bre

Driving Rain Testing on Redland 50 double roman roof tiles and the Manthorpe large format concrete interlocking tile vent

Prepared for: Mr Ben Hales, Product designer

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Contents

1 Introduction

This report describes rain penetration tests to prEN15601 carried out for Manthorpe Building Products on Redland 50 double roman roof tiles and Redland 50 Double roman roof tiles in conjunction with the Manthorpe large format concrete interlocking tile vent. The testing was performed at a roof pitch of 20º. The testing was undertaken during November 2010. It also describes High speed wind testing on the same test configuration carried out after the wind driven rain tests were completed.

These tests are based on BRE Proposal No. 128148 dated 11th November 2010, which was accepted by Mr Ben hales, Product designer, Manthorpe Building Products, Brittain Drive, Codnor Gate Business Park Ripley, Derbyshire, DE5 3ND on the 22nd October 2010.

The testing was witnessed by Mr Ben Hales.

2 Objective

The objective of these tests was to assess the driving rain performance of The Manthorpe large format concrete interlocking tile vent, referred to from here on as the “vent”, according to the procedures given in draft CEN standard prEN 15601 (November 2009 version): 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 20º. Two tests were carried out. Firstly on a roof with only Redland 50 double roman tiles installed, referred to from here on as the “tiles”. This was to allow a benchmark performance for the tiles to be established. Secondly With a roof with the same tiles fitted and the vent fitted in the centre. This was to establish the performance of the vent and to establish if the vent, tile interface caused any change in the overall performance of the tiles.

Tests were carried out using the following wind and rain combinations:

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

In addition some Ad-hoc testing was carried out after the principle tests were completed, this was firstly to establish the effect of raising the pitch on the performance of the vent after the failure point had been reached at the 20^0 pitch and the change in pressure required to bring about failure at the new pitch.

Additionally a high speed wind test was carried out to evaluate the performance of the vent and the tiles at high wind speeds, upto 50m/s. This was carried out at a pitch of 20^0 on the same test configuration used for the driving rain tests.

3 Test Specimens

The tiles and vent were installed on the BRE test rig by Mr Ben Hales. The reference tiles were commercially available Redland 50 double roman concrete tiles and were nailed and clipped to 25mm by 50mm timber battens with a head lap of 100mm.

The test product was the Manthorpe large format concrete interlocking tile vent, and was a plastic prototype designed to interface with the reference tiles. The vent was designed to replace one of the reference roof tiles and is installed into the roof in the same way as the tiles

Figure 1 and 2 shows details of the installed Vent and how it interfaces with the roof tiles, from above and below. Figure 3 shows an overall view of the Vent and Tiles on the BRE test rig.

The performance of the tiles and 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 prEN 15601:2009 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.

