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Technological Imagination in the Green and Digital Transition

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Chapter 75
Challenges and Potentials of Green Roof Retrofit: A Case Study

Nikola Miletić, Bojana Zeković, Nataša Ćuković Ignjatović, and Dušan Ignjatović

Abstract Green roofs are becoming common practice in building new public buildings and are considered the roofs for the future since they address the issue of energy and environment simultaneously, providing social, environmental and economic benefits. Despite these benefits, retrofitting an existing building with a green roof is not widely practiced. Undergoing such a project is no small task since it requires a thorough investigation of existing building's constraints, functional, material, and technological to even begin considering design options. Therefore, this process requires specific, case-sensitive approach, especially with the aim of improving the building's energy performance. This paper presents a methodological approach and design proposals of a green roof retrofit project, through a case study of Belgrade's "City Housing" building. This retrofit project presents an interesting research topic since it incorporates three distinct roofs, of all of different types, different ways of accessibility and levels of privacy, varying top-to-bottom from a simple extensive roof through a semi-public semi/intensive roof garden to a ground-level public park with trees and intensive vegetation. Also, since this building provides socially significant services, it is frequently visited by general public which presents a potential for introducing educational and demonstration elements in the retrofit project, not only the functional and technological ones. That way, this project can be a showcase example, promoting greening the roofs of Belgrade's existing public buildings as a way of improving their energy performance.

Keywords Green roof · Building retrofit · Energy efficiency

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75.1 Introduction

Energy refurbishment includes wide spectrum of actions among which improving thermal properties of building envelope takes the central spot. Applying green roof systems represents one way of improving energy properties of the roof since there are systems which are light in weight thus allowing for adding enough thermal insulation on the existing roof construction. While the thermal insulation affects thermal properties of the roof, the outer layer of vegetation brings numerous additional benefits, from decreasing heat in summer months, rainwater retention, air filtration, increasing biodiversity to psychological and social effects on their users. Green technology application is therefore being adopted and even incorporated into regulations by many countries around the world to address the issue of energy and environment simultaneously. However, this concept is relatively new for most of the builders, developers, and designers in Serbia. In Belgrade, Serbia's capital, there are not many buildings with green roofs due to lack of knowledge and awareness, financial affordability, lack of statutory mandate, or regulation in building design.

Apart from the excessive energy consumption, air pollution in Serbia has become a serious problem for human health. More parks and gardens are needed to restore balance. As free space for new greenery is limited on the ground, the alternative is to place them on the roofs of the existing buildings. In developed cities, roof areas account for about 40–50% of total impermeable surfaces of urban areas. It is also argued that retrofitting an old building with a green roof in is more cost-effective compared to a new building since old buildings are mostly poorly insulated and use a lot of energy annually. (Shafiquea et al. 2018).

The implementation of green roofs in Belgrade will certainly provide benefits as well as challenges to both public and private sector. The starting premise of this paper is that this new solution would most certainly increase thermal properties of the existing roof due to adding more thermal insulation, but the true question lies in discovering if the chosen green roof system allows for enough thermal insulation to be added, due to weight, building geometry, and existing infrastructure limitations, while providing additional benefits unique to a green roof. This paper aims to discover and address these benefits and challenges based on a case study of one public company administrative building—Belgrade's "City Housing" building.

75.2 Green Roof Retrofit—Pros and Cons

Climate of Serbia can be described as moderate-continental with more or less emphasized local characteristics. This climate is characterized by significant precipitation, and green roofs have proven their efficiency in rainwater retention, which ranges from 55 to 88%. (Shafiquea et al. 2018) Very high temperatures that are characteristic for summer season in Serbia can be effectively alleviated by existence of greenery on the roof tops, thus reducing the effects of urban heat island effect. A study in Toronto, Canada, found that the heat gain through the green roof was reduced by an average of 70–90% in the summer and heat loss by 10–30% in the winter. (Castleston et al. 2010) It also adds thermal mass to help stabilize internal temperatures year round.

