AWES-QAM-2-2024

QUALITY ASSURANCE MANUAL: FULL-SCALE WIND TESTING OF COMPONENTS OF BUILDING ENVELOPES AND ARCHITECTURAL FEATURES

AUSTRALASIAN WIND ENGINEERING SOCIETY, 2024

ACKNOWLEDGEMENTS

This first AWES Quality Assurance Manual for Full-Scale Wind Testing of Components of Building Envelopes and Architectural Features, is a collective effort of the following; A.W.Rofail, N.Truong, A.Faheem, M.Glanville, D.Henderson, L.Cochran, J.Kostas. J.Ginger, G.Simmons, N.Mackenzie, co-ordinated by A.W.Rofail.

PREFACE

This Quality Assurance Manual is intended to provide guidance to the practising construction industry professional on the conduct of full-scale wind testing, specifically for components of building envelopes and architectural features. This document can also serve as a testing standard for such tests. However, in some cases if may not be possible to meet all the requirements of this QAM due to practical wind tunnel testing limitations. In these cases the departures from the requirements should be documented and a qualitative sensitivity analysis to the deviation presented.

Full-scale testing of other objects such as cars, bicycles, helmets etc are excluded from the scope of this document. Also, this Manual deals with physical testing and does not include Computational Fluid Dynamics (CFD), where its application may overlap in some aspects of wind-noise, although it would be difficult for CFD to capture all aspects of wind noise.

The opening italicised paragraphs of each section are *minimum normative* requirements for wind tunnel testing. The subsequent paragraphs provide *informative* commentary to allow the user to understand the basis of the requirements and assess whether the minimum requirements are sufficient for a particular project.

SCOPE

This Quality Assurance Manual sets out minimum requirements for the wind testing of components of building envelopes and architectural features. Although primarily intended for use in Australasia, the requirements and commentaries are applicable internationally.

The Manual does not cover large scale or section model tests (e.g. wind tunnel testing for long-span bridges), or tests that require boundary layer flow simulation. This manual covers wind specifically and does not cover testing in full-scale for other effects such as thermal effects.

PART A. WIND TUNNEL TESTS FOR AERODYNAMIC SHAPE FACTORS

A1. Applicable Types of Samples. *This section provides guidance in relation for determining quasi-steady shape factors for geometric configurations that are not covered in the provisions in AS / NZS 1170.2 Appendix C or similar wind loading standards. This will normally require the measurement of both the longitudinal and lateral components of mean drag force. These may include:*

1. *Façade Ancillary Elements such as unusually shaped sunshades and balustrades*
2. *Ornamental sculptures and statues*
3. *Other uniquely shaped elements such as street and balcony furniture, hanging lighting/chandeliers, antennae etc.*
4. *Porous screens*
5. *Pedestal Paver Systems and Porous Wall Tiles systems*

This section will need to be supplemented by Part B where the samples are considered dynamic. If dynamic effects are identified when performing the aerodynamic tests as per the guidelines outlined in this section, it is important that the laboratory alert the designer for the need to also proceed with the dynamic test as per Part B.

A2. Size and Properties of the Test Sample.
The sample must be tested on prototypes (full-scale) where possible. However, the sample may be tested at a large scale subject to the following:

1. *Proper accounting for Reynolds Number effects and wind tunnel blockage (refer to AWES-QAM-01-2019).*
2. *Full geometric replication of the prototype.*
3. *The effect of the surrounds, including the subject building façade when determining incident wind flows.*

In some cases, to be able to meet the above requirements, it may be necessary to utilise a multi-scale approach as discussed in B5, where the local velocity pressure and turbulence intensity are measured at a smaller scale to incorporate the effect of the surrounds (refer to Section A4). These local wind conditions would then be combined with the shape factors or net pressure coefficients obtained using the large-scale section model.

A3. Wind Tunnel Setup. *The sample should be tested at a longitudinal turbulence intensity that is greater than 5% but must not exceed the lowest upstream turbulence intensity at the test sample height on the building.*

It is important to avoid a static pressure gradient between the reference pressure measurement location and the sample (see Section A3 of AWES-QAM-01-2019). A correction will otherwise need to be applied.
Sample mounts will usually include strain gauges or direct laser/dial gauges to measure sample deflections vs wind speed. Static mass/pulley calibrations are to be conducted on

fully assembled samples as part of every test, as previous calibrations can drift and are often unreliable.

