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A Study of Uncalcined Termite Clay Soil as Partial Replacement in Cement as a Sustainable Material for Roofing Tiles in Low Cost Housing Schemes in Kenya

Meshack Oduor Otieno, Charles K. Kabubo, Zachary Abiero Gariy

Abstract-The need for adequate roofing in developing countries is a vital problem for so many people. The solution of this problem is often linked to the import of iron sheets. The increasing economic burden that many less developed countries have to carry makes it harder to meet vital needs, such as roofing, by means of import. The efforts to find appropriate solutions based on locally available raw materials have thus become more and more important. The cost of conventional materials is too high; a considerable amount of this cost is due to the price of energy for manufacturing and to transportation costs, some materials such as cement poses adverse environmental effect. There is need therefore to provide alternative materials that are locally available, materials that can reverse the adverse environmental effect caused by excessive use of Portland cement and finally, materials that have small energy demand. The overall objective of this research was to assess the suitability of uncalcined termite clay powder partial replacement in cement for use in roofing tile for housing. For this termite clay powder replacement levels of 0 %, 10 %, 20%, 30% and 40% by weight of Ordinary Portland Cement was carried out to determine setting times, compressive strength, flexural strength and absorption rate. The chemical analysis of uncalcined termite clay soil obtained from Bondo district, Usigu sub location, Nduru village in Siaya County was found to be chemically suitable as pozzolanic material (SiO2+Al2O3+Fe2O3=93.053>70) required as stipulated by the ASTM C 618 standard. The optimal replacement level for termite clay soil was determined to be 10% replacement in cement achieving compressive strength of 44.9N/mm2, flexural strength of 6.5N/mm2 and absorption rate of 6.5. %.

Keywords- Roofing tiles, partial replacement, compressive strength, flexural strength, absorption rate.

I. INTRODUCTION

There is need for affordable building materials in providing adequate housing for the teaming populace of the world. The cost of conventional building materials continue to increase as the majority of the population continues to fall below the poverty line.

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Thus, there is need to search for local materials as alternatives for the construction of functional but low-cost buildings in both the rural and urban areas (Raheem, 2012). This research has used termite clay soil as partial replacement in cement as a binder to produce mortar for use as roofing tiles for housing in Kenya. The need for adequate roofing in developing countries is a vital problem for the great majority of the population. The solution of this problem is often linked to the import of iron sheets. The increasing economic burden that many less developed countries have to carry makes it harder to meet vital needs, such as roofing, by means of imports. The efforts to find appropriate solutions based on locally available raw materials have thus become more and more important (Gram, 1988). In this research uncalcined termite clay soil (TCS) was used as a pozzolanic material to partially replace Ordinary Portland Cement (OPC). Pozzolans are natural rocks of volcanic origin and composed of silica and alumina oxides but almost no lime. Therefore, they cannot develop hydraulic properties in the absence of hydrated lime. Hydrated lime or material that can release it during hydration (e.g Portland cement) is then required to activate the natural pozzolans as a binding material (Bakker, 1999). The activity of natural pozzolan, which is essentially determined by the reactive silica content, is also closely controlled by its specific surface area, chemical and mineralogical composition (Rogriguez-camacho, 2002; Terzibasioglu, 1995; Massazza, 1993). Cement is the most widely used construction material throughout the world with an estimated consumption of about 2.86 billion tonnes of Portland cement per annum worldwide. Cement production is however harmful to the environment due to carbon dioxide emission. Approximately 0.8 tonnes of CO2 is estimated to be released into the atmosphere per tonne of cement produced. With the cement industry accounting for 5%-8% of global CO2 emission, the cement industry is the second largest producer of this greenhouse gas (James Sarfo-Ansah et al, 2014). This research uses local materials (Termite clay soil) to partial replace cement- this is expected to reduce over reliance on cement thus reducing greenhouse gas and increasing access to affordable housing in Kenya. In Kenya twenty two percent (22%) of Kenyans live in cities, and the urban population is growing at a rate of 4.2% every year. With this level of growth, Nairobi requires at least 120,000 new housing units annually to meet demand, yet only 35,000 homes are built, leaving the housing deficit growing by 85,000 units per year.

