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INFLUENCE OF CURING MEDIA ON THE COMPRESSIVE STRENGTH OF TERMITE MOUND-LIME BLENDED CEMENT MORTAR

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Abstract: This paper presents the results of an experimental investigation of the compressive strength of blended cement mortar cubes containing termite mound and lime. Two mix ratios of 1:4 and 1:6 (cement: sand) with water-cement ratio of 0.65, and varying combination of termite mound and lime in equal amount ranging from 10% to 50% replacing cement were used. A total of 900 cubes were cast, cured in water, H_2SO_4 and HNO_3 for 7, 14, 21, 28 and 56 days in each medium. Test results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with Termite mound-lime specimens cured in water; whereas, the compressive strength decreases with increase in age, percentage replacement of cement with termite mound-lime as well as solution concentration when the specimens were immersed in acidic solution. The study concluded that termite mound-lime blended cement mortar is adequate for use as type S or N masonry mortar for construction purposes in non-acidic aggressive environment.

Keywords: *Compressive strength, lime, nitric acid, sulphuric acid, termite mound*

1.0 Introduction

Building materials account for between 40-60% of the total construction cost (Ayangade *et al.*, 2004; Olanipekun *et al.*, 2006), and this is attributed to the fact that basic conventional building materials like cement and aggregates are becoming increasingly expensive due to high cost incurred in their processes, production and transportation.

The utilization of locally available materials that can either reduce or replace the conventional ones are being investigated. For example, the used of rice husk ash (Zhang and Malhotra, 1996), corncob ash (Adesanya and Raheem, 2009), periwinkle shell ash (Olusola and Umoh, 2012), and calcined termite mound (Olaniyi and Umoh, 2013) have been ascertain suitable as cement supplements.

Termite mounds are available all over the world. However, the availability and distribution depend on soil and vegetation, climatic features and presence of water. In Nigeria, the most dominant species of mound building termites are the wood – feeding, the fungus growing *Macrotermes bellicosus* (M. Bellicosus) and the grass–harvesting *Trinevitermes* germinates. However, *M. bellicosus* constitute the dominant species and has a wider distribution in the south western zone of Nigeria.

The mound is usually made of clay whose plasticity has further been improved by the secretion from the termites while being used in building the mounds. It is therefore a better material than ordinary clay in terms of utilization for moulding (Odumodu, 1991), and in dam construction (Yohanna *et al.*, 2003). Heat treated termite mound clay has been reported to have resistance to wear, abrasion and penetration by liquids (Parker, 1998), and has cementitious properties which makes it a good cement supplement (Alake and Umoh, 2013); it equally has low thermal conductivity which could make it possible to reduce solar heat flow into building enclosure and regulate temperature fluctuations within the storage environment (Adegunloye, 2007). The use of termite mound in the production of mortar is scarce in literature hence the study to investigate the influence of curing media on the compressive strength of termite mound-lime blended cement mortar.

Mortar is a binding material which can be made with Portland cement, masonry cement, mortar cement or blended cements, some of which are combined with hydrated lime; and sand (fine aggregate) is usually added. The constituents are usually mixed together with water to a plastic paste. It is used in building construction for binding construction blocks such as sandcrete block and bricks together. It can also be used for plastering and rendering purposes.

Mortars are classified by ASTM C 270 (2006) into four Types: M, S, N and O. Each mortar Type has some basic characteristics as follows:

Type N mortar	- General all-purpose mortar with good bonding capabilities and workability
Type S mortar	- General all-purpose mortar with higher flexural bond strength
Type M mortar	- High compressive-strength mortar, but not very workable
Type O mortar	- Low-strength mortar, used mostly for interior applications and restoration

However, the descriptions above provide basic mortar characteristics, but each mortar Type can be used in a variety of applications. No single mortar is best for all purposes.
The compressive strength of mortar is sometimes used as a principal criterion for selecting mortar type, since compressive strength is relatively easy to measure, and is commonly relates to some other properties such as tensile strength and water absorption

of the mortar; it is considered a basis for assessing the compatibility of mortar ingredients.

Acid attack is one of the phenomena that may disintegrate cement-based materials (concrete and mortar) depending on the type and concentration of the acid. Certain acids such as oxalic acid are considered harmless, while weak solutions of some acids have significant effects (Bassel *et al.*, 2012). Acids generally attack and leach away the calcium compounds of the cement paste. This paper, therefore, investigate the compressive strength of mortar made from Portland cement blended with termite mound and lime subjected to acidic environments with a view to providing a basis for an effective utilization of termite mound and lime in building construction.

2.0 Materials and Methods

2.1 Materials

The materials used for this research work include: Portland cement, hydrated lime, termite mound, fine aggregate (sand), water and acid. The Dangote brand of Portland cement produced in Obajana factory, Kogi State, Nigeria and conformed to BS EN 197 (2000) which is equivalent to Nigeria Industrial Standard (NIS) 444-1 (2003) was used. The chemical composition is presented in Table 1. The lime was bought in an open market in Ile-Ife and slaked before use.

