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Durability of Termite Mound Lime-Blended Cement Mortar Mixtures

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Abstract: ***The study aimed at investigating the performance of blended cement mortar mixtures containing termite mound and lime with a view to ascertaining their suitability as materials for building construction. The objectives were to determine the effect of varying percentage replacement of cement with termite mound and lime on the compressive strength, water absorption and performance in magnesium sulphate environment of blended cement mortar. Tests were performed on 50 x 50 x 50 mm cube specimens for compressive strength and water absorption tests. Specimens tested for compressive strength are cured in magnesium sulphate concentration (2%). The tests were conducted in conformity with the relevant British standard. Data obtained were analyzed using the statistical methods of mean and analysis of variance. Test results were presented using graphical methods. The results revealed that the compressive strength of the mortar cubes increased with age and decrease with increasing percentage replacement of cement with lime and termite mound. At 25% termite mound content, the termite mound content, the percentage increase in compressive strength between the curing ages of 7, 14, 21 and 28 days were 66.73%, 69.23%, 84.62% and 100%. Maximum compressive strength of 8.13N/mm^2 and 5.20 N/mm^2 were obtained for mix ratios 1:4 and 1:6 at 25% replacement. For the magnesium sulphate environment, the maximum compressive strength of 7.46N/mm^2 and 6.80N/mm^2 were obtained for 1:4 and 1:6 at 25% replacement. This was obtained for cement/termite mound. The study concluded that up to 25% replacement of termite mound and lime was adequate for the replacement of cement in mortar.***

Keywords: **termite mound, suitability, mortar mixtures, water absorption, lime.**

I. INTRODUCTION

One of the fundamental needs of human is housing. Housing in this context encompasses, together with the shelter it provides, all infrastructural facilities installed, social services incorporated and environmental conditions considered in making the environment comfortable for habitation (Federal Republic of Nigeria National Housing Policy, 1991; Olusola *et al.*, 2004). In order to satisfy housing needs, various strategies and means are being devised by engineers, researchers, government in improving the standard.

Unfortunately, Nigeria, as in most developing countries, with a population of about 150million people is faced with the problems of getting this fundamental need met.

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The factors that might have contributed to this assertion include, among others, the lack of soft loans for housing projects, astronomical increases in the cost of conventional building materials, especially sand, cement and other 'concrete' components and lack of interest of government or the private sector in serious investment on building materials research and development, mass production and patronization. (Olateju, 1991; Olusola and Adesanya, 2004 and Anthonio, 2002).

The unbridled increase in the cost of conventional building materials stands as the major challenge or factor affecting housing delivery in Nigeria since materials account for between 40-60% of the total construction cost as reported in literature. (Ayangade *et al.*, 2004 ; Olanipekun *et al.*, 2005). This increase in the cost is caused by the high rate of importation of these building materials which comes with its attendant inflation, devaluation of currency, under development in science and technology which is an important criterion in the general development of a country.

A termite is any member of the order Isoptera, a group of social insects that eat wood and other cellulose – rich vegetable matter. They occur between latitude 45°N and 45°S where they are restricted by a combination of extreme aridity and lack of vegetation. (Badejo, 2002). They are also rarely found at altitudes above 3000m. (Wood, 1988).Termite live in organized colonies comprising hundreds to millions of individual inside a nest system which could be arboreal, epigeal or subterranean (Kang, 1978). A colony consists of several castes which are morphologically and functionally distinct. The reproductive start a colony usually after a nuptical flight when they drop to the ground shed their wings, pair up and burrow into the soil. The female lays the first batch of eggs which hatches into worker and soldier castes. The workers immediately embark on the task of construction of galleries and foraging for food. The male and female become the king and the queen respectively and they remain in the royal chamber constructed by the workers for the rest of their lives

About 2500 species of termite has been identified worldwide. Nearly all of them have been implicated in soil modification which can be brought about by construction of subterranean galleries, changes in distribution of plant nutrients, changes in nature and distribution of organic matter, changes in texture and physical disturbance of soil profiles (Wood, 1988). Only 300 out of these 2500 species has been recorded as pest (Logan *et al.*,1990). The degree of damage done by these pests to crops and wood is so enormous that people fail to

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recognize or simply refuse to acknowledge the positive role played by the majority of the species in the soil ecosystem. Most termite species are tropical or subtropical, but a few live in temperate regions. Termites have thrived on our planet for the past 250 million years. Technically, there are three major types of termite namely dry-wood, subterranean and damp-wood termite. Dry wood termites prefer to live above the soil, taking up residence in wood structures such as trees, houses and even furniture. Once established, a colony of wood-inhabiting termites can slowly weaken a wooden structure, but the visible evidence of damage may not be noticeable for at least two years. (Jone, *et al*.,1994).

