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Effects of lime mortars on masonry construction

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Abstract

The present investigation is an effort to demonstrate that lime gives such properties and has such an active construction in mortars so it can be considered as an irreplaceable constituent of them. There is a description of the lime uses and its contribution to masonry strength. A discussion is also included on the effect of lime on the durability of mortars, the autogeneous healing and the efflorescence of masonry.

1 Introduction

Masonry is a composite of units (bricks, blocks or stones) jointed together by mortar. So three factors affect the quality of plain masonry. The quality of the units, the quality of the mortar and the quality of the workmanship in putting them together[1]. Typically therefore emphasis has been placed in codes and standards on the properties and variability of the component materials, the view being that good masonry construction will results from a combination of good units and consistent, compatible mortar [2], [3], [4].

In the present work, the effect of lime mortar on masonry properties will be discussed. Lime mortars have been used since the early Egyptians, Greeks and Romans. Thousands of years before the role of lime become important and lime was considered as in irreplaceable mortar constituent to provide some basic properties to mortars.

Today in Greece, the 80-85% of lime uses it is destinated for structural uses while the corresponding percentage for the other countries is 10-15%. The most common building use of lime is in its hydrated form that is burned air calcium lime slaked with water. The

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process involved could be expressed in the form of the following chemical reaction :

$$CaO + H_2O \rightarrow Ca(OH)_2$$

The product is characterised as a hydrogel mass with plastic paste properties. These properties are very important for its workability and work carrying capacity. It contains about 30-50% free water in addition to the normal development that is chemical absorptice. The difference in free water content determines whether is a stiff putty or a sloppy putty.

2 Lime as a mortar constituent

Mortar is the material used for bonding or jointing the masonry units together. There are thus several important functions for this constituent material to fill. The mortar must bond the units together so that the masonry as whole can resist the applied loads. The mortar must have the strength within the masonry to resist the applied compressive loads. The strength of the bond between the mortar and the units is particularly important when flexural loading such that due to earthquake is considered. The bond strength depends critically on the competition between the mortar trying to retain its water in order to set and harden, and the unit trying to suck the water out. Typically minimum suction on the parts of the unit gives low bond strength and too much suction causes the mortar to dehydrate and not to strengthened.

Bond implies more than just strength : it also refers to water tightness. Crack between mortar and unit are open invitations for water to pass through masonry. A good bond provides a watertight joint to prevent rain penetrating the masonry.

Of the numerous also factors contributing to sound masonry one can mention the durability, the workability and the plasticity. The subject of durability in mortars embraces between others the consideration of autogeneous healing, efflorescence and air content.

3 Factors affecting strength and water retentivity

"Masonry cement" is basically a mixture of ordinary Portland cement and lime. The cements (masonry, Portland, lime) are usually combined in set proportions to give mortars of different properties.

Indeed, the main reason lime is present is to improve workability and water retentivity. Pure lime mortars are very workable, giving the mason plenty of time to lay the unit just so, but they take far too long to set and harden for modern construction demands. Pure Portland cement mortars, on the other hand, lose to much water too quickly, to the units and are thus difficult for a mason to work. Also the mortar may well no hydrate with a consequent lack of proper strength gain. Although this type of mortar was extremely hard and high in compression strength it was rigid and very brittle. The above mentioned observations influenced a change in mortar proportioning and a reintroduction of "low"

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and "high strength mortars" according to two extremes of high cement or high lime content. Different proportions are used to meet different demands [5].

Three volume proportions of Greek typical mortars are provided in Figure 1, together with the average compressive strength measured in the laboratory.

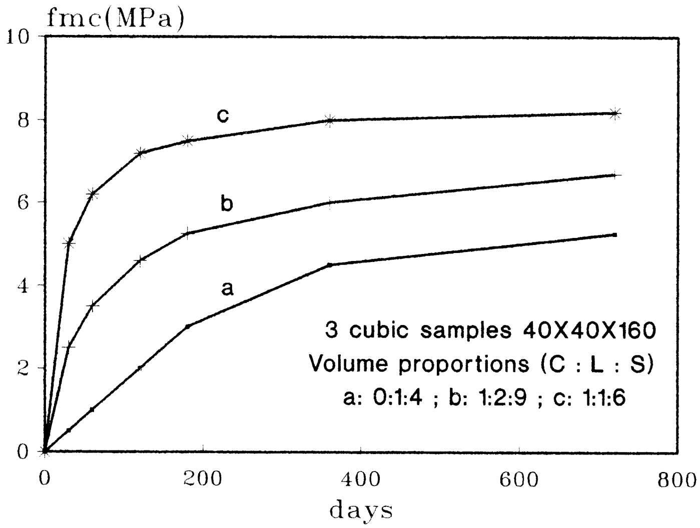

Figure 1. Range of mortar compressive strength versus time for three common Greek volume proportions.

