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BRE Test Report

Rain Penetration Tests on Manthorpe Small Format Slate Vent

Prepared for: Ben Hales

Date: 14th February 2017

Report Number: P107103-1000: Issue 2

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Executive Summary

This report describes rain penetration tests carried out on a Manthorpe Small Format Slate Vent to assess its resistance to driving rain. The vent was tested at roof pitches of 30º on a Natural Slate roof and 22.5º on a Fibre Cement slate roof. The tests were carried out using a monopitch roof test rig according to the procedures in CEN standard FprEN 15601. The test roof was positioned in the exit air flow of the BRE No.3 Boundary Layer Wind Tunnel. Two sets of test conditions were used, as follows:

- Sub test B - High rainfall with high wind speed
- Sub test D - Deluge - simulating maximum rainfall with no wind

These test conditions represent typical worse case conditions expected in Northern Europe during a 50 year return period. The following main conclusion can be drawn from this testing:

- The weathertightness performance of the Manthorpe Small Format Slate Vent is better than that of the surrounding Natural Slates and Fibre Cement slates.
- The ventilation opening is sufficiently weatherproofed to ensure that no ingress of water occurs when subjected to negative pressures down to a pitch of 22.5°.

When used with 500mm x 250mm fibre cement slates:

- The Manthorpe Small Format Slate Vent does not leak before the surrounding 500mm x 250mm Fibre Cement slates at a roof pitch of 22.5°
- The vent will perform satisfactorily at a minimum roof pitch of 22.5°. As weather tightness performance improves with roof pitch, the vent is expected to also perform satisfactorily at roof pitches above 22.5°.

When used with 400mm x 200mm natural slates:

- The Manthorpe Small Format Slate Vent does not leak before the surrounding 400mm x 200mm Natural Slate at a roof pitch of 30°
- The vent will perform satisfactorily at a minimum roof pitch of 30° when using this format of natural slates. As weather tightness performance improves with roof pitch, the vent is expected to also perform satisfactorily with this covering at roof pitches above 30°.

Table of Contents

1 Introduction

This report describes rain penetration tests carried out on the Manthorpe Small Format Slate Vent when installed with Natural Slate and Fibre Cement tiles. The tests reported herein were carried out at BRE, Garston Watford during January 2017 at roof pitches of 22.5º and 30º.

This test is based on BRE Proposal No. P107103-1000 dated 19th January 2017, which was accepted by Mr Ben Hales.

The testing was witnessed by:

Mr Ben Hales and Mr Mike Challinor from Manthorpe Building Products Ltd.

2 Objective

The objective of these tests was to assess the driving rain performance of the Manthorpe Small Format Slate Vent when installed with Natural Slate and Fibre Cement tiles according to the procedures given in CEN standard FprEN 15601: Hygrothermal performance of buildings: Wind-driven rain on roof coverings with discontinuously laid small elements – test method.

Tests were carried out at roof pitches of 22.5º and 30º, the testing was carried out using the following wind and rain combinations:

- High rainfall with high wind speed (defined in FprEN 15601 as the type B test)
- Deluge - simulating maximum rainfall with no wind (defined in FprEN 15601 as the type D test)

3 Test Specimen

The vent and tiles were installed on the BRE test rig by Manthorpe employees. For these tests Natural Slate and Fibre Cement tiles were used on separate rigs. Figure 1 shows the vent installed on the Natural Slate rig. Figure 2 shows the vent installed on the Fibre Cement rig.

