

COMPRESSIVE STRENGTH OF LIME MORTARS WITH SURKHI AND KANKAR AS POZZOLANS UNDER NORMAL AND HUMID CONDITIONS

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ABSTRACT: Kankar contains certain amounts of oxides of calcium and magnesium therefore it has possibility to take carbon dioxide during hardening while surkhi has no properties of lime in itself but act as a good pozzolanic material when mixed with lime. Pozzolanic materials react with lime in the presence of water at normal temperature. This study explores compressive strength of surkhi and kankar lime mortars through experimental study. The test samples were placed in normal and controlled conditions for 90 days and tested for compressive strength at intervals of 14, 28, 63 and 90 days. The research concludes that surkhi and kankar lime mortars behave differently in terms of compressive strength under normal and humid conditions but in both cases the pozzolans impart strength to lime mortar above specified range in different literature sources.

Keywords: Kankar Lime, Red Lime, Pozzolan, Fat lime, Relative Humidity, Compressive Strength.

1. INTRODUCTION

Kankar lime and Surkhi have been used as traditional pozzolanic materials for lime in the sub-continent. The use of lime became limited to the conservation and repair of the heritage buildings with the popularity of Portland cement which attains required strength in a short period of time as compared to lime mortar. Currently the use of lime mortar has again increased due to its environmental sustainability [1]. In Pakistan, there are few examples of residential, religious and recreational buildings that are being constructed with lime mortar and the most popular pozzolanic materials include kankar and surkhi.

The understanding of the material strengths and properties is essential when designing any structure. The strength of materials governs the member sizes and proportions. The strengths of cement and concrete can be predicted before the start of construction but it is difficult to predict the strength of lime mortar under various environmental conditions. [2]

Air lime (non-hydraulic lime) mortar hardens in the presence of environmental carbon dioxide and does not set under water. However, with the inclusion of pozzolanic materials, the factor that governs the strength depends on the ratio and composition of pozzolanic material used. Due to the presence of Calcium and Magnesium oxides the Kankar lime takes carbon dioxide and gains strength with the passage of time but Surkhi does not contain properties of lime therefore it has no chance to gain strength from environmental carbon dioxide. Surkhi mortar may gain strength from relative humidity as pozzolanic materials react with lime in the presence of water at normal temperature [3]. This experimental study investigates, to what extent the natural carbonation and relative humidity affects the strength of lime mortars prepared with kankar lime and surkhi. The experiments were modeled in such a way that one group of both the types of mortars was placed in laboratory (room indoor environment with usual activity) and the other group was placed in a closed chamber with higher relative humidity (95% RH).

2. MATERIALS AND METHODS

The test cubes of lime mortars for determination of compressive strength were made and standard procedures were adopted for the strength testing. The raw materials used in this study include Fat Lime (air lime), Kankar Lime and surkhi.

2.1. Fat Lime

In Pakistan ores of limestone are available in Jehlum, Kohaat, Hazara, Karachi, Sukker, Hyderabad and in areas of Baluchistan [4] as shown in figure 1. Limestone is calcined to make fat or quick lime. Figure 2 shows the lumps of quick lime as obtained from market. Quick Lime used in this research was taken from Pind Dadan Khan (Jehlum). Quick lime was tested to determine the time of slaking. It was found as quick slaking quick lime according to ASTM C5-03 [5]. So the lime was added to excess water conforming to the procedure for quick slaking lime prescribed by ASTM C5-03. It was allowed to slake for 24 hours after which it was sieved through a “malmal” cloth to filter out the impurities. This process of filtering is conventional in subcontinent since centuries. The filtered white lime water is left to mature for a minimum period of 3 months as general practice [6]. The matured lime is a thick and greasy material and can be termed as lime cream with pH ranging from 11.6 to 12.3. Lime can be used after one day of maturity but increasing the time of maturity improves the quality of lime mortar for construction purposes. Cultrone et al used 18 years matured lime for research purpose [7].

