



# **DRAFT GUIDE TO LHL CYCLIC TESTING**

**(Version 1)**

**9 April 2009**

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## **Important Notice and Disclaimer**

This draft Guide on Low-High-Low (LHL) Cyclic Testing (the Guide) is provided for general information and should not be taken as providing specific advice for any particular situation. In particular it is not mandatory or regulatory in nature. It is designed to assist in making information on this topic readily available.

The groups that have been involved in the development of this draft Guide accept no responsibility for the use of the information it contains and make no guarantee or representation whatsoever that the information is an exhaustive treatment of the subject matters contained therein or is complete, accurate, up-to-date or reliable for any particular purpose.

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In particular, and to avoid doubt, the use of the Guide does not—

- guarantee acceptance or accreditation of a design, material or building solution by any entity authorised to do so under any law;
- mean that a design, material or building solution complies with the Building Code of Australia (BCA);
- absolve the user from complying with any Local, State and Territory or Australian Government legal requirements.

## Preface

The Building Code of Australia (BCA) requires the cyclic testing of metal roof assemblies, its connections and immediate supporting members when used in cyclonic wind areas, as designated in Australian Standard AS/NZ 1170.2.

While the specification of the cyclic loading spectrum is a regulatory matter, the testing procedure and the interpretation of the results have been left to the testing laboratories to manage.

The Station is part of an industry group that has been working to develop a consistent approach in applying the LHL test regime results to determine design capacities. However, stakeholders in the LHL testing area (government agencies, designers and manufacturers) have requested that the Station issue a draft document to both provide preliminary information and to request feedback on this draft.

The intent of this Guide is to provide a nationally consistent test procedure and nationally consistent interpretation of the test results. This will enable the test to be carried out by different testing laboratories within a reasonable time frame on different types of equipment with some degree of consistency.

The industry group that provided input into this document has a long term aim of converting it into an Australian Standard. However, the need for the Guide is immediate and it is recognised that the Standard process will take sometime to achieve. Therefore the Station decided to publish the document as soon as possible, in a draft format and request feedback from all stakeholders. Accordingly, any stakeholder who wishes to make suggestions or comments on this guide is encouraged to send an email to the Station via our web page or direct to: [jcu.cts@jcu.edu.au](mailto:jcu.cts@jcu.edu.au)

The draft Guide has been prepared in the style of an Australian Standard with the use of 'shall' and 'must' for 'mandatory' clauses and 'should' and 'may' for 'informative' items. All 'Notes' are informative and have been set in italic.

Note that Section 7.2 details the CTS acceptance criteria, as all the members of the industry group did not agree on the definition of failure.

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## 1. Scope

This Guide covers the cyclic testing of metal roof assemblies, their connections and immediate supporting members to resist simulated wind loading. It includes the test method and the interpretation of test results.

*Notes:*

- 1. This Guide was designed to facilitate and standardize the application of the Low-High-Low pressure sequence specified in the Building Code of Australia (BCA).*
- 2. The cyclic loading sequence is the Low-High-Low cyclic testing regime specified in the BCA 2008. The same fatigue loading sequence is specified for Class 2 to 9 buildings (Specification B1.2, BCA 2008 Volume One) and for Class 1 & 10 buildings (Section 3.10.1, BCA 2008 Volume Two). For this test, the BCA specifies that "In cyclonic areas metal roof assemblies, their connections and immediate supporting members must be capable of remaining in position notwithstanding any permanent distortion, fracture or damage that might occur in the sheet or fastenings" under a defined pressure sequence (see Section 4 of this Guide). The purpose of this Specification is to ensure the performance of roofing system is adequate under cyclonic conditions i.e. the cladding should not be detached from the framing and become wind-borne debris which might cause damage to the surrounding area as well as a threat to life safety.*
- 3. It is important to differentiate between cyclic fatigue failure, associated with disengagement of cladding from its supports after repeated load applications and static failure which is associated with a strength capacity of a cladding system. Low cycle fatigue cracking of cladding, fixings, immediate supports and their fixings during tropical cyclones is a complex process where small changes in load, geometry or material properties can significantly affect the fatigue performance of the system. At present, there is no way to assess this type of performance apart from testing.*
- 4. This Guide is applicable to all forms of testing such as air box, air bag, mechanical testing etc.*