Figure 1 Small Format Slate Vent Tile installed with Natural Slate tiles

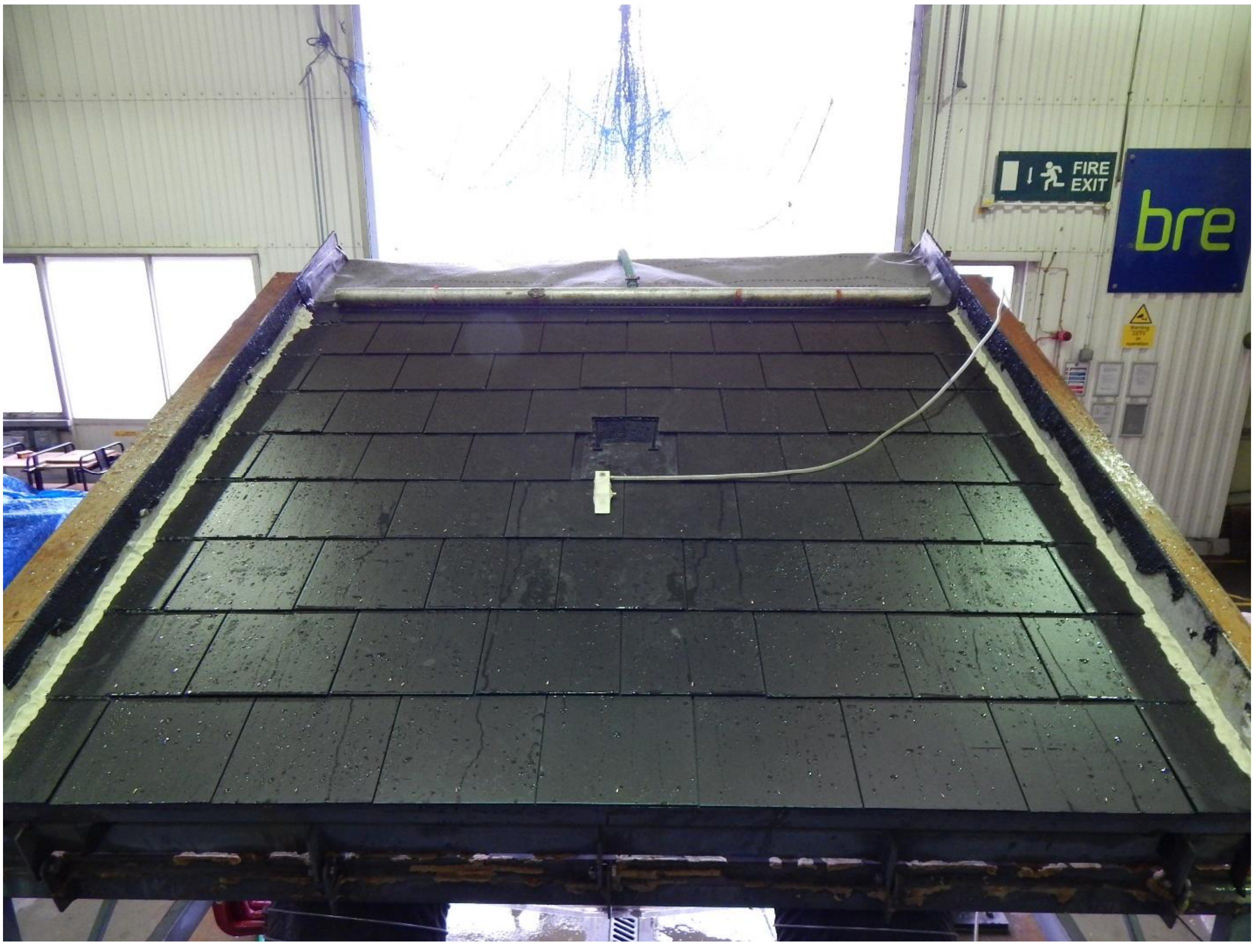

Figure 2 Small Format Slate Vent installed with Fibre Cement Tiles

The performance of the roof vent was investigated using a purpose-built monopitch test roof of nominal size 2m x 2m. On the underside of the test roof, and central to it, a 1.8m wide x 1.6m long shallow Perspex box (open area 2.88m^2) was mounted. It was this box that allowed the pressure underneath the tiles to be controlled. This test rig fully complies with the requirements laid down in FprEN 15601:2006 and has been calibrated to give the required uniformity of wind speed and rain flow across the test specimens. Results of the calibration tests on the BRE test rig and details of the turbulence intensity in the flow are presented in Annex B. Figure 3 & 4 show the roof vent and tiles under test.

Figure 3 Manthorpe Small Format Vent Tile with Natural Slate tiles under test

Figure 4 Manthorpe Small Format Vent Tile with Fibre Cement tiles under test

4 Test Procedure

Tests were carried out on the roof tiles with no vent in order to obtain the benchmark performance of the tiles. The tests were then repeated with a single vent tile in place with surround roof tiles. Then test specimens were installed on the BRE test rig positioned at the wind tunnel outlet. On the underside of the test rig, a Perspex pressure box enabled the pressure difference across the tiles to be varied during the testing. The edges around the pressure box were sealed to prevent the ingress of water during the rain penetration testing; this sealing also provided an effective aerodynamic seal between the air flow conditions above and below the tiles.

The wind tunnel velocity was measured using a Pitot-static tube placed in the wind tunnel free stream. A calibrated micro manometer was connected to this Pitot - static tube, and monitored the wind tunnel velocity during the testing.

The pressure in the Perspex box was increased or decreased by the use of a variable speed fan. The pressure difference between the static pressure above the roof and the pressure inside the pressure box was measured using a second calibrated micro manometer.

The test procedures complied with those set out in FprEN 15601. The tests were carried out with the test roof mounted at the exit of BRE's No.3 Boundary Layer Wind Tunnel so that the wind flow was directed perpendicular to the eaves. Two horizontal spray bars were mounted at the exit from the tunnel, so that water could be sprayed into, and mixed evenly with the air stream. A schematic diagram of the test arrangement is shown in Figure 5.The test conditions represent the worst case wind and rain combination likely to occur in Northern Europe during any 50-year period.

A spray nozzle was mounted above the roof so that water could be sprayed down onto the roof to provide deluge rain. The wind tunnel was not running during deluge rain testing.

