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COMPRESSIVE AND FLEXURAL STRENGTH OF TERMITE MOUND LIME BLENDED CEMENT MORTAR SUBJECTED TO SULPHATE ENVIRONMENT

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ABSTRACT

This study investigates the compressive and flexural strength of termite mound lime blended cement mortar subjected to sulphate environment, made from mixes containing cement/termite mound, cement/termite mound/lime and cement/lime and sand. Tests were performed on 50 x 50 x 50 mm mortar cube specimens for compressive strength and 50 x 50 x 250 mm prism specimens for flexural strength. Two mix ratios (1:4 and 1:6) and varying binder replacement of cement with lime or termite mound amounting to 0%, 10%, 20%, 30%, 40% and 50%. The strength measurements of mortar were performed at the ages of 7, 14, 21, 28, 56 and 90 days. The specimens were subjected to 2% and 4% MgSO4 environment. The test results showed that the compressive and flexural strength of the mortar increases with age and decrease with percentage replacement of cement with lime and termite mound. The mixes containing cement/termite mound showed relatively higher compressive and flexural strength than other mixes. The paper concluded that all the three types of blended cement tested would perform well at 10% replacement level.

Keywords: Compressive Strength, Flexural Strength, Termite mound, Lime, Cement, Magnesium sulphate

1. INTRODUCTION

Degradation of concrete to sulphate-bearing environments has been of concern since the early years of the past century. (Al-Amoudi (2002) and Metha et al. (1993) Sulphate attack is the destructive process acting on concrete due to the formation of expansive reaction products within concrete exposed to external sulphate sources. Sulphate attack is considered as one of the major deteriorative problems occurred when the cement based materials, such as concrete, mortars and buildings are exposed to this environment. Sulphate attack occurs when concrete is in contact with a source of sulphate ions, which can be groundwater, soil or rain water. Sulphate attack usually manifests itself by cracking and spalling of concrete accompanied by expansion and/or loss of strength. The resistance of concrete to sulphate attack is determined by several factors, such as water/cement ratio, permeability, and cement characteristics, which include fineness and cement composition. It has long been recognized that controlling cement composition, specifically tricalcium aluminate content improves concrete resistance to sulphate attack. (Natalya et.al 2006). Sulpate attack on concrete is primary attributed to sodium, magnesium and calcium sulphate salts. Due to the limited solubility of calcium sulphate in water at normal

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temperature, sulphate attack is normally ascribable to the presence of magnesium sulphate or sodium sulphate Al-Amoudi (1998).

Termites are social insects of the order Isoptera with about 3,000 known species, of which 75% are classified as soil-feeding termites. The diet of soil-feeding termites consists of no-cellular organic material mixed with clay minerals. Their gut is formed by five compartments that present rising gradients of pH, up to 12.5, and different status of oxygen and hydrogen (Brune et al., 1995; Brune & Kühl, 1996; Donovan et al., 2001; Eggleton & Tayasu, 2001). These characteristics are certainly important and may effectively contribute to mound soil chemical and physical characteristics.

The activities of termites are, perhaps more important than the activities of earthworms in the areas of day formation. Termites transport large quantities of materials from within the soil, depositing it on the surface. Some of the termites mould hills are about 5meters tall and 7 meters in diameter. The earth movement activity of termites results in greater than - normal content of days. (Mohammed 2006)
The pile of earth made by termites resembling a small hill is called a termite mound. It is made of clay whose plasticity has further been improved by the secretion from the termite while being used in building the mound. It is therefore a better material than ordinary clay in terms of utilization for moulding (Odumodu, 1991). Termite mound has been reported to perform better than ordinary clay in dam construction. (Yohanna *et al*. 2003). The clay from termite mound is capable of maintaining a permanent shape after moulding. Termite mound clay has been considered for use in silos construction because of its plasticity and less prone to crack when compared with ordinary clay. Heat treated termite mound clay units are resistance to wear, abrasion and penetration by liquids (Parker, 1998). Termite mound clay has low thermal conductivity and expectedly should reduce solar heat flow into building enclosure and regulate temperature fluctuations within the storage environment. (Adegunloye, 2007). Given its observed availability and its proposed use as a partial replacement for cement, the sustainability of termite mound is guaranteed. Lime to be used for this research is calcium hydroxide $Ca(OH)_2$ normally sold in commercial quantities in urban centres of the country.

Lime, a traditional modern material, has excellent plasticity and water retentivity, but it is slow in strength and slow to cure. Lime putty is made by slaking quicklime which is allowed it to age, it is a quality product but the aging process is time consuming. As a result the more convenient dry hydrated lime is generally used.

This study was conducted to investigate the compressive and flexural strength of termite mound lime blended cement mortar exposed to sulphate environment. Tests were conducted on cubes and beams to study the compressive and flexural strength of termite mound lime blended cement mortar. Durability studies were done on cement/termite, cement/termite/lime and cement/lime and comparison were made between the compressive and flexural strength.

2. MATERIALS AND EXPERIMENTAL PROGRAMME

The materials used in this investigation were Portland cement, Termite mound, sand, water and Calcium hydroxide. The termite mound used was obtained from Ile-Ife in Ife Central Local Government Area of Osun State in Nigeria as a solid mass. This was grinded and sieved with a 75 µm sieve at the Department of Building Laboratory of the Obafemi Awolowo University, Ile-Ife, Nigeria. The sample was then subjected to Chemical Analysis for determination of the oxide contents in Lafarge Cement (formerly West African Portland Cement Company – WAPCO), Sagamu Works Department. The result of the chemical analysis is as presented in Table1

Table 1: Result of Chemical Analysis of the Termite mound Sample

Elements	% Composition by weight
SiO_2	70.78
Al_2O_3	15.78
Fe_2O_3	5.69
CaO	-0.91
MgO	-0.60
SO_3	-0.12
K_2O	2.16
Na_2O	0.27
Mn_2O_3	0.02
P_2O_5	0.03
TiO_2	0.67
Cl-	0.00
SUM	93.77
LSF	-0.34
SR	0.97
AR	0.93
L.O.I	8.30

Two mix ratios (1:4 and 1:6) and varying binder replacement of cement with lime and termite mound amounting to 0%, 10%, 20%, 30%, 40% and 50% were used. Mortar mixes and cubes of size 50 x 50 x 50mm were prepared for compressive strength test while beams of 50 x 50 x 250mm for flexural strength and cast respectively in accordance with standard laboratory procedures. The control mix contained only Portland cement as the binder. In the other mixes Portland cement was partially replaced with respectively, 0, 10, 20, 30, 40 and 50% termite mound. The constituents were mixed in a laboratory mortar mixer till uniform consistency was obtained. The water/binder ratio used was 1.1 for mix ratio 1:4 and 1.45 for mix ratio 1:6 mortar.

In all cases batching was carried out by weight. The water was poured into the moulds, after casting and finishing the moulds were kept under laboratory condition for 24 hours and then demoulded. After demoulding, the specimens were divided into two groups. One group of the specimen was continuously cured under water while the second group was placed in four tanks with the following sulphate concentrations

(i) 2%, $MgS0_4$ (20,000mg/l)

(ii) 4%, $MgS0_4$ (40,000mg/l)

Two tanks were used for the compressive strength while the other two for the flexural strength.

The above exposure conditions represent very severe sulphate exposure conditions according to ACI 318-99. The specimens were cured for 7, 14, 21, 28, 56 and 90 days respectively, and tested for compressive strength. The compression test was carried out on the specimen by a 2000KN capacity testing machine. Three specimens from each mixture were tested at each testing age. The test procedure followed during the test was in conformity with ASTM C39. The flexural strength of the specimens is determined by conducting a three point bending test. The specimens after curing in water and magnesium sulphate solution were kept on the supports and the load is applied in a compression testing machine at a constant piston displacement of 1.25 mm per minute. The failure load is used to calculate the flexural load of the specimen.