As may be seen, increasing the amount of Portland cement, relative to lime gives mortars of higher strength named "strong mortars" (Figure 2). Strong mortars tend to produce masonry of almost linear (brittle) behaviour, whereas the weaker mortars tend to produce masonry with a behaviour more akin to concrete : it is often possible to observe strain softening and a post-peak descending branch. High lime content mortars tend to gain strength over much longer period than low lime content ones and also tend to give better resistance to rain penetration. The low strength mortars are thus preferable for any situation in which the masonry is not highly stressed.

But it must mentioned here that there is no standard type or composition of mortar in Greece. There is a wide range of mortar types. Some masons even add hydrated lime to their masonry cements. Also the same contractor that uses lime-cement mortars frequently adjusts his proportion of lime to cement to meet such variables in job conditions as temperature, type of masonry unit employed, quality of sand, load -

bearing requirements of wall, earthquake conditions and above or below grade. So in chilly weather or where sudden drops in temperature are imminent the cement content of mortars must frequently be increased to develop high early strength - cements sets much faster than lime. Thus, the mortar mix might be changed from a 1:1:6 to 1:1/2:4 1/2 (cement, lime and sand) or from a 1:2:9 to 1:1:6. Conversely in hot weather condition, as in Southern Greece, contractors frequently adjust their mix by increasing the lime content from 1:1:6 to 1:2:9 or 1:2:9 to 1:3:12. This is done to reduce the chance of cement setting too fast and to increase the water retentivity of the mortar so as to resist the increasingly high rate of suction imposed by hot, absorptive masonry unit. However, in earthquake areas of Greece, masonry is usually reinforced with steel to provide a monolithic strength and present the possibility of catastrophic cracking from earth tremors. Since maximum strength is desired the cement mortar must be gauged with only 10-25% lime by volume to provide a little plasticity.

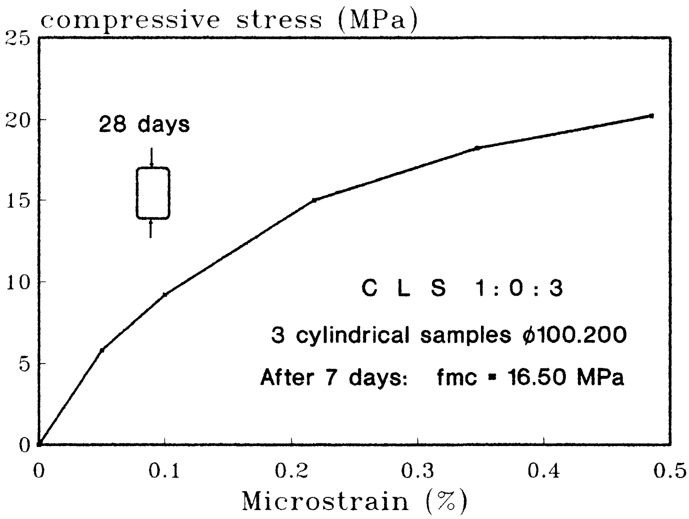

Figure 2. Mean compressive stress for masonry with a strong mortar.

Water retentivity can be measured by determining the flow of the mortar on a standard flow table. The mortar is then subjected to some standard suction and the flow measurement repeated. The final flow is expected as a percentage of the original flow and called retentivity. Water retention of samples measured in the Laboratory shows a variety of results depicted in Figure 3. From that figure is concluded that a high strength mortar contributes towards poorer workability and lower water retentivity all of which are undesirable in a well balanced mortar. Conversely lime provide the desirable characteristics of workability and high water retentivity.

4 Factors affecting bond and flexural bond strength

It is well known that units and mortar which are strongly bonded together will resist rain penetration better than a combination which has cracks along the interface of the two components. Many properties of both mortars and units have been studied in respect of their effects on bond strength [6]. In mortar water retentivity is thought to be most important. Generally a mortar with high retentivity will gives a watertight joint with low absorbency units. When the suction from the units is well balanced by the water retentivity of the mortar, good bond will generally result. Bond appears to be achieved through adhesion of mortar constituents to those of the unit by secondary polar bonding, and by mechanical keying of the relatively rough unit surface with crystals from the mortar constituent growing into the surface pits and capillaries of the unit.

