Comunicação apresentada Historical Mortars Conference, HMC 08 - Lisboa, LNEC, Setembro de 2008.

Conservation of old renderings - the consolidation of rendering with loss of cohesion

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SUMMARY:

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.

The main objective of this study is to define a methodology of conservative restore using strategies of maintenance of renderings and the traditional constructive techniques. The minimum intervention principle is maintained as well as the use of materials compatible with the originals ones.

This paper describes the technique and products used for the consolidation of the loss of cohesion. The testing campaign was developed under controlled conditions, in laboratory, and in-situ in order to evaluate their efficacy for consolidation of old renders. A set of tests is presented to evaluate the effectiveness of the process. The results are analysed and a reflection is added referring to the applicability of these techniques. Finally the paper presents a proposal for further research.

KEY-WORDS: lime mortars, techniques of restore, consolidation, lime water

INTRODUCTION

The external renders of old buildings are important elements of the build structure. Besides their protective function, they also have decorative function of great relevance for the image of the building. Their maintenance implies the conservation of traditional constructive techniques and the use of compatible repair materials, as similar as possible to the original.

One of their main degradation symptoms is the loss of cohesion, which consists in loss of mechanic resistance of mortar’s layers due to loss or alteration of the binder among particles, provoking several defects, such as peeling, disintegration, and powdering. These anomalies can not be repaired with current construction techniques, which are usually destructive and have as a consequence their substitution by new renders, losing the materials history and construction technology.

The consolidation of wall paintings and of stone surfaces has been the subject of some studies and several papers can be found about those matters [1, 2, 3 and 4]. However, the consolidation of lime based external renders is not yet well studied, and only a few scientific documents concerning the subject are known. These studies can be based on the larger experience collected on consolidation of stone and mural paintings.

PRODUCTS AND TESTS

Products

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 restoration of old lime mortars, it was decided, to study three different consolidants – lime water, additivated limewater and ethyl silicate – applied to mortars. Based on previous studies, the basic requirements of a consolidant are synthesized in table 1.

LIMEWATER - This is the oldest consolidation treatment known; Vitruvius described this technique: *...executed with lime and a large quantity of clean water* [5]. Its effectiveness is contested by some authors, but it is used by several technicians and there are scientific studies evidencing good results [4]. The material is compatible with lime mortars, besides being an economic treatment. The technique 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 [6].

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 [7].

ETHYL SILICATE – Ethyl silicate belongs to alcoxisilane family, used since XIXth century. The chemical composition of ethyl silicate has been modified throughout the years, and different formulations are commercialized, based on main components. After hydrolysis and condensation, ethyl silicates originate colloidal silica that is deposited inside the porous structure [1 and 2].

In this study the ethyl silicate used was Tegovakon® V[i], that is a tetraethoxysilane (TEOS). Ethyl silicate has been used as stone consolidant and more recently as wall paintings consolidant [8].

Table 1 - Basic requirements for lime mortars consolidant [2, 3, 4 and 9].

Type of consolidant	Property	Requirements
Consolidant for lost cohesion	Penetration	Good penetration from surface to the interior
	Porosity	Not to modify the porosity of the mortars to be treated
	Behaviour to the water	Good capacity of moisture transference from the interior to the exterior
	Chemical and physical compatibility	Good chemical and physical compatibility with mortars to be treated
	Aesthetic aspect	Not to change the rendering to be treated colour

The preparation of the products

The limewater used was kept in 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 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. 1 and 2).

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 and Tegovakon 3.

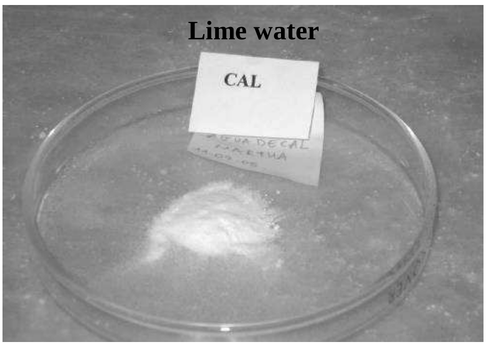

Fig. 1 Residue after drying of the simple limewater.

