STANDARDS
NEW ZEALAND
Paerewa Aotearoa

New Zealand Standard

Glazing in Buildings
Part 4 – Dead, Wind and Snow Loadings

Superseding NZS 4223:Part 1 (in part)

NZS 4223:Part 4:2000

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COMMITTEE REPRESENTATION

Part 4 of NZS 4223 was prepared by the Glazing in Buildings Committee (P 4223) for the Standards Council established under the Standards Act 1988.

The committee consisted of representatives of the following organizations:

Accident Rehabilitation and Compensation Insurance Corporation
Building Industry Authority
Building Research Association of New Zealand (Inc)
Glass Association of New Zealand
Insulated Glass Unit Manufacturers' Association
New Zealand Manufacturers Federation (Inc)
New Zealand Institute of Architects
New Zealand Safety Glass Association (Inc)
Registered Master Builders Federation of New Zealand (Inc)
Window Association of New Zealand (Inc)

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AMENDMENTS

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RELATED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

NZS 3604:1999	Timber framed buildings
NZS 4203:1992	General structural design and design loadings for buildings
NZS 4223:-	Glazing in buildings
Part 1:1985	The selection and installation of glass in buildings
Part 3:1999	Human impact safety requirements

JOINT AUSTRALIAN/NEW ZEALAND STANDARD

AS/NZS 2208:1996	Safety glazing materials in buildings
AS/NZS 4666:2000	Insulating glass units
AS/NZS 4667:2000	Quality requirements for cut-to-size and processed glass

AUSTRALIAN STANDARD

AS 1288:1994	Glass in buildings – Selection and installation

OTHER PUBLICATIONS

New Zealand Building Code Approved Document B1 Structure

LATEST REVISIONS

The users of this Standard should ensure that their copies of the abovementioned New Zealand Standards and referenced overseas Standards are the latest revisions or include the latest amendments. Such amendments are listed in the annual New Zealand Standards *Catalogue* which is supplemented by lists contained in the monthly magazine *Standards* issued free of charge to committee and subscribing members of Standards New Zealand.

FOREWORD

NZS 4223:Part 4:2000, supersedes the sections of Part 1 of NZS 4223:1985 *Code of practice for glazing in buildings*, concerning the selection of glazing for dead, wind and snow loading.

Preparation of this revision was undertaken by a Standards New Zealand committee representative of manufacturers, Government departments, research organizations and users.

Since the 1985 version of NZS 4223 was published, the New Zealand Loadings Standard, NZS 4203, has been revised in a limit state format. This was the first step to converting New Zealand's structural standards into limit state format. The 1985 version of NZS 4223 was written around the working stress design provisions of the earlier version of NZS 4203 which have since been superseded by the introduction of the limit state version. Hence it was no longer possible to derive the appropriate loads for input into NZS 4223.

The revision of this Part uses a soft conversion of the original working stress loads into limit state loads so that the two standards remain compatible. The expectation is that in future years a joint Australian/ New Zealand Standard will be produced which will derive from first principles the resistance to the limit state loadings.

REVIEW OF STANDARDS

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Chief Executive, Standards New Zealand, Private Bag 2439, Wellington 6020.

NEW ZEALAND STANDARD

GLAZING IN BUILDINGS

PART 4
DEAD, WIND AND SNOW LOADING

401 SCOPE AND GENERAL

401.1 Scope
NZS 4223:Part 4 provides information on the determination of minimum glass thicknesses for vertical and sloped glazing in New Zealand as governed by the limit state loadings.

401.2 Application
NZS 4223:Part 4 is intended to be used by designers and specifiers of glazing. It replaces the design requirements as given in NZS 4223:Part 1, *The selection and installation of glass in buildings*, clauses 103.9, 103.10 and 103.11 including amendments.

This Part aligns NZS 4223:1985 with the load requirements of NZS 4203.

401.3 Use of NZS 4223:Part 4 as a means of compliance with the New Zealand Building Code (NZBC)
It is intended that Part 4 of NZS 4223 will be called up in the Approved Documents as an Acceptable Solution for meeting Paragraphs B1.3.1, B1.3.2 and B1.3.4 for loads from Paragraph B1.3.3(a), (g) and (h) i.e. for loads arising from gravity, snow and wind.

401.4 Interpretation

401.4.1
The word "shall" identifies a mandatory requirement for compliance with NZS 4223. The word "should" refers to practices which are advised or recommended.

401.4.2
Where this Part has non-specific requirements such as the words "suitable", "adequate", "acceptable" or other similar qualifiers like "as far as is reasonably practicable" then the method described is outside the scope of this Part as an Acceptable Solution to the NZBC and shall be to the satisfaction of the Territorial Authority.

Also in this Part, where reference is made to "the manufacturer's recommendations or instructions or similar", these are outside the scope of this Part as an Acceptable Solution to the NZBC, and shall be to the satisfaction of the Territorial Authority.

Where this Part requires specific engineering design (SED) then this is outside the scope of this Part as an Acceptable Solution to the NZBC and shall be to the satisfaction of the Territorial Authority.

Only use the values set out in clauses and tables and do not extrapolate the values.

401.4.3
Notes are intended as comments on the corresponding mandatory clauses. They are not to be taken as the only or complete interpretation of the corresponding clause, nor should they be used

for determining in any way the mandatory requirements of compliance within this Part. This Part can be complied with if the note is ignored.

401.4.4
Where any clause in this Part contains a list of requirements, provisos, conditions, or the like, then each and every item in that list is to be adopted in order to comply with this Part unless the clause specifically states otherwise.

401.4.5
The full titles of reference documents, cited in this Part are given in the list of related documents immediately preceding the Foreword.

401.4.6
The terms "Normative" and "Informative" have been used in this Part to define the application of the Appendix to which they apply. A "Normative" Appendix is integral with this Part whereas an "Informative" Appendix is only for information and guidance. Informative provisions do not form part of the mandatory requirements of this Part nor do they form part of the Standard as an Acceptable Solution to the NZBC.

401.4.7
Unless inconsistent with the context, and subject to 401.6, terms defined in the New Zealand Building Code shall have the same meaning in this Part.

401.5 Glazing materials
Glass thicknesses determined from this Part apply only to glass conforming to the following Standards:

(a) AS/NZS 4666 for insulating glass units;

(b) AS/NZS 2208 and NZS 4223:Part 3 for toughened, laminated and wired safety glasses;

(c) AS/NZS 2208 for heat strengthened glass;

(d) AS/NZS 4667 for annealed and patterned glass.

401.5.1
Glazing shall be installed in accordance with NZS 4223:Part 1.

NOTE – Sand blasted glass is not included in this Part, however some information on its design is given in 4.C4 of Appendix 4.C.

401.6 Definitions
For the purposes of this Part the following definitions shall apply:

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.

ASPECT RATIO. The ratio of the length of the longer span (a) of a pane to the length of its shorter span (b).

DOUBLE GLAZING. Glazing that incorporates two panels individually glazed, separated with an air space for the purpose of sound insulation or thermal insulation, or both.

FOUR EDGE SUPPORT. Glass that is continuously supported on all four edges against loading in each direction.

GLASS AREA. (a) x (b) where (a) and (b) are respectively the longer and shorter span of the pane.

HEAT STRENGTHENED GLASS. Glass which has been strengthened by a special heat treatment, so that the residue stresses lie between those for ordinary annealed glass and toughened glass (see Table 4.C1 Note (5)).

INSULATING GLASS UNIT (IGU). Two or more panels of glass spaced apart and hermetically sealed in a factory, for the purpose of sound insulation or thermal insulation or both.

LIMIT STATE

SERVICEABILITY LIMIT STATE (SLS). This condition is reached when the building becomes unfit for its intended use through deformation, vibratory response, degradation or other physical aspects.

ULTIMATE LIMIT STATE (ULS). This condition is reached when the building ruptures, becomes unstable or loses equilibrium.

LAMINATED GLASS. A composite material consisting of two or more sheets of glass permanently bonded together by a plastic interlayer material.

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.

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.

PATTERNED GLASS.

BODY TINTED PATTERNED GLASS. Body tinted patterned glass is similar to clear patterned glass but with the whole of the glass tinted during manufacture. The tints are incorporated either to give solar control properties or for a decorative purpose.

CLEAR PATTERNED GLASS. This is translucent glass manufactured by the rolling process. Usually the deeper the pattern, the greater the obscuration and diffusion.

SAND BLASTED. A process whereby the surface of glass is obscured by means of a jet of sand or other abrasive propelled against it. The finish will be fine, medium or coarse, according to the pressure of the jet and the nature of the abrasive used.

SLOPED GLAZING. Glazing tilted 15º or more from the vertical.

SPAN. The clear distance between supports. For panels supported on all four edges, it corresponds to the smaller of the clear height or width of the opening.

TEMPERED GLASS. See TOUGHENED GLASS.

TOUGHENED GLASS. Glass that has been strengthened and given modified fracture characteristics by heat treatment so that the residue stresses are relatively high (greater than those for heat strengthened glass (see Table 4.C1 Note (5)).

TWO EDGE SUPPORT. Glass that is continuously supported on two opposite edges against loading in each direction.

WIRED GLASS. Wired glass has steel wire mesh completely embedded in it. Only one type of wire mesh is used and this is welded at all intersections, i.e. Georgian (12.5 mm square).

402 SELECTION OF VERTICAL GLASS TO WITHSTAND UNIFORM WIND LOADING

402.1 Scope

This section provides procedures for the selection of the minimum thickness of glass once a wind zone or wind pressure has been determined from NZS 3604 or Appendix 4.A.

The ultimate limit state design wind pressure on the glazing can also be determined from NZS 4203 and then used with the Charts in this Part. Such determination however involves specific engineering design and is outside the scope of this Part.

402.2 General

The following procedures are for vertical windows, and for two alternate support conditions:

(a) Four edge support; or

(b) Two edge support.

402.3 Determination of required thickness of glass

The following steps are required to determine the minimum glass thickness:

(a) Calculate the glass area, aspect ratio, or span between supports;

(b) Determine the wind zone from section 5 of NZS 3604 or the ultimate limit state wind pressure from the method described in 402.3.1. The wind zones of NZS 3604 relate to ultimate limit state design wind pressures as noted at the top of the Charts 1 to 12.

(c) Using the procedures described in 402.3.2 determine the required thickness.

402.3.1 *Wind pressure*

Wind pressure may be determined from the method described in Appendix 4.A. This method shall only be used when all the conditions of 4.A1 are satisfied. Table 4.A1 shall be used when the building concerned is situated on a flat area of land and table 4.A2 used in all other situations. For the purposes of this clause a flat area of land shall be taken as an area of land where the undulations are less than 25 m in height and the grounded slope is less than 1 in 10 (e.g. the floor of the Hutt Valley or the flat area of Christchurch).

402.3.2 *Determination of thickness of glass from Charts 1 to 12 as appropriate*

(a) *Four edge support*

Select the glass type to be used and using the appropriate Chart read along the vertical line corresponding to the wind zone obtained in 402.3(b) or wind pressure determined from 402.3.1, until the point where the vertical line for the wind zone or wind pressure intersects the horizontal line for the glass area. Read off the required glass thickness. If the point of intersection is between the lines, the next thicker glass is required.

