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TEST REPORT

Lucideon Reference:	UK233535 (QT-72418/2/JB)/Ref. 1/CR1
Project Title:	Determination of the Resistance to Wind Up-Lift of Buzon UK Ltd's Porcelain Decking Systems
Client:	Buzon UK Ltd Unit 6 Teddington Business Park Station Road Teddington Middlesex TW11 9BQ
For the Attention of:	Mr Mike Wilderink
Author(s):	Mr Justin Fryer
Report Date:	20 December, 2023
Purchase Order No.:	1322

This report supersedes the report issued on 30.11.23 and was re-issued following grammatical/typographical corrections.

Miss Lisa Cobden
Testing Team
Reviewer

Mr Justin Fryer
Testing Team
Project Manager

Lucideon Limited
Queens Road, Penkhull
Stoke-on-Trent
Staffordshire, ST4 7LQ, UK
T +44 (0)1785 331874
query@lucideon.com
www.lucideon.com
Reg. England 1960455

CONTENTS

1 INTRODUCTION

Buzon UK Ltd supply Porcelain Decking Systems.

They required a program of testing to establish the resistivity to wind uplift of four of their systems when used in conjunction with their Buzon A-FIX-WIND-SAFE adhesive.

Buzon UK Ltd provided four systems to be tested with two sizes of 20 mm thick porcelain tiles (600 mm x 600 mm and 1200 mm x 600 mm (L x W)).

The four systems were as follows: -

- Buzon A-PED Metal Pedestals.
- Buzon DPH Plastic Pedestals.
- Buzon A-PED-JOIST with Buzon A-PED Metal Pedestals.
- Buzon U-BRS-38MM Rail with Buzon DPH Pedestals.

Installation took place on 2 October 2023 with testing completed on 18 and 19 October 2023 in Lucideon Limited's Structures Laboratory, Queens Road, Stoke-on-Trent, ST4 7LQ.

2 SAMPLE CONSTRUCTION

Representatives from Buzon UK Ltd installed their systems within Lucideon Limited's Wind Uplift Rig Base, which was fully lined with 18 mm thick OSB3.

The sample was constructed such that each system had an equal proportion (1800 mm x 1500 mm approximately) of the test area as detailed in Figure 1 below.

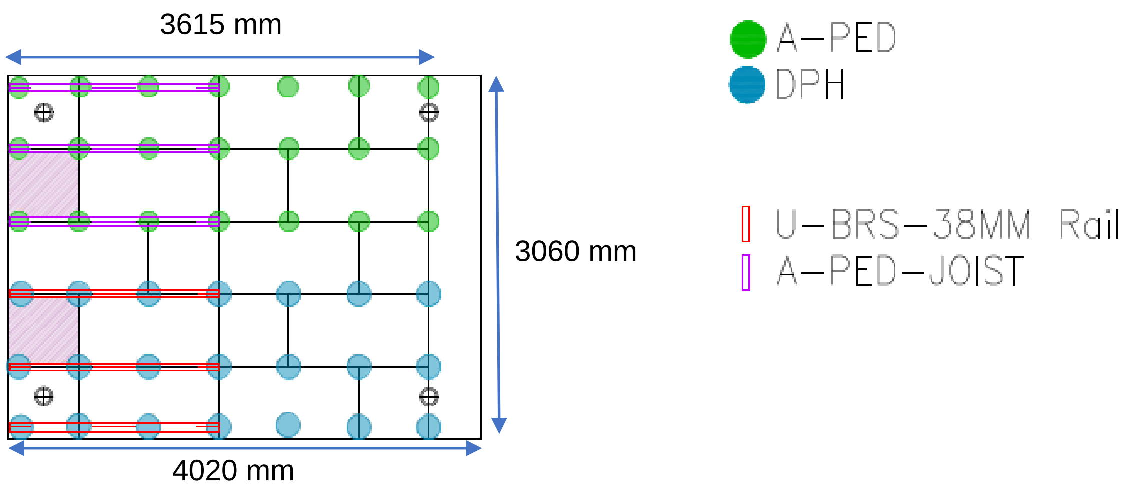


Figure 1 − Sample Construction Layout

The sample was constructed dry (without adhesive) first in order to ensure the installation was correct and level.

Once installed to the Buzon representatives satisfaction, each tile in turn was lifted using a Grabo Electric Vacuum Lifter, and either a small line of the adhesive was applied to the pedestal corner beneath the tile, or a single line along the top of the rail or joist beneath the tile was applied, the tile was then replaced and compressed slightly before repeating on each subsequent tile, until such time, as all but two tiles were adhered to their respective pedestals and/or rail/joist.

The two tiles that were left adhesive free can be seen highlighted in purple to the left-hand edge of Figure 1 above. These tiles were left free of adhesive, to allow access to the adjacent tiles and to act as control tiles for the wind uplift.

