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Strength Properties of Lime Based Paste with Metakaolin & Brick dust

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Abstract: Concrete is the most commonly used material for construction. The world wide the production of one tonne of cement emits CO_2 gas which results in a lot of environmental pollution. There is need for the alternative materials which are finely ground solid that has to be used to replace the portion of cement in the concrete mixture. In this work the supplementary materials such as lime, metakaolin, brickdust were used in the 100% replacement of cement in the mortar mixture. To study the influence of pozzolanas and chemical composition of the different materials is important to know the behaviour of the alternative supplementary materials. The specimens were casted to investigate the strength properties of lime-based pastes without any aggregates. In our work nine different sets of pastes with additions of metakaolin and brick dust were used to study the mechanical properties of the mortar. The different combination of mortar paste has casted and cured in water for 28 days curing period. To study the chemical composition of the materials XRD analysis is done for lime, brick dust and metakaolin samples. To study the mechanical properties of the mortar the compressive strength and tensile strength test has been studied. The specimens were casted in nine different combination that includes 90,80,70,60 percent of lime with 10,20,30,40 percent of metakaolin similarly with 90,80,70,60 percent of lime with 10,20,30,40 percent of brick dust has used. The study revealed that based on 9 different combinations the strength increases for the lime based metakaolin paste with 60 percent lime with 40 percent metakaolin at 28 days curing period.
Keywords: Lime, Brick dust, Metakaolin,Compressive strength and Tensile strength.

Introduction

The pozzolanic materials especially metakaolin were widely used because of its many applications in the construction industries. It also develops high early strength and improves the long term strength and durability characteristics in the concrete. The usage of this material will alter the pore structure in mortar and concrete(1). The effect of variation in strength properties by using pozzolanic materials such as flyash and metakaolin with the replacement level up to 40 to 50% were tried and statistical models has been developed by (2). The use of metakaolin in concrete enhances the compressive strength with the optimum level of replacement was reported as 7.5%. The results shows that there is a increase in compressive strength by 14.2% and tensile strength by 7.9% and flexural strength by 9.3% respectively(3). The effect of metakaolin on strength and workability of concrete is done experimentally which shows that use of metakaolin decreases the workability and the slump value gets lowered than that of the normal concrete. The usage of high range water reducing chemical admixtures are used to improve its workability(4). He (5) founded out the suitability of silica fume and metakaolin combination in concrete. He arrived the optimum dosage of silica fume and metakaolin were found to be 6% and 15% by weight. The specimens were casted three different age of concrete out of which the 28^{th} day compressive strength increased the with the metakaolin content for all the possible variations of silica fume.

Experimental Investigations

Materials used

Lime

Hydrated lime is white in colour. It is a fine powder with free flowing, free from all grits and impurities with a CaO content of about > 92%. It is supplied by Sigma minerals Ltd., having a size of <3mm. The specific gravity of lime powder is 2.23. In the present work lime used is 100% 90%, 80%, 70% and 60% respectively.

Metakaolin

It is one of the highly reactive materials which can be manufactured from kaolin clay under high temperature. Metakaolin is a dehydroxylated pozzolano material in the form of the clay which is rich in kaolinite mineral. It is white in colour with size of the particle is less than 3µm. The specific gravity of metakaolin is 2.5. In this work metakaolin is replaced with lime by 10%, 20%, 30% and 40% respectively.

Brick dust

Bricks which are rich in calcium and silicate were used, it has been crushed and sieved. Brick dust passes through 2.36 mm sieve and material retained in 300 µ were used for the study. The specific gravity of brick dust is 2.63. In this work brick dust is replaced with lime by 10%, 20%, 30% and 40% respectively.

The chemical composition of the mortar materials used for the present study is given in Table 1.

Table 1 Chemical composition of mortar materials

Description	Lime (%)	Metakaolin (%)	Brick Dust (%)
CaO	87	55	1.23
SiO_2	1.3	51	55.23
Fe_2O_3	15.14	15.14	8.02
K_2O	7.37	4.37	7.37
Al_2O_3	6.70	20	30.00
SO_3	3.75	3.75	3.75
MgO	1.6	1.6	5.03
P_2O_5	2.41	2.41	2.41
Cl	1.85	1.85	1.85
TiO_2	0.58	0.58	1.02
Na_2O	0.42	0.42	0.42
ZrO_2	0.19	0.19	1.03
MnO	0.14	0.14	0.14
SrO	0.13	0.13	0.13
BaO	0.12	0.12	0.12
ZnO	0.05	0.05	1.05
$CaOCO_2$	1.06	1.06	1.06

Methodology

Mix proportions

Nine different mix proportions are adopted by using Lime, Metakaolin and brick dust. The water to mortar paste ratio varies from 0.30 to 0.5. The compressive strength and tensile strength results were compared with 100% lime mortar paste. The different mix proportions used in the study are given in Table 2.

