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Reflectance properties analysis of mineral based mortars for renders: Research of their energy performance

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ABSTRACT

Passive performance of buildings is nowadays one of the key points, not only for reducing energy consumption of buildings, but also for decreasing "fuel poverty". Among the constructive systems in buildings, façades are the ones having higher influence on thermal performance in urban spaces. Lime renders are specialized systems which can improve not only the durability of the support but also the thermal properties. According to previous researches, a modification of their radiative properties can reduce thermal fluxes between 24% and 89%.

In this paper, the influences of the aggregate content in lime pastes, as well as the nature of the aggregates, colour and roughness, on the visible near and medium infrared reflectance are analyzed. Ten types of aerial lime mortars were prepared and two methods of reflectance determination were performed. Finally, the effect of the resulted reflectance on the constructive systems of façades was analyzed using pseudotime-dependent software, for which an annulation of the thermal fluxes or significant reduction of them can be observed, when modifying the aggregate nature.

1. Introduction

According to the International Energy Agency, the building sector is responsible for around 36% of the final energy consumption [1], which is mainly due to an energy-inefficient envelope followed by an intensive use of energy for conditioning [2]. In spite of the governmental efforts to improve the conditioning equipment of buildings in Spain (2005), 3.4% and 9.1% of the households cannot afford the electricity and gas–water bills, respectively [3,4]. Nowadays, "fuel poverty" is even more dramatic due to the economic crisis. Under these circumstances, energy efficiency strategies need to be considered; firstly, the constructive system performance and its adaptation to climate in order to achieve thermal comfort with the minimum energy consumption is to be analyzed, and, afterwards, the active systems effectiveness should also be taken into account [2,5].

In urban spaces, external and internal façades (courtyards or dividing walls) are the constructive system with the highest incidence on the energy demand [2]. For this reason, since the energy crisis of the 1970s, different materials and systems have been implemented to improve the thermal resistance of this constructive system, based on the conductive mechanism of thermal transmission. However, radiative properties have scarcely been analyzed, even though thermal fluxes can be reduced between 24% and 89% by modifying the radiative properties of the finishing element [6].

Moreover, 98% of the extraterrestrial solar energy is concentrated within 280 and 3000 nm [7] divided into 46% within 378–760 nm, and 29% and 15% in 762–1300 nm and 1305–2500 nm, respectively [8]. Hence, it is clear that a modification in the 378–760 nm as well as 762–2500 nm can considerably modify the performance of the surfaces. From those wavelengths onward, most of the energy is mainly absorbed by the water vapour and the carbon dioxide, while under 280 nm, the energy is absorbed by the ozone.

Concerning this, renders are commonly used as protection for the supports to guarantee structural stability as well as to adapt the building to the artistic aesthetic styles. Therefore, a thorough analysis of them is interesting from the energy point of view. In spite of the importance of this issue, the only publication related to renders is the one from Kolokotsa et al. [9] who, in 2012, published

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Table 1
Naming of the mixtures.

	Reference marble dust	Non-coloured microsilica 1	Non-coloured microsilica 2	Coloured microsilica 1	Coloured microsilica 2
1:1	R1	A1	B1	C1	D1
1:3	R2	A2	B2	C2	D2

a paper analysing the optical performance of several types of mortars applied over a brick support. In addition, reflectance of the Portland cement concrete was examined by Levinson and Akbari [10] and performed in 2010 with the publication of a prototype of a reflective floor tile [11]. In relation to the previous studies, some researches focused on the performance of the coatings [12,13]. The effect of coatings in social housing in summertime was simulated by Santamouris et al. [14]. However, the majority of materials and constructive systems were used to be placed on the roof and pavement [15–21].

In this paper, the influence of the aggregate content in lime pastes as well as the nature of the aggregates, colour and roughness on the visible, near and medium infrared reflectance are researched. Ten types of aerial lime mortars were prepared and two methods of reflectance determination were performed, namely, an experimental one based on the use of a pyranometer and a standard one with a spectrometer. Materials and methods were contrasted and some recommendations on their use have been extracted. Finally, the effect of the resulting reflectance on façades constructive systems has been analyzed using a pseudotime-dependent software.

