the primary restraint. This provides the main reference example for the application of AS1170.1 barrier loads. However the cantilevered balustrades have a height restriction imposed by a load condition they cannot experience. AS1288 defines zones for human impact, however the risk of injury from walking into an unseen barrier is not the same as the risk of loading the barrier to failure.

When people are pushing and shoving the loading is mostly at shoulder height, with a potentially diminishing exertion of force towards the knees, with the main zone of exertion being between the hips and the shoulders. The minimum height for a barrier is around the height of the waist and hips. A large force applied at shoulder height may dislodge a persons footing and tip them over a minimum height barrier. Hence a preference for higher barriers: but a higher barrier will not experience a load along its top edge. The load will likely be distributed over an area between shoulder height and waist height: roughly between 900mm and 1500mm above floor level. Heights above 1500mm will not experience the loading from human contact.

The infill loads are here not considered to be primary structural loads to be resisted by a barrier but to be loads for robustness of secondary elements. Therefore for a plate barrier or vertical rail barrier, the infill loads may not have adequate magnitude, whilst top edge loads are meaningless. However, for simplicity of calculation, a surface area load is likely converted into a line load applied at the midheight of the zone which is loaded. The zone defined between 900mm and 1500mm is 600mm wide, and for 1.5kPa of loading, that is equivalent to line load of 0.9kN/m, which is significantly less than the 3kN/m top edge loading for load category C5. Therefore supporting the view that infill loads are not appropriate for design of the primary restraint system.

Assuming that the magnitude of crowd loading comes from testing a rail type or minimum height barrier, then expect alternative types of barrier to have equal or greater base moments as befits their loading conditions. That is we can take the base moment obtained from applying 3kN/m at 1100mm as a reference (3.3kNm/m). If the barrier is higher than 1100mm then the load is not concentrated at the rail height but distributed over an area, and still expect to resist the same pressure imposed by a crowd. But since the load which can be exerted is dependent on the reach of the crowd, assume that as the height increases the load exerted decreases. This can be accommodated by assuming the base moment can be no higher than 3.3kNm/m.

Height m	Moment kNm/m	Load kN/m
1.100	3.3	3.00
1.200	3.3	2.75
1.300	3.3	2.54
1.400	3.3	2.36
1.500	3.3	2.20
1.600	3.3	2.06
1.700	3.3	1.94
1.800	3.3	1.83
1.900	3.3	1.74
2.000	3.3	1.65

Table 3: Modified Top Edge Loadings for Tall Barriers

However, whilst this provides benefit by not applying loads at heights which cannot be reached, the edge load is still an unrealistic load for the assessment of the panel which is loaded over its surface. Whilst minimum height panels are loaded at the top edge, taller panels are not. Therefore need to convert the top edge load into a suitable surface pressure.

MiScion Pty Ltd
STRUCTURAL DESIGN
PO Box 164
MAITLAND, SA 5573
email:sch@miscion.com.au

REF.:	**TN/300**
PAGE:	
DATE:	3/12/2016
Author:	SCH

Technical Notes: Barrier Design

To determine a suitable surface pressure the top edge load is assumed to be a concentration of the crowd pressure at a top rail or top edge of a low panel. The force cannot be applied higher than shoulder height 1500 mm, and cannot be applied lower than the centre of gravity (COG) of a standing person, where COG is assumed around hip or waist height and a suitable height for a rail is 900mm to 1100mm. Forces applied to a barrier around the height of thighs and knees, are assumed to be accommodated by the infill loads. Heights above shoulder level are considered to be walls of light weight construction and designed for 0.25kPa. Thus the height is split into 3 zones of loading.

Area Loading

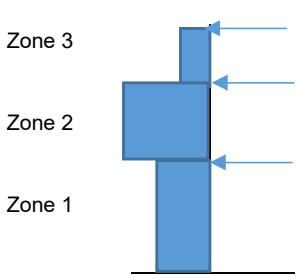
	Case 1	Case 2	Case 3	Case 4	Case 5	
Moment	3.3	3.3	3.3	3.3	3.3	kNm/m
Top	1.500	1.500	1.500	1.500	1.200	m
Bottom	1.100	0.900	0.560	0.000	1.100	m
Load Width	0.400	0.600	0.940	1.500	0.100	m
Load Height	1.300	1.200	1.030	0.750	1.150	m
Pressure	6.35	4.58	3.41	2.93	28.70	kPa

Case 1 : Preferred Design Case
Case 2 : Top of Zone 1: at minimum rail height
Case 3 : Top of Zone 1: at knee rail height
Case 4 : Zone 2 stretches down to floor
Case 5 : Barrier: 1.1m ≤ height ≤ 1.5m

