Energy and Buildings 114 (2016) 206–213

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Characterisation and assessment of near infrared reflective paintings for building facade applications

Michele Zinzi *

ENEA, Via Anguillarese 301, 00123 Rome, Italy

ARTICLE INFO

Article history:
Received 27 March 2015
Received in revised form 28 May 2015
Accepted 29 May 2015
Available online 1 June 2015

Keywords:
Cool materials
Cooling energy performances
Energy efficiency

ABSTRACT

Climate changes and urban sprawl dramatically increase the urban temperatures and the thermal quality in the built environment. Among several proposed mitigation techniques, cool roofs have now reached a broad audience, while the cool materials potentialities for façade applications are still little investigated. A novel masonry paint, produced with the inclusion of cool pigments, is investigated in this paper. A palette of colour is developed with the objective of covering a wide range of architectural integration solutions. Reflectance and emissivity are measured and calculated. The results strongly depend on the base colour used to prepare the sample; solar reflectance increase up to 0.16 is achieved for dark colours. A numerical analysis is carried out to evaluate the impact of the cool paint on the thermal response of a typical Italian residential building. Energy uses are calculated for different insulation levels and climatic conditions. Cooling energy uses are reduced in the 10–20% range; total energy uses are affected by several parameters with 5% maximum savings. Peak operative temperature reductions range from 0.5 to 1.6 °C for the building in free floating conditions, according to climate and insulation level. External surface temperatures are reduced above 6 °C during the peak irradiation hours.

1. Introduction

The increase of the city air temperatures is a phenomenon associated to climate changes and emphasised by the urban sprawl. Relevant consequences are the increase of thermal stress in the built environment and energy demand for cooling. Several studies carried out during the past years highlighted the impact of the urban heat island phenomenon on energy, environment and quality of life [1–6].

Techniques able to mitigate such trends in the building sector are gaining interest, especially in temperate/warm areas. Cool materials are construction materials characterised by two thermo-physical surface properties: (a) High solar reflectance (ρ_e), which expresses the ability of a material surface to reflect the incident solar radiation; (b) High thermal emissivity (ε), defined as the ability of a surface to release away the absorbed heat. Due to such properties, cool materials tend to remain cooler under the sun if compared to conventional products of the same colour. Cool materials are effective on buildings roofs, due to the high cumulate solar irradiation on near horizontal surfaces in summer; they are called cool roofs and are generally white to maximise the reflective potentialities of the structure.

Many calculation studies demonstrated the cool roofs impact in terms of increased thermal comfort and reduced cooling loads in buildings, characterised by different uses and under different climatic conditions [7–10]. Furthermore case studies on real building were carried out during recent years [11–13]. Cool coloured materials are a particular and innovative category of cool materials. They have a spectral response in the visible range able to reproduce the designed colour but present a very high reflectance in the near infrared range (NIR). This solution gives to dark construction materials a better performance under the solar radiation, with solar reflectance values higher than conventional materials. Several studies were carried out during the past years to develop these products, mainly based on near infrared reflective pigments and used for roof applications [14–17]. Cool coloured materials were also developed and tested to urban pavements and roads [18,19].

Applications and impact of cool materials for building façades are little investigated, one of the main reason is that the solar radiation impinging on vertical surfaces is lower than that on the horizontal and, as a consequence, the impact on energy savings are lower than that obtained for roof applications. The effect of cool materials on vertical surfaces is investigated in [20], even if the study was mainly addressed at the product development, more than focusing it on energy aspects related to a façade applications.

* Tel.: +39 0630486256; fax: +39 0630486256.
E-mail address: michele.zinzi@enea.it

http://dx.doi.org/10.1016/j.enbuild.2015.05.048
0378-7788/

Several circumstances, however, demonstrates a potential field of interest for cool façades. National and international environmental and energy targets push to improve the cooling energy performances of buildings, hence all the cost effective technologies are needed to reach such objectives. For high rise building the amount of total solar radiation on the façades is higher than that of the roof because of the building geometry. The surface temperature reduction, moreover, increases the lifetime of the façade finishing layers – this is particularly true for the ETICS (External Thermal Insulation Composite Systems), widely used in the building external insulation works. Being the insulation layer very close to the external surface of the envelope, the thermal load due to the solar radiation impinging on the façade is not transferred through the structure and cause a quick and strong increase of the material temperature surfaces, with consequent thermal stresses on paintings and plasters. Another relevant issue is that the reduction of the surface temperature causes a reduction of the heat released in the urban canyons, at street level as well, with a beneficial impact on urban temperatures.