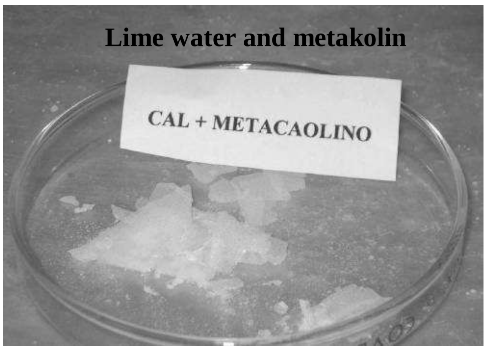

Fig. 2 Residue after drying of the limewater additivated with metakaolin

Application of the consolidants on lime mortar specimens and 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 and water absorption by capillarity.
- 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. 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.

In situ applications consisted on applications of the chosen consolidants on old plasters of a XVIII th century building with problems of loss of cohesion.

In situ and laboratorial tests

A test campaign for evaluation of the efficacy of the consolidation treatment was carried out through the tests presented in table 2.

Table 2 - Description of the consolidation tests

Type of consolidant	Laboratory tests	In situ tests
• **Limewater** • **Lime water with metakaolin** • **Ethyl silicate**	colour measurement, water vapour permeability, water absorption by capillarity, penetration of consolidant and mechanical resistance.	colour measurement, permeability to water under low pressure (Karsten tubes), control of salts and mechanical resistance (Shmidt impact hammer and Durometer tests).

Fig. 3 – Test with Schmidt impact hammer on ancient lime mortar

Fig. 4 – Test for evaluation of consolidation deepness with phenolphthalein agent

Fig. 5–Flexural strength test

Synthesis of the test results

The main test results, both laboratorial and in situ, are presented in tables 3 and 4 and illustrated in figs. 6, 7 and 8.

Table 3- Results of consolidation - in situ tests

In situ tests		**Results - Ancient lime mortars (XVIII century)**		
		Lime water	**Lime water with metakaolin**	**Ethyl silicate**
Colour identification NCS, index 2	Before consolidation	S 0500 - N	S 0500 - N	S 0500 - N
	After consolidation	**S 0500 - N**	**S 0500 - N**	**S 0502 Y**
Half-quantitative	Before consolidation	Negative for nitrate chloride and sulphate salts		

determination of salts (Strip test)	After consolidation	Negative for nitrate chloride and sulphate salts		
Compression strength using Schmidt impact hammer (VH) ISO 7619:1997 and ASTM C 805	Before consolidation	22.2	22.2	22.2
	After consolidation	**33.8**	**33.4**	**33.4**
Durometer hardness (Shore A). ISO 7619:1997 and ASTM D 2240	Before consolidation	37.1	37.1	37.1
	After consolidation	**59**	**65.2**	**67.6**

Table 4- Results of consolidation - Laboratory tests

Laboratorial tests		**Results - New air lime based mortars with volumetric dosage 1:3**		
		Lime water	**Lime water with metakaolin**	**Ethyl silicate**
Evaluation of consolidation deepness with phenolphthalein agent	Before consolidation	Penetration 4mm	Penetration 4mm	Not determined
Colour identification NCS, index 2	Before consolidation	S 0500 - N	S 0500 - N	S 0500 - N
	After consolidation	**S 0500 - N**	**S 0500 - N**	**S 0502 Y**
Half-quantitative determination of salts (Strip test)	Before consolidation	**Negative for nitrate chloride and sulphate salts**		
	After consolidation			
Capillary coefficient-0 -10 min ($Kg/m^2.min^{½}$) (EN 1015 – 18:2000). Cylindrical specimens	Before consolidation	1.16	1.16	1.16
	After consolidation	**1.13**	**1.08**	**0.11**
Permeability vapour diffusion (m) (Sd means) (EN 1015 – 19:1998)	Before consolidation	0.07	0.07	0.07
	After consolidation	**0.07**	**0.06**	**0.07**
Flexural strength (N/mm^2) (EN1015:11)	Before consolidation	0.28	0.28	0.28
	After consolidation	**0.39**	**0.43**	**0.47**

