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# Bond between 19th Century lime mortars and glazed ceramic tiles

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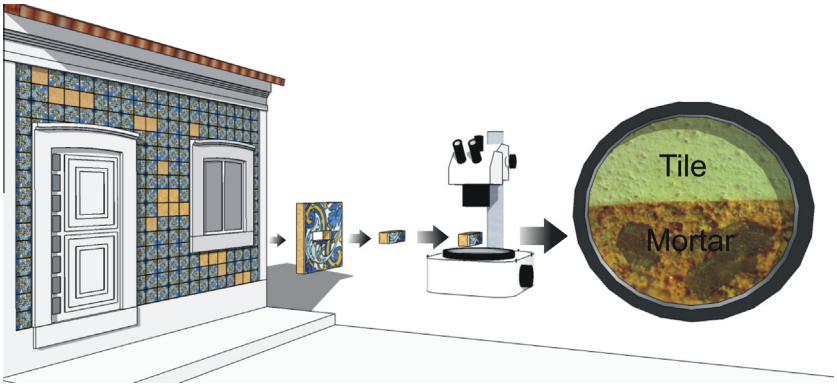
## HIGHLIGHTS

- Ceramic materials produced in 19th Century for the cladding of facades are studied.
- The bond between highly absorbent ceramic tiles and lime mortars is evaluated.
- Adherence extension on the tile/mortar interface is measured at mesoscopic scale.
- The bond strength is directly proportional to the adherence extension.
- The greatest influence on bond was exerted by the aggregate grain size and shape.

## GRAPHICAL ABSTRACT

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## ABSTRACT

This paper relates the study of the bond mechanism between lime mortars and glazed tiles. These materials were sampled from facades in Ovar-Portugal, which had been clad in the 19th Century. A thorough characterization of mortars and tiles was performed as well as an analysis of the interface between these materials, based on the quantification of the bond extension and strength. As main results, it can be stated that the bond strength values are directly related to the adherence extension (effective adherence surface) measured at mesoscopic scale and that the greatest influence on bond was exerted by the aggregate grain size and shape.



## 1. Introduction

During the 19th Century, before the widespread of cement use, mortar binders were commonly air lime or gypsum, with a well-known use that dates back millennia. In terms of the glazed ceramic cladding, during the 19th Century air lime based mortars were used for their attachment to the wall, sometimes with the use of some additional clay, with provenance from the sand, and material with some pozzolanic behavior.

Current research has focused on the study of the constituent materials of this system, focusing on the mortars and ceramic tiles. In the case of historic mortars, besides physical and mechanical characterization, the determinations of binder/aggregate proportion and of chemical composition have been undertaken. Various analytical methodologies have been used encompassing the analysis of thin sections by optical microscopy (petrographic analysis),

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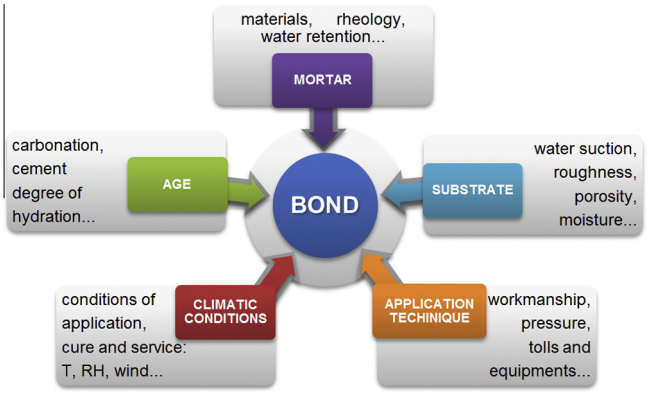


**Fig. 1.** Factors which exert influence on bond.

mineralogical (XRD) and chemical analysis (XRF), thermal analysis and the use of microscopy (SEM-EDS) [1–9]. Results have proved that the combination of methods is more effective [10] and some of these studies have enabled the establishment of parameters in terms of ancient mortar composition [11]. Recent studies [12] have enabled an advance in the quantification of the chemical composition of historical lime based mortars. For this purpose, techniques such as FTIR, SEM-EDS, LIBS and XRD spectroscopy were employed.

