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Studies on termite hill and lime as partial replacement for cement in plastering

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Abstract

This study investigated the compressive strength and water absorption capacity of $50 \times 50 \times 50$ mm mortar cubes made from mixes containing lime, termite hill and cement and sand. Two mix ratios (1:4 and 1:6) and varying binder replacements of cement with lime or termite hill amounting to 0%, 10%, 20%, 30%, 40% and 50% were used. Test results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with lime and termite hill. However, for mix ratio 1:6, up to 20% replacement of cement with either lime or termite hill, all the mortar cubes had the same strength; subsequently, the termite hill exhibited a higher compressive strength. For mix ratio 1:4, mortar cubes made from lime/cement and termite hill/cement mixtures had the same strength at 50% replacement. Generally, water absorption is higher in mixtures containing lime (18.10% and 14.20% for mix ratios 1:6 and 1:4, respectively, both at 50% replacement level) than those containing termite hill (16.10% and 13.02% for mix ratios 1:6 and 1:4, respectively, both at 50% replacement level). Termite hills seem to be promising as a suitable, locally available housing material for plastering.

Keywords: Compressive strength; Plastering; Water absorption

1. Introduction

In most economies, the construction industry plays a major role in the nation's economical growth with its multiplier effect on the economy. In Nigeria, owing to government economic policies, there has been an astronomical increase in the cost of construction; this sometimes leads to abandonment of some projects. Besides, provision of functional housing is becoming increasingly unaffordable for greater proportion of the populace. One step being taken in solving this lingering problem is the control of the escalating cost of building materials. This is being done through the sourcing, development and use of alternative, non-conventional, locally available materials suitable for construction, especially those that could partially replace cement, which is one of the most expensive construction materials in most developing countries. This proposal was further emphasized in the Nigerian New National Housing Policy, where it was stated that the nation should gradually and systematically develop appropriate capabilities to reduce construction cost and achieve self-sufficiency in the production of basic building materials and components from local resources at affordable cost.

To this end, a look at lime and termite hill as partial replacements for cement was taken with the aim of reducing the overall cost of plastering since cement constitutes the major expensive material in rendering. Termite hills (mounds) are available all over the world. However, the availability and distribution depend on soils and vegetation, climatic features and presence of water. In Nigeria, the most dominant species of mound-building termites are the wood-feeding and fungus-growing *Macrotermes bellicosus* and the grass-harvesting *Trinevitermes germinatus*. However, *M. bellicosus*

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Table 1
Dominant termites groups in different vegetation zones in Nigeria

Termite species	Mangrove and fresh water swamps	Rainforest	Guinea savanna	Sudan savanna
Macrotermes bellicosus	+	+	+	+
M. subhyalinus	+	+	+	+
Odontotermes sp.	+	+	+	+
Termes sp.	+	–	–	–
Cubitemes sp.	+	–	+	+
Cubitermes fungifaber	–	+	–	–
Thoracotermes macrothorax	+	+	–	–
Microtermes sp.	+	+	+	–
Amitermes evuncifer	+	+	–	–
Amitermes spp.	–	–	+	–
Anciostrotermes sp.	+	+	–	–
Spaerotermes sphaerothorax	–	+	–	–
Pseudocanthotermes sp.	–	+	–	–
Protermes spp.	–	+	–	–
Microcerotermes sp.	–	+	+	–
Procutermes spp.	–	+	–	–
Basidetitermes sp.	–	+	–	–
Pericapritermes sp.	–	+	-	–
Coptotermes sp.	–	+	–	–
Astrolotermes quietus	–	+	–	–
Schedorrhinotermes sp.	–	+	–	–
Thoracotermes macrothorax	–	+	–	–
Nasutitermes sp.	–	–	+	–
Trinervitermes spp.	–	–	+	–
Trinivitermes	–	–	–	+
Nasutiterminae	–	–	+	–
No of taxonomic groups	9	19	10	5

Source: Badejo [5].

constitute the dominant species and has a wider distribution in the south-western zone of the country. A survey of the distribution of termites, hence termite hills, has revealed that certain species are restricted to a particular vegetation zone while some are distributed all over the zones. The rainforest appears to have more dominant species than other vegetation as shown in Table 1.