To simulate a typical 7 metre rafter length, a sparge bar was mounted across the top edge of the roof. The sparge bar was used to provide the quantity of runoff water that could be expected from a further 5 metre run of roof up to the ridge.

It should be noted that the variable speed fan used to generate the pressure difference across the roof has a finite performance range. Hence the conditions stated below represent test conditions that are usually attainable. If these conditions could not be achieved (e.g. because the air leakage through the roof system is too great), conditions as near to the limits as possible were tested. Full details of the tests undertaken are given in the running sheets in Annex A.

i) High wind speed and High rainfall combination (FprEN 15601 Test B)

Water is sprayed at a rate equivalent to rainfall of 60mm/hour over the test area plus the run-off bar with a flow equivalent to 60mm/hour over the rest of a typical 7m roof. The wind speed was 13m/s. This represents conditions that on average will only occur once in any 50 year period in Northern Europe.

ii) Deluge Test – Maximum rainfall with no wind (FprEN 15601 Test D)

Water was sprayed onto the roof, with no wind, at a rate equivalent to a rainfall of 225mm/hour over the whole 2m square roof. The run-off spray bar at the top of the test section simulated a rainfall of 225mm/hour over the rest of a typical 7m roof. The test lasts for two minutes with an observer, beneath the box, checking for leaks. This represents conditions that on average will only occur once in any 50 year period in Northern Europe.

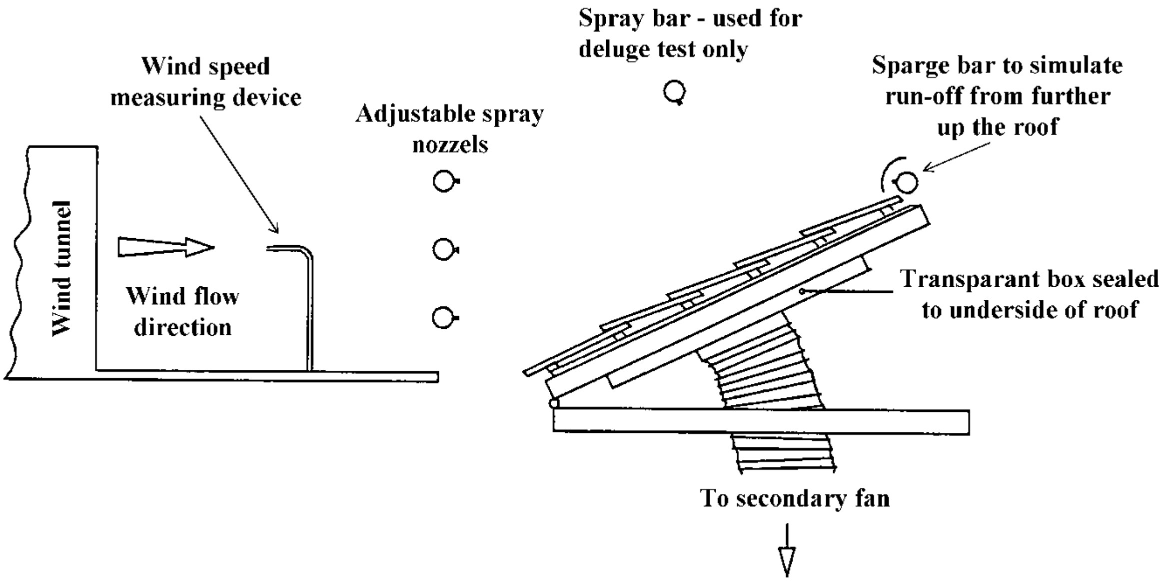

Figure 5 Schematic view of the BRE Rain Penetration Test Rig

The tests start with the pressure in the test box at the appropriate wet sealed box pressure (WSB), as described in Section 4.1. The pressure inside the box is then decreased by 10 Pascals increments and the cycle is repeated until the amount of measured leakage water exceeds 10gr/m^2/5min or as otherwise agreed with the customer.

4.1 Determining the wet sealed box pressure (WSB)

Before the driving rain testing starts, the WSB pressure must first be determined. This is the pressure that occurs within the pressure box at the appropriate wind speed and with the roof covering fully wetted (the pressure box is sealed during these measurements). This represents ambient conditions likely to occur on a real roof for the tiles under test. The WSB pressure is adopted as the reference zero pressure for subsequent testing according to the procedure given in FprEN 15601.

5 Results and Discussion

There is no pass-fail criterion given in FprEN 15601; this standard requires performance of a test product to be compared with the performance of a reference product which has known satisfactory performance under the same wind-rain conditions. Informative Annex C of this standard titled ‘Use of test results’ states that ‘For satisfactory performance of the product, the applied suction required to cause leakage of 10g/m2 per 5-minute step in the test specimen shall not be less than the applied suction value of the reference product test specimen at the same leakage rate and wind-rain conditions.’

For these tests the performance of the Small Format Slate Vent is compared with that of the surrounding Natural Slate tiles and Fibre Cement tiles tested without the Small Format Slate Vent.

