

Stabilizing Sandy Soil Using Reworked Earth Materials

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Abstract
The performance of termite reworked earth materials as potential stabilizing material for sandy soil was examined. The reworked earth materials were collected from three different termitaria and tested on a sand sample. The sandy soil was stabilized at six different levels 10%, 20%, 30%, 50%, 70% and 100% respectively. Soil classification tests which include consistency and particle size determination tests were carried out on the soil samples while the stabilized soil samples were subjected to compaction test and California bearing ratio test using the West African compaction method. The result of the CBR tests showed that the reworked earths(CBR) improved the bearing strength of the stabilized samples considerably at between 30% and 80% stabilization even though the effects of each of the reworked earth on the sandy soil varies. Also, only one of the three reworked earth samples meet up the recommended minimum CBR value of 80% specified by the Nigerian general specification on roads and bridges for sub-base materials.
Keywords: Reworked Earth, Termitaria, California Bearing Ratio, Stabilization, Sandy Soil

1. Introduction

Soil in engineering construction is either used as a material in the construction process or as part of the substructure and in this case serves as the foundation of the structure. In both cases, the engineering properties of the soil in relation to its suitability for the intended purpose or use are crucial to its performance during construction and throughout its design life. In highway construction soil is an important construction material which often times requires certain degree of improvement to ensure its suitability and durability in use. This improvement is termed 'stabilization' which can either be mechanical or chemical. Chemical stabilization involves the use of chemical substances while mechanical stabilization requires blending different soil materials to improve one or more properties of the original soil. The mechanical stabilization method is more economical and environmentally friendly, hence in the light of this, it will be safer and easier to use and as such should be encouraged in practice.

Soil improvement may be associated with human activities as well as the activities of certain social insects and burrowing animals such as earthworms, ants and termites. Termites are noted to play integral roles in soil development and are believed to be one of the primary soil producers in arid and semi-arid systems (Holt and Leepage, 2000). Termitaria are formed from soil cemented together with chewed up, partially digested wood, saliva and feces to produce a more durable building material (Longair, 2004). As a result of the various formation activities, termitaria soil have appreciable levels of some minerals such as nitrogen, acid-extractable phosphorus and cation than their surrounding which may be linked with both the concentration and subsequent decomposition of organic matter in and within the moulds (Jones, 1990). This is also in line with the view of Anderson and Wood, (1984) that higher degree of Ca, K, P and exchangeable cations were found in termitaria soil when compared with their surrounding topsoil and subsoil. Termites activities was also observed to have influence on the structure and some geotechnical properties of the reworked soil thereby making it stronger and having better geotechnical properties than the surrounding soils. Some properties which are often affected may include the particle size distribution, consistency limits, California bearing ratio and the unconfined compressive strengths (Adeyemi and Salami, 2004). Also, certain variation was observed in a study of the geochemical and geotechnical properties of eight termite reworked earth within three geological zones of University of Ibadan (Ayininuola, 2009). It was discovered that these properties varied within and from one geological zone to another.

The desire to utilize improved properties as discovered in the above references informed the investigation of reworked earth stabilizing potential on sandy soil. This will be of great benefits to Government Works Department especially at the grassroots level where termite reworked earth is readily available and will be useful to individual and communities interested in improving their road networks.

2. Literature Review

Soil stabilisation is aimed at reducing the effects of adverse moisture and stress condition by improving the materials response to external actions in terms of its strength, bearing capacity and durability in use (Farinde Oni and Abidoye, 2015). Stabilisation can be achieved either by physical or chemical means. Physical methods involves mixing soils of different particle sizes to obtain better gradation, compaction of soil samples to reduce pores thereby improving the density while reducing its permeability to moisture or draining moisture from such soil. Chemical methods involves the addition of chemical substances often blended into soil mixture to alter or modify soil properties so as to improve the soils performance in service (Rani and Suresh, 2013). Chemical methods using cements and lime are the most widely used methods for stabilising granular and clayey soil. These two additives have been used with much success in terms of strength and durability of stabilised soil. However, their production has been noted to have negative impact on the environment and as such may not be sustainable. This challenge has however favoured the use of environmentally friendly alternative additives either as whole or partial substitute to the conventional cement and lime. The utilisation of environmentally friendly materials are to a greater extent influenced by their availability and more importantly their performance. Therefore, a knowledge of the engineering properties and behaviour of such materials are required through laboratory investigation and subsequently in the field as may be deemed required.

