Critical Review on Lime Mortar

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Abstract- **In the 21st century, expansion of cities as well as sate construction process increase rapidly and cement mortar is most frequently used in building construction. During production of cement, huge amount of energy is needed and about 8 % of CO_2 is released to atmosphere during cement production. This paper represent Lime is the most sustainable binder due to lower production energy needs, lower CO_2 emission during production and CO_2 absorption by carbonation. In recent years various kinds of mortar were developed such high performance of mortar. This paper represented the method of lime mortar and past work carried out on lime mortar. A reviewed literature also shows the influence of Metakaolin, animal glue, Casein, nopal as powder (polysaccharide), nopal as mucilage olive oil, Linseed Oil and Herbs on lime mortar.**

Keywords: Lime mortar, Metakaolin, Linseed Oil, Mechanical Properties, CO_2, Animal glue, Casein

I. Introduction

Hydraulic mortars have already been used from Greek and Roman periods. Air-hardening lime was mixed with pozzolanas (natural or artificial) to obtain a mortar or concrete that could harden under water. Only from the end of the eighteenth century and the beginning of the nineteenth century on, a major change in binder type used for mortars is observed. Until then, air-hardening lime was the most popular binder used in the construction of buildings. From the end of the eighteenth century on, people began to experiment with the hydraulicity of binders. Smeaton discovered in 1756 the hydraulic properties of products obtained by burning limestones contaminated by clay, and Vicat proved in 1812 that the hydraulicity of these binders was the result of the simultaneous burning of limestone and clay. In 1824, J. Aspin discovered the first cement, and from 1835 (L.C. Johnson), Portland cement becomes the dominant binder in the building industry [1]. Natural hydraulic lime was used mostly during the nineteenth century and was the precursor of Portland cement. Belgium was well known for the export of natural hydraulic lime produced in the region of Tournai (southwest Belgium) during the nineteenth century [2]. From the end of the nineteenth century on, Portland cement and its derivatives became the major binding material in construction, mostly due to the standardization of its production. All the properties of specific cements are set, thus providing specific types of cement for specific purposes. During the production of air-hardening lime and natural hydraulic lime, parameters were not standardized, resulting in large variations in properties of the lime.

The main difference in the production of natural hydraulic lime and cement is the burning temperature. Natural hydraulic lime is produced from limestones containing a certain amount of clay impurities below the sintering temperature. When limestones containing silica and clay are burnt, the clay decomposes at temperatures between 400°C and 600°C and combines at 950±1250°C with some of the lime, forming silicates and aluminates. The top end of burning temperatures for natural hydraulic limes is 1250°C; sintering occurs at higher temperatures. Cement is produced from mixtures of limestone and clay burnt at temperatures exceeding 1400°C when sintering occurs and a clinker is formed. The composition of the hydraulic phases thus differs: C_2S is the major hydraulic phase in natural hydraulic lime, with some C3S due to local ``hot spots" in the lime kiln, while C_3S is the major phase in cement. Gehlenite (C_2AS), which is formed at temperatures below 1200°C, can still be observed in natural hydraulic lime [3] but not in the final product in the cement production. In natural hydraulic lime, a certain amount of free CaO remains that will convert to free Ca(OH)2 after slaking. In cement, all the CaO is combined in Ca silicates (mainly C3S) and Ca aluminates (ferrites) during sintering. The study of the production and characterization of natural hydraulic lime and hydraulic lime mortars is rather limited. Nevertheless, these mortars can be very important for the conservation of historic buildings where conservators mostly do not want to use cement. Several damage cases are known to have been caused by the use of cement in the conservation of historic buildings because cement is too hard, rigid and impermeable.

II. Mortar:

A mortar can be defined as a mixture of one or more inorganic or organic binders, mostly fine aggregates, water and sometimes additives and/or admixtures in the proportions necessary to give to the mixture proper workability in the fresh state and adequate physical and mechanical properties, outward aspect, durability etc, in the hardened state [7].

III. Lime Mortar:

It is tradition to used sand, water and lime into mixture of lime mortar. Basically fat lime is a material which used for the binding material and it would be added when making of mortar should start. For foundation work hydraulic lime is added. Lime to sand ratio is set around 1:2. In construction various types of lime is available as a construction material but as per IS:712-1984 lime should be classified as Class A to class F which are explain below table 1.