3.RESULTS AND DISCUSSION

Compressive and Flexural Strength of termite mound lime blended cement mortar subjected to 2% $MgS0_4$

The compressive and flexural strength variations with curing age at various levels of replacement with termite mound and lime for both mix ratios are shown in figs. 1-12. Test results showed that the compressive and flexural strength of the mortar cubes increase with age and decrease with increasing percentage replacement of cement with lime and termite mound. Fig. 1 showed that the compressive strength at 7 days for 10, 20, 30, 40 and 50% replacement of cement with termite mound are 3.06 N/mm^2, 2.80N/mm^2, 1.86N/mm^2, 1.73N/mm^2 and 1.60N/mm^2 respectively as against the control value of 3.20N/mm^2 for 1:4 mix proportion. Also fig. 7. showed the flexural strength at 7days for 0, 10, 20, 30, 40 and 50% termite mound replacement are 3.44N/mm^2, 3.36N/mm^2, 3,32N/mm2, 3.20N/mm^2 and 3.00N/mm^2 respectively as against the control value of 3.60N/mm^2 for 1:4 mix proportion. Beyond 10% termite mound substitution however, the compressive and flexural strength decreases significantly with respect to the control in 2% $MgS0_4$. A similar trend was observed for 1:6 mix ratio.

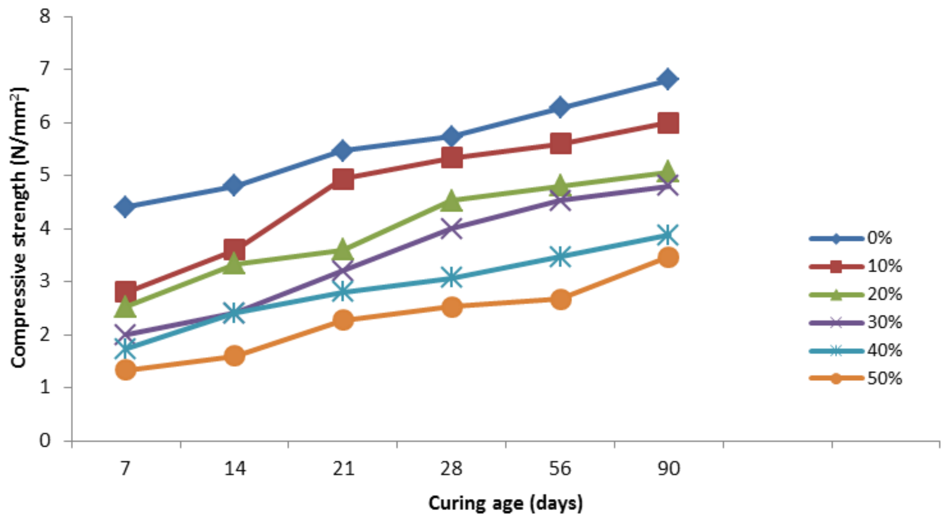
The results at 14 days follow the same trend as in 7 days with higher percentage strength increases fig. 1. and fig. 7. Indicated that the 10% termite mound has the highest compressive and flexural strength for 1:4 mix proportion. Similarly for 1:6 mix proportion the optimum compressive and flexural strength occur at 10%.

At 28 days fig. 1. Showed that the 10, 20, 30, 40 and 50% termite mound replacements have the lower compressive and flexural strength value of 3.06N/mm^2 and 3.44N/mm^2 both at 10% replacement level.

Compressive and Flexural Strength of termite mound lime blended cement mortar subjected to 4% $MgS0_4$

Fig. 13-18. show the variation of compressive strength of mortar cube made from the following mortar cube cement/termite mound, cement/termite mound/lime and cement/lime for water cement ratio of 1.1 and 1.45 for mix proportion of 1:4 and 1:6.subjected to 4% $MgSO_4$ At the percentage replacement from 0% to 50% termite mound. The compressive strength decreases with increase in percentage replacement of termite mound content irrespective of curing age. From figure 14, however, for mix 1:6 of cement/termite mound, there is a sudden increase in compressive strength at 10% replacement, between 7 and 14 days. The highest value of compressive strength recorded at 10% replacement level was 4.40 N/mm^2. It is noted that between 20% to 50% replacement of termite mound content the increase in compressive strength is comparatively gradual. However, for the two mix ratios for mortar cube made with cement/termite mound/lime had the same 7-day strength at 40% replacement. The same trend is observed at 50% replacement of cement with termite mound. Cement/lime specimen had the same 14 day-strength at 40% replacement. The same trend is observed for cement/lime which also exhibited the same 21-day strength at 50% replacement. Generally it can be concluded that for the mortar cube when subjected to 4% $MgSO_4$ environment. Mix ratio of 1:4 has the highest compressive strength.

Fig. 19-24. show the results of the flexural strength of mortar cube specimen subjected to 4% $MgSO_4$ at the curing ages of 7, 14, 21, 28, 56 and 90 days. Fig. 13. showed that the flexural strength at 7days for 10%, 20%, 30%, 40% and 50% termite mound replacement are 4.64 N/mm^2, 4.56 N/mm^2, 4.44 N/mm^2, 4.39 N/mm^2 and 4.20 N/mm^2 respectively as against the control value of 4.80 N/mm^2 for 1:4 mix proportion while for mix proportion 1:6 the flexural strength at 7days 4.56 N/mm^2, 4.52 N/mm^2, 4.36 N/mm^2, 4.24 N/mm^2 and 4.2 N/mm^2. While the compressive strength of the control was 4.68 N/mm^2. Beyond 10% termite mound replacement, however, the flexural strength decreases significantly with respect to the control. Similar trends were observed for cement/termite mound/lime and cement/lime. It was also observed that the flexural strength increased with increase in the cement content of the specimens. The flexural strength at 7 days for 10% termite mound replacement was 4.64 N/mm^2, 4.56 N/mm^2 for 1:4 and 1:6 mix proportions respectively.



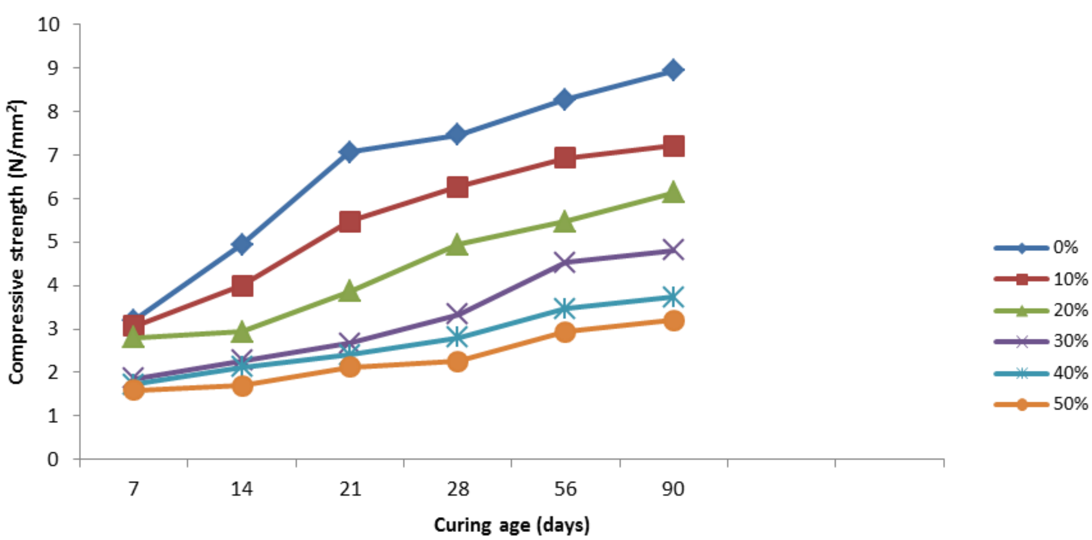


Fig. 1: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 2% MgS04 (Mix Proportion 1:4). For Cement/Termite mound