Linear Voltage Displacement Transducers (LVDT's) were positioned below the tiles to measure the deflection of the tiles during testing per Figure 2 below: -

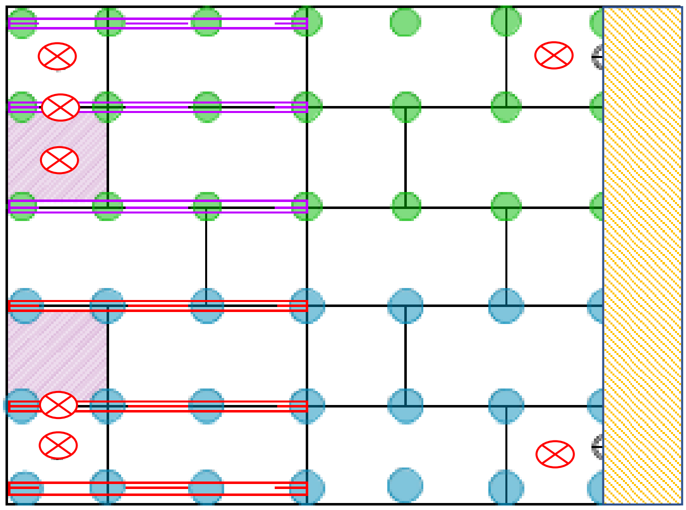


Figure 2 − Transducer Positions

A manometer was positioned on top of and underneath the tiles, to measure the air pressure at both levels during testing.

An LVDT was also positioned below the joists of the rig, to measure the deflection of the base that the sample was constructed onto.

All LVDT's and manometers were connected to a Data Logger and laptop to record data during testing at a frequency of 1 Hz.

3 TEST PROGRAMME

The samples were tested in 3 Stages: -

1. Stepped increase in 500 Pascal increments up to a maximum of 6000 Pascals.

2. A cyclic loading based upon EOTA Technical Report TR005:2003 Determination of the resistance to wind loads of partially bonded roof waterproofing membranes, with the section highlighted blanked off blocking free air movement below the tiles.
3. A cyclic loading based upon EOTA Technical Report TR005:2003 Determination of the resistance to wind loads of partially bonded roof waterproofing membranes, with the section highlighted open, allowing free air movement below the tiles.
4. Static load test of each system type using an airbag to simulate a direct wind load to the underside of the tile.

Parts 1, 2 and 3 of the test programme were devised to form an understanding of how the systems reacted to a wind uplift force of varying frequency and magnitude.

Part 3 of the test programme was devised to give an understanding, and a value, to the failure load and mode where the system could become susceptible to lesser magnitudes of wind loading and thus be deemed unsafe.

4 TEST METHOD

4.1 Stepped Increase Test

Each system was subjected to a continuous wind uplift pressure which increased at set intervals.

An initial wind up-lift pressure of 500 Pascals was imparted on the system for 20 seconds.

Following this the wind up-lift pressure was increased by 500 Pascals every 20 seconds, until the system failed, or the limit of the rig (6000 Pascals) was reached.

The system was monitored continuously throughout this testing with deflection and pressure measurements being taken per Section 3 of this report.

Photographs of the test set-up can be seen in the Plates Section of this report.

4.2 Cyclic Wind Loading

All samples were subjected to a number of proportional sequential loading cycles in accordance with Table 1 of EOTA TR 005:2003.

All cycles were in accordance with EOTA TR 005 Figure 2 – Proportional Array of Suction Pressures, which can be seen in Figure 3 below: -

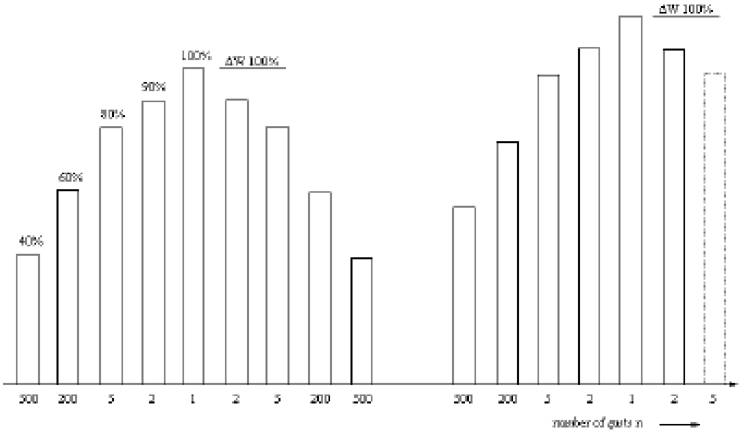


Figure 2 – Proportional array of suction pressures

Figure 3 – EOTA TR 005 Figure 2 – Proportional Array of Suction Pressures

The lapse time for each suction pressure was in accordance with EOTA TR 005 Figure 5 − Time/Suction Pressure Diagram of as seen in Figure 4 below: -