The termite mound used was obtained from Parakin a community in Ile-Ife, and brought to the Construction and Material Laboratory, Department of Building, Obafemi Owolowo University, Ile-Ife, Osun State, Nigeria and kept for 4-6 months for it to be properly dried. Thereafter, the mound was ground and sieved with a 75 µm wire mesh. The sample was then subjected to chemical analysis with the use of X-Ray Fluorescent Analyser called Total Cement Analyser Model ARL 9900 XP in Lafarge Cement laboratory, Sagamu, Ogun State, Nigeria.

fine sand used was soft sand; the sieve analysis conducted on the sand meets the requirement of ASTM C 144 (1991) for sand suitable to be used for masonry mortar, the physical properties of the sand is as presented in Table 2. The acids (H_2SO_4 and HNO_3) were gotten from the Department of Chemistry, Obafemi Awolowo University (OAU), Ile-Ife; while water for the study was obtained directly from the tap in the Construction and Materials laboratory, Building Department, OAU.

2.2 Proportioning and Mixing of Constituent Materials

Two mix ratios of 1:4 and 1:6 (cement: sand) with water-cement ratio of 0.65 was adopted. The cement content in the mixes was replaced with combined quantity of termite mound and lime (in equal amount) in the range of 10 % to 50 % at interval of 10 % by weight of cement. The calculated quantity of each of the materials, i.e. sand, grounded termite mound, lime, and cement, were measured and placed on a prepared levelled and impermeable clean surface. They were manually mixed with shovel until a homogenous colour was attained. Water was measured and added to the mixture and the mixing continued until a paste of uniform consistence was achieved. The wet mixture was poured into already prepared cube moulds of size 50mm

2.3 Casting and Curing

The wet mixture was filled into the moulds in two layers and each layer was compacted for 25 strokes and applied uniformly distributed over its surface as stipulated by BS EN 12390: 3 (2000). The top of each mould was smoothened and levelled and the outside surfaces cleaned. The moulds and their contents were covered with polyethene and kept in the laboratory for 24 hours. At the end of 24 hours, the specimens were removed from the moulds and divided into five sets. A set was cured in water bath maintained at 27± 2^0C and relative humidity of 90%, while a set in each of the remaining four sets were immersed in 1% and 3% solutions of trioxonitrate V (HNO_3) acid and Tetraoxosulphate VI acid (H_2SO_4).

2.4 Compressive Strength Test

Compressive strength test was conducted on both the control specimens cured in water and specimens exposed to acidic environment of different concentrations. A total specimen of 900 cubes consisting of 180 for the control test and 720 specimens subjected to acidic environment. The test was determined at curing ages of 7, 14, 21, 28 and 56 days in accordance to BS 1881: part 116: 1983 using a 2000 KN capacity compression testing machine.

The compressive strength of each cube was calculated, based on the mean of three specimens of each mixture and curing age, by dividing the load causing failure of the specimen by the cross-sectional area as follow:

$$\text{Compressive strength (N/mm}^2) = \frac{\text{Load at failure (N)}}{\text{Cross sectional Area (mm}^2)}$$

The effect of different acid types and concentrations on the compressive strength of the termite mound-lime blended cement mortars were evaluated. This was measured as the reduction (or loss) in compression strength by the expression (Eq. 1):

$$LCS\ (\%) = [(CS - LS)/CS] \times 100 \qquad (1)$$

Where LCS is loss in compressive strength (%), CS is the mean compressive strength (N/mm^2) of three specimens cured in water, and LS is the mean compressive strength (N/mm^2) of three specimens exposed to acidic environment.

3.0 Results and Discussion

3.1 Tremite Mound

The chemical composition of the termite mound sample used had silica (SiO_2) content of 70.78%; a combined percentage of silica (SiO_2) and Alumina (Al_2O_3) of more than 70%, a requirement of which a good binder should meet (Syagga *et. al* 2001; Pekmezei and Akyuz, 2004 and Justness *et. al*., 2005). The composition also meets the requirements of ASTM C 618 (2008) for a combined percentage content of SiO_2, Al_2O_3 and Fe_2O_3 of more than 70% as stipulated. Thus, termite mound can be considered a suitable material for use as a binder. The physical properties as presented in Table 2 indicates a moisture content of 2.20%; a liquid and plastic limits of 36% and 17.58%, respectively and a corresponding plasticity index of 18.42%. The plasticity index which is greater than 17 is an indication that the termite mound is a highly plastic soil (Murthy, 2007).

Table 1: Chemical Composition of Termite Mound and Portland cement obtained by XRF

Constituents	*Percentage Composition (%)*	
	Termite mound	*Portland cement*
SiO_2	70.78	20.60
Al_2O_3	15.78	5.85
Fe_2O_3	5.69	3.05
CaO	-0.91	51.44
MgO	-0.60	0.93
SO_3	-0.12	2.71
K_2O	2.16	0.97
Na_2O	0.27	0.14
Mn_2O_3	0.02	0.20
P_2O_5	0.03	0.17
TiO_2	0.67	0.28

Table 2: physical properties of Termite Mound and fine aggregate

Properties	*Termite mound*	*Fine aggregate (Soft Sand)*
Specific gravity	2.57	2.65
Coefficient of uniformity	3.0	4.37
Moisture content (%)	2.20	0.74
Fineness modulus	2.09	2.13
Liquid limit (%)	36.0	-
Plastic limit (%)	17.58	-
Plasticity index (%)	18.42	-

