

VERTICAL GARDENS IN THE ARCHITECTURE

Final degree project - Course 2019-20

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Abstract

The conceptual contributions of the work aim to recognize the different aspects that surround a green facade installed on a building. Today, terms such as comfort and environmental sustainability are widespread among the majority of the population. For this reason, the first part of the work delves into the qualities that vertical gardens bring from the urban and building point of view.

The second objective of the work is to study the different construction systems existing in the market. For this purpose, a search has been carried out in the different companies with patented green facade systems. Likewise, to complement the explanation of the facade system, the construction section of an existing building that incorporates the studied green facade has been carried out.

The work also comments on the importance of vegetation for Catalonia and specifically for the city of Barcelona. The tool used to carry out the research is the Biodiversity and Green Plan of Barcelona 2020 realized by the city administration. It is possible to observe the distribution of vegetation in the different districts of the city and compare the need for vertical gardens in each of them.

In the last part of the work, an analytical methodology is followed, studying three different buildings with a green facade. The section shows how the facades can be related to the interior space of the building and how their construction influences the way architecture is experienced.

Keywords: Green facade, Vertical garden, Sustainability, Comfort, Semi-outer space, Construction system

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1. Introduction

1.1 Justification

When dealing with the subject of green walls and facades, it is possible to distinguish two different points of view, environmental sustainability and the shaping of a space. Architecture is, without a doubt, the element that unites both aspects to obtain the greatest advantages of vertical gardens. On the one hand, environmental measures when designing are increasingly strict. However, on the other hand, the designer must never abandon the search for quality in spaces.

Today, the whole world is in an alarming situation regarding environmental sustainability. José Manuel Naredo rejects the power that the economic factor has acquired over the social and, above all, the environmental one. According to the United Nations Development Programme (UNDP), it is estimated that, as of 2017, human beings are responsible for the 1°C temperature increase due to global warming. In other words, to limit warming to 1.5°C, global CO₂ emissions should decrease by 45% between 2010 and 2030, and reach zero by around 2050 (United Nations, n.d.)

On the other hand, since the beginning of industrialization, the human being has been in charge of exhausting the resources provided by the planet, ignoring that they are finite, carrying out a transformation of the environment without taking into account the consequences that this change has for biodiversity and even for the human being itself. Although polluting industries have been confronted in recent years with increasingly strict measures and restrictions, we need to look at the places where energy consumption continues to increase over the years. In Spain, approximately 50% of the total energy consumed is related to housing. For this reason, local policies must introduce measures to reduce the environmental impact. Luís Balairón highlights the importance of a recovery in the construction sector aimed at adapting buildings to improve energy efficiency, which could make vertical gardens a common resource.

Within the vertical gardens it is possible to differentiate between green walls and green facades. At first sight both are the same, a set of plant species that rise vertically to cover the skin of a building. However, green walls lack the main function offered by any type of facade in a building. They are not capable of offering the subject a relationship between the interior and the exterior of the building since the wall becomes an impassable limit even for the eye. In other words, their architectural interest is limited to the users of the city.

In contrast, there are vertical garden construction systems that allow these visual limits to be eliminated, creating a totally different experience for the subject residing in the building. This typology of systems allows the creation of filters for the light, the view and even the space through a series of gardens. Normally, these gardens are used in double skin facades due to their lack of thermal insulation.

1.2 Objectives

The work aims to achieve four objectives covering different aspects of vertical gardens. Most people are not yet aware of the role these facades can play in the city and in buildings. For this reason, the first part of the work is dedicated to the functional aspects of green facades.

When designing a green facade, it is necessary to understand what qualities you want to provide to the building and what aspects are most notable in each of the systems. In the second block, we intend to carry out an investigation of the construction systems on the current market. In order to better understand them, they will be explained through the drawing of constructive sections of existing buildings.

Concern about the densification of cities is leading the administration to act on the problem. The next objective is to understand the current situation in the city of Barcelona and how vertical gardens can play a decisive role in public initiatives.

Finally, the architectural value of this type of facade is taken into account. For this reason, a chapter will be devoted to understanding the influence of green facades on the interior and exterior spaces of a building.

1.3 Historical context

Today, the architect has a wide variety of techniques to project a green facade. All these systems come from the architecture of past times. The builders of different places in the world took advantage of the knowledge they had of their climates to intuitively develop their constructions with local materials.

The vernacular architecture responded to the needs of the citizens, while providing certain aesthetic values. In much of northern Europe the use of vegetation such as grass was especially

developed. The builders understood that vegetation together with its substrate layer offered better insulation than typical buildings made of wood or stone.



Figure 1. Turf house, Bakkagerdi. Traditional style building in Iceland

1.3.1 Early period

Since the beginning of architecture, man has evolved, leaving a great imprint on the existing nature all over the planet. However, he was able to understand the great potential that vegetation could provide not only in the agricultural aspects, but in the creation of new microclimates that could surround palaces, houses and even cities.

According to some writings, the first recorded garden was built between 605 B.C. and 562 B.C. It is said to be the Hanging Gardens of Babylon, of which it is said that they occupied an area of 1600 m² and that they rose with a system of terraces up to 90 meters high, to the top of the temple (Ochoa, 1999).

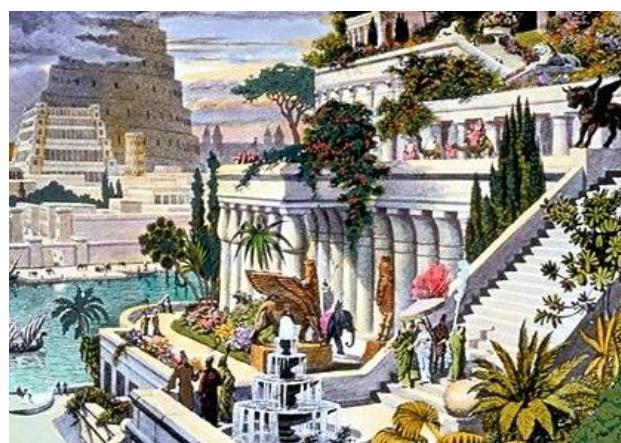


Figure 2. Representation of the Gardens of Babylon

However, it is not until later that the use of the garden becomes commonplace in homes. All the villas of the Roman period were formed by an atrium and a courtyard with vegetation as in the case of Pliny's Villa in Laurentum (100 BC).

1.3.2 Middle Age

The evolution of gardens in architecture suffered a hard blow after the fall of the Roman Empire. The life imposed by the barbarian invasions caused a stagnation in the use of vegetation. At the same time, however, a great deal of knowledge about the basic principles of botany was accumulated in the monasteries. As a result, simple gardens were obtained in terms of design but with great complexity in the species used and other aspects.

1.3.3 The Renaissance

During this time, the rediscovery of classical Roman architecture inspired the use of vegetation in architecture. At this time a new trend appeared that would influence later periods such as the Baroque, in which it was possible to include nature as an important part of the constructed building.

On the other hand, French gardens like Versailles are a representative example of plant architecture. The garden acquires an aesthetic sense where every detail is projected on the plane.

1.3.4 Modern and Contemporary Age

At the beginning of the 20th century, a new term appeared, organic architecture. It is an architectural movement raised against the rationalism of gardens projected until this century. There were great architects like Frank Lloyd Wright who were attached to organic architecture. This type of architecture wants to prevent it from becoming an imitation of nature. Its purpose is to ensure that, through the form of the architecture, the materials and other aspects, the building is able to integrate itself into a natural environment.

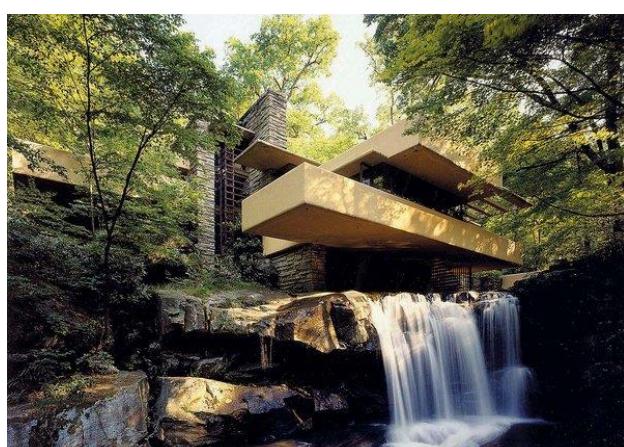


Figure 3. Waterfall house, Pennsylvania (1936 - 1938)

On the other hand, in 1988, the stainless-steel cable system appeared, which allowed for more verticality on the newer designs. At the same time, in the early 1990s, work was done on modular panel systems with trellises or gabions (Navarro, 2013).

2. Characteristics of plant facade

2.1 The green facade in the urban environment

When a green facade is planned, it must be taken into account that the level of performance goes beyond the building itself. The potential that this typology acquires is capable of influencing the city's metabolism. It is possible to improve the level of health of the population, as green facades act on the effects of climate change while providing a different perception of the city.

- **Heat island effect:** This phenomenon is produced by the incision of solar radiation on the surfaces of buildings and urban elements. The materials that form them absorb this energy which then returns to the city's surroundings, generating a specific increase in temperature. However, when incorporating the vegetation in the facades it should be taken into account that these organisms, when doing the photosynthesis, are capable of absorbing up to 35% of the light energy through their leaves. In other words, the difference in temperature emitted by a vertical wall of ceramic bricks and a green wall could reach 11.6°C (Pérez, Coma, Sol, Cabeza, 2016). In Yanill's thesis, he explains how this temperature reduction provides comfort to the citizen based on the dimensions of the street. The streets most sensitive to this change are those with a ratio $h / d > 2$ (where h is the height of buildings and d is the width of the street). (Guzmán, 2018)

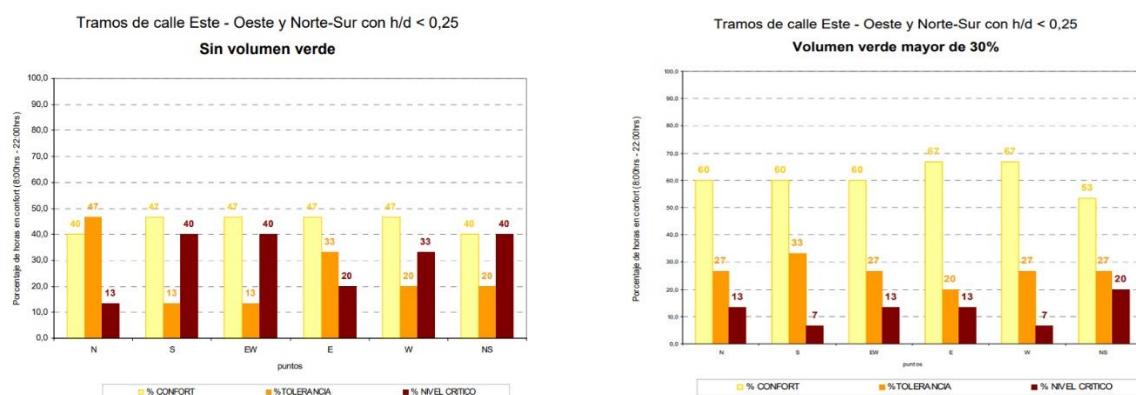


Figure 4. Comparison of comfort hours between a normal facade and another with more than 30% volume of vegetation. Source: (Echave, 2007)

As shown in the graphs above, considering a person's heat gains and losses in relation to radiation, temperature, humidity and wind throughout the day, the number of hours of thermal comfort in the streets with 30% of the surface covered by vertical gardens increases (Echave, 2007).

- **Decreased climate change effects:** The vegetation on the facade, through the process of photosynthesis, causes chlorophyll to capture solar energy and carbon dioxide (CO₂). The combination of this process with the water that the plants absorb through their roots results in glucose and oxygen (O₂) being expelled into the city's atmosphere. It is important to bear in mind that 1m² of a green roof is capable of producing the amount of oxygen a person needs to live a whole year.
- **Reduction of water runoff and retention of polluting particles and dust:** Vegetal facades can be translated as a barrier against external agents to the building. Pollutant particles emitted into the atmosphere by human actions can be trapped in this plant barrier. Daniel Lacueva explains that 1m² of plant cover traps a quantity of 130g of polluting particles per year. Likewise, although it has not been studied in depth, it can be deduced that this type of facade, like green roofs, is capable of retaining rainwater. (Babylon, n.d.)
- **Increase in green:** In dense cities like Barcelona, the creation of green walls can be a strategy to follow in order to introduce a green lung in the city. Elena Ruiz and Javier Turrillo explain in their study that the World Health Organization establishes minimum parameters of 10m² of urban green in consolidated areas, and up to 15m² / person in newly built areas (Ruiz, Turrillo, n.d.).
- **Aesthetic impact:** Some studies have carried out surveys of different citizens about the plant facades and their aesthetics. The vast majority of people support the aesthetic result of this type of facade. Moreover, the visual benefit in a totally artificial city is undeniable.

2.2 The green facade in the building

- **Erosion protection:** Vegetal facades and green walls are a good ally when it comes to protecting the building envelope from the weather. For example, a double skin with a layer of vegetation is capable of containing the force of the wind towards the interior of a building, but also of avoiding an acceleration of the erosion of the elements of the facade due to the force of the rain water.
- **Thermal isolation:** There are studies that support that, in the same way as green roofs, green facades and green walls are a good element to consider for thermal insulation. According to Gabriel Pérez, who states that between 20 and 60% of the energy consumed

in buildings is given by the design and construction of the building envelope. The results of the application of this system in a building are translated inside it as an increase in temperature and a lower relative humidity in winter and, conversely, a lower temperature and an increase in relative humidity in summer.

With empirical data, a reduction of up to 5.6°C can be observed during a day of high sunshine and 3.5°C during summer nights and up to 21°C in the surface temperature of the facade. In winter up to 30% of heat loss could be avoided with the use of perennial plants (Perez, Coma, Sol, Cabeza, 2011).

Depending on the plant species included in the facade, it is necessary to take into account the "shadow effect" since the incidence of direct solar radiation inside the building may or may not vary depending on whether the species is deciduous or perennial. This effect can reduce the demand for air conditioning in homes by 20-30% (Guzmán, 2018).

- **Acoustic isolation:** One of the studies that deals with the acoustics in the vegetable facades is that of Dr. Miguel Urrestarazu. The result was positive. Vegetal facades are capable of absorbing noise from the outside. However, due to the low density of the wall studied, the results were impaired. It is a green wall of 50 Kg/m² as opposed to the 200 Kg/m² of the brick or the 280 Kg/m² of the concrete blocks. On the other hand, it is necessary to take into account the construction system of the green wall since it could be a vibration bridge to the interior of the building (Azkorra, Pérez, Coma, Cabeza, Bures, Álvaro, Erkoreka, Urrustarazu, 2015).

3. Types of green walls and facades

When making a facade of any kind, it is necessary to take into account different factors such as its efficiency in transmitting heat, its waterproofing and, in aesthetic terms, its external appearance. On the other hand, the architect must take into account the needs required by the building when designing a green facade. This typology of facades is based on three basic needs: a plant species that covers the facade, an organic environment where this species can take root and grow (substrate) and a structure typology that supports the plant species.

On the basis of these three main elements, it is possible to classify these facades into different types that will provide some advantages or other advantages and disadvantages. For this reason, the architect must be aware of the existence of all the variables to ensure the best result in his project.

After searching for information about green facades and walls and their construction systems, it has been decided to classify them according to the planting method. This can be vertical or horizontal, depending on the surface of the substrate where the different species will be planted.

Green facades and walls	Vertical planting	Modular systems	In substrate	Modular panels	
				Metallic gabions	
				Plastic or ceramic cells	
			Hydroponic	Textile bags	
	Horizontal planting	Adherence creeks		Panels F+P	
				Vegetal concrete	
				Classic green wall	
				Double skin	
		Containers or planters	In situ planters		

Table 1. Classification of plant facades. Source: Own elaboration

3.1 Horizontal planting

The horizontal plantation is the one that is best known by the citizens. The plantation plane of the species is horizontal, so that, a priori, it is the most logical way to carry out a plantation. However, technology has offered a great variety of systems and makes this type of method increasingly specialized over the years.

3.1.1 Traditional system or Adherence creeks

As the name of this group indicates, these green facade systems arise from traditional green walls. The main characteristic of this type of facade is the species used. These are climbing plants or vines that are able to adhere to the walls of a building through the roots.

- *Classic green wall:* This can be named as the clearest example of a green wall. In this case, climbing species attach themselves to the walls of a building facade through adventitious roots or other elements (depending on the species). These types of plants tend to appear naturally in structurally weaker walls, such as an ordinary masonry wall where mortar and some porous rocks can be penetrated by such roots.

The main characteristic of this system is its simplicity and its ability to appear naturally, without human intervention. It also offers us protection against sunlight in the openings of the facade. However, the greatest advantages are to be found in the economic and maintenance element. It is only necessary to cultivate the climbing species and carry out minimal maintenance based on pruning and cleaning the openings in the facade when necessary.

On the other hand, the system offers some disadvantages. Depending on the species anchoring system on the wall, it can insert its roots through cracks and fissures in the facade or, if it is a species that is fixed with suction cups, it could leave marks on the facade, which would cause aesthetic damage if the plant surface were removed (Navarro, 2013). In aesthetic terms, the flexibility of the system is also scarce since there is no established guide for facade species.

The time needed to cover the facade with the species is long. Manfred Köhler conducted a study in which he said that these plants grew at a rate of 0.7 to 1.5 meters / year (Koehler, 2008).



Figure 5. Montjuic castle

- *Double skin facade:* This system arises from the need to avoid damage caused by the green wall system directly on the building facade. It is based on transferring what has been learned previously to a structure of wire cloth, steel mesh and metal latticework that is exempt from the building's facade and on which the climbing species rests to cover the entire surface.

