AS/NZS 4284:2008

Australian/New Zealand Standard™

Testing of building facades

STANDARDS Australia

STANDARDS NEW ZEALAND PAEREWA AOTEAROA

AS/NZS 4284:2008

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Australian Steel Institute
Building Research Association of New Zealand
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Testing of building facades

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PREFACE

This Standard was prepared by the Joint Australia/New Zealand Standards Committee BD-080 on Curtain Walls to supersede AS/NZS 4284:1995.

The Standard is based on 'Specification for the performance testing of building facades by the SIROWET method' published by CSIRO, Division of Building, Construction and Engineering now it is known as Manufacturing and Infrastructure Technology.

This Standards is derived from publication by the CSIRO on the method of facade testing developed by the CSIRO and known as SIROWET. These publications are the following:

(i) 'The SIROWET Rig, for testing weatherproofness of building facades' by N.G. Brown and E.R. Ballantyne, CSIRO Division of Building Research 1975.

(ii) 'Specification for the performance Testing of Building Façade by the SIROWET Method', January 1990. Division of Building, Construction & Engineering, CSIRO—Australia.

(iii) 'The SIROWET Method; Specification for the Performance Testing of Building Facades by the SIROWET Method', June 1992 ISBN 0 643 050930. This specification (TR92/6) is effective from 30 June 1992 and supersedes (TR 90/2) dated February 1990.

Consideration has been given to maintaining compatibility with NZS 4211:1985, *Specification for performance of windows* and with Amendment No. 3 which converts the earlier working stress basis to limit state design requirements. It should be noted that the water test pressure calculated in NZS 4211 Amendment No 3 is based on an alternative serviceability wind pressure definition and not equivalent to serviceability pressure determined in AS/NZS 1170.2.

The objective of this Standard is to provide those persons or organizations involved with the specification, design, purchasing and construction of building facades with a method for determining the performance of a building facade under wind and other optional loadings. This test method is applicable to complete facades and is intended to assess the overall system performance and interaction of the various facade components.

The Committee has made a number of significant changes and additions to the original SIROWET method and these include the following:

(a) Change to limit state principles from working stress.

(b) Addition of optional seal degradation, seismic and building maintenance unit (BMU) restraint tests.

(c) Addition of several appendices, including a pro forma for test loads and limits.

Test pressures nominated in the Standard represent minimum default values that should be applied to the test sample; however, selection of pressure values should be based on the proposed usage of the structure, its exposure conditions and of the expected performance of the facade.

For high rise residential and commercial building facades (buildings typically greater than 25 m) or at particularly exposed sites that incorporate curtain wall, strip windows, opening window sashes, sliding doors, bifolding doors and the like, the methods of test described in this Standard are applicable to prove performance of the system. Facade elements in these situations can be subjected to the same environmental factors such as a continuous facade on an office building—particularly wind-driven rain. The non-uniform nature of wind-driven rain has led to the adoption in this Standard of the cyclic pressure water test and the SIROWET method before it. Appropriate additional testing parameters, such as those described in Table 2.2 of AS 2047—1999, *Windows in buildings—Selection and installation* and AS 4420.3—1996, *Windows—Methods of test*, Method 3: *Operating force test* as well as the torsional rigidity of building elements as covered in Clause 13 of NZS 4211:1985 *Specification for performance of windows*, should also be considered for relevant elements.

The term 'informative' has been used in this Standard to define the application of the appendix to which it applies. An 'informative' appendix is only for information and guidance.

CONTENTS

STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Testing of building facades

1 SCOPE

This Standard sets out a method for determining the performance of a representative building facade under simulated conditions of loading. This Standard may be applied to all types of facades including low- and high-rise, commercial, industrial and residential buildings. Tests include displacement of the facade or prototype, water penetration and structural integrity at ultimate limit state as well as optional tests, including BMU restraint, seismic loading and seal degradation. This test method is applicable to prototype testing in a test facility and on-site testing.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS	
1170	Structural design actions
1170.4	Part 4: Earthquake loads
AS/NZS	
1170	Structural design actions
1170.0	Part 0: General principles
1170.1	Part 1: Permanent, imposed and other actions
1170.2	Part 2: Wind actions
NZS	
1170	Structural design actions
1170.5	Part 5: Earthquake actions—New Zealand
4211	Specification for performance of windows
ISO/IEC	
17025	General requirements for the competence of testing and calibration laboratories

3 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

3.1 BMU

Building maintenance unit.

3.2 Framing members

The elements, such as mullions and transoms that support facade panels.

3.3 Specifier

The person or party responsible for the facade Specification, nominating the use of this Standard, the test sample, sequence, pressures and performance criteria.

3.4 Test facility

Either a laboratory or any other facility registered by an accredited-testing agency in accordance with ISO/IEC 17025.

3.5 Uncontrolled water

Any leakage that is not contained and drained away during the water spray operation and for 5 min after the water spray has stopped during which time there is zero air pressure differential on the facade.

4 NOTATION

The following symbols are used in this Standard:

D_e = average of net end displacements, in millimetres

D_m = maximum displacement of member (generally at midspan), in millimetres

d_s = seismic test displacement amplitude at the serviceability limit state, in millimetres

d_u = seismic test displacement amplitude at the ultimate limit state, in millimetres

K_d = deflection amplification factor, in millimetres

M = overturning moment, in kilonewton metres

n = number of cycles in the seismic test

R_f = structural response factor

S = span of member between points of support (transducers), in millimetres

T = period of the seismic cycle, in seconds

W_s = positive serviceability test pressure, in millimetres

5 PRINCIPLE

A sample of the building facade forms one face of an externally mounted chamber and is sealed at its perimeter and then successively subjected to a structural test, a water penetration test and a strength test.

NOTES:

1 Additional tests requested by the Specifier may include an air infiltration test, seismic loading by in-plane displacements, a simulated seal degradation test and a BMU restraint load test.

2 For information on sample preparation, see Appendix B.

6 APPARATUS

The following apparatus is required:

(a) An externally mounted chamber of a size to fit to the test sample of the building facade. The fit shall be such as to seal the perimeter of the test sample against air and water penetration.

NOTE: The use of an internally mounted pressure box is suitable for all static pressure tests but may not adequately demonstrate water penetration in pressure-equalized systems in the cyclic pressure test.

(b) A reversible air pump with controls to pressurize and depressurize the chamber.

(c) Water sprays positioned so that when the sprays are in operation, the external face of the test sample is covered with water.

(d) Displacement transducers capable of measuring deflections to an accuracy of ±0.2 mm.

(e) An orifice plate or laminar flow elements or other airflow measuring device calibrated to a traceable standard.

(f) A manometer capable of measuring air pressure to an accuracy of ±2% of measuring range. The manometer used during the cyclic water test shall have a fast response time of at least 0.05 s.

7 SAMPLE PREPARATION

7.1 Test sample

The sample, with components, shall be representative both in size and shape of the facade of the building. Vertical and horizontal movement joints shall be included in the test sample. The joints shall be set on the sample within the design joint width including tolerances.

The materials of the test sample (glass, aluminium, stone, reinforced concrete, sealants, gaskets, etc.) shall be of the same type and size, have undergone the same method of construction, and have the same details, flashing and anchorage as the building facade.

If not an actual on-site representative sample of the wall of the building, the test sample shall be mounted and sealed into a simulated building frame in the same manner and by the same fixings that are intended to attach the facade to the building structure. The support frame shall be of similar stiffness to the supporting building structure.

NOTE: For discussion of the supporting structure, refer to Appendix B.

Simulated floor slabs and spandrel beams shall be to actual depth if, for example, in curtain walls, the air seal is connected to the slab. The internal finishes and linings shall be installed where they contribute to the air seal. The air seal of the test sample shall be continued to the air seal of the test chamber.

All framing members and other interconnected joints in the facade shall be sealed at the sample boundaries.

NOTE: This is to minimize the effects that the surrounding construction will have on the test performance of the sample.

All pressure equalization and drainage openings in the test sample shall be left open for the duration of testing.

NOTE: Transparent viewing panels (or other means of observation, such as an optical fibre probe) should be provided so that the performance of the test sample in areas that are not readily seen can be observed. They should be sized and sited to have a negligible minimal effect on the water and structural performance of the test sample.

7.2 Drawings

Shop drawings shall be supplied to the test facility before installation of the test sample. These drawings shall include the following:

(a) Test sample elevation and vertical and horizontal sections.

(b) Typical details of framing members and facade panels (including intersections of members).

(c) All fixing brackets and support details.

(d) Extent and type of sealants.

(e) Size, position and number of pressure equalization and drainage openings.

(f) Complete building in and blanking off details around the perimeter of the sample, including the chamber details where significant to sample performance.

(g) Location of transparent viewing panels if used.

(h) Method of installation.

(i) Location of displacement transducers.

8 PROCEDURE

8.1 Test sequence

8.1.1 *General*

The sample shall be subjected to the tests in Items (a), (b), (d) and (g). The other tests shall be carried out only if specified. The test sequence shall be as follows:

(a) Preliminary tests.

(b) Structural test at serviceability limit state.

(c) Air infiltration test.

