Compressive strength of rice husk stabilized termite hill soil

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Abstract: Termite hills are described as the structure built by termite using soil in the surrounding or within the earth. The mound has extremely hard walls constructed from bits of soil cemented with saliva and baked by the sun. This research is to determine the compressive strength of termite hill soil stabilized with rice husk. The study investigated the compressive strength of 150 mm x 150 mm x 150 mm cubes made from termite hill soil and rice husk in the different mix ratio of 50:50, 60:40, 70:30, 80:20, 100:0 and was cured for 28 d with crushing the cubes at 7 d interval. The weight, bulk density and dry density of the cubes at different THS/RH mix ratio ages were determined. Test results showed that the compressive strength of the cubes increases with age and increases with decrease in percentage of rice husk. However, the mix ratio of 50:50 has the least compressive strength of 0.4800 MN/mm^2 while the mix ratio of 80:20 has the highest compressive strength of 0.9244 MN/mm^2 compared to mix of 100% termite hill soil. The mean weight is 5.18 and 5.90 kg after 7 days for 50:50 and 100: 0 mixes respectively while the mean weight is 3.90 and 5.34 kg on the 28 d for the same mixes. The mean weight of the cubes increases with decrease in the proportion of RH in the mix within the same curing day but decreases with age of the cubes. Termite hill soil seems to be promising as a suitable, locally available housing material for farm structure.

Keywords: termite hill soil, clay, rice husk, compressive strength, cubes, structure, farm, Nigeria

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1 Introduction

Overtime man has spent extensive efforts and immeasurable amount of energy on the provision of housing, one of his basic needs but the problem of inadequate and prohibitive cost of housing delivery has persisted. The problem of inadequate housing will definitely persist except there is a deliberate policy designed toward adopting the concept of adaptable habitation. The concept of adaptable habitation is a new area of building engineering that deals with the adaptability of local resources, technologies, skills and manpower in the provision of affordable houses specific to particular communities (Theo and Voordt, 1990).

One of such adaptable local resources that have been widely used as building material is clay. Clay constructed storage structures include the rhumbus, the laterite-impregnated grass structure, the dried earth granaries, the Indian puss bin, hermetic clay pots, the Asia *kachia koth in* Asia and the Mexico store (IOWA 2003, Mijinyawa et al., 2007; Anon, 2012). The major advantage of the native rhumbus is its ability to provide a cool environment for storage due to the low thermal conductivity of about 1.15W/m K that is lower than that of concrete and metal silo (Osunde and Lasisi, 1998).

Termites are ecosystem engineers that modify the properties of the soil. Termite hill, mound or termitaria (Figure 1) is a structure used as shelter for the colony. They are often 6m in height and are characteristics features of much landscape in Africa, Latin America, Austria and Asia. The total mass of all of the termites in the world is more than the mass of all the humans in the

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world (Encyclopædia Britannica 2012, ; Wikipedia, 2012, Alabadan, 2013).

Figure 1 Termite hill

Collins (1981) and Kang (1978) reported about 6.4 termite hills per hectare of *Macrotermes bellicosus* in the Nigerian savanna and 17 mounds per hectare in the more humid south-western zone, respectively. The termite hills have extremely hard walls constructed from bits of soil from within the earth, cemented with saliva and baked by the sun, thus affecting the physical properties of this soil (Jouquet et al., 2004).

Termite hills have clay content about 20% than that of the adjacent soil, reflecting the insects' preference for smaller clay particles for construction. While being transported in the insects' mouth or their five gut compartments, the particles are saturated by alkaline and other chemicals, which add nutrient and contribute to the structures' robustness (Adekayode and Ogunkoya, 2009 and Mujinya et al., 2013).

The activities of these termites through their secretion improved the plasticity of the ordinary clay thereby making it a better material than the ordinary clay in term of utilization for moulding (Odumodu, 1991 and Edosomwan et al., 2012) and in dam construction (Yohanna et al., 2003).

Older termite hills rather than termite hills that still have termites living in them give better result. This is because the older termite hills have higher clay content (30% – 80%) than newer hills. Also the outer clay casing of termite hills is believed to be more suitable for construction than the inner nest material. Heat treated termite hill clay are resistance to wear, abrasion and penetration by liquid (Parker, 1998). Termite hill clay has low thermal conductivity and expectedly should reduce solar heat flow into the enclosure and regulate temperature fluctuations within the storage environment

Termite hills soil contains clay which consist of inorganic material (minerals and water) that makes them fire resistance and incombustible. Some hills contain chrysotile (more commonly known white asbestos), which also comes from the surrounding soil. Chrysotile is incombustible and thus improves fire resistance. Termite hills materials are all sourced on- site and are all biodegradable. Termite hill should be supplemented with phosphorus fertilizer before it can be used as soil amendment (Edosomwan et al., 2012).