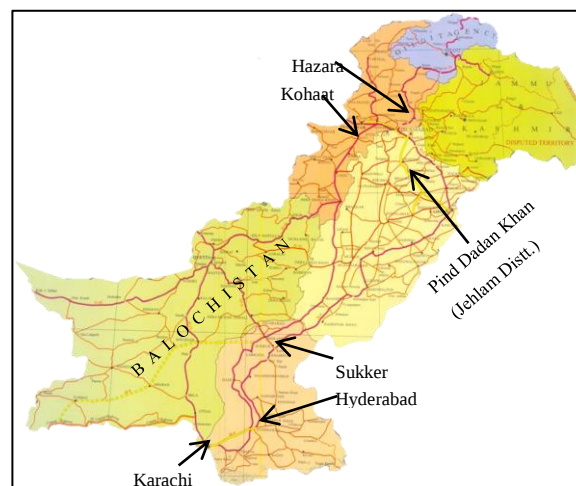


Figure 1: The ores of limestone in Pakistan.

2.2. Kankar Lime

Kankar Lime also known as Red Lime is obtained by burning kankar. Kankar is found in the nodular form under the surface of earth where the soil is damp and saline. It is argillaceous stone and is special kind of clay which is rich in iron.



Figure 4: Quick (white) Lime produced after burning of limestone

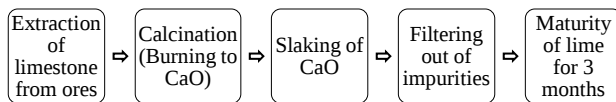


Figure 4: Flow diagram for preparation of white lime cream.

Traditionally kankar was usually taken from under the beds of rivers. In Lahore (Pakistan) it comes from Kasur. It is dug from the soil; stack piled in open area and kept till the end of the rainy season to wash out the dust. It is then taken to the kiln for calcination. The completely calcined kankar lime is then ground to fine particles and it is also termed as fine kankar lime. Semi calcined kankar lime can be used as coarse aggregate in the lime mortar. Its nodular shape is such that it has interlocking ability with other constituent materials when used in the mortar.

Kankar lime does not exhibit so much hydraulic property. It comes under the category of semi hydraulic lime as it has moderate hydraulic properties, however it can also work as a pozzolanic material when used in conjunction with white lime [8].



Figure 2: Fine ground, fully calcined kankar lime.



Figure 5: Semi calcined coarse kankar lime.

Kankar lime was taken from Kasur with the help of Punjab Department of Archeology in the burnt and prepared form (i.e. fine and coarse form) for the experimentation work in the laboratory. Figure 4 and 5 show the fine and coarse kankar lime respectively.

2.3. Surkhi (Brick Dust)

Surkhi is finely ground brick dust. It is burnt clay and is by-product of clay brick burning process. It is found on brick kiln as waste. The pozzolanic materials are added to lime to improve their strength and hydraulicity. The brick dust or surkhi also has properties of pozzolans. Pozzolans can also artificially be prepared and used in the form of brick dust [9]. In this experimental work surkhi was taken as waste from brick kilns, locally known as “keri” in Punjab. It was sieved through ASTM sieve #4. The particles passing through sieve #4 were used in lime mortar.

2.4. Preparation of samples

Two types of lime mortars were prepared using two pozzolans (kankar and surkhi). First type, kankar lime mortar (KLM) was prepared with lime cream, fine kankar lime & coarse kankar lime in the ratio of 1:1:2 by volume. Second type, surkhi lime mortar (SLM) was prepared by mixing white lime cream to surkhi; the ratios being 1:3 by volume. Punjab department of Archeology (Pakistan) has worked out these ratios for mortar used in masonry work for conservation of historic buildings.



Figure 6: Batching and mixing: K-Type (Left), S-Type (Right)

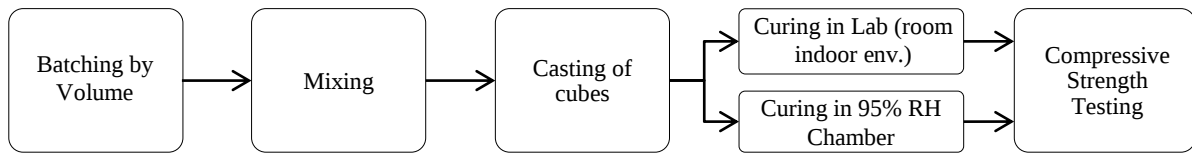


Figure 7: Flow diagram for the preparation and testing of lime mortar samples.