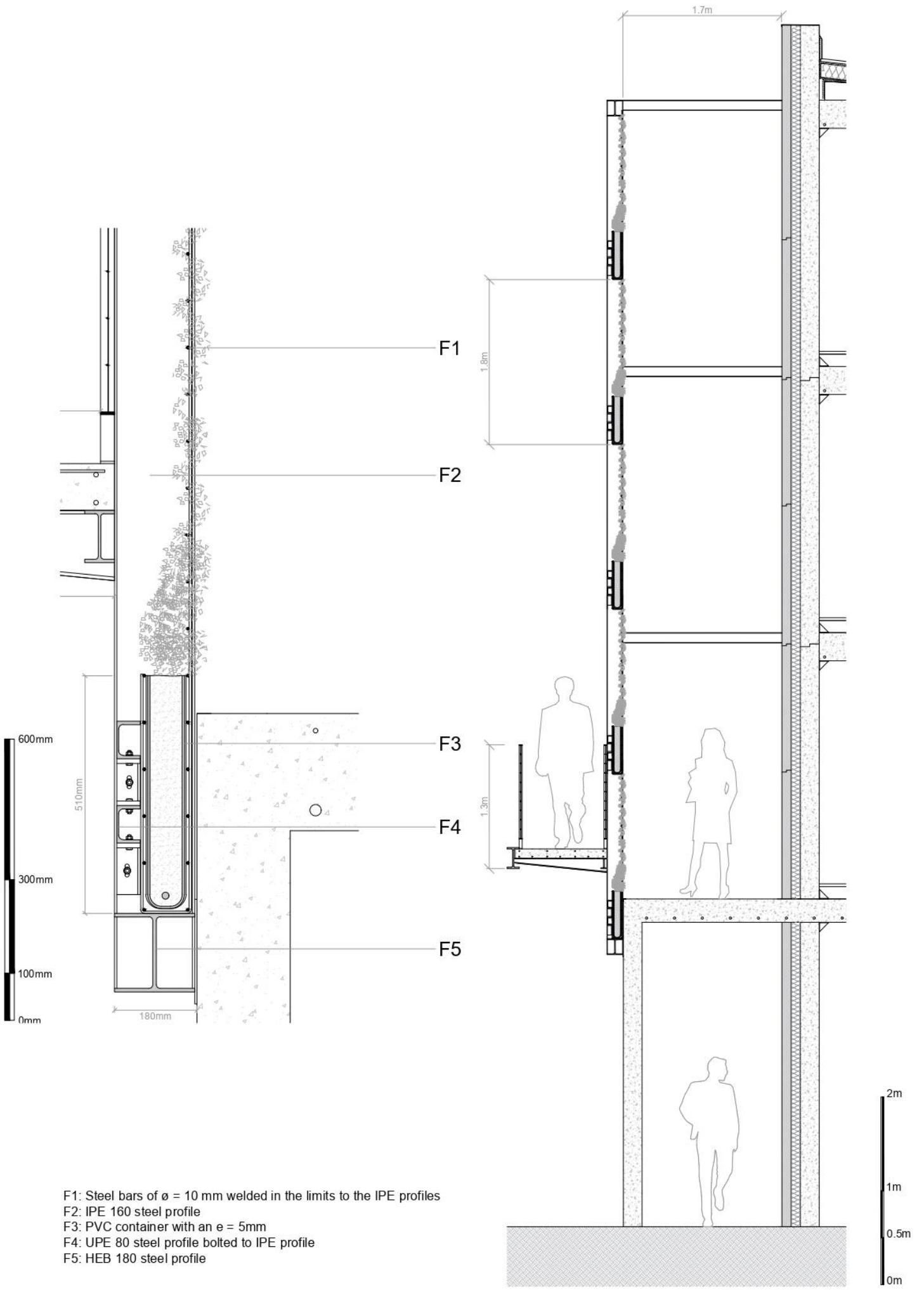
Architecturally, it is a good system for generating intermediate spaces in the buildings, as the green facade can function as a filter several meters away from the conventional facade.

Obviously, the advantages of this system with respect to the previous one is basically the decoupling of the plant species with the facade of the building, which allows a longer life of the facade and, consequently, a better thermal and watertight operation.

As far as aesthetics are concerned, even though it allows greater flexibility thanks to the guide system, it cannot be said that a great variety is possible because the type of species suitable for this system is reduced.



Figure 6. Facade of climbing plants of the Barcelona power station, Zona Franca



F1: Steel bars of $\varnothing = 10$ mm welded in the limits to the IPE profiles

F2: IPE 160 steel profile

F3: PVC container with an $e = 5$ mm

F4: UPE 80 steel profile bolted to IPE profile

F5: HEB 180 steel profile

3.1.2 Container or planters

This method is based on the typical planting of pots on the balconies of city buildings. However, this idea can be taken to the extreme or not, creating structures that rest on the facade where these containers can be added or even creating a building whose facade is a large pot.

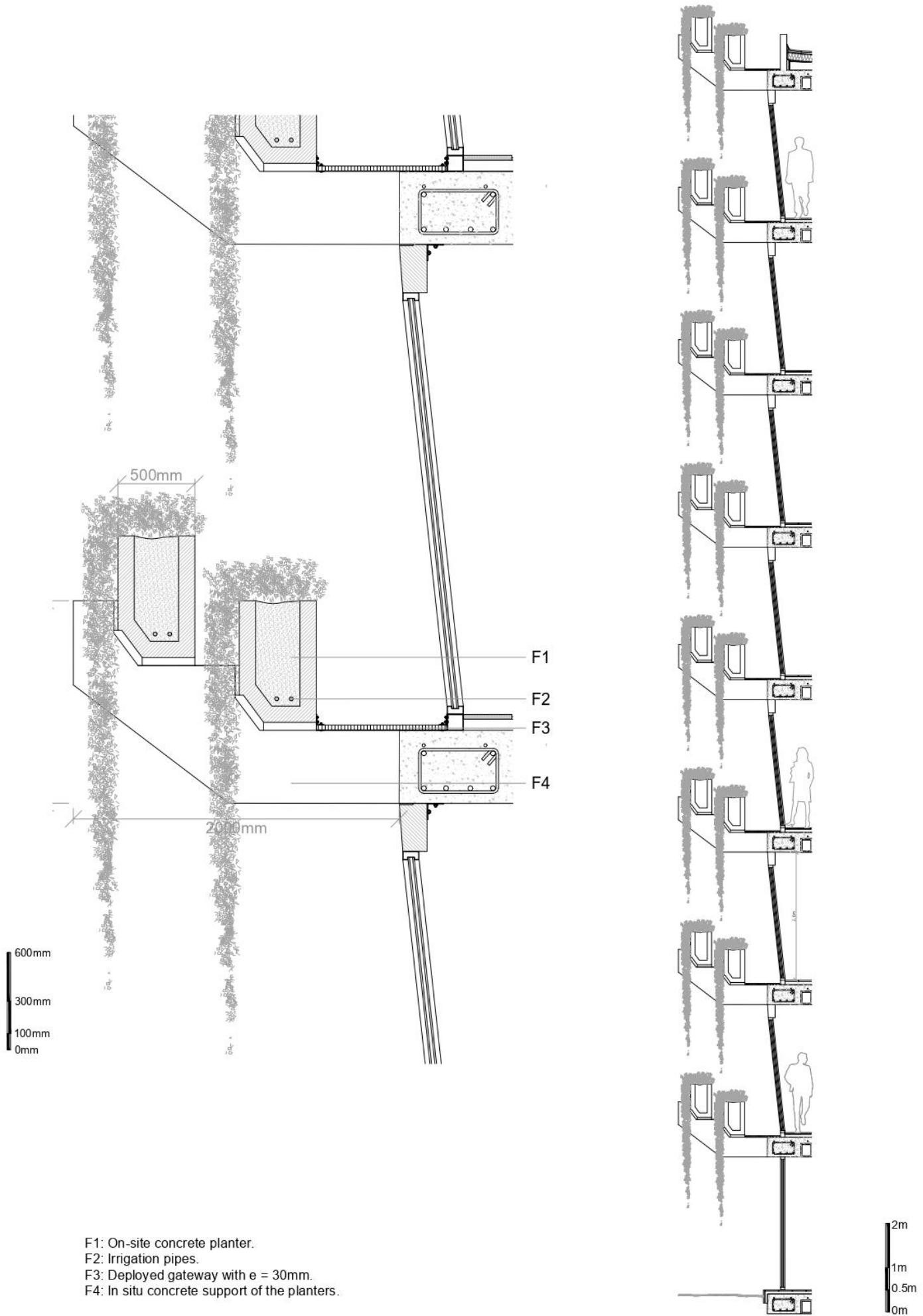
In situ planters: This strategy is implicit in the architectural project, so its use in the renovation of facades is excluded. The system is based on the creation of large containers in situ where to place the substrate to generate large pots for planting different plant species.

This system has some advantages such as the generation of a shadow factor in the openings of the building. However, its thermal insulation is not increased.

In terms of aesthetic and architectural values, this system can be very useful to generate a visual quality of the facade and also to establish a relationship between an intermediate space of the building and the outside.



Figure 7: Planeta building projected in 1976, Barcelona



F1: On-site concrete planter.
F2: Irrigation pipes.
F3: Deployed gateway with $e = 30\text{mm}$.
F4: In situ concrete support of the planters.

Plan 2: Constructive detail of the facade of the Planeta building. Source: Own elaboration

3.2 Vertical planting

Specialists refer to this type of planting when the plane of the substrate is on a vertical plane. Vertical planting is related to more contemporary systems and therefore requires higher maintenance and installation costs. However, these methods offer a wide variety of advantages over horizontal planting systems, for example, increased thermal and acoustic insulation.

These types of systems were born, in their great majority, in an era where the speed of installation is the priority, therefore, the great majority of these methods of vegetal facades are modular.

3.2.1 Solid substrate systems

The relationship between the following methods of building vegetal walls is the appearance of the substrate as a base for the growth of vegetal species.

- *Modular panels:* There are different companies that carry out this type of system. In this search we decided to explain the system through the SingularGreen Leaf Box system. This system is based on the fixing of 40 x 40 mm tubular profiles with a thickness of 3 mm to the load-bearing facade of the building through supports. The container panel is fixed to these profiles, which consists of a waterproof panel and a substrate panel with a plasticized metal mesh. (SingularGreen, n.d.)

The design flexibility is considerable, unlike traditional plant facades. However, the most positive aspect is the reduction of the waiting time for vegetation to cover the entire facade.

One of its main advantages is that the substrate is made of moss, which provides lightness to the containers, and also allows oxygenation of the roots. The moss is also able to provide savings in the irrigation of the plantations, as it is capable of storing 20 times its weight in water. Furthermore, as the panels are factory-made, installation is simple.

However, the main disadvantage of the system is the thickness of the facade, as it reduces the number of useful meters of the building.



Figure 8: Green facade of modular panels of the Celler Cooperatiu, Rubí

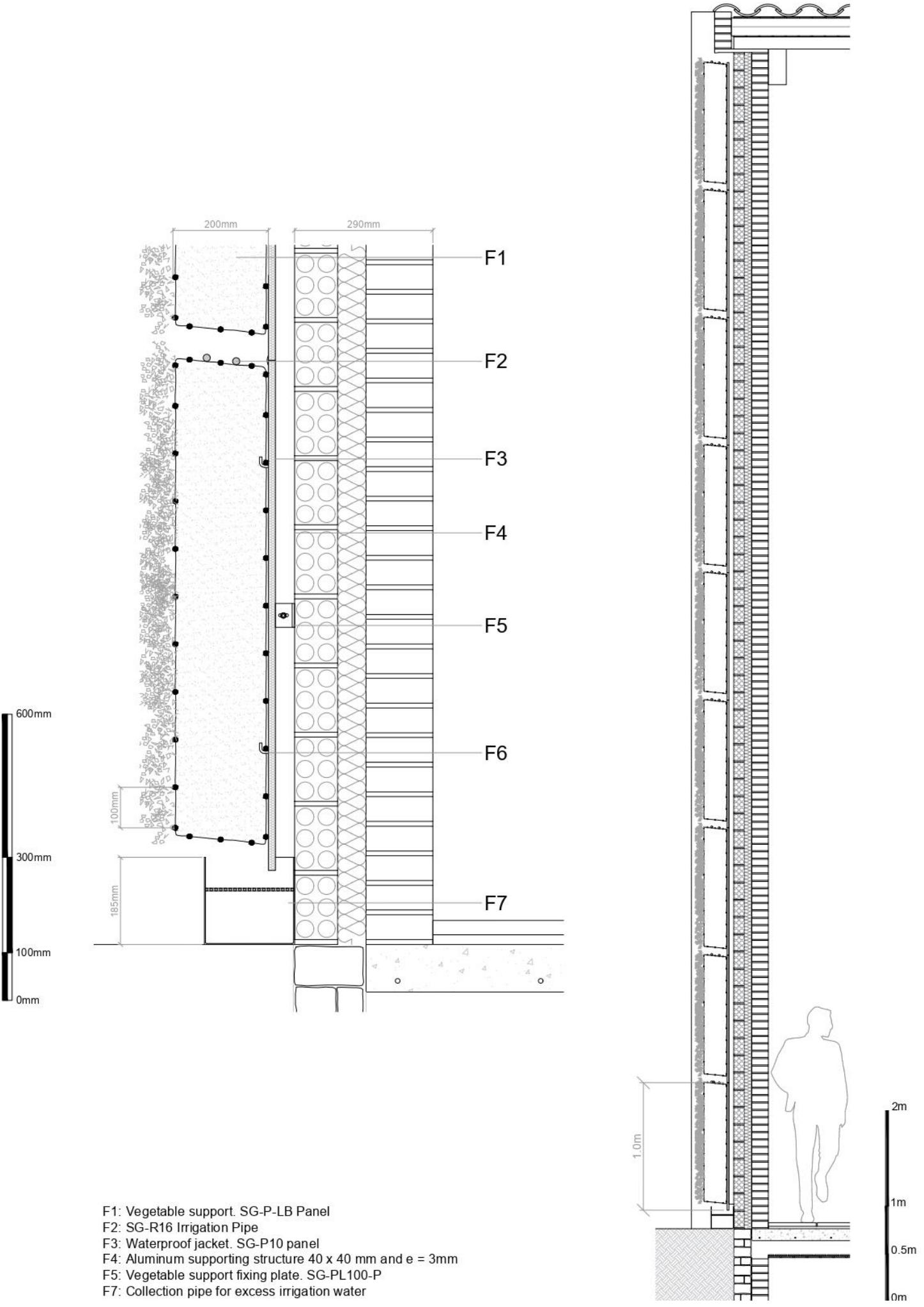


Table 2: Constructive detail of the facade of the Celler Cooperatiu de Rubí. Source: Own elaboration

- *Metallic gabions*: This system will be explained through Babylon Company. It is a constructive system of galvanized steel gabions with standardized measures of 50 x 104 cm and 14 cm of thickness of substrate. The mesh of the gabion forms a grid of 10 x 10 cm and the diameter of the wire is 4.5 mm. The gabion as a whole with the substrate is hung in metallic profiles in form of V of correct size.

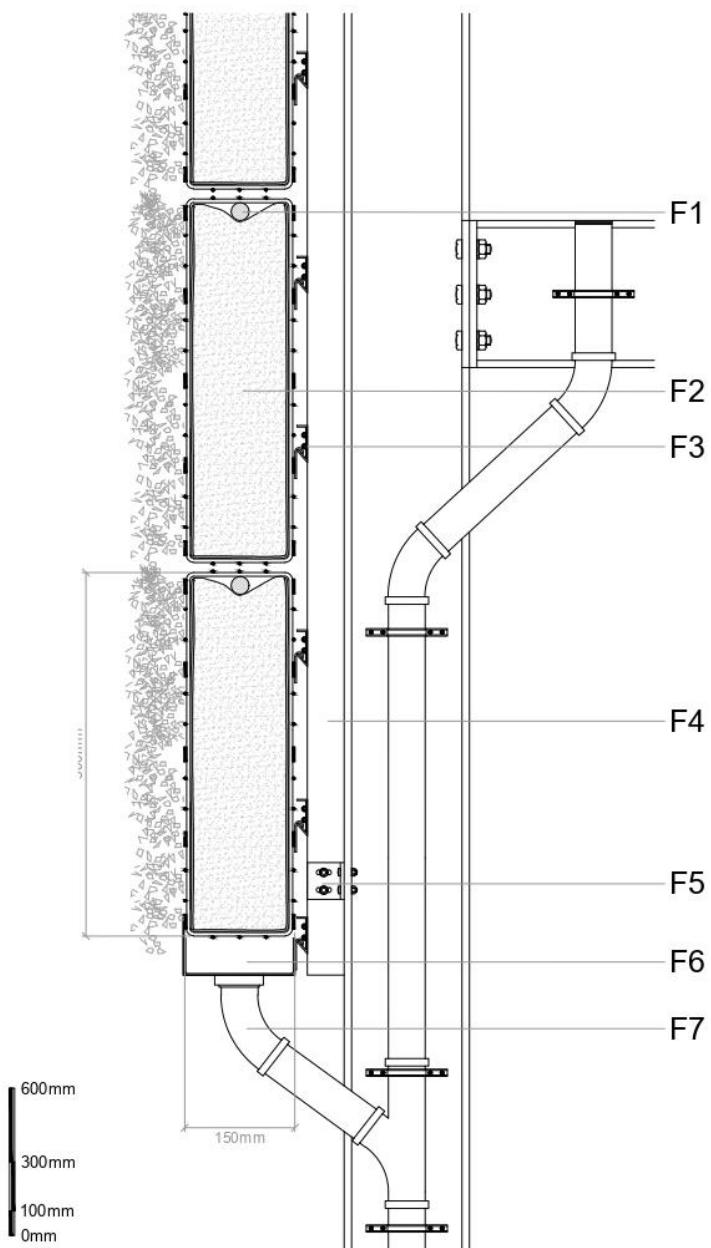
Like the previous system, the gabions with substrate allow a considerable flexibility in terms of aesthetics, however, the planting of species is limited to 100 units, as there is a strict weight limit for these containers (Babylon, n.d.).

The structure ignores the original facade of the project, thus avoiding possible damage to it. However, this implies an installation, not complex, but specialized that will require costs.

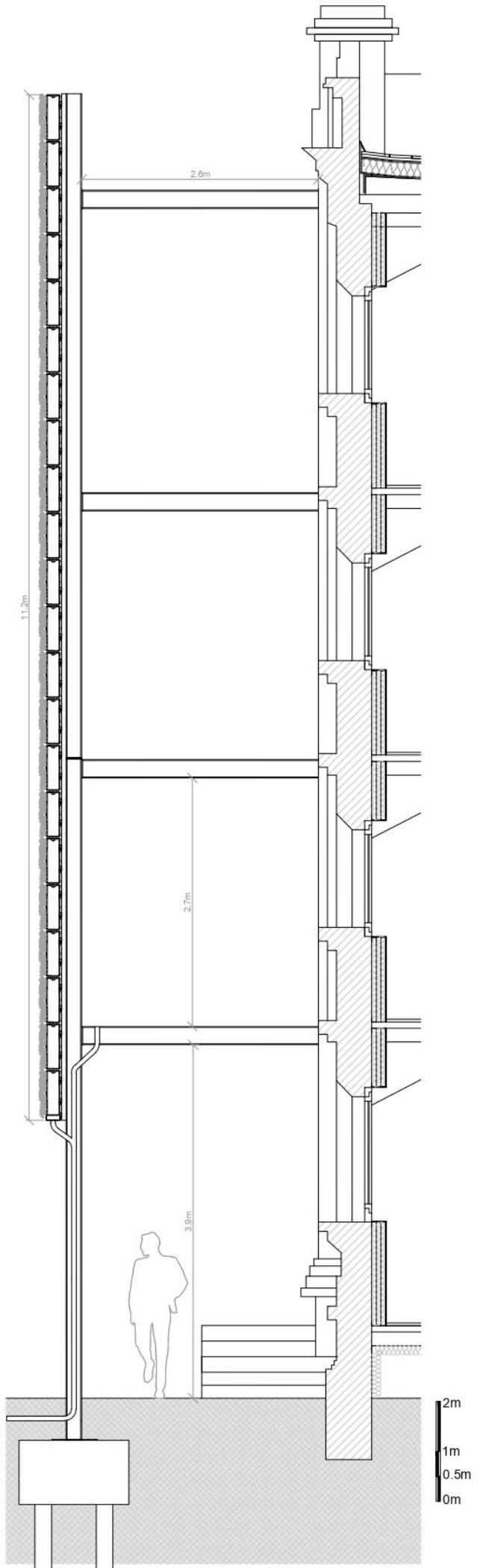
In addition, in the container panel system, the dimensional problem still appears, making the facade thicker than desired.



