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TEST REPORT

Smart Limited – MCS 012 uplift testing on PF1 and SF1 anchor and flashing kits

Prepared for: Smart Limited
Date: 12.09.2024
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1.Executive summary

Uplift testing was carried out for Smart on two separate products using the procedure set out in MCS 012 Issue 3.0. A summary of the results is as follows.

Table 1: PF1 kit - Plain tile anchor and flashing design uplift resistances

Limit State	Design Uplift Resistance	Failure Mechanism
Ultimate	2175 N	Screw heads broke off.
Serviceability	260 N	5 mm residual displacement limit exceeded.

Table 2: SF1 kit - Slate roof anchor and flashing design uplift resistances

Limit State	Design Uplift Resistance	Failure Mechanism
Ultimate	6984 N	Screw heads broke off.
Serviceability	1661 N	5 mm residual displacement limit exceeded.

The serviceability design uplift resistance will control the design for both systems.

2.Introduction

The proposal for the testing, P128636-1000 Revision 1, was accepted by Ben Share, Smart Limited on the 17th July 2024.

The testing for this report took place on the 6th August 2024, in Building 21, BRE, Watford WD25 9XX.

This report details the tests undertaken to assess the uplift performance of two products, see section 3 for details of the products. The tests were carried out using the procedure set out in MCS012 Issue 3.0 [1].

3.Specimen details

All component and product references in this report were provided by Smart Limited.

Each specimen consisted of the roof hook fixed to a rafter on the test rig. Details of each specimen are given below.

The specimens were installed by BRE?

3.1 Specimen 1

Table 3 shows the components in the PF1 kit and Figure 1 shows them installed on the test rig.

Table 3: PF1 kit components.

Component Name	Part number	Image
Bracket	RAS 1	
Rafter screw (80 mm x 6 mm)	P1	-
Plastic packer	-	-

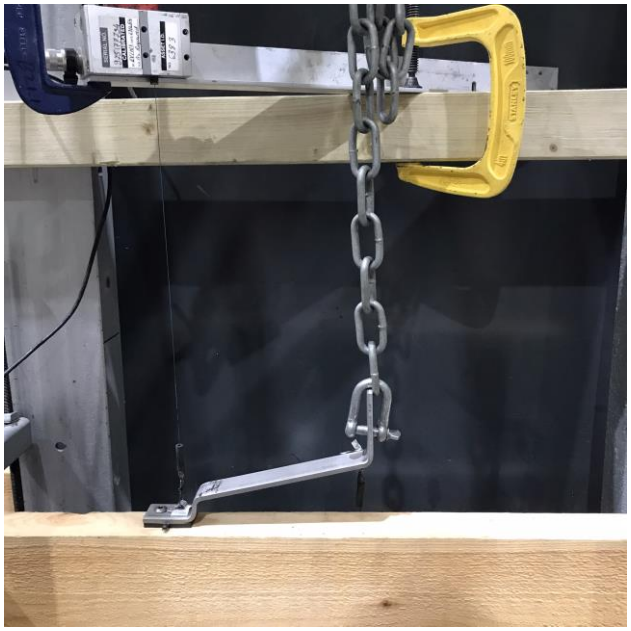


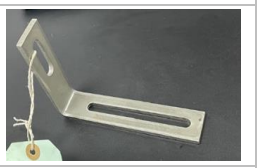
Figure 1: Specimen 1 on the BRE Test Rig.

3.2 Specimen 2

Table 4 shows the components in the PF1 kit and Figure 2 shows them installed on the test rig.

Specimen 2 was installed on top of a fibre cement slate.

Table 4: SF1 kit Components.

Component Name	Part number	Image
Bracket	RAS 3	
Flashing	SF1	
Rafter screw (120 mm x 6 mm)	S1	-
M8 Washer	S2	-
PA45 Foam scrim pad	S4	
31 mm rubber washer	S5	-