In addition to previously mentioned benefits, green roofs help mitigate air pollution. Two-year study conducted with the aim to determine the effect of extensive green roofs on the surrounding air resulted in conclusion that an extensive green roof absorbs and retains 189 g of CO_2 per m^2 per year. (Getter et al. 2009) Apart from the direct reduction, green roofs also have an indirect positive influence on building's thermal envelope, resulting in less energy spent for heating and less CO_2 released in the atmosphere. (Djordjević et al. 2018).

Green roofs are commonly classified into two major categories—intensive and extensive green roofs (Wilkinson and Dixon 2016). Intensive green roofs are categorized on the basis of substrate thickness (> 30 cm.), with a wide variety of plants/vegetation similar to ground-level landscapes, high water holding capacity, high capital, and maintenance costs and larger weight. Extensive roofs have substrate thickness of 7–10 cm, use mostly sedum as the vegetation layer and typically do not require irrigation. They require less capital and maintenance costs as compared to all other roofs. These roofs are usually very lightweight and useful where there are building weight restrictions.

There are also those green roofs with 15–30 cm substrate thickness and are referred to as semi-intensive and usually have small plants, shrubs, and grass. These roofs require regular maintenance and high capital costs for the better performance.

The major problem with green roofs is that they usually require high level of maintenance which building occupants have to organize by themselves. However, the advantage of public buildings is that they have publicly organized maintenance. In Serbia, availability of green roof manufacturers is also a problem, since the offer is limited, and the price of installation and maintenance is high compared to regular roofs. Green roofs also require highly skilled and experienced workers for installation and maintenance, which Serbia lacks.

75.3 Methodology

A set of requirements was created in order to verify if the building's roofs were suitable to undergo a process of green roof retrofit in terms of the following:

- Evaluating the bearing capacity of the existing building—aimed at identifying the possible solutions due to weight of different types of green roof;
- Analyzing pros and cons of different green roof types to know which one is most suitable to install. This step directly relates to the previous one. For example, installing extensive green roof offers ecological benefits, while intensive green roof can provide more substantial benefits like public spaces and allow more plants species but requires more space and has more weight;

- Examining the accessibility to roof, for construction and post-construction maintenance, including the availability of sufficient roof space;
- Valorization of different scenarios, determining their benefits in terms of socio-esthetic, functional, energy and financial aspect.

To calculate the potential influence of the green roof as well as the properties of the existing roof, a software package available on Serbian market was used—Knauf TERM 2 PRO since it complies with the current law and is widely used by professionals. Software is calculating annual energy need for heating according to the HDD methodology defined in the current regulations in Serbia. (Rulebook on Conditions, Content and Method of Issuing Energy Performance Certificates 2012; Rulebook on Energy Efficiency in Buildings 2011) Constraints coming from this kind of thermal analysis are not taking into account different occupancy regimes and heating regimes, as well as dynamic aspects of heat transfer through building elements as explained in previous research. (Ignjatović et al. 2018).

75.4 The Case Study—Belgrade's "City Housing" Building

The administrative building that is the subject of this research is part of a larger building complex, in a form of the letter "H." Each of its parts represents a separate functional zone, with different heating regimes and heating systems. The subject of this work is improvement of energy performance of one such independent part—office building of the "City Housing" public enterprise that occupies building's south-western part. (see Fig. 75.1) Considering that some parts of the building's envelope were reconstructed in the previous period—building's facade walls and window components, this research and design project is reduced exclusively to interventions on roof planes, specifically:

- Access plateau above the garage of the complex (zone 1—area of 597 m^2);
- Flat roof above the entrance hall (zone 2—area of 160 m^2);
- Flat roof above the first floor of the building (zone 3—area of 646 m^2).

This research has been used in real-case scenario and has been finalized in the form of technical documentation required for the construction.

The existing condition of the analyzed roof areas is rather poor. The pedestrian surface is not even, due to the deterioration of concrete tiles and their joints, which represents a potential risk. Also, concrete tiles are problematic from the aspect of rainwater retention and heat island effect because of concrete's high Solar Reflective Index (SRI). As for the rainwater runoff, since there is only one gutter per roof, inappropriately sized, overflows often occur. Finally, the structure of the roof layers does not have adequate thermal insulation properties, so additional insulation is required.

