Study on the Performance Enhancement of Lime Mortar

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***Abstract*: The traditional lime mortar is composed of hydrated lime, sand and water. Besides these constituents it may also contain additives aiming to modify fresh mortar´s properties and/or to improve hardened mortar´s strength and durability. Already in the first civilizations various additives were used to enhance mortar´s quality, among the organic additives, Milk was one of the most common additives. From literature we know that it was used already in Roman period to increase the compressive strength, but the mechanism and the technology, e.g. effects of different dosages, are not clearly explained. There are only few works studying the effect of Milk. Knowing the function of Milk in historical mortars is important for designing anew compatible repair mortar. Moreover, Milk addition could increase the sometimes insufficient durability of lime-based mortars used for reparation and it could be a natural alternative to synthetic additives. Mortars compositions have been selected with respect to composition of historical mortars; Milk was added in 5 different concentrations of 5%, 10%, 25%, 50% and 100% to the volume of water. The addition of 10% of Milk has proved to have positive effect on mortar properties. It improves mechanical characteristics of the lime mortar. On the base of the obtained results, the addition of 10% of Milk can be taken into consideration in the design of mortars.**

1. INTRODUCTION

1.1 General

"Mortar is defined as any material used in a plastic state which can be troweled, and becomes hard in place, and which is utilized for bedding and jointing. The word "mortar" is thus used without regard to the composition of the material, but simply defining its use as a bonding material, and to distinguish it from "stuccos" and "plasters". The traditional lime mortar is composed of hydrated lime, sand and water. Besides the constituents it may also contain additives aiming to improve fresh mortar´s workability and/or to improve hardened mortars' strength and durability. The idea of improving mortar´s properties by using various additives is not new, but something which has been hardened mortars' strength and durability. The idea of improving mortar´s properties by using various additives is not new, but something which has been known already by the first civilizations. Lime-based mortars used in ancient times were sometimes of poor quality; therefore masons were employing various additives to reach desired properties. There are records that egg whites, bullock´s blood, fruit juices, keratin and casein were used in Ancient Egypt. Bitumen as an oldest known natural organic additive was used already in Mesopotamia some 4000 years ago. Variety of substances of different origin were used, such as local agro products (cereals, juices from trees, fruits and vegetables), oils and fats, milk, eggs, but also blood, dung, urine or other materials like animal hair. Although it looks that almost everything available went into mixes, there seemed to be a method behind their madness. Unfortunately there is not much information in literature about the technology of mortars preparation. This being their live hood, masons were scared to write about the things they knew and often the knowledge and experience were buried with them. On the other side we have legends of excellent durability of some historic mortars, which has been accredited just to the use of natural polymeric additives. Nowadays it is quite complicated to analyze organic additives in historical mortars since they were probably added in very small amounts which may be under the detection limit of some analytical methods. Thus it is probable that most of the information of using natural polymeric additives is based on the study of historical sources rather than on the exact material analysis of preserved monuments. Lime-based mortars by itself are sometimes not meeting the requirements of certain types of restoration interventions due to their little durability. On the other hand, more durable cement mortars are not suitable for historical monuments restoration because of their excessively high strength and sulphate content. The use of additives seems to be a way to improve properties of lime-based mortars. Since the trends in the restoration of historic monuments are to prefer the use of natural materials, Milk can be a valid alternative to the synthetic additives. Furthermore, the replacement of synthetic additives by natural ones can be an actual topic even out of restoration field, using of Milk as a so called bio-admixture. In this research Milk is has been added in different percentages, i.e. 5%, 10%, 25%, 50% and 100% to the volume of water, in order to study its influence on mortar´s properties systematically.

1.2properties of Lime Mortar

Lime mortar is not as strong in compression as OPC mortar, but both are sufficiently strong for construction of non-high- rise domestic properties. Lime mortar does not adhere as strongly to masonry as OPC. This is an advantage with softer types of masonry, where use of cement in many cases eventually results in cement pulling away some masonry material when it reaches the end of its life. The mortar is a sacrificial element which should be weaker than the bricks so it will crack before the bricks. It is less expensive to replace cracked mortar than cracked bricks. Under cracking conditions, OPC breaks, whereas lime often produces numerous micro cracks if the amount of movement

