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Green Roofs - A Solution for the Sustainable Development of Urban Space

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Abstract

Urban green is fast diminishing in the dense cities resulting in a multitude of socio cultural and environmental problems. Urban ecology is the direct victim to the diminishing greens contributing to some extent towards global warming. Green roof concept as it has the potentialities to reduce the adverse ecological effect of the buildings by providing bio-physical diversity benefits, food, temperature and rainfall runoff regulation, wildlife habitat, as well as aesthetic and recreational opportunities. The aim of this paper is to analyze the benefits of implementing green roofs for the building, for the city and also for the society. In the same time the main errors encounter in the designing and construction stage of the green roofs are presented.

Keywords*: green roof, sustainable development, urban development*

Introduction

Nowadays, more than ever peoples are aware of the importance of protecting the nature and the living environment, and thus this are topics of interest for many countries. Cities expand their peripheries to accommodate more and more peoples attracted by the higher urban living standards than rural living standards. In a recent report of the United Nations, urbanization is forecasted to attain 83% by 2030 in developed countries (UN, 2019). A series of environmental issues arise from this, on a global scale, the most common one is the increased greenhouse gas emissions.

This worldwide urbanization led to an increase demand for new buildings, water, land, and energy (Felseghi, 2015). According to United Nations Environmental Program, the construction and maintenance of buildings account for about 40% of the global primary energy requirement and buildings account for 33% of the global greenhouse gas emissions (De Fino *et al.*, 2017). Therefore, the building sector is of particular interest in the reduction of energy use, in order to limit global warming and mitigate the impacts of climate change (Cascone and Sciuto, 2018).

In this context it arise the need to design sustainable buildings and urban spaces by considering the effect of building envelope technologies. Implementing various sustainable approaches (Maier, 2018c) and designing more environmentally friendly components for buildings leads to the realization of low-energy buildings. In addition, roofs are important components of buildings (Maier and Marusciac, 2011), accounting for nearly 20–25% of the overall urban surface area. Therefore, efficiently designed and integrated green roofs have great potential to affect the building and urban environments, replacing the lost green spaces and habitats in modern cities. Specifically, green roofs are engineered roofing systems, planted with different kind of plants on the top of a growth medium (Cascone, 2019).

A roof garden is actually very different from a green roof, although the two terms are often and incorrectly used interchangeably. A roof garden is an area that is generally used for recreation, entertaining, and as an additional outdoor living space for the building's resident(s). It may include planters, plants, dining and lounging furniture, outdoor structures such as pergolas and sheds, and automated irrigation and lighting systems. A green roof is usually constructed to cover a large area in the most economical and efficient means possible with an emphasis on improving the insulation and /or improve the overall energy efficiency within a building. Green roof concept can be most effective in urban areas where the lack of green-open spaces is a common phenomenon. The purpose of

this paper is to identify the main benefits of the green roofs and to highlight the challenges of executing this structures.

2. Benefits of green roofs

The results of increasing the innovation interest in the construction sector (Maier, 2019) can be seen also in the new ways to respond to the environmental issues. As a response to this issues engineers and architects began to look at ways to bring more nature in the urban environment. In the same time the each organization need to came up with solutions to sustainable development (Maier, 2018a) of the society (López-González *et al.*, 2020). In this context green roofs gain great attention because of their ecological advantages comparing to other build elements. The main obvious advantages of green roofs refer to improvement of energy performance, the urban microclimate conditions and the eater retention.

The advantages of green roofs are better felt in summer time conditions. Green roofs are in a continuous development, creating new innovative products or process (Maier, 2018b). The first advantage observed, in summer time conditions, is related to the increased thermal resistance and dissipation of the solar radiations. This is felt both at the building level and also at the outside temperature. The advantages of the green roofs can be observed also in the winter time when green roofs can store heat from solar radiations and reduces the heat loses through the roof part of the building (Cheng *et al.*, 2020). At freezing ambient air conditions, the process of water freezing further improves the energy efficiency of green roofs (Arkar *et al.*, 2019). Considering the multiple benefits of the green roofs we decide to analyse the benefits from three main category of beneficiaries (figure 1.)