Figure 9: Green facade of metal gabions from Espai Tabacalera, Tarragona



- F1: Irrigation pipe.
- F2: Metallic gabion covered with a plastic cell filled with earth.
- F3: Gabion support to the metal structure.
- F4: Supporting metal structure.
- F5: Plant support fastening.
- F6: Water collection system. Grid and metal channel.
- F7: Collector tube for water recycling.



Plan 3: Constrive detail of the facade of the Espai Tabacalera: Own elaboration

- *Plastic or ceramic cells*: Whether it is a system based on plastic cells or ceramic elements, both share great similarities with each other. For this reason, the ceramic system is explained in more detail. The SingularGreen Eco-Bin system was chosen for study.

The Eco-Bin works as a self-supporting ceramic masonry sheet supported by an existing wall. However, if the vertical garden is of considerable height, the cells can be punctually supported on an aluminum substructure made up of tubular tubes with 40 mm sides and supports where the set of cells is supported. A panel with two layers of geotextile sheet is placed on the substructure, which helps to direct the water for irrigation and prevents it from reaching the facade's wall.

This ceramic sheet is made up of small waterproof cells formed in pairs with an outer hexagonal section and an inner cylindrical section of 90 mm. They are placed like a common brick wall, with an inclination in the cells of between 7° and 15° to retain the water at the bottom. The holes in the cells are filled with the substrate for subsequent planting (SingularGreen, n.d.).

The system provides simplicity in its construction as it is a structure composed of metal uprights and supports and the ceramic wall turns out to be a simple masonry work.

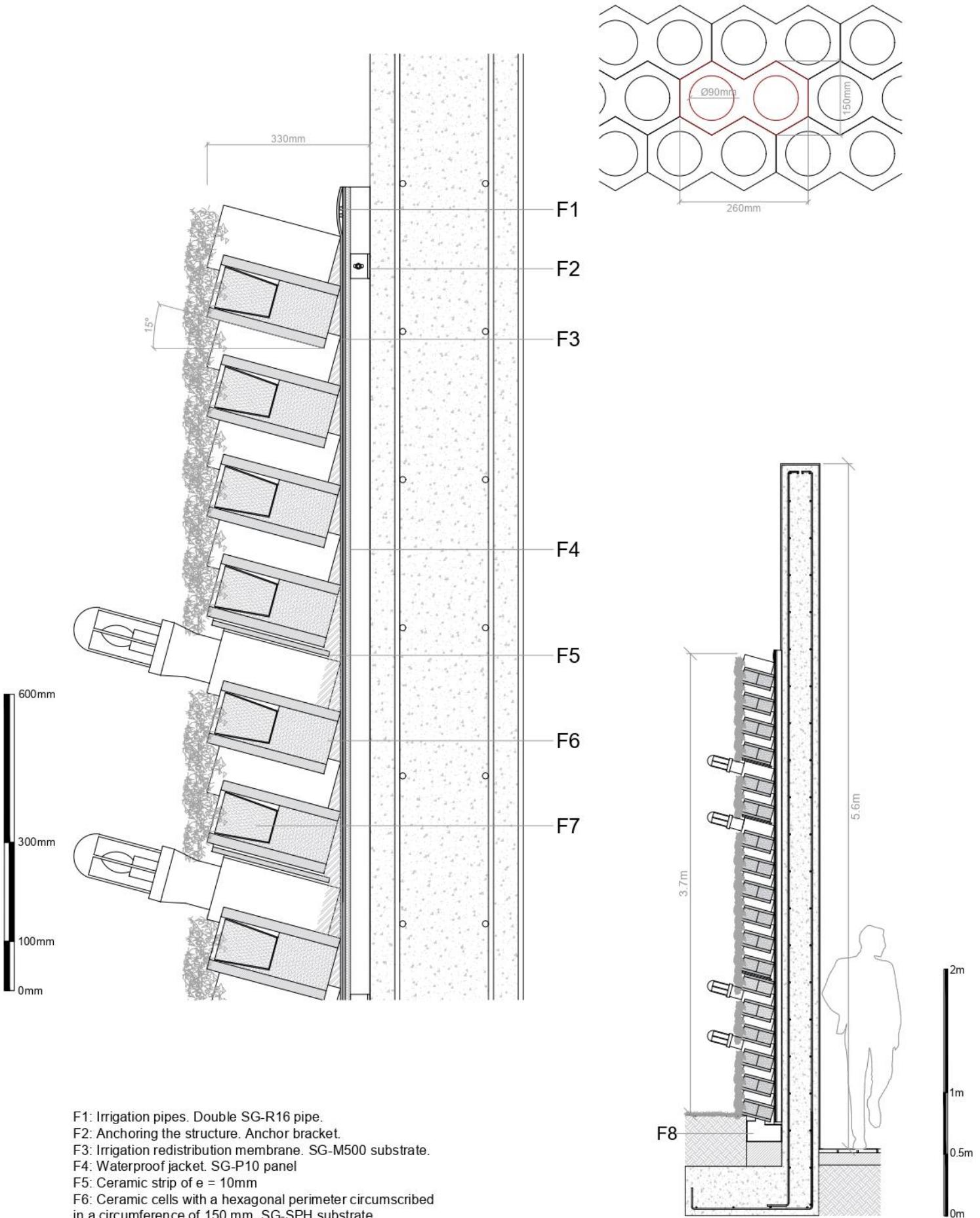
Likewise, the system provides great flexibility when it comes to creating an aesthetic on the facade, with the possibility of varying the different species such as the shade of the cells. Architecturally it is a good option when creating a green wall, however, the construction system limits the possibility of establishing a relationship between both sides of the vertical garden.

From the functional point of view, this typology generally offers an acoustic and thermal cushion (variable according to the species and density).

One of its greatest disadvantages is the impossibility of carrying out simple repairs, since it is an element formed in situ, which results in careful maintenance of the different elements.



Figure 10: Green wall with the ceramic cell system of the Ushuaia hotel, Ibiza



F1: Irrigation pipes. Double SG-R16 pipe.
F2: Anchoring the structure. Anchor bracket.
F3: Irrigation redistribution membrane. SG-M500 substrate.
F4: Waterproof jacket. SG-P10 panel
F5: Ceramic strip of $e = 10\text{mm}$
F6: Ceramic cells with a hexagonal perimeter circumscribed in a circumference of 150 mm. SG-SPH substrate.
F7: Planting container. Plot SG-m8.
F8: Water collection system. Grid and metal channel.

Plan 4: Constructive detail of the facade of the Ushuaia hotel. Source: Own elaboration

3.2.2 Hydroponic systems

Hydroponics consists of planting flora in places where there is no solid substrate. The nutrition of these plants is produced by means of aqueous solutions that already carry the minerals necessary for the growth of the plant. The greatest advantage of this type of system is the absence of substrate, so the weight of the entire installation is considerably reduced, being about 25.2 Kg / m² (Terapia urbana, n.d.).

The main disadvantages of hydroponic systems arise from technological challenges. They are contemporary methods that incorporate automated control technology. In addition, the personnel needed for the installation must be specialized, so finally the total cost of installing green walls of this type ends up being high.

- *Textile bags or mixed system:* Terapia Urbana has developed the Fytotextile system, which is based on the creation of bags with three different layers: waterproof, drainage and breathable. The first one, located at the back, prevents the irrigation water from coming into contact with the substructure, the drainage layer allows the water to slide by gravity to the planting bags located underneath and, the last layer, allows the roots to transpire and, consequently, improves their behaviour. The entire multilayer fabric is placed on a galvanized steel structure sized according to the project.

The system has modules of different sizes, both vertical and horizontal (S, S2, H1, H2, H3, V1, V2, V3) and the total thickness of the system is about 70 mm with a saturated module weight of 25.2 Kg / m² (Terapia urbana, n.d.).

The main advantage of the system is its lightness and flexibility, so it is possible to adapt the system to a curved wall, for example. The textile layers help the plant to have a better performance and a longer life.

As in the previous systems, the plant surface is quickly covered and the plants come from nurseries. The system also allows great flexibility in the design of the vertical garden. Its installation is not difficult but it is specialized, and in case of malfunction or leakage it is possible to remove the damaged module without damaging the whole green wall installation.

On the contrary, it is a system that cannot establish a relationship between the interior and the exterior of the building.

Another point against it is the useful life of the materials used, since the wear and tear of the green facade is high.

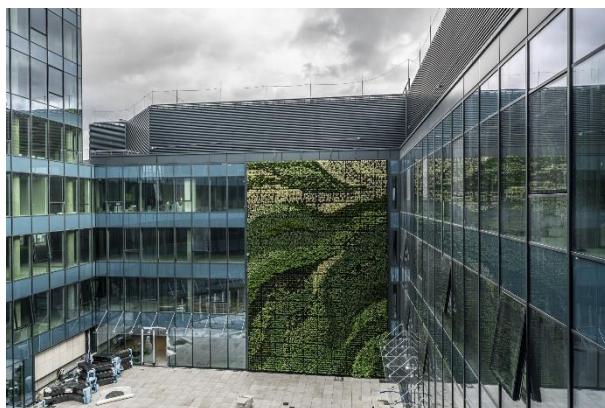
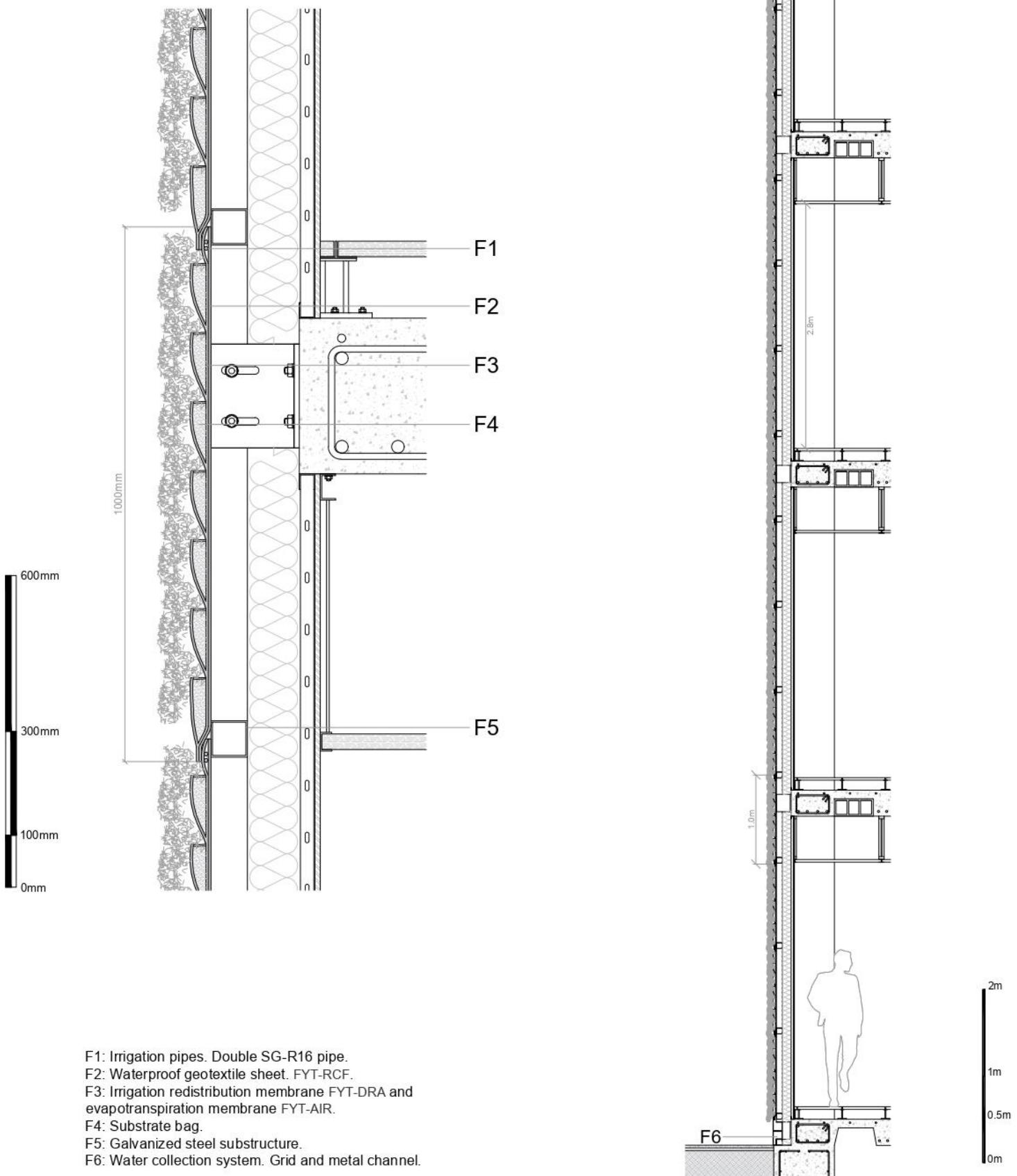


Figure 11: Posejdon building with textile bag system, Poland



F1: Irrigation pipes. Double SG-R16 pipe.
 F2: Waterproof geotextile sheet. FYT-RCF.
 F3: Irrigation redistribution membrane FYT-DRA and evapotranspiration membrane FYT-AIR.
 F4: Substrate bag.
 F5: Galvanized steel substructure.
 F6: Water collection system. Grid and metal channel.

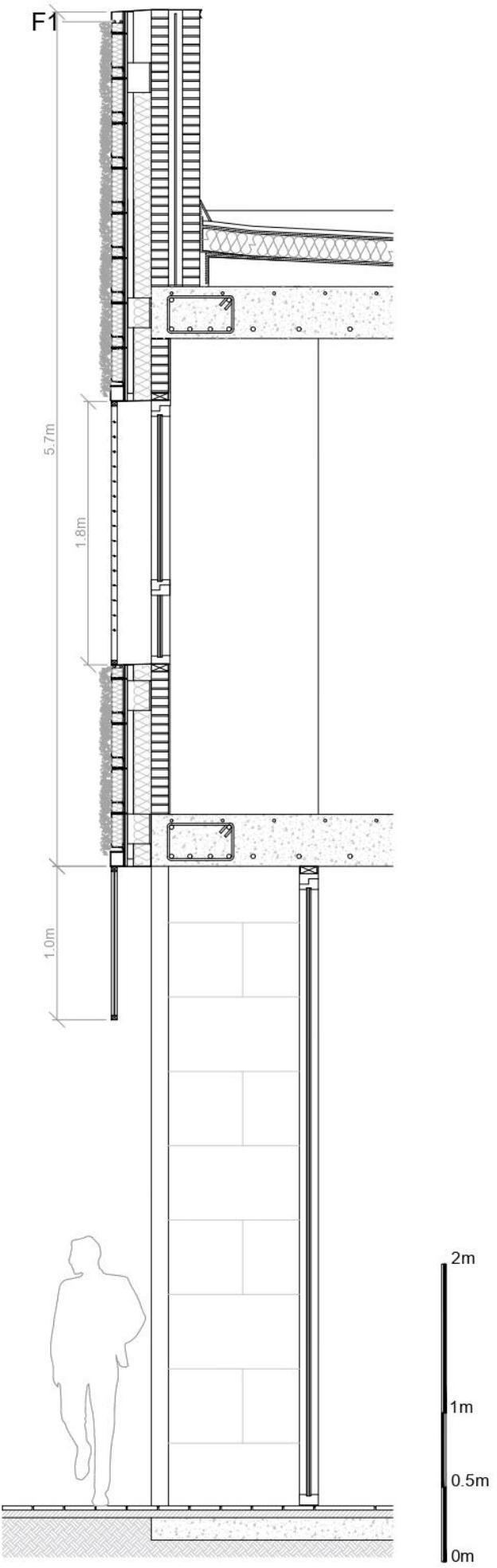
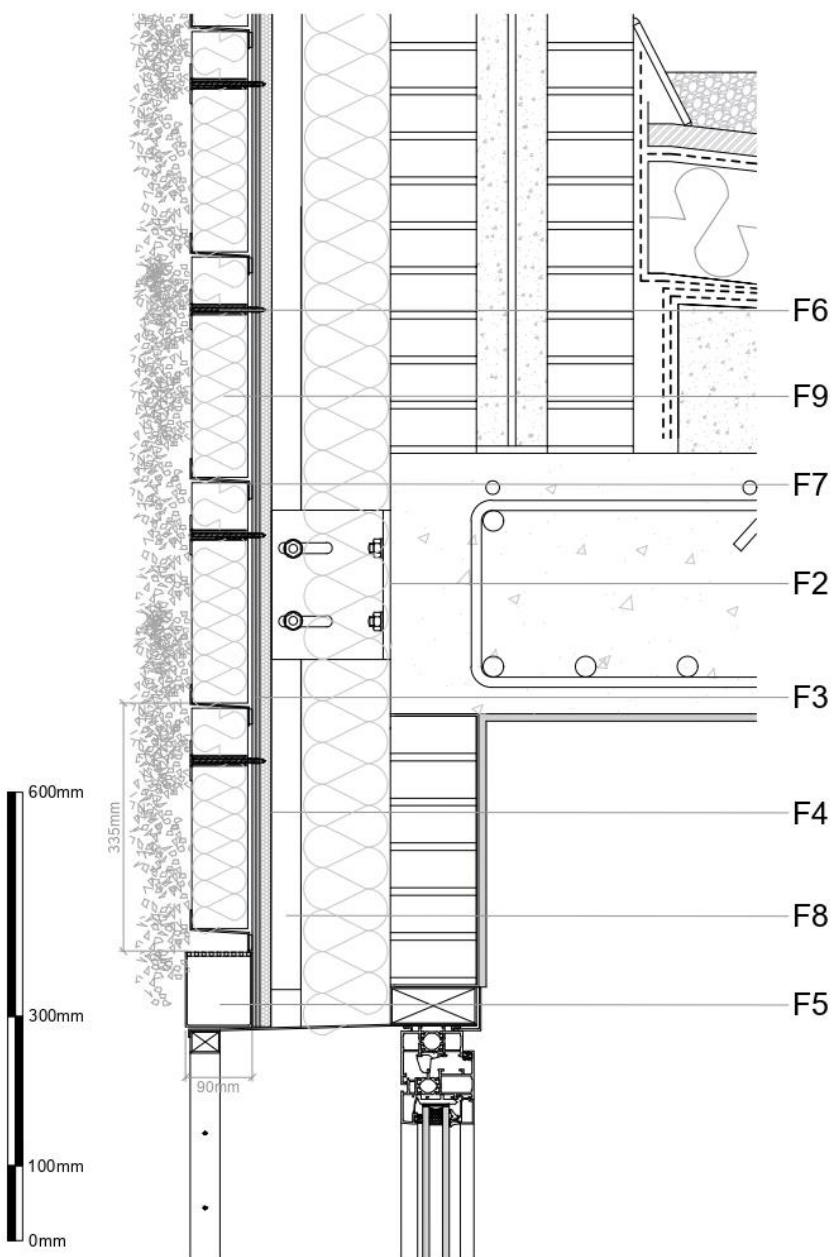
Plan 5: Constructive detail of the facade of the Poseidon building. Source: Own elaboration

- *F+P system*: This system developed by SingularGreen is similar to the one explained above for textile bags. In this case there is no solid substrate, but the plant species are directly rooted in the felt of the geotextile on which the aqueous solution with the nutrients runs. The greatest advantage of this system is the lightness it gives to the modules.

