LIFE my building is green

LIFE17 ENV/EN/000088

Application of Nature-Based Solutions for local adaptation of educational and social buildings to Climate Change

Action: Implementation of Nature-Based Solutions in the pilot buildings. Execution of works

Deliverable: Technical Manuals for the implementation of NBS prototypes in the different structures of the pilot buildings.

Date: 31/05/2023

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1. SUMMARY IN ENGLISH

This document is part of action C2. "Implementation of Nature-Based Solutions in the pilot buildings. Execution of works". It is based on the drafting of the technical projects of the pilot buildings of the project where the characteristics and design of the prototypes to be implemented are specified and detailed.

This deliverable includes the different NbS prototypes implemented in the schools of Évora and Oporto in Portugal and Solana de los Barros in Spain. The SbN have been organised according to roofs, façades and outdoor spaces. For each prototype, a general description of the prototype is presented, along with details of the materials used, the specifications and procedures to be taken into account for its implementation, as well as the applicable regulations.

2. RESUMEN ESPAÑOL

Este documento es parte de la acción C2. "Implementación de las Nature-Based Solutions en los edificios piloto. Ejecución de obras". Parte de la base de la redacción de los proyectos técnicos de los edificios piloto del proyecto donde se especifican y detallan las características y diseño de los prototipos que se van a implementar.

En este entregable se recogen los diferentes prototipos de SbN implementados en los colegios de Évora y Oporto en Portugal y de Solana de los Barros en España. Las SbN se han organizado según cubiertas, fachadas y espacios exteriores. Para cada prototipo se presenta una descripción general del mismo, se detallan los materiales que lo conforman, las especificaciones y procedimientos a tener en cuenta para su implementación, así como la normativa aplicable.

3. RESUMO EM PORTUGUÊS

Este documento é parte da acção C2. "Implementação de Soluções Baseadas na Natureza nos edifícios-piloto. Execução de obras". Baseia-se na elaboração dos projectos técnicos dos edifícios-piloto do projecto, onde as características e concepção dos protótipos a implementar são especificadas e detalhadas.

Esta entrega inclui os diferentes protótipos BMS implementados nas escolas de Évora e do Porto em Portugal e Solana de los Barros em Espanha. Os BMS foram organizados de acordo com telhados, fachadas e espaços exteriores. Para cada protótipo, é apresentada uma descrição geral do protótipo, juntamente com os detalhes dos materiais utilizados, as especificações e procedimentos a ter em conta para a sua implementação, bem como os regulamentos aplicáveis.

4. INTRODUCTION

The aim of this deliverable is to provide a detailed guide on the most important features of the prototypes installed in the project schools, detailing how to implement them. A technical handbook can be a valuable tool for stakeholders interested in implementing BMS and can encourage the replication of the solutions developed in the project in other buildings with similar problems and challenges.

A technical manual for the implementation of BMS should provide detailed information on its components, including technical specifications, installation and configuration instructions, as well as other relevant information. The compilation of lessons learned based on the experience gained in the development of prototypes and their implementation will facilitate the implementation of SbN, improving the efficiency, quality and accuracy of the process, reducing previous errors and problems.

The SbN prototypes have been organised according to three categories: roofs, façades and exterior spaces. For each prototype, a general description of the prototype and its constituent materials has been detailed. The specifications and procedures to be taken into account for their implementation, as well as the applicable regulations, are included in general for each category and, when applicable, specifically for each prototype.

5. COVERS

5.1 mBiGTray

5.1.1 Description

The mBiGTray system is a system of encapsulated extensive vegetation cover with the aim of being more resistant to periods without rain. It consists of a multi-layer tray encapsulated by a white waterproof sheet. In the upper part of the encapsulation there are holes through which the plant species emerge, allowing rainwater to be collected and reducing water loss. The design of the system together with the selection of suitable plant species meets the irrigation requirements, but is also compatible with an additional irrigation system.

Each module consists of two trays, a plant part and a water collection part. In the junction area of each module there are holes that allow water to enter from the water collection area to the area with the plant system. The vegetation part of the system occupies 50% of the surface and the rest is covered by the waterproof sheet, avoiding excessive thermal energy collection. The installation is carried out by means of a chequered system in which the planting areas alternate with the water collection areas, joining the modules by means of flanges in eyelets.

This prototype will be implemented in the EB1 school of Horta das Figueiras, Évora.

Illustration 1. Views of the mBiGTray prototype at EB1 da Horta das Figueiras

5.1.2 Materials

Illustration 2 shows the arrangement of the different materials. Depending on the specific characteristics of each project, the materials may vary.

The components of the system are as follows: two nodular HDPE trays with high mechanical resistance to compression (1 and 1'). One of the trays is covered with a blanket.

retainer (2) formed by a non-woven geotextile. In turn, the 10 cm thick substrate[1] (5) is wrapped with a geotextile sheet (4) and placed on the HDPE tray. The tray and substrate are then encased in the plasticised PVC sheet (3), preferably in white, forming a bag that stores rainwater. The remaining PVC sheet is placed on the other nodular tray to capture rainwater and carry it to the receptacle formed by the bag with the substrate.

Perforations shall be made in the PVC top layer and in the retaining blanket containing the growing substrate. Through these perforations, the plant species (6) selected by the site management shall be planted at a rate of 16 plants/m².

All bags are installed together with flanges (7) at the matching eyelets following the installation direction of the roof slope from top to bottom so that each square without substrate drains rainwater into the square bag with substrate resulting in a checkerboard installation.

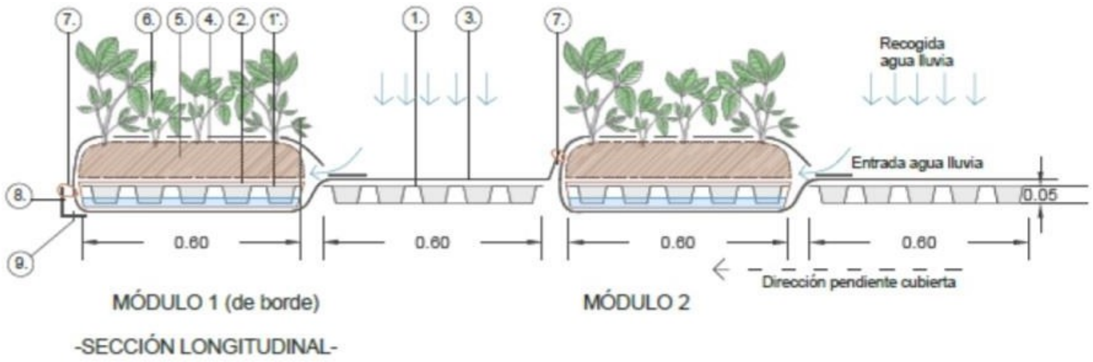


Illustration 2. mBiGTray construction detail. Source: Basic and execution project for school EB1 - Horta das Figueiras.

5.1.3 Specifications and procedures for implementation

The modules are **assembled** in the workshop. For transport to the construction site, the modules will be stacked one on top of the other, guaranteeing the conservation of the properties of the different materials, and avoiding puncturing or stressing the PVC sheet.

[1] Mixed substrate for turf-type green roof cultivation, consisting of the following composition: 25% Sphagnum peat; 20% vegetable compost; 20% volcanic 5-9 mm; 20% silica sand; 15% coconut fibre; pH: 7.5

Once on site, the modules are arranged in such a way that the squares are placed alternately to form a checkerboard pattern over the entire surface of the roof indicated in the project.

