

Biotope Framework Services

Structural Engineering Assessment of Biotope Living Wall System

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Contents

1	Introduction	1
2	Executive Summary	2
3	The System / Composition	4
3.1	Description of System	5
3.2	Technical Data For Euroform (Versapanel Eco) Backing Board	7
3.3	Fastener Description	8
3.4	Manufacturers Recommended Fastener Spacing : Backing Board (Refer to section 2.1 item 2)	8
4	Testing	8
4.1	Vinci Technology Centre (Report Reference: N950-15-17090).	8
4.2	Testing carried out by Lucideon (Reference: 15928 (QT-35314/1/SL)/Ref. 1).	12
4.3	Backing Board Saturated Performance (EJOT Report Reference 17101)	14
4.4	Stiffness, Strength and Impact Test for Versapanel Backing Board (Ceram Report 111197 (QT-16883/1/BW) 1C)	15
4.5	Performance in Fire for Biotecture Living Wall System Using Versapanel Backing Board	16
5	Discussion and Assessment of Test Results and Product Data	16
5.1	Product Data Sheets	16
5.2	Wind Load Testing by Lucideon	17
5.3	Tests on fixings on board following immersion in water for 48 hours	17
6	Structural Recommendations	22
7	Limitations	23
8	Standards & References	23
Appendix A	Biotecture Standard Layout Drawing	24
Appendix B	Biotecture Living Wall System Using Rockpanel – Vinci Testing	24
Appendix C	Biotecture Living Wall System Using Versapanel – Lucideon Wind Testing	24
Appendix D	Structural Testing of Euroform Versapanel – Ceram	24
Appendix E	Versapanel Saturated Board Pull Out Testing – EJOT	24
Appendix F	EJOT TBF Fastener Data Sheet	24

1 Introduction

Evolve Consulting Engineers Limited has been commissioned by Biotecture Limited to provide professional consultancy services associated with the structural engineering advice in support of the Biotecture Living Wall system.

It was agreed between Evolve and Biotecture that this advice will aim to cover the following:

- Testing carried out to date and clarify how this can be relied on, on a project by project basis
- Limitations of testing and to clarify what is and what is not covered by the tests
- Product validation data available from suppliers that can be relied upon and set out any limitations
- Structural Design that may be required (by the Client team) to support the Biotecture system for a project,
- References to design standards i.e. Eurocodes etc. relevant to the installation

This Report describes the testing carried by Vinci on a Biotecture Living Wall system comprising all the components making up the Living Wall but without planting. Since this test some components that affect the structural performance of the system have been changed, notably an alternative backing board supplied by Euroform, type Versapanel Eco and fixings. The previously specified backing board by Biotecture was an 8mm thick Rockpanel Durable cladding board.

The Versapanel Eco boards are supplied by Euroform as sheathing boards for external cladding on buildings. The advice on using Versapanel board is based on the comparisons of the two board's material property and also their respective test data. It also relies on technical guidance and recommendations provided by Euroform for the use of Versapanel Eco as a sheathing board.

This report summarises how the various pieces of data relate to the performance of the Living Wall system and/or its components.

Please note that this report is limited to the structural aspects of the backing board and cladding support rail system including any associated fixings. This Report is based upon information provided to Evolve by Biotecture Limited and it assumes that the information is correct and can be relied upon. Evolve is not responsible for any inaccuracies or errors in the information provided.

It should be noted that where the proposed installation of the Biotecture Living Wall system falls outside the guidance and recommendations summarised in the Evolve Report, additional design and possible testing may be required to suit the specifics of an individual project.

Please refer to Biotecture Limited for any clarification or advice in regards to the expected structural performance of the system where not covered by this Report. The appropriate professional advice should always be sought where the Biotecture Living Wall system is to be installed as over cladding to a structure.

2 Executive Summary

Reference should be made to the full version of the Report 'Structural Engineering Assessment of Biotecture Living Wall System' by Evolve. Key points to highlight are:

- The 'system', comprising 'Biotile' panels secured to the panel carrier rails, fixed to the backing board on support steelwork to simulate on-site conditions, has been tested by Vinci on behalf of Biotecture (refer test report by Vinci). This demonstrated that this installation performs under a serviceability wind load of 2400 Pa. It also proved the mode of failure, which is caused by a suction of 3640 Pa.
(It should be noted that the installation tested by Vinci included 'Rockpanel' cladding boards as the backing board and rivet fixings between the carrier rails and the board and between the board and the support steelwork)
- The current Biotecture Living Wall installation uses screw fixings and a 12mm Versapanel Eco panel manufactured by Euroform as the backing board.
- The Versapanel Eco backing board should be installed strictly in accordance with guidance and recommendations from Euroform in the Versapanel Technical Manual EV8.
- The Technical Manual states "Versapanel can be used for a wide range of applications including as a backing board (carrier panel) to cladding systems such as: Insulated Render Systems, Terracotta Cladding Systems, High Performance Cladding Panels, Brick Slip Systems and Coating Systems.
- Under instruction from Euroform, Lucideon carried out wind load testing on the Versapanel boards. The tests were carried out on 8mm board (the Biotecture installation uses a 12mm board) attached to a lightweight steel frame to simulate the on-site assembly with intermittent steel studs at 600mm centres. The results of the tests mirrored the Vinci test results where the components perform under a serviceability wind load of 2400 Pa. It also proved the mode of failure, which is caused by a suction of 3640 Pa.
- There is a reduction in the performance of the screw fixings when the Versapanel board is submerged in water for 48 hours

A summary of the findings and advice is:

- a) The specification and installation of the Biotecture Living Wall should adhere strictly to all manufacturer's recommendations and guidance
 - b) The wind load tests by Lucideon demonstrate that the panel performs adequately under wind loads. The service load of 2400 Pa from the wind test is more than the tabulated value of 600 Pa as suggested by Euroform for the Versapanel board.
 - c) Most conditions will fall within these limitations on wind pressure. For example, using a typical peak wind velocity pressure value of 1200 Pa and the maximum external wind load coefficient at eaves (Zone A) of 1.4 (*Table 7.1 BS-EN 1991-1-4: 2005*), the calculated wind load will be 1700 Pa. This value is less than the value achieved via wind test i.e. 2400 Pa in serviceable conditions.
 - d) For most typical internal cases for installing the Biotecture system, the internal applied wind loads will generally fall within the serviceability load of 2400 Pa and as such the system will be adequate to perform in these situations under wind loads.
 - e) It is recommended that Installations that fall outside the limitations set out in this Report should be reviewed by a suitably qualified structural engineer in order to determine whether the loads acting on the Living Wall from the wind pressures specific to the site fall within the performance data provided in this Report. Most installation cases should fall within the data provided, but wind effects may increase as a result of their particular setting, i.e.
 - Parapets on building
 - Situations where the building is close to a neighbouring building that is at least twice the average height of surrounding structures then increased wind velocities could occur (funnelling effects)
 - Exposed sites (coastal, exposed rural)
 - High-rise buildings
 - Critical sites such as public realm, playground, open spaces etc.
- a) The Biotecture Living Wall system and its supporting structural components should be considered as cladding when evaluating wind pressures.
 - b) If site specific conditions are outside the areas of guidance covered by the data provided in this Report, the fastener and board capacities will need to be re-evaluated to suit the wind loading. There may be a possibility that under high wind loading conditions (more than the values obtained from Test), the fastener spacing needs to be closed up to increase the capacity and/or the board may need additional structural members at closer centres to increase the loading capacity.

The following is a summary of fastener spacing recommendations for the various conditions for a Living Wall installation:

Condition	Fastener Spacing
a) Internal dry conditions	In line with manufacturer's recommendations
b) Wind load up to 2400 Pa in dry conditions	In line with manufacturers recommendations
c) In wind loading situations as described in section 5c and in areas of high wind pressures greater than 2400 Pa	Seek further guidance from a suitably qualified structural engineer
d) Saturated conditions of the board during temporary / construction conditions, in conjunction with when subjected to wind loads of up to 2400 Pa	Close up spacing to: 600 x 150mm

- c) It is recommended that the minimum steel thickness of all supporting members is 2.0 mm for receiving the backing board fasteners (see section 2.4).