Researches have been conducted for the purpose of reducing the cost of materials used in concreting, roofing, floor, floor finishes and so on by the replacement of the conventional materials with locally available materials. This follows the current trend of seeking alternatives to conventional materials using materials that the immediate environment can afford. Some of the locally available materials that have been found suitable are rice husk, corncob ash, sawdust ash and bamboo leaf ash as cement replacement materials, and palm kernel shells as replacement for the conventional coarse aggregates (gravel, granite, stone, marble, etc).

II. LITERATURE REVIEW

Concrete, the most widely used building material in industrialized countries, is based on Portland cement as binder. Portland cement is produced in Nigeria, but its production is inadequate to facilitate extensive rural housing development of higher quality. Moreover, the unabated continuous increase in the cost of cement is making this very important and essential construction material almost unaffordable for the low income earners. Attention is therefore being focused on the development of appropriate technology concepts, making use of local raw materials. (Olusola and Adesanya, 2004).

Shortage of building materials and the continuous increase in the cost of procuring them are just two out of all the factors responsible for the current acute short fall in the provision of adequate housing in urban and rural areas of Nigeria, particularly when most materials have to be imported (Osunade, 2002; Meukan *et al*., 2002).

Researches had been carried out in the past on the suitability of using locally available materials, even as they relate to mortar, termite mound and lime. A review of these previous research works will help in the actualization of this present one.

Mortar is the bonding agent that integrates masonry units into a masonry assembly. Mortar must be strong, durable, and capable of keeping the masonry intact and it must help to create a water resistant barrier. It must accommodate dimensional variations and physical properties of the brick when laid. These requirements are influenced by the composition proportions and properties of mortar; because concrete and mortar contain the same principal ingredients, it is often erroneously assumed that good concrete practice is also good mortar practice. In reality, mortar differs from concrete in working consistencies, methods of placement, and structural performance. Mortar is used to bind masonry units into a single element, developing a complete, strong and durable bond. Concrete however, is usually a structural element itself. Mortar is usually placed between absorbent masonry units, and loses water upon contact with the units. Concrete is usually placed in non-absorbent metal or wooden forms that absorb little, if any, water. The importance of the water cement ratio for concrete is significant, whereas for mortar it is less important. Mortars have a high water cement ratio when mixed, but this ratio changes to a lower value when the mortar comes in contact with the absorbent units (Schmitt, 2005).

The prime function of mortar is to bond masonry units into a monolithic mass. Conversely, mortar keeps the units apart, filling all the cracks and crevices and providing a uniform bedding surface. Bonding must be accomplished in such a way that the structural properties of the units are consolidated, at the same time ensuring a barrier to the entry of wind-driven rain. This requires a complete extent of bond if it is successful, will make the wall possess sufficient durability to withstand exposure to the elements. Lime mortar cures slowly by carbonation under the influence of carbon dioxide in the air, a process seriously retarded by cold, wet weather. Lime is not commonly used in the dry hydrated lime and it could be used on its own or mixed with cement.

Masonry Cement is a proprietary product containing Portland cement and an inert mineral filler (limestone) plus additive such as air entraining and wetting agents and water repellents. The additives provide the plasticity and water retentivity contributed by lime in cement-lime mortars. Some masonry cements are blended mixtures of Portland cement and hydrated lime, plus additives.

Lime mortar is created by mixing sand and quicklime, or quicklime and cement mortar and water. The earliest known use of lime mortar dates to about 4000BC in Ancient Egypt. Lime mortars were used throughout the world, notably in Roman Empire buildings throughout Europe and Africa.

Sahmaran *et al.* (2007) reported on the sulphate resistance of blended cements containing various amounts of natural pozzolan or Class C fly ash. The performance of the blended cement was monitored by exposing the prepared mortar specimens to a 5% Na_2SO_4 for 78weeks. Comparisons were also made on an ordinary Portland cement (produced with the same clinker as blended cements) and sulphate Portland cement (produced from a different clinker) water-cement ratio was another parameter selected which could affect the performance of mortars. The experimental result of expansion

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measurement showed that the effect of water cement ratio was more pronounced for the low sulphate resistance cement with higher C_3A amounts, while the blended cements were less affected by an increase in the water cement ratio.

