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TECHNICAL NOTE No.4
Simulated Windborne Debris Impact Testing of Building Envelope Components
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1 INTRODUCTION

The Cyclone Testing Station (CTS) is an independent authority on the effects of high wind and related damage to low-rise building systems in Australia, South East Asia and the Pacific.

The CTS provides a service to the building industry for testing the effects of wind forces on buildings and building components.

The CTS has the equipment and technical expertise to test existing and new building envelope components to comply with Australian and International standards.

2 WIND DRIVEN DEBRIS SIMULATOR AND TEST SET UP

The CTS normally conducts simulated windborne debris impact testing using the wind driven debris simulator testing facility.

2.1 Wind Driven Debris Simulator Testing Facility and Test Setup

Two differently sized wind driven debris simulators are available for simulated windborne debris testing. Both simulators consist of an air tank, which is pressurised by an air compressor, a solenoid valve to instantaneously release the air from the tank, and a barrel which allows the debris item to accelerate to the required velocity. A digital velocity meter is installed at the exit of each barrel to measure the velocity of the debris items, at their tail ends, before they impact the target. Impact velocities in the order of 50 m/s can be achieved.

2.2 Test Specimen

The test specimen should be manufactured to be representative of normal production. The specimen support conditions will be modelled as accurately as possible to simulate conditions used in practice. The CTS testing facility can accommodate specimens up to 2,000 mm high by 4,000 mm wide. Larger specimens can be tested, but should be discussed in advance with CTS staff.

3 SIMULATED WINDBORNE DEBRIS IMPACT TESTING OF BUILDING ENVELOPE COMPONENTS

The ability of building envelope components to resist windborne debris impacts in cyclonic regions is determined by testing the components or systems. The system should include any immediate supporting structure. Examples of components to be tested are windows, doors or impact protection systems (shutters, screens). In the case of wall cladding or panels and whenever else possible, a system should be tested.

4 DEBRIS ITEM TEST CRITERIA

4.1 Public Cyclone Shelters

The *Design Guidelines for Queensland Public Cyclone Shelters* impose mandatory criteria for the impact resistance of the building envelope with one of the main objectives being occupant protection. The structural design guidelines for debris loads state: "*The external fabric of public cyclone shelters is to be at least capable of resisting wind debris defined as:*

a) *Test Load A: A 100 mm x 50 mm cross-section piece of timber of 4 kg mass impacting end-on at 0.4 x $V_{10,000}$ for horizontal trajectories and 0.1 x $V_{10,000}$ for vertical trajectories.*
b) *Test Load B: Five spherical steel balls of 2 grams mass and 8 mm diameter, successively impacting at 0.4 x $V_{10,000}$ for horizontal trajectories and 0.3 x $V_{10,000}$ for vertical trajectories.*

In Queensland's tropical cyclone region (Region C) $V_{10,000}$ = 85 m/s. Thus, the required impact speeds are: 0.1 x $V_{10,000}$ = 8.5 m/s
0.3 x $V_{10,000}$ = 25.5 m/s
0.4 x $V_{10,000}$ = 34.0 m/s..."

The test sequence is stipulated in these Design Guidelines as follows:

"*A test specimen shall be subject to successive test loads applied in the following order:*

1) *Debris Test Load A*
2) *Debris Test Load B*

Test Load A shall impact the most critical location(s). The testing authority shall determine the most critical location(s)..." "*...by test. Test load B shall successively impact at various random locations on the test specimen.*"

The impact acceptance criteria specified in these Design Guidelines are as follows:

"*A test specimen shall:*

a) *Prevent a debris missile from penetrating through*
b) *If perforated, have a maximum perforation width of less than 8 mm*
c) *In the case of a debris screen, not deflect more than 0.8 times the clear distance between the screen and the glazing, at any stage of the test.*"

4.2 All Buildings in Cyclonic Areas

The windborne debris impact test is an optional test for envelope components of all buildings in cyclonic regions. Clause 2.5.8 of *AS/NZS 1170.2:2011 (Incorporating Amendment Nos 1, 2, 3 and 4), "Structural design actions – Part 2: Wind Actions"* states that: "*Where windborne debris impact loading is specified, the debris impact shall be equivalent to—*

a) timber member of 4 kg mass with a nominal cross section of 100 mm x 50 mm impacting end on at 0.4 V_R for horizontal trajectories and 0.1 V_R for vertical trajectories; and

b) spherical steel ball 8 mm diameter (approximately 2 grams mass) impacting at 0.4 V_R for horizontal trajectories and 0.3 V_R for vertical trajectories.

where V_R is the regional wind speed."

Note: As this standard does not provide guidance to determine whether an impact test has passed, the CTS has developed acceptance criteria to provide consistency when assessing the results of impact tests. Unless requested otherwise by the client, the acceptance criteria detailed in Section 5 will be adopted.

