Considerations about the use of lime-cement mortars for render conservation purposes

F. Pacheco Torgal*
University of Minho, Research Unit C-TAC, Sustainable Construction Group, Guimarães, Portugal
Joana Faria
University of Minho, Research Unit C-TAC, Sustainable Construction Group, Guimarães, Portugal
Arman Shasavandi
University of Minho, Research Unit C-TAC, Sustainable Construction Group, Guimarães, Portugal
Said Jalali
University of Minho, Research Unit C-TAC, Sustainable Construction Group, Guimarães, Portugal

Abstract

Some investigations about conservation renders points out that Portland cement based mortars should be avoided and should be replaced by lime-pozzolan mortars. However, this type of mortar is still under investigation and the majority of Portuguese construction enterprises operating in the field of building conservation do not possess enough know-how about them. Besides the absolute rejection of the use of Portland cement based mortars even with just a minimum amount appears to be a dogmatic position that is not fully grounded in scientific terms. These facts can influence the decision about the material's choice for conservation purposes, since in certain circumstances it may be preferable to apply blended mortars instead of an incorrect application of lime-pozzolan mortars.

Key words: Lime; pozzolans; mortars; Portland cement; render conservation

1. INTRODUCTION

The preservation of Portuguese architectural heritage is a national imperative due to the importance which it assumes in the context of the identity of a country with eight centuries of history and as a necessary condition for the preservation of this memory, or even for economic reasons related to the impact of Tourism on Portugal's economy. Only recently has the high level degradation of the architectural heritage caught the media attention, with the suggestive title "*A third part of Portuguese UNESCO architectural heritage at risk of collapse*" [1].Regarding the conservation of the building stock, the appearance of Portland cement based mortars came to displace air lime based mortars because the new binder, has a higher mechanical strength and a low setting time allowing for work completion in relatively short time. More recently it has been observed that Portland cement is not the magic formula that it was initially thought to be and it is responsible for several problems in the building rehabilitation area, where frequent pathologies are associated with its use. It is chemically incompatible with lime based mortars; it is responsible for the introduction of soluble salts; it has a low permeability and a high modulus of elasticity that is unable to accommodate for masonry deformations. Also, the Venice Charter, which gathers conservation principles no longer sees Portland cement as a preferred material, as it was been done under the Athens Charter, but accepts materials and modern techniques whose effectiveness is scientifically proven [2]. Some authors point out that the formulation of blended mortars "*not only the advantages of them come together but also their disadvantages*" [3]. However, an absolute rejection of mortars that can contain only minimal amounts of Portland cement is not supported by scientific evidence, but appears to be a dogmatic position that is not advisable. Although old lime based mortars have regained an increasing interest in the conservation field they remain a slow hardening binder. This poses serious obstacles in the implementation of renders that may have hardening times that could exceed 1 year [4]. However, this problem can be overcome by the use of formulations containing pozzolanic additives. Reducing of this problem to a simple accounting of the advantages and disadvantages between blended mortars and

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* torgal@civil.uminho.pt

lime-pozzolan mortars is a simplistic analysis of the problem, partly because in the conservation of certain monuments some original materials like aerial mortars must be used, and because it should broaden the discussion to a wider scope that may consider other factors intrinsic in the construction market, such as the level of training of technicians and workers and whether it can or can not influence this issue, and to what extent this may happens. This paper deals with conservation renders by reviewing previously published work. Furthermore, considerations about the training of technicians and workers working in this sector are also added.

2. CONSERVATION MORTARS

2.1 Previous considerations

The conservation of old renders has a high level of complexity that is inconsistent with amateur approaches from design to execution. This type of work should be preceded by an analysis of the depth of degradation and an analysis of the historical or artistic value of the property to be rehabilitated. In case of buildings with historical relevance, the first option should always be to undergo conservation of old renders through maintenance operations. If by any reason that is not possible a consolidation operation maybe needed. If the level of degradation is very high, partial or total replacement operations may be advisable, although this is usually the last option that should be taken into account [5, 6]. Any rehabilitation work must be preceded by an inspection of the materials to be restored, because ancient masonry walls are very irregular and in most cases renders have high heterogeneity thicknesses. Beyond what may be the implicit historical value in the use of original materials and techniques, there is the significant issue of the compatibility between substrate and conservation materials. Materials with different mechanical behavior and different physical-chemical characteristics, will lead sooner or later to situations of poor performance. Materials with different permeability levels, different modulus of elasticity, different adhesion levels or even with different levels of water absorption can hardly constitute a good conservation solution, because sooner or later they end up being the cause of pathologies. Some authors have analyzed the minimum performance characteristics of conservation mortars (Table 1).