(d) Water penetration test by static pressure followed by cyclic pressure test.

(e) Seismic test at serviceability limit state displacement (includes subsequent water penetration test).

(f) BMU restraint test.

(g) Strength test at ultimate limit state.

(h) Seismic test at ultimate limit state displacement.

(i) Seal degradation test.

8.1.2 *Variation of test sequence or retesting*

Where a variation of the test sequence is required, or if the test sample requires modification to gaskets, joint seals or drainage details to enable it to pass either the air infiltration or the water penetration test, both tests shall be repeated in full. Before retesting, the full positive and negative structural-test pressures (W_s) shall be applied to the test sample for 2 min each.

8.2 Preliminary tests

8.2.1 *General*

The tests in Clauses 8.2.2 and 8.2.3 shall be conducted before the structural test. Before prototype testing the information required in Appendix A shall be submitted by the Specifier.

8.2.2 *Static pressure*

The test sample shall be subjected to the positive and negative SLS design wind pressures. These pressures shall be maintained for 10 s at the positive requirement followed by 10 s at the negative requirement.

8.2.3 *Water*

Preliminary water tests shall be conducted under static and cyclic pressures in accordance with Clauses 8.5 and 8.6.

8.3 Structural test at serviceability limit state

8.3.1 *Structural-test pressures*

The structural-test pressures (W_s) are the positive and negative SLS design wind pressures. They shall be calculated in accordance with AS/NZS 1170.0 and AS/NZS 1170.2 and include all local pressure factors and internal pressures relevant to the location of the sample on the building.

The minimum serviceability requirements shall be for an annual probability of exceedance of 1/20 (0.05).

NOTE: Information on structural and strength test at ultimate limit state loading is given in Appendix C.

8.3.2 *Location of the displacement transducers*

The framework to support the displacement transducers shall be rigidly fixed independent of the test sample.

NOTE: The building frame (actual or simulated) is not part of the test sample.

Displacement readings shall be taken on the test sample at designated framing members, facade panels and window locations that would represent actual structural movement. Displacements shall be taken, at least, at the ends of the framing member or between fixings and at midspan, and also below and above (or to the left or right of) movement joints of framing members and across the shortest span of the largest panel or glass pane included in the test sample.

NOTE: Where members of facade framing systems are not simply supported over a single span, the points of maximum deflection are unlikely to fall midway between the support brackets connecting the facade to the building. In these cases the points of maximum deflection should be identified by structural analysis and displacement readings taken at these points.

Sufficient displacement transducers shall be located at the fixing brackets so that any differential movement between the various components and the support structure will be identified.

The location of all displacement transducers shall be nominated or approved by the Specifier.

8.3.3 *Pressure loading sequence*

Displacements shall be measured at all pressure (positive) and suction (negative) sequence steps by calibrated displacement transducers.

The loading sequence during test (as shown in Figure 1) consists of three modes and shall be as follows:

(a) An initial pressure differential equivalent to either the positive or the negative structural-test pressure shall be applied against the external face of the test sample for a period of 2 min which shall be taken as a settling/take-up period.

(b) The differential pressure shall be removed and the zero position of the transducers recorded after 2 min of zero pressure (see Figure 1, zero stage Z1).

(c) Differential pressures in the same direction as in Item (a) shall then be applied to the external face of the test sample in not less than five approximately equal steps, until the pressure reaches the structural test loading. The pressure shall be held at each step for at least 1 min before the displacements are recorded.

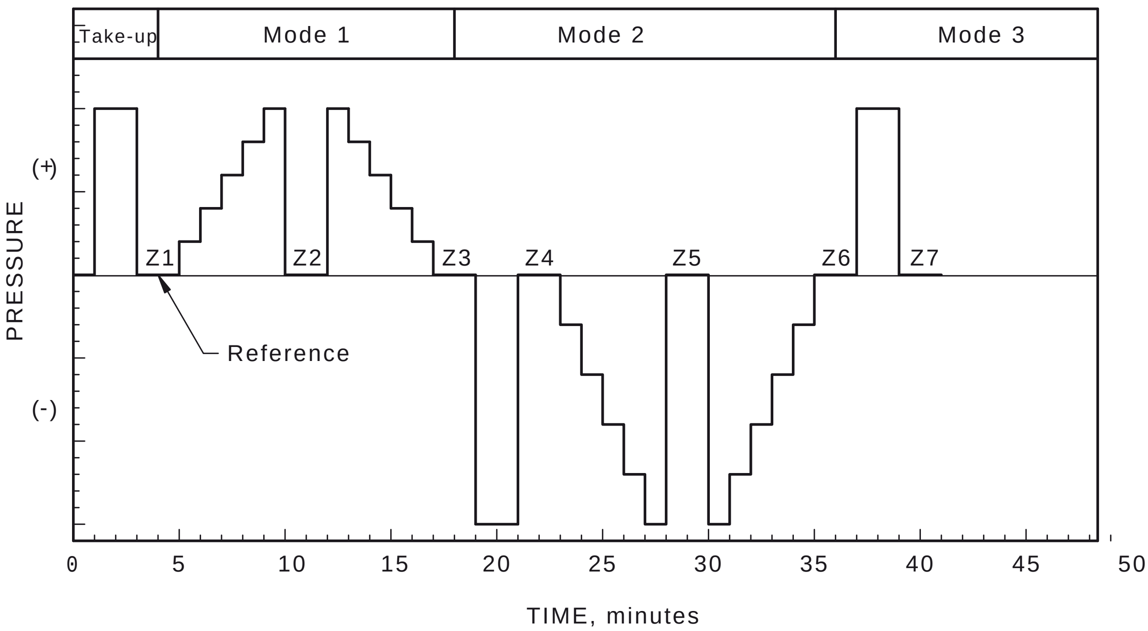
(d) The differential pressure shall be removed and the zero position of transducers recorded after 2 min of zero pressure (see Figure 1, zero stage Z2).

(e) The structural-test loading shall be applied again to the external face of the test sample and maintained for at least 1 min. The differential pressure shall then be reduced in the same number of steps as the increasing pressure regime ((see Item (c)). The pressure shall be held at each step for at least 1 min before the displacements are recorded. Also, the zero position of the transducers shall be recorded after 2 min of zero pressure (see Figure 1, zero stage Z3).

(f) The procedure in Items (a) to (e), inclusive, shall be repeated using the opposite structural test design loading.

(g) The procedure in Items (a) and (b) shall be repeated using the initial differential pressure.

NOTE: Items (b) to (e) are referred to as Mode 1, Item (f) as Mode 2 and Item (g) as Mode 3.



NOTE: The displacements used for deflection/span ratios are based on zero deflections at the reference stages Z1 and Z4. The reducing pressure steps from Z2 to Z3 and from Z5 to Z6 are optional.

FIGURE 1 TYPICAL STRUCTURAL TEST SEQUENCE

8.3.4 *Displacement measurement of spandrel panels*

If the facade specification requires displacement measurements of spandrel panels which form the exterior face of a spandrel box and the spandrel box is a pressure-equalizing design, a separate test is required.

Deflection measurements taken of the spandrel panels during the structural test sequence indicated above shall not be accepted as true readings of spandrel panel deflection, as the spandrel panels may not be under full test load, due to the extent of pressure equalization of the spandrel box chamber.

The spandrel panel measurement may be carried out immediately after the structural test sequence has been completed, or any other time before the strength test at ultimate limit state pressure.

Holes shall be installed in the prototype in a location agreed with the testing officer (usually in the back-pan), so that, when the test pressure is applied, the pressure difference will be across the spandrel panel. These holes may be installed before testing and covered for other tests.

Deflection transducers may be installed through the holes in the back-pan, to the internal surface of the spandrel panel or to the external surface of the spandrel panel.

The loading sequence of structural loadings shall be repeated as shown in Figure 1, taking deflection measurements of the spandrel panels. The test pressure for the spandrel panels may be reduced in accordance with the porosity provisions of AS/NZS 1170.2. During this test, pressure readings shall be taken both inboard and outboard of the spandrel panel(s) for which deflection measurements are being taken, to ensure that the pressure differential across the spandrel panel(s) is equal to the agreed spandrel test pressure.

When the spandrel deflection measurements have been taken and this test is complete, the holes shall be covered, so that the pressure difference in the spandrel box is applied across the back-pan and the prototype is effectively restored to the in-service condition. The hole covers shall be structurally continuous with the member to which they are attached and any sealant used in the covers is adequately cured before testing is resumed.

8.3.5 *Calculation of deflection/span ratio*

Where a framing member of the test sample is effectively supported at its ends only, its midspan deflection and resultant deflection/span ratio under load shall be calculated. The displacement for each transducer at the ends and midspan of the member and each mode (positive and negative) shall be reduced to a deflection and deflection/span ratio using the relationship—

$$\text{Deflection / span ratio is } 1 : \frac{S}{D_m - D_e}$$

where

S = span of member between points of support (transducers)

D_m = maximum displacement of member (generally at midspan)

D_e = average of net end displacements

The greater of the two deflections in positive and negative modes shall be used in the calculation of the deflection/span ratio for the members and panels. Significant variations in the ratios at the design pressure steps (that is either side of mid-mode steps) shall be noted in the final report.

