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Effects of extensive green roofs on rainwater drainage from a metalworking industry building

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ABSTRACT

This study examines how extensive green roofs impact the sizing of the rainwater drainage system for a metalworking building in northeastern Portugal. If the roof, measuring approximately 4,700 m^2, is constructed of sheet metal, the calculated flow rate that must be drained is 5,860.51 L/min. In contrast, if the roof is green and extensive, the calculated flow rate drops to 3,255.84 L/min. This represents a 44.44% retention of rainwater, which necessitates changes in the components of the drainage system. Additionally, the green roof delays the release of unretained water into the urban drainage system, thereby contributing to sustainable urban drainage and helping to mitigate urban flooding.

Keywords: Rainwater drainage systems; Green roofs; Portuguese regulations; Sustainability; Urban flooding mitigation.

INTRODUCTION

Vegetation on roofs is critical in helping cities adapt to climate change and aligns with sustainability principles. It promotes water retention, reduces surface runoff, and improves water quality (Calheiros & Pereira, 2023). As noted by Pineda-Martos *et al*. (2024), the importance of Nature-Based Solutions (NBS) is closely related to the concept of a circular economy, which advocates for regenerative design solutions to minimize resource input, energy consumption, and emissions. Moreover, strategies prioritizing resource conservation, greener environments, and water-sensitive systems can enhance resilience by providing essential ecosystem functions, such as stormwater management and mitigating the urban heat island effect. Green roofs are an example of NBS that can be integrated with other tools to promote a circular water economy in urban environments, reducing pressure on watercourses (Calheiros *et al*., 2022; Pearlmutter *et al*., 2020). These roofs can be installed on new and existing buildings, offering various benefits for users and the environment at individual, urban, and ecological scales. They have a high capacity for rainwater retention and delay excess water flow (not retained in the green roof system) into the urban drainage system (ANCV, 2019). Green roofs are classified based on the substrate depth as follows: extensive (<15 cm), semi-intensive (>15 cm and <25 cm), or intensive (>25 cm) (Calheiros *et al*., 2022; Calheiros & Stefanakis, 2021; ANCV, 2019). Extensive green roofs are more commonly implemented due to their lighter weight, lower cost, and reduced maintenance needs compared to other types (Calheiros & Stefanakis, 2021). Incorporating NBS into building and urban systems is essential for optimizing construction practices and fulfilling sustainability requirements. This study aims to analyze how extensive green roofs impact the sizing of rainwater drainage networks in a metalworking industry building compared to conventional roofs, following Portuguese regulations (Rodrigues, 2024).

RESULTS

The rainwater drainage system for the industrial building in Bragança has been designed in accordance with Decree 23/95, 23 August, along with the guidelines outlined in Pedroso (2016). The system demonstrates several differences when comparing conventional sheet metal roofing (CR) to extensive green roofing (GR):

- Roof area: 4,700 m^2;
- Runoff coefficient: 0.9 for CR and 0.5 for GR;
- Rainfall intensity: 1.4 L/min·m^2;
- Calculated flow rate using the rational method (Q = CIA): 5,860.51 L/min for CR and 3,255.84 L/min for GR;
- Rainwater retention by GR: 44.44%;
- Reduction in the size of rectangular gutters;
- Reduction in the diameter of downpipes;
- Reduction in the diameter of building collectors: the last collector measures 315 mm for CR and 250 mm for GR.

