INSTITUTO SUPERIOR TÉCNICO
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ACADEMIA MILITAR
DULCE ET DECORUM EST PRO PATRIA MORI

Green Roofs and Facades

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Extended Abstract

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December 2012

1. Introduction

The United Nations (UN) predicts that the world population and rural exodus will continue to increase [1]. Demographic studies indicate that by 2030 five thousand million people will live in cities [1]. As such it is crucial to ensure that urban locations can find a balance between environmental and personal needs.

On an international level there already exist numerous movements that defend sustainable development such as “The Natural Step” and the institution “Ecological Footprint”. On the national level the Sustainable Construction initiative has developed courses and workshops that promote general awareness of various issues such as the installing of green roofs in buildings. These systems enable greater acoustic insulation [2], better energy efficiency [3]; [4], and contribute towards the mitigation of UHI [5]; [6]; [7], flood peak [8] and atmospheric pollutant concentration effects [9].

This dissertation studies the performance of green roofs and facades, specifically their hydro and thermal characteristics in the Portuguese Mediterranean climate.

2. Concepts, state of the art development and regulation

Concepts such as sustainability and resilience are highly important to green roofs and facades, and as such it is important that there correct interpretation be linked with the systems.

Sustainability consists in the creation of a way of life this is both adaptable and compatible with the environment by finding ways of coexisting with nature without harming present or future ecosystems [10]. A resilient system is not only sustainable but capable of effectively resisting a negative stimulus [11]. There are presently various options to make cities more resilient, like for example the use of green roofs and facades.

On an international level there are numerous examples of green roofs such as Ford’s factory in Darborn or the Potsdamer Platz complex in Berlin. Both could be studied and later implemented in Portuguese factories and shopping centres. The largest green roof in Portugal is presently the ETAR (water treatment station) in Alcântara, Lisbon.

There are also various examples of green facades like the Acros Fukuoka in Japan or the Quai Branly in Paris. In Portugal the most relevant example are the Natura Towers in Lisbon. These examples could serve as case studies that could lead to further projects in Portugal.

In terms of legislation and regulation, Germany has been the country that has most pushed forwards specific norms related to green roofs and facades. The FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau) has published guides to help understand green roofs, guides that are permanently being updated and improved and serve as reference to many other countries. In the USA and Canada there is the LEED (Leadership in Energy and Environmental Design) certification that evaluates building parameters related to sustainability such as hydro and energetic efficiency, types of materials used, among others [12]. The certification consists in a points system where higher points indicated a higher level (silver, gold or platinum). Buildings with green roofs and facades usually manage to obtain better certification [13]. In Portugal there are presently no specific diplomas for green roofs and facades.

3. Systems

The systems used can be divided into two, green roofs and green facades. Each section includes the classification used to characterise each different possibility as well as the components used.

3.1. Green roofs

3.1.1. Classification

There is a large variety of options that can be adopted in green roofs. Some of the factors that can vary and need to be analysed include the depth of the substrate, type of use, watering, maintenance, type of plats used, and cost among others. Given the existing diversity green roofs are normally split into three categories:

- Extensive;
- Semi-intensive;
- Intensive.

The key differentiation between the categories is the depth of the vegetal substrate. The extensive roofs have a depth of 60-200 mm, the semi-intensive go from 120-250 mm and the intensive have a depth greater than 180 mm [14].

3.1.2. System components

There are some components that are common to all three categories such as:

- Structural support - The load capacity of the structural support has an influence on the choice of the green roof. This limitation is even more relevant when the roof is for an existing building as the load calculation for these building do not often consider posterior addition of vegetal substrate or water accumulation (from watering or rain). In new buildings, however, it is possible to design it taking into account these associated additional loads. Because of this new buildings usually have less structural restrictions.
- Roof waterproof membranes - "The main function of any roof, green or traditional, is to keep exterior water out of the building. Waterproofing is a topic too vast and complex to be studied in depth in this paper" [12]. The previous sentence indicates the main function of a roof and the complexity of waterproofing. Waterproofing systems are specific to each case, and the testing of impermeability as well as the installation of leak monitoring systems are processes that ensure correct membrane functioning.
- Anti-root membranes - The anti-root membrane stops the vegetation from damaging the waterproofing membrane ensuring that the roof's impermeability is not at risk.
- Thermal insulation - This layer is usually found above the waterproofing membrane (inverted roof system) or below (traditional roof system).