Table 1: General mechanical requirements concerning some characteristics for rendering mortars of ancient buildings [7,8]

Type of render	Mechanical characteristics (MPa)			Adhesion strength (MPa)	Restrained shrinkage behaviour			
	Rf	Rc	E		Fr máx (N)	G (N.mm)	CSAF	CREF (mm)
Exterior render	0.2-0,7	0.4-2.5	2000-5000	0.1-0.3	< 70	>40	>1.5	>0.7
Interior render	0.2-0,7	0.4-2.5	2000-5000					
Repoiting mortar	0.4-0,8	0.6-3	3000-6000	0.1-0.5				

Rt – Flexural strength; Rc – Compressive strength; E – Young modulus; Fr – Maximum force induced by restrained shrinkage; CREF – Resistance coefficient to cracking: CREF=G/Fr

As important as the materials used in rehabilitation works is their correct application [9]. Therefore if a correct conservation work requires the use of appropriate materials, it also requires a good mason for a good execution [10]. Render mortars must me executed in several layers, with decreasing mechanical strength [11]. Recent investigations describe some techniques and recommendations that must be taken under consideration in the execution of lime renders for old buildings [12]:

- Clearing the substrate from impurities and filling depressions;
- Using just the amount of water necessary to assure the minimum consistency;
- Using mechanical mixing supplemented by hand mixing;

- Hard projection of mortar followed by mason trowel compression;
-Protecting renders from sun exposure to prevent fast drying;
-Protecting renders from rain exposure to prevent carbonation inhibition;
- Applying several thin layers leaving enough time between them for the carbonation of the previous layer (at least a week);
Regarding to the last recommendation one must consider that specific circumstances may lead to carbonation times of several months (Table 2).

Table 2:Minimum time needed for the application of a lime mortar rendering inside a church in Portugal [4]

Spring			Summer			Autumn			Winter			Spring			Summer		
Layer 1																	
			Layer 2														
					Layer 3												

Even the use of hydraulic lime based mortars does not always guarantee successful results. Penas et al. [13] studied several hydraulic lime mortars, yielding a high results dispersion variability that in some cases do not meet the minimum mechanical requirements, which is due to the very different amounts of limestone and clay used in the manufacture process of this lime. This scenario thus allows a obvious inference, that this subject has an inherent complexity that makes it essential for the use of technicians and workers with a high level of expertise.

2.2 Lime-pozzolan mortars

The use of lime-pozzolan mortars has a tradition of thousands of years, having arisen by chance when accidentally one found the good mechanical performance of lime mortars with the addition of volcanic ash. Later some masons have also noted that similar performance was obtained in lime mortars to which powdered ceramic fragments (tiles or bricks) were added. The appearance of Portland cement dictates the end of the use of lime-pozzolan mortars because the former did not have a high a mechanical performance. The pozzolanic reactivity, ie the ability of the material to combine with calcium hydroxide is a complex property dependent on the fact that silica and alumina are not present in a high degree of crystallinity. Generally the reactive aluminosilicate pozzolan will react with the calcium hydroxide to form calcium silicates and aluminates. Despite being known for a long time this is not a sufficient condition to allow them to be used by the construction market, partly because the knowledge we reached is a empirical one and also because the quality requirements of modern construction processes, implies that this knowledge must be scientifically confirmed. This is the reason why in recent years we saw a resurgence of investigations surrounding these materials [14,15].Besides the numerous amount of pozzolan types that can be used in conservation mortars, widens the variables that should be investigated. Velosa [16] studied the influence of lime mortars for conservation purposes containing several artificial pozzolans (brick dust, metakaolin, silica fume) and also natural pozzolans from the Portuguese Azores islands. The results obtained by this author confirm the compatibility between lime-pozzolan conservation mortars and stone masonry substrates. They also confirm that these mortars have a high water vapour permeability, present a fast drying rate and have low susceptibility to cracking. More recently other authors [17] studied the use of rice husk ash as pozzolan for lime mortars, noticing that they lead to an increased resistance to soluble salts (sulfates and chlorides), clearly showing the importance of research needs in this field. Veiga et al. [18] point out there was insufficient knowledge regarding the application conditions for lime-pozzolan mortars, emphasizing that cure conditions may play a crucial role in determining its performance [19]. This reinforces once again the influence of the technical skills or the lack of them in workers, who will execute and in the technicians, who will supervise this type of mortars.