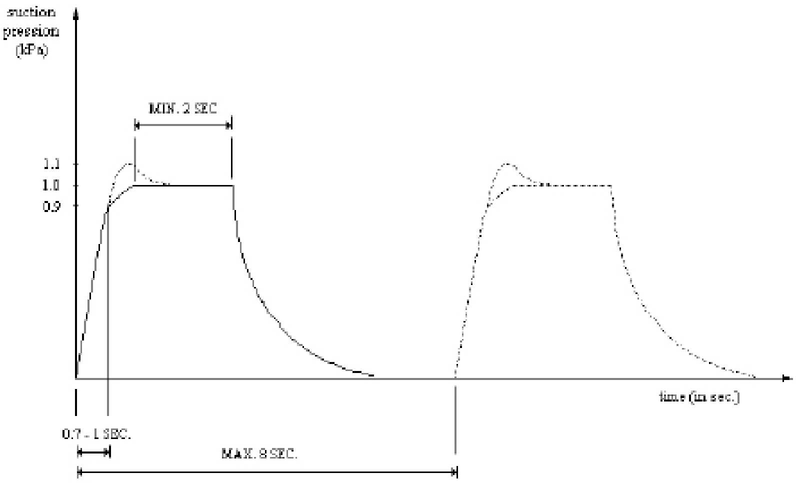


Figure 5 – Time/suction pressure diagram (trapezium)

Figure 4 – EOTA TR 005 Figure 5 – Time/Suction Pressure Diagram

The behaviour of the sample was observed during each cycle.

The loading was set at 6000 Pascals maximum giving the following pulses for the cyclic loading: -

Table 1 − Cyclic Wind Loading Pulses

Load %	Load (Pa)	No. of Pulses
40	2400	500
60	3600	200
80	4800	5
90	5400	2
100	6000	1

The system was monitored continuously throughout this testing with deflection and pressure measurements being taken per Section 2 of this report.

As stated within Section 3 of this report, the section highlighted in Figure 2 was blanked off for Part 2 of the Test Programme and left open for Part 3. The testing was identical for both parts aside from this alteration to the test sample.

Photographs of the test set-up can be seen in the plates section of this report.

4.3 Static Load Test

A box was constructed using plywood, of nominal dimension 400 mm x 400 mm x 180 mm (W x L x H), which fit underneath the tiles and between the pedestals.

An airbag was placed within the box and connected to a common manifold by way of a rubber pipe.

A manometer was also connected to the common manifold to record the static pressure within the bag during testing.

The common manifold was connected to a regulator which in turn was connected to a compressed air supply.

A scaffold framework was constructed, such that, an LVDT could be positioned directly above the geometric centre of the tile to be tested. The LVDT was connected to the tile, by way of a steel washer secured with duct tape and a strong magnet.

The manometer and the LVDT were connected to a Data Logger and laptop to record data during testing at a frequency of 1 Hz.

Air was slowly allowed to fill the bag until, such time, as the sample was deemed to have failed.

Photographs of the test set-up and failure modes can be seen in the Plates Section.

5 RESULTS

5.1 Stepped increase Testing

The samples were taken to a maximum load of 6000 Pascals without any detrimental effects to the system.

Table 2 − Deflection of Systems During Stepped Increase Testing

System	Deflection (mm) @ Load (Pa)					
	1200	2400	3600	4800	6000	Residual
Buzon A-PED	0.49	0.94	1.01	1.34	2.06	0.15
Buzon DPH	0.28	0.28	0.54	0.88	1.42	0.84
Buzon A-PED-JOIST	0.13	0.16	0.18	0.24	0.44	0.16
Buzon U-BRS-38MM Rail	0.00	0.00	0.00	0.00	0.02	0.01
Free Tile 1	0.20	0.31	0.98	2.89	6.18	0.09
Free Tile 2	0.10	0.83	1.99	4.07	7.48	0.15

Table 2 gives the maximum deflection of each system at the load stated, along with the residual deflection following testing.

We can see that there is a slight increase at each stage, for all but the Buzon U-BRS-38MM Rail which deflected almost nothing.

The free tiles, as expected, lifted the most, however, at no point did they become free of the surrounding system.

5.2 Cyclic Wind Loading

5.2.1 Blanked

The samples were taken to a maximum of 6000 Pascals in pulsed cycles as described within Section 4.2 of this report.

There were found to be no detrimental effects to any of the systems and no failures were observed during testing.

Table 3 – Deflection of Systems During Cyclic Wind Load Testing with Open End Blanked Off

System	Deflection (mm) @ Load (Pa)					
	2400	3600	4800	5400	6000	Residual
Buzon A-PED	0.66	1.17	1.22	1.22	1.24	0.08
Buzon DPH	0.16	0.22	0.25	0.41	1.11	0.03
Buzon A-PED-JOIST	0.23	0.40	0.45	0.53	0.57	0.38
Buzon U-BRS-38MM Rail	0.00	0.01	0.01	0.01	0.02	0.01
Free Tile 1	0.64	0.74	1.89	3.41	5.11	0.36
Free Tile 2	0.10	0.36	0.79	1.64	3.69	0.19

We can see from the values within Table 3 that they are lower than those of the stepped increase test. This is due to the way the test is conducted. The stepped increase test is a constant uplift pressure which increases incrementally, whereas, the cyclic test consists of pulses, of the same magnitudes as the stepped increase but for a shorter period and with a return to 0 in between them.