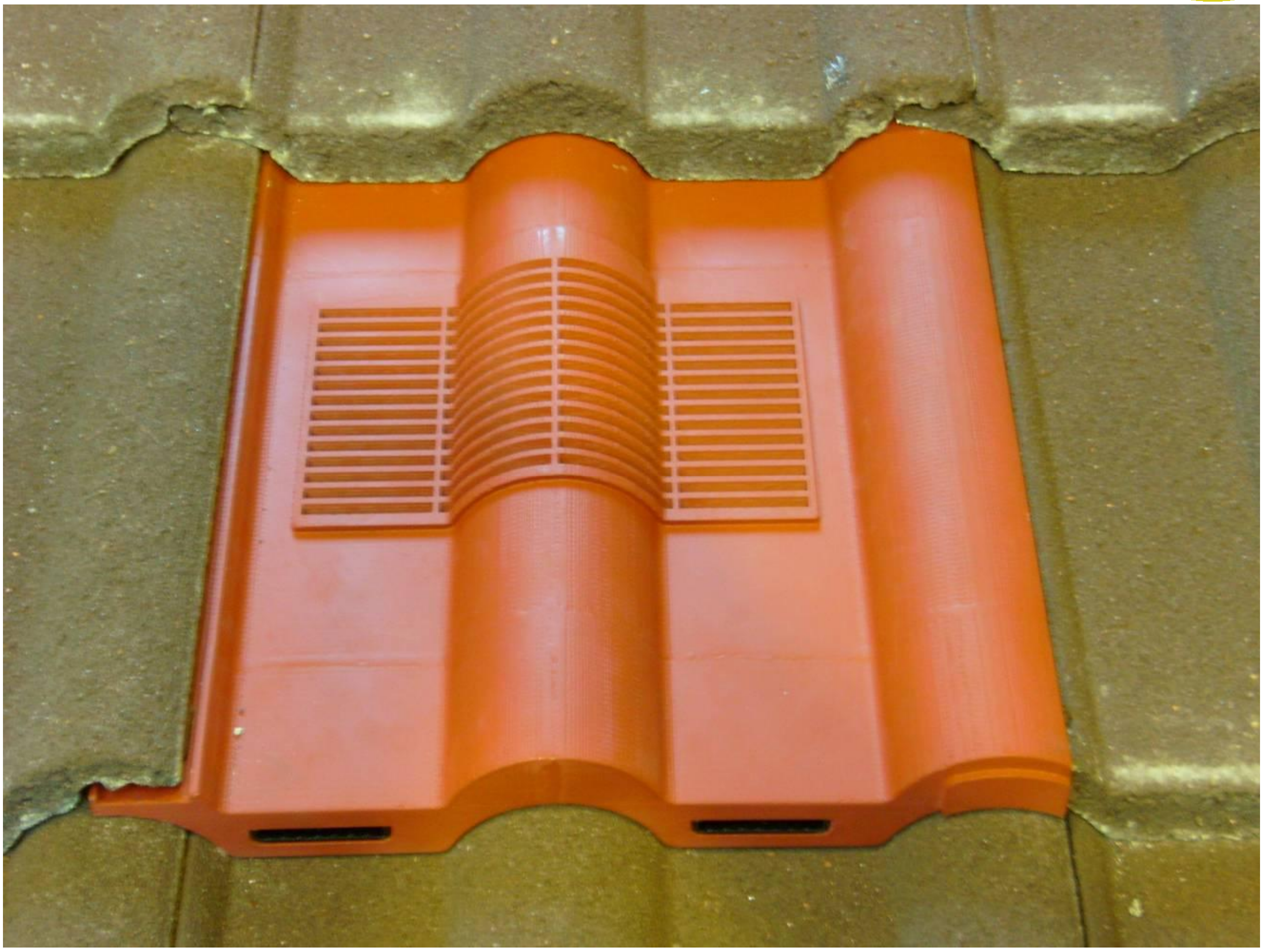

Figure 1 The Manthorpe large format concrete interlocking tile vent installed in the test roof

Figure 2 An underside view of the Manthorpe large format concrete interlocking tile vent installed in the test roof

Figure 3 An general view of the roof tiles and the Manthorpe large format concrete interlocking tile vent installed in the test roof.

4 Wind driven rain testing procedure.

The tiles and Vent 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 tiles and the pressure inside the pressure box was measured using a second micro manometer.

The test procedures complied with those set out in prEN 15601 ('Hygrothermal performance of buildings: Determination of the resistance to wind-driven rain of roof coverings with discontinuously laid small elements'). 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 4. 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 tiles 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 (prEN 15601 Sub-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 (prEN 15601 Sub-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.

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.