4.3 CTS Timber Debris Item Specification

The CTS timber debris item used for testing is a 100 mm x 50 mm cross-section piece of hardwood timber of 4 kg mass with end conditions as follows:

1. Straight cut
2. 2-3 mm round aris on all four edges

After each test is conducted the debris item will be examined for excessive wear/damage. If none of the end conditions below are observed the debris item may be used for another test. The debris item should be replaced if any of the following are observed:

1. Edge aris greater than 4 mm
2. Bruising covering more than 30% of any edge
3. Any segment larger than 10 mm is missing from any edge (including corners)
4. Any cracking that connects two parallel edges
5. Any indentation deeper than 5 mm that connects two parallel edges

Note: It may be necessary to perform each test using a new debris item if the debris item sustains damage and should be checked after each test.

5 CTS ACCEPTANCE CRITERIA

5.1 Testing Using Both Test Loads

The CTS test procedure and recommended acceptance criteria where both test loads are specified are:

1. Impact test specimen at the specified locations with timber debris item.
2. Inspect test specimen.
    a. If timber debris item did not penetrate and no obvious aperture is present →Pass
    b. If test specimen stops timber debris item but is left with an aperture smaller than 5000 mm^2 → Pass
    c. If test specimen stops timber debris item but is left with an aperture greater than 5000 mm^2 → Fail
    d. If test specimen stops timber debris item but timber debris item is visible from the inside (i.e. protruding through test specimen) → Fail
3. If test specimen(s) passes the timber debris item test requirements at all critical locations, impact the same or an identical, new test specimen with five spherical steel balls at various random locations. For a given component and configuration, only one series of five spherical steel balls is required.
4. Inspect test specimen.
    a. If none of the spherical steel balls penetrate through the test specimen → Pass
    b. If any of the spherical steel balls penetrates through the test specimen or test specimen is left with an aperture greater than 5000 mm^2 → Fail

5.2 Testing Using Timber Debris Item Only

The CTS test procedure and recommended acceptance criteria where only the timber debris item test load is specified are summarised below.

1. Impact test specimen at the specified locations with timber member.
2. Inspect test specimen.
    a. If timber debris item did not penetrate and no obvious aperture is present → Pass
    b. If test specimen stops timber debris item but is left with an aperture smaller than 5000 mm^2 → Pass
    c. If test specimen stops timber debris item but is left with an aperture greater than 5000 mm^2 → Fail
    d. If test specimen stops timber debris item but timber debris item is visible from the inside (i.e. protruding through test specimen) → Fail

5.3 Testing Using Steel Ball Only

The test procedure and proposed acceptance criteria where only the steel ball test load specified are summarised below.

1. Impact test specimen with five spherical steel balls.
2. Inspect test specimen.
    a. If none of the spherical steel balls penetrate through the test specimen → Pass
    b. If any of the spherical steel balls penetrates through the test specimen or test specimen is left with an aperture greater than 5000 mm^2 → Fail

6 TYPICAL TESTING REQUIREMENTS

It can be demonstrated that, shots projected only at the centre of a specimen will often not represent the critical load case and shots at other locations are required. The following testing requirements are subject to change at any time if new knowledge or evidence becomes available.

The testing requirements detailed in this section pertain to the timber debris item impact tests only. If both test loads are specified, the test specimen will be impacted with five spherical steel balls (at various random locations) after all critical locations have passed the timber debris item acceptance criteria.

6.1 Windows

Windows shall be tested as an assembly consisting of the glass and its typical frame including any seals. Note that the frame itself is not being tested; however, the connection between the glass and the frame is being tested. Normally three impact tests are conducted on glass panels at different locations:

1. Interface corner
2. Interface edge
3. Geometric centre

Where interior mullions or other glazed section joints and/or latches are present, additional impacts are to be performed at these locations:

4. Centre of mullion
5. Base of mullion

6.2 Doors

Doors shall be tested as an assembly consisting of the door and its typical frame including hinges, locks, latches, etc. Note that the frame itself is not being tested; however, the connection between the door and the frame is being tested.

In the case of hinged doors, two or three impact tests are conducted at different locations:

1. Near primary latch or operator
2. Near interface hinge joint
3. Near upper latch point (if present)

In the case of double door assemblies an additional impact is to be performed at the following location:

4. Centre meeting point or mullion

In the case of sliding doors, the following locations shall be impacted:

1. Near primary latch or operator
2. Near interface sliding joint
3. Near upper latch point (if present)

6.3 Impact Protection Systems

Impact protection systems such as shutters or screens shall be tested as an assembly consisting of the shutter or screen and its typical frame, including any accessories if applicable. Depending on test set-up and client requirements, the frame itself is not being tested; however, the connections between the shutter or screen and the frame are being tested.