Mode 1 deflection readings shall be referenced to Z1 and Mode 2 deflection readings shall be referenced to Z4.

NOTE: When stack joints are involved in the case of unitized curtain wall mullions, the maximum displacement may vary from the midspan between the support and the stack joint. In such instances it is recommended the transducer location for maximum displacement be checked with the aid of structural analysis software or design charts (see Figures C1 and C2).

8.3.6 *Calculation of successive member displacement*

The successive displacement of a member is the zero air pressure displacement (relative to the reading after initial take-up) measured during the structural performance test (refer to Figure 1)—

(a) between maximum pressures in Mode 1 (stage Z2);

(b) before take-up in Mode 2 (stage Z3);

(c) after take-up in Mode 2 (stage Z4);

(d) between maximum pressures in Mode 2 (stage Z5);

(e) before take-up in Mode 3 (stage Z6); and

(f) after take-up in Mode 3 (stage Z7).

8.3.7 *Calculation of maximum displacement*

The maximum displacement in Mode 1 shall be referenced to Z1 and maximum displacement in Mode 2 shall be referenced to Z4.

NOTE: Referencing of the mode of displacement to the Z4 zero values provides the equivalent member displacement as determined for Mode 1 while maintaining the successive member displacement values Z1 to Z7.

8.4 Air infiltration test

8.4.1 *Test pressure*

The air infiltration test pressure shall be as specified or taken as +150 Pa and –150 Pa.

8.4.2 *Procedure*

The total air infiltration rates through the test sample and the test enclosure shall be determined by applying both positive and negative test pressures. No further testing shall be required if the air infiltration rates determined on the combined test specimen and test enclosure are less than the purchaser-specified air infiltration rate or the value in Clause 9.3, and there is no requirement for actual infiltration rates through the test specimen.

Where the total air infiltration rate is greater than the purchaser-specified air infiltration rates or the value in Clause 9.3, or the purchaser/specifier requires actual air infiltration rates, the face of the test sample shall be sealed airtight by covering it with an impervious film. If this is not practicable, all joints, weepholes and glazing or sealant lines of the test facade shall be sealed with air-impervious tape and the air infiltration rates for the enclosure only determined. The air infiltration rates through the test sample shall be the difference between the total and sealed airflow meter readings at both positive and negative test pressures.

NOTE: Air infiltration testing is described in Appendix D.

8.5 Water penetration test by static pressure

8.5.1 *Test pressure*

The water penetration test pressure shall be nominated by the Specifier, or taken as the greater of 300 Pa or 0.3 W_s.

8.5.2 *Procedure*

The test facade shall be subjected to water sprayed completely and continuously over the exterior face of the test sample at a rate not less than 0.05 L/m^2 s (3 L/m^2 min).

At the start of the test, the water spray shall operate for 5 min with zero air pressure differential on the facade. This shall be followed by a further period of 15 min at the test pressure. Observations of the internal surface of the facade shall be carried out during the water spray operation and for 5 min after the water spray has stopped and there is zero air pressure differential on the facade.

Any water appearing on the inside surfaces of the facade shall be recorded, with the extent and, if possible, the source of leakage indicated.

8.6 Water penetration test by cyclic pressure

8.6.1 *Test pressure*

The water penetration test using cyclic pressure shall be carried out in three stages and shall take into account the geographical location and exposure of the building and shall be specified by the Specifier, or taken as the following:

(a) Stage 1 .... $0.15 \times W_s$ to $0.3 \times W_s$.

(b) Stage 2 .... $0.2 \times W_s$ to $0.4 \times W_s$.

(c) Stage 3 .... $0.3 \times W_s$ to $0.6 \times W_s$.

where

W_s = positive serviceability test pressure. (Should W_s pressure be less than 1000 Pa, use 1000 Pa instead of W_s in this Clause.)

NOTE: Where buildings are located in Wind Regions B, C and D as defined in AS/NZS1170.2, the test pressures as a function of the serviceability wind pressures (and velocities) should be increased in line with historic data for wind driven rain at the local area in question.

8.6.2 *Procedure*

This test shall be performed upon completion of the test for water penetration test by static pressure.

Should the cyclic water penetration test not commence within 30 min of the static water penetration test then immediately before the start of the cyclic test the exterior face of the test sample shall be completely sprayed with water at a rate not less than 0.05 L/m^2 s for 5 min with zero air pressure differential on the facade.

Water shall be applied continuously and completely cover the exterior face of the test sample at a rate not less than 0.05 L/m^2 s while a cyclic positive air pressure is applied to the exterior face for a duration of not less than 5 min. The applied test pressure shall be varied between the specified limits with a cycle time of 3 s to 5 s.

The cyclic pressure shall be recorded on a device capable of recording and graphically displaying the variations in pressure.

NOTE: Water gauge manometers and other slow response pressure indicators are unsuitable for this purpose.

The air pressure differential shall be reduced to zero for 2 min between each stage with the water spray still in operation. Observation of the internal surfaces of the facade shall be carried out during the water spray operation and for 5 min after the water spray has stopped during which time there is zero air pressure differential on the facade.

The appearance of any water on the inside surfaces of the facade shall be recorded, with the extent and, if possible, the source of leakage indicated.

NOTE: Further information on water penetration testing is given in Appendix E.

8.7 BMU restraint test

8.7.1 *Test load*

The load designated in this test shall be ultimate limit state and shall be specified by the Specifier, taking into account the size and operation of the BMU.

NOTE: There may be regulatory requirements that will determine the magnitude of the test load.

8.7.2 *Procedure*

The BMU restraint unit shall be fitted to a specified restraint point. A lanyard and clip or other restraint system as specified for use shall be attached to the restraint and the other end attached to a cable attached to a load cell reading device and this in turn attached to a cable which is attached to a tensile loading device applying the required load. The load shall be applied in three stages, as follows:

(a) The restraint shall be subjected to a tensile load applied orthogonally and horizontally to the sample, and applied for a minimum of 10 s.

(b) The restraint shall be subjected to a tensile load applied horizontally to the left of the anchorage point in the plane of the sample. This load shall be applied for a minimum of 10 s.

(c) Stage (b) shall be repeated with the load directed to the right of the anchorage point.

8.8 Structural test at ultimate limit state

8.8.1 *Test pressures*

The strength test pressures shall be the facade positive and negative ultimate limit state wind pressures calculated in accordance with AS/NZS 1170.0 and AS/NZS 1170.2 and shall include all local pressure factors and internal pressures relevant to the location of the sample on the building.

8.8.2 *Procedure*

The test sample shall be subjected to positive and negative strength test pressures. Each strength test pressure shall be maintained on the test sample for a period of 10 s.

The load period from zero to ultimate limit state pressure shall be 50 s to 60 s.

The sample shall be inspected at the end of each of the positive and negative pressure stages. Record all incidences of non-linear deflection and/or collapse.

8.8.3 *Spandrel panel*

If the facade specification requires a structural test at ultimate limit state spandrel panels shall be tested in a repeat structural test at ultimate limit state procedure. Follow the set-up requirements indicated in Clause 8.3.4. Repeat the procedure indicated in Clause 8.8.2 with pressure transducers which measure the pressure difference inboard and outboard of the spandrel panels. The number of spandrel panels instrumented is to be agreed with the involved parties before the test.

The structural test at ultimate limit state for the spandrel panels may be carried out either before or after the structural test at ultimate limit state for the other prototype members and components.

8.9 Seismic test

8.9.1 *Test displacement*

The sample shall be displaced in the plane of the facade sample for n cycles at a period T, for distance of $\pm d_s$ or $\pm d_u$ mm from the original setting position. The values of n, T and d_s or d_u shall be specified and based on the serviceability and ultimate limit states appropriate to the geographical region.

The appropriate values of d_s at serviceability and d_u at the ultimate limit state seismic displacements shall be determined by the building structural designer.

8.9.2 *Procedure*

One of the reaction beams shall be selected by the Specifier as a seismic loading floor. This beam shall be capable of sliding back and forth to simulate lateral seismic motion. The facade support brackets shall be attached to the moveable beam.

Lateral displacements of the sample shall be measured as the relative displacement between the lateral fixed support and moveable beam. The mechanism to move the beam shall be of sufficient strength to react to the required test period.

Inspect and report the condition of the prototype after the completion of all the cycles.

Serviceability limit state displacement test is first carried out, followed by a cyclic water penetration test, in accordance to Clause 8.6.

The ultimate limit state displacement test may be carried out before or after the ultimate limit state structural test.

NOTES:

1 No water test is required after the seismic test at ultimate limit state displacements.

2 Further information on seismic testing is given in Appendix F.

8.10 Seal degradation test

The Specifier shall designate areas of the sample where seals are to be removed or cut by knife to simulate long-term degradation of the sample. All changes to the sample shall be reported. A cyclic water penetration test shall be carried out in accordance with Clause 8.6.

9 PERFORMANCE REQUIREMENTS

9.1 General

The performance requirements listed in the remaining sections of Clause 9 shall be used in the absence of alternative performance requirements provided by the Specifier.

