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BRE Test Report

Determination of the uplift resistance of Carapace Slates to EN 14437

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1 Introduction and details of the test specimens

This report describes wind uplift testing carried out to EN 14437[1] – Determination of the uplift resistance of installed clay and concrete tiles for roofing – Roof system test method on Carapace Slates.

The Carapace Slate system comprises of – Martyn Can you please provide a description of the slates and the way they are laid and fixed

Figures 1 and 2 show views of the Carapace Slates.

This report provides details of the testing carried out and results obtained.

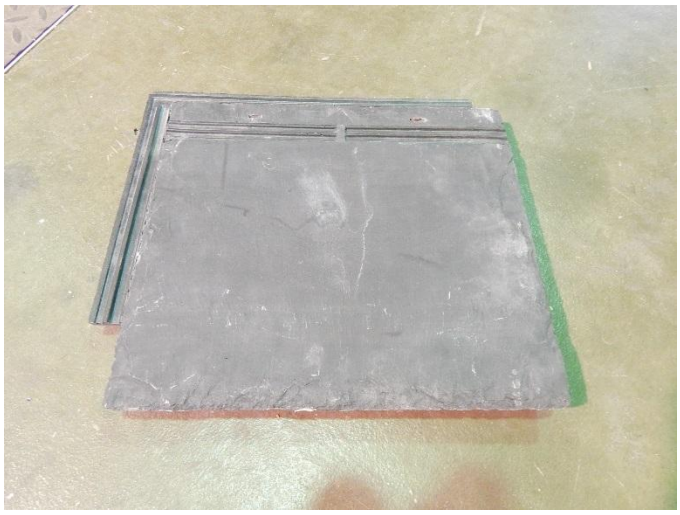

Figure 1 view on top surface of Carapace Slate

Figure 2 view on bottom surface of Carapace Slate showing integral fixing brackets

2 Details of the tests carried out

The testing was carried out according to EN 14437: 2004. The tests are carried out on a simulated roof structure comprising rafters at 600mm centres set at a roof pitch of 45º. Figure 3 shows the test rig with the specimens installed.