2.3 Blended mortars

The mortars containing aerial lime and Portland cement can be formulated in order to meet the requirements for conservation mortars such as high water vapour permeability, low strength and low modulus of elasticity. Veiga et al. [18] have shown that some blended mortars are able to meet minimum requirements for conservation mortars related to mechanical behaviour and water

performance. Car & Martinez [20] analyzed several blended mortars with increasing Portland cement percentage (Table 3), concluding that although an increase in cement content increases the amount of soluble salts, this amount does not increase in a proportional manner.

Table 3: Mortars samples tested: lime and cement content in volume and weight [20]

Composition	Apparent vol. powder lime:cement	Weigth powder lime:cement	Weigth (%) cement content/total binder	Apparent vol.paste lime:cement
D1	1:0	1:0	0	1:0
D2	10:1	5:1	17	11:1
D3	4:1	2:1	33	4.4:1
D4	2:1	1:1	50	2.2:1
D5	1:1	1:2	67	1:0.9
D6	1:2	1:4	80	1:1.8
D7	1:5	1:10	91	1:4.6
D8	0:1	0:1	100	0:1

According to these authors the presence of lime influences cement hydration, salts remain in a soluble state except for the mixtures with a high cement percentage (Fig.1).

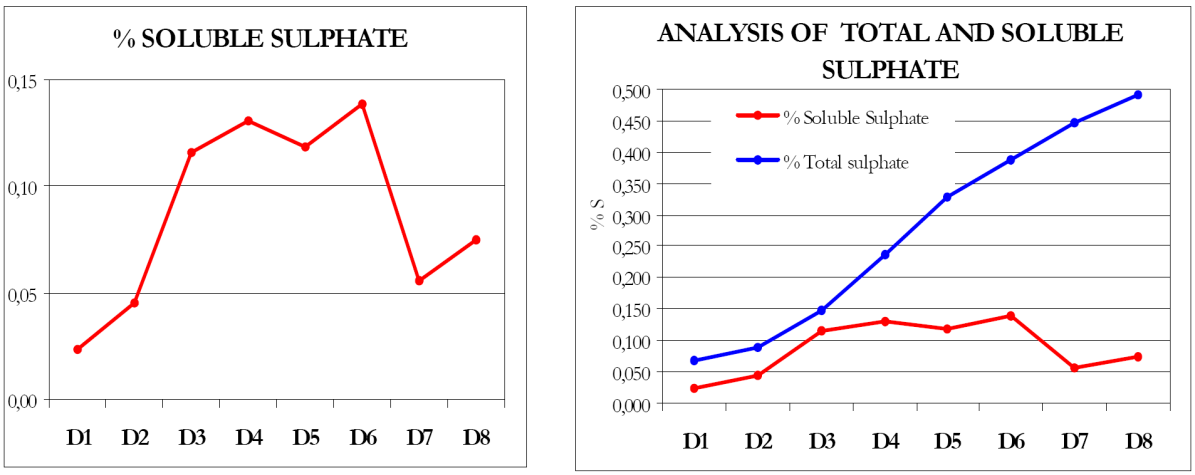

Fig 1: Interference of lime content in the hydration process of cement compounds blended mortars [20]

These authors confirmed that using mortars with a Portland cement percentage below 20% (as weight of total binder content) allows for an acceptable behaviour concerning compressive strength and water vapour permeability. It is true that the introduction of salts set undesirable situations, however, sulphate salts associated with Portland cement, "*have a low hygroscopic action, as for example calcium sulphate dihydrate (gypsum) that only undergoes dissolution with humidity levels of approximately 99% (20 º C), which is an uncommon situation*" [21].This means that using blended mortars (aerial lime + cement) maybe an acceptable solution for conservation mortars that are not submitted to high humidity levels. Also, Elpida Chrissy et al. [22] advocate the use of Portland cement in order to ensure a minimum mechanical strength at early ages, which helps to demystify some of the alleged demerits for blended mortars. This position is also supported by the work of other authors [23, 24].