- Drainage layer - Lack of water or its excessive accumulation can damage the plants in the vegetal substrate [15]. Due to this the draining layer has two functions; allow the flow of excess water from the roof and retain some water to regulate the quantity needed by the plants.
- Filter layer - The vegetal substrate has small sized particles that can affect the efficiency of the drainage layer, and the function of the filter layer is to avoid this.
- Vegetal substrate - It is especially important for the development of the plants that the substrate be well designed, and as such the characteristics of the vegetal substrate should depend on the location, the category of the green roof (extensive; semi-intensive or intensive) and the types of plants to be used. The chemical-physical characteristics of the substrate should be calculated by specialised personnel.

3.2. Green facades

There is less research into green facades when compared to that of green roofs, and because of this there is no specific categorisation as yet.

3.2.1. System components

- Structural support - As green facades have the buildings as structural support loads applied should take into account the materials used for the walls. In all systems it is necessary to carefully analyse the installation of the irrigation system and its location should be clearly identified in the project phase. The maintenance and cleaning systems should also be taken into account, especially in larger scale projects.
- Waterproofing membrane - In the majority of cases the waterproofing membranes are installed directly onto the structural support. The need to water increases the risk of infiltrations and therefore the waterproofing project should analyse the case of green facades implemented directly on the structural support.
- Plant support structure - The variety of systems for green facades has led to many different materials being used. The structures where the plants are located should promote their growth and their access to the water coming from the watering system. For such to occur the materials should have load resistance (taking into account the weight of factors such as the plant in its adult phase), allow water absorption and retention to avoid the need for constant watering.

3.3. Final considerations

The order of some of the components may vary according to the systems used. In some situations it may be necessary to use specific elements such as anti-vapour barriers. The reason for this variety is due to the numerous potential conditioning elements such as climate, the height of the building, solar exposition, the type of substrate, plants and materials used, and type of watering among others. This variety means that each green roof and façade is unique, and even similar cases may have different systems. One example is the adaptation required for considerably sloped roofs. In these situations every component has to be specifically chosen so that they are not dragged away by water or move due to gravity.

4. Thermal component

The European commission published directive 2002/91/CE states that the residential and tertiary sector absorb almost 40% of available energy and that these sectors are still expanding. The need to ensure energetic supply in the medium and long term is also clear in this directive, considering the need for the rational use of natural resources such as oil derivatives, natural gas and other fuels. This directive was applied in Portugal and currently integrates various diplomas linked to residential, office or state buildings.

It would be expected that in these diplomas there would be some information on how to integrate green roofs and facades so as to increase the use of passive systems that improve energy efficiency. However, there are no specific references to be found and thermal transmission must be analysed in each specific situation.

Research in this field is still in its infancy and some studies such as [6]; [16]; [17] and [18] have verified that there is a reduction of solar radiation due to the system functioning as a protective layer. Although the results obtained in each study showed improvements in thermal performance analytic methods varied and no author postulated the general fact that green roofs and facades work as thermal insulation in all cases. It is therefore currently usual to refer that green roofs and facades attenuate thermal fluctuations.

5. Hydro component

This component has been studied even less than the thermal one. Proof of this is the inexistence of hydro certification for buildings or equipment when compared to the obligatory thermal certification for new buildings and equipment. It seems therefore evident that this issue does not have such a detailed scope in terms of regulation as thermal performance. Nonetheless, through research of articles related to green roofs and facades there has been an increase of study linked to the hydro component [19]. This may be due to a growing global concern over hydro resources. The European Commission has also shown some distress related to this issue, emitting directive 2000/60/CE which establishes a community action plan related to water use.

In cases of light rain water retention in green roofs can reach up to 85%, with practically all of the water remaining in the substrate and vegetation, and in the cases of heavy rain can have a large retention capacity for at least 30 minutes [8]. According to [20], the benefit of green roofs is the initial attenuation of heavy rain. In terms of green facades, the objective is the filtering and purification of foul water. There currently exist systems such as BABYLON, patented by the companies patented by ASEPMA and Vivers Ter S.A. that are still in an experimental phase (ASEPMA, 2006).

6. Case Study

The sustainable construction initiative currently has courses that include both theory and practical study. As part of the case study two of these courses were attended:

- 1st Course – Renewable Prosperity – Living Roofs I;
- 2nd Course - Renewable Prosperity – Living Roofs II.

Throughout these courses a live roof project was developed in the headquarters of the League for the Protection of Nature (LPN).

The process used in the construction, monitoring and analysis of the LPN live roof (Figure **6.1**) are described below.

Figure 6.1 – LPN live roof.

6.1. The construction of the live roof

The living roof has an area of 14 m^2 and its structure has as its foundation a reinforced concrete slab. The finishing surface consists of a sloped levelling cement screed layer. These two layers already existed and the area was being used as a terrace.