In the case of glazed tiles, various techniques have been employed for the characterization of the ceramic body and of the glaze and results have been disseminated in various publications [13–18]. These research works have employed both destructive and non-destructive techniques such as Raman spectrometry, Stereoscopic analysis under the optical microscope, X-ray fluorescence spectrometry (XRF), spectrometry and X-ray diffraction (XRD), X-ray absorption near-edge spectroscopy (XANES), micro-X-ray fluorescence spectrometry (μ-EDXRF), wave length dispersive X-ray fluorescence spectrometry (WDXRF) and SEM-EDS, thermal analysis (TGA, DTA), Iron(II) and Iron(III) voltammetry, synchrotron radiation-induced X-ray fluorescence spectrometry (SRXRF), and X-ray absorption spectroscopy (XAS).

One of the main degradation forms of ceramic façades is the detachment of glazed tiles. Although this is clearly a result of fatigue due to different response of materials to temperature and relative humidity changes, it is also linked to a frailty in the bond between tile and attachment mortars. Adherence is therefore a complex property, as it depends on the interaction of two distinct materials and may be influenced by several factors. Factors that exert an influence in the mortar/porous ceramic bond are shown in Fig. 1. Among these factors some may be evidenced: (a) the characteristics and properties of the porous material in contact with the mortar, mainly represented by water suction, porosity and roughness [19,20]; (b) the characteristics of mortars and their constituent materials [19–25]; (c) the mortar's application technique [25–27]; (d) the climatic conditions at the time of execution and throughout the life span of the cladding or rendering [27–29] and (e) the time span after mortar application [21,30]. Other issues, such as the formation of efflorescence in the interface zone may also affect bond in the long run, and should be considered.

Although adherence plays an important role in the ceramic cladding system, few studies have been undertaken to evaluate this property in the context of historic ceramic elements and lime mortars. This may be partially due to the difficulty involved in sampling a significant quantity and the need for use of destructive tests. Taking this into account, the present work aims at evaluating the interface between the ceramic body and the attachment

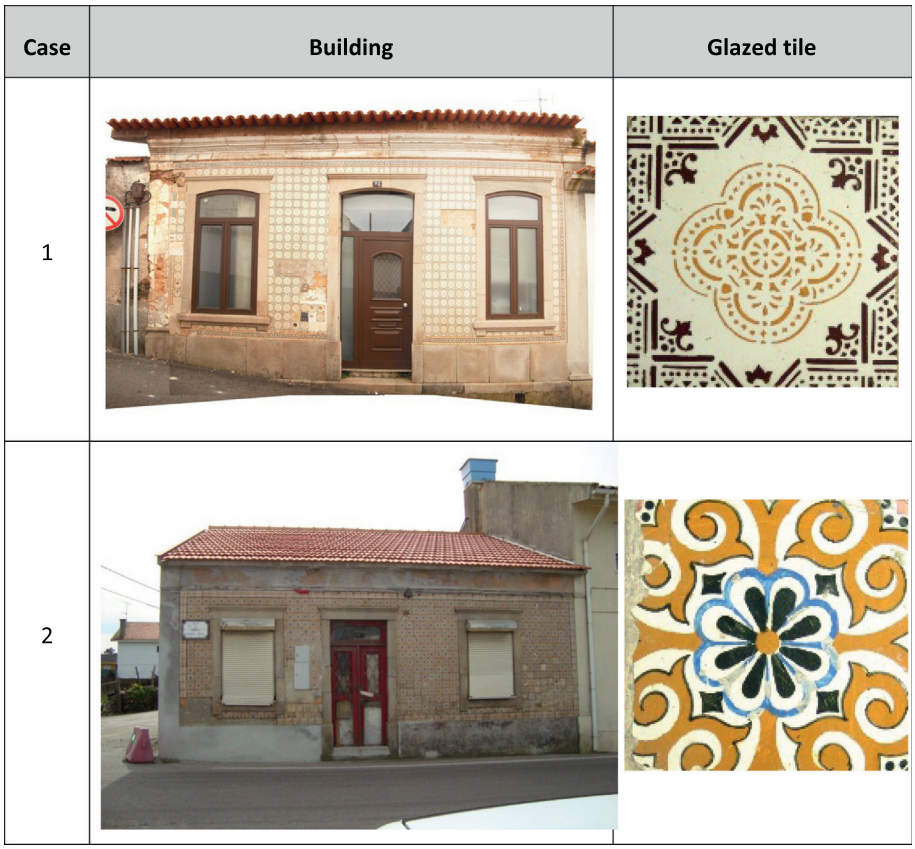


**Fig. 2.** 19th Century buildings from Ovar and correspondent façade tiles.