Conservation of Adobe Walls – Rendering Mortars

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ABSTRACT: Earthen construction is spread throughout various areas of Portugal, in the form of tapia or adobe, using different kinds of soil, natural fibres and air lime. In the region of Aveiro and its surroundings, adobe used to be the main construction material, employed in buildings, walls and wells. Adobe production was made industrially by a few producers, but opened the possibility for individual production and many made adobe themselves in order to build their dwellings or to divide their fields. However, in time, due to the introduction of Portland cement as a generalized binder and new construction techniques using industrial burnt brick, these buildings have been taken down or de-characterized and conservation is almost inexistent. Adobe is no longer produced in the region and very few lime kilns are functioning; furthermore, this traditional art, passed down through generations is almost lost and hardly anyone knows how to work with these materials. Currently, actions towards the conservation of these buildings usually encompass the introduction of a concrete structure and new renders with cement mortars.

However, this type of construction is highly sustainable due to endless recycling possibilities, low energy incorporation in adobe production and re-absorption of carbon dioxide by air lime mortars. Problems associated to its durability can be overtaken with the use of adequate materials and construction techniques, together with a careful maintenance. Renders play an essential role in the conservation of adobe walls as they regulate water intake and output; they must also attain mechanical and chemical compatibility with adobe in order to promote its conservation. In order to contribute towards the conservation of the vast adobe construction heritage still existent in the region of Aveiro, a programme encompassing the study of adobe blocks, rendering and joint mortars and aiming at the development of mortars compatible with adobe walls, was put into practice. Various mortars were designed, used air-lime and hydraulic lime as binders, a local siliceous sand and pozzolanic additions. They were tested for their mechanical and physical properties and application trials were also made over adobe blocks. From the results obtained, some of the composition proved promising for employment in the conservation of adobe constructions.

1 INTRODUCTION

In order to guarantee certain continuity with the past, because of the historical, emotional and artistic value of the construction (Venice Charter, 1964), it is essential to obtain relevant information on construction mortars when there is intention to proceed with a conservation intervention on an old building. The compatibility between old mortars or substrates and the rehabilitation materials is very important for the stability of the entire building. This compatibility involves chemical, physical and mechanical aspects. The search for this compatibility is also supported by that fact that old materials, about to be restored, already had proved to have adequate mechanical properties and acceptable performances throughout the time (Lanas & Alvarez, 2003; Moropoulou et al., 2005).

Common characterization techniques have proved essential in several methodologies when they were used for the identification of mortar constitutuents (Bakolas et al., 1998; Moropoulou et al., 1995; Paama et al., 1998). These techniques, including thermogravimetric and differential thermal analyses, X-ray diffraction, can be allied with others used to evaluate physical and mechanical properties (mechanical strength, density and porosity,) and altogether give a special contribute in the development of improved and compatible rehabilitation mortars. There were some attempts to merge the out coming information in order to conclude which is the most adequate mortar for each specific case (Marques, 2005; Moropoulou et al., 2003; Santos Silva, 2003).

In order to contribute towards the conservation of numerous adobe construction heritage still existent in several regions, a project involving the study of adobe blocks, rendering and joint mortars and aiming at the development of compatible mortars was set.

2 EXPERIMENTAL

2.1 *Materials*

A set of old mortars were chosen from different adobe constructions encompassing walls and residential buildings in Aveiro, as summarised in Table 1.These mortars were submitted to a set of analysis in order to evaluate their properties.

Taking into account ancient mortar characteristics determined on mortars displayed in Table 1, several mortars of known formulation were previously prepared and characterized, varying the type and proportion of binder and aggregates (Table 2). Air lime and hydraulic lime (NHL 5) were used as binders while siliceous sand was used as the aggregate. A natural pozzolanic addition, Cape Verde pozzolan, was also used in one of the formulations.

The amount of kneading water was the sufficient to achieve an adequate workability. After preparation, the samples were cured in a climatic chamber during 90 days (T = 23±2 ºC; H = 65±5%).