Lime cream was measured wet while the other constituent materials were measured dry as practiced conventionally by local people. They were mixed by hand and water was added to make a workable mortar. It was thoroughly mixed to make a paste of homogeneous colour. The mortar was moulded to 50mm cube moulds. The size of the cubes for compressive strength was kept according to ASTM C109M-02 [10]. The samples were taken out from the moulds after 24 hours of casting.

2.5. Curing environments

The lime mortar cubes were placed in two different environments. One group was placed in Lab (room indoor environment) with relative humidity varied naturally (RH-I) and other group was placed in a closed chamber with 95% relative humidity (RH95). Relative humidity was maintained in the controlled chamber by placing a water reservoir in that chamber. The size of water reservoir was determined by fixing relative humidity to 95%. Relative humidity was measured by mini weather station. The cubes were placed in these environments with maximum of 90 days and tested for compressive strength at 14, 28, 63 and 90 days.

2.6. Compressive strength testing

The samples were dried in sun for one day before testing for compressive strength. Compressive strength was tested using Kai Wei Universal Testing Machine (UTM) with 2000 KN capacity. This machine records the value of load for each 0.01 mm change in deformation. The loading rate was kept as 5 KN/min.

3. RESULTS AND DISCUSSION

Compressive strength of Surkhi Lime Mortar (SLM) at 14, 28, 63 and 90 days is 286psi, 307 psi, 325 psi and 326 psi respectively under normal indoor conditions in Lab as shown in figure 8. In first 14 days the samples gained 89% (286psi) of their 90 days compressive strength (326 psi). After completion of 28 days the compressive strength was 307 psi i.e. 96% of 90 days compressive strength. At 63 days (325 psi) samples attained nearly equal to 90 days strength. The trend of strength gain in SLM placed in lab indoor environment with time up to 90 days is shown in figure 8.

In case of Kankar Lime Mortar (KLM) the compressive strength at 14, 28, 63 and 90 days is 340 psi, 588 psi, 640 psi and 663 psi respectively under normal indoor conditions in Lab as shown in figure 8. In first 14 days the samples gained 51% (340psi) of 90 days compressive strength (663 psi). After completion of 28 days the compressive strength was 588 psi i.e. 89% of 90 days strength. At 63 days samples attained (640 psi) 97% of 90 days strength.

The comparative analysis of KLM and SLM at 14, 28, 63 and 90 days reflects that at 14 days the compressive strength of KLM is 19% more than SLM. At 28 and 63 days the difference goes to 91% and 95% respectively. The 90 days compressive strength of KLM is more than double the compressive strength of SLM. The comparison of strength gain in SLM and KLM placed in lab indoor environment with time up to 90 days is shown figure 8 in graphical and tabular form.