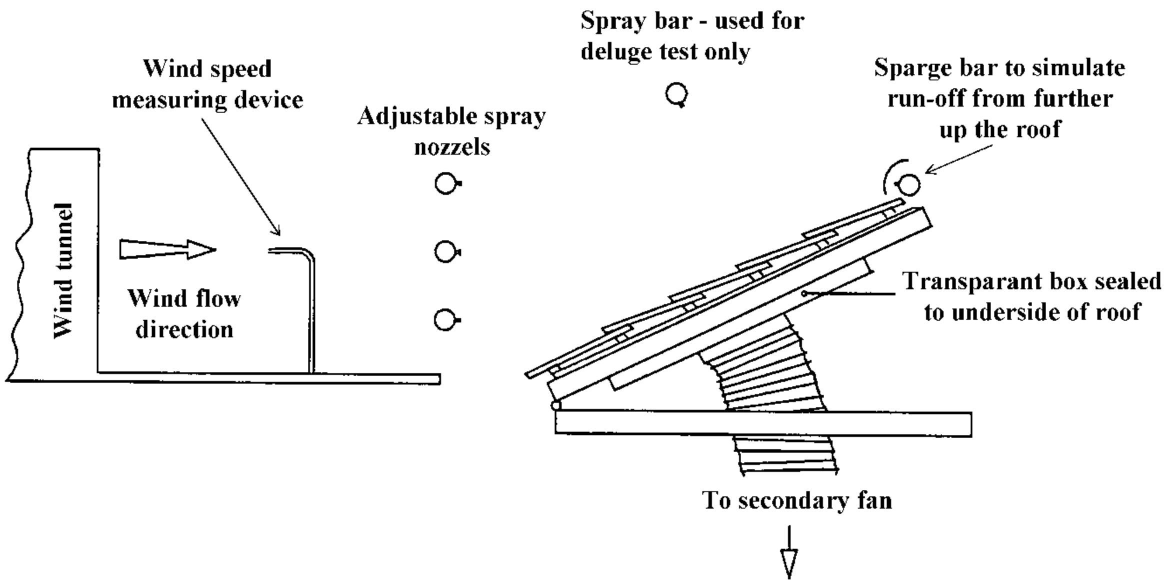

Figure 4 Schematic view of the BRE Rain Penetration Test Rig

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. The WSB pressure is adopted as the reference zero pressure for subsequent testing according to the procedure given in prEN 15601.

5 High speed wind testing procedure.

To allow high wind speeds to be achieved for this testing, liners were inserted into the mouth of the wind tunnel. This reduced the opening of the tunnel mouth and increased the speed of the air flow. Typically without reducing the size of the opening wind speeds of 30m/s are attainable and with the reduced opening speeds of around 50m/s are attainable, which are more representative of extreme weather conditions seen in the UK. The test platform was the monopitch roof used for the wind driven rain testing and this had both the tiles and the vent installed. The test pitch for the roof was set at 20^0.

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 wind speed was slowly increased in 5m/s steps and visual observations of the effect the wind had on the vent and tiles were made before the wind speed was increased by the next 5m/s step. This was continued to the maximum wind speed possible was attained or a failure of the tiles or vent occurred , the testing was filmed and recorded to DVD.

6 Wind driven rain testing. Results and discussion.

There is no pass-fail criterion given in prEN 15601. The performance criteria of a test product are compared with the performance of a reference product, in this case the Redland 50 Double roman tiles, which has a known satisfactory performance under the same wind-rain conditions. Normative 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.*

Typed copies of the result sheets filled in during the tests and giving observations made at the time are contained in appendix A. It should be noted that the remark 'no change' refers to the visible behaviour of the leakage. As the pressure difference across the test roof is reduced, in reality there is likely to be a progressive degradation of the weather-tightness. The other comments stated therein are self explanatory.

Deluge tests – Sub-test D

There were no leaks observed during the deluge test for the roof tiles at a roof pitch of 20º. There were some drops of water observed in the tile vent and on the underside of the tile vent and these were attributable to the porous nature of the vent. The vent was a one-off manufactured proto-type built up from layers of resin, the production process left the material somewhat porous and the applied paint wasn't quite adequate to seal the vent completely. In practice the vent would be made from moulded sections and the problem of porosity wouldn't be relevant. The small amount of spray observed in the pressure box, directly under the vent, was likely to be from spray produced on and near the openings in the vent drifting through the duct.

Wind and rain tests – Sub-test B

Figure 5 shows the pressure-leakage curves for the Redland 50 double roman tiles and the Manthorpe Large Format Concrete Interlocking Tile Vent at a pitch of 20º.

The pressure (or suction factor) at which $10g/m^2/5$ min of water leakage occurs is taken as the measure of the watertightness of a tile. 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 tile under wind driven rain conditions. The tiles performed a little better than the tile vent this was largely due to water starting to drip through the vent duct between 33Pa and 43Pa pressure difference, with a dramatic increase in leakage at the next pressure step. Comparable leakage for the tiles didn't occur until a pressure difference of 36Pa to 46Pa was attained with a more gradual increase in leakage after this point as the pressure difference was increased. From the test notes it can be seen that while there was some dripping beginning to start at the right hand interface between the tile vent and the adjacent tile this was in keeping with the general performance of the tiles as a whole.