Table 2. Mix proportions of mortar materials

Mix	Lime (%)	Metakaolin (%)	Brick Dust (%)	Water/Mortar paste
L	100	-	-	0.30
M1	90	10	-	0.37
M2	80	20	-	0.42
M3	70	30	-	0.46
M4	60	40	-	0.50
B1	90	-	10	0.35
B2	80	-	20	0.37
B3	70	-	30	0.38
B4	60	-	40	0.40

Casting and curing of mortar paste specimens

The different mix proportions were casted into cubes and cylinders to determine the compressive strength and tensile strength of mortar specimens. The size of the cubes is used in the present study was 100 mm x 100 mm x 100 mm. The size of the cylinder is taken as diameter to height ratio as 1:2. The cylinders were casted to the size of about 100 mm diameter and 200 mm height respectively. The lime and metakaolin mortar paste (M1 to M4) was prepared in the mass ratio of 9:1, 8:2, 7:3, and 6:4 respectively. Similarly lime and brick dust mortar paste (B1 to B4) is prepared in the mass ratio of 9:1, 8:2, 7:3 and 6:4 respectively. The required quantities of proportions of various mixes are shown in Table 2. The required quantity of water was added to the different mix variations based on the water to mortar paste ratio which are shown in Table 2. The dry materials such as lime and metakaolin are mixed thoroughly and then estimated quantity of water is added to the dry mixture and well mixed for about 2 - 3 min approximately to get a homogeneous mixture. After the mixing process gets over then the mortar paste is filled in the mould as three layers by giving 15 to 20 numbers of blows using tamping rod. For each mixes three cubical specimens are casted to test the compressive strength and three cylindrical specimens are casted to test the tensile strength of mortar paste. Totally 81 cubes and 81 cylinders for nine different combinations of mixes are casted to test the strength of mortar paste. After the casting of specimens, it has been left in room temperature for 24 hours. Then the specimens were removed from the mould and immersed in water for curing until the day of testing. All the casted specimens were tested for its strength at the ages of 7, 14 and 28 days of curing.

Results and Discussion

Effect of mechanical properties of lime and metakaolin mortar paste

Figure 1 shows the compressive strength of lime and metakaolin mortar paste for various mass ratios of 9:1, 8:2, 7:3, and 6:4 ratios respectively. Similarly Figure 2 shows the tensile strength of the above said mortar paste ratios. The compressive strength result shows that there is an increase in the compressive strength with the increase in the age of concrete. When lime and metakaolin mortar paste results compared with 100 % lime mortar paste there is an increase in the compressive strength. The percentage of increase varies by 13% for M1 mix, 25% for M2 mix, 29% for M3 mix and 43% for M4 mix for the age of 7 days. Similarly 10% for M1 mix, 14% for M2 mix, 39% for M3 mix, and 65% for M4 mix for the age of 14 days. Similarly 13% for M1 mix, 24% for M2 mix, 51% for M3 mix, and 84% for M4 mix for the age of 28 days. The important thing to be noted in that was increase in strength is found out in later ages of lime and metakaolin mortar paste when compare with 100% lime mortar paste also the mass ratio of 6:4 has greater increase in compressive strength for all ages of mortar paste and therefore the optimum ratio among all will be 60% lime and 40% metakaolin. The tensile

strength result shows there is an increase in the strength with increase in age of concrete. When lime and metakaolin mortar paste results compared with 100% lime mortar paste there is an increase in the tensile strength. The percentage increase varies by 39% for M1 mix, 67% for M2 mix, 50% for M3 mix and 42% for M4 mix for the age of 7 days. Similarly 33% for M1 mix, 45% for M2 mix, 39% for M3 mix, and 36% for M4 mix for the age of 14 days. Similarly 50% for M1 mix, 50% for M2 mix, 42% for M3 mix, and 36% for M4 mix for the age of 28 days. The important point to be observed is that increase in tensile strength for the mass ratio of 6:4 and hence 60% lime and 40% metakaolin is the optimum replacement. The failure of the specimen is brittle in nature due to the absence of reinforcing aggregates.

