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Air Lime Mortars with Vegetable Fat Addition: Characteristics and Research Needs

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Abstract Although history reveals that air lime mortars with added vegetable fat (ALVF) were used very often in the past, little knowledge about them survives to modern times. Little is known about the influence of fat addition on the mortars' durability, and some details about their manufacture and application are completely unknown. Even less is understood about the mechanisms that explain the behavior of ALVF-based mortars that also contain pozzolans. This paper reviews current knowledge about the characteristics of ALVF-based mortars in order to highlight questions that must be addressed in future research.

1 Introduction

The use of ALVF-based mortars dates back to the Roman Empire, as noted by Vitruvius [1, 2]. Portuguese architect Quirino da Fonseca published a book in the early 1990s, in which he mentioned the addition of small amounts of vegetable oil during the lime slaking process [3, 4]. He also mentioned that these materials were used by historic Portuguese masons to build fortresses, including Nossa Senhora da Conceição on Gerum island, Ormuz, in the Persian Gulf (Iran). The construction of that fortress took place in 1507 and comprised eight outer towers surrounding a central one.

In 1873, more than three hundred years after the construction of Nossa Senhora da Conceição, A.W. Stiffe, a lieutenant of the British navy, visited the interior of the fortress (Fig. 1) and described its conservation status for the Geographical Magazine. He stated that "*The mortar used was excellent, and much more durable than the stones* " [5]. This account provides a good impression of the durability of those mortars, primarily because they were placed in harsh conditions near the sea.

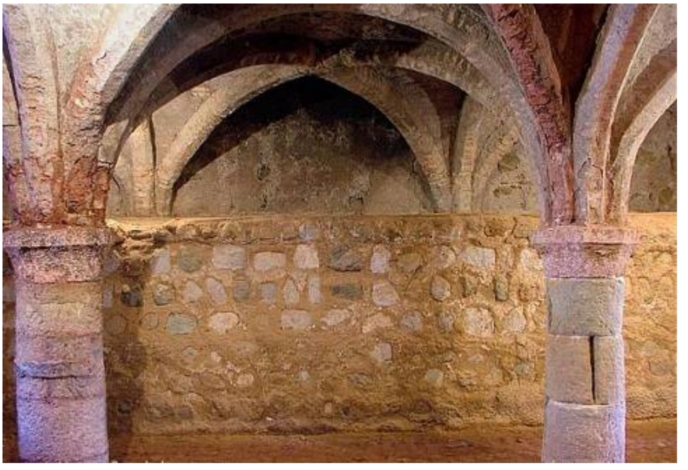

Fig. 1 Portuguese fortress of "Nossa Senhora da Conceição" (Persian Gulf, Iran)

In 1570, the Venetian architect Palladio, mentioned the use of linseed and nut oils to obtain waterproof lime-pozzolan mortars [6]. Manuel Azevedo Fortes, in his book "The Portuguese Engineer" published in 1729, mentioned the use of olive oil in the air lime slaking process, recommending that the olive oil should be added to lime while it is in a boiling state [4].

2 The Present

Since the middle of the 1990s a Portuguese manufacturer has sold an air lime called "D. Fradique" that is produced with the addition of olive oil waste. The production of this air lime started after the Portuguese architect Quirino da Fonseca was chosen to be in charge of the conservation works of the walls of the Castle S.Jorge in Lisbon. He then tried to reproduce the characteristics of ancient ALVF-based mortars. The firm responsible for the production of air lime uses a quasi-industrial process. After the calcination of limestone rocks they are ground in a jaw mill. The air lime is slaked by hand and the olive oil wastes are added at this time. Quirino da Fonseca recommends the following proportions to the manufacture of this air lime: 25kg of lime; 1.5kg of olive oil wastes; 10l of water. Of course the manufacturer uses other proportions that are under commercial secrecy [4]. The hardening of this air lime occurs by a carbonation mechanism, as with other air limes.

Table 1 Comparison between "D.Fradique" air lime mortars versus current air lime mortars [3]

Tests					Commercial air lime based mortars slaked with olive oil waste	Current air lime mortars
Mortar paste	Density (Kg/m^3)				1745	1999
Mortar paste	Workability (flow table %)				81	77
Hardened mortar	Apparent density (Kg/m^3)				1614	1783
Hardened mortar	Watertight capacity	Vapor permeability	Vapor permeability coefficient (ng/m.s.Pa)		29.1	26.46
Hardened mortar	Watertight capacity	Vapor permeability	Difussion layer thickness equivalent to a 1cm render		0.12	0.14
Hardened mortar	Watertight capacity	Cappillarity coefficient ($Kg/m^2.h^{0,5}$)			0.13	10.2
Hardened mortar	Watertight capacity	a) Moistute test	1cm-1/2h	b) Wetting delay (h)	0	271.6
Hardened mortar	Watertight capacity	a) Moistute test	1cm-1/2h	d) Wetting intensity ($mV.hx10^3$)	0	60.21
Hardened mortar	Watertight capacity	a) Moistute test	5cm-28h	Wetting delay (h)	38.69	146.02
Hardened mortar	Watertight capacity	a) Moistute test	5cm-28h	Wetting intensity ($mV.hx10^3$)	0.97	38.31
Hardened mortar	Fungal development resistance				Medium	High

a) Moisture test: Measurement of electric current inside mortar layers. Mortar specimens possess 1.5cm thickness and are applied over a fiber-cement sheet. Then mortar specimens are submitted to a water film.