A4. Test Configurations. *Testing to be performed at 10-degree incident wind angle increments. Testing needs to be undertaken for a range of both yaw (horizontal wind angle variation) and pitch (vertical wind angle variation) angles of attack.*
A single wind angle variation only will be needed for 2-dimensional section testing. Allowance for symmetry is acceptable. For example, if the sample is a panel of vertical louvres then the test needs to performed at different yaw angles. If the sample is a panel of horizontal louvres then testing is to be at different pitch angles.

If a distinct discontinuity is observed in the drag force between adjacent wind directions, then an intermediate wind direction should be tested.

If the multi-scale approach (Section B5) is required and the object is attached to a tall building then the section model needs to make allowance for a representative section of the building plan to account for the effect of corner streams, points of reattachment, etc.

Drag tests should also be conducted over the range of speeds available in the wind tunnel facility to check for Reynolds Number dependency. Be aware drag force coefficients can vary at Reynolds Numbers beyond the wind tunnel facility limits, particularly for curved shaped elements. If the sample is not sharp edged, then a broader range of wind speeds need to be tested. If it is not possible to match the Reynolds Number to meet the requirements of AWES-QAM-01-2019, then surface roughening may need to be implemented (e.g. Holmes and Burton, 2016) or testing to be undertaken using a higher velocity wind tunnel facility.

In the case of net pressure factors for pedestal pavers, the paver samples or geometric replicas must cover an area of at least 1800mm x 1800mm and be placed in an elevated box with correct modelling of the gaps and cavity depth and the wind speed causing uplift is to be observed. This test should be followed by a test with an instrumented tile at the lift-off location to accurately determine both the upper surface pressure and the net pressure across the paver (to assess the amount of pressure equalisation). Alternatively, assessment using measurement of aerodynamic admittance may be applied (Wood and Denoon, 2016) - however this approach does not fully capture the behaviour of the paver at the critical velocities. Paver lift-off tests should include at least two different cavity depths that represent the typical range for the project.

A5. Data Acquisition and Reporting. *Photographs of the sample and wind tunnel set-up must be included. The mean aerodynamic coefficients should be presented for at least 2 different wind speeds (at least 20% apart), demonstrating a collapse of the coefficients. If a Reynolds Number dependency is observed then testing must be undertaken at a wind speed that is at least 20% higher until a collapse in aerodynamic shape factors (to within 10%) is observed. If any dynamic effects were observed during the test, this must be pointed out in the report and a recommendation made to also undertake a dynamic test as per Part B.*

In the case of tests for paver systems, the key result is the assessment of the percentage of pressure equalisation across the paver for the different cavity depths tested (or the admittance function in the case of the alternative method).

The output in the case of the paver lift-off test can be used in combination with the estimated upper surface pressures to assess the risk of paver uplift.

References:

Australasian Wind Engineer Society, 2019, Quality Assurance Manual for Wind Engineering, AWES-QAM-01-2019

Holmes, J and Burton, D, 2016, "Drag Coefficients for rough circular cylinders revisited", 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston.

Standards Australia/ New Zealand Standard, 2021, "Wind Actions on Structures" AS/NZS 1170.2: 2021

Mooneghi, M., Irwin, P. and Chowdhury, A.G. "Large-scale testing on wind uplift of roof pavers", Journal of Wind Engineering and Industrial Aerodynamics, Volume 128, 2014, p22-36,

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PART B. TESTS FOR WIND-INDUCED DYNAMIC EXCITATION

B1. Size and Properties of the Test Sample.

Wind-induced dynamic excitation tests must be tested on full-scale prototypes. The sample must be prepared using the same material properties (weight, natural frequencies, and damping) and methods of fixing as that to be installed in practice. The sample may fall into one of the following categories:

1. *Repetitive fins, louvres, balusters, or prismatic shapes: For this the length must represent the full span between fixings. In the case where there is a façade behind the sample then this needs to be modelled.*
2. *Panels (porous and non-porous): To be able to capture any serviceability wind issues, the sample must be the full panel size and include perimeter fixings.*
3. *3 dimensional objects that are deemed to be dynamic (refer to Section B4): This includes prismatic shapes. No need to model adjacent elements that are not identical and parallel.*

The support frame needs to represent the stiffness of the intended support frame structure, and in many cases will require the prototype supporting bracketry to be included. Where the sample is attached to a façade then a panel (e.g., plywood, MDF) needs to be provided to represent the effect of the façade on the flow behind the subject elements.

