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GREEN ROOFS

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Abstract: Roofs are much more than mere 'functional components' that protect the structure of a building. They give character to both individual buildings and entire city quarters. Roofs attract urban designers looking for socially responsible concepts, which are opposed to the loss of natural living space and offer solutions to the problems such as precipitation management or the urban heat island effect of densely populated cities. This paper discusses extensive, intensive, and semi-intensive green roofs.
Keywords: green roofs, extensive greenery, intensive greenery

INTRODUCTION

Building design changes constantly, but the function of buildings always remains the same: protection, comfort, and warmth during winters and coolness during summers.

The research conducted over the past several decades indicates that buildings are the highest energy consumers (about 40% of total global consumption), so their environmental impact has come into focus in the previous years. In addition to standard energy efficiency measures, such as façade reconstruction or door and window replacement, increased emphasis has been placed on the construction of green roofs as a potential energy efficiency measure, wherever it is feasible, but primarily in urban environments.

Green roofs provide additional green surfaces in urban areas with limited open space, but they also raise the value of buildings. The appeal of these roofs is best corroborated by the fact that they can also be conceptualized as public gardens, or business or recreational spaces, which offer numerous possibilities for use [1, 2].

Green roofs are commonly built on flat rooftops. Flat-roofed buildings are one of the symbols of modern architecture. The most important representatives of this architectural trend are Le Corbusier, Walter Gropius, Bauhaus School representatives, Frank Loyd Wright, and others. Le Corbusier defined the roof garden as a key living space for future urban population.

Austrian architect Friedrich Stowasser was one of the first architects to stress the significance of green roofs as a means of non-aggressive resistance against negative evolution. He saw nature as heightened reality, a source of universal harmony, and he believed that it should be protected from its worst enemy – humans. He wanted the time spent in his buildings to imitate the time spent in nature. He also considered trees to be a constituent part of human constructions. Hence, his buildings typically include trees and shrubbery on rooftops.

In the late 20th century, the fundamental principles of green architecture were established, pertaining not only to green roofs, but also to extensive and intensive greenery on large buildings, as well as green façades.

In recent years, much attention has been given to roof gardens, which initiated the construction of numerous green roofs of extraordinary design.

Today, green roofs are constituent elements of bioclimatic architecture [3, 4].

ADVANTAGES & DISADVANTAGES OF GREEN ROOFS

Green roofs can serve as balconies, because their inclination should be minimal, only enough to allow water to drain. A 0.5% inclination is sufficient. On the other hand, the inclination should not exceed 40° due to erosion and in order to preserve the compactness of the green mass. There are construction technologies that

enable construction at higher inclinations, but they are also costly. Depending on the building statics, the weight of the green roof should also be considered. There are roofs with the soil layer as thick as 50 cm but there are also those very thin soil layers.

Green roofs have certain advantages over regular roofs:

- they reduce energy consumption in buildings because they act as thermal insulation, thus reducing building heating and cooling expenses by ca. 20%;
- they protect the roof from UV radiation and mechanical damage, which extends the roof's life;
- water is retained and it slowly evaporates, thus preventing high-volume drainage into the storm sewer, which in turn eliminates the need for additional sewerage infrastructure;
- they reduce dust levels in the surrounding area;
- they regulate air humidity;
- they provide new habitats for plants and animals;
- they absorb sound, thus reducing traffic noise levels;
- they raise the market value of the building;
- they create additional space for walking or resting;
- they enhance their surrounding visually and aesthetically.

However, these roofs also have some disadvantages:

- their cost is usually higher than that of regular roof systems;
- they require frequent maintenance, which also incurs additional costs;
- building structure has to bear additional load [1, 5].

GREEN ROOF TYPES

The most widely used green roof construction joins the reinforced concrete panel as the load bearing construction to the applied insulation system, depending on the desired effects and the thickness of greenery in the top soil layer and planted greenery [6 - 9] .

Table 1. Provides the features of extensive and intensive roofs

Parameter	Extensive	Intensive
Vegetation	Sedum, grass, medicinal and culinary herbs	Grass, ornamental shrubs, trees
Height	< 15cm	25–100cm
Irrigation	Mostly without	Always required
Weight	50–150kg/m²	250–1000 kg/m²
Walking space	None/Limited	Yes
Water tank	4-12mm	18-39mm
Load bearing capacity	Mostly sufficient	Requires very strong roofing construction
Maintenance	Very rarely	The same as regular gardens
Inclination	Up to 45º	Flat or terraced

Depending on their thickness, green roofs can be:

- extensive,
- intensive,
- semi-intensive.

Figure 1 shows buildings with green roofs.