All components of the sample are required to remain structurally intact as detailed on test sample drawings with no signs of visible damage or distortion following the structural performance, air infiltration and water penetration tests.

9.2 Structural test at serviceability limit state

9.2.1 *Deflection/span ratios*

When tested to serviceability wind pressures and using the method of calculation described in Clause 8.3.5, no framing members shall deflect by an amount greater than span/250 mm. For mullions, the span shall be taken to be the distance between fixing positions, in millimetres.

9.2.2 *Successive member displacement*

The successive member displacement calculated from Clause 8.3.6 shall not exceed 3.0 mm.

9.2.3 *Maximum displacement*

The maximum displacement of a framing member calculated from Clause 8.3.7 shall not exceed 20 mm, or a lower figure specified in the facade specification.

For frames greater than 5 m between supports, the maximum frame displacement shall be agreed with the Specifier, but not more than the limit described in Clause 9.2.1 (see Figure C2, Appendix C).

9.3 Air infiltration test

Air infiltration for airconditioned buildings shall not exceed 1.6 L/m^2s.

NOTE: If the total air infiltration of the sample and the test apparatus is less than the value given, the sealing of the test sample may be omitted and the test report should quote the total air infiltration reading of the sample and system. (Refer Appendix D.)

9.4 Water penetration test

Under static and cyclic pressures there shall be no leaks.

For both the static and cyclic water tests, a leak is considered to occur when one or more of the following occur:

(a) Water appears on any inside surface of the facade and is visible from an occupied space.

(b) Uncontrolled water appears on any inside surface of the facade.

(c) Water appears that is likely to wet insulation, fixtures and finishes.

(d) Water appears in other locations specified as unacceptable by the Specifier.

9.5 Seismic test at serviceability limit state displacement

The sample shall pass the criteria set for the cyclic water penetration test (see Clause 8.6) after the seismic test at the SLS displacements.

9.6 BMU restraint test

After the load is released in each step, any deformation of the sample at or near the loading point shall be recorded. A failure shall be recorded if the BMU restraint becomes unserviceable or separates from the sample.

9.7 Structural test at ultimate limit state

Under structural test at ultimate limit state there shall be no collapse of the test sample. Collapse shall mean any one or any combination of the following:

(a) Disengagement or partial disengagement of any framing member, facade panel or any part thereof.

(b) Failure of any fixings that connect the facade to the building structure.

(c) Failure of any stop, locking device, fastener or support which could allow an opening light to come open.

(d) Repeated breakage of glass resulting in loss of chamber pressure. Glass may only be replaced once before the sample is deemed to have collapsed.

(e) Repeated cracking of glass which does not result in loss of chamber pressure. Glass may only be replaced twice before the sample is deemed to have collapsed.

Any permanent distortion of a panel shall be noted and documented in the report.

NOTE: At the ultimate limit state load the sample may suffer permanent deformation and might not remain operational. This Clause is intended to protect people in the vicinity of the building should a window collapse under extreme conditions.

9.8 Seismic test at ultimate limit state displacement

The sample shall not collapse during or after the seismic test at ultimate limit state displacements. Any damage to the seals, members or panels shall be recorded and noted in the report. Collapse shall mean any one or any combination of the occurrences described in Clause 9.7(a) to (d).

9.9 Seal degradation test

The sample shall be observed for water penetration after the nominated seals have been altered.

NOTE: For domestic buildings in New Zealand it has been found that the removal of 10% of the air seal is appropriate.

10 TEST REPORT

10.1 Preliminary test report

The test report can be a separate report from the official test report, or incorporated as part of the official test report. All details of preliminary test(s) shall be included in the preliminary test report, including full details of all modifications/rectifications carried out on the facade test sample prior to the official test.

10.2 Official test report

The report shall include the following:

(a) The name of the project, client and Specifier, sample designer/manufacturer and installer as appropriate, as well as the time and date of the test, the test schedule, the identification of official persons observing the testing, name, location and accreditation of the testing facility and the testing officer with responsibility of measuring and recording data and producing the test report, and reference to preliminary test report(s) issued separately. Completed Appendix A form from the Specifier and a summary of results.

(b) A Certificate of Identification from the facade designer and manufacturer stating that the facade test sample is a true representation of the facade to be erected on the building and it incorporates identical materials and construction methods. The Certificate shall also include the comprehensive list of drawings, which shall describe the facade test sample, and included in the report.

(c) A general description of the facade test sample.

(d) Drawings of the test sample showing modifications, if any.

(e) Test sequence with pressures used in all tests.

(f) For the structural test, provide for each member—

(i) location of all transducers;

(ii) spans of relevant members, given as measured distances between transducers;

(iii) deflection/span ratios;

(iv) maximum displacement;

(v) a separate zero table, giving readings for Z1 to Z7;

(vi) successive member displacement; and

(vii) a full set of readings in an appendix.

(g) For the air infiltration test—

(i) the air infiltration through the test sample and the system for each of the air infiltration test pressures; and

(ii) an estimation of the test accuracy, based on good laboratory practice.

(h) For each of the static and cyclic water penetration tests full details of all leakages, including position extent and timing.

(i) Seismic test SLS displacements; the location of the moving support beam, damage to seals, members or panels and changes in movement joint positions and/or sizes.

(j) Ultimate limit state test; details of all permanent distortion and collapse.

(k) Seal degradation test; drawings and description of seals altered and observations made during the test.

(l) Details of the BMU restraint, its position on the sample and observations during and after loading.

(m) Seismic test ultimate limit state; report as per seismic test SLS.

(n) Reference to this Joint Australian/New Zealand Standard, i.e., AS/NZS 4284.

APPENDIX A

INFORMATION TO BE SUPPLIED BY SPECIFIER

(Normative)

The Specifier shall complete this test request form for specific test pressures and limits.

NOTE: Values specified in the Standard are defaults and the Specifier should refer to Appendices B to F for discussion of the basis of some limits.

TEST REQUEST FORM

Project:...

....

Client: ....

....

Specifier:..

....

Sample designer/manufacturer:...

....

Installer: ....

....

Date of test requested:...

....

Test schedule required: (Cross out those Sections not required—a, b, c, d and g are mandatory to claim compliance with this Standard, AS/NZS 4284.)

a—Preliminary	b—Structural at SLS	c—Air infiltration
d—Water at static and cyclic	e—Seismic at SLS with water	f—BMU restraint test
g—Strength at ULS	h—Seismic at ULS	I—Seal degradation

General description of test sample ....

....

....

Drawings of the test sample attached? Y/N

Certificate of Identification attached? Y/N

Position of any viewing panels for water test noted Y/N

SPECIFIC TEST REQUIREMENTS

Section	Test Name	Clause	Required parameters	
a	Preliminary test	8.2.1		
	SLS pressure	8.2.2/8.3	SLS(+) = Pa	
			SLS(–) = Pa	
	Water static	8.2.3/8.5	Static water test pressure = Pa	
	Water—Cyclic	8.2.3/8.6	Cyclic test pressure Stage 1 = Pa	
		8.2.3/8.6	Cyclic test pressure Stage 2 = Pa	
		8.2.3/8.6	Cyclic test pressure Stage 3 = Pa	
b	Structural test at SLS	8.3.2	Location of transducers noted on drawings? Y/N	
		8.3.3	Pressure steps?	
			Max. displacement? = mm	
Members or panels		Deflection/span limit ratio		
c	Air infiltration test	Test pressure	(+) = Pa	
			(–) = Pa	
		Air infiltration limit = (l/m²s)		
d	Water test (static and cyclic)	Pressure (Pa)	Duration (mins)	Duration and spray intensity
	Static			15 min, 0.05 L/m² s
	Cyclic 1			5 min, 0.05 L/m² s
	Cyclic 2			5 min, 0.05 L/m² s
	Cyclic 3			5 min, 0.05 l/m²s
Additional water penetration requirements?				
e	Seismic at SLS		(Water test repeated after)	
	Support beam movement allowed =			
	Number of cycles =			
	Frequency of movement =			
f	BMU restraint		Test load across face of sample = kN	
			Test load perpendicular to sample = kN	
g	Strength at ULS	Test pressure	(+) = Pa	
			(–) = Pa	
h	Seismic at ULS			
	Support beam movement allowed = mm			
	Number of cycles =			
	Frequency of movement = Hz			
i	Seal degradation		10% air seal removal? Y/N	
Describe seals to be altered				

APPENDIX B
SAMPLE PREPARATION
(Informative)

B1 INTRODUCTION

The test is a method of assessment of a facade system that has been designed by a competent person to meet the specified requirements of the Specifier. It is not an alternative method of proving a facade system. This Appendix relates to the preparation of a prototype test sample of the building facade. The two most important objectives in testing building facades are to evaluate the performance of the sample under exposure to simulated environmental conditions before production commences and to use the sample as an opportunity for the manufacturer to evaluate the fabrication and installation of the sample.

These objectives are based on the premise that the sample is a faithful representation of the proposed design (i.e., from drawings and design calculations) and, with the test amendments, a sample of the wall that will be constructed on to the building within the construction tolerances of the structural elements of the building.