3.2 *Effect of Termite Mound – Lime on Compressive Strength of Cement Mortar Cured in Water*

The effect of termite mound and Lime blended with cement on the compressive strength of two mix ratios of 1: 4 and 1: 6 were investigated. The results, as presented in Figures 1 and 2 show that the compressive strength of specimens with only cement mortar (that is 0% termite mound-lime content) in the two mix ratios increases from 9.40 N/mm^2 to 18.00 N/mm^2, and 7.40 N/mm^2 to 13.00 N/mm^2 at 7 days to 56 days for mix ratio 1: 4 and 1: 6, respectively.

With the blending of termite mound-lime with cement the compressive strength values changes. For instance, 10% replacement of cement with termite mound-lime recorded a reduction in the compressive strength with respect to the control by 10.64%, 12.96%, 23.88%, 29.27% and 26.17% for mix ratio 1: 4; and 13.51%, 5.26%, 8.00%, 10.34% and 20.00% for mix ratio 1: 6 at ages of 7, 14, 21, 28 and 56 days, respectively. This trend was observed for other replacement levels of 20%, 30%, 40% and 50% termite mound-lime with cement in both mix ratios.

It was observed that at each replacement level in mix ratio 1: 4, the compressive strength increases with curing age up to 30% content of termite mound-lime but the reversed was the case with 40% and 50% content; whereas in mix ratio 1: 6, the compressive strength increases with curing age in all the replacement levels but decreases with increase in the termite mound-lime content. It was equally observed that in all the mixes, the mix ratio 1: 4 had a higher compressive strength than mixes in the mix ratio 1: 6.

At 28 days hydration period, which is the standard age, the compressive strength for mix ratio 1: 4 were 16.4 N/mm^2, 11.7 N/mm^2, 10.80 N/mm^2, 9.80 N/mm^2, 6.60 N/mm^2, and 5.40 N/mm^2 for replacement level of 0%, 10%, 20%, 30%, 40% and 50%, respectively; while that of mix ratio 1: 6 were 11.60 N/mm^2, 10.4 N/mm^2, 6.40 N/mm^2, 6.40 N/mm^2, 5.60 N/mm^2 and 5.40 N/mm^2 for 0% to 50% termite mound-lime content, respectively.

From these results it can be said that mixtures containing 0% and 10% termite mound-lime content of mix ratio 1: 4 met the requirement for type S mortar as specified by ASTM C270 (2006) while other mixtures from both mix ratios could be classified into type N mortar for having attained a value above the minimum of 5.2N/mm^2 (ASTM C270; 2006). Therefore, the blending of cement with termite mound-lime up to 50% produced a general all-purpose mortar with higher flexural bond strength (Type S) and good bonding capabilities and workability (Type N).

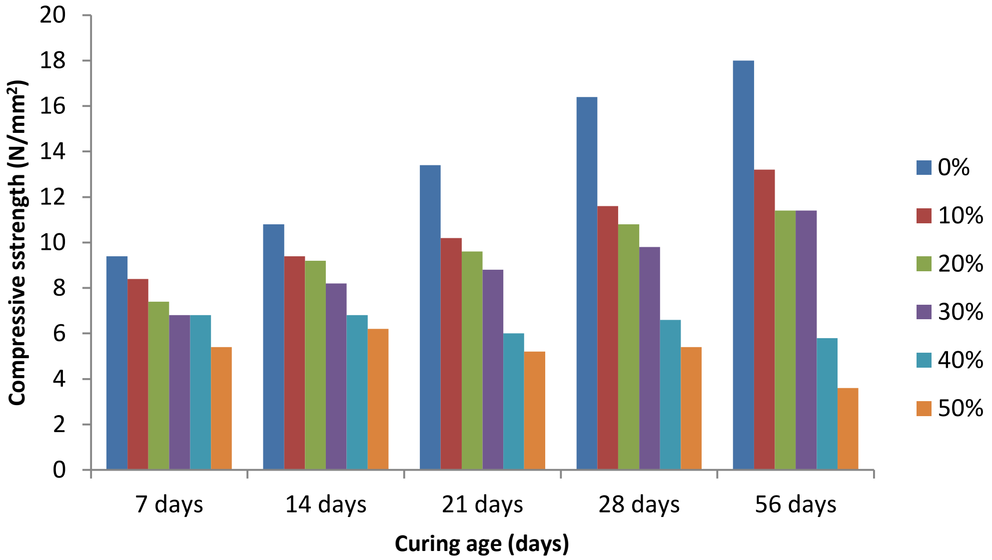

Figure 1: Variation of compressive strength against curing age for Termite mound-lime blended Cement Mortar mix ratio 1:4 cured in water