However, the company has improved this system by creating the F+P Preplant. Like the basic F+P system, it is supported by a metal structure made up of 40 x 40 mm tubes and a thickness of 3 mm. On this substructure, the corresponding waterproof panels are added on which the geotextile sheets are stapled through which the irrigation water will flow. The most positive aspect is the incorporation of a non-conventional substrate which is rock wool, normally used in conventional facades as thermal insulation. The panels are modulated to standard measurements of 100 x 60 cm and a thickness of 4 cm. This improvement in the system considerably increases the thermal behavior of the green facade without affecting its weight. The data translates into the addition of a resistance of 2,644 m². K/W, which means an increase of 270% over the existing insulation in the building's facade (Martínez, 2016).



Figure 12: Palacio de Congresos y Exposiciones Europa incorporating the F + P Preplant system, Vitoria - Gasteiz



- F1: Irrigation pipes. Double SG-R16 pipe.
 F2: Anchoring the structure. Anchor bracket.
 F3: Irrigation redistribution membrane. SG-M500 substrate.
 F4: Waterproof jacket. SG-P10 panel.
 F5: Water collection system. Grid and metal channel.
 F6: Plant support fastening. Aluminum deck SG-PL75.
 F7: Plant support fastening. Aluminum deck SG-PL75.
 F8: Supporting structure of the system. Aluminum profile 40 X 40 mm.
 F9: Inert substrate. SG-L50-100 panel.

Plan 6: Constructive detail of the facade of the Palacio de Congresos of Vitoria-Gasteiz. Source: Own elaboration

- *Vegetal concrete:* It is possible to talk about the LeafSkin system, developed by SingularGreen. It is a process that does not require a previous structural installation, so installation costs are drastically reduced. Different layers and membranes are projected on a concrete wall with the intention of waterproofing it and adhering the seeds of plant species to the wall.

At the level of thermal and acoustic comfort the contribution is dismissible, and aesthetically its resources are very limited since there cannot be a great variety of organisms capable of adapting to a concrete wall with these conditions.



Figure 13: Vegetal facade with biological concrete in the Prat Aeronautical Cultural Center.

3.3 Conclusions of constructive systems

After researching the different vertical garden construction systems, a summary table has been drawn up with the most important aspects to be taken into account when designing a green facade.

The following table shows the variety of characteristics offered by the construction systems on the market. It is not possible to highlight any of them above the others, as each of them has advantages over the others.

The construction costs in the following table are indicative, and in no way fixed. They depend on many factors, including the square meters that the vertical garden will acquire, the bigger it is, the more the price per square meter will be reduced. In the SingularGreen systems the prices are around 300 euros per square meter. However, the EcoBin system stands out, which could reach 400 euros per square meter. On the other hand, one of the most economical hydroponic systems is the LeafSkin (Vegetal Concrete), which can reduce its price to 150 euros/m² due to its method of planting, using the projection of seeds (SingularGreen).

System	Species	Cost	Maintenance	Thickness	Thermal isolation	Acoustic isolation	Installation time
Modular panels	Low-volume shrubs	459 €/m ²	Low	120 - 170 mm + Air chamber	Variable	Medium - High	Fast
Metallic gabions	Low-volume shrubs	295 - 400 €/m ²	Low	150 mm + Air chamber	Variable	Medium - High	Fast
Textile bags	Low-volume shrubs	400 €/m ²	High	70 mm	Medium - High	Medium - High	Fast
Plastics or ceramics cells	Low-volume shrubs	300 - 400 €/m ²	Medium - High	290 mm + Air chamber	Medium	Medium - High	Slow
Panels F+P	Low-volume shrubs	250 €/m ²	High	20 mm + Air chamber	Medium - High	High	Medium
Vegetal concrete	Mosses and lichens	150 €/m ²	High	—	Non-existent	Non-existent	Fast
Classic green wall	Climbing plant	Low	Low	—	Low	Low - Medium	Fast
Double skin	Climbing plant	45 €/m ²	Low	100 mm + Air chamber	Low	Low - Medium	Fast
In situ planters	Low-volume shrubs	Variable	High	Variable	Low	Low	Slow

Table 3. Summary of the comparison between the construction systems on the market. Source: Own elaboration

However, the maintenance cost of hydroponic systems that require greater monitoring than others due to their complexity can be highlighted.

On the contrary, systems using climbing species require less maintenance and also installation costs. However, the use of these systems is more likely to lose out on other factors such as acoustic and thermal insulation.

A wide variety of systems have been seen. This is due to the different conditions required for the buildings being designed today. The first difference can be seen in whether it is a public building or a block of flats. In a residential building, it is necessary to take into account that the maintenance costs will be contributed by the resident's association, which would make it possible to opt for the use of systems with low installation and maintenance costs, for example, a double-skin system.

Likewise, the façade of an isolated residential block cannot be designed in the same way as a block between party walls. The space occupied by the system, the speed of installation and the amount of light it allows to pass through the openings are factors to be taken into account, especially in places such as Ciutat Vella, where the buildings in party walls are located on narrow streets with little natural light. In this case, a good construction system would be a hydroponic system such as that of textile bags which, as it has no substrate, acquires less thickness. On the other hand, it would be necessary to evaluate the economic costs of maintenance that could acquire the vegetal facade.

In the case of a hotel, the economic relevance is less and aspects such as the way of relating to the interior architecture acquire importance. In this type of programme a good solution would be to opt for a system of planters in situ, as in Hotel Renaissance by Jean Nouvel in L'Hospitalet de Llobregat. In this case, the architect manages to turn a simple vertical access through a staircase into a visual spectacle by creating an interior atmosphere while being outdoors.

In public buildings it is also necessary to assess what are the requirements of the program of its interior. In the case of a school, factors such as acoustic and thermal insulation will be of great importance. On the other hand, in a library it will appear as a relevant factor how light enters the building. In these cases, the choice of a system can be more varied as the economy becomes dependent on the administration, which can provide more freedom. However, functional and architectural quality factors take on greater relevance.

4. Vertical gardens in Barcelona

Barcelona has a Mediterranean climate, characterized by a dry climate, warm in summer and humid throughout the year. The results obtained from research confirm that, in the case of Barcelona, springs and winters are synonymous with higher rainfall, making them the wettest seasons of the year. On the other hand, July sees the highest temperatures of the year, so it is the time when the effects of vertical gardens can be most appreciated with regard to thermal comfort.

City of Barcelona				
Catalonia, Spain				
Latitude 41.5 N 2.1 E				
Climate				
Type Mediterranean climate	Maximum average temperature (°C) 20	Minimum average temperature (°C) 16,5	Average precipitation (mm) 599 mm	Humidity (%) 64
Radiation				
Horizontal global (W/m ²) 174	Horizontal diffuse (W/m ²) 61			

Table 4. Environmental characteristics of the city of Barcelona. Source: (Rojas, Roset, Navés, 2015)

After explaining the contributions of green walls and facades to their environment, it is possible to confirm the benefit of these natural structures. However, in Catalonia there are many conditions regarding the density of cities. It is not possible to compare the density of cities like Lleida or Girona with the capital of the Autonomous Community. For this reason, at an urban level, Barcelona is a great example where vertical gardens can be implemented, as it would be possible to mitigate the "urban heat island" effect and contribute to the reduction of greenhouse gases expelled into the atmosphere by the activity of the cities.

On the other hand, investing in vertical gardens in the densest cities of Catalonia implies a new strategy of introducing vegetation into the city that avoids land occupation.

Likewise, since the first oil crisis, the aspects surrounding the environmental sustainability of cities have been masked by economic policies. However, in recent years, environmental issues have taken on increasing importance, becoming one of the most prominent topics on political agendas. A good example is the initiative of Barcelona City Council, which promotes greater involvement of vegetation in the city, not only in public spaces, but also on the facades and roofs of buildings.

The city of Barcelona has created the Barcelona 2020 Biodiversity and Green Plan. The city's most representative green systems appear in the plan. Each of these systems has been assessed on the basis of qualities, from the quality of the habitat to cultural interest.

The following table shows the assessments that Barcelona City Council has made of the attributes of the green facades:

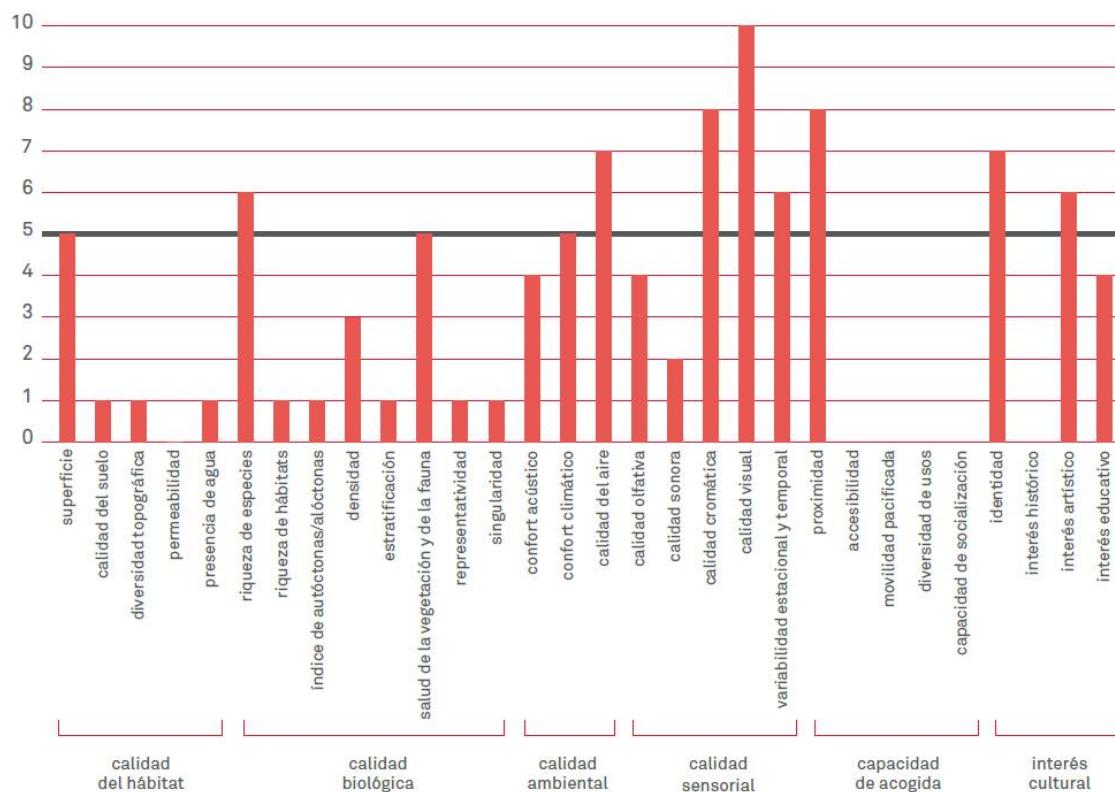


Figure 14. Attributes of green facades. Source: Plan del verde y la biodiversidad de Barcelona 2020

According to the graph, vertical gardens generate a wealth of species while improving the air quality of the city. On the other hand, this type of facade can create an attractive aesthetic for the public with a variety of colors.

The most outstanding values of vertical gardens are environmental and sensory, which greatly helps the purpose of architecture, which is to achieve a benefit for both the city and the building. For this reason, Catalonia is trusting in the implementation of this type of facades, even awarding prizes for their construction, as is the case of the vegetal facade of the Espai Tabacalera (Tarragona) in 2014. However, today the dismantling of the plant structure has just been ordered due mainly to maintenance problems.

In the documentation for the Barcelona 2020 Biodiversity and Green Plan, it is highlighted that Barcelona has 3,611 hectares of green areas, of which 30% are urban, 50% correspond to the municipal part of the Collserola Park and the remaining 20% belong to private property. In comparison with other provinces, Barcelona has 6.6 m² of green surface/house, which places it in second position behind the Community of Madrid.

One of the big problems with the city's plant structure is the lack of connectivity of green spaces and the small size of these, as 57% of the plant areas are less than 1,500 m². Finally, to date there has been a shortage of investment and confidence in vertical gardens and green roofs (Barcelona 2020 Biodiversity and Green Plan)

The following graph shows the vegetation of the city compared to the density of the inhabitants. Differentiating the different districts. There are three types of districts depending on the relationship between the vegetation and the inhabitants. Places like Sants-Montjuïc, Sarrià-Sant Gervasi and the Eixample have a large amount of free space that forms a dispersed urban environment. There are other neighborhoods where the relationship tends to be balanced. However, neighborhoods like Ciutat Vella and Gràcia are made up of high-density environments where public space is insufficient. For this reason, it is in these areas where the inclusion of vegetation is most important.

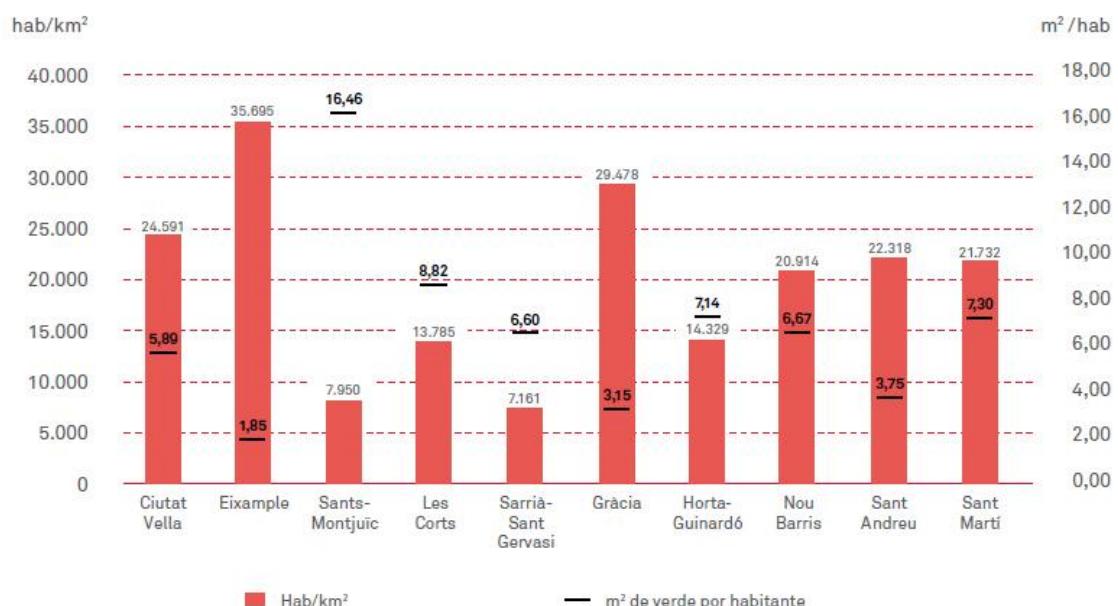


Figure 15. Comparison of the density of inhabitants and vegetation by districts. Source: Plan del verde y la biodiversidad de Barcelona 2020

In conclusion, it is in these denser areas where the plant facades can become more important due to the lack of public space. Likewise, by combining investment in this type of facade with the trends in Barcelona towards the disappearance of the automobile, an urban environment with air quality favourable to the city's health can be achieved.

5. Relationship between space and facade

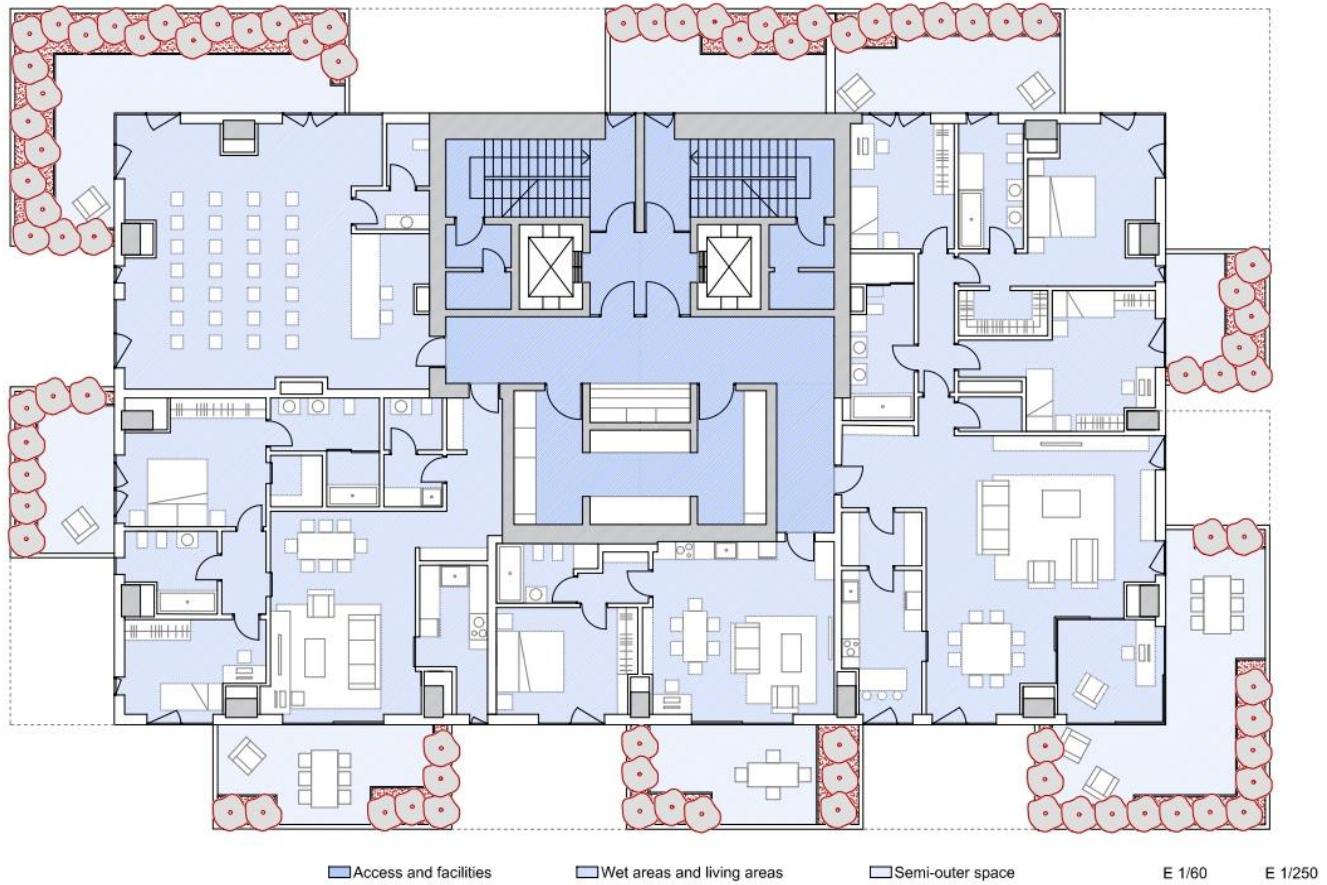
5.1 Bosco Verticale, Milan

This project, carried out by Boeri studio between 2007 and 2014, is located in the Italian city of Milan. This new architecture aims to expand the relationship between man and other living species in their daily lives. The project is part of a new architectural prototype focused on biodiversity. In this case, it involves the construction of two towers of 80 and 112 meters high that house a total of 800 trees and around 5,000 bushes, the equivalent of 30,000 m² of horizontal green surface (Boeri Studio, 2014).