Again, with all but the free tiles, we can see a slight increase up to around 4800 Pascals where the increase in deflection plateaus or slows down considerably. This could be due to the same explanation as previously, with the cyclic testing being a pulsing load it doesn't get a chance to lift the systems as much as a constant load before it is released. This would be more consistent with conditions in reality, where gusts of wind would cause vortex's to lift the surface finish for short periods.

5.2.2 Open Ended

The samples were taken to a maximum of 6000 Pascals in pulsed cycles as described within Section 4.2 of this report.

There were found to be no detrimental effects to any of the systems and no failures were observed during testing.

Table 4 − Deflection of Systems During Cyclic Wind Load Testing with Open End

System	Deflection (mm) @ Load (Pa)					
	2400	3600	4800	5400	6000	Residual
Buzon A-PED	0.59	1.12	1.19	1.28	1.30	0.06
Buzon DPH	0.09	0.15	0.23	0.34	1.00	0.14
Buzon A-PED-JOIST	0.49	0.97	0.97	0.98	0.55	0.04
Buzon U-BRS-38MM Rail	0.00	0.01	0.01	0.01	0.02	0.00
Free Tile 1	0.07	0.63	1.23	2.07	3.37	0.05
Free Tile 2	0.49	0.61	0.87	1.36	1.94	0.12

5.3 Static Load Test

Each sample was tested in turn and Table 5 below gives details of the failure load, deflection and mode for each test.

Table 5 − Results for Static Load Testing

System	Maximum Load		Deflection @ Max Load (mm)	Failure Mode	Comments
	Pa	kg/m^2			
Buzon A-PED	30490	3109.07	49.64	Debonding of the adhesive layer from the pedestal	The tile lifted the pedestals at the free edge and de-bonded from the tiles adhered to further tiles
Buzon DPH	11420	1164.50	14.64		
Buzon A-PED-JOIST	37960	3870.78	64.94	lifting of railed section until adhered area to the bottom face of the tile sheared from the tile	Larger 1200 mm tiles further along the railed section de-bonded in a peeling manner due to the lift of the rail
Buzon U-BRS-38MM Rail	87530	8925.43	60.59		

6 DISCUSSION

Wind can approach a building from any direction. It will hit a side elevation, causing it to be directed upwards and accelerated.

Once it reaches the top of the building it can return to its normal course, however, it leaves a void before settling back down over the roof.

This void is an area of negative pressure – which has the effect of trying to pull or suck the roof coverings off the remaining structure.

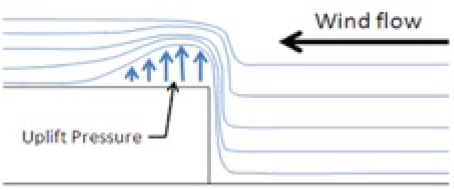


Figure 5 − Edge Zone of a Roof

You can see from Figure 5 above that the edge zone of a roof is the most likely to be affected by wind uplift.

As the wind can come from any direction, all corner and perimeter zones require a greater resistance to the effects of wind load when being secured.

The effect can be worsened if the edges of flat roofs are not correctly fixed, which can allow air to get underneath the roof covering.

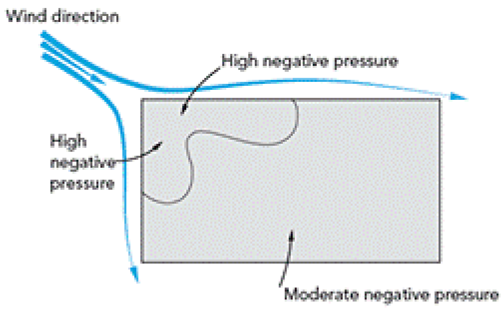


Figure 6 − Wind Striking an Object

When wind strikes a building, it is deflected to generate a positive pressure on the windward face. As it accelerates around the side of the building and over the roof, it creates a reduced or negative pressure in its trail.

The greatest pressures are experienced at the windward corners and edges of the roof, where the negative pressure exerted on the roof, can be several times that experienced in the central areas.

It is also important to take into account the location and exposure of the building to determine the effect of Wind Uplift. Northern England, Scotland & Northern Ireland typically will have much higher average wind speeds than those experienced in the South & South East.

Wind speed will also be higher in exposed areas such as on the coast and in open, rural, or hilly areas. Tall buildings with no surrounding protection would be more at risk; buildings that are sheltered in a town centre less so.

How does this apply to raised flooring on a flat roof??