The first layer installed by the group was a geotextile liner on 15 October 2011. Its function is to avoid damage to the waterproofing layer due to contact with any irregularity of the cement screed layer. The waterproofing membrane is made of PVC and was installed by Imperalum.

On 22 October 2011 the thermal insulation was installed. The material used by Esferovite SA was expanded polystyrene, available in 5cm and 10cm layer thickness, and was installed above the waterproofing membrane. The third practical session occurred on 26 November 2011. The walls that were exposed to UV rays were coated with a rubber aggregate, directly applied using silicone. As the coating was being applied another group prepared a drainage system. The use of an existing plastic basket encased with geotextile lining allowed an effective solution to be reached. This drainage system was installed and the system was then filled with large coarse material so as to avoid accumulation.

This was followed by the installing of the retention and drainage layer. The material used was indented polystyrene elastic foam “VYDRO” (the commercial brand). At the end it was necessary to place the substrate. The method used was to use rope and levers to elevate buckets with the material. Planting, watering and maintenance were left to LPN and as such the students did not have any part in these tasks. The system installed in the LPN live roof was designed by Sustainable Construction Living Lab and validated by individually and collectively by members of the Roof Rehabilitation work group (Figure 6.2).

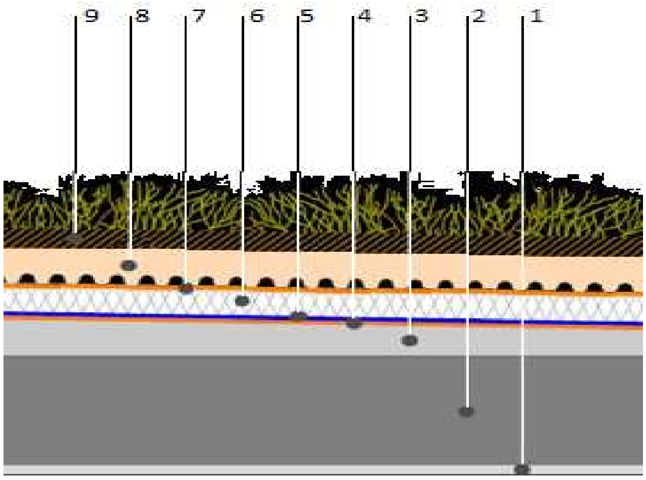

Figure 6.2 – Diagram of the LPN live roof; adapted from (Construçãosustentavel.pt).

Key:

1 – Interior finish;

2 – Reinforced concrete slab;

3 – Cement screed layer;

4 –Geotextile lining;

5 – Waterproof membrane;

6 – Expanded polystyrene layer (10cm);

7 – Geotextile lining;

8 – Indented elastic polystyrene foam rolls (10cm) (drainage layer);

9 – Vegetal substrate (minimum 10cm).

6.2. Monitoring of the living roof

On 31st of March it was possible to visit the LPN living roof with the watering and monitoring systems already in place. The analysis of the data is elaborated by LPN specialists and the practical results were obtained, illustrated in Figure 6.3.