In the case of cylinders in Type 1, wake interference is not likely when the spacing is greater than 15d (Eurocode 1-4). For other shapes the value of critical dimension, d, can be approximated as the dimension facing the wind.
Type 3 includes only prismatic shapes with an aspect ratio of less than 1:5 (as per Section 6.2 and 6.3 of AS/NZS 1170.2:2021).

Wind tunnel testing to predict the full stress/cycle range of fatigue wind loads on building elements such as façade ancillaries may require multiple scale wind tunnel testing as per item B5 below.

If the supporting rig exhibits any noticeable vibration, then its contribution may be filtered from the response spectrum provided that the corresponding peak in the spectrum is separated from the other peaks of interest by a factor of at least 1.3. Such a correction needs to be documented in the report.

B2. Wind Tunnel Setup.

In addition to the requirements of Section A3, a sweep of wind speeds from zero to the equivalent or close to the annual maximum mean freestream wind speed at the height of the sample on the building. Where the facility permits (and at the discretion of the operator and safety limits), wind speeds greater than that stated above would be recommended. The sample should be tested at a longitudinal turbulence intensity that is greater than 5% and less than the expected level of turbulence intensity of the approach wind at the building reference height and terrain. Special attention should be made when the wind speed reaches the critical velocity for the typical section shape and dimension.

Close observations and refinements in freestream wind speed need to be made during the wind tunnel test when the wind speed is close to the critical wind speed based on the Strouhal Number for the subject section shape and natural frequency.

B3. Test Configurations. *The sample is to be tested at a range of pitch and yaw angles for a minimum of 15-degree increments accounting for symmetry. The change in orientation needs to capture the different incident angles of the repeating element with respect to the other elements and the oncoming wind flow at the site which may be altered by the building itself or neighbours. In some cases, finer increments may be required to be able to achieve this.*
A single wind angle variation only will be needed for 2-dimensional section testing. Allowance for symmetry is acceptable. For example, if the sample is a panel of vertical louvres then the test needs to performed at different yaw angles. If horizontal louvres then testing is to be at different pitch angles.

There are likely to be orientations not possible to be tested due to size limitations of the testing facility with respect to the item being tested. The testing laboratory will need to consider the ability of being able to test the most likely critical orientations before proceeding.

B4. Identification and Measurement of Vibrations. *Vibrations are to be observed visually and aurally and where there are noticeable amplitudes, rattling and noise then this is to be video recorded and the amplitude of the vibration is to be measured and reported.*

Susceptibility to aeroelastic instabilities can be flagged during early design for some basic geometries and where the geometry allows it, reference is to be made to the Scruton Number (i.e., mass-damping parameter which is a measure of the propensity of a structure to exhibit resonant dynamic response).

Designers should be aware of the provisions in Section 5.3.4 of AS/NZS 1170.2:2021 for the case of building internal volume and cavity pressure oscillations. These effects are best measured in-situ.

B5. Assessment of Fatigue Life. *The methodology for the assessment of fatigue life needs to be determined on a case by case basis given the broad range of material properties and scale of elements being studied.*

If the façade element is relatively small in comparison to the building form, fatigue of structural elements such as façade ancillaries may require an understanding of the full stress/cycle range obtained using wind tunnel testing at combined scales:

- Small scale (say 1:400) as per AWES-QAM-01-2019 Part A to capture global wind contributions including approach/near field flows and meteorological data. At such model scales the features can be too small to instrument.

- Medium scale (say 1:20) as per AWES-QAM-01-2019 Part A to accurately capture local wind influences including the subject building forms and interference effects from adjacent architectural or façade elements, as well as pressure distributions along the span of the subject element (noting these will be equivalent static distributions)
- To be able to account for the surrounds as well as Reynolds Number effects, it may be required in some cases to also test a full-scale prototype in conjunction with one or both of the above tests as per Part A of this QAM*.

*In many simple geometry cases (e.g. falling under AS/NZS 1170.2-2021) and where the façade element has a sufficiently large cross section, there may not be a need to test at a large scale.