M. bellicosus hills from which the termite hill soil samples for this test were taken, are large cathedral-like mounds up to 8 m in height with an extensive below-ground central nest system. Collins [1] and Kang [2] reported about 6.4 mounds per hectare of *M. bellicosus* in the Nigerian savanna and 17 mounds per hectare in the more humid south-western zone, respectively. The material is a waste product and often destroyed by farmers. It has no competitive use.

Given its observed availability and its proposed use as a partial replacement for cement, the sustainability of termite hill is guaranteed. Lime, on the other hand, is in the form of hydrated lime [$Ca(OH)_2$] normally sold in commercial quantities in the urban centres of the country as a bagged powder.

This study therefore investigated, as a first step, the compressive strength and water absorption capacity of mortar cubes made from mixes containing lime, termite hill, cement and sand. The main objective is to encourage the use of these 'seemingly' less-fancied natural products as construction materials especially in low-cost housing. It is also expected to serve the purpose of encouraging housing developers in investing in house construction incorporating these materials.

2. Experimental programme

The basic materials used in this study are soft, common sand (the type used for rendering), ordinary Portland cement, lime, termite hill and water. Lime is not commonly used in construction in Nigeria and thus not easily available in Ile-Ife; it was purchased in its final usable powdery form from Ibadan in Oyo State of Nigeria. All the other materials were sourced from within Ile-Ife in Ife Central Local Government Area of Osun State. The maximum particle size of the fine sand used was 1.18 mm. The same maximum size was maintained for the grinded termite hill soil particles.

Termites as soil ecosystem engineers [3,4] affect the structure, mineral composition, organic matter content and porosity of soils by their tunnelling, mound building and construction of nests and galleries. Previous laboratory analysis of similar samples indicated higher concentration of Ca, K, P, C, N and exchangeable cations [5]. These were attributed to the high levels of faecal-derived organic matter and clay content of the mounds. The exceptional amounts of Ca found in concretionary form at the base of the *M. bellicosus* mounds may be as a result of evaporative processes, accelerated by the presence of calcium-rich ground water and impeded drainage. The samples have a higher pH than the surrounding soil as a result of accumulation of $CaCO_3$ from the subsoil. Soil samples of *M. bellicosus* hills have also been observed to contain organic matter [5]. It is to be noted, however, that the quality of the chemical nature of the termite hills depends on the feeding habit, soil type, species, depth of water table and the availability of material in their habitat since termites collect food from a wide area and bring a large percentage into the mound.

Two mix ratios (1:4 and 1:6) and varying binder replacements of cement with lime or termite hill amounting to 0%, 10%, 20%, 30%, 40% and 50% were used. The mortar mixes and cubes of size $50 \times 50 \times 50$ mm were prepared and cast, respectively, in accordance with standard laboratory procedures. However, water was added in each case until workable mixes were obtained. The water/binder ratio used was 1.45. Six replicates were used in each case. In all cases, batching was carried out by weight. Preliminary studies include mechanical sieve analysis of sand and termite hill soil particles, determination of the moisture content of the soils and the Atterberg's limits of the termite hill soil particles all carried out in accordance with BS 1377 [6]. The compressive strength and water absorption tests were performed on the cast cubes. The former was carried out using an ELE 28-kN unconfined compressive strength-testing machine.

3. Test results

3.1. Preliminary tests

The fineness moduli of the soil materials used were calculated as 2.07 for soft sand and 2.00 for termite hill. These values indicate fine aggregates of medium grading. Besides, the coefficients of uniformity were obtained as being approximately equal to 4.00 and 3.00 for soft sand and termite hill soil samples, respectively. The values show that the soil samples are uniformly graded (coefficient of uniformity between 1.0 and 5.0). Poorly graded soils (coefficient of uniformity less than 1.0) are unsuitable for plastering purposes. The as-used moisture contents of the common sand and the termite hill were obtained as 0.76% and 5.17%, respectively. Since termite hill is a cohesive soil, the Atterberg's limits were determined. The tests indicated values of 25%, 10%, 15% and 1.32 for the liquid limit, the plastic limit, the plasticity index and the liquid index, respectively. These values indicate that the termite hill is medium cohesive with its range of plasticity index between 10 and 20% [7].