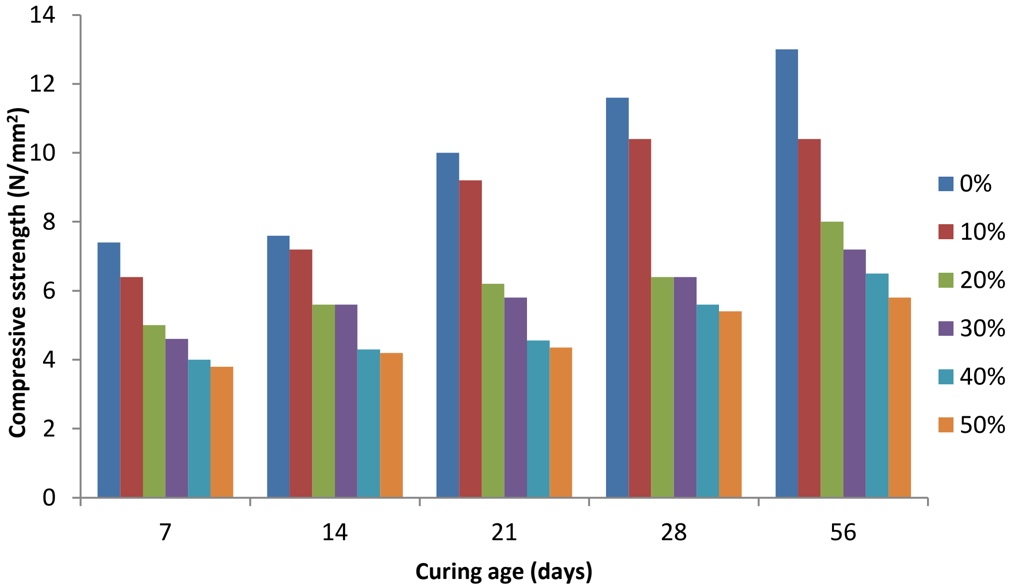

Figure 2: Variation of compressive strength against curing age for Termite mound-lime blended Cement Mortar mix ratio 1:6 cured in water

3.3 Compressive Strength of Termite Mound – Lime Cement Mortar in Acidic Environment

The compressive strength of termite mound-lime cement blended mortar specimens of 1: 4 and 1: 6 mix ratios exposed to Sulphuric and Nitric acids of 1% and 3% concentrations, in each acid type, are presented in Tables 2 and 3. The compressive strength is observed to reduce with increased in curing age, replacement level of cement with termite mound-lime from 0% to 50% as well as acid and concentration in each mix ratio. However, it is equally observed that a mix ratio of 1: 4 seems to be less effected by the acid attack than a mix ratio of 1: 6. For instance, the compressive strength attainment at 28 days in mix ratio 1: 4 and immersed in H_2SO_4 of 1% concentration reduces from 5.20N/mm^2 for the control to 1.04N/mm^2 for 50% termite mound-lime content; and that a concentration of 3% were much affected than 1% concentration, which is an indication that the higher the concentration of the solution the grater the effect of the attack. Nitric acid was observed to have less effect on the specimens when compared to Sulphuric acid.

It is worthy to note that the Ternary blended mortar made with termite mound-lime-cement has less resistance to acid attack than the control. The reason could be that the termite mound is not an amorphous pozzolan, since it was not calcined (Sabir *et al*., 2001), and therefore could not consume the calcium hydroxide [Ca $(OH)_2$] released during the hydration process of the cement, and became vulnerable to the acid attack. Therefore, the termite mound is not recommended for use without being calcined to make it amorphous before being used in acidic environment.

Table 3: Compressive Strength of Termite Mound - Lime Blended Cement Mortar Immersed In H_2S0_4

Termite mound and lime content (%)	*Curing Age (Days)*	*Compressive Strength (N/mm²)*			
		1% concentration		*3% concentration*	
		1:4 mix ratio	*1:6 mix ratio*	*1:4 mix ratio*	*1:6 mix ratio*
0	7	6.20	5.58	5.92	5.40
	14	5.90	4.20	5.72	4.80
	21	5.70	4.06	4.80	3.74
	28	5.20	2.80	4.20	2.40
	56	4.60	2.20	4.00	1.80
10	7	4.60	3.90	3.94	3.90
	14	4.18	3.20	3.88	2.80
	21	3.60	2.24	3.32	1.82
	28	3.30	1.80	3.20	1.28
	56	2.80	1.46	2.70	1.20
20	7	3.20	3.00	3.10	2.80
	14	3.14	2.80	2.80	2.40
	21	2.90	1.60	2.60	1.70
	28	2.76	1.36	2.58	1.30
	56	2.58	1.22	2.50	1.06
30	7	3.10	2.80	2.54	2.40
	14	2.50	1.90	2.02	1.90
	21	2.34	1.40	2.00	1.40
	28	2.32	1.20	1.92	1.20
	56	2.08	1.06	1.72	1.00
40	7	2.42	1.66	2.00	1.26
	14	2.32	1.40	1.80	1.08
	21	1.40	0.90	1.20	0.90
	28	1.28	0.84	1.12	0.90
	56	1.12	0.80	1.00	0.80
50	7	1.34	1.04	1.26	1.04
	14	1.14	0.80	1.00	0.80
	21	1.20	0.80	0.44	0.80
	28	1.04	0.50	0.40	0.80
	56	0.92	0.40	0.32	0.50