At the edges of the vegetated surface of the roof, the modules will be fixed. For this purpose, metal profiles will be provided, which will be screwed to the pre-existing roof finish on the horizontal surface of the profiles, using stainless steel screws and two watertight washers, guaranteeing the watertightness of the roof. On the vertical surface of the profiles, perforations will be made for the use of plastic flanges, which will anchor the modules on the sides, making the perforations coincide with the eyelets of the PVC sheeting of the edge modules. At the same time, the modules will be fixed to each other using the same system: with UV-resistant nylon flanges at the edge eyelets.

The recommended **vegetation** is of the genus sedum with a homogeneous distribution and a density of 16 plants/m^2 .

The system **drainage** is carried out through the same orifice that allows water to enter for accumulation.

The specifications and regulations common to green roofs are described in the following **sections 5.7 y 5.8**.

5.2 mBiGCUVE

The CUbierta VEgetal (CUVE) prototype meets the requirements of being easy to implement, modular, adaptable to any building, durable, accessible and compatible with the building.

5.2.1 Description

The CUVE - 1 roofs (elevated trays with extensive cover) consist of systems superimposed on the existing roof, separated from it, which generate the effect of a ventilated roof by creating an air chamber between the existing finishing gravel and the system in place (thus changing the current "hot" roof to a "cold roof"). The design consists of frames supported on raised plots, on which removable trays are placed to house an extensive thin roof solution, with an improved substrate and native species suitable for this thickness.

The CUVE-2 canopy (raised trays with pots and climbers) is a variant of the previous system. The frames contain larger containers at the ends and/or intermediate points for the planting of climbing plants. The use or not of deciduous species, bearing in mind that in the first case fallen leaves are generated, which should be removed for the proper functioning of the canopy.

These prototypes have been implemented in the school CEIP Gabriela Mistral, Solana de los Barros, Badajoz.


Views of the CUVE-1 and CUVE-2 prototypes in the Gabriela Mistral Primary School.

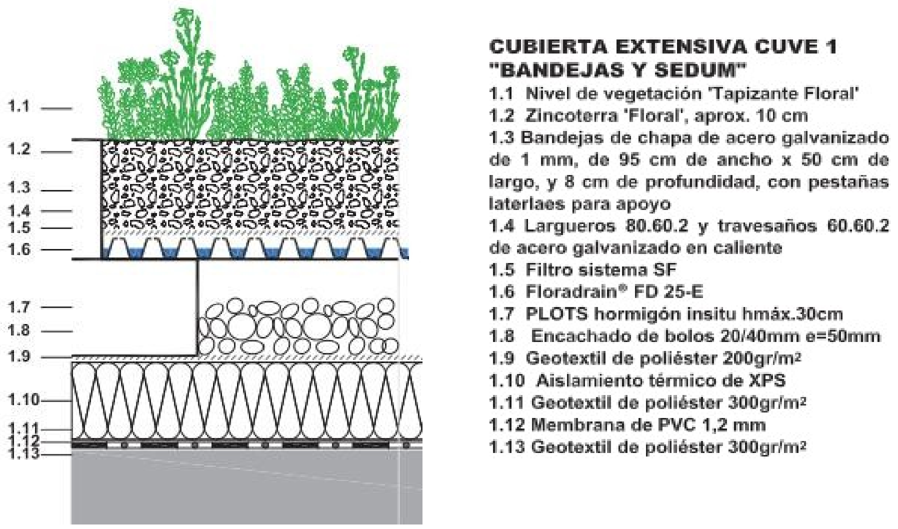
5.2.2 Materials

The following is a description of the materials and characteristics of the elements that make up the CUVE-1 roof based on the example of the materials used in the Gabriela Mistral Primary School. **Illustration 4 shows** the layout of the different materials. Depending on the specific characteristics of each project, the materials may vary.

The vegetation (1.1) is *Sedum* type, drought resistant, ground cover and low height with a density of 15 units/m^2 . Substrate (1.2) for extensive landscaping 10 cm thick (Zincoterra Floral). The composition of the substrate can be improved by using recyclable aggregates. Trays (1.3) of 1 mm galvanised steel sheet, 95 cm wide x 50 cm long and 8 cm deep. The trays have side flanges to support them on the frames. In the case of CEIP Gabriela Mistral, we have worked with modular racks and trays that take advantage of the commercial material available. Tubular frames (1.4), hot-dip galvanised steel beams and crossbars. Heat-welded polypropylene filter (1.5). It is placed over the drainage layer, separating it from the substrate. Drainage and water retention element (1.6) made of recycled polyolefin, pressure resistant. It has cavities for water retention and openings for aeration and diffusion. Plots (1.7) of in-situ concrete.

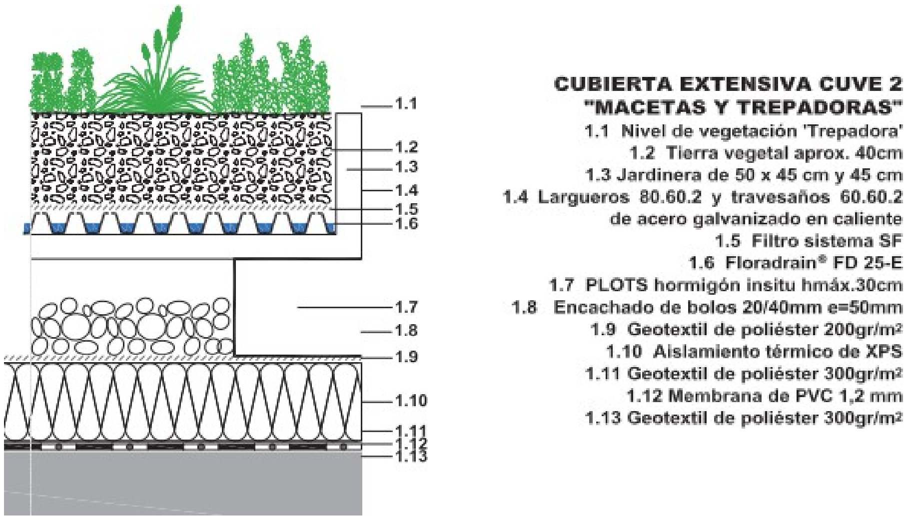
The plots support the frames and are placed on top of the roof finishing material. The plots support the frames and are placed on the finishing material of the roof[2] .

The CUVE-2 canopy consists of the following materials (Illustration 5). The vegetation (1.1) is of the climbing type (*Parthenocissus tricuspidata and Parthenocissus quiquefolia*). Substrate (1.2) of topsoil approximately 40 cm thick. Wooden planter (1.3) 50 x 45 x 45 cm. Tubular frames (1.4), hot-dip galvanised steel beams and crosspieces. Heat-welded polypropylene filter (1.5). It is placed over the drainage layer, separating it from the substrate. Drainage and water retention element (1.6) made of recycled polyolefin, pressure resistant. It has cavities for water retention and openings for aeration and diffusion. Plots (1.7) of in-situ concrete, with a maximum height of 30 cm. The plots support the frames and are placed on top of the roof finishing material.



Construction detail CUVE-1. Source: Basic and execution project CEIP Gabriela Mistral

[2] In the case of the CEIP Gabriela Mistral, the finishing material for the roofing is a bowling ball filling.



Construction detail CUVE-2. Source: Basic and execution project CEIP Gabriela Mistral

The specifications and regulations common to green roofs are described in the following **sections 5.7 y 5.8**.