## 2. Referenced Documents

The following documents are referred to in this Guide

### **Australian Building Codes Board**

Building Code of Australia: *Class 2 to 9 buildings (Specification B1.2, BCA 2008 Volume One)*

Building Code of Australia: *Class 1 & 10 buildings (Section 3.10.1, BCA 2008 Volume Two)*

## Australian Standards

AS/NZS 1170	Structural design actions
1170.0:	General Principles
1170.2:	Wind actions

### AS

1562.1	Design and installation of sheet roof and wall cladding
3566.1	Self-drilling screws for the building and construction industries – General requirements and mechanical properties
4040	Methods of testing sheet roof and wall cladding
4040.0	Introduction, list of methods and general requirements
4040.3	Resistance to wind pressure for cyclonic regions

### Notes:

1. *This Guide should be used in conjunction with and is complementary to AS 4040 Series. In particular, it is not intended to replace AS4040.3*

### Paper

Secombe C. J., Carne S. J., Martin B. A. (1996) *“Improvements in System Evaluation under Static & Cyclic Wind Loads” National Engineering Conference Darwin, NT 21-24 April 1996, The Institution of Engineers, Australia.*

## 3. Terminology

### 3.1 Definitions

For definitions of general terms relating to wind engineering used in this Guide, see Appendix A of AS/NZS 1170.2

### 3.2 Terms Specific to this Guide

Coefficient of variation of structural characteristics ( $V_{sc}$ ) – the coefficient of variation of the structural characteristics of the parent population, taking into account variation due to fabrication and material.

Design wind pressure ( $P_d$ ) – the ultimate limit state wind pressure calculated in accordance with AS/NZS 1170.2 for the part of the roof being tested including external, internal and local factors as appropriate

Factor for variability ( $k_t$ ) – a factor to allow for the variability of structural units.

Potential failure modes – the probable failure modes given the magnitude and nature of the load effects in the cladding, fixings, immediate supports or their fixings

Specimen – the entire assembled unit submitted for test as described in Section 5

Structural engineering principles – principles based on a linear-elastic response used to compute the load per fastener, the bending moments in the cladding or the supporting member and the movements of the fastener, the cladding or the supporting member.

Test load ( $P_t$ ) – the test action to be applied during testing (pressure or force) that is calculated as the design action multiplied by the appropriate factor for variability.

## 4. Summary of Test Method

### 4.1 Regulatory Requirements

#### (a) Loading Sequence

The loads are applied in a sequence from A to G as defined in Table 1.

**Table 1** Low-High-Low Pressure Sequence from the BCA

Sequence	Number of cycles	Load
A	4500	0 to 0.45 $P_t$
B	600	0 to 0.6 $P_t$
C	80	0 to 0.8 $P_t$
D	1	0 to 1.0 $P_t$
E	80	0 to 0.8 $P_t$
F	600	0 to 0.6 $P_t$
G	4500	0 to 0.45 $P_t$

Where  $P_t$  is the net ultimate limit state wind pressure on internal and external surfaces as determined in accordance with AS/NZS1170.2, modified by an appropriate factor for variability, as determined in accordance with Table B1 of AS/NZS 1170.0.

**Extract from Table B1** of AS/NZS 1170.0 – Values of  $k_t$  to allow for variability of structural units:

No of units to be tested	Coefficient of variation of structural characteristics ( $V_{sc}$ ) in %		
	10	15	20
	1	1.46	1.79
2	1.38	1.64	1.96
3	1.33	1.56	1.83
4	1.30	1.50	1.74
5	1.28	1.46	1.67
10	1.21	1.34	1.49

*Notes:*

1. *A coefficient of variation of 10% should be assumed for strength of metal claddings and metal supporting systems unless there is evidence showing that a higher figure is warranted.*
2. *A coefficient of variation of 15%-20% should be assumed for connection sub-assemblies unless there is evidence showing that a higher figure is warranted.*

**(b) Other Requirements**

For this LHL pressure sequence, the BCA also requires:

- The rate of load cycling must be less than 3 Hz
- The single load cycle (sequence D) must be held for a minimum of 10 seconds.