Clay has been used to produce bricks for building construction from very early dates. First, it was used without burning as sundried bricks, but nowadays burnt bricks are made from specially selected and mature brick-earth consisting of silica (35%-70%) and alumina (10%-20%) (Alabadan, 2009). Ndaliman (2001) reported that termite hills can further be improved to produced insulating refractory materials when 25% of additives (Corn Husk and Saw Dust) were used but a low values of refractoriness (1,200 ^{0}C) were recorded for these cases. Alabadan et al. (2005) reported that the substitution of cement with Bambara Groundnut ash in concrete formation was relatively possible not exceeding 10%.

Rice husk or hull is made of hard material including opaline silica and lignin to protect cover or coat the seeds or grains of rice. It is mostly indigestible to humans and a class A insulating material that are used as filling for used pits and rural unpaved roads during raining season. The utilization of rice husk will promote waste management for a friendly pollution free environment and increase the economic base of the farmer thereby encouraging more production (Wikipedia, 2014). The termite hills material is a waste product and often destroyed by farmers. It has no competitive use. Termite hill clay is being considered for use in silo construction because of its improved plasticity and thereby less prone to crack when compared with ordinary clay.

The objective of this study is to conduct an investigation to explore the possibility of using the enormous and wasted rice husk (RH) in stabilizing the strength of termite hill soil (THS).

2 Materials and methods

2.1 Materials and equipment

The materials used for this research are termite hill soil (THS), rice husk (RH), water, weighing balance, weighing pan, mallet, polythene sheet (thick), mixing tray, bucket, cup, mould (wood), digger, shovel and crushing machine.

2.2 Source of materials

One of the termite hills located in Gurara town along Minna-Bida road, Minna, Nigeria was dismantled with the digger, soil samples were collected in polyethylene bags and directly transported to the Department of Civil Engineering laboratory, Federal University of Technology, Minna, Nigeria. The packed polythene bags were stored in water filled containers to preserve the natural condition. Rice husk was collected from a rice mill in Chanchaga town located along Minna-Paiko road, Minna, Nigeria. The Chanchaga Water Treatment Plant, Minna water collected from the tap in Department of Civil Engineering laboratory, Federal University of Technology, Minna was used during the experiment.

2.3 Study area

The study area is Minna, Nigeria. It lies in the middle-belt zone of the country with latitude 09 °39’ N and longitude 06° 28’ E. The mean monthly rainfall is usually about 409 mm in August and none in February and March. The mean temperature is 28.5 ^{0}C in the wet season of August and 38.9 ^{0}C in the dry season of February and March (Alabadan, 2006). The experiment was conducted in September at the peak of the raining season.

2.4 Methods

2.4.1 Production of test cubes

Size reduction of the clay lumps into fine grains was achieved through pounding with pestle. Sedimentary jar test and sieve analysis of the THS were done according to Alabadan et al. (2012). The different mix ratio used are 50:50, 60:40, 70:30, 80:20, 100:0 for THS:RH. Batching of materials was done by weight according to Alabadan et al. (2012). Measurement of the weight of samples were done manually using measuring pan and weighing balance and the weight of the empty pan was noted before weighing of samples. 5 mix ratios with 3 replicates of the cubes for 4 crushing days gives a total of 60 cubes required for the research.

Mixing was done manually on a wide tray. The weighed THS was poured on the tray before required quantity of the RH was added to it and the two materials were then thoroughly mixed together. The natural moisture content of the THS was determined to know the quantity of water to be added to the soil during mixing. The clay was then mixed with water in the ratio of two volumes of termite mound to one volume of water.

The wet mixture was then poured into a 150 mm x 150 mm x 150 mm wooden mould placed in a manually operated moulding machine and vibrated to ensure compaction and appropriate shape forming. Compaction was done in accordance with the British Standard Compaction test (BS 1377, 1990). Sixty wooden moulds were produced, cleaned with spent engine oil water to allow for easy removal of the cubes and filled with the compacted fresh THS / RH mixture. Casting of cubes was done outside on a polyethene sheet placed over plywood for easy removal. The moulds were removed immediately. Curing of cubes was done in the open air but they were covered at evenings and opened in the mornings because of possible rainfall during the season.