Table 4: Compressive Strength of Termite Mound and Lime Blended Cement Mortar Immersed in HNO_3

Termite mound and lime content (%)	*Curing Age (Days)*	*Compressive Strength (N/mm²)*			
		1% concentration		*3% concentration*	
		1:4 mix ratio	*1:6 mix ratio*	*1:4 mix ratio*	*1:6 mix ratio*
0	7	5.80	5.50	5.50	4.98
	14	5.30	4.00	4.52	3.80
	21	4.90	3.60	4.30	3.30
	28	4.70	2.60	4.08	2.30
	56	4.50	1.80	3.80	1.50
10	7	4.10	3.60	3.50	3.44
	14	4.08	3.00	3.14	2.50
	21	3.40	1.88	2.90	1.50
	28	3.20	1.60	2.80	1.24
	56	2.70	1.20	2.04	1.10
20	7	3.02	2.42	2.86	2.40
	14	2.54	2.30	2.24	2.20
	21	2.20	1.50	2.06	1.14
	28	2.00	1.10	1.58	1.06
	56	1.80	1.10	1.40	0.80
30	7	3.10	1.70	2.20	1.60
	14	2.20	1.64	2.04	1.16
	21	2.10	1.10	2.00	0.80
	28	1.70	0.94	1.40	0.80
	56	1.34	0.90	1.30	0.80
40	7	1.80	1.50	1.44	1.00
	14	1.40	1.20	1.28	0.60
	21	1.20	0.80	1.12	0.50
	28	1.08	0.80	1.00	0.40
	56	0.96	0.76	0.88	0.26
50	7	1.32	0.90	1.20	0.52
	14	1.12	0.70	1.00	0.50
	21	1.10	0.66	0.44	0.50
	28	0.94	0.36	0.40	0.40
	56	0.92	0.32	0.32	0.26

3.4 Effect of Acidic Media on Compressive strength of Termite Mound – Lime Blended Cement Mortar

The effect of Sulphuric and Nitric acids on cement mortar and termite mound-lime blended cement mortar in term of their loss in compressive strength are presented in Figures 3 to 10. The loss in strength was computed based on reference specimens that were cured in water (Equation 1).

The percentage loss in compressive strength for specimens immersed in 1% H_2SO_4 solution range between 34.04% and 80.74% for mixtures of mix ratio 1: 4 (Figure 3), and 24.59% and 93.10% for mixtures of mix ratio 1: 6 (Figure 4). In 3% H_2SO_4 solution, the percentage loss increased to 37.02% and 92.59% for mixtures in the ratio of 1: 4 ratio (Figure 5), and 27.03% and 94.83% for mixtures of 1: 6 ratio (Figure 6). The high increase in the percentage loss in strength due to the H_2SO_4 attack confirmed the earlier findings by Neville (2000) that Sulphuric acid is very damaging to cement matrix as it combine an acid and Sulphate attack.

In Figures 7 and 8, the percentage loss in compressive strength for mixtures of 1: 4 and 1: 6 mix ratios when immersed in 1% HNO_3 solution range between 38.30% and 88.25%, and 25.68% and 94.48%, respectively. In 3% HNO_3 solution as shown in Figures 9 and 10, there is an increased in strength loss as it range from 41.49% to 92.59%, and 32.70% to 96.00% for mix ratio 1: 4 and 1: 6, respectively. The attack by Nitric acid is closely as severe as that of the sulphuric acid, its effect on cement-based materials at brief exposure have been observed to be more destructive since it transforms the calcium hydroxide [Ca $(OH)_2$] released during cement hydration into the highly soluble calcium nitrate salt and a low soluble calcium nitroaluminate hydrate (Olusola and Joshua, 2012).

Generally, a least value of strength loss was noticed with a curing age of 7 days and with cement mortar (that is 0% termite mound-lime content), while greatest values were noticed at 56 days in each replacement level of termite mound-lime with cement. It was equally noticed that deterioration became more pronounced with increased in the quantity of termite mound-lime content. This could be attributed to the fact that termite mound is not a very active pozzolan.

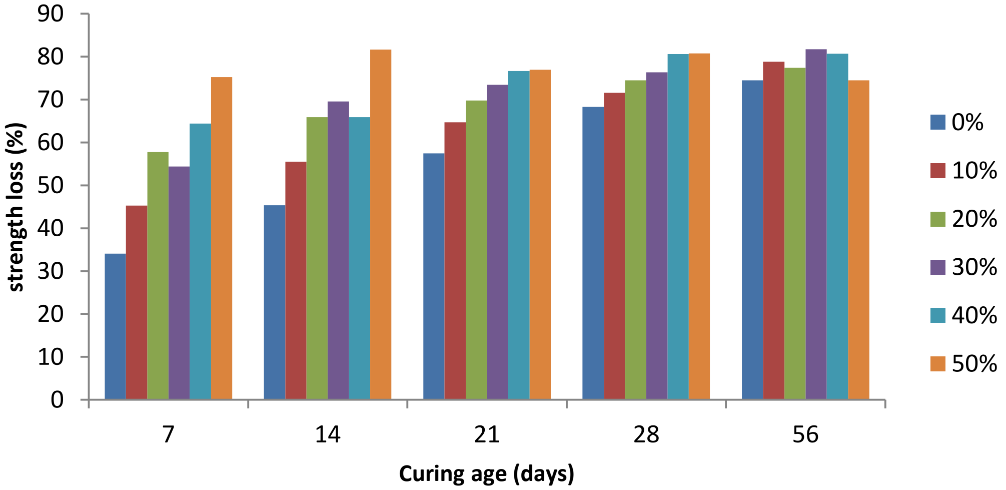

Figure 3: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:4 exposed in 1 % H_2SO_4 concentration