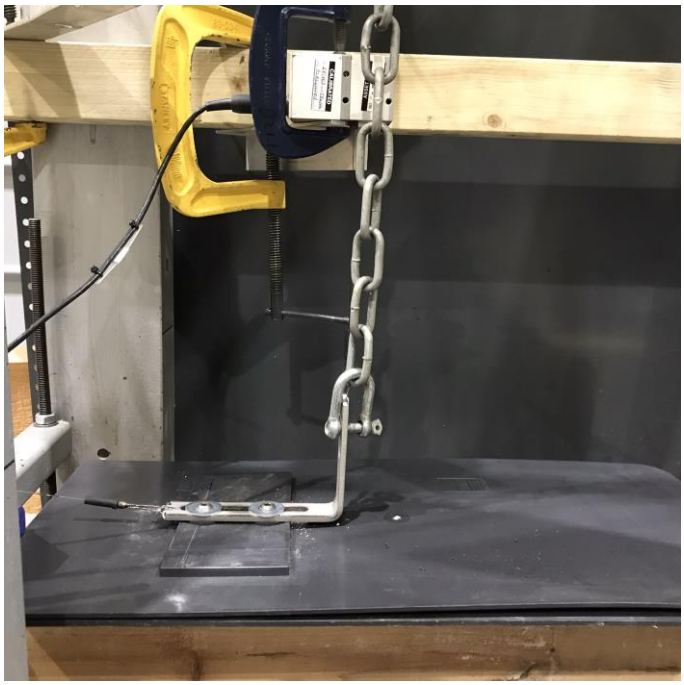


Figure 2: Specimen 2 on the BRE test rig.

4. Test setup

The uplift testing was conducted in accordance with MCS 012 Issue 3.0 [1] and the relevant sections of BS EN 14437:2022 [2], that MCS 012 references, using a purpose-built test rig that is described below.

Loads were applied to the specimens using a hydraulic ram. The loads were applied in accordance with clause 9.4.5 of BS EN 14437, F_t was determined with a trial test.

Failures were recorded and used to calculate design uplift resistances in accordance with Annex D of BS EN 14437:2022 [2]. Summary sheets explaining the failure criteria and calculation process is included in Appendix A along with the calculation for each system.

4.1 Test rig

The test rig comprises a timber rafter, a steel reaction frame, and a hydraulic ram. See Figure 3.

The loads were measured with a load cell, and displacements were measured with pull wires at two locations on the specimen.

Figure 3: Photo of test rig with specimen installed.

5. Test results

Three tests each took place for each specimen. Tables 5 & 6 show a summary of the test results for each specimen, with the full details and calculations in Appendix A. Figures 4 and 5 show the specimens during the tests. In both cases the serviceability design uplift resistance will control the design.

Table 5: PF1 kit design uplift resistances.

Limit State	Design Uplift Resistance	Failure Mechanism
Ultimate	2175 N	Screw heads broke off.
Serviceability	260 N	5 mm residual displacement limit exceeded.

Table 6: SF1 kit design uplift resistances.

Limit State	Design Uplift Resistance	Failure Mechanism
Ultimate	6984 N	Screw heads broke off.
Serviceability	1661 N	5 mm residual displacement limit exceeded.

Figure 4: Photo PF1 during the test. The hook had significantly deformed, and the screw head of one screws had broken off.

Figure 5: Photo SF1 during the test, the hook had significantly deformed.

References

[1] MCS 012 Issue 3.0 (2023), “The Solar Mounting Standard”, The MCS Service Company Ltd.

[2] BS EN 14437:2022, “Determination of the uplift resistance of installed clay or concrete tiles for roofing – Roof system test method”, BSI Standards Limited.

Appendix A - Calculations and data

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Uplift Resistance Failure Criteria and Data Requirements

This summary sheet is based on MCS 012 Issue 3.0, and BS EN 14437:2022.

The failure criteria for the test are: *A1.17 - MCS 012 Issue 3.0*

Ultimate Limit State (ULS)

a) Deformation of the system resulting in solar panel(s) coming free.
b) Breakage of a mechanical component between the panel and the roof structure.
c) Pulling out or breakage of the connection of the mechanical fixing to the roof.
d) Breakage of elements of the solar panel.

Serviceability Limit State (SLS)

e) If the maximum displacement of any part of the roofing or solar systems exposes the under-roof OR exceeds 75 millimetres (mm).
f) After releasing the force to zero the remaining displacement of any roofing element exceeds 5mm.
g) Solar panel(s) becoming insecure (loose).

The uplift resistance recorded for each test should be determined by: *9.4.6 - BS EN 14437:2022*

- For ULS failure, the uplift resistance is equal to the load at failure.
- For SLS failure, the uplift resistance is equal to the load at the previous load step where no failure had occurred.
- Each test should continue until a ULS failure occurs, noting any SLS failures if they occur.
- The load measured should be the load applied to a single panel.

No. of tests to be carried out *D.2.4 - BS EN 14437:2022*

- A minimum of 3 tests should be carried out.
- If after 3 tests $s_u / R_u > 0.15$ a further 2 tests should be carried out.
- If after 5 tests $s_u / R_u > 0.15$ a further 2 tests should be carried out.

