

Adhesives for outdoor architectural historic azulejo conservation

Sílvia R. M. Pereira

Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, spereira@lnec.pt

Jessica Musacchi

Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, jessica.musacchi@gmail.com

Maria de Lurdes Esteves

Museu Nacional do Azulejo, Lisbon, Portugal, mnazulejo.lurdesesteves@imc-ip.pt

Joana Loureiro

Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, joanagloureiro@gmail.com

Susana Cabral-Fonseca

Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, sbravo@lnec.pt

Helena Silva

Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, hsilva@lnec.pt

Maria Paula M. C. Rodrigues

Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, mprodrigues@lnec.pt

João Manuel Mimoso

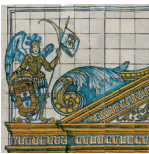
Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, jmimoso@lnec.pt

SUMMARY: Historic ceramic tiles – azulejos – are an important part of the cultural heritage of Portugal. However, there are not many studies about the materials used in their conservation to direct the conservator's choice. This work is, to our knowledge, the first comprehensive study on the adhesives used to bind fragments of architectural tiles. Attention is paid to the extreme conditions that may challenge the tiles when used outdoors.

Three types of adhesives commonly used in tile conservation have been studied (acrylics, epoxies and cellulose nitrates) and several parameters related to their workability, efficacy, compatibility and ageing behaviour were analysed.

Information was obtained about the adhesives characteristics and their suitability for the re-adhesion of fragmented azulejos in architectural outdoor environments.

KEY-WORDS: Adhesives, historic tiles, outdoor ceramics, conservation of azulejos



SUMÁRIO: Os azulejos são uma parte importante do rico património cultural português. Não existem, contudo, muitos estudos acerca dos materiais utilizados no seu restauro de forma a auxiliar a escolha dos conservadores. Neste trabalho é relatado o que cremos ser o primeiro estudo sobre adesivos utilizados no restauro de azulejos em contexto arquitectónico tendo em atenção as condições extremas a que podem estar expostos quando em ambiente exterior.

Foram estudados três tipos de adesivos que são correntemente aplicados em restauro de azulejos (acrílicos, epoxídicos e nitratos de celulose) e analisados vários parâmetros relacionados com a sua trabalhabilidade, eficácia, compatibilidade e comportamento no longo prazo.

O presente trabalho permitiu obter informação acerca das características dos produtos e da sua adequação para a re-adesão de fragmentos de azulejos em contextos arquitectónicos incluindo os expostos ao ambiente exterior.

INTRODUCTION

Tiles in architectural settings have no structural function. They are held to the wall by mortar and perform their function by keeping whole and hampering the penetration of water into the wall. Water is the prime cause of tile degradation since it can lead to the dissolution, transport and crystallization of damaging salts and induce a hydric expansion of the ceramic biscuit that often cannot be met by the glaze except through its cracking [1, 2, 3, 4, 5].

When tiles are fragmented and the fragments are glued back together, the main mechanical challenge suffered by the adhesion joins (Figure 1) is the stress due e.g. to the movements of the substrate and the interference with other tiles. Many adhesives have been or are presently used on restoration treatments of outdoor tiles. Acrylic, epoxy and cellulose nitrate based resins are some of the most commonly used especially in Portugal [6, 7].

A good tile adhesive would be one that would present some resistance to traction/flexural stress and elasticity to accommodate limited wall movements. Besides their efficacy, other important requirements for an adequate adhesive performance [8, 9, 10] would be a good chemical/physical compatibility with the historic ceramic substrate, good ageing behaviour, resistance to outdoor conditions (direct sun exposure, humidity and temperature variations) and to the often alkaline fluids circulating through the wall [11].

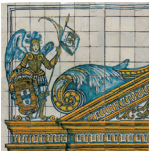


Figure 1. Tile fragments re-adhesion. A) Fragmented tile and b) Tile after fragment re-adhesion treatment. Images by Maria de Lurdes Esteves.

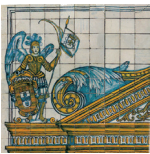
MATERIALS AND METHODS

Three types of adhesives frequently applied on ceramics or historic tiles have been studied: acrylics (Paraloid B44, Paraloid B67 and Paraloid B72); epoxies (Hxtal Nyl 1, Fynebond and Araldite 2020); and, cellulose nitrates (HMG, UHU Hart and Archaocoll 2000). The adhesives have been characterized by Fourier Transform Infrared Spectroscopy (FTIR), Dynamic Mechanical Analysis (DMA) bending and pulling tests before and after ageing and applied to join fragments of a reference ceramic material. Their performance was compared through optical microscopy and bending tests. Workability has been assessed from the easiness of use; the efficacy and compatibility through flexural strength and the macroscopic/microscopic appearance of the joins (before and after the tests); the ageing behaviour has been assessed after artificial (T-RH-UV radiation cycles, alkaline bath) and natural ageing of the samples. The results obtained in the reference ceramics have been validated with actual azulejos experiments.

SYNOPSIS OF THE RESULTS

The epoxy resins presented a short pot life and their low viscosity after preparation originated a high absorption by the porous ceramic matrix which implied the need of a second application or waiting for a proper viscosity increase (hours) before application. All the epoxies revealed a tendency to yellow with exposure, as well as chemical alterability revealed by FTIR after T-RH-UV ageing cycles. Through bending tests it was also found that their ultimate strength is too high, leading to breakage in the ceramic material rather than in the join (Figure 2). These results showed that when assessed against the requirements these adhesives are the less appropriate for the binding of tile fragments for architectonic integration.