is small. These micro cracks re crystallize through the action of 'free lime' effectively self-healing the affected area. Historic buildings are frequently constructed with relatively soft masonry units (e.g. soft brick and many types of stone), and minor movement in such buildings is quite common due to the nature of the foundations. This movement breaks the weakest part of the wall, and with OPC mortar this is usually the masonry. When lime mortar is used, the lime is the weaker element, and the mortar cracks in preference to the masonry. This results in much less damage, and is relatively simple to repair. Lime mortar is more porous than cement mortars, and it wicks any dampness in the wall to the surface where it evaporates. Thus any salt content in the water crystallizes on the lime, damaging the lime and thus saving the masonry. Cement on the other hand evaporates water less than soft brick, so damp issues are liable to cause salt formation and spalling on brick surfaces and consequent disintegration of bricks. This damp evaporation ability is widely referred to as 'breathability'. Lime mortar should not be used below temperatures of 5 °C (41 °F) and takes longer to set so it should be protected from freezing for three months.

2. MATERIAL PROPERTIES

In the present study, the effect of Milk on the properties of six various lime-based mortars has been studied. Mortars composition has been selected with respect to composition of historical mortar. The effect of milk addition on mortars mechanical (compressive strength) and physical properties (Initial and final setting time, specific gravity, fineness and consistency) have been studied.

2.1 Binder Setting Time Determination

Determination of initial and final setting time of hydrated lime, hydraulic lime, mixture of hydrated lime and pozzolan in proportion 1:1, mixture of hydrated lime, pozzolan and brick dust 1:0,5:0,5, mixture of hydrated lime, pozzolan and cement 1:0,9:0,1 mixture of hydrated lime, pozzolan and cement in proportion 1:0,8:0,2 and all previous binder mixtures modified by 1% and 3% per weight addition of Milk has been determined with the help of Vicat apparatus. Firstly the standard consistence was supposed to be determined. Standard consistence is characterized by the depth of penetration of plunger into binder paste, which is filled into Vicat ring placed on a glass base-plate. Standard consistence is such a proportion of binder and water that the distance between the bottom face of the plunger and the base-plate is (6±1) mm. Setting time is determined on the Vicat apparatus equipped with a steel needle. Initial setting time is defined as the time measured from zero time (mixing binder with water) at which the distance between the needle and the base-plate is (4 ± 1) mm. Final setting time is defined as the time measured from zero time (mixing binder with water) at which needle first penetrates only 0.5 mm into the specimen. Initial setting time of lime is found to be 2 hours. Final setting time of lime is found to be 48 hours.

2.2 Determination of Specific Gravity

It is defined as the ratio of the mass of void in a given volume of sample to the mass of an equal volume of water at the same temperature. If the volume of lime includes the voids, the resulting specific gravity is called as "apparent specific gravity", it refers the volume of lime includes impermeable voids. The specific gravity most frequently and easily determine and it is based on the saturated dry condition of the aggregate because the water absorbed aggregate in the pores of the lime does not take part in the chemical reaction of the cement. Therefore it is considered as a part of the lime. This test is done to determine the specific gravity of lime by density bottle method as per IS: 2720 (Part III/Sec 1) – 1980. Specific gravity is the ratio of the weight of a given volume of solids to the weight of an equivalent volume of water.

Specific gravity of fine aggregate= 2.457

Specific gravity of hydrated lime = 2.34

2.3 Sieve Analysis of Fine Aggregate

A set of IS Sieves 10mm, 4.75mm, 2.36mm, 1.18mm, 600Micron, 300Micron, 150 Micron, 75Micron is taken cleaned the sieves by using brush and arranged one over the other in such a way that the largest sieve opening come at top placed a received at bottom. Then weighted 2kg of dry sand and put in to the top most sieves. Then closed the top most sieve with a lid. Then the whole set of sieve shaped for 15 minutes. Then found the weight of sand retained on each sieve..The fineness modulus value is calculated as 2.75

3. EXPERIMENTAL INVSETIGATION

Concrete cube of size 150 mm x 150mm x150mm has been casted for the various curing periods were 3 days, 7 days, 14 days, 21 days, 28days.These specimens has been retested to found the strength.

