MUD BRICK STABILIZATION FOR LOW-COST HOUSING CONSTRUCTION IN BORNO STATE

Photo: A two-room mud bricks shelter constructed by Mercy Corps in Dikwa in March 2019

EXPLORING SHELTER SOLUTIONS FOR IDPS LIVING WITH HOST COMMUNITIES AND RETURNEES

MARCH 2022

ABSTRACT

This applied research paper is aimed at improving the quality of mud bricks using low-cost stabilization and compression techniques. The soil used in this study was obtained in Damboa and Ngala local government areas of Borno State, Northeast Nigeria. For this research, ordinary Portland cement and local straws (*Gamba grass* and *Chaqqa)* were used as partial replacement of clay soil by mass in the production of mud bricks. The replacement percentage used were 0%, 2.5%, 5% and 7.5% for cement replacement and 0.1%, 0.3% and 0.5% for straw replacement. Compressive strength and water absorption tests were performed in accordance with British Standard (BS) 3921:1985 to determine its suitability as a building material. The compressive strength and water resistance of the mud brick samples increased considerably with increase in cement and straw replacements at 28 days curing period. Therefore, stabilized compressed earth bricks (SCEB) technique has improved the quality of local mud bricks in the study area. This applied research, funded by USAID-Bureau of Humanitarian Assistance (BHA) under the program, Addressing Diverse and Acute Primary Threats to Human Security in Northeast Nigeria (ADAPT) was conducted by Mercy Corps Nigeria, in collaboration with the University of Maiduguri and Ramat Polytechnic.

INTRODUCTION

The continuous displacement of vulnerable people and destruction of shelters and household assets due to the insurgency continues to be the main drivers for shelter needs across Borno, Yobe and Adamawa states. The lack of adequate shelter exposes the most vulnerable people to significant protection risks threatening their dignity, physical well-being and living standards. Shelter needs remain high even after a number of years of humanitarian action since emergency shelters provided for IDPs have a short life span of six months and do not provide beneficiaries sufficient protection from the environment, are highly prone to wear and tear, and require periodic replacement to some provide privacy, dignity, and security.

Human population is growing faster than people can afford to build houses, thus creating housing shortage. In many countries like Nigeria, an average citizen cannot afford the cost of constructing a modest accommodation. It is therefore imperative to source for innovative and sustainable techniques to make low-cost and effective building materials available. Mud brick, an affordable low-cost building material made from the abundantly available lateritic soil, has associated problems with some of its properties, hence must be modified to ensure its suitability. The identified issues with mud brick include the compressive strength and water resistance which leads to durability problems, for instance, perforation of the walls and gradual erosion of the brick building.

Lateritic soil in its natural state generally has low bearing capacity and strength due to its high clay content. When lateritic soil contains a large amount of clay materials, its strength and stability cannot be guaranteed under load especially in the presence of moisture.

BACKGROUND OF THE STUDY

Mercy Corps conducted housing typology surveys in Dikwa, Damboa, Ngala, Bama and Gwoza local government areas of Northeast Nigeria from 2018 to 2019. The surveys showed that mud bricks are among the abundantly used, self-produced and economical construction material. The bricks have helped the IDPs, returnees and the host to repair their completely damaged shelters economically, compared to cement blocks that cost 20-25 times more depending on the location. Mud blocks are on high in demand for the major damaged shelters in the rural areas. Skills for casting these bricks are abundant in the rural LGAs, moreover, self-builders are also busy in making these bricks for their shelter repairs as observed in Mercy Corps areas of operations. The use of locally available stabilizers such as straws, husks and crushed dry leaves that act as a reinforcement to some extent, have also been observed. However, overall, the mud bricks observed in the field has poor quality. These poor quality bricks don't last long under the heavy rains and rain shortens the life of a mud block structure. Mercy Corps sees the critical need to take care of the mud bricks used in recovery efforts to ensure ongoing self-recovery and self-building efforts are sustainable.