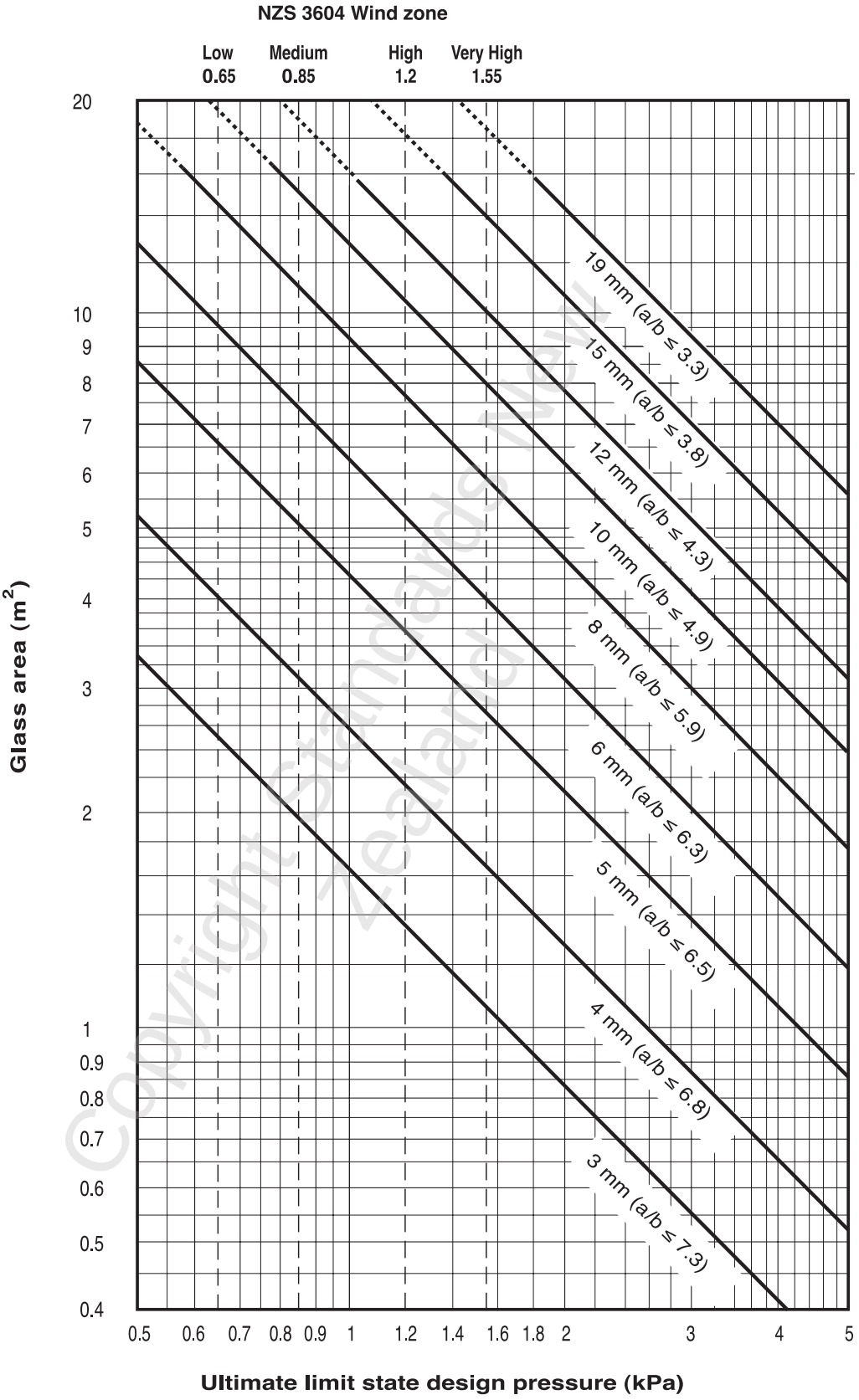
When the aspect ratio for glass four edge support exceeds that given in Charts 1 to 12 for the appropriate glass thickness, determine the width (minimum dimension) of the glass and use this value as the span and consider the glass as supported on two opposite edges.

(b) *Two edge support*

Select the glass type to be used and using the appropriate Chart, read along the vertical line corresponding to the wind zone obtained in 402.3(b) or wind pressure determined from 402.3.1 until the point where the vertical line for the wind zone or wind pressure intersects the horizontal line for the glass span. Read off the required glass thickness. If the point of intersection is between the lines, the next thicker glass is required.

NOTE –

(1) Compliance of a glass design with Charts 1 to 12 does not imply suitability for use. Human impact loading as determined from Part 3 of this Standard shall also be checked and the glass designed for the worst case.
(2) In the derivation of the charts for all glass except toughened glass a serviceability deflection of span/90 will not be exceeded if glass is selected from these charts. For toughened glass the serviceability deflection of span/60 is used and in some sizes this serviceability limit governs over strength.
(3) Some glass (particularly toughened glass) may be specifically designed for structural strength and exceed these deflection limits. However, glass of high strength may be so flexible it is unsatisfactory from an appearance point of view (toughening does not increase stiffness) and deflection limits should be considered as part of the overall design. Such designs are outside the scope of this Part.
(4) The designer should check the availability of glass before proceeding with the design, particularly for the larger areas or spans. Normal sizes are shown as solid lines for assistance.
(5) The Charts have been prepared with the minimum tolerances of the glass thickness specified in AS 1288 section 3.
(6) Appendix 4.C provides design guidance for non-standard thickness glass provided the minimum tolerances given in AS 1288 section 3 are complied with.
(7) Charts 9 and 10 are for insulating glass units. If the cavity between the panes is not hermetically sealed, or if either of the 2 windows can be opened then a window shall be designed on the basis that each glass is required to carry the full wind loading.



NOTE –
(1) For aspect ratios (a/b) greater than those shown use the two edge support charts.
(2) Dotted lines indicate sizes outside normal manufacturing recommendations.

Chart 1	Minimum glass thickness – Annealed glass – Four edge support

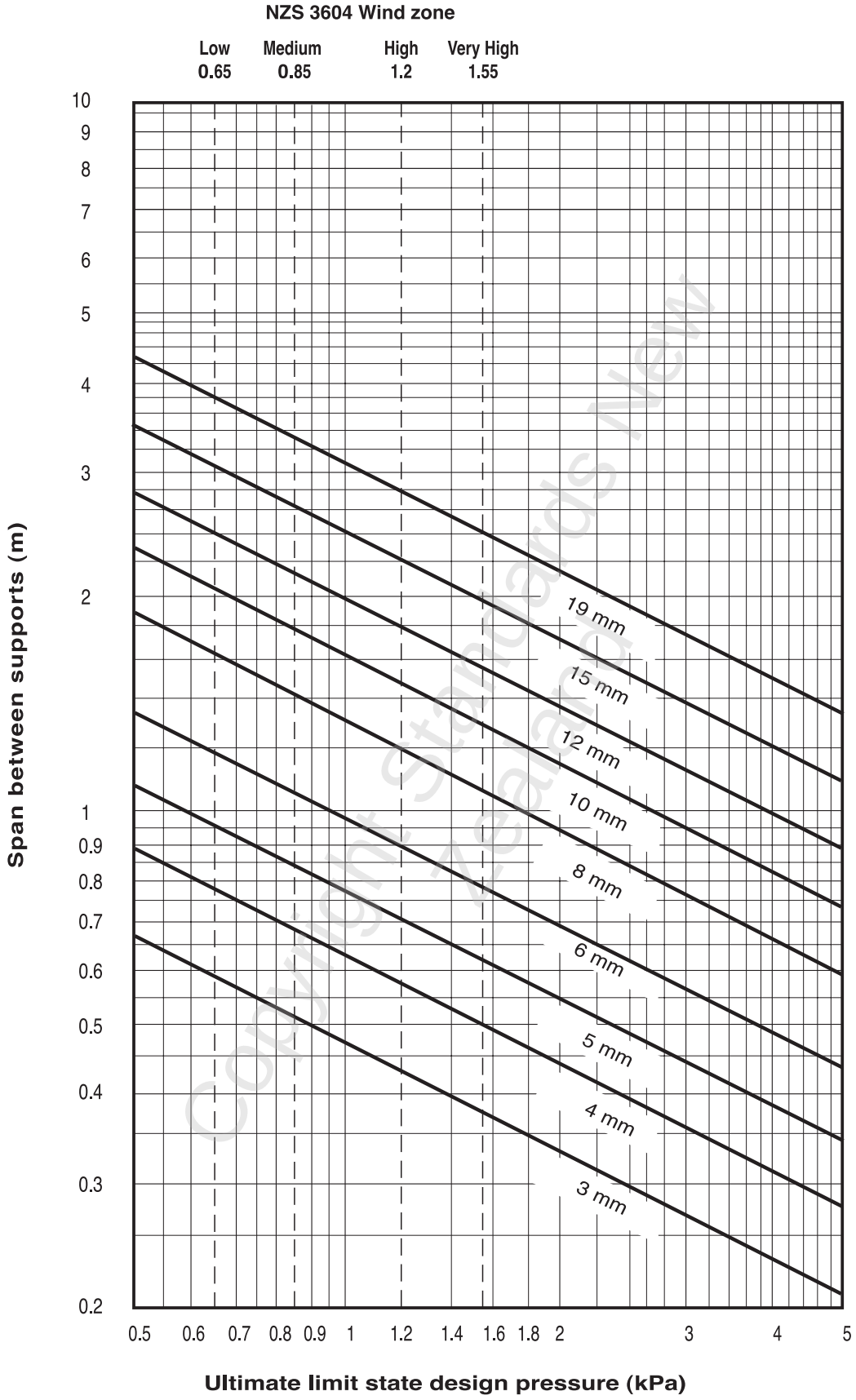
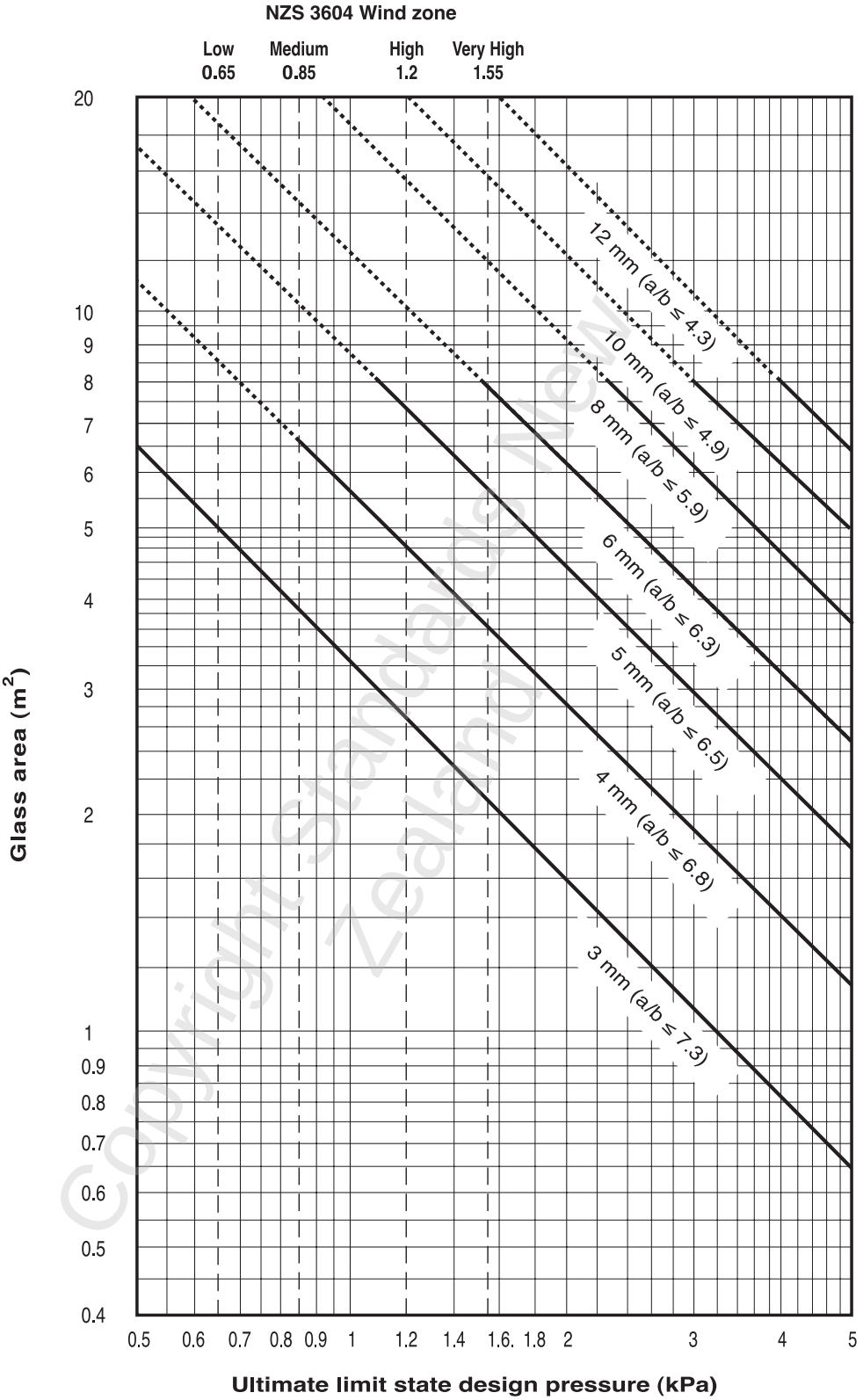


