OPTICAL PROPERTIES OF ETICS SURFACES – SENSITIVITY TO THE FINISHING SYSTEM COMPOSITION

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Abstract
Nowadays, climate change demands the improvement of the building envelope, aiming at reducing energy consumption and increasing service life. The External Thermal Insulation Composite Systems (ETICS) can significantly contribute to achieving this purpose, but their durability is affected by surface temperature variation and extreme values. The symptoms may include system shrinkage and surface degradation, including biological growth, colour change and accumulation of dirt. The optical and thermal properties of the system are key factors in reducing this type of degradation. High-reflectance materials can minimise surface temperature peaks and help ETICS overcome some system limitations. However, such reduction is affected by the system finishing composition and the render thickness, as they interfere with the reflected, absorbed, or transmitted heat. An experimental campaign was conducted to evaluate the modification of the optical properties of ETICS regarding finishing coat thickness and base coat composition. The reflectance was measured in nine distinct points with a modular spectrophotometer coupled with an integrating sphere, following the ASTM E903, and the thickness with a digital calliper. The preliminary results show that the system reflectance is affected by the finishing coat thickness and the underlayer colour. The modification in this layer could contribute to the change of the heat flux and the surface temperature, mainly in dark colours. The modification in this layer could contribute to the change of the heat flux and increase the surface temperature, mainly in dark colours, once the thickness of a layer can modify the interaction between the light and the coating and affect the ratio of reflection/absorption according to the basecoat.

1. INTRODUCTION
Concerning the impact of urban overheating due to climate changes, the buildings will suffer from alterations in the indoor air temperature and thermal comfort indices, requiring strategies to develop the building energy efficiency and the indoor environmental quality (air quality and temperature) [1]. The building envelope absorbs solar radiation, store and release heat via conduction, and exchange heat with the air through a convective process. In the meantime, materials with lower reflectivity will have a high surface temperature, heating the ambient air badly and modifying the thermal comfort [1]. The best performance coatings will reflect over 80% [2], while a reflectance lower than 40% can increase critical events due to thermal shocks [3].

Hence, increasing the reflectivity in the solar spectrum can be applied in building envelopes to decrease the surface temperature. The use of light colours on high reflectance coatings is due to obtaining higher total reflectance, and this spectrum corresponds to 40% of energy. However, developing high reflective colours is required to increase the reflectance in the infrared region, which is responsible for 50% of the solar energy and does not modify the colour aesthetic. For example, the white and lighters materials have a higher reflectivity in the visible spectrum and a good one in the near-infrared region (NIR) (higher than 50%). In comparison, colour materials perform differently according to the pigment and undercoating application [4]. For example, modifying the reflectivity in the NIR region can reduce the surface temperature up to 20 ºC compared to a regular reflectivity coating [5]. In other studies, 5 ºC in peak values [6] and up to 10% the frequency of surface temperature higher than 50 ºC [7].

In this way, the reflectivity of the finishing coat will affect the thermal comfort, energy consumption and durability of the envelopes. However, the optical performance in a multilayered system such as ETICS will depend on the thickness of the render coats, especially the properties of the finishing coat, such as the thickness and the colour, and the presence of the key coat. This paper evaluates the reflectance and aesthetical performance of a commercial finishing coat applied in several thicknesses over two different substrates to assess the effect of the thickness on the reflectance values and the optical performance of the ETICS.

2. EXPERIMENTAL METHODOLOGY

A set of samples of the finishing coat was used to evaluate the correlation between the reflectance of the system, the thickness of the finishing coat and the substrate type was assessed in two stages. Only the optical properties and thickness of the finishing coat were considered in the first stage. The same finishing coat was applied to the ETICS system in a commercial model in the second stage considering, in this case, the effect of the base coat.

The total (hemispherical) reflectance and the colour coordinates in the space CIELab were measured with a portable spectrophotometer (FLAME-T and FLAME-NIR Ocean Optics, range 200 – 1600 nm) with a 30 mm integrated sphere and a reference disk of Spectralon®. Total reflectance was calculated according to the selected ordinates of ASTM E903 [8] and the colour coordinates by ISO 11664-4 [9].