Fig. 75.1 Roof zones included in the intervention on "City Housing" building

75.4.1 Zone 1—Access Plateau Above the Garage

Even though the access plateau is not part of the building's thermal envelope, it is part of the retrofit project because of its functional, esthetic, and environmental potential.

This roof combines several different parts and processing: areas under extensive, semi-intensive and intensive green roof, plateaus made of composite wooden decking covered by a steel rectangular pergola used as the leisure area and paths made out of granite ceramic tiles, providing access for pedestrians and motor vehicles (see Fig. 75.2).

The plant species planned on this roof are various medium-sized deciduous trees, evergreen and deciduous shrubs, and ornamental grasses planted in planters made of light aggregate blocks. Benches are added on some of the planter walls.

As this part of the building is frequently visited by the members of the general public and as it is located next to a university, it possesses great educational and demonstrational potential and is designed to be a "showcase" example—showing how the green roofs can look and what types there are—having extensive, semi-intensive, and intensive roof segments all in one place, how they can be adapted to existing buildings, reduce energy consumption, and have an overall positive effect on the environment. Educational info-graphic board is planned to be placed on the plateau, toward the building entrance, explaining the measures taken in the retrofit project as well as the benefits such an intervention has in regard to building energy consumption, CO_2 emission, rainwater retention, and urban heat island reduction.

Fig. 75.2 Zone 1—access plateau above the garage—existing state (top), top view (bottom left), and rendering (bottom right)

75.4.2 Zone 2—Roof Terrace Above the Entrance Hall

Roof above the entrance hall of the building is retrofitted in the form of a mixed green roof with elements of the roof terrace. This roof area was designed as a kind of "garden" intended for the employees that work in the building, making it a semi-public place suitable for presentations, company meetings, and coffee breaks. It incorporates several different elements: plateaus and paths made of granite ceramic tiles or composite wooden decking with appropriate spaces for sitting and gathering, covered area under a steel pergola serving as a sunshade, and a base for the creeping plants to grow and green segments consisting of both extensive green roof, sedum as ground cover, and medium-sized vegetation that offers privacy and contributes to the atmosphere (see Fig. 75.3).

75.4.3 Zone 3—Flat Roof Above the First Floor

The area above the first floor is envisioned in the form of an extensive green roof. Plants of the succulent species (sedum species) of different colors and types are

Fig. 75.3 Zone 2—roof terrace above the entrance hall—existing state (top), top view (bottom left), and rendering (bottom right)

planted in organic geometric form on the appropriate sublayers of the extensive roof garden. Gravel is used for filling the drainage edges of the extensive roof, in order to rationalize the solution. For safety reasons, access to upper roof is restricted only to construction and maintenance workers via steel ladder (Fig. 75.4).