*Notes:*

1. *The aim of the test is to assess the performance of the roof cladding assembly under cyclic loading induced by cyclonic wind. Under this condition, there might be serious loss of strength of the connection assembly due to high stress low cycle fatigue.*
2. *Terms 'Coefficient of variation of structural characteristics' and 'No of units to be tested' are critical in the planning of the testing programme and the interpretation of the results. Refer to Sections 6 and 7 of this Guide.*

**4.2 Recommended Test Procedure**

- (a) Select the appropriate value of  $V_{sc}$ .
- (b) Determine the appropriate number of 'units to be tested' and the number of specimens (It is possible to have more than one unit to be tested per test specimen, see Section 6.2). The total number of 'units to be tested' equals the 'units to be tested' summed over all nominally identical test specimens.
- (c) Estimate the target value of  $P_t$ .
- (d) Perform the first cyclic test.
- (e) If the first test is successful then carry on the next test as decided in (b) using the same (or higher) value of  $P_t$ . If the test is not successful reduce value of  $P_t$  and go to (d).
- (f) If one of the replication tests fails, then  $P_t$  shall be lowered for retesting but the previous pass results shall still be counted in the assessment of  $k_t$  for the revised (lowered)  $P_t$ .



- (g) Determine appropriate factor  $k_t$  in accordance with Table B1. The ultimate strength design value to be adopted is  $(P_t/k_t)$ .

**Notes:**

*The selection of the target value of  $P_t$  for testing is critical for the success of the test. It should be less than the static load design capacity (i.e. test with sequence D only but to destruction). Therefore it might be convenient to establish the static design load capacity first (which is also required for non cyclonic design) and use it as an upper bound in deciding what the target test pressure for cyclic test should be.*

## **5. Apparatus**

### **5.1 General**

The arrangement of equipment should be capable of performing the test procedure within the allowable tolerances and without influencing the performance of the specimen under test.

### **5.2 Loading System**

The loading system should be capable of the following:

- Pressure or loading equipment and their measuring devices shall be capable of delivering the maximum test pressure  $P_t$  to within 5% of the nominated value.
- The upper limit of each pressure sequence shall not be less than the target value.
- The lower limit is considered satisfactory even if it is not reduced to zero, provided that the lower limit does not exceed 10% of the upper load limit of the same load sequence.
- The rate of load cycling must be less than 3 Hz.
- The single load cycle (sequence D) must be held for a minimum of 10 seconds.

### **5.3 Set-up**

Particular care should be taken at the edges of the test specimen to ensure that the specimen is not constrained in a manner that is significantly different to that which will occur in practice.

**Notes:**

1. *The high stress low cycle fatigue performance can depend on parameters such as the load per fastener, the bending moments in the cladding and the supporting member and the movements of the fastener, the cladding and the supporting member. The test apparatus should be able to deliver the required loading sequences without influencing the above responses unduly.*

2. *The method of load application should be selected depending on the purpose of the test. To obtain the static load capacity of a particular design a mechanical test set up is probably adequate. For the derivation of load tables, an air box test offers the most realistic and accurate modelling of the conditions. Care should be taken if inflatable air bags are used as they might impose constraints on the test specimen or hinder the deformation of the cladding such as in 'secret fixed' cladding systems. A paper by Seccombe et al (1996) reports on the comparative performance of airbox and airbag testing and notes that airbag testing of secret fix cladding overstates the cladding performance.*
3. *Care should be taken in the test setup such that no additional membrane action is provided to the cladding that it would not have in practice.*

## 6. Planning for the Test Program

### 6.1 Coefficient of Variation of Structural Characteristics ( $V_{sc}$ )

- The coefficient of variation of structural characteristics ( $V_{sc}$ ) shall be that of the production population to be established taking into account variation due to fabrication, material and installation.
- For roof assembly cyclic testing a value of 10% may be used in the absence of more reliable data.

