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BRE Test Report

MCS012 Testing of the SolFit Roof Integrated PV System on 100mm x 25mm timbers

Prepared for: Ewen Estill, SolFit Ltd

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BRE
Watford, Herts
WD25 9XX

Customer Services 0333 321 8811

From outside the UK:
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Prepared for:
Ewen Estill
SolFit Ltd
Midsummer, Fen house, Fen Road,
Cambridge, CB4 1UN

bre

Prepared by

Name Devinder Athwal

Position Senior Laboratory Technician

Date 28th January 2019

Signature

Authorised by

Name Dr Paul Blackmore

Position Associate Director

Date 28th January 2019

Signature

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Table of Contents

1 Introduction

This report describes testing carried out on SolFit Roof Integrated PV System with BISOL BTU-270 PV modules on 100mm x 25mm timbers. The testing was carried out using the MCS 012 method for wind uplift resistance [1].

The MCS 012 standard specifies the test procedures which shall be used to demonstrate the performance of PV modules and solar thermal collectors and/or their installation kits under the action of wind loads.

These test methods apply to ‘in roof’ and ‘above roof’ systems fixed to pitched roofs. They do not apply to systems mounted inclined above flat roofs or mounted on vertical walls.

This report presents the results from the wind uplift tests.

2 Details of the Test Specimens and Installation

The wind uplift resistance of the SolFit Roof Integrated PV System was investigated using a purpose-built monopitch test roof of nominal size 4m x 3.5m.

Two BISOL BTU-270 PV modules were installed on two sets of mounting rails top and bottom, each fixed using nine 5mm x 50mm wood screws. The left and right sides of PV panels were held by steel flashing that were fixed by three 35mm TEK screws per flashing panel. The top and bottom rails were fixed to 25mm x 50mm batten which were fixed to a 100mm x 25mm timbers. These timbers are representative of those used on boarded roofs used in Scottish practice. The SolFit Roof Integrated PV System was installed by Ewen Estill according to the manufacturers fixing instructions.

The component list for the PV system is as follows:

- Top mounting rail
- Bottom clamping strip (rail)
- Side hold down flashings
- 5mm x 50mm wood screws.
- 35mm TEK screws with 19mm bonded sealing washer
- BISOL BTU-270 PV modules.

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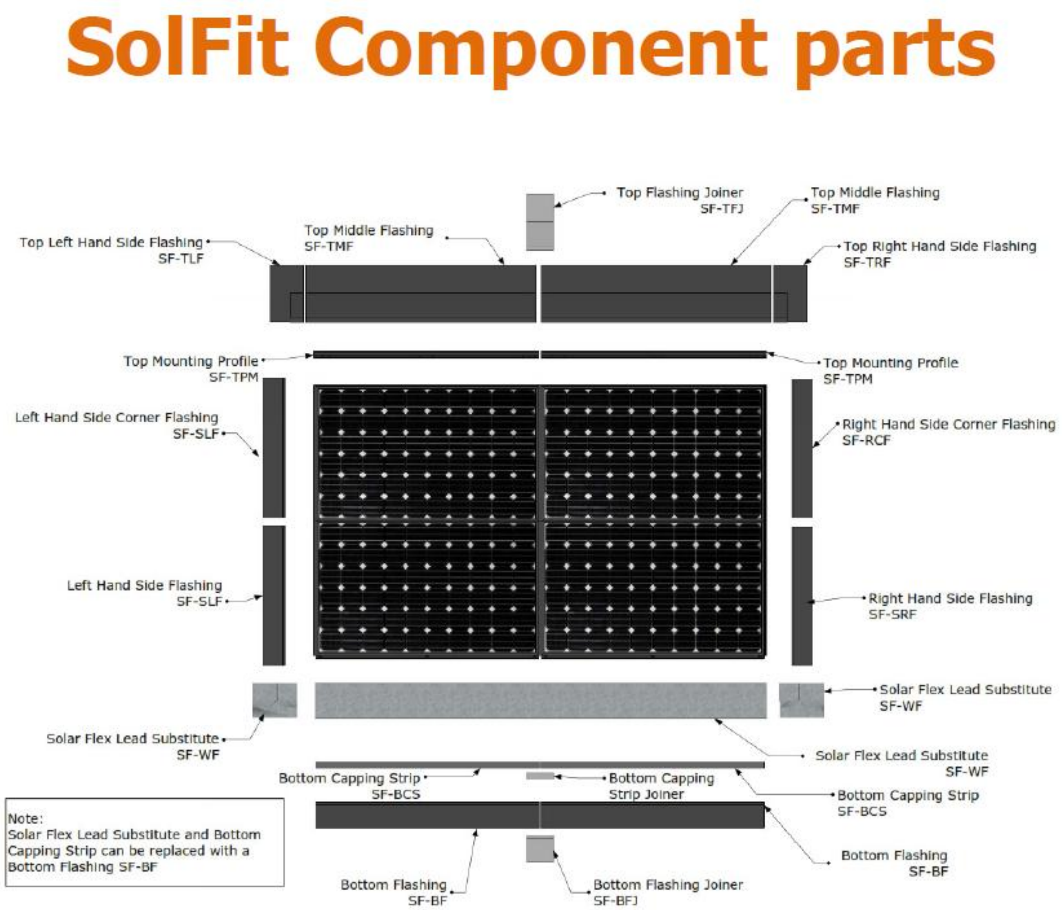