This facade-testing Standard provides the method for testing the facade, using a full-scale prototype of the wall under actual design conditions.

A prototype has the advantage that performance of actual materials in the facade, interaction at joints and fixing points, and visual appearance, can be critically assessed.

It is possible that as part of the testing procedure some modification will be required to reach the acceptance criteria successfully. The modifications will usually be related to penetration of water, but could also include deflection performance of the building facade frame or glass, or slippage at the joints or fixing points.

Modifications are permitted as part of the design development; however, it is important the modifications be documented in the test report. These modifications must then be incorporated in the ‘as-manufactured’ and ‘as-built’ facade, so that defects noted in testing do not recur on the actual project.

There have been instances where several tests were required before the facade met the required criteria to pass the test which can raise doubts with the specifying Specifier as to whether the wall is satisfactory. It is recommended, therefore that, if after four tests, modifications are still required, the designer should carry out a detailed review of the design. Further testing should only proceed when the problem has been identified and agreement has been reached with the specifying Specifier.

B2 TEST SAMPLE

For reasons given in Paragraph A1 the sample of facade selected for testing should be representative in size and shape of the facade of the building, taking into account number of storeys and extent in plan.

The aim is to simulate actual conditions so that the assumed design criteria relating to air infiltration, waterproofing and structural aspects, including deflection, performance at joints, and structural behaviour of the elements, can be assessed with confidence.

Where a facade is designed with a jockey sash or internal sash, not an integral part of the weatherproofing or structural performance of the facade, it is, nevertheless, recommended that this element be included in the prototype test sample. Removal of the sash may adversely influence air infiltration through penetrations for fixings and locks.

For a panelized or stick curtain wall system it is recommended that a sample width include at least three adjoining wall panels. This will simulate two typical mullions and two edge conditions. At the boundary of the prototype the restraint system used should be representative of the actual restraint system of the sample being tested. Variation in the degree of fixing of these restraints will influence the results of the test. Similarly, the sealing and flashing details should be representative of actual conditions.

For curtain walls for multistorey buildings, it is recommended that two expansion/stack joints be tested (See Figure B1).

The stiffness of the support system for the sample should be representative of the actual support system. Acceptance of the stiffness of the support system proposed should form part of the review by the Specifier.

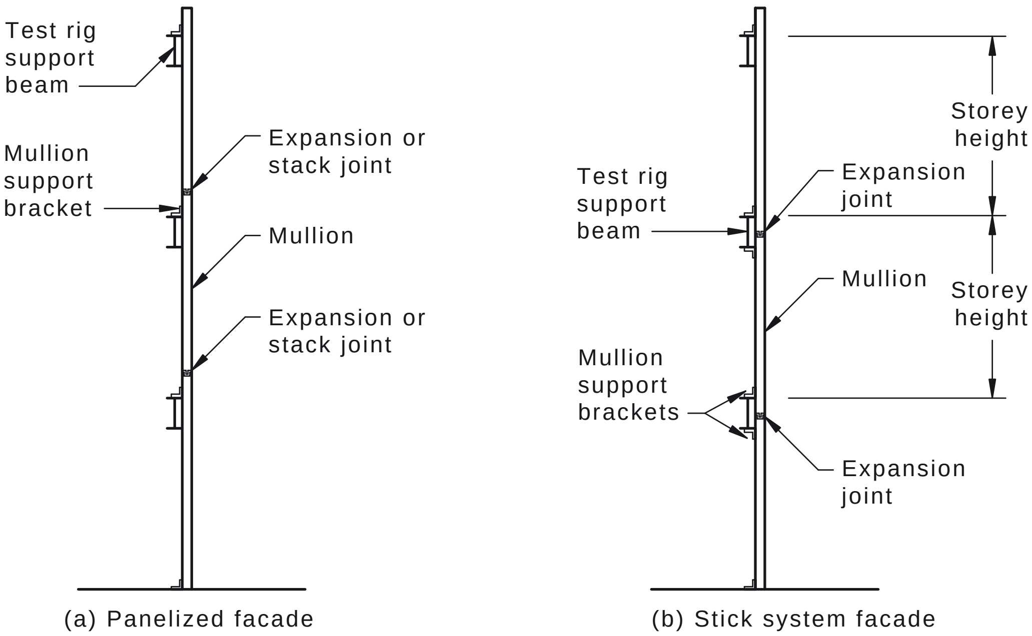


FIGURE B1 A TYPICAL CROSS-SECTION OF A BUILDING FACADE INDICATING TWO INTERMEDIATE EXPANSION/STACK JOINTS

Often no single panel of a building facade is representative of all the areas of the facade that the Specifier requires to have tested. The test sample can be designed specifically to include different areas of the facade within the test sample, such as corners, overhangs, column junctions, and changes to materials.

The stiffness of the curtain wall mullions in the test sample will almost never be identical to the typical curtain wall on the actual building. The actual curtain wall mullion will have different stiffness in the bottom and top two or three floors due to different start and end (boundary) conditions. There will often also be floors of different heights and longer mullions with extra added stiffeners and/or fixings.

The curtain wall designer should choose a representative part of the curtain wall for the test sample. Sometimes the structural test is run twice; once with one bracket per floor and a second time at higher building corner wind pressures with double fixings. The actual chosen test sample mullion set-up should be analyzed to determine its expected structural performance (deflection) during the structural test. The analysis must take account of the actual fixings of the curtain wall members to the structure; in particular, the fixity of the flashing at the top of the curtain wall must be correctly assessed. The deflection criteria should then be re-assessed in accordance with this analysis. The expected deflection for the test sample may be more or less than the listed nominal requirement in this Standard. The expected value should be a pointer to adequate performance on-site and that the system satisfies the specified criteria. Similarly, the maximum deflection point may not be at the middle point between supports and the transducer position should be chosen accordingly. It may also be appropriate to position one transducer at the middle point between supports and one at the expected maximum deflection point.

The final test sample configuration and its analysis should be agreed with the Specifier on the project. Selection of the test sample configuration is often made before the facade contract is awarded, so it may be necessary to modify the test sample configuration during the design development to suit the contractor's final design and the test rig size and capability.

Test rigs are available where multiple test samples can be tested within the one rig, such as side by side or back to back. This provides greater scope for testing elements of the facade. Where design loadings vary for the different samples, the rig should be able to be blocked off for each sample or one of the samples modified to accept the higher loading without distress.

The Standard has not included any provisions to test louvres; however, louvres may form part of the sample to simulate the boundary effects of adjacent facade panels, provided the inside face of the unit is sealed.

B3 REQUIREMENTS

Materials selected for the test sample are to be actual materials used for the facade. However, where these materials do not directly influence the performance of the sample under test, such as glass selection or special coatings, it is possible to test the sample with substituted materials. Use of substitute materials requires careful assessment by the designers and the Specifier. Such substitutes should be documented and included on test sample drawings and noted in the test report

Where pressure equalization is specified by the Specifier, it means that the pressure in the cavities of the facade are similar to the outside pressure in service. Under this condition the rear or inner seal of the facade provides the air and watertightness.

In some instances the facade designer may detail the spandrel cavity as a pressure-equalized zone to the external air pressure, to prevent water entry through a pressure drop and a failure in the external seal. The manufacturers have generally used thin metal sheets, known as back-pans, to contain the air pressure, and in some instances these sheets are not stiffened. As traditional engineering analysis of these sheets and their fixings (especially fixing spacing) tend to give conservative results it is essential that a less conservative design be adequately tested and that the test sample contain at least four back-pans, if the design is to be confirmed by the performance test. Generally the test facility will measure the pressure in the pressurized spandrel cavity and plot it against the external pressure. The Specifier may require this test data reported in the final report.

In order to monitor the sample under test conditions, transparent viewing panels (or other means of observation, such as optical fibre probe) should be provided, so that water performance in the cavities, in areas not readily seen, can be observed during the static and cyclic water tests.

The Specifier determining the sample shape and size should also take into account the worst specified project construction tolerances. This will generally entail a maximum distance between the structure and the building facade and the distance between horizontal structural elements (simulated floor edge beams) to be at or near maximum tolerance, so that movement joints are set in their most open position. If the sample is to be subjected to forced racking (seismic tests) and/or vertical movements (i.e., column shortening test) special consideration should be given to movement joint setting positions, so that the joint full open and full closed positions are tested, but not exceeded.

B4 INCLINED GLAZING

The SIROWET method upon which this Standard is based was originally developed to test the performance of vertical facades.

If inclined or overhead glazing systems are to be included in the test it may be necessary to vary test pressures to simulate the design wind pressures on these surfaces. This needs to be assessed by the Specifier.

The application rate of water as specified in Clauses 7.5 and 7.6 for the water penetration test has been chosen to provide complete coverage of the vertical test samples to ensure that any opening or crack in the facade system is wetted.

This may be considered too severe for inclined surfaces and a rate representative of peak rainfall conditions at the building location may be more appropriate. This needs to be assessed by the Specifier.