*Notes:*

- *The coefficient of variation (cov) of structural characteristics ( $V_{sc}$ ) should not be confused with the cov of the LHL Test results.*
- *For the testing of connections, a coefficient of variation of structural characteristics of 15% should be used unless data, typically obtained from the manufacturer, that capture the effects of fabrication, material and installation variations indicate a higher figure is required.*

### 6.2 Recommendations to Determine the Number of 'Units to be Tested'

For the purposes of selecting a factor for variability,  $k_t$ , a test specimen can contain more than one 'unit to be tested' if it can be shown by structural engineering principles that identical components that are part of a test specimen have the same potential mode of failure, that is they are subjected to equal load and deformation demands and have similar boundary constraints. For example, for cyclic cladding tests, each full cladding sheet (including both sidelaps) across the width of the test specimen can be counted as a 'unit to be tested'. Similarly, each internal row of fixings on each sheet can be counted as a 'unit to be tested'.

- No more than four (4) 'units' for any one test specimen can be counted. Where only a single specimen is tested no more than two 'units' can be counted.
- Adopt a maximum of 10 replications, the upper limit in Table B1 of AS/NZS1170.0.

*Notes:*

- *The application of this Clause will require considerable engineering judgement. For example, for testing corrugated cladding, corrugated cladding under AS1455 could not generally be considered as the same because the Standard only specifies the height of the corrugation but not the radius of the corrugation. The latter is critical in the assessment of low cycle fatigue performance.*
- *Features that may be critical in the determination of low cycle fatigue performance include bearing areas under the head of the fastener, thread conditions into the battens, distance between fastener head and supporting member, thickness and strength of the materials.*
- *Fasteners that are specified similarly in AS3566 are considered to be equivalent for the purposes of this procedure.*
- *When a batten or other supporting member is included in the test, the results may be considered to be applicable for other battens or supporting members that are equal or stronger and stiffer in all respects. In case of metal battens, for example, the results are applicable to cases with battens that have equal or greater base metal thickness ( BMT) and yield strength.*
- *On the basis of engineering judgement, it has been deemed prudent to be cautious when testing a single specimen. For example, a specimen may contain 4 'units to be tested'. If only a single specimen is going to be tested, then the number of 'units to be tested' is only two(2). However if two(2) specimens are going to be tested, then the number of 'units to be tested' can be as large as eight(8).*

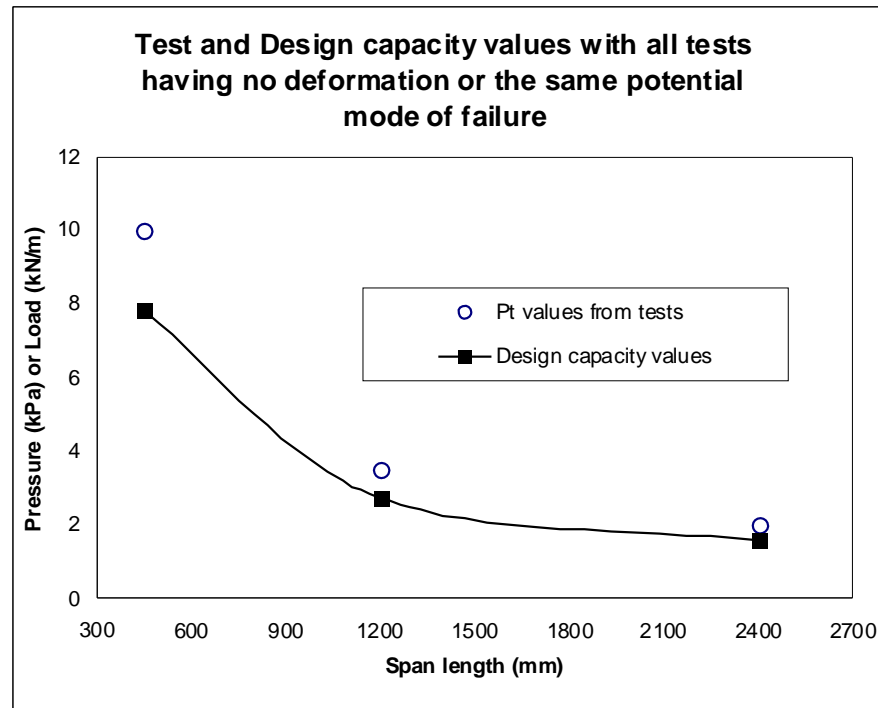
### **6.3 Recommendations for Establishment of Design Load Tables**