3.1 Compressive Stength Tests For Cement Mortar

Table 3.1 Compressive Strength Test For Cement Mortar

DAYS	COMPRESSIVE STRENGTH IN N/mm^2
3	8.16
7	15.1
14	21.43
21	28.57
28	35.7

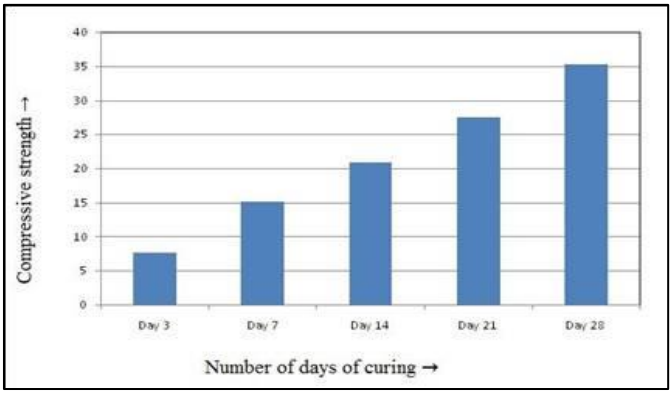

Fig.1 Compressive Strength For Cement Mortar

3.2 COMPRESSIVE STENGTH TESTS FOR LIME PUTTY

Table 3.2 Compressive Strength Test For Lime Putty

DAYS	COMPRESSIVE STRENGTH IN N/mm^2
3	4.08
7	5.1
14	5.1
21	7.14
28	8.16

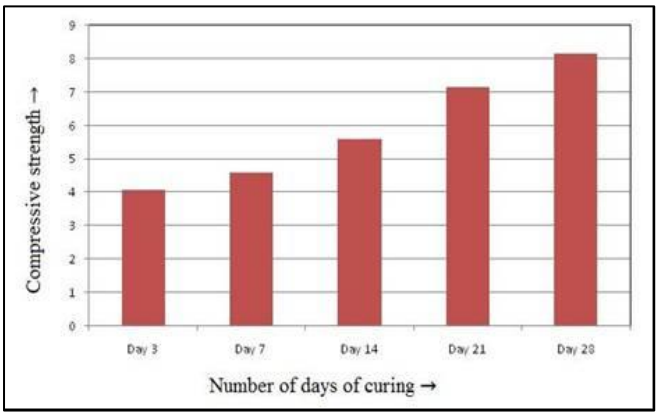

Fig.2 Compressive Strength For Lime Putty

3.3 Compressive Stength Tests For Lime Milk

Table 3.3 Compressive Strength For For Various Lime Milk

% of Milk	3days	7days	14days	21days	28days
0	4.08	4.08	6.12	6.12	7.14
5	4.08	5.1	6.12	7.14	8.16
10	4.08	5.1	6.12	7.14	9.8
25	4.08	5.1	5.1	7.14	8.16
50	4.08	4.08	5.1	6.12	7.14
100	4.08	4.08	4.0	5.1	6.12

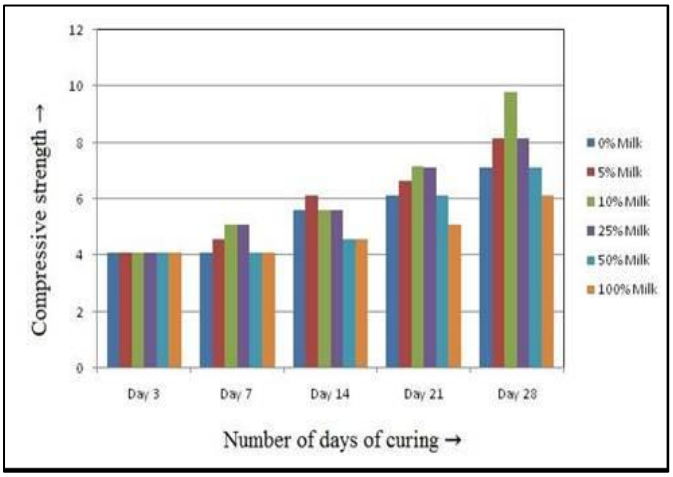

Fig.3 Compressive Strength For Lime Milk **Conclusion**

4.CONCLUSION

In the present study, the effect of Milk on the properties of lime-based mortars has been studied. Milk was added in five different concentrations of 5%, 10%, 25%, 50% and 100% to the volume of water with respect to composition of historical mortars. Addition of Milk showed to have different effect on some properties of hardened mortars depending on the amount added. Addition of 10% of Milk is improving mortars' strength, but the strength of mortars with 5%, 25%, 50% and 100% is dramatically reduced comparing to unmodified mortars. The explanation of the decreased strength of mortars with 10% Milk addition might be that Milk is limiting contact between binder phase and the grains of aggregate, but could be also related to the effect of Milk on the properties of fresh mortar. Milk seems to increase cohesion among the grains of binder and by this way increasing the consistency of a mortar. In 10% addition the effect is positive the cohesion between binder grains leads to increased consistency, which is still sufficient for required workability.

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