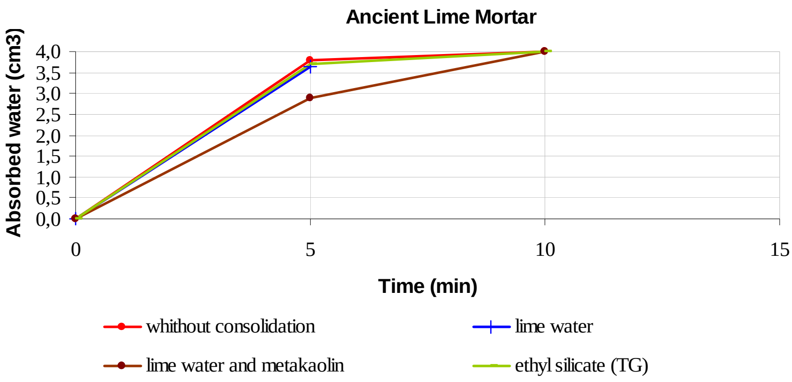

Fig. 6– Evaluation of the permeability to water under low pressure (karsten tubes)

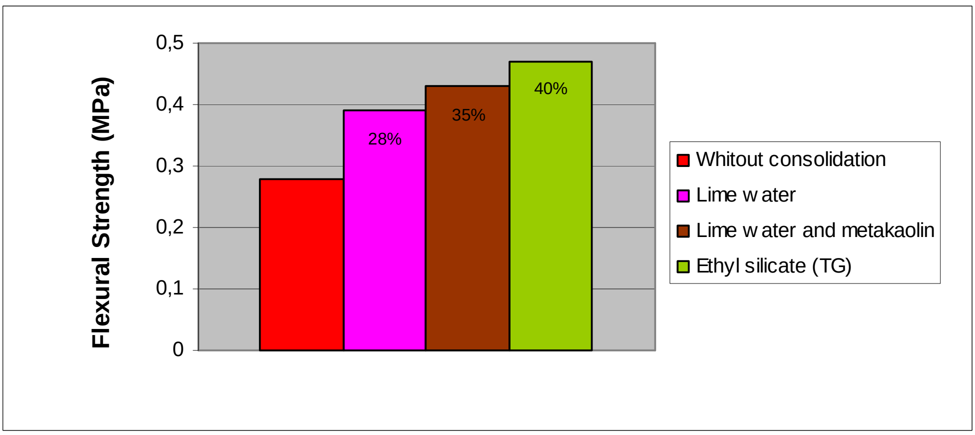

Fig. 7 – Evaluation of resistance increase (laboratorial test)

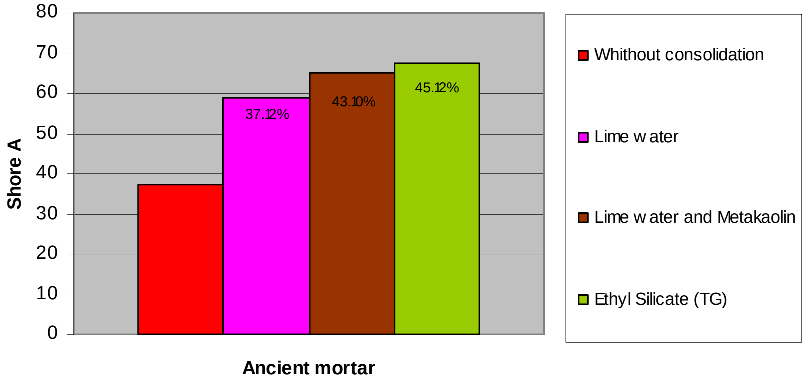

Fig. 8 – Evaluation of resistance increase (in situ test using a durometer)