This study presents the first results on cool paintings for façade applications, including the experimental measurements of the solar reflectance and the numerical analysis to predict the energy and thermal response for building applications.

2. Materials and methods

Objective of the study is the characterisation and the assessment of cool coloured materials for façade applications, to be used in new constructions and in building renovation. A colour palette of conventional and cool colours was prepared for the experimental characterisation and the comparison of the relevant radiative properties. The impact of the solar reflectance of a cool coloured paints, higher than a conventional paint of equivalent colours is then assessed through a numerical analysis, which implements the energy performance of a reference building under different boundary conditions.

The product selected for the implementation of cool façades is an acrylic based masonry paint with quartz filler, typically used as finishing layer in the building construction technology. Two product categories were addressed:

- Pastel colours. These colours are widely used in the Mediterranean urban area, recalling the vernacular architecture, where light colours were used to reduce the solar loads through the building envelope. Typical applications concern seasonal houses, used only during the summer: they have no heating requirements but can suffer of overheating during the cooling season. In this category the resulting surface colour of the paint is obtained starting from a white background;
- Dark colours. They are often required in new and under renovation buildings because of: Customer preferences; conservation of the original façade aesthetics in case of renovation; restraints set by local authorities implementing as the *Piano Colore* (Colour Plan) in Italy, a regulatory instrument of the building code which allows only some colours to be used for roofs and façades. Even if these motivations are not energy and environmental conscious, it is necessary to address the low-carbon vision agreed at international level for these materials as well. In this category the resulting surface colour of the paint is obtained starting from a black background.

Fig. 1 shows the full colour palette developed for the characterisation. Samples on the left are conventional paints while samples on the right are produced using cool coloured pigments. Colours are classified as follow: S1 blue; S2 green; S3 oxide yellow; S4 orange; S5 dark red; S6 beige grey; S7 brown grey; S8 amber grey; S9 dark grey; S10 chocolate brown. The figure shows the colour matching of the two product typologies. The samples were prepared with two wet coats (125 μm each) on an aluminium substrate. The total paint thickness was 125 μm after complete drying.

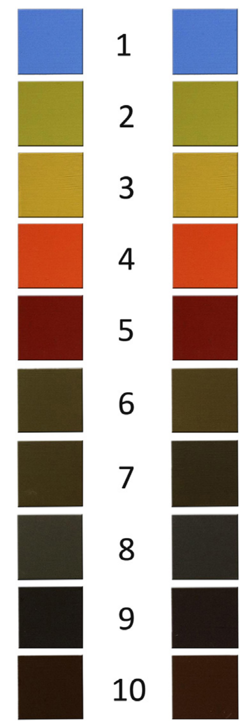

Fig. 1. Standard and cool coloured samples.

The potentialities of cool façade are then explored by numerical analyses in order to assess the impact on a reference building in terms of: Cooling and total energy uses in case of building equipped with a cooling system; evolution of the operative temperature in case of not cooled building; evolution of surface temperatures on selected building orientation. The calculations are carried out for a single colour in the standard and cool version.

3. Experimental

Specimens, sized 7 cm × 7 cm, were prepared for the characterisation of the material radiative properties. Reflectance and emissivity measurements were carried out in laboratory following specific standards; procedures and instruments are following described.

3.1. Reflectance measurements

Reflectance (ρ) measurements were carried out with a Perkin Elmer Lambda 950 commercial spectrophotometer. It is a double beam type and it is equipped with a 150 mm Spectralon coated integrating sphere produced by Labsphere. Measurements were carried out in the 300–2500 nm wavelength range covering the whole solar spectrum as defined in the standard reference [21]. The spectral resolution is 5 nanometres. The measurement uncertainty is ±0.01. The slit aperture was set to 2 nm in the visible range and in servo mode in the near infrared range – in this modality the slit size varies according to the optimal energy input.

The broad band values in the visible (v), near infrared (NIR) and solar (e) spectra were calculated according to [21].