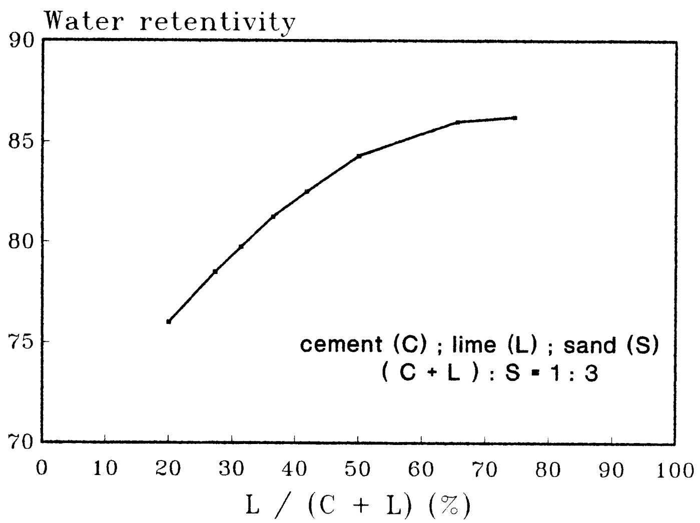

Figure 3. Relation between mortar composition and water retentivity.

Typically tests on the effect of the various parameters associated with mortars and units on the bond strength between the two have involved varying one parameter while keeping others constant. Although, on site, many of the parameters would be varying simultaneously and one can reveal some unexpected effects [7] generally all the studies showing increased bond strengths with more lime in mortars.

5 Factors affecting durability of masonry

The major factors affecting durability of masonry are the durability of components, the workmanship, the detailing and maintenance of the masonry. The majority of durability problems arise from the presence of moisture [8]. In the case of high lime mortars rainwater is absorbed into the mortar dissolving minute amounts of uncombined lime (calcium hydroxide) which penetrates into the cracks or voids and soon carbonates and precipitates, thereby filling or plugging the interstices. This phenomenon cannot occurs with high cement mortars because they have much less lime for dissolution. This is a self healing aspect of lime in mortar which helps masonry involved increased moisture resistance.

Efflorescence is another problem. Unsightly white staws appear on the masonry as salt leach out the mortar or are soaked up from the ground. The positive role of lime in confronting the efflorescence of masonry is attributes first to the impeding of water penetration which is from the causes of appearance of this phenomenon but mainly to its extremely low content in soluble salts as well as in sulphur which is much lower than cement on an average. Under high moisture load the qualitative determination of harmful and efflorescent salts in the binding materials (lime, sand and bricks) alone are not always adequate for the evaluation of actual efflorescent behaviour. However, their permissible limits, according to standards, have proved very valuable in building practice under normal moisture load. The efflorescent behaviour is depending on the mortar/cement quality and the constant or alternating environmental influences. In addition the use of high lime content mortar such as a proportion 1:2:9 (cement, lime and sand respectively by volume) containing much more carbonate with no impurities than high cement mortar much of which is argillaceous and earthy. So limes on an average contain less efflorescence potential than cement.

Jointing can have a major influence on masonry durability ; weather joints are best because they sed the water out of the joints and down the face of masonry. Detailing is important in order to avoid water collecting on parts of masonry. Of more recent structures, those built with thin joints seem less prone to serviceability problems than others.

6 Factors affecting workability and plasticity

Of mortar properties, those dealing with workability and plasticity have been studied most. Factors related to these two significant features

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required for a good mortar can be concentrated to the size and shape of its crystals.

To fulfil its prime purpose, the results of various investigations by several researchers lead to the conclusion that lime hydrate crystals and special dolomitic which are smaller than calcium have a unique shape most suitable for a plasticizing agent. In a lime mortar the individual lime crystals spread extensively throughout and around the larger particles of Portland cements and aggregates. Surface are measurements confirm the small particles size of lime, so it must be noticed the superiority of lime surface area over the other mortar components.

As is investigated by Hedin [8] lubrication is very important for the movement of particles in a mortar. It is known that each crystal will be surrounded by a layer of water one molecule thick. As the crystals spread around the sand and Portland cement particles they provide the necessary lubrication for increased workability.

7 Conclusions.

The properties of masonry can vary widely given the choices of unit and mortar. A comparison of various types of mortar as relating to the properties of the component material alone showing that the high lime mortar is considered to give very high water retentivity, low compression and tensile strength, very high extend of bond and very high bond durability. In contrast high cement mortar gives low water retention, high compression strength, low extend of bond and moderate bond durability. So it is apparent that both lime and Portland cement are indispensable in a well balanced all purpose mortar. Lime and Portland cement are therefore mixed in order to compromise the needs of workability and water retentivity at the masonry construction stage, with the desire for rapid setting, hardening and strength gain for structural load bearing.

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