Conservation of old renderings - the consolidation technique through traditional and sustainable materials: the lime water (a study methodology)

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ABSTRACT: The study of external renderings in the scope of the conservation and restore has acquired in the last years great methodological, scientific and technical advances. These renderings are important elements of the built structure, therefore besides possessing a protection function, they possess often a decorative function of great relevance for the image of the monument. The maintenance of these renderings implies the conservation of traditional constructive techniques and the use of compatible materials, as similar to the originals as possible. In the present paper, a study carried on at LNEC – Laboratório Nacional de Engenharia Civil, Lisbon, Portugal – on restore techniques for old historical renderings[1]. In this research the aim is also to study the economic and technical viability of the use of traditional and sustainable techniques.

1 INTRODUCTION

The renderings that cover the exterior façades of historical buildings – simple plain renderings or decorated, painted renderings – are a part of the architectural structure of the old monument and of the image of the city, so they must be preserved. Their conservation is very important, not only for the aesthetic reason, but also for their importance for the materials' history and the construction's technology.

It is known that during the restore work many of these old renderings are removed indiscriminately, often due to lack of knowledge about the used techniques and the feasibility of their repair, other times for thinking that repair is more expensive than substitution for a new one. Being conscientious of the importance of these renderings for the monument, and to make practicable their conservation, it is fundamental and of great utility the study of the restore techniques applied to external renderings.

This paper presents preliminary work of a larger study on consolidation techniques for lime renderings' repair. Consolidation techniques using lime water are presented and a description is carried out of the testing program prepared to evaluate the efficacy of these techniques. A few of the tests have been carried out and their results and conclusions are also presented. Preliminary to the definition of the experimental program, a survey was performed about the main defects existent on old Portuguese renders. The following defects seem to be the most frequently observed:

- loss of cohesion, that is the loss of the mechanic resistance of mortar's, layers due to loss or alteration of the binder among particles, provoking several defects, such as: peeling, desegregation, pulverulence, etc. (Fig. 1)
- loss of adhesion, that is the separation or detachment that can occur in the different layers of a mortar or between mortars and the support provoking defects such as: detachments, cracks and lacuna.

Figure. 1 Plaster whit loss of cohesion

[1]This investigation inserts in the scope of the Ph.D thesis *The conservation and restore of external renderings of old buildings - a methodology of study and repair* that Martha Lins Tavares is developing in LNEC and FA/UTL, with the support of FCT (Foundation for Science and Technology) and inserted in Project FCT | POCTI/HEC/57723/2004 - *Lime renders conservation: improving repair techniques and materials on architectural heritage* that is being developed in LNEC/Lisbon.

This work presents an approach to the consolidation of renderings with loss of cohesion (TAVARES, 2005).

Several consolidants have been used lately to restore cohesion to old mortars. Nevertheless, some of them change significantly the properties of the render and for this reason they generate new anomalies and functional problems for the building. Conscious of the importance of the use of a sustainable technology and of traditional materials for the restore of old lime mortars, it was decided, at a first step, to study the limewater consolidation methodology to re-establish the lost cohesion.

2 THE TRADITIONAL MATERIALS FOR CONSOLIDATION OF THE LOSS OF COHESION OF LIME MORTARS

2.1 *Description of the material*

In this work we will study the effects of two types of limewater for consolidation: *simple limewater* and *additivated limewater.*

SIMPLE LIMEWATER - This is the older consolidation treatment of which there is knowledge; Vitruvio in its treatise described this technique: *...executed with lime and a large quantity of clean water* (GÁRATE, 1994). Its effectiveness is contested by some authors, but it is still very used by some technicians; and several scientific studies have been carried through proving its effectiveness (BRAJES, 1999). The material is compatible with lime mortars, besides being a sufficiently economic treatment. This method consists of successive applications of a calcium hydroxide solution on the damaged rendering. The calcium hydroxide reacts with the carbon dioxide becoming calcium carbonate, which precipitates in the material's pores thus reducing the voids' volume (CASAL, 2001).

ADDITIVATED LIMEWATER - Metakaolin was used as an additive to improve the adhesion of limewater to the substrate and consequently to improve the lime mortar's mechanical resistance. Metakaolin is a mineral obtained through kaolin's heat treatment and grinding, resulting in a material of raised pozzolanicity, capable of quickly consuming calcium hydroxide, and whose pozzolanic activation by calcium hydroxide supplies products of strong structure and similar composition as those produced with portland cement (SAMPAIO, 2000).

2.2 *The preparation of the products*

The limewater used was kept in the laboratory in a closed bucket for some years. The metakaolin used was *MetaStar 501*of Imerys. It was decided to use a concentration of metakaolin in limewater similar to the concentration of lime in *simple limewater*. For this, it was necessary to know the amount of lime in 1 liter of simple limewater by drying the liquid in a stove. The measured amount of lime in simple limewater was 2 g. To prepare the additivated limewater the same amount of metakaolin was added to limewater.

