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Experimental Investigation on Termite Mound Soil Composite Brick Reinforced with Natural Fibres and Natural Stabilizer

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ABSTRACT: Since land improvement is inevitable for many conditions in the context of civil engineering, experiments are underway to search for methods to improve the properties of the soil and to develop new additives. An attempt is made here to test the properties of the termite mound by expecting an increase in soil strength parameters. Termite clay has undergone physical, chemical and biological changes, so termite mound has many desirable properties as a foundation and building material. Experiments have shown that termite mound soil has better geotechnical properties compared to the surrounding control soil. The older generation is traditionally recorded as having stabilized clay by mixing unknown substances into locally available mound clay. This set of studies identified a possible natural stabilizer with termite mound, which demonstrated a significant increase in the strength parameters of the test soil. The same clay mixture is used to make stabilized composite clay bricks, which gives a result comparable to traditional burnt clay bricks.

KEYWORDS: Composite brick, Termite soil, Liana plant, Natural stabilizer.

I. INTRODUCTION

Termites live in communities and their nests are considered as mounds because they are exposed to the earth's surface. The structure of the mounds is very complex, and they come in a variety of shapes and sizes. Termites play a major role in nutrient recycling, movement and transport of soil material. Termites increase the content of organic carbon, clay and nutrients. The chemical and physical properties of these biologically regenerated soils differ from those of their surrounding areas. The heated termite mound is resistant to abrasion, wear and penetration by liquids and has semantic properties, making it a good cementing agent, which has a low thermal conductivity, allowing it to reduce solar heat flux in the building premises and control temperature fluctuations. The present study is useful to know the soil properties of termite mound. In this article the advantages of termite soil, strength behavior of fibres, adhesive properties of lianas, ancient soil stabilization and stabilized clay brick production, were studied.

Paper is organized as follows. Section II describes different process involved in the process of mound soil composite brick preparation. The materials used for making natural stabilizer and the mound soil composite brick are given in Section III. Section IV furnish the methodology and the procedure to prepare the specimen and the test conducted. Section V presents experimental results showing results of specimens tested. Finally, Section VI presents conclusion.

II. RELATED WORK

Soil stabilization

Soil stabilization means changing soils to improve their physical properties. It increases the shear strength of the soil, improves its load-bearing capacity and can control its swelling-shrinking properties. There are many methods available such as stabilization using cement, lime, bitumen, slag, fly ash, etc., electrical stabilization, chemical stabilization, floor stabilization by grouting, floor stabilization by geotextiles and fabrics, etc. The main advantages of soil stabilization are and controlling the setting time and curing time, increasing the compact density of the soil, improving the permeability of the soil and increasing the strength and durability.

Ancient stabilization technique

It is known from the villagers that older generations of people used termite mound to build houses. Binding agents are very necessary for wall construction when cement and other modern materials are not known. Older generations of

people made a certain soil mixture through ancient stabilization methods by adding some natural ingredients to the locally available termites mound soil (TMS). No documentation is available on how this soil mixture was prepared. Such a soil mixture has some thixotropic properties and gives great strength for drying. Those old houses provide excellent seasonal comfort to the residents for hot and cold weather.

Fibres

Fibres can generally be classified as either man-made or natural. Man-made fibres are usually glass, polyethylene, polypropylene, nylon, polyester, steel and polyvinyl alcohol. Natural fibres include coir, pineapple, sisal, palm, bamboo and sugarcane. Based on the weight or volume fibres are cut to a predetermined length and mixed with the soil matrix in a specific ratio. Combining fibres by weight is a common method and fibre fractions often take up less than 1%. The inclusion of fibres in the mound clay matrix is for increasing the compressive and shear strength of the composite brick.

Composite brick

Clay has been used by civilizations around the world for many years as a building material. Many different methods have been developed and these methods vary according to the local climate and local customs and traditions. Methods derived from traditional methods are adopted to improve the quality of brick construction. A composite brick is a brick made by adding ingredients other than the conventional ingredients to improve their properties. Through a trial and error method, clay-water mixtures are mixed with additives such as animal hair, animal manure and various plant fibres to obtain the desired property of composite brick.

III. MATERIALS USED

Mound soil

The mound was collected from Paingottoor, Ernakulam. The mound soil is red in colour and contains a certain amount of natural water content. Termite mound is very difficult in nature. In order to build these structures and ensure their resistance against environmental hazards (e.g., extreme rainfall events, hunting by mammals and invertebrates), termites give specific physical and chemical properties to the soil in the mound walls.

