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RESEARCH ARTICLE

Retrofitting with vegetation recent building heritage applying a design tool—the case study of a school building



Katia Perini*

Faculty of Architecture, University of Genoa, Genoa 37-16123, Italy

Received 10 April 2013; received in revised form 5 June 2013; accepted 6 June 2013

KEYWORDS

Vertical greening systems;
Green roofs;
Retrofitting;
Design tool;
Process tree

Abstract

Several researches show the environmental and microclimatic benefits of the integration of vegetation in architecture; however the potentialities of vertical and horizontal greening systems to retrofit buildings are still not much investigated. The retrofitting project of the Barsanti Institute of Camogli (Genoa, Italy) is presented, a building dated back to the sixties with serious architectural and efficiency problems, located in a considerable landscape area. The development and application of a design tool (process tree), for horizontal and vertical greened surfaces, allows to evaluate the potentialities of vegetation to retrofit and to relate the encountered efficiency problems and the climate characteristics with the choice of plant species, system, and technology more suitable for the specific situation (of which environmental and economic impact are also evaluated) and to define a design approach for the systematic consideration of the many parameters involved.

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1. Introduction

The integration of vegetation on buildings with green façades or roofs allows to obtain an improvement of the

building's efficiency, ecological and environmental benefits. The environmental benefits of greening the building envelope operate at a range of scale (Perini, 2012). The benefits related to the larger scale (neighbourhood or city) mainly regard the improvement of air quality, urban wildlife (biodiversity), the mitigation of urban heat island effect, and the storm water management (Ottel  et al., 2010; Sternberg et al., 2010; Dunnet and Kingsbury, 2008; Onishi et al., 2010); the ones regarding the building scale concern the building envelope performances and the indoor and outdoor comfort (Dunnet and Kingsbury, 2008; Mazzali et al., 2013; Perini et al., 2011; Kumar and Kaushik, 2005).

*Tel.: +39 3282144076.

E-mail addresses: Katiaperini@hotmail.com,
katia.perini7@gmail.com.

Peer review under responsibility of Southeast University.



Production and hosting by Elsevier

Green roofs are passive cooling techniques that stop incoming solar radiation from reaching the building structure below. Insulation properties depend on the green roof type (Kumar and Kaushik, 2005). Several properties of green roofs contribute to their thermal characteristics: direct shading of the roof, evaporative cooling from the plants and the growing medium, additional insulation values from both the plants and the growing medium, and the thermal mass effect of the growing medium (Liu and Baskaran, 2003).

A vertical green layer can contribute to the building envelope performances by creating an extra stagnant air layer which has an insulating effect (Perini et al., 2011) and reduces the energy demand for air-conditioning up to 40-60% in Mediterranean climate, according to Alexandri and Jones (2008) and to Mazzali et al. (2012), with results which refer to an ideal (adiabatic) room behind the façade. Leaves, thanks also to the phototropism effect, filter the direct sunlight on the façade (Bellomo, 2003).

Vertical greening systems can be classified into façade greening and living wall systems (Köhler, 2008). Green façades are based on climbing plants planted directly at the base of the façade or supported by cables or meshes and with planter boxes placed at several heights; for indirect green façades many materials can be used as support for climbing plants such as steel (coated steel, stainless steel, galvanised steel), different types of wood, plastic or aluminium.

Living wall systems (LWS), which are also known as green walls and vertical gardens, are constructed through the use of modular panels, each of which contains its own soil or other artificial growing mediums, for example foam, felt, perlite and mineral wool, based on hydroponic culture, using balanced nutrient solutions to provide all or part of the plant's food and water requirements (Dunnet and Kingsbury, 2008; Perini et al., 2012).

Green roof systems thanks to integrated solutions allow cultivating grass, shrubs and bigger or smaller trees. These are commonly classified in: intensive, semi-intensive and extensive solutions, which have different uses, stratigraphy (substrate thickness) and vegetation (Dunnet and Kingsbury, 2008).

The field of retrofitting plays a fundamental role aiming to give more green areas to cities to improve environmental conditions (Frazer, 2005). Buildings consume a significant amount of energy over their life-time; the energy consumption of these in Europe is about 40% of the total energy demand (Thormark, 2002; Ardenete et al., 2008). Large scale retrofitting with emphasis on energy efficiency will be needed to reach European standards relative to the 20% reduction (compared to the data of 1990) with respect to primary energy consumption, which generates an output of gases responsible for global overheating (Verbeeck et al., 2008). Many of the vegetation's characteristics can be exploited to retrofit, as it will be shown. It is possible to refer especially to the recent built heritage; it often has problems connected to building envelopes un-insulated with also lack thermal mass. This is also the building heritage with the worst architectural value free of cultural and historical limits (Nuzzo and Tomasinsig, 2008).

A design exemplification is presented; this allows to evaluate the opportunities given by the integration of

vegetation in architecture to retrofit and enhance the performance of a school building.

Applying a design tool allows to relate the encountered efficiency problems, the existing building and climate characteristics - which have to be considered to optimise energy efficiency and occupant comfort (Mitterer et al., 2012) - with the plant species, system, and technology more suitable for the specific situation, considering durability aspects and environmental and economic sustainability. The analytical evaluations - with respect to architectural, structural, and material characteristics and to the encountered functional and performance problems - allows defining the main design parameters to consider for the application of the design tools developed (process trees). Afterwards the adherence to the requirements of the design parameters is estimated and finally, the assumption of some possible systems, material, and plant species suitable for this specific situation is made.

2. Description and analysis

The subject of the project exemplification presented is the Barsanti Institute of Camogli (Genoa, Italy Figure 1); this is located inside the territory of the Regional Park of Portofino and, due to its position has a notable visual impact in the territory. The Institute was built after the second war (fifties-sixties of last century) and is placed on the South-East and North-Western axis. The building is three floors high, long and narrow; the surface area is of 2505 m². An L shaped terrace is located on the second floor in front of the canteen with South East orientation; this terrace is bigger than the one on the third floor in front of classrooms (East façade). Two different elements compose the roof: the one on the South is flat and cannot be walked on, the other one is constituted by a series of equal pitches covered by Genoese slate plates. Reinforced concrete beams and pillars make the bearing structure with two layers of bricks plastered with air cavity and concrete-bricks floors.

Figure 2 summarises the architectural, structural, and material characteristics; all the building envelope parts are analysed and a tag (colour) is assigned to every part; this tag is used to synthesise the analytical and design results.

The climate and environmental characteristics play an important role especially in the case of interventions made by the integration of vegetation for the plant species choice (with respect to the plants ecological needs). The climate is Mediterranean. The minimum winter temperatures recorded in the last thirty years are 5 °C, the maximum are between 10 °C and 15 °C; summer's temperatures vary between a minimum of 18 °C and maximum of 30 °C. The average rainfall is around 80 mm; winter wind mainly blows from the north where the San Rocco Mountain works as a barrier (www.comuni-italiani.it; www.ilmeteo.it).

The main lacks of architectural and performance efficiency were found; thanks to the analysis phase and are based on direct observation and on the Province of Genoa Report on the actual state of the Barsanti Institute. The design exemplification regards retrofitting the building envelope; therefore the analysis identified the problems connected to it. The main lacks of architectural and

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