3.2. Compressive strength

The compressive strength variations with curing age at various levels of percentage replacement of cement with termite hill and lime for both mix ratios are shown in Figs. 1–4. Test results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with lime and termite hill. However, for mix ratio 1:6, up to 20% replacement of cement with either lime or termite hill, all the mortar cubes had roughly the same 28-day strength, though the cement/termite hill mixture had higher early (7-day) compressive strength at these replacement levels. Subsequently, the cement/termite hill mortar cubes exhibited a higher compressive strength. For mix ratio 1:4, mortar cubes made from cement/lime and cement/termite hill mixtures had almost the same strength only at 50% replacement level. At replacement levels less than 50%, the cement/termite hill mixtures exhibited greater strength. Generally, it was observed that mortar cubes made from cement/

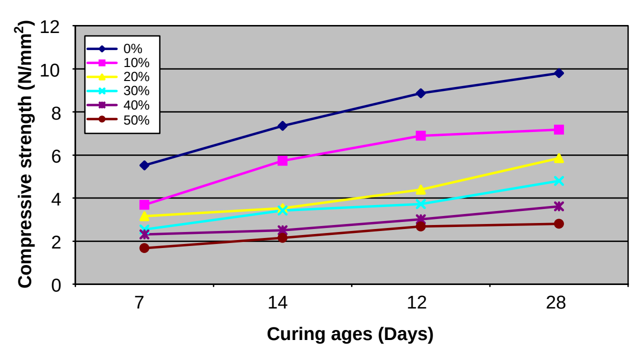

Fig. 1. Compressive strength vs. curing ages of cement + termite hill of 1:6 mix proportion.

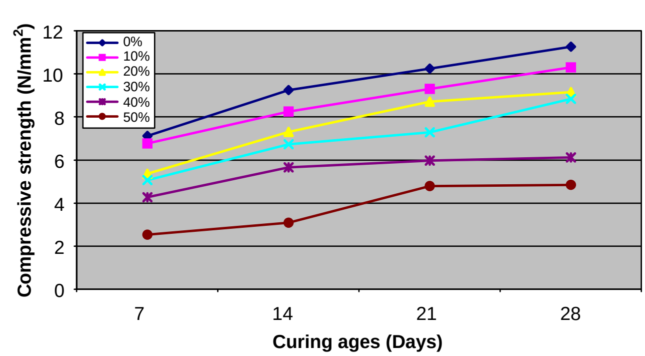

Fig. 2. Compressive strength vs. curing ages of cement + termite hill of 1:4 proportion.

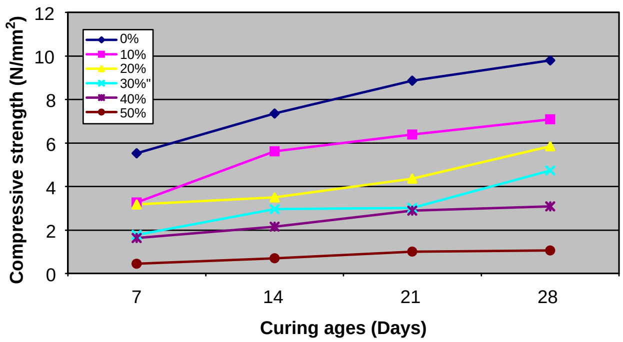

Fig. 3. Compressive strength vs. curing ages of cement + lime of 1:6 mix proportion.

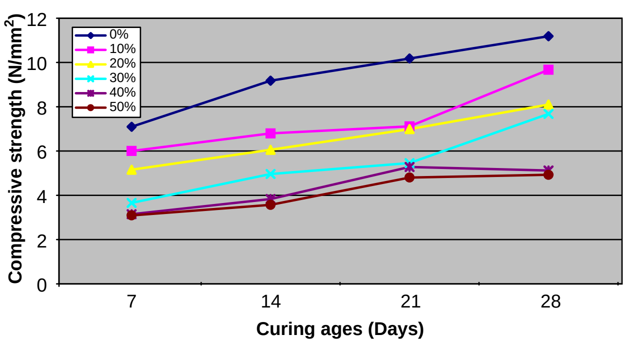

Fig. 4. Compressive strength vs. curing ages of cement + lime of 1:4 mix proportion.