Copies of the result sheets filled in during the tests and giving observations made at the time are contained in Annex A.

5.1 Deluge Test – Sub-test D

At roof pitches of 22.5º and 30º there were no leaks observed during the deluge test on either the tiled roof or the tiled roof with Small Format Slate vent at any part of the roof or from the tile vent.

5.2 Wind and Rain test – Sub-test B

In Fpr15601 the pressure (or suction factor) at which $10g/m^2/5$ min of water leakage occurs is taken as the measure of the water tightness in these tests. Table 1 shows the pressure factors for the Manthorpe Small Format Slate Vent with Natural Slate tiles and Fibre Cement tiles as well as for the Natural Slate tiles and Fibre Cement tiles installed on their own without the vent.

The pressure factors given in Table 1 show the relative performance of the product, the larger (or more positive) the pressure factor the better the relative performance of the roof under wind driven rain conditions.

Figure 6 shows the pressure-leakage curves for the Manthorpe Small Format Slate Vent.

It can be seen from Table 1 and Figure 6 that there is no significant difference in performance for the Manthorpe Small Format Slate Vent installed with Natural Slates and for the Natural Slates on their own without the vent. There is also no measurable difference in performance for the Manthorpe Small Format Slate Vent installed with Fibre Cement tiles and the Fibre Cement tiles installed on their own without the Vent.

At a roof pitch of 30º the pressure factors are 39Pa and 41Pa with and without the Small Format Slate Vent on a Natural Slate roof. At a roof pitch of 22.5º the pressure factors are 44Pa and 43Pa with and without the Small Format Slate Vent on a Fibre Cement roof.

The log sheets in Appendix A showing observations made during the testing show that no rain leakage was observed coming through the vent at normal suction pressures. The Vent was taken to high suction pressures after leakage tests were completed yet no leakage was observed coming through the Vent. However, at these high suction pressures there was significantly more leakage from the surround Natural Slates and Fibre Cement slates. The Manthorpe Small Format Slate Vent did not cause any leakage at the tile interfaces or worsen the weathertightness performance of the roof.

Product	Pitch (°)	Pressure factor (Pa)
Natural Slate no vent	30°	41
Fibre Cement tiles no vent	22.5°	43
Natural Slate with Manthorpe Small Format Slate Vent	30°	39
Fibre Cement Tiles with Manthorpe Small Format Slate Vent	22.5°	44

Table 1 Pressure factors for the tiles and Manthorpe Small Format Slate Vent at a leakage rate of $10 g/m^2/5min$

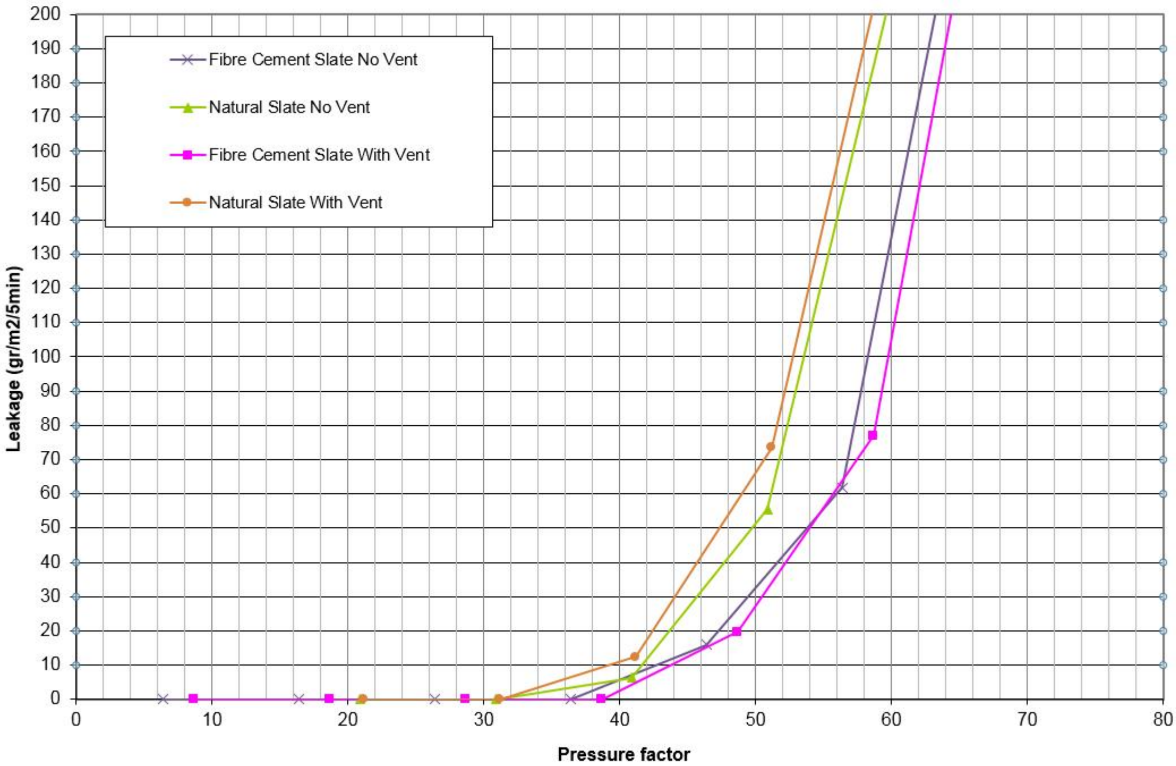

Figure 6 Pressure factor v leakage curves for the Natural Slate and Fibre Cement tiles and Manthorpe Small Format Slate Vent