Termite mound walls are rich in clay rather than sand, thereby increasing hardness and improving water resistance. The soils in the mounds have different clay mineral compositions that are predominant at the soil surface and are often characterized by low C content but high mineral nutrients, and higher CEC than the surrounding soil. This change in soil properties can be caused by the selection of soil aggregates and the change of soil from different depths of the profile to the soil surface. However, it is difficult to estimate the relative significance of these two processes. Fungus-growing termites retrieve their material (wet soil cells) very deep in profile, even up to the water table to find the moisture needed for the colony and their symbiotic fungus. Termite mound soils originate from different depths, the ratio of which is impossible to determine accurately. However, the physical-chemical properties give the clay a specific fingerprint or signature, which can then be compared to the soil profile.

Control soil

Control soil is collected 3 m away from the termite's mound after removing the top vegetations. The control soil is dark brown

Liana plant

Lianas are wood climbers and are often found in tropical forests. They are also known as structural parasites because they do not take water or nutrients directly from the host tree, but indirectly affect plant growth due to the plant's greater water absorption capacity from deeper soil. Compared to other plant growth forms in tropical forests, lianas timber is under tremendous development of self-help climbers and are clearly characterized by the diversity of organization systems. In using undergrowth or other plants of the canopy as support, lianas save a significant portion of the energy needed to produce supporting tissues. This behavior enables them to accumulate more resources, thus energizing physical activity, increasing their growth, leaf production, and sexual and vegetative reproduction.

Bral fish

Bral fish is a freshwater fish. The body of the bral is long and cylindrical, with a huge mouth and a snake head. They are often found in ponds, paddy fields and rivers. The secretion of bral makes glue like consistency in water. Brals live in aerated and oxygen depleted water sources. Therefore, they are suitable for profitable culture in shallow systems.

Hair fibre

Hair thread is a natural fibre formed by a protein called keratin, which contains the high sulphur concentration of the amino acid cysteine. Hair threads are a major component of the outer layer of most mammals. The major physical properties of hair depend largely on its geometry. Features to improve the physical and mechanical properties of hair include elastic adhesion due to both cuticle scales and significant adherence to motion control (sensitivity), as well as the ease of comb, softness, volume, shine and softness. The evaluation of these effects on the hair is carried out by several methods, namely: optical and electron microscopy, mechanical resistance measurement, shine evaluation and optical coherence tomography (OCT). The properties of hair fibre are shown in table 1

Table 1: Properties of hair fibre

PROPERTIES	REMARKS
Cross section	Circular
Diameter	17 – 100 μm
Length	5 – 50 mm
Elongation	1.5 times its dry weight
Tensile strength	Equal to copper wire of similar diameter
Outer coating	Cuticle
Protein present	Keratin

The human hair fibre of random length varies between 5mm to 50 mm was used as reinforcing material in this study. The average diameter of hair fibre was 58.5 μm . Fibre contents proved more influential and effective in stabilization of soil than the length of fibre. Addition of fibre resulted in decrease in plasticity and increase in hydraulic conductivity

IV.METHODOLOGY

i. Determination of geotechnical properties of mound soil and control soil

The following properties are found out as per the standards

- Initial moisture content (IS: 2720 (Part II) – 1973)
- Consistency limits (IS: 2720 (Part 5) – 1985, (Part 6) – 1972)
- Specific gravity (IS: 2720 (Part 3 / Sec 1) – 1980)

ii. Preparation of natural stabilizer

Natural stabilizer (N.S) is a mixture of bral fish secretion and liana juice extract. Pour the water containing the Bral fish secretion into this squished liana stem. In approximate proportions, add ½ litre of bral fish secretion per 1 kg of liana stalks. After 12 hours, the gum type solution is squeezed out from the mixture.

iii. Preparation of stabilized soil mix

In the first stage, the clay soil is mixed only with the natural stabilizer, where the optimum N.S content is obtained from the standard proctor test. Optimal N.S content is then fixed. Hair fibre percentage of 0, 0.25%, 0.5%, 0.75% and 1% by dry weight of the soil was taken to the above selected mixture and the optimum fibre percentage was found by keeping the N.S content constant. The obtaining percentage is selected for natural stabilizer and hair fibres and soil samples are prepared.