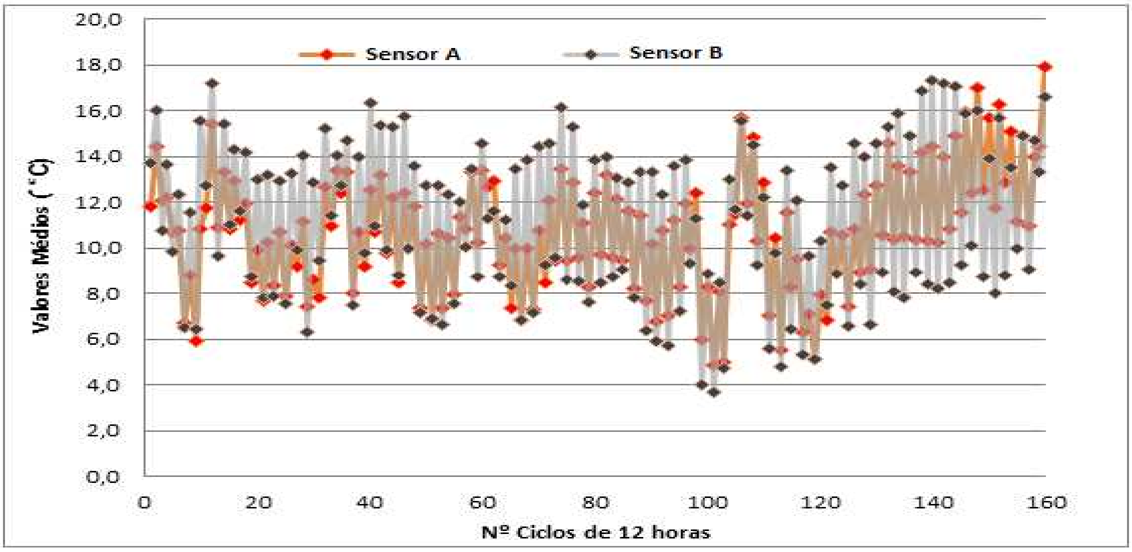

Figure 6.3 –Graph of the registered temperature of the thermal insulation sensor (Sensor A, brown), and the atmospheric temperature two metres above the substrate (Sensor B, grey) (Renewable Prosperity Course, 2012).

In the case study monitoring started in January 2012, with measurements being taken every ten minutes. Data treatment resulted in an average value for each twelve hour cycle. Figure 6.3 illustrates the first one hundred and sixty cycles (equivalent to eighty days) as well as the corresponding average temperature. These were registered from the beginning of the monitoring process until the last day of the second course. The objective of the use of cycles was to aid visual understanding of the graphs. From the analysis of the results it can be seen that:

- In twelve cycles the maximum average temperatures were higher in Sensor A and in twenty three cycles the minimum average temperatures were lower in sensor A when compared to sensor B;
- Thermal amplitude (the difference between the absolute value of one cycle and the next for the same sensor) shows that in six cases the green roof had higher amplitude than the exterior environment.

Maximum thermal amplitude between the green roof and the exterior environment was 5,57ºC, whilst the minimum was -0,77ºC.

In the thermal component chapter it was stated that green roofs should be used as external and interior thermal amplitude regulates and not exclusively for thermal insulation. From the obtained data the average of the thermal amplitudes is 2,49ºC.

7. Conclusions

This study intended to characterise green roofs and facades according to existing systems, analyse their thermal and hydro properties as well as present the case study. Based on this the best solution in terms of green roof and façade is to use a dynamic, flexible, continuous and self-correctable approach.

Throughout history green roofs have had two different contextual types, Roof gardens and Sod roofs.

Legislation and regulation should be versatile due to the large variety of defining factors such as climate, cultural aspects, financial capacity and building types. Regulatory solutions can be extrapolated according to location but their adaptation and constant perfecting are important aspects for the successful use of green roofs and facades.

The components of green roofs and facades are varied, and some are present in all construction solutions, regardless of their category:

1. Structural support;
2. Waterproofing membrane;
3. Vegetal substrate;
4. Plants.

The alteration of an installation or materials used can lead to changes in the functioning of the system, which can be adapted according to specific objects.

Research in the thermal component indicates that green roofs and facades contribute to attenuate building thermal amplitudes, when compared to those of the exterior. The improvement of energy efficiency generally corresponds to a reduction in building air conditioning and heating.

The majority of study in the field of green roofs is linked to the hydro component. Attenuation of water flow during floods in urban situations is of great importance in some cities (like Portland, USA), which can be achieved through the use of green roofs. There is specific legislation in this case and the results are being monitored by the city council. City water management is complex and climate changes can lead to catastrophic situations. The capacity of green roofs to attenuate flood effects has been shown in numerous research papers. The quality of rain water also improves when it is filtered through a vegetal substrate, which could be used for watering or washing, or enable water treatment plants to use less chemical additives.

The case study enabled various important aspects related to green roofs to be analysed:

- Specialised labour, good access, and multi-skilled teams are important factors when developing good quality green roofs;
- Monitoring is essential to optimise results and improve implemented solutions;
- In terms of periodic maintenance, the existence of a technical manual is essential for non-specialised personnel to successfully maintain the roof's good condition.

The green roof should have thermal properties that enable good living standards. Comfort temperature in the interior of buildings is normally around twenty two degrees. This means that the green roofs should have the following function:

- If the exterior temperature is significantly higher than this comfort value then the green roofs should enable the interior to have temperatures lower than the exterior;
- If the exterior temperature is significantly lower than the comfort value then the objective is to avoid the heat from the interior from escaping to the exterior.

In the case study there were times when the green roof did not perform as desirable, and as such should not be used only as thermal insulation.

Throughout this study it was difficult to obtain research related to the economic impact that green roofs and facades may have. All of the system should be analysed as a whole, and because of this the improved energy efficiency, quality of life and consequent reduction of costs for local governments is hard to quantify. For these reasons further study in this field should be made, with research and testing that help quantify the benefits of green roofs and facades.

As well as the objectives mentioned, this paper aims to simultaneously stimulate further study in this field leading to greater knowledge of design, installation and maintenance of green roofs and facades.

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