Additional testing was carried out from the point of failure at the 20^0 pitch to establish at what point the vent would fail at as the roof pitch was increased. The roof pitch was increased and the pressure was slowly increased until leakage from the vent duct was observed. As the data from a full test is not produced by this approach pressure leakage factors cannot be calculated, but it does provide a useful indication of the performance of both the vent and the tiles. As can be seen from the test observations in Appendix A, The pressure at which the vent leaked increase progressively as the roof pitch was increased and that the leaking at the tile/vent interface was similar to the leakage observed in the rest of the roof.

Table 1 Pressure factors for Redland Double roman tiles and the Manthorpe Large Format Concrete Interlocking Tile Vent at a leakage rate of 10g/m^2/5min

Product	Pitch (°)	Pressure factor (Pa)
Redland 50 double roman tiles	20	42
Manthorpe Large Format Concrete Interlocking Tile Vent	20	36.5

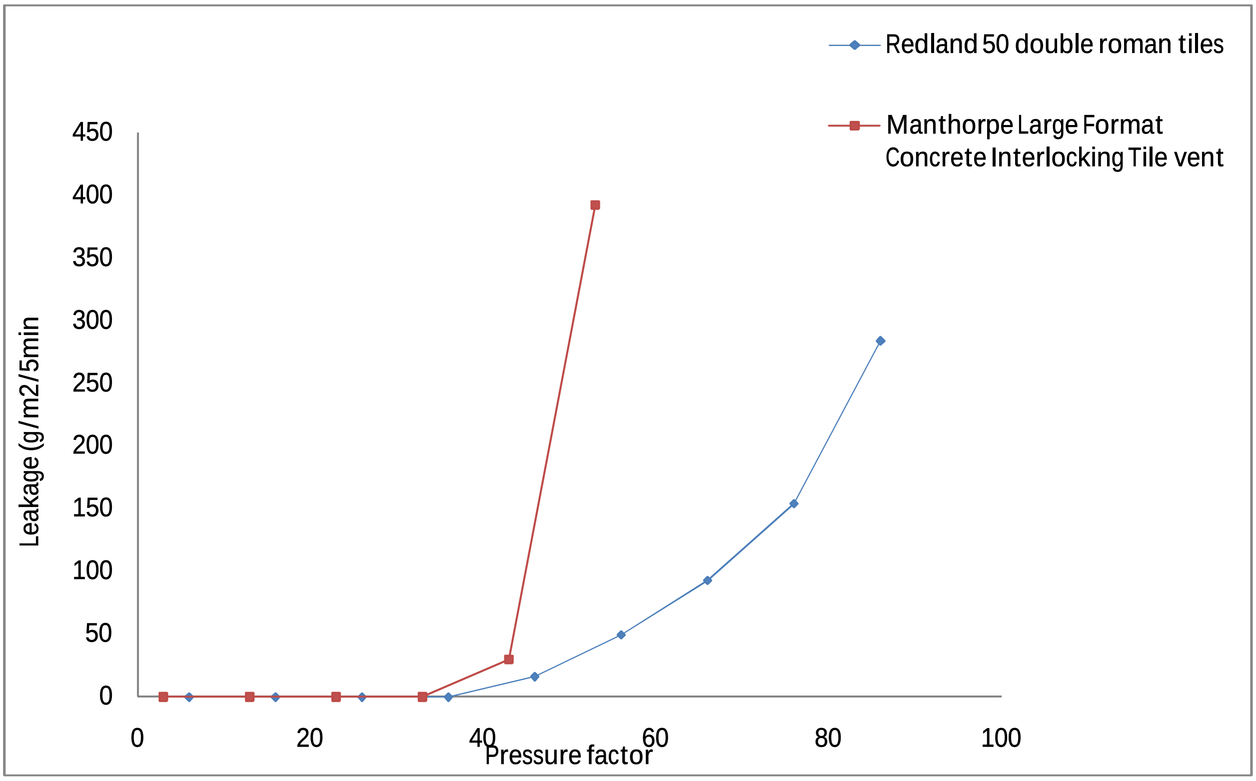

Figure 4 Pressure factor v leakage curves for Redland 50 double roman tiles and the Manthorpe Large Format Concrete Interlocking Tile Vent.