#### 6.3.1 For establishing load tables for cladding or supporting members

Where load tables for the cladding, or supporting member such as a batten, are to be established from the results of the tests:

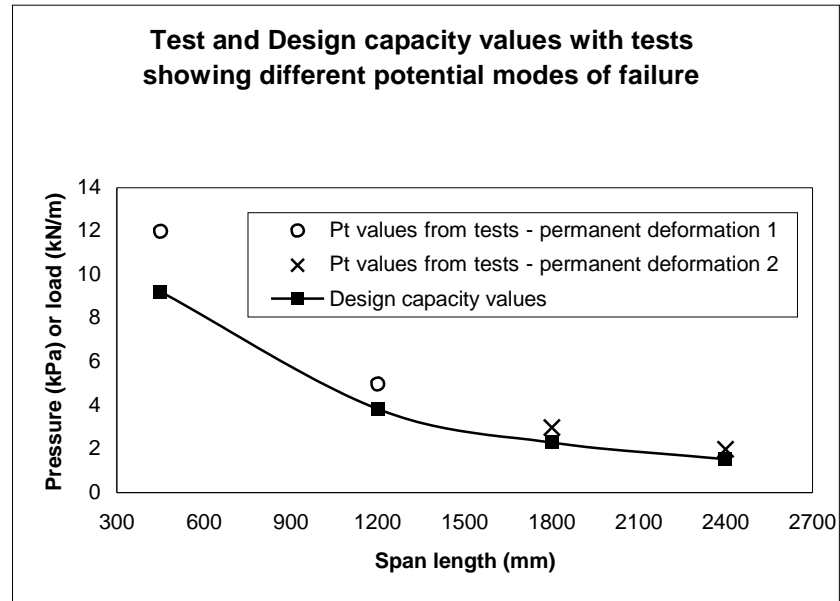
- For any one cladding or member profile, thickness, single or continuous span type and fastener configuration, a minimum of three successful tests must be carried out for the full range of spans.

- The spans chosen must include the lowest and highest spans and at least one value in between as shown in the Figure 1.



**Figure 1: Typical Load Span Chart (3 span values)**

- If it is envisaged that the potential failure mode will change for any of the tests, provisions should be made to carry out at least one further test at a different span value, until a minimum of two span values have the same potential failure mode.



**Figure 2: Typical Load Span Chart  
(2 different potential modes of failure)**

- The results of double or triple span tests can be converted to statically equivalent loads using standard structural engineering principles to determine load tables for all continuous span types. The results of single span tests shall not be used to determine the capacity of continuous span configurations.
- Similar sets of tests shall be carried out for every thickness of the cladding, and different fastener configurations.
- A number of configurations should be tested for the establishment of design load tables.
- A minimum of three spans for the same Base Metal Thickness (BMT) and potential mode of failure, if any, is necessary for the establishment of design load table.

*Notes*

1. *Single span tests have markedly lower support reactions, and so connection forces, than occur at the first interior support of a double or triple span test.*
2. *To obtain better results, further tests could be carried out at the same values of  $P_t$  and span, or the number of span values tested could be increased. Both these options would increase the number of units, hence allowing a lower value of  $k_t$  to be used for the determination of all the capacities.*

### 6.3.2 For establishing connection design capacity

Where a connection capacity is to be established from testing

- Capacities for connections that are different to those used in cyclic testing for cladding or support members, shall be established by testing.
- A minimum of three successful tests shall be carried out for establishing the capacity of the connection.