Figure 1 Drawing showing the installation of the SolFit Roof Integrated PV System

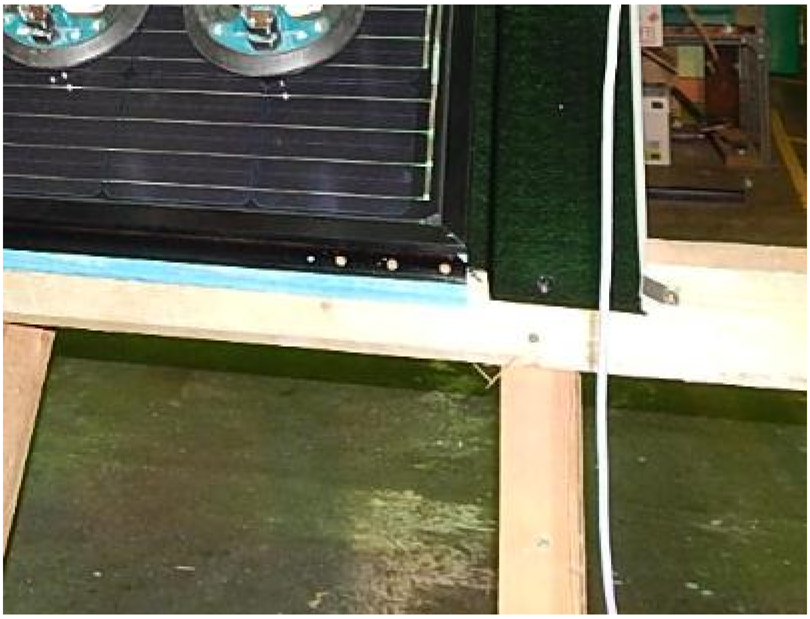

Figure 2 Close up photo showing the batten arrangement below the bottom rail

3 Details of the Tests Carried Out

The recommended test method in MCS012 for wind uplift testing is based on BS EN 14437:2004 [2], which is a test method originally designed for test wind uplift resistance of roof tiles and slates. The tests are carried out on a simulated roof structure comprising rafters at a roof pitch of 45º.

Twelve pneumatic rams with suction cups were attached to each PV tile to apply a force to simulate wind uplift loads.