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As a result of this mismatched supply and demand, housing prices have increased 100 percent (%) since 2004. This pushes lower income residents out of the formal housing market and into the slums (The ABC's of Affordable Housing in Kenya). The Constitution of Kenya, 2010 in the Economic and social rights 43(1) b- provides that, every person has the right to accessible and adequate housing and to reasonable standards of sanitation (Kenyan constitution, 2010). For the Country to realize and provide this right, it is important for new building code to cater for construction using locally available, cheap and environmental friendly materials. Further, there should be a deliberate effort to promote these materials as opposed to conventional imported, expensive materials which make housing to be beyond reach to many citizens. The UN Human settlements program confirm that a sixth of the world's population, nearly one billion live in slums, and that the number could double by 2030 if serious steps are not taken. Even more alarming is that almost half the world's urban population lives in slums, with sub-Saharan Africa having the largest percentage of its urban population living in slums, a whopping 71%. For most developing countries, the major concern is still revolving around poverty in terms of food security, health concerns, water provision, shelter provision, and infrastructure provision. Amongst these, shelter provision is one of the key areas identified by governments as a priority for action. Despite the fact that the right to adequate housing as a basic human right is enshrined in the Universal Declaration of Human Rights and the International Covenant on Economic, Social and Cultural Rights, provision of shelter in most of the developing countries is still way below expectations. The sorry situation persists despite the well-known fact that access to safe and healthy shelter is essential to a person's physical, psychological, social and economic well-being and should be a fundamental part to national and international action. For the African continent, the level of deprivation of shelter and infrastructure is shocking, and calls for immediate action. Whereas the African region is blessed with indigenous raw construction materials which could be adapted for local use, expensive imports of materials and construction technologies continue to account for a bigger percentage of the total cost of construction at the expense of the traditional construction sector which is characterized by construction methods and materials which have hardly improved at all over the years. The unfortunate consequence is the springing up of informal settlements where there is severe short-age of affordable, good quality housing, roads, clean water and water treatment facilities. Thus, it is imperative that appropriate measures be adopted to improve overall efficiency and productivity by ensuring the development of a soundly based construction sector that will play a pivotal role in the evolvement of human settlements (Oyawa, 2009).

II. MATERIALS AND METHODS

Termite clay soil obtained from Majengo-Nduru Village, Siaya County in Kenya was used in this research. A chemical characteristic of the soil was determined to ascertain its pozzolanic characteristics. Ordinary Portland cement obtained from Bamburi Cement Company in Kenya and conforming to KS EAS 18-1:2001 CEM I 42.5 N was used. Sand used was Standard sand conforming to CEN, EN 196-1, and ISO 679:2009, obtained from Kenya Bureau of Standards. Replacement levels for uncalcined termite clay soil of 0%, 10%, 20%, 30%, and 40% by weight of cement was used. Consistency, setting times, compressive strength, flexural strength and absorption rate was determined. Consistency and setting times tests was carried out according to BS EN 196-3:2005, Strength test was carried out according to BS EN 196-1:2005, Water absorption was done according to KS 02-444:1984. Termite clay soil (TCS) was ground into powder using a mechanical grinder, this material was sieved and particle size passing a 150µn sieve was used in this research.

III. RESULTS AND OBSERVATION

A. Standard Consistency and Setting times

Table 1: Consistency and Setting Times

C%	TCS %	%Cst	I.S.T	F.S.T
100	0	25	110	195
90	10	27	124	199
80	20	28	134	209
70	30	33	145	220
60	40	34	154	240

C%-Percentage ce ment, TCS%-Percentage termite clay soil, %Cst-Consistency, I.S.T-Initial setting time, F.S.T-Final setting time. The consistency increased with increase in TCS partial replacement in cement. Up to 30% replacement satisfies the requirement of BS EN 196-3:2005 of the usual range of values of between 26-33%. The initial setting time increased with increase in TCS partial replacement in cement, up to 40% partial replacement satisfies the requirement in KS EAS 18-1:2001 of ≥60 for cement of strength class 42.5N as shown in Table 1 above.

B. Chemical analysis

Table 2: Chemical Analysis of Termite Clay Soil

Chemical composition	Quantities (%)
SiO_2	59.096
Fe_2O_3	18.417
Al_2O_3	15.540
TiO_2	2.266
K_2O	2.258
SO_3	0.744
CaO	0.716
MnO	0.646
ZrO_2	0.202
V_2O_5	0.088
NbO	0.027

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The chemical analysis of uncalcined Termite clay soil (TCS) obtained from Bondo district Usigu sub location and Nduru village, was carried out and the results are given above, $SiO_2 + Al_2O_3 + Fe_2O_3 = 93.053 > 70$ required, was chemically suitable as stipulated by the ASTM C 618 standard.

B. Compressive strength

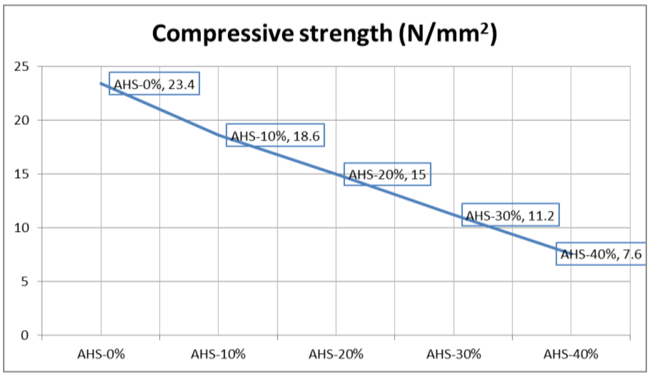

Figure 1: Graph of compressive strength against termite clay soil (%) replacement at 2 day.