3 The System / Composition

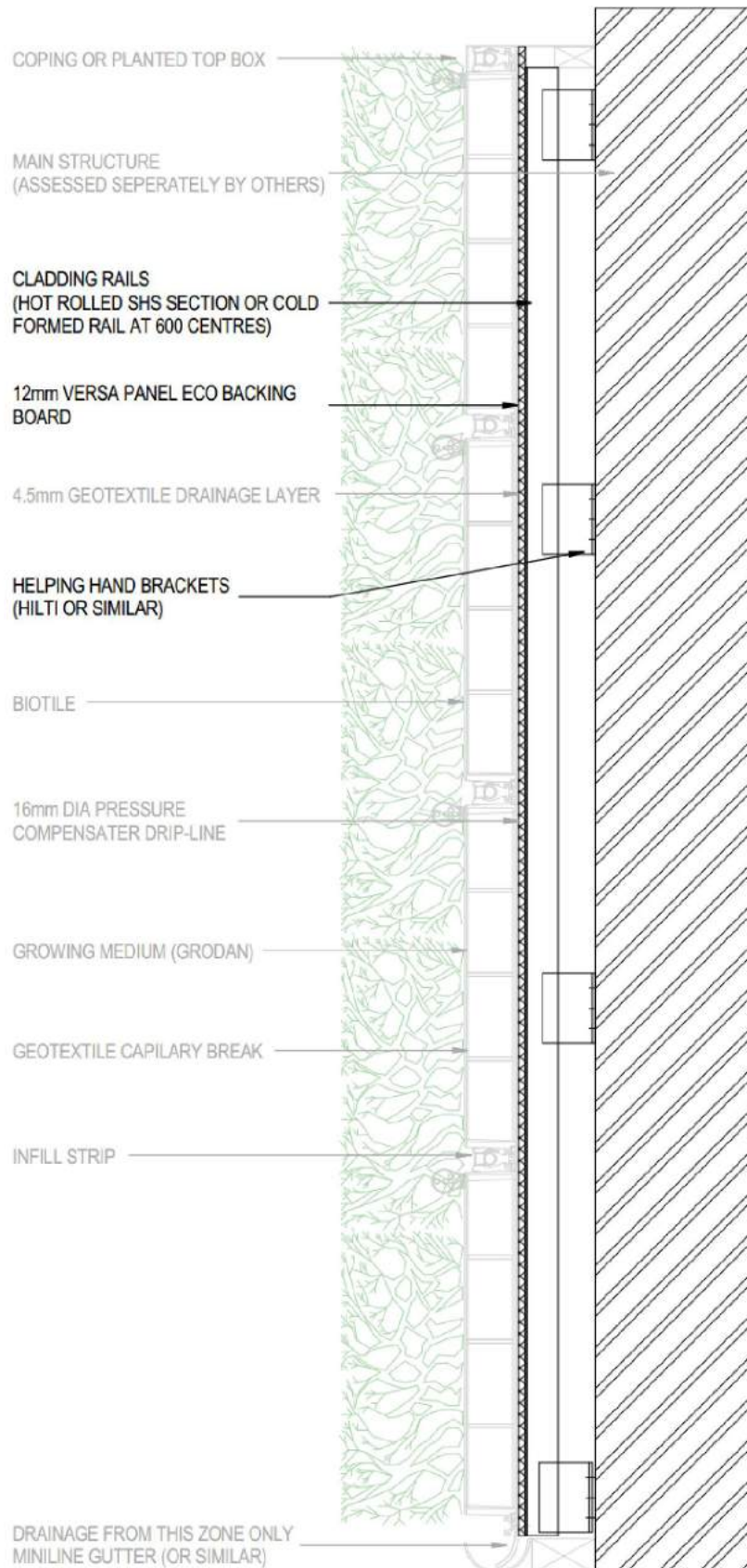


Figure 1 : Typical Cross Section (note: secondary structural components highlighted in bold)

3.1 Description of System

The Biotechture Living Wall System is formed using Biotile modules each nominally 600mm wide x 450mm high x 62mm thick constructed from Polypropylene. The following is a component breakdown description of the system provided to Evolve by Biotechture Limited:

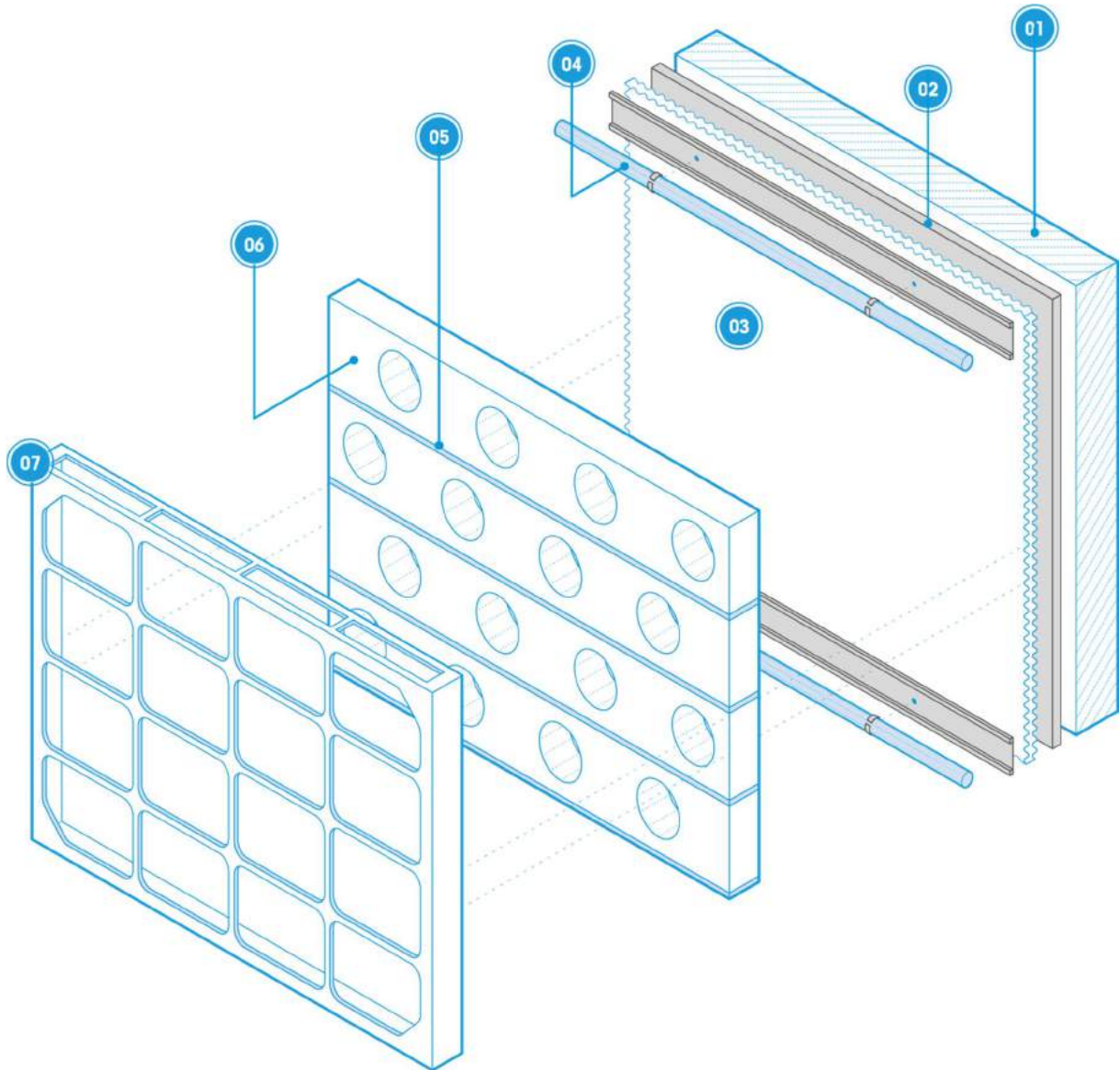


Figure 2 : Biotechture Living Wall System Components



Figure 3 : Unplanted Panel

1. Support system: (to be read in conjunction with section 1 of the report)
 - a) Primary Structure: this is either the external cladding to the building if it is robust enough to support the Biotecture Living Wall system or the building structure itself. A separate check is required by a structural engineer to assess the adequacy of the primary structure. This report does not cover this aspect of the system.
 - b) Secondary Structure: this includes components such as a bespoke galvanised hot rolled steel frame or Hilti helping hand system at a maximum of 600 mm centres, 12mm Versapanel Eco backing board, aluminium helping hand brackets and associated fixings. This report is commenting on the secondary structure part of the system.
2. Waterproof backing board: The backboard is fixed to the support structure and is the fixing layer for the carrier rails. Biotecture Limited is using a 12mm thick Versapanel Eco as a backing board in their Living Wall system.