2.4 Commercial pre-pack mortars for conservation purposes

Another hypothesis for conservation mortars apart from lime-pozzolan mortars and blended mortars could be the use of commercially available pre-pack mortars. However, these materials present several disadvantages. They are not cost-efficient, in many cases they present an excessive mechanical performance even above the requirements for conservation mortars and last but not the least, the fact that manufacturers do not usually disclose their full composition may lead to compatibility problems with the masonry substrate [26].

3 TECHNICIANS AND WORKERS LEVEL OF EXPERTISE

A simple comparison between the advantages and disadvantages of blended mortars versus lime-pozzolan mortars, does not allow for an adequate framework of the subject examined in this manuscript. The conditions related to the execution of those mortars and, most important the level of expertise of workers and technicians must also be addressed. In Portugal the majority of workers in the construction industry have a low education level. The majority of them have only 4 to 6 years of study, and their expertise in the construction field was acquired over some decades. This could lead to unsuccessful lime-pozzolan mortars execution. Moreover, the majority of Portuguese construction enterprises are a one-person businesses that does not even have technical support that can supervise the implementation of this type of work. The most recent Portuguese legislation on this subject ("Portaria" No. 1371/2008 of December 2 related to the equivalence between the work categories and the cost of construction works "permission classes" and "Portaria" No. 16/2004 of 11 January about staff requirements), has evolved because it makes it mandatory that a minimum of technicians must be employed by construction companies, but on the other hand it is rather permissive because it allows for technicians with only 1 year post-secondary education in Polytechnic Institutions (CET´s). Futhermore, this situation is exarcebated by the fact that CET´s technicians can be responsible to construction companies possessing a legal authorization for the execution of construction works that can go up to Class 4 permission (construction works with a value up to 1.328 million euros). And even if it is theoretically possible to admit that for the construction of new buildings this may not generate real problems the same cannot be said for conservation works, which possess a high complexity level. Since the majority of conservation works fall under the limit of class 4 it would be a good idea if the Portuguese legal framework for the construction sector lower permission classes for building rehabilitation works. Even the few hundred construction enterprises that employ full time Civil Engineers do not take full advantage of that for conservation or rehabilitation purposes, because Portuguese Civil Engineering Curricula is excessively structured around new buildings. Furthermore, this training has a majority of calculus based courses (structural, geotechnical, hydraulic, thermal, acoustic etc etc etc), and very few about building materials (one or two) so it is very difficult to ensure a minimum knowledge about conservation mortars. This scenario does not allow great expectations for the sudden drop (and not expected) in the use of blended mortars in favour of the indiscriminate use of lime-pozzolan mortars, because this option could lead to an increase in execution based pathologies. Thus, and until substantial changes in training of technicians and workers operating in the conservation field, is achieved it can be assumed that there will be circumstances, such as the conservation works on buildings without historical value, for which the use of blended mortars can be an reprehensible option but still a lesser evil, provided they comply with minimum performance requirements in terms of mechanical behavior and water performance.

4. CONCLUSIONS

Lime based mortars cease to be used because they were associated with exaggeratedly long hardening periods. This binder has been replaced by Portland cement that allows performing the same works with a minimum of time, but in the meantime it has proved to be a source of pathologies. Some elements of the scientific community have repeatedly recommended the use of lime-pozzolan mortars as the most suitable for conservation purposes, other authors refer to this as the only admissible solution, completely excluding the possibility of the use of Portland cement even in minimum percentages. However, lime-pozzolan mortars are still under investigation and their use requires the existence of skilled labor. The fact that the Portuguese construction market is composed mostly by workers with little or no training in terms of building materials and less about conservation materials, influences the importance of the right choice of conservation mortars and makes clear the importance of execution conditions in this type of work. It can then be assumed that is feasible to use blended mortars for conservation purposes in buildings with low humidity levels or that does not posses a high historical value.

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