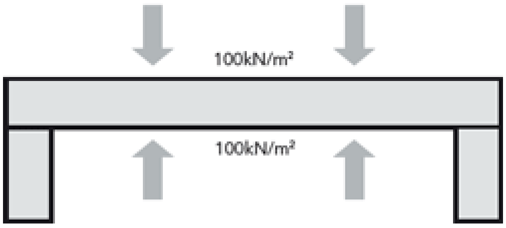


Figure 7 − Pressures in Normal Situations

When there is no wind, the air pressure on the upper surface of a roof system is the same as that on the underside. Wind changes this equilibrium by reducing the atmospheric pressure on the surface of the roof system.

The atmospheric pressure acting on the underside of the roof will remain the same or may be increased if windows or doors are open on the windward side of the building.

The result is a net upward push acting on the underside of the roof. This upward thrust will be exerted on the lowest air impermeable layer in the roof construction, which will be required to stop air flowing further into the system (the diaphragm).

In most roof constructions there is one layer that provides the dominant barrier against the upward thrusting flow of air, and this is referred to as the critical layer.

In roof constructions where the deck is continuous (e.g. screeded concrete) it will be deemed to be the critical layer, but for **air permeable decks (i.e. those with joints)** the critical layer will occur somewhere in the roof system itself, this is because the gaps within the air permeable layer allow the air pressure to equalise below and above and hence not act as a diaphragm.

This pressure equalisation isn't instant, however, there can be a time of a few seconds, dependant on the air flow rate of the air permeable deck, where the pressure differential will act upon the deck itself until pressure equalisation occurs.

It is for this reason, that any surface that is added to the upper face of a flat roof, should be tested for uplift resistance, to establish that under extreme pressures it has the ability to pressure equalise, prior to the wind uplift force causing a failure of that layer, wind uplift prevention systems would need to be implemented should this be the case, however, they would not be required for systems that allow a sufficient air flow rate between them to pressure equalise prior to any failure.

To give some context to the results obtained during testing: -

It has been recorded that, gusts of up to 100 mph (44.70 ms^{-1}) occur in the UK on average once every 50 years and as such it was deemed prudent to test beyond this maximum potential wind speed.

Wind Pressure (Nm^{-2}) = ½ x Air Density (kgm^{-3}) x wind speed² (ms^{-1}) x Drag Coefficient.

The air density was taken as 1.25 kgm^{-3}.

The wind speed = 44.70 ms^{-1}.

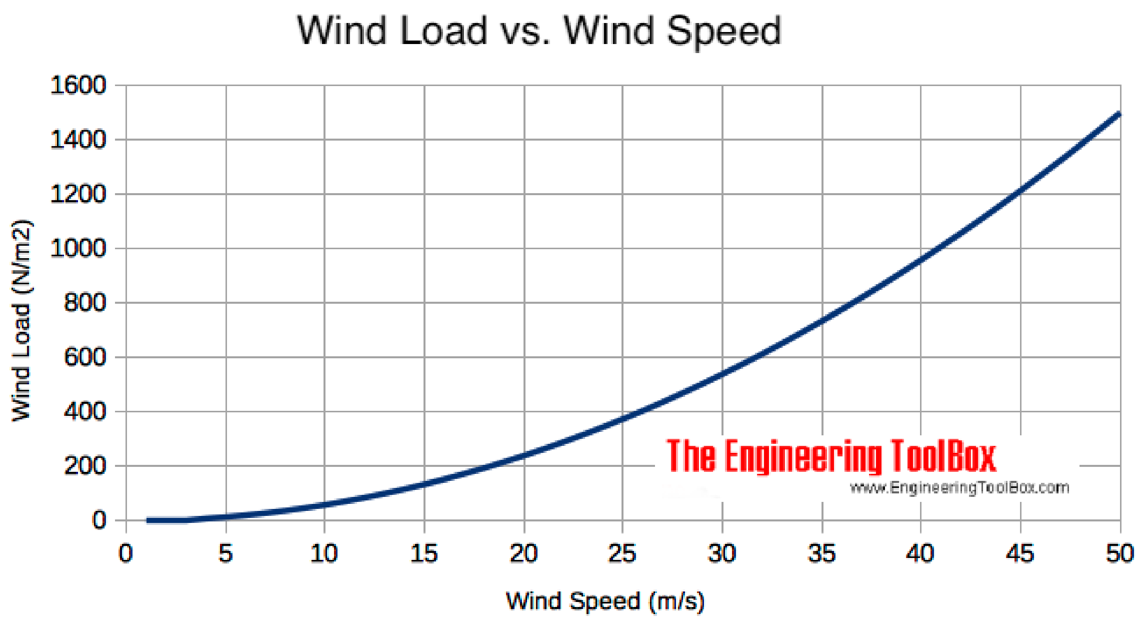
The drag coefficient (taken as 1.0).

This gave a pressure of 1225.73 Nm^{-2} (1.23 kilopascals).

In any particular situation, the wind load, dependant on the basic wind speed (the value of wind speed for a 3 second gust), which varies across the country, the height above ground, the degree of protection from other buildings and also geographic features (e.g. escarpments.) is determined in accordance with BS EN 1991-1-4:2005 +A1:2010 and this is, of course, very specific to the building, its location orientation etc.