APPENDIX C

STRENGTH TEST AT ULTIMATE LIMIT STATE LOADING

(Informative)

Structural elements of a building facade are designed and detailed by limiting stress, strain and deflections. During the design process, stresses and strains are easily interchanged in the calculations; however, on the prototype facade stresses are only determined by measuring strains. The most common method of determining strain is by strain gauges meticulously attached to the accessible aluminium surfaces. Strain gauging metal surfaces is cumbersome, difficult and costly in comparison to deflection measurements. Also, when measuring strains the test engineer has to assume maximum strain locations and these locations may be at areas where sealant is applied. Further assumptions on the structural behaviour of a component consisting of two parts may lead to results that are no better than data based on deflection measurements. These shortcomings of strain measurements have given rise to the use of a deflection limiting criterion for the structural performance test.

The limiting deflection span ratio has been based on empirical data, and the limits stated in the SIROWET Standard were satisfactory for the Australian construction experience. As noted in Appendix B, a compromise is made in regard to the selection of the size of the sample and the location of the support brackets to mullions, and the deflections on the prototype may not be truly representative of the final building facade. The building facade consultant should always compare the sample deflections with the theoretical calculations and establish reasons for significant variations.

The deflection of a member is determined by a minimum of three displacement transducers. Support deflections are measured to allow for slippage and end member deflections. For example, a transom attached to the midspan of a mullion will have end span deflections that usually exceed the midspan elastic deflection of the transom. Also the span of the member should be based on the distance between the transducers, measuring the deflection of the member.

For panelized curtain wall systems the mullion span is the distance between the bottom of the unit to the mullion bracket (see Figure C1). The definition of mullion span is based on the curvature of the framing members under lateral loading as shown in Figure C2 for a continuous panelized or stick system.

The only default deflection/span ratio listed in the Standard (see Clause 9.2.1) is for framing members. This value has been derived linearly from the average decrease in wind pressure from permissible to SLS. No default deflection/span ratios are given for the elements as a direct function of the fixing system, and the Specifier should establish limits from other Standards and guidelines.

In the calculation of the positive and negative pressure deflection/span ratios, the deflections either side of the mid-mode zero stages (i.e., Z2 and Z5) are used. It is uncommon for the deflection/span ratios to be equal for a similar positive or negative structural test pressure, due to the effects of slippage in the elements of the framing members.

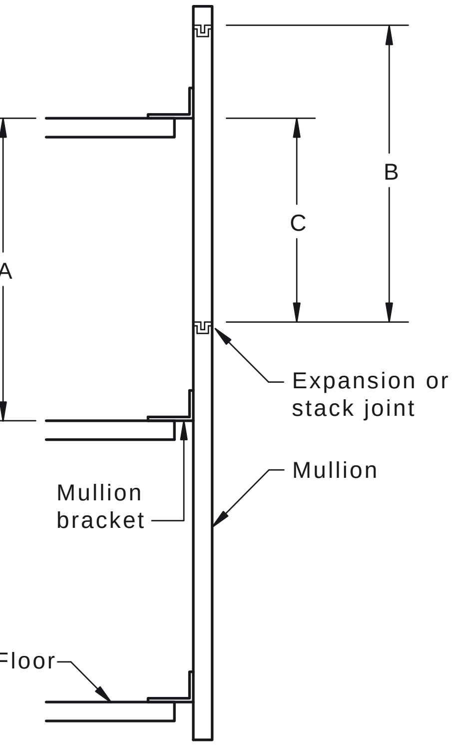


FIGURE C1 A TYPICAL CROSS-SECTION OF A PANELIZED BUILDING FACADE INDICATING THE FLOOR TO FLOOR HEIGHT (A), THE PANEL HEIGHT (B) THE VISION MULLION SPAN (C_1) AND THE SPANDREL MULLION SPAN (C_2), SOMETIMES NOTED BY MANUFACTURERS

The test facilities will also generally interpolate or extrapolate from the actual calibrated pressure to the nominated test pressure as the air-handling system cannot be held constant at the nominated pressure due to chamber leakages and the precision of the pressure flow devices. In these cases it is considered that linear interpolation or extrapolation is acceptable when the difference in pressure from the nominated to the measured is within ±2% and ±5% for test facilities and field sites respectively.

With the structural performance test pressure changing from a working stress pressure (i.e., permissible stress limit) to a SLS pressure, the accumulated damage to the glass panels has been reduced and the probability of glass failing during testing of the sample is lowered. Some regions may have lower ratios of serviceability to permissible limit state pressure, so the ultimate load may become critical in these areas.

The maximum displacement limit (see Clauses 8.3.7 and 9.2.3) on the sample that was specified in the SIROWET Standard was based on research findings. This limit has also been confirmed by testing at CSIRO Manufacturing and Infrastructure Technology to be satisfactory and prudent in terms of user comfort. With the change from permissible to SLS pressures the deflection limit has changed to the default of 20 mm and applied to the framing members. The architect and building owner should be aware that the centre lateral deflection on large glazing units may be high in strong winds and cause concern among building users.

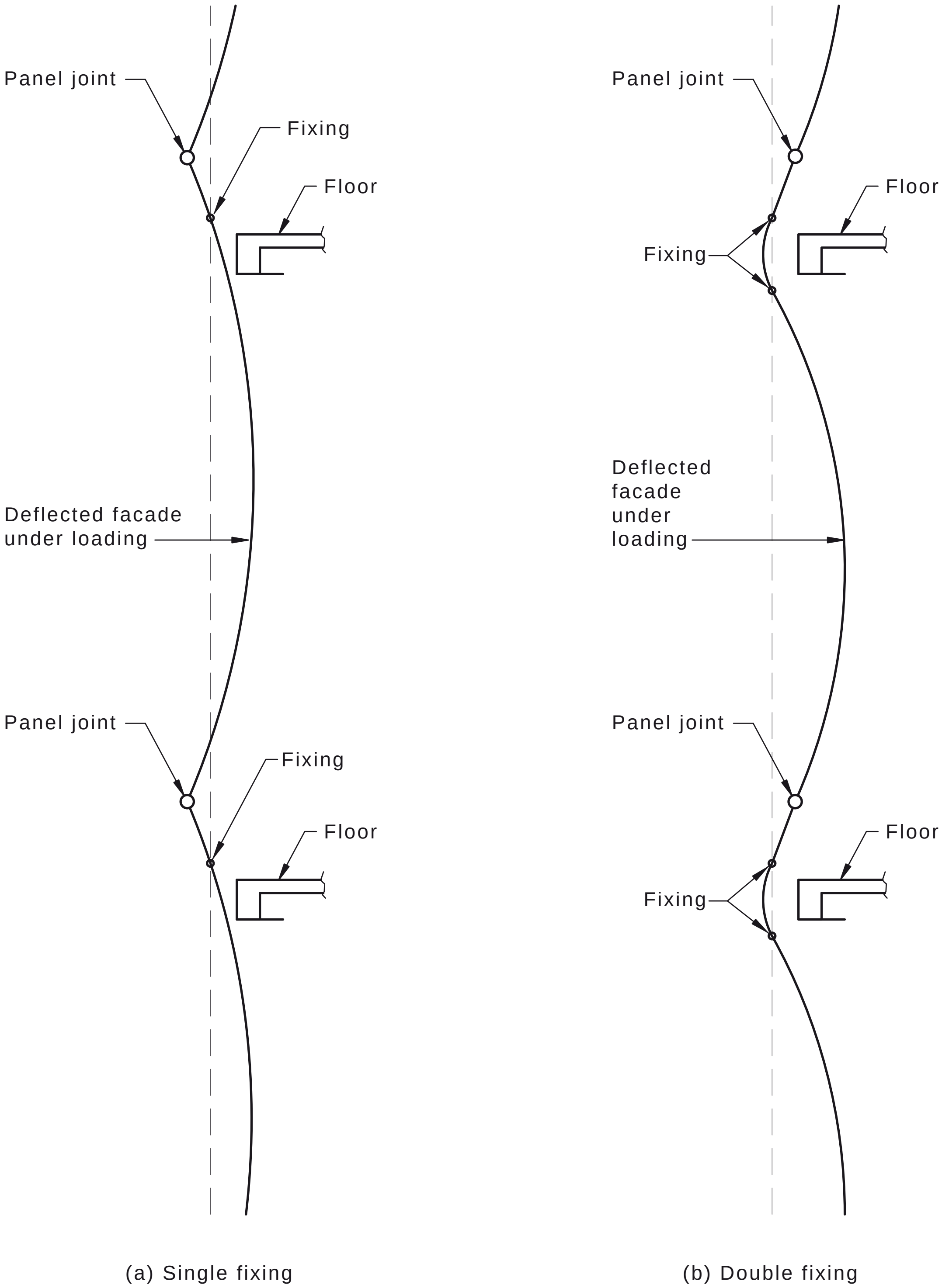


FIGURE C2 TYPICAL DEFLECTED SHAPES OF A CONTINUOUS PANELIZED OR STICK SYSTEM FRAME UNDER LATERAL LOADING WITH SINGLE AND DOUBLE FIXING SYSTEMS

During the calculations of the maximum displacement it is also acceptable to interpolate or extrapolate the deflection based on the small difference between the measured and nominated test pressure. The small difference noted previously (i.e., ±2% and ±5% for test facility and field sites respectively) can occur, due to difficulties in testing large samples in externally mounted and internally mounted chambers.

