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Smart cool mortar for passive cooling of historical and existing buildings: experimental analysis and dynamic simulation

Federica Rosso[a,*], Anna Laura Pisello[b,c], Veronica Lucia Castaldo[c], Franco Cotana[b,c], Marco Ferrero[a]

[a]*DICEA,Sapienza University of Rome, Via Eudossiana 18, Rome 00184, Italy*
[b]*Department of Engineering, University of Perugia, Via G. Duranti 93, Perugia 06125, Italy*
[C]*CIRIAF- Interuniversity research center- University of Perugia, Via G. Duranti 67, Perugia 06125, Italy*

Abstract

In order to mitigate Urban Heat Island Effect and global warming, both governments and scientific community are working to reduce energy consumptions. In particular, the construction sector has a high potential in reducing energy demand, by means of both active and passive solutions. The European building stock is mainly composed by existing buildings as well as historical ones, which happens to be the less energy efficient ones. Moreover, retrofit operations are more complex on historical buildings, due to strict regulations for the preservation of such historical and cultural heritage. Considering this challenge, in this work we described and in lab analyzed possible passive solutions specifically designed for historical and existing buildings. In particular, we developed innovative cool colored mortars and tested them in lab, as well as investigated cool colored mortars, cool clay tiles and cool natural gravels performance when applied as envelope and roof elements, by means of dynamic simulation.

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Keywords: Cool colored materials; mortars; historical buildings; existing buildings; dynamic simulation.

* Corresponding author. Tel.: +39 06 4458 5121.
E-mail address: federica.rosso@uniroma1.it

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1. Introduction

Buildings account for almost the 40% of total primary energy consumption, being the most energy intensive sector [1–4]. Transportation sector, which is the second one in terms of consumptions, is responsible for the 33% of total consumptions. As from the famous quote by Winston Churchill, "With Great Power Comes Great Responsibility" and, as a direct consequence, governments and scientific community efforts are directed towards the reduction of energy consumptions in the building sector [5]. This is particularly important since energy consumption is directly linked to emissions, which on their turn are among the causes of global warming [6,7] and Urban Heat Island Effect (UHIE) [8].

The operation of reducing energy consumption in buildings can be pursued on many levels, by exploiting different strategies, for example acting on the single construction element [9], or on occupants' behavior [10] or on the employment of more efficient energy systems [11]. The selected strategy would depend on many factors, in particular on the building type and characteristics.

For this reason, in order to better direct research and energy retrofit activities, it is interesting to consider the characteristics of European building stock, as reported by BPIE [12]. In Europe, buildings constitute 4'324'782 km^2 of land area and 24 billion m^2 of floor space. With respect to Italy, around 40 $kgCO_2\ m^2$ are emitted due to buildings' energy utilization. Moreover, the 40% of the total number of buildings was built before 1960, while the 49% were constructed between 1961 and 1990 and only the 14% between 1991 and 2010. This is in line with other European countries mean percentages [12], and given the large historic patrimony of many of these countries, part of the constructions labeled as "before 1960" are historic and protected buildings. Studies have evidenced that historical buildings are the less energy-efficient ones [13]. This data demonstrate with incontrovertible evidence that tapping the potential of existing and historical buildings would permit to save a large quantity of energy, reduce emissions and mitigate UHIE and global warming.

However, the energy retrofit of historical buildings is challenging, since interventions need to be in line with preservation aims. Indeed, historical districts and buildings are protected by national regulations, which have the objective of protecting such cultural heritage sites [14]. Standard interventions on envelope (e.g. external insulation, while internal insulation is a viable strategy [15,16]) are not always feasible, while the employment of efficient construction elements depends on the esthetic appearance of the construction element itself. The exteriors of the protected building cannot be modified, since it has to maintain and preserve its original aspect. For existing buildings that are not historical, many retrofit options are instead available [17–20]. The most common interventions on existing and historical buildings comprise windows replacement with more energy efficient ones and energy system update [21–23]. Passive cool materials strategy usually implies the application of light-colored materials on buildings' envelope [24–26], in order to boost the solar reflectance in the visible part of the spectrum: however, it appears clearly that in historical buildings this is not a common solution, due to color matching issues with the original envelope. By looking at historical cities aspect, while walking on the streets or having an aerial view, the most common colors are red (bricks or plaster), white-cream (plaster or stone), or gray (plaster or stone) for the envelope and brownish-reddish red clay tiles on the roofs, which are often sloped (Fig. 1).

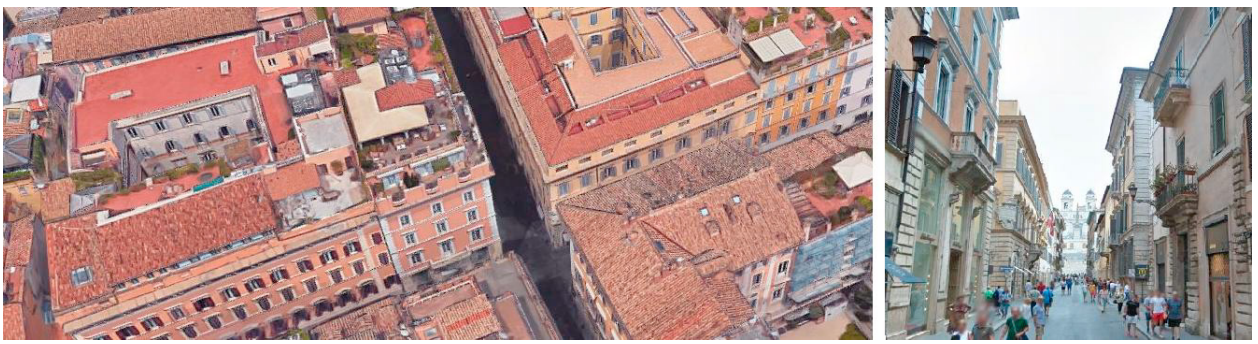

Fig. 1. Views of the historical Rome city center, displaying typical colors, red clay tiles for roofs, reddish, white-cream envelopes.