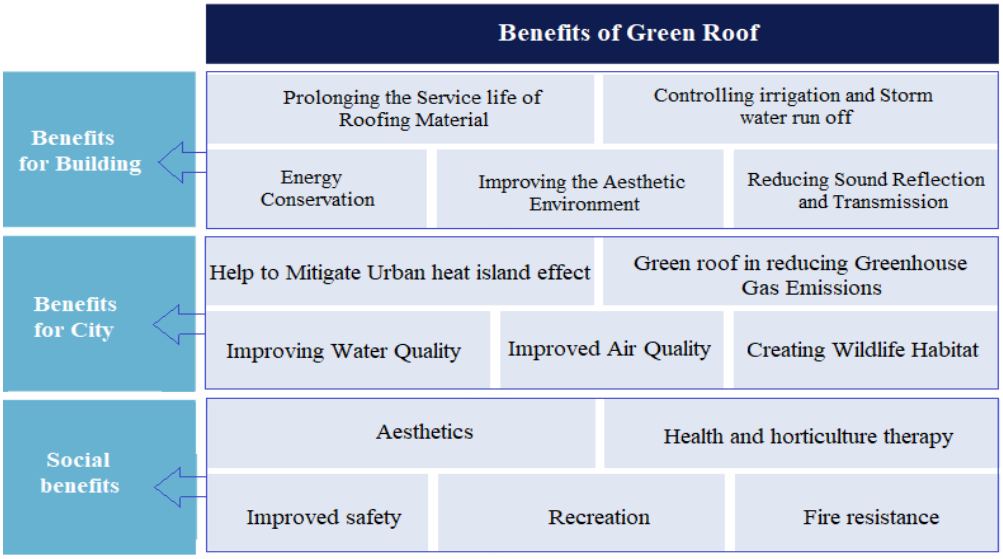

Figure 1. The main benefits of green roofs from building, city and social point of view (author proposal)

When speaking of **Benefits for the Building** one of the benefit is related to the *prolonging the service life of roofing material*. Green roofs protect roofing membranes from extreme temperature fluctuations, the negative impact of ultraviolet radiation and other physical damages. It is estimated that Green roof extends the life of the existing roof fabric by up to 70%. Protection of roof membrane resulting in a longer material lifespan, decreased maintenance and savings in replacement cost (Cascone and Sciuto, 2018).

Another benefit from the category of benefits to the building is that a green roof can *control irrigation and storm water runoff*. The plants capture and hold rainwater. Water is stored in the growing media released to the atmosphere through evaporation and evapotranspiration. Green roofs, in summer, depending on the plants and depth of the growing medium, retain about 70-90% of the precipitation that falls on them, and in winter retain

between 25-40% (De Fino *et al.*, 2017). The next benefit felt at the building level is the *energy conservation.* In summer, green roof planting shades the building from solar radiation and through the process of evapotranspiration cools the air reducing the temperature. Reduced energy consumption can cut cooling cost up to 50% and heating by 25% (De Fino *et al.*, 2017).

Improving the Aesthetic Environment is other benefit from the building benefits category. Green roofs contribute significantly towards the aesthetic appeal of urban roof-scape. Green roofs can integrate a building with its natural surroundings, besides offering opportunities for growing a wide range of aesthetically pleasing and vigorous, native plant species on a large and small scale buildings and structures. The last benefit from this category is r*educing sound reflection and transmission.* Green roofs can be designed to insulate for sound. The growing medium tends to block lower sound frequencies and the plants block higher frequencies. Tests show that green roof with 12 cm substrate layer can reduce 40 decibels and that of 20 cm can reduce sound by 46-50 decibels.

In the category of **benefits for the city** we can identify the effect of green roof over the *improvement of the water quality*. Green roofs help reduce storm water runoff and also moderate the temperature of the water besides acting as natural filters (absorbs metals and pollutants) for runoff water. Other benefit can be felt also on the i*mprovement of the air quality*. Green roofs filter fine, airborne particulates as the air passes over the plants. They trap up to 85% particulates on the surface areas of the greenery. Plants also absorb gaseous pollutants through photosynthesis (De Fino *et al.*, 2017). *Creating Wildlife Habitat* is another benefit from the benefits for the city category. Green roofs are valuable in conserving and restoring endangered habitats and vegetation types. A greater diversity of plant species tends to support a greater diversity of animal species (Cascone and Sciuto, 2018). Green roofs can also h*elp to mitigate urban heat island effect.* Cities of concrete and tarmac retain heat and create 'urban heat islands', as much as 5^0C warmer than surrounding suburbs. Plants through transpiration directly cool the air and can reduce surface roof temperatures by as much as 40^0C. In the end the city can benefit from the green roofs because it *reduces the greenhouse gas emissions*. Buildings are responsible for almost half (48%) of all energy consumption and greenhouse gas emissions and consume 76% of all power plant-generated electricity.