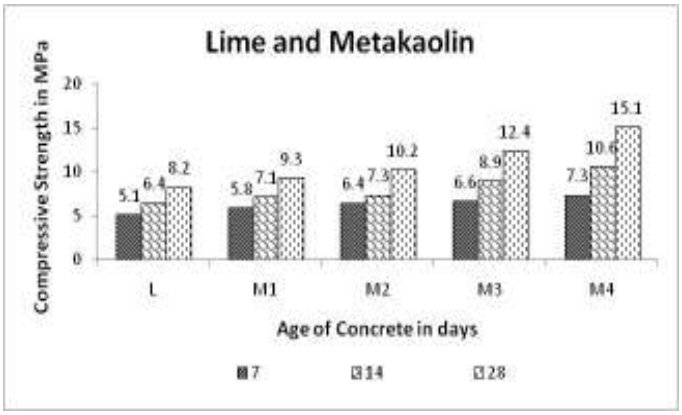

Figure 1 Effect of Compressive strength for Lime and Metakaolin mortar paste

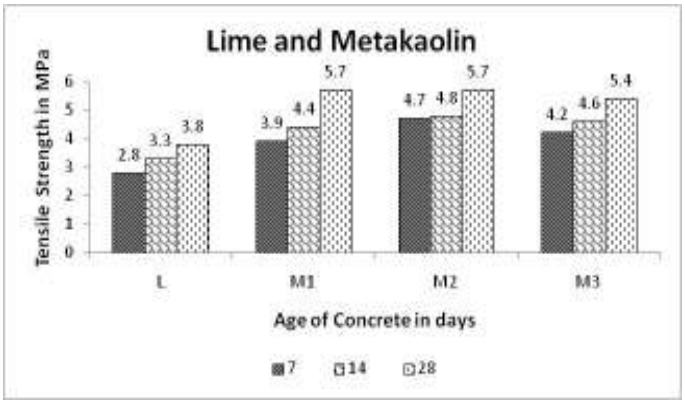

Figure 2 Effect of Tensile strength for Lime and Metakaolin mortar paste

Effect of mechanical properties of lime and brick dust mortar paste

Figure 3 shows the compressive strength of lime and brick dust mortar paste for various mass ratios of 9:1, 8:2, 7:3, and 6:4 ratios respectively. Similarly Figure 4 shows the tensile strength of the above said mortar paste ratios. The compressive strength result shows that there is an increase in the compressive strength with the increase in the age of concrete. When lime and brick dust mortar paste results compared with 100 % lime mortar paste there is an increases in the compressive strength only at the early ages of mortar paste. The percentage of increase varies by 9% to 23% for 7 days and 3% to 13% decrease in strength for 14 and 28 days of mortar. When results were compared with 100% lime mortar paste also the mass ratio of 6:4 has greater increase in compressive strength for all ages of mortar paste and therefore the optimum ratio among all will be 60% lime and 40% brick dust. The tensile strength result shows there is an increase in the strength with increase in age of concrete. When lime and brick dust mortar paste results compared with 100% lime mortar paste there is an increase in the tensile strength. The percentage increase varies by 7% for B1 mix, 25% for B2 mix, 35% for B3 mix and 60% for B4 mix for the age of 7 days. Similarly 21% for B1 mix, 36% for B2 mix, 57% for B3 mix, and 48% for B4 mix for the age of 14 days. Similarly 21% for B1 mix, 34% for B2 mix, 44% for B3 mix, and 52% for B4 mix for the age of 28 days. The important point to be observed is that increase in tensile strength for the mass ratio of 6:4 and hence 60% lime and 40% brick dust is the optimum replacement.