The cellulose nitrates adhesives yellowed from the beginning, even before any artificial ageing simulation. Chemical alteration was detected by FTIR after T-RH-UV cycles ageing. These adhesives also presented the highest degradation rate of their mechanical properties with ageing.



The acrylic resins studied showed high variability in the properties and performance. Paraloid B72 has proved to be the one having more adequate characteristics (workability, good adhesion strength, low chemical alterability, non-yellowing) for the binding of tile fragments for outdoor use, followed by Paraloid B44. It presented however a mixed adhesive-ceramic failure mode (Figure 2) which could lead to partial damage of the original material in the vicinity of the bond line.

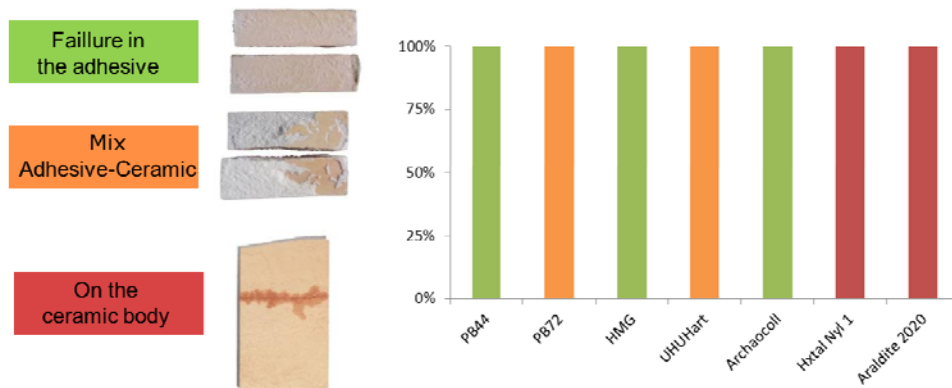


Figure 2. Depiction and occurrence quantification of failure mode types of the bonded ceramic fragments through bending tests. In green – adhesive failure; in orange - mixed adhesive-ceramic failure; and in red- cohesive failure of the ceramic body (epoxies).

CONCLUSIONS:

The results obtained allowed a better understanding of the behaviour and characteristics of the most commonly applied adhesives used for tile fragments binding. According to our results Paraloid B72 ® and Paraloid B44 ® were the adhesives that showed more adequate properties for the purpose.

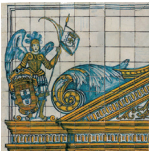
Further research on glaze to biscuit re-adhesion and the tentative development of more appropriate materials is however still necessary.

Acknowledgements

The authors acknowledge FCT for financial support for the execution of this work (Project CerAzul: PTDC/CTM-CER/119085/2010).

The participation of LNEC is encompassed by Project 0202/111/19014 of the *Plano de Investigação e Inovação do LNEC 2013-2020*.

The authors thank Nova Terracotta Lda. for the supply of the reference ceramic biscuits.



Bibliographic references

- ¹ MIMOSO, J.M. & Pereira, S. *Sobre a degradação física dos azulejos de fachada em Lisboa*, Relatório 303-NPC, Laboratório Nacional de Engenharia Civil, 2011.
- ² MIMOSO, J.M. - *Levantamento em obra de Patologias em azulejos históricos: visitas realizadas em 2009-2010*, Relatório 22-NPC, Laboratório Nacional de Engenharia Civil, 2011.
- ³ MIMOSO, J.M, Pereira, S. & Santos Silva, A. - *A research on manufacturing defects and decay by glaze loss in historical Portuguese azulejos*, Relatório 24-NPC, Laboratório Nacional de Engenharia Civil, 2011.
- ⁴ PEREIRA, S. & Mimoso, J.M. - *Salt degradation of historic portuguese azulejos*, Relatório 203-NPC, Laboratório Nacional de Engenharia Civil, 2011.
- ⁵ PEREIRA, S. & Mimoso, J.M. - *Degradation forms of historical Portuguese tiles under accelerated salt ageing*, In Proc. Azulejar, Aveiro, Portugal, 10-12 Outubro.
- ⁶ PEREIRA, S; Esteves, L; Mendes, M.T; Musacchi, J; Delgado Rodrigues, J. & Mimoso, J.M - *Cerazul: Assessment and development of materials and techniques for the conservation of historic azulejos*, In Proc. Azulejar, Aveiro, Portugal, 10-12 Outubro.
- ⁷ MENDES, M.T; Pereira, S; Ferreira, T; Mirão, J. & Candeias, A. - *In Situ Preservation and Restoration of Architectural Tiles, Materials and Procedures: Results of an International Survey*, International Journal of Conservation Science, 6, 1, 2015, 51-62.
- ⁸ ALLEN, K. - *Adhesion and Adhesives: some fundamentals, Adhesive and Consolidants*, IIC Preprints of the Paris Congress, 1984.
- ⁹ DOWN J., M.A. MacDonald, J. Tétreault & R. S. Williams - *Adhesives testing at the Canadian Conservation Institute, an evaluation of selected poly(vinyl acetate) and acrylics adhesives*, Studies in Conservation nr.41, 2011.
- ¹⁰ NEL, P. - *Issue associated with adhesives used on archeological pottery*, EMAC'07 Budapest, Vessels: inside and outside, pag. 187-196.
- ¹¹ CABRAL-FONSECA, S. - *Durabilidade de materiais compósitos de matriz polimérica reforçados com fibras usados da reabilitação de estruturas de betão*, PhD thesis, Minho University, Portugal, 2008.