2.4.2 Compressive strength test

Compressive strength test of the respective cubes was carried out in accordance with the British Standard (BS 1881 1983). A calibrated and electrically powered hydraulic-press called The Denis Tension crushing machine with a capacity of 2000kN was used for the crushing. The weight, bulk density and dry density of the cubes at different THS/RH mix ratio ages were determined before crushing. Three cubes each for each mix ratio were crushed at 7^{th} day, 14^{th} day, 21^{st} day and 28^{th} day curing period.

The cube was centrally positioned to received maximum load before failure will occur, when the knob was turned from unload to load, the upper plate started moving down gradually towards the cube and once it was compress the terminal started recording the load sustain by the cube and cracking began. Immediately failure is reached the knob is turned to the unload position and the upper plate moves up to met original position, reading was noted from the screen and the value of the compressive strength of each noted accordingly.

3 Results and discussion

The sedimentary jar test showed that percentage of debris was 16%, sand 44%, clay 36%, and silts 4% corresponding to heights 8, 22, 18 and 2mm, respectively. The soil contained reasonable amount of clay and sand that can enable the sticking together of the soil components. In addition, the sieve analysis showed the various granular distributions of the THS and 13.41% of samples were retained in the first sieve size of 5 mm (Alabadan et al., 2012).

The initial moisture content of the THS was determined and presented in Table 1. The soil has mean natural moisture of 12.73 % that helps in determine the quantity of water required for the mix. The samples were collected in September during rainy season. The low value may be due to the presence of organic content, increase in clay content, higher percentage of chemical/enzymes in the mound soil and presence of finer soil particles. The value is in agreement with the value of Alabadan and Omosekeji (2012) that the above data reflected that the termite hill soil is still plastic/elastic even with a low moisture content and accordingly can be moulded into shapes.

Table 1 Natural moisture content

	F1	B5
Wt of can, g	9.8	24.0
Wt of can + wet soil, g	29.6	56.0
Wet of can + dry soil, g	27.0	53.0
Moisture Content, %	15.11	10.34
Mean Moisture Content, %	12.73	

The weight, bulk density and dry density of the cubes at different THS/RH mix ratio ages were determined and reported in Table 2. The mean weight is 5.18 kg and 5.90 kg after 7^{th} days for 50:50 and 100: 0 mixes respectively while the mean weight is 3.90 kg and 5.34 kg on the 28 d for the same mixes. The mean weight of the cubes increases with decrease in the proportion of RH in the mix within the same curing day but decreases with age of the cubes. The bulk and dry densities exhibit this pattern of behavior. This may due the increase of clay content in the 100:0 mix leading to a decrease of pore sizes and rate of water diffusion which agreed with the report of Jouquet et al. (2004).

Table 2: Mean weight and density of cubes

		THS : RH RATIO				
Curing period, d		50:50	60:40	70:30	80:20	100:0
7	Weight, kg	5.18	5.31	5.44	5.55	5.90
	Bulk density, kg/m^3	1534.82	1573.33	1611.85	1644.44	1748.15
	Dry density, kg/m^3	1361.50	1395.66	1429.83	1458.74	1550.74
14	Weight, kg	4.7	4.95	5.39	5.45	5.07
	Bulk density, kg/m^3	1392.59	1466.67	1597.04	1614.81	1502.22
	Dry density, kg/m^3	1235.33	1301.05	1416.69	1432.46	1432.46
21	Weight, kg	4.35	4.67	5.29	5.13	5.54
	Bulk density, kg/m^3	1288.89	1383.70	1567.41	1520.00	1641.48
	Dry density, kg/m^3	1143.34	1227.45	1390.41	1348.35	1456.12
28	Weight, kg	3.90	4.23	5.00	4.72	5.34
	Bulk density, kg/m^3	1155.56	1253.33	1481.48	1398.52	1582.22
	Dry density, kg/m^3	1025.07	1111.80	1314.18	1240.59	1403.55

The graphical representation of the behavior of the cubes in terms of compressive strength during the curing is shown in Figure 2. The performance characteristics of termite hill clay stabilized with rice husk is very important when it comes to their strength compliance and suitability for usage in the construction of farmstead infrastructure.

