Conservation of old renderings – the consolidation of renderings with loss of cohesion

Conservação de revestimentos antigos – a consolidação de revestimentos com perda de coesão

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Abstract

The study of external renderings in the scope of conservation and restoration has acquired in the last years great methodological, scientific and technical advances. These renderings are important elements of the built structure, for 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 restoration using strategies of maintenance of renderings and traditional constructive techniques. The minimum intervention principle is maintained as well as the use of materials compatible with the original 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 the 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.

Keywords

Lime mortars; techniques of restoration; consolidation; lime water.

Resumo

O estudo dos revestimentos exteriores tem vindo a adquirir, nos últimos anos, avanços metodológicos, científicos e técnicos. Estes revestimentos são elementos importantes da estrutura edificada, pois para além de terem uma função protectora apresentam também muitas vezes uma função decorativa relevante para a imagem do edifício. A manutenção destes revestimentos implica a conservação das técnicas construtivas tradicionais e o uso de materiais de restauro compatíveis e o mais similar possível ao original.

Uma das principais formas de degradação é a perda de coesão, que consiste na perda da resistência mecânica das camadas de reboco devido à perda ou à alteração da ligação entre partículas, provocando diversas anomalias, tais como: desagregação e pulverulência. Estas anomalias não podem ser reparadas com as técnicas actuais da construção, que prevêem a sua substituição por novos revestimentos, perdendo-se a história dos materiais e da tecnologia da construção.

O principal objectivo deste estudo é definir uma metodologia de restauro conservativa, usando estratégias de manutenção dos revestimentos e das técnicas construtivas tradicionais, onde haja uma intervenção mínima, utilizando materiais compatíveis com os originais. Escolheu-se a técnica de consolidação como método para a preservação destes revestimentos.

Neste artigo descreve-se a técnica e os produtos utilizados para a consolidação da falta de coesão, apresenta-se um conjunto de ensaios para avaliar a respectiva eficácia, analisam-se os resultados obtidos e em conclusão faz-se uma reflexão sobre a aplicabilidade destas técnicas. Mediante os resultados obtidos apresenta-se ainda um conjunto de propostas para ensaios futuros.

Palavras-chave

Argamassas de cal; técnicas de restauro; consolidação; água de cal.

Introduction

The external renders of old buildings are important elements of the built structure. Besides their protective function, they also have a 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 the 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 [1-4]. 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 the 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 con-

Table 1 Basic requirements for lime mortars consolidant [2-4, 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 colour of the rendering to be treated

densation, ethyl silicates originate colloidal silica that is deposited inside the porous structure [1-2].

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

The preparation of the products

The limewater used was kept in laboratory in a closed bucket for some years. The metakaolin used was MetaStar 501of 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 L 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 limewater pH was 10.3, that of the additivated limewater was 7.3 and the pH of Tegovakon was 3.0.

Fig. 1 Residue after drying of the simple limewater.

Fig. 2 Residue after drying of 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 resistance tests.

The procedure for 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 23 °C 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 either the specimen was completely damp or 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 m^2; prismatic specimens with a treated area of 0.0064 m^2.

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

In situ and laboratory tests

A test campaign for evaluation of the efficacy of the consolidation treatment was carried out comprising the tests presented in table 2 and illustrated in figs. 3-5.

Synthesis of the test results

The main tests results, both in laboratory and in situ, are presented in tables 3 and 4 and illustrated in figs. 6-8.

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 metakaolin 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 (tables 3 and 4).

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

Evaluation of the mechanical resistance in situ and in laboratory: the results obtained at in situ tests with the Schmidt impact hammer and the 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 (tables 3-4 and figs. 7-8).

Evaluation of the behaviour to water: the tests on ancient mortars (XVIII century) with Karsten tubes showed that these ancient mortars consolidated with limewater and ethyl silicate are extremely permeable to water; using limewater with metakaolin as consolidant they become less permeable (fig. 6). The obtained results

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, w ater 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 (Schmidt impact hammer and Durometer tests).

Table 3 Results of consolidation - in situ tests on ancient lime mortars (XVIII century).