AHS-TCS-Termite clay soil

Figure 1, shows the compressive strength of uncalcined Termite clay soil at replacement levels of 0%, 10%, 20%, 30% and 40% at 2day. *Up to 30% replacement satisfies the requirement of KS EAS 18-1:2001 of ≥ 10N/mm² for 42.5N OPC*. The compressive strength at 2 day shows a decrease in strength as shown in figure 1 above.

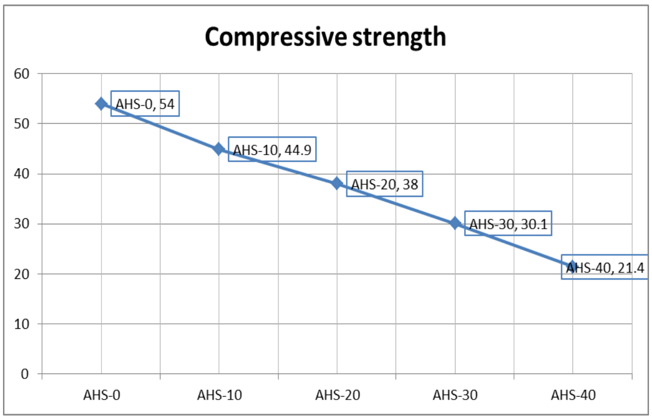

Figure 2: Graph of compressive strength against termite clay soil (%) partial replacement in cement at 28 day

Up to *10%* replacement achieves *44.9N/mm²* which satisfies the requirement *of KS EAS 18-1:2001 of ≥ 42.5 N/mm² and ≤ 62.5N/mm² for 42.5N OPC*. The compressive strength showed a general decline as shown in Figure 2.

D. Flexural Strength

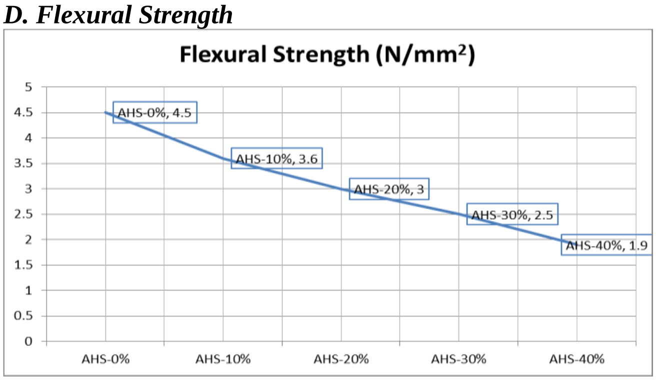

Figure 3: Graph of flexural strength against termite clay soil (%) partial replacement in cement at 2day.

The flexural strength decreased from *0%* to *40 %* replacement levels. Up to 20% replacement satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles* of minimum *2.80 N/mm²* for individual tiles as shown in Figure 3 above.

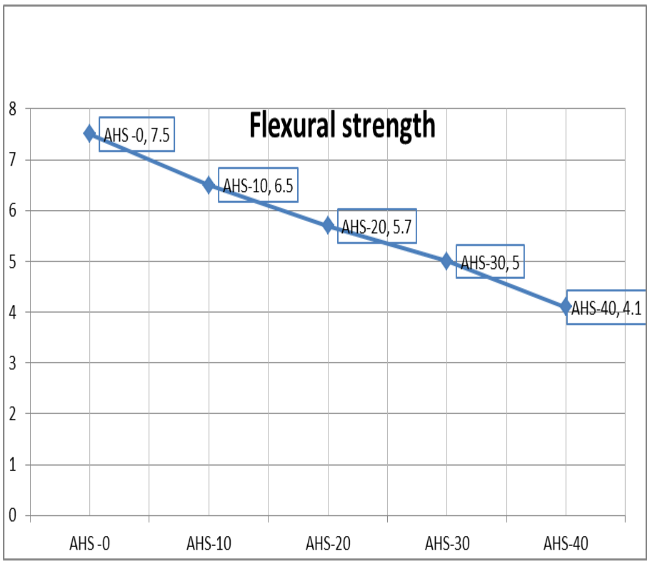

Figure 4: Graph flexural strength against termite clay soil (%) partial replacement in cement at 28 day.

At 28 day flexural strength, up to 40 % replacement satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles of minimum 2.80 N/mm²* for individual tiles. The Flexural strength of uncalcined TCS partial replacement in cement decreased as shown in Figure 4 above.

