NZS 4223.4:2008

Incorporating Amendment No. 1

New Zealand Standard

Glazing in buildings

Part 4: Wind, dead, snow, and live actions

Superseding NZS 4223:Part 4:2000

NZS 4223.4:2008

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COMMITTEE REPRESENTATION

This Standard was prepared under the supervision of the P4223 Committee for the Standards Council established under the Standards Act 1988

The committee consisted of representatives of the following nominating organisations:

Building Research Association of New Zealand Limited
Department of Building and Housing
Glass Association of New Zealand
Institution of Professional Engineers New Zealand
New Zealand Safety Glass Association
Window Association of New Zealand

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AMENDMENTS

No.	*Date of issue*	*Description*	*Entered by, and date*
1	29 February 2016	Updates and corrects current standard, and incorporates Amendments No 1 and No 2 of AS 1288	Incorporated in this edition

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Superseding NZS 4223:Part 4:2000

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REFERENCED DOCUMENTS

Reference is made in this document to the following:

New Zealand standards

NZS 3504:1979 (Amd 1 Feb '16)	Specification for aluminium windows
NZS 3604:1999	Timber framed buildings
NZS 3619:1979 (Amd 1 Feb '16)	Specification for timber windows
NZS 4223	Glazing in buildings
Part 1:2008	Glass selection and glazing
Part 2:2016 (Amd 1 Feb '16)	Insulating glass units
Part 3:2016 (Amd 1 Feb '16)	Human impact safety requirements
Supp 1:2008	Supplement 1 to NZS 4223.1:2008 and NZS 4223.4:2008
NZS 4229:1999	Concrete masonry buildings not requiring specific engineering design
NZS 4232 (Amd 1 Feb '16)	Performance criteria for fire resisting enclosures
Part 2:1988	Fire resisting glazing systems

Joint Australian/New Zealand standards

AS/NZS 1170	Structural design actions
Part 0:2002	General principles
Part 1:2002	Permanent, imposed and other actions
Part 2:2002	Wind actions
Part 3:2003	Snow and ice actions
AS/NZS 2208:1996	Safety glazing materials in buildings AS/NZS 4666:2000
AS/NZS 4666:2012 (Amd 1 Feb '16)	Insulating glass units
AS/NZS 4667:2000	Quality requirements for cut-to-size and processed glass
AS/NZS 4668:2000	Glossary of terms used in the glass and glazing industry

Australian standards

AS 1288:2006	Glass in buildings – Selection and installation

Other document

New Zealand Building Code Approved Document B1 Structure

LATEST REVISIONS

The users of this Standard should ensure that their copies of the above-mentioned New Zealand Standards are the latest revisions. Amendments to referenced New Zealand and Joint Australian/New Zealand Standards can be found on www.standards.co.nz.

FOREWORD

NZS 4223 applies to glazing in buildings.

The Standard comprises four parts:

- Part 1:2008 – Glass selection and glazing;
- Part 2:2016 – Insulating glass units;
- Part 3:2016 – Human impact safety requirements;
- Part 4:2008 – Wind, dead, snow, and live actions.

This Standard applies to glazing in all buildings and applications other than those excluded in the scope.

This Standard, including Amendment No. 1, provides a methodology for determining the minimum glass thickness for vertical and sloped overhead glazing to resist limit state actions. This methodology is deemed to provide solutions that meet the glass thickness requirements set out in NZS 4223.1.

The sections have been amended and revised to update the Standard and allow for New Zealand-specific considerations.

Amd 1
Feb '16

REVIEW OF STANDARDS

Suggestions for improvements of this Standard will be welcomed. They should be sent to the Chief Executive, Standards New Zealand, Private Bag 2439, Wellington 6140.

NOTES

New Zealand Standard

Glazing in buildings

Part 4: Wind, dead, snow and live actions

1 SCOPE AND GENERAL

1.1 Scope

NZS 4223.4 provides a method for the determination of minimum glass thickness for vertical and sloped overhead glazing in New Zealand to resist limit state actions.

The following are excluded from the scope of NZS 4223 Parts 1, 2, 3, and 4:

(a) Glazing in lift cars and liftwells (refer to NZS 4223.1, Appendix A for guidance);

(b) Furniture glass, cabinet glass, vanities, glass basins, refrigeration units, internal glass fitments and glass wall linings, framed internal wall mirrors, and mirrors not specifically covered by these parts;

(c) Buildings and structures with no public access intended for non-habitable building structures for horticultural or agricultural use;

(d) Restoration or repairs to existing decorated glass;

(e) Glazing applications that might fail due to stresses other than tensile stresses, such as glass floors;

(f) Plastic glazing materials;

(g) The construction and installation of windows (refer to NZS 3504, NZS 3619, and NZS 4232.2);

(h) Glass blocks, pavers, slumped, formed, or cast glass;

(i) Point-fixed or point-supported systems, used for glazing, cladding, signage, and the like, not specifically covered by these parts (refer to Part 1 for design criteria and guidance for specific design). Amd 1 Feb '16

1.2 Application

NZS 4223.4 is intended to be used by designers and specifiers of glazing. It replaces NZS 4223.4:2000 and NZS 4223.1:1985 Clause 103.11.

1.3 Compliance with NZBC

NZS 4223.4 is intended to provide a means of compliance with the New Zealand Building Code Acceptable Solution B1/AS1.

1.4 Interpretation

For the purposes of this Standard the word 'shall' identifies a mandatory requirement for compliance with the Standard. The word 'should' refers to practices which are advised or recommended.

The terms 'Normative' and 'Informative' have been used in this Standard to define the application of the Appendix to which they apply. A 'Normative' Appendix is an integral part of a Standard whereas an 'Informative' Appendix is only for information and guidance and does not form part of the mandatory requirements of the Standard.

NZS 4223 is based on AS 1288 which provides advice and information in commentary clauses. NZS 4223 includes this advisory material as informative notes in the text of the Standard. Such notes are not to be taken as the only or complete interpretation of the relevant clause and the Standard may still be complied with if the notes are ignored. However, where notes form part of a table or figure in NZS 4223, these provide normative information that forms an integral part of the requirements of the Standard. Table or figure notes thus form a mandatory part of NZS 4223.

1.5 Definitions

Amd 1 Feb '16

For the purposes of this Standard the following definitions apply. Refer to AS/NZS 4668 for additional definitions.

Annealed glass — Glass which is cooled gradually during manufacture in an annealing operation to reduce residual stresses and strains which can be produced during cooling.

NOTE – Annealed glass includes plate, sheet, and float glass and is not a safety glass.

Area — The area of the panel between sightlines after glazing, calculated using the sight size.

Aspect ratio (AR) — The ratio of the longer side of a panel to its shorter side.

Four-edge support — Glass that is continuously supported on all four edges.

Frame — A structure manufactured from timber, metal, glass, or other durable material or combinations of materials, such as glass fins and structural sealant, supporting the full length of a glazed panel edge.

Glazing — Glazing consists of:

(a) The installation of glass in prepared openings in windows, door panels, partitions, and the like; and

(b) Glass panes for installation into a building.

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Heat-strengthened glass — Glass that has been strengthened by a special heat treatment, so that the residual stresses lie between those for ordinary annealed glass and toughened glass. Refer to NZS 4223.1 for allowable surface compressive stress.

Heat-strengthened laminated safety glass — Laminated safety glass utilising two or more panels of heat-strengthened glass in the make-up and satisfy the relevant requirements of a safety glazing material Standard (i.e. AS/NZS 2208).

Insulating glass unit (IGU) — Two or more panels of glass spaced apart and factory sealed with dry air (hermetically) or special gases in the unit cavity. Often abbreviated to IGU or referred to as the unit.

Laminated glass — A composite material consisting of two or more sheets of glass permanently bonded together by a plastic interlayer material to form a stock sheet or pane. Amd 1 Feb '16

Laminated safety glass — Laminated glass that satisfies the relevant requirements of a safety glazing material Standard (i.e. AS/NZS 2208).

Limit states — States beyond which the structure no longer satisfies the design criteria.

Serviceability limit states (SLS) — States that correspond to conditions beyond which specified service criteria for a structure or structural element are no longer met. The criteria are based on the intended use and may include limits on deformation, vibratory response, degradation or other physical aspects.

Ultimate limit states (ULS) — States associated with collapse, or with other similar forms of structural failure. This generally corresponds to the maximum load-carrying resistance of a structure or structural element but, in some cases, to the maximum applicable strain or deformation.

Live load — A variable action resulting from the intended use or occupancy of the structure.

NOTE – This term replaces 'imposed loads' as used within the AS/NZS 1170.1.

Maximum thickness — The thickness of a panel of glass at the maximum thickness tolerance.

Minimum thickness — The thickness of a panel of glass at the minimum thickness tolerance.

Monolithic glass — A single thickness piece of glass as opposed to laminated or an insulating glass unit.

Nominal thickness — The commonly used dimension by which the thickness of a panel of glass is generally described.

NOTE – The actual thickness of particular panes of glass may not coincide with the nominal thickness.

Pane — Single piece of glass cut to size for glazing.

Panel — An assembly containing one or more panes.

NOTE – Panels may be fully framed, partly framed or fully unframed.

Sightline The perimeter of the opening, which admits daylight (also known as glazing line).

Sightsize The clear unsupported opening size that admits light (also known as daylight).

Amd 1 Feb '16

Slenderness factor Span-to-thickness ratio (span divided by the minimum thickness).

Sloped glazing Glazing that is inclined at up to 75° to the horizontal.

Sloped overhead glazing Glazing that is inclined at up to 75° to the horizontal and located, wholly or partially, directly above an area that may be occupied by people.

Span The dimension between supports. For panels supported on all four edges, it corresponds to the smaller of the sight size dimensions. For panels supported on two opposite edges only, it is the sight dimension.

Toughened glass Glass that is subjected to special heat or chemical treatment so that the residual surface compression stress and the edge compression stress is greater than heat-strengthened glass (refer to NZS 4223.1 for allowable surface compressive stress).

NOTE –

1. Toughened glass is not necessarily toughened safety glass.
2. In general, the heat treatment or chemical treatment process greatly reduces the tendency of glass to fracture under the action of external forces and changes of temperature.
3. After being toughened, the glass cannot be cut, drilled, ground, or otherwise reworked. Etched, sandblasted, engraved, or otherwise worked surfaces should have such surface working carried out prior to toughening.
4. Surface treatments should be kept as shallow as possible to ensure that the glass can be adequately toughened. These can reduce the design capacity (refer to NZS 4223.1).
5. Toughened glass is also known as 'tempered glass'.

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Toughened laminated safety glass Laminated safety glass utilising two or more panes of toughened glass in the make-up that satisfies the relevant requirements of a safety glazing material standard (refer to AS/NZS 2208).

Amd 1 Feb '16

Toughened safety glass Toughened glass that satisfies the relevant requirements of a safety glazing material Standard (i.e. AS/NZS 2208).

Two edge support Glass that is continuously supported on two opposite edges.

2 VERTICAL GLAZING

2.1 General

This Section sets out a methodology for determining the minimum glass thickness to be used to resist the limit state design wind pressures.

The location of the glass within the building may require additional considerations, such as human impact, which may impose a minimum glass thickness, or a provision for a specific glass type, or both, that exceed the requirements of this Part (refer to NZS 4223.1 and NZS 4223.3).

Application of this Section will satisfy the limit state requirements of NZS 4223.1 for strength and deflection.

The limitation of area for monolithic annealed glass shall also be applicable (refer to NZS 4223.1 and NZS 4223.3).

The provisions of this Part are applicable provided the ultimate limit state wind pressure, or other loads that are of 3 seconds duration or less, are not greater than 10.0 kPa.

NOTE – When users are selecting glass for structures not designed to NZS 3604 or NZS 4229, they should not attempt to use the NZS 3604 wind zone pressures given in Table 1 and Table 4 because the building may have an importance level that is greater than 2.

2.2 Design wind pressure

The ultimate limit state design wind pressure (p_u) shall be determined from either:

(a) First principles, in accordance with AS/NZS 1170.2; or

(b) Appendix A; or

NOTE – Appendix A gives a simplified method for determining ultimate and serviceability limit state design wind pressures.

(c) Table 1, for structures designed in accordance with NZS 3604 and NZS 4229.

NOTE – These Standards are for non-specific design of importance level 2 buildings up to 10 m high. Amd 1 Feb '16

Table 1 – Wind pressures for NZS 3604 and NZS 4229 structures

Wind zone	**Ultimate limit state design wind pressure – General** (kPa)	**Ultimate limit state design wind pressure – Within 2.4 m of corners** (kPa)
Low	0.72	0.80
Medium	0.96	1.06
High	1.36	1.50
Very high	1.76	1.93
Extra high	2.13	2.34

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2.3 Insulating glass units

When loads are shared between panes of glass within an insulating glass unit, each pane of glass shall be checked individually for the limit state design wind pressures multiplied by the relative load-sharing factor, in accordance with NZS 4223.1.

For IGUs with two panes of equal thickness multiply the limit state design wind pressure (p_u) by a k_{pane} factor of 0.625 and use the resultant pressure in Figure 1 to Figure 35 to determine each pane thickness (t_{pane}).

2.4 Maximum span for glass panels subjected to wind actions

2.4.1 General

The maximum span for a given nominal thickness of ordinary annealed, laminated, heat-strengthened, and toughened glass, for a given panel size shall be determined in accordance with 2.4.2, 2.4.3 or 2.4.4, as applicable for the relevant support conditions. For heat-strengthened laminated and toughened laminated glass, the maximum span shall be determined in accordance with 2.4.5.

For the purpose of this Section, the minimum thickness of glass shall be as given in AS/NZS 4667 or Table 2.

For non-standard glass thicknesses, the maximum span (*B*), shall be determined by multiplying the maximum span determined for the glass type and nearest nominal thickness, by the thickness of the non-standard glass divided by the minimum thickness of the glass from Table 2.

NOTE – For example, if the maximum span of a 6 mm nominal annealed glass is 1000 mm, then the maximum span of 5.4 mm non-standard glass would be (1000 x (5.4/5.8)) = 931 mm.

For laminated glass composites, the combined minimum thickness of the glass sheets shall be used excluding the interlayer thickness.

2.4.2 Rectangles of glass supported along all four edges

For rectangles of glass supported along all four edges, the maximum span (*B*) for a design wind pressure (p_u) shall be determined either:

(a) Graphically from Figure 1 to Figure 34; or

(b) Using the formula and the corresponding constants provided below the graph for each type of glass and thickness, where *B* is the smaller rectangular glass panel dimension; or

(c) From the tables in NZS 4223 Supplement 1.

NOTE –

1. Linear interpolation is permitted between the lines for each aspect ratio. The curve for aspect ratio 5 is applicable for rectangular glass panels having an aspect ratio of 5 or greater.
2. For an example calculation, see Appendix B.

2.4.3 Rectangles of glass supported on two opposite edges

For rectangles of glass supported on two opposite edges, the maximum span (*B*) for a design wind pressure (p_u) shall be determined either:

(a) Graphically from Figure 1 to Figure 34;

(b) Using the formula and the corresponding constants provided below the graph for each type of glass and thickness, where *B* is the span between supports; or

(c) From the tables in NZS 4223 Supplement 1.

NOTE –

1. A more economical design might be obtained by following the design procedures given in NZS 4223.1; and
2. For an example calculation, see Appendix B.

Table 2 – Glass thickness

Nominal thickness (mm)	**Minimum thickness** (mm)
Monolithic glass	
3	2.8
4	3.8
5	4.8
6	5.8
8	7.7
10	9.7
12	11.7
15	14.5
19	18.0
25	23.5
Laminated glass[1,2]	
5	4.6
6	5.6
8	7.6
10	9.6
12	11.6
16	15.4
20	19.4
24	23.4
Wired glass	
6	5

NOTE –

1. For laminated glass, the thickness is the total thickness of the sheets in the laminate and does not include the thickness of interlayer, e.g., 6 mm may apply to 6.38 mm, 6.76 mm or 7.52 mm, etc. An example of the methodology used in this Section is given in Appendix B.
2. This table applies to symmetrical and non-symmetrical glass.

2.4.4 Rectangles of glass supported on three edges

For rectangles of glass supported on three edges, the nominal glass thickness shall be determined as for glass supported on two opposite edges (see 2.4.3). Alternately, specific design can be used. The span is the distance between the two supported opposite edges.

Silicone butt joints of adjacent panels in the same plane shall be considered as an unsupported edge when using Figure 1 to Figure 34.

2.4.5 Heat-strengthened laminated and toughened laminated glass

For heat-strengthened laminated and toughened laminated glass, the maximum span for a given nominal thickness and panel size shall be determined from Figure 27 to Figure 34 respectively with the design wind pressure (p_u) being divided by the appropriate glass type factor, c_1 (refer to NZS 4223.1 or Table 3), as applicable for the relevant support conditions. For example, for heat-strengthened laminated glass at 2 kPa = p_u/c_1 = 2 / 1.6 = 1.25 kPa.

Table 3 – Glass type factor c_1

Glass type	Factor c_1
Ordinary annealed	1.0
Heat-strengthened*	1.6
Toughened*	2.5
Wired	0.5
*The glass type factors for heat-strengthened and for toughened glass are based on the minimum stresses specified in NZS 4223.1. For higher induced stress, correspondingly higher glass type factors may be used provided the level of safety is not reduced. The glass type factor may be determined from: $c_1 = (f'_t + \text{minimum induced surface compression stress}) / f'_t$.	

2.4.6 Serviceability checks

The serviceability limit state design wind pressure, p_s, shall be determined from first principles, in accordance with AS/NZS 1170.2 or Appendix A.

For structures designed in accordance with NZS 3604 and NZS 4229, serviceability limit state design wind pressures from Table 4 may be used for glazing design.

NOTE – These Standards are for non-specific design of importance level 2 buildings up to 10 m high. Amd 1 Feb '16

Table 4 – Serviceability limit state wind pressures for NZS 3604 and NZS 4229 structures

Wind zone	**Serviceability limit state design wind pressure – general** (kPa)	**Serviceability limit state design wind pressure – within 2.4 m of corners** (kPa)
Low	0.51	0.57
Medium	0.68	0.76
High	0.97	1.08
Very high	1.25	1.38
Extra high	1.51	1.67

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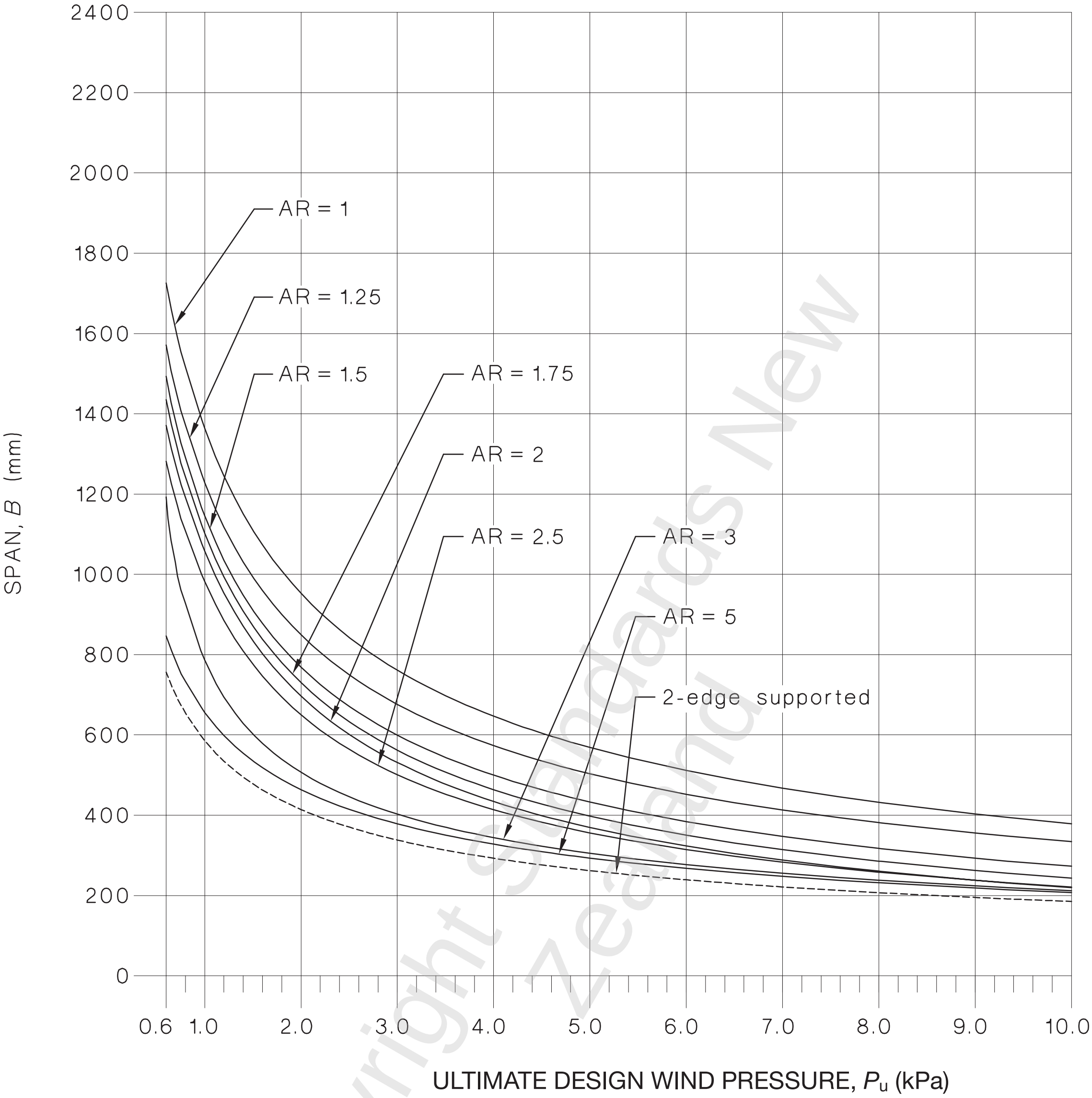
Glass complying with Figure 35 will satisfy the serviceability deflection limits specified in NZS 4223.1.

The slenderness factor (B/t) for the selected nominal thickness shall be determined either graphically or using the formula and the corresponding constants provided below the graph for the appropriate aspect ratio. Linear interpolation is permitted between the lines for each aspect ratio. For rectangular glass panels having an aspect ratio greater than 5, the two-edge support line shall be used.

2.5 Organic safety films and other glass coatings

The structural effects of an organic safety film or other glass coatings shall be ignored in the design of glass. Organic safety film or other coated glass shall be designed as monolithic glass.

Figure 1 – Maximum span for monolithic 3 mm annealed glass



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

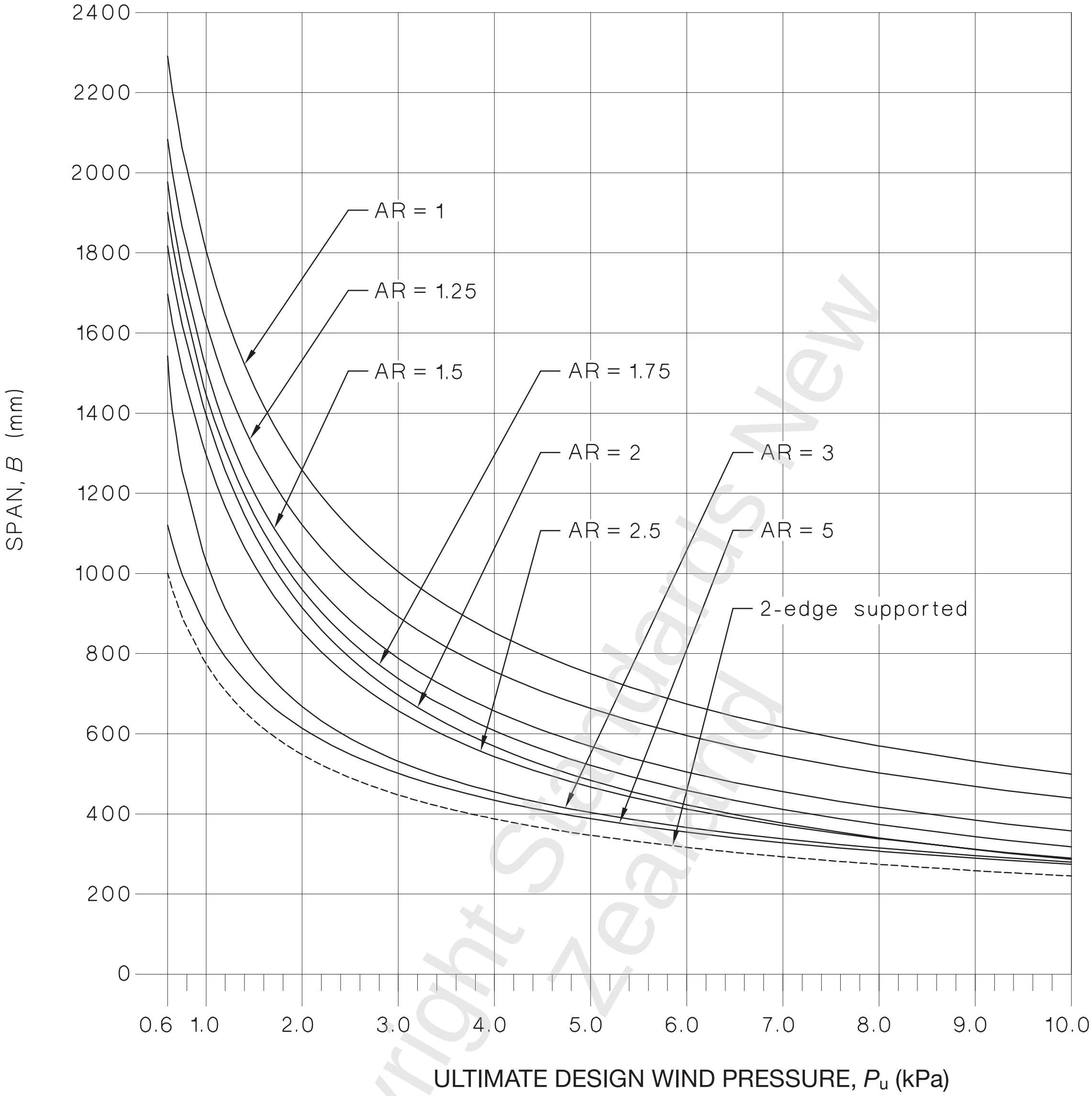
Constant	Four-edge supported annealed glass parameters for each aspect ratio								Two-edge supported
	AR=1	AR=1.25	AR=1.5	AR=1.75	AR=2	AR=2.5	AR=3	AR=5	
k_1	1558.4	1373.2	1313.4	1343.4	1381.9	1184.5	667.6	655.7	585.6
k_2	0.25	0.2	0.2	0.3	0.4	0.3	–0.3	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	4.2	–1.4	–22.68	–12.6	–11.2	2.8	–8.4	0	0

NOTE –

(a) Curves for AR = 1 to AR = 5 are to be used for four-edge supported glazing only.

(b) Refer to NZS 4223.1 for the maximum allowable area for 3 mm glass.