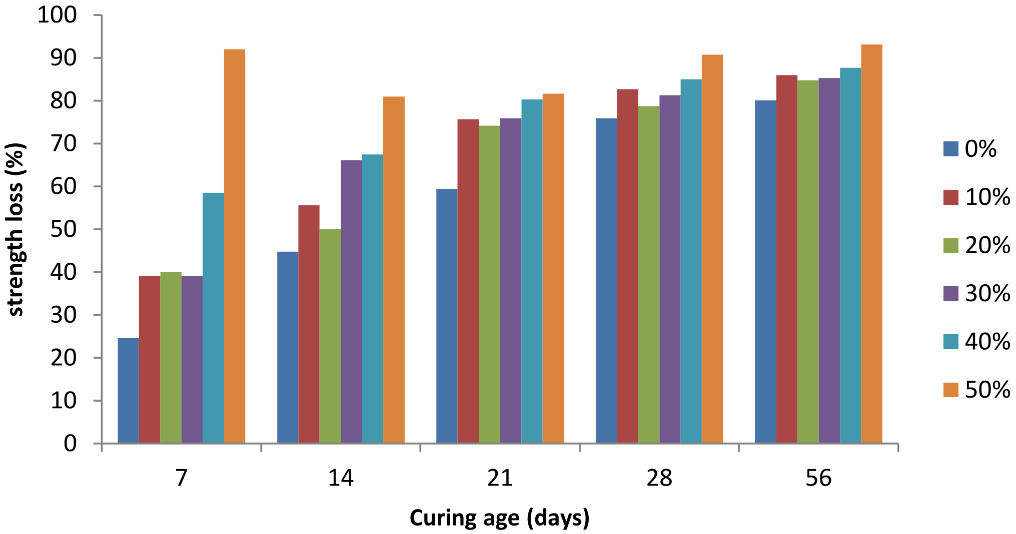

Figure 4: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:6 exposed in 1 % H_2SO_4 concentration

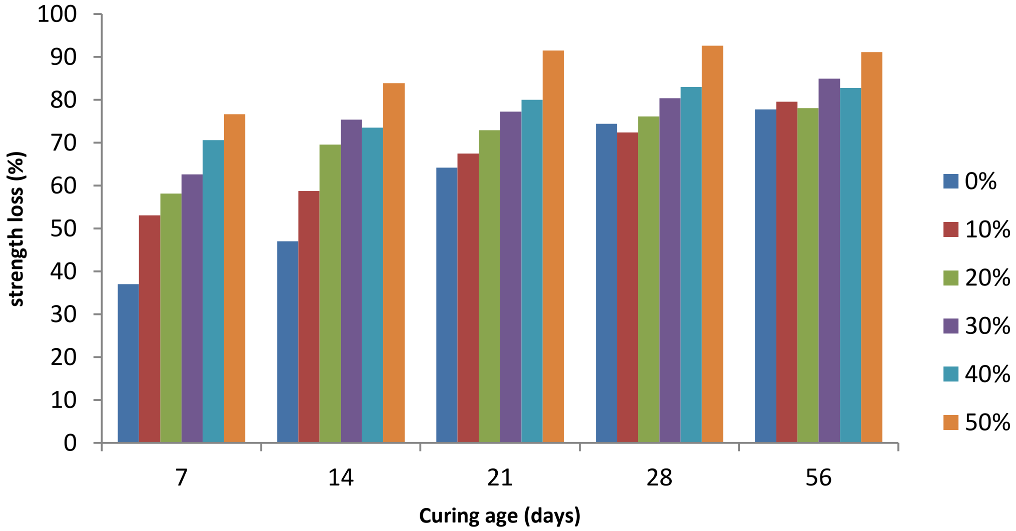

Figure 5: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:4 exposed in 3 % H_2SO_4 concentration