5.3 <u>mBiGCUVE-SUS</u>

5.3.1 <u>Description</u>

CUVE-SUS (CUVE-SUS) is an extensive cover system with an improved substrate that includes recycled aggregates from construction and demolition waste to drain the cover. The combination of the substrate with a finer granulometry favours the adequate water levels required by the vegetation, without reducing the air volume of the substrate, avoiding substrate compaction. In addition, it is also possible to increase the organic matter of the substrate by means of a special formulation of the soil microbiota to reduce the water requirements of the system.

This prototype has been implemented in the school CEIP Gabriela Mistral, Solana de los Barros, Badajoz.

Illustration 6. Views of the CUVE-SUS prototype at CEIP Gabriela Mistral

5.3.2 Materials

The materials and characteristics of the elements that make up the CUVE-SUS roof are presented below. **Illustration 7** shows the layout of the different layers of the system. Depending on the specific characteristics of each project, the materials and thicknesses may vary.

The vegetation (1.1) is varied, with different varieties of perennials[3] and small herbaceous ground cover[4] a density of 15 units/m^2 . Substrate (1.2) for extensive landscaping 10 cm thick (Zincoterra Floral). Heat-welded polypropylene filter (1.3). It is placed over the drainage layer, separating it from the substrate. Drainage and water retention element (1.4) made of recycled polyolefin, resistant to pressure. It has cavities for water retention and openings for aeration and diffusion. Separation mat (1.7).

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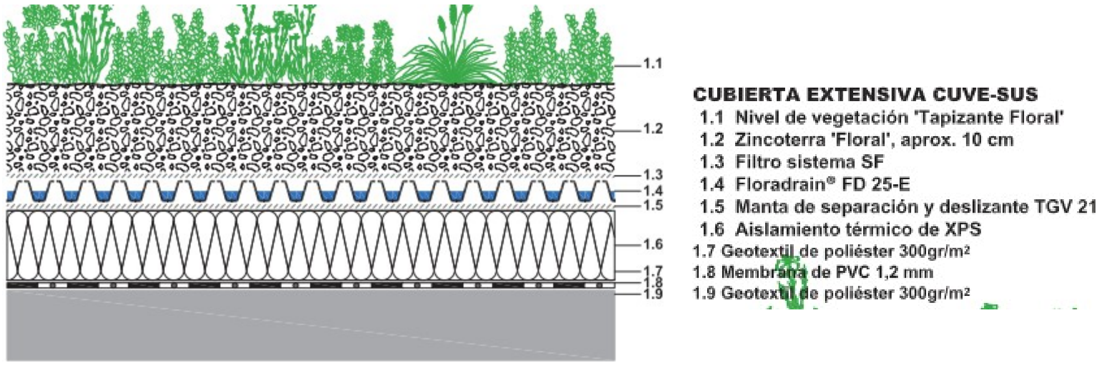
[3] In the case of CEIP Gabriela Mistral, up to 16 different species have been installed (*Dianthus carthusianorum; Festuca Cinerea Hybride; Gypsophila repens; Helianthemum nummularium; Koeleria glauca; Petrorhagia saxifraga; Saponaria ocymoides; Satureja montana ssp. illyrica; Saxifraga paniculata; Sempervivum hybrids; Cerastium; Hieracium pilosella; Potentilla neumanniana; Prunella grandiflora; Thymus doerfleri Bressingham; Thymus serpyllum*)

[4] In the case of the CEIP Gabriela Mistral, Sedum types (Album, Acre, Reflexum, Sediforme, Rupestre, Ochroleucum, etc.) have been installed.



Construction detail CUVE-SUS. Source: Basic and execution project CEIP Gabriela Mistral

5.3.3 Specifications and procedures for implementation

The **substrate** implemented in the CUVE-SUS system is an improved substrate with the inclusion of recycled aggregates.

The specifications and regulations common to green roofs are described in the following **sections 5.7 y 5.8**.

5.4 mBiGUL

5.4.1 Description

The mBiGUL prototype is a multifunctional system based on the Green Urban Living (GUL) system. The GUL system[5] served as inspiration for the development of the mBiGUL prototype. It consists of 4 layers. An expanded cork conglomerate ICB (Insulation Cork Board) is used at the base. On top of this, a filter layer is placed, which serves as a separation layer with the substrate to prevent the substrate particles from detaching and collapsing the water run-off. An Intensive Technical Substrate is used, which is characterised by a high mineral component, free of parasites, weed species and pathogenic germs and a high structural resistance. The vegetation layer is planted on top.

This prototype will be implemented in the EB1 Falcão school, Porto.

[5] http://www.itecons.uc.pt/projectos/greenurbanliving/index.php?module=sec&id=546&f=1

Views of the mBiGUL prototype at EB1 Falcão.

5.4.2 Materials

The materials and characteristics of the elements that make up the GUL green roof are described below. **Figure 10 shows** the arrangement of the different materials.

Vegetation[6] (1.1) of herbaceous, sub-shrubs and vines, planted in alveoli. The planting strategy is designed to encourage biodiversity in the vegetation cover. Intensive Technical Substrate (1.2) for 12 cm thick landscaping. This substrate is a product developed by LandLab[7] and is made up of special mineral-based components, which give it a medium-thickness texture, high and balanced capillarity and drainage. Heat-welded polypropylene/polyethylene filter (1.3). It is placed between the substrate layer and the cork plate. ICB expanded cork agglomerate (1.4) 8 cm thick. It performs the functions of excess water drainage, thermal insulation, waterproofing protection and sound insulation. Finally, an anti-root waterproofing sheet (1.5) is installed on top of the finishing material of the roof.

Perimeter strips of gravel 30 cm wide are installed. The gravel to be incorporated must be washed river gravel, free of parasites, weeds and pathogenic germs, with a grain size between 7 and 11 mm.

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[6] The following species have been planted in the school EB1 Falcão, Porto: *Allium schoenoprasum, Carex buchananii, Festuca amesthystina, Limonium vulgare, Satureja montana, Saponaria ocymoides, Sedum album, Sedum floriferum, Sedum sediforme, Sedum spurium, Petrorhagia saxifraga.*

[7] https://www.landlab.pt/pt/inicio

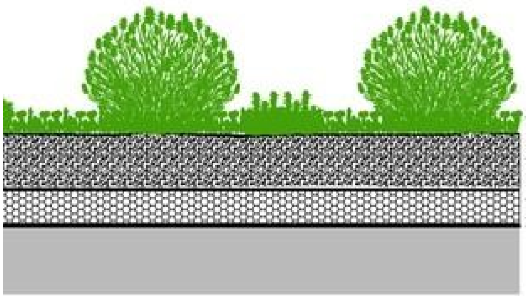

Illustration 10. mBiGUL construction detail. Source: Basic and implementation project EB1 Falcão

5.4.3 Specifications and procedures for implementation

Vegetation shall be provided in pots, be of the indicated size and have well-developed roots. Planting holes shall be in proportion to the size of the root ball or root system of the plant. All plantings should be watered immediately after planting. The planting must follow a planting module of 2*2 m (see Annex EB1 Falcão) with a density of 17.75 un/m^2 .

This green roof system is non-intrusive, using no fixings, avoiding any contact and damage to the base waterproofing layers of the building. It also acts as protection for the existing waterproofing system of the roof. Prior to the installation of the green roof, the space must be clean, free of debris and the existing waterproofing layer must have an anti-root waterproofing layer.