Table 1 classification of lime as per IS:712-1984

Class	Purpose
A	Eminently hydraulic lime used for structural purposes.
B	Semi-hydraulic lime used for masonry mortars, lime concrete and Plaster Undercoat.
C	Fat lime used for finishing coat in plastering, white washing, Composite Mortars etc., and with addition of pozzolanic materials for Masonry mortar.
D	Magnesium/dolomitic lime used for finishing coat in plastering, etc.
E	Kankar lime used for masonry mortars.
F	Siliceous dolomitic lime used for undercoat and finishing coat of Plaster.

III. SCOPE

The preliminary aim of this paper is to study the work done on lime mortar as a historical construction material.

III. REVIEW OF LITERATURE

[1] K. Callebauta, J. Elsenb, K. Van Balenc, W.Viaenea (2001) investigate the characterization of nineteenth century hydraulic restoration mortars used in the Saint Michael's Church in Leuven (Belgium). The mortars were used as restoration mortars for weathered mortar joints. A historical study of old works descriptions and mineralogical, petro graphical and chemical analyses have been used to illustrate these hydraulic mortars. The different hydraulic phases are identified using petro graphical analysis, X-ray diffraction analysis (XRD), scanning electron microscopy (SEM) equipped with an energy dispersive X-ray spectrometer (EDX) and chemical analyses. Based on the presence of gehlenite (C_2AS), the dominance of C_2S, the large amounts of portlandite, the chemical analyses and on the historical sources, these hydraulic mortars are characterized as natural hydraulic lime mortars [4].

[2] Koenraad Van Balen (2003) This paper aims to clarify different ways to prepare lime and to explain in which way this preparation influenced the use lime over time. The Understanding of the lime cycle and the hardening Lime and hydraulic lime over time is the subject of this contribution. Recent research has contributed to a Better understanding and therefor this information will be used to update information that, although known to some, was not available to a wider scientific Audience. Burning, slaking and carbonation are the major steps in the lime-cycle leading to the air-hardening lime Mortar. Lime mortar has been used since antiquity. Its preparation and its use have been understood by generations although during time schemes understanding have changed. Looking today at historical perceptions the lime cycle helps to identify the proper understanding certain material properties and the use lime mortar in the past [5].

[3] L.Ventola, M. Vendrell, P. Giraldez, and L. Merino (2011) experimental work focus on several mixtures of lime, sand (used as an aggregate) and water with different organic components (polysaccharides, proteins and fatty acids) were prepared following traditional methods used in South America and Mexico. During research work six types of non-hydraulic lime mortars were tested which are shown in table 2. During these experimental work water and weight loss, mechanical resistance (compressive strength), carbonation, Mineralogical analysis (XRD) and Texture analysis (SEM) was observed [6].

Table 2 Non hydraulic lime mortar

Type	Description	Type	Description
Type 1	Lime + aggregate (river sand) + water (blank sample)	Type 4	Lime + aggregate (river sand) + water + nopal as powder (polysaccharide)
Type 2	Lime + aggregate (river sand) + water + animal glue (protein)	Type 5	Lime + aggregate (river sand) + water + nopal as mucilage (polysaccharide)
Type 3	Lime + aggregate (river sand) + water + casein (protein)	Type 6	Lime + aggregate (river sand) + water + olive oil (fatty acid)

[4] Eva Cechova (2009) Research focus the effect of linseed oil on the properties of six various lime-based mortars has been studied. Mortar mixtures were prepared in three different versions: unmodified and with 1% and 3% addition of linseed oil by the weight of binder. Parameters involved in study were effect of linseed oil addition on mortars mechanical (compressive and flexural strength, dynamic modulus of elasticity) and physical properties (open porosity, water absorption through capillarity) have been studied. Changes in pore size distribution have been investigated by means of mercury intrusion porosimetry and the effect of oil addition on mortar structure has been studied by means of scanning electron microscopy. Dispersion of oil in mortar structure was verified by observing their cross-sections under microscope with UV light, which evokes fluorescence of linseed oil. FTIR analysis of binder pastes was performed in order to observe linseed oil's possible chemical changes in mortar (formation of carboxylate salts, cross-linking of fatty acids molecules). Finally, mortars durability against salt crystallization (NaCl and Na2SO4) and freeze-thaw cycles was tested. The addition of 1% of linseed oil has proved to have positive effect on mortars´ properties. It improves mechanical characteristics and limits water absorption into mortar without affecting significantly the total open porosity or decreasing the degree of carbonation. On the other hand, the 3% addition of linseed oil is making mortar to be almost hydrophobic, but it markedly decreases mortars´ strength. However, all types of tested lime-based mortars with the oil addition showed significantly decreased water and salt solution absorption by capillary rise [7].