The drying of *limewater additivated* with metakaolin was also carried out and it was easily observed that the two dry products presented very differentiated structures. The residue of the *simple limewater* was presented as a powder (calcium carbonate) with formation of small crystals, while the residue of the *additivated limewater* presented a greater amount of plate shaped crystals (Figs. 2, 3).

The pH of the two types of consolidants was measured, and the values were compared. The simple lime water pH was 10,3 and the additivated limewater was 7,3.

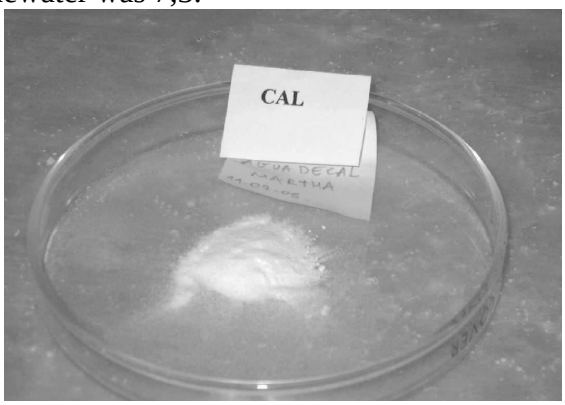

Figure 2 Residue after drying of the simple limewater

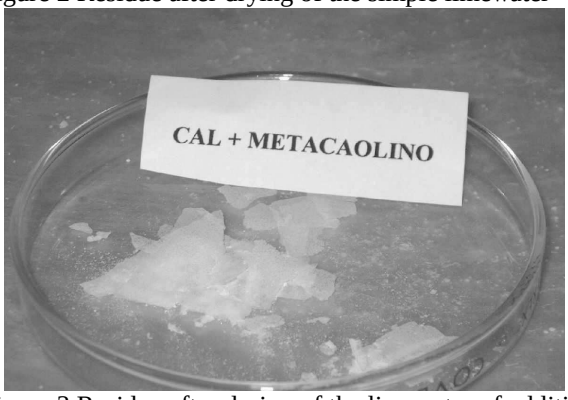

Figure 3 Residue after drying of the limewater of additive

2.3 *Experimental methods for evaluation of the efficacy of the consolidation (before and after the consolidant application*

2.3.1 *The* in situ *tests and determinations carried out were the following:*

– Color measurement_- measurement of the colour through an atlas NCS (Natural Colour System) before and after the application of the consolidant, to verify if there is a change in the aesthetic aspect of the rendering.

– Permeability to water under low pressure (Karsten tubes) – measurements of permeability to water before and after the application of the consolidant to verify the impact of the treatment on this property.
– Controlled penetration tests - tests applied before and after the consolidation treatment to evaluate the resistance of each layer and to get information on the mechanical resistance of the internal layers (VEIGA, 2000).
– Cohesion tests - the superficial cohesion of plasters and painted surfaces is evaluated before and after the consolidation treatment (Fig 4) (VEIGA, 2000).
– Ultrasounds – measurements applied before and after the treatment of consolidation to evaluate the improvement on the mechanical resistance of the damaged zones these (MAGALHÃES, 2002).
– Control of salts – in situ tests with colorimetric strips permit to verify if the consolidant introduces salts into the wall.

Figure 4 Sphere Shochk test

2.4 *Application of the consolidants on lime mortar specimens, on wallets and on old mortars*

Three different kinds of experimental applications were accomplished with the consolidants.

Several specimens were prepared with air lime and sand mortar with volumetric ratio 1:3. Different shapes and dimensions were adopted according to the tests to perform:
– Cylindrical bases with 200 mm diameter and 20 mm thickness for water vapour permeability, water absorption by capillarity and accelerated artificial weathering tests.
– Prismatic bases with 40 mm x 40 mm x 160 mm for flexural resistant tests.

The laboratorial specimens consisted on applications of the chosen consolidants on the described mortar bases, for subsequent analyses in laboratory.
In situ applications consisted on:
– Applications of the chosen consolidants on wallets in external environment, rendered with air lime and pozzolan mortar with problems of loss of cohesion.
– Applications on old plasters of a XVIII th century building with problems of loss of cohesion.

Before the consolidant products' application the colour measurements of the mortar were performed with atlas NCS (Natural Colour System). The product was first applied on the laboratory specimens in a room conditioned at 23ºC T and 50% HR, using the spraying technique with a manual spray, from a distance of 50 cm; after each application the specimens and spray were weighed for the verification of the consolidant consumption. The application was interrupted when it was verified that the specimen was completely damp or either the back of the specimen was wet; this saturation effects happened approximately after 25 applications. The tested specimens had two different shapes and sizes: cylindrical specimens with a treated area of 0,0314 m²; prismatic specimens with a treated area of 0,0064 m².