The GUL plates must be installed with the grooves facing upwards. The TG filter must be installed on top of them, folded over the individual structural beams. An overlap of 20 cm between the rows must be ensured.

The specifications and regulations common to green roofs are described in the following **sections 5.7 y 5.8**.

5.5 mBiGSECAR

5.5.1 Description

The mBiGSECAR prototype uses the Sedum Carpet solution, a coconut fibre-based structure pre-planted with vegetation of the genus *Sedum* L. It is a sustainable and 100% biodegradable vegetation cover solution that reduces installation time.

This prototype will be implemented in the EB1 Falcão school, Porto.

5.5.2 Materials

The materials and characteristics of the constituent elements of the SECAR green roof are described below. **Illustration 11 shows** the arrangement of the different materials. The vegetation (1.1) consists of a *Sedum* mat (Landlab) made up of different varieties[8] . Underneath, a jute net (1.2) is placed on top of the technical substrate for intensive roofing (Landlab) (1.3), with 40% mineral material and 60% organic plant components. This is followed by a drainage and containment sheet (1.4) made of expanded polystyrene with cavities for water retention and a drainage channel system on both sides. This is followed by the protective and moisturising blanket (1.5), made of synthetic fibres resistant to decomposition and approx. 7 mm thick. In the last layer there is a waterproofing sheet with anti-root characteristics (1.6).

Illustration 11. mBiGSECAR construction detail. Source: Basic and implementation project EB1 Falcão

5.5.3 Specifications and procedures for implementation

Once the irrigation system has been installed, the jute netting and Sedum mat can be installed. The Sedum mat should be in one piece, uniform in colour, with a moist substrate and no signs of disintegration or dehydration. On arrival at the site, the Sedum mat shall be unrolled and installed as soon as possible. In addition, trampling should be avoided in order to

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[8] In the school EB1 Falcão, Porto, the following species have been planted: *Sedum album* "Coral carpet", *Sedum album* "Murale", *Sedum acre*, *Sedum lydium*, Sedum *sexangulare*, *Sedum hispanicum* "Minus", *Sedum spurium* "Fuldaglut", *Sedum floriferum*, Sedum *kamschaticum*, *Sedum hybridum* "Immergrunchen", Sedum *reflexum*

to ensure a better finish of the work. The mat should only be installed after a cooling irrigation of the floor surface.

Once the substrate has been compacted and the vegetation surface is uniform, a preliminary test of the irrigation system shall be carried out to ensure that the water distribution is uniform and efficient in the vegetation zone.

The specifications and regulations common to green roofs are described in the following **sections 5.7 y 5.8**.

5.6 mBiGBioSol

5.6.1 Description

The mBiGBioSol prototype is the combination of a green roof and a set of solar panels, generating a perfect symbiosis between energy efficiency, biodiversity and sustainable production. On the one hand, the roof provides a series of environmental and economic benefits, including the promotion of biodiversity or the regulation of the interior temperature, with the consequent savings in air conditioning. On the other hand, solar panels allow the production of electricity from renewable and neutral sources, with no carbon emissions into the atmosphere. Moreover, the combination of the two optimises their individual action; the panels provide shade and protection from the elements to the roof, while the plants on the roof contribute to the cooling of the panels thanks to processes such as evapotranspiration.

Structurally, mBiGBioSol consists of a modular fixing and support system for photovoltaic solar panels, composed of a modular drainage base to which the panel support is fixed. The drainage base contains ballast and substrate on which the vegetation is planted.

This prototype will be implemented in the EB1 Falcão school, Porto.

5.6.2 Materials

The materials and characteristics of the constituent elements of the BioSol green roof are described below. **Figure 12** shows the arrangement of the different materials and structures.

First, the waterproofing and anti-root film (1.10) is installed when necessary. The protection and absorption blanket (1.9), which has the function of retaining water and nutrients, is made of synthetic polypropylene fibre and is applied over the drainage layer (1.9) of embedded recycled polyethylene, with cavities for water retention and perforations.

for ventilation. A non-woven filter (1.8) made of rot-resistant polypropylene is placed on top. 7 cm thick gravel layer (1.7). The technical substrate for intensive roofing (Landlab) (1.6), made from special mineral-based, pathogen-free components, and the *Sedum* mat[9] (Landlab) (1.5) are laid on top. The base of the solar panels (1.4) is filled with river gravel.

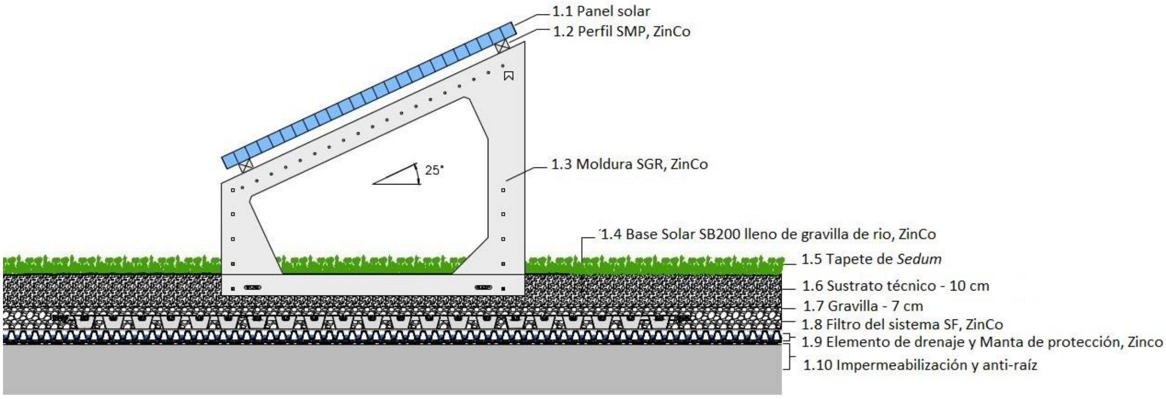


Illustration 12. mBiGBioSol construction detail. Source: Basic and implementation project EB1 Falcão

5.6.3 Specifications and procedures for implementation

Once the irrigation system has been installed, the Sedum mat can be installed. The Sedum mat shall be in one piece, uniform in colour, with a moist substrate and no signs of disintegration or dehydration. On arrival at the site, the Sedum mat shall be unrolled and installed as soon as possible. In addition, trampling should be avoided to ensure a better site finish. The mat should only be installed after a cooling irrigation of the floor surface.

Once the substrate has been compacted and the vegetation surface is uniform, a preliminary test of the irrigation system shall be carried out to ensure that the water distribution is uniform and efficient in the vegetation zone.

The specifications and regulations common to green roofs are described in the following **sections 5.7 y 5.8**.

[9] In the school EB1 Falcão, Porto, the following species have been planted: *Sedum album* "Coral carpet", *Sedum album* "Murale", *Sedum acre*, *Sedum lydium*, Sedum *sexangulare*, *Sedum hispanicum* "Minus", *Sedum spurium* "Fuldaglut", *Sedum floriferum*, Sedum *kamschaticum*, *Sedum hybridum* "Immergrunchen", Sedum *reflexum*

5.7 Specifications and procedures for the implementation of green roofs

The common specifications for the implementation of the different green roof prototypes are described below.