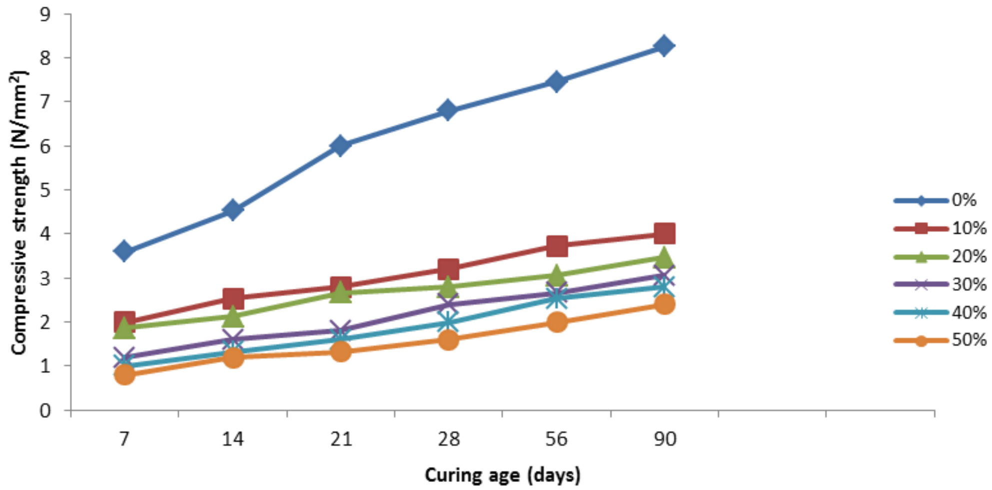


Fig. 2: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 2% MgS04 (Mix Proportion 1:6) For Cement/Termite mound

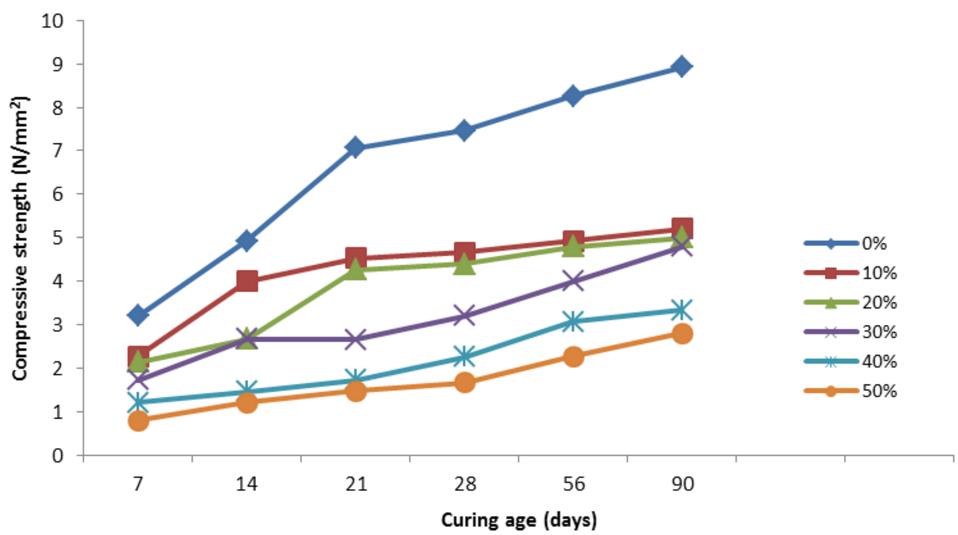


Fig. 3: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 2% MgS04 (Mix Proportion 1:4) For Cement/Termite mound/Lime

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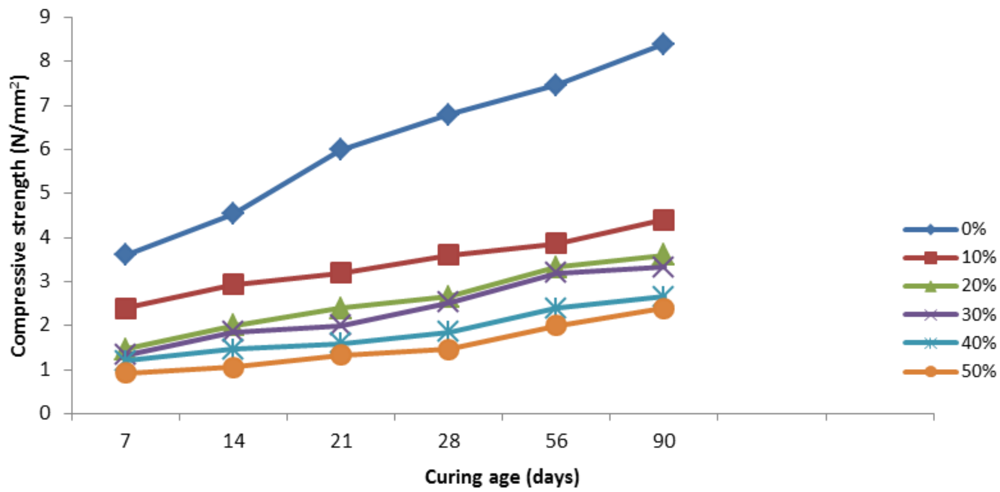

Fig. 4: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 2% MgS04 (Mix Proportion 1:6) For Cement/Termite mound/Lime

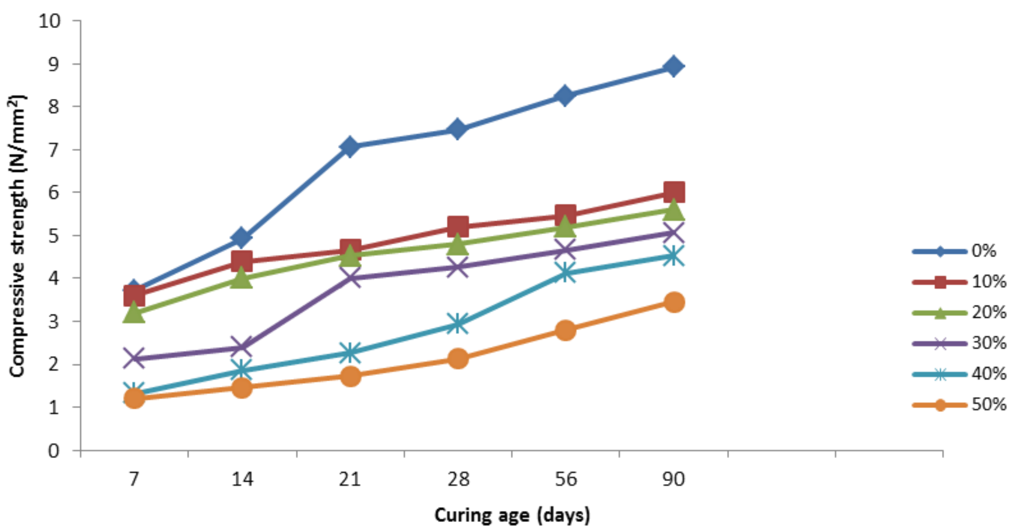

Fig. 5: Vaiation of Compressive Strength with Curing ages for various percentage replacement Subjected to 2% MgS04 (Mix Proportion 1:4) For Cement/Lime