E. Water absorption rate

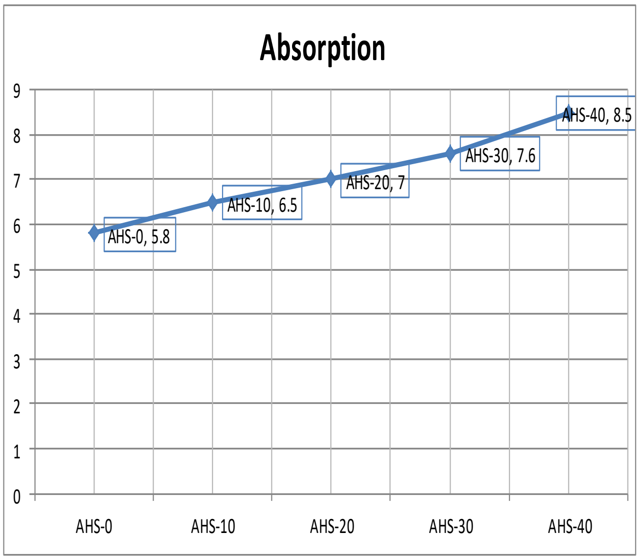

Figure 5: Graph of absorption against termite clay soil (%) partial replacement in cement at 28 day.

At 28 day Absorption rates, there is a general increase of absorption rates with increase in % replacement of Cement. Up to 40 % replacement satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles of maximum 10 %* water absorption as shown in Figure 5 above.

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F. Optimal replacement

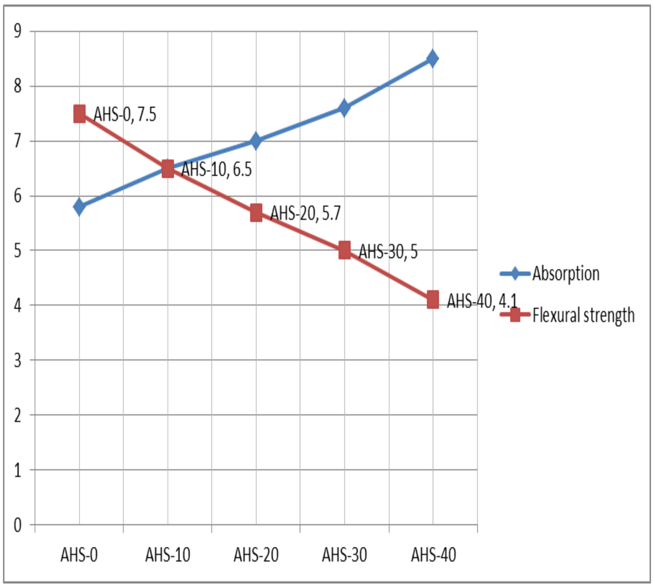

Figure 6: Graph of flexural strength and absorption against ant hill soil (%) partial replacement in cement at 28 day.

Optimal replacement is 10% of termite clay soil with the flexural strength *of 6.5 N/mm^2 and 6.5 % absorption rate*, which satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles of minimum of 2.80 N/mm^2* for flexural strength and a maximum of 10% absorption.

IV. CONCLUSIONS

i. The chemical analysis of uncalcined ant hill soil obtained from Bondo district Usigu sub location and Nduru village, was carried out and the results shows, SiO_2 + Al_2O_3 +Fe2O3 = 93.053 > 70 as required, which was chemically suitable as stipulated by the ASTM C 618 standard.
ii. Compressive strength at 28 day strength for uncalcined Termite clay soil partial replacement in cement, Up to 10% replacement satisfies the requirement *of KS EAS 18-1:2001 of minimum of 42.5 N/mm^2 for 42.5N OPC.*
iii. At 28 day flexural strength, up to 40 % replacement satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles of minimum 2.80 N/mm^2* for individual tiles. The Flexural strength of *uncalcined TCS* partial replacement in cement decreased.
iv. At 28 day Absorption rates, there is a general increase of absorption rates with increase in % replacement of Cement. Up to 40 % replacement satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles of maximum 10 %* water absorption.
v. *Optimal replacement is 10%* of termite clay soil (TCS), with the flexural strength of *6.5 N/mm2 and 6.5 % absorption rate*, which satisfies the requirement of *KS 02-444: 1984 Specification for concrete roofing tiles* of minimum of 2.80 N/mm^2 for flexural strength and maximum of 10% absorption.

V. RECOMMENDATIONS

i. Uncalcined Termite clay soil (TCS) is chemically suitable as pozzolanic material and can be used as partial replacement for cement up to 10%. Further research should be done for activated (Calcined) TCS.
ii. More research should be done on effect of Concrete roofing tiles partially replaced with TCS on exposed weather.

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