In situ tests		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 determination of salts (Strip test)	Before consolidation	Negative for nitrate chloride and sulphate salts		
	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

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

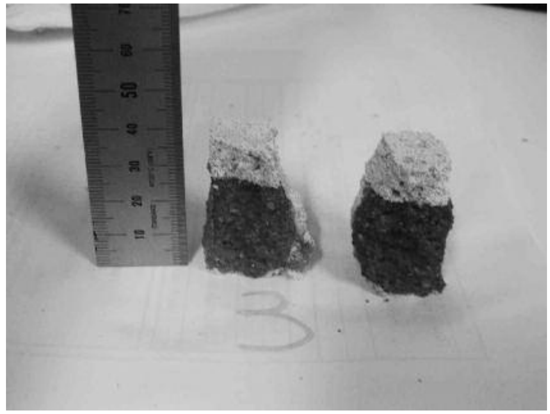

Fig. 4 Test for evaluation of consolidation deepness with phenolphthalein agent.

Fig. 5 Flexural strength test.

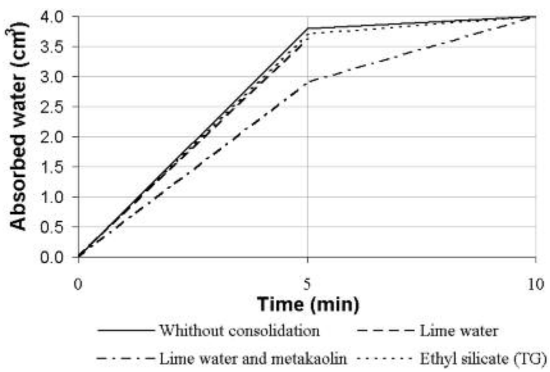

Fig. 6 Evaluation of permeability to water under low pressure, in ancient lime mortars (karsten tubes).

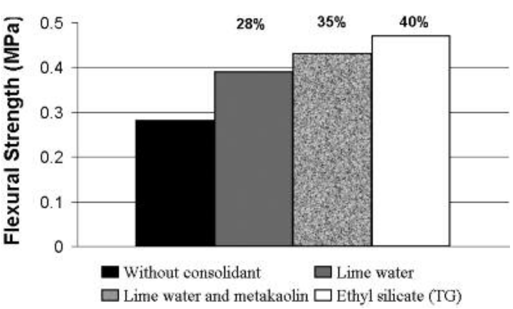

Fig. 7 Evaluation of resistance increase (laboratory test).

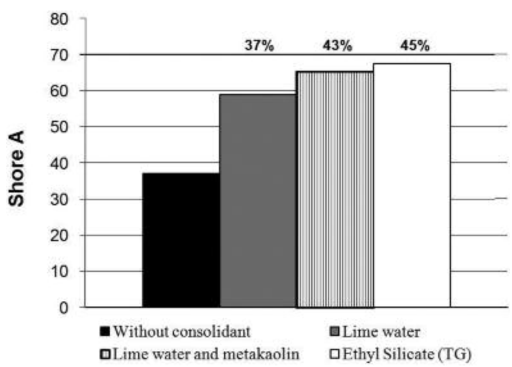

Fig. 8 Evaluation of resistance increase of ancient mortar (in situ test using a durometer).

Table 4 Results of consolidation - Laboratory tests. New air lime based mortars with volumetric dosage 1:3.

Laboratory tests		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

in terms of water absorption by capillarity in laboratory show that the capillarity coefficient is similar for specimens without consolidant and consolidated with limewater or limewater with metakaolin but it is lower for specimens consolidated with ethyl silicate. Concerning water vapour permeability, none of the consolidation treatments produces 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 the 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 (lime) renderings and considering the results of the set of tests carried out, it is possible to recommend the use of limewater and limewater with metakaolin for consolidating old renderings with low cohesion. These consolidants increase the mechanical resistance of the superficial layers. It was important to verify that the selected consolidants did not introduce in the rendering any changes in water vapour permeability, nor any salts previously inexistent.

For old mortars with severe cohesion problems it is possible to recommend the use of ethyl 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, which is due to the increasing of calcium carbonate introduced in the mortar, promoting cohesion and mechanical resistance of lime renders.

Consolidation 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.

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