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Air lime mortars for conservation of historic tiles: Bond strength of new mortars to old tiles

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HIGHLIGHTS

- Historic 19th century tiles and tiled façades are studied.
- Lime mortars are compatible with historic materials and must be used in conservation works.
- Moisture in tile body improves bond strength with mortars.
- Aggregate grain size has a great influence on bond strength.
- Adequate values of bond strength may be reached using lime mortars for reapplication of old tiles.

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ABSTRACT

The present work studies the bond strength between new mortars and old tiles. The influence in tile/mortar bond strength of moisture content of tiles, mortars aggregates grain size distribution and nature, binder/aggregate ratio, different tile ceramic parts, water absorption and porous characteristics of historic tiles and new mortars were evaluated. Laboratory bond strength tests were performed with 6 different types of old tiles and it were performed 3 bond strength tests in situ.

Tile/mortar bond strength values rise with an increased moisture content on tile. Most presented mortar compositions are suitable for reapplication of historic tiles as they present bond strength values (≈0,04 MPa–0,10 MPa) similar to in-situ tests.

1. Introduction

The massive use of tile coatings in Europe during the 19th century was due to their hygienic characteristics, great artistic potential and the emergence of industrial techniques that greatly influenced building materials and construction practice. In Portugal, glazed ceramic tiles have been used in interior wall panels and decorative interior wall motives for centuries, in important or rich buildings. However, in the 19th century, tiles began to be often used as the outer coating of current buildings [1], creating a very specific effect on the urban environment. This application on building façades, which had its starting point in Portugal [2], or, according to other authors, in Brazil [3,4], increased with the development of industrialized production of tiles, which took place during this time period. This semi-industrial production allowed the economic access to this material for a greater number of people. The trend to coat the exterior facades of the buildings in Portugal began in the north of the country, and is especially evident in the cities of Porto and Ovar. The use of the pattern tiles on the exterior façades was verified in Portugal, Spain, Brazil and in isolated cases in the Portuguese Colonies. At the time the trend did not spread to other countries of Europe. The tiled façade coating system is substrate, regularization mortar render plus an application mortar or a single mortar and the tiles.

The old tiled facades of that period, some more than 100 years old, are now in need of maintenance. The ageing of materials and

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external aggressive agents lead to loss of function of some constituent materials over time leading to lack of adhesion of mortars, lack of adhesion on tile mortar/interface and gaps in glaze part of tile. Currently it is extremely relevant to define materials and techniques for tile reattachment. For this purpose, new mortars must be used either to ensure the reattachment of the old tiles with loss of adhesion or to bond new replacement tiles in areas which display lack of old tiles in the facades.

The mortars found in exterior tiled facades of the 19th century were common air lime and sand mortars [5]. The sand was extracted from neighboring areas and sometimes presents very coarse grains and, in some cases, small amounts of clay particles [6].

The reapplication of old ceramic tiles with new mortars must respect the principles of compatibility with existing materials, durability and reversibility [5].

1.1. Compatibility

The mortar must be compatible with existing materials so as not to contribute towards their degradation, to promote their protection and contribute to the durability of the whole façade [7–9]. Compatibility in this type of materials should be analyzed according to three main aspects: 1) Physical compatibility; 2) Mechanical compatibility; 3) Chemical compatibility. The physical compatibility, studied in this work, involves porous phenomena and water percolation behavior in the materials. Mechanical compatibility is guaranteed by the mechanical characteristics of moderate mechanical strength and high deformability that the air lime mortars present [7]. Additionally, it must be verified that the bond strength is enough to guarantee stability but it is not higher than the tensile strength of both the tile and the masonry. Chemical compatibility is guaranteed by the raw materials of the new mortars which are the same as the mortars of the old facades [6,1,10].

1.2. Durability

The new mortars must have durability so that it is not necessary to perform short term works, while reducing the risk of falling tiles. The requirement of durability reinforces the idea of using similar compositions to existing mortars. In fact, most tile bonding mortars are today in good function conditions despite their long life time (in some cases 200 years) [10].

1.3. Reversibility

Any new mortar used in the conservation of ancient buildings must provide the reversibility of intervention for several reasons: the need of a new repair work, decontamination or cleaning of tiles; verification of physical and/or chemical incompatibilities after application; possible need to repair the support of the building requiring the removal of some tiles.