Fatigue wind load results obtained above can be input into computational stress modelling. Limits in computational modelling can be overcome through prototype fatigue tests, noting there will likely be a limited stress/cycle range produced in prototype wind tunnel tests. Note that for some materials with endurance limits such as aluminium, the high cycle stresses can be wind load governing over the design life.

In the case of prototype testing for fatigue, static impact response tests should be conducted before and after testing of the prototype to document any changes in natural frequency of the samples, which may indicate fatigue of sample and/or fixing elements.

B6. Data Acquisition and Reporting. *The wind tunnel report should include photographs of the test setup for a number of different configurations/orientations, details of equipment used to measure the wind speed, locations and orientations of accelerometers, strain and displacement gauges, video recordings and spectra of the vibrations of the subject sample. In addition, the report needs to include comments on the observations of the response at the critical wind speed as well as any wind speeds and test configurations where aerodynamic instabilities were observed.*

Sampling should be performed at a frequency least 10 times highest fundamental mode of interest.
Sampling/observation to be conducted for approximately 1 minute to allow time for establishment of vibration.
Spectra of prototype vibration (when observed) at the various testing wind speeds should be compared to identify different modes of vibration/excitation.

PART C. FUNCTIONALITY TESTING OF FAÇADE COMPONENTS

C1. Applicable Types of Samples. *This section covers tests for the functionality of façade components, which includes the safe operability of windows and doors under strong wind conditions, the ventilation performance of ventilated double skin facades or other tests of façade components that require testing in a wind tunnel, such as:*

1. *Operable envelope elements such as bifolding or pivoting windows or doors.*
2. *Shading, privacy screening and architectural feature elements on facades that may be pivoting, sliding, bi-folding or intended to move in any way*
3. *Ventilated double-skin facades*

This section does not cover the testing for deflection or strength of Type 1 samples when in the closed and latched position, which is covered by a range of performance standards. Rather this section supplements other standards (such as AS/NZS 4284) and covers aspects of the serviceability of these elements such as the safe operation or ability to operate under serviceability wind conditions.

This section does cover the testing of Type 2 sample in the closed and latched position but only in terms of operability. This section may be adapted for testing for serviceability limit state (SLS) and ultimate limit state (ULS) wind conditions for Type 2 samples if the wind tunnel is able to achieve these wind speeds, noting that Type 2 samples can often be porous in nature and cannot be reliably tested under other standards.

This section covers the validation of the internal flow rates within ventilated facades (Type 3 samples).

C2. Size and Properties of the Test Sample. *If the test is for the safe operability of a window or door or sunshade element, the test must be carried out at full-scale using the same component hardware as proposed on-site. The same frame system that supports the component must be used, and the surrounding form of the façade must be replicated.*

For the case of ventilated façade systems, these must be tested at full-scale. If necessary, a 2D section in full-scale or scaling down of the internal volume, internal dimensions and vent details may be implemented provided it is undertaken in a way as not to affect Reynolds number and with proper scaling of Helmholtz resonance effects.

If the primary purpose of a ventilated façade system is to assess flow rates, and a large-scale model is used, it may not be possible to use the same model to assess both flow rates and Helmholtz effects. This must be clearly stated in the test report. In some cases it may not be possible to model the volume of a room as well as Helmholtz effects and an in-situ full-scale test may be required.

C3. Test Setup. *The sample should be tested at a longitudinal turbulence intensity that is greater than 5% and less than the expected level of turbulence intensity of the approach wind at the building reference height for the most open approach terrain.*

C4. Test Configurations. *In the case of sample Type 1, as described in Section C1, the most critical angles of attack for the incident wind need to be tested based on the possible configurations of operation of the sample.*
For the various Type 2 samples the following shall apply:

- *Sliding samples must be tested both latched and unlatched state.*
- *Bi-folding samples must be tested latched and unlatched state in both fully open and fully closed positions*
- *Pivoting samples must be tested in both fully open and fully closed positions*
- *Other samples that are intended to move in any way must be tested based on the possible configurations of the operation of the sample*
- *Each state and position should be tested with wind normal to the sample, as well as 45 and 90 degrees either side of normal to the sample*

For sample Type 3 testing should be undertaken for a range of angles of incidence from normal incidence to obtuse angles at no more than 15-degree increments, accounting for symmetry.
For Types 1 and 2, the wind speed needs to represent wind speed close to an annual maximum peak to test functionality. However, if the wind tunnel facility can generate the required gust wind speeds, then the above procedures can also be used to test for SLS and ULS cases.