First of all, the **vegetation** should be suitable for the thickness of the substrate, watering conditions, maintenance and climatic conditions of the site. For example, in a Mediterranean climate, plant tolerance to solar radiation and drought resistance should be taken into account. For the appropriate selection of plant species, it is recommended to consult document *C2. Guide for the choice of plant species adapted to climate change.*

Rainwater drainage must be ensured, either because the system allows maintaining the collection points of the existing roofs, preserving the previous situation or providing new collection points. In addition, prior to the installation of green roofs, a test must be carried out to check the correct functioning of the rainwater drainage system.

If the building conditions allow it, rainwater can be collected from the roof and conveyed to a collection tank for use in the irrigation network. In this case, a water drainage network must be provided to convey the rainwater from the roof by gravity to the planned collection tanks. Rainwater storage tanks must be of high chemical and mechanical resistance, with an outlet tap. Their capacity should be adequate for the rainwater expected to be collected. The tanks require annual cleaning maintenance.

It is necessary to check that the **waterproofing of** the roof is adequate to protect the existing structure and prolong the life of the roof, prevent leaks and ensure proper moisture retention in the green roof. To ensure that the roof is completely watertight, a waterproofing test is carried out on the roof. If the roof needs to be **re-waterproofed**, the existing materials are removed, the roof is re-waterproofed and the watertightness is checked.

If it is considered necessary to include irrigation for the plant species implemented, an **irrigation water supply network must be** installed, which will form part of the building's network. The design and sizing of the distribution, diameter and stopcocks will be based on the expected consumption in order to ensure adequate plant development and avoid wasting water resources. The irrigation network may be equipped with a pumping and by-pass system in order to be able to operate directly from the network. The pumping system includes the possibility of adding fertilisers and pH-regulating acid to the storage tank. In the case of rainwater storage, it shall be stored beforehand.

The **electrical installation** will consist of a new switchboard in the irrigation room, and power supply and protection for pumps, metering devices, programming, etc.

Covers must be accessible for inspection or **maintenance** visits.

5.8 Regulations

Depending on the type of work, it will be necessary to comply with the respective regulations of each country. The basic documents (DB) applicable to green roofs according to the Technical Building Code (CTE) in Spain are listed below.

DB-SE Structural safety

In order to install a green roof over an existing roof, a load assessment must be carried out and structural safety must be checked once the green roof system is installed.

DB-SUA Safety in use and accessibility

- Safety against the risk of falls: account shall be taken of slippery floors, unevenness and access by ladders or ramps.
- Accessibility: The installation of green roofs can be accompanied by a proposal to make them accessible. To do so, accessibility conditions have to be met

DB-HS Health

- Protection against moisture: the degree of waterproofing must be complied with.
- Water supply: if irrigation is installed, new irrigation supply points must be provided.
- Water drainage: in the case of collecting water from the roof for reuse, a rainwater collection network must be provided, making connections to the existing downpipes.

DB-HE Energy saving

The scope of application, the quantification of the requirement and the justification for compliance with the requirement must be defined.

6. FACADES

6.1. mBiGToldo

6.1.1 Description

The mBiGToldo prototype is a system of vertical surfaces with very thin vegetation. The system consists of a waterproof sheet on which a non-woven felt is adhered and on which a seeded substrate is projected. Due to the low thickness of the substrate, a hydroponic irrigation system is integrated which is distributed by gravity across the surface of the substrate. A channel for collecting excess irrigation is integrated in the lower area, which connects to the irrigation station. It can be framed with a frame and separated from the façade, creating a shading system or parallel to the façade.

This prototype will be implemented in the EB1 schools of Horta das Figueiras, Évora, where it will be arranged parallel to the façade; and CEIP Gabriela Mistral, Solana de los Barros, Badajoz, where the arrangement is perpendicular.

Illustration 13. View of the mBiGToldo prototype at CEIP Gabriela Mistral

6.1.2 Materials

Figure 14 shows the arrangement of the different materials. Depending on the specific characteristics of each project, the materials may vary.

When the system is installed parallel to the façade, the materials are as follows. PVC sheet reinforced with fibreglass acts as the support structure. It includes special fittings for untensioning and dismantling the tarpaulin; the retaining blanket made of double-layer polyester-acrylic non-woven fabric, adhered to the waterproofing fabric by means of an adhesive.

specific for PVC tarpaulin; substrate for green roof, consisting of a mixture of *Sphagnum* peat or wood fibre and black peat, stabiliser for hydroseeding, a mixture of seeds[10] , organic fertiliser and soil improvers. The irrigation system consists of a drip irrigation pipe at the top and a lower gutter to collect excess water, which will be returned to the storage tank to optimise consumption.

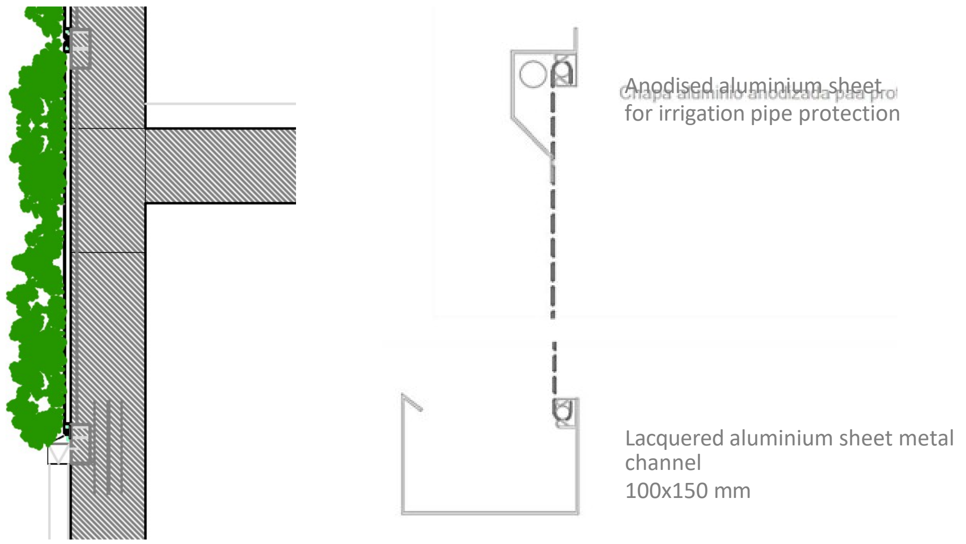


Illustration 14. mBiGToldo construction detail. Source: Basic and execution project EB1 of Horta das Figueiras.

In case the plant canopy is separated from the façade perpendicularly, it is a type of FAVE system and is detailed in the following section.

6.1.3 Specifications and procedures for implementation

Vegetation should be easily propagated by seed and should be able to adapt to local conditions. The amount of seed to be applied depends on the species, but for the indicated mixture the amount of seed applied shall be approximately 10 g of seed per square metre.

Due to the low substrate thickness, a **hydroponic irrigation** system is integrated, which is distributed by gravity over the substrate surface. This irrigation is carried out by means of a watering station.

[10] For Évora, seeds of species such as *Festuca rubra*, *Agrostis stonolonifera*, *Sagina subulata* or *Cymbalaria muralis*

hydroponic irrigation with a suitable programming to cover the needs of the vertical garden at all times of the year and according to the environmental conditions to be generated.

A **channel** is integrated in the lower area that collects excess water and connects to the irrigation station, creating a closed circuit. In case it is not possible to recover the excess water to the irrigation station, a drainage system for the excess water has to be provided under the garden.

6.2. mBiGFAVE

The proposed system is modular, dismountable and adaptable to any building.