The new mortars should be appropriate to the performed work and have the characteristics mentioned above to enable an adequate interaction with pre-existing materials and according to some studies that prove that mortars found on the old tiled facades of this period were air lime mortars [10,1,6]. For this purpose, air lime mortars fulfill these requirements. This kind of materials provided the tile/mortar bond for over 100 years. The increasing use of hydraulic binding mortars from the beginning of the 19th century and cement as a binder in the 20th century led to a tendency of using those new materials, most of them using Portland cement as a binder, which has undoubtedly stronger mechanical properties [11–16]. The use of mortars with cementitious binders is completely inadequate for this kind of works because they are chemically incompatible, namely they have high contents of salts, and mechanically incompatible, due to high strength and low deformability, with the original materials [11,17,8]. Therefore lime mortars should be used, but there is a need to assure a good bond between mortar and tile.

The adhesion mechanism of air lime mortars is mostly physical. The fine particles of the mortar, transported by water, penetrate into the tile porous structure and the connection is developed over time. The characteristics of the mortars depend on many factors such as curing conditions [18–20] and exterior aggressive factors. The case of the binding mortars and glazed tiles system is very particular because the mortar is protected from the atmosphere by the glazed tile and the joints are the more permeable part of the facade. Mortar/tile bond strength depends on the workmanship quality during the application [21], presence of soluble salts on its composition and external conditions [22], but mainly it depends on the characteristics of tiles and mortars [23] and on the characteristics and conditions of the support.

The objective of this work is to evaluate the adhesive ability of air lime and sand mortar compositions similar to the original tile application mortars. This objective will be attained through the use of traditional old tiles from the original façades and the study of physical characteristics of old tiles and new mortars. For this purpose a tensile bond strength test with specimens of six façades was studied. Moisture content of tiles, aggregate type and binder/aggregate ratio of mortars were varied.

2. Materials and methods

2.1. Materials

2.1.1. Tiles

The studied tiles were taken from 6 different 19th century tiled facades with some degradation problems (Table 1) of Ovar city. The tiles are from JPV & filhos, JPV and AACosta – Devesas factories, located in the north part of Portugal, and Sacavém, located close to the capital city, Lisbon. Tiles are from late 19th century period and were mostly applied on exterior facades, except T2 tiles, which were taken from inside the building, a kitchen. All these tiles were tested without any treatment, only washed in water. Figs. 1–6 show a sample of the tiles from each facade. Table 1 shows the conditions of old tiles, mortars and tile/mortar adhesion.

Tiles T1-T5 have the common ceramic part found in majority of tiles applied in exterior façades; They are called by "calcic tiles". The ceramic part of these tiles is constituted by kaolinite clays, quartz, talk (or dolomite) and calcite. These tiles had a firing temperature between 1100 °C and 1150 °C. Ceramic part of T6 tile, called "white paste", is only constituted by quartz and kaolin and had a firing temperature between 1150 °C and 1360 °C. All glazes are lead glazes. T1 and T3-T5 have a double glaze layers, one very white layer (engobe) just after the ceramic body and after that a transparent glaze. T2 have one single opaque glaze and T6 have a single transparent glaze [24].

The glaze is the part of the tile exposed to weather and outdoor aggressive agents. The glaze of the old tiles is often deteriorated due to long-term exposure, mostly, presenting some gaps and loss of pattern. Only the glaze of T6 tile has micro cracking in all its extension. The majority of mortars are compact and in good condition, but T1, T2 and T6 systems present mortars with some cohesion problems. The weak adhesion conditions of mortars with cohesion problems are also evident. These are due to the mortars age and their natural loss of function and some cracks outside the façades (top of building, window frame stone and substrate) that provided the entrance of water to the system and accelerate the degradation.

2.1.2. Mortars

The mortars mixture were prepared with a Portuguese hydrated air lime (Lusical H100), classified as CL 90-S according to EN 459-1:2010 [25]. Two siliceous sands with different grain sizes distributions were used:

1) Mix sand M: mixture of three siliceous sands with different grain sizes, including a fine sand, a medium sand and a coarse sand in 0,66:1:1 volumetric ratio, respectively. The Mix sand aims to simulate the characteristics of common sands used in Lisbon region;
2) River sand R: washed river sand from Tejo River (Lena Agregados).

The particle size distribution curves of the sands are shown in Fig. 7.

Mortar mixes with 1:2 and 1:3 binder/aggregate (b/a) volumetric ratio were developed with both sands M and R: 1:2M, 1:2R, 1:3M, 1:3R. The amount of water used was calculated so as to obtain an adequate consistency in mortars for this type