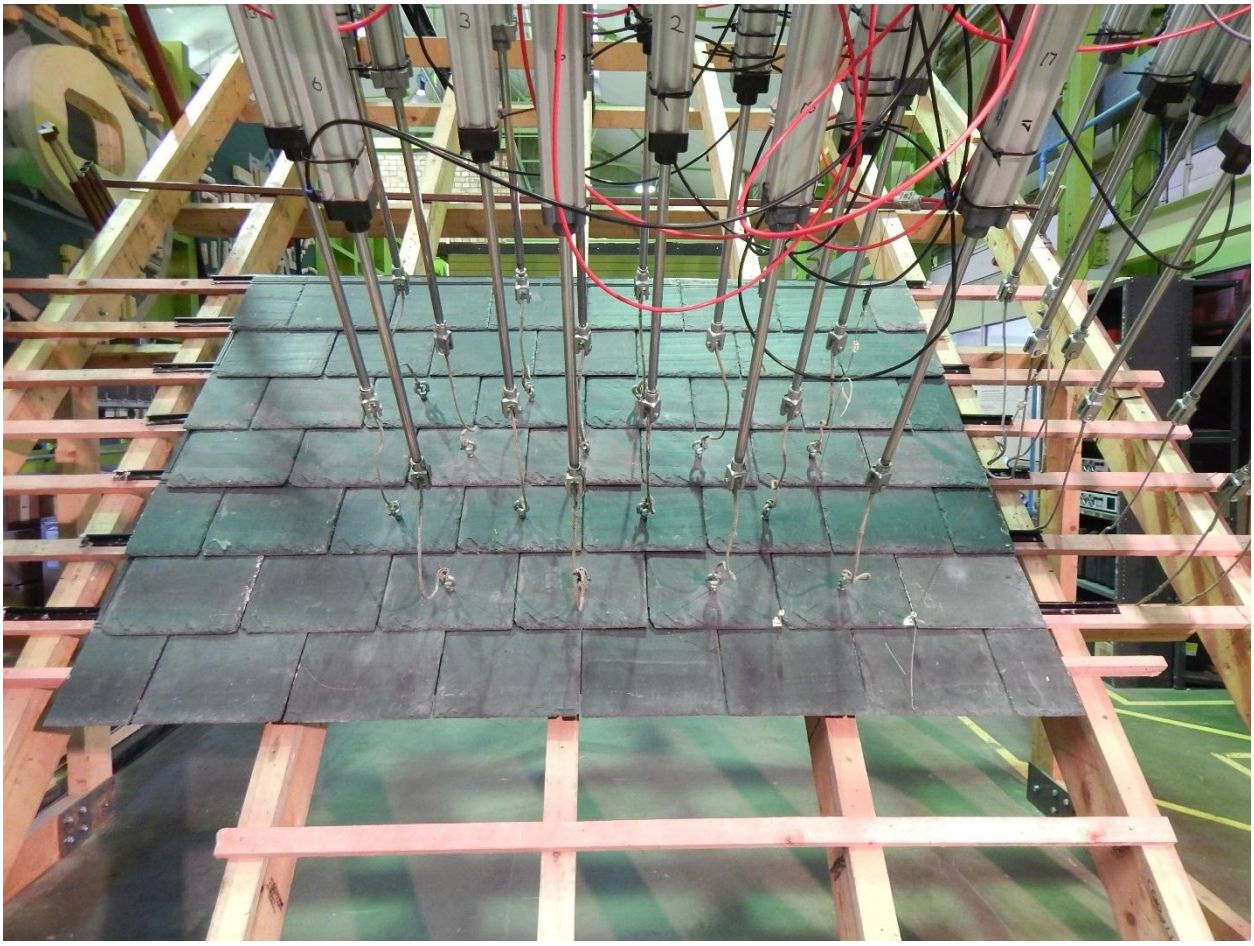

Figure 3 General view of the BRE test rig with the Carapace Slates installed

The test products were laid on the test rig by SunScape Systems Ltd staff as they would be installed in practice on a roof in broken bond. All slates were mechanically fixed using the integral proprietary fixing system Forty-nine slates were installed in seven courses with seven slates per course. The central sixteen slates were loaded as shown in Figure 3. The loaded tiles were numbered as shown in Figure 4.

13	14	15	16
9	10	11	12
5	6	7	8
1	2	3	4

Figure 4 Numbering sequence used for loaded tiles

The testing was carried out using 16 pneumatic rams each fixed to the centre of the exposed area of the 16 loaded slates using flexible cables. A trial test was carried out to establish the expected failure load. The loads were then applied as specified by EN 14437 with a first load increment of 60% of the expected failure load followed by increments of approximately 5% of the expected failure load. After each load was applied it was removed and the residual deflection was measured. This was repeated until failure occurred where failure is defined as one of the following:

- Breakage of the mechanical fixing between tile and batten
- Pull-out or breakage of the mechanical connection to the roof structure
- Breakage of the roofing element
- The maximum deflection of any roof tile exceeds 75 x l_h/400, where l_h is the hanging length of the roof tile.
- The residual displacement of the roof tile exceeds 5mm after releasing the applied load
- The roof tile becoming disengaged from the batten

The displacement of the tiles was measured using two calibrated displacement gauges. The applied force was measured using a calibrated load cell.

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3 Test results

The measured maximum displacements and residual displacements in the test are given in Table 1.

Total load (Kg)	Force (N)	Under load displacement	
		Displacement 1 (mm)	Displacement 2 (mm)
0	0	0.0	0.0
80	785	1.8	1.4
115.2	1130	2.6	1.7
129.6	1271	2.7	2.0
144	1413	3.4	2.8
152	1491	3.5	2.9
160	1570	3.6	3.0
176	1727	4.0	3.4
192	1884	4.2	3.8
208	2040	4.4	4.1
224	2197	4.9	4.5
256	2511	5.7	5.1
288	2825	6.3	5.8
320	3139	6.9	6.4
384	3767	8.6	7.8
416	4081	9.1	8.4
448	4395	9.7	9.4
480	4709	10.3	10.0
512	5023	11.1	10.8
544	5337	11.9	11.5
576	5651	12.7	12.3

Total load (Kg)	Force (N)	Residual displacement	
		Displacement 1 (mm)	Displacement 2 (mm)
0	0	0.0	0.0
80	785	1.3	1.0
115.2	1130	2.0	1.1
129.6	1271	2.2	1.3
144	1413	2.5	1.7
152	1491	2.6	1.8
160	1570	2.6	1.8
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Table 1 Results from the uplift tests

The slates failed due to either the integral slate clip disengaging from the slate below or the head of the slate disengaging from the metal rail. Figures 5 and 6 show the failure slates.