6.2.1. Description

The FAchada VEgetal (FAVE) system is a light and modular substructure that can be used to support different plant solutions, separated from the façade and anchored to the façade at the slab level to facilitate its adaptation to any building. It is designed for a maximum of 2 floors and can be dismantled. Possible horizontal and vertical surfaces are generated above and in front of the openings, at greater or lesser distances. Depending on the orientation of the façade and the layout of the openings in each building, plant species are placed on these surfaces to provide shading. This system can serve as a support for two possible SbN:

FAVE 1: Containers with guide plants, such as climbers and creepers, are placed on the lattice to cover and create horizontal and vertical surfaces that are opaque to the sun's rays.

FAVE 2: Vegetated awnings (see prototype mBiGToldo) are arranged in the framework, generating continuous surfaces arranged in the frames on which suitable species grow on the surface.

These two varieties of the FAVE prototype have been implemented in the school CEIP Gabriela Mistral, Solana de los Barros, Badajoz.


View of the mBiGFAVE 1 and 2 prototype at CEIP Gabriela Mistral.

6.2.2. Materials

The following is a description of the materials and characteristics of the elements that make up the FAVE system based on the example implemented at CEIP Gabriela Mistral. **Figure 15** shows the layout of the different materials. Depending on the specific characteristics of each project, the materials and measurements may vary.

The substructure[11] consists of a framework of hot-dip galvanised tubular steel profiles. The horizontal part is made up of beams and cross members anchored to the façade. The vertical part is made up of straight legs, cylindrical section tubular profiles anchored to the ground by means of HA-25 shafts. The right feet are protected by a 25 mm circular cork panel lining attached to the posts with adhesive, Velcro and/or flange. **Figure 17** shows the formation of the substructure.

For the FAVE 1 system, vertical posts[12] are provided with tubular tubes to support the wooden pots. Guide wires are installed to allow the climbing of the plants.

[11] In the case of CEIP Gabriela Mistral, the dimensions of the module are: 2 mt wide x 2 mt separation from the façade x 3 mt high.

[12] In the case of CEIP Gabriela Mistral, there are 4 vertical posts per planter; and 8 vertical posts per crossbar and crossbeam.

3 mm solid galvanised steel wires anchored to the tubular profiles with galvanised steel hooks. The vegetation[13] is climbing and is planted in the pots.

For the FAVE 2 system, a (1) clickable aluminium profile is added to fix the PVC RF sheet. The (2) Leaf Skin tensile membrane consists of a PVC RF anti-root PVC sheet, double-sided textile substrate and double-sided L+S Ecoactiv substrate. (3) Frame made of hot-dip galvanised steel tubulars. (4) Hot-dip galvanised steel channel to collect excess water.

Illustration 16. Construction detail of the mBiGFAVE. Source: Basic and execution project CEIP Gabriela Mistral

[13] In the case of CEIP Gabriela Mistral, the vegetation is: *Hedera helix* (ivy), *Jasminum fruticans* (wild jasmine), *Jasminum officinale* (common jasmine), *Trachelospermum jasminoides* (starry jasmine), *Lonicera etrusca* (Etruscan honeysuckle), *Lonicera implexa* (Mediterranean honeysuckle), *Vitis vinifera* (grapevine), *Parthenocissus quinquefolia* (virgin grapevine), *Parthenocissus tricuspidata* (Japanese grapevine), *Clematis cirrhosa* (Andalusian vine), *Clematis campaniflora* (clematis).

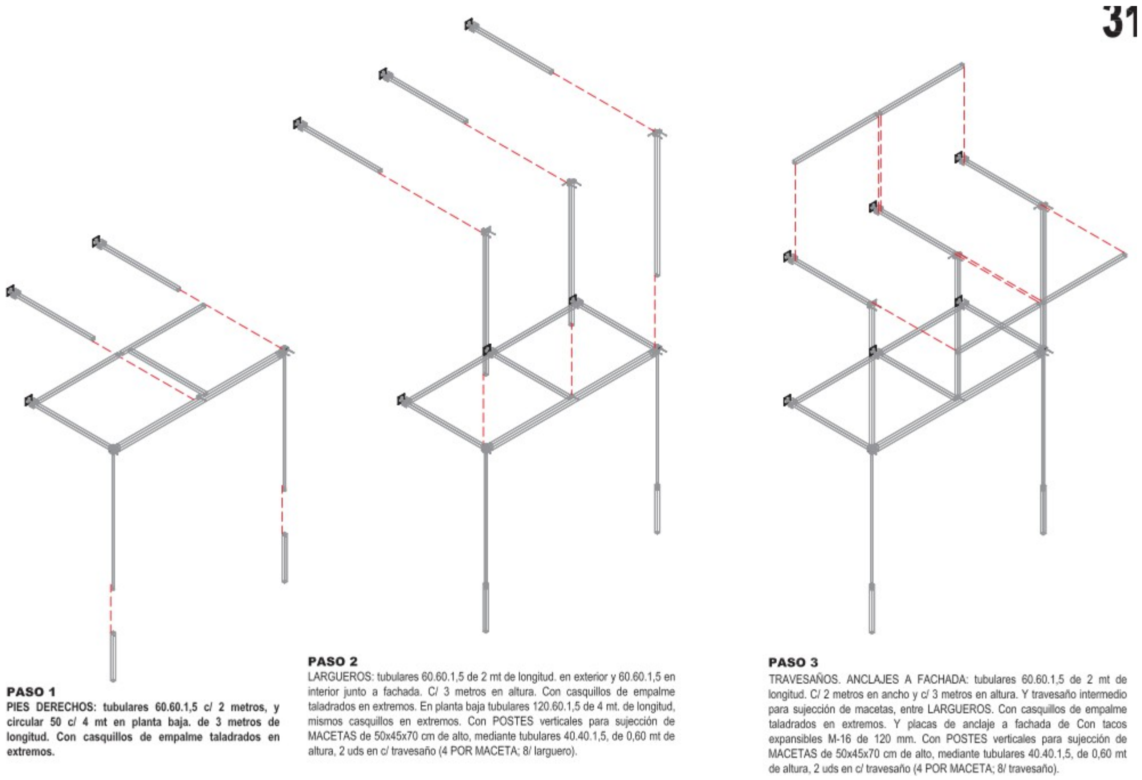


Illustration 17. mBiGFAVE system formation. Source: Basic and implementation project CEIP Gabriela Mistral

6.2.3. Specifications and procedures for implementation

The **vegetation** in FAVE 1 is climbing and deciduous, to protect it from the sun's rays in summer and allow it to pass through in winter.

As for FAVE 2, it has to meet the same irrigation and drainage requirements as the mBiGToldo prototype.

6.3. mBiGFAC

6.3.1. Description

The mBiGFAC prototype consists of a system of inter-spaced cables that support the development of a certain species of climbing vegetation. This solution contributes to the shading of the façades, protecting them from strong sun exposure in the spring and summer months.

The original prototype resolves the green façade parallel to the façade and with the cables emerging at ground level. However, there can be variants in which the green surface is inclined and with the cables emerging at a certain height from ground level, making them inaccessible to users, avoiding accidents and facilitating the maintenance of climbing vegetation.

This prototype has been implemented in the EB1 Falcão School, Porto and EB1 of Horta das Figueiras, Évora.

6.3.2. Materials

The materials and characteristics of the elements that make up the mBiGFAC façade are described below. **Figure 18** shows the arrangement of the different materials. Depending on the specific characteristics of each project, the materials may vary.