b) Wetting delay: Time between the moment that mortar specimens contact the water film and the beginning of water detection by moisture apparatus, which happens when electric current decreases to 95%.

c) Test time: Time between electric current decrease due to specimen wetting and the moment that electric current reaches 95% again.

d) Wetting intensity. Area below the curve of electric current, mV, with time.

According to some authors [4] the mortars made with commercial air lime slaked with olive oil wastes have several advantages over current air lime-based mortars (Table 1):

- Higher workability;
- Higher water vapor permeability
- Lower water absorption by capillarity
- Higher waterproofing behavior
- Higher resistance to fungal development

In a study of the behavior of several mortars used as renders for rock masonry, Sá [4] found that although mortars based on commercial air lime slaked with olive oil wastes are more waterproof than other mortars, they also have low impact resistance and low adhesion resistance (Table 2).

Table 2 Comparison of mortars properties [4]

Test	Mortars according to the binder used			
	Commercial air lime slaked with olive oil wastes (1:3)	Air lime	Hydraulic lime (1:3)	Air lime and cement (0.5:0.5:3)
Flexural resistance-Rt (MPa)	0.22	0.21	0.20	0.47
Compression resistance-Rc (MPa)	0.65	0.44	1.56	2.67
Rt/Rc	0.34	0.48	0.13	0.17
Impact resistance with a sphere Ø impact (mm)	18.6	20.7	12.6	11.8
Adhesion resistance (MPa)	0.048	0.056	0.057	0.129
Water absorption by Carsten tubes-10 min (cm^3)	0.1	36.1	2.1	3.1
Water absorption by capillarity (water mass after 5min - g)	2.22	23.92	9.66	8.57

The presence of the vegetable oil creates a less porous structure, which delays the carbonation process while also delaying the resistance development. Veiga [7] mentioned that the use of renders based on this particular type of lime may lead to some failures that can be explained by the carbonation delaying effect mentioned above.

Vegetable oils are composed of glycerides (esters of glycerol and fatty acids), which are not chemically stable in highly alkaline environments like cement mortar. The carboxyl group of the fatty acid anion will coordinate strongly with calcium oxide in such environments [8].

Other authors [9] study the water-resistance of hydraulic binders mixed with vegetable oil fat. These authors mention that using just 0.5% vegetable oil by cement weight allows good mortar performance and that rapeseed oil is one of the cheapest and most effective oils, more so even than olive oil.

The majority of additives used to enhance waterproofing of concrete and mortars (resins and polymers) come from the oil industry [10]. Therefore, sustainable development requires that new environmental friendly additives must be investigated. It is not without irony that the past can teach us something in this area.

Holz [11] mentioned that one of the disadvantages of the use of mortar renders based on vegetable oils is that UV lights can oxidize the fatty acids, reducing the waterproofing ability near the surface. Cechova et al. [12] study mortars with 1% of linseed oil addition. These authors state that oil addition increases both flexural and compressive strength of hydraulic mortars, but for air lime mortars an inverse behavior was observed. Both mortars demonstrate a decrease in water absorption, but this effect is more profound for air lime mortars, for which water absorption is ten times lower.

More recent investigations [13] confirm that oil addition delays setting time because it slows down the penetration of water molecules to the grains of binder. Further, mortar performance is dependent on the quantity of oil used. The use of 1% linseed oil improves mortar strength, but when 3% is used air lime mortars exhibit a strength reduction. Results also show that oil addition improves resistance to salt and freeze-thaw cycles for both percentages [13].

3 Research Needs

Current knowledge about air lime mortars containing vegetable fat is an area with many gaps to be filled. It is important to know how the slaking process influences the properties and the durability of mortars. Although oil addition increases the mortar's resistance to water, that must be controlled in order to avoid water vapour reduction. The mechanisms for lime-pozzolan mortars with vegetable oil also deserve research efforts. It is important to determine whether the addition of oil during lime production oil influences the carbonation process, the pozzolanic reaction, or the formation of hydraulic phases. Different vegetable oils must be studied, in particular rapeseed soil, because it is a low cost additive in Portugal.

4 Conclusions

Air lime mortars with vegetable fat addition have been used since ancient times, apparently with very good results. The interest in these mortars has been revived for historic reasons but also for purposes of sustainability. The use of air lime mortars with vegetable fat addition still requires further investigation.

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