Check

Load Height 1	1.300	1.200	1.030	0.750	1.150		
Line Load 1	2.54	2.75	3.20	4.40	2.87	kN/m	Applied at mid height of loading zone
Moment	3.3	3.3	3.3	3.3	3.3	kNm/m	
Load Height 2	1.500	1.500	1.500	1.500	1.200	m	Applied at top of loading zone
Line Load 2	2.2	2.20	2.2	2.2	2.75	kN/m	
Moment	3.3	3.3	3.3	3.3	3.3	kNm/m	

Table 4: Pressures for Tall Barriers (Zone 2)



Top of Barrier
Shoulder Height 1500mm
Minimum height barrier 1100mm

Zone 1: Infill loads
Zone 2: Primary Load to be Restrained
Zone 3: Light Weight Construction

h1 : Top of zone 1
h2 : Top of zone 2
h3 : Top of zone 3

NB: For barriers less than or equal to 1.1m high, top edge loading applies.

MiScion Pty Ltd
STRUCTURAL DESIGN
PO Box 164
MAITLAND, SA 5573
email:sch@miscion.com.au

REF.:	**TN/300**
PAGE:	
DATE:	3/12/2016
Author:	SCH

Technical Notes: Barrier Design

TESTING of BARRIERS

The main reference for testing of barriers is AS1657 and this tends to be in conflict with the loading and testing requirements in AS1170, these need to be reconciled where a barrier is not for use with industrial platforms and needs to comply with the higher performance criteria of AS1170 barrier load categories.

AS1657:1992 Fixed platforms, walkways, stairways and ladders - Design, construction and installation.

Appendix C: Testing of guard rails

When testing Posts it is permitted to have three posts with railings between, test load is to be applied to end post {Not as shown in Fig B1 (AS1657:1992)}

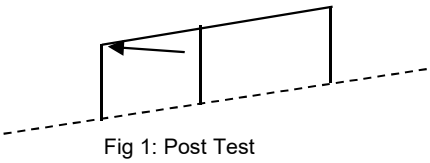


Fig 1: Post Test

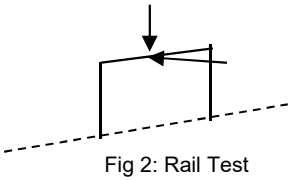


Fig 2: Rail Test

1. Testing of posts, only considers the point load requirement for guardrailing, therefore reaction from UDL on top rail is ignored.
2. Testing of guardrail only two posts are used, therefore UDL along handrail not considered to be on adjacent spans at the same time. Testing typically by application of point load, therefore UDL replaced by point load producing equivalent bending moment in the rail.
3. No magnification of the prescribed nominal loads for testing purposes, but does place constraints on residual deflection of handrails after test load removed. No acceptance criteria is provided for posts.

Constraint on residual deflection for handrail: L/90 from vectorial combination of horizontal and vertical loading.
ADOPT: Similar deflection constraint at top of post. [eg. load applied to handrail at post]

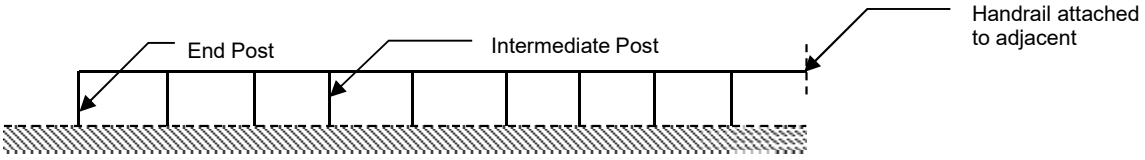
These residual deflections are difficult to determine by calculation, since most design theory is based on linear elastic properties of materials, rather than non-linear plastic properties. However from a calculation viewpoint the deflection under load has to be greater than or equal to the residual.

Since the loads used for the tests are unfactored they are here taken to be serviceability loads with psi[s]=1, and therefore the residual deflection limit is a serviceability criteria.

Modification by AS1657:2013 : 100mm maximum deflection; 20mm maximum residual.

Types of post:

1) End Post {one incoming handrail}
2) Intermediate Post {incoming handrails to both sides}
3) Corner Post {two incoming handrails at 90° to each other on plan.}
{With proprietary systems posts often not suitable for use at corners and two posts used. Alternatively no post at corner and rail has bend.}



Issues

1. Handrail can be loaded along entire length
2. Handrail can be pattern loaded
3. Configuration of a given installation unknown (for design of standard system)
4. System to be designed to cater for variety of installations
5. Handrail deflects horizontally and so does post (compatibility of deflections)
6. Vertical deflection of posts assumed negligible
7. Constraints on horizontal deflections are taken to be at point of applied load. (eg. handrail/guardrail level)
8. Custom Structural sections are typically only symmetrical about vertical axis. (eg. T-Section, Teardrop)
9. Outwards loads expected to be greater than inwards loads for barrier placed at edge of floor.
{eg. Pull from a group of people is less than push from a group of people}