2.1. STAGE 1 – THICKNESS AND UNDERCOAT

A finishing coat composed of select mineral fillers, resins in aqueous dispersion, pigments and specific additives with a grey colour was moulded in five thicknesses (Table 1) to study the effect of the substrate and the thickness of the finishing coat in the optical properties as reflectance and colour. To guarantee the thickness, a plastic mould of 10 cm X 10 cm was used (Figure 1a), and the samples with different thicknesses (Figure 1b) were measured over two underlayers in nine points (Figure 1c).

Table 1. Table caption.

Sample ID	Mould nominal thickness (mm)	Mould real thickness (mm)
#1	1.0	1.06 ± 0.039
#2	1.5	1.72 ± 0.024
#3	2.0	2.28 ± 0.067
#4	2.5	2.42 ± 0.034
#5	4.0	4.16 ± 0.158

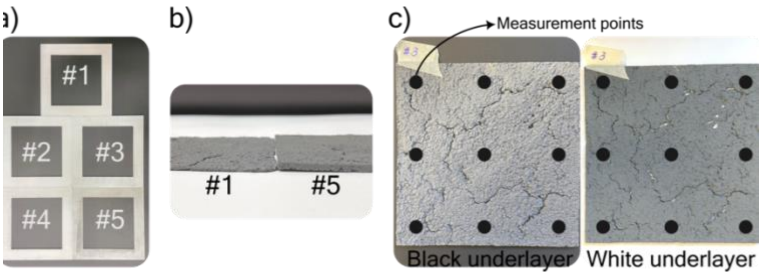

Figure 1. Process for analysing the influence of thicknesses – Stage 1. a) Plastic moulds for 5 different thicknesses; b) Ratio between the smallest and the largest thicknesses; c) Sample over the black and white substrate with the indication of measurement points.

2.2. STAGE 2 – SYSTEM EVALUATION

The finishing coat (same as stage 1) was applied in a commercial ETICS to evaluate the performance of the envelope system. The assembled system comprises a 4 cm EPS insulation board and a multilayered render, base coat and finishing coat (Figure 2a). In this stage, the reinforced base coat (composed of cement, mineral fillers, resins, synthetic fibres, special additives, and a glass fibre mesh) was applied over the EPS slab (Figure 2b). Thickness, reflectance, and colour were measured in nine points. After that, the system received the finishing coat, and the measurements were retaken for the complete system.

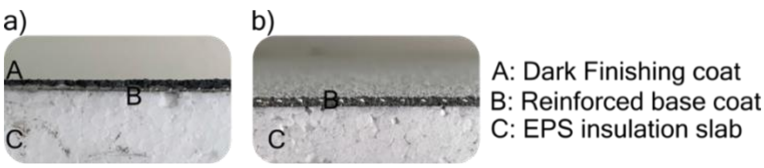

Figure 2. Sample to evaluate the system reflectance – Stage 2. a) Assembled system with reinforced base coat and finishing coat; b) Preliminary evaluation of the substrate – base coat.

3. RESULTS AND DISCUSSION

The first analysis evaluated the reflectance of the substrates used as underlayers to measure Stage 1 and Stage 2. Figure 2 presents the average of nine measurements with the standard deviation. In Stage 1, white and black cardboard were used as an underlayer to measure the finishing coat samples with different thicknesses, while in Stage 2, the finishing coat was applied over the base coat.

Table 2. Reflectance of the underlayer.

Stage	Underlayer	Total reflectance
1	White	1.000 ± 0.0338
	Black	0.191 ± 0.0234
2	Base coat	0.409 ± 0.0356

As expected, the white cardboard presents the highest reflectance once the white required a total reflectance higher than 0.80. In contrast, the black cardboard should show a reflectance lower than 0.20. The base coat presents a grey colour result of the cement composition and a reflectance relative to the colour, in this case, the middle between the black and white [4].