The test requirements are as follows:

- Where the flashing or sealing kits provides any uplift resistance then these should be included in the test.
- The roof pitch shall be 45deg +/- 2 degrees.
- A minimum of one solar panel should be tested and the test shall be repeated three times with new fixings each time.
- The uplift load shall be applied using a cable(s) or equivalent methods to provide uniform loads. This\these may be fixed to the solar collector by drilling a hole(s) through the collector or by using suction cup devices attached to the glass cover plate.
- The detailed construction of the test rig in terms of the batten sizes, rafter spacing and all fixings shall satisfy the minimum specification (worst case) of the manufacturer/supplier of the solar panel and all materials shall be of a quality typical of real construction. The minimum requirements of BS 5534 shall also be satisfied.

The load testing was repeated three times. For each test, new PV modules, brackets, rails and screws were used.

The loads were applied in a minimum of five increments (as required by the standard). After each load was applied it was removed and the residual deflection was measured. The maximum deflection under load and the residual deflection were measured at four positions on the PV module as shown in Figure 2.

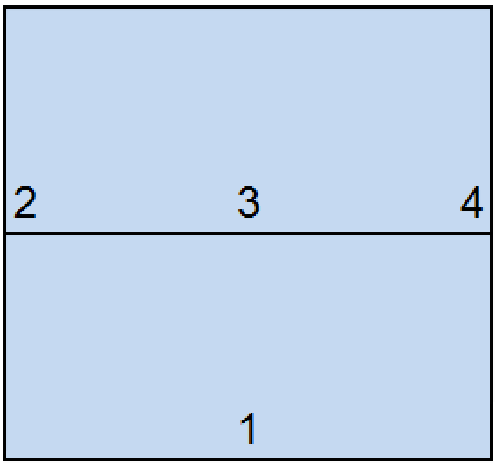

Figure 2 Schematic showing positions where deflections were measured (on the mid and end clamps)

The loading cycles were repeated in increasing load increments until failure occurred; where failure is defined as any of the following:

- Breakage of a mechanical fixing between PV module and support frame.
- Pull-out or breakage of the mechanical connection between the support frame and the roof structure.
- Breakage of the PV module.
- The residual displacement exceeds 5mm after releasing the applied load, providing this displacement degrades the weathertightness of the roof
- If the maximum displacement of any roofing element which exposes the under-roof exceeds 75mm.