Sample Types 1 and 2 will need the test configurations to account for the operable range of the component about the axis of rotation of the component. In addition, the test for these types of samples must include cases where the wind is normal and parallel to the façade and with the configuration of the component ranging from open to closed. Where the range of the operability of the component is 30 degrees or more, then it is recommended that the test is undertaken at approximately 15-degree increments.
If the sample involves testing of a ventilated façade cavity, then testing should be undertaken for a range of both vertical and horizontal angles of incidence.

C5. Data Acquisition and Reporting. *Photographs of each typical test configuration must be included in the report both before and after the test. These need to include close-up photographs of any damage. For façade component operability tests a video must be recorded and provided with the report. When testing in any open configuration, the peak wind speed in the wind tunnel will need to be measured and reported. The wind speed and angle of incidence under which any damage or motion occurs should also be recorded. The report needs to clearly define what is considered a pass or fail.*
For tests of ventilated facades, a video of the flow direction needs to be recorded (e.g. using tufts) as well as the magnitude of the local mean wind speed inside the cavity. The external wind conditions should also be recorded.

With regards to determining pass or fail criteria, guidance should be sought from the client if no relevant standards exist.
Improvements/design iterations that may be made during the test process need to be reported.
Where sub-components, such as a latch, may not have failed but have shown signs of stress this should be noted in the report in consideration to the design life of the facade.

PART D. WIND TUNNEL TESTS FOR WIND-NOISE

D1. Size and Properties of the Test Sample.

Wind-noise tests shall be tested on prototypes (full-scale) where possible. If this is not possible due to the size of the sample, then a reduced extent (but still full-scale) prototype could be considered. Such a scenario would require the input of the client, façade and (possibly) structural engineers to ensure the alteration of prototype size does not significantly alter the aerodynamic behaviour of the sample yet provides sufficient representation of the dynamic properties of the original prototype as well as capturing details such as crevices in the support frame such that conclusive evaluations of the likelihood of the façade element to generate acoustic tones.

The sample must be prepared using the same material properties (mass, natural frequencies, and damping) and methods of fixing. Length must represent the full span between fixings. The sample support needs to be a rigid frame that represents the stiffness of the support structure such as a concrete floor/ceiling slab. In the case where there is a façade behind the sample then this needs to be modelled. In the case of repetitive elements, a minimum of 1m extent and a minimum of 3 repetitive elements must be used unless the spacing is more than 10 times the chord length.

Wind-noise tests should be conducted on (full scale) prototypes whenever possible because some sources of wind-noise may not be able to be accurately replicated even in a large-scale model. If a decision is made to adopt a minor variation to a critical dimension such as the span of a fin, this will need to involve all interested parties to confirm the suitability of the test sample.

If testing at smaller than full-scale, corrections will need to be made for the measured frequency of the noise tones. In this case reference should be made to scaling techniques such as by Jacobs (2017), Ver and Beranek (2005). For example, if there are perforated fins at 2m spacing then a full-scale sample of one perforated fin (to be supplied by the proposed manufacturer) needs to be tested as well as a reduced scale to test for the interaction between the large fin elements as per B5 (provided the damping characteristics, mass distribution, range of reduced velocities are matched). The frequency of the noise can be scaled in this case (refer to Ver and Beranek (2005) and Jacobs (2017)). Notwithstanding the above, a scale model can pose a risk as it will not be able to replicate all the potential wind noise mechanisms such as noise generated by the frame or by gaps within the individual blades. For this reason, use of a large-scale model is outside of the scope of this standard and is not recommended for the reasons mentioned above.