To give a feel for this, the pressure from a 3 second gust at 10 m above the ground, would range from around 0.6 kNm^{-2} in a city centre anywhere in England, to 1.4 kNm^{-2} in open country.

To this wind load is applied a partial safety factor which is taken from BS EN 1990, which covers the Basis of Structural Design. These factors can also be complicated to select but a common number used is 1.5. Thus, the wind load for which an element must be designed is defined.



7 CONCLUSION

Buzon UK Ltd contracted Lucideon Limited to provide a Test Programme for their Porcelain Tile Systems when used with their Buzon A-FIX-WIND-SAFE adhesive, such that they could demonstrate the safety of each system under wind uplift conditions.

When compared to tiles that had been adhered it was seen that the tiles, which were un-adhered lifted up to three times as much at maximum load during each test.

Systems with rails or joists performed significantly better with deflection values at around half, when compared with those of pedestals only.

We can see from the static tests that it would take over a metric ton of direct load to dislodge a 600 mm x 600 mm x 20 mm (L x W x D) tile, to the point, where it was free from the system and could be considered a safety risk to buildings and persons. This is the worst-case scenario of the smallest tile at the edge, with load sharing from only two sides rather than three or four.

From the test results we can see that it takes an extreme force to push each system, when used in conjunction with the adhesive, to the point where a tile is free and could be deemed a safety risk.

NOTE: The results given in this report apply only to the samples that have been tested.