Figure 3 presents the combined results of Stage 1 and Stage 2. The results concerning Stage 1 are identified by the samples ID of Table 1 (#1 to #5) over the white (WCB) and black (BCB) underlayer, and Stage 2 identify the finishing coat (FC) applied over the base coat on the insulation slab as described in Figure 2.

The thickness measurements were carried out using a digital calliper in 9 points. The mean and standard deviation of these measurements are shown in Figure 3a. Concerning the thickness of the coatings, a statistical analysis shows a significant difference between samples #5, #2 and #1. In contrast, samples #3, #4 and FC can be classified as the same evaluation group. Regarding the FC applied in the system, the ETICS manufacturer recommends a thickness between 1.0 mm and 2.0 mm. However, it was found a thickness of 2.7 mm. Revel*, et al.* [10] and Baneshi*, et al.* [11] describe that the thickness coating, mainly in paint films, will affect the total reflectance value, where the reflectance can be modified according to the underlay colour/reflectance on thin layers.

Regarding the total reflectance (Figure 3b), the results of Stage 1 (BCB and WCB) indicate that the thickness affects the reflectance when the coating is thinner than 2.3 mm, Samples #1 and #2. In this stage, a change in the underlayer from white (WCB) to black (BCB) cardboard reduces the total reflectance on this thickness range. A similar effect also was verified by Song*, et al.* [12]. Notwithstanding, significant differences in the reflectance changing the underlayer for thicknesses higher than 2.3 mm were not observed (case of Samples #3 and #4 and FC). But a considerable reflectance reduction was distinguished on samples with higher thickness than 3.0 mm, case of Sample #5, a possible indication of the retroreflective or backscattering phenomena [13].

The colour aesthetic was evaluated considering the lightness coordinate (L*) in Figure 3c. The results indicate that all samples, regarding the base coat and the white cardboard, are considered medium dark tones [14]. The European Assessment Document of ETICS, EAD 040081-00-0404 [15], does not indicate parameters of performance/durability related to colour. However, the previous version of the European Association for External thermal insulation composite systems (EAE) guidelines mentions the HBW parameter associated with Lightness, which has recommended values higher than 30 [16]. This recommendation follows the argument that lighter colours have high reflectance, as proposed by several studies [4,17,18]. In this study, the dark underlayer strongly affects the Lightness compared to the lighter underlayer (base coat and the white cardboard).

Figure 3d exhibits a good correlation between the reflectance and the thickness for both assessed stages. Thus, the underlayer affects the dependence of the thickness, where the samples measured over the white underlayer (WCB) are more affected by the thickness modification than the black ones.

