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Adobe with Termite Mound Soil for Sustainable House Construction in Gambella

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Abstract

The Gambella community in Ethiopia uses their indigenous knowledge of mixing termite mounds soil with locally available straws to build their mud houses. Mud houses constructed with termite mounds are comparatively stronger than those prepared with other soils, but they have severe durability issues due to shrinkage cracks that necessitate regular maintenance which is not affordable by many. This research paper presents technology intervention to resolve these issues faced by the community by introducing an alternative method of house construction called adobe. As part of this research 144 blocks of adobes were cast by using locally available materials and their performance was evaluated by conducting several strength and durability tests. The experimental results revealed that adobe prepared with termite mounds soil, 1.5% straws, and 2.5% of binder provides excellent strength and durability. The compressive strength was measured to be 2.6 MPa. Enhanced durability in terms of reduced shrinkage (17%), a low initial rate of absorption (0.29), and water absorption (0.26) were found in the adobe blocks. This indicates adobe is certainly the best solution to the existing houses' durability issues and a best-class sustainable solution for the construction of houses in Gambella, Ethiopia.

Keywords: Adobe, Chikka Bets, Compressive strength, Durability, Mud Houses, Straw

I. Introduction

As per the indigenous knowledge of the Gambella community of Ethiopia, termite mound soils are the most suitable soils to build their traditional mud houses. Another perspective of the existing mud houses is the overconsumption of wood leading to large-scale deforestation thereby creating a negative impact on the environment along with soil erosion. There has been some research conducted in past to come up with Adobe blocks using locally available soil and straws along with a suitable binder [1], [2], [3] and the results are promising. So, in this research work an attempt has been made to make technical interventions to resolve

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the issues faced by the Gambella community regarding their house construction. This research work also aimed at identifying the suitability of termite mound soil, optimum percentage of binder, and reinforcing agents for preparing the adobes to achieve the maximum strength and durability from the adobe houses along with avoiding the shrinkage cracks. The issues related to mud houses have been presented in Fig. 1.

Fig. 1: Major issues related to mud houses

II. Materials and Methods

The materials employed in this reseaerch were termite mound soil, straws, cement, and water available in the vicinity of the study site. All the tests were conducted as per Indian standards.

A. Laboratory Tests on Termite Mound Soil and Local Straws

To make the adobe units, soil taken from the Nuer zone of Gambella town after consultation with the Gambella community for their most preferred soil to build houses were used as presented in Fig. 2.

Fig. 2: Material procurement

Soil tests were carried out by using ASTM standard procedures [4],[5] and soil classifications are identified according to the unified soil classification system (USCS) as presented in Fig. 3 below. The soil properties are a Natural Moisture Content of 19.21%, Air-dry Moisture Content of 15.25%, Specific Gravity of 2.64, Liquid Limit of 38%, Plastic Limit of 19%, Plastic Index of 19, Maximum Dry Density of 1.78gm/cc^3, and Optimum Moisture Content 15.5%.

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Fig. 3: Soil and straw properties testing in the laboratory

The locally available straws are agriculture wastes plentily available in Gambella and used as the roof material for traditional houses. Water content analysis, specific weight analysis, and water absorption rate analysis were done on the straw fiber. The experimental test results are Cross-section (Circular), Length 30mm, Range of Diameter 0.2-1.2mm, Specific Weight 0.67g/cm^3, Natural Moisture Content 13.24%, Water Absorption in 5 minutes (g/min) 0.71, Water Absorption in 10 minutes 0.372(g/min), and Water Absorption in 1 hour 0.062(g/min).

PPC Dangote cement with a compressive strength of 32.5 MPa was employed in this study. It is highly durable cement with less cost and less emission of carbon dioxide compared to OPC cement. As the main ingredient in the production of the Adobe units., potable water without contaminants and taste that is odorless was used.

B. Preparation of Adobe Units and Mix Proportions

All adobe units prepared for this research have a brick shape as presented in Fig. 4. One hundred forty-four (144) adobe units were prepared and cured by air-drying. The adobe unit samples were prepared with the dimension of 190mm x 90mm x 90mm. The mix of adobes has been presented in Table I.

Fig. 4: Preparation of adobe units

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Table I: Mix Proportion of Different Adobe Mixes

Sr. No	Denotation	Soil (%)	Cement (%)	Straw (%)
1	A	97.5	3.5	Nil
2	B	97.5	3.5	0.5
3	C	97.5	3.5	1.5
4	D	97.5	3.5	2.5
5	E	97.5	3.5	3.5

C. Strength Tests

1) Compressive strength test: The compressive strength test was done to find out the amount of compressive load the adobe units can bear without fracturing and to define the stress-carrying capacity of adobe units as shown in Fig. 5. The tests of compressive strength and stress-carrying capacity of theadobe unit specimens were done after 28 days of air curing and drying.