If the instantaneous deflection of the impact protection system is to be measured during impact, a deflection indicator is fixed on the rear face of the shutter/screen at the target impact location. During impact, a high speed video of the deflection indicator is recorded and subsequently analysed to determine the shutter/screen deflection.

Three impact tests are normally performed at the following locations:

1. Interface corner
2. Interface edge
3. Geometric centre

Where interior studs or supports are present, additional impacts are to be performed at these locations:

4. Near interior stud/support
5. Directly on stud/support

6.4 Roof and Wall Cladding Systems

Roof and Wall cladding shall be tested as a system consisting of two sheets, fastenings and supporting members assembled as it will be in practice. The test is not intended to test the supporting structure, but does test the system as a whole. In the CTS' experience typically the critical impact locations are as follows:

a. Centre of one sheet adjacent to an internal support
b. Centre of one sheet adjacent to an end support
c. Adjacent to lap on underlapped sheet adjacent to an end support
d. Centre of one sheet at midspan
e. Adjacent to lap on underlapped sheet at midspan

The above impact locations refer to a uniform cladding profile. Additional or fewer tests may be conducted, depending on the cladding type. Cladding systems are typically installed in various span types (single, multi) and over a range of span lengths. Therefore, certain impact locations have the most adverse effect on specific span types and length.

Example:
A designer requires verification of one span configuration (e.g. 600 mm triple span). Tests on the above five (5) critical impact locations need to be conducted to show compliance. The test programme in this case would be the following:

On the 600 mm triple span cladding system

a) Centre of one sheet adjacent to an internal support
b) Centre of one sheet adjacent to an end support
c) Adjacent to lap on underlapped sheet adjacent to an end support
d) Centre of one sheet at midspan
e) Adjacent to lap on underlapped sheet at midspan

Example:
A cladding manufacturer wants to verify that the entire span range of one of his products is resistant to impact of wind borne debris. In this case the above five (5) locations could be split up into the following spans to avoid unnecessary repeat tests that do not provide additional assessment information.

1. *Multi span set-up at shortest span length (critical for punching shear failure mode)*
   a) Centre of one sheet adjacent to an internal support
   b) Centre of one sheet adjacent to an end support
   c) Adjacent to lap on underlapped sheet adjacent to an end support
2. *Single span set-up at longest span length (critical for sheet separation failure mode)*
   d) Centre of one sheet at midspan
   e) Adjacent to lap on underlapped sheet at midspan

6.5 Roof and Wall Panel Systems

Roof and wall panels shall be tested as a system consisting of two panels, fastenings and supporting members assembled as it will be in practice. The test is not intended to test the supporting structure, but does test the system as a whole. In the CTS' experience typically the critical impact locations are as follows:

a. Centre of one panel adjacent to an internal support
b. Centre of one panel adjacent to an end support
c. Directly on panel-to-panel interface joint at midspan
d. Near panel-to-panel interface joint at midspan

The above impact locations refer to panels with a flat or uniform profile surface. Additional or fewer tests may be conducted, depending on the panel type. Panel systems are typically installed in various span types (single, multi) and over a range of span lengths. Therefore, certain impact locations have the most adverse effect on specific panel types and length.

Example:
A designer requires verification of one span configuration (e.g. 1,200 mm triple span). Tests on the above four (4) critical impact locations need to be conducted to show compliance. The test programme in this case would be the following:

On the 1,200 mm triple span cladding system
a) Centre of one panel adjacent to an internal support
b) Centre of one panel adjacent to an end support
c) Directly on panel-to-panel interface joint at midspan
d) Near panel-to-panel interface joint at midspan

Example:
A panel manufacturer wants to verify that the entire panel span range of one of his products is resistant to impact of wind borne debris. In this case the above four (4) locations could be split up into the following spans to avoid unnecessary repeat tests that do not provide additional assessment information.

1. *Multi span set-up at shortest span length (critical for shear punch failure mode)*
   a) Centre of one panel adjacent to an internal support
   b) Centre of one panel adjacent to an end support
2. *Single span set-up at longest span length (critical for panel separation failure mode)*
   c) Directly on panel-to-panel interface joint at midspan
   d) Near panel-to-panel interface joint at midspan

6.6 Additional Tests

If, in the opinion of the CTS, a possible critical impact location for any given test sample is not listed above, additional impact test(s) may need to be performed.

7 TEST REPORT

After completion of testing, the CTS will issue a commercial in confidence test report describing the test methods and results.

Note that the CTS test procedures are conducted in accordance with its quality management system which is NATA accredited. Simulated windborne debris impact tests are accredited up to a velocity of 45 m/s.

8 REFERENCES

- AS/NZS 1170.2:2011 – Structural Design Actions – Wind Actions
- Design Guidelines for Queensland Public Cyclone Shelters 2006