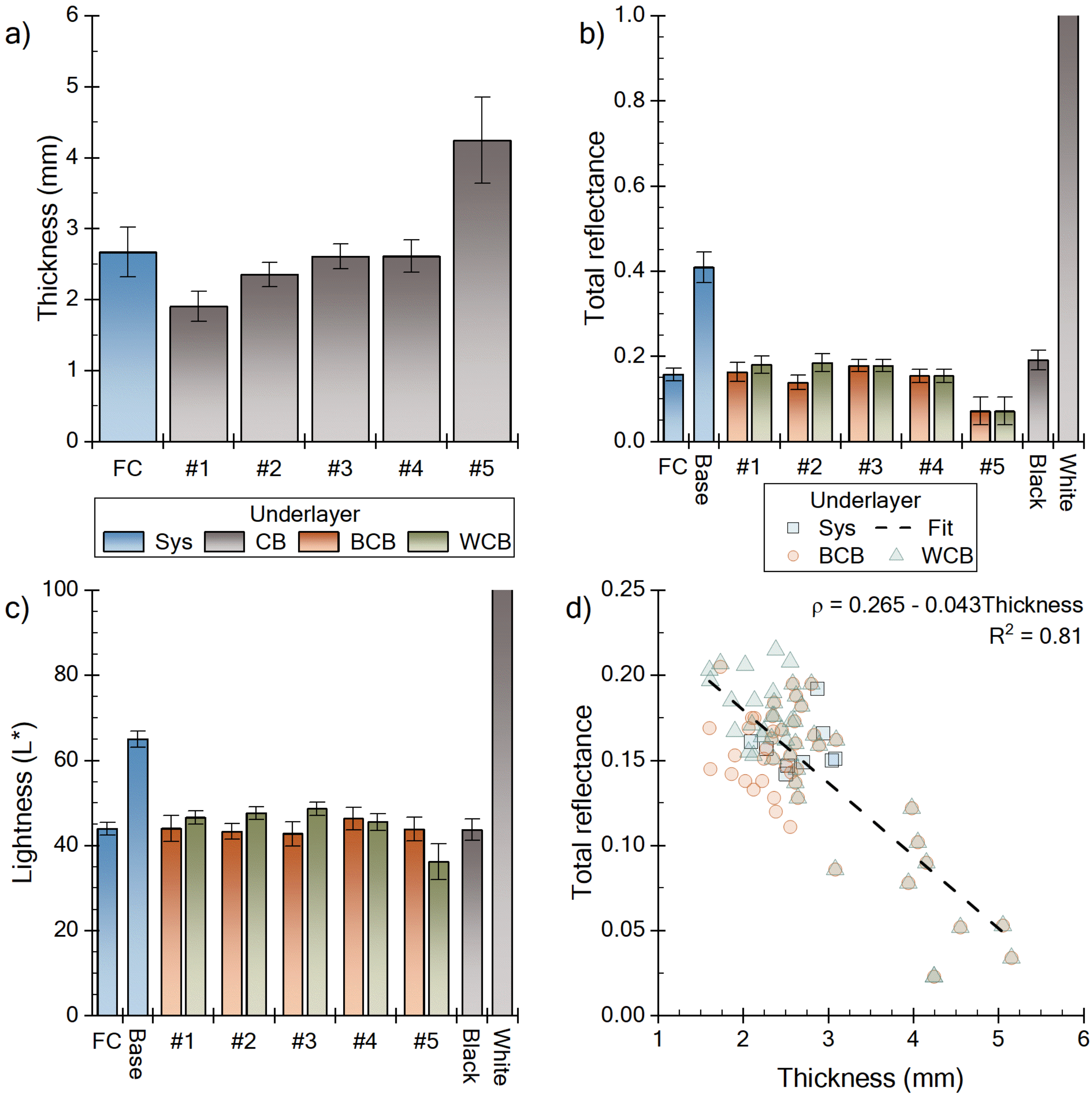

Figure 3. Combined results for both stages. a) Samples thickness; b) Sample reflectance considering the underlayers; c) Lightness (L*) coordinate for samples; d) Correlation between the reflectance and the thickness.

4. CONCLUSIONS

In a simplistic approach, the thickness could influence the optical perception (opaque, translucent, transparent) of materials and the light beam behaviour (scattering and backscattering) inside of coatings affecting the reflectance of a multilayered system such as ETICS.

The results indicate that the underlayer on multilayer systems could affect the reflectance and the colour of finishing coatings in façade systems of ETICS. In the case of dark finishing coatings, using a light underlayer can modify the colour aesthetic, where the colour could become lighter than required and increment the total reflectance. In turn, thickening the finishing coat can reduce the underlayer effect over the optical properties, requiring further investigation about optimising the optical reflectance based on the ETICS constitution and construction method.

The construction process of ETICS can affect the optical properties regarding the thickness of the coatings, which will depend on the site construction work and the technical specification of the number of layers of the systems. Some of the commercial technical sheets of ETICS indicate a need to apply a key coat in the finishing coat's colour to guarantee a homogeneous aesthetic of the colour. These two factors, thickness, and the number of layers, will contribute to the optical and thermal behaviour of the system.

This research is limited by the preliminary evaluation of the thickness and the optical properties of several compositions of ETICS, mainly related to the finishing coat. The next step is evaluating the impact of the present results on the thermal behaviour of ETICS façades to improve the solar reflectance provided by the ETICS constitution.

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