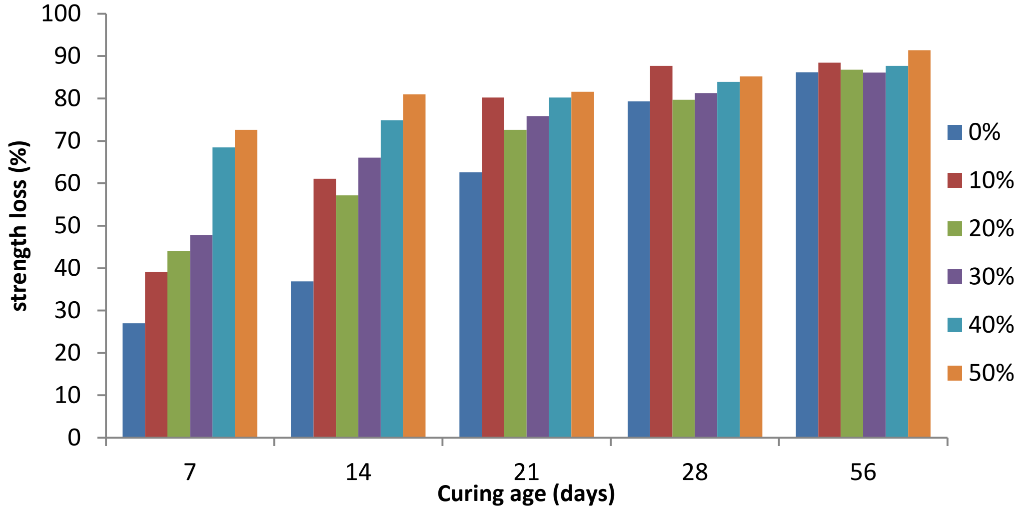

Figure 6: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:6 exposed in 3 % H_2SO_4 concentration

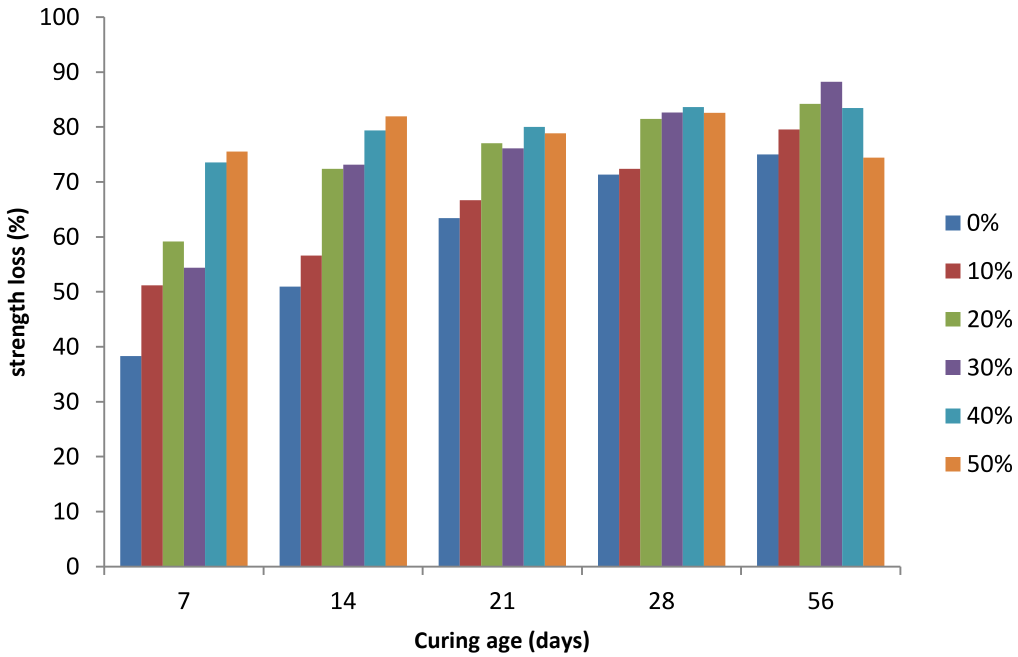

Figure 7: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:4 exposed in 1 % HNO_3 concentration

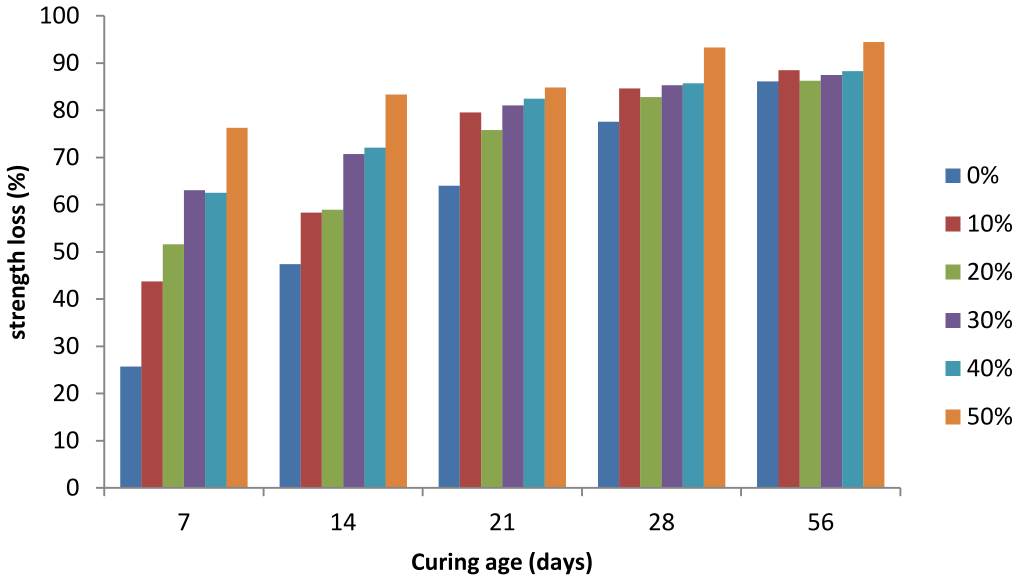

Figure 8: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:6 exposed in 1 % HNO_3 concentration