[5] P.Thirumalini (Gummipoondi), Dr.S.K.Sekar August (2009) researcher has review to identify the various herbs (Curd, Dal urd, Jute Fiber, Gum from Plant, Raw sugar, Straw, Glue, Jagger sugar) used in traditional construction and its role in modifying the fresh and hardened properties of lime mortar. It also helps to retrieve the traditional concept of additional of admixture to concrete. By shifting ourselves to use such eco-friendly (natural) admixtures in mortar will lead the construction industry towards sustainable expansion. They also terminate that the lack of traditional knowledge and skills has made eco friendly construction techniques and practice obsolete. The aboriginal knowledge of various plants and animal derivative used in construction industry must be retrieved and its role in improvement of properties of concrete has to be studied in detail. If traditional admixtures are used in concrete; the environmental harmful impact of use of chemical admixture can be eliminated [8].

[6] A.Moropoulou, A.Bakolas, P.Moundoulas, E.Aggelakopoulou, S.Anagnostopoulou, (2005) researcher focus on restoration mortars with analogous chemical composition of binders, aggregates and mineral additions, as they derive from the study of historic mortars, were evaluated regarding the strength development and the lime reaction, up to 15 months of curing. For this purpose six lime mortar mixtures (shown in table 3) were tested in laboratory regarding their chemical and mechanical characteristics. The obtained results show that most of them present a slow rate of chemical and mechanical evolution, with the exception of hydraulic lime mortar and mortar with lime putty–natural pozzolanic addition. The best mechanical behaviour was observed in mortars with lime powder and lime powder–artificial pozzolanic addition. These materials present also a low ratio of compressive to flexural strength (f_c/f_f). Further investigations on these materials would determine the time where their chemical and mechanical characteristics become stable. Only at that time, it would be possible to compare the compatibility characteristics of the restoration mortars with those employed in the past. Figure 1 and figure 2 represents the results of mechanical tests (compressive strength and flexural strength) at 1, 3, 9 and 15 months duration [9].

Table 3 Weight ratios of the various components used in the mortar manufacture

Mortar	Ratios per weight
NHLA (hydraulic lime Mortar)	NHL2:Aggregates(a)¼1:2.3
LPA	Lime putty:Aggregates¼1:1.5
LPoA	Lime powder:Aggregates¼1:1.8
LPMA	Lime putty:Earth of Milos:Aggregates¼1:1:2
LPCPA	Lime putty:Ceramic powder:Aggregates¼1:1:2
LPoCPA	Lime powder:Ceramic powder:Aggregates¼1:1:2

[a] Aggregates: mixed sand (0–1 mm) and crushed brick (1–6 mm).

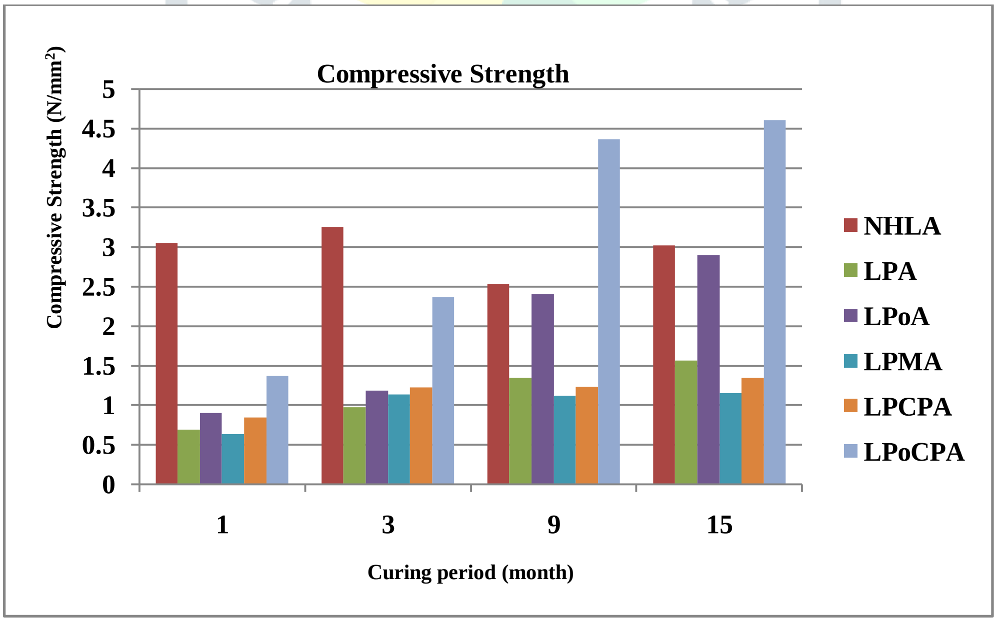

Figure 1Compressive strength of restoration mortars up to 15 months of hardening.