Before the application of the products on wallets and on old building walls the *in situ* tests described in 2.2 were carried out. The area of application of the product in these zones was of 0,036 = m², in external natural environment with a measured temperature of 26º C; the application technique was also spraying, being interrupted when an excess of liquid was observed at the surface; this happened after 30 applications on each zone.

3 RESULTS OF IN SITU TESTS

The application of the consolidants was finished two months ago, which is not enough for an evaluation of their behaviour. The accomplishment of new tests on consolidated surfaces must be started 3 months after the application, at minimum, when there is some assurance of lime carbonation and of stabilisation of reactions.

In tables 1 and 2 and Fig. 5 the main results obtained before the application of the consolidants are summarised, thus informing on the state of current conservation of these renderings.

Table 1. Chromatic identification and half-quantitative determination of salts

	Ancient lime mortars (building of XVIII th cent.)	Lime + pozzolan mortars 5 years old (wallet 54)	New mortar specimens (air lime + sand 1:3)
Colour identification NCS, index 2	S 1005 Y 50 R	S1000N	S 0500N
Half-quantitative determination of salts (*Strip test*)	Negative for nitrate chloride and sulphate	Not determined	Not determined

Table 2 – Evaluation of the rendering cohesion

	Ancient mortar (building of XVIII th cent.)			Lime + pozzolan mortars 5 years old (wallet 54)[2]		
Controlled penetration (mm)	1ª penetration	6	Mean value	1ª penetration	16	Mean value
	2ª penetration	1	9	2ª penetration	14	15
	3ª penetration	2		3ª penetration	14	
Sphere Impact (Ø, mm)	12			15		

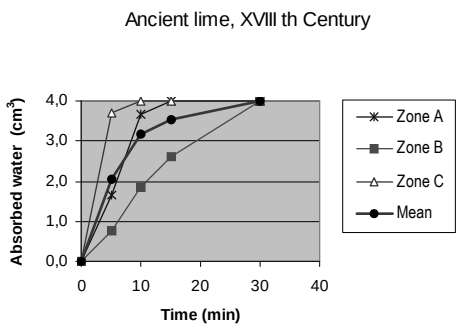

Figure 5 Evaluation of the permeability to water under low pressure

4 FINAL CONSIDERATIONS

The study to verify the viability and effectiveness of the limewater as a consolidant of lime mortars with loss of cohesion is still in course, however some points can be distinguished to follow during the work:

- The use of Metakaolin as an additive in limewater lowered the alkalinity of the product; it was also observed that the *additived limewater* when drying forms a product with plate shaped crystals; this must be followed to assess its influence on the improvement of the mechanical resistance of the mortar after treatment.

Concerning the tests and measurements performed before the application of the consolidants, some conclusions were extracted:

- The tests on ancient mortars with the Karsten tubes showed that they are extremely permeable to water and, as verified with *Strip tests*, they do not contain soluble salts. It is important to verify the changes on permeability to water induced by consolidation treatments and to assess if consolidants don't introduce any salts in the mortar.
- The results obtained at *in situ* tests of Sphere impact and Controlled penetration showed some differences: lower deformability and higher resistance to the penetration in *ancient mortars* compared with *lime + pozollan mortar (wallet 54)* which presents lower resistance to penetration.
- To try to evaluate the state of conservation of the mortar in deeper layers, the test of controlled penetration was carried out with resource to three collisions, measuring each one's penetration. In *ancient mortars*, the second and third collisions indicate some increase of mortar's resistance in depth, or either the loss of cohesion is restricted to the first layers, existing a good adhesion to the substrate.
- Thus it is possible to conclude that on the old building walls tested the consolidation can be carried out only on the first layers. The *lime + pozollan mortar (wallet 54)* showed lower resistance at deep layers, so in this case the consolidant must achieve a higher penetration.
- It can also be concluded that the results of the *in situ* tests on the two kinds of specimens will supply more information on the state of conservation of these renderings, and to guide the choice of their treatment, technique and type of consolidant more adjusted for each defect.

With the continuity of the study concerning these consolidants – lime water and additivated lime water – it is aimed to contribute to the creation of ecological and economically viable materials, through the promotion and use of traditional technologies.

LNEC's aim with this study is to deepen the knowledge in this area, and to diffuse it among national and international technicians, as a way to contribute for an improvement of conservation interventions on old walls' renderings, through the use of traditional and sustainable materials.

5 AKNOWLEDGMENTS

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