Periodica Polytechnica
Architecture

46(2), pp. 78-87, 2015
DOI: 10.3311/PPar.8337

RESEARCH ARTICLE

Requirements for Designing Living Wall Systems – Analysing System Studies on Hungarian Projects

Alexandra Tamási[1*], Gergely Dobszay[1]

Received 17 June 2015

Abstract

The concept of green façade design has recently come into prominence. Considering it as a new trade that requires its own professionals is quite new. The current innovative structural solutions have extended the research field of green walls to an interdisciplinary level. Architecture, horticulture, engineering (lighting technology, fertilizing technology) are now essential spheres, which can be supported by IT technologies. Studies concerning green walls are cost-benefit analyses, their potential for energy savings or their role in decreasing air pollutants. The fact that 22 m2 plant surface saves 1 tonne of CO2 highlights the application of vertical gardens. Hardly any research examines the practical use and requirements of living wall systems. Although serving the same purpose of creating a vertical green surface, each system has different requirements. The aim of this paper is to reference the essential requirements and important practical information that must be considered when designing a living wall.

Keywords

green wall, green façade, living wall, vertical gardening, vertical landscaping

[1] Department of Building Constructions, Faculty of Architecture,
Budapest University of Technology and Economics,
H-1111 Budapest, Műegyetem rkp 3., Hungary

[*] Corresponding author, e-mail: atamasi@epsz.bme.hu

1 Introduction and benefits of living walls

According to United Nations research, 66 % of people will live in urban areas by 2050. (World Urbanization Prospects, 2014) The living wall as an essential part of future conurbations by contributing to the resilience of cities has been thoroughly researched. (Colding and Barthel, 2013) Its increasing potential for vertical farming highlights the green walls' place in urban design, and consequently a need for an understanding of its technical background. The English terminology makes a difference between "green façade" and "living wall". "Green façade" refers to the use of climbing plants without the technical complexity of living wall systems. (Pérez et al., 2011) "Living walls" are usually pre-vegetated panels fixed onto the building envelope, either an external or internal wall.

Although the benefits of living walls have been discussed in many studies, it is worth briefly referring to some key points. Green walls not only lower the energy consumption of the building during hot weather, but a study shows that an ivy-covered wall has better thermal properties and can be effective against cold as it works as a solar filter. (Bolton et al., 2014) On an urban scale, green walls contribute to reducing the Urban Heat Island effect thanks to the evapotranspiration of plants. (Iino and Hoyano, 1996) Plants help to improve air quality, as they absorb the Volatile Organic Compounds through their leaves and growing medium. "NASA research from 1985 showed the ability of some plants to filter and absorb atmospheric pollutants such as benzene and n-hexane. Consequently, green walls can be considered effective against sick-building syndrome". Similar research has also been carried out in Australia to show the high performance of several indoor plants. (Wood, 2003)

During the winter, a considerable amount of heat is conducted through the structure of the building because of the natural filtration characteristics of building materials; this raises the question as to whether green wall systems could play a role in reducing building wind speed. A research concluded that living walls can significantly reduce wind velocity if the air gap between the wall and green surface is optimized to 40-60 mm. (Perini, 2011)

Table 1 Sortment of different green facade systems

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Container and/or trellis system	**Trellis**				x			x																					x		
	Planting container																														
Surface system	**Felt system**	x	x									x											x		x			x			x
	Vegetation mat																		x			x								x	
	Planting pot															x											x				
	Building element								x	x																					
	Modular			x		x	x				x		x	x	x		x	x		x	x			x		x					

Although it is particularly complex to measure how people benefit psychologically from the existence of living walls, there is an increasing raft of work to show that they can play a significant role in human health and wellbeing. (De Vries et al., 2003)

2 Terminology and limitations of the study

According to the referred papers, from a typological approach, three different types of living walls can be defined: container and/or trellis system, felt system, panel system. (Loh, 2008) There have been several publications that aimed to group the different systems. At some point, these papers go into detail without outlining the very essentials, furthermore, they do not give the most applied and applicable solutions. (Pitha et al., 2011; Pfoser et al., 2014)

To give a more accurate image of the very essential design inputs and requirements of green walls, this paper aims to detail the three mentioned living wall systems to define new approaches. In group 1, container and trellis systems were split into two different sets even though they can be used together on the same structure. In group 2, felt system and vegetation map are examined. In group 3, panel systems are analysed in accordance with their construction in which case three different systems must be introduced: planting pot, building element, modular system. (Table 1)

The suggested separation helps to understand the operation of living walls more thoroughly by focusing on the structural and technical background.