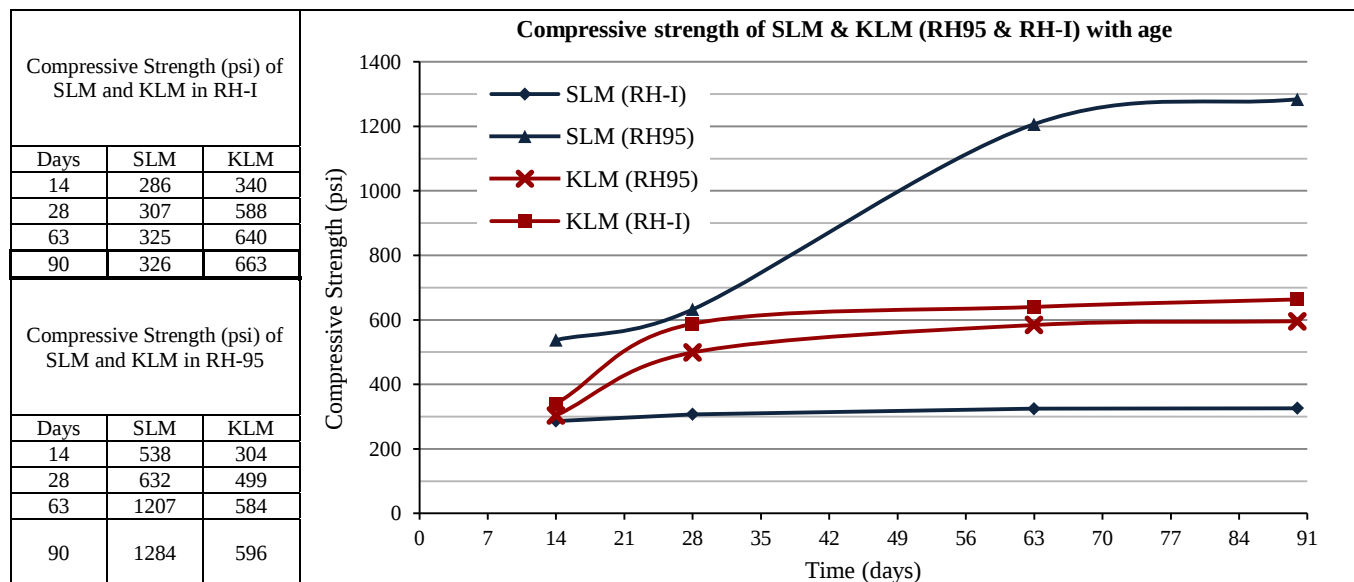


Figure 8: Comparison of Compressive strength of SLM and KLM placed in lab indoor environment and in chamber with 95% RH.

Compressive strength of Surkhi Lime Mortar (SLM) at 14, 28, 63 and 90 days is 538 psi, 632 psi, 1207 psi and 1284 psi respectively in controlled chamber with 95% relative humidity. In first 14 days the samples gained 42% (538 psi) of their 90 days compressive strength (1284 psi). After completion of 28 days the compressive strength was 632 psi i.e. 49% of 90 days compressive strength. At 63 days (1207 psi) samples attained 94% of 90 days strength. The trend of strength gain in SLM placed in chamber with 95% RH up to 90 days is shown in figure 8.

In case of Kankar Lime Mortar (KLM) the compressive strength at 14, 28, 63 and 90 days is 304 psi, 499 psi, 584 psi and 596 psi respectively in controlled chamber with 95% relative humidity as shown in figure 8. In first 14 days the samples gained 51% (304 psi) of 90 days compressive strength (596 psi). After completion of 28 days the compressive strength was 499 psi i.e. 84% of 90 days strength. At 63 days samples attained (584 psi) 98% of 90 days strength.

The comparative analysis of KLM and SLM in controlled chamber with 95% relative humidity at 14, 28, 63 and 90 days reflects that at 14 days the compressive strength of SLM is 77% more than KLM. At 28 the difference decreased to 27% but at 63 days and 90 days compressive strength of SLM is 207% and 216% of the compressive strength of KLM respectively. The comparison of strength gain in SLM and KLM placed in chamber with 95% RH with time up to 90 days is shown figure 8.

Comparing normal indoor and controlled conditions of relative humidity for KLM and SLM samples the compressive strength is attained more in case of SLM in controlled condition whereas in case of normal indoor condition KLM achieved more strength in comparison to SLM. However, the maximum strength is gained in controlled condition by SLM samples as compared to all other samples. The kankar lime samples were placed in an enclosed chamber therefore the amount of CO₂ reduced with passage of time resulting decrease in strength whereas KLM samples placed outside the chamber showed increase in strength. Figure 8 explains in detail the comparison of Compressive strength of SLM and KLM placed in lab indoor environment and in chamber of 95% RH

4. CONCLUSIONS

- Under normal conditions of indoor environment (normal RH $\approx$ 35%) the compressive strength of KLM at 14, 28, 63 and 90 days remained greater than SLM. The compressive strength of KLM at 90 days was almost double the compressive strength of SLM.
- In controlled chamber with 95% relative humidity the compressive strength of SLM remained higher than KLM samples which was 2.16 times greater at 90 days.
- The compressive strength of KLM samples placed in enclosed chamber with 95% relative humidity is lesser than those placed in normal environment. It may be due to the reduced concentration of CO₂ which has already

been consumed by lime mortar.

5. RECOMMENDATIONS

- Surkhi may be recommended for use as pozzolanic material in lime mortar for under-ground construction where drying process of mortar is slow in the absence of natural carbon dioxide.
- Kankar lime mortar is recommended for normal conditions of relative humidity.
- It is recommended that future research may be carried out to explore the effect of carbonation on compressive strength of lime mortars under controlled conditions.

ACKNOWLEDGEMENTS

The authors highly acknowledge the help of Mr. Malik Maqsood, Director, Punjab Department of Archeology, Lahore and Mr. Nasir Javed, Lecturer Department of Architectural Engineering and Design, UET, Lahore.

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