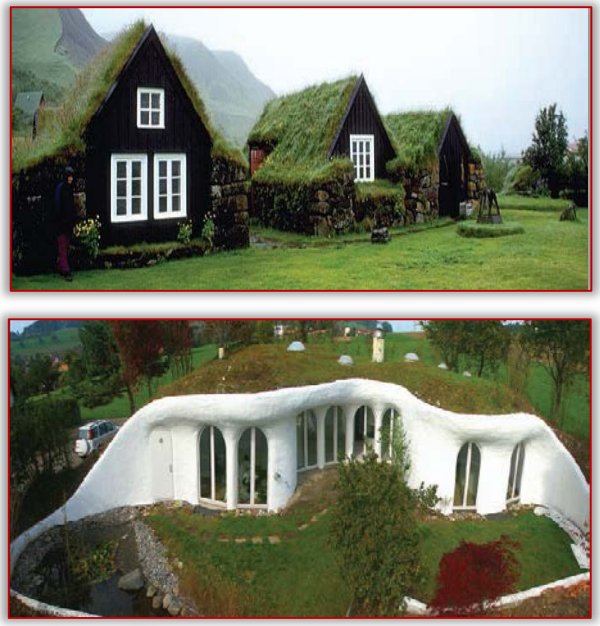

Figure 1. Green roofs: 1) Green roofs of the Skogar museum, Iceland; 2) Earth house in Switzerland

EXTENSIVE GREEN ROOFS

Extensive green roofs are impassable roofs. They should be planted with grass that is extremely resilient to drought and with ground cover plants no more than 30 cm in height, i.e. extensive greenery, which requires only 5-15 cm thick soil layer. The structural load of such roofs is 50 to 200 kg/m².

Extensive covers are suitable for inclined roofs and for converting old roofs into green without any changes in the construction, which is not adjusted to bear larger loads. Extensive roofs are not intended for recreation, heavy weights, or trees.

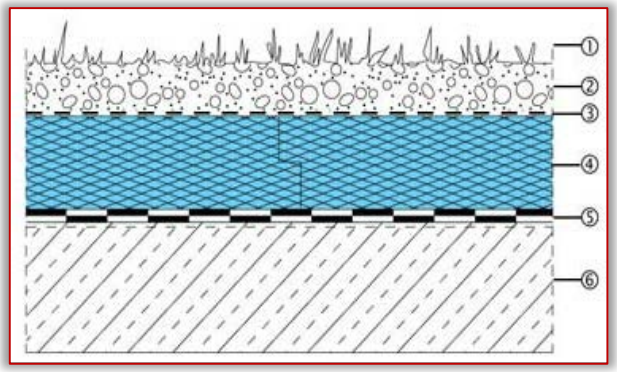

Figure 3. Single-layer extensive green roof: 1) extensive lawn – vegetation; 2) drainage vegetation layer 80-100 mm thick; 3) fabric (e.g. polypropylene) 110-140 g/m²; 4) insulation material; 5) bituminous waterproofing sheet; 6) concrete ceiling

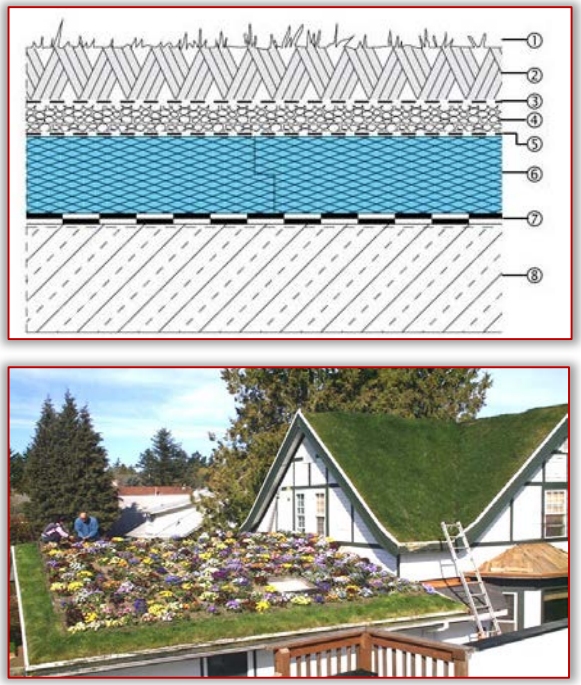

Figure 2. Extensive roof with drainage system: 1) extensive lawn – vegetation; 2) soil layer 80-100 mm thick; 3) separation/filtration layer; 4) drainage layer; 5) fabric (e.g. polypropylene) 110-140 g/m^2; 6) insulation material; 7) bituminous waterproofing sheet; 8) concrete ceiling

INTENSIVE GREEN ROOFS

Roof gardens – intensive roofs – are multifunctional green roofs, which retain large amounts of water. It is suitable for lawns, perennial plants with deeper substrate, shrubs, and trees.