Trial test *9.4.3 - BS EN 14437:2022*

- A trial test should be conducted, where the total force on the solar panels is increased at a rate of less than 50 N/s until one of the ULS failure criteria is met.
- The total applied force at failure, F_t, should be recorded below.
- Alternatively if F_t is known from experience then a trial test need not be carried out.

For this set of tests F_t was determined with a trial test.

F_t = 3300 N

Uplift Resistance Test Data

The data in these tables is a summary of the test data.

Table 1: Record of uplift resistances for each test.

Test	ULS Failure			SLS Failure		
No.	$R_{u,i}$ (N)	Type	Description	$R_{s,i}$ (N)	Type	Description
1	3220	C	Screw head broke off.	335	F	5 mm residual displacement limit exceeded.
2	2904	C	Screw head broke off.	309	F	5 mm residual displacement limit exceeded.
3	3343	C	Screw head broke off.	304	F	5 mm residual displacement limit exceeded.
4	-	-		-	-	
5	-	-		-	-	
6	-	-		-	-	
7	-	-		-	-	

$s_u / R_u =$ 0.072

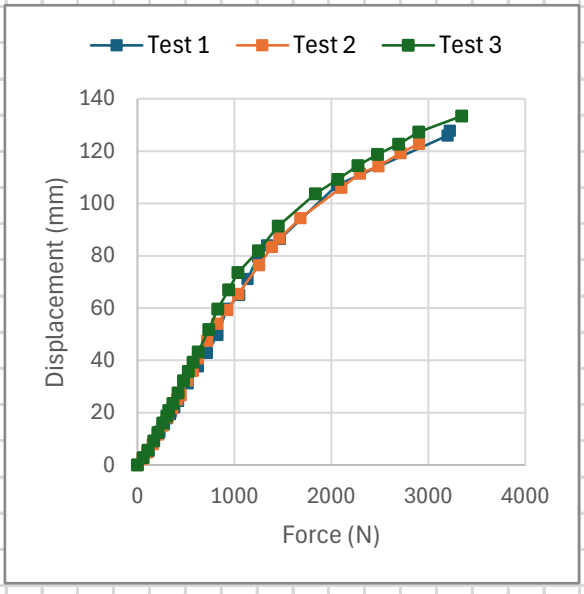

Figure 1: Under load displacement.

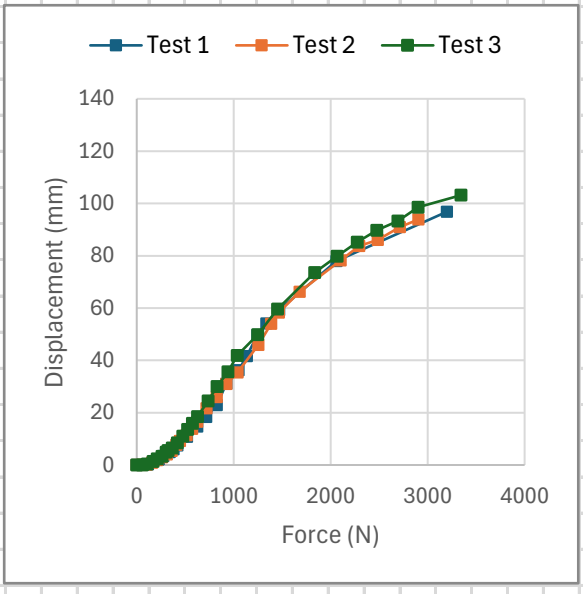

Figure 2: Residual displacement.

Uplift Resistance Calculation

This calculation follows the procedure set out in MCS 012 Issue 3.0, and Annex D of BS EN 14437:2022.

Symbols and abbreviations *Annex D - BS EN 14437:2022*

$R_{u,i}$	uplift resistance for test i when a ULS failure mode occurred
R_u	mean value of the uplift resistance from all tests with a ULS failure mode
s_u	standard deviation of the uplift resistance from all tests with a ULS failure mode
n_u	number of tests that have been carried out with a ULS failure mode
$R_{k,u}$	characteristic value of the uplift resistance for ULS
$R_{d,u}$	design value of the uplift resistance for ULS
$R_{s,i}$	uplift resistance for test i when a SLS failure mode occurred
R_s	mean value of the uplift resistance from all tests with a SLS failure mode
s_s	standard deviation of the uplift resistance from all tests with a SLS failure mode
n_s	number of tests that have been carried out with a SLS failure mode
$R_{k,s}$	characteristic value of the uplift resistance for SLS
$R_{d,s}$	design value of the uplift resistance for SLS
k_n	a statistical factor depending upon the number of tests, n.
A	the area the load has been applied to
γ_M	a partial safety factor defined by MCS 012 *A1.18 - MCS 012 Issue 3.0*