Lee and Wood 1991, Malaka 1992 and Kooyman and Onok, 1987 have reviewed the effects of termites on the chemical and physical composition of soils extensively. It is now widely accepted that termites affect the structure, mineral composition, organic content and porosity of soil by their tunneling, mound-building and construction of nests and galleries (Logan, 1992).

Termite modified soils in mounds have been compared with adjacent soil by many researchers (Anderson and Wood, 1984) who have reported that there are highest concentrations of Ca, K, P and exchangeable cations in termite mounds than the adjacent topsoil and subsoil. These have been attributed to the high level of faecal derived organic matter and clay content of the mounds. In particular, the exceptional amounts of Ca found in concretionary form at the base of some Macro termites mounds are apparently the result of evaporative processes accelerated by the presence of Calcium-rich groundwater and impeded drainage (Hesse, 1995). There is indeed empirical evidence that the concentration of Calcium carbonate in mound is equivalent to an agricultural dressing of 11 tonnes/ ha if spread on the surrounding land (Badejo, 2002). The large increase in available phosphorous in mounds of soil feeding termites observed by Anderson and Wood (1984) has been attributed by Wood (1988) to the high PH in the hindgut of the soil feeders.

III. METHODOLOGY AND MATERIALS

The approach will be more of an experimental methodology; it involves mainly laboratory experimental work. It discusses the materials, instrumentation, basic laboratory analysis, tests and the experimental procedures for the main aspect of the work. The proposed methods of data collection and treatment including appropriate data statistical analysis will be discussed. A combination of descriptive statistics, empirical and graphical relationships and principle of full factorial experimental design will be used in the treatment of the data generated from the laboratory tests. Relative comparisons will be made with the existing related data obtained from the literature as the cases may require.

A. Materials and Preliminary Laboratory Analysis of Samples

The basic materials to be used for this study are soft common sand (the type used for rendering), Ordinary Portland cement, lime, termite mound and water.

B. Cement content

For an equivalent grade the assurance of minimum cement content was used and batched by weight to comply with the specified minimum cement content if the compressive strength results for the equivalent grade are to comply with the requirements of clause 3.1.6.2.of BS 5328 Part 4:1990

C. Lime mortar

Mortar is the bonding agent that integrates masonry units into a masonry assembly. Mortar must be strong, durable, and capable of keeping the masonry intact and it must help to create a water resistant barrier. It must accommodate dimensional variations and physical properties of the brick when laid. These requirements are influenced by the composition proportions and properties of mortar; because concrete and mortar contain the same principal ingredients, it is often erroneously assumed that good concrete practice is also good mortar practice. In reality, mortar differs from concrete in working consistencies, methods of placement, and structural performance. Mortar is used to bind masonry units into a single element, developing a complete, strong and durable bond. Concrete however, is usually a structural element itself. Mortar is usually placed between absorbent masonry units, and loses water upon contact with the units. Concrete is usually placed in non-absorbent metal or wooden forms that absorb little, if any, water. The importance of the water cement ratio for concrete is significant, whereas for mortar it is less important. Mortars have a high water cement ratio when mixed, but this ratio changes to a lower value when the mortar comes in contact with the absorbent units (Schmitt, 2005).

D. Termite mound

A termite is any member of the order Isoptera, a group of social insects that eat wood and other cellulose – rich vegetable matter. They occur between latitude 45°N and 45°S where they are restricted by a combination of extreme aridity and lack of vegetation. (Badejo, 2002). They are also rarely found at altitudes above 3000m. (Wood, 1988).Termite live in organized colonies comprising hundreds to millions of individual inside a nest system which could be arboreal, epigeal or subterranean (Kang, 1978). A colony consists of several castes which are morphologically and functionally distinct. The reproductive start a colony usually after a nuptical flight when they drop to the ground shed their wings, pair up and burrow into the soil. The female lays the first batch of eggs which hatches into worker and soldier castes. The workers immediately embark on the task of construction of galleries and foraging for food. The male and female become the king and the queen respectively and they remain in the royal chamber constructed by the workers for the rest of their lives.

E. Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it and allows it to flow more freely. Less water in the cement paste will yield a stronger, more durable concrete; more water will give a freer-flowing concrete with a

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higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete, to form a solid mass.

