GLASS IN BALUSTRADES (INDUSTRY ADVICE)

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Introduction

The Australian Standard AS1288-2006 (Glass in buildings – selection and installation) sets out a deemed to comply solution for some predetermined balustrade configurations for residential buildings up to 8.5 metres high, and commercial buildings up to 10 metres high using the following references:

- Australian Standard AS4055 (Wind loads for housing)
- Australian Standard AS1170 series (Structural design actions); and
- The National Construction Code (NCC formerly the Building Code of Australia or BCA).

These design load specifications are meant to ensure the barrier has sufficient strength to withstand collapse in cases where a person falls against it.

The balustrade should also be rigid and strong enough to withstand a distributed load which can be applied by people leaning against it. The design load differs depending upon the type of occupancy of the building and the specific use of the balustrade. Reference to Table 3.3 of AS1170.1 will provide the appropriate imposed actions value based on the type of occupancy for that part of the building or structure. This imposed actions value can then be used in the balustrade Tables 7.1 -7.3 of AS1288 -2006. In most cases nomination of the correct usage and load should be sought from the building designer or from a suitably qualified person.

Essentially, balustrade design must be able to resist three primary loads:

- Dead Load (DL) - the weight of the permanent glass component.
- Live Load (LL) – any direction variable load applied inwards, outwards or downwards.
- Wind Load (WL) – the wind pressure imposed on the balustrade.

There can be negative and positive loads applied to the structure. Secondary loads that also may need to be considered are snow, shrinkage, thermal, settlement, dynamic and seismic loads. In structural analysis, three kinds of imposed loads are generally used:

- Concentrated loads that are single forces acting over a relatively small glass area such as point load.
- Line loads that act along a line, for example the top edge of exposed glass or handrail.
- Distributed (or surface) loads that act over a glass surface area such as people leaning against a balustrade.

The imposed actions of a Live load can be summarized as per the below table.

Nature of Load	Description of Load	Unit of Load
Point Load	Is a load acting on a single point. Is also referred to as a concentrated load.	Often referred to as a P or L measured as units of kN (Kilonewton per metre)
Uniformly Distributed Load	Is a load that is evenly spread along the length of glass or over the area of glass.	The UDL load may be represented as rate per lineal metre kN/m (Kilonewton per metre)
Uniformly Varying Load	Is a load that may vary along the length/ height of a glass panel in a linear fashion.	Measured as kN/m (Kilonewton per metre)

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Whilst all these loads need to be taken into account in the determination of glass used in balustrades, the live and wind loads are the main considerations for the AS1288 Section 7 Balustrades deemed to comply solutions.

The following information is required to determine the glass requirement for balustrade glazing:

- type of balustrade (either structural or infill)
- type of handrail, if any (handrail or no handrail or interlinking handrail)
- level to be protected (above or below 1 metre fall distance)
- method of glazing (fixing method 2, 3 or 4 edge support, infill or cantilever)
- type of occupancy (to determine loads applicable)
- minimum required loads (combination of all the above criteria)
- wind load of location (determined from various standards)

These will then give you the required information to determine the thickness and maximum height or span of glass required to use for a particular application.

Live Load Consideration

Principally these imposed load actions for barriers (live loads) in Table 3.3 of AS1170.1 are divided into the two balustrade types: Structural (top edge) and Infill. Both require determination of the design loads (distributed kN/m & kPa) and (Point kN) applicable to the balustrades type exemplified in AS1288 Section 7 (see the table extracts below). The glass type, thickness, height or span can then be selected acccording to the adjacent rows and columns of AS1288 Tables 7.1 to 7.3 design load limitations using the most stringent height or span maximum allowable dimension for the combined loads selected.