*Notes:*

*1. These provisions are intended to apply when the capacity of a connection is being carried using a tensile testing or similar machine. Such tests are often useful to investigate any effect of changes in screw type, thickness or profile of supporting member, and connection of the supporting member to the member below. The specimen should be a minimum of 150mm long, and normally consists of one or more screws and small section(s) of cladding and/or supporting member. The assembly should mimic actual construction components and practice.*

*2. The difference between this test and the full scale test could be the use of a different supporting member under the sheeting, a different connection between the supporting member and its supporting member, or a different type of screw. For example a 150mm length of batten can be tested to quantify the strength of the batten foot connection to the member below, or the roofing screw pull out from the batten. The full LHL cycle sequence should be followed as for the full scale sheeting tests.*

*3. Once the capacity of the connection is found, a full scale test should be carried out involving the connection to identify any differences in potential failure mode or strength. If there is a difference, additional full scale testing may be necessary to further quantify the capacity of the member or screw.*

### 6.4 Test Specimen Materials and Fabrication

- The test specimen shall consist of cladding elements, fastenings and immediate supporting members assembled together in a manner identical to those parts of the particular roof which the test specimen is intended to replicate.
- All details of the test specimens shall be specified and reported.

*Notes:*

*For tests carried out to establish load tables, consideration should be given to the following features to ensure the validity of the tests:*

- *The width of the test specimen should be at least two cladding elements wide and include at least one cladding overlap. For cladding systems in which the interlocking of the edges of adjoining cladding elements is essential to their fastening, at least two sheet interlocks should be incorporated in the test specimen.*
- *Continuous cladding should be supported by no fewer than three members to represent a double end span condition.*
- *For non-continuous cladding elements where side overlaps and end overlaps are required for transferring fastener loads, such as roof tiles and clips, a minimum of four elements wide by four supporting members should be considered (e.g. sixteen cladding elements in total).*

## **7. Interpretation of Test Results**

### **7.1 General Principles**

- Interpolation of design capacities derived under test is acceptable but extrapolation of parameters outside the test range is not permitted.
- Test results from one fastener (or cladding) may be considered as acceptable for another fastener (or cladding) in the same application if both fasteners (or both claddings) have the same critical features that will determine their cyclic load capacities.
- All tests should show have similar potential failure modes or have no visible damage after the test to count as part of the same series. Where the potential failure mode changes for any of the tests, at least one further test must be carried out at a different span value, until a minimum of two span values have the same potential failure mode
- If any test fails, further testing shall be carried out at the same span with a lower value of  $P_t$  until a pass is obtained as described in Section 4.2(f).

### **7.2 Recommended Acceptance Criteria**

The test shall be considered as successful if the following conditions are met:

- The specimen shall have sustained the full loading sequences as given in Section 4.1.

- There shall be no loss of load carrying capacity of any components of the specimen.

*Notes:*

- *The purpose of the test is to prevent the loss of integrity of the building envelope and the generation of wind-borne debris. Excessive deformation should not be considered as failure. Distortion, permanent deformation etc. are acceptable as long as there is no loss of load carrying capacity.*
- *The loss of one fastener is a loss of load carrying capacity and so should be treated as failure. This requirement recognizes that once one fastener fails there will be load shedding to any immediately adjacent fasteners which in turn will very likely fail, as they will then be “overloaded” (a cascade or unzipping effect).*
- *For a cladding test where the potential modes of failure include severe buckling and/or plastic hinge “foldlines”, membrane action may be a significant factor that assists the cladding to support that pressure, especially for relatively long cladding spans. As noted in Section 5.3 of this guide, such membrane action may not be able to be resisted by the “real life” cladding supports, when the cladding is installed in practice. For such cases, the test report should describe the initiation of buckling or plastic mechanism formation (including the load at which it was observed) and also note that membrane action was likely a significant factor to support the loading and that the supports should be designed to resist this action.*



## Annex A – Worked Examples

### A1. Metal Roof Cladding

A metal roof cladding triple span test specimen with identical internal and end supports adopts a ( $V_{sc}$ ) of 10% and uses two replications, giving  $k_t = 1.38$ . The test specimen passes a LHL cyclic test, (using a test pressure of 6.0 kPa) but with severe cracking around the screws. For this one test, the strength limit state design capacity will be 4.34 kPa (= 6.0/1.38).