Figure 2 – Maximum span for monolithic 4 mm annealed glass

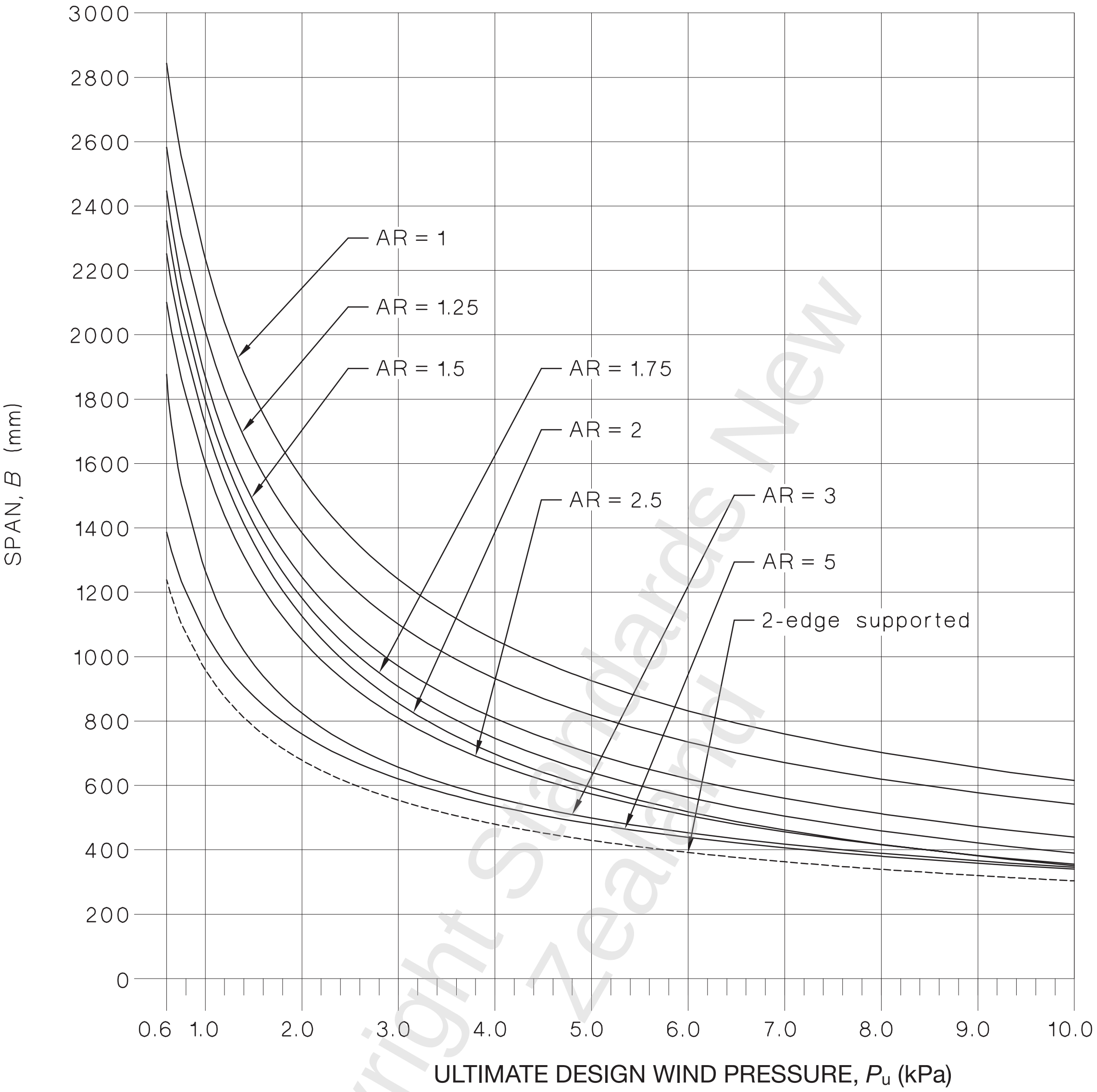


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2050.7	1807.5	1725.7	1758.9	1804.6	1549.8	884.0	867.8	774.9
k_2	0.237712	0.19017	0.19017	0.285254	0.380339	0.285254	–0.28525	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	5.7	–1.9	–30.78	–17.1	–15.2	3.8	–11.4	0	0

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

Figure 3 – Maximum span for monolithic 5 mm annealed glass

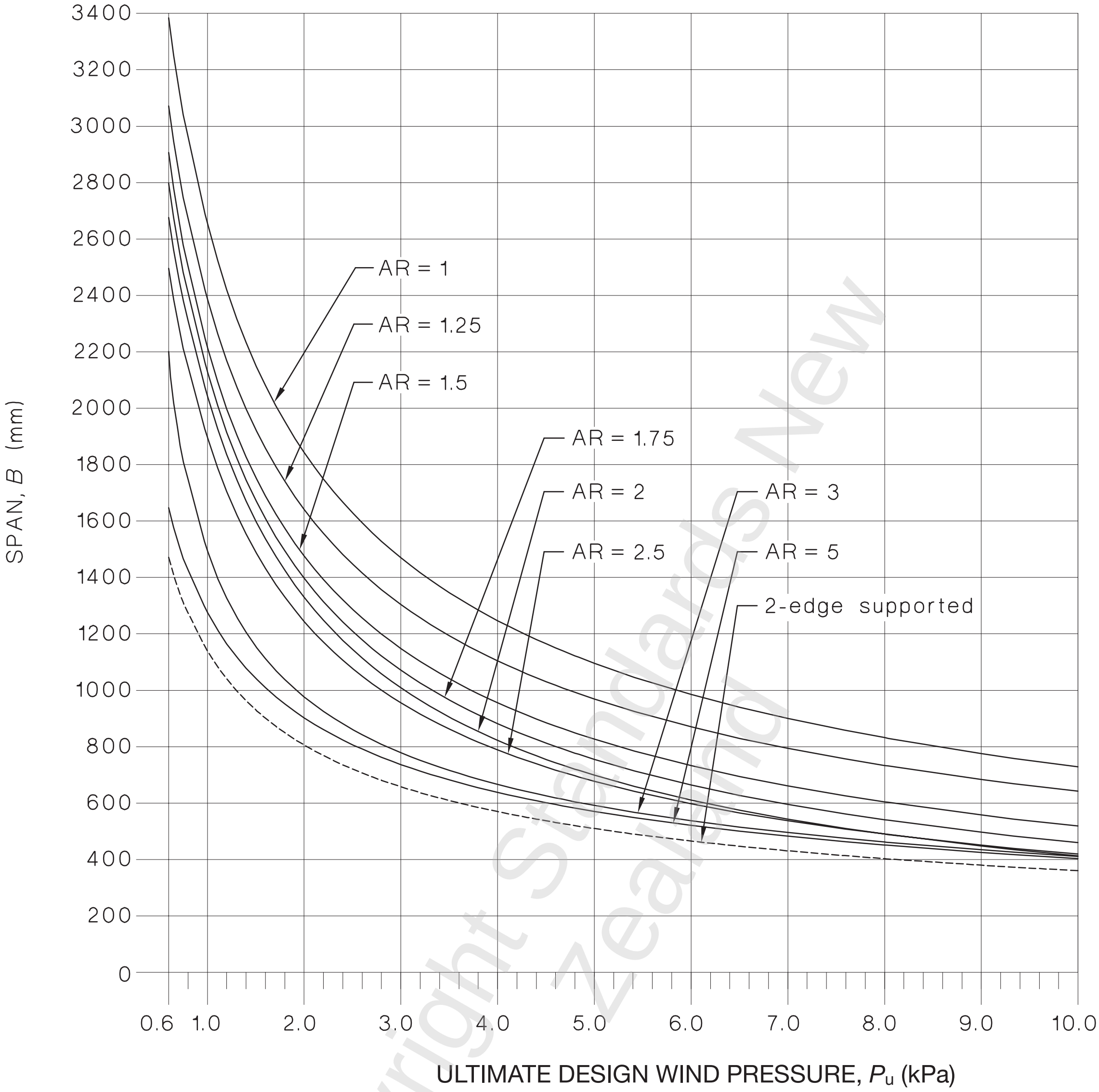


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2527.1	2227.9	2124.1	2159.0	2210.3	1910.2	1094.8	1074.2	959.3
k_2	0.228312	0.182649	0.182649	0.274974	0.365299	0.273974	–0.27397	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	7.2	–2.4	–38.88	–21.6	–19.2	4.8	–14.4	0	0

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

Figure 4 – Maximum span for monolithic 6 mm annealed glass

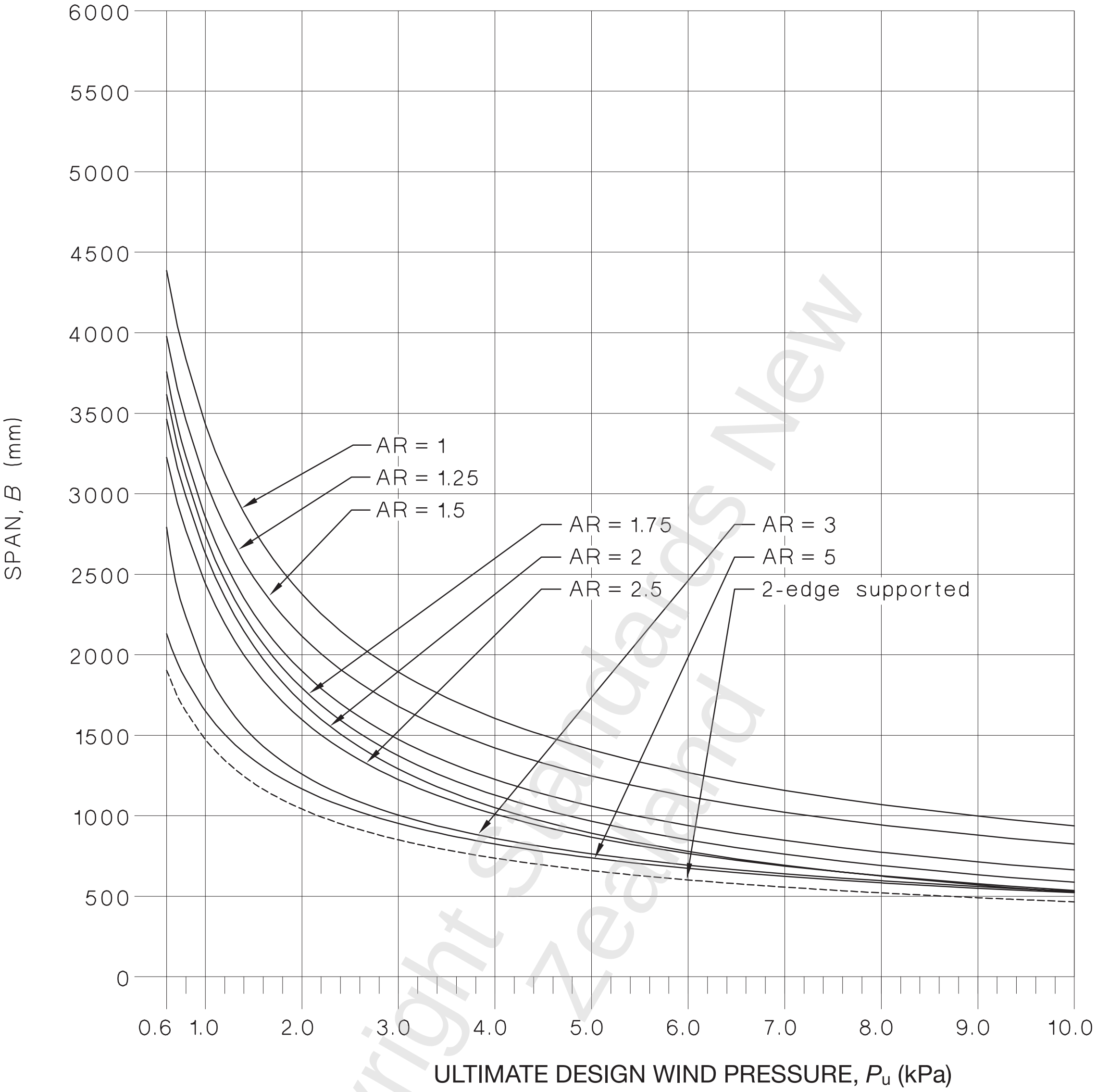


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2990.8	2637.2	2511.3	2546.6	2602.4	2241.4	1301.2	1276.2	1139.7
k_2	0.220697	0.176558	0.176558	0.264836	0.353115	0.264836	–0.26484	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	8.7	–2.9	–46.98	–26.1	–23.2	5.8	–17.4	0	0

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

Figure 5 – Maximum span for monolithic 8 mm annealed glass

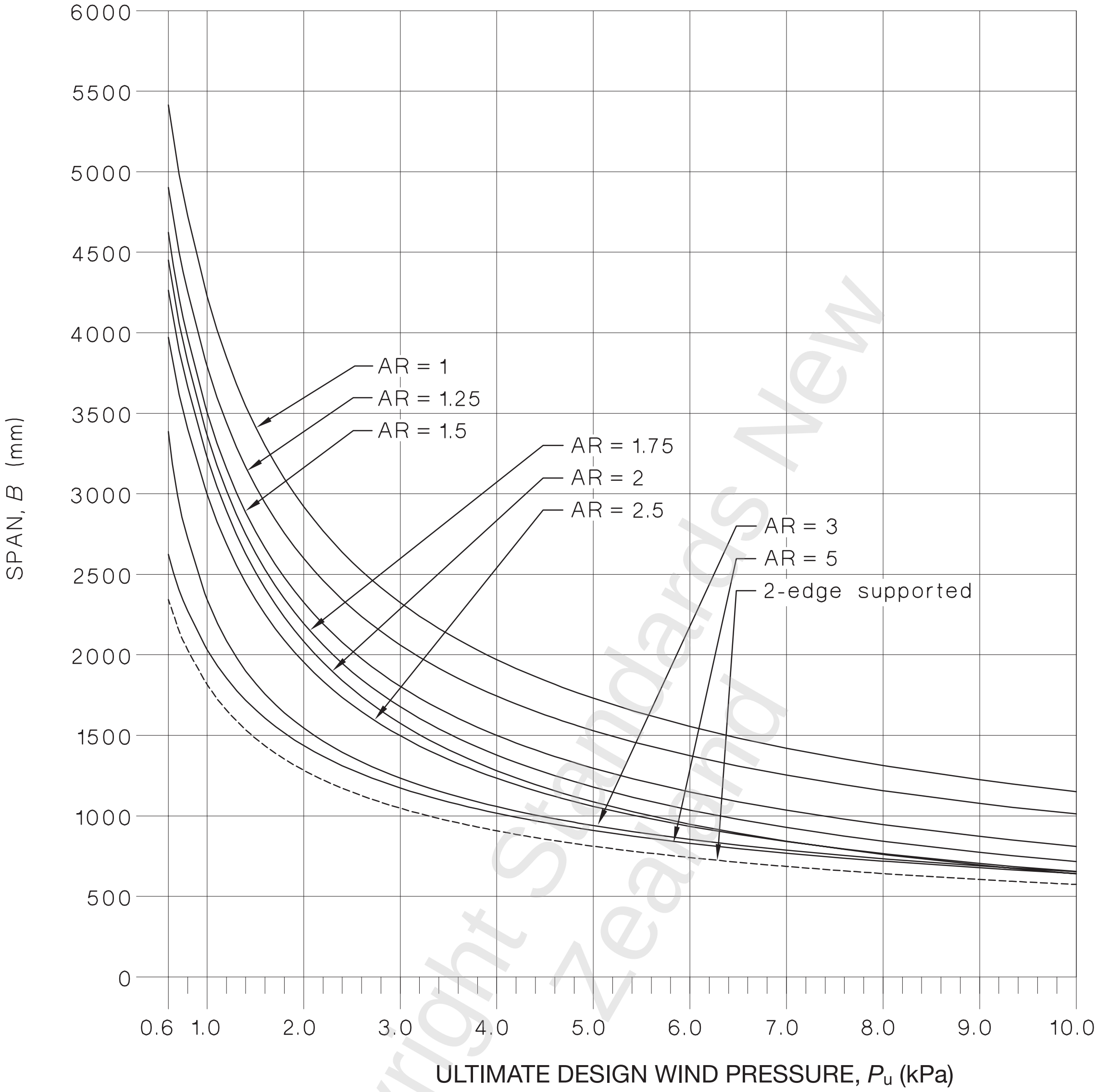


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	3843.7	3390.2	3222.3	3255.6	3317.7	2863.4	1683.3	1649.9	1473.4
k_2	0.209295	0.167436	0.167436	0.251154	0.334872	0.251154	–0.25115	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	11.55	–3.85	–62.37	–34.65	–30.8	7.7	–23.1	0	0

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

Figure 6 – Maximum span for monolithic 10 mm annealed glass

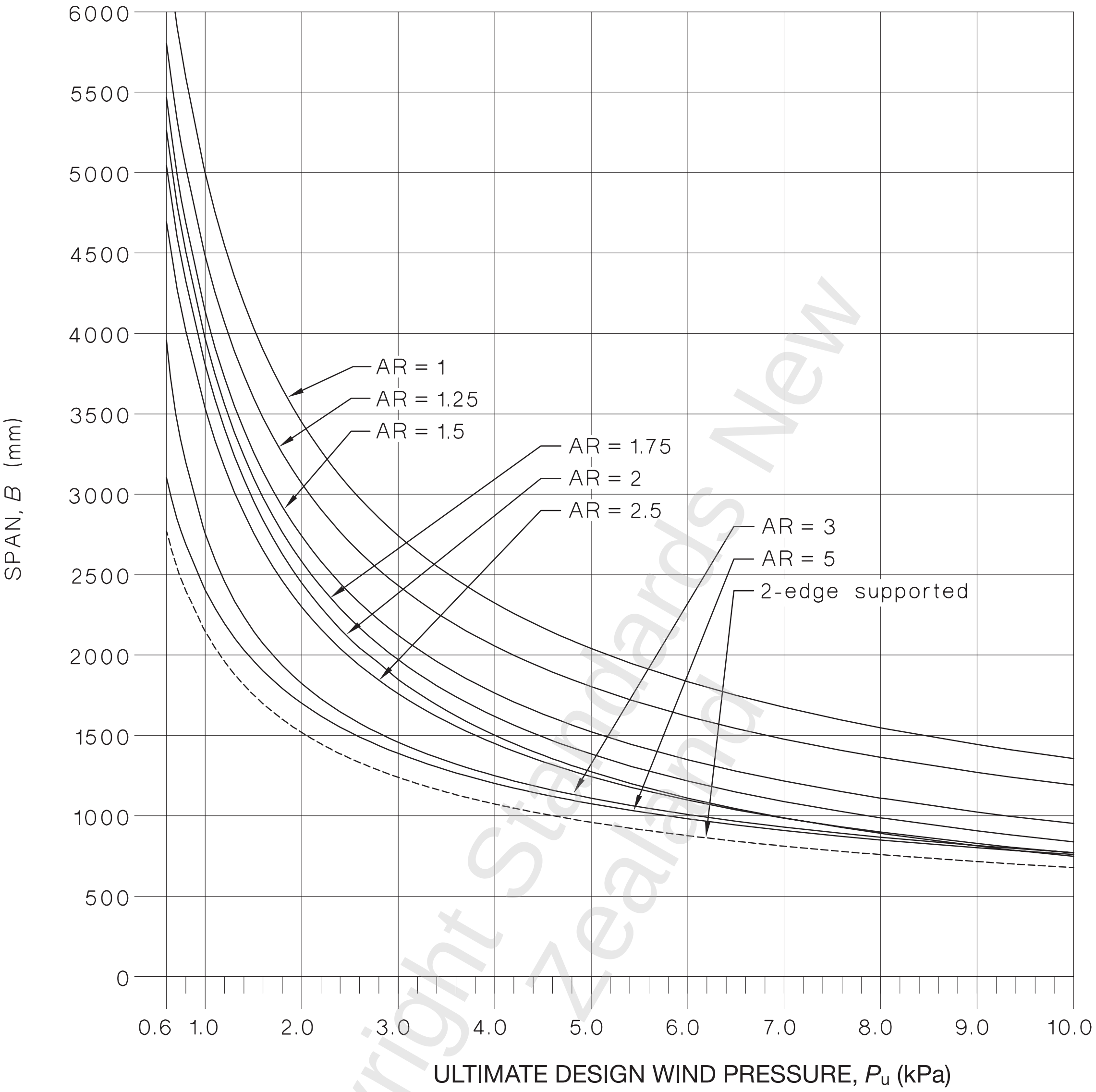


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	4709.2	4154.6	3942.6	3970.9	4036.8	3490.2	2074.0	2031.8	1814.4
k_2	0.200004	0.160003	0.160003	0.240005	0.320006	0.240005	–0.24	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	14.55	–4.85	–78.57	–43.65	–38.8	9.7	–29.1	0	0

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

Figure 7 – Maximum span for monolithic 12 mm annealed glass

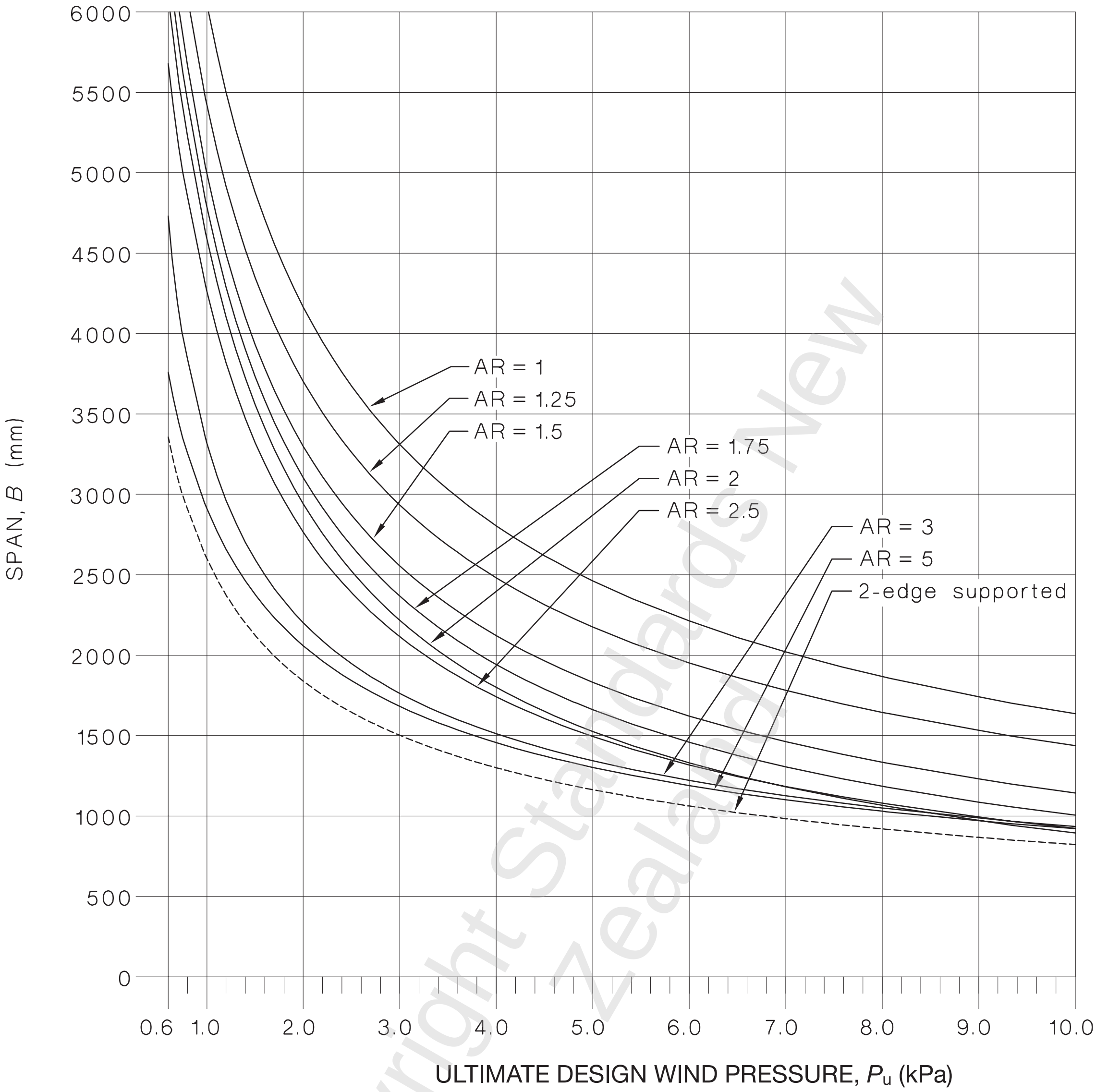


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	5548.0	4895.6	4639.5	4660.5	4728.2	4094.0	2455.2	2404.1	2146.9
k_2	0.192461	0.153969	0.153969	0.230953	0.307937	0.230953	–0.23095	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	17.55	–5.85	–94.77	–52.65	–46.8	11.7	–35.1	0	0

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

Figure 8 – Maximum span for monolithic 15 mm annealed glass



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

Constant	Four-edge supported annealed glass 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	6685.2	5900.5	5582.8	5590.3	5657.8	4907.6	2975.3	2911.9	2600.3
k_2	0.183827	0.147062	0.147062	0.220593	0.294124	0.220593	–0.22059	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	21.75	–7.25	–117.45	–65.25	–58	14.5	–43.5	0	0

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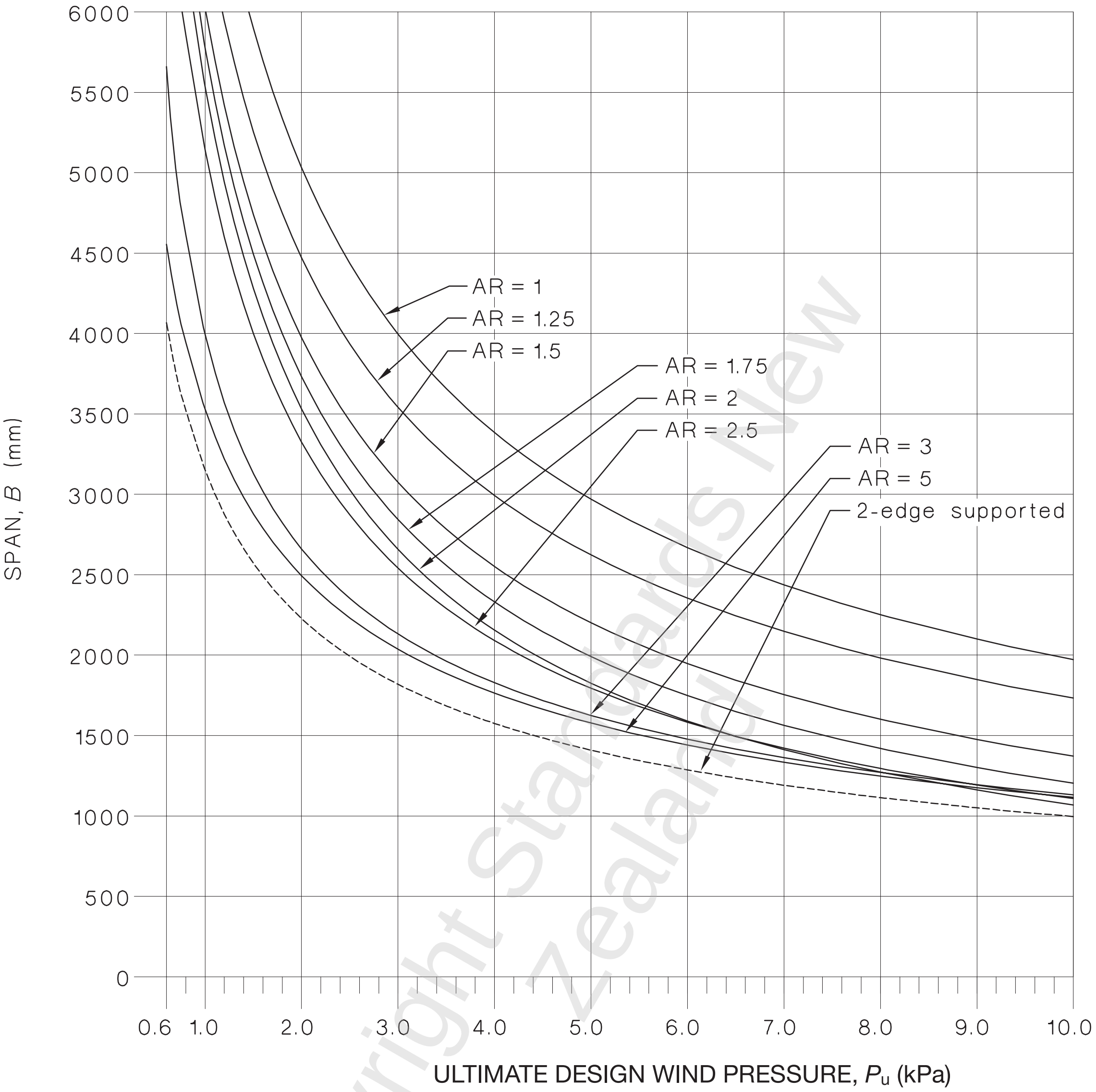
NOTE – Curves for AR = 1 to AR = 5 are to be used for four-edge supported glazing only.