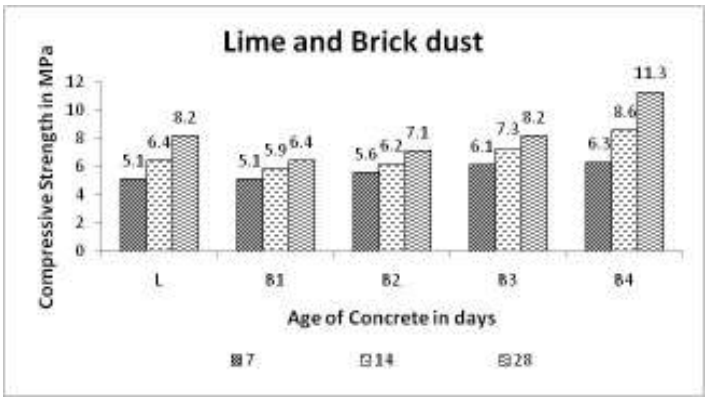

Figure 3 Effect of Compressive strength for Lime and Brick dust mortar paste

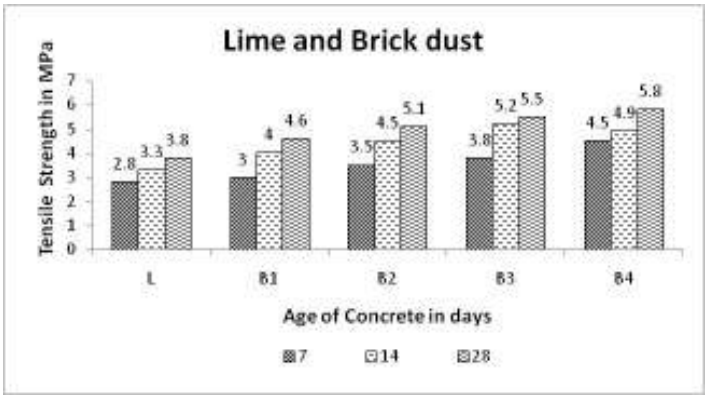

Figure 4 Effect of Tensile strength for Lime and Brick dust mortar paste

Effect of age on strength properties of lime, metakaolin and brick dust

Figure 5 & 6 shows the compressive strength and tensile strength for different age of mortar mixes of lime, metakaolin and brick dust for various mass ratios of 9:1, 8:2, 7:3, and 6:4 ratios respectively. The compressive strength of metakaolin paste is greater than lime and brick dust paste for all the ages of mortar mixes. The percentage increase is about 13% to 43% for 7 days, 10 % to 65% for 14 days and 13% to 84% for 28 days age of mortar paste. The tensile strength of metakaolin paste is also greater than lime and brick dust for all the ages of mortar mixes. The percentage increase is about 39% to 67% for 7 days, 33% to 45% for 14 days, and 36% to 50% for 28 days age of mortar paste. Therefore its clearly reveals that among the three different material properties metakaolin material along with lime for the ratio of 6:4 is the optimum mix.

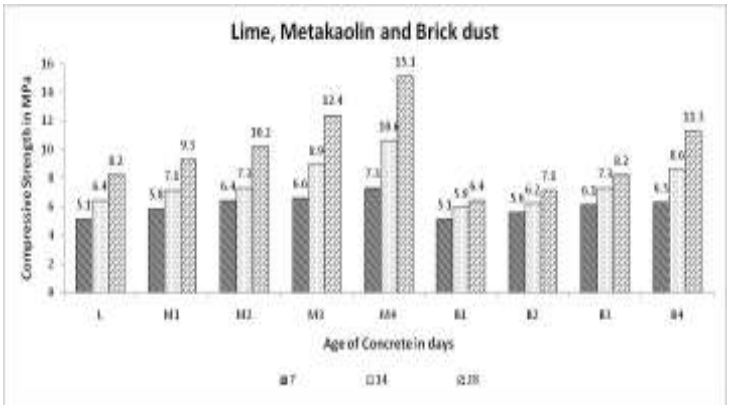

Figure 5 Effect of age on Compressive strength of Lime, Metakaolin and Brick dust

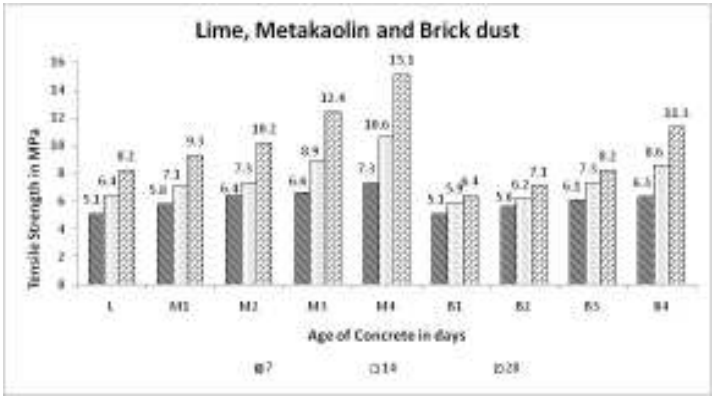

Figure 6 Effect of age on Tensile strength of Lime, Metakaolin and Brick dust

Conclusions

This work has been made to produce an alternate mortar paste which is found reliable and the following broad conclusions from the study.

1. Cement has been replaced to 100% with three different materials such as lime, metakaolin, and brick dust with the mass ratio of 9:1, 8:2, 7:3, and 6:4 respectively. The greater increase in compressive strength and tensile strength has developed only for metakaolin material with various mass ratios.
2. The strength characteristics has developed more when compared with lime and brickdust mortar paste due to presence of high percentage of alumina and silica content with less percentage of calcium content in the material properties.
3. From the various mass ratios of different materials 6:4 ratio is the optimum value of material replacement of lime with metakaolin and brick dust. Also regarding the age of mortar paste the 28 days strength values have showed greater increasing trend for metakaolin.
4. This type of mortar paste not only use as the replacement of cement but can be use for all types of repair and rehabitation works and also it can be used to make a light weight structure which will possible able to construct structures in the earthquake prone zones in Tamilnadu.

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