At the end of the testing on the Vent installed with the fibre cement slates the suction pressure was increased incrementally to a suction of -170pa. The Vent showed no sign of leakage through the opening. Some leakage was observed near the bottom corners of the Vent, although the surrounding roof was leaking heavily at this time and it was not possible to say whether the leakage was from the vent/tile interface or from the surrounding roof.

6 Summary

Tests to assess the relative performance of Manthorpe Small Format Slate Vent were carried out according to the procedures of the wind-driven rain test method FprEN15601. The Manthorpe Small Format Slate Vent was tested with Natural Slate tiles and Fibre Cement slates at roof pitches of 30º and 22.5º respectively.

The results show that the weathertightness performance of the Manthorpe Small Format Slate Vent is better than that of the surrounding natural and fibre cement slates. At high suction pressures no leakage was observed falling from the vent, although at these pressures the surrounding roof was leaking heavily. The Vent was subjected to a suction pressure of -170pa after Test B was completed, the Vent showed no sign of leakage through the opening however some leakage could be seen at the bottom corners, although the surrounding roof was leaking heavily.

When used with 500mm x 250mm fibre cement slates:

- The Manthorpe Small Format Slate Vent did not leak before the surrounding 500mm x 250mm Fibre Cement slates at a roof pitch of 22.5°

- The Manthorpe Small Format Slate Vent will perform satisfactorily at a minimum roof pitch of 22.5°. As weather tightness performance improves with roof pitch, the vent is expected to also perform satisfactorily at roof pitches above 22.5°.

When used with 400mm x 200mm natural slates:

- The Manthorpe Small Format Slate Vent did not leak before the surrounding 400mm x 200mm Natural Slate at a roof pitch of 30°

- The Manthorpe Small Format Slate Vent will perform satisfactorily at a minimum roof pitch of 30° when using this format of natural slates. As weather tightness performance improves with roof pitch, the vent is expected to also perform satisfactorily with this covering at roof pitches above 30°.

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Appendix A - Test report sheets for the Manthorpe Small Format Slate Vent

Roof Pitch 30º - Natural Slates s – no vent

1.Product name: Natural Slate 400mmx200mm	2.Client:Manthorpe
3. Bond: Broken	4.Lap: 100mm
5. Batten Gauge: 150mm	5.Material: Natural Slate
7. Fixing: 30mm Copper Nails Tile Clips	6. Pitch: 30°
9. Date commenced: 24/01/17	7: Other remarks: Ben Hales & Mike Challinor witnessed

Dry seal box pressure:	41.5	
Wet seal box pressure relative roof:	32.4	
Wet seal box pressure relative to the lab:	30.9	
Manometer instrument number(s):	1928	

Test : D Deluge				
Rainfall rate : 225mm/hr		Wind speed :0m/s		
Deluge bar flow rate:22 l/min		Run off bar flow rate:37 l/min		
Date of test:				
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Comments:
0	0	2	0	No leakage

Test : B High wind speed with high rainfall rate				
Rainfall rate:60 mm/hr		Wind speed 13 m/s		
Top bar flow rate:3.9 l/min		Bottom bar flow rate:4.4 l/min		
Runoff bar flow rate: 11 l/min		Date of test: 24/01/17		
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	
10	0	5	0	No leakage Some moisture seen on joins between tiles.
0	5	10	0	Central section moisture bubbling in tile joins on 2nd course. 5th course droplets running along back of tiles, no droplets falling. 2nd course droplets starting to come through join and run along backs of tiles.
-10	10	15	18	Central section, courses 2, 3, 4, & 6 droplets falling every 15 – 30 seconds from side joins. Water can be seen bubbling in almost every join. LHS 6th course water coming through side join and running onto batten, droplets forming, falling every 5-10 seconds. 2nd and 3rd course droplets beginning to fall from side joins after 3 minutes, falling every 10 – 15 seconds.
-20	15	20	142	RHS courses 2, 3, 5 & 7 droplets forming at all joins, intermittently falling. LHS 6th course, steady droplet falling constantly. 2nd, 3rd & 4th as above. Central section 5th course droplets falling every 5 seconds from side join. Droplets now forming from all side joins on courses 2nd – 7th, falling every 2-3 seconds.
-30	20	25	476	RHS 4th course steady droplets falling almost constantly. Courses 2, 3, 5 & 7 increasing. LHS courses 3, 4, 5 & 7 heavy leakage through joins, constant flow of droplets. Central as above, increasing. Courses 2 – 7 droplets falling every 2-3 seconds. RHS droplets now constant from 6 & 7 after 3:30 minutes.