Chart 2	Minimum glass thickness – Annealed glass – Two edge support



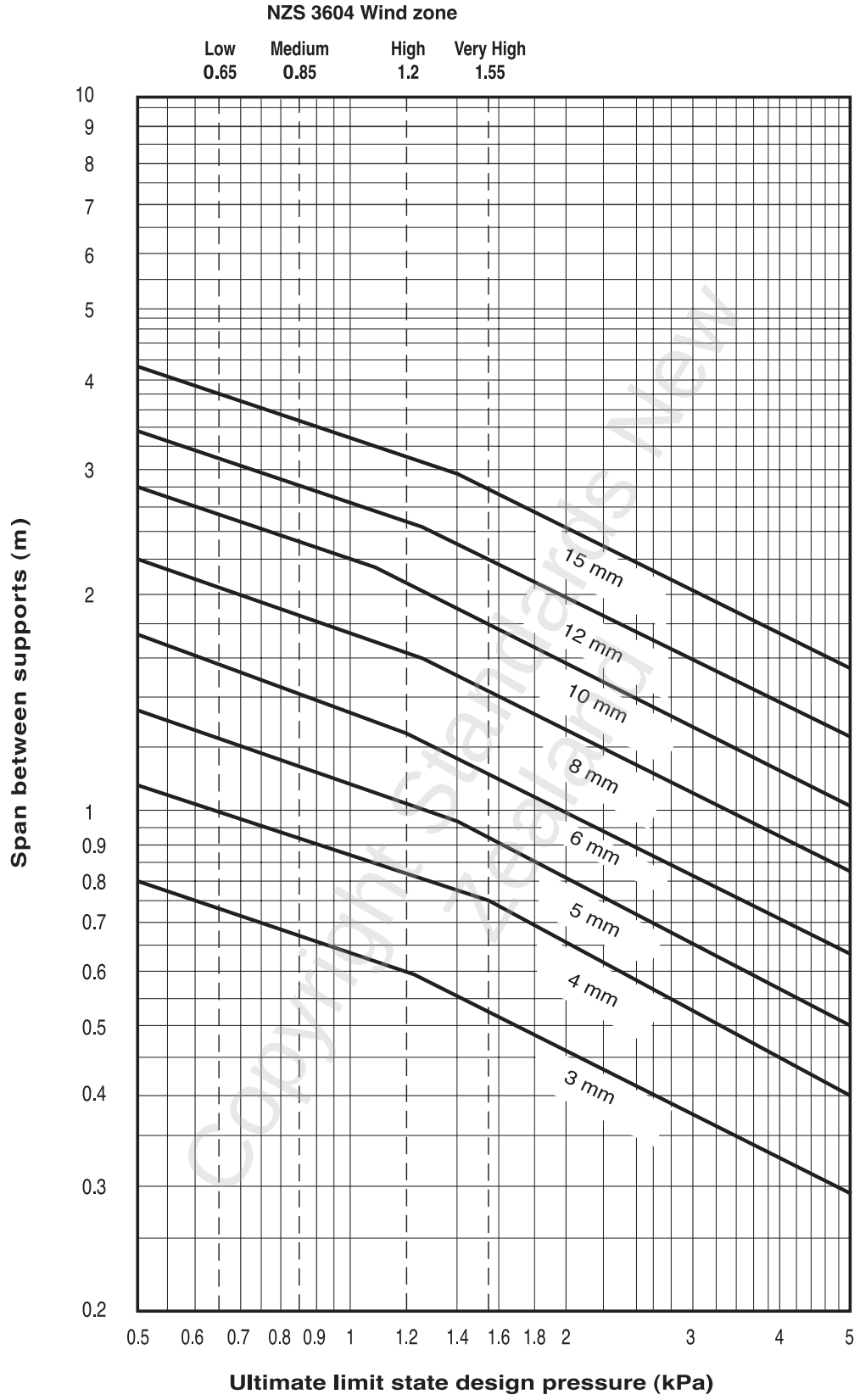
NOTE –

(1) For aspect ratios (a/b) greater than those shown use the two edge support charts.

(2) Dotted lines indicate sizes outside normal manufacturing recommendations.

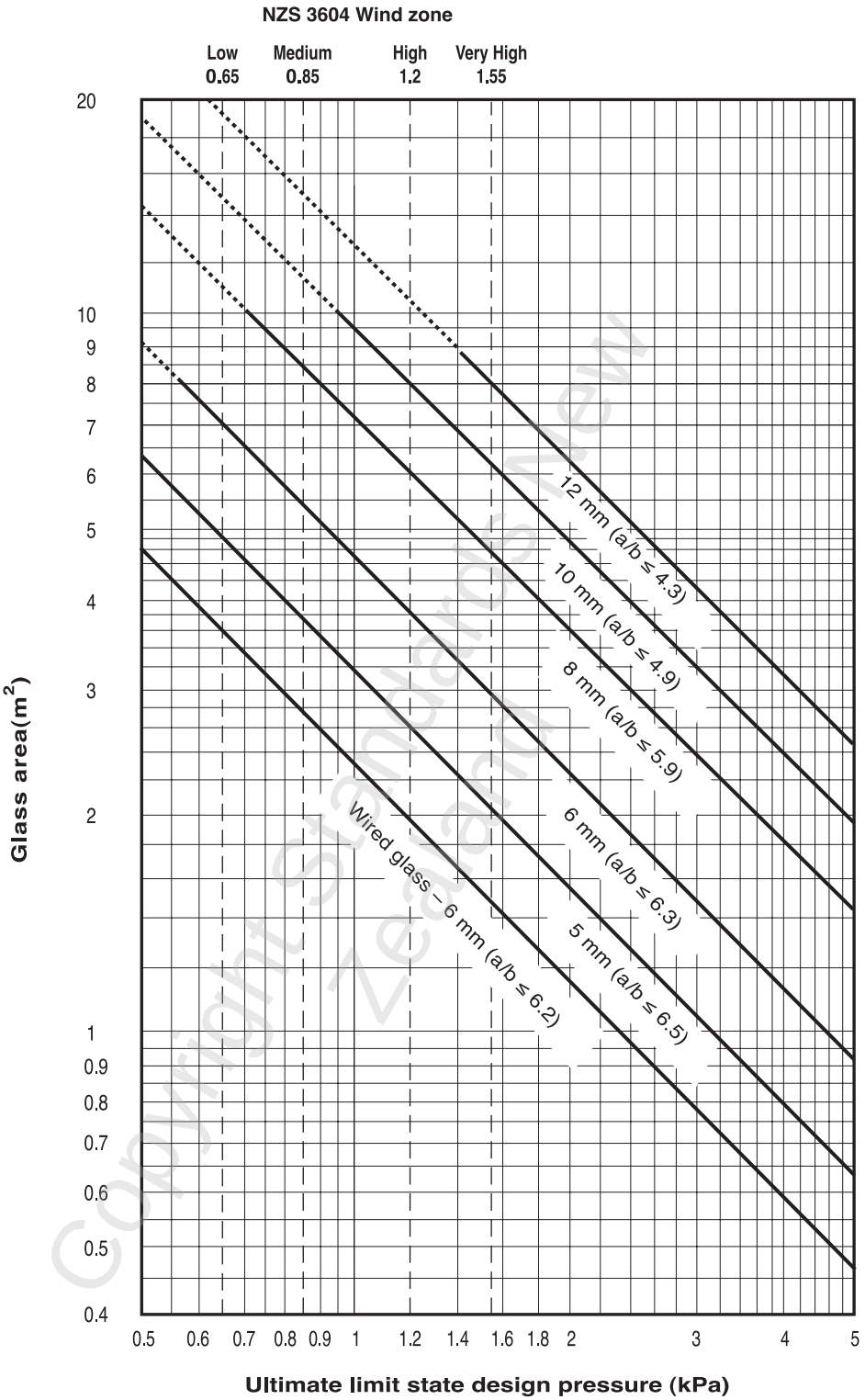
(3) The maximum span of toughened glass of a given thickness has been restricted by a serviceability deflection limit of span/60. Spans above those shown may lead to glazing which, although mechanically safe, has large and possibly visually disturbing deflections under load.

Chart 3	Minimum glass thickness – Toughened glass – Four edge support



NOTE – The maximum span of toughened glass of a given thickness has been restricted by a serviceability deflection limit of span/60. Spans above those shown may lead to glazing which, although mechanically safe, has large and possibly visually disturbing deflections under load.

Chart 4	Minimum glass thickness – Toughened glass - Two edge support



NOTE –

(1) The lowest line above is for wired glass. All other lines relate to laminated glass.

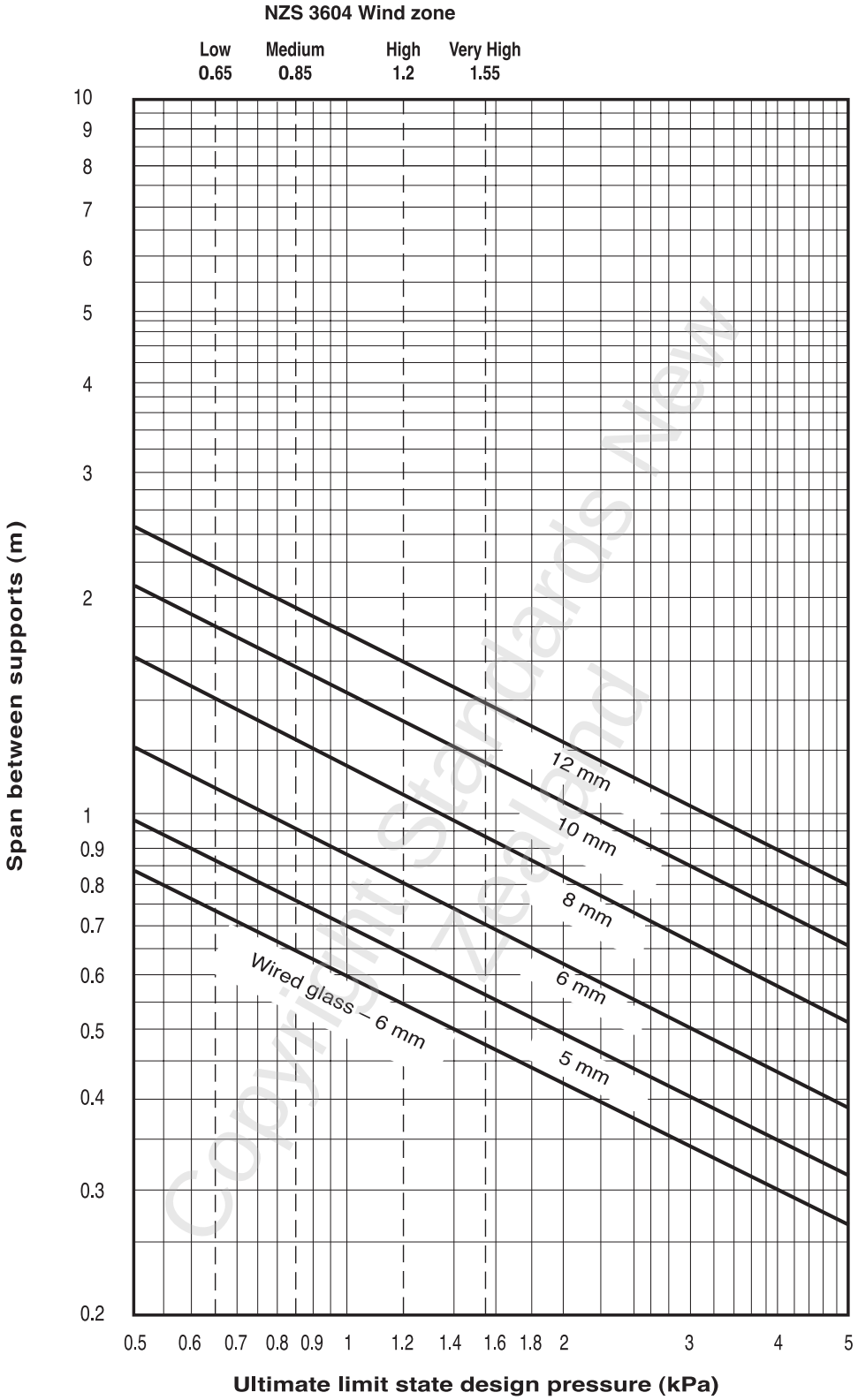
(2) Thicknesses of laminated glass given in the Chart represent the combined thickness of the individual glass panes and do not include the thickness of the plastic interlayer material.