termite hill mixtures exhibited greater compressive strength than those made from cement/lime mixtures. At zero replacement level, the 28-day mortar cube compressive strengths for specimens made from mix ratios 1:6 and 1:4 are 9.80 N/mm^2 and 11.26 N/mm^2, respectively. Both mixes exhibited good compressive strength (5.85 N/mm^2) up to 20% replacement for mix ratio 1:6. For mix ratio 1:4, the cement/lime mixture had good compressive strength (7.72 N/mm^2) up to 30% replacement level while the cement/termite hill mixture had good compressive strength up to 40% replacement level (8.84 N/mm^2 at 30% replacement level and 6.12 N/mm^2 at 40% replacement level). For all the replacement levels considered, the coefficients of variation of test results range between 1.20% and 2.13%. These values could be considered excellent from an engineering standpoint.

3.3. Water absorption

Fig. 5 shows the rate at which the mortar cubes absorb water within 24 h of casting. As the percentage replacement of cement increases, the quantity of water absorbed increases. Generally, water absorption was

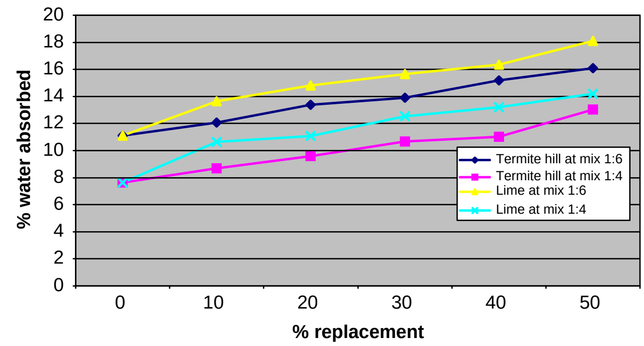

Fig. 5. Water absorbed vs. % replacement of 1:4 and 1:6 mix proportions.

higher in mixtures containing lime (18.10% and 14.20% for mix ratios 1:6 and 1:4, respectively, both at 50% replacement level) than those containing termite hill (16.10% and 13.02% for mix ratios 1:6 and 1:4, respectively, both at 50% replacement level). At 0% replacement level, the percentage of water absorbed was 11.11% for mix ratio 1:6 and 7.63% for mix ratio 1:4. The percentages of water absorbed at 20% replacement level for mix ratio 1:6 were 13.39% and 14.80% for cement/termite hill and cement/lime mixtures, respectively. At 30% replacement level, up to which the mortar cubes made from mix ratio 1:4 showed good compressive strength, the percentages of water absorbed were found to be 10.66% and 12.55% for cement/termite hill and cement/lime mixtures, respectively. These values are still comparable with the values obtained for normal mortar mixtures using only cement as binder. For all the replacement levels considered, the coefficients of variation of test results range between 1.38% and 2.41%. These values are low and could be considered reasonable from an engineering standpoint.

4. Discussions and recommendation

The results of the analysis indicated that using a mix ratio of 1:6 for mortar, cement/lime and cement/termite hill binder mixtures had the same strength up to 20% replacement level while above this percentage the cement/termite hill binder mixtures exhibited a higher strength than the cement/lime binder mixtures. Using ratio 1:4, the two types of mixtures had the same strength only at 50% replacement while at lesser percentages, the cement/termite hill mixtures had greater strength. The rate of water absorption in the mixtures containing lime as partial replacement for cement was greater than in cement/termite hill mixtures. Generally it can be concluded that termite hills seem to be promising as a suitable material for plastering. Besides, a mix ratio of 1:4 showed good qualities both in terms of compressive strength and water absorption. Thus the cost of rendering can be reduced using these replacements. Hence it would not be out of place to recommend that to produce a good mortar in terms of strength, durability and water absorption, the overall percentage replacement of cement in the binder mixture should not contain more than 30% and 40% for mix ratios 1:6 and 1:4, respectively. With further studies on the long-term weather exposure performance of mortar containing these replacements, most especially cement–termite hill/sand mortar mixtures, it will no doubt be widely acceptable as a suitable material for mortar in masonry building construction. Besides, these innovations will contribute effectively to the provision of affordable housing for the low and medium income earners in Nigeria and other countries where similar materials are available.

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