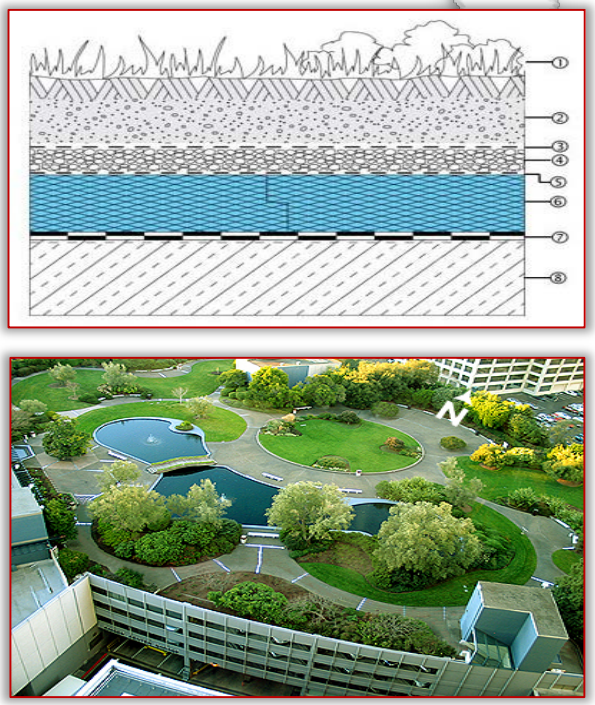

Figure 4. Intensive green roof: 1) vegetation; 2) drainage soil layer 200 mm thick; 3) separation/filtration layer; 4) drainage layer; 5) fabric (e.g. polypropylene) 110-140 g/m^2; 6) insulation material; 7) bituminous waterproofing sheet; 8) concrete ceiling

Such roofs allow the integration of pathways, terraces, access roads, playgrounds, swimming pools, etc. There are essentially no limits to the design provided that the building structure allows it. Intensive green roofs are passable and are covered in large shrubbery, trees, and other taller plants ranging from 0.50 m to 4.0 m. Medium and tall shrubbery and shorter trees, i.e. intensive greenery, require ca. 1.20 m thick soil layer for normal growth, while their load on the structure is 300-500 kg/m^2.

Intensive green roofs have a relatively flat surface with 1-1.5% or up to 3% inclination. Intensive roofs require considerably more care and maintenance, for instance, more frequent fertilization and larger amounts of minerals for large plants to grow. Depending on the choice of plants, sometimes water tanks are required, as well as irrigation, fertilization, and maintenance systems, just like with regular gardens.

SEMI-INTENSIVE GREEN ROOFS

Semi-intensive green roofs share the properties of extensive and intensive roofs. Parts of these roofs are passable and are used for rest or recreation. They are designed as extensive roofs with low maintenance requirements, while being accessible and open for public use, which is a property of intensive roofs. They include plants 0.25-0.50 m tall, with the soil ca. 0.20 m thick, which adds about another 250 kg/m^2 load on the building structure. The plants that are usually used for these roofs are also very low-maintenance, e.g. grasses or medium-height sedums.

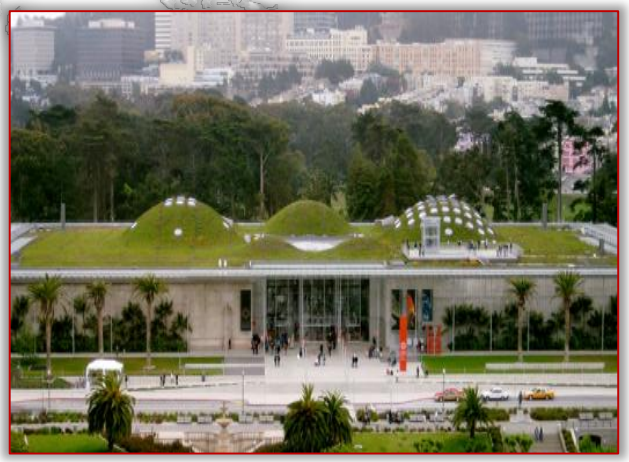

Figure 5. Semi-intensive green roof

CONCLUSIONS

Green roofs can be found in many countries, having recently grown quite popular in urban areas, where particular and more resilient plants are used, with a special drainage technique. Flat, usually concrete, roofs are a common issue in cities, as they often leak and create problems for the upper floor occupants. Through conversion into green roofs, they become useful and aesthetically pleasing. Green roofs protect the roof structure from extreme temperature shocks, provide space for walking or resting, reduce water drainage

issues, reduce heat radiation and reflection with their green layers, aesthetically enhance the surrounding area, completely eliminate the negative effects of dust, and reduce the negative impact of traffic noise. They also protect the roof insulation and roofing from UV radiation and balance out daily temperature fluctuations, thus extending the life of the roof system.

Note

This paper is based on the paper presented at The VIth International Conference Industrial Engineering and Environmental Protection 2016 – IIZS 2016, organized by University of Novi Sad, Technical Faculty "Mihajlo Pupin" Zrenjanin, in Zrenjanin, SERBIA, October 13–14, 2016, referred here as [10].

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