Figure 9 – Maximum span for monolithic 19 mm annealed glass

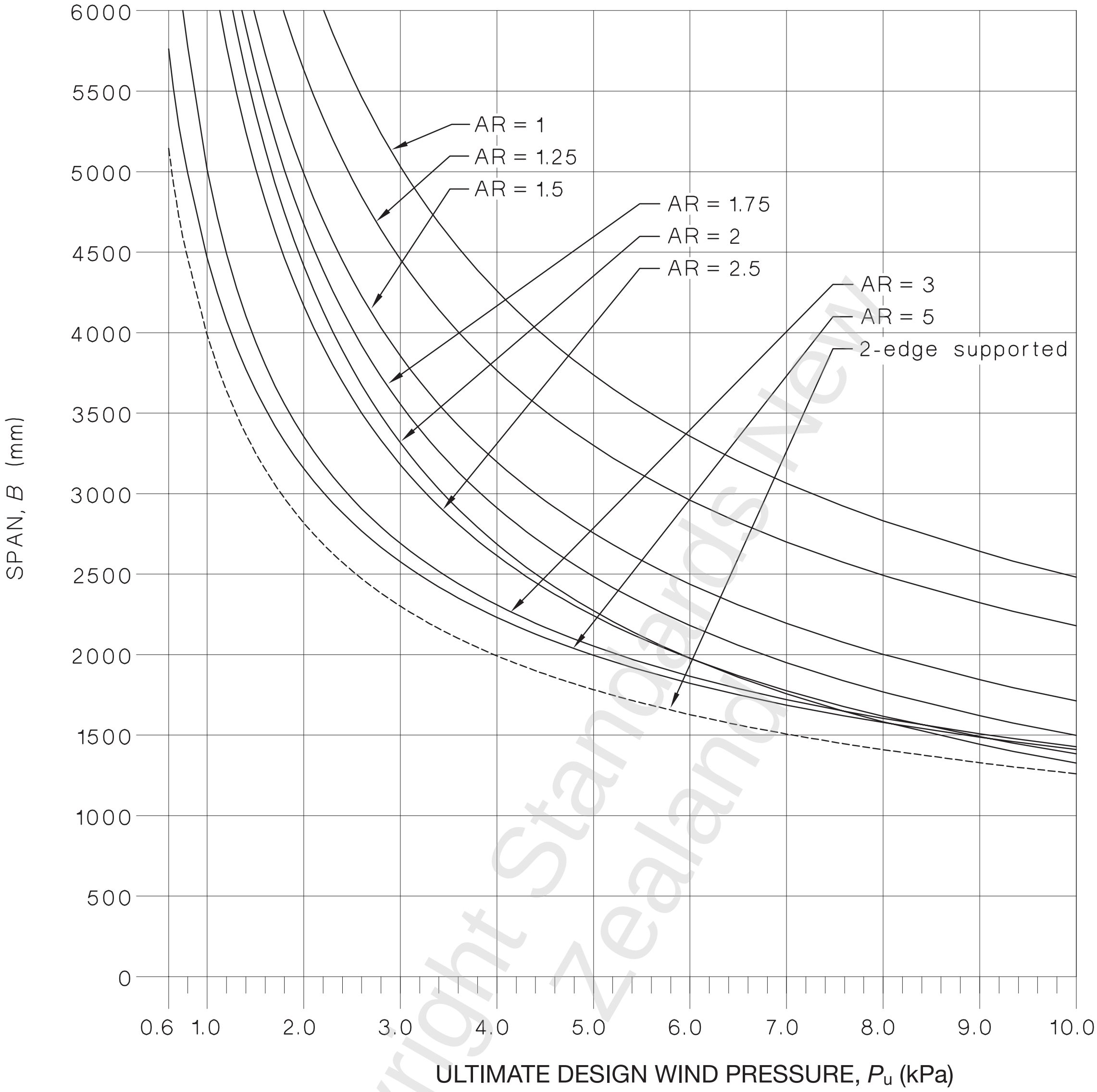


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	8056.1	7112.3	6717.8	6704.5	6768.0	5881.7	3607.1	3528.2	3150.6
k_2	0.175127	0.140102	0.140102	0.210152	0.280203	0.210152	–0.21015	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	27	–9	–145.8	–81	–72	18	–54	0	0

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

Figure 10 – Maximum span for monolithic 25 mm annealed glass



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

Constant	Four-edge supported annealed glass 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	10118.2	8935.8	8421.5	8368.2	8419.2	7334.6	4566.2	4462.9	3985.3
k_2	0.164398	0.131519	0.131519	0.197278	0.263037	0.197278	–0.19728	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	35.25	–11.75	–190.35	–105.75	–94	23.5	–70.5	0	0

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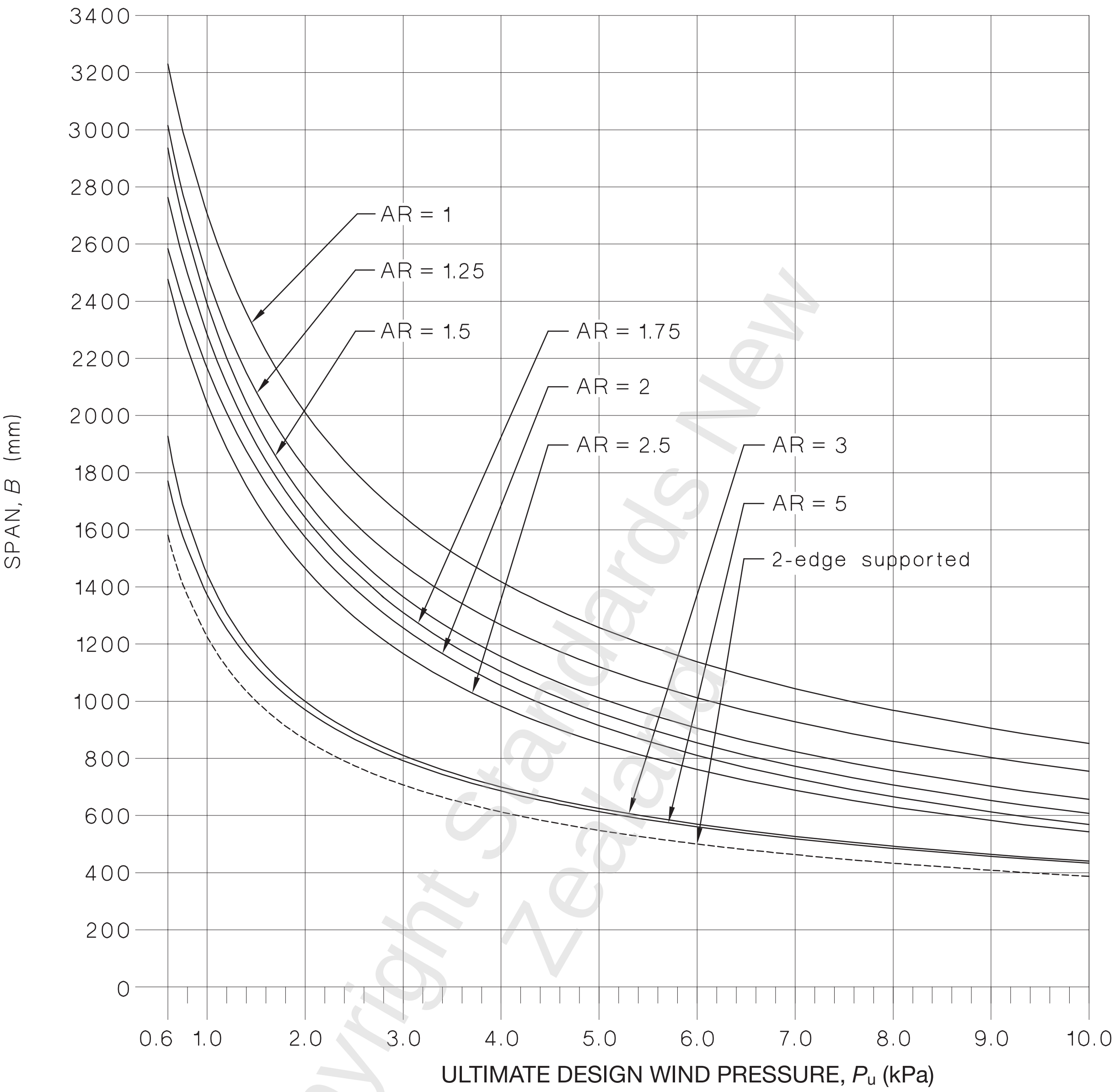
NOTE – Curves for AR = 1 to AR = 5 are to be used for four-edge supported glazing only.

Figure 11 – Maximum span for monolithic 4 mm toughened glass

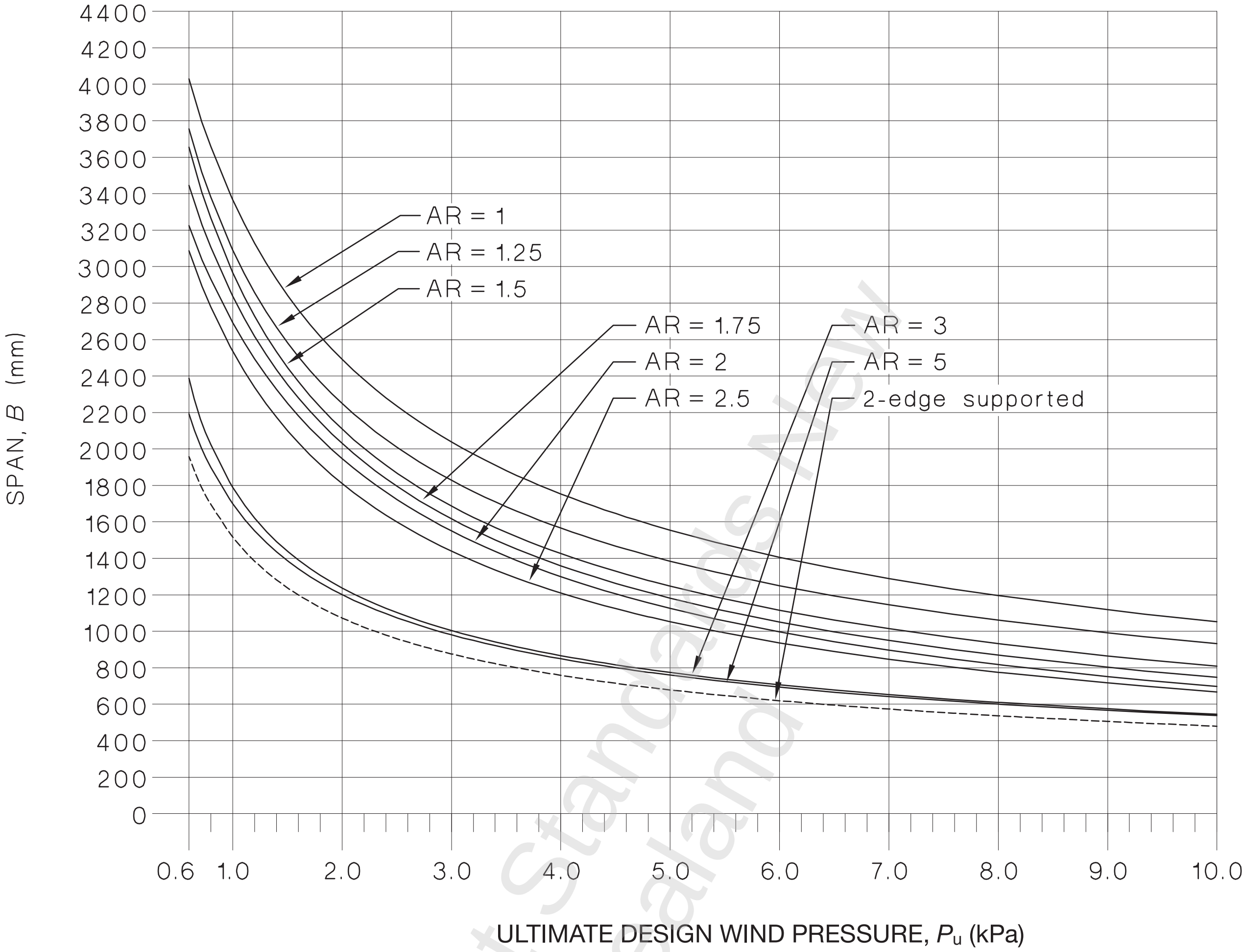


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	3594.2	3152.6	3108.6	3374.9	3634.8	3012.9	1382.5	1372.1	1225.3
k_2	0.59428	0.475424	0.475424	0.713136	0.950848	0.713136	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	5.7	–1.9	–30.78	–17.1	–15.2	3.8	–11.4	0	0

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

Figure 12 – Maximum span for monolithic 5 mm toughened glass

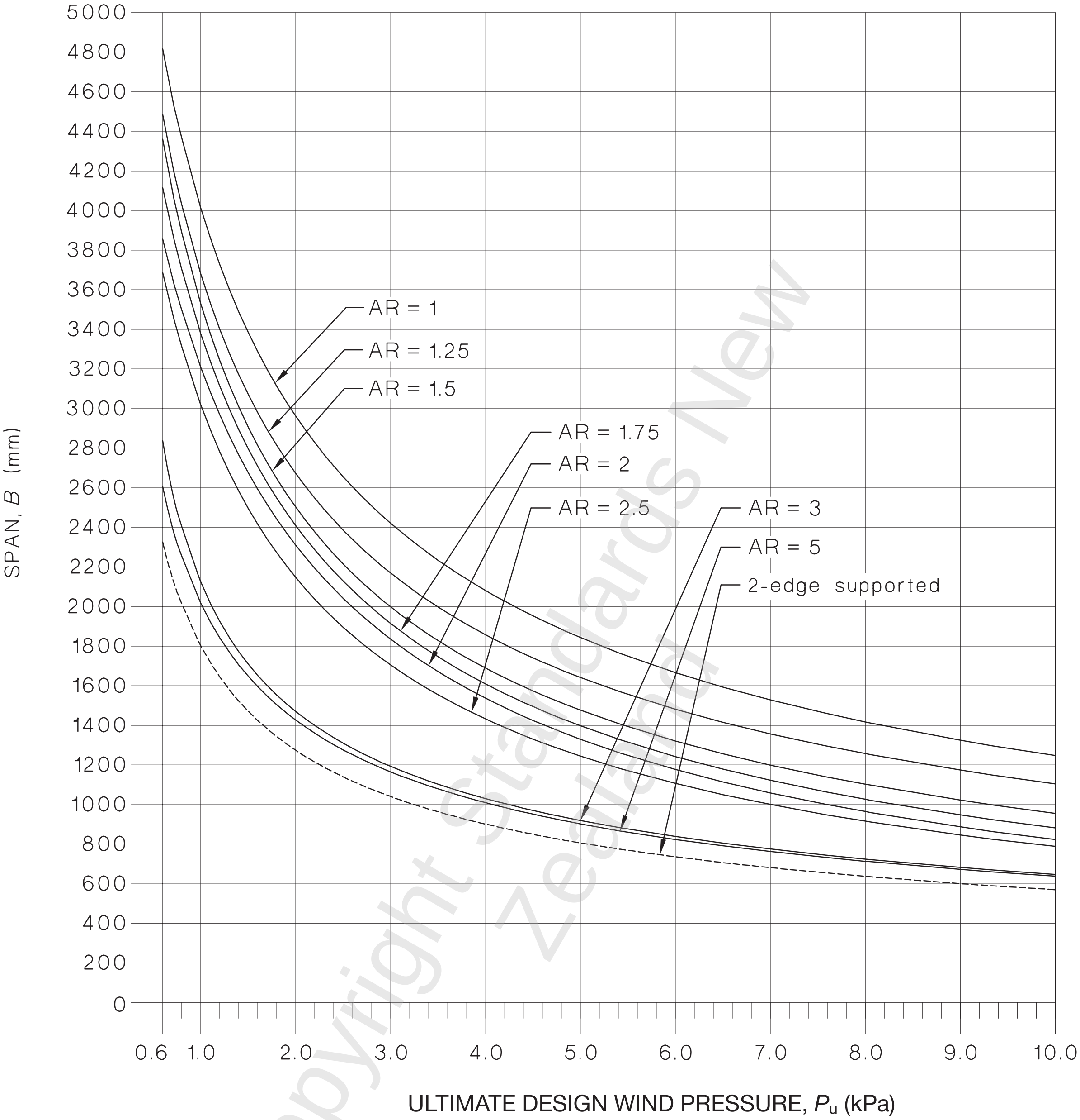


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	4429.2	3885.9	3826.2	4142.5	4452.0	3696.0	1712.3	1698.5	1516.8
k_2	0.57078	0.456624	0.456624	0.684935	0.913247	0.684935	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	7.2	–2.4	–38.88	–21.6	–19.2	4.8	–14.4	0	0

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

Figure 13 – Maximum span for monolithic 6 mm toughened glass

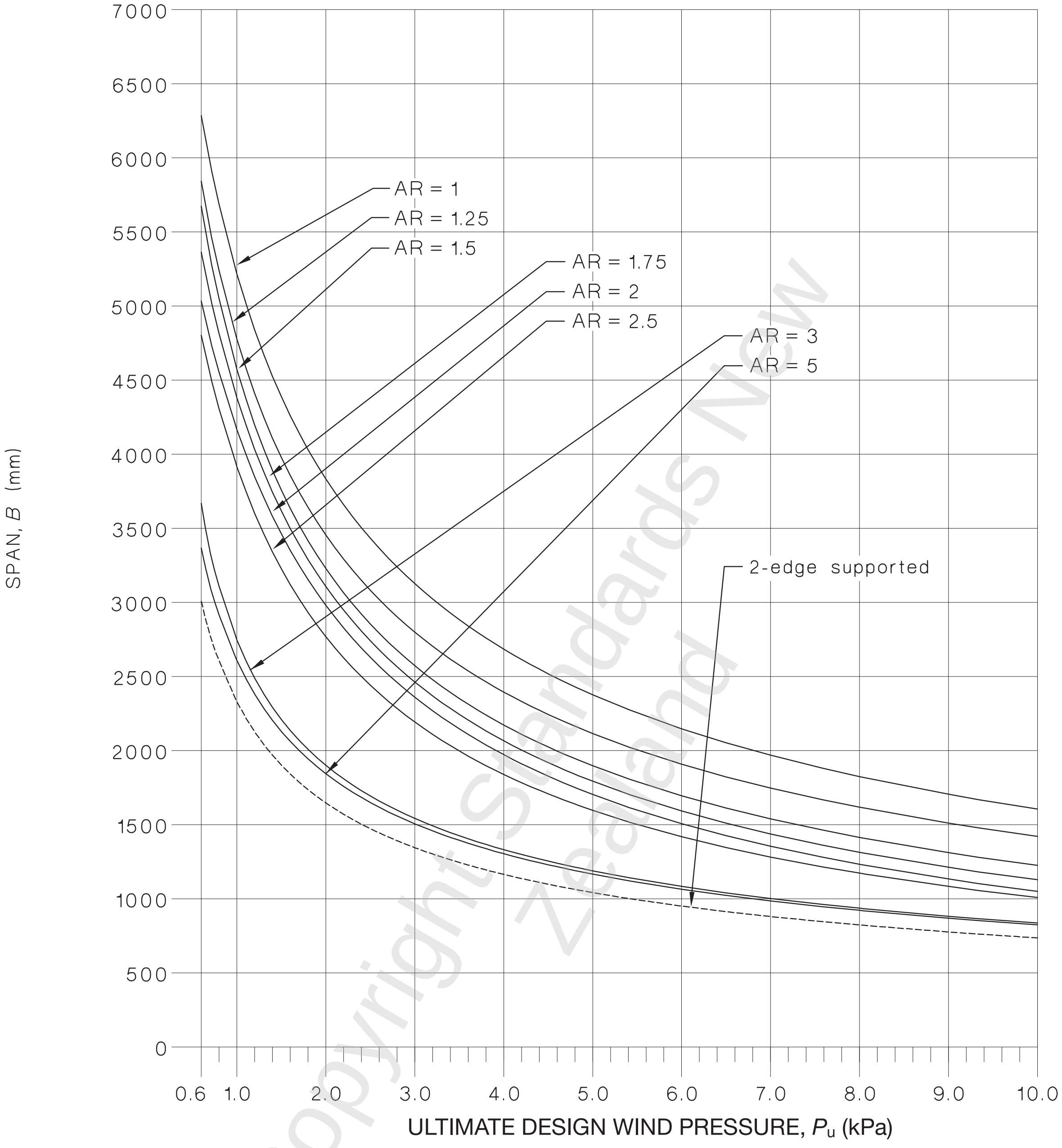


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	5241.9	4599.7	4523.7	4886.2	5241.8	4357.5	2035.1	2017.9	1801.9
k_2	0.551743	0.441394	0.441394	0.662091	0.882788	0.662091	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	8.7	–2.9	–46.98	–26.1	–23.2	5.8	–17.4	0	0

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

Figure 14 – Maximum span for monolithic 8 mm toughened glass

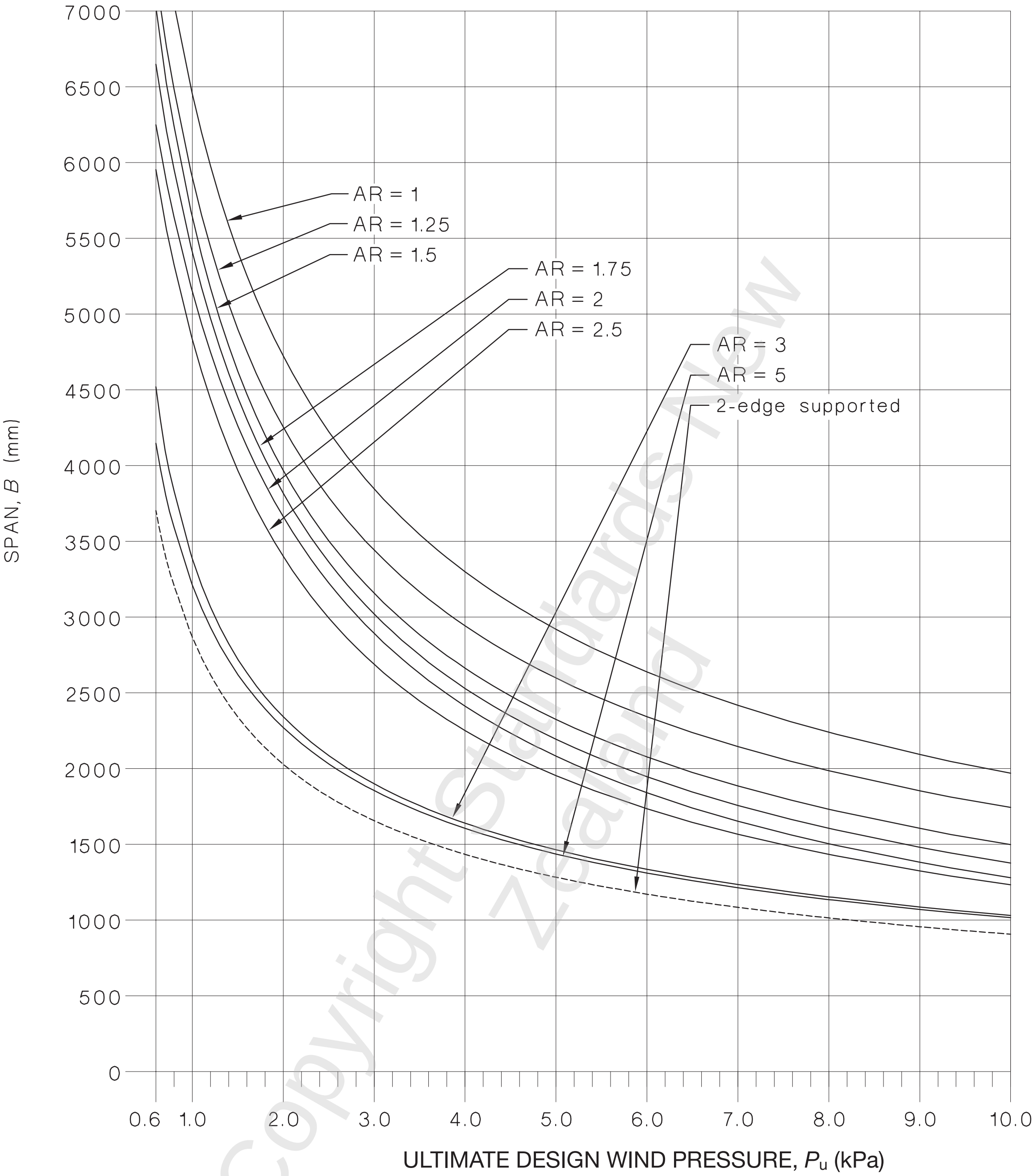


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	6736.6	5913.0	5804.5	6246.7	6682.5	5566.5	2632.7	2608.8	2329.6
k_2	0.523238	0.41859	0.41859	0.627885	0.83718	0.627885	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	11.55	–3.85	–62.37	–34.65	–30.8	7.7	–23.1	0	0

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

Figure 15 – Maximum span for monolithic 10 mm toughened glass

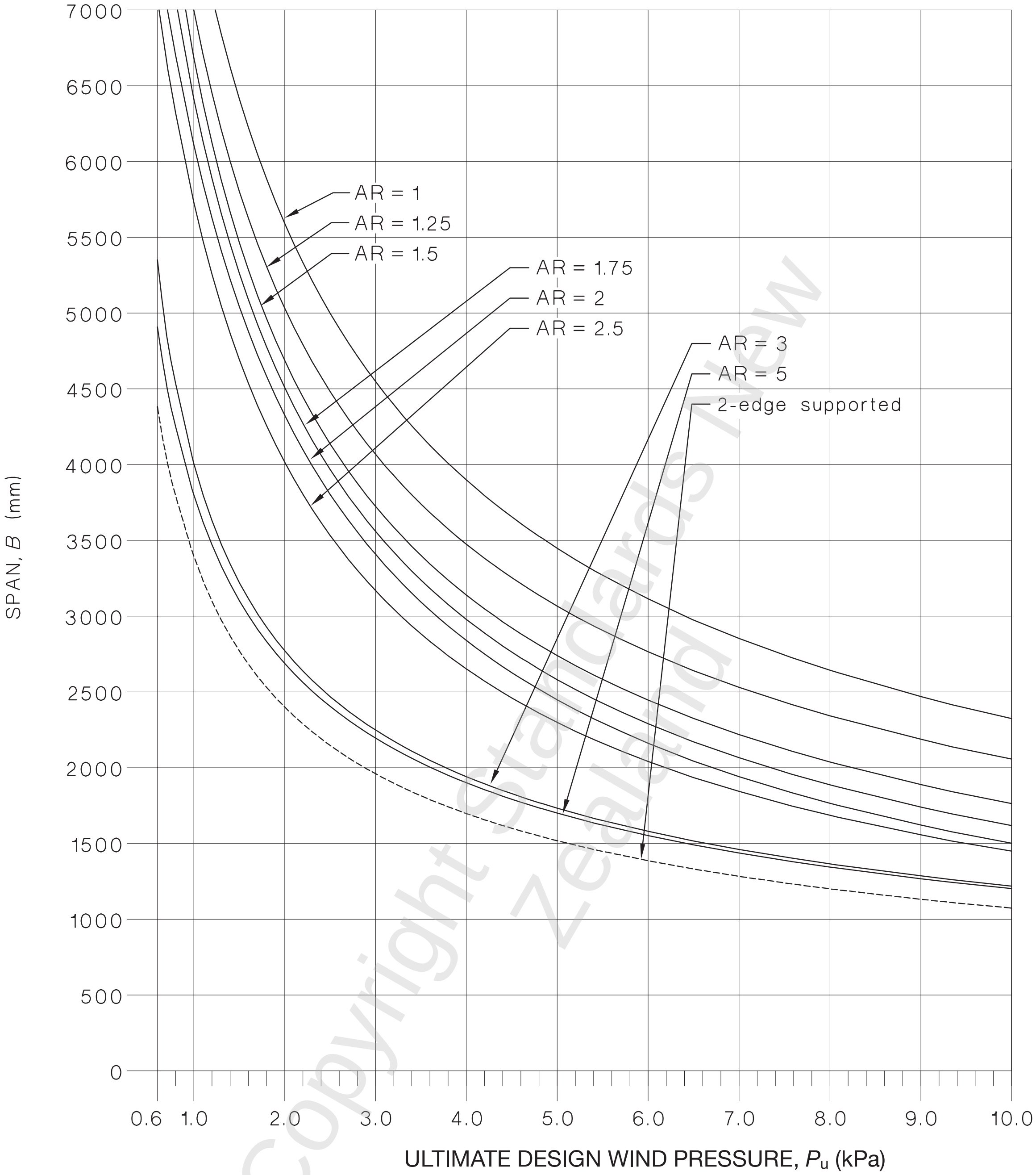


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	8253.7	7246.3	7101.9	7619.1	8131.1	6785.1	3243.8	3212.6	2868.8
k_2	0.50001	0.400008	0.400008	0.600012	0.800016	0.600012	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	14.55	–4.85	–78.57	–43.65	–38.8	9.7	–29.1	0	0