Formulas *Annex D - BS EN 14437:2022*

$$R_u = \frac{1}{n_u}\sum R_{u,i} \quad (D.1)$$

$$s_u^2 = \frac{1}{n_u - 1}\sum \left(R_{u,i} - R_u\right)^2 \quad (D.2)$$

$$R_{k,u} = R_u - k_n \cdot s_u \quad (D.5)$$

$$R_{d,u} = \frac{R_{k,u}}{\gamma_M} \quad (D.7)$$

The same equations can be used for SLS calculations replacing 'u' with 's' *(D.3, D.4, D.6, D.8)*

SLS resistance is only calculated where SLS failure occurred 3 or more times. *D.2.4 - BS EN 14437:2022*

In the calculation on the next page the characteristic uplift resistance is converted from a load (N) to a pressure (Pa) using the area the load has been applied to.

$$pressure\ (Pa) = \frac{load\ (N)}{area\ (m^2)}$$

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Values

Values for k_n

Table D1 - BS EN 1990:2002+A1:2005

n	3	4	5	6	7
k_n	3.37	2.63	2.33	2.18	2.08

Values for γM

A1.18 - MCS 012 Issue 3.0

Failure Mode	γ_M
Ultimate Limit State (ULS)	
Deformation resulting in panels coming free	1.1
Failure in a metal component	1.1
Failure in a plastic component	1.25
Pull out from a metal component	1.25
Failure in a timber component or pull out from a timber component	1.44
Serviceability Limit State (SLS)	1.0

Calculation

n_u	3	
R_u	3156	N
s_u	226	N
k_n	3.37	
$R_{k,u}$	2393	N
γ_M	1.1	
$R_{d,u}$	**2175**	**N**
n_s	3	
R_s	316	N
s_s	17	N
k_n	3.37	
$R_{k,s}$	260	N
γ_M	1.0	
$R_{d,s}$	**260**	**N**

Uplift Resistance Failure Criteria and Data Requirements

This summary sheet is based on MCS 012 Issue 3.0, and BS EN 14437:2022.

The failure criteria for the test are: *A1.17 - MCS 012 Issue 3.0*

Ultimate Limit State (ULS)

a) Deformation of the system resulting in solar panel(s) coming free.
b) Breakage of a mechanical component between the panel and the roof structure.
c) Pulling out or breakage of the connection of the mechanical fixing to the roof.
d) Breakage of elements of the solar panel.

Serviceability Limit State (SLS)

e) If the maximum displacement of any part of the roofing or solar systems exposes the under-roof OR exceeds 75 millimetres (mm).
f) After releasing the force to zero the remaining displacement of any roofing element exceeds 5mm.
g) Solar panel(s) becoming insecure (loose).

The uplift resistance recorded for each test should be determined by: *9.4.6 - BS EN 14437:2022*

- For ULS failure, the uplift resistance is equal to the load at failure.
- For SLS failure, the uplift resistance is equal to the load at the previous load step where no failure had occurred.
- Each test should continue until a ULS failure occurs, noting any SLS failures if they occur.
- The load measured should be the load applied to a single panel.

No. of tests to be carried out *D.2.4 - BS EN 14437:2022*

- A minimum of 3 tests should be carried out.
- If after 3 tests $s_u / R_u > 0.15$ a further 2 tests should be carried out.
- If after 5 tests $s_u / R_u > 0.15$ a further 2 tests should be carried out.

Trial test *9.4.3 - BS EN 14437:2022*

- A trial test should be conducted, where the total force on the solar panels is increased at a rate of less than 50 N/s until one of the ULS failure criteria is met.
- The total applied force at failure, F_t, should be recorded below.
- Alternatively if F_t is known from experience then a trial test need not be carried out.

For this set of tests F_t was determined with a trial test.