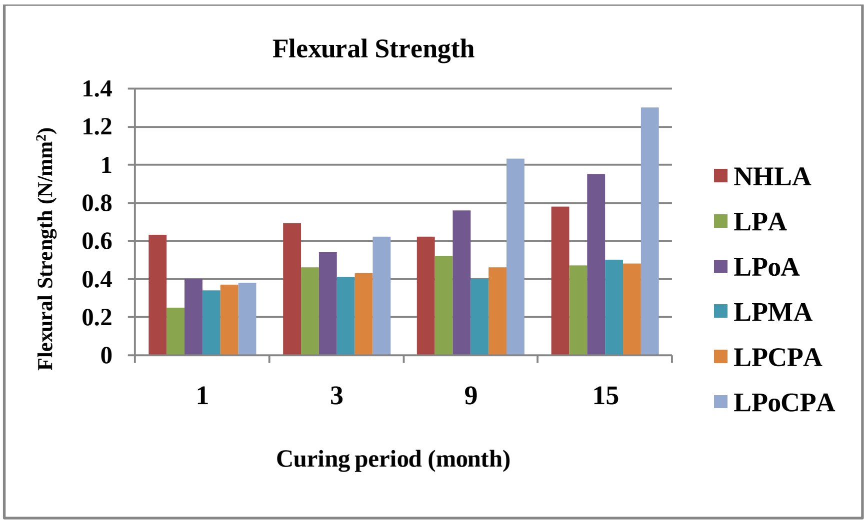

Figure 2 Flexural strength of restoration mortars up to 15 months of hardening.

[7] A. Velosa, R. Veiga. This paper represents the effect of different types of Metakaolin on lime mortar. During study two different types of Metakaolin was used and its details are shown in table 3. Table 4 shows mortar compositions (in volume) and water/dry mortar ratio (W/M) in which both binders and aggregates are considered. During experimental work compressive strength, flexural strength, elastic modulus and Capillary coefficient of different lime mortar was observed. Figure 3, figure 4 and figure 5 and figure 6 represents the results of compressive strength, flexural strength, elastic modulus and Capillary coefficient respectively [10].

Table 4 categorization of Metakaolin

Product	Color	Apparent density (kg/m^3)
K_1	White	315.0
K_2	Light orange	638.8

Table 5 Mortar composition

Product	Lime	K1	K2	Sand	W/M (% weight)
L	1	-	-	15	15
MK1	1	1	-	4	21
MK2A	1	-	1	4	15
MK2B	1	-	0.5	2.5	15