iv. Determination of optimum stabilizer content

Standard proctor test

The test is performed as per IS: 2720 (Part 8 – 1983). A compaction curve is drawn between the dry density and the Natural Stabilizer content. Optimum Natural stabilizer Content corresponding to the maximum dry density is obtained from this curve.

v. Preparation of stabilized composite brick

Here two types of bricks are made with fibre and without fibre. The size of the bricks is similar to that of a traditional clay brick (190x90x90) mm. The ground was dug from the termite mound using a metal spike. When the natural

stabilizer is mixed, it is poured slowly and the soil-stabilizer is thoroughly kneaded by hand with constant attention to the homogeneity of the mixture. In the initial experiment, the maximum dry density (MDD) of the soil corresponding to the optimum N.S content (ONC) of 25% was found. The obtained soil mixture is divided into two parts from one part of which the hair fibre is to be added. The hair fibres were mixed until normal homogeneity was achieved. After achieving the appropriate composite, the bricks were formed using a wooden mould with suitable dimensions to get a conventional brick. The obtained mud block baked under sunlight for 7 days. It is then transferred to a kiln having 700-1500°C for 15 days. After 15 days the bricks are formed.

vi. Tests on composite bricks

Compressive strength test

The compressive strength of the block is one of its most important engineering properties. The compressive strength of stabilized mound blocks depends on the type of soil and the type and amount of stabilizer used to form the brick. Maximum strengths are obtained by properly combining the appropriate materials and the right soil type. It has been established from the literature that the durability of bricks increases as its strength increases. 3 numbered bricks from each group are tested on a compression test machine.

V. EXPERIMENTAL RESULTS

Properties of mound soil and control soil

From the results, the variability of soil properties of mound soil and control soil can be observed in table 2 and table 3 as given below.

Table 2: Properties of termite mound soil

PROPERTIES	VALUES
Moisture content, (%)	28.57
Specific Gravity, G	2
Liquid Limit, L.L (%)	44
Plastic Limit, P.L (%)	28
Plasticity Index, P.I (%)	16

Atterberg's limits also reflect the engineering properties of these soils. The liquid limit is 44% and the plastic limit is 28%. More than 50% of particles are passing through 4.75 mm (56%) in sieve analysis, so it belongs to the sand. More than 12% of particles passing through 75 micro (41%) soils are sand with fine. The plasticity index finally obtained is 16%, which is more than 7%. The soil is therefore classified as clay sand (S.C.). Water repellent is caused by developing internal bonds due to organic matter (saliva and excretion) in the soil.

Table 3: Properties of control soil

PROPERTIES	VALUES
Moisture content, (%)	33.33
Specific Gravity, G	1.82
Liquid Limit, L.L (%)	32
Plastic Limit, P.L (%)	20
Plasticity Index, P.I (%)	12

Here on control soil, the liquid limit is 32% and the plastic limit is 20%.

Comparison of consistency limits

From the values obtained, it can be observed that the termite mound soil has high liquid limit and plastic limit which shows that they have high clay fraction content than control soil. The comparison is shown in figure 1.

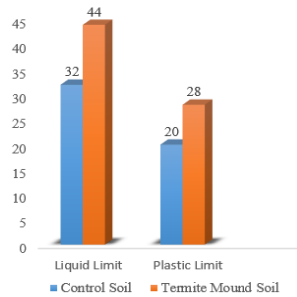


Fig. 1. Comparison of consistency limits

Properties of stabilized soil

Optimization of natural stabilizer content

In standard proctor test compaction tests, the natural stabilizer is poured slowly while mixing thoroughly by hand with constant attention to the homogeneity of the clay-stabilizer mixture. By increasing the % of the natural stabilizer content by 15-50% the range of densities achieved with different moisture content leads to a simple bell-shaped curve. The maximum compacted dry density (ρ_{dmax}) obtained is 1.686g/cm^3 and the optimum natural stabilizer content (ONC) is 25%. The graph between dry density and natural stabilizer content is shown in figure 2 and the result of standard proctor test of stabilized soil is observed below in table 4.