Another limit adopted from the SIROWET Standard is the slippage of members at the ‘at rest’ pressures. The Committee has considered that there is no apparent reason to change these values even though some criticisms have been expressed by manufacturers that the 3 mm limit should be increased for large panels with an area exceeding 10 m^2. Currently there is no research data to indicate that the 3 mm limit should be increased and, in addition, it may not be appropriate to change the limit as the wind loading induced on to the test sample is lower, due to the lower test pressures (i.e., permissible to SLS). Therefore, this Standard has maintained the default 3 mm limit.

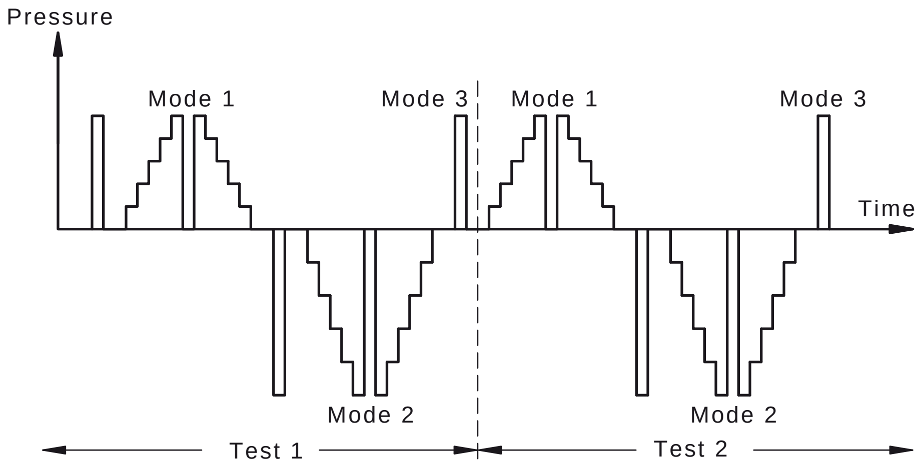
The 1 mm support slippage limit in the SIROWET Standard has been deleted as experience has shown that a sample not meeting the 3 mm limit is usually a result of slippage at the support. For large panels the Specifier may wish to limit the deflection at the top of the support bracket to avoid excessive rotation of the support.

When testing samples with corner units, the horizontal slotted holes in support brackets connected to the main sample face should be avoided, due to the lateral in-plane loads applied from the corner unit. Alternatively, a locking device may be used in the facade support bracket at the corner unit.

Multiple structural tests may be carried out if there is a requirement for many displacement measurements or if the sample consists of multiple loading zones. The test procedure for each test shall consist of that outlined in Clause 8.3.3(a) to (g) (see Figure B3.)

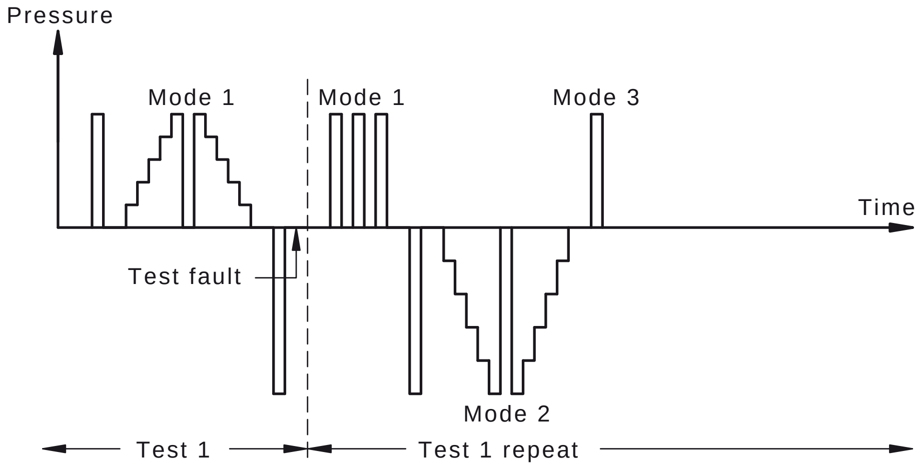
Should the sample or the data collection system fail during one of the three modes in the structural test, the additional structural test shall commence at Clause 8.3.3(a). The intermediate steps of Modes 1 and 2 are not required if the transducer layout has not changed or one mode with all intermediate pressure steps has been completed before to the partial completion of the structural test (see Figure B4).

This Standard allows for a glass unit to break during the structural test at ultimate limit state load as it is statistically unreasonable for glass to maintain integrity when subjected to the ultimate limit state pressures. The intent of accepting the failure of an additional glass unit is based on the same strength premise; however, the replacement glass in the same unit on a sample should not fail. The failure should always be investigated as it may be caused by excessive frame deflections. Where the cause of breakage of a glass unit has been identified as handling damage by the test engineer or the Specifier, it is common in the industry for a replacement timber panel to be attached to the sample and the structural test at ultimate limit state test restarted if a similar glass unit is on the sample.



NOTE: The take-up for the second test is not necessary.

FIGURE C3 TEST PROCEDURE FOR MULTIPLE STRUCTURAL PERFORMANCE TESTS



NOTE: In this case the intermediate steps of Mode 1 are not necessary.

FIGURE C4 TEST PROCEDURE FOR STRUCTURAL PERFORMANCE TESTS WHERE EQUIPMENT OR SAMPLE FAILURE PREVENTS THE COMPLETION OF MODE 2

REFERENCE

1 ROONAN, B. and VOROBIEFF, G. The Structural Performance of High Rise Building Facades, Second National Structural Engineering Conference 1990, I.E. Aust.

APPENDIX D
AIR INFILTRATION TESTING
(Informative)

The air infiltration and exfiltration test results (commonly referred to as air infiltration) are used by mechanical service engineers to design air-handling and stair-pressurization systems. This test may also reflect on the water resistance performance as a 'leaky' sample may have a large air infiltration result.

The air infiltration test is a measure of the air leakage of the whole sample, and it has always been difficult to ensure that the sample elements are representative in size in relation to the typical building floor. If openable windows are included in the sample, the area or length of the openings should be included in the report for information. In ASTM E283 the leakage rate is sometimes reported in terms of the area and volume per 'crack' length. The Specifier may wish to specify limits according to the number of openable windows per floor rather than rely on area-based air leakage rates. This condition may apply when the major area of the sample consists of an openable window.

The air infiltration test is one of the most difficult tests to perform with a great degree of accuracy and the testing Specifier should take this into consideration when reviewing the results. It has been generally accepted in the industry that airflow measurements below 0.1 L/m^2 s are difficult to obtain using an orifice plate. However, the technique to determine air infiltration and exfiltration detailed in Clause 8.4.2 is simple and cost-effective, and assumes that the sample and chamber leakage rates do not change during the test procedure. This assumption appears to hold true for most samples provided sufficient care is taken to ensure that the sample is constructed with a suitable and continuous flashing.

In some situations, the air infiltration rate specified in the tests is used in the design calculation of the air-handling and stair-pressurization systems. Clause 9.3 allows the test facility to forego the sealing of the sample of the test if the total air loss through the sample is less than the limit. In some situations in an 'airtight' building, facades can make it difficult for occupants to open stair exit doors, and the Specifier may insist on a full procedure air infiltration test to establish the actual air loss through the sample.

Testing has shown that the air infiltration and exfiltration rates are not necessarily similar as the stiffness of the building facade varies according to the wind loading direction. If openable windows are included in the test sample these can give different results, depending on the window seal design.

This Standard has provided a default value for the air infiltration limit at a specified chamber pressure, and it is noted that the increase in the chamber pressure from the adopted value in the SIROWET Standard is indicative of the quality building facade installed on buildings. However, it is strongly suggested that the Specifier seeks to apply more suitable limits matching the needs of the building owner (see Table D1). The Specifier should note that by reducing the air infiltration rate substantially below 1.6 L/m^2s this may increase the cost of the building facade.

Where a sample consists of a large area of openable windows or doors in relation to the total sample (generally greater than 50%), a combined air infiltration limit may be stated in terms of area and length of 'crack'. For instance, in NZS 4211, an additional allowable air loss of 0.6 L/m^2s is provided for openable fixtures at 150 Pa chamber pressure. Note that if two openable parts meet, such as the interlocking stiles of a sliding door, the common length is normally counted once.

TABLE D1

SUGGESTED AIR INFILTRATION RATES

Chamber Pressure (Pa)	Air rate limit ($L/m^2.s$)	Building Type
±150	1.6	All airconditioned buildings.
±150	8.0	All non-airconditioned buildings

In view of the accuracy of the test method described in this Standard, it is an acceptable practice in the industry to report the leakage rate of the sample as the sample and chamber leakage rate (i.e., when there is no seal over the sample) if the air infiltration rate is less than the limit stated by the Specifier or the default value. Should the Specifier wish to seek greater accuracy in the air infiltration measurements or if the results are near the limit, the method of determining the air leakage error noted in ASTM E283 may be used.