If a second test specimen, using identical cladding, fasteners and supports, but with a different triple span length, also passes a LHL test (with the same potential mode of failure) then both test specimens can use a value of ( $k_t = 1.30$ , based on four replications). Now the first test specimen will have a higher strength limit state design capacity of 4.62 kPa (= 6.0/1.30).

### A2. Roof Sheeting to Batten Connection Capacity

A manufacturer needs to determine the capacity of a roofing screw XXX fixed to the top flange of a 0.75mm thick batten when subjected to the LHL test. A test pullout value can be chosen and numerous small scale samples can be tested using mechanical means for the sequence of cycles shown in Table 1. Assume the first estimate of  $P_t$  is 2kN, and 3 tests are to be carried out using this value. The first two pass, the third fails by the screw pulling out of the batten before the test regime was completed. A further test is then done using a value of 1.9kN for  $P_t$ , and this passes the test.

The capacity of the connection can be based on the lower value of 1.9kN for  $P_t$ , with three replications, as there were three successful tests with  $P_t$  values either equal or higher. Hence the design capacity of the connection can be computed as follows.

$$\begin{aligned} V_{sc} \text{ for connection} &= 15\% \\ \text{No of replications} &= 3 \\ k_t &= 1.56 \text{ from Table B1} \end{aligned}$$

Hence the Strength Limit State design capacity of the connection using screw XXX in 0.75mm thick roof batten =  $1.9/1.56 = 1.22\text{kN}$ .

If this screw is to be used to connect a roofing profile to the 0.75mm thick batten, the theoretical Strength Limit State design reaction value at each screw point should be limited to a maximum of 1.22kN.

Note: Instead of testing the connection on its own, if a test is carried out on the entire batten as described in Example 6, the value of  $V_{sc}$  could be reduced to 10% when

computing the capacity of the connections from the roofing screws to the top flange of the batten.

### A3. Span Table for Roof Cladding

A manufacturer of a corrugated cladding profile requires pressure versus span tables for the cladding system fixed to pine battens. A cyclic load is applied to the cladding spans via an airbag loading system. Three different double span test configurations are chosen; 600/600, 900/900 and 1200/1200, each test specimen with no replications. All three test specimens do pass a LHL test and exhibit the same potential mode of failure. Therefore there are three replications for determining the factor for variability. The cladding span tables generated from this test program shall be constrained within the 600 to 1200 mm span limits.

### A4. Roof Cladding Capacity

A manufacturer needs to determine the LHL capacity of a cladding XXX fixed to steel supports over a range of spans. (It is assumed the supports have adequate thickness to resist screw pull out.)

1. Estimate the initial "Target" test pressure ( $P_t$ ) based upon previous data and or static testing results.
2. Conduct LHL testing at  $P_t$ .
3. If the roof cladding specimen fails the LHL test, then reduce  $P_t$  accordingly and retest.
4. If the roof cladding specimen passes, apply  $k_t$  using a  $V_{sc}$  of 10%, to calculate a design value.
5. **To determine the number of replications (based on Section 6.2 of this guide):** Each full sheet width (including both sidelaps) can be counted as a unit to be tested. Each different span tested using identical roof cladding, fixings and supports, with the same potential mode of failure, can be counted as replications.

For example, suppose three different single spans are to be tested, to produce a load span curve for the cladding and the uplift test rig can test two full cladding sheet widths (including both sidelaps) test samples. (Note: All tests must have the same potential mode of failure)

Number of replications = (No. of tests) (units per test) =  $3 \times 2 = 6$ .

Reading from the table for 6 replications, we get  $k_t = 1.27$

6. Say  $P_t = 5$  kPa, for one of the spans tested. Then the design value becomes =  $5/1.27 = 3.94$  kPa.

Hence, the Strength Limit State design value for this span is 3.94 kPa.