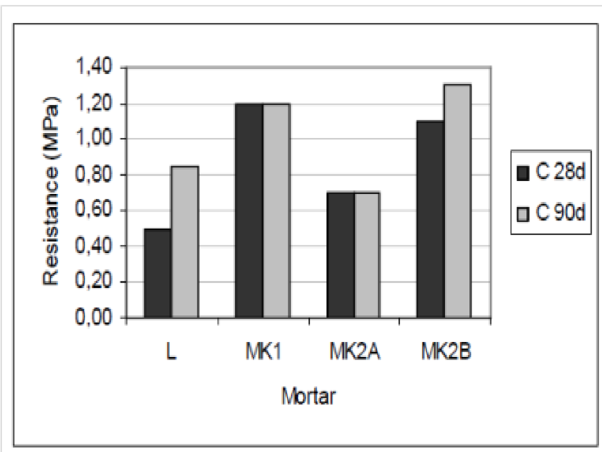

Figure 3 Compressive strength of mortars at 28 and 90 days

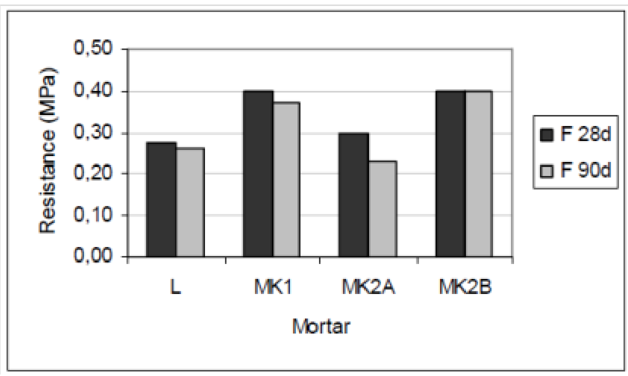

Figure 4 flexural strength of mortars at 28 and 90 days

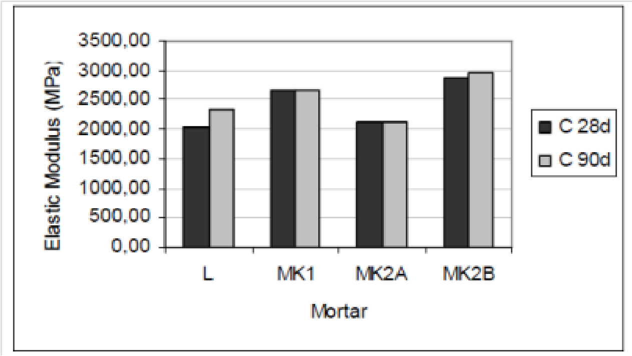

Figure 5 Elastic Modulus of mortars at 28 and 90 days

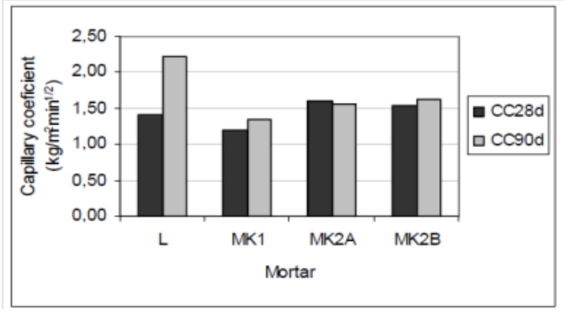

Figure 6 capillary coefficient of mortars at 28 and 90 days

[8] J.M.Khatib, E.M.Negim and E.Gjonbalaj, (2012) Parametric study for compressive strength, density and ultrasonic pulse velocity of mortar containing high volume of Metakaolin (MK) as partial substitution of cement was determined. Various mortar mixes was illustrated in the study and mortar mixes consisted of Portland cement (PC), Metakaolin (MK), water and sand. The control mix (M1) had a proportion of 1 (PC): 3 (sand) without MK. In the other mixes (M2-M6), PC was partially replaced with 10%, 20%, 30%, 40% and 50% MK (by mass) respectively. The water to binder ratio for all mixes was maintained at 0.5 and the binder consisted of PC and MK. The results indicate that the maximum strength of mortar occurs at around 20% MK. Compressive strength starts to reduce when MK goes beyond 30%MK as cement replacement. Attempts were made to link the compressive strength with ultrasonic pulse velocity [11].

[9] R. Eires, identifies lime and Metakaolin amounts, curing time and temperature as key factors affecting both the mechanical and durability properties of mortars using Metakaolin-lime mixtures. In order to improve application- specific mortar performance along mechanical, durability and bactericidal lines, the present work employs a small percentage of activators that bring about effects in terms of bactericidity, strength gain enhancement and strength improvement at long curing time. Parameter involved in study was compressive strength of lime Metakaolin mixture at 25% +75 % and 50 % + 50 % respectively. Results obtained signify that a mixture with 25% of lime and 75% of Metakaolin has a better overall performance in terms of mechanical properties. Also temperature effect on Metakaolin-Lime Mixtures was carried out. To evaluate the influence of curing temperatures on compressive strength, test specimens were molded with 75% of Metakaolin, 25% of lime and small amounts of calcium chloride (2% of lime mass). Furthermore, specimens were cured at 10º, 20º, 30º, 40º and 50ºC, with a relative humidity of 100%. Figure 7 illustrate the Compressive strength of mortars using different Metakaolin-lime contents. Figure 8 and figure 9 shows the Temperature effect on Metakaolin/lime mixtures up to 28th and 90th day [12].