The backing board is connected to the support structure using a screw type fastener EJOT TBF 4.8 x 45mm at 600mm maximum centres.
3. Rear drainage layer (void former): The void former is a geo-textile material secured by the cladding rail. This enables all drainage water to flow to the rear of the panels so that even moisture content can be maintained for the full height of the wall.
4. Aluminium rail and dripline (also called as panel carrier rails): The aluminium rails carry and hold the Biotiles and they are fixed to the backing board using 25 x 4.2mm stainless steel Accuscrew at a maximum centre of 300mm.
5. Capillary breaks: The capillary breaks are a separation layer that regulates the rate with which water passes through each panel.
6. Growing medium: This is a hydroponic growing medium which is a specific grade of Rockwool.
7. Panel Box: Injection moulded polypropylene casing to support the Grodan growing medium.

3.2 Technical Data For Euroform (Versapanel Eco) Backing Board

These extracts are taken from the data available from Euroform (manufacturers of Versapanel) during the typing of this report. Reference should always be made to the current technical manual and data available at the time of design of the installation and any clarification over the technical data should be provided by the manufacturers.

Extract from page 15 of Euroform (Versapanel) Technical Manual EV10:

Density (average)	1300Kg/m ³	Surface Alkalinity	pH between 11 and 13
Modulus of Elasticity	4500N/mm ²	Moisture Content (ex production)	9% + 3% by weight
1. Thickness tolerances Calibrated: Unsanded: 2. Length: 3. Width: 4. Squareness:	8-37mm+0.3mm 8-10mm+0.7mm 12-19mm+1.0mm 22-42mm+1.5mm +5mm +5mm -2.5mm on panel diagonal difference	Thickness Swelling (24hrs immersion)	0.7% (average)
		Dimensional Stability	0.11% for an increase in relative humidity from 65% to 90% 0.16% for an increase in relative humidity from 65% to saturation
Bending Strength (min)	9N/mm ²	Thermal Conductivity	0.26 W/m.k. Coefficient
Permissible design value	2.25 N/mm ²	Sound Insulation	See characteristics guide Also acoustic information
Tensile strength (parallel to surface)	4.0N/mm ²	Fire Rating	Tested to BS 476 Part 6.7 - classified as Class 0 building board with a Class 1 surface spread of flame. European classification to EN 13501-1: B1 (B-s1 d0 excluding floors), (B1-s1 floors) For further information see Fire Information.
Tensile strength (perpendicular to surface)	0.5N/mm ²	Bonding Agent:	Versapanel is odourless, Since the bonding agent is free from formaldehyde.
Compression strength (min)	15 N/mm ²		

Extract from page 24 of Euroform (Versapanel) Technical Manual EV15: (Note : Data associated with a dry board)

12mm EUROFORM - VERSAPANEL CEMENT PARTICLE BOARD													
Span (mm)	Uniformly distributed load (kN/m ²)						Concentrated load (kN on 50mm x 50mm square)						
	Load limited by stress	Load limited by deflection		Load limited by stress	Load limited by deflection		Span (mm)	Load limited by stress	Load limited by deflection		Load limited by stress	Load limited by deflection	
		Span/300	Span/500		Span/300	Span/500			Span/300	Span/500		Span/300	Span/500
300	4.7	-	3.7	5.9	-	-	300	0.2	-	-	0.3	-	-
400	2.6	-	1.6	3.2	-	2.9	400	0.2	-	-	0.3	-	-
500	1.6	1.3	0.8	2.0	-	1.5	500	0.2	-	-	0.3	-	-
600	1.1	0.8	0.5	1.4	-	0.9	600	0.1	-	-	0.1	-	-
700	0.7	0.5	0.3	1.0	0.9	0.5	700	0.1	-	-	0.2	-	-
800	0.5	0.3	0.2	0.7	0.6	0.4	800	0.1	-	0.1	0.2	-	-
900	0.4	0.2	0.1	0.5	0.4	0.3	900	0.1	-	0.1	0.2	-	-
1000	0.3	0.2	0.1	0.4	0.3	0.2	1000	0.1	-	0.1	0.2	-	-

3.3 Fastener Description

There are two fixings which are considered in the system when using a 12mm Euroform (Versapanel Eco) backing board:

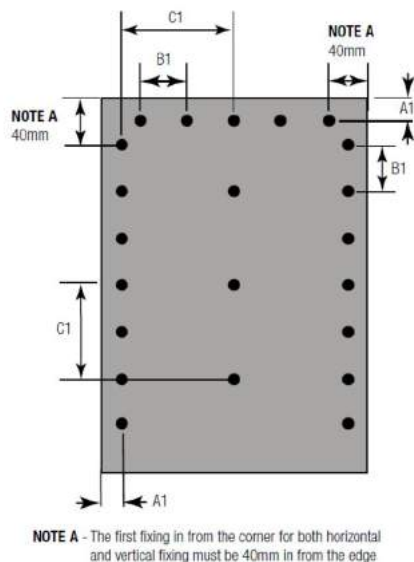
- a) To fix the panel carrier rails to the backing board: 25mm Accu screw at 300mm maximum centres. Refer to section 2.1 item 4 of this report.

No.8 (4.2mm) X 1 Inch (25.5mm) Pozi Self Tapping Countersunk Screws (DIN 7982C Z) - A2 Stainless Steel
Accu Product Code (APC): SPKT-No.8-1-A2

- b) To fix the backing board to the main support structure: EJOT TBF 4.8 x 45mm at 600mm maximum centres (see 2.4 below).

3.4 Manufacturers Recommended Fastener Spacing : Backing Board (Refer to section 2.1 item 2)

Extract from page 11 of Versapanel Technical Manual EV8:



Board Thickness mm	Centres mm			
	A	A1	B1	C1
8	40	15	200	400
10 - 12	40	15	300	600
16 +	40	30	400	600

The Versapanel Eco backing board should be installed strictly in accordance with guidance and recommendations from Euroform.

4 Testing

The following tests have been carried out and documents are appended and are available separately from Biotecture upon request. The Tests described below have been specified and compiled by Biotecture Limited and relevant results provided to Evolve for information. In order to validate their Living Wall system, Biotecture arranged for testing by Vinci Technology Centre as described below. This testing is supplemented with EuroForm's own testing of their Versa Panel Eco board also described below.

The following summarises the various testing carried out on the system, although full Test Reports are appended to this report.