(3) Laminated glass shall be symmetrical i.e. it shall have the same thickness of glass either side of the plastic interlayer material. Laminated glass that is unsymmetrical is outside the scope of this Part.

(4) For aspect ratios (a/b) greater than those shown use the two edge support charts.

(5) Dotted lines indicate sizes outside normal manufacturing recommendations.

Chart 5	Minimum glass thickness – Laminated and wired glass – Four edge support



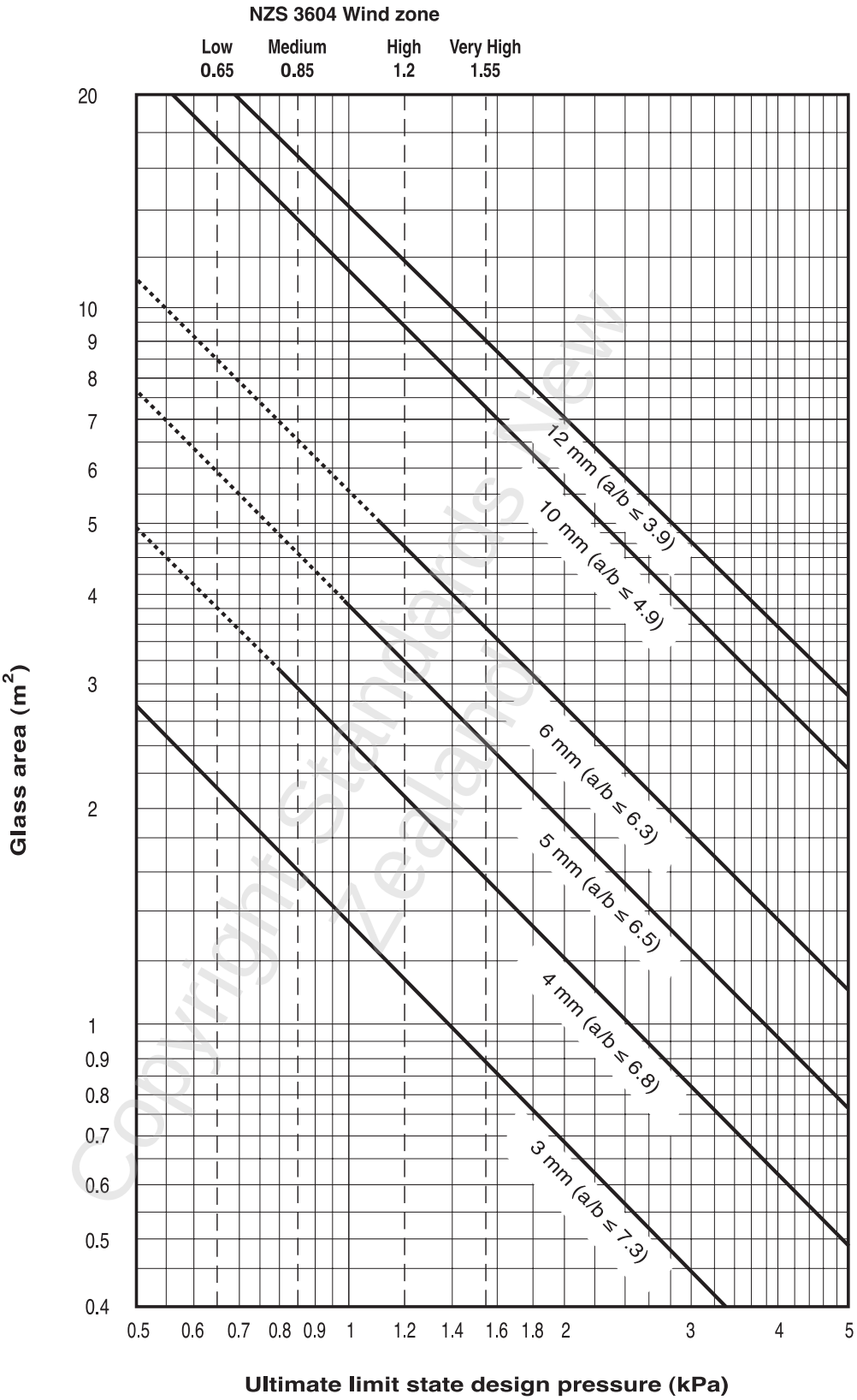
NOTE –

(1) The lowest line above is for wired glass. All other lines relate to laminated glass.

(2) Thicknesses of laminated glass given in the Chart represent the combined thickness of the individual glass panes and do not include the thickness of the plastic interlayer material.

(3) Laminated glass shall be symmetrical i.e. it shall have the same thickness of glass either side of the plastic interlayer material. Laminated glass that is unsymmetrical is outside the scope of this Part.

Chart 6	Minimum glass thickness – Laminated and wired glass – Two edge support



NOTE –
(1) For aspect ratios (a/b) greater than those shown use the two edge support charts.
(2) Dotted lines indicate sizes outside normal manufacturing recommendations.

Chart 7	Minimum glass thickness – Patterned glass – Four edge support

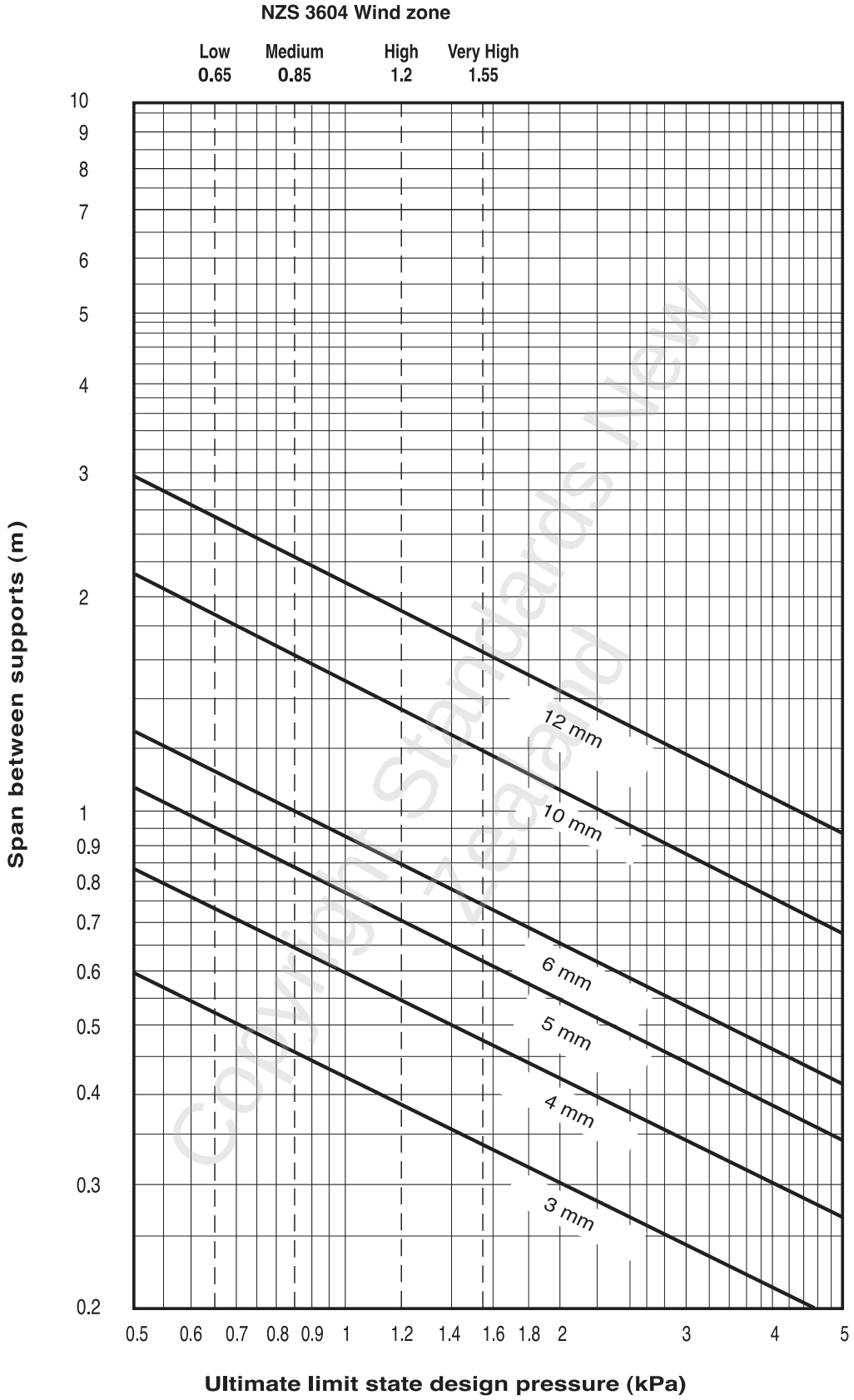
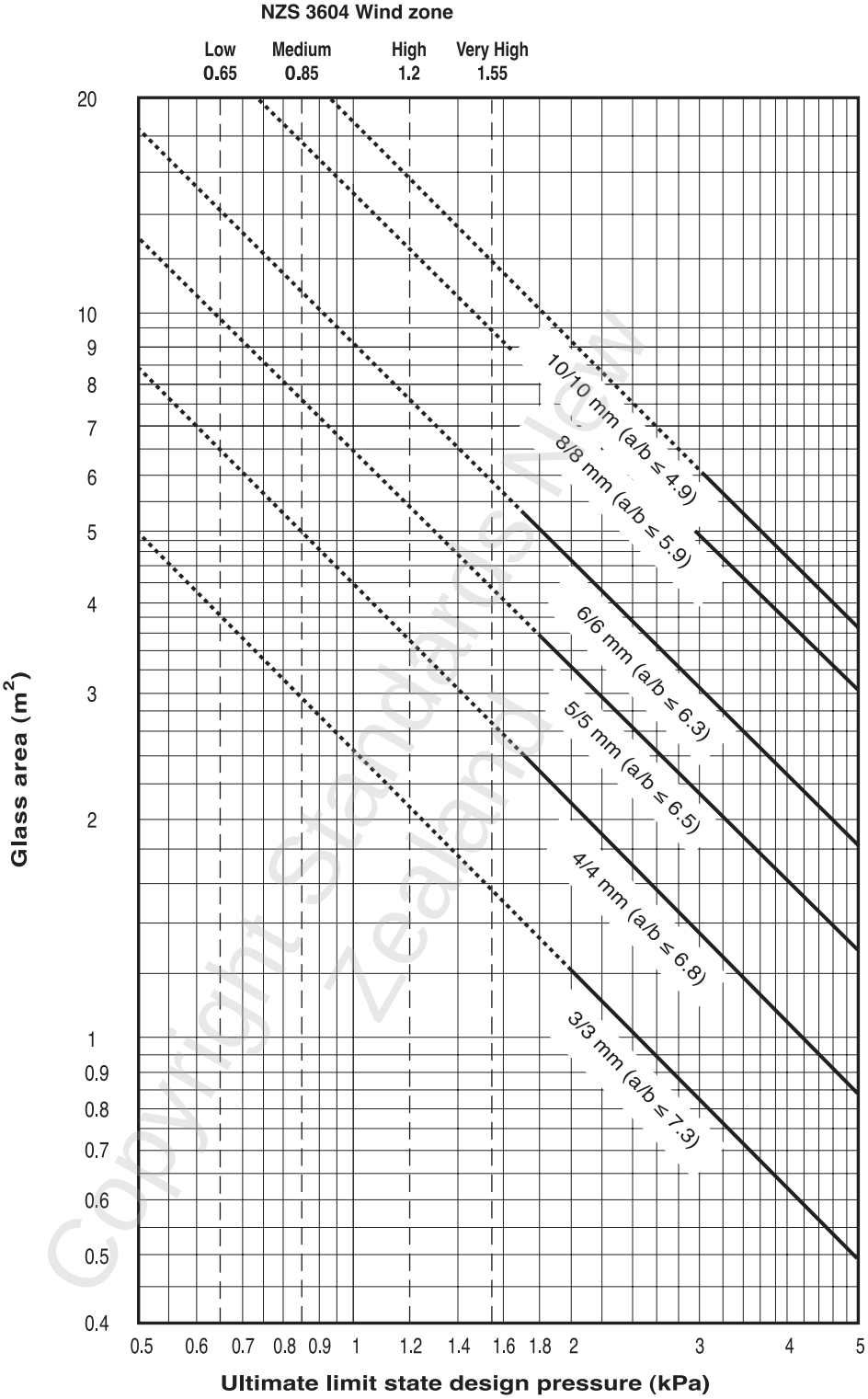