Extract from Table 3.3—AS/NZS 1170.1:2002 Minimum Imposed Actions for Barriers

TABLE 3.3 - AS/NZS 1170.1:2002 MINIMUM IMPOSED ACTIONS FOR BARRIERS							AS1288 Table 7.1 & 7.2 Structural Balustrade	AS1288 Table 7.3 Infill Balustrade
Type of occupancy for part of the building or structure	Specific uses	Top edge			Infill		Design Load kN/m	Balustrade Infill Design load
		Horizontal kN/m	Vertical kN/m	Inwards, outwards or downwards kN	Horizontal kPa	Any direction (see Note 2) kN		
A Domestic and residential activities	All areas within or serving exclusively one dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs (see C3)	0.35	0.35	0.6	0.5	0.25	0.35	0.5 kPa
							0.75	1.0 kPa
							1.50	1.5 kPa
							3.00	0.25 kN
							0.60kN*	.5 kN
	Other residential, (see also C)	0.75	0.75	0.6	1.0	0.5		1.5 kN

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After confirming the glass type, thickness, height or span, serviceability limit state wind loads checks will still need to be performed. Serviceability is the behavioral ability of the glass material to withstand a variety of in situ loads continually applied to balustrade glass and are an applied safety control. These include factors such as durability, overall stability, fire resistance, deflection, cracking and excessive vibration, but the main consideration on balustrade glass is deflection and vibration under wind loads.

Wind Load Consideration

AS1288 sets outs deemed to comply guidelines for serviceability limit states by controlling or limiting deflection if designed in accordance with Section 4 of the Standard using a 25 year return period. The maximum deflection for all glass under serviceability limit state shall be limited to:

A) Span/60 for two-, three- or four edge supported panels.
B) Height/30 (or cantilever length /30mm maximum) for cantilever panels such as cantilevered structural glass balustrade.

Note: Structural cantilever glass balustrades require first principle design analysis to gain a resultant figure.

For two and three edge supported balustrade panels and infill balustrade panels, you should initially determine the slenderness factor (B/t) glass span/ by minimum glass thickness, then from the balustrade designers' serviceability wind load specification, complete the deflection calculation using the allowable span formula in Figure 4.35 in Section 4 to gain a resultant deflection number higher than the B/t slenderness number.

NOTE: Minimum glass thickness, not nominal thickness should be used in the calculation (as seen in the example below). The span for two/three edge supported glass is the distance between the supported edges, whereas in four edge supported glass the span is the smaller dimension of height or width.

Method for verifying serviceability limit state in glass balustrading

1. Find the slenderness factor of the glass by dividing the span of the glass (derived from Tables 7.2 and 7.3) by the MINIMUM glass thickness (this is the B/t). For example, 1000 mm span divided by 5.8 mm minimum thickness of glass (6 mm nominal) = 172.41.

2. Verify the slenderness factor in one of two ways (or both) by:

    a. Refer to Figure 4.35 of Section 4 of AS1288-2006. Read the slenderness factor from the left vertical axis of the figure and run a line horizontally till it meets the aspect ratio of the glass under consideration. Drop a line vertically to read the resultant wind loading to verify compliance with the required serviceability limit state Ps (kPa).

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b. By utilizing the formula seen at the bottom of Table 4.35 (see page 5) using the provided constants and required SLS (Ps). Example: Using SLS of 1.25 kPa with a slenderness B/t = 172.41.

Using AR=1: Max B/t=603.79 x (1.25+-0.1)$^{-0.5247}$+1.64 = 562.73
Using 2 edge: Max B/t=195.45 x (1.25+ 0)$^{-0.3333}$+ 0 = 181.44

If the resultant deflection number is less than the B/t slenderness number then a recalculation is required using a thicker glass for the glazing application being considered.

The glass thickness required for glazing application is the thicker glass as determined from both the live load and wind load considerations.

It should be noted that glass fixing methods vary greatly and often determine the glass type and thickness required. Sufficient suitable edge cover / clamping are crucial to the glass performance under the load considerations and as such may require further analysis for performance adequacy. Additional verifications may be required for glass fixing methods or design outside of the parameters set in the examples of AS1288-2006.

Other than for a single dwelling, any monolithic toughened glass balustrades that are over 5 metres from the surrounding ground level must also be heat soaked.

Cantilever Spigot balustrade greater than 1 metre fall distance with interlinking handrail (compliant glazing).