4.1 Vinci Technology Centre (Report Reference: N950-15-17090).

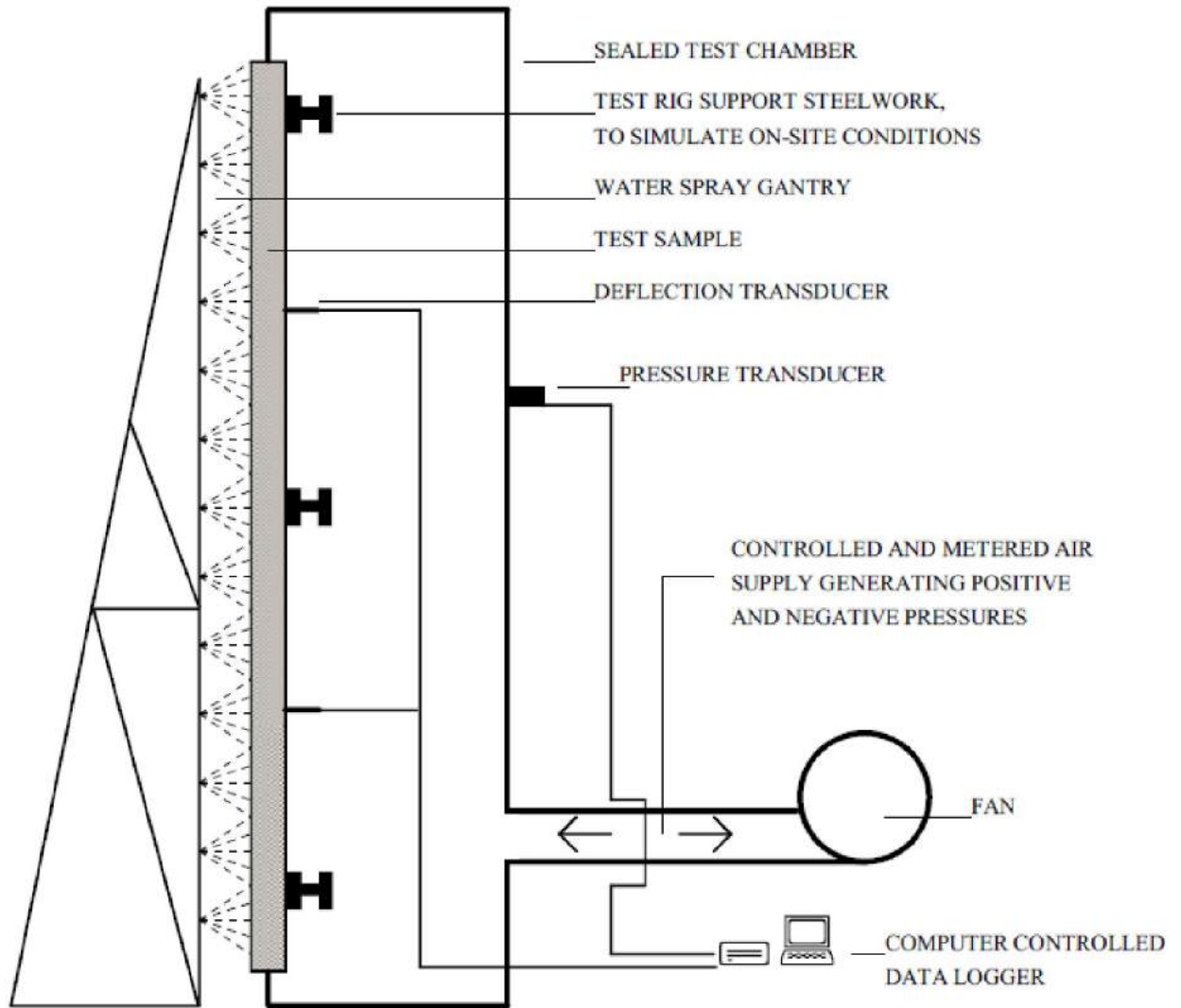
All testing carried out in accordance with Centre for Window & Cladding Technology - CWCT 2005 guidelines. The testing was carried out by Vinci Technology Centre (Report Reference: N950-15-17090) and is appended to the report.

Vinci carried out the test on the system for wind resistance, water tightness and impact resistance. The test sample measured 3.0 m wide by 4.8 m high and comprised 50 Biotecture 600 x 450 plant panels secured to an 8 mm thick Rockpanel Durable backing wall. The test was carried out using screws as fasteners but was subsequently replaced with rivets as described below in detail.

The test sample was mounted on a rigid test rig with support steelwork designed to simulate the on-site/project conditions. The test rig comprised a well-sealed chamber, fabricated from steel and plywood.

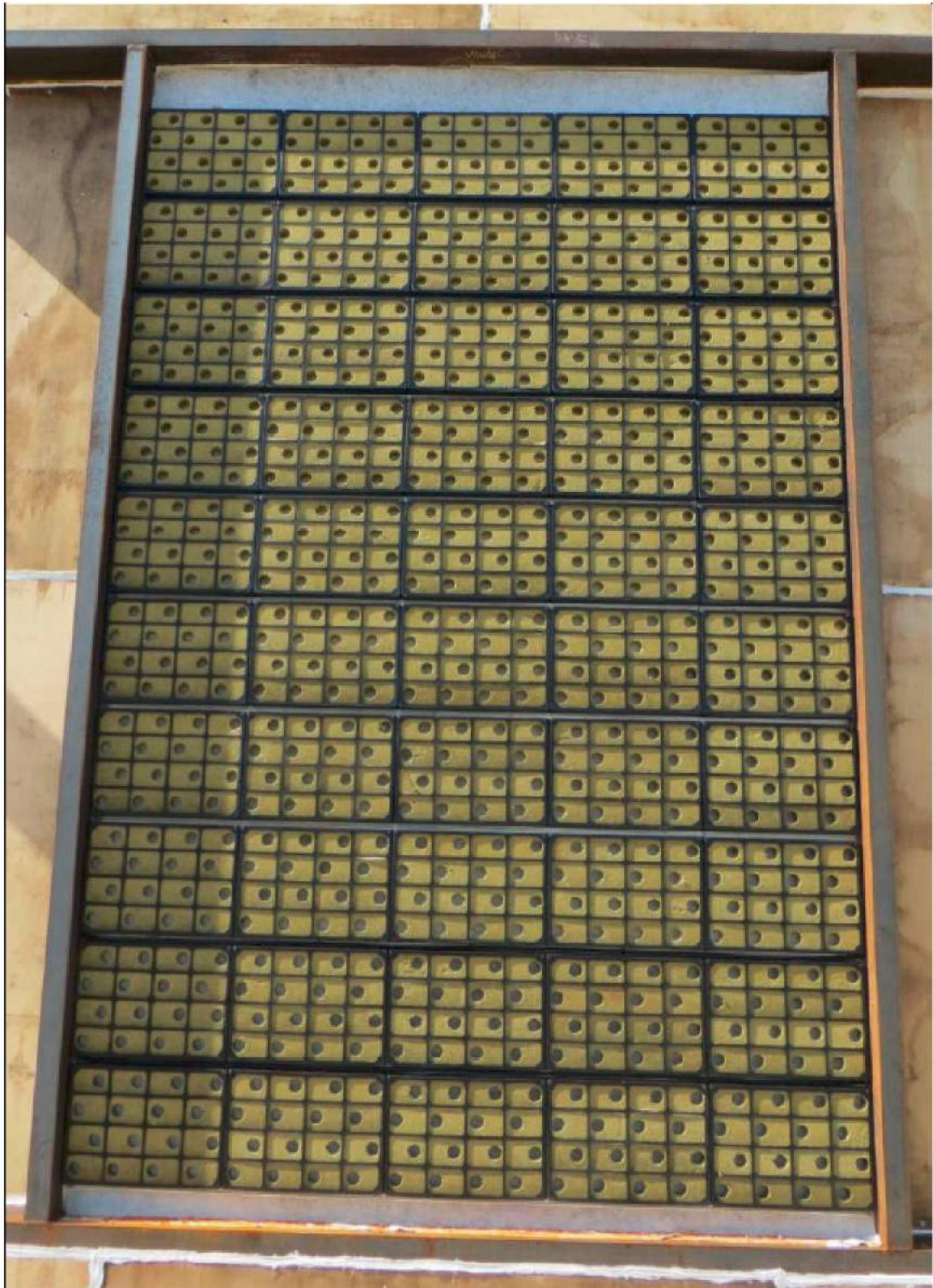
The summary points as reported by Vinci are as follows :

TYPICAL TEST RIG SCHEMATIC ARRANGEMENT



SECTION THROUGH TEST RIG

TEST SAMPLE ELEVATION



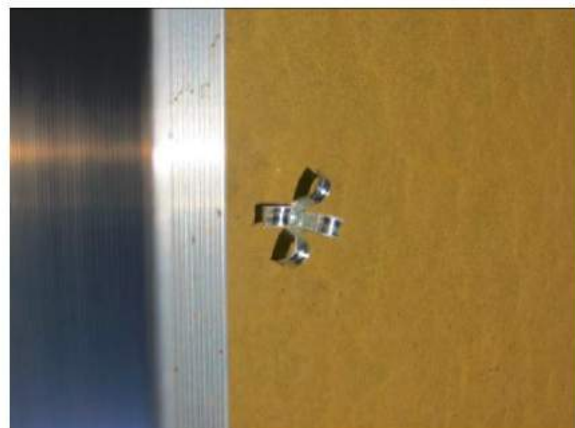
BACKING WALL



FRONT OF ALUMINIUM PEEL RIVET



INTERNAL VIEW OF ALUMINIUM PEEL RIVET



- Wind Resistance
 - Simulated Wind Load Testing of 8 mm Rockpanel cladding panel in dry conditions.
 - Fixings: The test was initially carried out using a 4.2 x 13mm stainless steel tek screw to connect the backing board and carrier rails. However during the negative wind pressure conditions in the serviceability test, the panels started to pull away from the fixings.