D2. Wind Tunnel Setup. *The type of wind tunnel must be reported (anechoic vs regular wind tunnel | open jet vs closed circuit). Tests should be run over a sweep of wind speeds from zero to the maximum wind speed that the wind tunnel can generate*. The mean wind speed and longitudinal turbulence intensity should be measured upstream of the sample for a distance greater than the diagonal dimension of the sample and reported. The turbulence intensity should be greater than 5% but must not exceed the lowest upstream turbulence intensity at the test sample height on the building.*

*As a guide it is recommended that the maximum test wind speed in the wind tunnel exceed (or where not possible, approach) the equivalent of an annual maximum mean wind speed after correcting for the building's reference height and local upstream terrain. If the facility if able to then the range of wind speeds should be extended to the equivalent of a 10 or 20year return period. Test wind speeds should be include at least one integer multiple of wind speed (to determine the acoustic source type and scaling parameters) and with a swept wind speed over the full range of test speeds to assess the potential for wind induced resonance effects.

D3. Test Configurations. Refer to Section A4. *The sample is to be tested at a range of pitch and yaw incident wind angles for directional increments not greater than 15-degrees, accounting for symmetry. The change in orientation needs to capture the different incident angles of the repeating element with respect to the other adjacent façade elements and the oncoming wind flow.*

Consideration needs to be made for blockage effects as well as boundary layer effects from the walls and ceiling when determining the sample size. Furthermore, local acceleration effects due to the finite size of the sample need to be considered with respect to adverse findings (i.e. false positives of noise and excess vibration due to flow acceleration around the sample, which may not be a realistic depiction of the actual façade).
There are likely to be orientations not possible to be tested due to size limitations of the testing facility with respect to the item being tested. The consultation will need to consider the ability of being able to test the most likely critical orientations before proceeding.

D4. Acoustic Measurement Setup. *Acoustic measurements are sometimes needed when a narrow-band frequency tonal noise is observed, it is important that the following parameters are considered and reported:*

- *distance between the sample and the microphone must be between 1m and 5m.*
- *The local wind speed at the microphone must be recorded.*
- *All microphones must be protected by a 7" foam windscreen or nose cone unless they are located outside of the flow stream and the local wind is less than 5m/s (refer to Rogers (2017)).*
- *Noise measurements are to be obtained with and without the test sample in place (for the same critical wind speeds). Narrow-band spectral analysis should be carried out for configurations both the with and without sample.*
- *Noise levels are to be reported in the form of Sound Pressure Level (dbA/m^2)*

In some cases a decision (client based or otherwise) is made to assess its impact rather than eliminate the noise source. In this case the following additional parameters also need to be reported:

- *Both narrow-band and third-octave spectral analysis should be carried out for configurations both the with and without sample.*
- *Noise levels are to be reported in the form of Sound Pressure Level (dbA/m^2)*

While the identification of acoustic tones can be done by the wind tunnel engineers, evaluation of the noise with respect to a standard or design specification should be done by a suitably qualified acoustic engineer.

The most important range of frequencies are in the range 50Hz and 8kHz. Background, broad spectrum, noise will be present from the flow in the wind tunnel and should be characterised. Additional narrow band sources could be generated by the wind tunnel's Variable Speed Controller unit (it is possible in some units to increase the pulse rate to 16kHz) or from user known noises specific to the wind tunnel facility. If the sample is mounted on a test rig, tests should be carried out with the test rig in isolation to ensure it is not a source of additional broadband or narrowband noise or if it is, then these are characterised. The acoustic properties of the wind tunnel should be reported (e.g., Anechoic wall finishes or reflective finishes, constrained wind tunnel or open jet etc.)

D5. Data Acquisition and Reporting. *The wind tunnel report should include photographs of the test setup for several different configurations/orientations and details of equipment used to measure the wind speed. In addition, the report needs to include detailed descriptions (or a test matrix) of the different test configurations as well as comments on the observations for each test configuration. The range of wind speeds tested needs to be recorded. Where noise is observed from the sample, the test configurations and range of wind speeds where this occurred needs to be included in the report. If a tonal noise is observed and it was decided to assess its impact rather than eliminate the noise source then the report needs to include acoustic measurements and narrow-band spectra as per the procedure outlined in Section A4, above. The model numbers of all equipment used; and in the case where acoustic measurements are taken, this should include the model details of the noise level meter as well as the maximum local wind speeds at the anemometer location and shielding devices, location from the sample etc.*

References

Jacob, M.C. (2017) "Introduction to Experimental Aeroacoustics", STO-EN-AVT-287-03

Roger, M. (2017) "Microphone Measurements in Aero-acoustic Installations", STO-EN-AVT-287-07