Table 1: Selected buildings, samples and abbreviations

Building	sample	Abbreviations
Major Pessoa House	Adobe Rendering mortar Joint mortar	MP
Seixal House	Adobe Rendering mortar Joint mortar	CS
University House	Rendering mortar Joint mortar	CP
Train Station wall	Adobe	MC
Wall of Tribunal dos Menores	Adobe Rendering mortar Joint mortar	TM
House at Largo Maia Magalhães	Adobe Rendering mortar	LMM
Aveiro Museum	Rendering mortar Joint mortar	FM

Table 2: Compositions of studied mortars.

Sample	Blinder	Pozzolanic additions	binder/pozzolan/aggregate volumetric ratio	Kneading water (%)
CA	Air lime	-	1:0:3	18
CAP	Air lime	Cape Verde	1:1:3	18
CH	Hydraulic lime	-	1:0:4	17

2.2 *Analyses*

The main constituents of ancient samples were determined by XRD (Rigaku Geigerflex D/max Series, Cu-kα radiation, between 4º and 80º (2θ), with a scanning speed of 3º/min) and by differential thermal and thermogravimetric analyses (DTA/TGA, SETARAM - LabSys, heating rate of 5ºC/min, up to 1000 ºC).

These ancient samples as well as the laboratory prepared ones were characterized regarding their mechanical properties and capillary water behaviour. The mechanical characterization involves measurements of dynamic elastic modulus (E), flexural and compressive strengths (Fs; Cs), following standard methods (EN 1015-11). Capillary absorption coefficient was measured according to EN 1015-18 European standard. The capillary absorption coefficient C is the water mass m absorbed per unit time, through a unitary surface of a dried sample in contact with a water layer, and taken from the $(m/A)=C.t^{0.5}$ relation, where m is the absorbed water mass, A is the contact area between the sample and the water layer and t is the test time.

Since reasonably large samples having regular dimensions are needed, these determinations are difficult to perform with the samples removed from the walls, justifying the low number of determinations on old mortars and the determination of the coefficient C only in the linear zone before the saturation state (fig. 1).

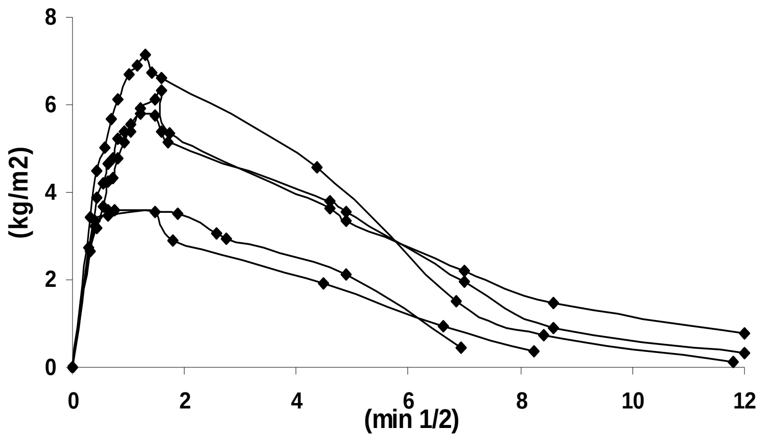

Figure 1: Absorption and drying curves on ancient rendering mortars.

Grain size distribution of old mortars was determined by using normalized sieves (ISO 3310 - number 3 series). The siliceous sand used in the formulation for compatible mortars, M, presents a particle size distribution matching the aggregate size determined for old mortars (fig. 2).

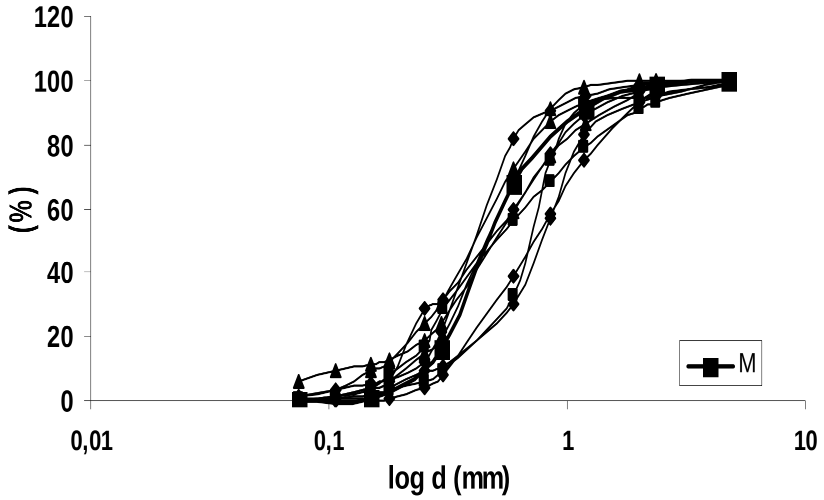

Figure 2. Particle size distribution of old (thin line) and adjusted aggregate for new mortars (thick line).