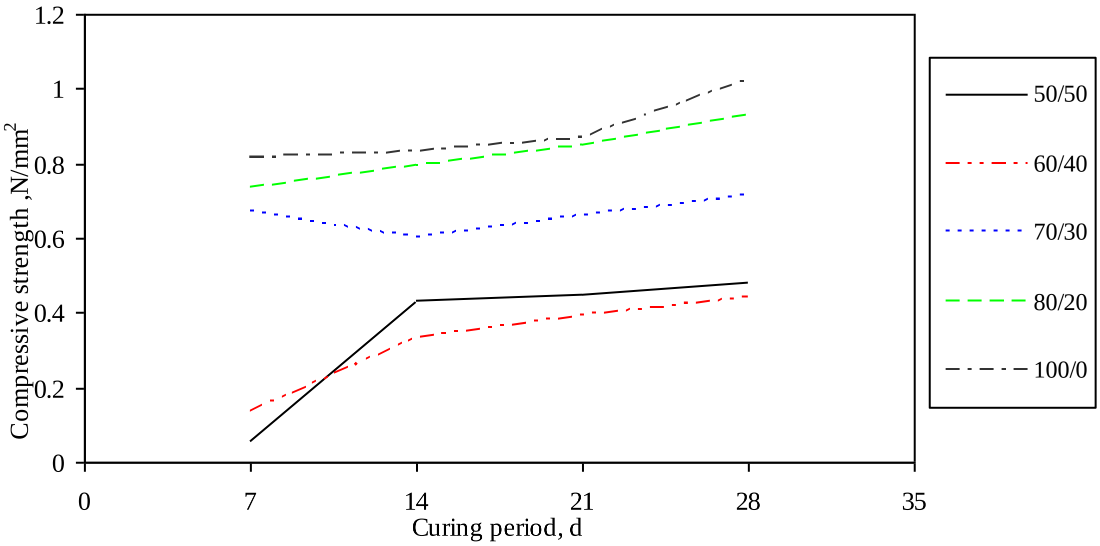

Figure 2 Compressive strength of THS/RH with curing period

From Figure 2, the result obtained on the 7th day showed that the mix ratio of 50:50 has the least compressive strength value of 0.0578 N/mm^2 when compared with the mix ratio of 100:0 with the highest value compressive strength value of 0.8163 N/mm^2. The above observed pattern is similar for compressive strength at 14th, 21st and 28th days curing period.

The lowest and highest compressive strength are 0.0578 N/mm^2 (7th day) and 1.0235 N/mm^2 (28th day) for 50:50 and 100:0 mixes respectively. The compressive strength increases with age and with reduction in the proportion of RH in the mixes. Higher proportion of RH corresponds to lower strength. It was observed the higher strength also corresponds to lower weight and densities. Alabadan et al. (2012) reported that the compressive strength of lime treated termite hill cubes increased from 4.58 N/mm^2 on the 7th day to 11.02 N/mm^2 on the 28th day but decreases with increasing replacement of termite hill with lime. All the values of compressive strength are however lower than the strength recorded on the 7th, 14th, 21st and 28th days of curing for THS/lime bricks by Alabadan et al. (2012) and Houben and Guillard (1994) specific requirements for such bricks. The control (100:0 mix) performed better because of the increase in the plasticity values of the mound soils due to the higher percentage of chemical/enzymes of termites, organic content and the clay content (Mujinya, 2013). A detailed study indicated that the main oxides present in THS are SiO_2, Al_2O_3 and Fe_2O_3. It may be possible to suggest that the higher percentage of Al_2O_3 may contribute to the cementation of mound soils. This indicates the termite mounds are having more cohesion and this makes the soil more stable.

The results of compressive strength for the control and 20% RH are not significantly different at $P<0.005$ level of significance using F-test. The correlation is 92%. Other relationships with the control are significantly different at $P<0.005$ level of significance. Similarly, the compressive strength after crushing on the 28th day the result obtained indicate that the mix ratio of 50:50 and 60:40 were not significantly different at $P<0.005$ level of significance.

The graph of 80/20 mix ratio rose progressively during the hydration periods. However, all the mix ratios compressive strength on the 14th day was higher than those of the7th day except those of 70/30. The rate of increase of strength was observed to be higher for the control than others. The analysis of result illustrated in Figure 2 showed that bricks made with the mix ratio of 100:0 developed higher strength at all levels of replacement and the entire mix ratio samples developed about 80% of their 28th day strength in 7th day. This means the THS/RH cubes developed most part of their 28th day compressive strength at an early stage.

4 Conclusions

The result obtained from the compressive strength test at all proportion of mixing showed that the compressive strength of the cubes increases with age and decreases with increase in percentage of rice husk. The behavior of the mixes showed that stabilizing the THS with RH should not exceed 20%. Termite hill soil is a promising and suitable locally available housing material for farm structure.

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