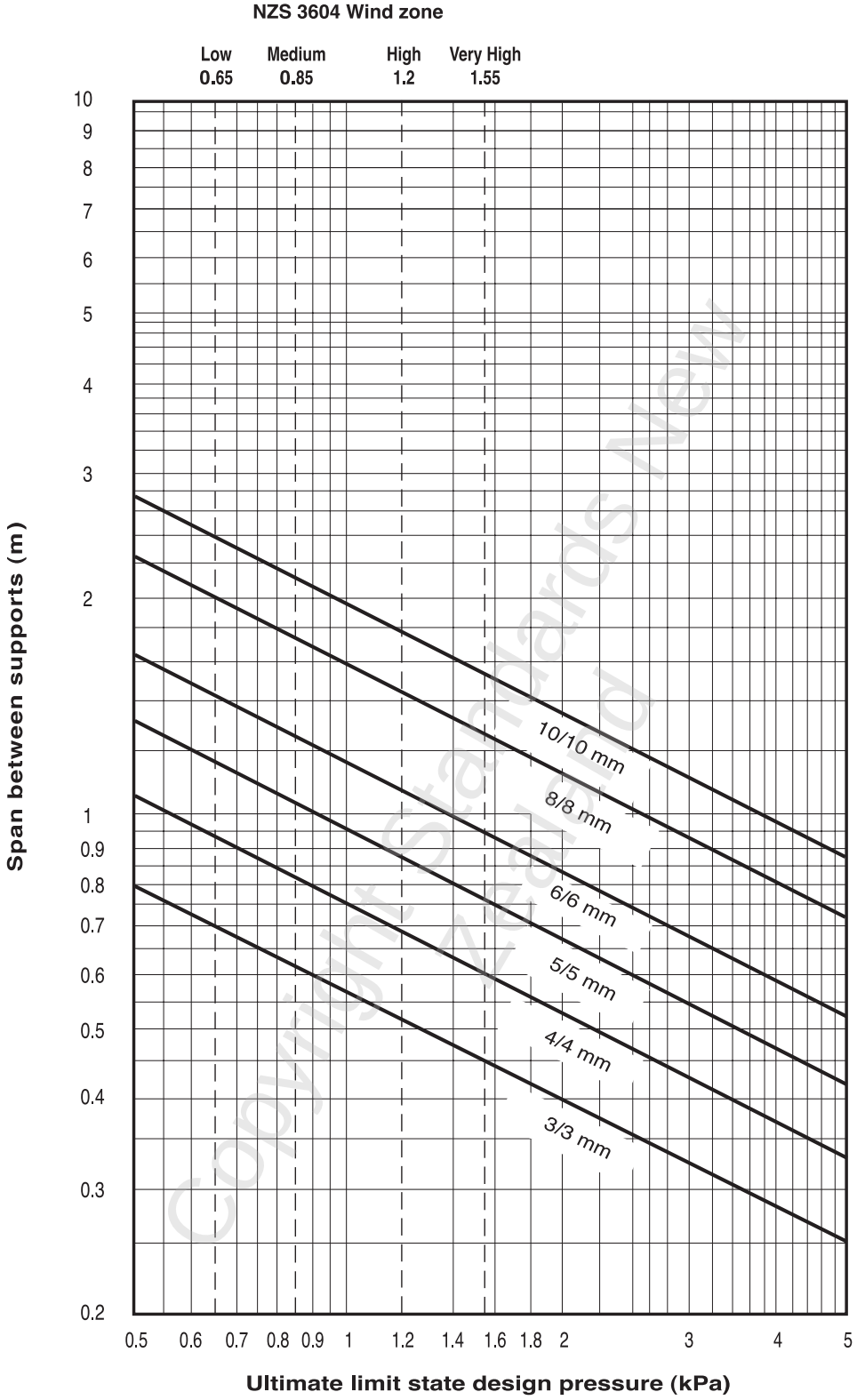
Chart 8	Minimum glass thickness – Patterned glass – Two edge support



NOTE –

(1) The charts are for units using annealed glass. For other combinations consult the manufacturer.
(2) For non-symmetrical units use the thickness of the thinner of the two panes.
(3) For stepped edge units, (i.e. where the 2 panes are not of identical size) design from Chart 1 based on the thickness of one pane or consult the manufacturer.
(4) For aspect ratios (a/b) greater than those shown use the two edge support charts.
(5) Dotted lines indicate sizes outside normal manufacturing recommendations.
(6) 3/3 mm means a unit made up of two panes each 3 mm thick.

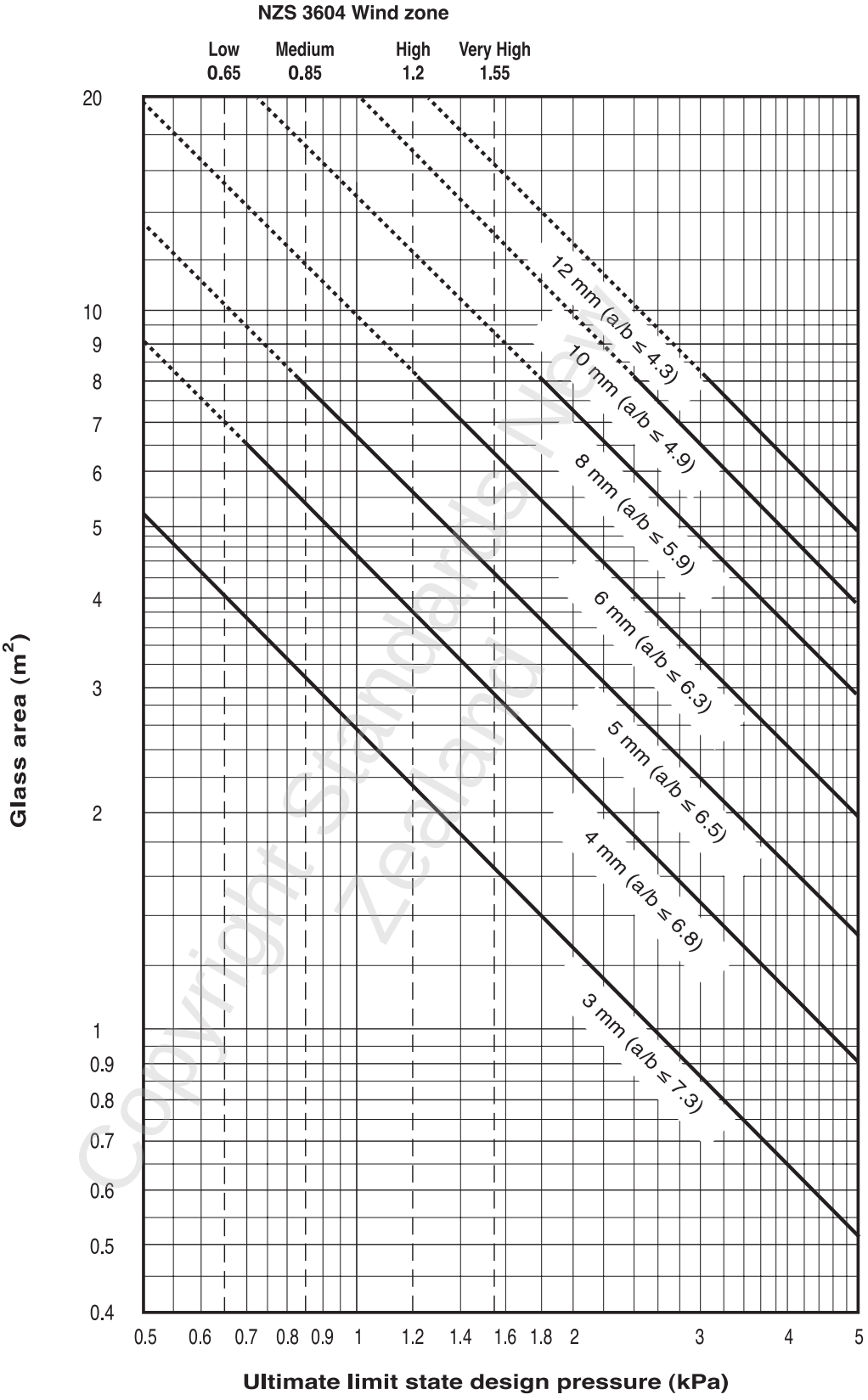
Chart 9	Minimum glass thickness – Insulating glass units – Four edge support



NOTE –

(1) The charts are for units using annealed glass. For other combinations consult the manufacturer.
(2) For non-symmetrical units use the thickness of the thinner of the two panes.
(3) For stepped edge units, (i.e. where the 2 panes are not of identical size) design from Chart 2 based on the thickness of one pane or consult the manufacturer.
(4) 3/3 mm means a unit made up of two panes each 3 mm thick.

Chart 10	Minimum glass thickness – Insulating glass units – Two edge support



NOTE –
(1) For aspect ratios (a/b) greater than those shown use the two edge support charts.
(2) Dotted lines indicate sizes outside normal manufacturing recommendations.

Chart 11	Minimum glass thickness – Heat strengthened glass – Four edge support

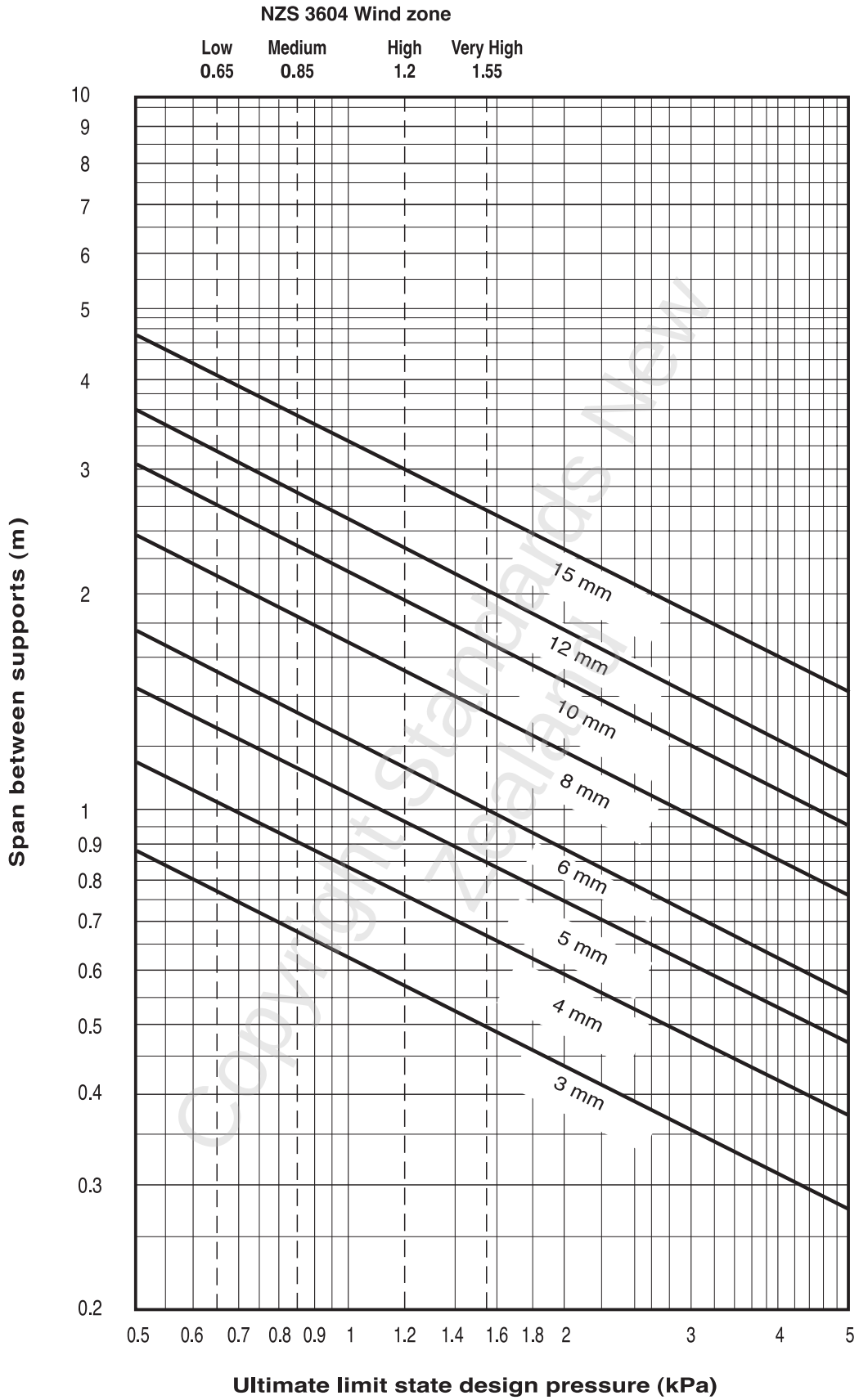


Chart 12	Minimum glass thickness – Heat strengthened glass – Two edge support

403 SELECTION OF SLOPED GLAZING TO WITHSTAND DEAD, WIND AND SNOW LOADINGS

403.1 Scope

This Part caters for design of sloped glazing to withstand ultimate limit state pressures from gravity, snow and wind. This Part does not describe a procedure for designing for maintenance loads and if these are expected then specific engineering design is required.