7 High speed wind testing - results and discussion

As can be seen from the test notes and video the unsupported edge of the vent was shaking and lifting a little more than 5mm at the maximum wind speed attainable by the wind tunnel of 46.5m/s which equates to a wind speed of 167kmh or 104mph. There was no movement observed in the tiles. It is likely that the tiles and vent could have withstood higher wind speeds but due to the limitations of the wind tunnel this was unable to be verified. It should be noted that the vent tile tested was a prototype made by a rapid prototyping process. Production parts would be injection moulded which would be stronger and stiffer.

To put a wind speed of 46.5m/s into context, from BS6399: Part 2 (the British Standard for wind loading on buildings) the design wind speed to be expected on a two-storey house in the London area in a fifty year design life would be of the order of 25m/s to 35m/s (depending on factors such as the roof height, distance to sea and distance from the edge of the town and the heights and spacing of surrounding buildings). For a similar house in a town in Scotland the design wind speed would vary from about 35m/s to 45m/s. These examples exclude the effects of topography and ground altitude. If the building is on the top of a steep hill then the wind speeds can be increased by up to 36%, wind speeds also increase by about 10% for every 100m increase in ground level. To determine the actual design wind speed at any particular site it is necessary to follow the procedures given in BS6399-2.

8 Summary

Wind driven rain testing.

Tests to assess the relative performance of The Redland 50 double roman tiles and the Manthorpe Tile Vent were carried out according to the procedures of the draft wind-driven rain test method prEN15601. The results show that The Manthorpe Large Format Concrete Interlocking Tile Vent tile performed comparably to the surrounding Redland 50 double roman tiles. The tiles and tile vent did eventually fail at a negative pressure of 42 and 36.5 Pa respectively and this was due to water coming through the tile to tile interfaces and through the tile duct. Visual observations show that vent/tile interface was comparable in performance to the tile/tile interfaces.
Additional testing showed that a slight increase in pitch from 20° to 22.5° of the roof increased the performance of the tile vent significantly beyond that of the surrounding tiles. Based on this finding a slight modification has been proposed to the internal geometry of the production product which would have the same effect as an increase of pitch of 5°. This modification is likely to take the failure point of the tile vent above that of the surrounding tiles.

High speed wind testing.

The vent and tiles tested are able to withstand the wind speeds of at least 46.5m/s and so will provide adequate resistance against wind uplift for most of the UK, although this should be confirmed by a specific wind uplift calculation for the site which takes into account the local topography, ground altitude, etc.

Appendix A – Test report sheets for Redland 50 Double Roman Tiles and the Manthorpe Large Format Concrete Interlocking Tile Vent and additional testing.

Redland 50 double roman tiles.

Product name: Redland 50 double roman tiles	Company: Manthorpe
Bond: straight	Lap: 100mm
Material: Concrete	Pitch: 20$^{0.}$
Fixing: Nails and clips	Batten gauge: 318
Additional:	Date commenced: 2/11/2010.

Notes.
Dry box pressure +6 Pa
Wet box pressure with water running (deluge) -5 Pa
Wet box pressure no water running -6 pa
Pressure 150mm above roof surface +20Pa

Test : D Deluge				
Rainfall rate : 222mm/hr	Wind speed :0m/s			
Deluge bar flow rate:22 l/min	Run off bar flow rate:37 l/min			
Date of test: 2/11/2010				
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Comments:
0	0	2	0	No leaks