This paper does not draw conclusions on the requirements of green façades and climbing plants as these subjects have been widely published and commented on. (Osterhoff and Finke, 2002)

3 Working principles – defining new approaches

The examination of 30 different systems, currently existing on the market, led to the recognition of a need for the requirements necessary to design living walls. Table 1 shows the range of systems, each marked with a number representing a product. The examination covers the most representative living wall systems commonly used across Europe and the United States. In this paper, three different trellis/container systems, seven felt systems and 20 different panel systems are reviewed. Among them, a wide range of modular systems are examined due to their technical complexity and their increasing demand. This examination does not cover all of the many living wall products; however, the selected examples are sufficient to represent the different solutions applied and types used, enabling conclusions to be drawn. Additionally, some Hungarian projects were examined to highlight the problematic issues.

4 Viewpoints of the examination

The first patent for a living wall system was given to Stanley Hart White followed by Patrick Blanc who is considered to be the inventor of green walls. (White, 1938) Over the last 10 years, the number of patents has increased, qualifying a need for research on the topic of living walls. (Köhler, 2008)

Concerning the different systems, the most important input data were examined: materials, loads, possible construction of layers, foliage density, costs and maintenance. As a result, this paper may serve as guideline to designers and better inform the selection of a particular system.

4.1 Materials

A wide range of materials can be used: stainless steel, aluminium, recycled plastic, stone wool, felt and wood depending on the system and architectural aspects. (Table 3)

4.2 Growing medium

Essentially, two different kinds of growing mediums exist, used alone or in mixtures: organic and inorganic. Inorganic growing mediums have several advantages compared to organic substrates including soil based mixtures. Pests and weeds are less likely to arise when using inorganic materials and those such as perlite are substantially lighter than their organic counterparts.

4.3 Loads

After arriving at a decision on a system's application through the design process, dead loads can easily be calculated, which then define the strength of the supporting structure. Vertical loads: plants and substrate (calculated from the weight of the material and growing medium) and fixing elements. Approximate characteristic loads of the different systems were calculated to help the design process. (Table 3) Horizontal loads (wind) must also be taken into consideration, both calculated according to technical rules of Eurocode.

4.4 Layers

All of the structures have to meet the requirements of façade cladding systems regarding strength of materials, building construction, fire-protection and thermal properties. They have to be constructed to avoid moisture in structure, consequently, an air gap is recommended to ventilate any build up of humidity.

4.5 Foliage density

In the design process, the appearance of the green wall immediately after construction may play a significant role. There are several approaches on the market that can provide an almost 100 % plants coverage. (Table 3)

4.6 Costs

According to Table 3, three different types of cost level was named. These data aim to give comparative costs although they may vary in unique cases. On an approximate basis, felt and modular system's costs, including plants and an irrigation system, can vary from 500 to 1500 euro.

4.7 Maintenance

The maintenance of both green walls and living wall systems also have to be taken into consideration. Effective maintenance, an ongoing cost ensures that the plants will grow and flourish.

5 System-specific approaches

5.1 Container and/or trellis system

Two different types of holding structures: container and trellis must be discussed at this point; they may be used separately or together.

Trellis system

Trellis systems are used when climbing plants require a supporting structure (Fig. 1). If the façade to be planted is linked to the ground, plants are planted into the soil or an additional holding structure can be used for the growing medium.

At this point trellis and container systems can meet. (Fig. 1) To illustrate the point regarding maintenance, although relatively simple systems, due to a breakdown of one part of the irrigation pipeline and lack of maintenance a trellis system at the Metropolitan Cultural House (Budapest, District XI.) is currently not working. (Fig. 2)