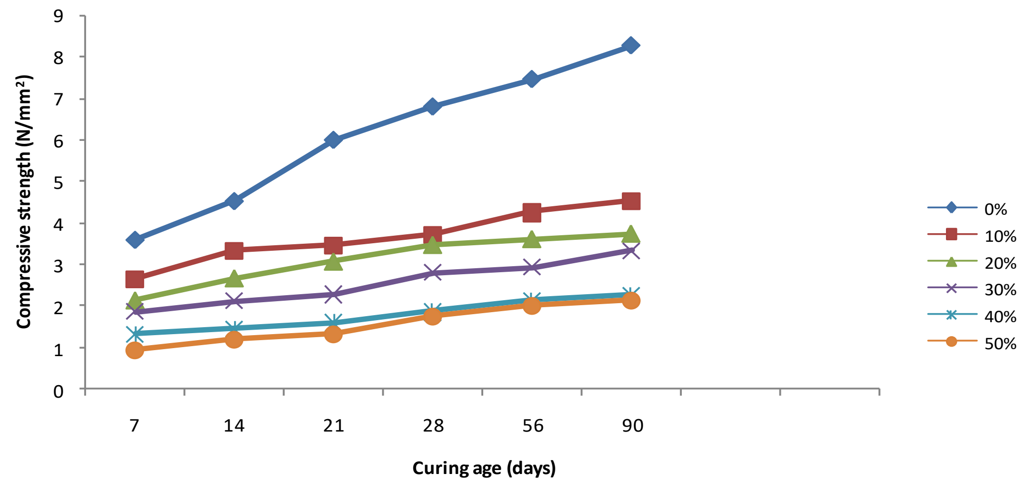

Fig. 6: Variation of Compressive Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:4) For Cement/Lime

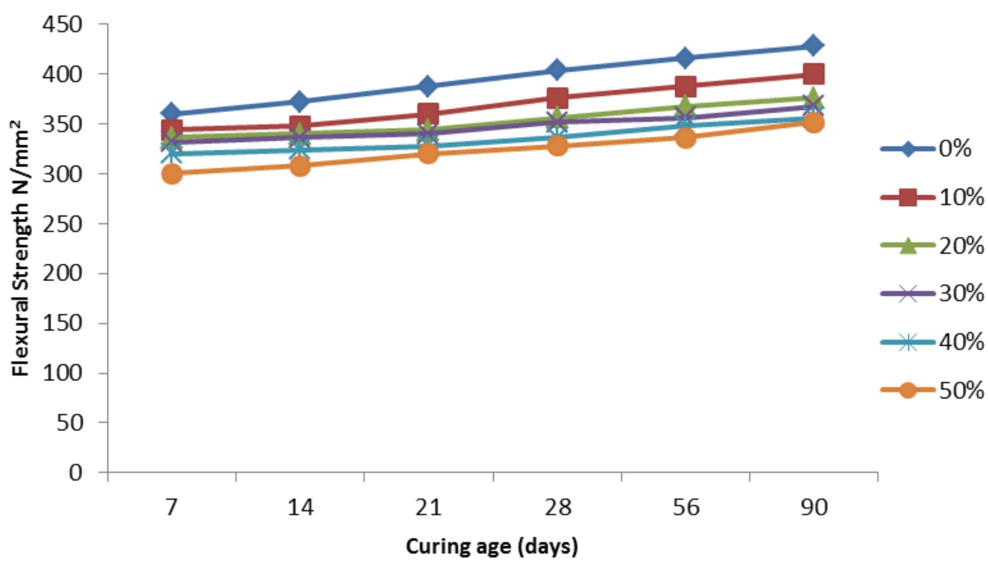

Fig. 7: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:4) For Cement/Termite

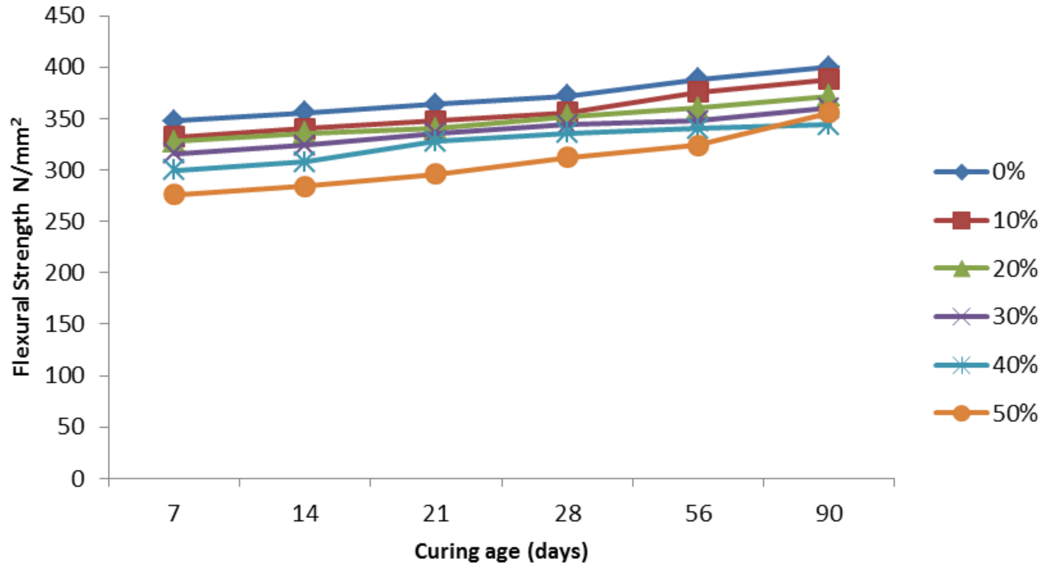

Fig. 8: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:6) For Cement/Termite

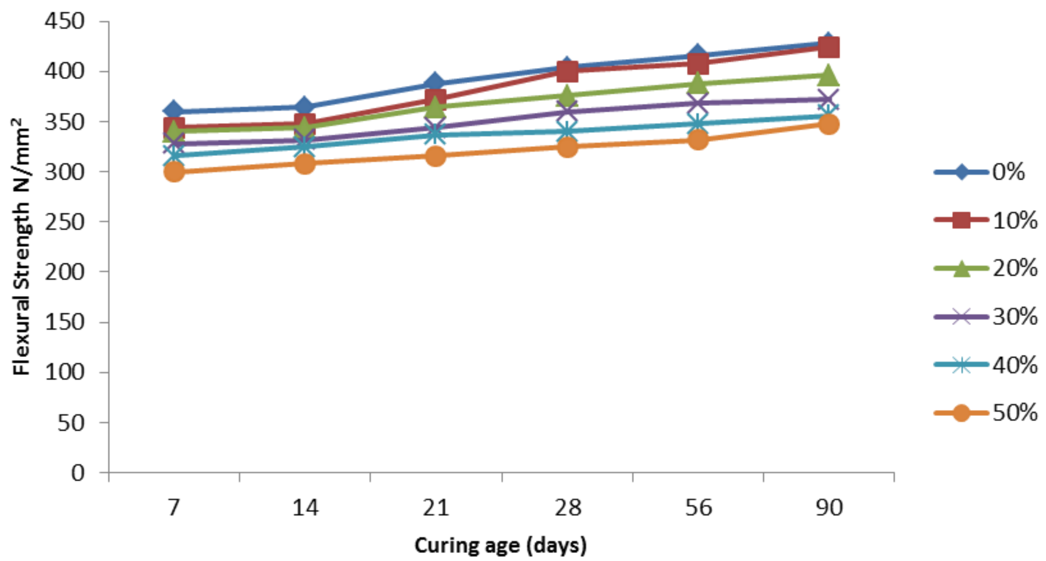

Fig. 9: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:4) For Cement/Termite/Lime