The ultimate limit state design wind pressure on the glazing can also be determined from NZS 4203 and then used with the Charts of this Part. Such determination however involves specific engineering design and is outside the scope of this Part.

403.2 Design loadings

This section shall be followed to determine the design pressures applied to the glazing.

403.2.1 *Combined design loads*

All components of the design are expressed as pressure, with positive or negative signs according to whether the loads are acting inwards or outwards.

Dead

The design pressures resulting from dead load shall be determined from table 4.1.

Wind

Wind pressure shall be determined from Appendix 4.B.

All the conditions of 4.B1.1 must be satisfied. Table 4.B1 or table 4.B2 shall be used to determine the Basic ULS wind pressure with table 4.B1 being used when the building concerned is situated on a flat area of land and table 4.B2 used in all other situations. For the purposes of this clause a flat area of land shall be taken as an area of land where the undulations are less than 25 m in height and ground slope is less than 1 in 10 (e.g. the floor of the Hutt Valley or the flat area of Christchurch).

The Basic ULS wind pressure shall then be used in table 4.B3 to determine the ultimate limit state wind design pressures for both the downward and uplift cases.

Snow

The snow load appropriate for the building's location shall be determined from figure 4.1. The snow loading used for the design of sloped glazing depends on the angle of the glazing and shall be as given in table 4.1.

403.2.2 *Combined design loads on sloping roofs*

The combined design loads to be considered for glass on sloping roofs are:

Case 1 Dead (maximum) + wind (↓)
Case 2 Dead (maximum) + snow + wind (↓)
Case 3 Dead (minimum) + wind (↑)

Whichever of the above cases causes the worst load effect shall be taken as the ultimate limit state design pressure which shall then be used in Charts 1 to 12 as appropriate depending on the type of limit state design glazing and its support.

Table 4.1 – Dead loads and snow loads

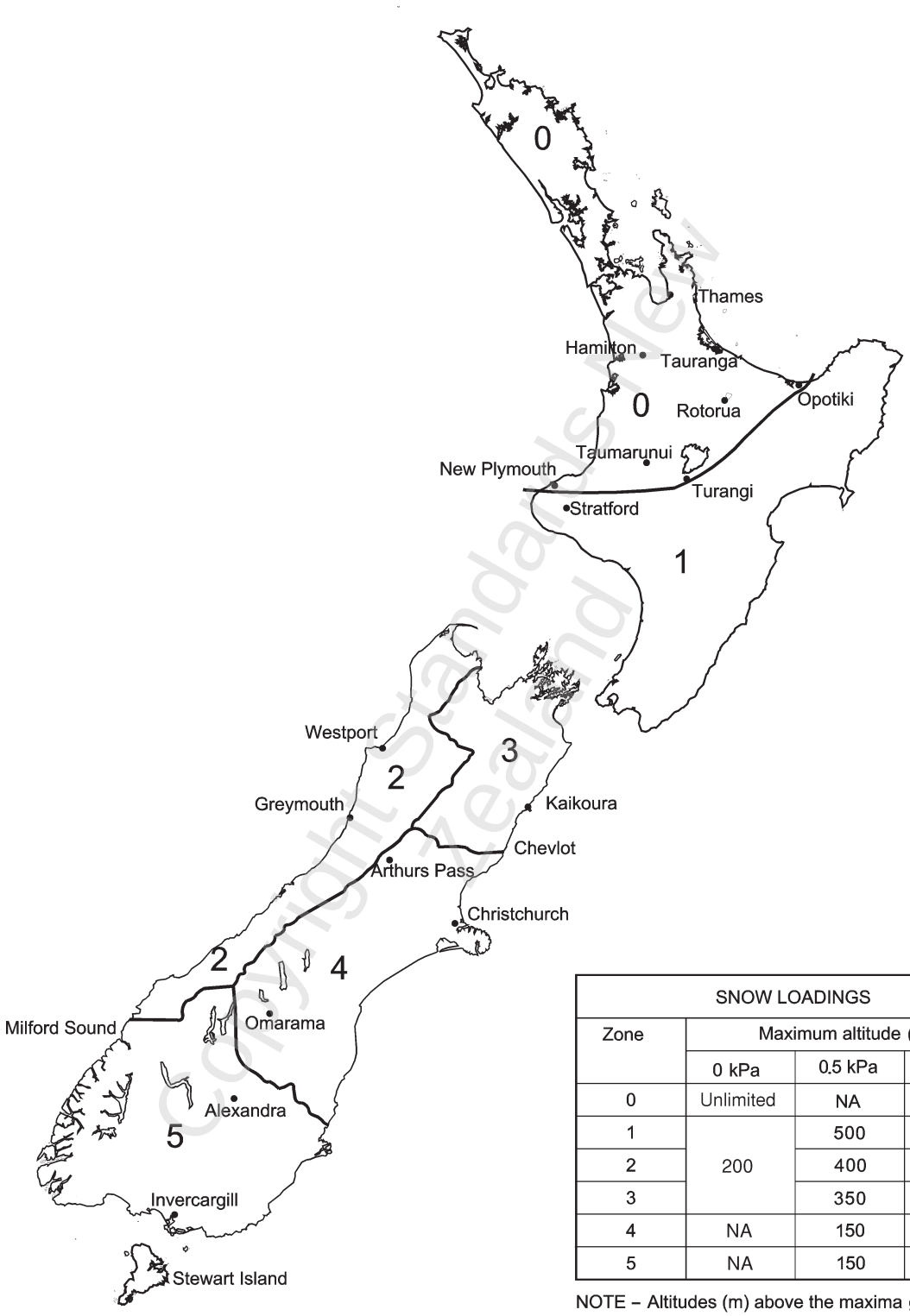
Angle of glass to the horizontal(°)	Single glazing(1)		Insulating glazing units(1)		Snow loading	
	Dead (maximum) (kPa)	Dead (minimum) (kPa)	Dead (maximum) (kPa)	Dead (minimum) (kPa)	0.5 kPa maximum (kPa)	1 kPa maximum (kPa)
0	0.47	0.14	0.94	0.28	0.50	1.00
5	0.46	0.13	0.92	0.26	0.49	0.98
10	0.46	0.13	0.92	0.26	0.49	0.98
15	0.45	0.13	0.90	0.26	0.48	0.96
20	0.44	0.13	0.88	0.26	0.47	0.94
25	0.42	0.12	0.84	0.24	0.45	0.90
30	0.41	0.12	0.82	0.24	0.43	0.86
35	0.38	0.11	0.76	0.22	0.41	0.82
40	0.36	0.10	0.72	0.20	0.38	0.76
45	0.33	0.10	0.66	0.20	0.36	0.72
50	0.30	0.09	0.60	0.18	0.32	0.64
55	0.27	0.08	0.54	0.16	0.29	0.58
60	0.23	0.07	0.46	0.14	0.25	0.50
65	0.20	0.06	0.40	0.12	0.21	0.42
70	0.16	0.05	0.32	0.10	0.17	0.34
75	0.12	0.04	0.24	0.08	0.13	0.26

NOTE –

(1) Single glazing based on 6 mm glass, insulating glass units on 6 mm + 6 mm glass.

(2) Dead (maximum) equals 1.2 x 2.6 x the dead load of the glass = 3.12 x the dead load of the glass and dead (minimum) equals 0.9 x the dead load of the glass.

(3) It is necessary to introduce an adjustment for the effect of sustained loading on glass. Under short-term loading, glass is considerably stronger than it is under long-term loading, and the strength factor between the 3-second loading of a wind gust and the sustained loading caused by snow and the weight of glazing is approximately 2.6. Therefore, by adding these sustained loads to wind loads, it is reasonable to recognize their more damaging effect by multiplying them by 2.6, but not where the weight merely serves to diminish the effect of a wind suction.



SNOW LOADINGS			
Zone	Maximum altitude (m)		
	0 kPa	0.5 kPa	1 kPa
0	Unlimited	NA	NA
1	200	500	750
2		400	550
3		350	550
4	NA	150	250
5	NA	150	450

NOTE – Altitudes (m) above the maxima given for 1 kPa require specific engineering design.

Figure 4.1 – Snow zones

403.2.3 *Procedure for selecting two edge supported sloping glass*
The following procedure shall be followed:

1. Enter the appropriate Chart with the maximum ultimate limit state design pressure determined from 403.2.2.

2. The glass thickness immediately above the intersection of this line and the line from the span under consideration shall be selected.

3. If the glass thickness is different from 6 mm or 6 mm + 6 mm for insulating glass units, multiply the dead load value from table 4.1 by the ratio of the determined thickness divided by 6 and recalculate the design pressure from the load combinations.

4. Re-enter the chart at the new pressure to determine the new thickness required.

5. Repeat steps 3 and 4 until the glass thickness does not change, and select this thickness.

403.2.4 *Procedure for selecting four edge supported sloping glass*
The following procedure shall be followed:

1. Enter the appropriate Chart with the maximum ultimate limit state design pressure determined from 403.2.2.

2. The glass thickness immediately above the intersection of this line and the line from the area under consideration shall be selected.

3. If the glass thickness is different from 6 mm or 6 mm + 6 mm for insulating glass units, multiply the dead load value from table 4.1 by the ratio of the determined thickness divided by 6 and recalculate the design pressure from the load combinations.

4. Re-enter the chart at the new pressure to determine the new thickness required.

5. Repeat steps 3 and 4 until the glass thickness does not change, and select this thickness.

6. Check that the aspect ratio is less than the maximum aspect ratio given for the glass thickness on the chart. When the aspect ratio for glass four edge support exceeds that given in Charts 1 to 12 for the appropriate glass thickness, determine the width (minimum dimension) of the glass and use this value as the span and consider the glass as supported on two opposite edges.

APPENDIX 4.A
METHOD FOR DETERMINATION OF THE WIND LOADING ON VERTICAL GLAZING

(Normative)

4.A1

The procedures of this Appendix shall only be used when the following requirements are satisfied:

(a) The top of the glazing is no more than 10 m above the ground;

(b) There are no unusual topographic features surrounding the building such as steep cliffs or steep sided valleys which may cause channelling of the wind;

(c) 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;

(d) There is no large opening on any wall of the structure whose area is greater than 50 % of the sum of the areas of the openings in the remaining walls;

(e) The building is not situated in a lee zone shown in figure 4.A1.

The ultimate limit state design wind pressure shall be determined from tables 4.A1 or 4.A2 as appropriate.

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 from NZS 3604, as described in 402.3(b), or by specific engineering design from NZS 4203.

NOTE – These tables are based on NZS 4203 using the basic wind speed for the particular wind region, factored by the multipliers applicable to the site and with a C_p factor of 1.1.