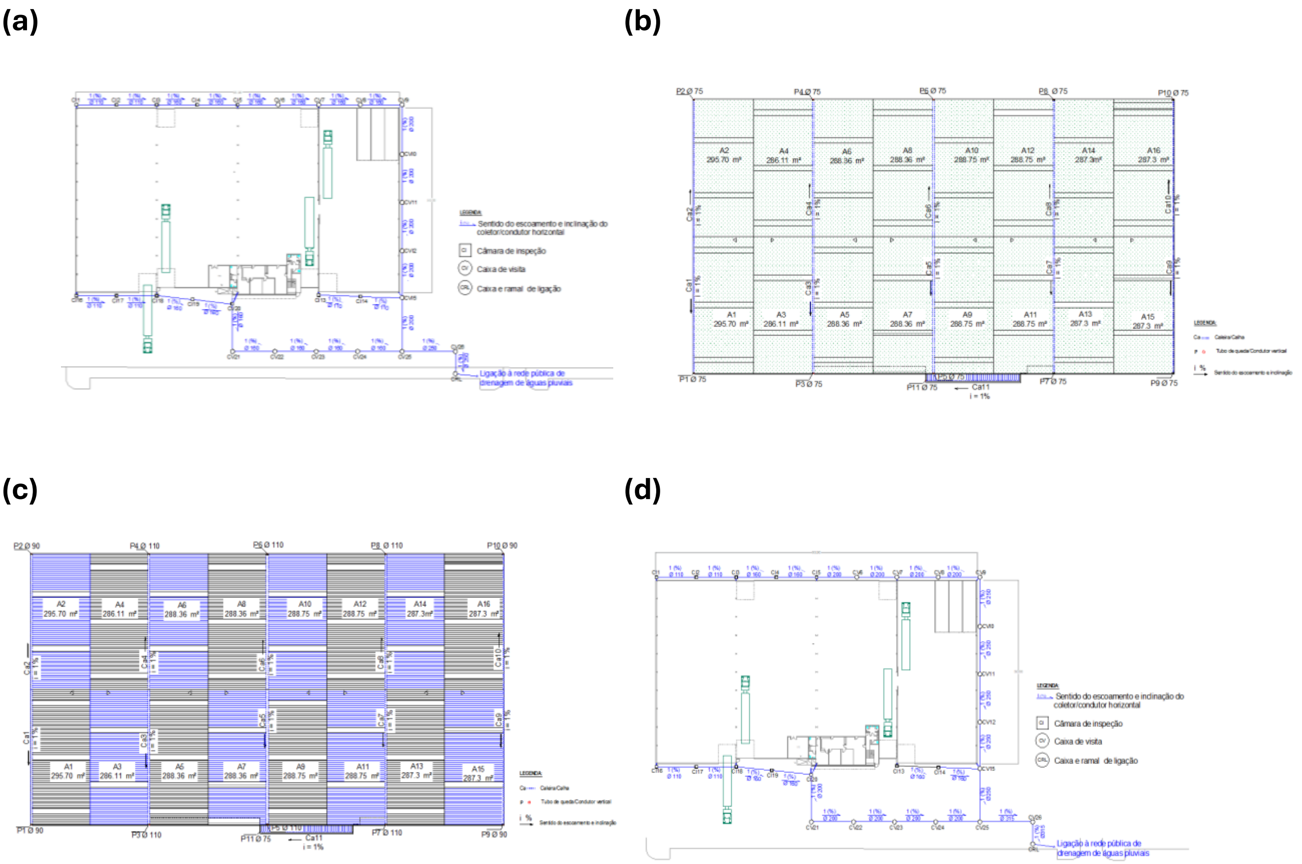

Figure 1 - Rainwater drainage network: extract of the roof plan (a) and first floor (b), conventional roof; extract of the roof plan (c) and first floor (d), green roof.

While this case study focuses on the scale of the building, the potential impact of this NBS on the city could be significant. According to Brandão *et al*. (2017), if 75% of the flat roof area in the municipality of Lisbon were converted to green roofs, approximately 166500 to 224000 m^3 of water could be retained during extreme rainfall events. This would help relieve pressure on drainage systems and prevent flooding.

CONCLUSIONS

While conventional roofs allow rainwater to run off quickly, which can increase flooding, green roofs help absorb this water, slowing runoff and promoting evapotranspiration. This process enhances the effectiveness of stormwater management in buildings and urban areas.

Green roofs must integrate with the built environment, incorporating existing gray infrastructure to create circular, resilient, and resourceful cities. To enhance their effectiveness, new buildings should include these systems, along with retrofitting existing structures (Calheiros & Pereira, 2023).

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REFERENCES

ANCV. *Guia técnico para projeto, construção e manutenção de coberturas verdes*. 1.ª ed., Porto: Associação Nacional de Coberturas Verdes, 2019.

Brandão, C., do Rosário Cameira, M., Valente, F., Cruz de Carvalho, R. & Paço, T.A. (2017). Wet Season Hydrological Performance of Green Roofs Using Native Species under Mediterranean Climate. *Ecological Engineering*, Vol.102, pp.596-611. https://doi.org/10.1016/j.ecoleng.2017.02.025

Calheiros, C.S.C. & Pereira, S.I.A. (2023). Resilience of green roofs to climate change. In *Adapting the Built Environment for Climate Change*, pp. 273-296. https://doi.org/10.1016/C2021-0-02571-2

Calheiros, C.S.C. & Stefanakis, A.I. (2021). Green Roofs Towards Circular and Resilient Cities, *Circular Economy and Sustainability*, Vol.1, pp.395-411. https://doi.org/10.1007/s43615-021-00033-0

Calheiros, C.S.C., Castiglione, B. & Palha, P. (2022). Chapter 14 - Nature-Based Solutions for Socially and Environmentally Responsible New Cities: The Contribution of Green Roofs. In *Circular Economy and Sustainability*, Vol.2, pp. 235-255. https://doi.org/10.1016/B978-0-12-821664-4.00015-7

Decreto Regulamentar n.º 23/95, de 23 de agosto. Regulamento Geral dos Sistemas Públicos e Prediais de Distribuição de Água e de Drenagem de Águas Residuais.

Pearlmutter, D., Theochari, D.;, Nehls, T., Pinho, P., Piro, P., Korolova, A., Papaefthimiou, S., Mateo, M.C.G., Calheiros, C., Zluwa, I., *et al*. (2020). Enhancing the Circular Economy with Nature-Based Solutions in the Built Urban Environment: Green Building Materials, Systems and Sites. *Blue-Green Systems*., Vol.2, pp.46-72. https://doi.org/10.2166/bgs.2019.928

Pedroso, V. *Manual dos Sistemas Prediais de Distribuição e Drenagem de Águas*. 3.ª ed. Lisboa: Laboratório Nacional de Engenharia Civil, 2016.

Pineda-Martos, R. *et al*. (2024). Implementing Nature-Based Solutions for a Circular Urban Built Environment. In: Bragança, L., Cvetkovska, M., Askar, R., Ungureanu, V. (eds) Creating a Roadmap Towards Circularity in the Built Environment. Springer Tracts in Civil Engineering. Springer, Cham. https://doi.org/10.1007/978-3-031-45980-1_28

Rodrigues, J. (2024). Influência de Soluções baseadas na Natureza no dimensionamento de sistemas prediais de drenagem de águas pluviais: Casos de estudo. Dissertação de mestrado, Instituto Politécnico de Bragança.