Test : B High wind speed with high rainfall rate				
Rainfall rate:110 mm/hr			Wind speed 13 m/s	
Top bar flow rate:8 l/min			Bottom bar flow rate:8 l/min	
Runoff bar flow rate: 13 l/min			Date of test: 2/11/2010	
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Observations
10	0	5	0	One or two spots of fine spray.
0	5	10	0	Underside of tiles above heads slightly damp, spray a little heavier.
-10	10	15	0	No change.
-20	15	20	0	1st course left hand side, hanging drip from tile head. 1st course right hand side, hanging drip from tile head. Top course left hand side, hanging drip from tile head. 3rd course, right hand side hanging drip in side lock.
-30	20	25	0	1st course 4 tile heads with drips at 1 in 10s. Top course 1 tile head drip at 1 in 20s. 2nd course left hand side, right hand side and centre, tile heads drips at 1 in 10s. 3rd course right hand side, side lock drip 1 in 10s.
-40	25	30	47	1st course tile heads drips at 1 in 5s. 2nd course, side lock drips at 1 in 5s. 3rd course right hand side, side lock bubbling 4 drips at 1 in 2 to 5s. Occasional drips blowing over the tile heads.
-50	35	40	96	1ST Course, centre 2 side locks occasional drips, right hand side 2 side locks drips at 1 in 2 to 5s. 2nd course, right hand side 2 side locks drips at 1in 2 to 5s and centre 2 side locks drips at 1 in 5s. 3rd course right hand side, side lock 1/2dps. 1st 3 courses most tile heads with hanging drips.
-60	40	45	125	2nd course right and left hand sides, side locks dripping 1dps. 3rd course left hand side, side lock dripping 1dps.
-70	45	50	176	Similar with a drip rate increase.
-80	50	55	374	All but 2 side locks dripping to some extent progressively less higher up the roof

Redland 50 double roman tiles with Manthorpe large format, concrete interlocking tile vent.

Product name: Redland 50 double roman tiles with "Manthorpe large format, concrete interlocking tile vent."	Manthorpe
Bond : straight	Lap: 100mm
Material: Concrete	Pitch: $20^{0.}$
Fixing: Nails and clips	Batten gauge: 318
Additional:	Date commenced: 2/11/2010.

Notes.
Dry box pressure +6 Pa
Wet box pressure with water running (deluge) -1 Pa
Wet box pressure no water running -3 pa
Pressure 150mm above roof surface +20Pa

Test : D Deluge				
Rainfall rate : 222mm/hr		Wind speed :0m/s		
Deluge bar flow rate:22 l/min		Run off bar flow rate:37 l/min		
Date of test: 2/11/2010				
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Comments:
0	0	2	0	A few drops of water visible inside the vent a few drops of water on the underside of the vent (material is porous). A tiny amount of very fine spray under the vent.

Test : B High wind speed with high rainfall rate				
Rainfall rate:110 mm/hr		Wind speed 13 m/s		
Top bar flow rate:8 l/min		Bottom bar flow rate:8 l/min		
Runoff bar flow rate: 13 l/min		Date of test: 2/11/2010		
Pressure difference (Pa)	Time (min:sec) Start	End	Water collected (g)	Observations
50 to 10	0	5	0	A little fine spray from the tiles. One or two drops of water on the inside of the vent.
0	5	10	0	Occasional drips from the inside of the vent. Water is visibly permeating through the vent material. Some fine spray from the tiles and the underside of tiles above head locks damp.
-10	10	15	0	No change
-20	15	20	0	1st course left hand side hanging drip from tile head, dripping every 30 to 45s. 1st course right hand side, drip running down the tile clip, 1 drip in 30 to 45s. 4th course right hand side hanging drip on the tile clip, 1 drip in 30 to 45s. 3rd course right hand side hanging drip in side lock, 1 drip in 30 to 45s.
-30	20	25	0	1st course right hand side, drip at tile head1 in 5s. 3rd course right hand side, side lock drip 1 in 10s. 1st course left hand side, tile head 3 hanging drips, drips at 1 in 30 to 45s. Right hand side lock between vent and tile 5 hanging drips dripping at 1 in 30 to 45s.Hnging drips on the inside of the vent duct, occasional dripping.
-40	25	30	67	2nd course left of centre, side lock bubbling and drips at 1in 5s to 1/2dps varying. 3rd course right hand side, side lock bubbling and drips at 1in 5s to 1/2dps varying. 5th course left of centre, tile head with hanging drips. Drips and short runs of water from the vent duct ½ to 1dps varying. Right hand side lock with vent, hanging drips and dripping 1 in 10s.
-50	35	40	816	Water pouring in through vent duct. Small drip rate increase for the rest of the roof. Test stopped.

Additional testing.

Redland 50 double roman tiles with the Manthorpe large format, concrete interlocking tile vent.

The roof pitch was raised from 20^0 in steps to the pitches indicated below and the pressure was changed until leakage from the vent duct was observed.