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

Figure 16 – Maximum span for monolithic 12 mm toughened glass

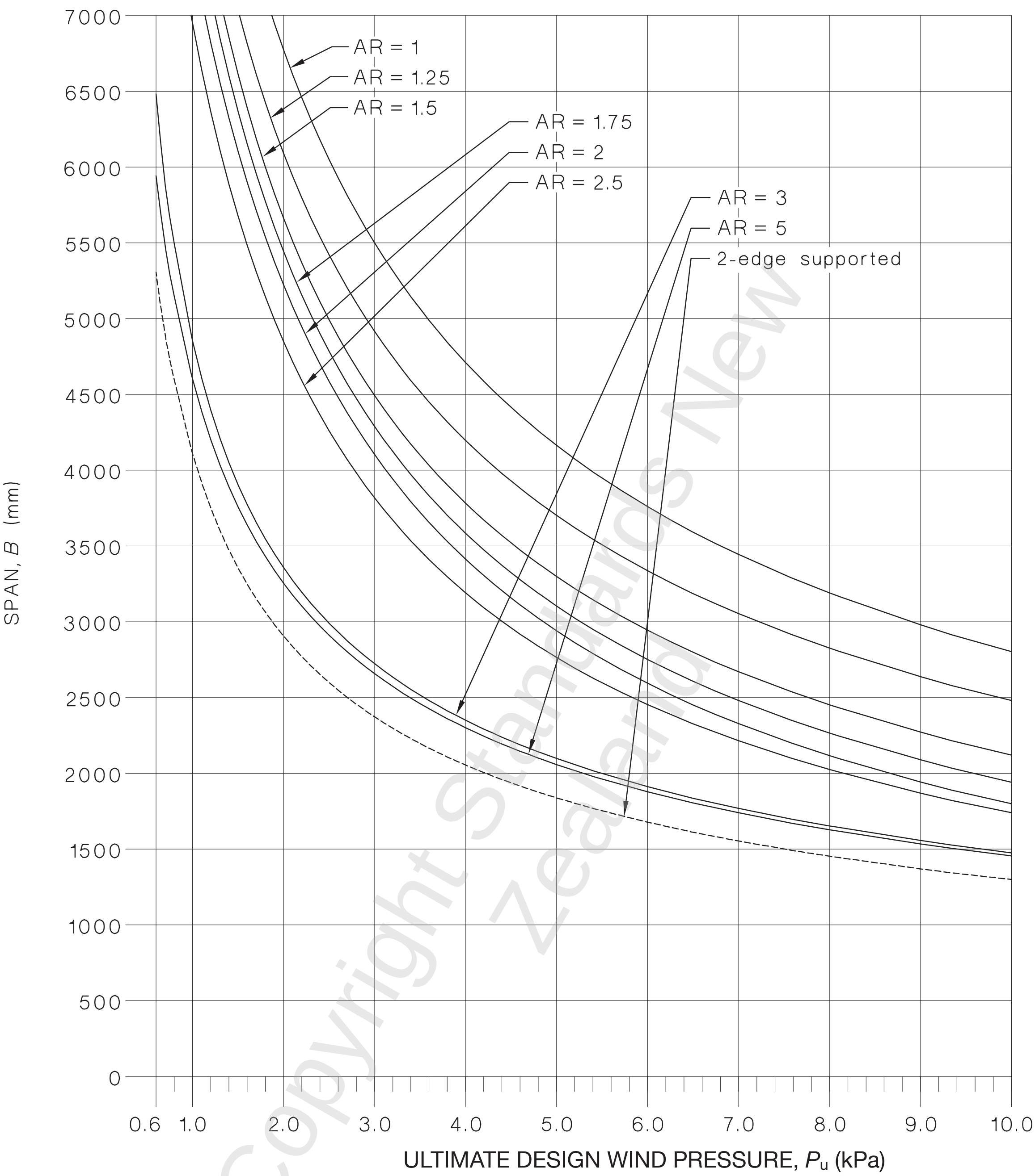


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	9723.8	8538.8	8357.3	8942.2	9523.6	7959.0	3839.9	3801.2	3394.5
k_2	0.481152	0.384922	0.384922	0.577382	0.769843	0.577382	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	17.55	–5.85	–94.77	–52.65	–46.8	11.7	–35.1	0	0

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

Figure 17 – Maximum span for monolithic 15 mm toughened glass

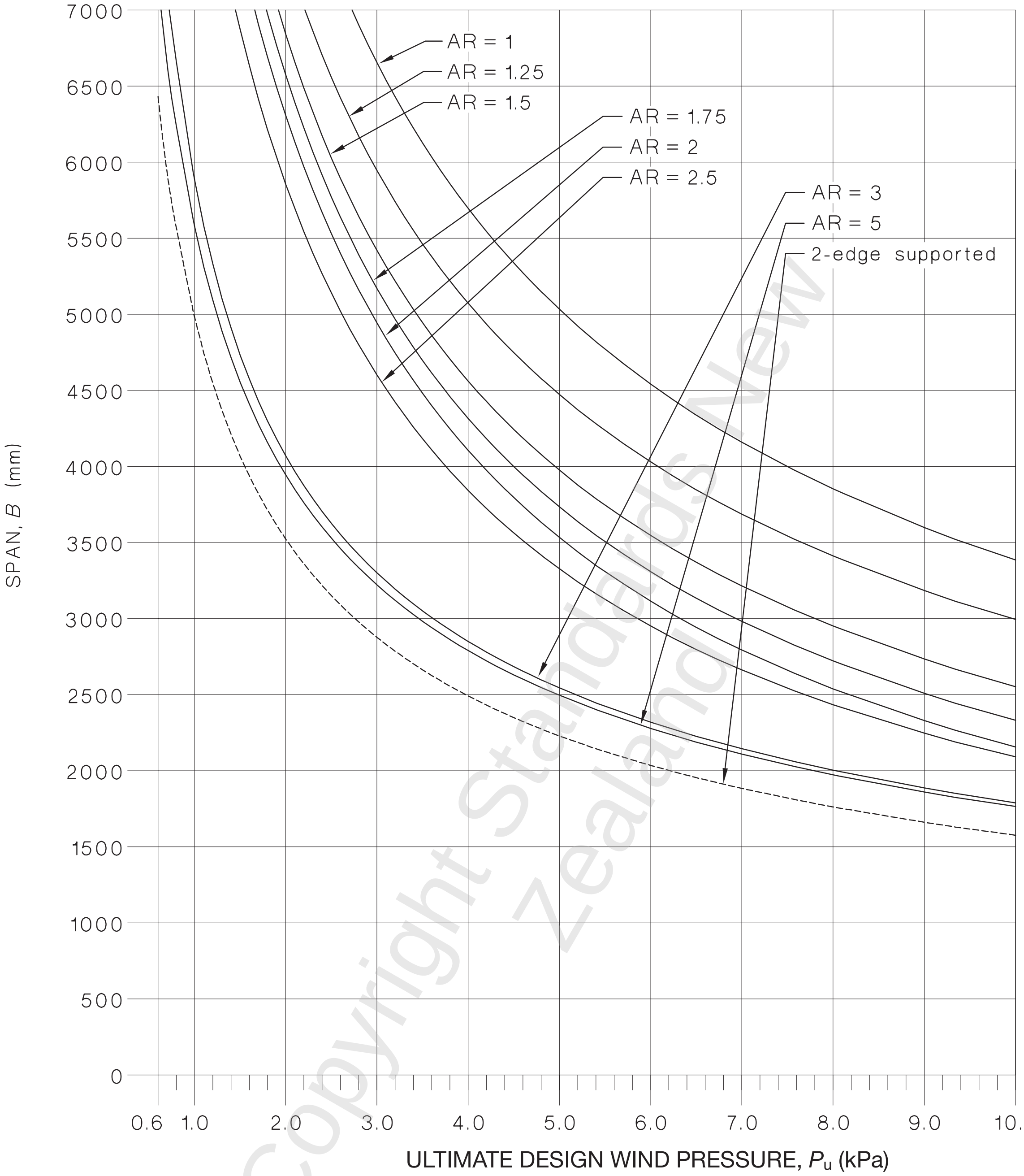


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	11716.9	10291.5	10056.5	10726.3	11396.0	9540.7	4653.4	4604.1	4111.4
k_2	0.459568	0.367655	0.367655	0.551482	0.735309	0.551482	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	21.75	–7.25	–117.45	–65.25	–58	14.5	–43.5	0	0

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

Figure 18 – Maximum span for monolithic 19 mm toughened glass

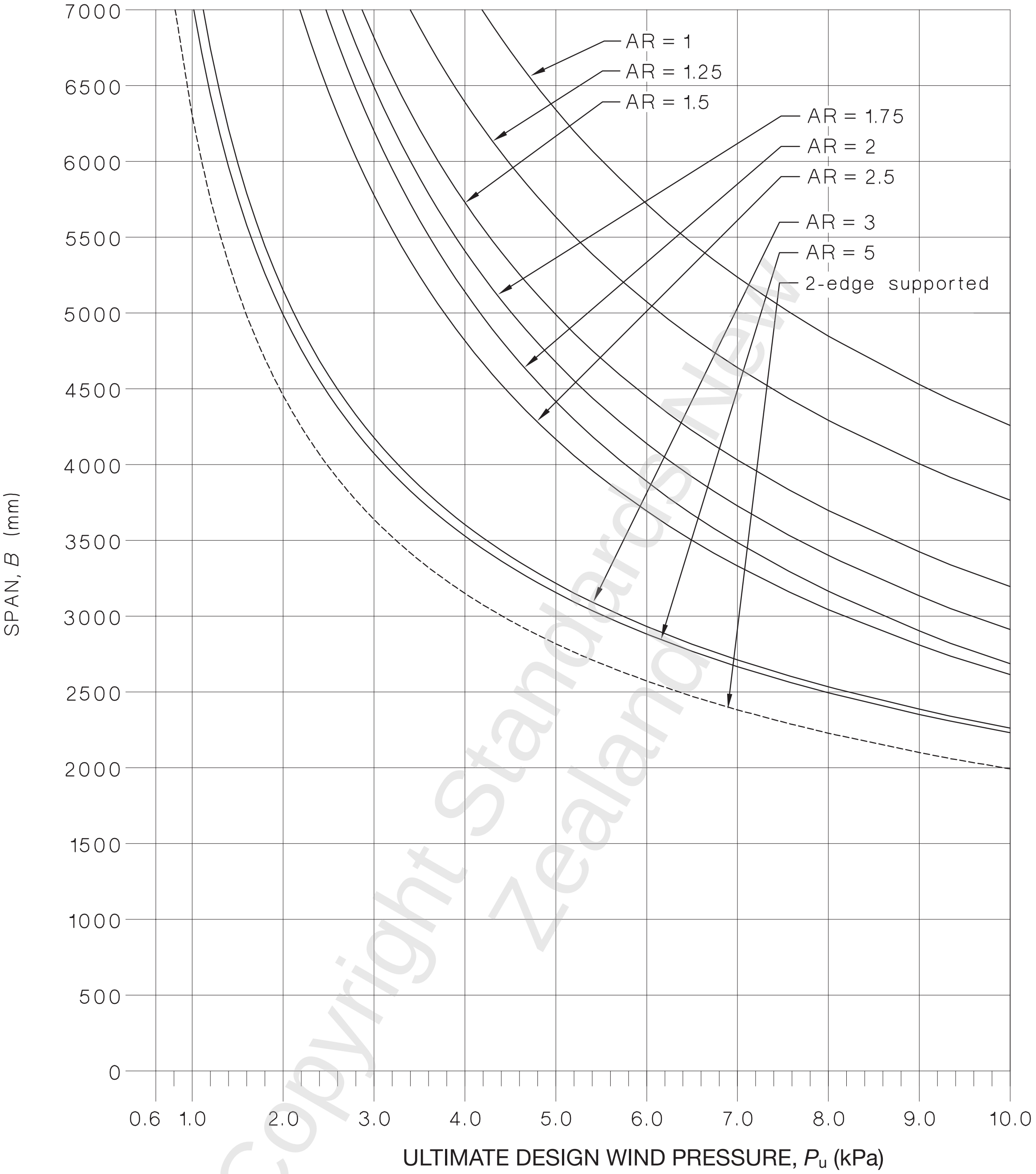


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	14119.6	12405.0	12101.1	12864.1	13632.2	11434.2	5641.5	5578.5	4981.6
k_2	0.437817	0.350254	0.350254	0.525381	0.700508	0.525381	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	27	–9	–145.8	–81	–72	18	–54	0	0

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

Figure 19 – Maximum span for monolithic 25 mm toughened glass

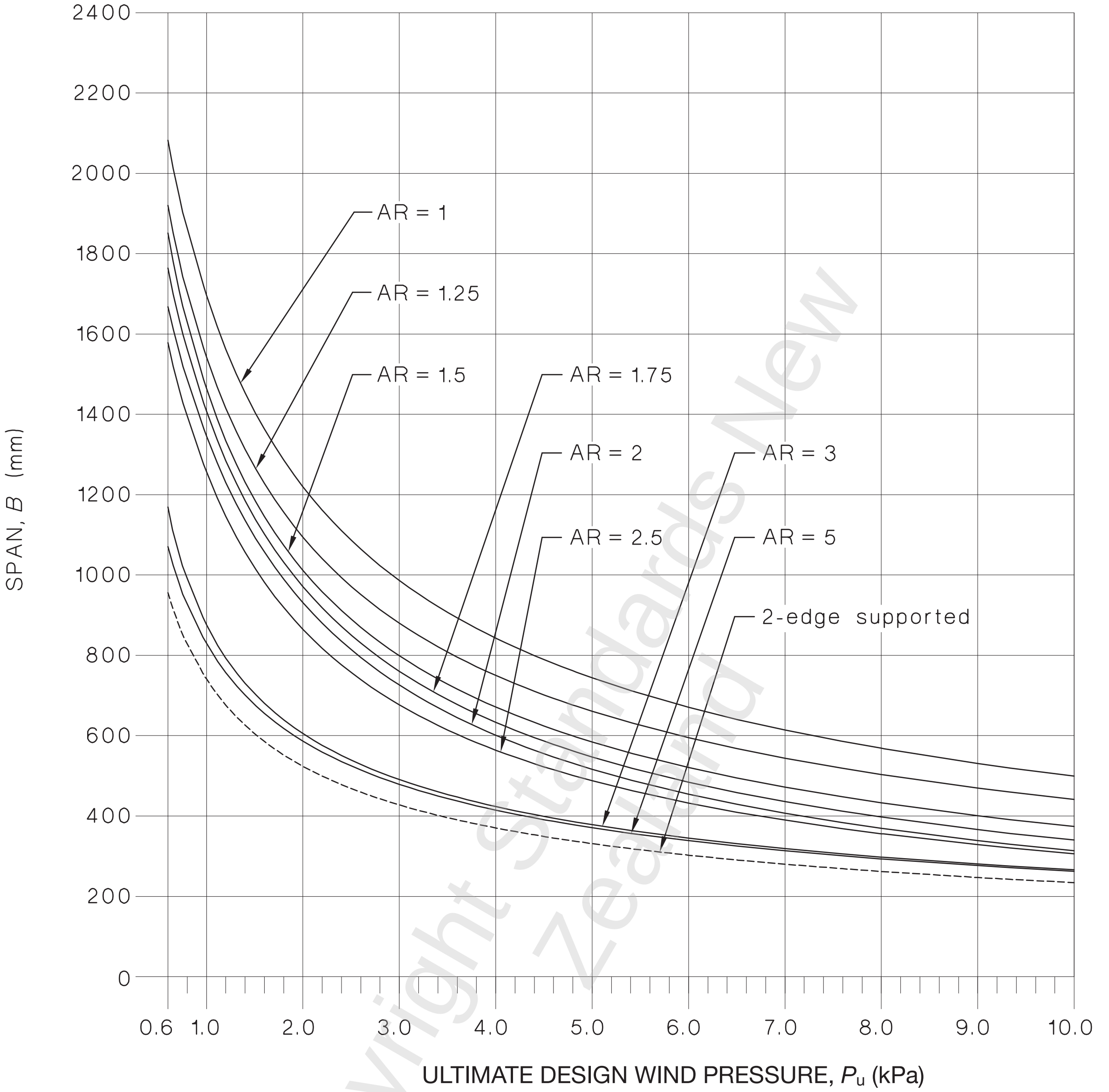


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	17733.9	15585.7	15170.0	16056.4	16958.2	14258.8	7141.5	7056.4	6301.3
k_2	0.410996	0.328797	0.328797	0.493195	0.657593	0.493195	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	35.25	–11.75	–190.35	–105.75	–94	23.5	–70.5	0	0

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

Figure 20 – Maximum span for monolithic 3 mm heat-strengthened glass

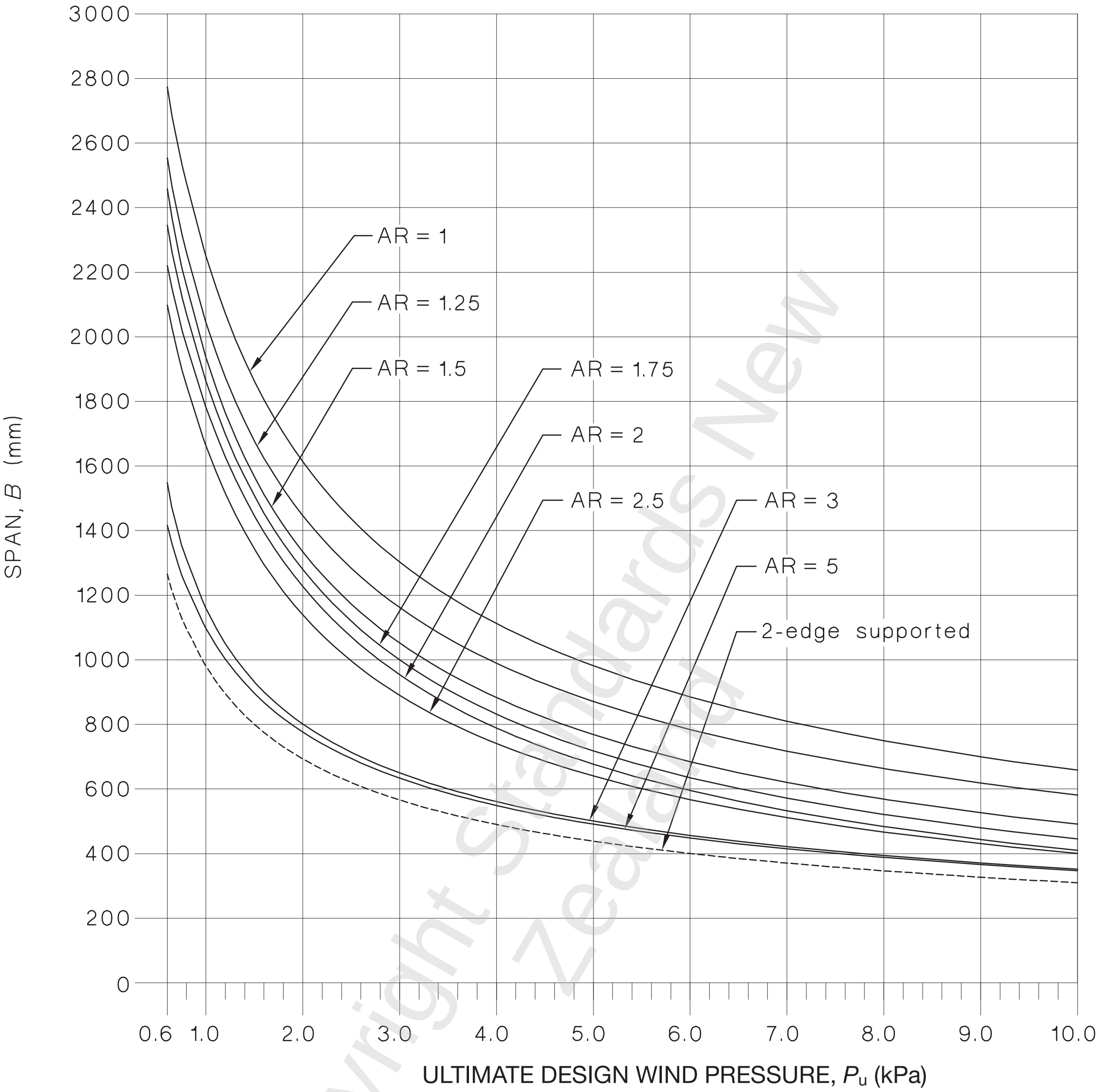


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2078.2	1826.7	1776.3	1876.6	1979.1	1665.8	839.7	829.4	740.7
k_2	0.4	0.32	0.32	0.48	0.64	0.48	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	4.2	–1.4	–22.68	–12.6	–11.2	2.8	–8.4	0	0

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

Figure 21 – Maximum span for monolithic 4 mm heat-strengthened glass

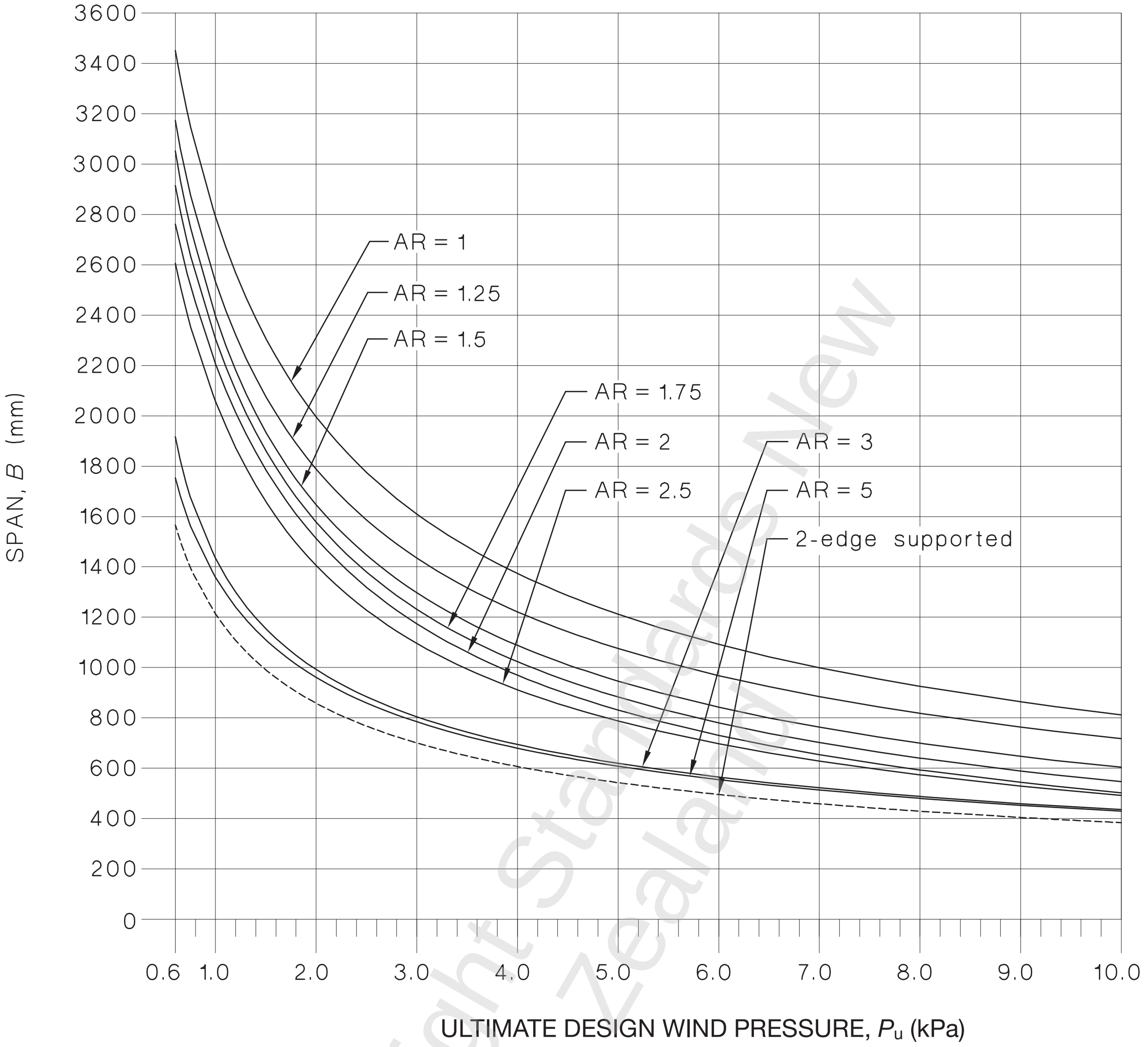


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2734.6	2404.4	2333.9	2457.1	2584.4	2179.6	1111.9	1097.7	980.2
k_2	0.380339	0.304271	0.304271	0.456407	0.608543	0.456407	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	5.7	–1.9	–30.78	–17.1	–15.2	3.8	–11.4	0	0

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

Figure 22 – Maximum span for monolithic 5 mm heat-strengthened glass

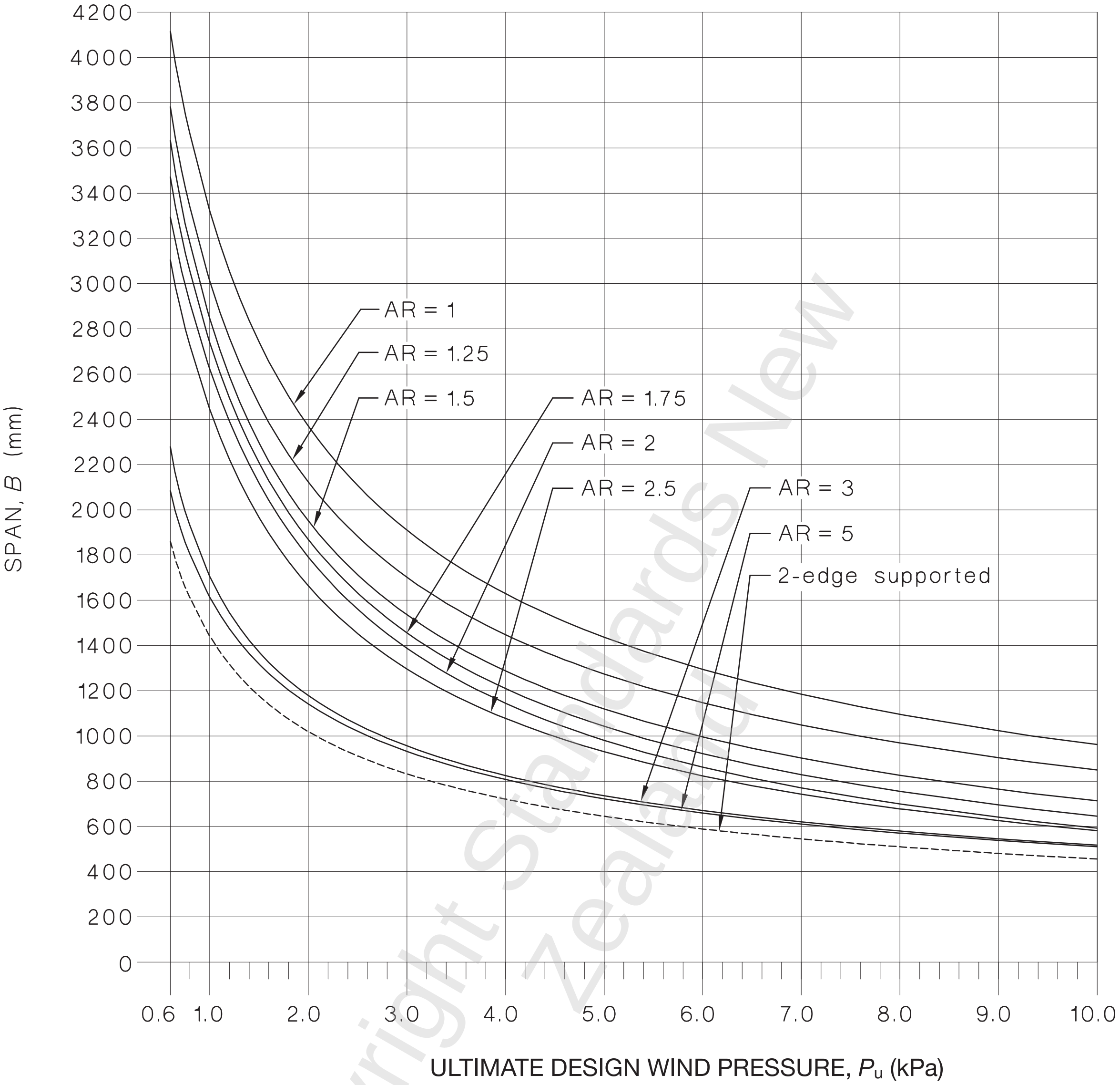


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	3370.0	2963.6	2872.6	3015.9	3165.4	2673.7	1377.1	1358.8	1213.4
k_2	0.365299	0.292239	0.292239	0.438359	0.584478	0.438359	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	7.2	–2.4	–38.88	–21.6	–19.2	4.8	–14.4	0	0