The test was then conducted with remedial works to the fixings. For the second test the carrier rails were riveted using 4.8 x 30mm aluminium peel rivets and the backing board remained with a "tek screw" fixing.
 - Serviceability: The maximum positive and negative wind pressure applied to the system was 2400 Pa, and no permanent damage was noted upon completion of the test.
 - Safety: The maximum positive and negative wind pressure applied was 3600 Pa and no permanent damage was noted upon completion of the test.
- Water Tightness
 - The testing consisted of water being sprayed onto the sample at a certain flow rate along with maintaining a constant air flow rate of 600 Pa. Throughout the test the inside of the sample was examined for water penetration.
 - The outcome of the test suggests there was no water penetration to the internal face of the sample throughout the testing. Also no standing water was recorded in the sample.
- Impact Test
 - The testing was in accordance with BS 8200: 1985 Code of Practice for design of non-loadbearing external vertical enclosures of buildings.
 - The soft body impactor comprised a canvas spherical/conical bag 400 mm in diameter filled with 3 mm diameter glass spheres with a total mass of approximately 50 kg suspended from a cord at least 3 m long. It was swung in a pendular movement to hit the sample normal to its face.
 - The impact energies recorded were 120 Nm for serviceability and 350 Nm and 500 Nm for safety.
 - No damage to the sample was observed.

4.2 Testing carried out by Lucideon (Reference: 15928 (QT-35314/1/SL)/Ref. 1).

The following test has been carried out and documents are appended. The Tests described below have been specified and compiled by Euroform and relevant results provided to Evolve by Biotecture for information.

Lucideon carried out the wind loading test using an 8mm Versapanel backing board. The boards are attached to a lightweight steel frame (LSF) of dimensions 3000 mm x 3000 mm. Four boards 2400 mm x 1200 mm and labelled '8 mm Versapanel' were used in the test. The steel frame (LSF) comprises of The LSF comprised of four perimeter C-sections with a depth of 200 mm and width of 75 mm. There were four studs 200 mm deep by 50 mm wide located between two parallel perimeter sides. The four intermediate studs were fixed at 600 mm centres.

The Versapanel boards were installed onto the LSF using Euroform EMF1 40 mm x 4.75 mm fixings. The fixings were installed at 300 mm centres around the perimeter of the total board area and to the intermittent studs at 600 mm centres. Fixings were also installed 40 mm from the corners and 15 mm from the edges.

The current proposals for the Biotecture living wall system is to use a 12mm thick Versapanel Eco as backing board.



Plate 1 - General View of Panel Showing LVDT Measuring Positions

- All testing in accordance with Centre for Window & Cladding Technology - CWCT 2005 guidelines.
 - Wind Resistance
 - Simulated Wind Simulated Wind Load Testing of 8 mm Versapanel to CWCT Standards. The wind pressures applied were positive (pressure) and negative (suction) and performance of the board was assessed for serviceability conditions and then to failure.
 - Fixings: The recommended fastener as per Euroform is EMF1 4.8mm x 45mm. The fastener used in the test was Euroform EMF1 40 mm x 4.75 mm fixings.

It should be noted that some of the fastener spacing in the wind loading test is different to the one suggested by the manufacturers (see section 2.4 above):

Dimension Reference	Used in Test	Manufacturers recommendation (see above)
B1	300 mm	200 mm
C1	600 mm	400 mm
A1	15 mm	15 mm
A	40 mm	40 mm

However this represents a worst case scenario and as such the loading capacities (wind pressure and suction) obtained from the wind load test may be higher if the centres as recommended by manufacturers had been adhered to. It is also worth mentioning that using a 12mm board (as adopted by Biotope) instead of an 8mm board (as adopted in the Test) will further enhance the resistance values obtained from the Wind Test.

- Serviceability: The maximum positive and negative wind pressure applied to the system was 2400Pa, and no permanent damage was noted upon completion of the test.

- Failure: The failure negative wind load (wind safety test) was 3640 Pa. The mode of failure was Pull-through of fixings.



Plate 2 – Showing Failure of Half Board Pulling Away from Fixings

4.3 Backing Board Saturated Performance (EJOT Report Reference 17101)

There were concerns about the performance of the Versapanel Eco backing board for resistance to pull out failure, in conditions where the board was saturated.

The following test has been carried out and documents are appended and are available separately from Biotecture upon request. The Tests described below have been specified and compiled by EJOT and Biotecture and relevant results provided to Evolve for information.

- Testing was carried out by EJOT to ascertain the performance of the board under saturated conditions. Test data can be obtained from Biotecture Limited (Report Reference 17101)
- The 12mm Versapanel backing board is immersed in water for 48 hours and the pull over and pull out test were carried out using a Tensometer. Also for comparisons of performance i.e. loading, the same test was carried out under dry conditions.
- Pull out test description: Aluminium rail (panel carrier rail) fixed to the backing board. This is essentially a failure mode of the thread of the screws pulling through the board.
- Pull over test description: Backing board fixed to the support secondary structure. This is essentially a failure mode of the head of the fixing pull through the board.

Picture of Hounsfield Tensometer



- The board remained dry internally even after soaked for 48 hours. Or in other words the water has not penetrated fully to the inside of the board. Hence the test is not representative of a fully saturated board.

4.4 Stiffness, Strength and Impact Test for Versapanel Backing Board (Ceram Report 111197 (QT-16883/1/BW) 1C)

- The testing was carried out by CERAM research limited (Reference: 111197/1C). The results are tabulated below. As the testing did not cover a 12mm board thickness as used in the Biotecture Limited system, this data should be used for information only.

Table 1
Results of Strength Tests

Board Thickness (mm)	Panel Joint		Centre of Panel Width	
	Failure Load (kN)	Deflection at Failure (mm)	Failure Load (kN)	Deflection at Failure (mm)
19	2.80	16.81	4.78	12.76
22	4.64	7.27	6.34	10.81
25	4.91	6.35	6.59	9.84
28	5.35	14.40	7.30	7.01

Failure modes -

- Centre of Panel Width: punching shear
- Panel Joint: punching shear and shear failure of tongue & groove joint

Table 2
Results for Stiffness Tests – Loaded on Joint

Board Thickness (mm)	01 (mm)	04 (mm)	21 (mm)	24 (mm)	f ₂₁ (kN)	f ₂₄ (kN)	W _m (mm)	R (kNmm ⁻¹)
19	0.86	2.85	1.31	2.95	0.38	1.50	2.42	0.69
22	1.03	3.26	1.51	3.30	0.46	1.85	2.68	0.78
25	0.74	2.43	1.11	2.56	0.50	2.00	2.09	1.03
28	1.07	3.07	1.52	3.27	0.50	2.00	2.50	0.86

Table 4
Set/Differential for Impact Test

Board Thickness (mm)	Drop Height (mm)	Initial Set (mm)	Final Set (mm)	Joint-Before Differential Set (mm)	Joint-After Differential Set (mm)
19	600	Sample failed at 600mm drop height			
22	600	+0.35	+0.27	0.61	0.49
25	900	+0.06	-0.43	0.65	0.85
28	900	+0.20	-0.06	0.75	0.70

NB: positive dimensions indicate upward bow or movement, negative figures indicate downward Bow or movement

4.5 Performance in Fire for Biotecture Living Wall System Using Versapanel Backing Board

Performance under fire is outside the remit of this Report. Please refer to IFC Fire Consultants report PAR/16691/01.

5 Discussion and Assessment of Test Results and Product Data

As stated in Section 1 'Introduction', the aim of this Report is to describe testing carried out where relevant to the structural performance of the Living Wall installation, identify any relevant product data provided by suppliers to support the installation and clarify limitations that may require further study, investigation or potentially testing.

This does not extend to the Primary Structure to which the installation is attached. This requires separate assessment by a suitably qualified structural engineer.

