

Structural Engineering Assessment of PlantBox Living Wall System

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1 Introduction

Evolve have been appointed by Biotecture to provide advice on typical support loadings and details for the new PlantBox system to be installed against a structural support. This report solely considers the stability of the PlantBox stack and its fixings of the PlantBox to a support structure. It is based upon information provided to Evolve by Biotecture 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.

2 System / Composition

The PlantBox system by Biotecture Limited is a stackable, modular and self-watering living wall system formed of connected units, which are in turn made up of the component units as shown in Section 3.2 of this report. A typical system layout is shown in Figure 1, where a stack of 10 is shown restrained back to a support structure. The restraints are discussed in further detail in Section 4.2 and the support structure is discussed further in Section 5.

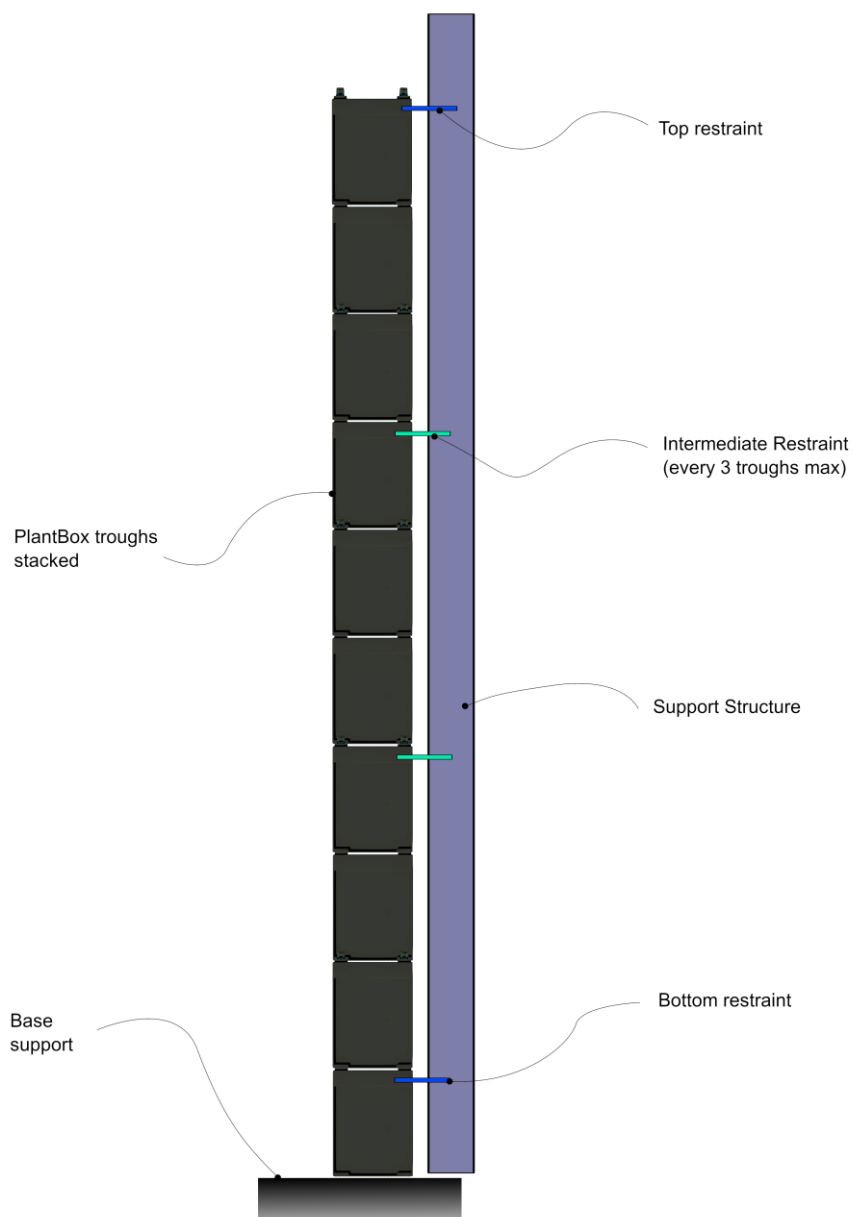


Figure 1: Typical System Layout

3 PlantBox Living Wall Properties

3.1 Materials

The PlantBox units are made up of 100% Recycled Polypropylene as detailed in Appendix A. The wall thickness of the PlantBox components is 2.5mm thick, as advised by Burrell Innovation, with overall dimensions as shown in Figure 3.