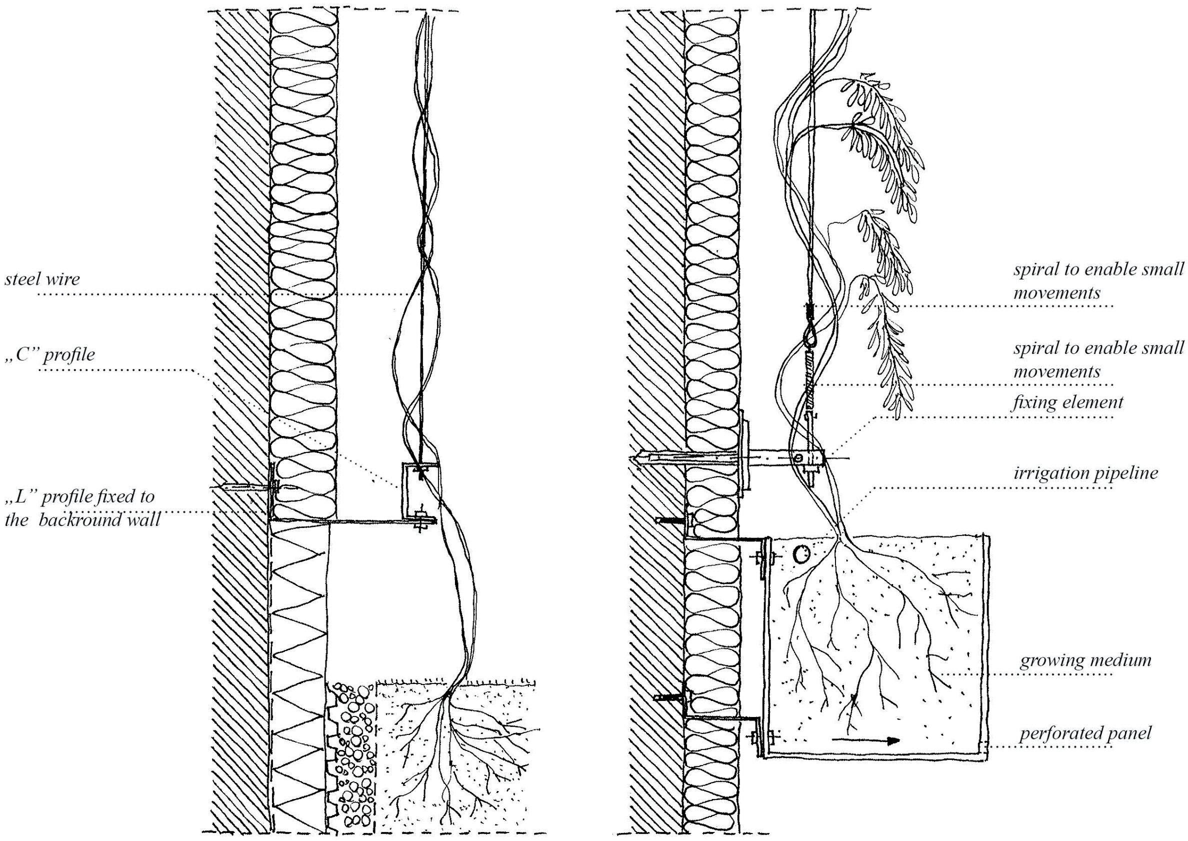

Fig. 1 Trellis system linked to ground or with additional holding structure

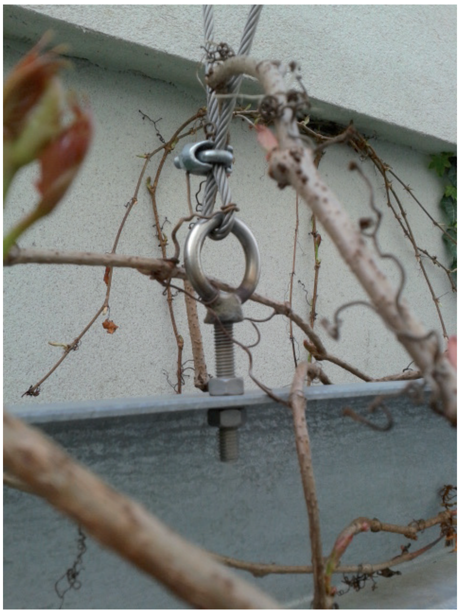

Fig. 2 Detail of a fixing point on a trellis system

Planting container

Planting containers can be used for both climbing and non-climbing plants. (Fig. 3) This system is recommended where there is no ground-contact. An important design principle is the capacity of containers; this needs to be specified dependent on the needs of the plant's root zone, and defines the health and growth of plants. Irrigation and fertilizer system have to be built to ensure water and nutrition.

The excess water must be able to drain from the bottom of each container to avoid decay. Either the container can be perforated (on the bottom or better on the side to prevent water dripping onto the plants placed below) or the water can be collected in a gutter and piped to the drainage or recirculation system.