F. Compressive strength

Various tests and analyses were carried out on the selected samples in order to ensure that they comply with various established standards on which this research work is based. The preliminary test to be carried out on the soil samples will be grading (sieve analysis), mechanical analysis to determine the physical components of termite mounds namely moisture content and Atterberg limits and chemical analysis of termite mound to determine the basic oxide composition.

Three mortar mixtures used are cement/termite mound, cement/termite mound/lime and cement/lime mixtures. Cubes cast from these mixtures were tested for their compressive strengths at ages 7, 14, 21and 28days for the two mixes of 1:4 and 1:6 the results of the compressive strength of the mortar cube specimens are presented in Tables 1 to 4 and figures 1 to 4. While the mean compressive strength for each curing age and its percentage of the 28-day strength are shown in the tables, the figures show the effect of percentage replacement of cement with termite mound and lime and mix proportion on the compressive strength of the mortar. The figures show that for the two mix ratios investigated, the compressive strength generally increases with curing age and decreases with increasing percentage replacement of cement with lime and termite mound.

For normal mortar at 0% replacement level of cement with termite mound and lime, that is, at 100% cement, for 1:4 mix proportion with a water binder ratio of 1.1, the percentage increase in strength between the two consecutive curing ages are 50.80%, 77.12%, 86.96%, 100% respectively. As shown in from Table 1 and Figure 1 that the percentages increase in strength was higher within the curing age of 7 and 14days. The compressive strength at 7-day curing age was 4.13 N/mm^2 and the corresponding compressive strength at 14-day curing age was 6.27 N/mm^2.

The same explanation holds for the behavior of termite mound lime blended cement for mix proportion 1:4 with a water binder ratio of 1.1 at replacement level of 25% of cement with termite mound the mean compressive strength at that level for the curing ages of 7, 14, 21 and 28 days are 3.60, 5.80, 6.67 and 7.20N/mm^2. The percentage increases in strength are 50%, 80.56%, 92.64% and 100%. It can be noticed that there was a higher increase in compressive strength between the curing age of 7, 14, 21 and 28days.

IV. DATA PRESENTATION AND ANALYSIS

The data obtained are hereby presented and analysed.

A. *Compressive strength of blended cement/termite mound specimen (1:4)*

Table 1 shows the Compressive strength of blended cement/termite mound specimen(1:4). It showed that there is a percentage increase in strength at the level for the curing ages.

Table 1: Compressive strength of blended cement / termite mound specimen (mix proportion 1:4)

Percentage replacement of Cement with termite mound	Curing Age (days)	Mean compressive strength (N/mm^2)	Percentage of 28 days strength
0	7	4.13	50.8
	14	6.27	77.12
	21	7.07	86.96
	28	8.13	100
25	7	3.6	50
	14	5.8	80.56
	21	6.67	92.64
	28	7.2	100
50	7	2.8	2.8
	14	4.13	4.13
	21	4.93	4.93
	28	6.13	6.13
75	7	2.13	43.2
	14	2.93	59.43
	21	3.6	73.02
	28	4.93	100
100	7	1.87	51.94
	14	2.13	59.17
	21	2.93	81.39
	28	3.6	100

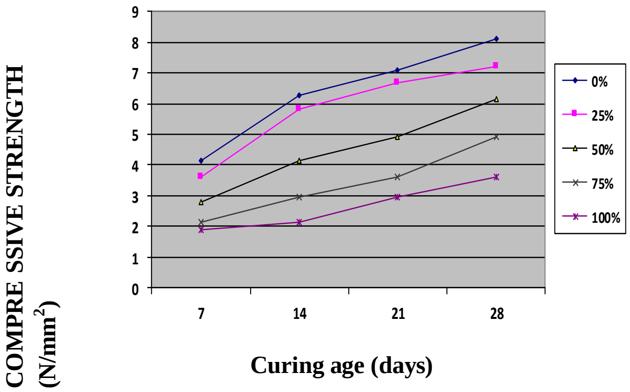

Fig. 1: Variations of compressive strength of blended cement / termite mound specimen (mix proportion 1:4)

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For mix proportion 1:6 the percentage increase in strength between the curing ages are 66.73%, 69.23%, 84.62% and 100%. It can be seen from Table 2 and Figure 2 that the percentage increase in compressive strength was higher between the curing age of 14 and 21days at replacement of 0%, 25%, 50%, 75% and 100% for which the compressive strengths are 3.60 N/mm^2 and 4.40 N/mm^2, 3.47 N/mm^2 and 3.87 N/mm^2, 2.40 N/mm^2 and 2.50 N/mm^2, 1.87 N/mm^2 and 2.13 N/mm^2, 1.77N/mm^2 and 2.00N/mm^2 respectively. Table 2 shows the Compressive strength of blended cement/termite mound specimen(1:4). It showed that there is a percentage increase in strength at the level for the curing ages.