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Roof Pitch 30º - Natural Slate tiles – with Small Format Slate Vent

1.Product name: Small Format Slate Vent	2.Client:Manthorpe
3. Bond: Broken	4.Lap: 100mm
5. Batten Gauge: 150mm	5.Material: Natural Slate 400mm x 200mm
7. Fixing: 30mm Copper Nails Tile Clips	6. Pitch: 30°
9. Date commenced: 25/01/17	7: Other remarks: Ben Hales & Mike Challinor witnessed

Dry seal box pressure:	39.3	
Wet seal box pressure relative roof:	26.6	
Wet seal box pressure relative to the lab:	31.2	
Manometer instrument number(s):	1928	

Test : D Deluge				
Rainfall rate : 225mm/hr	Wind speed :0m/s			
Deluge bar flow rate:22 l/min	Run off bar flow rate:37 l/min			
Date of test:				
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Comments:
0	0	2	0	No leakage

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Test : B High wind speed with high rainfall rate				
Rainfall rate:60 mm/hr				Wind speed 13 m/s
Top bar flow rate:3.9 l/min				Bottom bar flow rate:4.4 l/min
Runoff bar flow rate: 11 l/min				Date of test: 25/01/17
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	
10	0	5	0	No leakage
0	5	10	0	LHS 2nd course droplets forming, not falling. 6th course droplets forming from side joins. Central 2nd course droplets forming from side join, starting to fall after 3 minutes.
-10	10	15	36	LHS 2nd course droplets falling every 2-3 seconds. Central 2nd course droplets falling every 2 seconds from side joins. Central section, side join on other side of tile to the right of Vent droplet falling every ten seconds. Tile above vent droplet falling every 5-10 seconds. No leakage coming from edges around vent.
-20	15	20	176	LHS 2nd as above, 3rd and 5th course droplets beginning to form, falling every 10-15 seconds. Central 3rd course droplet starting to fall every 10 seconds, 2nd course as above. 4th course droplets starting to fall from side lock after 3 minutes. RHS 3rd & 4th course droplets falling every 10 seconds. After 3 minutes had increased to every 5 seconds. Occasional flurry of droplets coming from 3rd.
-30	20	25	495	RHS 3rd and 4th course droplet falling every 3-5 seconds. Central courses 2, 3 & 4 steady droplet coming from side join, falling every 2-3 seconds. Tile to right of vent droplets falling constant in same place as mentioned previously. Tile above vent constant flow of droplets. LHS courses 2, 3, 5 & 6 steady droplets falling every 2 seconds. No leakage coming from edge of tile vent nor through vent. All leakage coming from tiles.
				Visual test run at 37.5° - Taken to -60pa at which pressure the Small Format Slate Vent did not leak however the surrounding roof showed heavy leakage. Some moisture could be seen at the bottom corners of the vent which may be caused by leakage running along the beck of tiles above the vent.

Roof Pitch 22.5º - Fibre Cement Tiles – No Vent

1.Product name: Fibre Cement	2.Client:Manthorpe
3. Bond: Broken	4.Lap: 100mm
5. Batten Gauge: 200mm	5.Material: Fibre Cement 500mm x 250mm
7. Fixing: 30mm Copper Nails Tile Clips	6. Pitch: 22.5°
9. Date commenced: 25/01/17	7: Other remarks: Ben Hales & Ben Challinor witnessed

Dry seal box pressure:	42.9	
Wet seal box pressure relative roof:	19.6	
Wet seal box pressure relative to the lab:	16.4	
Manometer instrument number(s):	1928	

Test : D Deluge				
Rainfall rate : 225mm/hr		Wind speed :0m/s		
Deluge bar flow rate:22 l/min		Run off bar flow rate:37 l/min		
Date of test:				
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Comments:
0	0	2	0	No leakage

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Test : B High wind speed with high rainfall rate				
Rainfall rate:60 mm/hr			Wind speed 13 m/s	
Top bar flow rate:3.9 l/min			Bottom bar flow rate:4.4 l/min	
Runoff bar flow rate: 11 l/min			Date of test: 25/01/17	
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	
10	0	5	0	No leakage
0	5	10	0	No leakage
-10	10	15	0	Central 3rd course some moisture bubbling in side join.
-20	15	20	0	Central 3rd course droplets forming from side join, starting to fall after 2 minutes.
-30	20	25	46	Central 3rd & 4th course droplets falling from side join every 3 seconds, occasional flurry from build-up of water. RHS 2nd course droplets falling every 3-5 seconds. LHS 7th course droplets forming, falling every 10-20 seconds. Courses 5 & 6 droplets started to fall from side join after 3 minutes.
-40	25	30	132	LHS 6th course constant droplet from side join. 7th course droplets falling at increased rate, every 3-5 seconds. Central 3rd & 4th course as above, 6th course droplets falling every 5-8 seconds. 4th course occasional flurry of droplets as water builds up at side joins. RHS 2nd & 5th course droplets falling from side join, started as only occasional, now constant droplet after 4 minutes.
-50	30	35	580	As above, all areas increasing. LHS courses 4, 5, 6 & 7 constant droplets falling, occasional flurry. Central 2nd & 3rd constant flow of water from side join. RHS 2nd droplets falling every 2-3 seconds. 3rd steady flow of water after 3 minutes.