The installation, comprising 'Biotile' panels secured to the panel carrier rails, fixed to the backing board on support steelwork to simulate on-site conditions, has been tested by Vinci on behalf of Biotecture (test report by Vinci appended). This demonstrated that this installation performs under a serviceability wind load of 2400 Pa. It also proved the mode of failure, which is caused by a suction of 3640 Pa.

It should be noted that the installation tested by Vinci included 'Rockpanel' cladding boards as the backing board and rivet fixings between the carrier rails and the board and between the board and the support steelwork.

Since this test by Vinci, the Biotecture Living Wall installation has evolved by using screw fixings, not rivets, and a 12mm Versapanel Eco panel manufactured by Euroform as the backing board.

The following data has been provided to Biotecture by Euroform to validate the use of the Versapanel Eco panels as the backing board:

- Product Data Sheet
- Wind Load testing by Lucideon (test report appended): Note test carried out on 8mm board
- Tests on fixings on board following immersion in water for 48 hours

5.1 Product Data Sheets

Euroform describe Versapanel as:

- Comprehensively tested
- Class 'O' fire rating
- Fully external/internal
- Offers FSC Chain of Custody certification (see Versapanel Eco)
- Rot, moisture and impact resistance
- CE marked
- Available in bespoke sizes and edge details
- Has its own range of approved fixings

Versapanel is a cement particle board, similar to 'Rockpanel', and one of its applications is described by Euroform as a sheathing panel for steel framed systems (SFS).



Images by Euroform

The boards are used as a base for an exterior weatherproof layer.
Reference should be made to Euroform for full product details.

5.2 Wind Load Testing by Lucideon

Under instruction from Euroform Lucideon carried out wind load testing on the Versapanel boards. The tests were carried out on 8mm board attached to a lightweight steel frame to simulate the on-site assembly with intermittent steel studs at 600mm centres,

The results of the tests mirrored the Vinci test results where the components perform under a serviceability wind load of 2400 Pa. It also proved the mode of failure, which is caused by a suction of 3640 Pa.

It should be noted that the current Biotecture Living Wall installation uses a 12mm board, which will have an enhanced performance to the 8mm board used in the Lucideon test.

Also, the spacing of the fixings used in the test was greater than the recommended spacing by Euroform. The recommended fixing spacing should be followed, which is likely to enhance the performance of the backing board to that demonstrated in the test.

5.3 Tests on fixings on board following immersion in water for 48 hours

At the request of Biotecture, EJOT carried out tests on the fixings on 12mm Versapanel Board following immersion in water for 48 hours.

The board was inspected after the 48 hours period and it was recorded that the board remained dry internally. Therefore, the tests represent performance of a board exposed to water for 48 hours, but not the performance of a fully saturated board.

The pull out and pull over values (saturated and dry) obtained from the test was compared against wind suction pressure obtained from wind test to ascertain the performance of the backing board in the temporary condition during construction where it is exposed to the environment.

Please see below the various graphs showing pull out and pull over failure values obtained from the tests carried out by EJOT and Biotecture. We have highlighted the average values we have used in our assessments.

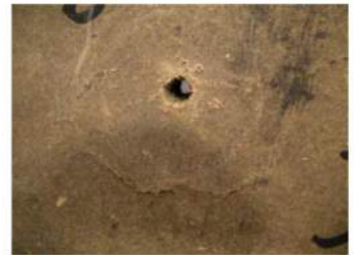
Internal ID - 935



Euroform

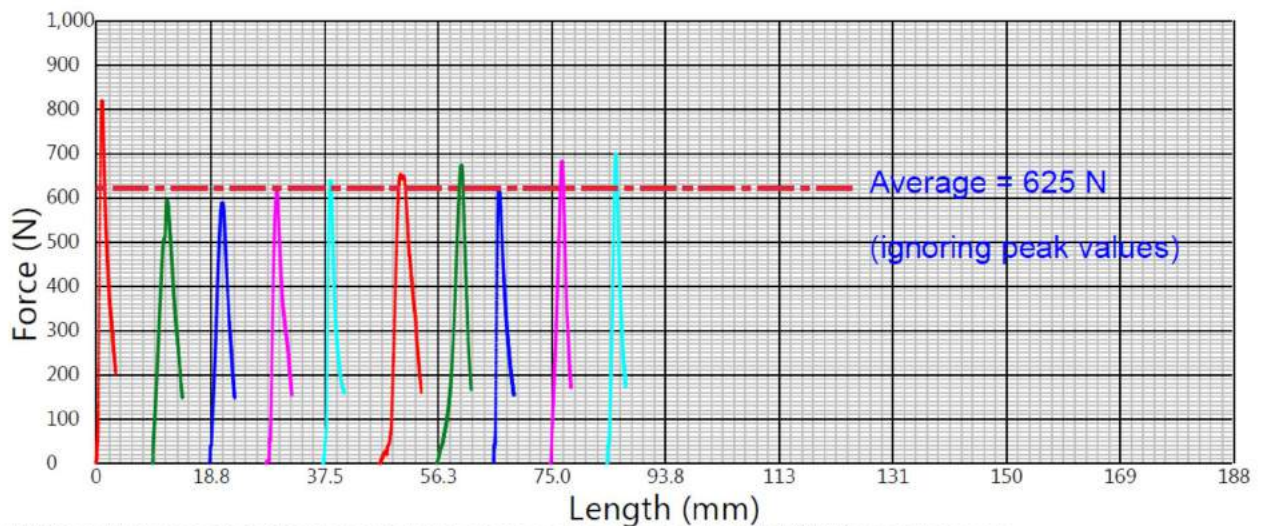
Pullout from soaked 12mm Verspanel with TKR 4.8 x 60

Product Code: TKR 4.8 X 60
 Batch Reference: 008709513
 Product Description: Pullout from soaked 12mm Verspanel with TKR 4.8 x 60
 Batch End Date and Time: 31/07/2017 14:39
 Operator: MW
 Temperature: 19.5
 Relative Humidity: 50



NOTES :

Specimen Number	Yield N	Yield mm	Max Force N	Elongation at Max mm
1.00	818	0.993	820	3.28
2.00	N/F	N/F	593	4.93
3.00	588	2.06	588	4.17
4.00	55.0	0.571	617	4.18
5.00	638	1.22	638	3.46
6.00	26.7	0.855	652	6.81
7.00	673	4.04	673	5.69
8.00	618	0.883	618	3.33
9.00	682	1.85	682	3.42
10.0	700	1.38	700	3.04
Average	533	1.54	658	4.23
SD	287	1.05	67.9	1.23
Maximum	818	4.04	820	6.81
Minimum	26.7	0.571	588	3.04
Range	792	3.47	232	3.78
Median	638	1.22	645	3.81

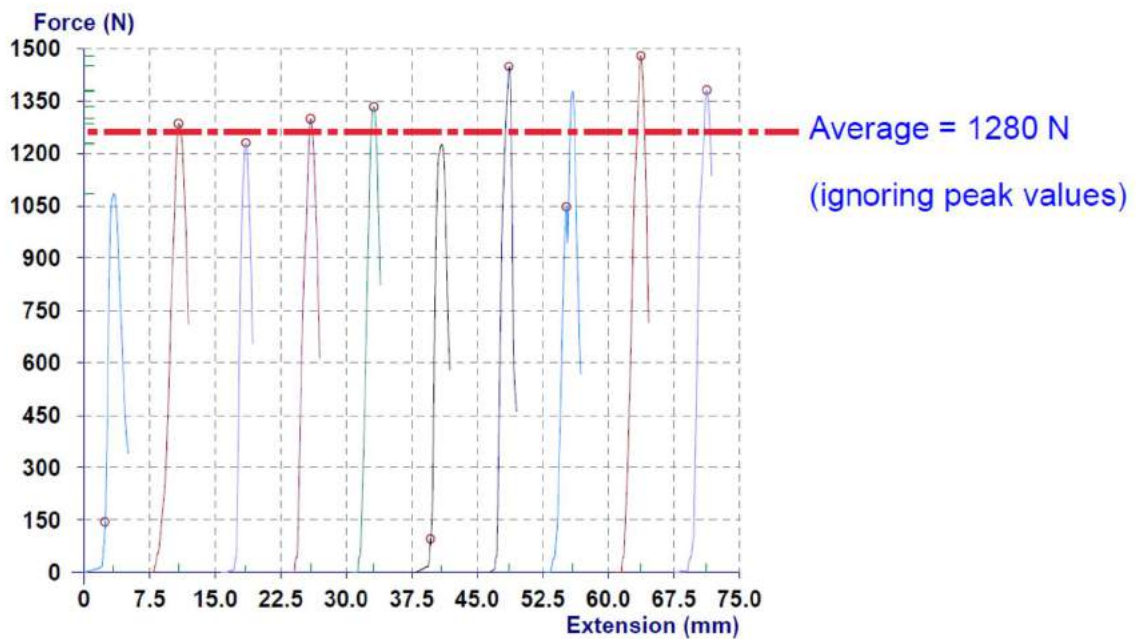


N.B. The results above are obtained from tests carried out in accordance with equipment conforming to BS 5427 on a random sample of fasteners. Information supplied should form part of a general guide only.
 EJOT UK LTD, Hurricane Close, Sherburn Enterprise Park, Sherburn in Elmet, LEEDS LS25 6PB.
 Tel. 01977 687040
 www.ejot.co.uk