Table 2: Compressive strength of blended cement/termite mound specimen (mix proportion 1:6)

Percentage replacement of Cement with termite mound	Curing Age (days)	Mean compressive strength (N/mm^2)	Percentage of 28 days strength
0	7	3.47	66.73
	14	3.60	69.23
	21	4.40	84.62
	28	5.20	100.00
25	7	3.07	65.74
	14	3.47	74.30
	21	3.87	82.87
	28	4.67	100.00
50	7	2.13	53.25
	14	2.40	60.00
	21	2.53	63.25
	28	4.00	100.00
75	7	1.73	54.06
	14	1.87	58.44
	21	2.13	66.56
	28	3.20	100.00
100	7	1.60	63.24
	14	1.77	69.96
	21	2.00	79.05
	28	2.53	100.00

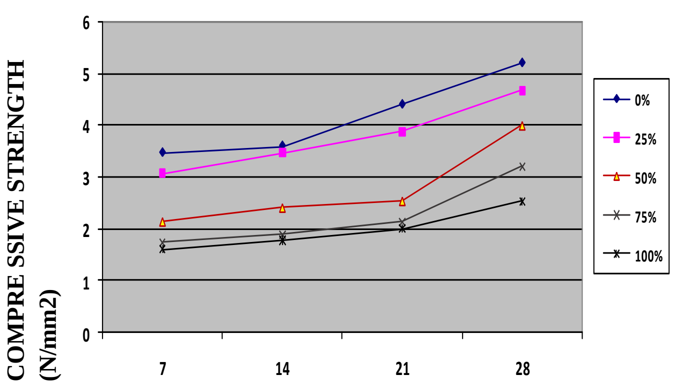

Fig. 2: Variations of compressive strength of blended cement/termite mound specimen (mix proportion 1:6)

Table 3 shows that the compressive strength at 7 days for 0%, 25%, 50%, 75% and 100% percentage replacement of cement with termite mound are 3.20 N/mm^2, 3.06 N/mm^2, 2.80 N/mm^2, 1.86 N/mm^2 and 1.73 N/mm^2 respectively as against the control value of 3.20 N/mm^2 for 1:4 mix proportion. Strengths decreases significantly with respect to the control in 2% $MgSO_4$. A similar trend was observed for 1:6 mix ratio.

Table 3: Compressive Strength of Blended Cement/Termite Mound Specimen Subjected to 2% Magnesium Sulphate Environment (mix proportion 1:4)

Percentage replacement of Cement with termite mound	Curing Age (days)	Mean compressive strength (N/mm^2)	Percentage of 28 days strength
0	7	3.20	42.90
	14	4.93	42.90
	21	7.06	66.09
	28	7.46	100.00
25	7	3.06	48.88
	14	4.00	63.90
	21	5.46	87.22
	28	6.26	100.00
50	7	2.80	56.80
	14	2.93	59.43
	21	3.86	78.30
	28	4.93	100.00
75	7	1.86	55.86
	14	2.27	68.17
	21	2.67	80.18
	28	3.33	100.00
100	7	1.73	61.79
	14	2.13	76.07
	21	2.40	85.71
	28	2.80	100.00

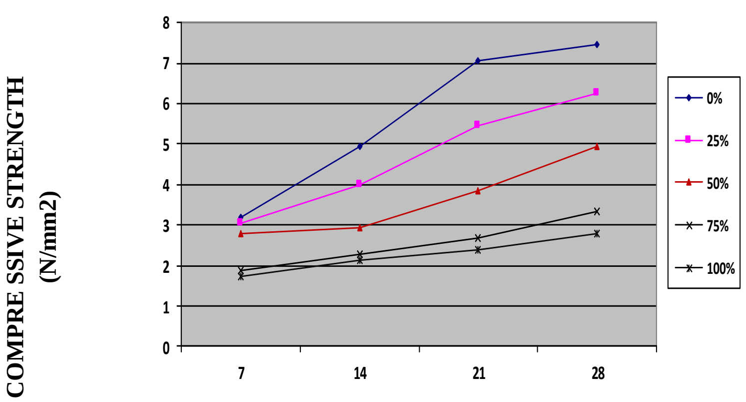

Fig. 3: Variations of compressive Strength of Blended Cement/Termite Mound Specimen Subjected to 2% Magnesium Sulphate Environment (mix proportion 1:4)

