The 56th International October Conference on Mining and Metallurgy
22-25 October 2025, Bor Lake, Bor, Serbia
www.ioc.tfbor.bg.ac.rs

DOI: 10.5937/IOC25645K

Review paper

APPLICATION OF WASTE MATERIALS IN GREEN ROOFS

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Abstract

Green roofs are becoming increasingly popular as a sustainable architectural solution that provides numerous economic, environmental, and social benefits. Selecting a suitable substrate and drainage layers is important for having a sustainable green roof with good water retention and energy-saving potential, runoff water quality, and plant growth. There is a need to replace materials currently used in green roofs with more environmentally friendly products. Within such context, this paper discusses the application of different recycled and waste materials in green roofs and identifies what waste materials can be used in green roofs in Serbia. The use of locally available recycled materials can reduce the carbon footprint of green roofs, improve their life cycle, and reduce the cost of construction. This paper sheds light on the design of green roofs with better performance and reduced environmental impact.

***Keywords**: green roof, waste, recycling*

1. INTRODUCTION

In recent years, green roofs have gained more attention due to the numerous economic, environmental, and social benefits they can provide. They reduce energy consumption, air pollution, the urban heat island effect, stormwater runoff, etc. [1]. Green roofs are a part of green infrastructure especially important in densely built urban environments. Installing green roofs on existing buildings can significantly increase the percentage of green spaces in cities. Green roofs consist of the following common components from bottom to top (Figure 1): waterproof layer, root barrier, drainage layer, filter layer, growing substrate, and vegetation. The first layer of green roofs, which is installed directly on the roof structure, is the waterproofing layer, which protects the roof from water penetration. For existing roofs, bitumen, gravel, polyurethane coatings, or foils are mainly used. For new roof constructions, single-layer membranes, such as ethylene propylene diene monomer rubber or thermoplastic polyolefin, are used. Root barrier protects the waterproofing layer and roof structure from possible penetration of plant roots and fertilizers, as well as from mechanical damage that can occur during the installation of the green roof. For this layer polyethylene foil, rubber, or some other artificial material is used. The function of the drainage layer is to enable the drainage of excess water from the green roof.

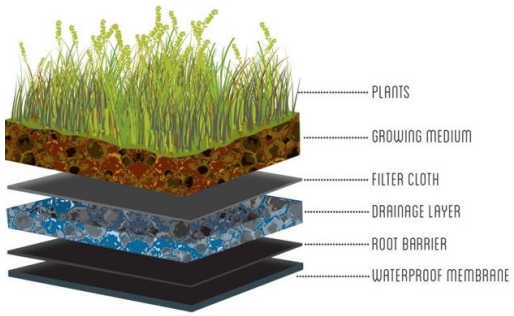

Figure 1. Green roof layers [2]

The drainage layer can be made of artificial material or in the form of a granular layer of expanded clay or gravel. The filter layer prevents the passage of the substrate components to the drainage layer. It is usually made from geotextile. The growing, substrate as the most important component of a green roof, should provide nutrients and water for plants. This layer consists of 80% natural or artificial mineral ingredients (stone, brick, perlite, clay) and 20% organic matter (pine bark and compost). The vegetation type depends on the climatic conditions, the roof slope and orientation, and the thickness and composition of the substrate. Construction waste encompasses all waste generated as a result of demolition, construction, and renovation activities in Europe, accounting for 25-30% of total generated waste [3]. The efforts of the European Union are focused on recycling 70% of construction waste. There is potential to achieve additional benefits by using recycled and waste materials in green roofs.

2. WASTE MATERIALS IN GREEN ROOFS

The use of recycled waste materials for drainage and substrate layers of green roofs can be the solution to reduce the overuse of natural materials. Porous stone materials such as expanded clay, pumice, or natural pozzolana are used for drainage layers in green roofs, whereas rubber crumbs from waste tires have recently been employed as a substitute [4]. Experimental results showed that rubber crumbs can be a good substitute for stone materials contributing to the reduction of waste and energy required for the transformation of stone materials. Green roof led to a 5% lower consumption of electrical energy when rubber crumbs were used, while a 14% reduction when pozzolana was used [5]. The polyethylene granules, from recycled agricultural plastic waste used for greenhouse covering, have physical properties comparable to those of perlite and, therefore, are suitable for the drainage layer in green roofs [6]. Compared to the perlite, granules have a lower specific weight while higher permeability thanks to larger particle size and to the cavities on the granule surface that allow water storage and evaporation, providing support to vegetation development. Foam glass and crushed porcelain are the most common recycled waste materials used in the substrate layer to improve green roof hydrological performance [7]. Crushed bricks in green roof substrates was found to have lower bulk density and higher porosity than crushed concrete, making them suitable for green roof substrates [8]. Medium-sized crushed brick particles (3-5 mm) exhibit the most significant potential for enhancing the functionality of green roof substrates and facilitating plant growth, while construction waste particles that are either too small or too large are unsuitable for use in green roof substrates.