Pullout SW8R 4.8x60 from 12mm Versapanel

Product Code : 12mm Versapanel
 Batch Reference : 12mm versapanel
 Product Description : Pullout with SW8R 4.8x60
 Date : 15/04/2009
 Operator : TT
 Temperature [C] : 21.0
 Relative Humidity : 38%



No.	Yield N	Yield mm	Max Force N	Elong at Max mm
1	145	2.385	1084	3.398
2	1286	3.320	1286	3.320
3	1230	3.535	1230	3.535
4	1299	3.430	1299	3.430
5	1334	3.176	1334	3.176
6	96	2.160	1226	3.430
7	1449	3.640	1449	3.640
8	1047	2.715	1377	3.365
9	1479	3.730	1479	3.730
10	1382	3.790	1382	3.790
Mean	1075	3.188	1314	3.481
Median	1292	3.375	1316	3.430
Std. Dev.	517	0.576	117.0	0.1916
Maximum	1479	3.790	1479	3.790
Minimum	96	2.160	1084	3.176
Range	1383	1.630	395	0.614

N.B. The results above are obtained from tests carried out in accordance with equipment conforming to BS 5427 on a random sample of fasteners. Information supplied should form part of a general guide only.

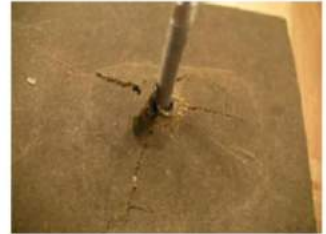
EJOT UK LTD, Hurricane Close, Sherburn Enterprise Park, Sherburn in Elmet, LEEDS LS25 6PB.
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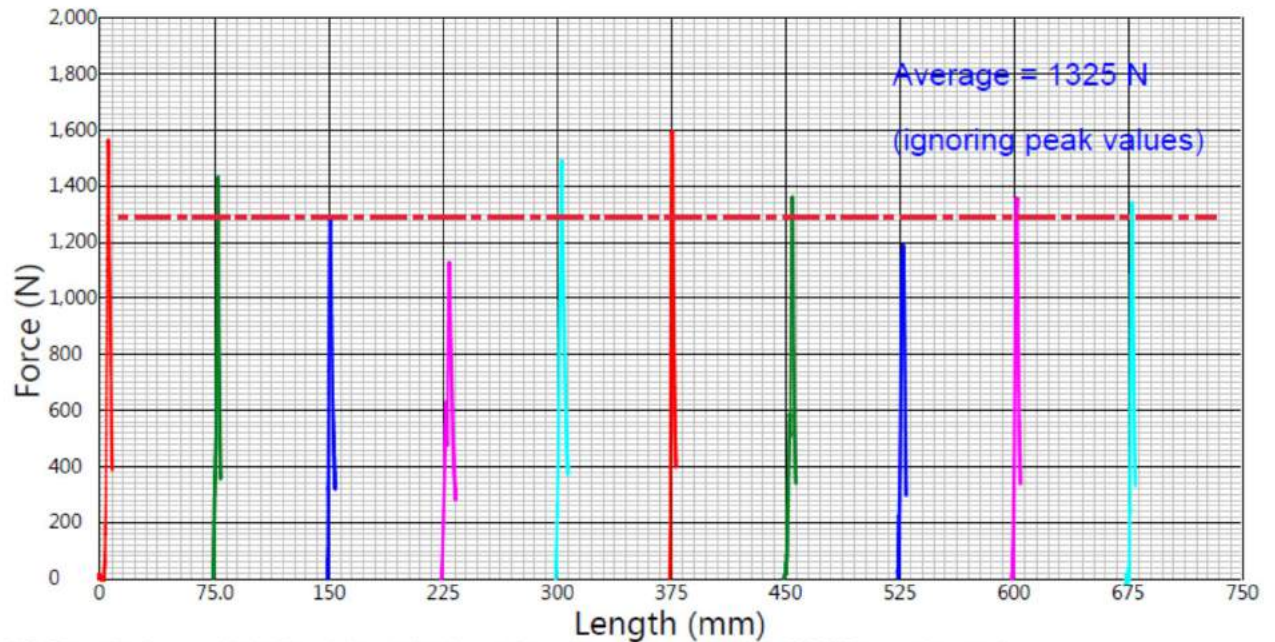
Pullover from soaked 12mm Versapanel with TBF 4.8 X 66

Product Code: TBF 4.8 X 66
 Batch Reference: N/A
 Product Description: Pullover from Wet 12mm Versapanel using TBF 4.8 X 66
 Batch End Date and Time: 31/07/2017 10:08
 Operator: MW
 Temperature: 19
 Relative Humidity: 52



Specimen Number	Yield N	Yield mm	Max Force N	Elongation at Max mm
1.00	15.0	0.201	1560	8.83
2.00	1430	3.51	1430	5.15
3.00	1280	1.96	1280	5.35
4.00	630	3.54	1130	9.32
5.00	272	1.16	1490	8.10
6.00	1600	1.77	1600	4.07
7.00	587	3.95	1360	7.79
8.00	228	0.789	1190	5.24
9.00	1360	3.07	1360	5.28
10.0	15.0	0.0166	1340	5.85
Average	741	2.00	1370	6.50
SD	619	1.45	152	1.83
Maximum	1600	3.95	1600	9.32
Minimum	15.0	0.0166	1130	4.07
Range	1580	3.93	468	5.25
Median	608	1.86	1360	5.60

NOTES :

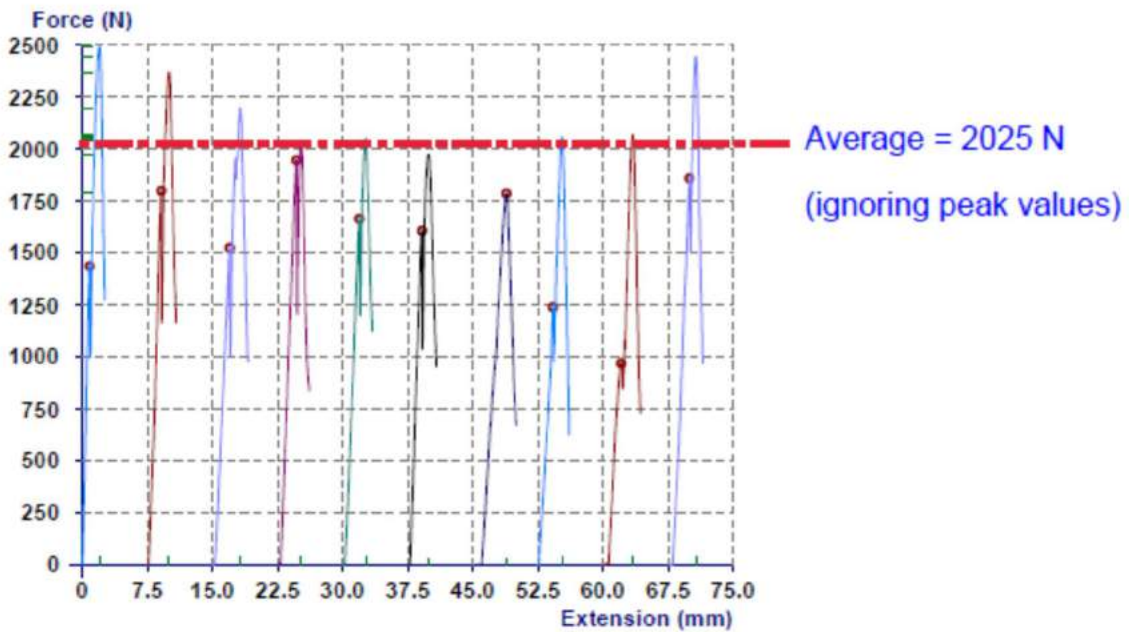


N.B. The results above are obtained from tests carried out in accordance with equipment conforming to BS 5427 on a random sample of fasteners. Information supplied should form part of a general guide only.
 EJOT UK LTD, Hurricane Close, Sherburn Enterprise Park, Sherburn in Elmet, LEEDS LS25 6PB.
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Pullover TBF 4.8x66 from Euroform supplied 12mm Versapanel