REFERENCE

1 ASTM E283 Test method for determining rate of air leakage through exterior windows, curtain walls, and doors under specified pressure differences across the specimen

APPENDIX E

WATER PENETRATION TESTING

(Informative)

Most building facades for multistorey buildings in Australia and New Zealand are currently designed in accordance with the drained-joint and pressure-equalization principles. Water is likely to penetrate these building facades when essential parts of the wall (for instance, rain-screen, drip edges, air seal) are not functioning. Some recent attempts to computer model this interaction by computational fluid dynamics and the physical entities have yet to create sufficient evidence to eliminate prototype testing. Irrespective of the tools used to evaluate the building facade, there are three environmental factors relating to the water test. These are—

(a) static versus cyclic applied air pressure;

(b) the duration of the water test; and

(c) the intensity of water sprayed on the sample.

The technology for applying cyclic air pressure to simulating wind gusts on a 9 m high by 8 m wide sample, and maintaining low test costs, have frustrated engineers for decades. It is recognized that the static air chamber test is simple and reproducible, but far from reality. In an externally mounted chamber the cycling of air pressure about some mean pressure provides a nearer solution to simulate wind gust effects. Also, the cyclic air pressure can be applied to the whole sample whereas the aeroplane engine test has a limited area of simulated wind gust.

Air pressure values measured on unitized curtain wall samples with connecting spandrel, mullion and transom cavities and successfully designed to pressure-equalization principles indicate, in both static and cyclic pressure modes, that the internal chambers are near full pressure-equalization to the chamber pressure. Therefore, probable water penetration during a static test is by capillary suction, kinetic energy and surface tension, and these methods are the least common mechanisms for water penetration experienced today. More commonly, water penetration failure in a static test is due to out-of-plane deflections and rotations at junctions of the sample high enough to form breaks in the air seal.

In Australia, the dynamic water test commenced in the 1960s using a wind generator, such as an aircraft engine with a 4 m diameter propeller. The wind generator was also adopted by American engineers with the test procedure detailed in AAMA 501.183. The test wind speed is 55 km/h and produces a minimum pressure of 137 Pa. Along with the low external pressure the positive airflow coverage applied on the sample is generally limited to one floor.

The cyclic water test using an externally mounted chamber does not provide a close approximation to natural conditions as the frequency and pressure range during a storm are not uniform and consistent in time. However, the cyclic action over the whole sample is stringent and repeatable, and therefore it becomes a reliable and cost-effective method of performance evaluation.

Brown and Ballantyne (Ref. 1) recognized in the 1970s that the water penetration test pressure for both the static and cyclic tests was a function of the building height and associated with the positive wind pressure. Also, the frequency of occurrence of wind-driven rain on a building face was considered 'somewhat less' than the wind speeds listed in the wind code.

Research efforts for the determination of the joint wind and rain probability commenced in the 1990s at CSIRO-DBCE (Ref. 2). One of the difficulties faced in using the data at meteorological stations was that the wind records were hourly mean wind speeds recorded at 3 h time intervals averaged over the 10 min period before the hour. It was well known that the duration of many wind-driven storms lasted for 10 to 30 min. The published data did establish that—

(i) wind speeds increased for increasing return periods at a constant rainfall intensity; and

(ii) for the same return period the extreme wind speeds decreased with increasing rainfall intensity.

In the late 1980s industry experts had decided to maintain the 300 Pa SIROWET test pressure for the static test and nominate the cyclic water penetration test pressure in three stages, as follows:

(A) Stage 1 .... 300 Pa to 600 Pa.

(B) Stage 2 .... 30% W_s to 60% W_s.

(C) Stage 3 ....on instructions from Specifier.

In Stage 2, W_s refers to the structural design (i.e., positive SLS) pressure. The 300 Pa value nominated in Clause 8.5.1 is a default value, and the building facade designer should select an appropriate pressure based on the building exposure.

The third component in the establishment of suitable test requirement to assess the water resistance of building facade systems is the water spray intensity at the sample. Currently the SIROWET Standard specifies 0.05 L/s m^2 (or 3.0 L/min m^2) whereas ASTM E547 and ASTM E331 specifies 0.057 L/s m^2 (or 3.4 L/min m^2). The ASTM Standard has been converted from imperial units (i.e., 4 gals/h ft^2) and the water spray quantity is equivalent to the direct impingement of rain on the wall at the rate of 203 mm/h (ASTM E547).

The default test duration and water spray contents have not changed from the SIROWET method; however, the proforma test sheet in Appendix A allows the Specifier to change these values, based on regional weather data.

In both this Standard and ASTM Standards, the water spray pattern is uniform, covers the whole sample, and is calibrated using a ‘catch-box’ test in accordance with ASTM E547. More importantly, the upper half of the sample has little run-off and the quantity of run-off increases down the sample. If the external dynamic air pressure is generated by propeller the water flow across the sample appears to be radial and downwards, and this provides additional kinetic energy to water.

REFERENCES

1 BROWN, N.G. and BALLANTYNE, E.R. *The SIROWET Rig for Testing the Weatherproofness of Building Facades*, CSIRO Division of Building Research, 1975.

2 CHOI, E.C.C. *Extreme Wind Speeds During Rainfall—Proceedings of Second Workshop on Wind Engineering*, Australian Wind Engineering Society, Melbourne, February 1992.

3 ASTM E331 Test method for water penetration of exterior windows, skylights, doors, and curtain walls by uniform static air pressure difference

4 ASTM E547 Test method for water penetration of exterior windows, skylights, doors and curtain walls, and doors by cyclic static air pressure difference

5 AAMA 501.2 Quality assurance and diagnostic water leakage field check of installed storefronts, curtain walls, and sloped glazing systems

APPENDIX F

SEISMIC TESTING

(Informative)

Designing a building facade for earthquake resistance requires a full understanding of the behaviour of the building when subjected to seismic ground motions. In most instances the building structure will vibrate to its first mode of vibration and this may be calculated using the approximation in AS 1170.4 and NZS 1170.5. The structure vibration is generally much lower than the natural frequency of vibration of the building facade components.

It is costly to design and construct a building to withstand the maximum probable earthquake and therefore the designer and the building owner are required to establish an acceptable level of damage at an appropriate risk level. The acceptable level of risk should include the degree of glazing unit collapse, the reduction in air and water penetration resistance, and other performance indicators relevant to the type of facade.

It is common to allow for post-elastic building response during ultimate limit state earthquakes. This is implied in the building response factor (R_f), and deflection amplification factor (K_d) of AS 1170.4, and in Section 7 of NZS 1170.5. The calculated elastic deformation should be amplified by K_d or in accordance with Section 7 of NZS 1170.5 to determine the maximum post-elastic response at roof level. This maximum response is then applied as an ultimate limit state drift.

In ‘shear-walled’ buildings the maximum drift can usually be assumed to be linear up to building height. In ‘framed’ buildings 75% of the maximum drift is likely to occur over the lower six storeys and the ultimate drift limit specified in the test should make allowance for this effect. It is common for post-elastic drift to be factored by 1.3 to allow for secondary effects, such as plastic hinge elongation and ‘floor growth’ (i.e., known to occur during extreme response).

Because the forces for displacement of shear-wall facades are generally greater than those that can be achieved in a prototype test enclosure and the likelihood of glazing components set in these shear-walls are not dimensionally stressed during seismic events, it is recommended that seismic testing within the scope of this Standard should only be undertaken with flexible framed systems, such as stick and panelized curtain walls and light frame construction.

This appropriate value of d_s at serviceability and d_u at the ultimate limit state seismic displacement should be determined by the building structural designer.

The seismic test program has been developed for in-plane displacements only and typical of the building racking initiated by the movement of one floor relative to adjacent floors (i.e., inter-storey drift). At the SLS, the structural system and building facade should remain in the elastic state and it is anticipated that the building owner would expect the building to be functional after this seismic loading.

In Clause 7.9 of this Standard, a water penetration test by cyclic pressure is recommended after a seismic test at the SLS displacement to observe the change in performance of the sample. In some test specifications the consultant has specified an additional air infiltration test. However, it is difficult to get significant results, due to the damage to the surrounding flashing during the seismic loading.

Temporary repair techniques to the building facade may be examined after seismic loading and these repair techniques may be tested and compared against a water penetration criterion.

Test displacements and application have been detailed as sinusoidal as it is the building response rather than the ground response which is likely to be applied to the prototype. The period of cycling (T) should be sufficiently rapid to ensure a realistic slip of gaskets and seals if used in the building facade components. The New Zealand experience and research (BRANZ report) indicates that the period of displacement should be expressed as a peak velocity, typically greater than 10 mm/s. In addition, BRANZ notes that the minimum number of cycles (n) is 10 and additional repeated cycling may be required where a dry-glaze gasket system is used.

REFERENCE

1 THORNTON, S.J and KING, B.B BRANZ Technical Recommendation No. 15 (1993), *Proposed test and evaluation procedure for external curtain wall glazing systems to simulate seismic loading*.

NOTES

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Standards Australia is an independent company, limited by guarantee, which prepares and publishes most of the voluntary technical and commercial standards used in Australia. These standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth government, Standards Australia is recognized as Australia's peak national standards body.

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