A planted container system was integrated into the façade of a large shopping centre. Again the lack of proper maintenance led to significant deterioration. This has now been rectified and for the last two years the wall has been in blooming health. (Fig. 4)

5.2 Surface system (Fig. 5)

Felt system

The great advantage of felt systems is in their flexibility, which allows to cover almost all the forms of façade.

The disadvantage of this system is its limited buffering capacity. In colder conditions, especially during some hour of frost, the very thin root zone can be easily frozen. (Fig. 6)

Because of the limited space of the pocket cut into the felt layer, less developed plants can be used; this in turn limits the density of the plant foliage, which needs time to develop. Under indoor conditions felt systems are commonly used as planners do not have to deal with the vagaries of the weather.

Some of the material of the surface layer, like geotextile was a research topic concerning its contribution to urban sustainability in case of green walls. (Dan, 2013)

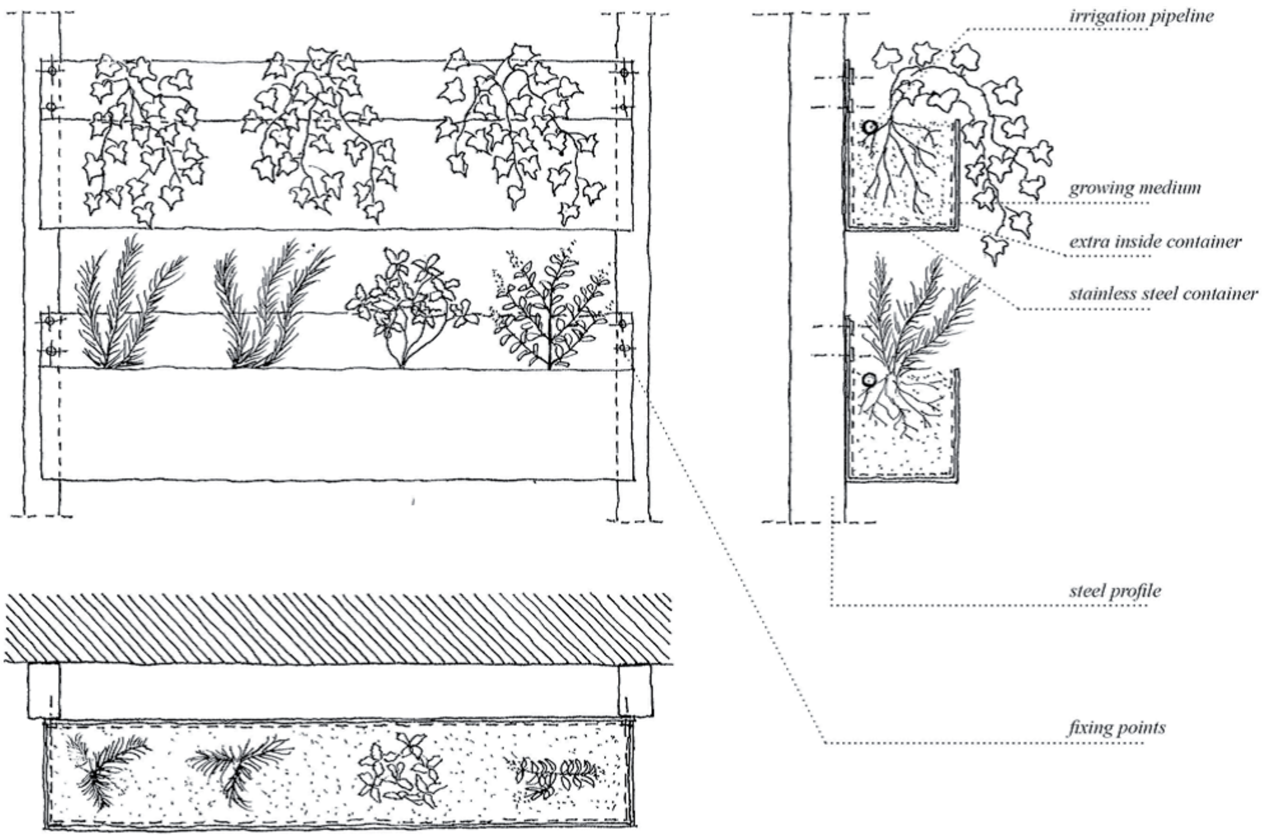

Fig. 3 Planting containers' capacity designed to the needs of roots

Fig. 4 Blooming greenwall in planting containers after months of right maintenance