Sandy soils are known to be non-cohesive and may lack the necessary binding force to ensure good compaction and hence may be highly permeable to moisture penetration. Cohesiveness of soil is essential to its compactability and hence densification which enhance its behaviour under load. Minke (2000) suggested that to improve the cohesiveness or binding force of such soils the addition of clayey materials in powdery form may be considered. Termite reworked earth materials are obtained from termite moulds which often exhibits different properties from the surrounding soils which has been associated with various termite activities (Kormaan and Onck, 1987, Ayininuola, 2009). Termite reworked earth contains clay and silt particles in sufficient amount which are responsible for its plasticity and hence enhance its mouldability and compaction. In line with this Farinde et al. (2015) noted that reworked earth materials can be used to improve the grading of poor engineering soils in order to enhance their bearing strength (Farinde *et al*., 2015). Improvement in grading characteristics of soils may further improve other engineering properties of such soils like compaction and moisture-density properties.

Previous studies on termite reworked earth showed that termites through their activities influences the physical and chemical characteristics of soil which is why these soils differ in characteristics and behavior to the surrounding soils (Ayininuola, 2009; Adeyemi and Salami, 2004). Also, reworked earth is said to have higher amount of silt and clay and found to be stronger than the surrounding soils (Ekundayo and Orhue, 2002). Abe and Oladapo (2014) find out that the reworked earth exhibit better index properties than the surrounding lateritic soils proving it to be a better engineering soil. The plasticity indices and linear shrinkage were observed to be lower compared to that of laterite. Reworked earth materials was found to improve the maximum dry density, California bearing ratio and the unconfined compressive strength of the stabilised lateritic soil samples which was attributed to the increase in sand particles (Farinde *et al*., 2015). This study investigated the effects of termite reworked earth in improving some geotechnical properties of granular soil in order to enhance its use in construction.

3. Materials and Methods

The reworked earth samples were collected from three different termite molds in Ilora area of Oyo State Nigeria. The molds were broken down into lumps and exposed to the atmosphere to get rid of the termites and then carefully pulverised to individual soil particles which were then bagged and labeled GT1, HRT and GT2 indicating the sampling places. The sandy soil was collected along a major street in Araromi area of Oyo State, bagged and taken to the laboratory. The soil samples (sandy soil, GT1, HRT and GT2) were subjected to grain size test, specific gravity, Atterberg's limits test (liquid limit LL, plastic limit PL, plasticity index PI and linear shrinkage LS) in accordance with BS 1377 (1990).

The sandy soil was stabilized at six levels of 10%, 20%, 30%, 50%, 70% and 100% respectively with the three termite reworked earth differently and subjected to California bearing ratio (CBR) test using the west African compaction energy level and the triaxial strength test (undrained) at the optimum moisture content (OMC) as detailed in BS 1377 (1990).

4. Results and discussions

The results of the classification tests carried out on the test materials, the moisture-compaction test of the stabilised soil samples, the bearing strength and the shear strength test for the stabilized soil samples were discussed below;

4.1 Physical properties

The sieve analysis and consistency limit test results indicated in figure 1 and table 1 showed that the soil samples had considerable amount of sand while the reworked earths contain clay and silts up to between 50 and 60%. The sandy soil sample has medium and coarse sized particle up to 90% with about 2% gravel size and less than

