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ECO-EFFICIENT PLASTERS FOR INCREASED INDOOR AIR QUALITY AND COMFORT

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DOCTORATE IN CIVIL ENGINEERING

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A mio padre, mia madre e mia sorella.

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L'un lito e l'altro vidi infin la Spagna,
fin nel Morrocco, e l'isola d'i Sardi,
e l'altre che quel mare intorno bagna.

Io e' compagni eravam vecchi e tardi
quando venimmo a quella foce stretta
dov'Ercule segnò li suoi riguardi

acciò che l'uom più oltre non si metta;
da la man destra mi lasciai Sibilia,
da l'altra già m'avea lasciata Setta.

"O frati," dissi, "che per cento milia
perigli siete giunti a l'occidente,
a questa tanto picciola vigilia

d'i nostri sensi ch'è del rimanente
non vogliate negar l'esperienza,
di retro al sol, del mondo senza gente.

Considerate la vostra semenza:
fatti non foste a viver come bruti,
ma per seguir virtute e canoscenza".

*(Dante Alighieri, Divina commedia -
Inferno canto XXVII).*

ABSTRACT

Indoor walls and ceilings are often coated with plasters. Due to the large surface in contact with indoor air, the plasters can passively contribute to moisture regulation and pollutant removal. The work presented intends to better understand this contribution, while enhancing, when possible, the plasters formulations for the purpose. The first step was to analyze the hygroscopic response of traditional and modern binder-based plasters. To do so, a first study was run to quantify the relative humidity fluctuations indoor. Then, the methods fitting the most the real indoor microclimates were selected for testing. The campaign was run along with bibliographic research, to match laboratory results with those ones present in literature. The compatibility with the preexisting materials and products and the eco-efficiency of the plasters are two parameters that were kept in mind during the work. According to that, clay and gypsum based plastering mortars were selected as the most promising materials. Both, in fact, are present in traditional architecture, besides being suitable solutions for new construction, and have low embodied energy. However, while the clay-based plasters showed a high hygroscopic behavior, the gypsum-based ones showed a lower one. For this reason, the latter was modified through the addition of biomass and the clay-based plasters were kept as a benchmark along the study. The plant selected for the scope is *Acacia dealbata*, an invasive species that plays a role in the spread of wood fires in Portugal. The biowaste addition was aimed at enhancing the moisture buffering of gypsum-based plasters without jeopardizing other properties or their carbon footprint. Good results were obtained, increasing the moisture buffering ability of the gypsum plaster up to double, even if still lower than the clay-based ones. The ozone reactivity and primary and secondary emission rates (VOCs) of the innovative gypsum-based plaster and the clay-based ones were also analyzed. The ozone removal ability of the gypsum-based plaster was improved by the biomass addition, the primary emissions increased a little, but the secondary ones were very low. Clay-based plasters overall confirmed their low emissions and ozone removal activity.

Keywords: sustainable mortars, gypsum, earth, clay, air lime, passive moisture regulation, hygroscopic behavior, biomass, *Acacia dealbata*, bark, pollutant removal, ozone, volatile organic compounds (VOCs), primary and secondary emissions.

RESUMO

As paredes e os tetos interiores são frequentemente revestidos com rebocos. Devido à grande superfície em contacto com o ar interior, os rebocos podem contribuir passivamente para a regulação da humidade e remoção de poluentes. O trabalho apresentado pretende compreender melhor esta contribuição; ao mesmo tempo, e quando possível, quer melhorar as formulações dos mesmos rebocos para o efeito. O primeiro passo foi analisar a resposta higroscópica de rebocos tradicionais e modernos com base em diferentes ligantes. Com esse propósito foi realizado um primeiro estudo para quantificar as flutuações da humidade relativa no interior. Assim, os métodos mais representativos dos microclimas internos monitorizados foram selecionados para ensaiar os rebocos. A campanha experimental foi realizada em conjunto com uma pesquisa bibliográfica, para combinar os resultados laboratoriais com a literatura. Os parâmetros de compatibilidade com os materiais e produtos preexistentes e de ecoeficiência dos rebocos foram tidos em conta ao longo do trabalho de tese. Dessa forma, argamassas com base em gesso e com base em terra argilosa foram selecionadas como mais promissoras. De facto, ambas fazem parte da arquitetura tradicional além de serem soluções adequadas para novas construções e têm baixa energia incorporada. No entanto, enquanto os rebocos com base em terra argilosa apresentam um comportamento higroscópico elevado, os com base em gesso apresentam um comportamento higroscópico mais baixo. Por esta razão, o estudo avançou com a modificação da formulação de rebocos de gesso através da adição de biomassa, enquanto os rebocos de terra foram mantidos como referência ao longo do estudo. A planta selecionada para a adição foi a *Acácia dealbata*, uma espécie invasora responsável pela propagação de incêndios florestais em Portugal. A adição de biorresíduos teve como objetivo aumentar a resposta higroscópica dos rebocos de gesso sem comprometer outras propriedades e sem aumentar as respetivas emissões de carbono. Foram obtidos bons resultados, com o aumento da capacidade de *buffer* de humidade do gesso até ao dobro, embora sendo ainda inferior à capacidade dos rebocos de terra. Também foram analisadas a reatividade ao ozono e as taxas de emissão primária e secundária de compostos orgânicos voláteis de rebocos com base em gesso formulados e de rebocos de terra. A capacidade de remoção de ozono do reboco de gesso foi melhorada pela adição de biomassa, as emissões primárias aumentaram um pouco, mas as secundárias foram muito baixas. Os rebocos de terra confirmaram, em geral, as baixas emissões e a atividade de remoção de ozono.

Palavras chave: rebocos sustentáveis, gesso, terra, argila, cal aérea, regulação passiva da humidade, comportamento higroscópico, biomassa, *Acacia dealbata*, casca, remoção de poluentes, ozono, compostos orgânicos voláteis (COVs), emissões primárias e secundárias.

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