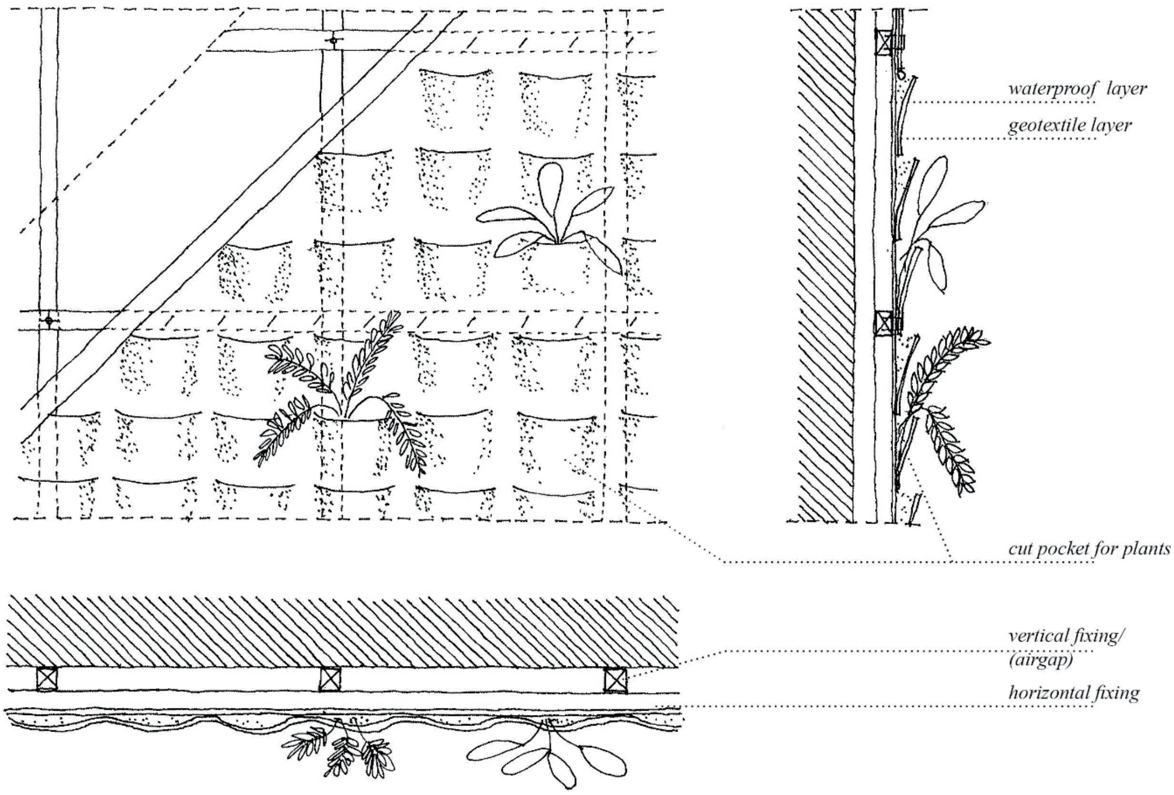

Fig. 5 The great advantage of a felt system is in its flexibility

Fig. 6 Felt system may consist of different layers

Vegetation mat

This system's base is made of waste plastic. Usually sedums and extensive plants are planted in it. The sedum layer is placed on the waste plastic layer so the plants need to grow their roots into it. A Hungarian example of this system, currently in very poor condition, can be found in Budapest, District XII on the wall of a petrol station. The cause of its condition may be system-specific. Based on observations, the sedum plants do not seem able to grow their roots into the plastic layer, possibly a physiological problem?

5.3 Panel system

The panel system requires a thorough design and construction process. In the meantime, it provides high architectural and technical value. In most cases, it is time-proven construction that may be designed in accordance with the lifespan of the building. Due to its high technical complexity, plants can live under controlled conditions that contribute to their adaptability.

To ensure the appropriate volume for the growing medium, panel systems have a heavier structure that must be taken into consideration when calculating loads. The size of the panels provided by the manufacturer maybe varied in unique cases.

Planting pot (Fig. 7)

Planting pot systems usually consists of a background steel netted frame and pots filled with growing medium. Pots can be suspended on the horizontal grid of the frame. (Fig. 8)

Mostly, it is used under indoor conditions, constructing it to an outside façade requires greater technical attention to the fixings.