Figure 3 shows the PV system ready for test

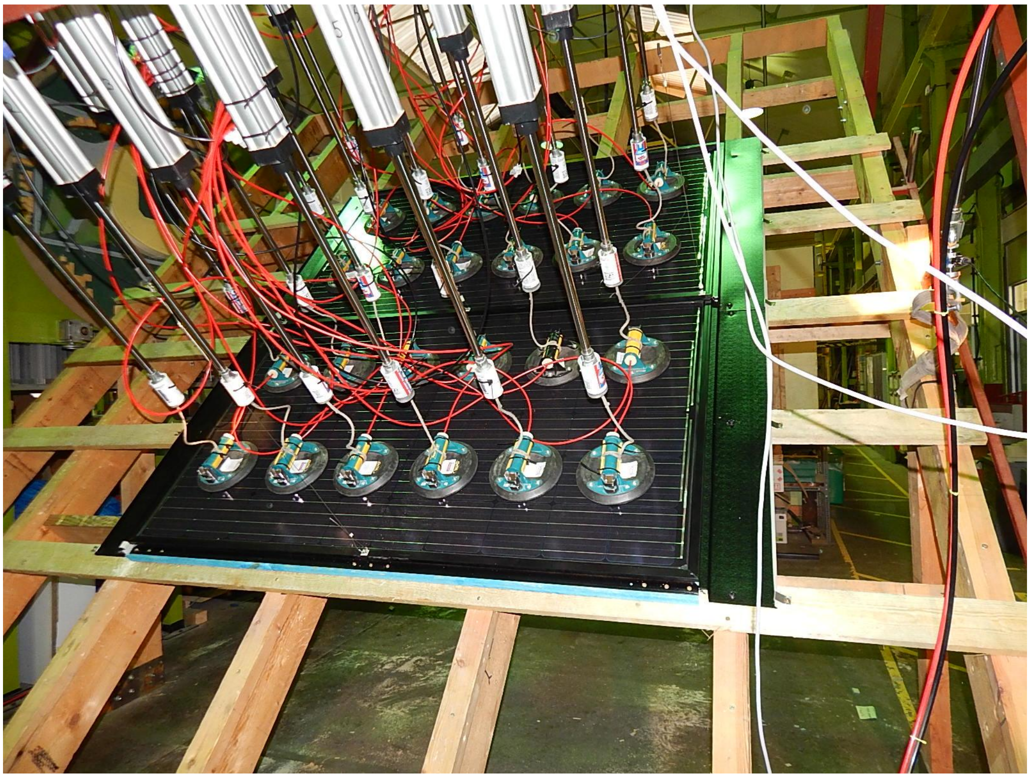

Figure 3 View of the PV system with loading rams attached ready for test

4 Results

4.1 Determination of the characteristic uplift resistance

EN 14437:2004 requires the characteristic uplift resistance R_k to be determined from equation 1:

$R_k = R_x - k_n s_x$ … (1)

Where

R_x is the mean uplift resistance determined from $R_x = \frac{1}{n}\sum R_i$

s_x is the standard deviation of the resistance determined from $s_x = \sqrt{\frac{1}{n-1}\sum (R_i - R_x)^2}$

k_n is a statistical factor = 3.37 (for a sample size of 3 from Table D.1 in EN 14437)

R_i is the individual measured value from each test

EN14437 requires that the coefficient of variability given as s_x / R_x be <0.1 after each batch of three tests. If this value exceeds 0.1 then at least two additional tests must be carried out.

The design wind uplift resistance is determined by dividing the characteristic uplift resistance by a safety factor. MCS012 specifies a range of partial factors to be used to calculate the design resistance of the system as follows:

- Failure of a metal component: 1.1
- Pull-out of a metal component: 1.25
- Failure in a timber component: 1.44
- Serviceability limit failure: 1.0

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4.2 Test Results

The 5mm residual deflection limit was not exceeded at any measurement location in any of the tests, therefore there was not a serviceability limit state failure of this system. The failure mode in each test was pull-out of the BISOL BTU-270 PV modules from the side flashing, i.e. an ultimate limit state failure condition.

Table 1 gives the calculated values of R_k, R_x, s_x and s_x/R_x and the individual failure loads from the test results at ultimate failure. Figures 4, and 5 show the system at failure.

Test configuration	Test number	Measured force (N)	Failure mode
100mm x 25mm	1	8664	Slipped out off flashing
100mm x 25mm	2	9253	Slipped out off flashing
100mm x 25mm	3	8546	Slipped out off flashing

Mean force (N)	**8821.2**
Standard deviation (N)	**378.4**
Coefficient of variability	**0.043**
Characteristic wind uplift pressure	**4451.9**

Table 1: Results from failure at ultimate limit state

These results apply to a single PV module. The coefficient of variability (s_x/R_x) is less than 0.1 so this is a valid test result.

The characteristic uplift resistance of the system in the tests was 4451.9Pa. This has been determined by dividing the characteristic uplift resistance in Newtons calculated from Equation (1) by the area of the PV panel taken as 1.695m^2 (1.695m x 1.000m) to give the characteristic uplift resistance in Pascals (Newtons per metre squared).

The partial safety factor for ultimate failure depends on the failure mechanism. For pull-out of a metal component the partial factor is 1.25, as the metal frame of the module pulled out of the metal flashing this partial factor applies. The partial factor to be used is therefore 1.25.

This gives a design wind uplift resistance of 4281.6/1.25 = **3562Pa**.