Local mud bricks are made by mixing earth with water, placing the mixture into molds, and drying the bricks in the open air. Strong tension fibers, such as straw are often added to bricks to help reduce cracking. Mud bricks are joined with a mud mortar and can be used to build walls, vaults, and domes. The appearance of mud bricks reflects the materials they are made from, usually earthy, with their color determined by the color of clays and sands in the mix. Finished walls can range from a strong expression of the brick patterns to a smoothly continuous surface. Some of its properties and advantages are:

- Economical
- Fireproof
- Durable
- Non-toxic
- Environmentally-friendly
- Provides thermal insulation
- Provides low sound transmission levels
- Is culturally and social acceptable
- Locally developed

Underneath Borno State is the Chad pattern, a chain of clay and sand. The most important element to be considered when searching for the right earth mixture for compressed mud bricks is the clay content as it acts as the natural binder of the earth mixture. The clay content in the mixture should be between 8-30% for a good, stabilized mud bricks.

This study aims to improve the quality of locally produced mud bricks using local techniques in the study area, looking at the soil properties for suitability and using strength analyses through different stabilizers and ratios, as well as, examining the environmental aspects.

METHODOLOGY

The materials used in this research are lateritic soil, Ordinary Portland Cement (OPC), local straws, water, and compressed earth brick machine. The soil is collected at a minimum depth of 0.6 meters at the river banks in Damboa and Ngala, Borno State, Northeast Nigeria.

The soil samples were air-dried for 14 days to allow partial elimination of natural water which may affect analysis, then sieved through 4.75mm opening to obtain the final soil samples for the tests. The test conducted include natural moisture content, specific gravity, sieve analysis particle size distribution (PSD), liquid limit, plastic limit, plasticity index. The moisture content theoretically falls in the range of 0 to ∞. However, in sandy soils, water content usually found varies between 10% to 30% and in clayey soil it ranges from about 5% to possibly over 300%.

Photo 1: Soil proportioning for mixing

The specimen was prepared with the desired levels of stabilisations of 0%, 2.5%, 5%, and 7.5% of Ordinary Portland Cement (OPC) and 0.1%, 0.3% and 0.5% of local straw, respectively. The bricks of size 295 x 140 x 90mm were moulded using the OSKAM V/F machine with a hydraulic press for block making. Compressive strength and water absorption tests were conducted on the mud brick samples after 28 days curing period.

Photo 2: Compressed stabilized mud brick samples

RESULTS AND DISCUSSIONS

The summary of the results obtained from the various laboratory experimental tests conducted on the mud bricks to determine its suitability as a construction material are shown below:

Table 1: Physical Parameters of the Earth Material

	PROPERTIES	VALUES (Damboa)	VALUES (Ngala)
1.	Colour	Reddish Brown	Greyish Brown
2.	Natural Moisture Content	19.3%	17.6%
3.	Percentage passing sieve no BS 200	85.96%	87.65%
4.	Liquid Limit	32.5%	30.0%
5.	Plastic Limit	21.5%	20.5%
6.	Plasticity index	11.0%	9.5%
7.	Specific Gravity	2.59	2.68
8.	AASHTO Classification	A-2-6	A-2-4

Using the (AASHTO, 1986) method of classification, both soil samples fall into group A-2 (silty or clayey gravel and sand), a suitable soil for compressed mud brick stabilization.

Atterberg limit test by the Casagrande method was performed in accordance with (BS 1377 1990) to ascertain plasticity index (PI) of the soil samples. The results are presented in Table 1 above. The PI of 11% for the soil sample does not exceed the maximum value of 35% stipulated by (BS 1377 1990) thus indicating a good laterite soil that is cohesive and hence able to receive proper compaction to enhance the strength and durability characteristics of the laterite. Hence, the soil sample is suitable for cement stabilization.

Table 2: Summarized Compressive Strength and Water Absorption Tests Results for Damboa Mud Brick Samples

	Sample	Description	Avg. Weight of block (g)	Avg. Compressive strength (N/mm^2)	Avg. Water absorption (%)
1	S	Soil only	7500	5.23	23.32
2	C2.5	2.5% cement	7500	5.18	20.40
3	C5	5% cement	7600	8.67	19.81
4	C7.5	7.5% cement	7650	9.25	17.22
5	ST0.1	0.1% straw	7500	5.37	23.06
6	ST0.3	0.3% straw	7400	6.75	22.5
7	ST0.5	0.5% straw	7400	6.79	24.00
8	Adobe	Conventional	6300	2.07	31.09