Table 2 shows the failure loads and modes of failure of the slates.

Applied force (N)	Failure Mode (see Figure 4 for key to slates)
3767	No 8 slate right hand side clip disengaged No 13 slate right hand side clip disengaged
4709	No 9 slate right hand side clip disengaged
5023	No 14 slate right hand side clip disengaged No 15 slate – head of slate disengaged from metal rail No 16 slate – head of slate disengaged from metal rail

Table 2 Failure load and mode of failure of the slates

Figure 5 Integral clip disengaged from slate below

Figure 6 Head of slates 15 and 16 disengaged from metal channel

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3.1 Calculation of the strength of the clip

Annex E of EN 14437 gives a procedure for determining the design uplift resistance of the clip $R_{d,f}$ which is the value normally specified by National Authorities for use in design.

In order to calculate this value, the measured failure loads must be corrected for the influence of the weight of the roof tiles using equation 2 (given in Annex E.1 of EN 14437)

$$R_i = (R_{r,i} - 16W_k)/m \qquad ...(4)$$

Where $R_{r,I}$ is the maximum uplift resistance measured in the test = 3767N

W_k is the theoretical uplift force required to lift an unfixed slate. However, as these slates cannot be laid unfixed the average weight of the slates has been used instead determined by taking the average weight of 10 slates = 1.383kg = 13.567N

M is the number of fixed roof tiles in the loaded area = 16

R_i = (3767 – 16 x 13.567)/16 = **221.9N**

The characteristic value of the clip strength $R_{k,f}$ should be determined based on the characteristic failure load. However, as only one uplift test was carried out it is not possible to calculate the characteristic value, therefore for this test the value of R_i has been taken as $R_{k,f}$. This result should therefore be regarded as indicative.

The design value of the uplift resistance $R_{d,f}$ is given by the following equation (from EN 14437 Annex E.2)

$$R_{d,f} = \frac{R_{k,f}}{\gamma} \qquad ...(5)$$

Where γ is the partial safety factor for resistance

EN 14437 Annex G.2 suggests that where the partial safety factor will be in the range 1.0 to 1.2.

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4 Conclusions and Discussion

This report describes tests carried out to determine the characteristic wind uplift resistance of the Carapace Slate system. The results from these tests show that the indicative value of the characteristic uplift resistance is **221.9N**.

To put the uplift resistance value of 221.9N in to context the expected wind load on the slates needs to be determined using BS 5534.

In BS 5534 the wind load on the slates, F_t, is given by equation H.1 reproduced below: (or equations H.2 to H.5 for slate overhangs >60m):

$F_t = q_p \times \gamma_Q \times K_{FI} \times c_{p,net} \times A_t \times S$

Where q_p = peak velocity pressure (a typical maximum value in the UK is 2000Pa)

$\gamma_Q = 1.5$

$K_{FI} = 0.9$

A_t = exposed area of slate (= 0.305m x 0.215m = 0.0656m^2)

$c_{p,net}$ = net pressure coefficient (the largest $c_{p,net}$ value from BS 5534 Table H.1 = 1.04)

S = substrate shielding factor

Taking a typical worse case example where q_p = 2000Pa, γ_Q = 1.5, K_{FI} = 0.9, A_t = 0.0656, S = 1, $c_{p,net}$ = -1.04

F_t = 2000 x 1.5 x 0.9 x -1.04 x 0.0656 x 1 = -**184.2N**

The indicative uplift resistance of the Carapace Slate system is 221.9N which exceeds the 184.2N which is the typical maximum wind uplift force expected in the UK.

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5 References

1 BS EN 14437:2004, Determination of the uplift resistance of installed clay and concrete tiles for roofing – Roof system test, BSI, 2004

Report Ends