A concrete base structure is buried approximately 20 cm below ground level, which will serve as an anchorage for the steel cables, installed by placing M10 stainless steel eyebolts.[14] At the top, there are brackets that are anchored to the façade of the building and from which the stainless steel cables depart. Depending on the length of the cables, they may have intermediate anchorage points. At the base, there is a bed of topsoil on which the planting of *Parthenocissus tricuspidata* will take place.

For the variation of the prototype, a metal gantry is provided and separated from the façade to which the stainless steel cables are anchored (**Figure 19**).

[14] The distance between cables will be determined by each construction project: e.g. every 60 cm EB1 Falcão and every 30 cm in EB1 de Horta das Figueiras.

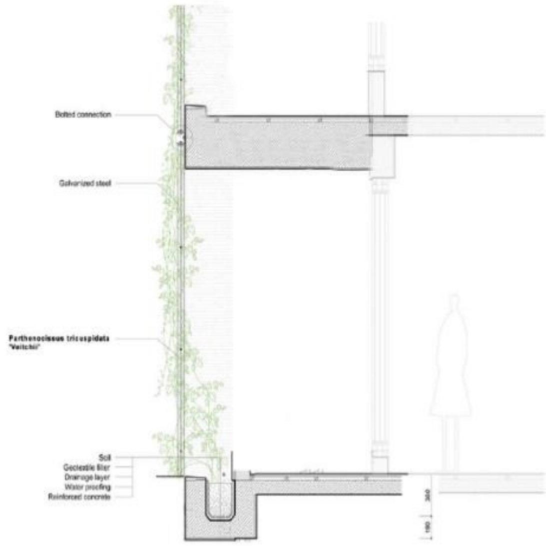


Illustration 18. Construction detail of the mBiGFAC.

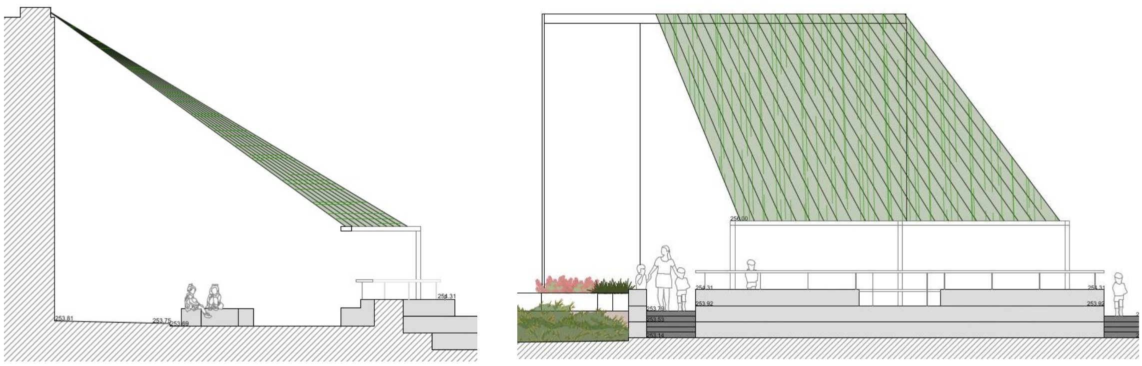


Figure 19. mBiGFAC variant profile. Source: Basic and execution project EB1 of Horta das Figueiras.

6.3.3. Specifications and procedures for implementation

The **plant species** selected for this prototype is the virgin vine, *Parthenocissus tricuspidata* "Veitchii". This species is fast-growing and has a deciduous leaf, which allows sunlight to pass through in winter and protects the building from direct sunlight in summer. The vegetation must be pruned to maintain its growth within the area allocated to it.

As it is a small flower bed, drip irrigation is used.

As it takes several years for the climbing vegetation to completely cover the entire surface area generated by the cable system, the installation of micro-perforated screens can be considered to ensure immediate shading of the outdoor spaces and associated facades. As the vegetation progresses in its development, they will be removed.

All **metallic material** used in this system must be stainless steel or galvanised.

6.4 Specifications and procedures for the implementation of green façades

The common specifications for the implementation of the different green façade prototypes are described below.

The **vegetation** shall be appropriate to the type of substrate, irrigation conditions, maintenance and climatic conditions of the site. For the appropriate selection of plant species, it is recommended to consult document *C2. Guide for the choice of plant species adapted to climate change.*

If it is considered necessary to include irrigation for the plant species implemented, an **irrigation water supply network must be** installed, which will form part of the building's network. The design and sizing of the distribution, diameter and stopcocks will be based on the expected consumption in order to ensure adequate plant development and avoid wasting water resources. The irrigation network may be equipped with a pumping and by-pass system in order to be able to operate directly from the network. The pumping system includes the possibility of adding fertilisers and pH-regulating acid to the storage tank. In case of storing rainwater, it shall be stored beforehand.

The **electrical installation** will consist of a new switchboard in the irrigation room, and power supply and protection for pumps, metering devices, programming, etc.

6.5 Regulations

Depending on the type of work, it will be necessary to comply with the respective regulations of each country. The following are the basic documents (DB) applicable to green façades according to the Technical Building Code (CTE) in Spain.

DB-SE Structural safety

In order to comply with structural safety, the structure of the green façade system must be calculated and the loads transmitted to the building must be assessed.

DB-SI Fire safety

Alteration of the building configuration affecting the external spread of fire to other buildings or sectors shall be taken into account.

It is recommended that up to a height of 3.50 m, deciduous woody species should not be placed at this height. Non-woody evergreen species may be used instead.

DB-SUA Safety in use and accessibility

- Safety against the risk of impact with fixed elements: the substructure of green facades must have a clear height of more than 2.2 mt.
- Accessibility: it has to be assessed whether the substructure of the green façades respects, modifies or alters the existing itineraries, having to ensure accessible itineraries.

DB-HS Health

- Protection against damp: In case of alterations to the existing façade, the conditions required by DB must be fulfilled. The façade must be water-resistant, have a drainage system to allow water drainage and allow adequate ventilation.
- Water supply: if irrigation is installed, new irrigation supply points must be provided.

DB-HE Energy saving

The scope of application, the quantification of the requirement and the justification for compliance with the requirement must be defined.

7. OUTDOOR SPACES

7.1. mBiG_SUVE

7.1.1. Description

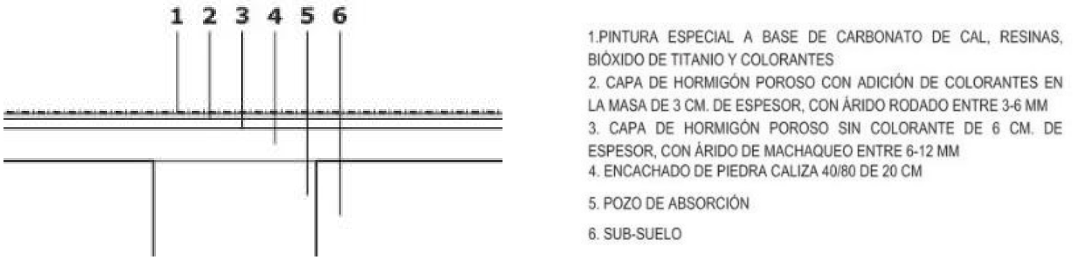
The SUVE prototype consists of draining paving designed to improve runoff water management. It facilitates the collection of water by draining it into the ground to avoid discharging it into the municipal network. There are two types of paving: CLASS 3 porous concrete drainage paving; and drainage-vegetated paving, made of prefabricated concrete pieces with joints that allow plant species to grow.