Table 3: Summarized Compressive Strength and Water Absorption Tests Results for Ngala Mud Brick Samples

	Sample	Description	Avg. Weight of block (g)	Avg. Compressive strength (N/mm^2)	Avg. Water absorption (%)
1	S	Soil only	7450	6.51	21.94
2	C2.5	2.5% cement	7400	6.77	19.92
3	C5	5% cement	7450	8.11	18.43
4	C7.5	7.5% cement	7500	9.98	14.79
5	ST0.1	0.1% straw	7400	4.49	21.93
6	ST0.3	0.3% straw	7330	5.96	23.21
7	ST0.5	0.5% straw	7450	6.51	21.94
8	Adobe	Conventional	7400	6.77	19.92

From Table 2 and 3, The results of water absorption are a function of the cement content, which means the higher the cement content the higher the resistance of the bricks. Bricks with higher water absorption rate could be used for partitioning and for non-load bearing walls. The results revealed that stabilized compressed mud brick with 7.5% cement stabilizer produced the best result with highest compressive strength and lowest water absorption as compared with the other brick samples for both locations.

A preliminary cost assessment conducted to determine the average cost of compressed stabilized mud bricks with 7.5% cement replacement using manual and automatic earth compression machines by local mud brick artisans showed that 1 unit of 295 x 140 x 90mm size compressed stabilized mud brick cost around 57-60 naira. A simple 2-single rooms house with veranda constructed with the compressed and stabilized mud bricks will cost around 322,000 naira, which is about three times less than the cost of a cement block house of the same size, or around 901,000 naira based on market prices conducted in January 2022.

CONCLUSION

Based on the summary of the research conducted, the following conclusions were drawn:

- The soil samples have significant characteristics that make it suitable for compressed cement stabilized mud bricks.
- The strength of the soil sample increased with increasing cement stabilisation level from 0% through 7.5%. The highest compressive strength of $9.25N/mm^2$ was achieved with 7.5% cement stabilization level of the sample at curing age of 28 days. The maximum strength obtained at 28 days is within the minimum strength requirement recommended for the construction of low-rise buildings.

- The water resistance of the samples increased with increasing cement stabilisation level from 0% through 7.5%, though the optimum cement content to achieve 100% water resistance of the bricks was not established in this research.

- Stabilization with straw showed no significant increase in strength with increasing the percentage level. It is also concluded that mud bricks stabilized with straw has no significant improvement in the water absorption rate of the bricks.

- Stabilized compressed mud bricks produced with OSKAM V/F machine showed the best result in terms of both strength and water resistance capacity, as the machine compresses with a higher pressure of 150 bar compared to the conventional method adopted by local mud brick producers.

RECOMMENDATIONS

Based on the findings of the research conducted, the following recommendations were made:

- To leverage available, low-cost yet suitable material for construction, the Government of Nigeria, as well as development and humanitarian organizations should use mud bricks for their low-cost housing construction.

- Due to the heterogeneous nature of the soil, further research should be done to explore soil samples from other locations and source for other local stabilizers.

- Further research should be conducted to determine the weathering effects of the stabilized mud bricks.

- The bricks produced with low water resistance should be used as partition walls to prevent them from the weathering effect, as this will reduce the overall cost of construction as well.

- When mud bricks are intended to be used as external walls, sand-crete blocks should be used in sub-structure and the roofing should be projected at least 600mm to minimize the effect of weathering.

- For mass production of the mud bricks and enhancing community empowerment, OSKAM V/F machine or any hydraulic machine is recommended for best results. Local communities can be engaged and trained on the operation of the machines to produce the mud bricks in large quantity. The OSKAM V/F machine is operated by skilled laborers for mass production which serves as a livelihood opportunity to the laborers.

Some environmental mitigation measures are recommended during soil excavation for mud brick production in the communities:

- A preliminary site assessment prior to undertaking excavation work should be conducted.
- Clay pits should be located at least 500m away from the community for safety reasons.
- Clay pits should be barricaded all the time for the entire duration it is being used.
- Clay should be harvested traditionally or locally in cyclical form.
- Trees can be planted to give the area new environmental value and economic value in few years to come. Tree planting will control the influence of soil erosion on reclaiming land, increase soil fertility and re-establish nutrient cycle of the soil.

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