Table 4: Dry density of natural stabilizer content

PROPERTIES	VALUE
Maximum Dry Density (g/cc)	1.686
Optimum Natural Stabilizer Content(%)	25

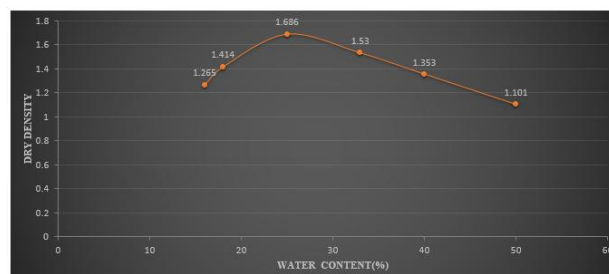


Fig. 2. Variation of Dry density with Natural stabilizer content

Optimization of natural hair fibre content

It is clear from the table given below that the compressive strength of the soil increases when fibre is added to the stabilized clay. The maximum compressive strength value of stabilized mound soil is obtained as 70kN/m^2 when the hair fibre content is 0.5%. the compressive strength of various % of fibre content is given in table5.

Table 5: Compressive Strength by % Increase in Fibre Content

SOIL SAMPLE	COMPRESSIVE STRENGTH (kN/ m^2)
ONC + Mound Soil	35.23
ONC+ Mound Soil + 0.25% fibre	39.99
ONC+ Mound Soil + 0.50% fibre	69.76
ONC+ Mound Soil + 0.75% fibre	47.53
ONC+ Mound Soil + 1% fibre	39.23

Comparison of compressive strength test of different soil sample

By compression strength test, it can be seen from the bar chart that the compressive strength of the termite soil is 35.23 kN/m² by the application of the stabilizer. The compressive strength of the soil mixture to which the hair fibre is added is 69.76 kN/m² and the compressive strength of conventional fired clay brick 20.45 kN/m². As it is clear from the bar chart, the soil stabilized by fibre strength is 2 times greater than that of mound soil with natural stabilizer and 3.5 times greater than that of conventional burnt clay brick. The voids are completely filled with particles due to the presence of additives and the tensile strength increases with the addition of fibres. The comparison of compressive strength is shown in figure 3.

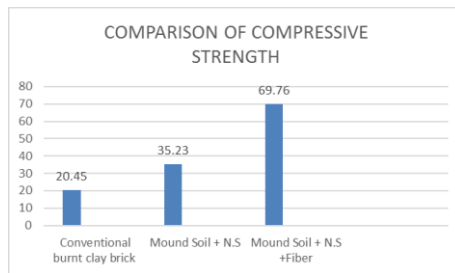


Fig 3: Comparison of Compressive strength

Test results of composite brick

Compression test

Fibre reinforced soil is a composite material. By introducing fibres evenly across the soil, the strength of the bond increases, thereby increasing the shear strength. Consider a soil element at stress equilibrium. Such an element is subject to both diagonal tension and compression. Because the soil is so weak in tension, it will fail diagonally due to diagonal tension. When the fibres enter the soil, the fibres have tension and can withstand additional loads. From Table 6, we can see that the average compressive strength of fibre-reinforced brick is 1.4 times higher than that of conventional burnt clay brick.

Table 6: Test result of compressive strength

Type of brick	Length (mm)	Breadth (mm)	Avg. compressive strength (N/mm ²)
Stabilized brick without fibre	190	90	4.2
Stabilized brick with fibre	190	90	11.5
Conventional burnt clay brick	190	90	8.4

VI. CONCLUSIONS

The engineering and indicator properties of the termite mound soil and control soil were determined in the laboratory. Advanced geotechnical properties of termite soil stabilized with some natural additives have been investigated and the main conclusions are summarized as follows:

- The geotechnical characteristics of the termite mound and control soil were studied. The mound soil has better properties than the surrounding control soil.
- The plasticity index obtained for termite soil is 16%, which is more than 7%. The soil is thus classified as clay sand (CS).
- The plastic limit and liquid limit value are higher compared to the control soil and the values are 28% and 44% respectively.
- The results obtained from the laboratory tests show that the termites mound soil is much superior to the control soil.
- Maximum dry density was found to be 25% from the graph.
- Experimental research found that the natural stabilizer content obtained was 25% and the hair fibre content is 0.5% by dry weight of the soil.
- The compressive strength of the brick stabilized with hair fibre is 2 times higher than the mound soil with N.S.

- The compressive strength of the brick stabilized with hair fibre is 1.4 times higher than that of conventional fired clay brick.

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