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Roof Pitch 22.5º - Fibre Cement – with Small Format Slate Vent

1.Product name: Small Format Slate Vent	2.Client:Manthorpe
3. Bond: Broken	4.Lap: 100mm
5. Batten Gauge: 200mm	5.Material: Fibre Cement 500mm x 250mm
7. Fixing: 30mm Copper Nails Tile Clips	6. Pitch: 22.5°
9. Date commenced: 25/01/17	7: Other remarks: Ben Hales & Mike Challinor witnessed

Dry seal box pressure:	35.5	
Wet seal box pressure relative roof:	19.9	
Wet seal box pressure relative to the lab:	18.7	
Manometer instrument number(s):	1928	

Test : D Deluge				
Rainfall rate : 225mm/hr		Wind speed :0m/s		
Deluge bar flow rate:22 l/min		Run off bar flow rate:37 l/min		
Date of test:				
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Comments:
0	0	2	0	No leakage

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Test : B High wind speed with high rainfall rate				
Rainfall rate:60 mm/hr				Wind speed 13 m/s
Top bar flow rate:3.9 l/min				Bottom bar flow rate:4.4 l/min
Runoff bar flow rate: 11 l/min				Date of test: 25/01/17
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	
10	0	5	0	No leakage
0	5	10	0	No leakage Some water in side join of LHS 3rd course.
-10	10	15	0	Central 3rd course some moisture bubbling in side join.
-20	15	20	0	LHS 6th course droplets starting to fall. Central 3rd course droplets forming as soon as -20pa was reached, droplets started falling after 2 minutes. No leakage near vent.
-30	20	25	57	Central 2nd & 3rd course droplets falling every 5 seconds from side join. LHS as above, droplets starting to fall every 2-4 seconds.
-40	25	30	165	LHS courses 5 & 6 steady droplets falling constantly. Central 2nd & 3rd course constant flow of droplets started once -40pa was reached. RHS 2nd course constant flow of water after 3:30 minutes.
-50	30	35	622	As above, all areas mentioned increasing. LHS 4, 5, 6, & 7 steady flow of droplets, 4 and 7 started once -50pa was reached. Central 2nd and 3rd course constant flow of water. Tile above vent starting to form droplets from side join, falling every 15 seconds. No leakage from edge of Vent tile or through vent.
				Roof taken to a box pressure of -170pa, no leakage observed through vent opening although some leakage could be seen at lower corners of the Vent. Surrounding roof leaking heavily at this point at a far greater rate.

Appendix B - Calibration results for the BRE test rig

FprEN 15601 requires details of the rig calibration to be included in the test report. The following information provides a brief description of the calibration of the BRE test rig.

FprEN 15601 has specific calibration requirements for the test facility to ensure that the distribution and magnitude of the wind speed, driving rain and runoff water are all within required limits. The requirement for the wind speed generation is a fan system capable of generating wind blowing parallel to the rafters of the test specimen with a spatial variation of the wind speed over the specimen of not more than 10 %. This is achieved by measuring the wind speed at not less than 9 positions uniformly distributed at a height of 200 + 10 mm over a flat boarded area which replaces the test specimen, at the relevant roof pitch. The calibration wind speed shall be 10 + 0.5 m/s at the centre of the test specimen. Figure B1 shows the end of the BRE wind tunnel and Figure B2 shows the wind speed calibration of the BRE test rig using ultrasonic anemometers.