10% passing the 0.075mm sieve hence a poorly graded sand. The termite reworked earths materials are silty-clay with more than 50% passing the 0.075mm (No. 200) sieve with their sand content ranging between 40-50% while the silt and clay content ranges between 50-60%. The sand is granular classified as A-1-b (0) according to AASHTO classification and SP according to the unified system. The reworked earth were classified as silty clay with sand with GT1 being of low plasticity (A-4, ML-CL) while GT2 and HRT were of medium plasticity (A-6, ML-CL). Consistency test determined by atterbergs limit gives insight to the ease or otherwise of moulding and workability of the soil samples. Two of the reworked earth samples are of medium plasticity while GT1 is of low plasticity and the linear shrinkage also less than 10%. The values indicated in table 2 showed that the materials are of low swelling potentials and might not witnessed excessive volumetric changes in use. The specific gravity of sand obtained was 2.72 which is higher than the values for the termitaria soils given as 2.43 for GT1, 2.51 for HRT and 2.52 for GT2.

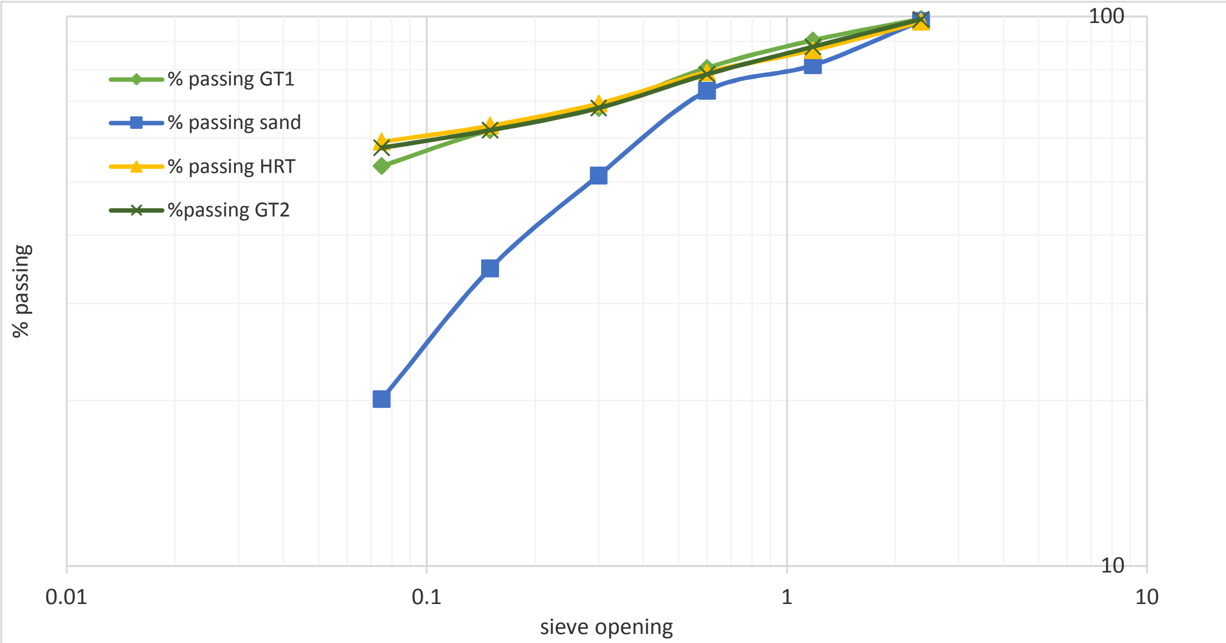

Figure 1: Gradation curve for the soil samples

Table 1: *Results of the Atterberg limit test*

Soil Sample	Atterberg Limit			
	LL	**PL**	**PI**	**LS**
GT1	31.50	23.18	8.32	8.27
HRT	36.00	23.45	12.55	9.30
GT2	30.50	19.87	10.63	8.56