2. Materials and methods

2.1. Materials

Following the general criteria "grease over lean", the traditional finishing layer of the renders is commonly made of a blend of fine aggregate and aerial lime [22]. A dolomitic marble dust is the most common aggregate used in Spain. Hence, a mortar comprised by this aggregate and an aerial hydrated lime CL90S, in a proportion ratio 1:1, in volume, was used as reference. In addition, the effect of the aggregate content was analyzed by the selection of a high proportion ratio 1:3, in volume – one commonly used as base layer. Table 1 shows the names of the mixtures.

The effect of the aggregate nature was evaluated by the substitution of the reference dolomitic marble dust for two types of coloured microsilica dust, which were selected to avoid the "optical roughness" effect [23]. At the same time, colour influence was evaluated by the selection of other two types of ochre-pinkish coloured microsilica dust. Fig. 1 shows the appearance of the mixtures.

Mixtures were poured into 110 mm × 110 mm moulds of 10 mm thickness to simulate a render or plaster. Then they were compacted according to UNE EN 196-1. After 7 days of curing time, the samples were demoulded and stored under laboratory conditions (60% RH and 20 °C) for 90 days to ensure the stabilization of the mineralogical properties. At this curing time, samples were mechanically smoothed and treated with sandpapers of 40, 60 and 100 grit sizes. This was done to examine the effect of roughness on the measurements. Afterwards, specimens were dried at 40 ± 5 °C during 7 days and introduced into a desiccator in order to achieve the laboratory temperature and later placed into sealed bags, where they were preserved up to the test day.

2.2. Methods

Reflectance measurements were performed by two methods: a standard one based on the use of a spectrophotometer [24], and, alternatively, a portable pyranometer was used to compare the resulted data, because of its higher availability compared to the previous one.

2.2.1. Portable pyranometer

The portable pyranometer used was a LICOR 189. This instrument measures the integrated total irradiation, independently from the incidence angle, within the 300–1100 nm wavelength range. It is equipped with a photovoltaic detector and, although its response does not cover the complete spectral range as thermopile ones do, its price and simplicity are some of the advantages taken into account for using it [25]. The procedure consisted on comparing the irradiance measurements when placed looking at the sky and facing down, with a 3 s difference between them; this implies not paying attention to temporal drift of irradiation. The device was calibrated every ten measures. However, in spite of it, under natural lighting conditions, a total error of ±5% is implied according to the manufacturer specifications, for which the typical absolute error is of 3% in the range of environmental temperatures from 15 °C to 35 °C, as well as the cosine effect [26]. This value is in accordance with similar devices [25,26].

Tests were performed in June 2009 and 2010. Selection of the days and hours was based on the maximum height of the sun with the minimum variation of the type of radiation: direct-diffuse, although variability of the sun and its effect on the measurements was controlled by performing the test in a north room with diffuse radiation towards the sun, following Akbari et al. recommendations

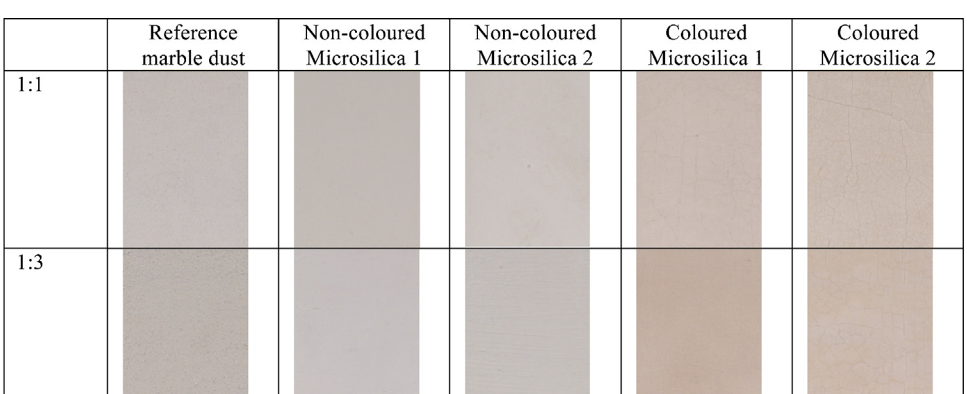

Fig. 1. Photographs of the mixtures.