

NOVEL NANOMATERIALS WITH HIGH SOLAR REFLECTANCE FOR ENERGY EFFICIENT ENVELOPE SYSTEMS

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In memoriam of my brother Francisco and my grandfather Abraão,
To my beloved son Pedro Nuno.

If I have seen further than others, it is by standing upon shoulders of giants.

Isaac Newton

Abstract

Exposure to weathering conditions requires selecting and applying solutions with appropriate durability to preserve façades without the need for frequent extensive rehabilitation actions. The consequent heat gain from solar radiation exposure accelerates the degradation of the most exposed façade layer, reducing their service life. An attractive solution to mitigate this overheating is the incorporation of functional nanomaterials in the façades finishing coatings, which reflect a part of the solar radiation in the near-infrared region. This solution may have an even higher influence on dark-coloured coatings, whose use has been increasing by architects and final consumers. To design more energy-efficient buildings, applying thermal insulation systems, such as External Thermal Insulation Composite Systems (ETICS), is necessary. These systems experience significant surface temperature fluctuations (amplified by the dark colour application), causing dimensional variations and naturally leading to cracking.

Therefore, this Doctoral Thesis proposes a strategy combining these two façade solutions: dark-coloured finishing coatings applied on ETICS, aiming to improve solar reflectance and reduce the surface temperature. The study focused on developing new dark-coloured formulations with reflective nanomaterials, without excessively changing the visual aesthetics. A systematic study of their intrinsic properties was performed to understand and predict the nanomaterials' behaviour and ability to reflect or absorb. Subsequently, a commercial TiO₂ Rutile and a newly developed nanocomposite, combining two nanomaterials, were included in a dark-coloured commercial finishing coating for ETICS and the surface properties were evaluated. The thermo-optical properties revealed an overall total reflectance increase for the two samples (15% and 20%) compared to only 12% of the non-modified finishing coating, providing a similar visual aesthetic. The reflectance improvement observed with the incorporation of nanomaterials certainly impacted the surface temperature, as the modified finishing coatings showed better performance and durability, as evidenced in the accelerated ageing test as thermal oscillations responsible for fractures are reduced.

From these results, this strategy could emerge as a promising solution for low-cost dark reflective coatings that can be easily applied on building façades.

KEYWORDS: Envelope Systems; Near-Infrared Reflectance; Finishing Coats; Nanomaterials; ETICS.

Resumo

A exposição de edifícios às condições atmosféricas exige a seleção e aplicação de soluções duráveis para preservar fachadas sem intervenções frequentes e extensas. O ganho térmico da radiação solar acelera a degradação da camada mais exposta, reduzindo sua vida útil. Uma solução é incorporar nanomateriais funcionais nos revestimentos de acabamento das fachadas, refletindo parte da radiação solar no infravermelho próximo. Esta solução pode ter uma influência ainda maior em revestimentos de cores escuras, cujo uso tem aumentado entre arquitetos e consumidores finais. Para desenhar edifícios energeticamente mais eficientes, a aplicação de sistemas de isolamento térmico, como ETICS (Sistema Composto de Isolamento Térmico Externo), é essencial. No entanto, estes sistemas sofrem flutuações térmicas à superfície significativas (ampliadas pela aplicação de cores escuras), causando variações dimensionais e, naturalmente, fissurando.

Assim, a presente tese de Doutorado propõe uma estratégia inovadora que combina duas soluções de fachada: revestimentos de cor escura aplicados em ETICS para melhorar a refletância solar e reduzir a temperatura superficial. O estudo foca-se no desenvolvimento de formulações de cor escura com nanomateriais reflectantes, preservando a sua estética. Uma análise das propriedades intrínsecas dos nanomateriais foi conduzida para prever comportamento e capacidade de reflexão ou absorção. Posteriormente, nanomateriais de TiO_2 Rutilo comercial e um nanocompósito desenvolvido (combinando dois nanomateriais), foram incorporados num revestimento de acabamento comercial escuro para ETICS e foram avaliadas as suas propriedades superficiais, em comparação com um sistema de referência sem modificação. As propriedades termo-ópticas revelam um aumento na reflectancia total para as duas novas formulações (de 15% e 20%), em comparação com apenas 12% do revestimento não modificado, não alterando excessivamente a sua cor. A otimização da reflectancia, observado pela inclusão dos nanomateriais, certamente influencia a temperatura superficial uma vez que os revestimentos modificados apresentaram melhor desempenho e durabilidade, conforme evidenciado nos ensaios de envelhecimento acelerado, onde as oscilações térmicas responsáveis por fissuras foram reduzidas. A partir dos resultados obtidos, esta estratégia pode emergir como uma solução promissora para a formulação de revestimentos de cor escura com reflectancia otimizadas de baixo custo, sendo facilmente aplicados em fachadas.

KEYWORDS: Sistemas da envolvente; Refletância infravermelho próximo; Revestimentos de acabamento; Nanomateriais; ETICS.

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