22.5^{o}pitch
-60Pa, occasional drips from the vent.
-65Pa, continuous dripping from the vent.
The vent/tile interface behaved in a similar manner to the rest of the tiles.

25^{o}pitch
-70Pa, no dripping.
-75Pa, Occasional drips.
-85Pa, several drips at 1dps from the vent. 1 to 2 dps from right hand side of the vent.
-90Pa, steady dripping from the vent.
The vent/tile interface behaved in a similar manner to the rest of the tiles.

30^{o}pitch
-100Pa resulted from the change in pitch. 1 dps from the vent duct and 2dps from the right hand side lock of the vent.
The vent/tile interface behaved in a similar manner to the rest of the tiles.

Appendix B - High speed wind testing

Redland 50 double roman tiles with Manthorpe large format, concrete interlocking tile vent.

Product name: Redland 50 double roman tiles with “Manthorpe large format, concrete interlocking tile vent.”	Manthorpe
Bond : straight	Lap: 100mm
Material: Concrete	Pitch: 20^0
Fixing: Nails and clips	Batten gauge: 318
Additional:	Date commenced: 2/11/2010.

Wind speed (ms)	DVD chapter	Observations
0 - 15	1	No visible movement of the tiles or vent.
15 - 20	2	No visible movement of the tiles or vent.
20 - 25	3	No visible movement of the tiles or vent.
25 - 30	4	No visible movement of the tiles or vent.
30 - 35	5	No visible movement of the tiles, slight shaking of the tile vent.
35 - 40	6	No visible movement of the tiles. Right hand, unsupported edge of the tile vent shaking a little.
40 - 45	7	No visible movement of the tiles. Right hand, unsupported edge of the tile vent shaking a little and lifting about 5mm at the bottom.
45 - 46.5	8	No visible movement of the tiles. Right hand, unsupported edge of the tile vent shaking a little and lifting a little more at the bottom.

Appendix C – Calibration results for the BRE test rig

prEN 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.

prEN 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 C1 shows the end of the BRE wind tunnel and Figure C2 shows the wind speed calibration of the BRE test rig using ultrasonic anemometers.

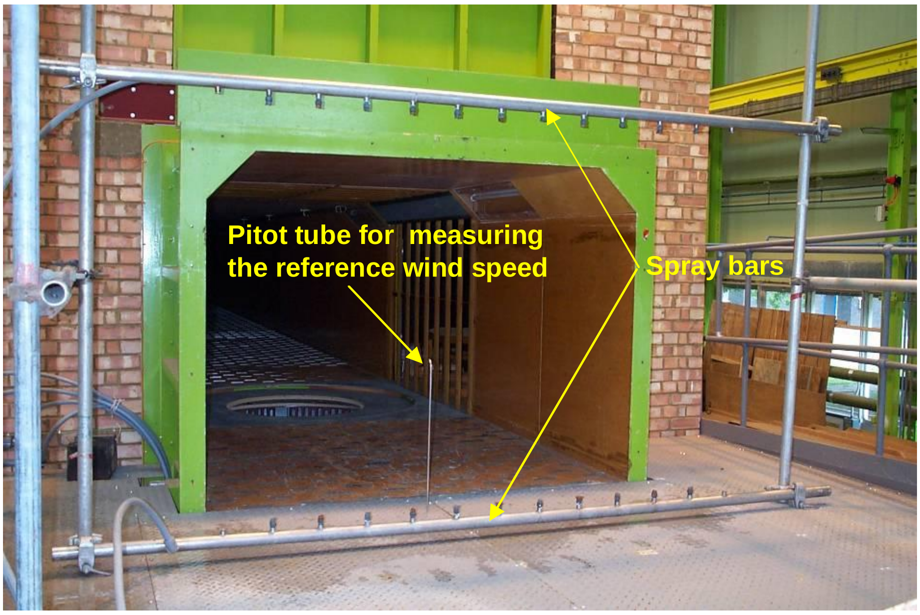

Figure C1 The end of the BRE wind tunnel

Figure C2 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 C1 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 C1 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 C3 to C6 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 C2. From Table C2 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 C2 Calibration of driving rain variability


Figure C3 Bottom spray bar


Figure C4 Top spray bar


Figure C5 View of the test rig at the end of the tunnel


Figure C6 View of the 16 rainfall collection buckets on the test rig