4.2 Moisture-Compaction properties

The results of the optimum moisture content (OMC) and maximum dry density (MDD) of the compacted stabilised samples were presented in table 2 and figure 2. The result showed a significant reduction in the optimum water content giving rise to the maximum dry density obtained for all the stabilisation levels investigated compared to that recorded for the unstabilised granular soil sample. The highest maximum dry density (MDD) occurred at the lowest OMC for each of the three reworked earth material. For instance, those of GT1 samples occurred at 30%, while for HRT and GT2 it occurred at 50% and 70% additive respectively. Also, the reworked earth samples resulted in increase in the maximum dry density at all stabilisation levels although in varying amount. This implied that the reworked earth samples improved the compactability of the granular soil as a result of the increasing cohesiveness achieved by adding reworked earth materials. It was also observed that the plasticity of the reworked earth influences the moisture-density behaviour of the stabilised samples, for instance, HRT with the highest Plasticity Index had the highest MDD followed by GT2 which is next in line. This is in line with established fact that moisture and clay content influences the compaction and density characteristics of soil.

Table 2: *Compaction moisture-density properties for the stabilized soil samples*

Soil sample	properties	Stabilisation Level (%)						
		0	10	20	30	50	70	100
GT1	MDD(Kg/M3)	1740	1840	1970	2050	2010	1990	1980
	OMC %	14.20	8.02	9.75	6.76	10.80	11.50	11.40
HRT	MDD (kg/M3)	1740	1850	1980	2410	2400	2040	2030
	OMC %	14.20	11.80	9.23	10.30	9.00	9.00	11.20
GT2	MDD (kg/M3)	1740	1800	1920	2090	2020	2140	2070
	OMC (%)	14.20	12.80	8.70	8.80	8.60	6.00	8.10

4.3 Bearing Strength and Shear Strength Properties of the Compacted Samples

The California bearing ratio test is used to evaluate the strength properties of subgrade and sub-base materials. Figure 2 showed the results of the bearing ratio for the compacted samples at the various stabilisation levels. The three reworked earth stabilised samples showed considerable improvements over the unstabilised granular soil sample. This may be linked to the improved grading of the stabilised samples and the presence of cohesive soil fraction in the stabilised soils compared to the granular soil sample. GT1 and HRT attained their peak value of about 60% at 30% and 50% stabilisation levels respectively while GT2 attained its peak value of 114% at 70% stabilisation level. One reason for this may be linked with the plasticity indices of the reworked earth samples, for instance GT2 with the least plasticity index has higher CBR values although at higher replacement levels. This might be due to a better blend of the soil particles which enhanced its compaction-density properties and subsequently its bearing strength. However, it was noticed that the additive with the highest bearing capacity has the lowest shear stress resistance and vice-versa this may be due to effect of pore pressure. Also it was observed that the additives had effect on the shear strength parameters of the stabilized soil samples. It could be seen that at 30% level additive GT1 has its peak values for shear strength while HRT has its peak values at 70% and GT2 has its peak values at 70%. This further reinforced previous opinions that reworked earth varies in their properties and behavior, as a result the properties of reworked earth need to be ascertained before use as it may be difficult to generalise such results.