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

Figure 23 – Maximum span for monolithic 6 mm heat-strengthened glass

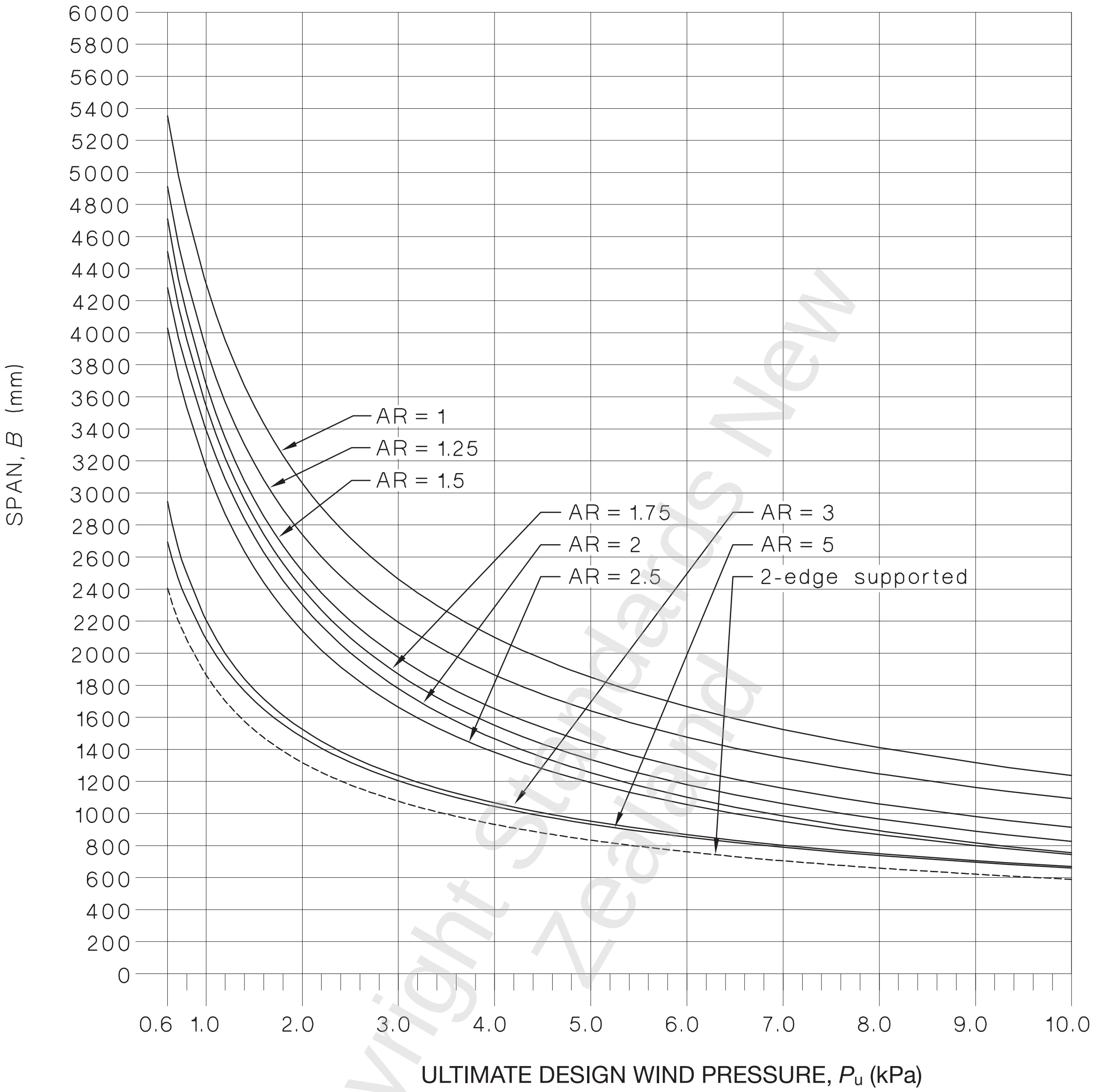


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	3988.4	3508.0	3396.3	3557.3	3727.0	3152.2	1636.7	1614.3	1441.6
k_2	0.353115	0.282492	0.282492	0.423738	0.564985	0.423738	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	8.7	–2.9	–46.98	–26.1	–23.2	5.8	–17.4	0	0

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

Figure 24 – Maximum span for monolithic 8 mm heat-strengthened glass

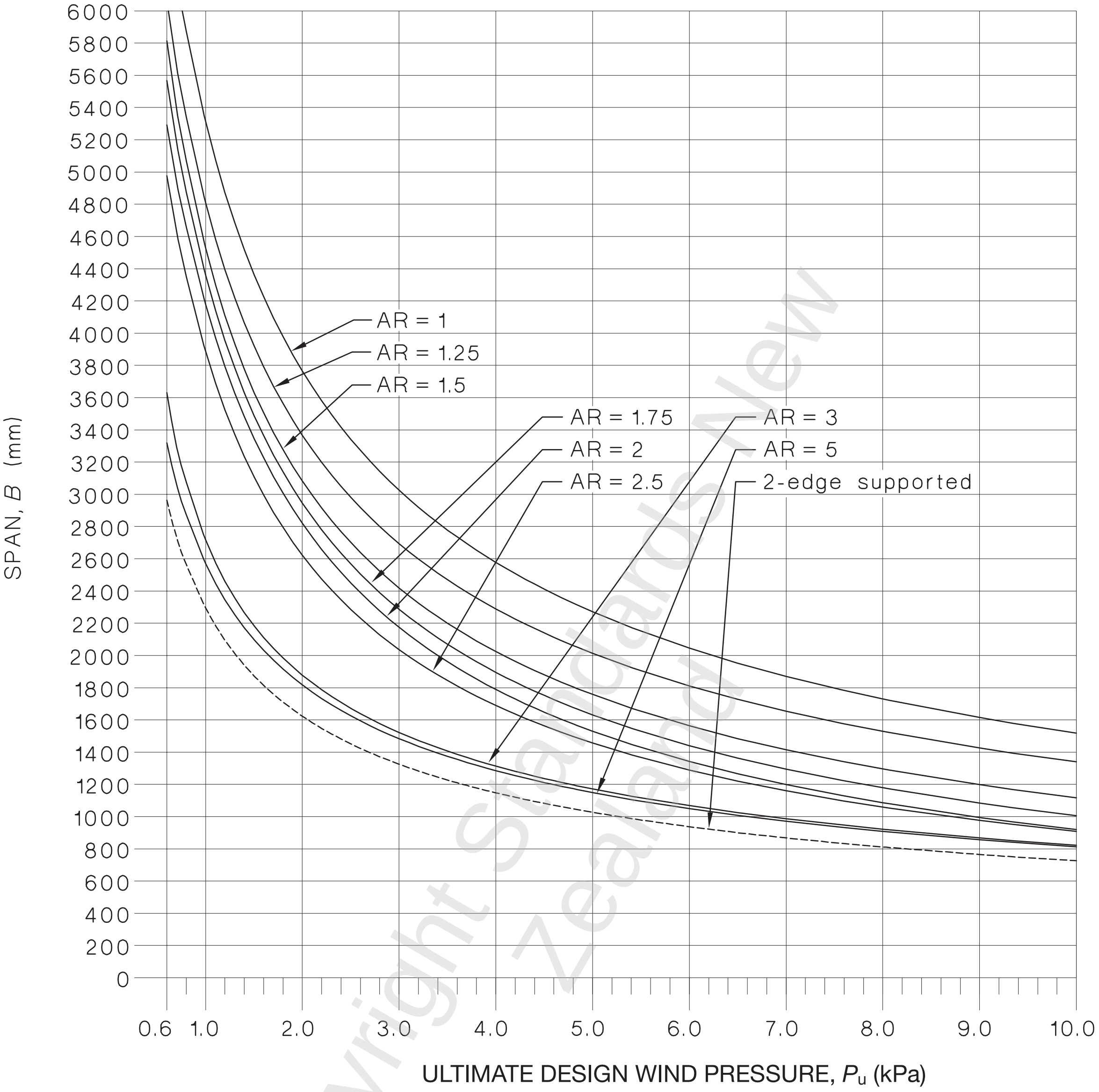


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	5125.6	4509.6	4357.8	4547.8	4751.4	4026.9	2117.3	2087.0	1863.7
k_2	0.334872	0.267898	0.267898	0.401847	0.535796	0.401847	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	11.55	–3.85	–62.37	–34.65	–30.8	7.7	–23.1	0	0

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

Figure 25 – Maximum span for monolithic 10 mm heat-strengthened glass

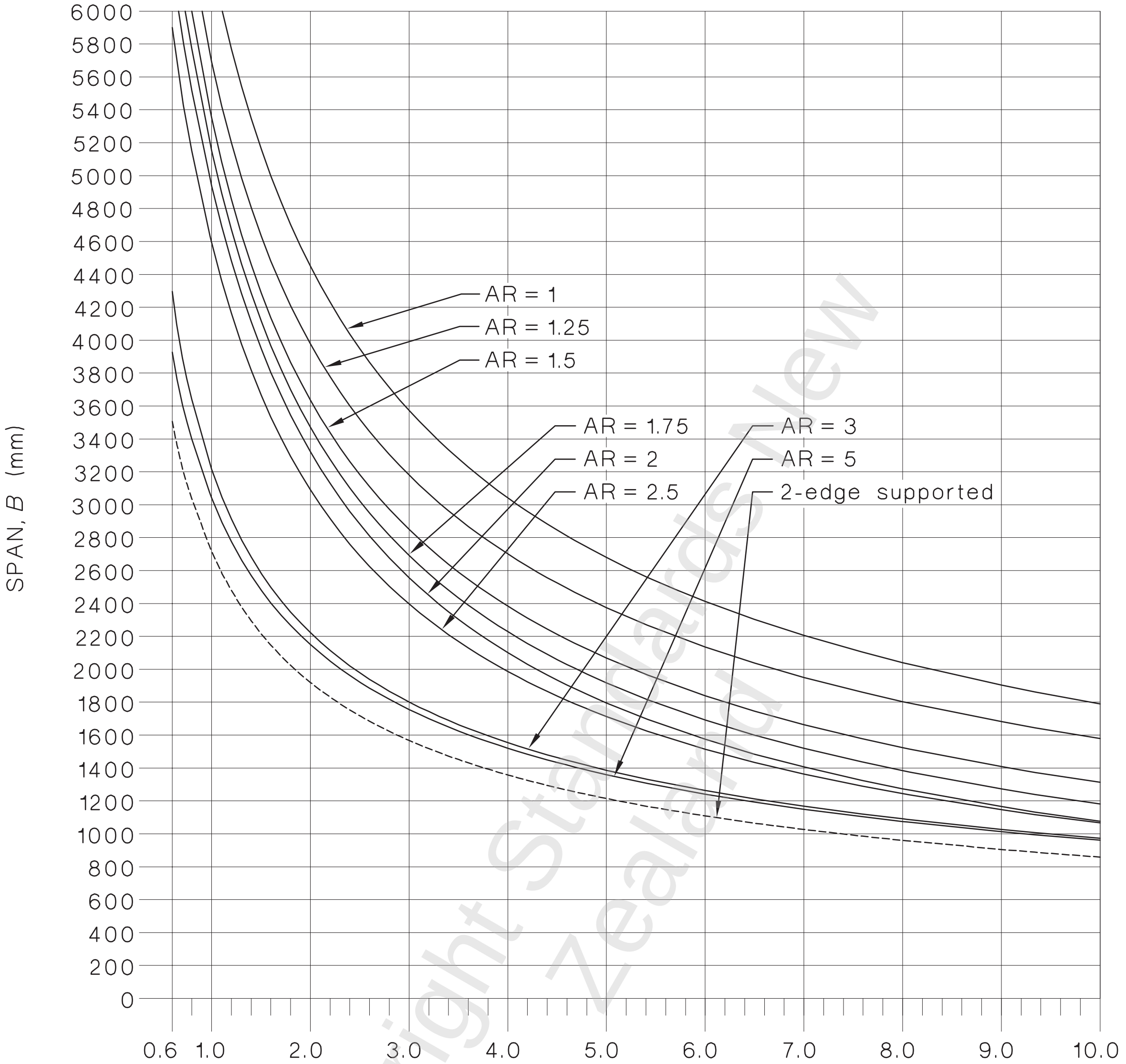


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	6279.9	5526.5	5331.9	5547.0	5781.4	4908.4	2608.8	2570.1	2295.1
k_2	0.320006	0.256005	0.256005	0.384008	0.51201	0.384008	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	14.55	–4.85	–78.57	–43.65	–38.8	9.7	–29.1	0	0

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

Figure 26 – Maximum span for monolithic 12 mm heat-strengthened glass

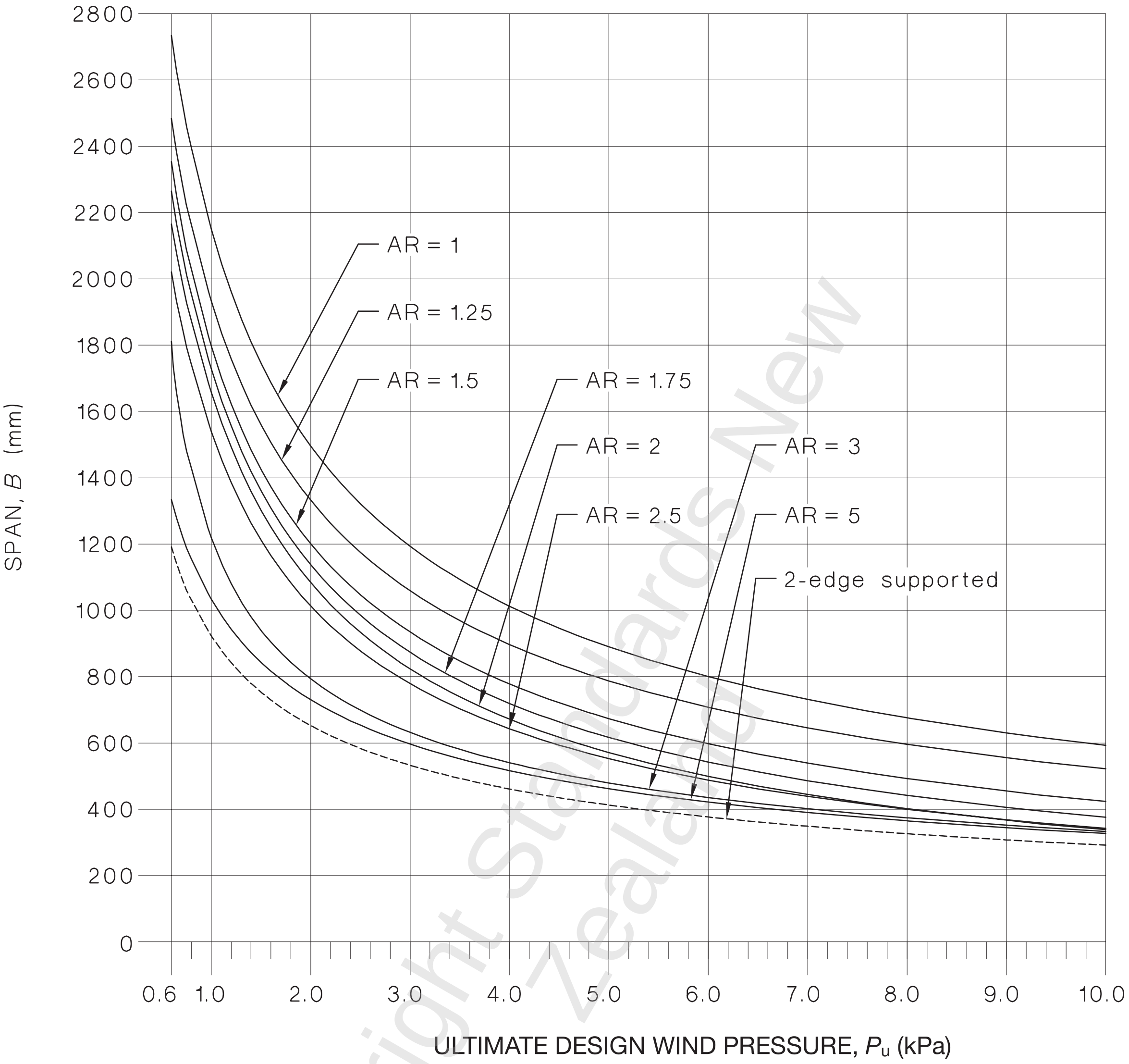


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	**Four-edge supported annealed glass 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	7398.5	6512.2	6274.4	6510.3	6771.5	5757.6	3088.2	3041.0	2715.6
k_2	0.307937	0.24635	0.24635	0.369525	0.4927	0.369525	–0.1	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	17.55	–5.85	–94.77	–52.65	–46.8	11.7	–35.1	0	0

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

Figure 27 – Maximum span for 5 mm annealed laminated glass

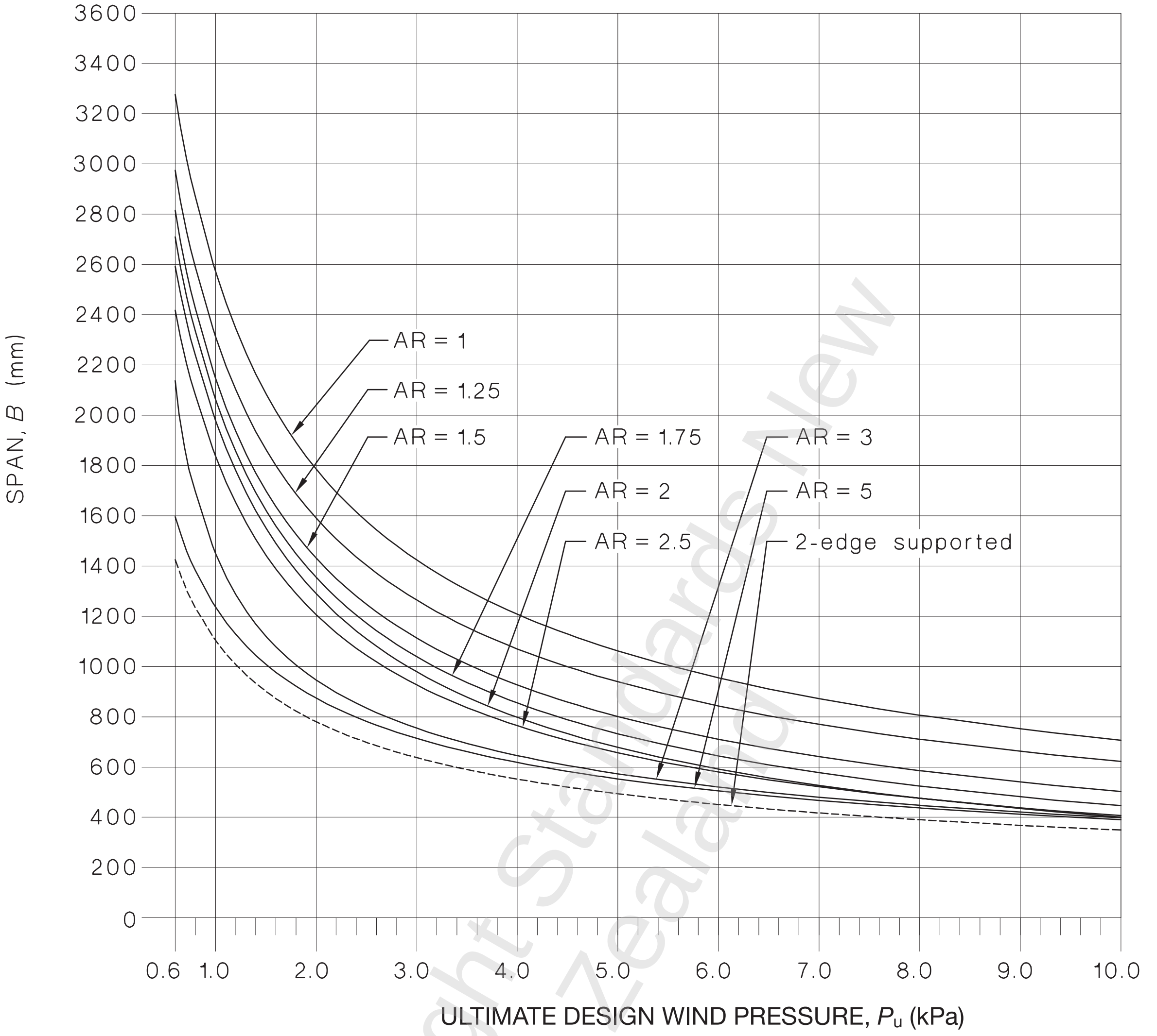


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2432.9	2144.8	2045.4	2080.0	2130.3	1831.9	1053.0	1033.3	922.8
k_2	0.230024	0.184019	0.184019	0.276029	0.368039	0.276029	–0.27603	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	6.9	–2.3	–37.26	–20.7	–18.4	4.6	–13.8	0	0

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

Figure 28 – Maximum span for 6 mm annealed laminated glass

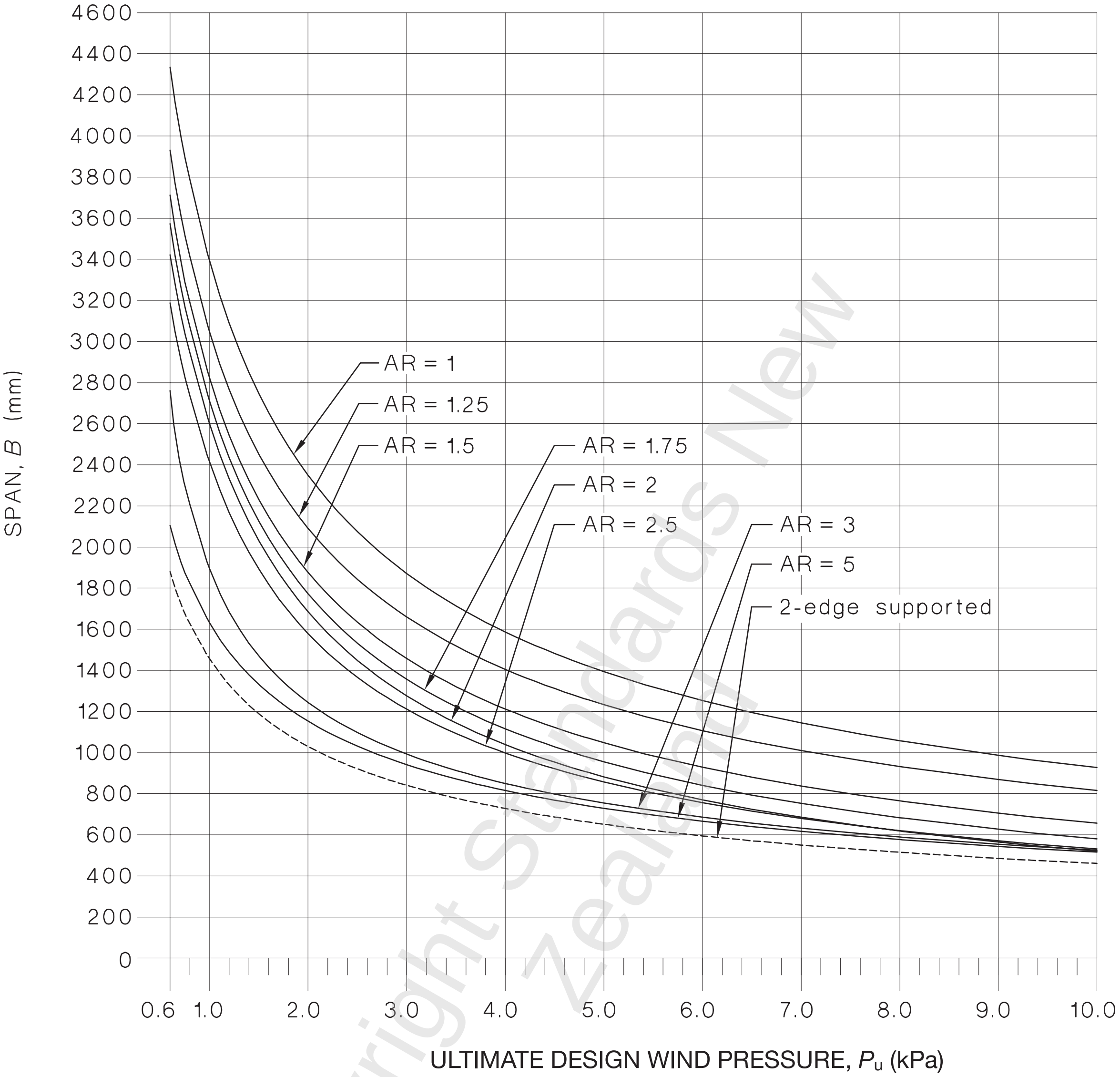


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	2899.0	2556.1	2434.7	2469.9	2524.9	2174.2	1260.2	1236.1	1103.9
k_2	0.222109	0.177687	0.177687	0.266531	0.355375	0.266531	–0.26653	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	8.4	–2.8	–45.36	–25.2	–22.4	5.6	–16.8	0	0

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

Figure 29 – Maximum span for 8 mm annealed laminated glass

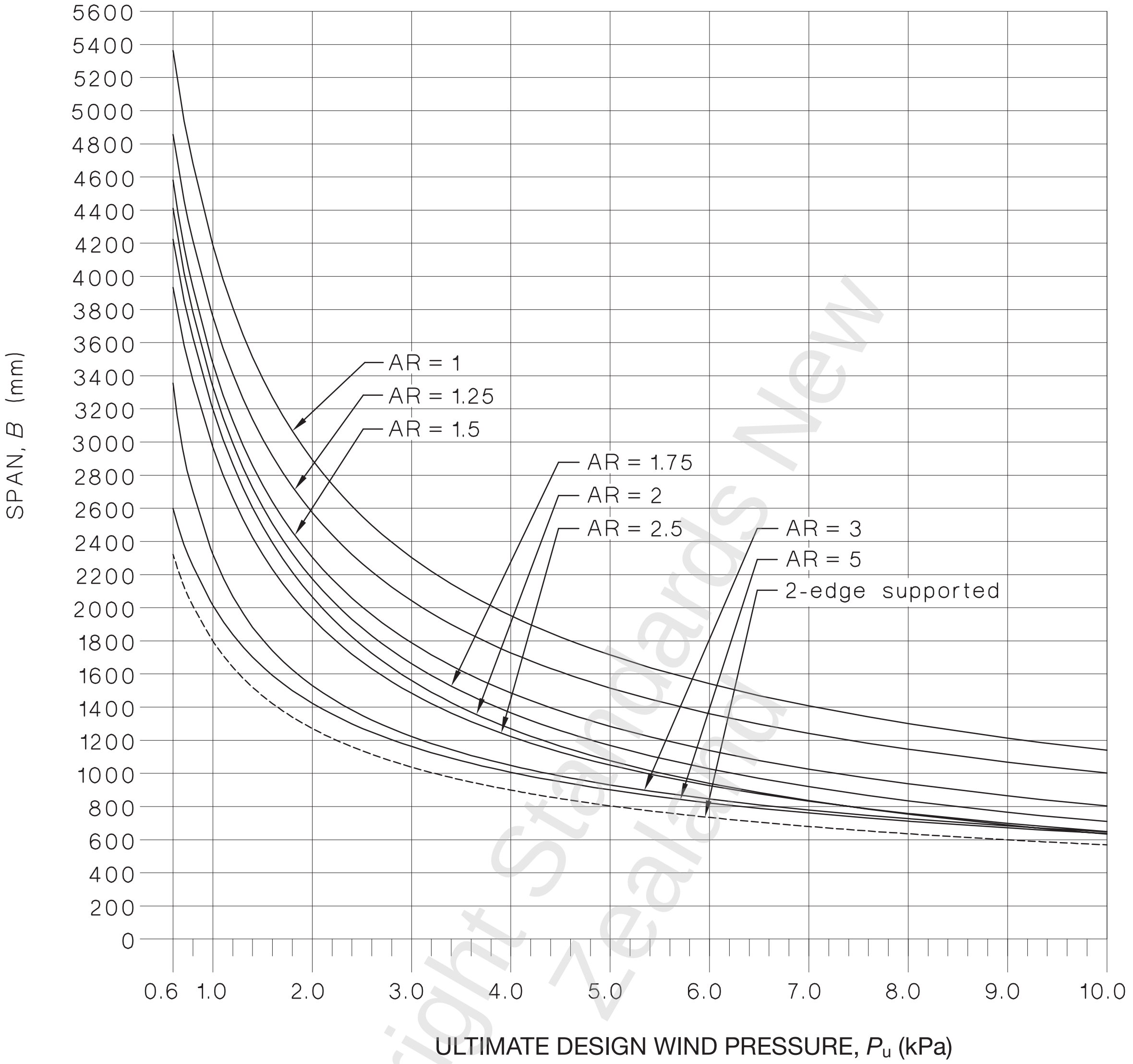


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	3799.6	3351.2	3185.6	3219.1	3280.9	2831.3	1663.5	1630.6	1456.1
k_2	0.209821	0.167857	0.167857	0.251785	0.335714	0.251785	–0.25179	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	11.4	–3.8	–61.56	–34.2	–30.4	7.6	–22.8	0	0