Ver, I. and Beranek, L.L. (2005) "Noise and Vibration Control Engineering", 2nd Ed. John Wiley & Sons

APPENDIX I. MECHANICAL TESTS FOR ULS LOADS

This informative section provides guidance in relation to the mechanical testing for the design ULS (Ultimate Limit State) loads for the range of architectural elements and building appendages such as:

- Mounting brackets for satellite dishes
- Cladding, Sunshade, and Screen Systems
- Building Mounted Solar Panels Systems

Many codes and standards already cover the methodology for testing to ULS design loads. A sample list of such standards include:

- AS/NZS 4505:2012 – Garage doors and other large access doors
- AS/NZS 4284:2008 – Testing of Building Facades
- AS 4040.0:1992 – Methods of testing sheet roof and wall cladding
- AS 4040.3:2018 – Methods of testing sheet roof and wall cladding for Cyclonic Winds
- ASTM E330: Standard Test Method for structural performance of exterior windows, doors, skylights and curtain walls by uniform static air pressure difference

It is recommended that the user refer to the Standards Australia website to determine the applicable standard: https://www.standards.org.au
AS/NZS 1170.0 Appendix B could be used to conduct ULS testing if no appropriate standard is found. For example, Appendix B could be an appropriate path to test balcony balustrades to the loads specified in AS/NZS 1170.1.

A procedure for wind driven debris testing has been developed by the Cyclone Testing Station and can be accessed via the following link: https://www.jcu.edu.au/__data/assets/pdf_file/0003/1171362/Tech-Note-4-Windborne-Debris-Impact-Testing.pdf

Testing of cladding systems and roof systems is commonly undertaken using a pressure chamber, as described in AS 4040.3.

The use of a wind tunnel for testing ULS loads for elements such as louvres should incorporate the appropriate load factors (e.g. AS1170.0, Table B1), as well as ensure the longitudinal turbulence intensity in the wind tunnel greater than 5% and does not exceed the expected turbulence intensity of the approach wind for the reference height of the structure and for the more open terrain as determined from Table 6.1 of AS/NZS 1170.2: 2021.

APPENDIX II. WIND TESTS FOR WIND AND RAIN INGRESS

This informative section provides guidance in relation to the testing for wind and rain ingress serviceability for the range of architectural elements and building appendages such as:

- Rain ingress through weather louvres and other ventilators
- Effective area tests for louvres
- Façade performance under wind-driven rain
- Rain ingress through tiled roofs

Many codes and standards already cover the methodology for testing to serviceability design criteria. A sample list of such standards include:

- AS/NZS 4284:2008 – Testing of Building Facades
- AS/NZS 4740: - Rain Ingress through weather louvres and other Ventilators
- AS/NZS 4740:2000 (R2016) – Natural Ventilators
- BS/EN 13030: - Performance testing of louvre subjected to rain
- ASTM E1105: Standard Test Method for field determination of water penetration of installed exterior windows, skylights, doors and curtain walls by uniform or cyclic static air pressure difference.
- ASTM E283: Standard Test Method for determining rate of air leakage through exterior windows, curtain walls, and doors under specified pressure differences across the specimen.
- ASTM E547: Standard Test Method for water penetration of exterior windows, skylights, doors, and curtain walls by cyclic static air pressure differences.

AS/NZS 4284 covers testing for serviceability deflections, rain ingress and leakage in façade systems and is based on the use of a pressure chamber.

AS/NZS 4740 covers both effective area tests and wind driven rain for ventilators and weather louvres.

BS/EN 13030 has the same test as AS/NZS 4740 but applies only to weather louvres and not other types of ventilators. The performance categorisation for weather louvres contained within BS/EN 13030 is much more accurate than that in AS/NZS 4740
It is recommended that the user refer to the Standards Australia website to determine the applicable standard: https://www.standards.org.au

The use of a pressure chamber is not recommended for testing of rain ingress or leakage in other systems that involve inclined surfaces and interfacing with soffit linings and other edge details. For these, it is more appropriate to test in a large wind tunnel. In these cases, it is important to set up an approach turbulence intensity that is representative of the upstream longitudinal turbulence intensity and the design rain intensity. Such a test must be conducted at full scale. Given that the flow structure in this case is significantly influenced by the wall and hence the specimen must include an appropriate section of wall, eaves, etc.