Product Code : 12mm Versapanel
Batch Reference : Pullover TBF 66
Product Description : 12mm Vers Panel
Date : 14/12/2009
Operator : TT
Temperature [C] : 22
Relative Humidity : 35%



No.	Yield N	Yield mm	Max Force N	Elong at Max mm
1	1435	0.816	2490	1.936
2	1798	1.580	2368	2.440
3	1523	1.950	2195	3.185
4	1945	2.184	2035	2.668
5	1663	1.900	2050	2.636
6	1606	1.640	1972	2.356
7	1784	3.878	1784	3.878
8	1238	1.752	2055	2.756
9	968	2.100	2068	3.460
10	1858	2.490	2443	3.230
Mean	1582	2.027	2146	2.853
Median	1634	1.925	2061	2.712
Std. Dev.	302.5	0.787	224.8	0.578
Maximum	1945	3.878	2490	3.878
Minimum	968	0.816	1784	1.936
Range	978	3.062	706	1.942

N.B. The results above are obtained from tests carried out in accordance with equipment conforming to BS 5427 on a random sample of fasteners. Information supplied should form part of a general guide only.

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Summary of test graphs above (ignoring the peak values):

Test / Mode of Failure	Dry Condition – Average Values	Saturated Condition – Average Values
Pull Out	1280 N	625 N
Pull Over	2025 N	1325 N

The summary of the points in this Section are:

- Tests and product data demonstrate that the Biotecture Living Wall system performs under a serviceability wind load of 2400 Pa. The serviceability load of 2400 Pa from the Wind Test is more than the tabulated value of 600 Pa as suggested by the manufacturers Euroform in their product brochure.
- Wind Test by Vinci Technology Centre for the Biotecture system using Rockpanel as backing board also demonstrated that the system performs adequately under a serviceability load of 2400 Pa.
- The failure mode for the system is the backing board pulling away from its supporting structure under wind suction. Both tests indicate a suction of 3640 Pa causing failure.
- We considered the performance of the board under saturated conditions to cover a scenario where the backing board has been installed and then has been left exposed to the element. Based on our assessment of the information provided by Biotecture, we recommend the fixings centres to be closed up in areas where high wind pressures are encountered, which in a building is typically around eaves and corners. The fixings are typically at 600mm centres and to cater for this situation of high wind pressure and a saturated board, the fixings will need to be 600 x 150mm centres.

The board will be weather protected as soon as the rear drainage layer and carrier rails have been fixed. It is preferable to try to fix this immediately after the backing board so reducing the risk of the board becoming wet/saturated.

- The wind pressure value used in our assessment (obtained from the wind test) would represent a likely wind pressure value encountered at the eaves and corners of a building. The fixing centres can revert back to the manufacturers recommended values in areas outside the high wind pressure.

6 Structural Recommendations

Following the review of the various test data as discussed in the previous sections above, please see below our recommendations:

- The specification and installation of the Biotecture Living Wall should adhere strictly to all manufacturers recommendations and guidance
- The wind load tests by Lucideon suggest the panel performs adequately under wind loads. The service load of 2400 Pa from the wind test is more than the tabulated value of 600 Pa as suggested by manufacturers.

Using a typical peak wind velocity pressure value of 1200 Pa and the maximum external wind load coefficient at eaves (Zone A) of 1.4 (Table 7.1 BS-EN 1991-1-4: 2005), the calculated wind load will be 1700 Pa. This value is less than the value achieved via wind test i.e. 2400 Pa in serviceable conditions. For most typical internal cases of installing the Biotecture system, the applied wind loads will generally fall within the serviceability load of 2400 Pa and as such the system will be adequate to perform in these situations under wind loads.

- Installations should be reviewed by a suitably qualified structural engineer to determine whether the loads acting on the Living Wall from the wind pressures specific to the site fall within the performance data provided in this Report. Most installation cases should fall within the data provided, but wind effects may increase as a result of their particular setting, i.e.
 - Parapets on building
 - Situations where the building is close to a neighbouring building that is at least twice the average height of surrounding structures then increased wind velocities could occur (funnelling effects)
 - Exposed sites (coastal, exposed rural)
 - High-rise buildings
 - Critical sites such as public realm, playground, open spaces etc.
- The Biotecture Living Wall system and its supporting structural components should be considered as cladding when evaluating wind pressures.

- h) If site specific conditions are outside the areas of guidance covered by the data provided in this Report, the fastener and board capacities will need to be re-evaluated to suit the wind loading. There may be a possibility that under high wind loading conditions (more than the values obtained from Test), the fastener spacing needs to be closed up to increase the capacity and/or the board may need additional structural members at closer centres to increase the loading capacity.

The following is a summary of fastener spacing recommendations:

Condition	Fastener Spacing
e) Internal dry conditions	In line with manufacturers recommendations
f) Wind load up to 2400 Pa in dry conditions	In line with manufacturers recommendations
g) In wind loading situations as described in section 5c and in areas of high wind pressures greater than 2400 Pa	Seek further guidance from a suitably qualified structural engineer
h) Saturated conditions of the board during temporary / construction conditions, in conjunction with when subjected to wind loads of up to 2400 Pa	600 x 150mm

- i) It is recommended that the minimum steel thickness of all supporting members is 2.0 mm for receiving the backing board fasteners (see section 2.4).

7 Limitations

Reference should be made to Section 1 for the purpose of this Report.

This Report does not certify, nor does it provide any form of certification of, the Biotecture Living Wall installation and its components.

This Report does not consider the structural performance of the Primary Structure to which the Biotecture Living Wall is to be attached. This would require separate study on a case by case basis.

The comments and discussion provided by this Report are based on product data and testing data commissioned by others with no instruction from Evolve Consulting Engineers Limited. Evolve will not be responsible for any inaccuracies or errors in the information provided to Evolve.

It is the responsibility of anyone using this Report to confirm that all aspects of the Biotecture Living Wall fully comply with the descriptions and limitations set out in the Report and all relevant Standards, Norms, Regulations and Codes of Practice.

This Report is intended to comment on the structural performance of the Biotecture Living Wall system. It does not extend to other areas of performance such as cladding, watertightness, thermal and acoustic performance, fire etc. Separate advice should be sought from Biotecture Limited.

8 Standards & References

- BS EN 1991-1-4 : 2005 Eurocode for wind actions
- BS EN 634 : Part 1 & 2 Cement bonded particle boards
- Centre for Window & Cladding Technology (CWCT) Standard Test Methods 2005
- CWCT Technical note 2 : Wind loading on cladding
- CWCT Technical note 3 : Wind loading on cladding & wall of low-rise buildings
- CWCT Technical note 4 : Issues related to wind loading on tall buildings

- BRE Digest 477 Part 3 : Wood based panels – Cement Bonded Particleboard
- BRE Digest 477 part 3 - Wood-based panels: Cement-bonded particleboard
- Approved Document A 'Structure' Section 3 'Cladding' of the Building Regulations

Appendix A	Biotecture Standard Layout Drawing
Appendix B	Biotecture Living Wall System Using Rockpanel – Vinci Testing
Appendix C	Biotecture Living Wall System Using Versapanel – Lucideon Wind Testing
Appendix D	Structural Testing of Euroform Versapanel – Ceram
Appendix E	Versapanel Saturated Board Pull Out Testing – EJOT
Appendix F	EJOT TBF Fastener Data Sheet