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

Figure 30 – Maximum span for 10 mm annealed laminated glass

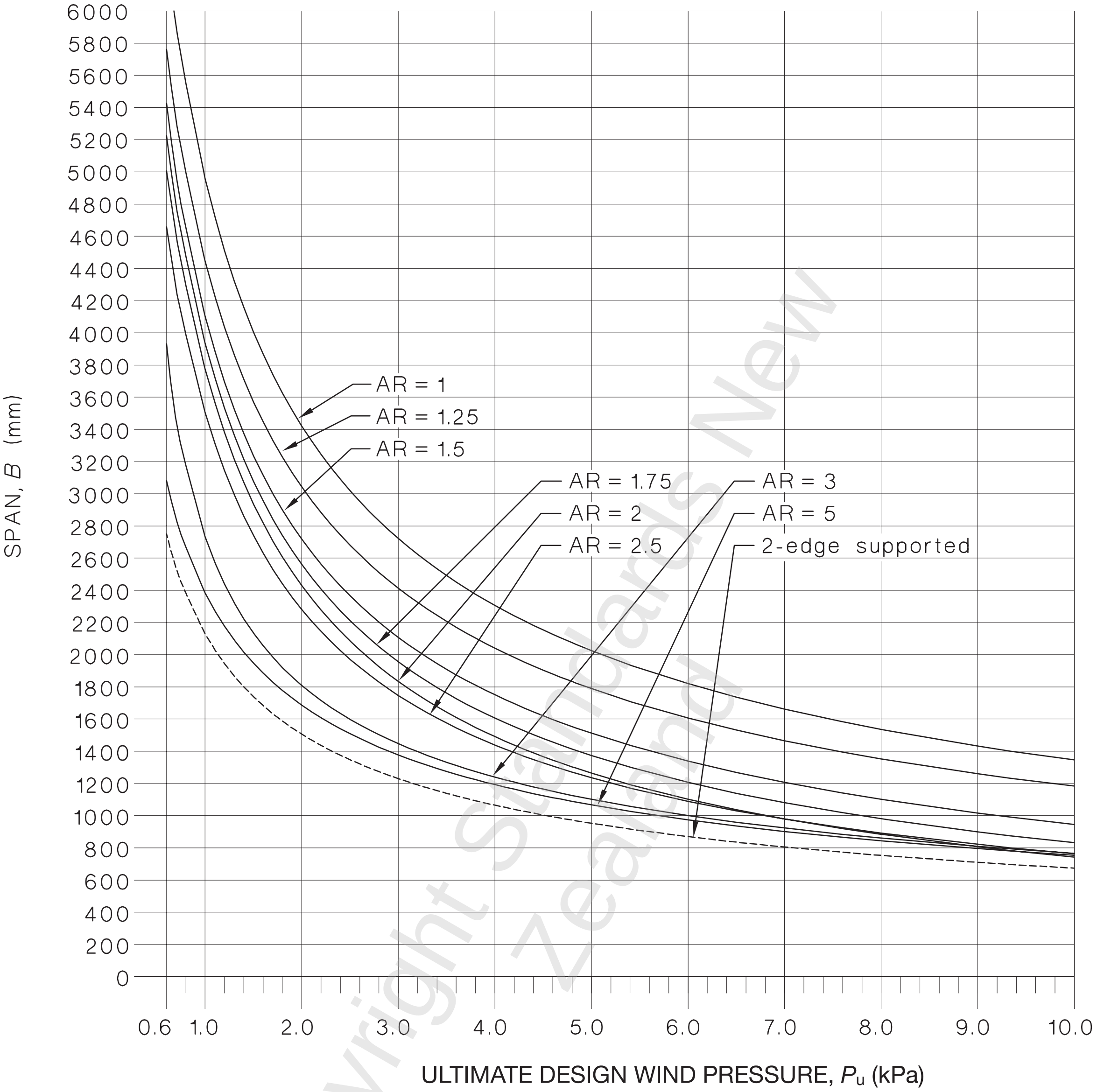


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	4666.6	4117.0	3907.1	3935.8	4001.6	3459.4	2054.7	2013.0	1797.6
k_2	0.200421	0.160337	0.160337	0.240505	0.320673	0.240505	–0.24051	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	14.4	–4.8	–77.76	–43.2	–38.4	9.6	–28.8	0	0

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

Figure 31 – Maximum span for 12 mm annealed laminated glass

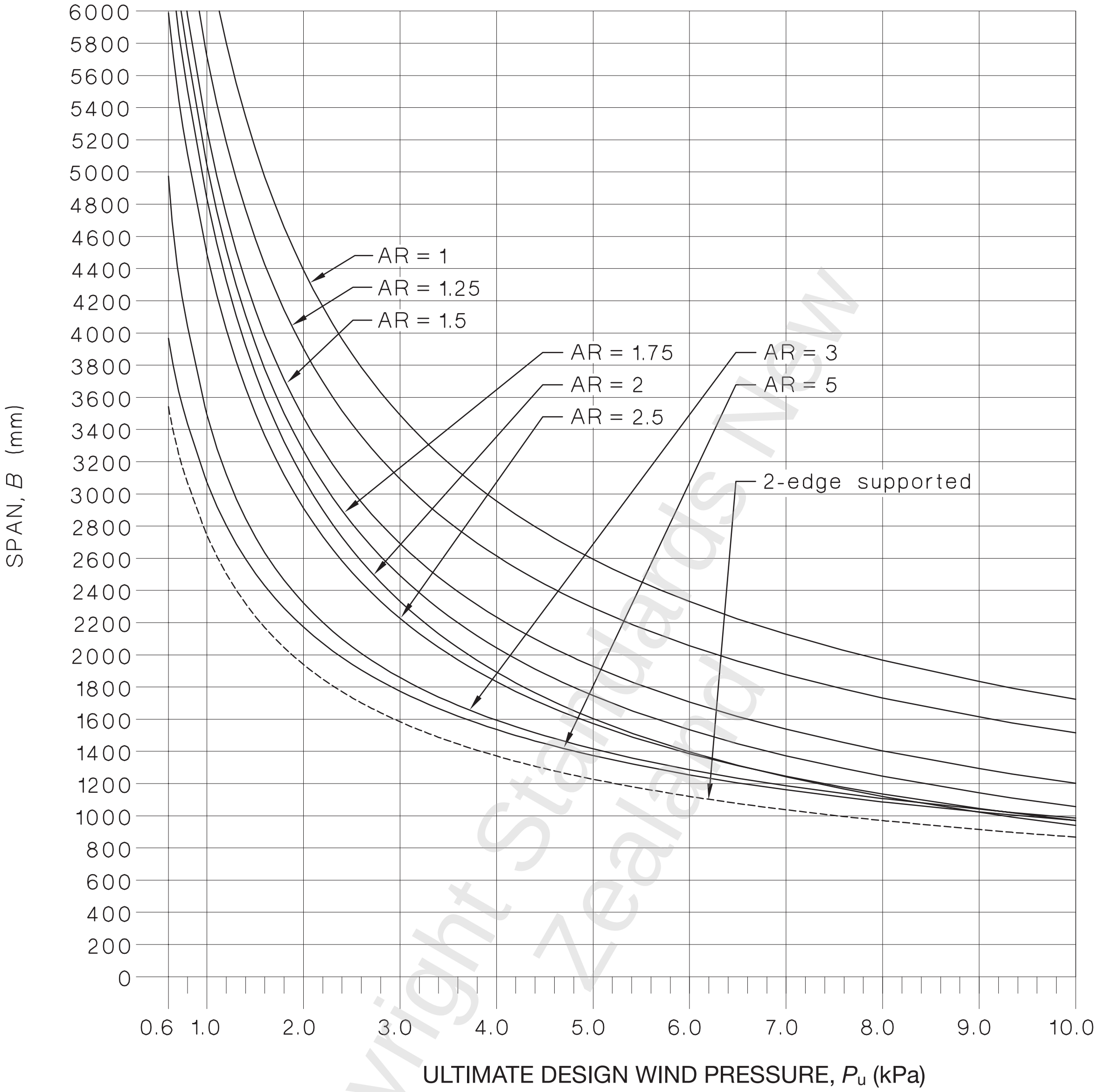


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	5506.6	4859.1	4605.1	4626.5	4694.2	4064.3	2436.3	2385.7	2130.4
k_2	0.192806	0.154245	0.154245	0.231367	0.30849	0.231367	–0.23137	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	17.4	–5.8	–93.96	–52.2	–46.4	11.6	–34.8	0	0

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

Figure 32 – Maximum span for 16 mm annealed laminated glass

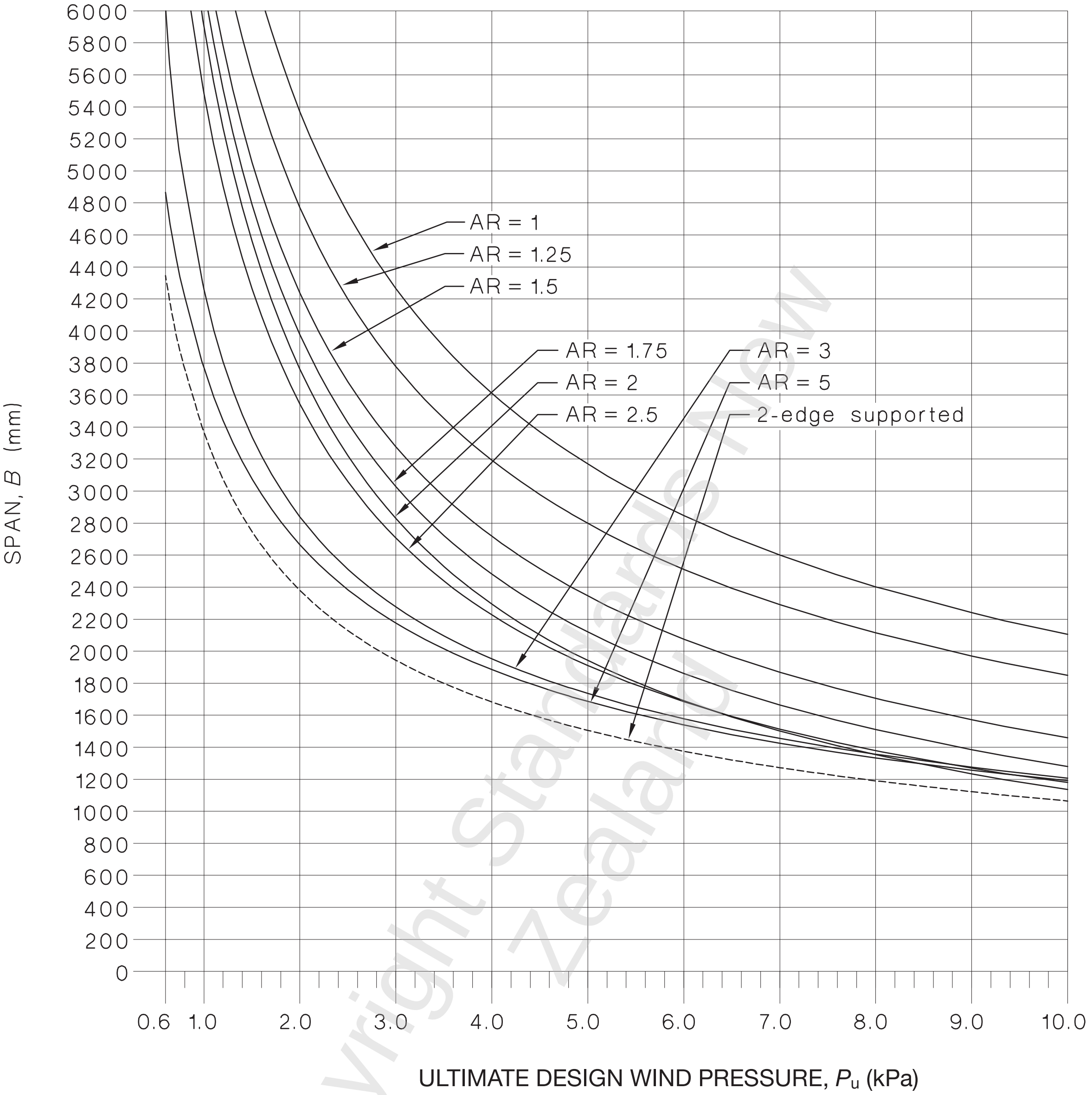


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	7042.7	6216.4	5879.0	5881.5	5948.3	5162.3	3139.6	3072.2	2743.4
k_2	0.181404	0.145123	0.145123	0.217685	0.290247	0.217685	–0.21769	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	23.1	–7.7	–124.74	–69.3	–61.6	15.4	–46.2	0	0

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

Figure 33 – Maximum span for 20 mm annealed laminated glass

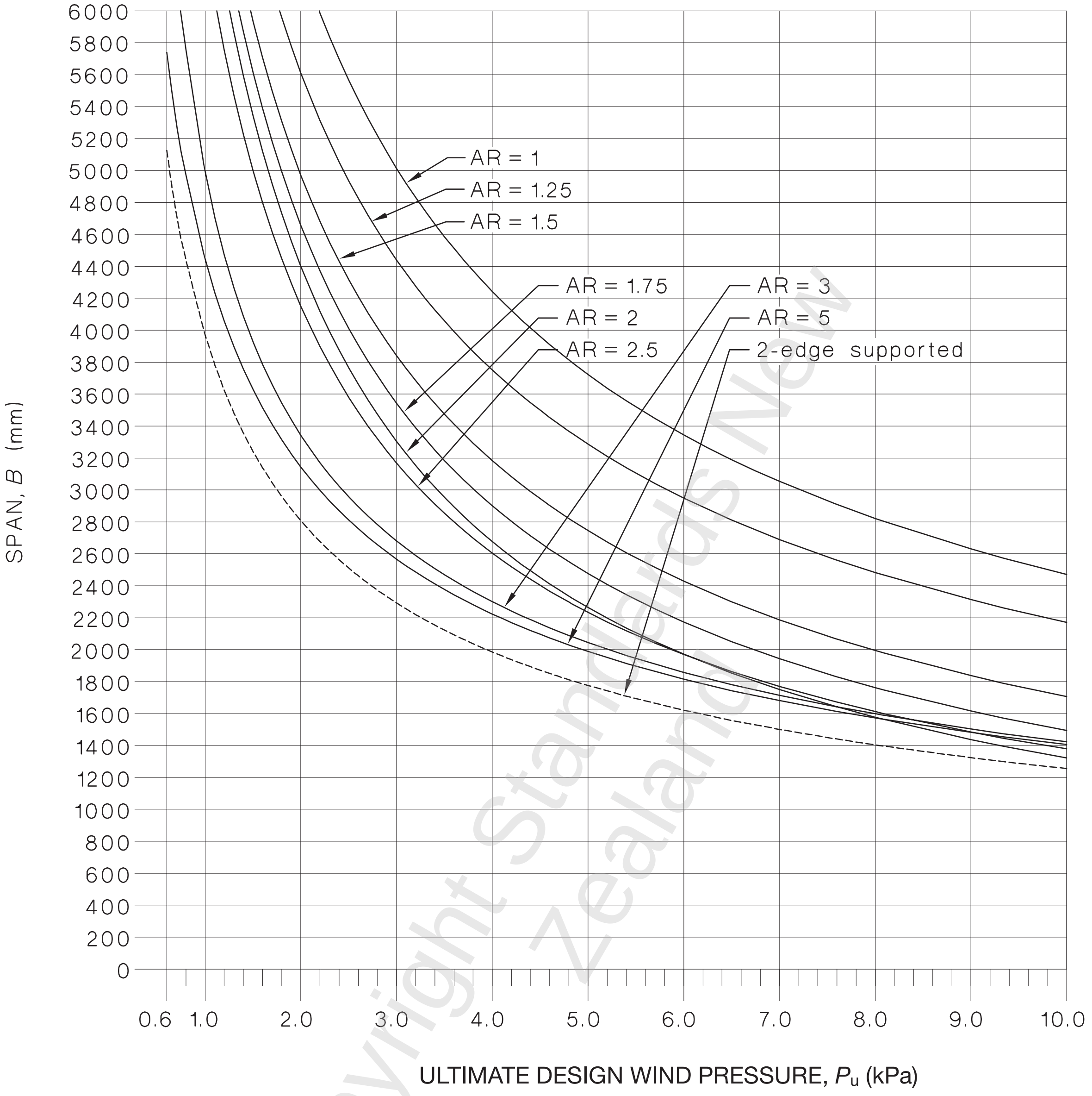


The maximum span B is given by: $B = k_1 \times (p_u + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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	8590.8	7585.1	7160.0	7137.2	7198.3	6259.8	3854.9	3769.7	3366.3
k_2	0.172113	0.13769	0.13769	0.206536	0.275381	0.206536	–0.20654	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	29.1	–9.7	–157.14	–87.3	–77.6	19.4	–58.2	0	0

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

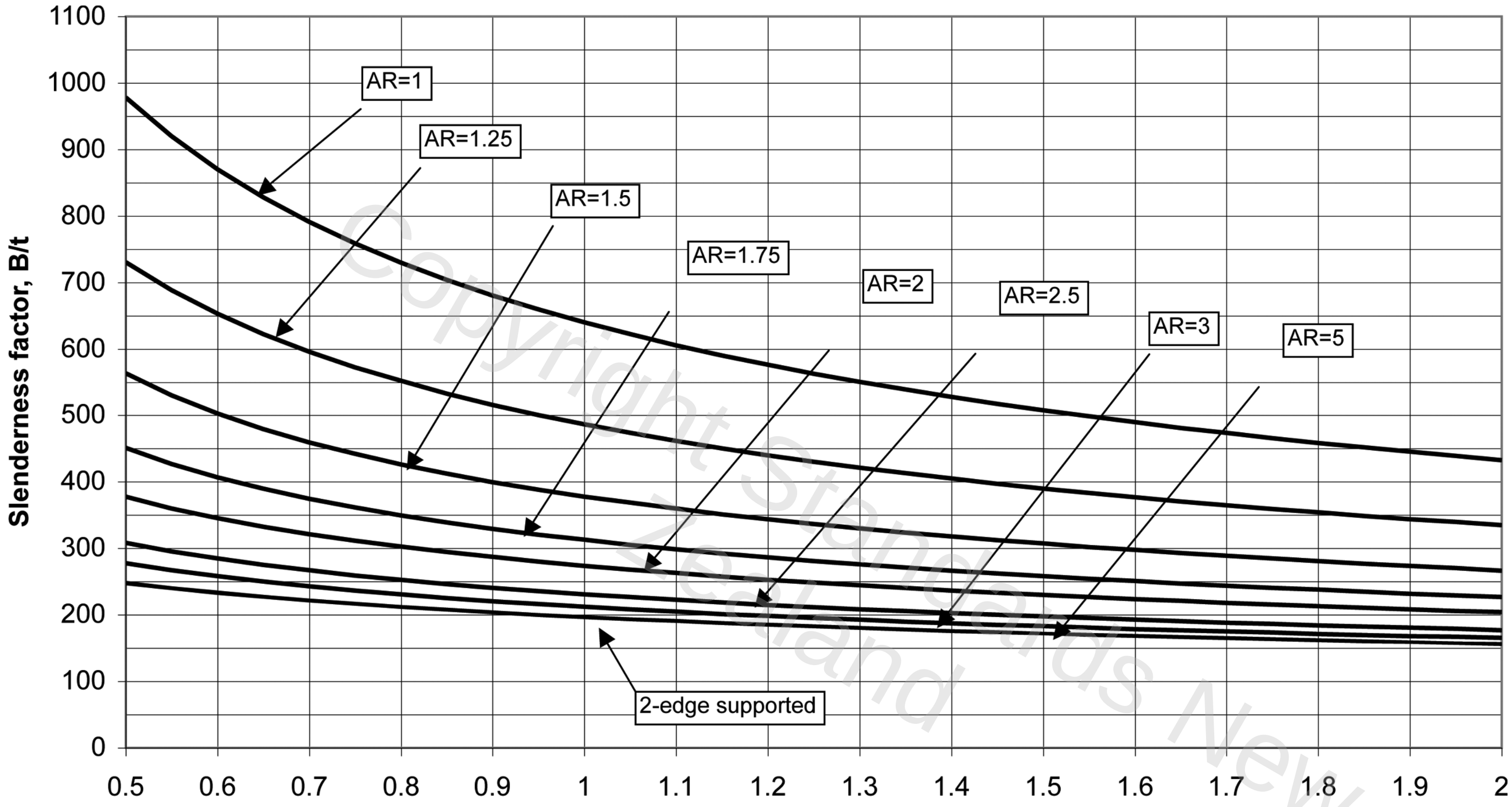
Figure 34 – Maximum span for 24 mm annealed laminated glass



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

Constant	Four-edge supported annealed glass 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	10081.6	8903.5	8391.3	8338.8	8390.1	7308.9	4549.1	4446.2	3970.4
k_2	0.16457	0.131656	0.131656	0.197484	.263312	0.197484	–0.19748	0	0
k_3	–0.6124	–0.6071	–0.6423	–0.7112	–0.7642	–0.7255	–0.4881	–0.5	–0.5
k_4	35.1	–11.7	–189.54	–105.3	–93.6	23.4	–70.2	0	0

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

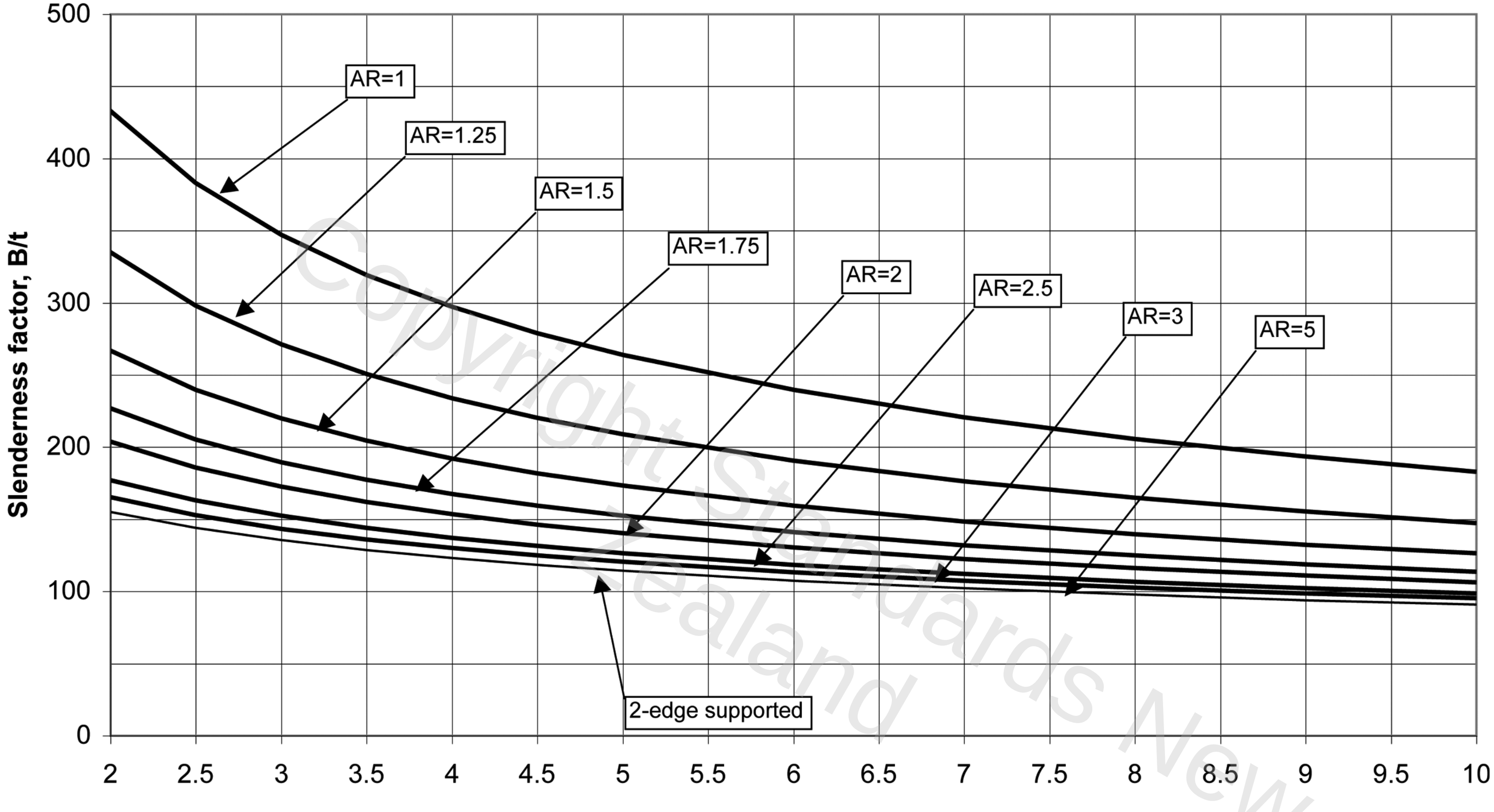


Serviceability Design Wind Pressure, p_s (kPa)

(a) Design wind pressure 0.5 - 2 kPa

NOTE – The curves for the determination of *B/t*, based on a maximum deflection of Span/60, have been provided with two different serviceability design wind pressure scales to assist the user with readability of the figures.

Figure 35 – Curves for *B/t* allowable for deflection of glass limited to span/60



(b) Design wind pressure 0.2 – 10 kPa

NOTE - The curves for the determination of *B/t,* based on a maximum deflection of Span/60, have been provided with two different serviceability design wind pressure scales to assist the user with readability of the figures.

Figure 35 – Curves for *B/t* allowable for deflection of glass limited to span/60 (continued)

The slenderness factor B/t is given by: $B/t = k_1 \times (p_s + k_2)^{k_3} + k_4$

Constant	Four-edge supported annealed glass 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 –

1. Curves for AR = 1 to AR = 5 are to be used for four-edge supported glazing.
2. Curve AR = 5 can be used for two-edge supported glazing or calculate using the formula and corresponding constants.

3 SLOPED GLAZING

3.1 General

This Section applies to glass that is glazed on a slope with an angle up to 75° to the horizontal, and operable roof light windows. It does not apply to glass louvres or vertical openable windows that are inclined at 75° or more to the horizontal in the closed position.

Glazing inclined at angles equal to or greater than 75° to the horizontal shall be designed in accordance with NZS 4223.1 and other relevant sections of this Part, as applicable.

Compliance with the requirements of Clause 3.4 is deemed to meet this Section.

Where the requirements of other sections exceed the requirements of this Section, they shall govern.

NOTE – See Appendix C for the fracture characteristics of various glass types. The selection process should include a risk assessment based on the risk of injury to persons below due to falling glass as well as the risk of injury to persons who might fall through the glazing in the event of breakage.

3.2 Design criteria

All single-sloped overhead glazing shall be laminated safety glass, except where the highest part of the glazing is less than 5 m from the finished floor level (FFL), in which case toughened safety glass may be used.

All insulating glass units (IGUs) in sloped overhead glazing shall have safety glass in the upper and lower panes (see Appendix D).

Where the highest part of the glazing is more than 5 m above the FFL, laminated safety glass shall be used for the lower pane.

NOTE – Laminated safety glass plies can be a combination of annealed, heat strengthened or toughened glass.

The glazing and its component members and connections shall be designed in accordance with NZS 4223.1. Amd 1 Feb '16

3.3 Loads and actions

The selection of sloped overhead glazing in this Part for stability, ultimate strength and serviceability limit states accounts for the action effects directly arising from the following loads:

(a) Imposed wind actions specified in AS/NZS 1170.2;

(b) Dead loads, including glass weight, snow and ice actions specified in AS/NZS 1170.3;

(c) Live load (concentrated point load) of 0.5 kN in accordance with AS/NZS 1170 (surfaces over which boards or ladders are required to be laid) as a uniformly distributed load applied over a circular area of 0.01 m^2 normal to the glass surface.

All other live load applications, such as accessible roofs (e.g. R1 street awnings) are subject to specific design and are outside the scope of this Standard.

NOTE –

1. For IGUs, apply the point load separately to the uppermost pane.
2. If the glazing is required to support a 1.1 kN live load for maintenance or other purposes, then Appendix F can be used for design.

3.4 Selection of sloped overhead glass

3.4.1 General

Glass thickness shall be determined in accordance with 3.4.2 to 3.4.7.

3.4.2 Wind loads

The wind pressures shall be determined from either:

(a) AS/NZS 1170.2, or

(b) Appendix E.

The wind load design pressure shall be used in 3.4.6 to determine the ultimate limit state design pressure for the combined loads.

Amd 1 Feb '16

NOTE – The serviceability limit state design load will be used to check deflection.

3.4.3 Dead loads

The dead load design pressure resulting from the weight of the glass shall be determined from Table 5. For nominal glass thickness other than 6 mm, the dead load figures in Table 5 shall be multiplied by the ratio of the nominal glass thickness divided by 6 to determine the design pressure. For glass angles that fall between the angles in the table, the row with the next lower angle from Table 5 shall be used for the maximum dead load determination.

Amd 1 Feb '16

This design pressure shall be used in 3.4.6 to determine the ultimate limit state design pressure for the combined loads.