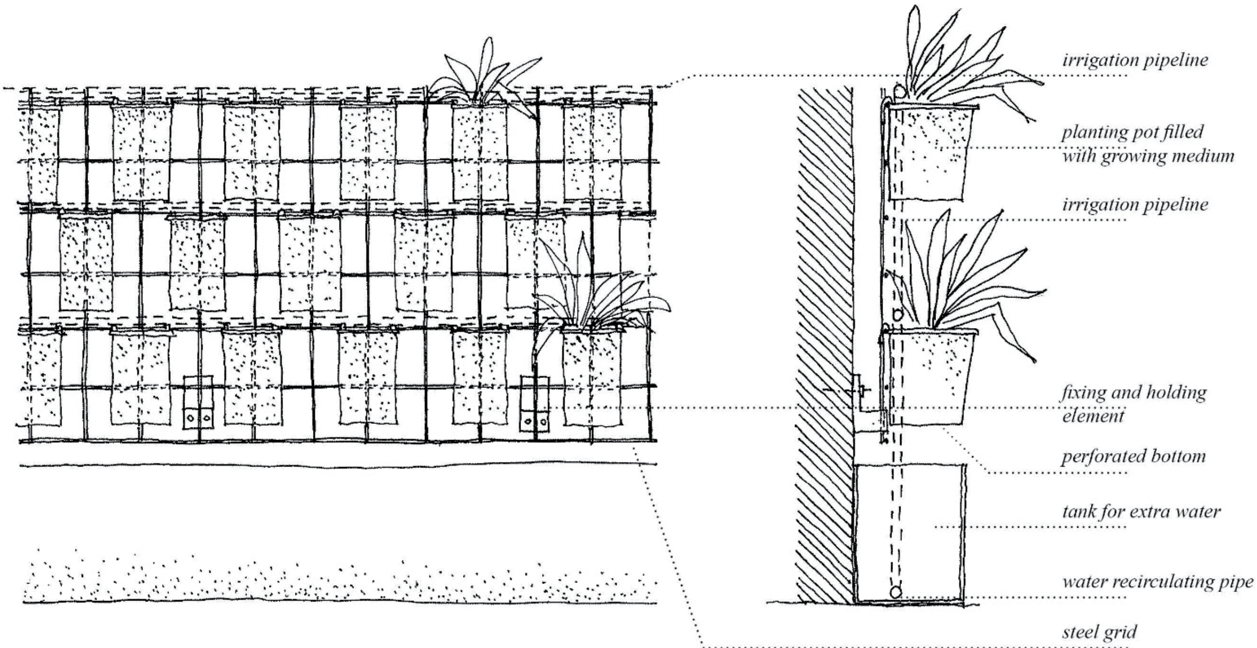

Fig. 7 Planting pots are mostly used under indoor conditions

Fig. 8 Irrigation pipeline is provided on every level

Table 2 Examined systems

1	Patrick Blanc	http://www.verticalgardenpatrickblanc.com/
2	Vertiko	http://www.vertiko-gmbh.de/
3	Optigrün	http://www.optigruen.de/
4	Jakob	http://www.jakob.com/display/JAK/Jakob+Home
5	Biotecture	http://www.biotecture.uk.com/
6	Mobilane	http://www.mobilane.hu/
7	Mobilane	http://www.mobilane.hu/
8	Bloomwall	http://www.bamboohome.co.uk/department/bloomwall/
9	Schadenberg combi gruen	http://www.schadenberg.nl/combi-groen/
10	gsky	http://gsky.com/
11	90degreen	http://www.90degreen.com/
12	Sempergreen	https://www.sempergreen.com/
13	Cultiwall	http://www.cultiwall.nl/en-gb/home.aspx
14	BrightGreen	http://www.brightgreenusa.com/
15	binfen	http://www.binfengreenwallsystem.com/
16	marklaurence	http://www.marklaurence.com/
17	myplantconnection	http://myplantconnection.com/
18	verticalgardenbudapest	http://verticalgardenbudapest.com/#hu
19	greenwall.pro	http://greenwall.pro/hu/
20	Scotscape	http://www.scotscapelivingwalls.net/
21	tonn	http://www.tonn.nl/
22	nedlaw	http://www.nedlawlivingwalls.com/
23	ELT easy green	http://www.eltlivingwalls.com/
24	MOPA	http://www.mohanyespafra.hu/
25	greenfortune	http://www.greenfortune.com/
26	Plantart	http://www.plantart.hu/hu/
27	Botanikart	http://botanikart.hu/
28	Helix	http://helix-pflanzen.de/
29	econoplas	http://www.econoplas.co.uk/
30	plantwalldesign	http://www.plantwalldesign.com/eng/home.html