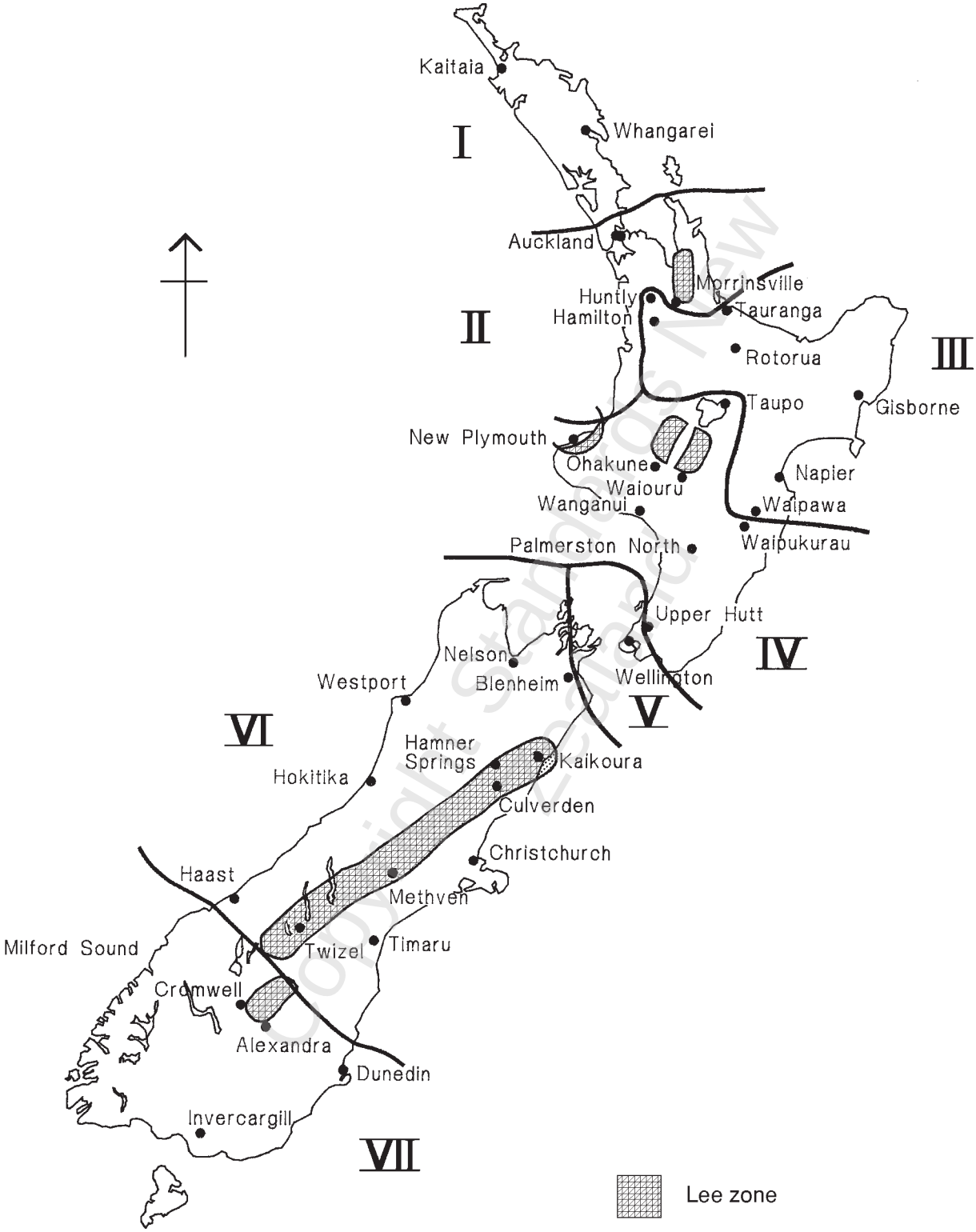


Figure 4.A1 – Wind regions and lee zones

Table 4.A1 – Ultimate limit state wind pressure (ULS) (kPa) for flat land areas (i.e. areas of land where the undulations are less than 25 m in height and ground slopes are less than 1 in 10 (e.g. plains))

Wind region from figure 4.A1	Maximum glazing height above ground (m)	Terrain category			
		1	2	3	4
I	3	1.34	0.99	0.77	0.77
	5	1.51	1.13	0.77	0.77
	10	1.72	1.37	0.94	0.77
V, VII	3	1.29	0.95	0.74	0.74
	5	1.45	1.09	0.74	0.74
	10	1.65	1.32	0.91	0.74
IV	3	1.18	0.87	0.68	0.68
	5	1.33	1.00	0.68	0.68
	10	1.52	1.21	0.83	0.68
II, VI	3	1.13	0.84	0.65	0.65
	5	1.27	0.96	0.65	0.65
	10	1.45	1.16	0.80	0.65
III	3	1.06	0.76	0.59	0.59
	5	1.16	0.87	0.59	0.59
	10	1.32	1.06	0.73	0.59

The terrain categories are defined as follows:

Category 1 Exposed open terrain with few or no obstructions.

Category 2 Open terrain, grassland with few well scattered obstructions having heights generally from 1.5 m to 10.0 m and water surfaces.

Category 3 Terrain with numerous closely spaced obstructions having the size of domestic houses (3.0 m to 5.0 m high).

Category 4 Terrain with numerous large, high (10.0 m to 30.0 m high) and closely spaced obstructions such as large city centres and well-developed industrial complexes.

Table 4.A2 – Ultimate limit state wind pressure (kPa) for other than flat land

Wind region from figure 4.A1	Maximum glazing height above ground (m)	Terrain category			
		1	2	3	4
I	3	3.19	2.35	1.83	1.83
	5	3.58	2.69	1.83	1.83
	10	4.08	3.25	2.24	1.83
V, VII	3	3.06	2.25	1.75	1.75
	5	3.44	2.58	1.75	1.75
	10	3.91	3.12	2.15	1.75
IV	3	2.81	2.07	1.61	1.61
	5	3.16	2.37	1.61	1.61
	10	3.59	2.86	1.97	1.61
II, VI	3	2.69	1.98	1.54	1.54
	5	3.02	2.27	1.54	1.54
	10	3.44	2.74	1.89	1.54
III	3	2.45	1.81	1.41	1.41
	5	2.76	2.07	1.41	1.41
	10	3.14	2.50	1.72	1.41

The terrain categories are defined as follows:

Category 1 Exposed open terrain with few or no obstructions.

Category 2 Open terrain, grassland with few well scattered obstructions having heights generally from 1.5 m to 10.0 m and water surfaces.

Category 3 Terrain with numerous closely spaced obstructions having the size of domestic houses (3.0 m to 5.0 m high).

Category 4 Terrain with numerous large, high (10.0 m to 30.0 m high) and closely spaced obstructions such as large city centres and well-developed industrial complexes.

NOTE – Table 4.A2 covers all other situations than those included in table 4.A1 and it may be more efficient to use the NZS 3604 procedure to determine the glass thickness, or conduct a specific engineering design in accordance with NZS 4203, the latter being outside the scope of this Part.

APPENDIX 4.B
METHOD FOR DETERMINATION OF THE WIND PRESSURE ON SLOPED GLAZING

(Normative)

4.B1

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

(a) The top of the glazing is no more than 10 m above the ground;

(b) There are no unusual topographic features surrounding the building such as steep cliffs or steep sided valleys which may cause channelling of the wind;

(c) 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;

(d) There is no large opening on any wall of the structure whose area is greater than 50 % of the sum of the areas of the openings in the remaining walls;

(e) The building is not situated in a lee zone shown in figure 4.A1.

The basic ULS wind pressure shall be determined from tables 4.B1 or 4.B2 as appropriate with reference to figure 4.A1 for the wind region.

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 NZS 4203.

NOTE – These tables are based on NZS 4203 using the basic non-directional wind speed for the wind region, factored by the multipliers applicable to the site and with a C_p factor of 1.0.

4.B1.1

The figure determined from tables 4.B1 or 4.B2 shall then be used in table 4.B3 depending on the roof angle to determine the ultimate limit state wind design pressure for both the downward and uplift cases.

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

1. Select tables 4.B1 or 4.B2 depending on whether or not the site is flat (see 403.2).

2. From the table read off the basic ULS wind pressure depending on the wind region the building is located in, the terrain category and the height of the glazing under consideration.

3. Enter table 4.B3 with basic ULS wind pressure determined in step 2 above.

4. For the appropriate roof slope and next higher pressure increment in the first column in table 4.B3, read off the wind (↑) and wind (↓) pressures. Linear interpolation is acceptable for more accurate determination of design pressures.

   For canopies and awnings of all slopes attached to the sides of buildings, select the ULS wind pressure from the 61º – 75º glazing angle column of table 4.B3.

5. Continue at step 1 of 403.2.3 for two edge supported sloping glass or step 1 of 403.2.4 for four edge supported sloping glass.

Table 4.B1 – Basic ultimate limit state (ULS) wind pressure (kPa) for sloped glazing for flat land areas (i.e. areas of land where the undulations are less than 25 m in height and ground slopes are less than 1 in 10 (e.g. plains))

NOTE – Use pressures for entry into column 1 of table 4.B3.

Wind region from figure 4.A1	Maximum glazing height above ground (m)	Terrain category			
		1	2	3	4
I	3	1.22	0.90	0.70	0.70
	5	1.37	1.03	0.70	0.70
	10	1.56	1.25	0.86	0.70
V, VII	3	1.17	0.86	0.67	0.67
	5	1.32	0.99	0.67	0.67
	10	1.50	1.20	0.82	0.67
IV	3	1.08	0.79	0.62	0.62
	5	1.21	0.91	0.62	0.62
	10	1.38	1.10	0.76	0.62
II, VI	3	1.03	0.76	0.59	0.59
	5	1.16	0.87	0.59	0.59
	10	1.32	1.05	0.72	0.59
III	3	0.94	0.69	0.54	0.54
	5	1.06	0.79	0.54	0.54
	10	1.20	0.96	0.66	0.54

The terrain categories are defined as follows:

Category 1 Exposed open terrain with few or no obstructions.

Category 2 Open terrain, grassland with few well scattered obstructions having heights generally from 1.5 m to 10.0 m and water surfaces.

Category 3 Terrain with numerous closely spaced obstructions having the size of domestic houses (3.0 m to 5.0 m high).

Category 4 Terrain with numerous large, high (10.0 m to 30.0 m high) and closely spaced obstructions such as large city centres and well-developed industrial complexes.

Table 4.B2 – Basic ultimate limit state (ULS) wind pressure (kPa) for sloped glazing for areas other than flat land areas

NOTE – Use pressures for entry into column 1 of table 4.B3.

Wind region from figure 4.A1	Maximum glazing height above ground (m)	Terrain category			
		1	2	3	4
I	3	2.90	2.13	1.66	1.66
	5	3.26	2.45	1.66	1.66
	10	3.71	2.95	2.04	1.66
V, VII	3	2.78	2.05	1.60	1.60
	5	3.13	2.35	1.60	1.60
	10	3.56	2.84	1.95	1.60
IV	3	2.55	1.88	1.46	1.46
	5	2.87	2.16	1.46	1.46
	10	3.27	2.60	1.79	1.46
II, VI	3	2.44	1.80	1.40	1.40
	5	2.75	2.06	1.40	1.40
	10	3.13	2.49	1.72	1.40
III	3	2.23	1.64	1.28	1.28
	5	2.51	1.88	1.28	1.28
	10	2.85	2.28	1.57	1.28

The terrain categories are defined as follows:

Category 1 Exposed open terrain with few or no obstructions.

Category 2 Open terrain, grassland with few well scattered obstructions having heights generally from 1.5 m to 10.0 m and water surfaces.

Category 3 Terrain with numerous closely spaced obstructions having the size of domestic houses (3.0 m to 5.0 m high).

Category 4 Terrain with numerous large, high (10.0 m to 30.0 m high) and closely spaced obstructions such as large city centres and well-developed industrial complexes.

NOTE – Table 4.B2 covers all other situations than those included in table 4.B1 and it may be more efficient to conduct a specific engineering design in accordance with NZS 4203, the latter being outside the scope of this Part.