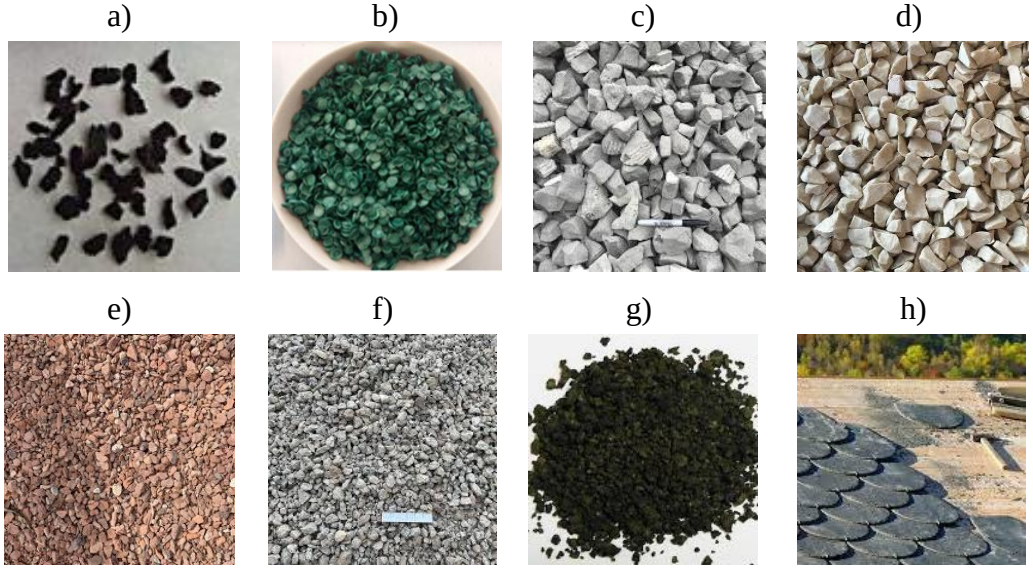

Figure 2. Waste materials used in green roofs: a) rubber crumbs, b) recycled polyethylene, c) foam glass, d) crushed porcelain, e) crushed brick, f) crushed concrete, g) cork granules, h) roof shingles

The study [9] presents a "Geogreen" modular system design with plants and substrate made from the mixture of two industrial wastes used as precursors, mine waste mud, milled glass, and expanded black cork granules. Roof shingles processed into aggregate form have a high conductivity value, which may result in good plant growth and reduce roof loads [10]. Experimental testing of green roof substrates made from waste clay from excavations, fly ash and sewage sludge, paper ash from recycled newspapers, and carbonated limestone from quarry fines had legal leachate limits for drinking water [11]. Moreover, the addition of organics reduced the pH of the recycled aggregates, making growing conditions for plants more favorable in these substrates. When it comes to LCA, recycled lightweight local materials used in green roofs instead of natural ones reduce environmental impacts, however, high energy is consumed for the tile, brick, or concrete crushing [12]. Coal bottom ash and fly-ash-based lightweight aggregates had good performance with minor environmental damage [13]. Non-recyclable sewage waste, such as used tampons, sanitary pads, and wet wipes compressed into panels can be used as a base for plant growth in green roofs. These lightweight products often contain absorbing polymers, which are bad for the environment, but can absorb a lot of water in green roofs [14].

3. WASTE IN SERBIA

Construction waste accounts for more than 75% of all waste in Serbia, while around 100 million tons of construction waste is generated in Serbia annually, according to the Serbian Association for Demolition, Decontamination, and Recycling [15]. 75% of construction waste is soil excavations while 12-25% is rubble, concrete, tiles and the rest are wood and metals. About 50% of the housing stock in the country is ready for a serious restructuring or removal, while more than 3 million of them are in the final phase of their life cycle [16]. Currently, less than 5% of construction waste is recycled in Serbia. The country aims to recycle 40% of this construction waste by 2030. Only 60% of the total amount of waste in Serbia is disposed of in a controlled way on the municipal sanitary landfill [17]. From April 2025, contractors are obliged to prepare a waste management plan and obtain approval for that plan from the competent authority as a prerequisite to the issuance of a construction permit, according to the new Rulebook on Arranging, Managing, Disposing and Landfilling Construction Waste [18]. This should reduce the number of illegal construction waste dumps. There is currently no practice of separate collection and scheme for recycling waste from construction and demolition in Serbia. Only high-value recyclable waste, such as metal, is recycled, while other recyclable materials are disposed of in landfills or at unsecured local dumpsites [3]. By the end of 2027, Serbia will build five construction waste processing plants in the Srem-Mačva regions, the city of Pirot, Subotica, Užice, and Valjevo. The gravel, worn-out wooden materials, or concrete will be turned into a new construction material in the processing facility. About 40 million tons of mining waste are produced each year which is regulated by the Law on Mining and Geological Explorations [18]. Power utility "Elektroprivreda Srbije" generates around 7 million tons of ash per year, where only 3% is used in the cement industry, while most is disposed of in ash and slag dumps [19].

4. CONCLUSION

This research investigates the innovative use of different waste and recycled materials in green roofs. The previous studies were mainly focused on the reuse of crushed brick, crushed concrete, porcelain, and foam glass in the substrate and drainage layers to improve the stormwater hydrological performance of green roofs. The reuse of waste material can provide potential benefits such as savings of resources and raw materials, reduction of material costs, transport, and machinery. This paper demonstrates how implementing circular principles in green roofs can contribute to resource conservation and environmental protection. The reduction of waste disposal to landfills and costs can be achieved by making it mandatory for green roofs to contain a certain percentage of waste materials. The use of recycled waste for more efficient green roofs can ensure more sustainable communities.

ACKNOWLEDGEMENTS

The research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-136/2025-03/200017).

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