Figure 16. Bosco Verticale project, Milan

The architects of the project intend to propose a clear and innovative solution to the current proposals to introduce green spaces in dense cities. When they create a vertical garden, the occupation of urban land with vegetation is limited.



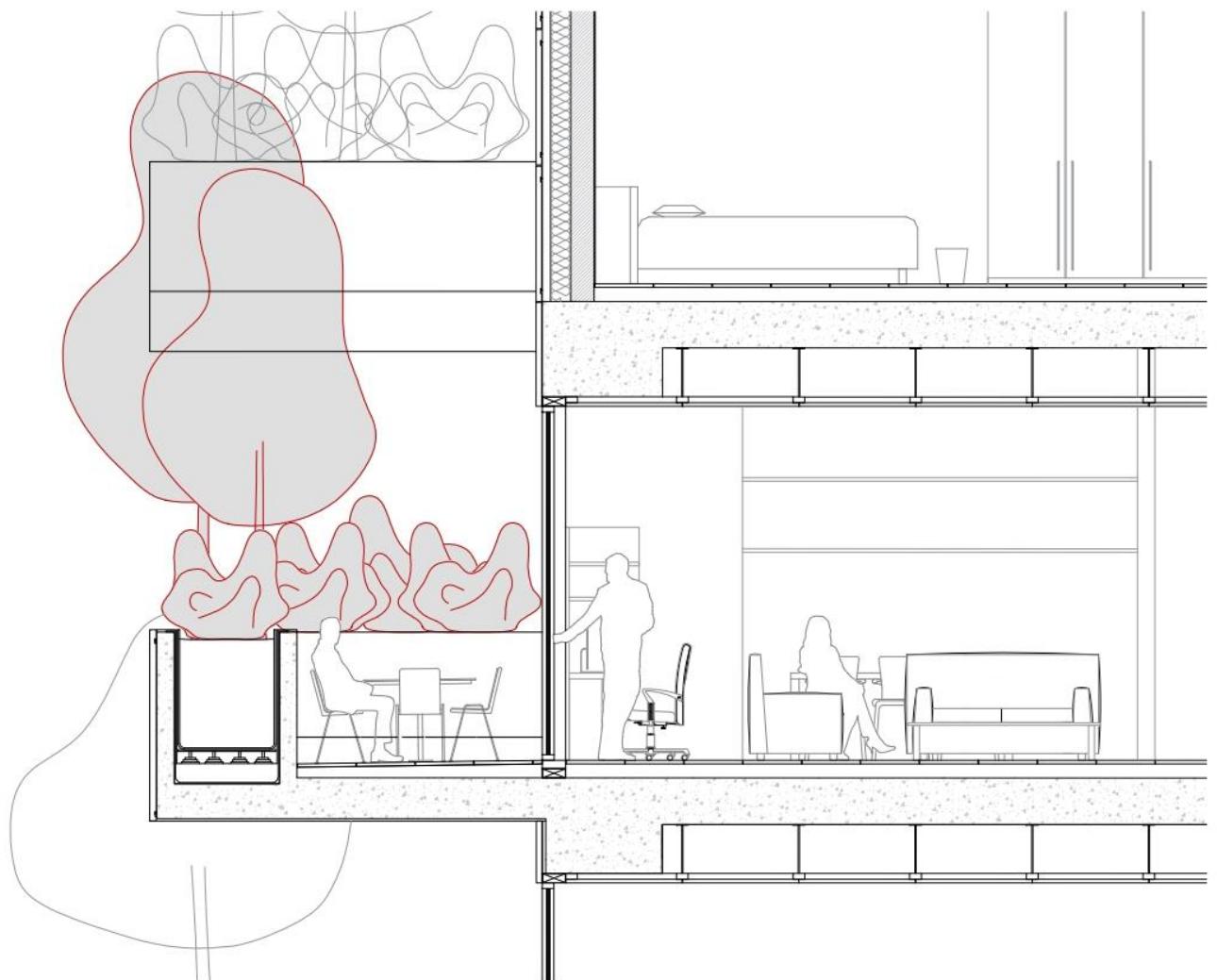
Plan 7: Standard plan of one of the towers of the Bosco Verticale project. Source: Own elaboration

In the previous plan you can see the floor plan of one of the two towers which will serve to explain the relationship established between the vegetation and the architectural space which in this case is for residential use.

The contour of the building can be compared to a high rise. The vertical reinforced concrete structure is formed by a perimeter of rectangular pillars and a nucleus displaced to one of the facades to absorb the forces of the wind. From this point onwards, the functional scheme of the buildings accompanies the structure, i.e. the vertical accesses, the technical spaces and the installation steps (dark colour) are incorporated inside the core.

On the second gradient are the different types of dwellings, following a radial distribution in the interior, leaving, as far as possible, the wet areas in the interior area and the living areas next to the facade (intermediate colour).

Finally, the perimeter of the facade is surrounded by a series of balconies with a 3 meters cantilever to house the planters where the vegetation will be planted (light colour). The differentiation of the plants in height helps to create a play in the terraces that makes that there are not 2 continuous plants with the aligned balconies. In this way, it is possible to place the highest vegetation, such as small trees.



Plan 8: Constructive detail of a terrace of the Bosco Verticale project. Source: Own elaboration

Observing the general plan and the section at the same time, it is possible to understand the complexity that the visuals acquire towards the outside from the inside of the house. The entire semi-outdoor space is surrounded by vegetation, which makes a clear view of the city impossible. However, in most of the terraces there is a zone free of vegetation that allows a strategic view.

Just as in many buildings the terrace is perceived as an addition that stands out from the building's facade, this is not the case of this project. From the outside, an overwhelming amount of

vegetation is perceived, making it impossible to clearly distinguish where the facade is. On the other hand, from the balcony, the shade and microclimate generated by the vegetation causes a sensation of not having left the interior of the house. Other factors such as the similarity of the pavement between the terrace and the interior and the large windows that open up to the balconies enhance the relationship that is established between both spaces. In a way, it can be said that it is possible to eliminate the carpentry from the facade and the set of balconies and the living area would form a unit.



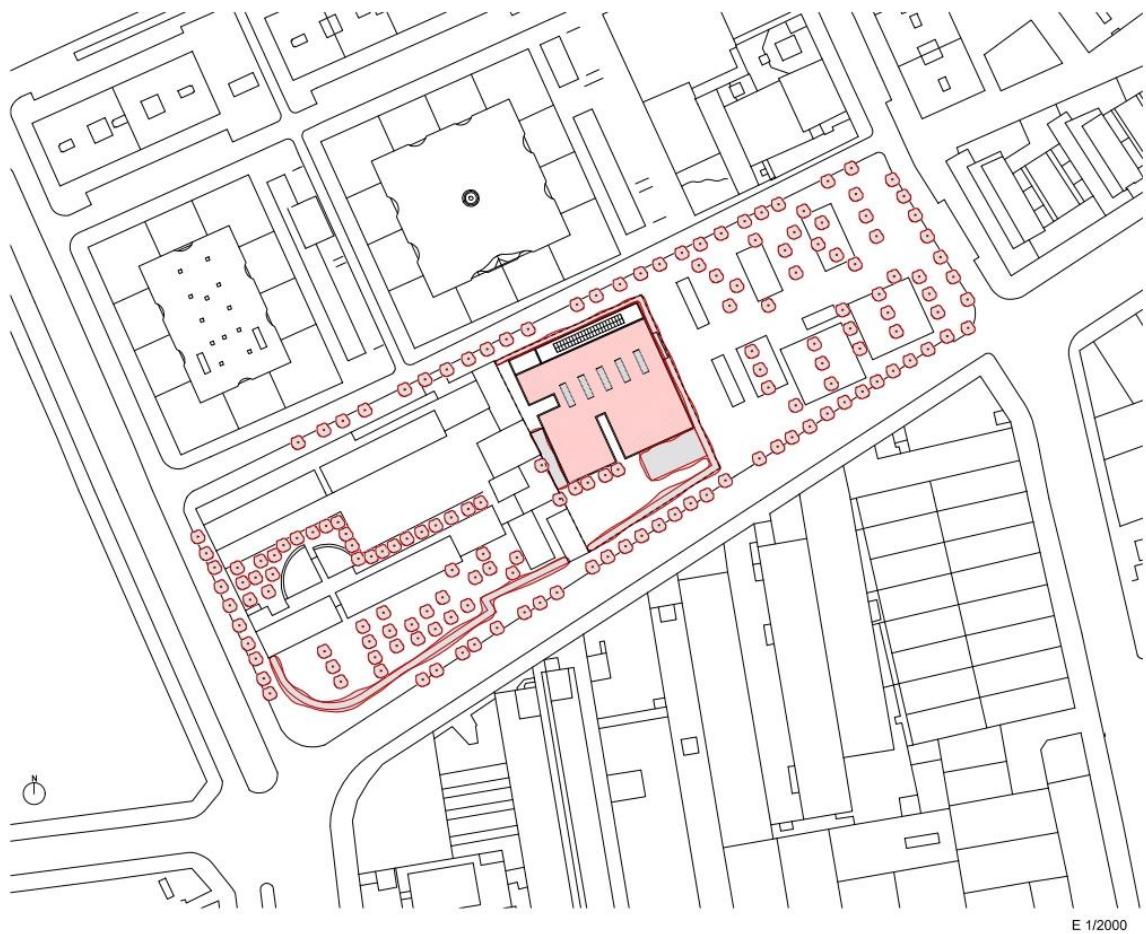
Figure 17: Photograph from inside to outside area

5.2 Baró de Viver civic center, Barcelona

This civic center was built in 2014 and designed by the architects of Territori 24. The building achieves a high quality in its spaces and is energy rated with an A, despite having a budget 34% lower than the average of public facilities in the city of Barcelona. The building incorporates 1,700 m² of equipment with different programs such as leisure areas, workshops and exhibitions.



Figure 18. Render of the exterior image of the green facade of the Baró de Viver building. Source: Territori 24

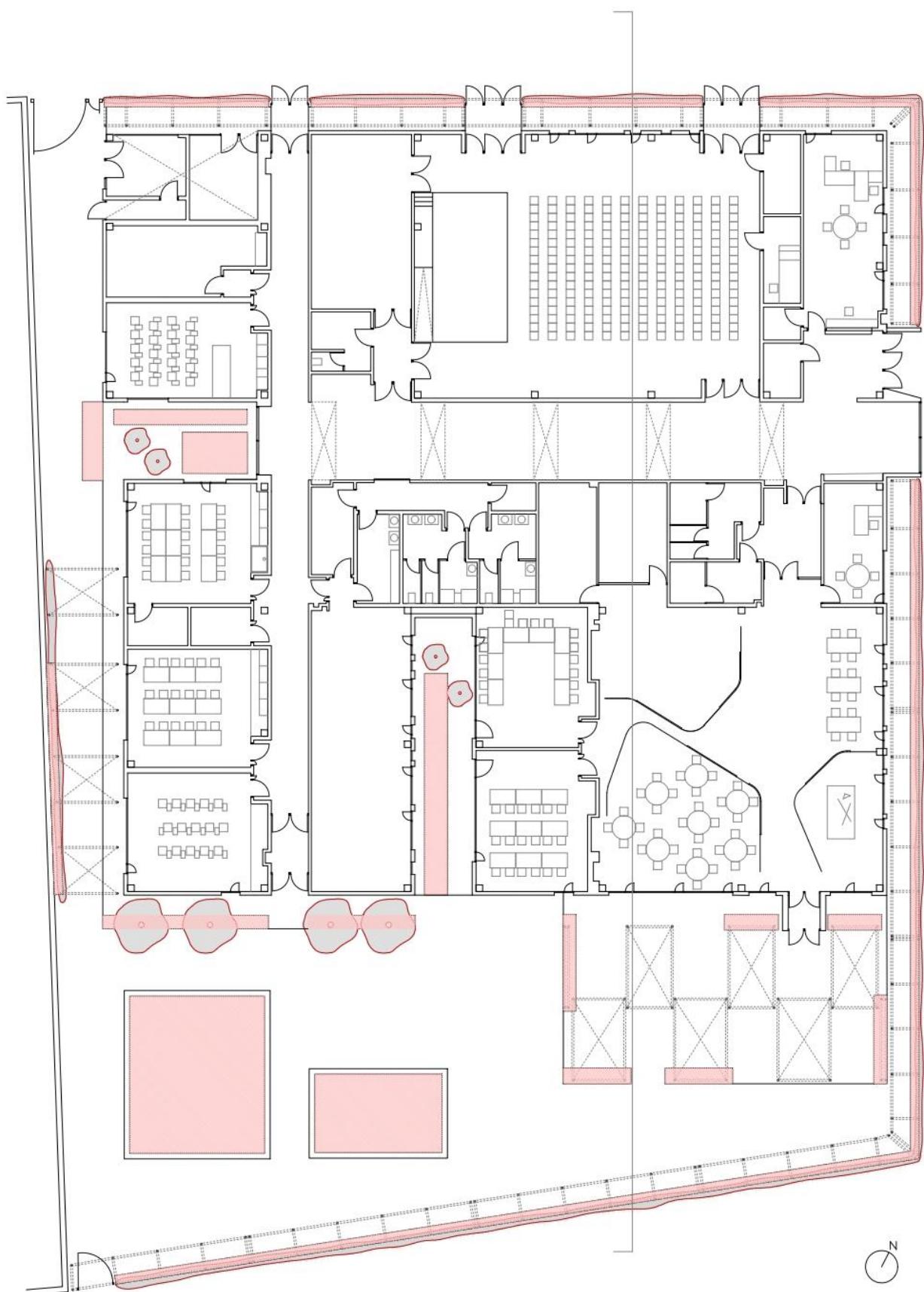


Plan 9: Site plan of the Baró de Viver project. Source: Own elaboration

In the above location map, the block where the civic center is located has an attached nursery school. Although they are two different projects, both share the same building system when creating the boundary of the plots. It is a fence that acquires a great thickness to be able to introduce vegetal species in it and to create a green wall. Although it only appears in the school in the south and west zones, the civic center is completely surrounded by it.

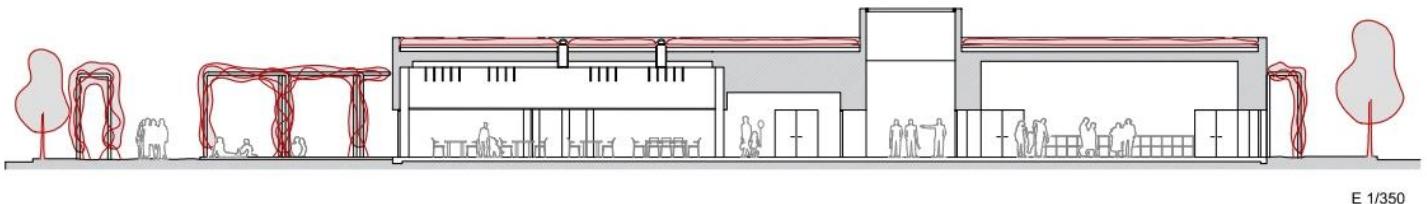
On the other hand, it should be noted that this enclosure with a green border does not end there, but rather aims to achieve a greater dimension by growing at different points in the form of a pergola and even joining it with the green roof.

In the following floor and section plans it can be seen with greater precision how the vegetation limit acts at different points on the perimeter of the building, that is, the relationship of the vegetation facade with the space is different according to the orientation of the building's facade. Along the northern and much of the eastern facade, the plant boundary and the functional envelope of the building acquire a significant thickness, which can be accessed for maintenance reasons, although the intention is for both facades to form a unit.