2) Water strength test: The water strength test determines the water strength coefficient for wet and dry compressive strength of adobe unit trial specimens. This test was carried out for all adobe unit trial specimens after 28 days of curing and air drying as presented in Fig. 6.

D. Durability Tests

1) Shrinkage test: Before drying and after 28 days of dry curing , the shrinkage test is deone to determine the volume change of adobe unit trial specimens. The volume of the adobe specimens was measured immediately after the casting of the adobes and allowed to dry cure for 28 days. The volume of the adobes was again measured after 28 days.

2)Water absorption by capillarity: The water absorption properties of adobe are determined by conducting a water absorption test according to BS EN 772-11 as presented in Fig. 7.

Fig. 5: Compressive strength test on adobe block

Fig. 6: Adobe block for water strength test

Fig. 7: Adobe block for water absorption test

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III. Results and Discussions

A. Soil Test Results for Optimum Stabilizer

Table II indicates the test outcomes of the standard proctor test of soil-cement mix differ with cement amounts of 0%, 2.5%, and 3.5%. Hence, the adding of 2.5% cement is an ideal value that will be employed in adobe mixes since it has provided maximum dry density.

Table II: Standard Proctor Test to Find Optimum Amount of Cement

Mixes	Maximum Dry Density (gm/cc)	Optimum Moisture Content (%)
Soil	1.74	15.6
Soil + 2.5% Cement	1.78	15.1
Soil + 3%Cement	1.72	15.8

B. Compressive Strength Test Results of Adobe Units

From Table III, it can be clearly seen that with the inclusion of straws in the adobes, the compressive strength increases, and the maximum strength can be observed for Mix C (Soil+2.5% Cement+1.5% straw fiber). The compressive strength value demanded by international standards for traditional Mudbrick is 1 MPa and for Mix C it is 2.6 MPa. This implies that the locally available termite mounds soil and straws can serve as ingredients to produce adobe units for house construction.

Table III: Compressive Strength of Adobe Units at 28 Days Curing Period

Sr. no.	**Mix**	**Compressive strength in MPa**
1	A	2.27
2	B	2.29
3	C	2.6
4	D	2.4
5	E	1.99

C. Water Strength Test Results of Adobe

Water strength test results of the different adobe mixes have been presented in Table IV. The minimum permissible value of this coefficient is 0.5. The test results indicate that mix C (Soil+2.5% Cement+1.5% straw fiber) has the highest water strength value of 0.58. This indicates that the strength loss in adobes after exposure to wetting is lowest for Mix C.

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Table IV: Water Strength of Adobe Units at 28 Days Curing Period

Sr. no.	Mix	Water strength
1	A	0.46
2	B	0.51
3	C	0.58
4	D	0.53
5	E	0.52

D. Shrinkage Test Results of Adobe

Shrinkage test results of the different Adobe mixes are presented in Table V. It can be clearly seen from the test results that with the increase in fiber contents, the shrinkage is reduced. This indicates that the locally available straws have a positive influence on arresting the shrinkage cracks.

Table V: Shrinkage Test Results of Adobe Units

Sr. no.	Mix	Reduction in volume (%)
1	A	22.44
2	B	19.61
3	C	17.96
4	D	17.25
5	E	16.12

E. Water Absorption Test Results of Adobe

Water absorption test results of the different adobe mixes are presented in Table VI. The test results clearly show that with the increase in fiber contents, water absorption is reduced. This indicates that the locally available straws have a positive influence on arresting the water absorption of mud blocks.

Table VI: Water Absorption Test Results of Adobe Units

Sr. no.	Mix	Absorption [Kg/(m² × min)]
1	A	0.46
2	B	0.52
3	C	0.44
4	D	0.26
5	E	0.32

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IV. Conclusions and Recommendations

Based on the experimental investigations of this research, the following conclusions have been made.

- The termite mound soils have better strength compared to other soils because of the high calcium content which is released from the termite saliva.
- Cement is the most suitable binder for the termite mound soils for adobe preparation.
- The optimum percentage of the binder for the termite mound soil is 2.5% by weight.
- The optimum percentage of straw for the preparation of adobe is 1.5% by volume of the soil mass.
- The optimum combination of adobe constituent materials from a strength and durability perspective is soil, 2.5% cement, and 1.5% straw.
- The introduction of straws as reinforcing agents enhances the shrinkage resistance capacity and water resistance capacity of adobes.

The utilization of Adobe as building construction technology is cost-effective and would help in reducing the dependency on wood for the construction of mud houses thereby reducing deforestation.

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