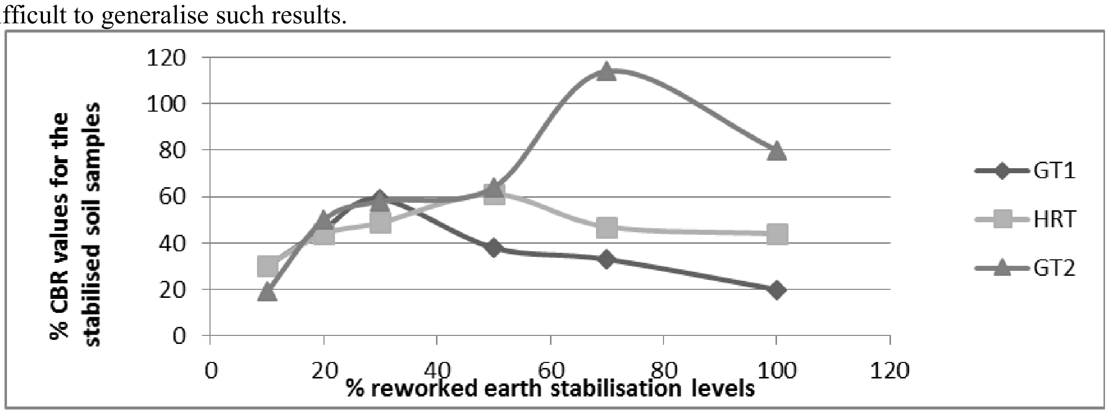

Figure 2: *The graph of CBR performance at each stabilization level for the three termitaria soils*

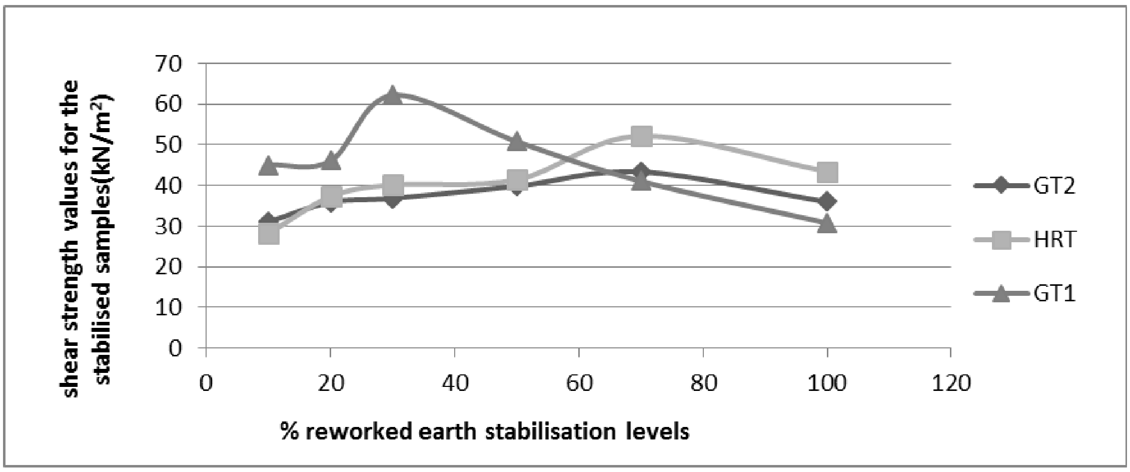

Figure 3: *Graph of shear stress values for the three reworked earth stabilised soil samples*

5. Conclusion

Geotechnical properties are known to be essential factors that can influence the behavior and thus performance of soils as road construction materials. These properties investigated showed that termite reworked earth improved the dry density of the sandy soil which consequently improved the strength properties of the stabilized soils. Generally it can be seen that the termite reworked earths improved the bearing strength properties of the sandy soil thereby making it a potential stabilizing agent with stabilizing quantities ranging from 30% to 100%. Termite reworked earth improves the cohesiveness of the granular soil and thus have effects on its moisture-density properties as well as its plasticity and compactability. Termite reworked earth stabilised samples showed increase in the maximum dry density of stabilised samples for all the stabilisation levels investigated, although rate of the increment varies. The reworked earth materials reduced the optimum moisture content of the stabilised samples when compared to the initial unstabilised sand sample. It shows a potential in reducing the porosity and increasing the densification of granular soils. The reworked earth materials showed an increase in the bearing capacity of the stabilised sample compared to that of the initial granular material. It can therefore be concluded that termite reworked earth materials is a potential stabilising additive for granular soils. GT2 which has the least plastic and liquid limits has the largest bearing strength meeting the required Nigerian road and bridges specification for usage as sub-base material although it attained this at high levels of stabilization (70% and 100%) (Nigerian general specification).

Finally, the three reworked earth materials studied showed fairly good additive potential for the sandy soil and can therefore be used as stabilising agents for sand.

6. References

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