3. RESULTS

Figure 3 presents a typical XRD pattern for the old rendering mortar (MP5 sample). The identification of XRD peaks was performed in this and other mortar samples as well as on the adobe associated with the mortars. These results are summarized in Table 3. In all cases, the major components found were quartz and calcite. These findings are related with the use of siliceous sand and lime as original constituents of the mortars. The presence of halite in the mortars is related to the fact that this is a region very close to the sea and, hence, suffering its effect trough the used raw materials and atmosphere.

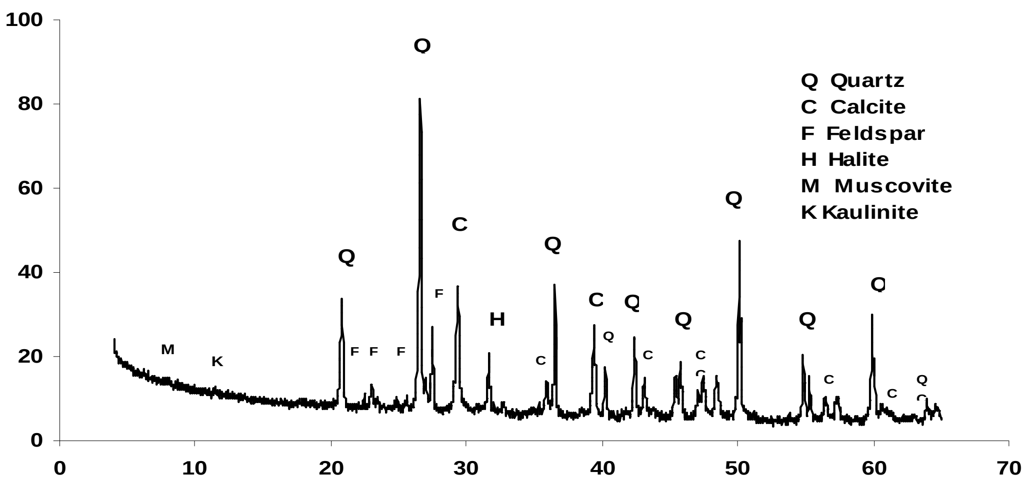

Figure 3: Typical XRD pattern from an old rendering mortar (MP5).

Figure 4 shows the calcite decomposition peak, near 780 ºC that has a small bump that could be related to the presence a minor amount of dolomite or a finer fraction of calcite. In the range of

200-600 ºC a small weight loss is observed correspondent to organic matter decomposition. The initial peak, below the 100ºC, is due to the moisture loss of the sample.

A joint analysis of the results obtained by the TGA and the results from the XRD enables the determination of the weight ratio between the binder and the aggregate. The estimated old mortar binder:aggregate ratio is in the range of 1:3 to 1:9, corresponding to a relationship, in volume, between 1:1 and 1:4.

Table 3: Identification of constituents of ancient rendering mortars by XRD.

Material	Ancient rendering mortars
Major constituents	Quartz Calcite
Minor constituents	Feldspar Calcium phosphate Halite Muscovite Kaolinite