NOTE: If one of the spans tested fails,  $P_t$  then must be reduced and the test repeated for this particular span. The failed result is discarded for the purposes of determining

$k_t$ , therefore in this case the number of replications would still be 6 and  $k_t=1.27$  from the table.

### A5. Tile Clips

A manufacturer of concrete tile roof cladding system requires testing of the tile clips to resist a cyclonic wind load. A cyclic load is applied to the tiles via computer controlled hydraulic rams. The test configuration consists of six rows of tiles by six courses wide. The central sixteen tiles (four rows by four tiles) are cyclically loaded (the additional tiles are required in the setup to ensure the tiles and clips have the correct orientation as two edges of a tile lap under its neighbour). Although sixteen tiles are loaded, only two tile clips are fully loaded (the other tiles have neighbours that are not fully loaded and so do not have the same load per tile clip). Therefore this test specimen has two replications and may use the  $k_t$  value for a ( $V_{sc}$ ) of 10%, as permitted by Section 6.2.

### A6. Roof Batten Span Table

A manufacturer of metal roof battens wants to produce design load span tables. The tables are to show span of batten versus distributed load along batten. An airbox is used to apply a cyclic load to the cladding which is attached to the battens. Three different triple span test configurations are chosen for the batten spans; 600/600/600, 900/900/900 and 1200/1200/1200. Roof cladding would be screwed to the battens in a double span arrangement using three battens spaced at say 900 mm apart. Cyclone assemblies could be used on the cladding to help guard against failure of the cladding prior to failure of the central batten. The battens are screw fixed to pine members representing top chords (e.g. for the 600/600/600 test, four pine members would be spaced 600 mm apart). For this example the central batten is the batten under test and the batten span tables shall be constrained to between 600 to 1200 mm

Potential modes of failure of the batten could include:

- Failure at the batten top flange by a cladding screw pulling out of top of batten
- Bending/buckling failure of batten,
- Batten tearing around a screw fixing it to a truss member (failure at the batten feet).

However only those test results with nominally the same load to the connection being considered and with a similar potential mode of failure shall be counted for determining number of replications.

To illustrate this concept of different potential modes of failure, consider the following:

Assume that for this program, the calculated reactions at the internal batten supports for all three tests are nominally the same and that all three of the test specimens pass LHL tests and show signs of cracking around the batten feet. Therefore these three specimens can be counted as replicates for this mode of deformation/damage, but as each test specimen has two identical internal supports (showing similar modes

of damage), the total number of replications is six and so all three test specimens may use the  $k_t = 1.2.7$  value for a ( $V_{sc}$ ) of 10%, as permitted by Section 6.2.

The smaller span test specimen (using a 600 mm triple span) passed a LHL test but with a higher test pressure that causes some cracking and doming to the batten top flange, around the cladding screws, as well as the cracking to the batten feet. This is a different mode of damage (potentially cladding screw pull-out, if the pressure was increased too much). For this test specimen, there are more than two full cladding sheets screw fixed to the batten and so this test can count as two replications. Therefore for this 600 mm test specimen, when assessing strength controlled by cladding screw pullout, a value of  $k_t = 1.38$  value can be used. Note that the other longer span tests had a significantly lower load from the cladding screws to the batten top flange and so cannot be counted as replications.

Compare the treatment of the results for the successful test for the 600 mm triple batten span, allowing for the two potential modes of failure, if this test supported a test pressure of 6 kPa.

#### **Potential Failure at the Batten Top Flange by Cladding Screw Pullout**

Design value for roof cladding pressure (900 mm double span) to top batten flange =  $6.0/1.38 = 4.35$  kPa

This value should be used when calculating the capacity of the batten when cladding screw pull-out (for these screws at the screw spacing used in the test) controls the design.

#### **Potential Failure at the Feet of a Batten at an Internal Support**

Design value for roof cladding pressure (900 mm double span) to top batten flange =  $6.0/1.27 = 4.72$  kPa

This design cladding pressure value should be used when calculating the capacity of the batten when the internal reaction at the batten supports (for these batten feet screws fixed to the support type used in the test) controls the design.