Polypropylene is light, exhibits a high resistance to cracking, acids, organic solvents and electrolytes. As a base material, polypropylene typically has a high degradation rate when exposed to UV light. It also has a high thermal expansion coefficient which limits its high temperature application to under +120 degrees Celcius. Low temperatures (below -20 degrees Celsius) makes it brittle. Contact with metal has an adverse effect on its heat-aging stability.

3.2 PlantBox Component Units

Product Code	Description	QTY Per Assembly	Material	Component Diagram
00.01-trough	PlantBox Trough & Reservoir	1	100% Recycled Polypropylene	
00.02-side-panel-rhs	Side Panel (RHS)	1	100% Recycled Polypropylene	
00.03-side-panel-lhs	Side Panel (LHS)	1	100% Recycled Polypropylene	
00.04-shelves	Shelves	2	100% Recycled Polypropylene	
00.05-float-indicator	Float Indicator	1	100% Recycled Polypropylene	
00.06-shelf-divider	Shelf Divider	2	100% Recycled Polypropylene	
00.07-filter	Filter	1	100% Recycled Polypropylene	
00.08-vert-clip	Vertical Connection Clips	4	100% Recycled Polypropylene	
00.09-align-clip	Horizontal Alignment Clip	3	100% Recycled Polypropylene	
00.10-cap-felt	Capillary Felt	3	Felt	
00.11-poly-float	Polystyrene Float	1	Polystyrene	
00.12-rockwool	Grodan (Rockwool) Shredded Grodan WGA 25		Rockwool	

Figure 2: Table showing PlantBox Components

3.3 Dimension and Weight

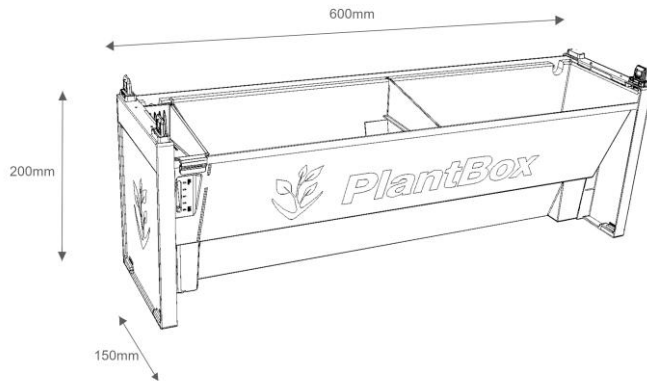


Figure 3: Typical PlantBox Unit

Single Trough Dimensions	600mm x 200mm x 150mm
Single Trough Self Weight	2 kgs
Trough Reservoir Weight (1.8 litres)	1.8 kgs
Allowed Planting Weight per trough	2 kgs
Fully Saturated Weight per m ² elevation	70 kgs
Density of polypropylene	1.06 g/cm ³
Flexural Modulus of polypropylene	1900 N/mm ²
Yield Strength of polypropylene (typical values assumed – confirmation required)	20-40 N/mm ²
Shear Strength of polypropylene (typical values assumed – confirmation required)	14N/mm ²

4 Structural Assessment

The individual plant boxes are installed stacked vertically as shown below in Figure 4 and Figure 5. The PlantBox unit(s) requires a base to support its weight, W , and restraints at higher level to provide lateral support in 2 directions, P and F . For our assessment, the applied vertical load components comprise of the dead load, and the applied lateral load component comprises of internal pressures/wind loading. Due to the variation of lateral loading and backing structure, the fixing requirements will be treated separately as discussed further in this section and as per section 5.