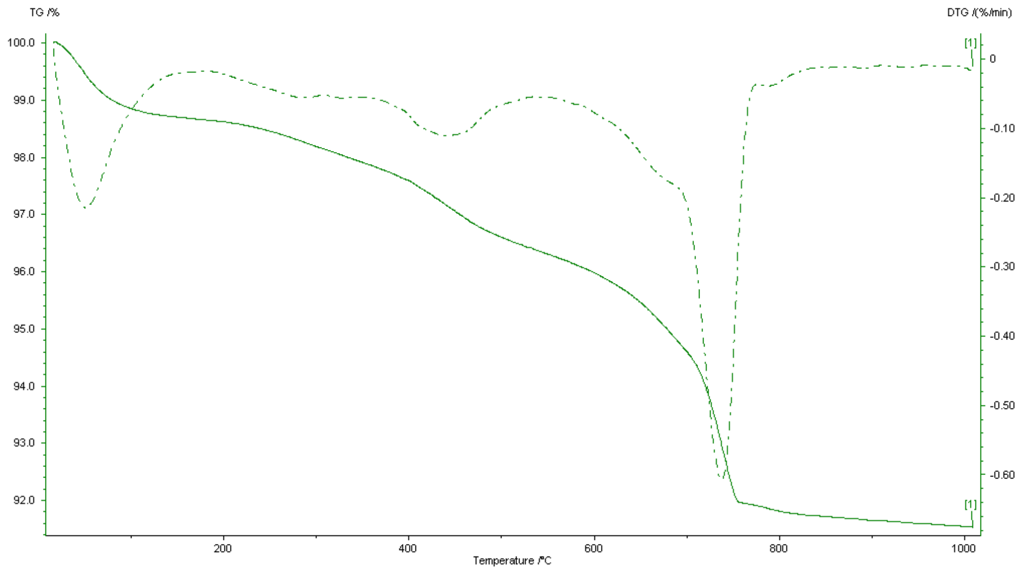

Figure 4: Typical DTA/TG analysis on an old rendering mortar (MP5).

Using the previous results as a guide and a table of minimum requirements for rendering mortars in adobe masonry walls (table 4) set by a recent work [Veiga, 2004], various formulations were developed with the purpose of obtaining mortars compatible with adobe walls.

Table 5 shows the results of the capillary, mechanical strength and Young modulus, at 90 days. Regarding the modulus of elasticity, all samples have values within the range of acceptable minimum requirements. Although the CA and CH compositions present values of mechanical strength within the range allowed by the minimum requirements, CAP formulation presents a lower value than expected.

The capillary coefficient values (C) submitted by the CA mortars and CH are very high and the application of these mortars over adobe walls, extremely prone to degradation due to the action of water is therefore not recommended. The value presented by the CAP formulation seems to be the most appropriate for use in adobe masonry walls.

Table 4: Minimum requirements for rendering mortars in adobe masonry walls.

Rendering mortar	Mechanic strength at 90 days (MPa)			Capillary Coefficient
	Rf	Rc	E	C $(kg/m^2.h^{1/2})$
	0.2-0.7	0.4-2.5	2000--5000	8<C<12

Table 5: Results of mechanical strength and capillary for the studied mortars.

Sample	Mechanical strength at 90 days (MPa)			Capillary Coefficient
	Rf	Rc	E	C $(kg/m^2.h^{1/2})$
CA	0.90	1.1	4296	17
CAP	0.55	0.75	3473	8
CH	0.4	1.3	2330	18

Figure 5 shows the application of the formulated compositions on an adobe brick removed from one of the target buildings. Mortars were applied in a single layer of 2cm, simulating current application practice. During a the time span of one year no evident cracking occurred and adhesion tests will be performed in the near future to assess the performance of these mortars over an adobe substrate..

Figure 5. Mortars applied on adobe bricks.

4. CONCLUSIONS

Old mortars applied over adobe were studied in terms of their constitution, revealing a similar composition, with an air lime binder and siliceous sand as main components, but varied binder:aggregate ratios. Taking into account the results obtained by this analysis, several rehabilitation mortars with air-lime and hydraulic lime as binders were prepared and tested for their mechanical and physical properties and application trials were also made over adobe blocks. Comparing the obtained results with expected values for mortars to be applied in rehabilitation works, a mortar with air lime, Cape Verde pozzolan and siliceous sand was selected as the most appropriate, especially due to its lower capillary absorption.

These results will enable the application of conservation mortars on adobe constructions that have suffered degradation actions and that are commonplace in the region of Aveiro, promoting the protection of our earthen construction heritage, that is extremely rich in this part of Portugal. The input towards sustainability is achieved by the preservation of existent buildings, together with the use of sustainable materials, such as air lime and natural pozzolanic materials.

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