STUDY OF THE RADIANT PROPERTIES OF CERAMIC TILES

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1. INTRODUCTION

Many urban centres have significantly higher average temperatures than their surroundings, forming so-called urban heat islands (UHIs). Dark surfaces, particularly roofs and paving, absorb solar radiation during the day and re-radiate this as heat, during the day as well as during the night[1]. In order to use dark materials on building exteriors (reducing the UHI and the energy consumption associated with air-conditioning[2]), it is necessary to try to maximise their reflectance in the NIR, which does not affect the colour and constitutes about 52% of the total solar energy.

COOL-Coverings is a European project for developing construction materials with greater reflectance in the NIR. This requires characterising the behaviour of façade tiles on exposure to the sun and establishing appropriate measurement methods for simulating and predicting this behaviour.

2. EXPERIMENTAL

A series of 19 porcelain tiles with different colours and textures were selected, which are used on façades.

The temperature that the tiles reached on exposure to the sun on a flat roof in Castellón, Spain (39°59'44.49"N – 0º 3'53.22"W) in July 2010, was measured. The experimental assembly consisted of an insulating base on which test pieces sized 15x15 cm of the different tiles were set. The temperature of the tile bottom surface (T_{bot}) was continuously recorded with a T-type thermocouple, while the temperature of the exposed top surface (T_{top}) was measured hourly, by hand, with a K-type thermocouple. The solar irradiation, effective temperature of the sky, air temperature, and wind speed were also measured.

Tile solar absorptance was measured using two different methods[3]: a) a Model SSR-ER v6 solar spectrum reflectometer from Devices & Services Company (ASTM C1549 standard test method) and b) a Model V-670 UV-Visible-NIR spectrophotometer from JASCO Co, equipped with an integrating sphere (ASTM E903 standard test method). In both cases the tables of solar irradiation in *ASTM G-173-03: Hemispherical Solar Spectral Irradiance at Air Mass 1.5 for a 37° Tilted Surface* were used. The thermal emittance at ambient temperature was determined with an emissometer from Devices & Services Company (ASTM C1371 standard test method).

3. RESULTS

The results obtained for the radiant properties of the 19 samples are detailed in Table 1, together with the maximum temperature reached on 27 July 2010 on the tile bottom surface (T_{bot}). A wide range of absorptance values (0.32 to 0.9) were found: the darker the tile colour, the greater its absorptance. However, the measured emittance values were practically constant (0.79 to 083) and independent of the colour.

The temperatures measured at the exposed top surface (T_{top}) and at the bottom surface (T_{bot}) practically coincided, so that both measurements could be used to monitor the evolution of the tiles under solar exposure. If an energy balance of the system is drawn up, assuming that the effective temperature of the sky, of the surroundings and of the air is very similar, and that the emittance is constant for all tiles, a linear relationship is found between the surface temperature (T_s) and solar absorptance (α_S)

$$T_s = T_{air} + \frac{G_S}{h_R + h_c}\alpha_S$$

where T_{air} is the air temperature, G_S is solar irradiation, and h_R and h_C are respectively the coefficients of heat transmission by radiation and convection. Figure 1 shows that the relationship between the maximum temperature reached by the tiles (T_{max}) and their solar absorptance was linear, confirming the accuracy of the measurements.

Sample	$\alpha_{S,JASCO}$ [a]	$\alpha_{S,SSR-ER}$ [b]	ε	T_{max}
1	0.90	0.863	0.79	68.1
2	0.69	0.65	0.81	61.7
3	0.43	0.39	0.81	51.1
4	0.56	0.54	0.81	57.9
5	0.87	0.86	0.83	71.5
6	0.68	0.66	0.83	62.4
7	0.41	0.40	0.83	49.6
8	0.54	0.52	0.83	55.6
9	0.86	0.85	0.82	69.7
10	0.72	0.70	0.83	63.1
11	0.33	0.32	0.84	46.8
12	0.75	0.72	0.83	64.3
13	0.34	0.34	0.83	49.0
14	0.60	0.58	0.83	58.6
15	0.79	0.81	0.83	67.4
16	0.41	0.40	0.83	50.8
17	0.74	0.71	0.83	61.7
18	0.55	0.55	0.83	57.2
19	0.77	0.75	0.83	64.6

Table 1

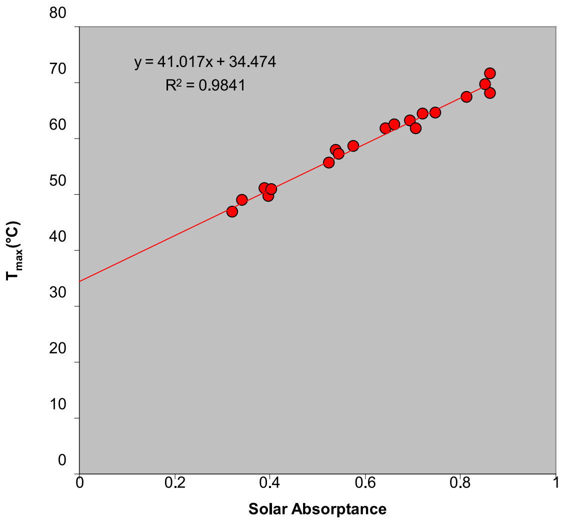

Figure 1.

4. CONCLUSIONS

The parameter that determines tile behaviour under solar exposure is solar absorptance. A good linear correlation was found between T_{max} and the absorptance measurements made with the JASCO V-670 and SSR-ER v6 instruments, which not only means that is there an excellent correlation between both methods, but that the values obtained are actually representative of the solar absorptance of the samples and that they can be used to predict tile behaviour under solar exposure.

ACKNOWLEDGEMENTS

This work has been funded by the European Community in the Seventh Framework Programme (FP7/2007-2013), project COOL-COVERINGS: FP7-2010-NMP-ENV-ENERGY-ICT-EeB 260132.

The authors also thank Dr. Guillermo Monrós and Dr. Mario Llusar (Department of Inorganic and Organic Chemistry, Universitat Jaume I, Castellón) for their help in measuring spectral reflectance.

REFERENCES

[1] AKBARI, H.; BRETZ, S.; KURN, D. M. ; HANFORD J. Peak power and cooling energy savings of high-albedo roofs. *Energy and Buildings* 25, I I7- 126, 1997.

[2] SYNNEFA, A.; SANTAMOURIS; M.; APOSTOLAKIS, K. On the development, optical properties and thermal performance of cool colored coatings for the urban environment. *Solar Energy* 81, 488–497, 2007.

[3] LEVINSON, R.; AKBARI, H.; BERDAHL, P. Measuring solar reflectance—Part II: Review of practical methods. *Solar Energy* 84, 1745–1759, 2010.