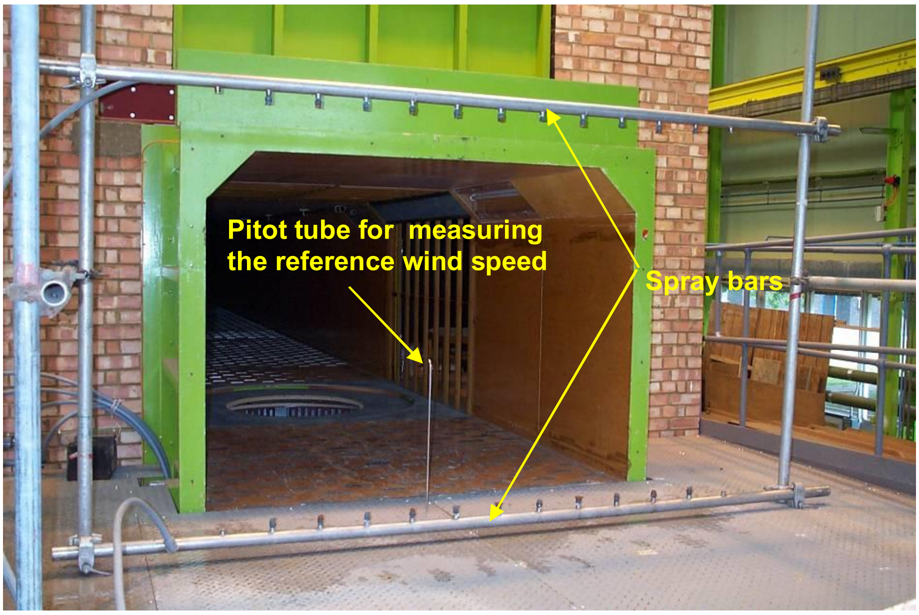

Figure B1 The end of the BRE wind tunnel

Figure B2 Calibration of the wind speed over the test specimen area

The standard requires the turbulence intensity (*t*) in the oncoming wind to be less than 10 %. The turbulence intensity *t* (%) is expressed as t = 100u/U, where *u* and *U* are the RMS and mean wind speeds respectively, measured over a duration of not less than 5 minutes. *u* and *U* are defined as shown below:

RMS (root mean square) wind speed $u = \sqrt{\dfrac{\sum_{i=1}^{n}(v_i^2 - U)}{n-1}}$

Mean wind speed $U = \dfrac{\sum_{i=1}^{n} v_i}{n}$

Where v_i is the individual wind speed measurement over the specimen;

n is the number of measurements

Table B1 shows the calibration measurements. The maximum turbulence intensity across the specimen is 5.57% and occurs at location 5 in the centre of the specimen. In all cases the turbulence intensity is within the limit of 10% allowed by the draft standard.

10m/s nominal speed

Location	mean wind speed U	V	W	Variation from mean % U	Turbulence intensity u'	v'	w'
1	9.83	0.90	-0.69	-0.98	0.03	0.01	0.02
2	10.21	1.29	-0.30	2.85	0.03	0.02	0.02
3	9.56	0.10	0.83	-3.67	0.03	0.02	0.02
4	9.64	1.44	-0.26	-2.88	0.03	0.02	0.02
5	10.48	1.68	0.02	5.57	0.03	0.01	0.01
6	9.66	0.87	0.85	-2.69	0.03	0.02	0.03
7	9.86	1.02	0.60	-0.71	0.03	0.02	0.02
8	10.14	1.40	0.48	2.14	0.04	0.02	0.02
9	9.96	0.32	0.31	0.37	0.03	0.02	0.03
Mean	9.93	1.00	0.21				

locations (facing tunnel)

1	4	7
2	5	8
3	6	9

Table B1 Calibration measurements of wind speed in the BRE wind tunnel facility

The requirements for the rain generating device are a capability for generating a stable rain fall rate for the roof pitch under test. The spatial variation of rainfall must be not more than ±35% over the area of the test specimen during a time period of 5 min±10s. During the same time period of 5 min ±10s the rainfall rate shall vary by not more than ±2%. The actual rainfall rate that should be applied depends on the geographical location. Rainfall conditions are given in the draft standard for three climates: Northern European Coastal, Central Europe and Southern European. In all cases the rainfall rain varies with pitch angle. This means that the test rig must be calibrated for every pitch angle that is likely to be used. The variation in rainfall rate with pitch angle can be very small, for example in the Northern European climate Sub-Test A the rainfall rate varies between 124mm/hr and 130mm/hr for pitches between 15° and 45°. In practice it is not possible to control the rainfall rate on the roof to such small tolerances. The degree of variation in rainfall rate allowed by the draft standard is ±35% which is generally much wider than the range of rainfall rates specified for each pitch angle.

Figures B3 to B6 show the calibration of the driving rain in the BRE test rig. The results of the calibrations for Sub-Tests A, B and C for the Northern European Coastal climate are shown in Table B2. From Table B2 it can be seen that the degree of variability in Sub-Tests A, B and C is close to but just within the allowable limit of ±35%.

% variation of water collected in buckets			
Bucket No	Test C	Test B	Test A
1	-3	-11	-7
2	-3	-21	-26
3	14	9	-22
4	-29	9	26
5	11	-2	22
6	16	-9	24
7	34	24	19
8	29	28	29
9	-17	-15	5
10	-22	3	-1
11	-8	7	-16
12	30	13	-4
13	-21	-29	-21
14	-18	-2	-28
15	-5	-5	-21
16	-9	3	23
Maximum %	34	28	29
Minimum %	-29	-29	-28

Table B2 Calibration of driving rain variability


Figure B3 Bottom spray bar


Figure B4 Top spray bar


Figure B5 View of the test rig at the end of the tunnel

Figure B6 View of the 16 rainfall collection buckets on the test rig

Report Ends