Building element

This system can be considered as a green "brick" or a similar structural construction to gabion walls. (Fig. 9) Walls of this system can be either freestanding or supported. (Fig. 10)

Modular

The huge variety of different products and solutions enables the selection of a system that best suits a particular project. Some of them are considered to high-end solutions that ensure the best quality living walls and the most beautiful results.

Due to their optimized root zone volume, the possibility to reach a 100 % density immediately after construction, the potential to have a fully automated hidden irrigation system and adaptable to possible further research options have brought modular systems into prominence. (Fig. 11)

6 Indoor use

The above mentioned solutions may be used both indoors and outdoors. Under indoor conditions, light is the most important factor to consider besides nutritional and water.

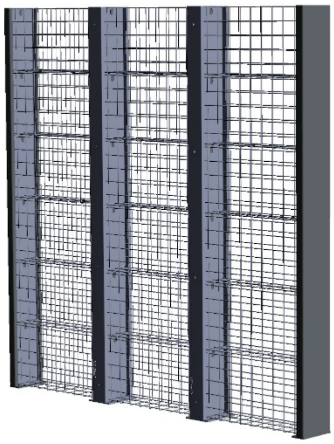

Fig. 9 The structural construction of a greenwall as a building element

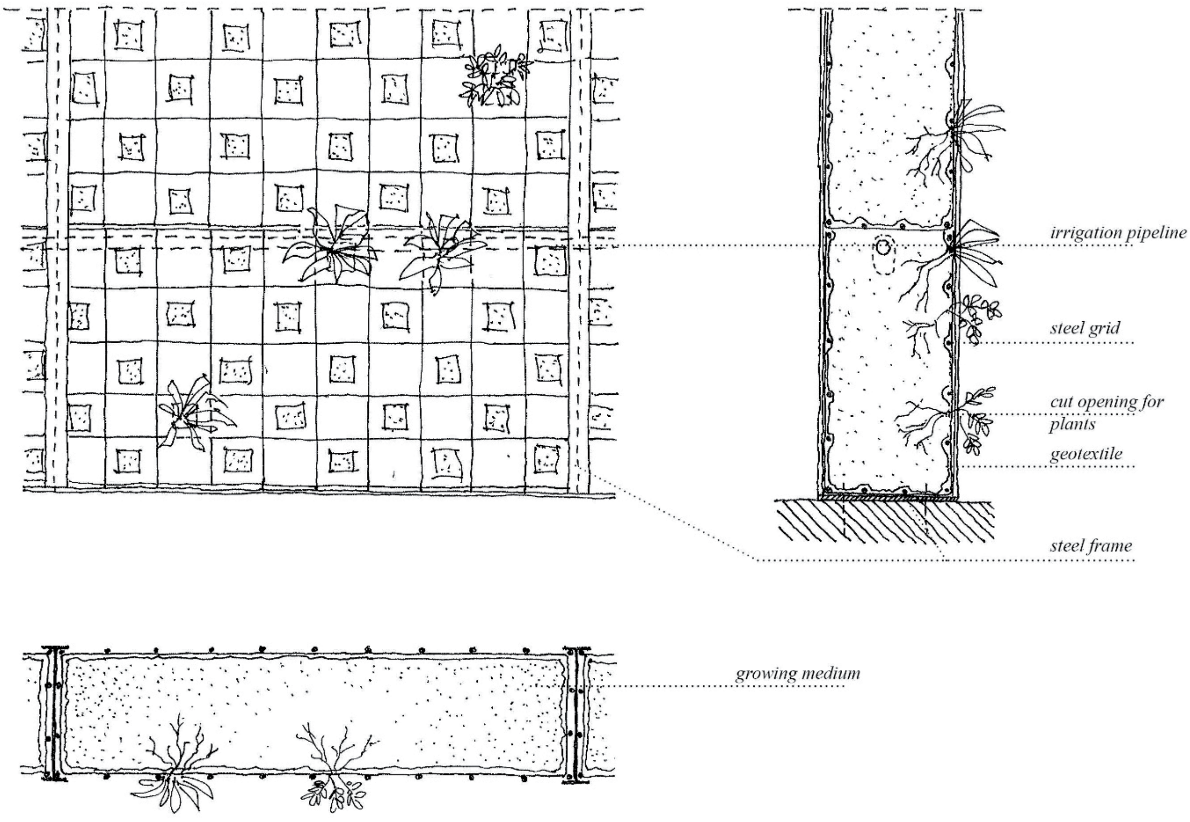

Fig. 10 Greenwall as building element

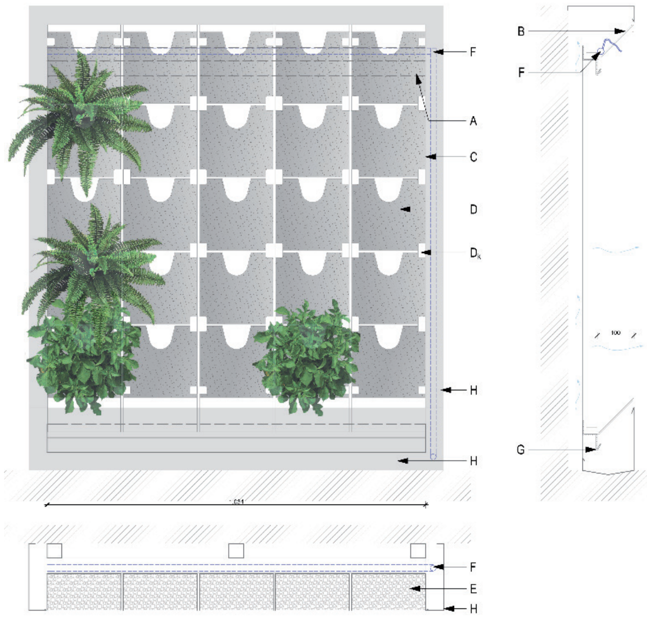

Fig. 11 Stainless steel modular greenwall system serves an optimal solution for outside walls

Table 3 Examination of the systems

	Trellis	Planting container	Felt system	Vegetation mat	Planting pot	Building element	Modular
Structural materials	metal/wood	metal/wood/ plastic	PVC/textile	PVC/(stone wool)/waste plastics	metal/wood/ plastic	plastic/recycled paper	metal/plastic/ stone wool/felt
Growing medium	organic/ (inorganic)	organic/ inorganic	non	non	organic/ inorganic	organic/ inorganic	organic/ inorganic
Typical thickness of planting layer (excl. plant) (mm)	~5	>100	~10	100	~100-200	150-250	100-200
Loads (kN/m^2)	0.06-0.50	0.50-2.75	0.70	0.40	0.50-1.5	>1.50	>0.30