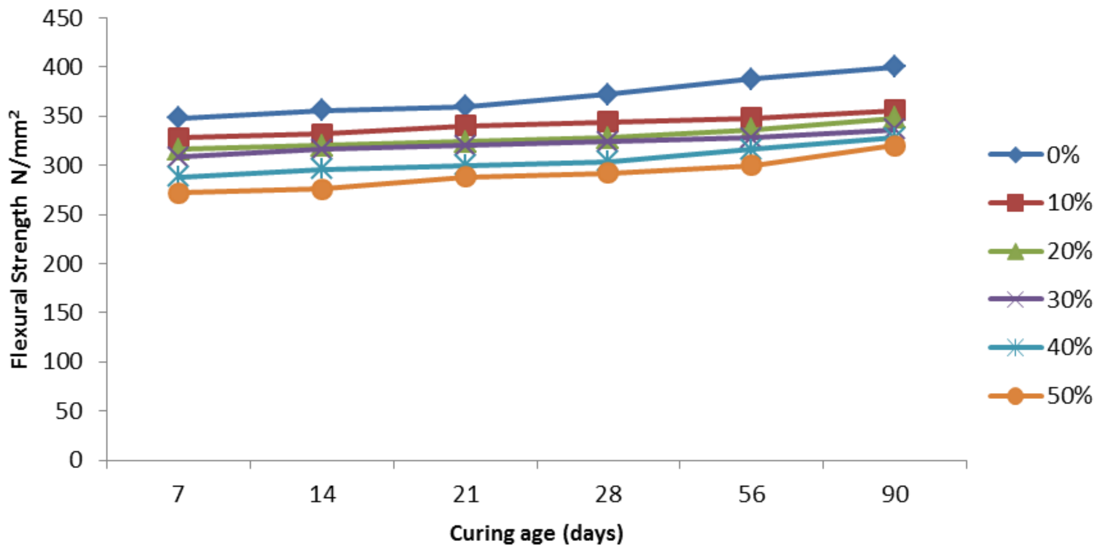

Fig. 10: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:6) For Cement/Termite/Lime

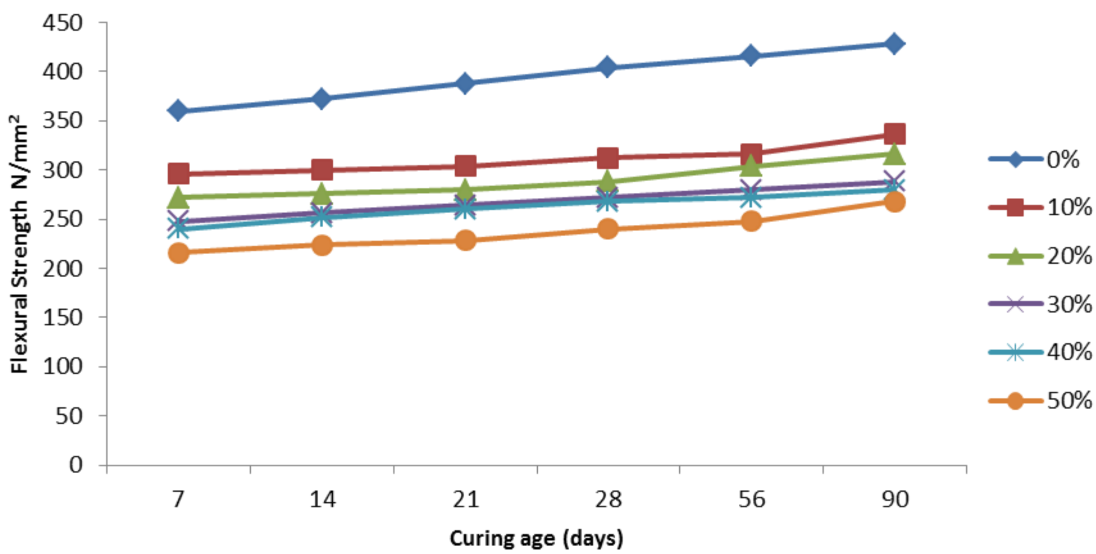

Fig. 11: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:4) For Cement/Lime

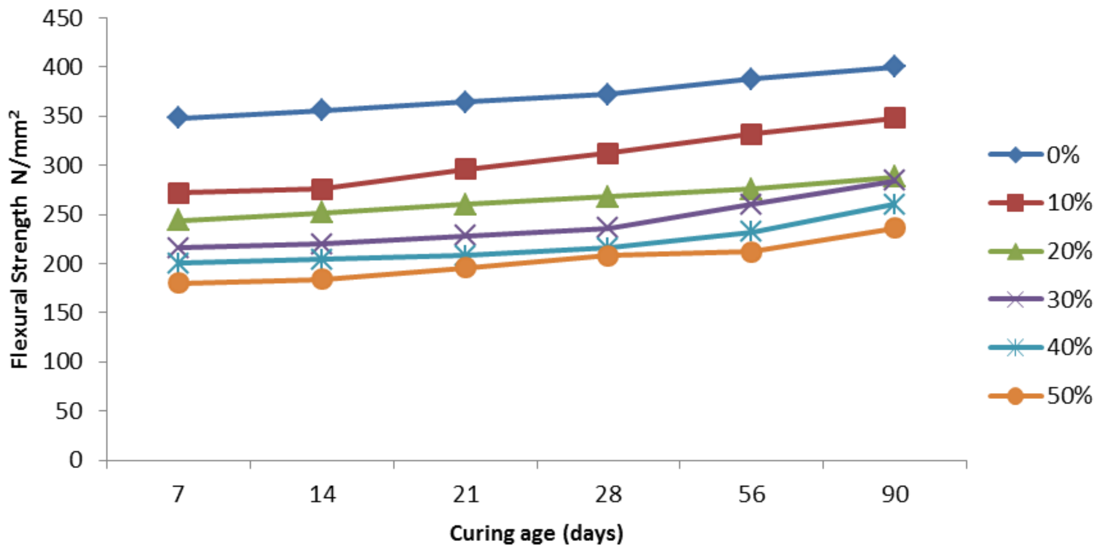

Fig. 12: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 2% MgS04 (Mix Proportion 1:6) For Cement/Lime

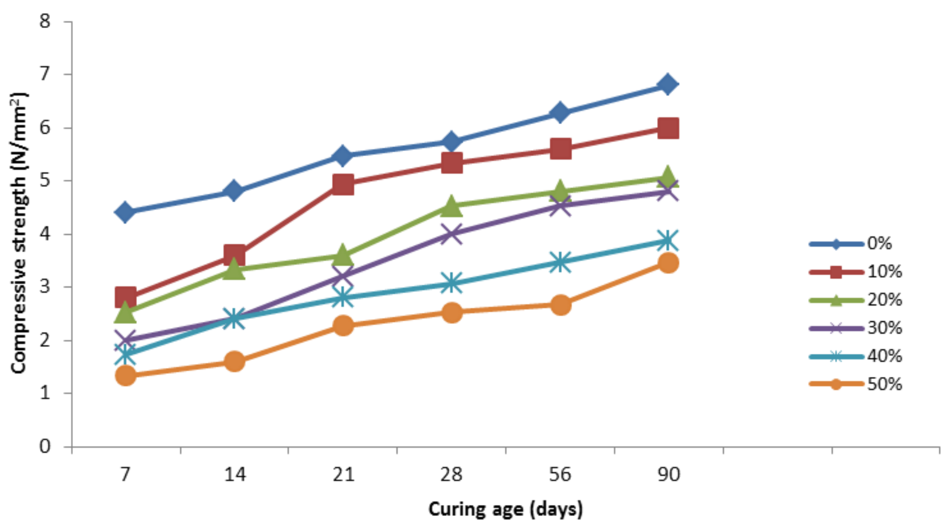

Fig. 13: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 4% MgS04 (Mix Proportion 1:4). For Cement/Termite mound