DISCUSSION AND ANALYSIS OF THE TEST RESULTS

Evaluation of the aesthetic aspect and half-quantitative determination of salts: the colour of render consolidated with lime water and lime water with metakolin did not change; but render consolidated with ethyl silicate becomes a little darker. Using *Strip colorimetric tests*, it was verified that the treated render did not contain soluble salts (table 3 and 4).

Evaluation of the consolidant penetration: the evaluation of the depth of the consolidant demonstrated that limewater and limewater with metakolin penetrate only in the mortar superficial layers, so its use is recommended only for mortars with superficial loss of cohesion (table 4).

Evaluation of the mechanical resistence *in situ* and in laboratory: the results obtained at *in situ* tests with Shmitdt impact hammer, and durometer, and at laboratory test (flexural and compressive strength) demonstrated an increase of resistance on the mortars superficial layers after treatment. The highest strength increase was obtained with ethyl silicate followed by limewater with metakaolin and simple limewater (table 3, 4 and figs 7 and 8).

Evaluation of the behaviour to water: the tests on ancient mortars (XVIIIth century) with Karsten tubes showed that these ancient mortars consolidated with lime water and ethyl silicate are extremely permeable to water; using limewater with metakolin as consolidant they become less permeable (fig 6). The obtained results in terms of water absorption by capillarity in laboratory show that de capillarity coefficient is similar for specimens without consolidant and consolidated with limewater or limewater with metakolin but it is lower for specimens consolidated with ethyl silicate. Concerning water vapour permeability the consolidation treatment does not produce a barrier to water vapour diffusion (table 4).

FINAL CONSIDERATIONS

The study verified the viability and effectiveness of consolidants for lime mortars.

The use of metakaolin as an additive in limewater decreased the alkalinity of the product and increased the mechanical resistance of treated mortars, when compared with the mortars consolidated with simple limewater. It was also observed that the *additivated limewater* dries with formation of plate shaped crystals; this must be followed to assess its influence on the improvement of the mechanical resistance of the mortar after treatment.

Due to the extreme chemical compatibility of limewater with old rendering and considering the results of the set of tests carried out, it is possible to recommend the use of limewater and limewater with metakolin for consolidation old rendering with low cohesion. These consolidants increase mechanical resistance of the superficial layers. It was important to verify that consolidants did not introduce in the rendering any changes in water vapour permeability, as well as any salts previously inexistant.

For old mortars with severe cohesion problems it is possible to recommend use the ethy silicate as consolidant, as it was the consolidant that mostly increased the mortars resistance.

The study of these consolidants – limewater and additivated limewater – can contribute to the creation of ecological and economically viable materials, through the promotion and use of traditional technologies.

This study must be developed with other products that can be added to limewater in order to improve its effectiveness, due to the increasing of calcium carbonate introduced in the mortar, promoting cohesion and mechanical resistance of lime renders.

Consolidation technique is a rather complex method of restoration, because different materials can be used with this purpose and there are theoretical questions concerning the use of reversible materials. In fact, the consolidation method is always irreversible. The success of a good consolidation treatment depends not only on the chosen product, but also on the application and on the intrinsic characteristics and the conservation state of the material to treat, as well as on the ability and good sense of the restorer.

AKNOWLEDGEMENTS

The authors acknowledge the contribution for this study of FCT, the Portuguese Foundation for Science and Technology. This investigation is carried out within 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 and within the Project FCT | POCTI/HEC/57723/2004 - Lime renders conservation: improving repair techniques and materials on architectural heritage, that is being developed in LNEC/Lisbon (http://conservarcal.lnec.pt).

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[i] The ethyl silicate used in the study was a BIU International product. For more information: www.biu.pt