END OF REPORT

PLATES

Plate 1 – Buzon A-PED Pedestal

Plate 2 – Buzon DPH Pedestal

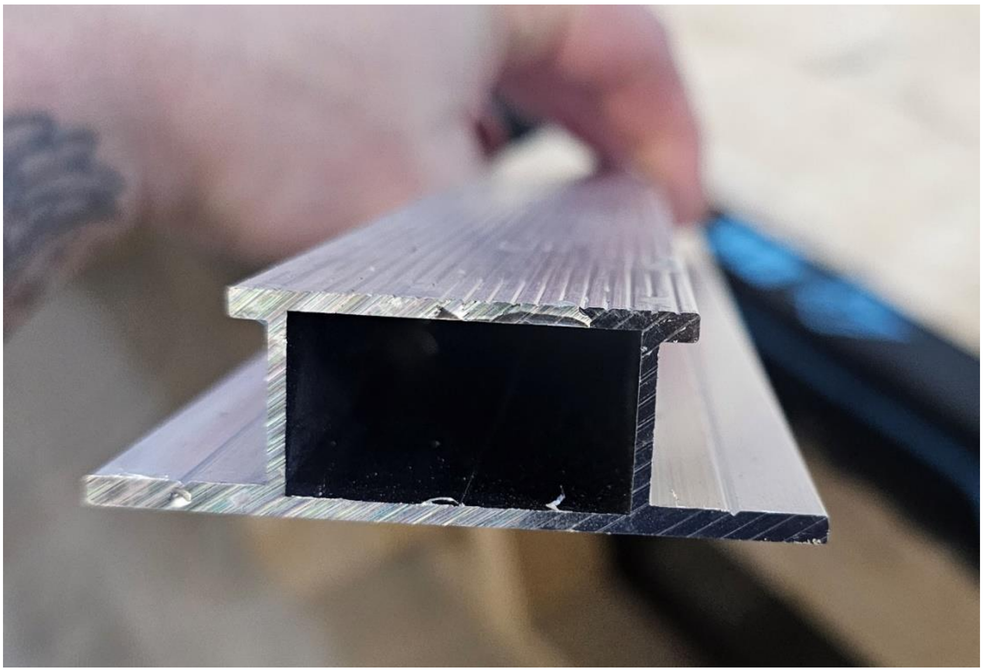


Plate 3 – Buzon A-PED-JOIST

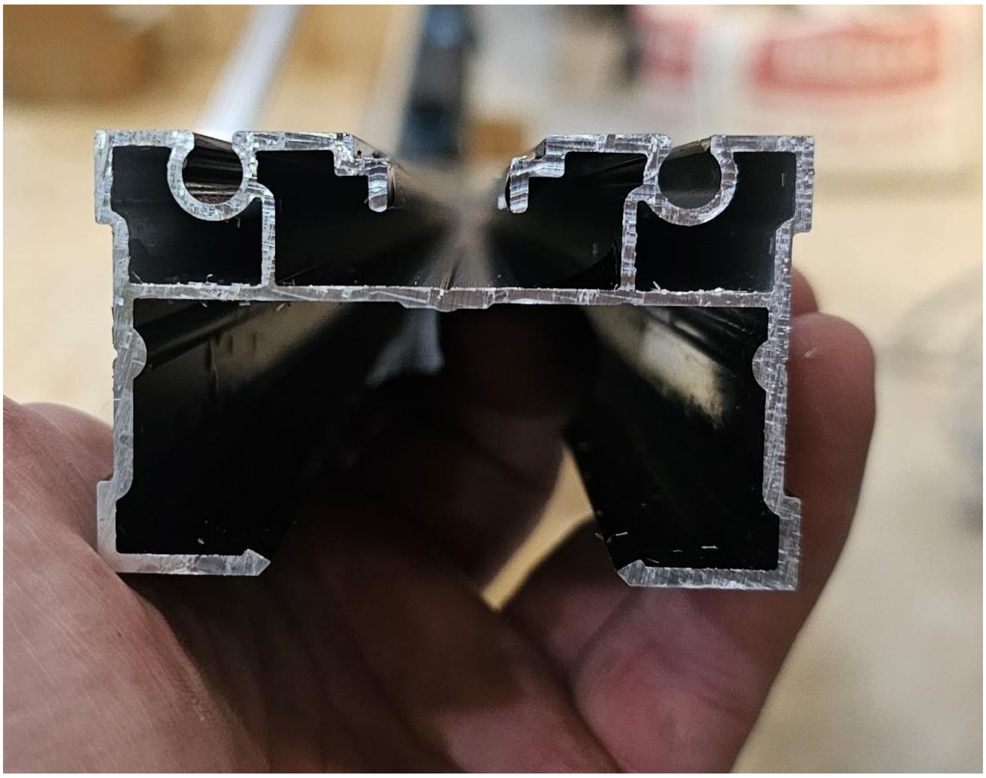


Plate 4 − Buzon U-BRS-38MM Rail

Plate 5 – Buzon A-PED and Buzon DPH Pedestals with Tiles

Plate 6 – Buzon U-BRS-38MM Rail with Tiles

Plate 7 – Buzon A-PED-JOIST with Buzon A-PED Pedestal and Buzon A-PED-TABS-PLATE

Plate 8 − Sample Completed Dry (no adhesive)