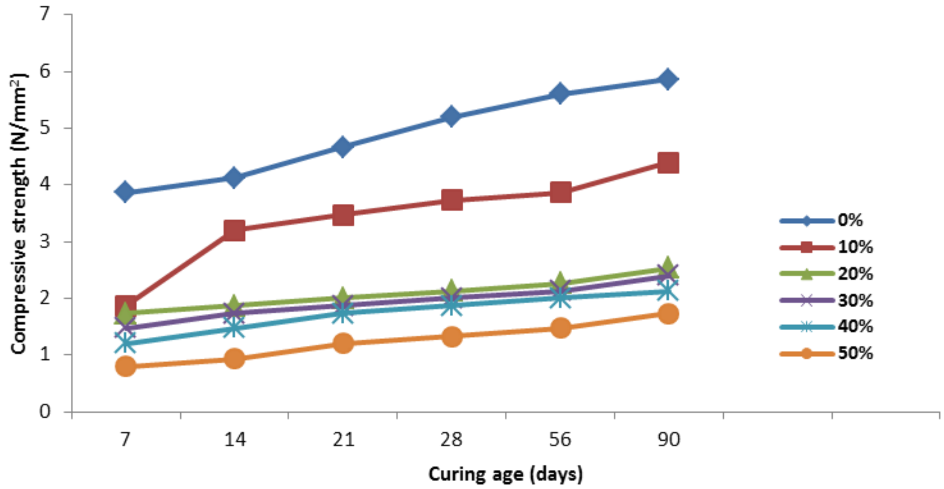

Fig. 14: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 4% MgS04 (Mix Proportion 1:6). For Cement/Termite mound

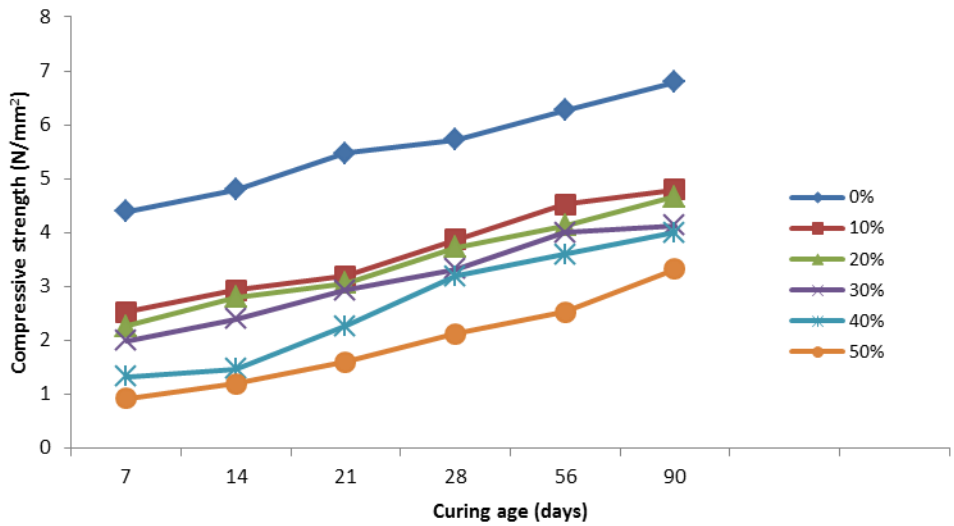

Fig. 15: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 4% MgS04 (Mix Proportion 1:4). For Cement/Termite mound/Lime

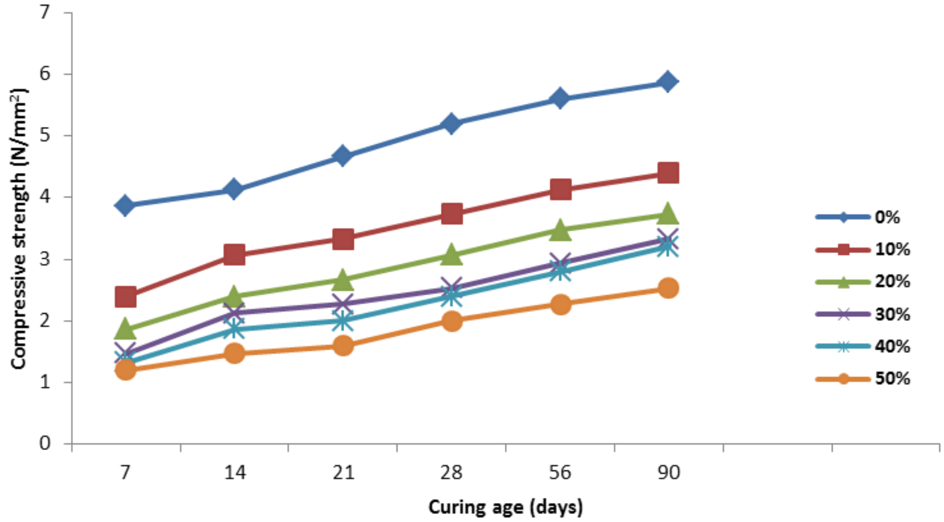

Fig. 16: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 4% MgS04 (Mix Proportion 1:6). For Cement/Termite mound/Lime

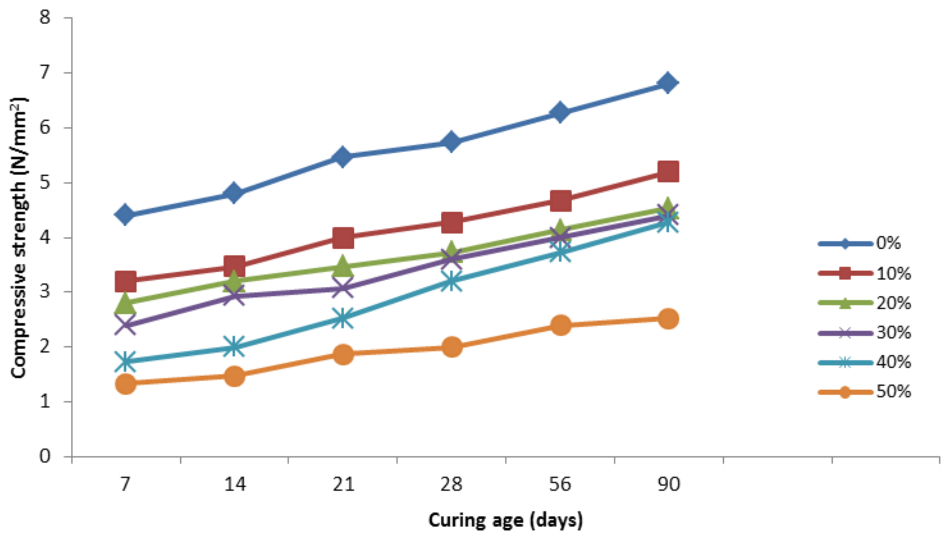

Fig. 17: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 4% MgS04 (Mix Proportion 1:4). For Cement/Lime