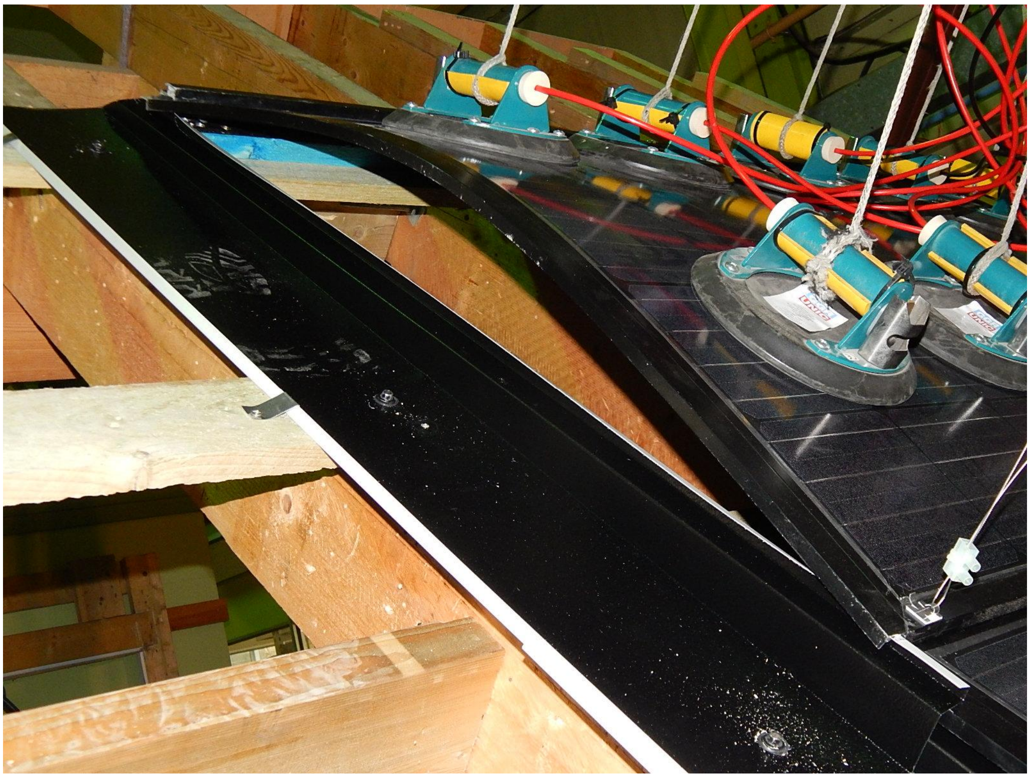

Figure 3 Pull-out of the panel on the top left

5 Conclusions

This report describes tests carried out to determine the characteristic wind uplift resistance of the SolFit Roof Integrated PV System with BISOL BTU-270 PV modules fixed to 100mm x 25mm timbers, when tested in accordance with MCS 012.

The following conclusions can be drawn from these tests:

- The system failed due to pull-out of the BISOL BTU-270 PV module from the flashing. This is an ultimate limit state failure.
- The design uplift resistance of the system as tested on is **3562Pa** based on a partial safety factor of 1.25 at ultimate limit state failure.

The testing was carried out with the system fixed to 100mm x 25mm timbers. This result is therefore representative of the uplift resistance of the system when fitted to a boarded roof.

MCS 012 does not have pass/fail criteria for the wind uplift resistance of pitched roof installation kits for solar systems. The design uplift resistance obtained from the MCS 012 test should be compared with the expected design wind uplift pressure at the site (with the appropriate partial factors applied). If the design uplift resistance is greater than the design wind uplift pressure, then the system will be suitable for use at that particular location. If the design uplift resistance is less than the design wind uplift pressure, then the system will not be suitable for use at that location without increasing the wind uplift resistance by, for example increasing the size or number of the fixing screws or rails.

6 References

1) MCS012; Microgeneration Certification Scheme, Roof performance tests for solar thermal collectors and PV modules, Issue 1.2.

Report Ends