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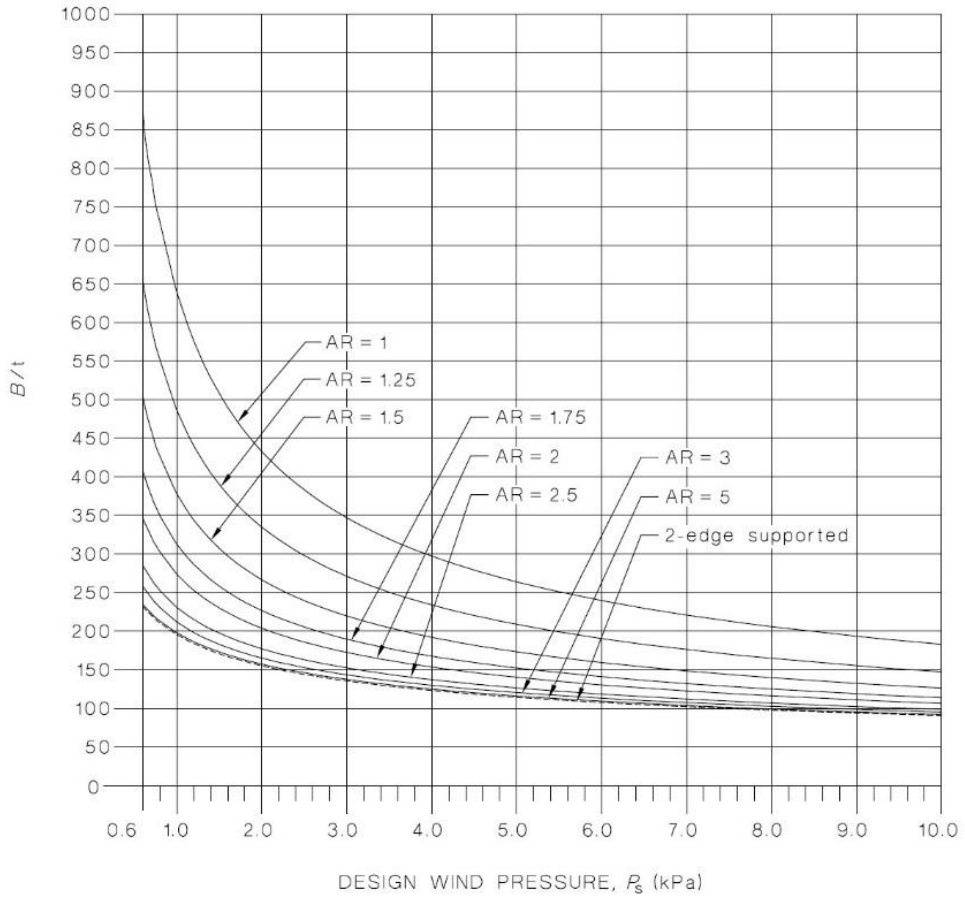
Figure 4.35 Curves for B/t Allowable for Deflection of Glass Limited to Span/60



The allowable span B is given by: $B = k_1 \times (P_s + k_2)^{k_3} + k_4$

Constant	Four-edge supported parameters for each aspect ratio								Two-edge supported
	AR=1	AR=1.25	AR=1.5	AR=1.75	AR=2	AR=2.5	AR=3	AR=5	
k_1	603.79	459.45	350.14	291.45	261.60	222.19	204.68	197.89	195.45
k_2	–0.1	–0.1	–0.15	–0.15	–0.1	–0.1	–0.1	0	0
k_3	–0.5247	–0.5022	–0.4503	–0.4149	–0.397	–0.3556	–0.3335	–0.332	–0.3333
k_4	1.64	2.06	1.29	0.95	1.1	0.29	–0.05	0.03	0

NOTE: Curves for AR = 1 to AR = 5 are to be used for four-edge supported glazing only.

FIGURE 4.35 CURVES FOR *B/t* ALLOWABLE FOR DEFLECTION OF GLASS LIMITED TO SPAN/60

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