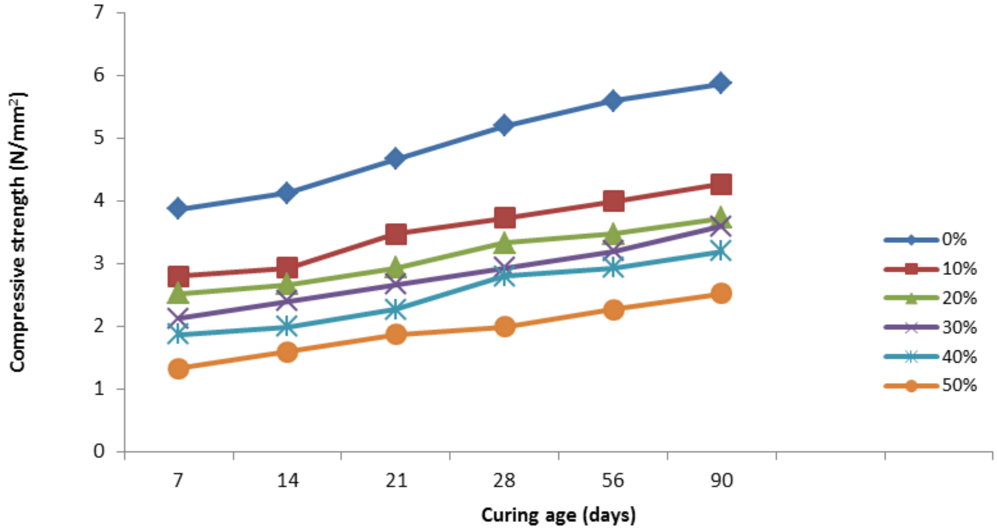

Fig. 18: Variation of Compressive Strength with Curing ages for various percentage replacement Subjected to 4% MgS04 (Mix Proportion 1:6). For Cement/Lime

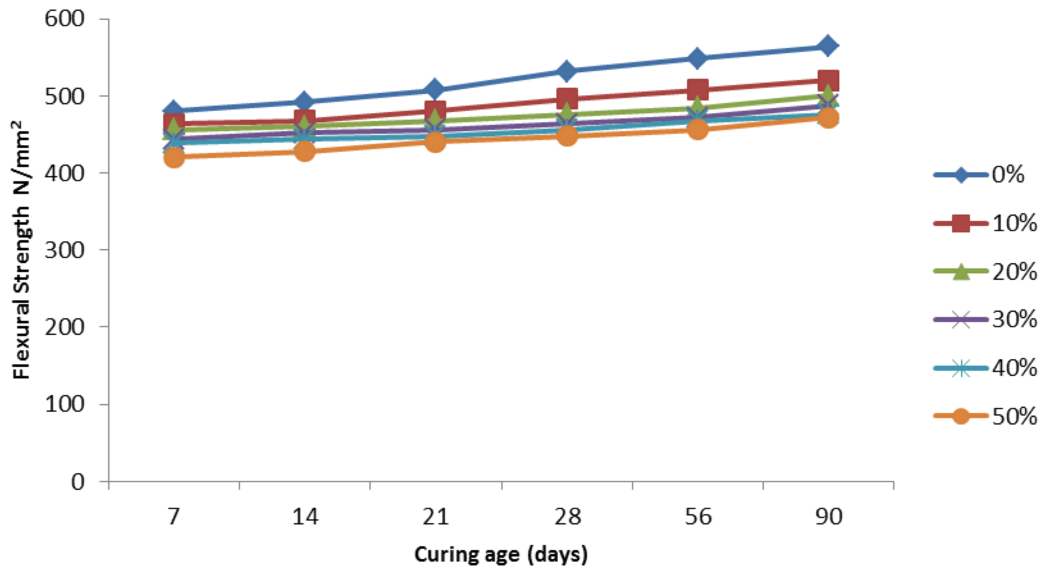

Fig. 19: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 4% MgS04 (Mix Proportion 1:4) For Cement/Termite

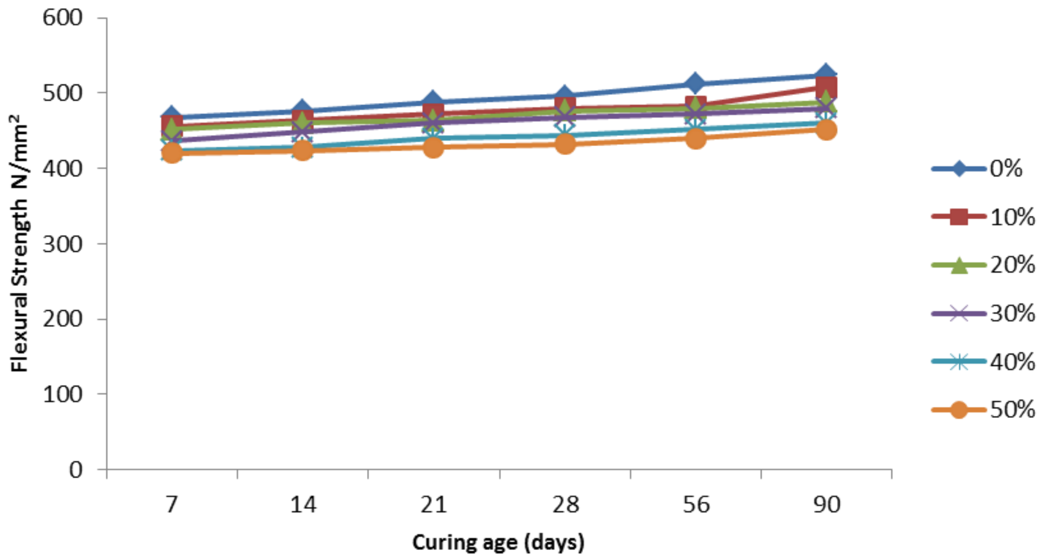

Fig. 20: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 4% MgS04 (Mix Proportion 1:6) For Cement/Termite

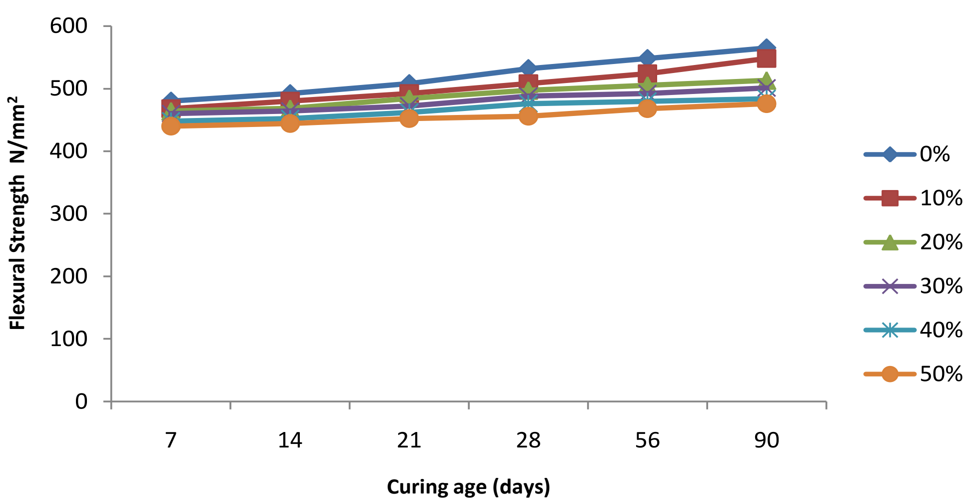

Fig. 21: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 4% MgS04 (Mix Proportion 1:4) For Cement/Termite/Lime