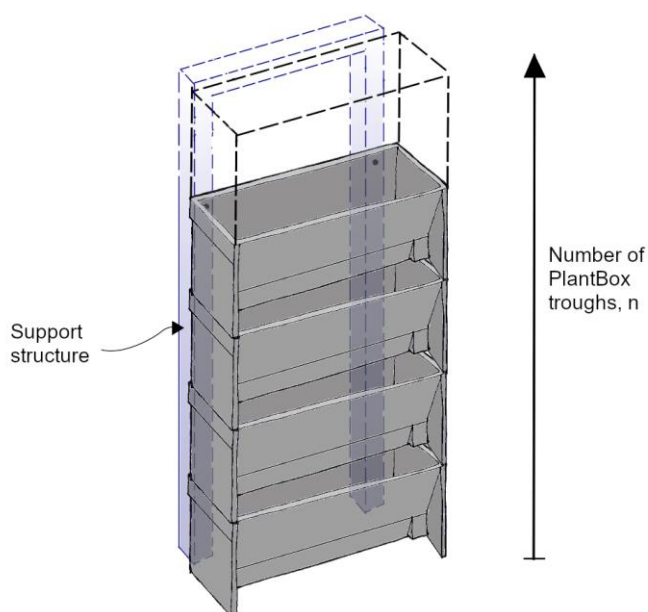


Figure 4: Typical PlantBox stack with backing rails

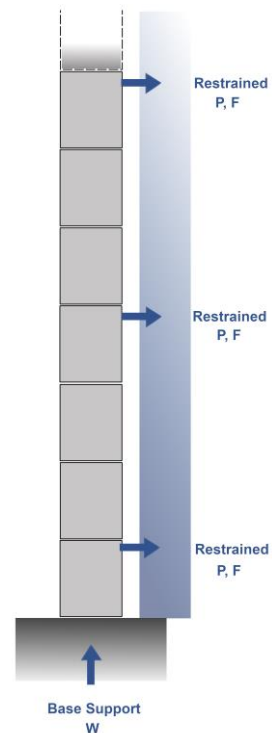


Figure 5: Restrained

4.1 Possible Load Conditions

Dead Load = Self weight of box + growing medium + plants = $70 \text{ kg/m}^2 = 0.7 \text{ kN/m}^2$ (elevation)

Applied Lateral Load = Varies from 0.2 to 1.4 kN/m^2 (elevation) to allow for generic conditions

The loads used for this assessment are based on normal use and excludes the following;

- Vehicular impact loads, therefore it is recommended that the PlantBox system is set above the level of typical vehicle impact height
- Any other accidental loads
- Climbing loads

For the purposes of this analysis, a factor of safety of 2 has been adopted in the calculations.

4.2 Restrained Stacks of PlantBox Troughs

The analysis focusses on determining the fixings required to ensure that the stacked troughs remain stable in operation. These are restricted to fixings to a support structure. This configuration assumes that the base is supported and the stack of PlantBox troughs tied back at the top troughs and at set positions between the base and top trough as detailed below.

Number of PlantBox troughs				1	2 to 10	11 to 20	21 to 30	31 to 40
Max Base Weight, W (kN)				0.2	1.7	3.4	5.0	6.7
				Max Restraint Load (kN)				
Applied Lateral Load (kN/m ²)	Internal	0.2	Pull-out, P	0.05	0.07	0.09	0.09	0.09
			Lateral Shear, F	0.01	0.02			
	External Sheltered	0.6	Pull-out, P	0.07	0.20	0.26	0.28	0.29
			Lateral Shear, F	0.02	0.05			
	External Exposed	0.8	Pull-out, P	0.10	0.29	0.35	0.37	0.38
			Lateral Shear, F	0.02	0.07			
		1	Pull-out, P	0.12	0.36	0.44	0.47	0.48
			Lateral Shear, F	0.03	0.09			
		1.4	Pull-out, P	0.17	0.50	0.61	0.65	0.67
			Lateral Shear, F	0.04	0.13			

Notes:

1. Top and bottom trough must be restrained
2. Intermediate restraints to be provided every 3 troughs (max)
3. Base support and structure providing lateral restraint to be design for the loads above
4. Cases exceeding / not covered within the parameters above are to be subjected to further checks

Figure 6: Tied-back trough stack

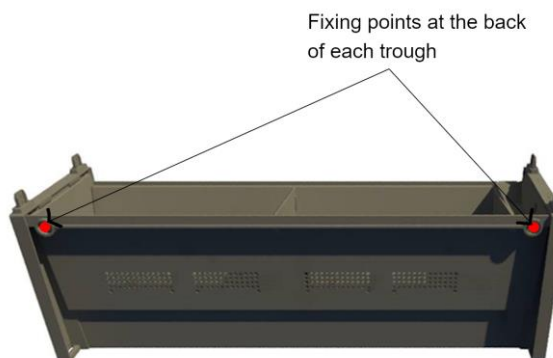


Figure 7: 2 fixing points at the back of each troughs

The options for backing structure and the nature of their fixings are discussed separately in Section 5 of this report and should be referred to as it ties in with the requirements in Figure 6. Figure 7 shows the positions of the fixing points at the back of the troughs.

5 Backing Structure

The following materials could be used to form a support structure to restrain the stack of PlantBox troughs.

- Plywood
- Aluminium channels/rails
- Steel channels/rails
- Masonry and Concrete
- Plasterboard (internal application only)

5.1 Plywood

For external use, Class III plywood (to EN636-3 S) is suitable. Marine Ply (to BS1088 2003) is also a possible option, however it rarely has proof of strength performance and is not recommended for load bearing uses unless this strength data is available from the manufacturer. The plywood should be designed to support the loads in Figure 6.