Table 4 shows that the compressive strength at 7 days for 0%, 25%, 50%, 75% and 100% percentage replacement of cement with termite mound are 3.60

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N/mm^2, 2.00 N/mm^2, 1.86 N/mm^2, 1.20 N/mm^2 and 1.00 N/mm^2 respectively as against the control value of 3.60 N/mm^2 for 1:6 mix proportion. Strengths decreases significantly with respect to the control in 2% $MgSO_4$.

Table 4: Compressive Strength of Blended Cement/Termite Mound Specimen Subjected to 2% Magnesium Sulphate Environment (mix proportion 1:6)

Percentage replacement of Cement with termite mound	Curing Age (days)	Mean compressive strength (N/mm^2)	Percentage of 28 days strength
0	7	3.60	52.94
	14	4.53	66.62
	21	6.00	88.24
	28	6.80	100.00
25	7	2.00	62.50
	14	2.53	79.06
	21	2.80	87.50
	28	3.20	100.00
50	7	1.86	66.43
	14	2.13	76.07
	21	2.66	95.00
	28	2.80	100.00
75	7	1.20	50.00
	14	1.60	66.67
	21	1.80	75.00
	28	2.40	100.00
100	7	1.00	50.00
	14	1.33	66.50
	21	1.60	80.00
	28	2.00	100.00

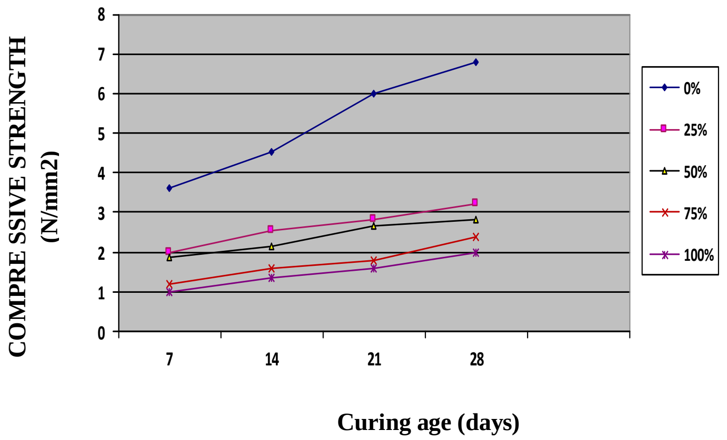

Fig. 4: Variations of compressive Strength of Blended Cement/Termite Mound Specimen Subjected to 2% Magnesium Sulphate Environment (mix proportion 1:6)

V. DISCUSSION

It is the need for the effective utilization of locally available building materials and for converting the waste product – termite mound and lime into binder was highlighted with a view to widening the scope of locally available building raw materials. The results of data obtained from laboratory tests and data were generated on chemical composition of termite mound as well as the compressive strength, effect of sulphate, water absorption of mortar. The effects of percentage replacement of cement with termite mound and mix proportion on the properties mentioned above were also investigated. The results of the analysis showed that all the factors investigated had significant effects on the strength and durability characteristics of termite mound-lime blended cement mortar. In view of the findings, appropriate conclusions were drawn and recommendations made for effective utilization of the termite mound- lime blended cement mortar.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusion

The construction of building in Nigeria is no doubt undergoing very turbulent times due to escalating cost of materials. To achieve housing delivery at affordable rate, this is the right time for the use of local sourced materials. It was found in the course of carrying out this research work that termite mound-lime blended cement mortar mixture are not only high quality building materials but economical and as well abundantly available.

B. Recommendations

This research confirmed that termite mound and lime exhibited binding properties and indicated that 25% replacement of cement with termite mound and lime would be economical and effective for the improvement of mortar. As termite mound lime blended cement mortar is an innovative technique, there is a room for more research and investigations. The following recommendations were made based on the findings:

1. Use of local construction materials to reduce the high cost of cement.
2. Involvement of private partnership and professional in the built environment.
3. Public awareness and enlightenment of the government policy on housing.
4. Provision of housing finance through mortgage for low income earners.
5. Government should provide for mass housing in the country.

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