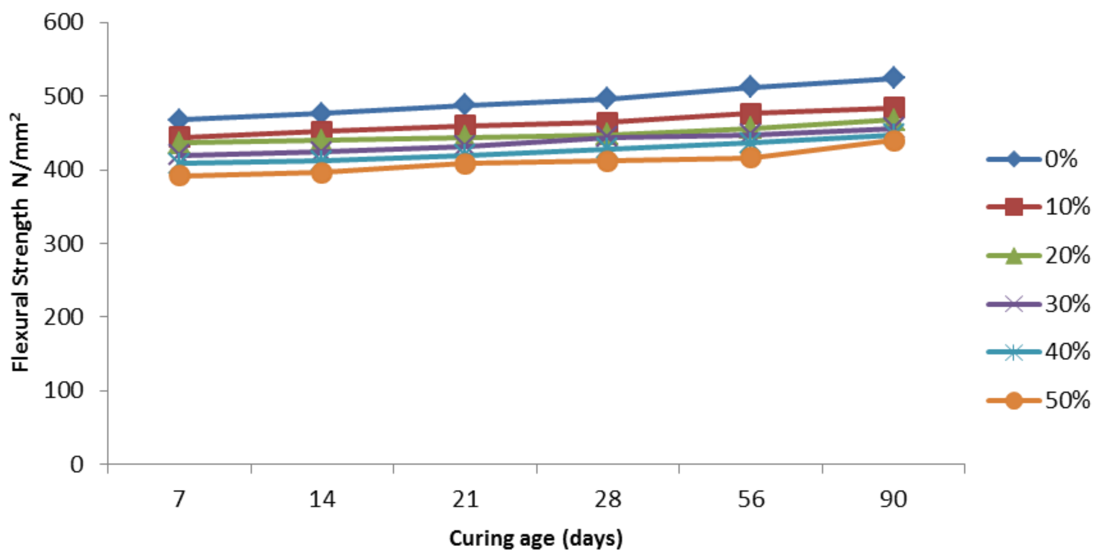

Fig. 22: Variation of Flexural Strength with Curing ages for various percentage replacemen subjected to 4% MgS04 (Mix Proportion 1:6) For Cement/Termite/Lime

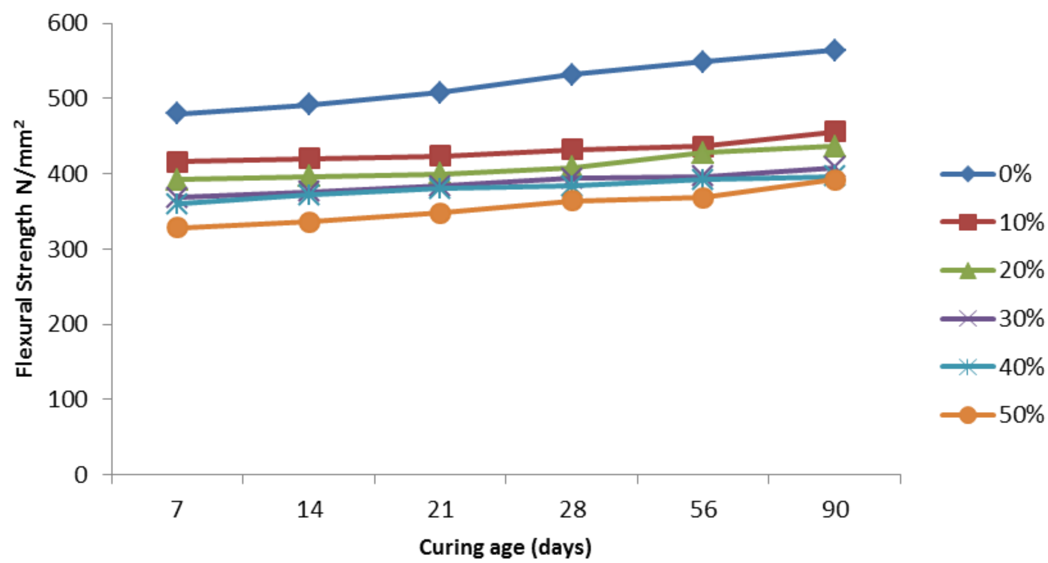

Fig. 23: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 4% MgS04 (Mix Proportion 1:4) For Cement/Lime

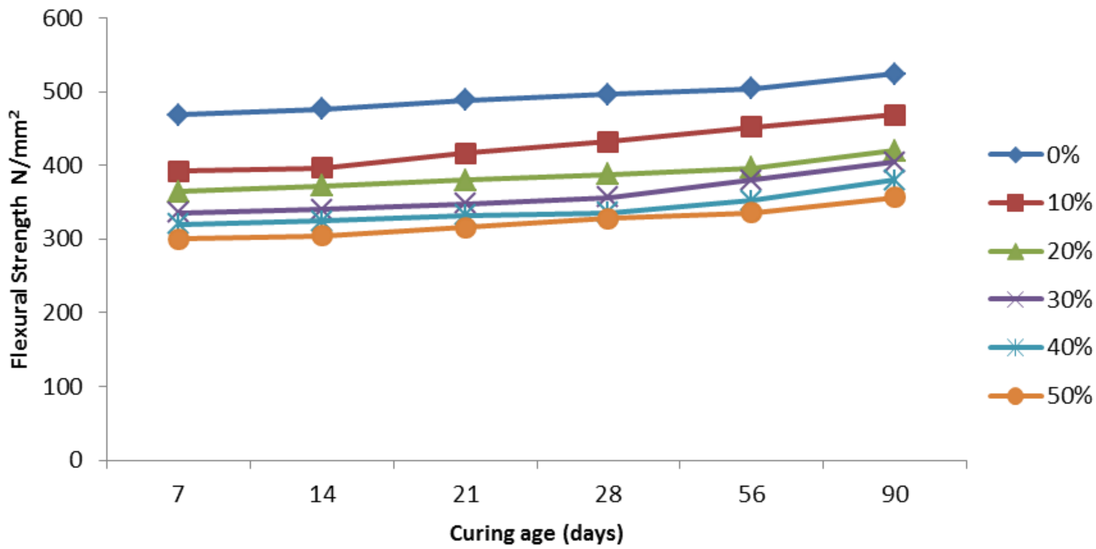

Fig. 24: Variation of Flexural Strength with Curing ages for various percentage replacement subjected to 4% MgS04 (Mix Proportion 1:6) For Cement/Lime

CONCLUSION

This paper discusses the results of an experimental programme carried out to investigate the compressive and flexural strength of termite mound lime blended cement mortar subjected to 2% and 4% magnesium sulphate. Two mix ratios 1:4 and 1:6 and two water binder ratio of 1.1 and 1.45 were used. As a result of this experimental study, the following conclusions were made:

1. The resistance of termite mound lime blended cement mortar at mix ratio 1:4 and water/binder ratio 1.1 to sulphate attack was found to be higher than that of termite mound lime blended cement mortar at mix ratio 1:6 and water/binder ratio 1.45.
2. The test results show that the compressive strength increases with increase in curing age from 7 days to 90 days.
3. The incorporation of termite mound increases the flexural strength of mortar at early age. Higher percentages of termite mound replacement (beyond 10%) led to reduction in flexural strength. The highest flexural strength was obtained at the optimum termite mound replacement of 10%.
4. In the resistance of mortar to chemical attack in a sulphate environment when compared with the control it was observed that there was significant decrease in both the compressive and flexural strength this was due to the reaction of the specimen with magnesium sulphate.

5. The results of this experiment indicated that the inclusion of termite mound and lime into mortar significantly enhanced the strength, especially durability characteristics of mortar in varying magnitude. The results of this investigation also showed that termite mound could be conveniently used to obtain durable mortar.

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