Green roofs can bring **social benefits** also. In this category we can identify *aesthetics*, planting gardens, both at ground level and in the sky, alters both the sensible and psychological climate for the better. *Health and horticulture therapy, t*he variety of sounds, smells, colors and movement provided by plants, can add significantly to human health and wellbeing (Fotopoulou *et al.*, 2018). Other benefit can refer to *improved safety*, a garden on the roof is often considered safer than a garden at grade, because access to the roof is often restricted to building tenants, there is less likelihood of assault or vandalism. *Recreation* is another benefit for the society. Green roof compensates the lack of green open space in many urban areas. Studies show that leisure activities in natural settings such as gardens and parks help people to cope with stress and in meeting other non-stress-related needs. Finally the last benefits from this category is referring to *fire resistance*. Green roof can help slow the spread of a fire to and from the building through the roof, particularly when the growing medium is saturated (Cascone, 2019).

3. Challenges of green roofs constructions

Considering the multiple benefits of the green roof, it can be stated that the initial investment can be amortized over time, but in order to benefit from these benefits it is important that the roofs are built correctly and efficiently. When green roofs are not proper build not only that they will not offer benefits or the building owners but the cost of repairing them can have a serious impact on the budget (Zhang, He and Dewancker, 2020). There are situations when green roofs occasionally fail to behave like they were design and thus a series of issues arise for the roofs and also for the building. The most common failure include leaks in the roof structure, dying of plants, soil erosion or slope instability (Opatowski, 2018).

In this section of the paper we perform an analysis of the most common green roof failures and how to prevent them. In the analysis process we focus on highlighting the best practices and lessons that can be learned from each potential failure of the green roof system. In this way solution can be offered to the owners, the designers or maintenance staff, solutions that can help to anticipate and overcome any challenges regarding the green roofs.

Choosing the right roofing system is one of the most important aspect to consider regardless of the green roof type. A less maintenance roof with an extensive system having shallower layer or a higher maintenance roof, an

intensive system, with deeper soil must be chosen also according to the roofing system (Kumar and Kaushik, 2005). Among the main failure problems identify in the literature we can find:

Damaging the plant life. This is the most visible failure of the green roofs, thus the green part of the roof is transforming in a brown color and the advantages of plants on the roof are lost. The common solution to this problem is to correctly balance the growing medium, the soil layer, with the plants regime of maintenance and water (Teotónio *et al.*, 2020). This means that it is important to respect the correct soil depth, the porosity, the irrigation and the drainage recommendations. In most of the cases green roofs are installed on terrace roofs, with little or no slope. In cases where the green roof is installed on sloping roofs erosion problems can appear. In this case it is important to minimize soil slippage and anchor trees.

Problems on the drainage system. Even if most green roofs seems to be flat roofs, the reality is that in many cases this is not true, the roofs are having a lot of highs and lows. The existence of plants is strictly related to the presence of water and, especially in summer conditions, there is the need for irrigations. In this sense a good drainage system is essential. The water drainage issues must be resolved before installing planting medium and the plants themselves (Nardini, Andri and Crasso, 2012). There is a common belief that the presence of the soil and plants will absorb all the water and no drainage is needed. This is obvious a big mistake and failure in ensuring the proper drainage system will cause a lot of structural problems for the building. In the same time too much water is bad or the plants. According to (Opatowski, 2018) the best way to prevent ponding is to create a 1:60 slope on flat roofs.

Problems of erosion and uplifting. These are particularly problematic at corners and edges of the roof especially on higher ones. A solution is to include a band of pebbles or paving at the edge and retain trims at the eaves(Green roofing failures: Root causes, 2008). Making sure that vegetation is sectioned and contained by edges of pebbles or gravel paving will allow good drainage of water without taking soil and plants with it. Often these "pathways" double as access for the maintenance staff, so they may already be included in the design (Opatowski, 2018).

Problems of uneven distribution in dead load on the roofing structure. From structural point of view choosing a green roof system will increase the dead load acting on the roof structure. In calculus the dead load is considered to be a uniformly distributed load on the entire structure, thus each of the roof structural element is carrying out a specific equal load. The reality is that depending on the contractor skills and equipment an uneven distribution of the green roof layers can occur. This variations along with live loads acting on the roof can cause local structural failure. Thus it is important that for each job site a proper load distribution should be ensured, from the designing phase and this must be checked in the execution phase. The roof structure must be design so as to resist additional forces on a roof and the possibility of rain-saturated soils. In the execution phase and in the exportation phase must be adapted solutions not to allow concentrated loads are not created by piling up soil or materials.