Plate 9 − Buzon A-FIX-WIND-SAFE Adhesive

Plate 10 – Part 1 of the 2-Part Adhesive

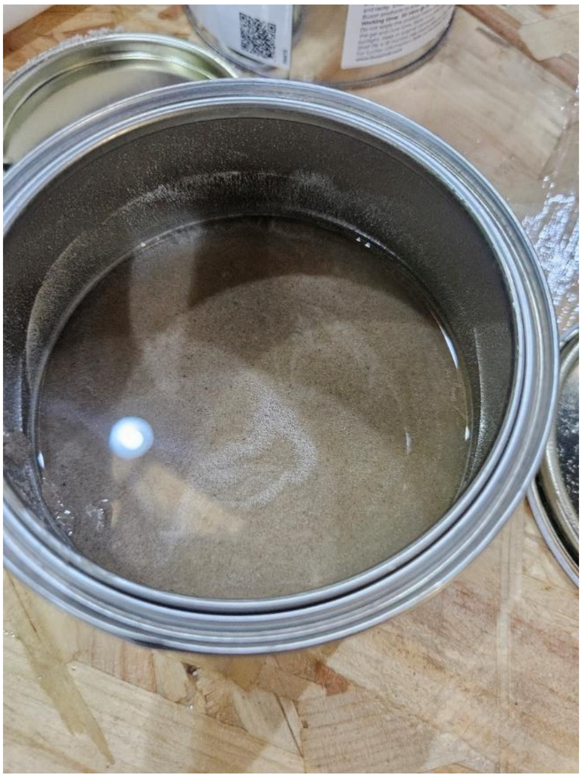


Plate 11 – Hardener (Part 2) of the 2-Part Adhesive

Plate 12 − Adhesive Mixed using Plastic Paddle Attached to Drill

Plate 13 − Mixed Adhesive Transferred into a Plastic Tube

Plate 14 − Adhesive Applied to Tile Spacer/Pedestal Tops

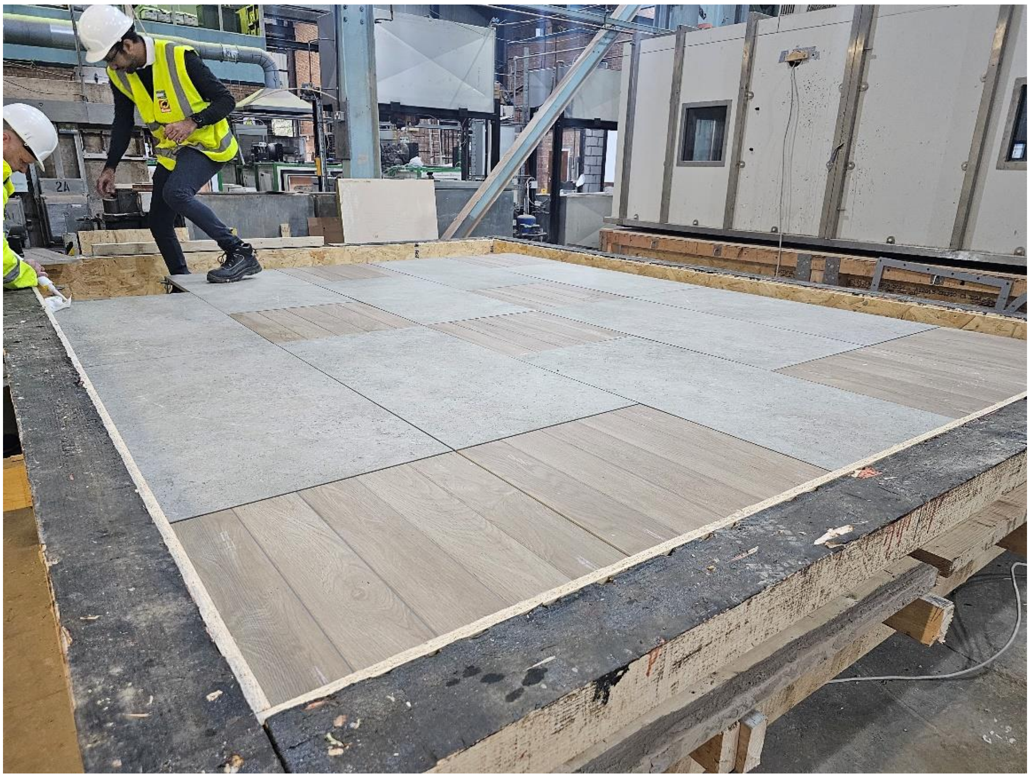


Plate 15 − Completed Test Sample

Plate 16 − Sample Within the Test Rig

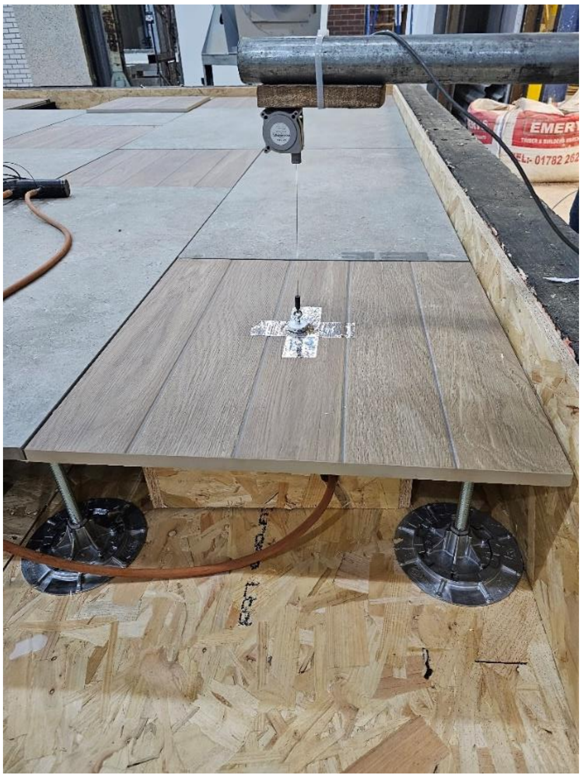


Plate 17 − Static Load Test Set-Up (1)

Plate 18 − Static Load Test Set-Up (2)

Plate 19 − Tiles Lifting During Load Testing

Plate 20 − Tiles Lifting During Load Testing of A-PED-JOIST Section

Plate 21 − Tiles Not Under Test Have Failed Due to the Rails Lifting

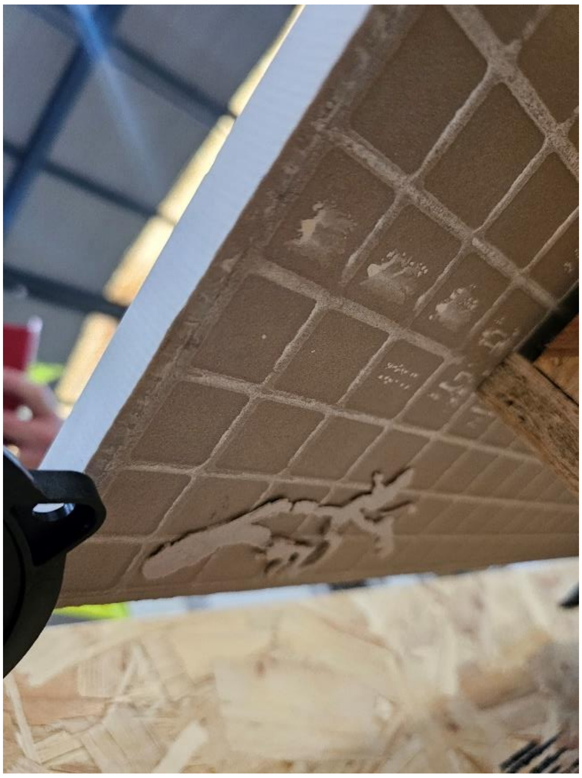


Plate 22 − Typical Failure Beneath the Tile (debonding of the adhesive from the pedestal)