F_t = 8000 N

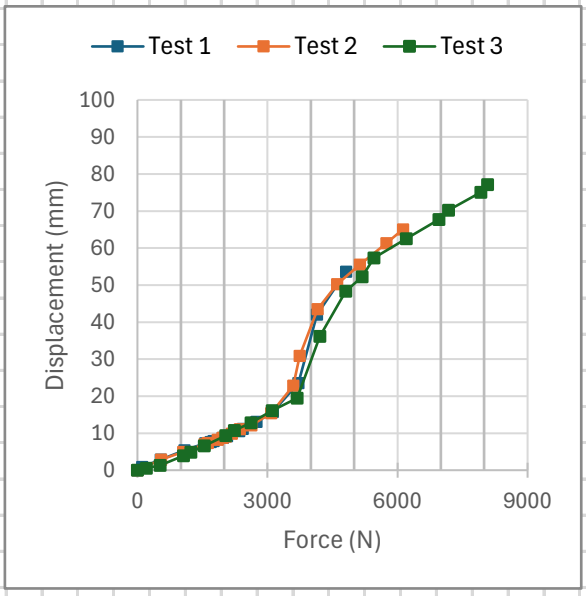
Uplift Resistance Test Data

The data in these tables is a summary of the test data.

Table 1: Record of uplift resistances for each test.

Test	ULS Failure			SLS Failure		
No.	$R_{u,i}$ (N)	Type	Description	$R_{s,i}$ (N)	Type	Description
1	7969	C	Screw head broke off.	2346	F	5 mm residual exceeded
2	8208	C	Screw head broke off.	2177	F	5 mm residual exceeded
3	8078	C	Screw head broke off.	2035	F	5 mm residual exceeded
4	-	-		-	-	
5	-	-		-	-	
6	-	-		-	-	
7	-	-		-	-	

$s_u / R_u =$ 0.015



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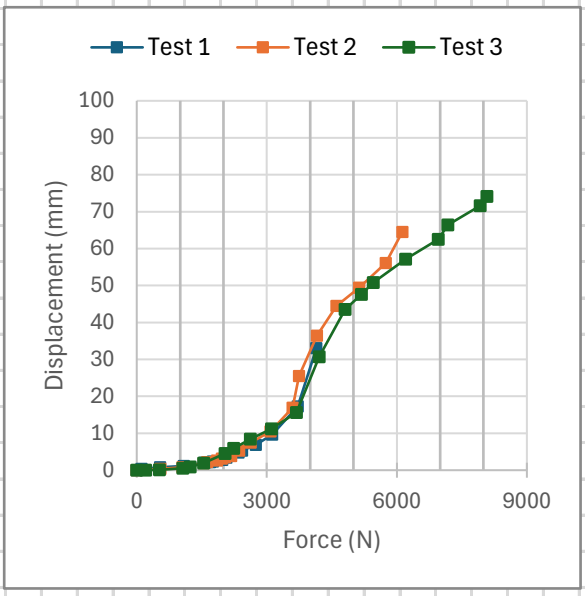

Figure 2: Residual displacement.

Uplift Resistance Calculation

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Symbols and abbreviations *Annex D - BS EN 14437:2022*

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$R_{k,u}$	characteristic value of the uplift resistance for ULS
$R_{d,u}$	design value of the uplift resistance for ULS
$R_{s,i}$	uplift resistance for test i when a SLS failure mode occurred
R_s	mean value of the uplift resistance from all tests with a SLS failure mode
s_s	standard deviation of the uplift resistance from all tests with a SLS failure mode
n_s	number of tests that have been carried out with a SLS failure mode
$R_{k,s}$	characteristic value of the uplift resistance for SLS
$R_{d,s}$	design value of the uplift resistance for SLS
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In the calculation on the next page the characteristic uplift resistance is converted from a load (N) to a pressure (Pa) using the area the load has been applied to.

$$pressure\ (Pa) = \frac{load\ (N)}{area\ (m^2)}$$

Values

Values for k_n

Table D1 - BS EN 1990:2002+A1:2005

n	3	4	5	6	7
k_n	3.37	2.63	2.33	2.18	2.08

Values for γM

A1.18 - MCS 012 Issue 3.0

Failure Mode	γ_M
Ultimate Limit State (ULS)	
Deformation resulting in panels coming free	1.1
Failure in a metal component	1.1
Failure in a plastic component	1.25
Pull out from a metal component	1.25
Failure in a timber component or pull out from a timber component	1.44
Serviceability Limit State (SLS)	1.0

Calculation

n_u	3	
R_u	8085	N
s_u	119	N
k_n	3.37	
$R_{k,u}$	7683	N
γ_M	1.1	
$R_{d,u}$	**6984**	

n_s	3	
R_s	2186	N
s_s	156	N
k_n	3.37	
$R_{k,s}$	1661	N
γ_M	1.0	
$R_{d,s}$	**1661**	

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