The exact fixing type depends on the dimensions and specifications of the fixing and the plywood. For example, when fixing to a 18mm thick plywood, 1 No #14 wood screws (6.3mm diameter) with minimum 16mm penetration into the panel would be suitable.

5.2 Aluminium channels/rails

Aluminium is lighter than steel and is suitable for internal and external use treated or untreated, though some restrictions apply when using untreated aluminium externally. The aluminium specification should be designed to support the loads in Figure 6. The layout of the aluminium is to be coordinated to suit the setting out of the fixing points.

When fixing to an aluminium channel, the troughs should be screwed.

5.3 Steel channels/rails

Stainless steel or galvanised mild steel is suitable for internal and external use. This material is heavier and stronger than aluminium. The steel specification should be designed to support the loads in Figure 6. The layout of the steelwork is to be coordinated to suit the setting out of the fixing points.

When fixing to steelwork, the troughs should be screwed.

5.4 Masonry and Concrete

Masonry (brick or blockwork) or concrete is suitable for internal and external use. The masonry or concrete specification and thickness should be designed to support the loads in Figure 6. It is recommended that the masonry or concrete structure should provide a uniform fixing surface for the troughs to ensure that the restraint requirements are met.

When fixing to a masonry or concrete wall, the troughs should be resin anchored.

5.5 Plasterboard

Plasterboard is suitable for internal use only. The plasterboard specification and thickness should be designed to support the loads in Figure 6.

When fixing to plasterboard, the trough should be fixed using Fischer Cavity metal fixing.

6 Executive Summary

The PlantBox system by Biotecture Limited is a stackable, modular and self-watering living wall system formed of connected 600mm x 200mm x 150mm units. The living wall system uses layers of capillary felt to wick moisture up to the plants that are situated on the trough shelves – ensuring a fully self-contained irrigation system

This section gives a summary of the report and reference should be made to the full version of the report “Structural Engineering Assessment of PlantBox” by Evolve. The study carried out in this report is solely numerical and is dependent on typical figures obtained from various sources as found in the Appendices and References. There are many different possible support structures and these usually vary between sites.

Key points to highlight are as follows:

1. The “system”, comprising PlantBox troughs stacked up, is to be supported at the base and laterally restrained at the top and at intermediate points at centres max every three troughs.
2. The following chart provides a guidance to the design loads for the support structure and the fixings. Loads for W are overall loads and loads for P and F are for each restraint point.

Number of PlantBox troughs				1	2 to 10	11 to 20	21 to 30	31 to 40
Max Base Weight, W (kN)				0.2	1.7	3.4	5.0	6.7
				Max Restraint Load (kN)				
Applied Lateral Load (kN/m ²)	Internal	0.2	Pull-out, P	0.05	0.07	0.09	0.09	0.09
			Lateral Shear, F	0.01	0.02			
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			Lateral Shear, F	0.02	0.05			
	External Exposed	0.8	Pull-out, P	0.10	0.29	0.35	0.37	0.38
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		1	Pull-out, P	0.12	0.36	0.44	0.47	0.48
			Lateral Shear, F	0.03	0.09			
		1.4	Pull-out, P	0.17	0.50	0.61	0.65	0.67
			Lateral Shear, F	0.04	0.13			

3. The fixing options depends on the choice of structural support, which could be made up of plywood panels, aluminium channels/rails or steel channels/rails, masonry, concrete or plasterboard. The design of the support should be carried out on a case by case basis to accommodate the site conditions. Different fixing types are recommended for the different support structure.
 - Plywood: Wood screws
 - Aluminium / Steel: Grade 8.8 Bolts
 - Masonry / Concrete: Resin Anchors
 - Plasterboard: Fischer Cavity metal fixing (limited to 0.3kN)
4. The advice in the report is valid for PlantBox troughs stacked not higher than 40 troughs and lateral loading not exceeding 1.4kN/m². If either is exceeded, further advice on its stability should be sought from a suitably qualified structural engineer.
5. The loads used for this assessment are based on normal use and excludes the following
 - Vehicular impact loads, therefore it is recommended that the PlantBox system is set above the level of typical vehicle impact height
 - Any other accidental loads
 - Climbing loads

7 Appendix

Bpi PLASgran datasheet
PlantBox PLUS datasheet

8 References

Burrell Innovation IFC files

<https://omnexus.specialchem.com/selection-guide/polypropylene-pp-plastic#Properties>

<https://www.eurocodeapplied.com/design/en1993/bolt-design-properties>

https://www.fischer.ae/-/media/fixing-systems/fiae/service/sales-and-technical-documents/fixing-compasses/kompass_panel-building-materials-en-screen.ashx