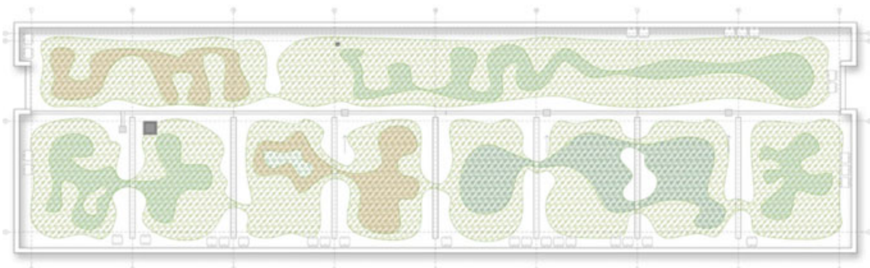

Fig. 75.4 Zone 3—flat roof above the first floor—top view

75.5 Results and Discussion

Bearing capacity of the existing construction is the most important requirement when discussing green roof retrofit project since it determines what type of the green roof and the depth of the substrate is possible to apply on the building in question. If the existing construction is not able to bear the load of the preferred green roof, it is possible to reinforce the construction. However, this is a complex process requiring a lot of additional work and substantial financial investment. Also, such an action can reduce the depth available for the green roof layers depending on the existing building's geometry. The research of the available project documentation of the building in question established that the load-bearing capacity of the existing slabs provides the possibility for the planned refurbishment project according to the set requirements. Zone 1 and zone 2 roofs have a 0.55 kN/m^2 less weight with all the green roof and insulation layers added than the existing roof, while the zone 3 roof weighs 0.6 kN/m^2 more than the existing roof. In order to have medium-sized trees on the zone 1 roof, which require larger amounts of soil, planters made out of light aggregate blocks were placed directly above columns and other structural elements to support their additional weight.

The refurbishment of existing roof by implementing green roof solution requires freeing the construction of the excess layers in order to place the new ones. Some research suggests leaving existing screed to falls made of perlite concrete, since it is a light material with thermal properties better than other materials used for this purpose like cement (Djordjević et al. 2018), but since we cannot be sure what the current state of the materials in existing roof is, it may be best to remove them all, up to the structural slab.

When adding layers of the new roof, it is necessary to calculate the heat transfer coefficient of the newly formed structure of thermal envelope. By current regulations (Rulebook on Energy Efficiency in Buildings 2011), the highest allowed value of the heat transfer coefficient of the refurbished flat roof is Umax = 0.20 W/m^{2}K for the elements above heated areas and Umax = 0.40 W/m^{2}K for those elements above unheated areas. The U coefficient for the existing roofs has the value of 0,545 W/m^{2}K. When applying suggested green roof solution, the calculations show that only 8 cm of thermal insulation is needed for the zone 1 to fulfill the requirements set by the regulations, while 20 cm of thermal insulation is needed for zones 2 and 3 (about a quarter of the thermal envelope), and bring U coefficient to 0.174 W/m^{2}K thus reducing buildings energy needs for heating by 11%. (Fig. 75.5).

Since the current legislation does not take into account the layers of substrate on top of the hydro-isolation as thermal insulating material when calculating U coefficient, it is obsolete to speak about green roof's thermal characteristics without the simulation and calculation procedures which take into account the positive effects of thermal mass in lowering energy need. Researches that take these effects into detail consideration show that energy consumption for cooling can be reduced up to 35% and for heating up to 10%. (Cascone et al. 2018).

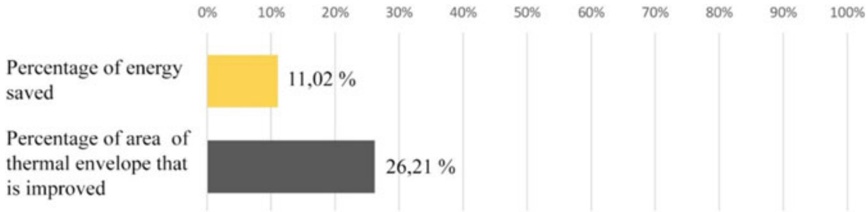

Fig. 75.5 Diagram comparing the percentage of energy saved for heating with thermal envelope area intervened upon

75.6 Conclusions

This model offers a demonstrational know-how for old building refurbishment using green roof implementation. In this approach, energy reduction is not a main motive of building refurbishment, but it is seen as just one of the benefits.

On the urban scale, it is shown how green roofs contribute to reduction of urban heat island effect by reducing solar radiation index, mitigation of air pollution by absorbing CO_2 and better rainwater retention, thus reducing the negative effect our cities have on the environment and presenting an adequate architectural response to our planet's changing climate.

On the building scale, even though the green roof has no positive impact on roof's thermal properties itself (without additional thermal insulation), it can be concluded that green roof presents a god solution for future refurbishment projects since it allows for enough thermal insulation to be added having in mind load-bearing characteristics of the existing structure. Therefore, it makes room for improvement in aspect of building's thermal and structural properties, while improving its user's quality of life from ecological, psychological, and social aspect.

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