Table 4.B3 – Ultimate limit state (ULS) design wind pressures for sloping glass in buildings (kPa)(1)

Basic ULS wind pressure from table 4.B1 or table 4.B2 (kPa)	Pitched or monoslope roof at angle, measured from the horizontal, of:									
	0° – 15°		16° – 30°		31° – 45°		46° – 60°		61° – 75° (2)	
	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)
0.5	0.30	–1.00	0.45	–0.70	0.65	–0.60	0.75	–0.60	1.05	–0.60
0.6	0.36	–1.20	0.54	–0.84	0.78	–0.72	0.90	–0.72	1.26	–0.72
0.7	0.42	–1.40	0.63	–0.98	0.91	–0.84	1.05	–0.84	1.47	–0.84
0.8	0.48	–1.60	0.72	–1.12	1.04	–0.96	1.20	–0.96	1.68	–0.96
0.9	0.54	–1.80	0.81	–1.26	1.17	–1.08	1.35	–1.08	1.89	–1.08
1.0	0.60	–2.00	0.90	–1.40	1.30	–1.20	1.50	–1.20	2.10	–1.20
1.1	0.66	–2.20	0.99	–1.54	1.43	–1.32	1.65	–1.32	2.31	–1.32
1.2	0.72	–2.40	1.08	–1.68	1.56	–1.44	1.80	–1.44	2.52	–1.44
1.3	0.78	–2.60	1.17	–1.82	1.69	–1.56	1.95	–1.56	2.73	–1.56
1.4	0.84	–2.80	1.26	–1.96	1.82	–1.68	2.10	–1.68	2.94	–1.68
1.5	0.90	–3.00	1.35	–2.10	1.95	–1.80	2.25	–1.80	3.15	–1.80
1.6	0.96	–3.20	1.44	–2.24	2.08	–1.92	2.40	–1.92	3.36	–1.92
1.8	1.08	–3.60	1.62	–2.52	2.34	–2.16	2.70	–2.16	3.78	–2.16
2.0	1.20	–4.00	1.80	–2.80	2.60	–2.40	3.00	–2.40	4.20	–2.40
2.2	1.32	–4.40	1.98	–3.08	2.86	–2.64	3.30	–2.64	4.62	–2.64
2.4	1.44	–4.80	2.16	–3.36	3.12	–2.88	3.60	–2.88	5.04	–2.88
2.6	1.56	–5.20	2.34	–3.64	3.38	–3.12	3.90	–3.12	5.46	–3.12
2.8	1.68	–5.60	2.52	–3.92	3.64	–3.36	4.20	–3.36	5.88	–3.36

Table 4.B3 – Ultimate limit state (ULS) design wind pressures for sloping glass in buildings (kPa)(1) (continued)

Basic ULS wind pressure from table 4.B1 or 4.B2 (kPa)	Pitched or monoslope roof at angle, measured from the horizontal, of:									
	0° – 15°		16° – 30°		31° – 45°		46° – 60°		61° – 75° (2)	
	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)	Wind (↓)	Wind (↑)
3.0	1.80	–6.00	2.70	–4.20	3.90	–3.60	4.50	–3.60	6.30	–3.60
3.2	1.92	–6.40	2.88	–4.48	4.16	–3.84	4.80	–3.84	6.72	–3.84
3.4	2.04	–6.80	3.06	–4.76	4.42	–4.08	5.10	–4.08	7.14	–4.08
3.6	2.16	–7.20	3.24	–5.04	4.68	–4.32	5.40	–4.32	7.56	–4.32
3.8	2.28	–7.60	3.42	–5.32	4.94	–4.56	5.70	–4.56	7.98	–4.56
C_p	0.60	2.0	0.9	1.4	1.3	1.2	1.5	1.2	2.1	1.2

NOTE –
(1) Dead and snow loads are not included.
(2) For all canopies and awnings, use the 61° – 75° column of the table.

APPENDIX 4.C
BASIS FOR DETERMINATION OF THICKNESS OR AREA OF GLASS IN ACCORDANCE WITH THE REQUIREMENTS FOR WIND LOADING

(Informative)

4.C1 Rectangles of glass supported on all sides (four edge support)

4.C1.1
The following equations are derived from AS 1288 and were used to formulate the figures.

(a) For glass up to and including nominal 6 mm thickness

$$pA = K_1 = 0.2t^{1.8} \quad \text{(Eq. C1)}$$

(b) For glass greater than nominal 6 mm thickness

$$pA = K_2 = 0.2t^{1.6} + 1.9 \quad \text{(Eq. C2)}$$

where
p = design wind pressure (kPa)
A = area of the glass (m^2)
t = thickness of the glass (mm)
K = a constant for a given glass thickness.

NOTE – The design wind pressure has been factored up by 1.28 from working stress as a soft conversion to the limit state design in the preparation of the charts.

4.C2 Rectangles of glass supported on two opposite sides only (two edge support)

4.C2.1
Thus the maximum dimension of the span for any glass thickness or design wind pressure is calculated from the following equation:

$$b^2p = C = t^2f/750 \quad \text{(Eq. C3)}$$

where
b = span (m)
t = thickness of glass (mm)
f = design stress of the glass (mPa)
p = design wind pressure (kPa)
C = a constant for a given glass thickness

NOTE – The design wind pressure has been factored up by 1.28 from working stress as a soft conversion to limit state design in the preparation of the charts.

4.C2.2
In these tables the design stress used for glass was 16.7 MPa (the design stress for annealed glass).

4.C3 Maximum aspect ratios for rectangles of glass supported on all sides

4.C3.1

For each thickness of glass there is an aspect ratio, a/b, above which the rectangle of glass given by the figures for glass supported on all sides would be more conservative than that given by the graphs for glass supported on two opposite sides only, it being assumed that the span between the supports is the short side, b. The value of a/b at which exactly the same thickness, of glass would be given by either criterion can be determined as follows:

(a) For glass up to and including 6 mm thickness:

(i) For four edge support, equation (C1) can be written as:

$$abp = 0.2t^{1.8} \quad \text{(Eq. C4)}$$

(ii) For two edge support, equation (C3) can be written as:

$$b^2p = 16.7t^2/750 \quad \text{(Eq. C5)}$$

Dividing (Eq. C4) by (Eq. C5):

$$a/b = 8.98/t^{0.2} \quad \text{(Eq. C6)}$$

This gives the maximum aspect ratio for the application of Chart 1 for any thickness, t, up to 6 mm.

(b) For glass thicker than 6 mm:

(i) For four edge support, the equation (C2) can be written as:

$$abp = 0.2t^{1.6}+1.9 \quad \text{(Eq. C7)}$$

(ii) For two edge support, the equation (C3) can be written as:

$$b^2p = 16.7t^2/750 \quad \text{(Eq. C8)}$$

Dividing (Eq. C7) by (Eq. C8):

$$a/b = 44.91\ (0.2t^{1.6} + 1.9)/t^2 \quad \text{(Eq. C9)}$$

This gives the maximum aspect ratio for the application of Chart 1 for any thickness, t, greater than 6 mm. It will be noted that the values of a/b given by equations (C6) and (C9) are independent of p.

4.C4 Consideration of glass other than ordinary annealed glass

4.C4.1

The following approximate factors can be used to calculate the strength of different types of glass. The graphs shown on Charts 1 to 12 should be used if more accurate calculations are required.

Table 4.C1 – Factor for relative resistance to wind load for glasses of equal thickness

Type of glass	Pressure factor	
	Area factor	Span factor
Ordinary annealed glass	1.0	1.0
Sand blasted annealed(1)	0.5	0.7
Wired	0.5	0.7
Laminated(2)	0.8	0.9
Patterned(3)	1.0	1.0
Insulating glass units (2 panes)(4)	1.5	1.2
Heat strengthened(5)(a)	1.6	1.3
Toughened(5)(b) and (6)	2.0	1.4

NOTE –

(1) Sandblasting will significantly reduce the strength of all glass types and there are no standards controlling the sandblasting of glass.

(2) If the maximum working temperature of the laminated glass is greater than 70 °C, then the pressure factor shall be reduced to 0.6.

(3) For any patterned glass, the thickness is measured at its minimum thickness whence the appropriate relationship applies.

(4) Based on the two panes having equal nominal thickness. For unequal nominal thicknesses, the manufacturer's advice should be sought.

(5) The pressure factor has been based on the following minimum stresses:

(a) Heat strengthened glass: When tested in accordance with AS/NZS 2208 Appendix I, heat strengthened glass shall have stresses within one or the other of the following limits:

(i) Surface compression: 24.14 MPa to 68.94 MPa.

(ii) Edge compression stress: 37.93 MPa to 66.87 MPa.

(b) Toughened glass: When tested in accordance with AS/NZS 2208 Appendix I, toughened glass shall have:

(i) Surface compression of not less than 68.94 MPa; or

(ii) Edge compression of not less than 66.87 MPa.

For higher induced stresses, correspondingly higher pressure factors may be used provided that the level of safety is not reduced.

(6) Toughened glass deflection: Serviceability deflection has been restricted to span/60.

4.C4.2
The maximum area of any of the types of glass shown in table 4.C1 that can be used in four edge support shall be obtained by determining the area of annealed glass that could be used and multiplying by the area factor of the actual glass to be used.

4.C4.3
The maximum span of any of the types of glass shown in table 4.C1 can be used in two opposite edges supported which shall be obtained by determining the span of float glass that could be used and multiplying by the span factor of the actual glass to be used.

4.C4.4
For normal toughened glass the allowable deflection is span/60 for both four and two edge support. If the system can allow greater deflection, the manufacturer should be consulted.

4.C4.5 *EXAMPLE 1*
Consider annealed glass, size 1.8 m x 1.2 m, in a rectangular plan building 10 m high in the flat urban area of Dunedin and calculated as follows:

(a) Calculations of glass area and aspect ratio – for glass supported on four edges.
Area = 1.8 x 1.2 = 2.16 m^2
Aspect ratio = 1.8/1.2 = 1.5

(b) Determination of ultimate limit state design wind pressure using Appendix 4.A, the terrain category is 3. From table 4.A1 the ultimate limit state wind pressure is 0.91 kPa.

(c) Determination of thickness of glass – for glass supported on four edges.
From the appropriate graph for annealed glass with four edge support (Chart 1), the line of 0.91 kPa crosses the area of 2.16 between 3 mm and 4 mm thickness. Therefore the 4 mm thickness is required. The calculated aspect ratio of 1.5 determined in (b) does not exceed the value of 6.8 given as an upper limit on the graph.

4.C4.6 *EXAMPLE 2*
Insulating glass units, consisting of 6 mm annealed glass for both panels are required to withstand an ULS design wind pressure of 3.1 kPa. Determine the maximum area permissible.

The area factor for insulating glass units is 1.5 from table 4.C1 and Chart 1 at an ULS design wind pressure of 3.1 kPa, the maximum area of annealed glass is 1.95 m^2. Using the area factor of 1.5, the maximum area of an insulating glass unit will be 1.95 x 1.5 = 2.93 m^2.

4.C5 Non-standard glass thickness

4.C5.1
For non-standard glass thickness, linear interpolation as defined in section 3 of AS 1288 shall apply.

4.C5.2
To determine the minimum thickness required, use the minimum tolerance from AS 1288 in accordance with the method from Appendix A.

APPENDIX 4.D
WORKED EXAMPLE
(Informative)

4.D1

A conservatory is to be built onto the side of an existing house. The roof is pitched at an angle of 45 degrees. The height to the apex is 4 metres. The building is located in a flat suburban area in Lower Hutt (Terrain Category 3). Glass is to be supported on two edges with the suggested span between aluminium supports at 650 mm. What type and thickness of glass would be used?

4.D2

Determine the ultimate design loads on glass as follows:

(a) *Wind load*

From table 4B.1, the basic ULS wind pressure is 0.67 kPa. Enter column 1 of table 4B.3 at 0.7 kPa (next pressure increment). From the column for a 45º roof pitch, read the "Wind(↓)" and "Wind(↑)" ULS design pressures of 0.91 kPa and –0.84 kPa.

(b) *Glass dead weight*

From table 4.1, for 45º slope, select the glass dead weights, dead(maximum) of 0.33 kPa and dead(minimum) of 0.10 kPa.

(c) *Snow load*

From figure 4.1, for flat land areas below 200 metres altitude in Lower Hutt, there is no snow load requirement.

(d) *Load combinations*

Combine the loads in (a), (b) and (c) in accordance with 403.2.2 and select the greatest pressure.

Case 1 Dead (maximum) + Wind (↓) = 0.33 + 0.91 = 1.24 kPa
Case 2 No snow load so case 2 need not be considered
Case 3 Dead (minimum) + Wind (↑) = 0.10 + (–0.84) = –0.74 kPa

4.D3 Glass size and thickness

If the conservatory is to be used as a sun room, safety glass must be used in the roof.

From Chart 6, for two edge supported laminated glass at an ULS design pressure of 1.24 kPa and a span of 650 mm, the minimum glass thickness is 6 mm;

or

From Chart 4, for two edge supported toughened glass at an ULS design pressure of 1.24 kPa and a span of 650 mm, the minimum glass thickness is 4 mm. Adjust the dead(maximum) down by 4/6 (=0.67) to 0.22 kPa and the dead(minimum) down by 4/6 to 0.07 kPa. Case 1 then becomes 1.13 kPa and case 3 becomes –0.77 kPa. From Chart 4, 4 mm minimum glass thickness is still required.

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