Plan 10: Plan of the distribution of the Baró de Viver civic center. Source: Own elaboration

E 1/2000 E 1/300



Plan 11: General section of the Baró de Viver civic center. Source: Own elaboration

E 1/350

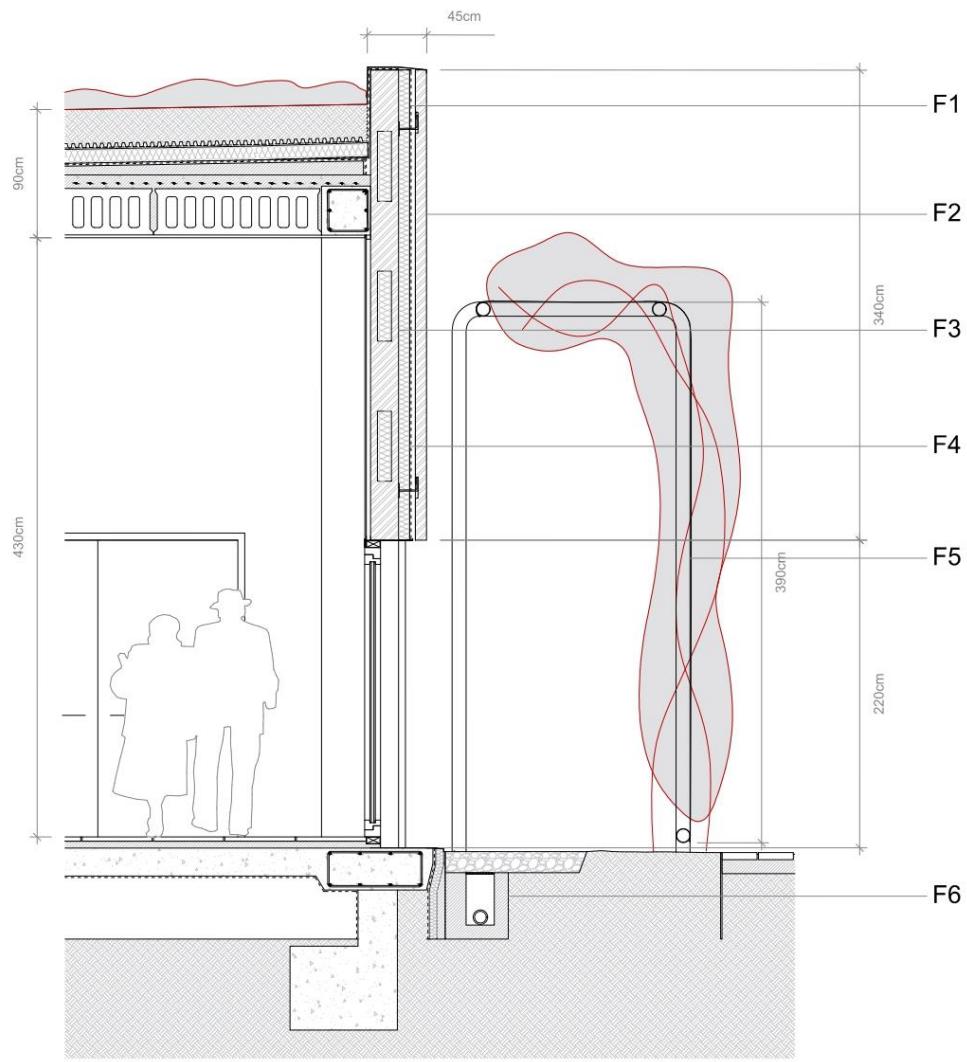
On the other hand, in the southern part of the site, the two facades begin to function by themselves, leaving the function of the building's envelope to the concrete panels and the land's limit to the plant structure. This generates a large patio to the south of the plot with an external filter that cannot be physically crossed, but visually through the climbing plants.

To further enhance the nature in this space, the entire courtyard is formed by a natural grass pavement, leaving only a few strategic points where a concrete slab rises. In this way, the open leisure space is totally differentiated from the perimeter access for maintaining the plant filter.

The following section of the construction shows the thickness of the building envelope added to the green facade. Both work independently as they never touch each other. For this reason, it is possible to create the plant filter that generates different spaces.

The thermal, structural and watertight envelope resides in the interior facade which consists of an upper and a lower part. The upper part consists of a lightweight structural panel of 20 cm, accompanied by a vapor barrier, a 2 cm air chamber and a 10 cm thick insulation. An 8 cm thick panel with an outer layer of aggregates of different shades is used for the finish.

On the other hand, the lower part has a wooden finish and is supported by metal profiles where the thermal insulation is included. All these elements are accompanied by a vapor barrier and a tyvek.



E 1/40

- F1: Polyethylene vapor barrier
- F2: White concrete and basalt aggregate finisher panel. $e = 8\text{cm}$
- F3: Lightened structural panel. $e = 20\text{cm}$
- F4: XPC extruded polystyrene. $e = 8\text{cm}$
- F5: Galvanized steel structure with tubular profiles of $\varnothing = 15\text{cm}$ and $e = 3\text{mm}$
- F6: Perimeter system for collecting water from the concrete deck with a conduit channel.

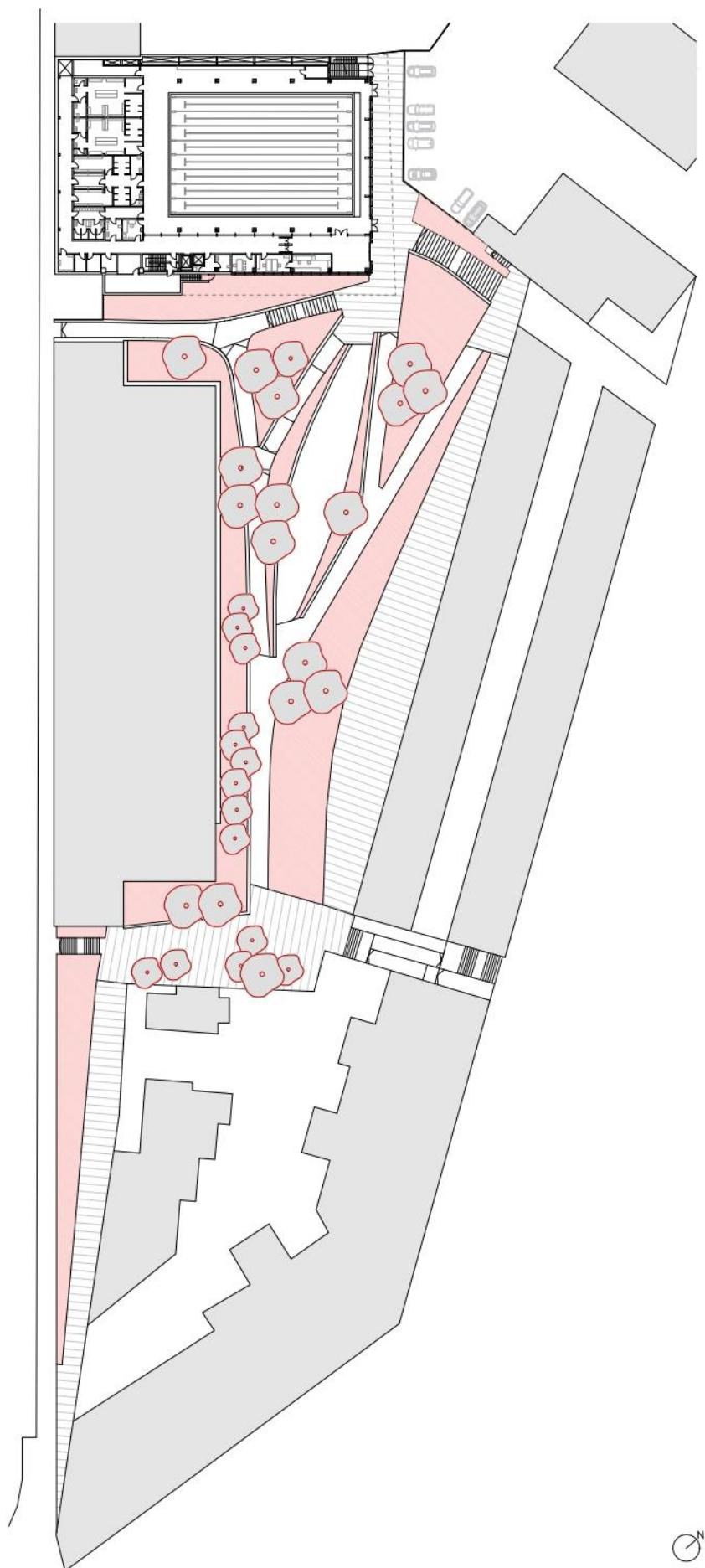
Plan 12: Constructive detail of the green facade of the Baró de Viver building. Source: Own elaboration

5.3 Turó de la Peira Sports Center, Barcelona

This sports center was designed by architects Anna Noguera and Javier Fernández in 2018. The construction is very complex in relation to the urban fabric of the city due to the physical and social situation. Before the intervention, the team of architects faced an abandoned space without any urban organization and with a shortage of architectural, landscape or social values.

The first strategy of the project was to organize the program of sports tracks and swimming pools in height, which allowed a large part of the space within the block of the area to be liberated.

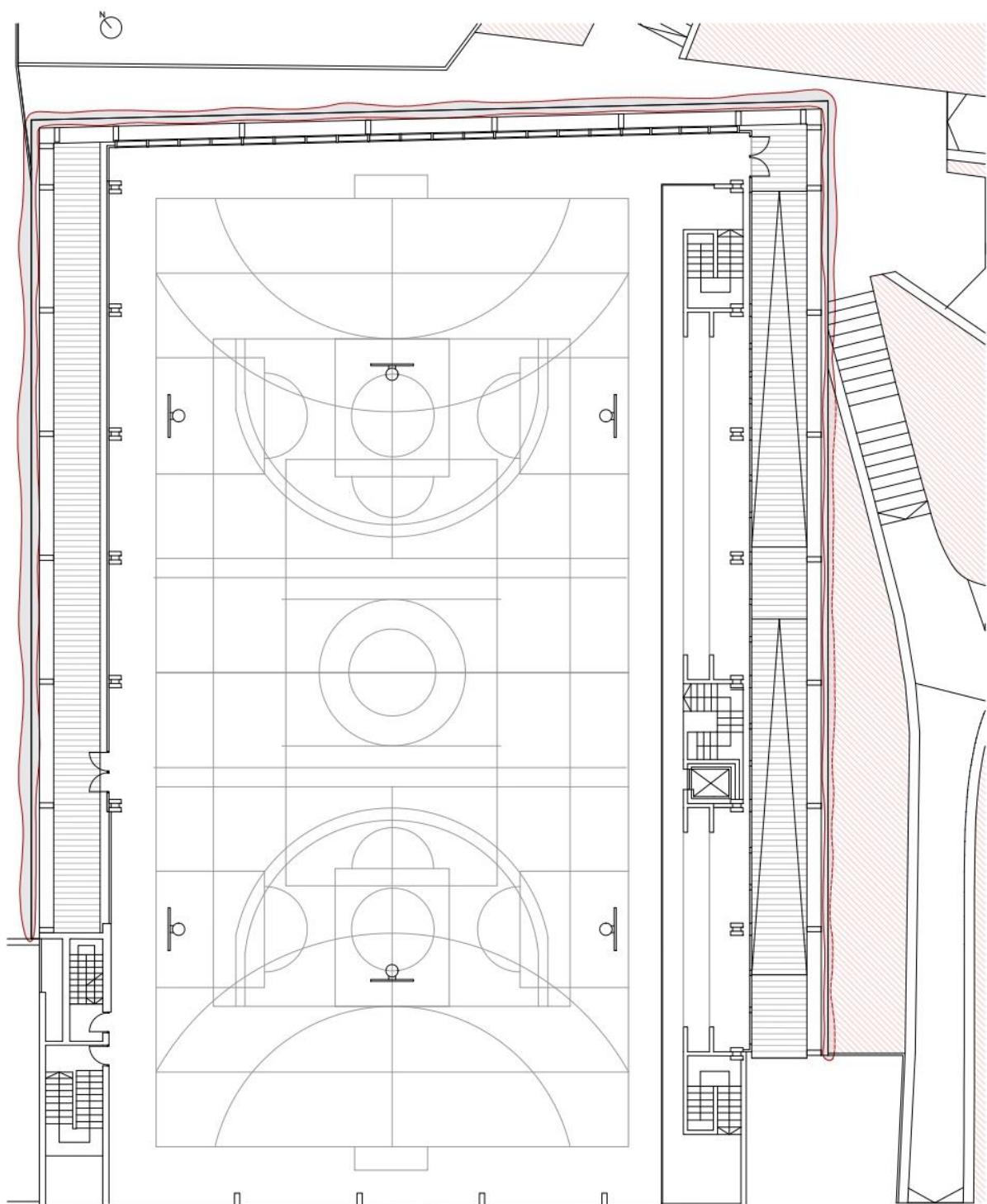
The following plan shows the new relationship between the place and the building through the incorporation of vegetation. In this way, the architects manage to generate a new social meeting point to reactivate the place. The ground floor of the building is equipped with a program of indoor swimming pools, a large area of changing rooms, toilets and a reception.



Plan 13: Site plan of the Turó de la Peira project. Source: Own elaboration

E 1/1000

One of the most outstanding characteristics of the building is the position of the main entrance, located on the facade opposite the main street. The position of this is due to the intention of the architects to enhance the interior of the block.



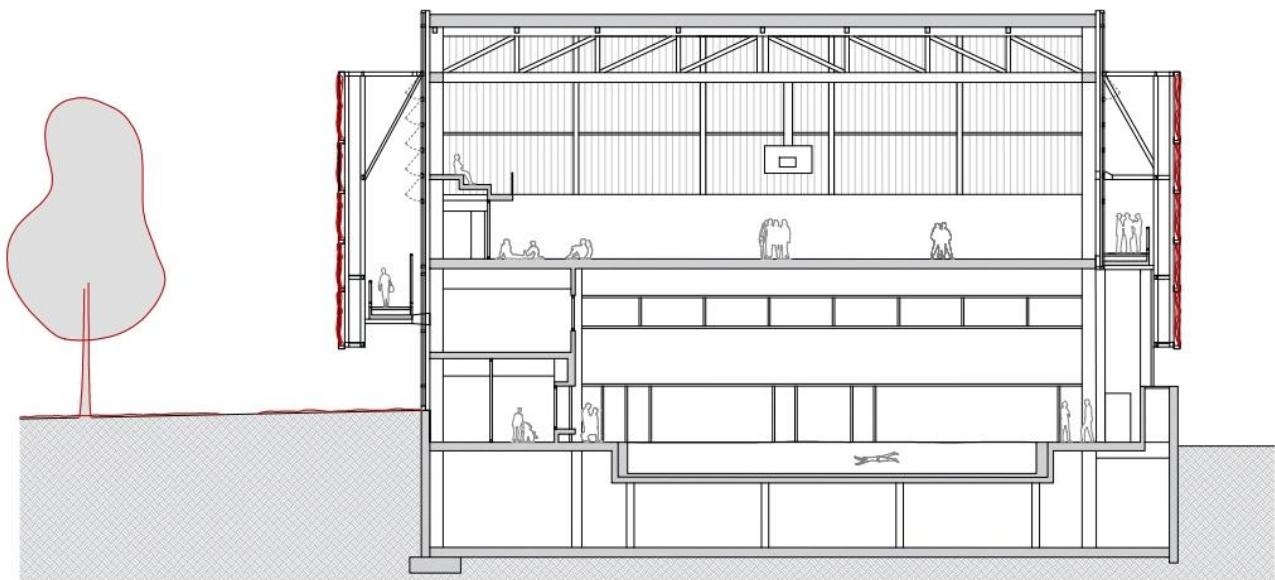
Plan 14: Plan of the upper floor of the sports center. Source: Own elaboration

As shown in the map above, the second-floor program is dedicated to a large sports court and is accessible by elevator and stairs. However, the building encourages access from the main street through a perimeter walkway under a porch, so that on the top floor there are horizontal perimeter communications, leading the designers to create an architectural space in this walkway.



Figure 19: Perimeter ramp access to the upper floor of the building

As can be seen in the next section, the proposed solution is the construction of a green facade that leaves the walkway in an intermediate space, protected from external views, but physically open.



Plan 15: General section of the Turó de la Peira sports center. Source: Own elaboration

On the other hand, the vertical garden causes a continuity of the park inside the block, fully involving the building in the urban fabric. However, this second vegetable skin does not reach the ground, leaving a ground floor without any kind of filter.

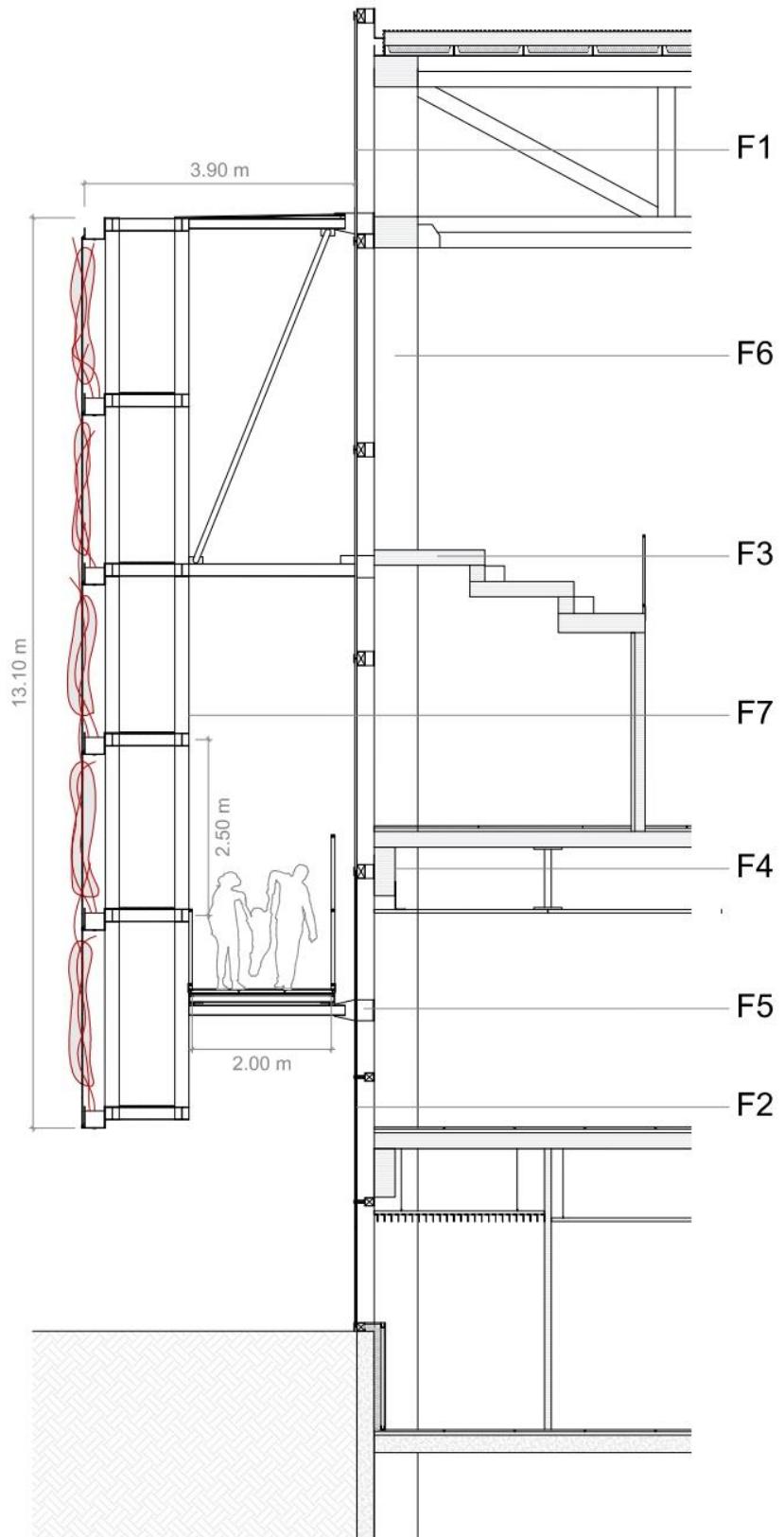
As in the Baró de Viver civic center, the vegetation used is of climbing species due to its good functioning as an architectural filter between spaces. For this reason, the system used is based on the placement of small planters attached to a metal mesh where the climbing plants can be supported and grow.