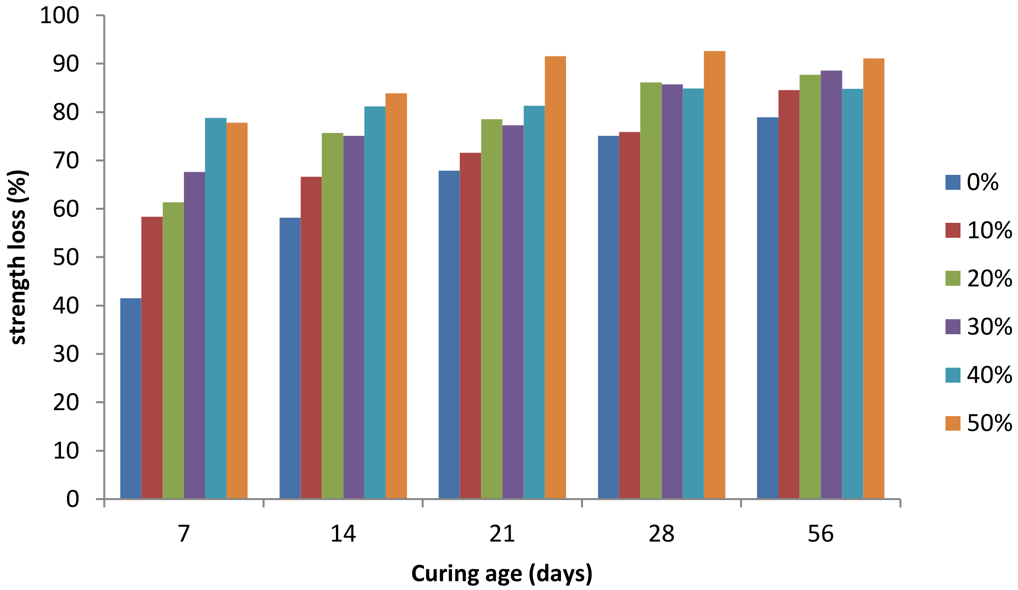

Figure 9: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:4 exposed in 3 % HNO_3 concentration

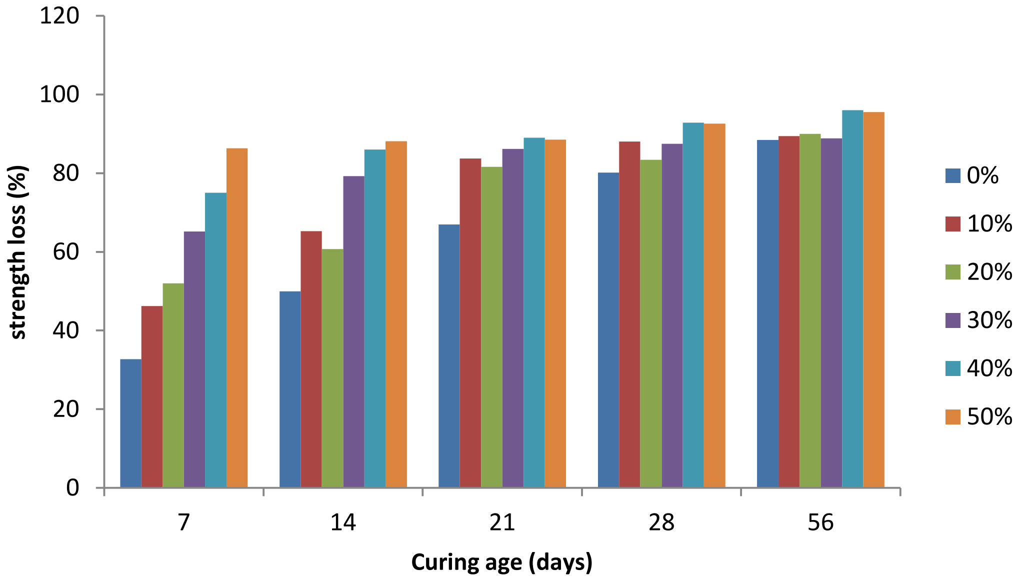

Figure10: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:6 exposed in 3 % HNO_3 concentration

4.0 Conclusions

The following conclusions can be made from this study:

- The compressive strength of the mortar increases with age but decreased with percentage replacement of cement with termite mound - lime when cured in water.
- The compressive strength of the mortar when immersed in acidic medium, decreases with increased in curing age as well as replacement level of cement with termite mound-lime
- The higher in concentration of the acidic medium, the higher the effect of the acid on the compressive strength of termite mound - lime blended cement mortar.
- The effect of H_2SO_4 on the compressive strength was more aggressive than that of HNO_3.
- The mixtures of mix ratio 1:4 performed better than mixtures of mix ratio 1:6 in terms of compressive strength and its resistance to acid attack.

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