Table 5 – Loads perpendicular to the glass due to self (dead) weight and snow

Angle of glass to horizontal (deg.)	**Single glazing** (annealed)		**Single glazing** (heat strengthened and toughened)		**IGUs** (annealed or laminated)		**IGUs** (heat strengthened and toughened)		**Snow loading**		
	Dead (Max.)	**Dead** (Max.)	**Dead** (Max.)	**Dead** (Max.)	**Dead** (Max.)	**Dead** (Max.)	**Dead** (Max.)	**Dead** (Max.)	**1.0 NZS 3604** (Max.)	**1.5 NZS 3604** (Max.)	**2.0 NZS 3604** (Max.)
	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)	(kPa)
0	0.57	0.13	0.35	0.13	1.14	0.26	0.71	0.26	3.23	4.84	6.45
5	0.57	0.13	0.35	0.13	1.13	0.26	0.70	0.26	3.21	4.82	6.43
10	0.56	0.13	0.35	0.13	1.12	0.26	0.70	0.26	3.18	4.77	6.35
15	0.55	0.13	0.34	0.13	1.10	0.26	0.68	0.26	3.12	4.67	6.23
20	0.54	0.12	0.33	0.12	1.07	0.25	0.66	0.25	3.03	4.55	6.06
25	0.52	0.12	0.32	0.12	1.03	0.24	0.64	0.24	2.92	4.39	5.85
30	0.49	0.11	0.31	0.11	0.99	0.23	0.61	0.23	2.79	4.19	5.59
35	0.47	0.11	0.29	0.11	0.93	0.22	0.58	0.22	2.64	3.96	5.28
40	0.44	0.10	0.27	0.10	0.87	0.20	0.54	0.20	2.47	3.71	4.94
45	0.40	0.09	0.25	0.09	0.81	0.19	0.50	0.19	2.28	3.42	4.56
50	0.37	0.09	0.23	0.09	0.73	0.17	0.45	0.17	2.07	3.11	4.15
55	0.33	0.08	0.20	0.08	0.65	0.15	0.41	0.15	1.85	2.78	3.70
60	0.28	0.07	0.18	0.07	0.57	0.13	0.35	0.13	0.00	0.00	0.00
65	0.24	0.06	0.15	0.06	0.48	0.11	0.30	0.11	0.00	0.00	0.00
70	0.19	0.05	0.12	0.05	0.39	0.09	0.24	0.09	0.00	0.00	0.00
75	0.15	0.03	0.09	0.03	0.29	0.07	0.18	0.07	0.00	0.00	0.00

Amd 1 Feb '16

NOTE –

1. Single glazing based on 6 mm glass, IGUs on 6 mm + 6 mm glass.
2. Dead (maximum) = 1.2 x 1/c_3 x dead load of the glass.
3. Dead (minimum) = 0.9 x dead load of the glass.
4. Snow loads on glass = 1.0 x 1/c_3 x the NZS 3604 snow load case adjusted for glass slope.
5. c_3 is required in the calculation of the values in the above table to compensate for the use of these pressures when entering the wind load charts, where c_3 is taken as 1.0.
6. For annealed and laminated glass under long-term duration, c_3 is 0.31.
7. For heat-strengthened and toughened glass under long-term duration, c_3 is 0.5.
8. Snow is not expected to accumulate on roof slopes greater than or equal to 60° to the horizontal (AS/NZS 1170.3). Amd 1 Feb '16
9. Specific design shall be applied in any situation where snow may accumulate due to parapets, other obstructions, multi-pitch roofs, or adjacent buildings.
10. Specific design will also apply where snow can slip from a higher surface on to the glass.

3.4.4 Snow loads

The snow load design pressure appropriate for the building location shall be determined from either:

(a) AS/NZS 1170.3; or

(b) Figure 36 for buildings for the 1.0 kPa, 1.5 kPa and 2.0 kPa snow load in NZS 3604 and Table 6.

For the snow load determination it is permissible to linearly interpolate between the snow load value in Table 5 for the roof slope above and below the actual slope.

Table 6 – Maximum altitudes (m) for the application of 1.0 kPa, 1.5 kPa and 2.0 kPa snow loads on the sloping roof for each snow region

Roof Slope (Degrees)	Region N1			Region N2			Region N3			Region N4			Region N5		
	1.0 kPa	1.5 kPa	2.0 kPa	1.0 kPa	1.5 kPa	2.0 kPa	1.0 kPa	1.5 kPa	2.0 kPa	1.0 kPa	1.5 kPa	2.0 kPa	1.0 kPa	1.5 kPa	2.0 kPa
Up to 10	720	960	1200	570	780	860	530	720	850	210	440	600	420	660	900
20	950	1140	1260	680	840	940	620	830	940	300	540	940	550	820	940
30	1040	1230	1350	820	970	1070	790	940	1070	440	940	1070	740	940	1070
40	1260	1390	1480	940	1120	1270	940	1120	1270	940	1120	1270	940	1120	1270
50	1480	1630	1740	1270	1510	1690	1270	1510	1690	1270	1510	1690	1270	1510	1690
≥ 60	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit

NOTE – Snow loads need not be considered below the following altitudes:

(a) 400 m in Region N1;

(b) 200 m in Region N2;

(c) 150 m in Region N3.

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This snow load design pressure shall be used in 3.4.6 to determine the ultimate limit state design pressure for the combined loads.

Figure 36 – Snow regions

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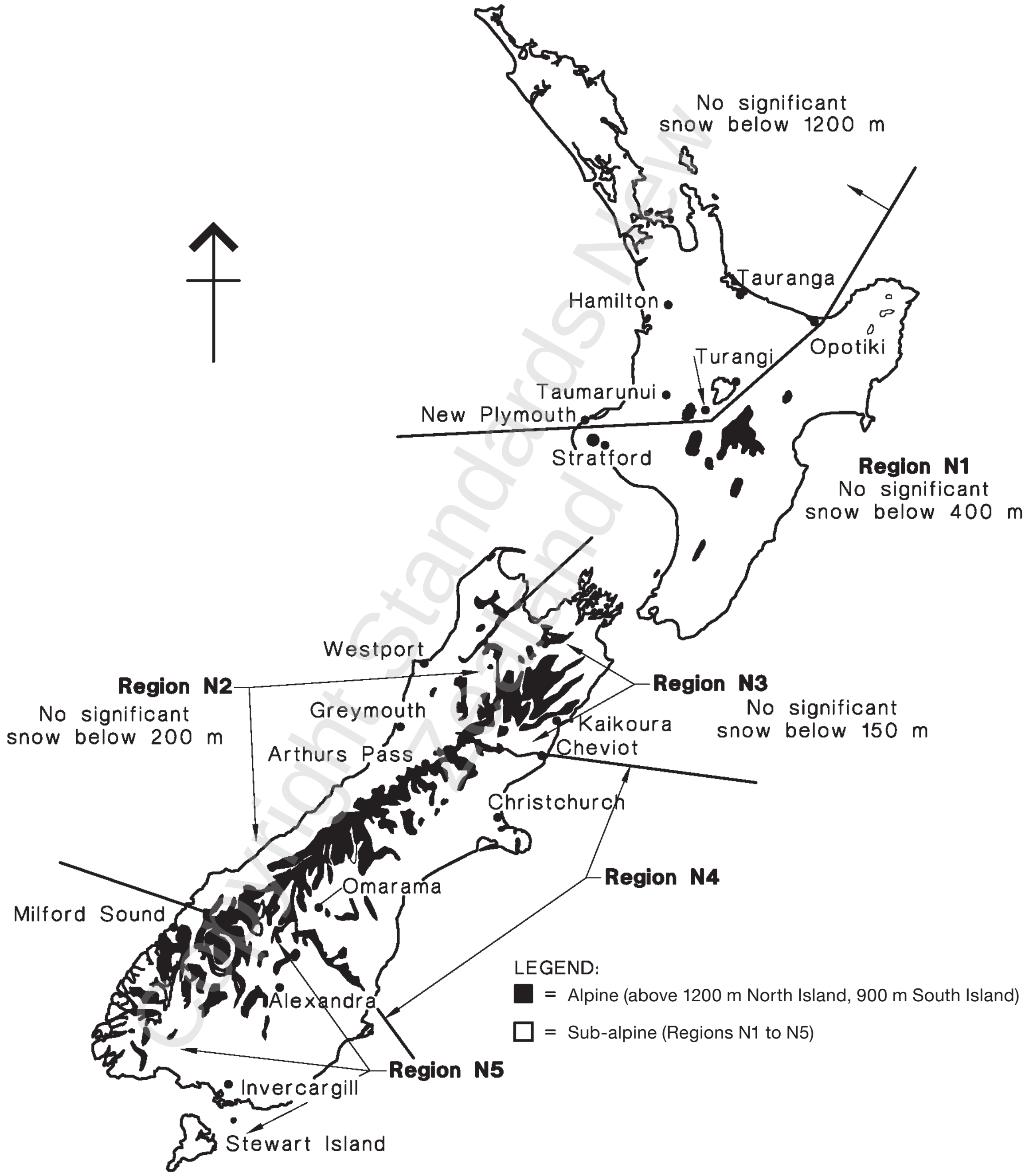

NOTE: This map is approximate only and altitude above mean sea level shall be used to determine snow region. For sub-alpine regions in the South Island (N2, N3, N4 and N5) the regions coincide with the 1988 county boundaries. Where an alpine region exists between sub-alpine regions, the alpine region separates the 2 sub-alpine regions (which extend downwards from 1200 m altitude).

3.4.5 Live loads

Sloped overhead glazing shall be considered as surfaces over which boards or ladders are required to be laid to support live loads incidental to maintenance, and shall be designed to support a concentrated live load of 0.5 kN as determined from AS/NZS 1170.1.

Glazing is deemed to comply with this Section if the glass is selected in accordance with Table 7 to Table 10.

When using these tables, the following criteria apply:

(a) The 0.5 kN concentrated load shall be applied as a uniformly distributed load over a circular area of 0.01 m^2 or more;

(b) Street awnings and roofs used for floor type activities are not covered by this Standard. These are subject to specific design;

(c) Point-fixed glazing systems are not included and require specific design.

NOTE –

If the glazing is required to support a 1.1 kN live load for maintenance or other purposes, then Appendix F can be used for design.

3.4.6 Combined loads (dead, wind, snow)

The combined design loads for sloped glazing shall be calculated as follows:

Case 1 Dead (maximum) + wind (downward)

Case 2 Dead (minimum) + wind (upward)

Case 3 Dead (maximum) + snow.

3.4.7 Glass thickness

Step 1 – The worst load combination effect from 3.4.6 shall be taken as the ultimate limit state design pressure and shall be used in Figure 1 to Figure 34, as appropriate, depending on the glazing type and its support, to determine the minimum glass thickness.

Step 2 – The minimum glass thickness, for the selected glass type, to support the live load shall also be determined from Table 7 to Table 10 .

Step 3 – The greater of the two thicknesses from Step 1 and Step 2 shall be used as the nominal glass thickness.

NOTE –

1. A worked example is given in Appendix B.
2. Table 7 to Table 10 include a serviceability deflection limit of span/60 or 20 mm maximum. If smaller deflections are required, specific design is required.
3. The maximum spans given in Table 7 to Table 10 have been restricted to 2000 mm. If larger spans are required, specific design is required.

Table 7 – Maximum span of annealed laminated glass

Live load (kN)	Nominal thickness[1] (mm)	Maximum span (mm)			
		Four-edge support			Two-edge support
		AR=1	AR=2	AR=3	
0.5 (Flat or pitched)	6	400	250	250	—
	8	1200	850	800	—
	10	1900	1800	1500	250
	12	2000	2000	1800	700
	16	2000	2000	2000	1200
	20	2000	2000	2000	1550
	24	2000	2000	2000	1900

NOTE –

1. For laminated glass, the thickness shown in Table 7 to Table 9 does not include the thickness of the interlayer, e.g. 6 mm may apply to 6.38 mm, 6.76 mm or 7.52 mm.

Table 8 – Maximum span of heat-strengthened laminated glass

Live load (kN)	Nominal thickness[1,2] (mm)	Maximum span (mm)			
		Four-edge support			Two-edge support
		AR=1	AR=2	AR=3	
0.5 (Flat or pitched)	8	2000	1800	1600	800
	10	2000	2000	1800	1400
	12	2000	2000	1950	1950

NOTE –

1. For laminated glass, the thickness shown in Table 7 to Table 9 does not include the thickness of the interlayer, e.g. 6 mm may apply to 6.38 mm, 6.76 mm or 7.52 mm.
2. For laminated heat-strengthened or laminated toughened glass (Table 8 and Table 9), not less than 0.76 mm thickness of interlayer is required to enable successful lamination.

Table 9 – Maximum span of toughened laminated glass

Live load (kN)	Nominal thickness[1,2] (mm)	Maximum span (mm)			
		Four-edge support			Two-edge support
		AR=1	AR=2	AR=3	
0.5 (Flat or pitched)	8	2000	2000	1850	1350
	10	2000	2000	2000	1750
	12	2000	2000	2000	2000

NOTE –

1. For laminated glass, the thickness shown in Table 7 to Table 9 does not include the thickness of the interlayer, e.g. 6 mm may apply to 6.38 mm, 6.76 mm or 7.52 mm.
2. For laminated heat-strengthened or laminated toughened glass (Table 8 and Table 9), not less than 0.76 mm thickness of interlayer is required to enable successful lamination.

Table 10 – Maximum span of monolithic toughened glass

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Live load (kN)	Nominal thickness (mm)	Maximum span (mm)			
		Four-edge support			Two-edge support
		AR=1	AR=2	AR=3	
0.5 (Flat or pitched)	4	1800	1300	1100	250
	5	2000	1450	1300	450
	6	2000	1700	1500	700
	8	2000	2000	1900	1400
	10	2000	2000	2000	1800
	12	2000	2000	2000	2000

APPENDIX A – SIMPLIFIED METHOD FOR DETERMINING ULTIMATE AND SERVICEABILITY LIMIT STATE DESIGN WIND PRESSURES

(Normative)

A1 Wind loading for vertical glazing in buildings of height ≤ 10 m

The design wind pressures for vertical glazing in all buildings with an average roof height of less than or equal to 10 m may be determined from Table 12. The criteria and limitations used in developing the appropriate design wind pressures applicable to Table 12 are provided in Table 11. The Ultimate limit state and serviceability limit state design wind pressures given in Table 12 have been determined for corner locations in buildings and may be conservative if applied to other locations. Lower design wind pressures could be obtained for other locations in the buildings by using the criteria specified in AS/NZS 1170.2.

Table 11 – Building limitations applicable to Table 12

Aspect	Limit
Design wind pressure	Glazing in walls only
Average roof height	≤ 10 m
Floor plan	Rectangular or combination of rectangular units. All walls equally permeable
Internal pressures	All walls equally permeable
Building importance level in accordance with AS/NZS 1170.0	Level 2 – 500-year return period
Building shielding	NS – no shielding
	PS – Partial shielding (minimum 1 building of equal height providing shielding)
Topographic multiplier	See AS/NZS 1170.2 (slope of terrain)
Building geographic location limit	Not in a lee zone (shaded areas in Figure E1)
Wind direction	All directions

Table 12 – Ultimate and serviceability limit state design wind pressures for glazing in walls of buildings with limitations as detailed in Table 11

Region	Terrain category		Ultimate and serviceability design wind pressure (kPa)											
			Topographic slope (M_t)											
			<0.05		0.05		0.10		0.20		0.30		≥ 0.45	
			PS	NS	PS	NS	PS	NS	PS	NS	PS	NS	PS	NS
A6 and A7	TC4	ULS	0.64	0.89	0.75	1.04	0.87	1.20	1.12	1.55	1.41	1.95	1.88	2.60
		SLS	0.43	0.60	0.51	0.70	0.58	0.81	0.76	1.05	0.95	1.32	1.27	1.76
	TC3	ULS	0.79	1.09	0.92	1.27	1.06	1.46	1.37	1.90	1.72	2.38	2.30	3.18
		SLS	0.53	0.74	0.62	0.86	0.72	0.99	0.93	1.28	1.16	1.61	1.55	2.15
	TC2	ULS	1.58	1.58	1.84	1.84	2.13	2.13	2.75	2.75	3.46	3.46	4.62	4.62
		SLS	1.07	1.07	1.25	1.25	1.44	1.44	1.86	1.86	2.34	2.34	3.12	3.12
	TC1	ULS	1.98	1.98	2.31	2.31	2.67	2.67	3.45	3.45	4.34	4.34	5.79	5.79
		SLS	1.34	1.34	1.56	1.56	1.80	1.80	2.33	2.33	2.93	2.93	3.92	3.92
W	TC4	ULS	0.83	1.14	0.96	1.33	1.11	1.54	1.44	1.99	1.81	2.50	2.41	3.34
		SLS	0.59	0.81	0.68	0.95	0.79	1.09	1.02	1.41	1.28	1.78	1.71	2.37
	TC3	ULS	1.01	1.40	1.180	1.63	1.36	1.88	1.76	2.44	2.21	3.06	2.95	4.09
		SLS	0.72	0.99	0.84	1.16	0.97	1.34	1.25	1.73	1.57	2.18	2.10	2.91
	TC2	ULS	2.03	2.03	2.37	2.37	2.73	2.73	3.54	3.54	4.44	4.44	5.93	5.93
		SLS	1.44	1.44	1.68	1.68	1.94	1.94	2.51	2.51	3.16	3.16	4.22	4.22
	TC1	ULS	2.55	2.55	2.97	2.97	3.42	3.42	4.43	4.43	5.57	5.57	7.44	7.44
		SLS	1.81	1.81	2.11	2.11	2.43	2.43	3.15	3.15	3.96	3.96	5.29	5.29

NOTE –

1. The design wind pressures have been calculated using the regional wind speeds of AS/NZS 1170.2 with an average recurrence interval of 500 years for the ULS and 25 years for the SLS.
2. The design wind pressures have been calculated on the basis of generalised assumptions. Detailed calculations based on specific buildings may yield lower pressures.
3. The multipliers and factors used are as follows:
   (i) Direction multiplier M_d – 1.0 (any direction)
   (ii) Terrain/height multiplier $M_{z,cat}$ – Based on an average building height of 10 m.

Terrain category	All wind regions	Description
Terrain category 1	1.12	Very exposed open terrain with few or no obstructions and enclosed, limited-sized water surfaces at serviceability and ultimate wind speeds in all wind regions, for example flat, treeless, poorly grassed plains; rivers, canals and lakes; and enclosed bays extending less than 10 km in the wind direction.
Terrain category 2	1.0	Open terrain, including grassland, with well-scattered obstructions having heights generally from 1.5 m to 5 m, with no more than two obstructions per hectare, for example farmland and cleared subdivisions with isolated trees and uncut grass.
Terrain category 3	0.83	Terrain with numerous closely-spaced obstructions having heights generally from 3 m to 10 m. The minimum density of obstructions shall be at least the equivalent of 10-house size obstructions per hectare, for example suburban housing or light industrial estates.
Terrain category 4	0.75	Terrain with numerous large, high (10 m to 30 m tall) and closely-spaced obstructions, such as large city centres and well-developed industrial complexes.

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(iii) Shielding multiplier M_s

Terrain category	No shielding	Partial shielding
Terrain Category 4	1.0	0.85
Terrain Category 3	1.0	0.85
Terrain Category 2	1.0	1.0
Terrain Category 1	1.0	1.0

(iv) Topographic multiplier M_t for slopes

Slope	M_t
< 0.05 (flat ground)	1.00
0.05	1.08
0.10	1.16
0.10	1.32
0.30	1.48
≥ 0.45	1.71

(v) Net aerodynamic shape factor C_{fig} – 1.3 (near wall corner).

APPENDIX B – CALCULATION EXAMPLES

(Informative)

B1 Example calculations for vertical glazing thickness selection

B1.1 Four-edge support

The building is an importance level 2 structure. It is desired to find the nominal thickness of toughened glass, 2050 mm × 1500 mm, supported along all four edges, required to be used with an ultimate limit state design wind pressure of 3.2 kPa (with a corresponding serviceability design wind pressure of 2.1 kPa).

The steps are as follows:

(1) First select the appropriate graphs to use. In this case Figure 11 to Figure 19 'Curves for allowable span for monolithic toughened glass';

(2) Calculate the Aspect Ratio, AR = 2050/1500 = 1.37;

NOTE – There is no curve for AR = 1.37. We must therefore interpolate between the next highest AR (AR = 1.5) and the next lowest AR (AR = 1.25).

(3) Starting with Figure 11, draw a vertical line at ULS design wind pressure = 3.2 kPa (see Figure B1);

(4) Draw 2 horizontal lines. One at the intersection of AR = 1.5 and ULS = 3.2 kPa, and the other at the intersection of AR = 1.25 and ULS = 3.2 kPa (see Figure B1);

(5) Reading the spans, *B* from the left-hand side of the graph (or by using the formula below the graphs) gives:

For AR = 1.25, *B* = 1428 mm, For AR = 1.5, *B* = 1316 mm;

(6) Interpolating between these 2 values gives Span:

B = 1316 + ((1.5 – 1.37) / (1.50 – 1.25)) × (1428 – 1316) = 1374 mm;

As the required span is 1500 mm, then 4 mm toughened glass cannot be used for this size and design pressure and, therefore, it is necessary to repeat the process on the next chart for thicker glass;

(7) From Figure 12, the horizontal lines drawn at the intersection of the vertical line at 3.2 kPa with the AR = 1.25 and AR = 1.5 curves (see Figure B2) gives (by using the formula below the graphs):

For AR = 1.25, *B* = 1766 mm, For AR = 1.5, *B* = 1625 mm

Interpolating between these two values gives:

Span, B = 1625 + ((1.5 – 1.37) / (1.50 – 1.25)) × (1766 – 1625) = 1698 mm.

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Therefore, as the required span is less than this, the minimum nominal thickness of toughened glass required is 5 mm to satisfy the strength requirements;

(8) Finally, by using Figure 35, check that the deflection limits are not exceeded. Draw a vertical line at the serviceability design wind pressure = 2.1 kPa. Then draw two horizontal lines. One at the intersection of AR = 1.5 and 2.1 kPa, and the other at the intersection of AR = 1.25 and 2.1 kPa. Then, reading the slenderness factors, *B/t* from the left hand side of the graph (or by using the formula below the graphs) gives:

For AR = 1.25, *B/t* = 326.4, For AR = 1.5, *B/t* = 260.5

Interpolating between these two values gives the maximum allowable slenderness factor;

$B/t = 260.5 + ((1.5 - 1.37) / (1.50 - 1.25)) \times (326.4 - 260.5) = 294.8$ mm

For 5 mm glass (4.8 mm minimum thickness) and a span of 1500 mm, the slenderness factor *(B/t)* is 312.5. Therefore, 5 mm toughened glass cannot be used in this case as the deflection would be excessive. The next highest thickness (6 mm) has a minimum thickness of 5.8 mm and thus the slenderness ratio would be 1500/5.8 = 258.6 and therefore the deflection criteria would not be exceeded using 6 mm toughened glass for this panel;

(9) Therefore, the nominal thickness of toughened glass required in order to meet both the deflection and strength criteria for this glass size is 6 mm.

B2 Example calculations for sloping glazing thickness selection

B2.1 Four-edge support

Consider a pane of laminated glass on a 45° slope and 5 m above the ground. The building is an importance level 2 structure. The opening area is 1 m x 1 m and the glass is supported on all four edges. The site of the building is on the flat with a Terrain category 3 in wind region A7. The AS/NZS 1170.3 snow loading is 1.0 kPa.

(1) Select the loads perpendicular to the glass due to the dead weight of the glass from Table 5.

Dead (maximum) = 0.40 kPa

Dead (minimum) = 0.09 kPa

(2) From Table 13, the basic ultimate limit state wind pressure is 0.84 kPa and the serviceability limit state wind pressure is 0.57 kPa.

(3) Using Table 15 at this pressure in Column 1, read off the Wind (↑) and Wind (↓) for the 45° roof slope (interpolation between pressures is acceptable).

ULS Wind (↑) = – 1.18 kPa   SLS Wind (↑) = – 0.80 kPa

ULS Wind (↓) = 1.28 kPa   SLS Wind (↓) = 0.87 kPa

(4) From Table 5, the 1.0 kPa Snow (maximum) loading perpendicular to the glass = 2.28 kPa. Amd 1 Feb '16

(5) The ULS load combinations are:

Case 1	Dead (maximum)	+	Wind (↓)	=	0.40	+	1.28	=	1.68 kPa
Case 2	Dead (minimum)	+	Wind (↑)	=	0.09	+	– 1.18	=	– 1.09 kPa
Case 3	Dead (maximum)	+	Snow (maximum)	=	0.40	+	2.28	=	2.68 kPa (governs)

(6) Using the figures (Figure 27 to Figure 34) for annealed laminated glass at a design wind pressure of 2.68 kPa and an AR = 1. Check that the maximum span of 5 mm annealed laminated glass is acceptable to resist the uniform loads (see Figure 27).

(7) Check the thickness for the concentrated live load. From Table 7, a minimum glass thickness of 8 mm is required to resist the 0.5 kN concentrated load.

(8) Therefore, the required glass thickness is the greater of 5 mm and 8 mm = 8 mm.

(9) Check the serviceability limit state.

(10) The SLS load combinations are:

Case 1	Dead	+	Wind (↓)	=	0.33	+	0.87	=	1.20 kPa (governs)
Case 2	Dead	+	Wind (↑)	=	0.33	+	– 0.80	=	– 0.47 kPa
Case 3	Dead	+	Snow	=	0.33	+	0.71	=	1.04 kPa

(11) Note that Dead (SLS) is Dead (maximum) divided by 1.2, and Snow is Snow (maximum) multiplied by 0.31.

(12) Using Figure 35, determine the slenderness factor, *B/t*, at a pressure of 1.20 kPa and AR = 1.0. This is 575, which means for a glass thickness of 8 mm, B = 4600 mm which is greater than 1000 mm. Therefore, the ultimate limit state loading condition governs.

B2.2 Two-edge support

Consider a pane of laminated glass on a 45° slope and 5 m above the ground. The building is an importance level 2 structure. The opening area is 2000 mm x 1000 mm and the glass is supported on the two long edges only. The site of the building is on the flat with a Terrain Category 3 in wind region A7. The AS/NZS 1170.3 snow loading is 1.0 kPa.

(1) Select the loads perpendicular to the glass due to the dead weight of the glass from Table 5.

Dead (maximum) = 0.40 kP

Dead (minimum) = 0.09 kPa

(2) From Table 13, the basic ultimate limit state wind pressure = 0.84 kPa, and the serviceability limit state wind pressure is 0.57 kPa.

(3) Using Table 15 at this pressure in column 1, read off the Wind (↑) and Wind (↓) for the 45° roof slope (interpolation between pressures is acceptable).

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ULS Wind (↑) = – 1.18 kPa SLS Wind (↑) = – 0.80 kPa

ULS Wind (↓) = 1.28 kPa SLS Wind (↓) = 0.87 kPa

(4) From Table 5, the 1.0 kPa Snow (maximum) loading perpendicular to the glass = 2.28 kPa.

(5) The ULS load combinations are:

Case 1	Dead (maximum)	+	Wind (↓)	=	0.40	+	1.28	=	1.68 kPa
Case 2	Dead (minimum)	+	Wind (↑)	=	0.09	+	–1.18	=	–1.09 kPa
Case 3	Dead (maximum)	+	Snow (maximum)	=	0.40	+	2.28	=	2.68 kPa (governs)

(6) Use the figures for annealed laminated glass (Figure 27 to Figure 34) at a design wind pressure of 2.68 kPa and two-edge support and check the maximum span. From Figure 30, annealed laminated glass of 10 mm thickness is acceptable to resist the uniform loads at 1000 mm span.

(7) Check the thickness for the concentrated live load on laminated annealed glass. From Table 7, a minimum glass thickness of 16 mm is required to resist the 0.5 kN concentrated load for two edge support, at 1000 mm span.

(8) Therefore the required glass thickness is the greater of 10 mm and 16 mm = 16 mm.

(9) Alternatively try another glass type and repeat the process. From Table 8, 10 mm laminated heat strengthened glass may be used.

(10) Check the serviceability limit state.

(11) The SLS load combinations are:

Case 1	Dead	+	Wind (↓)	=	0.33	+	0.87	=	1.20 kPa (governs)
Case 2	Dead	+	Wind (↑)	=	0.33	+	–0.80	=	– 0.47 kPa
Case 3	Dead	+	Snow	=	0.33	+	0.71	=	1.04 kPa

(12) Note that Dead (SLS) is Dead (maximum) divided by 1.2, and Snow is Snow (maximum) multiplied by 0.31.