In the constructive detail, it is possible to clearly differentiate where the thermal and watertight envelope of the plant filter is located. The interior facade is formed by a wall of rods with metallic profiles that is supported by the wooden structure of the building. It is worth noting the change in the facade material as the building reaches height, as it moves from a glass envelope to a polycarbonate wall due to the programme of its interior.

The perimeter platform is two meters wide, allowing for fluid circulation, but also allowing for exit to the outside while remaining inside the building envelope protected from the visions.

This envelope provides great protection against the incision of direct light to the perimeter platform and to the interior of the building. However, the architects decided to improve the protection against direct light with polycarbonate panels that turn it into a diffused light that allows the comfortable development of sports activities.

Finally, there are openings in this facade that generate a renewal of the natural air inside the building. This effect is enhanced by the green facade, which reduces the temperature behind its green barrier and allows for renewal with higher quality air.



E 1/100

- F1: Stick wall with a polycarbonate screen with $e = 60 \text{ mm}$
- F2: Stick wall with a glass screen
- F3: Slab of laminated wood, type CLT with $e = 226 \text{ mm}$
- F4: Wood plywood girder
- F5: Galvanized steel anchor for joining wood and steel
- F6: Glued and laminated wood structural pillar
- F7: Galvanized steel structure. Green facade support

Plan 16: Construction section of the facade of the sports center. Source: Own elaboration

6. Conclusions

After carrying out the first part of the work, it is possible to confirm that the vertical garden can become a type of facade widely used by today's architects, as it combines an attractive aesthetic for the citizen, while providing positive environmental and comfort values. However, these values are conditioned by the construction system used as not all of them provide the same characteristics. For this reason, it can be said that, when designing a green facade, it is easier to offer an urban environmental improvement rather than thermal comfort inside the building, since the values that make up the urban scale depend to a greater extent on the vegetation and not on the construction system used to place the vegetation.

On the other hand, we can highlight the very small number of companies dedicated to innovation in green facade construction systems. Furthermore, the information that can be acquired on the websites of these companies is scarce and sometimes confusing. However, these companies include an extensive catalogue of projects in which they have participated with their systems.

Some companies offer complete systems for sale. However, it is the architect who can decide whether to manipulate the system to create a mixed one, for example, in the power station of Barcelona, where the gabion becomes a mesh that rises vertically to support climbing species.

In Barcelona the need has arisen to introduce green in the city. However, after studying the Biodiversity and Green Plan of Barcelona 2020, a great imbalance in the distribution of the city's vegetation can be observed. There are districts that are so dense that the most effective way of introducing vegetation into their streets can be from the creation of green facades in the rehabilitation of buildings.

Finally, through the three cases studied, the influence of the green facade towards the interior space of the building has been verified. In all cases the vegetation has had the common function of controlling the visuals both from the outside of the building and from the interior. However, in each one of them it has achieved this by establishing limits to the space and relating them in one way or another to the space inside or outside the building. (Hablar del confort térmico y acústico)

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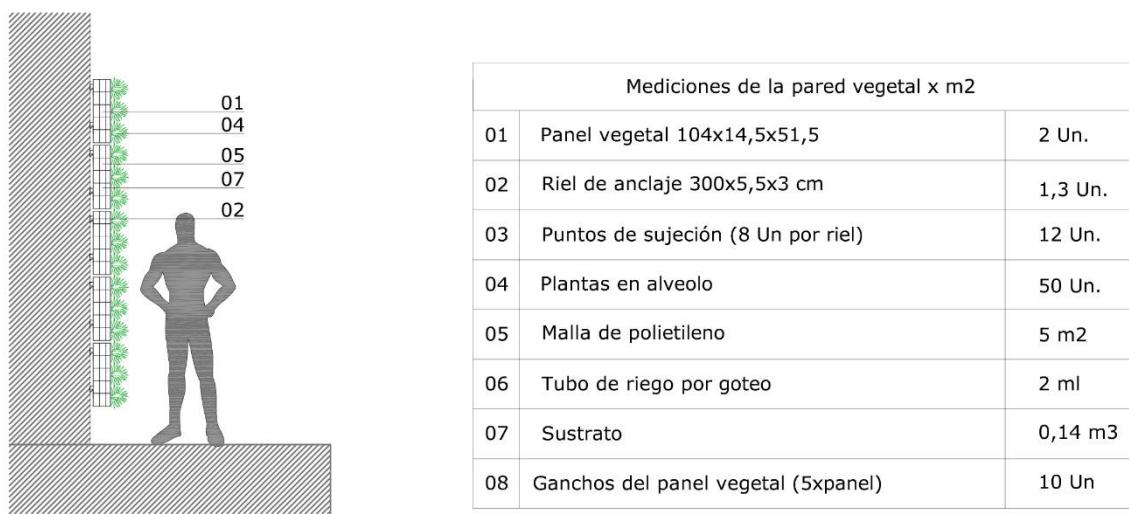
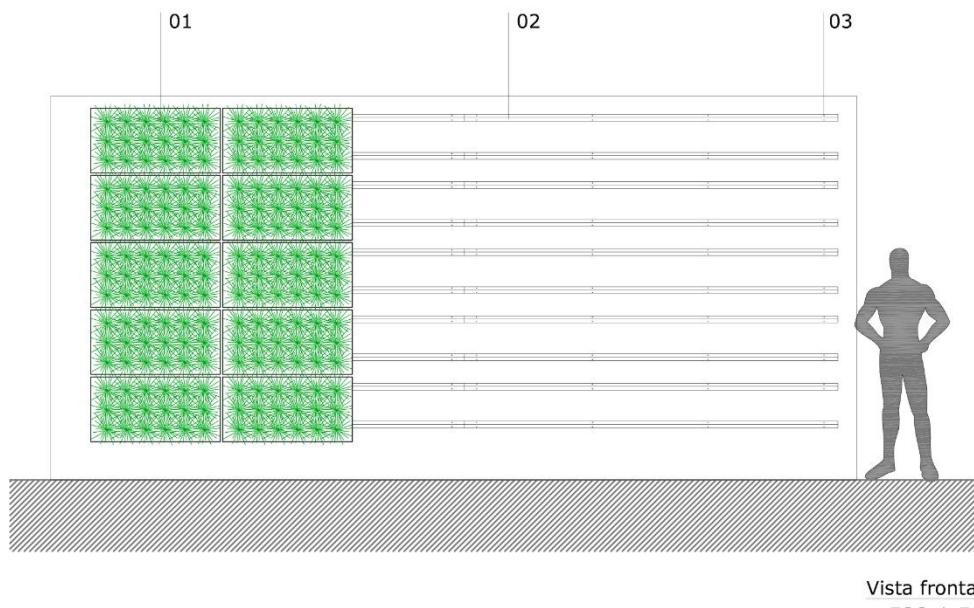
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9. Annexes

Annex A



Vista lateral
ESC. 1:50

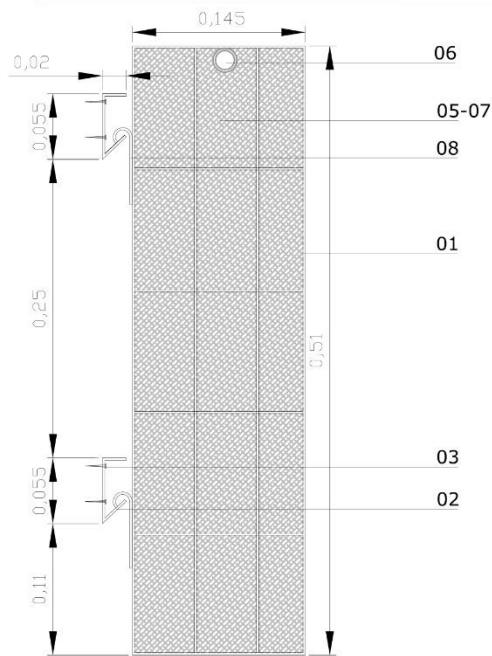


Pared vegetal Babylon

02

Ctra N- 141 Km 107-17162
Bescanó - Girona

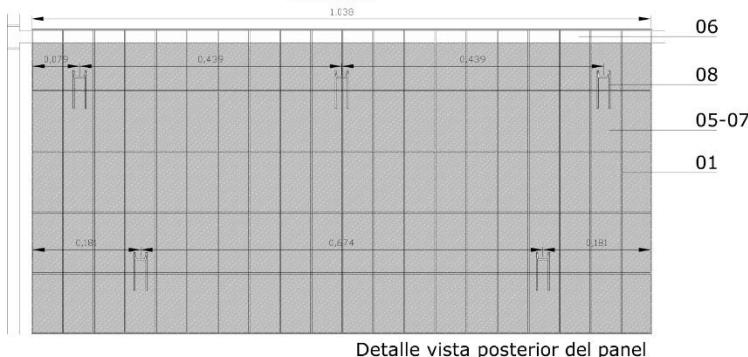
www.v-ter.com / viventer@v-ter.com
Apdo. 30-17160 Anglès-Girona



Detalle vista lateral del panel



Panel enganchado en el riel



Detalle vista posterior del panel



Estructura de alambre del panel vegetal



|04

01

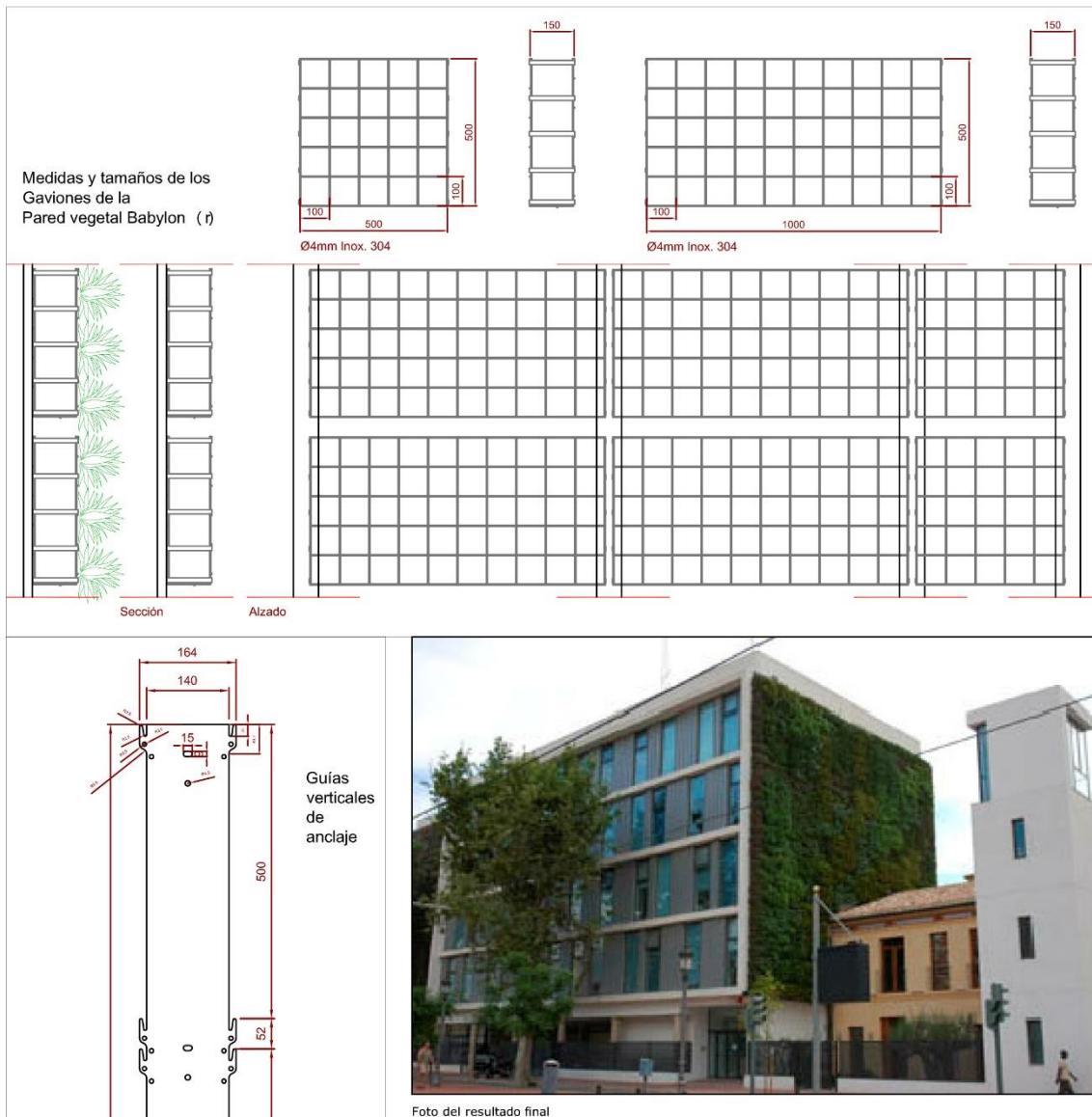


06 02 01



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Detalles técnicos constructivos de la PARED VEGETAL BABYLON (r)



Gaviones de acero inoxidable de dimensiones 100x50x15 cm o 50x50x15 cm. La sujeción de los gaviones a la pared o estructura se realiza mediante guías verticales fijadas con tornillería metálica tipo Fischer FBN. Precultivo y plantación en vivero de las especies vegetales para garantizar el correcto funcionamiento y efecto estético inmediato des del mismo momento de su instalación en obra.

APLICACIONES: Sistema modular de pared vegetal para recubrimiento de paredes exteriores o interiores.

COMPONENTES PARED VEGETAL BABYLON	
MÓDULOS	GAVIÓN de acero inoxidable de 100x50x15 cm o 50x50x15 cm
PERFILERÍA DE ANCLAJE	Perfilería horizontal o vertical fijados a la fachada o estructura auxiliar
PESO aprox.	100 Kg/m ² en saturación de agua y plantas
RIEGO	Tubería de riego Uniboline a cada 50 cm en altura
PLANTAS	Seleccionada en cada proyecto según orientación y ubicación de la fachada
SUMINISTRO Y MONTAJE	
1. Precultivo en vivero	
2. Transporte del material a obra	
3. Preparación de la superficie. Fijación de las guías de anclaje a la fachada o estructura auxiliar.	
4. Colocación de los gaviones con planta en la perfilería	
5. Montaje del sistema de riego	
REQUISITOS	
Fachada o estructura auxiliar que soporte mínimo 100 kg/m ² .	

Annex B



MEMORIA TÉCNICA
SISTEMA F+P – Revisión 01/11

MEMORIA TÉCNICA SISTEMA F+P

DESCRIPCIÓN

Sistema de jardín vertical F+P para fachadas destinado a la plantación de especies vegetales con pendiente comprendidas entre 30º y 90º compuesto por estructura metálica portante dimensionada según solicitudes de carga a viento y estado del soporte, módulos rectangulares Ug-P20 de estructura impermeable de doble capa, sustrato tejido no tejido Ug-M500 y plantación de especies vegetales de variedades idóneas para el clima de la zona (seleccionadas en colaboración con la dirección facultativa) a razón de 40 plantas/m². Incluso instalación de riego Ug-RF, mediante tubería hidroporosa.

COMPOSICIÓN DEL SISTEMA

- Capa 0: Rastrelado de perfiles metálicos. Dimensiones según solicitudes de carga a viento y estado del soporte.
- Capa 1: Módulos rectangulares Ug-P20 de PE EXT expandido 906 Ug-P10 20mm.
- Capa 2: Tejido no tejido de poliéster-algodón Ug-M500, espesor 1,5mm + 1,5mm.
- Capa 3: Cobertura vegetal de especies seleccionadas según ubicación y características de la fachada.

ESPESOR DEL SISTEMA (en mm)

Grosor Total : 20 mm

PESO TOTAL DEL SISTEMA (EN KG/M²)

Capas 1 y 2: 10 kg.

Capa 3: 10 a 15 kg.

Cantidad de agua almacenada: 5 litros/m²

Peso Total Saturado 25-30 kg/m²

INFORMACIÓN TÉCNICA DE LOS MATERIALES

Panel de soporte Ug-P20

- Producto: Panel de PE EXT Ug-P20
- Grosor: 20 mm
- Color: negro
- Resistencia a los rayos UV: ilimitada.
- Límites de temperaturas: -50°C hasta +50°C
- Durabilidad > 50 años.

Características	Norma	TOLERANCIA	UNIDADES
		GARANTIZADA	
		O MINIMO	
Indice de Fluidez 21.6 Kg	ASTM D1238	29	g/ 10 min
Temperatura VICAT	ASTM D 1525	128	°C
Densidad 23°C	ISO 1183	0.70-0.85	g/cm3

Tejido no tejido Ug-M500

- 90% Poliéster + 10% algodón biodegradable, rafia de polietileno integrada.
- Punto de rotura: 5,5 kN/m
- Permeabilidad al agua: 5 litros por m²/sec
- Durabilidad: 50 años.

Solicitudes de la capa de Ug-M500:

- Resistencia a tracción frente a solicitudes de viento.
- Medio de cultivo.
- Separación: impide el contacto entre materiales no compatibles. Actúa de barrera permeable.
- Drenaje.
-

Urbanarbolismo

Grupo UnusualGreen

Plaza Gabriel Miró nº18 3ºB, Alicante

966282640 - 665493172 – fachadasvegetales@urbanarbolismo.es - <http://www.urbanarbolismo.es>

Sistema de riego Ug-RF

Sistema de riego Ug-RF: Riego con líneas de tubo hidroporoso.

Las líneas están conectadas a los 2 ramales principales para garantizar una presión igual en todos los tubo hidroporosos.

La instalación incluye programadores, electroválvulas, controles de cunal, sondas, cables, arquetas, reductores de presión, abrazaderas etc.

Las tomas de corriente y de agua se encontrarán cercana con suficiente presión para suministrar agua al sistema.

Sistema de telecontrol y telegestión de riego IQ2 RainBird, permite monitorizar en tiempo real el funcionamiento del jardín vertical y mejora los tiempos de respuesta ante eventuales correcciones que se necesite realizar en el sistema.

Selección de especies

Criterio: selección de especies vegetales en función de la orientación de fachada, el clima de la zona y los requerimientos de mantenimiento.

A definir una vez cerrado presupuesto ajardinamiento vertical.

Requerimientos anexos al jardín vertical no incluido en el sistema:

- Toma de agua 1,5kg/cm² lugar de montaje sistema de fertirrigacion.
- Conducción agua polietileno 32mm hasta pie de jardín vertical.
- Lugar protegido para instalación de aparatos control.
- Canalización lixiviados agua, a definir en colaboración con la dirección facultativa.

Tiempo de ejecución

Para 100m² aproximadamente 10 días laborales.