Layers							
1	background wall	background wall	background wall	background wall	backgorund wall	background wall	background wall
2	air gap	(air gap)	air gap/vertical lumber	scaffold	air gap	(air gap)	air gap
3	trellis and plants	container with growing medium	horizontal lumber	waterproof layer	pot with growing medium	holding element with growing medium	module with growing medium
4		*plants*	*waterproof layer*	*drainage*	*plants*	*plants*	(drainage layer)
5			*drainage layer*	*substrate*			*(front facing)*
6			*geotextile*	*plants*			*plants*
7			*plants*				
Foliage density % (after construction)	0	0-80	10-60	10-60	10-50	10-50	30-100
Costs	low	low-high	fair	fair	fair-high	fair	fair-high
Maintenance	low	low-high	high	fair-high	fair-high	fair-high	fair-high

7 Conclusion

This paper intends to serve as the starting point for design considerations for Hungarian architects and others.

Patrick Blanc, in his patent, discussed the needs of plants as water, nutrients and light. The increasing spread of hydroponic systems and nowadays aquaponics illustrates this soilless system approach. Combining it with modular systems creates considerable potential not just for greening buildings, but for vertical farming. An approach that may help to ensure the "smart cities" of the future and their integrated approach.

Based on this systematic approach this study may serve as a basis for further research on living walls especially their potential for improved thermal characteristics. To date, this particular aspect has generally been examined with climbing plants. The thermal input data for living wall systems need to be similarly assessed. The adaptation and use of living walls under different climate zones is another direction for further research.

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