(13) Using Figure 35, determine the slenderness factor, *B/t*, at a pressure of 1.20 kPa and two edge supported. This is 180, which means for a glass thickness of 16 mm, *B* = 2880 mm which is greater than 1000 mm. Therefore, the ultimate limit state loading condition governs. Amd 1 Feb '16

Figure B1 – Example monolithic 4 mm toughened glass

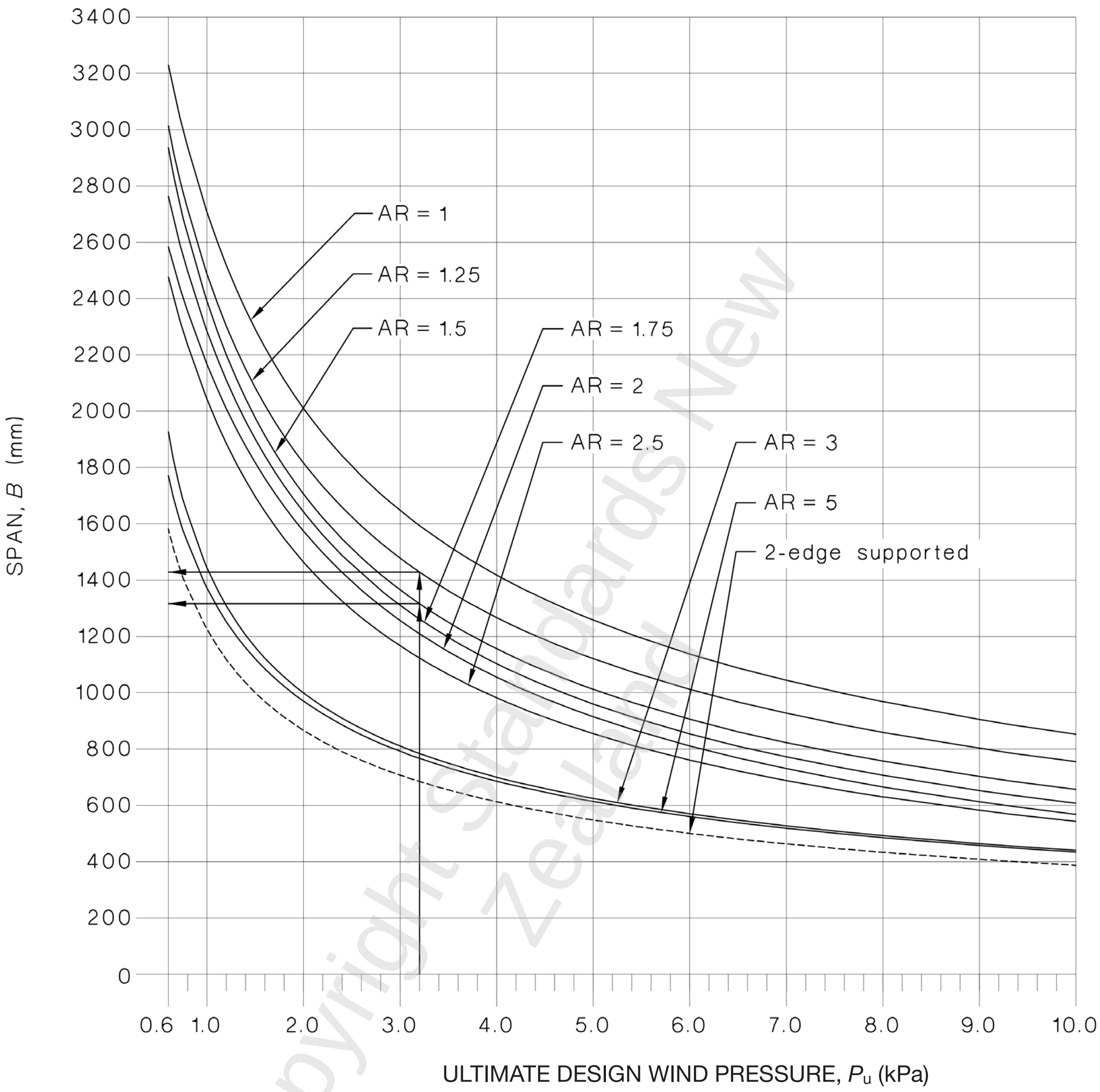

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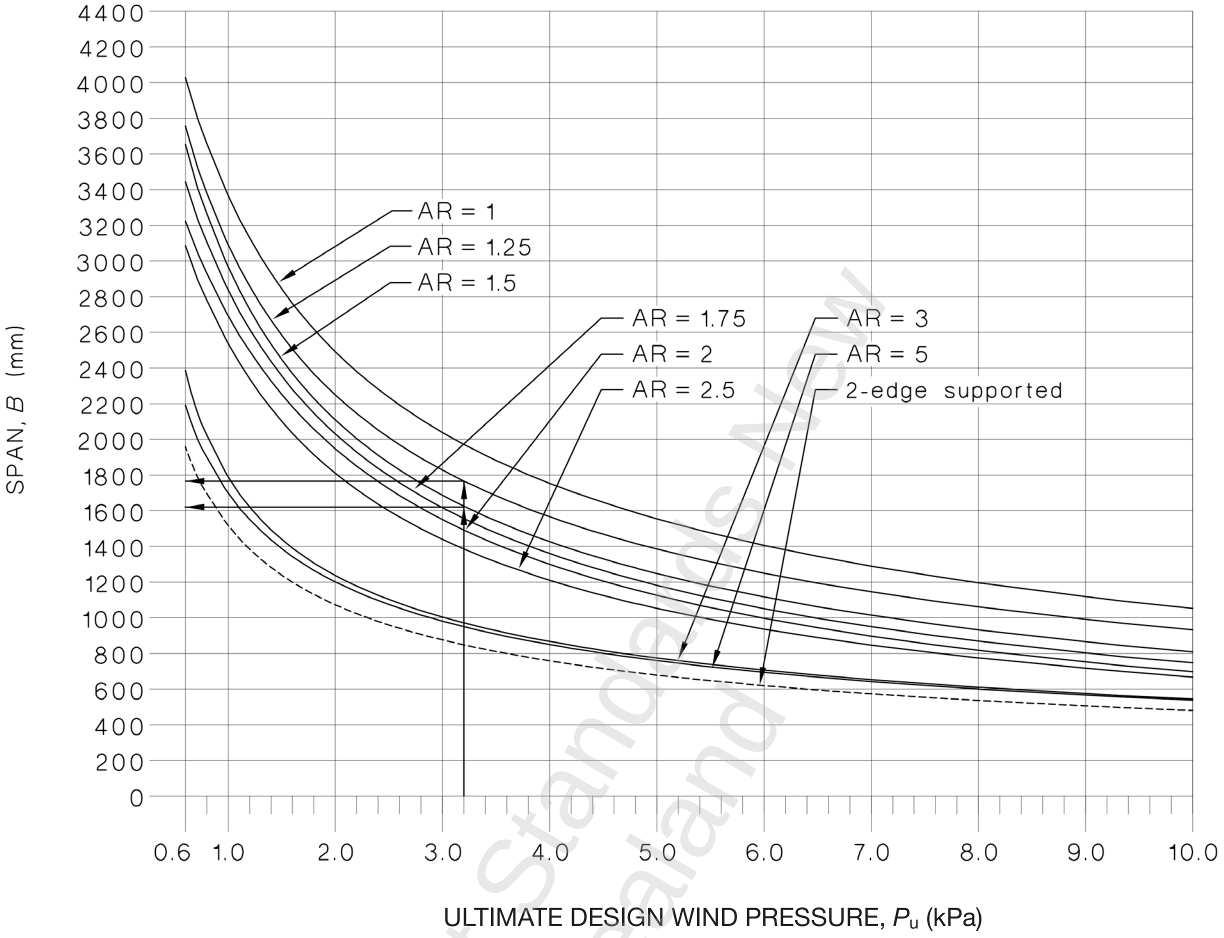
Figure B2 – Example monolithic 5 mm toughened glass



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APPENDIX C – SLOPED OVERHEAD GLAZING FRACTURE CHARACTERISTICS

(Informative)

C1 Safety when accessing sloped overhead glass

Glass in sloped overhead glazing may be susceptible to impact damage from people walking or falling on the glass or from falling objects. If the building has human access space directly beneath the sloped glazing, then the safety of the occupants beneath the glazing should be considered as well as the safety of the workers above the glazing who may make contact with the glazing. For this reason, only safety glazing material is permitted to be used in sloped overhead glazing. However, different types of safety glazing materials have different breakage characteristics, and it is therefore important to choose the most appropriate glass type for the particular conditions applicable to the building in question.

C2 Toughened safety glass

In the event of glass breakage, toughened safety glass fractures into small harmless fragments relative to annealed glass. However, once fractured, this glass will not prevent penetration of the impacting object (or person) and the object (or person) would fall to the floor level below. Access to toughened overhead glass is unsafe unless suitable protection such as roof ladders, walk boards, safety mesh, or fall arrest systems are used.

The breaking behaviour of toughened glass is generally characterized by the formation of small relatively harmless particles. However, under certain conditions, depending on the method of framing and means of breakage, there can be clumping together of small particles or the formation of long splines of glass. If these breakage patterns occur, they may increase the risk of injury. The use of toughened glass is accordingly limited in area and limited to low height applications above less frequently occupied spaces.

C3 Laminated safety glass

In the event of glass breakage, laminated safety glass tends to adhere to the plastic interlayer and not to fly or fall apart. The likelihood of glass falling out in large pieces is limited provided that the glass is fully framed and the impact that causes the breakage is not great.

The post-breakage performance of laminated glass may be improved by increasing the thickness of the plastic interlayer.

C4 Heat-strengthened laminated safety glass

Heat-strengthened laminated safety glass has a similar performance to laminated safety glass as the breakage pattern of heat-strengthened glass is close to that of ordinary annealed glass. Heat-strengthened laminated glass has a strength advantage over ordinary annealed laminated glass and will be less susceptible to accidental and thermal breakage.

C5 Toughened laminated safety glass

Toughened laminated safety glass may not have the same post breakage performance as laminated and heat-strengthened laminated safety glass as it breaks into small particles. In the event of simultaneous breakage of both toughened glass sheets, it is possible for the entire toughened laminated panel to sag and fall out of the frame.

C6 Safety wired glass

In the event of glass breakage, the embedded wire mesh of safety wired glass tends to hold the glass pieces together. The likelihood of glass falling out in large pieces is limited, provided that the glass is fully framed and the impact that causes the breakage is not great. It is possible for the entire safety wired glass panel to sag and fall out of the frame.

C7 Insulating glass units

Insulating glass units have two or more panes to consider when accessing safety and guidance is given in Appendix D.

C8 Special combinations and applications

Complex laminated combinations of annealed, heat-strengthened and toughened glass can be used with a range of interlayers to provide special breakage characteristics, and these can also be combined into IGUs.

In addition, some applications require point fixings, resulting in the fracture characteristics and retention of the glass by the fitting becoming complex and critical.

Therefore these special combinations and applications require specific design. Amd 1 Feb '16

APPENDIX D – SLOPED AND OVERHEAD GLAZING – INSULATING GLASS UNITS

(Informative)

The information in D1 and D2 is taken from Appendix E, clause E8 of AS/NZS 4666.

D1 Definition

Sloped glazing is glazing that is inclined at up to 75 degrees to the horizontal.

D2 Design and glazing

The following should be considered for sloped and overhead glazing:

(a) Use a glazing system especially designed and engineered for sloped glazing;

(b) Use design actions and design data for sloped glazing not for vertical glazing;

(c) Provide adequate edge clearances and edge cover for the units;

(d) Support individual unit load weight with shoes or transoms;

(e) Protect all edge seals from UV and sunlight exposure if they are not silicone secondary sealed;

(f) Use only sealants that are compatible with the IGU seals, gaskets, glass and frame;

(g) Maintenance requirements such as cleaning and foot traffic;

(h) Solar control glasses to control glare and solar heat gain;

(i) Thermal stress breakage causes such as shading flashings and structure backups;

(j) The best airspace and glass type to provide the best insulation (U-value);

(k) Ventilation, condensation and the effects of air conditioning systems;

(l) Ensure rain water and condensation drain from the glazing system;

(m) The weight of the IGU when determining the size of the IGU;

(n) The effects of unit deflection on seal life and aesthetics;

(o) Glass selection (see D3).

D3 Glass selection

D3.1 Sloped glazing

All IGUs in sloped overhead glazing should have safety glass in accordance with section 3. Where the highest part of the glazing is more than 5 m above the finished floor level, laminated safety glass should be used (each ply may be a combination of annealed, heat-strengthened or toughened glass).

Amd 1 Feb '16 Consider the sloped and overhead glass fracture characteristics as detailed in Appendix C.

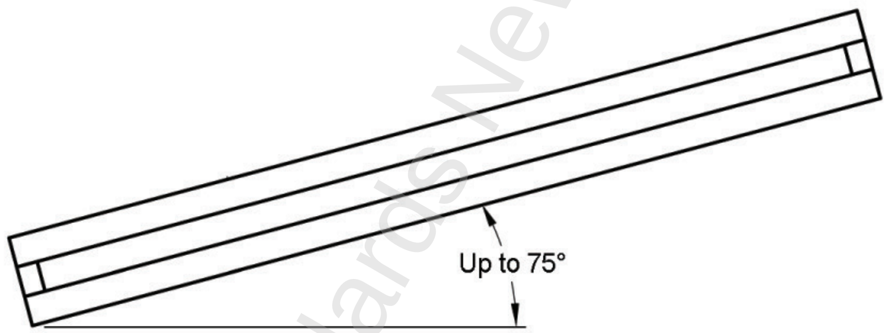
D3.2 Upper glass pane options

The following should be used:

(a) Toughened safety glass (normally used to support live loads);

(b) Laminated safety glass (each ply may be a combination of annealed, heat-strengthened or toughened glass).

Figure D1 – Insulating glass unit sloped glazing combinations



D3.3 Lower glass pane options

The following should be used:

(a) Toughened safety glass (only if the highest part is under 5 m from finished floor level);

(b) Laminated safety glass (each ply may be a combination of annealed, heat-strengthened or toughened glass). Amd 1 Feb '16

APPENDIX E – METHOD FOR THE DETERMINATION OF THE WIND PRESSURE ON SLOPED GLAZING

(Normative)

E1

The procedures of this appendix shall only be used when the following apply:

1. The top of the glazing is less than 10 m above the ground;
2. There are no unusual topographic features surrounding the buildings such as steep cliffs or steep sided valleys which may cause channelling of the wind;
3. The building containing the glazing is not dedicated to the preservation of human life or for which the loss of function would have a severe impact on society;
4. There is no large opening on any wall of the structure whose area is greater than 50 % of the sum of the areas of openings in the remaining walls;
5. The building is not situated in a lee zone shown in Figure E1.

Where one, or more, of the above conditions is not met then the method described in this Appendix can not be used and the ultimate limit state wind pressure shall be determined by specific engineering design from AS/NZS 1170.2.

The basic pressure (either ultimate limit state or serviceability limit state) shall be determined from Table 13 or Table 14 as appropriate with reference to Figure E1 for the wind region.

NOTE – Table 13 and Table 14 are based on AS/NZS 1170.2 using the regional 500-year (ULS) or 25-year (SLS) return period wind speed and a wind direction multiplier of 1.0 (that is, covers all directions), factored by the multipliers applicable to the site and with a C_{fig} of 1.0.

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Table 13 – Basic limit state (ULS or SLS) wind pressure (kPa) for sloped
glazing **or flat land areas**

Wind region	Maximum glazing height above ground (m)	Terrain category							
		1		2		3		4	
		ULS	SLS	ULS	SLS	ULS	SLS	ULS	SLS
A6–7	3	1.19	0.81	1.01	0.68	0.84	0.57	0.68	0.46
	5	1.34	0.91	1.01	0.68	0.84	0.57	0.68	0.46
	10	1.52	1.03	1.22	0.82	0.84	0.57	0.68	0.46
W	3	1.53	1.09	1.29	0.92	1.08	0.76	0.88	0.62
	5	1.72	1.22	1.29	0.92	1.08	0.76	0.88	0.62
	10	1.96	1.39	1.56	1.11	1.08	0.76	0.88	0.62
NOTE – This applies to areas of land where the undulations are less than 25 m in height and ground slopes are less than 1 to 10 (for example, plains).									

The terrain categories are defined as:

Category 1 Very exposed, open terrain with few or no obstructions and enclosed, limited-sized water surfaces at serviceability and ultimate wind speeds in all wind regions; for example flat, treeless, poorly grassed plains; rivers, canals and lakes; and enclosed bays extending less than 10 km in the wind direction.

Category 2 Open terrain, including grassland, with well-scattered obstructions having heights generally from 1.5 m to 5 m, with no more than two obstructions per hectare; for example farmland and cleared subdivisions with isolated trees and uncut grass.

Category 3 Terrain with numerous, closely spaced obstructions having heights generally from 3 m to 10 m. The minimum density of obstructions shall be at least the equivalent of 10-house size obstructions per hectare; for example suburban housing or light industrial estates.

Category 4 Terrain with numerous large, high (10 m to 30 m tall) and closely spaced obstructions, such as large city centres and well-developed industrial complexes. Amd 1 Feb '16

Figure E1 – Wind regions and lee zones

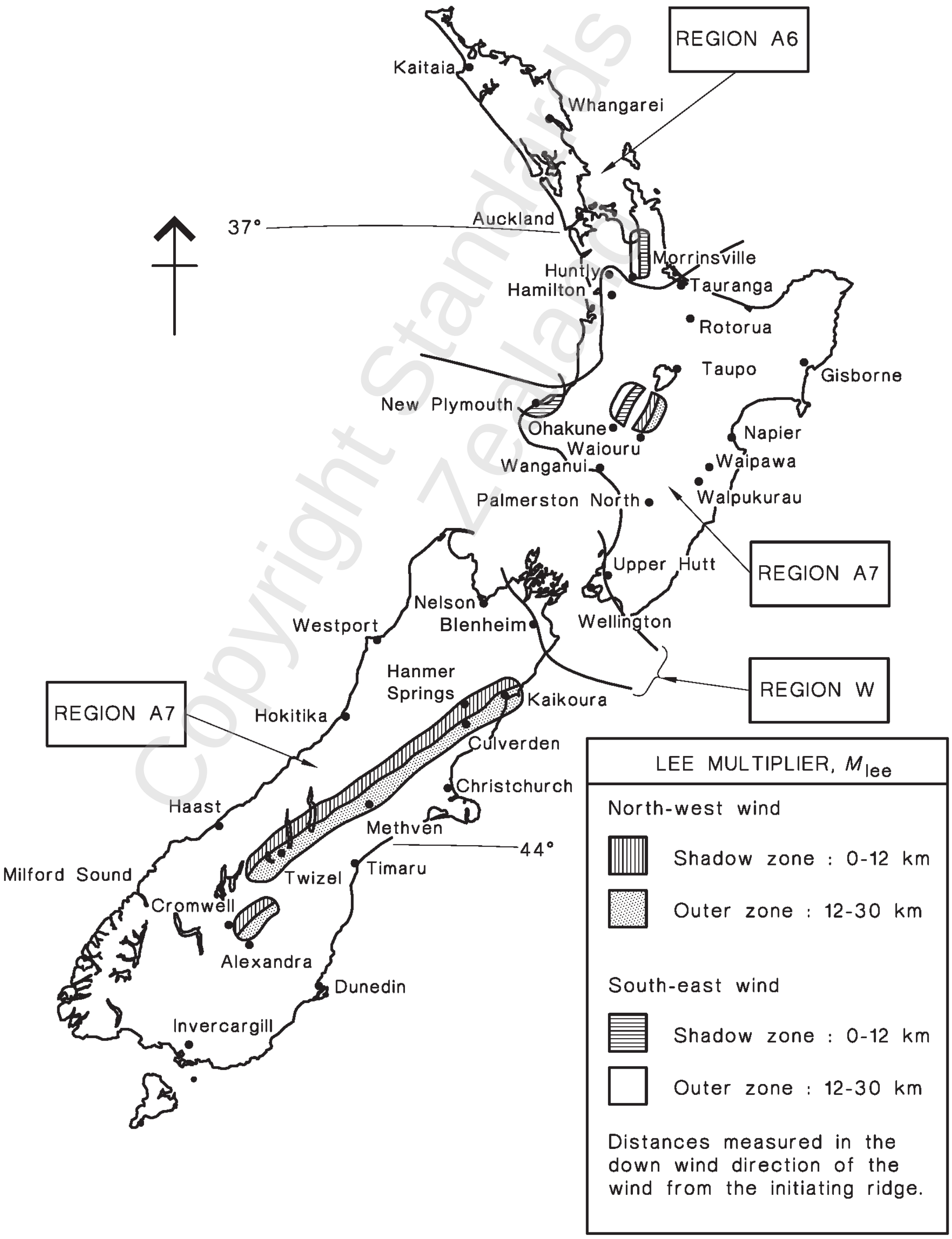

Table 14 – Basic ultimate limit state (ULS or SLS) wind pressure (kPa) for sloped glazing for areas other than flat land areas

Wind region	Maximum glazing height above ground (m)	Terrain category							
		1		2		3		4	
		ULS	SLS	ULS	SLS	ULS	SLS	ULS	SLS
A6–7	3	3.48	2.35	2.94	1.99	2.45	1.65	2.00	1.35
	5	3.92	2.65	2.94	1.99	2.45	1.65	2.00	1.35
	10	4.46	3.01	3.55	2.40	2.45	1.65	2.00	1.35
W	3	4.47	3.18	3.78	2.69	3.14	2.23	2.57	1.82
	5	5.03	3.58	3.78	2.69	3.14	2.23	2.57	1.82
	10	5.72	4.07	4.56	3.24	3.14	2.23	2.57	1.82

The terrain categories are defined as:

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Category 1 Very exposed, open terrain with few or no obstructions and enclosed, limited-sized water surfaces at serviceability and ultimate wind speeds in all wind regions; for example flat, treeless, poorly grassed plains; rivers, canals and lakes; and enclosed bays extending less than 10 km in the wind direction.

Category 2 Open terrain, including grassland, with well-scattered obstructions having heights generally from 1.5 m to 5 m, with no more than two obstructions per hectare; for example farmland and cleared subdivisions with isolated trees and uncut grass.

Category 3 Terrain with numerous, closely spaced obstructions having heights generally from 3 m to 10 m. The minimum density of obstructions shall be at least the equivalent of 10-house size obstructions per hectare; for example suburban housing or light industrial estates.

Category 4 Terrain with numerous large, high (10 m to 30 m tall) and closely spaced obstructions, such as large city centres and well-developed industrial complexes.

NOTE – Table 14 covers all other situations than those included in Table 13 and it may be more efficient to conduct a specific engineering design in accordance with AS/NZS 1170.2, the latter being outside the scope of this Part.

E2

The number determined from Table 13 or Table 14 for the appropriate limit state (ULS or SLS) shall then be used in Table 15, to determine the design wind pressure for both the downward and uplift cases depending on the roof angle.

The following procedure, which applies to all glass types, shall be followed:

(1) Select Table 13 or Table 14 depending on whether or not the site is flat (see 3.4).

(2) From the table, read off the basic wind pressure (either ULS or SLS as appropriate) depending on the wind region the building is located in, the terrain category and the height of the glazing under consideration.

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(3) Enter Table 15 with the basic wind pressure determined in the previous step.

(4) For the appropriate roof slope and the next higher pressure increment in the first column in Table 15, read off the wind (↑) and the wind (↓) pressures. Linear interpolation is acceptable for more accurate determination of design wind pressures.

For canopies and awnings of all slopes, attached to the sides of buildings, select the wind pressure (either ULS or SLS as appropriate) from the 51° – 75° glazing angle column of Table 15.

(5) The determined values for the ULS pressures shall be input to the equations in 3.4.6 to determine the pressures associated with each ULS load combination.

NOTE – For serviceability checks the dead load will not be critical and in cases where snow load is included the glass curvature will be constant over time. In these circumstances, conduct the serviceability check for wind load by entering Figure 35 or Figure 36 with the value obtained from Table 15. Amd 1 Feb '16

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Table 15 – Limit state (either ULS or SLS) design wind pressures for sloped glazing in buildings (kPa)

Basic pressure from Table 13 or Table 14	Pitched or monoslope roof at angle (measured from the horizontal)							
	0° to 10°		11° to 30°		31° to 50°		51° to 75°	
	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)
0.50	0	-0.90	0.55	-0.70	0.76	-0.70	0.92	-0.70
0.75	0	-1.35	0.83	-1.05	1.14	-1.05	1.38	-1.05
1.00	0	-1.80	1.10	-1.40	1.53	-1.40	1.85	-1.40
1.25	0	-2.25	1.38	-1.75	1.91	-1.75	2.31	-1.75
1.50	0	-2.70	1.65	-2.10	2.29	-2.10	2.77	-2.10
1.75	0	-3.15	1.93	-2.45	2.67	-2.45	3.23	-2.45
2.00	0	-3.60	2.20	-2.80	3.05	-2.80	3.69	-2.80
2.25	0	-4.05	2.48	-3.15	3.43	-3.15	4.15	-3.15
2.50	0	-4.50	2.75	–3.50	3.81	-3.50	4.61	-3.50
2.75	0	-4.95	3.03	–3.85	4.20	-3.85	5.08	-3.85
3.00	0	-5.40	3.30	-4.20	4.58	-4.20	5.54	-4.20
3.25	0	-5.85	3.58	–4.55	4.96	-4.55	6.00	-4.55
3.50	0	-6.30	3.85	-4.90	5.34	-4.90	6.46	-4.90
3.75	0	-6.75	4.13	-5.25	5.72	-5.25	6.92	-5.25
4.00	0	-7.20	4.40	-5.60	6.10	-5.60	7.38	-5.60
4.25	0	-7.65	4.68	-5.95	6.48	-5.95	7.84	-5.95
4.50	0	-8.10	4.95	-6.30	6.87	-6.30	8.30	-6.30
4.75	0	-8.55	5.23	-6.65	7.25	-6.65	8.77	-6.65
5.00	0	-9.00	5.50	-7.00	7.63	-7.00	9.23	-7.00
5.25	0	-9.45	5.78	-7.35	8.01	-7.35	9.69	-7.35
5.50	0	-9.90	6.05	-7.70	8.39	-7.70	10.15	-7.70
5.75	0	-10.35	6.33	-8.05	8.77	-8.05	10.61	-8.05
6.00	0	-10.80	6.60	-8.40	9.15	-8.40	11.07	-8.40
C_{fig}	0	-1.8	1.1	-1.4	1.5	-1.4	1.8	-1.4

NOTE –

1. Dead and snow loads are not included.
2. For all canopies and awnings, use the 51° – 75° columns of the table.

APPENDIX F – MAXIMUM SPANS FOR 1.1 KN LIVE LOADS

(Informative)

F1

Guidance for selecting the appropriate glazing thicknesses required to support a 1.1 kN live load is given in Table 16 to Table 19.

F2

The following should be considered when using Table 16 to Table 19:

(a) The minimum glass thickness to support the 1.1 kN live load, for the selected glass type, should be determined from Table 16 to Table 19. In the tables the 1.1 kN concentrated load has been assumed to be applied as a uniformly distributed load over a circular area of 0.01 m^2 or more;

(b) Glazing must also be checked for the worst distributed load combination from 3.4.6; and

(c) The greatest thickness selected from Table 16 to Table 19, and from 3.4.6 must be used as the nominal glass thickness.

Table 16 – Maximum span of laminated annealed glass

Live load	**Nominal thickness**	**Maximum span** (mm)			
		Four-edge support			**Two-edge support**
(kN)	(mm)	**AR=1**	**AR=2**	**AR=3**	
1.1	6	–	–	–	–
	8	250	–	–	–
	10	550	350	330	–
	12	1200	825	750	–
	16	2000	1600	1500	450
	20	2000	2000	2000	850
	24	2000	2000	2000	1200

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Table 17 – Maximum span of laminated heat-strengthened glass

Live load	Nominal thickness	Maximum span (mm)			
		Four-edge support			Two-edge support
(kN)	(mm)	AR=1	AR=2	AR=3	
1.1	6	–	–	–	–
	8	1450	950	900	–
	10	2000	2000	2000	250
	12	2000	2000	2000	800
	16	2000	2000	2000	1600
	20	2000	2000	2000	2000
	24	2000	2000	2000	2000

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Table 18 – Maximum span of laminated toughened glass

Live load	Nominal thickness	Maximum span (mm)			
		Four-edge support			Two-edge support
(kN)	(mm)	AR=1	AR=2	AR=3	
1.1	6	–	–	–	–
	8	2000	2000	2000	250
	10	2000	2000	2000	850
	12	2000	2000	2000	1900

Table 19 – Maximum span of toughened glass

Live load	Nominal thickness	Maximum span (mm)			
		Four-edge support			Two-edge support
(kN)	(mm)	AR=1	AR=2	AR=3	
1.1	6	1300	850	800	–
	8	2000	2000	2000	400
	10	2000	2000	2000	1000
	12	2000	2000	2000	1950

NOTES

NOTES

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