Problems with the plant and soil selection. The survival of the green roof is determined by correct plant and soil selection. Sedums (similar to succulents) are often selected because they can survive in a variety of climates and require a growing medium that is dry and has low amounts of organic matter (VanWoert *et al.*, 2005). But depending on the needs of your specific project, you may require shrubs or flowers to make the roof more ornamental. If this is the case, make sure you work closely with your contractor to make sure they are knowledgeable of what does best in your local climate. That means using native plants and native soil (although soil left over from the construction site may not necessarily be the best choice). If the architect or contractors are not familiar with soil and plant selection for the local region, hire a horticulturist (Opatowski, 2018). In designing phase of green roofs, the choosing of the plants should be done by a good collaboration between the designer and provider of the roof system.

Problems from improper plant handling. The effect of improper plant handling techniques can causes a series of problems for the green roofs. The green roof contractor should have a working knowledge of plant handling and establishment techniques. A green roof is a living building component, and the plants must be stored and handled with care to ensure their viability. Landscaping is a key trade for the successful installation of a green roof, and landscape contractors have the knowledge and experience with plant material to ensure that the green roof is properly installed and to ensure that precautionary measures are in place to respond to variable climactic conditions. Recognizing the need for this expertise, many roofing contractors who are serious about integrating green roofs into their business models have developed green roof divisions that focus on plant handling, installation, and maintenance (Challenges to Green Roof Construction, 2006).

Problems with moisture penetration. Water has a phenomenal capacity to track through construction. Establishing the point of water entry from manifestation inside the building can be challenging. Before remote testing – such

as thermal imaging, electronic leak detection or radio frequency testing – can be attempted, the plants and growing medium may have to be removed. The simplest solution may be to re-roof from scratch. According to (Green roofing failures: Root causes, 2008) waterproofing failures may be caused by:

- Plant root disruption. The effect of rhizomes such as couch grass or Japanese Knotweed may need to be tested separately. Ensure the waterproofing layer is resistant to root growth or incorporate a root resistant membrane
- Poor detailing at junctions, penetrations and edges. If at all possible, avoid penetrations or concentrate them in one area. Keep the roof design simple and minimize junction variations. All junctions should be planned in three dimensions to give installers a clear guide for what is expected. At upstands the waterproofing layer should finish at least 150 mm above the finished roof surface. Allow for drainage at the base of facades.
- Failure of waterproofing upstand. To maintain longevity of the waterproofing membrane, incorporate protection from direct sun exposure.
- Inadequate slope. Flat roofs will result in ponding unless there is at least a 1:60 slope.

Over-watering and over-fertilizing. Over-watering and over-fertilizing typically occur when the cause of plant loss is not apparent. The symptoms of over-watering are very similar to the symptoms of under-watering, and the same is true for over fertilization, therefore, they are easy to misdiagnose. Over-watering can be corrected by cutting off supplemental water. Over-fertilizing can be ameliorated in some cases by adding other amendments to balance nutrient ratios available to plants. It does take time for nutrient levels to stabilize, and additional maintenance may be required during this time. Laboratory testing of growth medium samples should be conducted before beginning a nutrient amendment course (Challenges to Green Roof Construction, 2006).

Green roofs are also accused of such disadvantages as leakage, condensation of water in the thermal insulation layer, or moulding of their bottom surface. These are not disadvantages, but rather the results of errors made during the design or construction of the cover. The specificity of green roofs, the fact that they constitute a type of water storage, causes that even the slightest deviations result in big losses. Thoughtful design and professional and careful construction ensure the reliable use of such roofs.

Conclusions

In today's society the role of nature is extremely important. Especially in urban areas, innovative technologies that can help to bring more natural elements are becoming more and more successful. One of the most popular solution is choosing green roofs for buildings. Green roofs are also used as a response to the increase requirements of sustainability and biodiversity as well as decreasing the energy consumption, green gas generation and urban heat island in the cities.

Initially they only constituted protection against unfavorable weather conditions, but over time humans began to notice more and more value and possibilities of using this kind of roof cover. Their properties are studied by many researchers. Numerous studies and experiments allow us to confirm the advantages of green roofs. Not only do they protect from heat or cold, but they also have a major impact on improving the living conditions and functioning of the human body, which is not unimportant to one's health. They allow for leisure, recreation and contact with nature even in tightly-built cities. They protect against their bustle and reduce pollution. Green roofs create a good microclimate and, in addition, neutralize the effect of urban heat islands. Green roofs are not only very useful for the environment, they also have many aesthetic qualities. They improve the appearance of cities, give a chance to beautify the ugly, unused roofs of many buildings.

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