MANTENIMIENTO

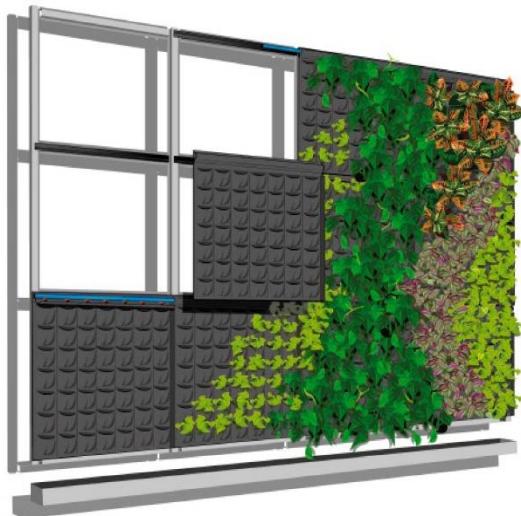
El mantenimiento del sistema F+P es mínimo, el sistema de riego está completamente automatizado y gestionado mediante telecontrol. El crecimiento vegetativo se gestiona variando las características de la solución hidropónica reduciendo la necesidad de podas.

Los trabajos de mantenimiento a futuro no necesariamente han de ser contratados a Urbanarbolismo.

Annex C



Sistema Fytotextile® para jardín vertical



El sistema Fytotextile® para fachada vegetal, está compuesto por módulos flexibles multicapa producidos industrialmente, que se conectan a una subestructura anclada al muro soporte. Los módulos están formados por una matriz de bolsillos donde se alojan las plantas para jardín vertical, incluyendo su propio sustrato, lo que facilita la adaptación y desarrollo. Es un sistema desarrollado y patentado por Terapia Urbana en la Universidad de Sevilla.

Los módulos permiten un fácil registro del sistema de riego, facilitando el mantenimiento. Fytotextile® es adecuado para jardines verticales de mediana y gran dimensión, y su sistema de instalación es sencillo y profesional.

Fytotextile® ha sido instalado con éxito en más de 16.000 m² de jardines verticales por todo el mundo.

Componentes del sistema



Estructura Auxiliar:
Formada por perfiles de acero galvanizado, adaptada y calculada según proyecto, para fijación de los módulos Fytotextile®.



Módulo Fytotextile®:
Sistema modular textil multicapa para cultivo semi-hidropónico con una alta densidad de plantación por m²



Sistema de riego y control:
Todos nuestros Jardines Verticales cuentan con un sistema de riego y control adecuado al tamaño y las necesidades de cada jardín.



Selección de especies:
Planta natural seleccionada en función del diseño paisajístico y los condicionantes climáticos específicos de cada proyecto. (ubicación, orientación, insolación,...)

Requisitos previos para instalar un jardín vertical



Punto de agua

Punto de abastecimiento AFS que garantice una presión de 1-2 atm



Alimentación eléctrica

Punto de conexión eléctrica de 220v 16A ubicada en espacio técnico



Punto de desagüe

Punto de evacuación situado en la base del jardín (según esquema de riego).



Espacio técnico

Para ubicar el sistema de riego y control

- Sistema de riego a solución perdida: Armario de 0,90 x 0,90 x 0,50 m aprox
- Sistema de riego recirculado: Consultar dimensiones (aprox 4,00 m²)



Iluminación auxiliar

Necesario para Jardines Verticales con condiciones lumínicas insuficientes.



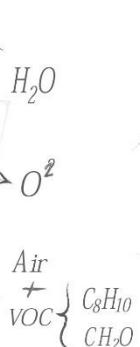
Módulo Fytotextile®

Sistema modular patentado compuesto por tres capas de material sintético y orgánico, flexible y de reducido espesor, con bordes conectables en todo el perímetro del módulo y capacidad para 49 bolsillos de plantación. Con pestaña superior practicable para incluir línea de riego por goteo.

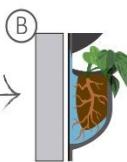
La I+D+i realizada desde 2006 por el **Grupo de Naturación Urbana** e Ingeniería de Biosistemas AGR 268, de la Universidad de Sevilla, hacen de Fytotextile un sistema tecnológicamente diferenciado del resto de sistemas disponibles en mercado.



*El sistema multicapa Fytotextile crea las condiciones más saludables para las raíces de la planta, gracias a la excelente transpiración de la capa exterior, que optimiza el **equilibrio** entre agua, aire y sustrato para cada planta.*



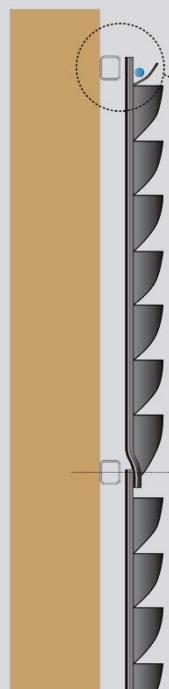
Capa impermeable
La capa posterior protege la pared evitando el contacto con el agua



Capa drenante
El riego se distribuye de forma homogénea por la capa intermedia, optimizando el consumo



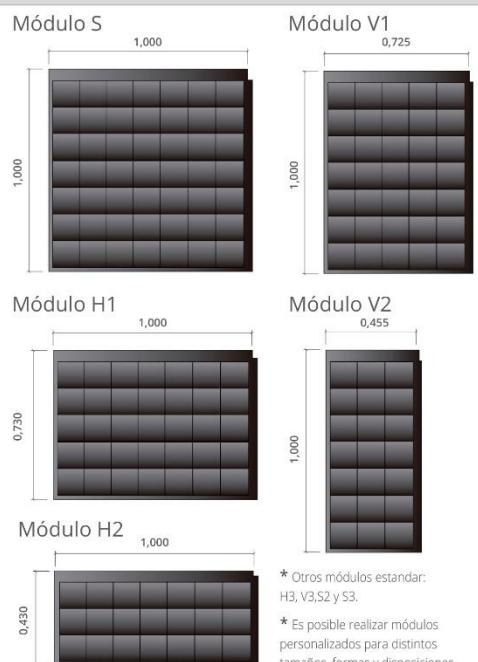
Capa transpirante
La capa exterior mejora la transpiración del sistema radicular



Espesor de módulo	20 mm
Espesor del sistema	70 mm
Peso del módulo	2,1 Kg
Peso saturado y plantado (sistema)	25,2 Kg/m ²

Información Técnica

Tamaños Estándar



* Otros módulos estándar: H3, V3, S2 y S3.

* Es posible realizar módulos personalizados para distintos tamaños, formas y disposiciones

Ventajas del Sistema Fytotextile®



Mejora la aireación de las raíces y el comportamiento de la planta



Estructura optimizada de capas

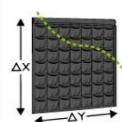
- C. Impermeable
- C. Riego
- C. Aireación



Reparto uniforme del riego para un consumo eficiente



Sistema ligero y flexible



Personalizable para adaptarlo a diferentes formas



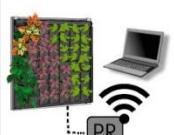
Rápida cubrición de la superficie del Jardín

2 Meses

Ventajas de la instalación



Instalación sencilla en 4 pasos



Control remoto del sistema



Fácil mantenimiento y acceso a instalaciones



Test y certificados del sistema Fytotextile®



Fytotextile® RF y RF+: Comportamiento frente al fuego

El sistema Fytotextile® ha sido sometido a distintos test experimentales por Applus según norma UNE-EN ISO 11925-2:2011 y UNE-EN 13823: 2012+A1:2016, para obtener su reacción frente al fuego. Hemos desarrollado un módulo Fytotextile-RF con una clase CLASE B-s2,d0 certificada



Fytotextile® AD: Durabilidad del sistema

Los módulos Fytotextile han sido sometidos a ensayos de envejecimiento acelerado por Applus® basados en el estándar UNE-EN ISO 4892/2, y testados los resultados según método UNE-EN ISO 13934-1, obteniendo una resistencia a tracción en el material exterior de más de 10 veces la carga máxima de solicitud para la exposición más prolongada sin protección



Fytotextile® C+: para climas muy cálidos

Hemos desarrollado y ensayado en la Universidad de Sevilla un nuevo sistema Fytotextile® C+ con una mayor capacidad de retención de agua para climas muy cálidos



Fytotextile® AT: Resistencia a tracción y desgarro

El sistema Fytotextile® ha sido ensayado en la Universidad de Sevilla para determinar la resistencia máxima del conjunto y de sus componentes, arrojando valores hasta 6 veces superior a la carga máxima de uso.



Fytotextile® F: Comportamiento ante congelación

Los módulos Fytotextile® presentan un buen comportamiento ante ciclos continuados de congelación y descongelación, sin apreciarse cambios en las características físicas y mecánicas.



Terapia Urbana desarrolla, produce y comercializa los módulos Fytotextile® sólo para profesionales.

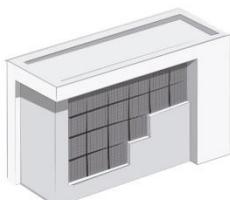
Se realiza un control de calidad en fase de producción que garantiza las prestaciones para las que ha sido diseñado

El sistema se somete a constante mejora y desarrollo que lo dotan de características técnicas para dar solución a las exigencias constructivas



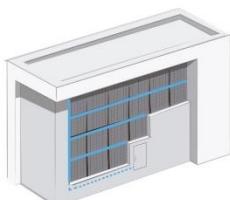
✓ Diseño de Subestructura Auxiliar

Acorde a la modulación realizada se diseña la estructura auxiliar necesaria para la correcta instalación de cada jardín. Se facilita despiece estructural completo y diseños de los detalles singulares para cada caso.



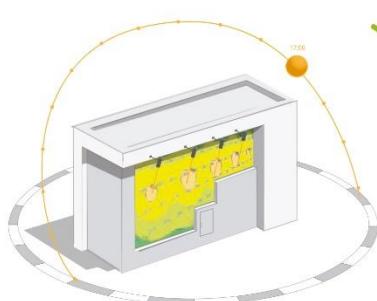
✓ Diseño del despiece de módulos

En función de la forma de cada jardín, se diseña el despiece de módulos necesario para su correcta ejecución. Se facilitan planos de montaje con indicación de los tipos de módulos, su ubicación y forma de montaje.



✓ Diseño de Sistema de riego y control

Atendiendo a la ubicación y características de cada proyecto se definen los esquemas de riego y control óptimos, con indicación de ubicación y descripción de todos los componentes necesarios.



✓ Estudio y diseño de Iluminación Auxiliar / Soleamiento

Dependiendo de la ubicación del jardín vertical se realiza un estudio de soleamiento para jardines verticales en exterior, o un estudio de iluminación auxiliar para jardines interiores, utilizando la tecnología más avanzada y prescribiendo las luminarias más adecuadas. Con los resultados obtenidos se realiza la selección de especies y en caso de ser necesario se definirá la iluminación necesaria para garantizar el correcto desarrollo de la planta en interior.



✓ Diseño Paisajístico y selección de especies.

A partir de un estudio previo de todos los condicionantes externos que afectan a cada instalación se realiza una selección de especies adecuada a cada caso. El diseño se realiza teniendo en cuenta las necesidades del cliente. Se facilita planos de plantación por módulo con indicación de especies seleccionadas y calibre de planta.

Annex D



MEMORIA TÉCNICA
SISTEMA LEAF.BOX – Revisión 00/11

MEMORIA TÉCNICA SISTEMA LEAF.BOX

DESCRIPCIÓN

Jardín vertical sistema leaf.box, compuesto por una capa aislante e impermeable de espuma de poliuretano 35Kg/m³ de 20mm, estructura portante de perfilería de aluminio, paneles leaf.box Ug-15 o Ug-10 construidos a medida, realizados en varilla metálica, cerrados con alambre galvanizado, electro-soldado y plastificado, rellenos de sustrato de fibras vegetales Ug-ms05, y plantación de especies vegetales de variedades idóneas para el clima de la zona (seleccionadas en colaboración con la dirección facultativa) en módulos Ug-ms10 a razón de 40 plantas/m². Incluso instalación de riego mediante tubería exudante propia del muro.

COMPOSICIÓN DEL SISTEMA

- Capa 0: Impermeabilización de espuma de poliuretano 35Kg/m³, 20mm
- Capa 1: Estructura portante, perfilería de aluminio
- Capa 2: Panel leaf.box Ug-15 o Ug-10
- Capa 3: Sistema de riego exudante Ug-RL
- Capa 4: Vegetación en módulo de plantación Ug-p10.

ESPESOR DEL SISTEMA (en mm)

Espesor del sistema leaf.box Ug-10 : 120 mm + cámara de aire trasera

Espesor del sistema leaf.box Ug-15 : 170 mm + cámara de aire trasera

PESO DEL SISTEMA (en kg/m²)

Peso total plantado y saturado de agua 45-60 kg/m²

INFORMACIÓN TÉCNICA DE LOS MATERIALES

Impermeabilización de espuma de poliuretano 35kg/m³

La Espuma de Poliuretano es un material sintético y duroplástico, altamente reticulado y no fusible, que se obtiene de la mezcla de dos componentes generados mediante procesos químicos a partir del petróleo y el azúcar: el Isocianato y el Poliol.

La aplicación de espuma de poliuretano impermeabiliza, aísla, y sella eficazmente, evitando la formación de humedades por condensación y elimina los posibles puentes térmicos.

- Producto: Espuma de poliuretano.
- Espesor: 35kg/m³ – 20mm
- Conductividad térmica: Baja 10 °C = 0,028 W/m·K
- Resistencia térmica: 0,71 m²·K/W
- Color: Amarillo
- Resistencia a los rayos UV: ilimitada.
- Durabilidad > 50 años.

Solicitudes de la capa de la membrana impermeable:

- Impermeabilidad.
- Antirraíces.
- Aislamiento.

Sustrato de fibras vegetales Ug-ms05

Sustrato de fibras vegetales de musgo *Sphagnum maguellanicum* deshidratado, no fosilizado ni descompuesto, instalado en los paneles leaf.box.

- Humedad: <20%.
- Materia orgánica sobre materia seca: >95%
- Densidad aparente seca: <1g/cm³
- Conductividad eléctrica (CE): <2dS/m
- pH: 4,8
- Porosidad en volumen: 90%
- Impurezas (restos vegetales, minerales...): <3%

Solicitudes del sustrato Ug-ms05:

- Aislamiento: aumenta la capacidad aislante del jardín vertical.
- Retención de agua: Absorbe y retiene hasta 20 veces su propio peso.
- Gran durabilidad: Material imputrescible.

Módulo de plantación Ug-ms10

Vegetación para plantación especialmente cultivada previamente en sustrato Ug-ms05

Solicitudes del módulo de plantación Ug-p10:

- Plantación en sustrato Ug-ms05.
- Estado sanitario óptimo de la vegetación.

Sistema de riego exudante Ug-RL

El tubo poroso exudante Ug-RL riega por todo su recorrido, es un sistema de riego localizado que puede instalarse en superficie o enterrado. Es un tubo desarrollado a partir de un tejido técnico. Esta nueva tecnología le confiere al tubo Ug-RL unas características únicas para su utilización en zonas especialmente críticas por falta de agua. El tubo Ug-RL destaca frente a los demás sistemas de riego localizado por tener una constitución dinámica de los emisores de caudal.

- Emisores de caudal de goteo autocompensante de : 8-12-25-50-100 l./h.
- Diámetro del tubo poroso: 15 mm.
- Presión de trabajo recomendada: 1-3,5 bares
- Filtración : 120 a 160 mesh
- Caudal: 1,75-10 litros/hora/metro (recomendado según el caudal del emisor de riego y longitud escogida)
- Longitud máxima de linea : de 1,5 a 25 m. si conectamos por un lado de la cinta y 50 m. conectando por ambos lados.

Sistema de monitorización y control de riego IQ2 RainBird, gracias al cual se consigue programar, monitorizar y manejar el sistema de riego desde una localización central. Puede controlar y adaptar automáticamente el funcionamiento y los tiempos de riego según las condiciones de la instalación y las condiciones ambientales (cambios meteorológicos, roturas de tuberías, etc.) de acuerdo con los parámetros definidos por el responsable del mismo.

Posibilidad de sistema de bombeo adicional (en caso de que no haya suficiente presión de agua).

Selección de especies

A definir según ubicación geográfica, orientación del jardín, situación del jardín (interior o exterior) de acuerdo con la dirección facultativa.

Requerimientos anexos al jardín vertical no incluidos en el sistema.

- Toma de agua 1,5kg/cm² en el lugar de montaje sistema de fertirrigación.
- Conducción agua polietileno 32mm hasta pie de jardín vertical.
- Lugar protegido para instalación de aparatos control.
- Canalización lixiviados agua (canaleta 30x20cm).

Tiempo de ejecución

Para 100m² aproximadamente 10 días laborales.

MANTENIMIENTO

El mantenimiento del sistema de jardín vertical leaf.box puede ser llevada a cabo por cualquier persona con una pequeñas nociones de jardinería.

Una vez totalmente enraizado el sistema, y gracias a las características del sustrato Ug-ms05 no es necesario un proceso de abonado.

El control del riego es totalmente automático y autónomo de manera que el mantenimiento consta de la revisión periódica de las instalaciones, además, y gracias al sistema de monitorización de riego IQ2, las alertas de posibles fallos, son instantáneas.

Estos trabajos a futuro no necesariamente han de ser contratados a Alicante Forestal siendo el promotor del mismo al encargado de proporcionarlos siguiendo las directrices de los sistemas de Alicante Forestal.



PANEL IMPERMEABLE SG-P10 - FICHA TÉCNICA

REVISIÓN 02/18

FICHA TÉCNICA PANEL IMPERMEABLE SG-P10

El panel impermeable SG-P10 está formado por placas extrusionadas a base de policloruro de vinilo flexible de 10mm de espesor de color blanco, cuya presentación comercial es en planchas de 3.050x2.050mm.

PROPIEDADES FÍSICAS			
Densidad relativa	0,625	gr/cm ³	-
Absorción de agua	0,19	%	ISO 62: Método 1

PROPIEDADES MECÁNICAS			
Resistencia a tensión	19,37	Mpa	ISO R527
Alargamiento en rotura	17,89	%	ISO R527
Módulo de flexión	0,903	Gpa	ISO 176
Resistencia a choque Charpy	1,43	kJ/m ²	ISO 179
Dureza Shore D	63	-	ISO 868

PROPIEDADES TÉRMICAS			
Coeficiente de dilatación lineal	0,498x10 ⁻⁶	°C ⁻¹	-
Temperatura deformación por calor	57,75	°C	ISO 75: Método A
	68,40		ISO 75: Método B
Conductividad térmica	0,06	W/mk	DIN 52612

OTRAS PROPIEDADES			
Clasificación al fuego	B2 Classe 2 M2 Classe 2		DIN 4102 CSE RF 37777 MFP 92 501 BS 476 Part 7
Resistencia química	Resistente contra ácidos, acústicos y todos los detergentes habituales		
Resistencia en la superficie	>10 ¹⁴	Ω	DIN 53481
Resistencia Rayos UV	Ilimitada (sin exposición)		
Límite de temperaturas	-50°C / +80°C		

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