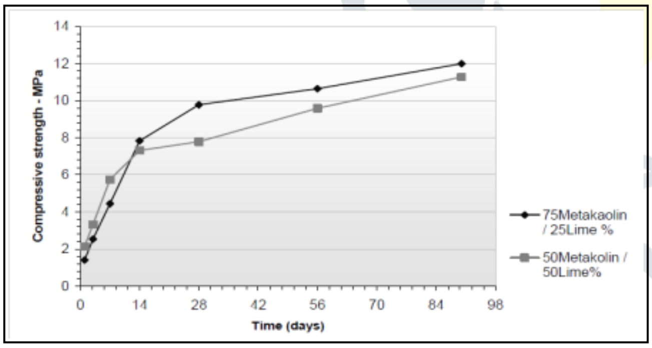

Figure 7 Compressive strength of mortars using different metakaolin-lime contents

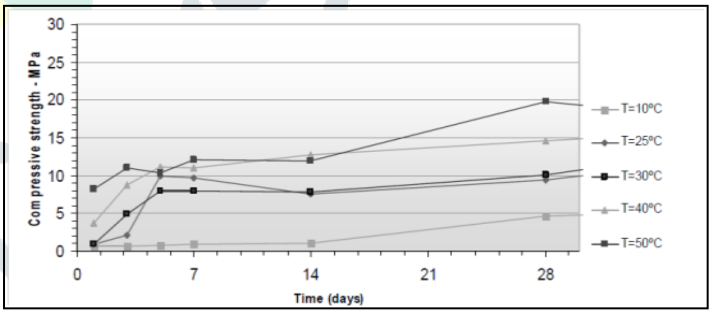

Figure 8Temperature effect on metakaolin-lime mixtures until 28 days

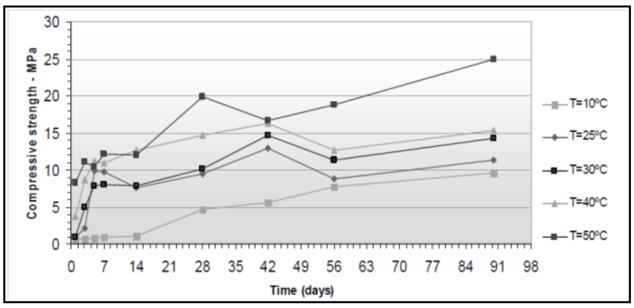

Figure 9Temperature effect on metakaolin-lime mixtures until 90 days

[10]A. Gameiro, A.Santos Silva, P. Faria, J. Grilo, T. Branco, R.Veiga, and A. Velosa(2014) This work evaluates the influence of binder: aggregate ratio on the mineralogical and mechanical properties of air lime–Metakaolin mortars. Mineralogical analysis showed that binder: aggregate ratio affects the extent of carbonation and pozzolanic reactions with curing. The pozzolanic reaction occurs mostly at lower curing times (28 days), while, at higher curing ages, carbonation reaction is mostly dominant. The exceptions are mortars with 1:1 (air:- lime) volumetric ratio with 30% and 50% MK in which the pozzolanic reaction is still dominant. The reduction in the mechanical resistance of some compositions observed from 28 to 90 days is related to the calcium aluminate hydrate instability in the presence of free lime. This instability is expected to disappear after the total consumption of free lime, either by pozzolanic or carbonation reaction [13].

V. SUMMARY OF FINDINGS

1) Tricalcium Silicate (C_3S) hardens rapidly and is largely responsible for initial set and early strength.
2) The Large proportion of free $Ca(OH)_2$ and the lower quantities of Sio_2,Al_2O_3, and Fe_2O_3 in Chemical Analyses point to the use of natural hydraulic lime for these mortars.
3) The addition of animal glue as additive increased the mechanical strength of the mortar (after 28 days).
4) The use of olive oil as additive reduce the pore system by half (in percentage of volume0 and decrease the pore size.
5) If traditional admixture is used in concrete the environmental negative impact of use of chemical admixture can be eliminated.
6) The mix design with 75% Metakaolin and 25 %lime showed better mechanical performance at curing time longer than 14 days.
7) From the various mass ratios of different materials 6:4 ratio is the optimum value of material replacement of lime with Metakaolin. Also regarding the age of mortar paste the 28days strength values have showed greater increasing trend for Metakaolin.
8) A further advantage of lime pozzolan mortars is their lower environmental impact when compared to cement mortars.
9) For each particular pozzolanic product there are specific formulations that produce better results for the application that is being considered.
10) Taking into account cracking susceptibility and durability (climate and salts) must be undertaken.

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