This prototype has been implemented in the CEIP Gabriela Mistral school, Solana de los Barros, Badajoz, and in the EB1 school in Horta das Figueiras, Évora.

View of the mBiGSUVE prototype in CEIP Gabriela Mistral

7.1.2. Materials

The materials used in the porous concrete pavement are as follows. On the subfloor, a 15 - 20 cm thick layer of stone facing is laid. On top of this layer, one or two layers of porous concrete are laid. The system can be finished with a special paint for the material used (see Illustration 21 and Illustration 22).



Construction details of the porous concrete pavement. Source: Basic and execution project CEIP Gabriela Mistral.

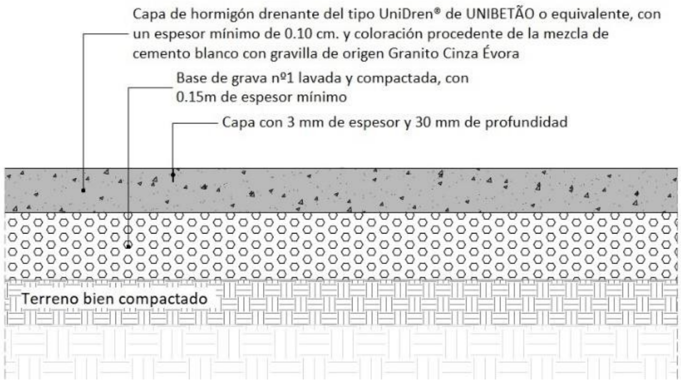


Illustration 22. Construction detail of the porous concrete pavement. Source: Basic and execution project EB1 of Horta das Figueiras.

The materials used in the drainage-vegetated paving are detailed below (see **Illustration 23**). Prefabricated cobblestone, with straight faces and lugs for spacing and drainage, of the terana green breinco type or equivalent, placed on a bed of compacted sand 3-4 cm thick at 70% and 30% of topsoil and fertilised and sown with grass[15] . The last layer is a sub-base of gravel 2/22 mm.

[15] In the case of CEIP Gabriela Mistral: 10% *Lolium perenne*, 10% *Poa pratensis*, 10% *Agrostis* spp., 70% *Festuca.* spp.

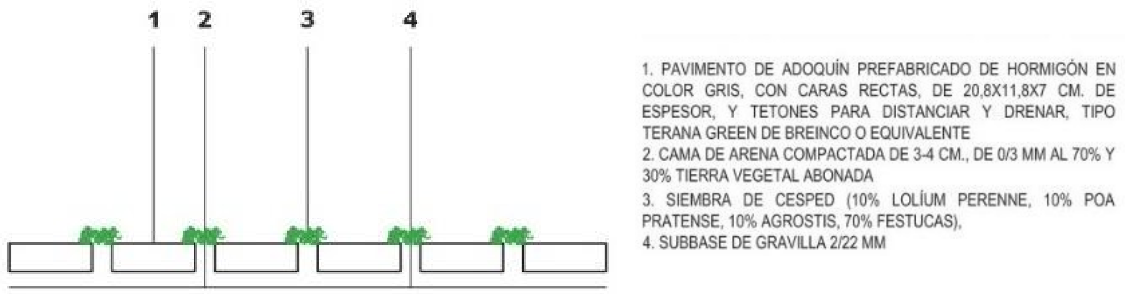


Illustration 23. Construction details of the drainage-vegetated pavement. Source: Basic and execution project CEIP Gabriela Mistral

7.1.3 Regulations

Depending on the type of work, it will be necessary to comply with the respective regulations of each country. The basic documents (DB) applicable to permeable floorings according to the Technical Building Code (CTE) in Spain are detailed below.

DB-SUA Safety in use and accessibility

- Safety against the risk of falling: the flooring must comply with the degree of slipperiness.
- New pavements must comply with accessibility conditions.

7.2. mBiGPond

7.2.1. Description

The prototype consists of an artificial lake with the aim of improving biodiversity and rational water management. Rainwater is collected from the roofs of the building, stored in a retention tank and directed to the pond. Riparian vegetation with riparian characteristics is planted, which also serves as phytoremediation, helping to maintain water quality. Urban ponds play an important role in the formation of small aquatic ecosystems of low demand and complexity. Flood zone, margins, shallow water zone, deep water zone and pond bottom. Ponds represent an interesting solution in productive areas, favouring the infiltration and availability of water in the soil thus reducing the need for irrigation, contributing to nutrient cycles, promoting biodiversity and attracting pollinators and natural enemies.

This prototype will be implemented in the EB1 Falcão school, Porto.

7.2.2. Materials

The dimensions of the pond determine its water storage capacity, which must be sized according to the rainfall of the site. Figure 24 shows the arrangement of the different elements of the mBiGPond prototype.

The pond shall be waterproofed with a geotextile fabric with chemical and biological resistance. A PVC liner with resistance to ageing, atmospheric attack and root penetration shall be placed on top of this fabric. The waterproofing shall reach half the height/depth of the pond. The pond shall receive the collected water through a buried rigid PVC pipe. The structure must be accompanied by artificially planted vegetation .[16]

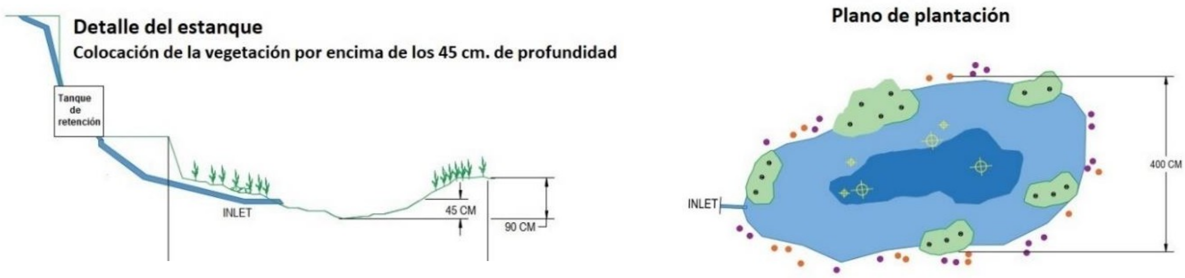


Illustration 24. Detail of the mBiGPond model. Source: Basic and implementation project EB1 Falcão

7.1.4 Specifications and procedures for implementation

For greater efficiency and stability of the ponds, the ponds should receive rainwater collected in green roofs.

To reduce water losses from these structures, appropriate **waterproofing** techniques must be used. The waterproofing of the pond is done by using a geotextile fabric to prevent the waterproofing membrane from rupturing.

Vegetation should be aquatic species and/or tolerant to very wet and flooding environments, depending on the part of the pond where they are planted.

[16] The species planted in EB1 Falcão are: *Iris pseudacorus*, *Nymphaea alba*, *Alisma lanceolatum*, *Potamogeton nodosus*, *Parthenocissus tricuspidata*.

8. BIBLIOGRAPHY

Annex 1. mBiG NBS prototypes. Deliverable A2. Development of NBS Databases and Working Matrix

Deliverable A2. NBS Projects of Porto's Pilot School - EB1 Faclão

Deliverable A2. Construction project of Évora's Pilot School - EB1 Horta das Figueiras

Deliverable A2. Basic project and execution - CEIP Gabriela Mistral